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REGIONAL AQUATICS MONITORING

in support of the

JOINT OIL SANDS MONITORING PLAN

Final 2015 Program Report

April 2016

Prepared for:

Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA)
Edmonton, Alberta

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ALBERTA ENVIRONMENTAL MONITORING, EVALUATION AND REPORTING AGENCY

Prepared by:

HATFIELD CONSULTANTS

KILGOUR AND ASSOCIATES LTD.

and **WESTERN RESOURCE SOLUTIONS**

APRIL 2016

AEM7250.2

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ACKNOWLEDGEMENTS

The 2015 aquatics monitoring program was conducted in support of the Joint Oil Sands Monitoring Plan by the Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA) and the Hatfield Implementation Team under the direction of AEMERA, consisting of Hatfield Consultants (Hatfield), Kilgour and Associates Ltd. (Benthic Invertebrate Communities component) and Western Resource Solutions (Acid-Sensitive Lakes component).

The Hatfield Implementation Team would like to thank:

- Alberta Environment and Parks for conducting the field work required for the Acid-Sensitive Lakes component and providing water quality data from their ongoing Long-Term River Network monitoring programs for inclusion in the program report;
- Water Survey of Canada for access to their hydrology data for stations in the Athabasca oil sands region; and
- Oil sands industry representatives for providing discharge and withdrawal data specific to their operations, as well as a review of the land change analysis related to their development area.

In addition, the Hatfield Implementation Team would like to acknowledge the following contractors and laboratories that assisted with the 2015 Program:

- Alberta Innovates Technology Futures (chemical analyses);
- ALS Laboratory Group (chemical analyses);
- AXYS Analytical Services Ltd. (chemical analyses);
- Maxxam Analytics (chemical analyses and toxicity testing);
- Dr. Jack Zloty (benthic invertebrate taxonomy);
- Sue Salter, Cordillera Consulting (benthic invertebrate taxonomy QA/QC)
- Flett Research Ltd. (non-lethal fish tissue analyses);
- North/South Consultants Inc. (fish ageing);
- Dr. Chris Kennedy, Simon Fraser University (fish MFO analyses);
- University of Alberta Limnological Laboratory (chemical analyses for the Acid-Sensitive Lakes component);
- Teck Resources Ltd. (estimates of Potential Acid Input for the Acid-Sensitive Lakes component); and
- Dr. John Gibson, University of Victoria (run-off estimates for the Acid-Sensitive Lakes component).

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AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First Version of 2015 Draft Program Report for Regional Aquatics Monitoring in support of the Joint Oil Sands Monitoring Plan	March 31, 2016		
2	Final Version of 2015 Draft Program Report for Regional Aquatics Monitoring in support of the Joint Oil Sands Monitoring Plan	April 27, 2016	Dr. Wade N. Gibbons Project Director	Melissa Langridge Assistant Program Manager

EXECUTIVE SUMMARY

OVERVIEW

In 2012, the governments of Canada and Alberta developed a "Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring" (Canada and Government of Alberta 2012) specific to the Athabasca oil sands region of northeastern Alberta. The implementation plan was to build and expand on existing environmental monitoring programs for the Athabasca oil sands region, including the Regional Aquatics Monitoring Program (RAMP, www.ramp-alberta.org). RAMP was implemented in 1997 as a multi-stakeholder aquatics monitoring program to assess the health of rivers and lakes within the Athabasca oil sands region and to assess potential cumulative effects of oil sands development. The intent of the new joint implementation plan was to enhance these monitoring activities and work to integrate environmental monitoring across all environmental components (i.e., air, water, land, and biodiversity), which were historically monitored independently through separate organizations or programs.

As part of the Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring, the Joint Oil Sands Monitoring Plan (JOSMP, www.jointoilsandsmonitoring.ca) was initiated and executed from 2012 to 2015 to characterize the state of the environment in the Athabasca oil sands region, understand the cumulative effects of and changes to that environment, and develop recommendations for an integrated environmental monitoring program with an adaptive management framework for implementation. The RAMP Committees worked with the governments of Canada and Alberta to align aquatics monitoring activities historically undertaken by RAMP into the JOSMP, completing this process by April 1, 2014.

The Alberta Environmental Monitoring, Evaluation, and Reporting Agency (AEMERA, www.aemera.org) was established in 2014 and given the responsibility for the integration of all environmental monitoring in the province of Alberta, specifically to collect credible scientific data and other relevant information on the condition of Alberta's environment and to provide the public with open and transparent reporting and access to the data and information. The intent of AEMERA is to provide timely collection and objective reporting of scientific data and information on air, land, water, and biodiversity, including information necessary to understand cumulative effects, in order to better inform the public, policy makers, regulators, planners, researchers, communities, and industries.

With the expiry in March 2015 of the "Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring", AEMERA assumed responsibility for the coordination and implementation of the JOSMP in the Athabasca oil sands region. The transition of the JOSMP to AEMERA in 2015 included an expansion of aquatics monitoring previously conducted under the JOSMP to provide an increased coverage of the Athabasca oil sands region, a greater sampling frequency, and an increase in potential contaminants examined.

This document reports on the results of aquatics monitoring conducted under the JOSMP by AEMERA and Hatfield Consultants (Hatfield) under the direction of AEMERA in the 2015 Water Year (WY: 1 November 2014 to 31 October 2015); this monitoring was implemented on the basis of monitoring study designs developed by AEMERA. In this report, the aquatics monitoring conducted under the JOSMP by AEMERA and Hatfield in the 2015 Water Year, and the analysis and reporting of the results of this monitoring, are collectively termed the 2015 Program.

The study area for the 2015 Program was defined as the major watersheds in the Athabasca oil sands region within which oil sands developments have been approved. Monitoring for the 2015 Program occurred as far south as the town of Athabasca and extended north to the Athabasca River Delta. The watersheds in which monitoring occurred in the 2015 Program included:

- lower Athabasca River;
- major tributary watersheds/basins of the lower Athabasca River including the Clearwater River, Christina River, Hangingstone River, High Hills River, Horse River, Gregoire River, Steepbank River, Muskeg River, MacKay River, Ells River, Tar River, Calumet River, and Firebag River;
- select minor tributaries of the lower Athabasca River (McLean Creek, Mills Creek, Beaver River, Poplar Creek, Fort Creek, Pierre River, Eymundson Creek, Redclay Creek, and Big Creek);
- select minor tributaries to Christina Lake (Sunday Creek, Birch Creek, Jackfish River, Sawbones Creek, and two unnamed creeks);
- a minor tributary of the lower Peace River catchment (Alice Creek), which flows into Lake Claire of the Athabasca River Delta;
- specific wetlands and shallow lakes in the vicinity of current or planned oil sands and related developments; and
- a selected group of 50 regional acid-sensitive lakes.

The study area also included the Athabasca River Delta as the aquatic receiving environment for any oil sands developments occurring in the Athabasca oil sands region.

The monitoring approach for the 2015 Program incorporated a combination of both stressor- and effects-based monitoring approaches. Using impact predictions from the various oil sands environmental impact assessments (EIAs), specific potential stressors were identified and monitored to document *baseline* conditions, as well as potential changes related to oil sands development. Examples include specific water quality variables and changes in water quantity. In addition, there was a strong emphasis in the 2015 Program on monitoring sensitive biological indicators that reflect and integrate the overall condition of the aquatic environment such as benthic invertebrate communities and fish populations. Combining both monitoring approaches enabled a more holistic understanding of potential effects on the aquatic environment related to the development of oil sands projects to be achieved.

The scope of the 2015 Program focuses on the following key components of boreal aquatic ecosystems:

1. Climate and hydrology, monitored to provide a description of changing climatic conditions in the Athabasca oil sands region, as well as changes in the water level of selected lakes and in the quantity of water flowing through rivers and creeks.
2. Water quality in rivers and lakes, monitored to identify anthropogenic and natural factors affecting the quality of streams and lakes in the Athabasca oil sands region and to assess the potential exposure of fish and invertebrates to organic and inorganic chemicals.

3. Benthic invertebrate communities and sediment quality in rivers, lakes, and the Athabasca River Delta, monitored because they reflect habitat quality, serve as biological indicators, and are important components of fish habitat.
4. Fish populations in rivers and select lakes, monitored as they are biological indicators of ecosystem integrity and are a highly valued resource in the region.
5. Water quality in regional lakes, monitored to assess potential changes in water quality as a result of acidification.

A weight-of-evidence approach was used for the analyses of monitoring data obtained in the field component of the 2015 Program by applying multiple analytical methods to interpret results and determine whether any changes have occurred due to oil sands developments. The analyses:

- were conducted at the watershed/river basin level, with an emphasis on watersheds in which development has already occurred, as well as the lower Athabasca River at the regional level;
- used a set of measurement endpoints representing the health and integrity of valued environmental resources within each component; and
- used specific criteria (criteria used in oil sands project EIAs, provincial and federal water quality and sediment quality guidelines, and environmental effects monitoring criteria) for determining whether or not a change in values and levels of measurement endpoints had occurred and the extent of the significance of any change with respect to the health and integrity of valued environmental resources. The magnitude of change in the values of measurement endpoints was described as **Negligible-Low**, **Moderate**, or **High** relative to *baseline* conditions (see the tabular summary following the Executive Summary for details regarding these criteria).

The 2015 Program Report uses the following definitions for monitoring status:

- ***Test*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of oil sands developments; data collected from these locations are designated as *test* for the purposes of data analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but simply that data collected from these locations are being tested against *baseline* conditions to assess potential changes; and
- ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2015) or were (prior to 2015) upstream of all oil sands developments; data collected from these locations are designated as *baseline* for the purposes of data analysis, assessment, and reporting.

Land change due to oil sands development activities that had occurred in the study area up to and including 2015 was estimated with satellite imagery in conjunction with more detailed maps provided by a number of oil sands companies. Land change in the study area as of 2015 was estimated to be approximately 128,486 ha, which was an increase of 4,496 ha from 2014. The total area of land change represented approximately 3.49% of the total area of the watersheds in which these oil sands development activities are occurring, compared to 3.47% in 2014. The percentage of the area of watersheds with land change as of 2015 varied from less than 1% for many watersheds (MacKay, Horse, Pierre River, and Upper

Beaver watersheds), to 1% to 5% for the Steepbank, Calumet, Firebag, Ells, Christina, and Hangingstone watersheds, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, Poplar Creek, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries between Fort McMurray and the confluence of the Firebag River.

ASSESSMENT OF 2015 WY MONITORING RESULTS

A tabular summary of the 2015 WY results by watershed and component is presented at the end of this Executive Summary.

Lower Athabasca River and Athabasca River Delta

Hydrology Hydrometric monitoring for the Athabasca River was conducted at three *test* stations. The mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge in the 2015 WY were 1.1%, 1.8%, 0.7%, and 1.4% lower, respectively, in the Athabasca River observed (*test*) hydrograph than in the estimated (*baseline*) hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Water quality was monitored in the 2015 WY in the Athabasca River at ten *test* stations and one *baseline* station, and in the Athabasca River Delta at four *test* stations. Monthly data from 2015 indicate variations across months at all stations for most water quality measurement endpoints, with concentrations of TSS and associated nutrients and metals highest during freshet and concentrations of TDS and associated dissolved constituents highest during lower flows in the fall. Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years. Differences in water quality in fall 2015 for all stations monitored in the Athabasca River and Athabasca River Delta and regional *baseline* fall conditions were classified as **Negligible-Low**.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities and sediment quality were monitored in the Athabasca River Delta in fall 2015 at four depositional *test* stations. Variations in benthic invertebrate community measurement endpoints compared to historical *baseline* conditions were classified as:

- **Negligible-Low** at Big Point Channel, Fletcher Channel, and Embarras River; and
- **Moderate** at Goose Island Channel on the basis of high abundances (greater than 120,000 individuals per m^2) and the dominance of tubificids.

Concentrations of sediment quality measurement endpoints were below guideline concentrations in fall 2015, with the exception of:

- total arsenic at *test* stations on the Embarras River and on the Athabasca River at Northlands and above the Muskeg River;
- Fraction 3 hydrocarbons at *test* stations on Goose Island Channel and the Embarras River; and
- predicted PAH toxicity at *test* stations on Big Point Channel, Embarras River, and on the Athabasca River at Northlands and above and below the Muskeg River, and at a *baseline* station on the Athabasca River at Poachers Landing.

Fall sediment quality results for stations monitored in 2015 on the Athabasca River mainstem and in the Athabasca River Delta were not classified. A Sediment Quality Index could not be calculated for these stations because there are no regional *baseline* concentrations for sediment quality for either the Athabasca River mainstem or the Athabasca River Delta against which the 2015 conditions could be assessed.

Fish Populations (Wild Fish Health) Wild fish health monitoring was conducted in the Athabasca River in fall 2015 at five *test* reaches and four *baseline* reaches using trout perch as the target species. There was a concentration of changes in values of wild fish health measurement endpoints starting at the *test* reach below the Muskeg River confluence, becoming more prominent at the *test* reach above the Ells River confluence, and then dissipating at the *test* reach near the Athabasca River Delta. A similar spatial trend was found in liver enzyme activity (i.e., Ethoxyresorufin-O-deethylase [EROD] induction) of trout perch, measured to evaluate the potential exposure of fish to contaminants such as PAHs. When each monitoring reach was compared to the reach located immediately upstream (i.e., considered a "*baseline*" reach for comparison purposes in an effort to test for specific influences of interest), the classification of results for wild fish health was assessed as:

- **High** at *test* reaches below the Firebag River and above the Ells River;
- **Moderate** at *baseline* reaches at Poachers Landing, above Fort McMurray, and below Fort McMurray at Northlands, and at *test* reaches below the Muskeg River and near the Athabasca River Delta; and
- **Negligible-Low** at the *test* reach above the Muskeg River.

Muskeg River Watershed

Hydrology Hydrometric monitoring of the Muskeg River watershed in the 2015 WY was conducted at 11 *test* stations and two *baseline* stations. The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were +2.1%, +11.1%, -3.8%, and +4.6%, respectively, in the observed *test* hydrograph compared to the estimated *baseline* hydrograph. The differences in mean open-water discharge, annual maximum daily discharge, and open-water minimum daily discharge were classified as **Negligible-Low** and the difference in mean winter discharge was classified as **Moderate.** The results of a quantitative longitudinal assessment of the Muskeg River suggest that the magnitude of hydrologic impacts was generally **Moderate** to **High** in the mid reaches of the Muskeg River between Jackpine and Stanley creeks and generally **Negligible-Low** to **Moderate** above Stanley Creek.

In the 2015 WY, the water level of Kearl Lake generally decreased for most of the water year, and stabilized from July to October, 2015. Lake levels were typically between the historical lower quartile levels and historic minimum levels, with occasional periods in summer that were below historic minimum levels.

Water Quality Water quality was monitored in the Muskeg River watershed in the 2015 WY at nine *test* stations on the Muskeg River, two *test* and two *baseline* stations on Jackpine Creek, one *test* station on Wapasu Creek, one *test* station on Stanley Creek, and one *test* station in Kearl Lake. At long-term monitoring stations in the Muskeg River mainstem and its tributaries, water quality was similar to previous years, and concentrations of most water quality measurement endpoints were within the range of *baseline* conditions. Monthly trends in water quality for 2015 at monitoring stations established in 2015 were similar to monthly trends in water quality at the long-term stations. Continuous monitoring data indicated higher concentrations of dissolved oxygen in lower-river stations than at stations located in slower-flowing, lentic stations further upstream on the mainstem. Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years. Differences in water quality conditions at all stations in fall 2015 compared to regional *baseline* water quality conditions were classified as **Negligible-Low**.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in the Muskeg River in fall 2015 at one erosional *test* station and two depositional *test* stations, in Jackpine Creek at one depositional *test* station and one depositional *baseline* station, and in Kearl Lake at one depositional *test* station. Variations in the values of measurement endpoints for benthic invertebrate communities were classified as:

- **Negligible-Low** at all *test* reaches of the Muskeg River: (i) the benthic invertebrate communities at these reaches in fall 2015 contained fauna typically associated with good environmental conditions; (ii) there were no significant differences in values of benthic invertebrate community measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance that also implied degrading conditions for benthic invertebrate communities; and (iii) none of the excursions in values of benthic invertebrate community measurement endpoints in fall 2015 outside of normal ranges implied degrading conditions for benthic invertebrate communities.

- **Negligible-Low** at the lower *test* reach in Jackpine Creek: (i) the benthic invertebrate community in fall 2015 contained a rich and diverse fauna, including several taxa that are typically associated with relatively good environmental conditions; (ii) none of the significant differences in values of benthic invertebrate community measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities; and (iii) while the value of one of the six measurement endpoints in fall 2015 (equitability) was beyond the inner tolerance limit of the 95^{th} percentile of the normal range of values of prior years, the excursion did not imply degrading conditions for benthic invertebrate communities.

- **Negligible-Low** at the *test* station in Kearl Lake: (i) the benthic invertebrate community in fall 2015 contained a diverse fauna and included several taxa that are typically associated with relatively good environmental conditions; (ii) none of the significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities; and (iii) while values of three of the six measurement endpoints in fall 2015 were beyond the inner tolerance limit of the 95^{th} percentile of the normal range of values of prior years, none of these excursions outside of normal ranges implied degrading conditions for benthic invertebrate communities.

Values of sediment quality measurement endpoints were within the range of regional *baseline* conditions at all stations within the Muskeg River watershed, with the exception of total metals and carbon-normalized total PAHs at the middle *test* station on the Muskeg River, carbon-normalized total PAHs at the *baseline* station on Jackpine Creek, and total metals (when normalized to percent fine sediments) at the *test* station on Jackpine Creek. Sediment quality at all river stations within the Muskeg River watershed indicated **Negligible-Low** differences from regional *baseline* conditions. Sediment quality index values were not calculated for Kearl Lake because lakes were not included in the regional *baseline* calculations of sediment quality.

Fish Populations (Fish Communities) Fish communities were assessed in the Muskeg River watershed in fall 2015 at one *test* reach in the Muskeg River, and at one *test* and one *baseline* reach in Jackpine Creek. Differences in measurement endpoints for fish communities were classified as:

- **Negligible-Low** for the *test* reach in the Muskeg River compared to regional *baseline* reaches: (i) there were no significant differences in values of fish community measurement endpoints that implied a negative change in the fish community, and (ii) the mean values of all measurement endpoints for fish community monitoring at the *test* reach in fall 2015 were within the ranges of regional *baseline* values.

- **Negligible-Low** at the lower *test* reach in Jackpine Creek: (i) there were no significant changes in values of fish community measurement endpoints that explained greater than 20% of the variance in annual means, and (ii) although there have been decreases in abundance at the *test* reach since 2010, abundance, CPUE, richness, and diversity were higher in 2015 compared to 2014, which may indicate improving conditions for fish communities.

Fish Populations (Wild Fish Health) Wild fish health was assessed in fall 2015 at one *test* reach in the Muskeg River using lake chub as the target species. Because an upstream *baseline* reach on the Muskeg River was not sampled in 2015, quantitative comparisons for assessing potential effects could not be conducted; qualitative comparisons of values of wild fish health measurement endpoints were therefore made against regional *baseline* reaches in other watersheds where lake chub was monitored in 2015. Values of wild fish health measurement endpoints of female lake chub at the *test* reach in the Muskeg River were relatively similar to measurement endpoints of female lake chub at regional *baseline* reaches with the exception of relative liver size, which were smaller in fish at the *test* reach in the Muskeg River. Temporal comparisons were not possible because 2015 was the first year of fish health monitoring at this *test* reach.

Steepbank River Watershed

Hydrology Hydrometric monitoring for the Steepbank River watershed in the 2015 WY was conducted at two *test* stations. The 2015 WY, mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were all 0.44% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality Water quality monitoring was conducted in the 2015 WY at five *test* stations on the Steepbank River. There were clear temporal variations in water quality measurement endpoints at individual stations across months in the 2015 WY. Concentrations of nutrients and metals had within-year temporal trends similar to the levels of particulates (i.e., total suspended solids), while concentrations of major ions had within-year temporal trends similar to trends in concentration of total dissolved solids.

Generally, water quality measurement endpoints in the 2015 WY fell within historical monthly ranges of available historical data. Continuous water quality data indicated consistently high dissolved oxygen and typically low turbidity at all monitoring stations. There were **Negligible-Low** differences in water quality conditions for all stations in fall 2015 compared to regional *baseline* water quality conditions. Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years.

Fish Populations (Fish Communities) Fish communities were assessed in the Steepbank River in fall 2015 at one lower *test* reach and one upper *baseline* reach. Differences between values of fish community measurement endpoints at the lower *test* reach compared to *baseline* conditions were classified as **High** as three of the five measurement endpoints (abundance, richness, and CPUE) have significantly decreased over time; these significant trends explained more than 20% of the variation in annual means.

Tar River Watershed

Hydrology Hydrometric monitoring for the Tar River watershed in the 2015 WY was conducted at one *test* station and one *baseline* station. The 2015 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 29.06% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph for the Tar River near the mouth. These differences were classified as **High**. Differences in the values of the three hydrologic measurement endpoints between *test* and *baseline* cases were assessed as **High** from the mouth of the Tar River to approximately 6 km upstream, **Moderate** for the next 7 km upstream, and **Negligible-Low** for the next 7 km to the upper *baseline* station.

Water Quality Water quality was monitored in the 2015 WY at one *test* station and one *baseline* station on the Tar River. There were no obvious monthly trends in values of most of the water quality measurement endpoints at either station from May to October 2015. Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years. The ionic composition of water at both stations was consistent with historical observations and most water quality measurement endpoints were within the range of previously-measured concentrations and consistent with regional *baseline* concentrations. Water quality index values calculated for fall 2015 indicated **Negligible-Low** differences in water quality for fall 2015 at both stations compared to regional *baseline* ranges.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in the Tar River in fall 2015 at one depositional *test* reach and one erosional *baseline* reach. Variations in the values of measurement endpoints for benthic invertebrate communities of the Tar River were classified as **Moderate** at the lower *test* reach: (i) the benthic invertebrate community at the *test* reach in fall 2015 did not contain taxa typically associated with good environmental conditions, (ii) Ephemeroptera were missing from the benthic invertebrate community in fall 2015 and have not been present at the *test* reach since 2012, indicating a compromised community and degraded conditions; and (iii) two benthic invertebrate community measurement endpoints had significant differences in values between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means and which implied degrading conditions for benthic invertebrate communities.

Sediment quality was monitored in fall 2015 at the lower *test* station on the Tar River. Differences in sediment quality conditions in 2015 between the *test* station and regional *baseline* conditions were classified as **Negligible-Low** as all sediment quality measurement endpoints at the *test* station in fall 2015 were within regional *baseline* concentrations. Concentrations of naphthalene, retene, and total parent PAH values in fall 2015 were below previously-measured minimums, while concentrations of the heavier hydrocarbon fractions (Fraction 3 and 4) exceeded previously-measured maxima. Concentrations of measurement endpoints of sediment quality were below guideline concentrations in fall 2015, with the exception of predicted PAH toxicity and the PAH hazard index. There have been significant increases in concentrations of Fraction 1, 2, 3, and 4 hydrocarbons at this *test* station over the period of the monitoring record.

Fish Populations (Fish Communities) Fish communities were assessed in fall 2015 at one *baseline* reach in the Tar River. Mean values of all measurement endpoints were higher at the *baseline* reach in fall 2015 compared to fall 2014. Differences between values of fish community measurement endpoints at the lower *baseline* reach compared to the normal range of variability for *baseline* conditions were classified as **Negligible-Low** because there were no significant changes in measurement endpoints that explained more than 20% of the variance in annual means.

MacKay River Watershed

Hydrology Hydrometric monitoring for the MacKay River watershed in the 2015 WY was conducted at one *test* station and three *baseline* stations. The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.009%, 0.021%, 0.016%, 0.021% higher, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Water quality was monitored in the MacKay River watershed in the 2015 WY at three *test* stations and two *baseline* stations on the MacKay River and at three *baseline* stations on the Dover River. There was generally low monthly variation in concentrations of water quality measurement endpoints between May and October in the 2015 WY. Concentrations of all water quality measurement endpoints in fall 2015 at long-term monitoring stations on the MacKay River were within previously-measured concentrations with the exception of total parent PAHs at the *baseline* station, with a measured concentration in fall 2015 that exceeded the previously-measured maximum concentration. The only significant trends in fall concentrations of water quality measurement endpoints were decreases in arsenic and sulphate at the *test* station near the MacKay River mouth. Concentrations of all water quality measurement endpoints in fall 2015 were within the range of historical fall concentrations and regional fall *baseline* concentrations with the exception of a number of major ions at the Dover River stations with concentrations that exceeded the 95th percentile of regional *baseline* concentrations and total suspended solids at several stations with concentrations that were below the 5th percentile of regional *baseline* concentrations. Water quality index values calculated for fall 2015 indicated **Negligible-Low** differences in water quality for fall 2015 at all stations in the Mackay River watershed compared to regional *baseline* ranges.

Sediment Quality Sediment quality was monitored in the MacKay River watershed in fall 2015 at two *test* stations and one *baseline* station on the MacKay River, and at three *baseline* stations on the Dover River. Values of all sediment quality measurement endpoints were below guideline concentrations at all stations of the Dover River and the upper stations of the MacKay River and, with the exception of total PAHs (absolute and carbon-normalized) and the PAH hazard index level at the lower *test* station on the MacKay River, all sediment quality measurement endpoints were within the ranges of regional *baseline* conditions for stations within the MacKay River watershed. Sediment quality index values calculated for fall 2015 indicated **Negligible-Low** differences in sediment quality for fall 2015 at all stations in the Mackay River watershed compared to regional *baseline* ranges.

Fish Populations (Fish Communities) Fish communities were monitored in fall 2015 at one *test* reach in the lower MacKay River. Differences in measurement endpoints of the fish community at the *test* reach were classified as **Negligible-Low**. There were no significant changes in measurement endpoints over time and mean values of most measurement endpoints for fish community monitoring at the *test* reach in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints. Species richness was above the regional *baseline* range, indicating a positive change.

Fish Populations (Wild Fish Health) Wild fish health was assessed at two *test* reaches and one *baseline* reach in the MacKay River using longnose dace as the target species, and at three *baseline* reaches in the Dover River using lake chub as the target species. The classification of effects for reaches of the MacKay River was assessed as:

- **Moderate** for the lower *test* reach because an exceedance of the effects criteria associated with significant differences was measured in one of five measurement endpoints (relative liver size of male longnose dace) compared to the upper *baseline* reach in the MacKay River; and

- **Negligible-Low** for the middle *test* reach because no significant differences were measured in any of the measurement endpoints compared to the upper *baseline* reach in the MacKay River.

Reaches of the Dover River consisted solely of *baseline* reaches in fall 2015; therefore, no classification of results could be assessed.

Calumet River Watershed

Hydrology Hydrometric monitoring for the Calumet River watershed in the 2015 WY was conducted at one *test* station. The 2015 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were 4.24% higher, 0.25% lower, and 0.25% lower, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Water quality was monitored in the Calumet River in the 2015 WY at one *test* station and one *baseline* station. There were inconsistent within-year trends in the concentrations and levels of most of the water quality measurement endpoints at the lower *test* station from May to September 2015. Temporal trends in the concentrations of all major ions except potassium and sulphate were similar to temporal trends in the concentration of total dissolved solids, but temporal trends in concentration of particulate-associated metals were not similar to temporal trends in the concentration of total suspended solids. Concentrations of most water quality measurement endpoints were within previously-measured ranges for both stations. Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years. Concentrations of all water quality variables were within the regional baseline concentrations in fall 2015, with the exception of total suspended solids. Water quality index values calculated for fall 2015 indicated **Negligible-Low** differences in water quality for fall 2015 at both stations compared to regional *baseline* ranges.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in fall 2015 at one depositional *test* reach and one depositional *baseline* reach in the Calumet River. Variations in measurement endpoints for benthic invertebrate communities at the lower *test* reach were classified as **Negligible-Low.** Although values of benthic invertebrate community measurement endpoints at the lower *test* reach differed from upper *baseline* reach, none of the differences indicated degrading conditions for benthic invertebrate communities at lower *test* reach. The lower *test* reach contained a rich and diverse benthic invertebrate community, with various genera of mayflies, stoneflies and caddisflies, which indicate good habitat quality.

Values of sediment quality measurement endpoints were within the range of regional *baseline* conditions with the exception of total PAHs (absolute and carbon-normalized) and total hydrocarbons at the lower *test* station and total metals at the *baseline* station, all of which exceeded the 95th percentile of regional *baseline* concentrations. Concentrations of Fraction 2 and 3 hydrocarbons, chrysene, and dibenz(a,h)anthracene in sediment exceeded the guidelines at the *test* station in fall 2015 while concentrations of Fraction 3 hydrocarbons and total arsenic exceeded the guidelines at the *baseline* station. Temporal trend analyses for sediment quality measurement endpoints were not possible for either station due to the limited years of historical data available. Sediment quality index values calculated for fall 2015 indicated **Moderate** and **Negligible-Low** differences in sediment quality for fall 2015 at the lower *test* station and the upper *baseline* station, respectively, compared to regional *baseline* ranges.

Firebag River Watershed

Hydrology Hydrometric monitoring in the Firebag River watershed in the 2015 WY was conducted at two *test* stations and one *baseline* station, and the McClelland Lake levels were recorded at one *test* station. The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.50%, 0.52%, 0.22%, and 0.56% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

The water level at McClelland Lake in winter of the 2015 WY was generally above historic maxima from November 2014 to mid-May 2015, when the annual peak lake level was recorded. Water levels then generally fell for the remainder of the water year. Water levels were above the median historic level until early August, and were between the mean and the lower historic quartile for the remainder of the water year.

Water Quality Water quality was monitored in the Firebag River watershed in the 2015 WY at two *test* stations and one *baseline* station on the Firebag River, as well as at one *test* lake (McClelland Lake) and one *baseline* lake (Johnson Lake). Water quality of the Firebag River and McClelland and Johnson lakes were similar to measurements in previous years, with similar water quality at upper and lower Firebag River stations and generally consistent monthly trends at all riverine and lacustrine stations. Concentrations of most water quality measurement endpoints and ion balance at all were within the previously-measured historical ranges. Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years. Water quality index values calculated for fall 2015 indicated **Negligible-Low** differences in water quality for fall 2015 at all stations on the Firebag River compared to regional *baseline* ranges. Concentrations of water quality measurement endpoints for lake stations were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in fall 2015 at one depositional *test* reach in the Firebag River, one *test* lake, and one *baseline* lake. Variations in measurement endpoints of benthic invertebrate communities were classified as:

- **Moderate** at the lower *test* reach in the Firebag River: richness in lower *test* reach was significantly lower in fall 2015 than the mean of all prior years; this difference accounted for more than 20% of the variation in annual means and was indicative of degrading conditions for benthic invertebrate communities.

- **Negligible-Low** at McClelland Lake: (i) while there were statistically-significant temporal differences in values of benthic invertebrate community key measurement endpoints that accounted for more than 20% of the variation in annual means, none were indicative of degrading conditions for benthic invertebrate communities; (ii) values of all benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limits for the normal range of variation of previous years; and (iii) the general composition of the community in terms of relative abundances of benthic taxa, presence of fully aquatic forms and presence of generally sensitive taxa, such as the mayfly *Caenis* and two types of caddisflies, suggested that the community of McClelland Lake was in good condition and generally consistent with *baseline* conditions.

The benthic invertebrate community of Johnson Lake in fall 2015 showed some variation in composition from 2014, with an increase in richness and the presence of EPT taxa, which were not observed in 2013. In addition, the presence of permanent aquatic forms such as amphipods, gastropods and bivalves indicated that Johnson Lake was in good condition for benthic invertebrate communities in fall 2015.

Sediment quality index values calculated at the lower *test* station on the Firebag River for fall 2015 indicated **Negligible-Low** differences in sediment quality compared to regional *baseline* ranges. Values of sediment quality measurement endpoints were not compared to regional *baseline* concentrations for McClelland Lake or Johnson Lake because lakes were not included in the calculation of *baseline* concentrations.

Ells River Watershed

Hydrology Hydrometric monitoring for the Ells River watershed in the 2015 WY was conducted at one *test* station and one *baseline* station. The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.15% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences are classified as **Negligible-Low**.

Water Quality Water quality was monitored in the Ells River watershed in 2015 WY at four *test* stations and *two* baseline stations on the Ells River, and in two *baseline* lakes: Gardiner Lake; and Namur Lake. Concentrations of a number of water quality measurement endpoints showed intra-year variation at both *test* and *baseline* stations, with concentrations of total suspended solids and associated nutrients and metals being highest in May and concentrations of total dissolved solids and associated ionic constituents being highest in July and August. Concentrations of most water quality variables were higher at Gardiner Lake than at Namur Lake. Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years. Water quality index values calculated for fall 2015 indicated **Negligible-Low** differences in water quality for fall 2015 at all stations on the Ells River compared to regional *baseline* ranges. Concentrations of water quality measurement endpoints for Gardiner and Namur lakes were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in fall 2015 at one depositional *test* reach in the Ells River, and at depositional *baseline* stations in two lakes. Differences in measurement endpoints for the benthic invertebrate community at the *test* reach in the lower Ells River were classified as **Negligible-Low**: (i) significant increases in Correspondence Analysis (CA) Axis 1 scores over time were not indicative of degrading conditions, and (ii) all measurement endpoints were within the inner tolerance limits of the normal range of variation for previous years of sampling, with the exception of %EPT, which was not significantly different in fall 2015 than in previous years, signifying no change in conditions.

The benthic invertebrate communities of both Namur and Gardiner lakes in fall 2015 were consistent with relatively high quality benthic habitats, with the presence of Ephemeroptera and Trichoptera taxa and permanent aquatic forms (e.g., bivalves, gastropods).

Sediment quality was assessed in fall 2015 at three *test* stations and one *baseline* station on the Ells River, and two *baseline* lakes.

Differences in sediment quality index values calculated for stations on the Ells River for fall 2015, compared to regional *baseline* conditions were:

- **High** at the lower *test* station due to high concentrations of petroleum hydrocarbons and PAHs;
- **Moderate** at the *test* station near the mouth due to high concentrations of petroleum hydrocarbons and PAHs; and
- **Negligible-Low** at the middle *test* station and upper *baseline* station.

Sediment quality index values were not calculated for *baseline* stations in Namur Lake and Gardiner Lake because lakes were not included in the regional *baseline* calculations. No sediment guidelines or threshold values were exceeded at either lake station in 2015.

Fish Populations (Fish Communities) Fish communities were monitored at one *test* reach in the Ells River. Differences in measurement endpoints for the fish community at the *test* reach were classified as **Negligible-Low**: (i) mean values of all measurement endpoints for fish community monitoring at the *test* reach in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints, (ii) while the statistically-significant decreases in abundance and the Assemblage Tolerance Index (ATI) over time from 2010 to 2015 are consistent with a potential negative change in the fish community at the *test* reach, less than 20% of the variance in annual means is explained by these decreasing trends.

Fish Populations (Wild Fish Health) Wild fish health was assessed in fall 2015 at two *test* reaches and one *baseline* reach in the Ells River using lake chub as the target species. The classification of effects for reaches of the Ells River was assessed as:

- **Moderate** for the lower *test* reach because female lake chub were significantly younger than female lake chub at the middle *test* reach, and male lake chub were significantly younger than both the middle *test* and upper *baseline* reaches and magnitude of these significant differences exceeded the Environment Canada effects criteria; and

- **Negligible-Low** for the middle *test* reach because there were no significant differences in values of measurement endpoints for wild fish health at middle *test* reach compared to the upper *baseline* reach.

Clearwater River Watershed

Hydrology Hydrometric monitoring for the Clearwater River watershed in the 2015 WY was conducted at one *test* station and two *baseline* stations. The assessed hydrologic change classification for the Clearwater River was **Negligible-Low**, which was based on the calculated hydrologic change from the Christina River and then proportionally scaled to the increased watershed size in the Clearwater River.

Water Quality Water quality was monitored in the Clearwater River watershed in the 2015 WY at two *test* stations and one *baseline* station on the Clearwater River, and at one *baseline* station on the High Hills River. The ionic composition of water at all stations in the Clearwater River watershed in fall 2015 was similar to previous years. Concentrations of most water quality measurement endpoints measured in fall 2015 were within the ranges of regional *baseline* conditions. Differences in water quality conditions in fall 2015 compared to regional *baseline* conditions were:

- **Moderate** at the *baseline* station in the upper Clearwater River; and
- **Negligible-Low** at the lower *test* station on the Clearwater River and at the *baseline* station on the High Hills River.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in the Clearwater River watershed fall 2015 at one depositional *test* reach and one depositional *baseline* reach in the Clearwater River, and at one erosional *baseline* reach in the High Hills River. Variations in measurement endpoints of benthic invertebrate communities were classified as **Negligible-Low** at the *test* reach in the Clearwater River: (i) variations in CA Axis 1 scores at the *test* reach were unlikely to be related to oil sands development given similar trends were observed at both the *test* and *baseline* reaches, and (ii) the percentage of sensitive EPT taxa was higher at the *test* reach than at the *baseline* reach, indicating that conditions are not degrading in the lower Clearwater River. The benthic invertebrate community of the *baseline* reach in the High Hills River reflected good water and sediment quality, with a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies.

Differences in sediment quality conditions in fall 2015 at both *test* and *baseline* stations in the Clearwater River watershed compared to regional *baseline* sediment quality conditions were **Negligible-Low**.

Christina River Watershed

Hydrology Hydrometric monitoring for the Christina River watershed in the 2015 WY was conducted at nine *test* stations and three *baseline* stations. The water balance analysis was conducted for the *test* station near the mouth. Water balance analysis showed that differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrographs were +0.05%, +0.06%, +0.06%, and +0.05%, respectively. These differences were classified as **Negligible-Low**.

Water Quality Water quality was monitoring in the Christina River watershed in the 2015 WY at four *test* stations and one *baseline* station on the Christina River, four *test* stations, and two *baseline* stations on tributaries to Christina Lake, two *test* stations on tributaries to the Christina River, and two *test* lakes.

Concentrations of most water quality measurement endpoints in the Christina River and its tributaries exhibited relatively consistent seasonal changes, with total dissolved solids and dissolved ions lowest in May during freshet, and higher in months with lower flows. Concentrations of some water quality measurement endpoints (e.g., total dissolved solids, boron, sodium, chloride, and sulphate) were generally higher in each month at the lower *test* station on the Christina River and on Gregoire River than at other *test* and *baseline* stations. Concentrations of most water quality measurement endpoints were within the historical monthly ranges.

Concentrations of water quality measurement endpoints in fall 2015 were within regional *baseline* concentrations with few exceptions, including total dissolved phosphorus, sodium, calcium, chloride, and total boron, which exceeded the 95th percentile of regional *baseline* concentrations the lower *test* station on the Christina River and on Gregoire River and *baseline* stations on the upper Christina River and Birch Creek. In contrast, concentrations of total suspended solids, total dissolved solids, total boron, total mercury, magnesium, and potassium were lower than the 5th percentile of regional *baseline* concentrations at *test* stations in Jackfish River, Gregoire River, Sawbones Creek and two unnamed creeks flowing into Christina Lake and at *baseline* stations in Birch Creek and Sunday Creek. The ionic composition of water at all stations in the Christina River watershed in fall 2015 was similar to previous years. Differences in water quality in fall 2015 at all stations in the Christina River and its tributaries compared to regional *baseline* conditions were classified as **Negligible-Low**. Classifications were not generated for *test* stations in Christina Lake and Gregoire Lake because lakes were not included in the regional *baseline* conditions given the ecological differences between lakes and rivers.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in the Christina River watershed in the 2015 WY at three depositional *test* reaches, one erosional *test* reach, and one depositional *baseline* reach on the Christina River, four depositional *test* stations and two depositional *baseline* stations on tributaries to Christina Lake, two erosional *test* stations on tributaries to the Christina River, and two depositional *test* lakes.

Variations in measurement endpoints for benthic invertebrate communities in the Christina River were classified as:

- **Moderate** at the lower depositional *test* reach because while the benthic invertebrate community at the *test* reach in fall 2015 included several taxa that are typically associated with relatively good environmental conditions, values of all measurement endpoints for fall 2015 were outside the inner tolerance limits of the normal range of variation from previous years of sampling, including a lower %EPT than previous years.

- **Negligible-Low** at the middle depositional *test* reach because the significant difference in CA 1 Axis scores over time that accounted for more than 20% of the variance in annual means did not imply degrading conditions for benthic invertebrate communities, and values of all measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of variation from previous years of monitoring.

- **Negligible-Low** at the upper depositional *test* reach because no significant changes in values of measurement endpoints at the *test* reach were measured between 2015 and 2014 and values of all measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches.

Variations in values of measurement endpoints for benthic invertebrate communities at the erosional *test* reach in the Christina River in fall 2015 were not classified because there are only two years of data for this station, which were collected eight years apart; during this time the reach changed from *baseline* to *test*.

Differences in values of measurement endpoints for benthic invertebrate communities at reaches monitored in fall 2015 in Sunday Creek were classified as **High** because the results of temporal and spatial comparisons contain significant differences in values for three measurement endpoints – richness, equitability, and %EPT – for the *test* reach that explain more than 20% of the variation in annual means.

Variations in values of measurement endpoints of benthic invertebrate communities monitored in fall 2015 in Sawbones Creek were classified as **Moderate** because there were significant differences in values of two measurement endpoints (abundance and %EPT) in the temporal comparisons that accounted for more than 20% of the variance in annual means.

Variations in values of measurement endpoints of benthic invertebrate communities at the two unnamed creeks that flow into Christina Lake were classified as **Negligible-Low** because there were no significant variations over time at the monitored reaches and values of all measurement endpoints in fall 2015 for the monitored reaches were within normal ranges for *baseline* reaches.

Variations in the values of measurement endpoints for benthic invertebrate communities of the Jackfish River in fall 2015 were classified as **Moderate**. While the benthic invertebrate community in fall 2015 contained a benthic fauna that reflected good water and sediment quality, two of the three significant differences in values of measurement endpoints (taxa richness and %EPT) between 2015 and the mean of the prior years that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities. It should be emphasized that values of measurement endpoints for benthic invertebrate communities for 2015 were adjusted to account for the change in sampling gear and this classification should be interpreted with caution.

Variations in the values of measurement endpoints for benthic invertebrate communities of Gregoire River for fall 2015 were classified as **Negligible-Low**. The benthic invertebrate community monitored on the Gregoire River in fall 2015 contained a benthic fauna representative of a healthy erosional river and none of the significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.

Variations in values of the measurement endpoints of the benthic invertebrate community in Christina Lake in fall 2015 were classified as **High** because there were significant differences in values of all measurement endpoints in the temporal comparisons that accounted for more than 20% of the variance in annual means; it is worth noting that the lake in 2015 contained a diverse benthic fauna that included several permanently aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies and caddisflies).

Differences in measurement endpoints of the benthic invertebrate community in Gregoire Lake in fall 2015 were classified as **Negligible-Low** given none of temporal comparisons for benthic invertebrate communities of Gregoire Lake accounted for significant variation.

In fall 2015, concentrations of sediment quality measurement endpoints were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations at all stations. Differences in sediment quality conditions in fall 2015 at all sediment quality stations in the Christina River watershed were **Negligible-Low** compared to regional *baseline* conditions. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations for Christina Lake or Gregoire Lake because lakes were not included in the calculation of *baseline* concentrations.

Fish Populations (Fish Communities) Fish communities were monitoring in fall 2015 at one *test* reach of the Christina River, four *test* reaches and two *baseline* reaches in tributaries to Christina Lake, and one *test* reach in Jackfish River. Differences in values of fish community measurement endpoints for the *test* reaches in the Christina River, Jackfish River and Sunday Creek were classified as **Negligible-Low** because: (i) there were no significant changes in values of measurement endpoints for these *test* reaches in either spatial comparisons to *baseline* reaches or in changes over time that implied a negative change in the fish communities at those reaches; and (ii) mean values of all measurement endpoints at these *test* reaches were within the ranges of regional *baseline* values for these measurement endpoints.

No spatial or temporal comparisons were conducted for Sawbones Creek or the two unnamed creeks flowing into Christina Lake; reliable statistical analysis was not possible for these reaches because too few fish have been captured at these reaches during the entire monitoring period. Similarly, comparisons of values of fish community measurement endpoints to regional *baseline* values were not made for these reaches.

Fish Populations (Wild Fish Health) Wild fish health was assessed at one *test* reach in the Jackfish River, one *test* reach in Sawbones Creek, and one *test* reach on Sunday Creek using slimy sculpin as the target species. Classification of results for wild fish health monitoring in the Christina River watershed in 2015 was not possible because no *baseline* reaches were sampled in the Christina River watershed for the wild fish health component in 2015 and the target fish species, slimy sculpin, was not sampled at any regional *baseline* reach during the 2015 Program.

Hangingstone River Watershed

Hydrology Hydrometric monitoring for the Hangingstone River watershed in the 2015 WY was conducted at two *test* stations. For the 2015 WY, the differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrograph for the Hangingstone River were all 0.30%. These differences were classified as **Negligible-Low**.

Water Quality Water quality monitoring was conducted at two *test* stations on the Hangingstone River in the 2015 WY. Monthly variation in water quality showed similar trends at both *test* stations, with concentrations of suspended solids and several associated nutrients and metals highest during freshet and lowest in September and October at open-water low flows, and concentrations of total dissolved solids and most dissolved ions and metals showing an inverse relationship with flow. Generally, concentrations of most water quality measurement endpoints were higher at the lower *test* station than at the upper *test* station. Monthly water quality measurement endpoints at both stations were generally within historical monthly ranges. Concentrations of all water quality measurement endpoints in fall 2015 were lower than or within the previously-measured ranges except chloride at both stations (higher than previously-measured maximum concentrations), and naphthenic acids, oilsands extractable acids, and total alkylated PAHs at the upper *test* station (lower than previously-measured minimum concentrations). Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years. Differences in water quality in fall 2015 between *test* stations and the regional *baseline* fall conditions were classified as **Moderate** for the lower *test* station and **Negligible-Low** for the upper *test* station.

Benthic Invertebrate Communities Benthic invertebrate communities were monitored at one erosional *test* reach in the Hangingstone River. Variations in the values of measurement endpoints for benthic invertebrate communities of the Hangingstone River were classified as **Negligible-Low** because values of all six benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of *baseline* values for erosional habitats. In addition, the benthic invertebrate community in fall 2015 contained numerous taxa associated with good environmental conditions including a diverse and rich fauna.

Fish Populations (Wild Fish Health) Wild fish health was assessed at the upper *test* reach of the Hangingstone River in fall 2015 using longnose dace as the target species. Because an upstream *baseline* reach on the Hangingstone River was not sampled in 2015, quantitative comparisons for assessing potential effects could not be conducted. To provide context to the results for the *test* reach on the Hangingstone River, qualitative comparisons of measurement endpoints were made with a *baseline* reach on the MacKay River that also used longnose dace as the target species. These comparisons indicated that longnose dace in the Hangingstone River were relatively younger with smaller relative gonad and liver sizes than longnose dace in the MacKay River. Temporal comparisons were not possible because 2015 was the first year of fish health monitoring at the upper *test* reach in the Hangingstone River.

Pierre River Area

Hydrology Hydrometric data were collected in the 2015 WY from four *baseline* stations in the Pierre River area to develop hydrographs for each watershed but water balances were not completed given that there had been no oil sands development in the Pierre River area as of 2015.

Water Quality Water quality was monitored in the 2015 WY at four *baseline* stations in the Pierre River area. Monthly water quality samples collected between May and September in Big Creek exhibited higher concentrations of total suspended solids, associated metals, and PAHs in May and June during high flows, and higher concentrations of dissolved constituents, total dissolved solids and associated major ions in fall during low flows. Concentrations and levels of water quality measurement endpoints at all four *baseline* stations in fall 2015 were generally within the range of available previously-measured concentrations and regional *baseline* conditions. Ion balance was similar to historical observations at all stations except the station in Big Creek, because a historically-low concentration of sulphate was measured at that station in fall 2015. Water quality guideline exceedances in the 2015 WY were consistent with water quality guideline exceedances identified by the RAMP and JOSMP in previous monitoring years. Differences in water quality in fall 2015 between *baseline* stations in Big Creek, Pierre River, and Redclay Creek and regional *baseline* fall conditions were classified as **Negligible-Low**, while differences in water quality in fall 2015 between the *baseline* station in Eymundson Creek and regional *baseline* fall conditions was classified as **Moderate**.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in fall 2015 at three depositional *baseline* reaches and one erosional *baseline* reach in the Pierre River area. The benthic invertebrate communities in Big Creek, Eymundson Creek, and Pierre River were typical of sandy-bottomed rivers with a high abundance of chironomids and worms, which are indicative of poor water quality conditions. EPT taxa were present, as were permanent aquatic forms. Overall, a decrease in the abundance of worms and an increasing proportion of EPT taxa indicated stable conditions. The benthic invertebrate communities in Redclay Creek had a lower proportion of tolerant worms and chironomids in 2015, indicating good habitat quality.

Sediment quality measurement endpoints were within the range of regional *baseline* conditions at all sediment quality stations in the Pierre River area, with the exception of total metals, carbon-normalized total PAHs, and normalized total metals at Eymundson Creek, normalized total metals at Pierre River, and carbon-normalized total PAHs at Big Creek. Differences between sediment quality in fall 2015 at all sediment quality stations in the Pierre River area and regional *baseline* conditions were classified as **Negligible-Low**.

Miscellaneous Aquatic Systems

Fort Creek, McLean Creek, and Horse River

Water Quality Water quality was monitored in the 2015 WY at one *test* station on Fort Creek, one *test* station on McLean Creek, and one *test* station on the Horse River. Differences in water quality in fall 2015 between these *test* stations and regional *baseline* fall conditions were classified as:

- **Negligible-Low** at Fort Creek as concentrations of most water quality variables in fall 2015 were within regional *baseline* concentrations. Concentrations of a number of water quality measurement endpoints have increased over time in Fort Creek, particularly dissolved ions. Guideline exceedances occurred most frequently between July and September and included total phenols and sulphides, which have commonly exceeded guidelines in previous sampling years;
- **Negligible-Low** at McLean Creek: concentrations and levels of all water quality measurement endpoints in fall 2015 were within the ranges of regional *baseline* concentrations, with the exception of total dissolved solids and several associated ions, including calcium, sodium, chloride, and sulphate, all of which were higher than their respective 95^{th} percentile of regional *baseline* concentrations;
- **Negligible-Low** at Horse River: although there were seasonal fluctuations, concentrations of water quality measurement endpoints in fall 2015 were within the ranges of regional *baseline* concentrations.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were monitored in fall 2015 at one depositional *test* reach in Fort Creek. Variations in measurement endpoints for benthic invertebrate communities were classified as **High** because while the presence of clams, snails, and particularly of stoneflies in fall 2015 suggested that the quality of benthic habitat at the *test* reach is good, there were significant differences in values of three of the benthic invertebrate community measurement endpoints (abundance, richness, and equitability) between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means and which suggested degrading conditions for benthic invertebrate communities.

Differences in sediment quality conditions in fall 2015 between the *test* station on Fort Creek and regional *baseline* conditions were classified as **Negligible-Low**. Values of measurement endpoints of sediment quality at the *test* station on Fort Creek were below guideline concentrations in fall 2015, with the exception of Fraction 3 hydrocarbons and chrysene, and concentrations of all sediment quality measurement endpoints in fall 2015. Concentrations of measurement endpoints were within the ranges of regional *baseline* concentrations with the exception of total hydrocarbons, with a concentration that was above the 95th percentile of regional *baseline* concentrations.

Poplar Creek and Beaver River

Climate and Hydrology Hydrometric monitoring for the Poplar Creek watershed in the 2015 WY was conducted at one *test* station and one *baseline* station. The 2015 WY mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were all -0.25% less in the observed *test* hydrograph than in the estimated *baseline* hydrograph. The mean open-water discharge was 43.12% higher in the *test* hydrograph than in the estimated *baseline* hydrograph and this difference was classified as **High**. The results of a longitudinal assessment suggested that the effects on mean open water flow that were classified as **High** occurred in the lowest 3.5 km of Poplar Creek. (i.e., the portion downstream of the Poplar Creek spillway).

Water Quality Water quality was monitored in the 2015 WY at one *test* station on the Poplar River and at one *test* and one *baseline* station on the Beaver River. In general, the highest concentrations of metals and ions occurred in December 2014 and August 2015 at the *test* station on the Poplar River while particulates and total metals at the *test* station on the Beaver River were highest in June 2015. Guideline exceedances occurred most frequently in September in the Poplar River while guideline exceedances occurred equally frequently in June, August, and September in the Beaver River. Concentrations of total phenols, sulphides, and dissolved iron exceeded guideline concentrations at all stations, while concentrations of total silver in January and total zinc in November exceeded water quality guidelines on the Poplar River. There were **Negligible-Low** differences between water quality conditions at all stations in fall 2015 compared to regional *baseline* conditions, with most water quality measurement endpoints within the ranges of regional *baseline* concentrations.

Benthic Invertebrate Communities and Sediment Quality Benthic invertebrate communities were sampled in fall 2015 at one depositional *test* reach in Poplar Creek and one depositional *baseline* reach in the Beaver River. Variations in values of measurement endpoints of benthic invertebrate communities at the *test* reach in Poplar Creek were classified as **Moderate**. While the benthic invertebrate community in Poplar Creek in fall 2015 was in generally good health, as evidenced by trends and levels of %EPT and had a range of fauna typical for a sandy-bottomed river, significant differences in values of equitability between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.

Differences in fall 2015 sediment quality conditions between the *test* station in Poplar Creek and the *baseline* station in Beaver River and regional *baseline* conditions were classified as **Negligible-Low**.

Sediment quality measurement endpoints were within the ranges of regional *baseline* conditions for both stations with the exception of total PAHs in sediments of the Beaver River. Concentrations of all sediment quality measurement endpoints were below guideline concentrations at the *baseline* station in the Beaver River in fall 2015 and concentrations of Fraction 3 hydrocarbons and chrysene exceeded published guidelines at the *test* station in Poplar Creek.

Alice Creek

Water Quality Water quality monitoring was initiated in reaches of Alice Creek in fall 2015 at two *baseline* stations. Differences in water quality in fall 2015 between *baseline* stations in Alice Creek and regional *baseline* fall conditions were classified as **Negligible-Low**, with most water quality measurement endpoints within regional *baseline* concentrations.

Sediment Quality Sediment quality monitoring was initiated in reaches of Alice Creek in fall 2015 at two *baseline* stations. Differences in fall 2015 sediment quality conditions between these stations and regional *baseline* conditions were classified as **Negligible-Low**. Concentrations of all sediment quality measurement endpoints were within regional *baseline* concentrations at both *baseline* stations in Alice Creek. Concentrations of all sediment quality measurement endpoints were below published guidelines at the lower *baseline* station, while predicted PAH toxicity and total arsenic concentrations exceeded guideline values at the upper *baseline* station.

Fish Populations (Wild Fish Health) Wild fish health monitoring was conducted at two *baseline* reaches in Alice Creek in fall 2015, using lake chub as the target species. Results from the lower *baseline* reach indicated that lake chub exhibited lower relative gonad size in females and a lower mean age and relative liver size in both males and females compared to the upper *baseline* reach.

Isadore's Lake

Water Quality Concentrations of most water quality measurement endpoints in fall 2015 at the *test* station in Isadore's Lake were within the range of previously-measured concentrations and concentrations and levels of water quality measurement endpoints were below water quality guidelines in fall 2015 with the exception of sulphide. Shifts in ion balance and significant increasing trends in concentrations of many dissolved ions suggest a gradual and ongoing change in water quality in Isadore's Lake over time.

Benthic Invertebrate Communities and Sediment Quality Variations in values of measurement endpoint of the benthic invertebrate community in Isadore's Lake at the *test* station were classified as **Negligible-Low**. While there were a number of significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means, none of these implied degrading conditions for benthic invertebrate communities.

Sediment Quality The following significant temporal trends in fall concentrations of sediment quality measurement endpoints were measured at the *test* station in Isadore's Lake: (i) increasing concentrations of Fraction 2, 3, and 4 hydrocarbons, total alkylated PAHs and total PAHs; and (ii) decreasing concentrations of total metals. Concentrations of all sediment quality measurement endpoints in fall 2015 were within the ranges of regional *baseline* concentrations with the exception of Fraction 3 hydrocarbons and total arsenic.

Shipyard Lake

Water Quality Concentrations of most water quality measurement endpoints in fall 2015 at the *test* station in Shipyard Lake were within previously-measured concentrations with the exception of sulphide. The ionic composition of water in Shipyard Lake has occasionally shifted toward influences of sodium and chloride, particularly in 2010, and also from 2013 to 2015. This observation is consistent with significant temporal trends of increasing concentrations of sodium, potassium, and chloride and a decreasing trend in calcium concentration.

Benthic Invertebrate Communities and Sediment Quality Variations in values of measurement endpoints of benthic invertebrate communities for the *test* station in Shipyard Lake in fall 2015 were classified as **Negligible-Low**. While there were a number of significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means, none of these implied degrading conditions for benthic invertebrate communities.

Significant temporal trends in concentrations of total hydrocarbons (Fractions 1, 2, 3, and 4) and total alkylated PAHs were measured in sediments in fall 2015 at Shipyard Lake. Concentrations of sediment quality measurement endpoints were below guideline concentrations, with the exception of Fraction 3 hydrocarbons; total arsenic, benz[a]anthracene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, and phenanthrene.

Acid-Sensitive Lakes

Results of the analysis of the acid-sensitive lakes in 2015 compared to the historical data suggested that there have been no significant changes in the water chemistry of the 50 lakes across the years of monitoring that could be attributed directly to acidification. These results were consistent with the revised estimates of potential acid input suggesting that only 19 of the 50 ASL lakes (all remote from the industrial developments) were actually exposed to acidifying deposition.

In 2015, there were no exceedances of the ASL effects criterion for any of the measurement endpoints in the Canadian Shield, West of Fort McMurray and Northeast of Fort McMurray subregions. These three subregions were classified as having a **Negligible-Low** indication of incipient acidification. The Stony Mountains, the Birch Mountains and the Caribou Mountains were classified as having a **Moderate** indication of incipient acidification largely because of increases in the sum of base cations; these increases in the sum of base cations were not attributed to catchment acidification but increases in alkalinity loadings to these lakes.

SPECIAL STUDIES

Three studies were also conducted in 2015 in support of the JOSMP that are not part of the regular monitoring program:

1. Study to explore relationships between turbidity, total suspended solids (TSS), and discharge in tributaries to the Athabasca River: The objectives of the preliminary study were to: (i) calibrate levels of turbidity obtained from the data sondes to concentrations of TSS; and (ii) assess the value of collecting total TSS samples specifically along with discharge measurements, which has been conducted historically as part of the Climate and Hydrology component for the RAMP/JOSMP. The results suggested that site-specific relationships exist between turbidity and

TSS in the study area and that further turbidity-TSS calibrations for data sonde stations in the JOSMP network would be useful to characterize the *baseline* or current conditions, identify disturbances, and calculate sediment budgets between monitoring stations. Uncertainties associated with the derivation of continuous TSS data from a discharge record were deemed to be greater than the increase in uncertainty using computed discharge values with TSS samples collected during routine water quality sampling. Therefore, discontinuing TSS sampling along with manual discharge measurements would only marginally increase the uncertainty in any TSS-discharge relationship that is developed.

2. Expanded fish community study: The objective of the expanded fish community study was to test the adequacy of the historical methods used to sample fish communities under the RAMP/JOSMP by comparing the results obtained using the historical five sub-reach sampling approach with the results of an expanded ten sub-reach sampling approach that also used supplemental fishing methods. The results of the study demonstrated that additional information can be gained by expanding the fish sampling effort and that selective electrofishing can improve the ability to identify fish species present at a monitoring reach. The range of potential bias showed that measurement endpoint estimates calculated using the historical survey efforts can be half as much or double those estimated using expanded methods. In addition, estimates generated using an expanded ten sub-reach sampling approach allowed for more precise estimates of measurement endpoints. Selective electrofishing further increased the number of fish species caught at each monitoring reach, including sensitive species that were not recorded using the primary electrofishing methods.

3. Pilot program for evaluating the status of fish in the Athabasca River: The objective of the pilot study was to evaluate the feasibility of monitoring fish populations of the lower Athabasca River using the Alberta Fisheries approach for sampling key sportfish species (walleye, goldeye, lake whitefish, and northern pike), and more generally on the fish community as a whole, during the summer season. Catches of sportfish during the pilot study were low compared to previous summer inventories conducted by the RAMP/JOSMP, and were likely a result of the low water levels in the Athabasca River observed during summer 2015. Results of the pilot study confirmed that summer is typically a poor time to sample for most sportfish species in the study area as resident populations of targeted species are often low.

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Summary assessment of the 2015 aquatic monitoring results in the oil sands region, Alberta.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions						Acid-Sensitive Lakes[7]
	Hydrology[1]	Water Quality[2]	Benthic Invertebrate Communities[3]	Sediment Quality[4]	Fish Communities[5]	Wild Fish Health[6]	
Athabasca River	🟡	🟡	-	-	-	🟡 / 🟠 / 🟤	-
Athabasca River Delta	-	🟡	🟡 / 🟠	n/a	-	-	-
Muskeg River	🟡 / 🟠	🟡	🟡	🟡	🟡	n/a	-
Jackpine Creek	nm	🟡	🟡	🟡	🟡	-	-
Stanley Creek	-	🟡	-	-	-	-	-
Wapasu Creek	-	nm	-	-	-	-	-
Kearl Lake	nm	n/a	🟡	n/a	-	-	-
Steepbank River	🟡	🟡	-	-	🟤	-	-
Tar River	🟤	🟡	🟠	🟡	n/a	-	-
MacKay River	🟡	🟡	-	🟡	🟡	🟡 / 🟠	-
Dover River	nm	🟡	-	🟡	-	n/a	-
Calumet River	🟡	🟡	🟡	🟡 / 🟠	-	-	-
Firebag River	🟡	🟡	🟠	🟡	-	-	-
Moose Creek	nm	-	-	-	-	-	
McClelland Lake	nm	n/a	🟡	n/a	-	-	-
Johnson Lake	-	n/a	n/a	n/a	-	-	-
Ells River	🟡	🟡	🟡	🟡 / 🟠 / 🟤	🟡	🟡 / 🟠	-
Namur Lake	-	n/a	n/a	n/a	-	-	-
Gardiner Lake	-	n/a	n/a	n/a	-	-	-
Clearwater River	🟡	🟡 / 🟠	🟡	🟡	-	-	-
High Hills River	nm	🟡	n/a	-	-	-	-
Christina River	🟡	🟡	🟡 / 🟠	🟡	🟡	-	-
Sawbones Creek	nm	🟡	🟠	🟡	nm	nm	-
Sunday Creek	nm	🟡	🟤	🟡	🟡	nm	-
unnamed creeks (east and south of Christina Lake)	nm	🟡	🟡	🟡	nm	-	-
Birch Creek	nm	🟡	n/a	🟡	nm	-	-
Jackfish River	nm	🟡	🟠	-	🟡	nm	-
Gregoire River	nm	🟡	🟡	-	-	-	-
Christina Lake	nm	n/a	🟤	n/a	-	-	-
Gregoire Lake	nm	n/a	🟡	n/a	-	-	-
Hangingstone River	🟡	🟡 / 🟠	🟡	-	-	n/a	-
Pierre River	nm	🟡	n/a	🟡	-	-	-
Eymundson Creek	nm	🟠	n/a	🟡	-	-	-
Big Creek (Unnamed Creek)	nm	🟡	n/a	🟡	-	-	-
Redclay Creek	nm	🟡	n/a	-	-	-	-
Fort Creek	nm	🟡	🟤	🟡	-	-	-
Poplar Creek	🟡 / 🟤	🟡	🟠	🟡	-	-	-
McLean Creek	-	🟡	-	-	-	-	-
Horse River	-	🟡	-	-	-	-	-
Beaver River	-	🟡	n/a	🟡	-	-	-
Alice Creek	-	🟡	-	🟡	-	n/a	-
Mills Creek	nm	-	-	-	-	-	-
Isadore's Lake	nm	n/a	🟡	n/a	-	-	-
Shipyard Lake	-	n/a	🟡	n/a	-	-	-
Stony Mountains	-	-	-	-	-	-	🟠
West of Fort McMurray	-	-	-	-	-	-	🟡
Northeast of Fort McMurray	-	-	-	-	-	-	🟡
Birch Mountains	-	-	-	-	-	-	🟠
Canadian Shield	-	-	-	-	-	-	🟡
Caribou Mountains	-	-	-	-	-	-	🟠

Legend and Notes

🟡 **Negligible-Low** change — "-" program was not completed in 2015 WY; nm – not measured in the 2015 WY

🟠 **Moderate** change — n/a – classification not completed as there were no *baseline* conditions against which to compare or reach was sampled to add to regional *baseline*

🟤 **High** change

[1] **Hydrology:** (i) Measurement endpoints were calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High; (ii) Not all hydrology measurement endpoints were calculated for each watershed because of differing lengths of the hydrographic record for 2015. The hydrology results presented are for those measurement endpoints that were calculated; (iii) Mean Open-Water Season Discharge, Annual Maximum Daily Discharge, and Minimum Open-Water Season Discharge in the Muskeg River assessed as **Negligible-Low**; Mean Winter Discharge assessed as **Moderate**; (iv) Mean Open-Water Season Discharge in Poplar Creek was assessed as **High**, while Mean Winter Discharge, Annual Maximum Daily Discharge, and Mean Open-Water Season Discharge were assessed as **Negligible-Low**.

[2] **Water Quality:** (i) Classification based on adaptation of CCME water quality index; see Section 3.2.2.4 for a detailed description of the classification methodology; (ii) Water quality in the Clearwater River was assessed as **Negligible-Low** at the lower station, and **Moderate** at the middle station; (iii) Water quality in the Hangingstone River was assessed as **Moderate** at the lower station and **Negligible-Low** at the middle station.

[3] **Benthic Invertebrate Communities:** (i) Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology; (ii) Benthic invertebrate communities in the Athabasca River Delta were assessed as **Negligible-Low** at Big Point Channel, the Embarras River, and Fletcher Channel, and **Moderate** at Goose Island Channel; (iii) Benthic invertebrate communities in the Christina River were classified as **Moderate** at the lower reach and **Negligible-Low** at all other reaches.

[4] **Sediment Quality:** (i) Classification based on adaptation of CCME sediment quality index (Section 3.2.3.2); (ii) Sediment quality in the Calumet River was assessed as **Moderate** at the lower reach and **Negligible-Low** at the upper reach; (iii) Sediment quality in the Ells River was assessed as **Moderate** near the mouth, High at the lower reach, and **Negligible-Low** at the middle and upper reaches.

[5] **Fish Populations (Fish Communities):** Classification based on exceedances of measurement endpoints from the regional variation in baseline reaches (Section 3.2.4.1).

[6] **Fish Populations (Wild Fish Health):** (i) Classification based on exceedances of measurement endpoints from the regional variation in baseline reaches (Section 3.2.4.2); (ii) Classification for the Athabasca River was based on exceedances of measurement endpoints at each monitoring reach relative to the reach located immediately upstream on the Athabasca River (i.e., considered a "*baseline*" reach for comparison purposes) in an effort to isolate potential effects related to specific influences of interest; see Section 3.2.4.2 for a detailed description of the classification methodology. Wild fish health in the Athabasca River was assessed as **Negligible-Low** above the Muskeg River, **Moderate** in reaches between Poachers Landing and Northlands (below Fort McMurray), below the Muskeg River and near the Athabasca Delta, and **High** in reaches above the Ells River and below the Firebag River; (iii) Wild fish health in the MacKay River was assessed as **Moderate** at the lower reach and **Negligible-Low** at the middle reach; (iv) Wild fish health in the Ells River was assessed as **Moderate** at the lower reach and **Negligible-Low** at the middle reach.

[7] **Acid-Sensitive Lakes:** Classification based on the frequency in which values of seven measurement endpoints in 2015 were more than twice the standard deviation from their long-term mean in each lake.

1.0 INTRODUCTION

In 2012, the governments of Canada and Alberta developed a "Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring" (Canada and Government of Alberta 2012) specific to the Athabasca oil sands region of northeastern Alberta. The implementation plan was to build and expand on existing environmental monitoring programs for the Athabasca oil sands region, including the Regional Aquatics Monitoring Program (RAMP, www.ramp-alberta.org). RAMP was implemented in 1997 as a multi-stakeholder aquatics monitoring program to assess the health of rivers and lakes within the Athabasca oil sands region and to assess potential cumulative effects of oil sands development. The intent of the new joint implementation plan was to enhance these monitoring activities and work to integrate environmental monitoring across all environmental components (i.e., air, water, land, and biodiversity), which were historically monitored independently through separate organizations or programs.

As part of the Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring, the Joint Oil Sands Monitoring Plan (JOSMP, www.jointoilsandsmonitoring.ca) was initiated and executed from 2012 to 2015 to characterize the state of the environment in the Athabasca oil sands region, understand the cumulative effects of and changes to that environment, and develop recommendations for an integrated environmental monitoring program with an adaptive management framework for implementation. The RAMP Committees worked with the governments of Canada and Alberta to align aquatics monitoring activities historically undertaken by RAMP into the JOSMP, completing this process by April 1, 2014.

The Alberta Environmental Monitoring, Evaluation, and Reporting Agency (AEMERA, www.aemera.org) was established in 2014 and given the responsibility for the integration of all environmental monitoring in the province of Alberta, specifically to collect credible scientific data and other relevant information on the condition of Alberta's environment and to provide the public with open and transparent reporting and access to the data and information. The intent of AEMERA is to provide timely collection and objective reporting of scientific data and information on air, land, water, and biodiversity, including information necessary to understand cumulative effects, in order to better inform the public, policy makers, regulators, planners, researchers, communities, and industries.

With the expiry in March 2015 of the "Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring", AEMERA assumed responsibility for the coordination and implementation of the JOSMP in the Athabasca oil sands region. The transition of the JOSMP to AEMERA in 2015 included an expansion of aquatics monitoring previously conducted under the JOSMP to provide an increased coverage of the Athabasca oil sands region, a greater sampling frequency, and an increase in potential contaminants examined. These changes have resulted in greater harmonization of the aquatic monitoring components of the JOSMP.

This document reports on the results of aquatics monitoring conducted under the JOSMP by AEMERA and Hatfield Consultants (Hatfield) under the direction of AEMERA in the 2015 Water Year; this monitoring was implemented on the basis of monitoring study designs developed by AEMERA. In this report, the aquatics monitoring conducted under the JOSMP by AEMERA and Hatfield in the 2015 Water Year and the analysis and reporting of the results of this monitoring are collectively termed the 2015 Program.

1.1 MONITORING OBJECTIVES

1.1.1 Overall Monitoring Objectives of the JOSMP

There were a number of objectives for monitoring in the Athabasca oil sands region that were taken into account during the development of the JOSMP by the governments of Canada and Alberta:

- support sound decision-making by governments as well as stakeholders;
- ensure transparency through accessible, comparable, and quality-assured data;
- enhance science-based monitoring for improved characterization of the state of the environment and collect the information necessary to understand cumulative effects, including future impacts from multiple stressors;
- improve analysis of existing monitoring data to develop a better understanding of historical baselines and changes; and
- reflect the trans-boundary nature of the issues and promote collaboration with the governments of Saskatchewan and the Northwest Territories.

1.1.2 Aquatic Monitoring Objectives

The development of the aquatics component of the JOSMP was based on the following objectives of the JOSMP (JOSMP 2015):

- monitor aquatic environments in the Athabasca oil sands region to detect and assess cumulative effects and regional trends;
- collect aquatic baseline data to characterize variability in the Athabasca oil sands region;
- collect and compare aquatic data against which predictions contained in Environmental Impact Assessments (EIAs) can be assessed;
- collect aquatic data that assists with the monitoring required by regulatory approvals of oil sands and other developments; and
- continuously review and adjust the program to incorporate monitoring results, technological advances, and community concerns and new or changed approval conditions.

1.2 BACKGROUND

With an estimated 293.125 billion m^3 (1.845 trillion barrels) of total reserves of bitumen (initial volume in place) (AER 2015), the Alberta oil sands (i.e., Athabasca, Cold Lake, and Peace River deposits) are the largest of Canada's known petroleum resources. The Alberta oil sands are a significant component of the world's petroleum resources, with its 26.43 billion m^3 (166 billion barrels) of remaining established bitumen reserves[1] (AER 2015) being equivalent to approximately 10% of the world's known reserves of

[1] Established crude bitumen reserves were defined as mineable reserves that were anticipated to be recovered by surface mining operations and in situ reserves that were anticipated to be recovered through wellbores using in situ recovery methods (AER 2015). Remaining established bitumen reserves were established bitumen reserves less cumulative bitumen production.

conventional crude oil[2] (US Energy Information Administration 2015). Total bitumen deposits in the Athabasca oil sands region (including Wabasca) are the largest of Alberta's three oil sands regions, containing 82.7% of the total provincial reserves, with the total deposits in the Cold Lake and Peace River areas being significantly smaller (AER 2015).

In 1967, Great Canadian Oil Sands Ltd. (now Suncor Energy Inc.) initiated the first commercially-successful bitumen extraction and upgrading facility in the Athabasca oil sands region. Since that time, investment and development in the Athabasca oil sands region near Fort McMurray in the Regional Municipality of Wood Buffalo (RMWB) has increased substantially. Approximately 30.6% of the estimated established bitumen reserves in the Athabasca oil sands region were under active development as of the end of 2014, and 5.3% of the estimated established bitumen reserves of the Athabasca oil sands region had been extracted by the end of 2014 (Table 1.2-1).

Table 1.2-1 Status of bitumen reserves in the Athabasca oil sands region.

Bitumen Reserve and Production Indicators	Volume (million barrels)	
Initial Volume in Place (total reserves)		1,525,122
Estimated Established Reserves		146,152*
Established Reserves under Active Development as of 31 December 2014		44,719
Mineable	42,934	
in situ	1,784	
Cumulative Production as of 31 December 2014		7,792
Mineable	6,233	
in situ	1,559	
Remaining Established Reserves		138,359

Data from AER (2015); all figures are as of December 31, 2014.

* Estimated established reserves were calculated by applying the ratio of estimated established reserves to the total bitumen reserves for the entire province to total reserves in the Athabasca oil sands region.

The increasing development of the Athabasca oil sands resource has been accompanied by an increase in environmental monitoring and research conducted in the Athabasca oil sands region and increasing interest among stakeholders in ensuring that measures in place to monitor any potential effects on the environment are effective. Site-specific monitoring is conducted by individual oil sands companies to meet approval requirements. Oil sands companies also provide support to research to gain a better understanding of local aquatic resources and their response to regional development. Cumulative long-term regional monitoring (i.e., for status and trends reporting) and surveillance monitoring (i.e., typically short-term to address specific questions) of water, biodiversity, and air in the Athabasca oil sands region is now directed through AEMERA in collaboration with other organizations, universities, and oil sands companies. In 2012, AESRD (now Alberta Environment and Parks, AEP) developed the Lower Athabasca Regional Plan (LARP) that identifies and sets resource and environmental management outcomes for air, land, water and biodiversity, and guides future resource decisions while considering social and economic impacts (Government of Alberta 2012).

2 The world's known reserves of conventional crude oil were based on 2014 data as 2015 data were not available at the time this report was prepared.

1.3 STUDY AREA

The study area for the 2015 Program was defined as the major watersheds in the Athabasca oil sands region within which oil sands developments have been approved (Figure 1.3-1)[3]. Monitoring in 2015 occurred as far south as the town of Athabasca and extended north to the Athabasca River Delta (ARD). The lower Athabasca River is the dominant waterbody within the study area and hydrologically links the upper (southern) portion of the study area to the lower (northern) portion.

The southern portion of this study area is within the Mid-Boreal Uplands and Wabasca Lowland Ecoregions, both of which are part of the Boreal Plains Ecozone. This area is dominated by the Athabasca, Clearwater and Christina rivers, as well as a series of smaller rivers, primarily the Hangingstone, Gregoire, and Horse rivers. The area is characterized by a predominantly sub-humid mid-boreal ecoclimate, closed stands of trembling aspen, balsam poplar with white spruce, black spruce, and balsam fir occurring in late successional stages, as well as cold and poorly-drained fens and bogs covered primarily with tamarack and black spruce. The western part of the southern portion of the study area has little relief and is poorly-drained.

The northern portion of the study area for the 2015 Program is dominated by the Athabasca River from Fort McMurray to the ARD (Figure 1.3-1) and is part of the Slave River Lowlands Ecoregion of the Boreal Plains Ecozone. The mineable portion of the estimated established bitumen reserves of the Athabasca oil sands region lies within this portion of the study area and is characterized by an undulating sandy plain containing mixed boreal forest. Approximately 50% of this portion of the study area is covered by peatlands and sporadic and discontinuous permafrost. The area is partially bordered to the west by the Birch Mountains and to the east by intermittent slopes including the Muskeg Mountains, which extend northward from the Clearwater River Valley. At the ARD, the Athabasca River becomes an interconnected series of braided channels and wetlands flowing into Lake Mamawi and Lake Athabasca. This area experiences a low subarctic ecoclimate, with black spruce as the climax tree species, open stands of low, stunted black spruce with dwarf birch and Labrador tea, and a ground cover of lichen and moss.

As the Athabasca River flows northward, several smaller tributary streams and rivers join and contribute to the overall flow. Figure 1.3-2 provides a hydrologic schematic of the study area showing the size of the larger tributaries relative to the lower Athabasca River. Although approximate, the diagram shows that: (i) there is a range of tributary sizes; and (ii) the size of the lower Athabasca River is much larger than any tributary, even the Clearwater River.

[3] The exception to this is a number of the lakes monitored in the Acid-Sensitive Lakes component that are outside of the study area described in Section 1.3. The location of the Acid-Sensitive Lakes is described in this Section 3.1.5 of this report.

Figure 1.3-1 Study area for the 2015 Program and locations of oil sands developments.

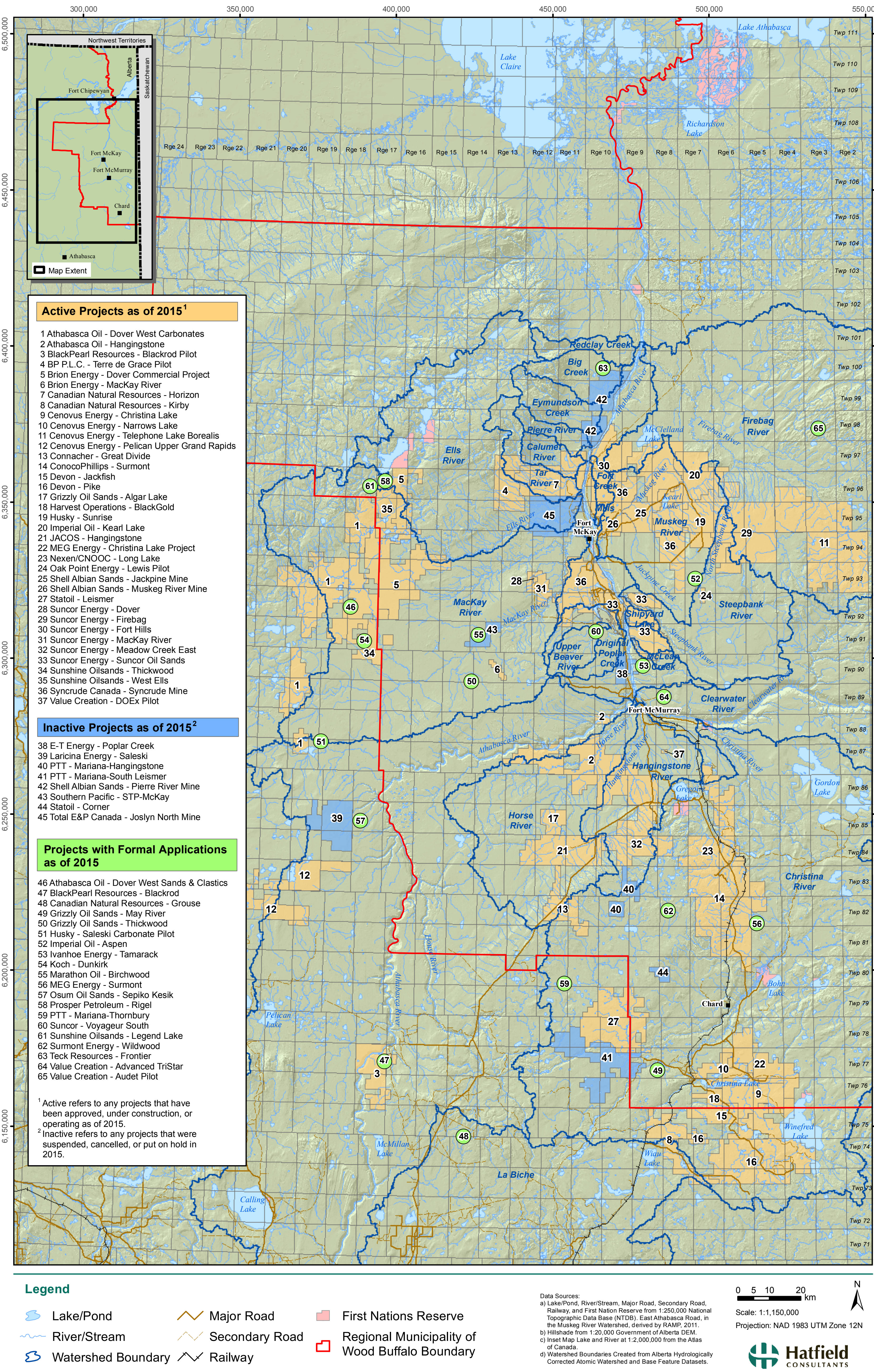

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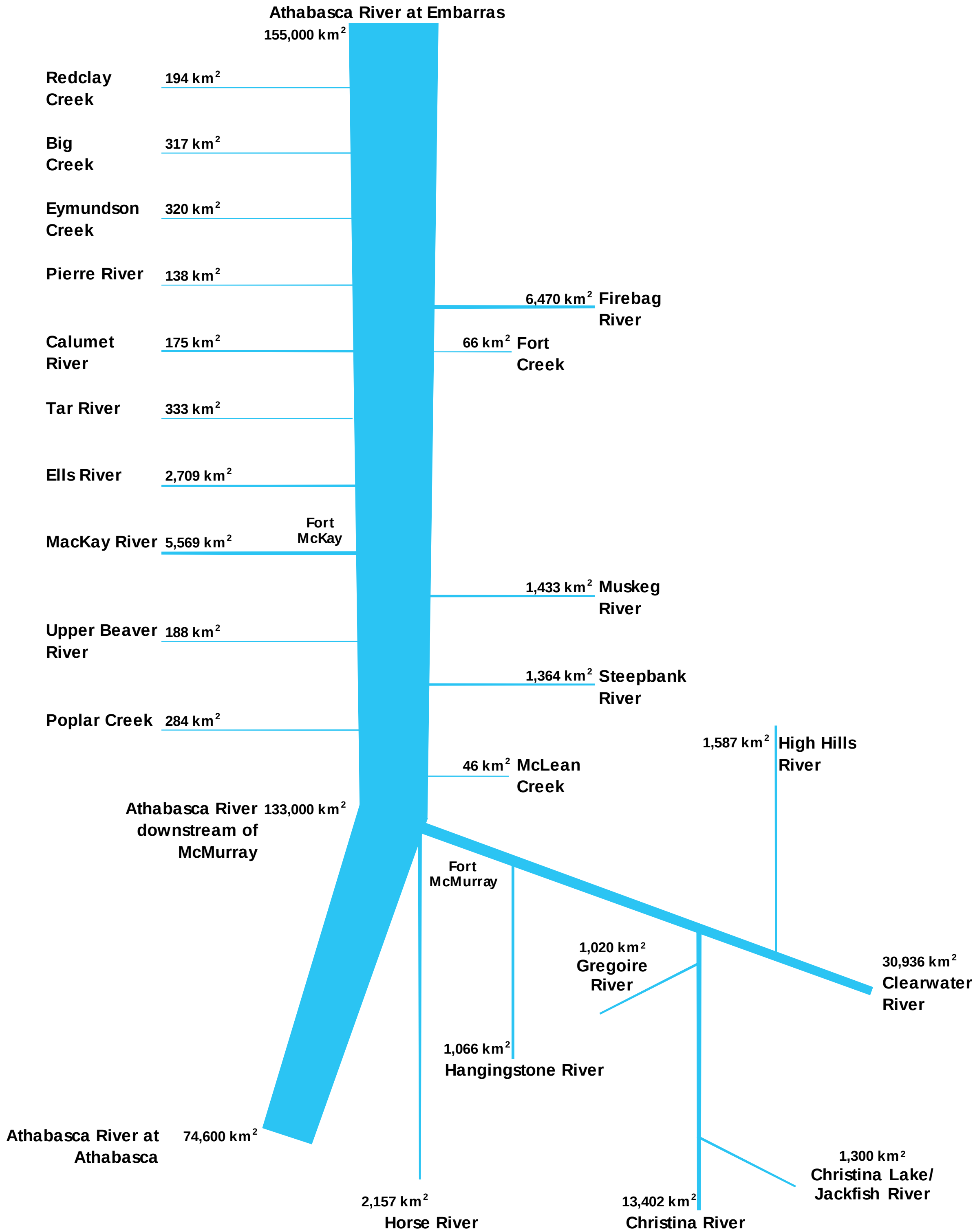
Figure 1.3-2 Hydrologic schematic of the study area for the 2015 Program.



Note: Drainage areas of Athabasca River tributaries derived from watershed boundaries provided by AEP.

Some of the larger tributaries of the Athabasca River include, in upstream to downstream order[4]:

- Clearwater-Christina rivers – the Clearwater River originates in Saskatchewan, joins the Athabasca River at Fort McMurray, and includes the contribution of the Christina River, a large tributary of the Clearwater River whose watershed includes several in situ oil sands developments including the Cenovus Christina Lake and Narrows Lake projects, the ConocoPhillips Surmont Project, Devon Jackfish and Pike projects, Grizzly May River Project (in application), Harvest BlackGold Project, MEG Energy Christina Lake and Surmont (in application) projects, Nexen Long Lake Project, Statoil Leismer Project, PTT Thornbury Project (in application), Surmont Energy Wildwood Project (in application), and portions of the Suncor Meadow Creek East, Canadian Natural Kirby and Grouse (in application), and Connacher Algar and Great Divide projects;

- Hangingstone River – a river originating in the southwestern portion of the study area, joining the Clearwater River immediately upstream of Fort McMurray, and whose watershed includes the Value Creation Tristar Pilot project, and portions of the Suncor Meadow Creek East, JACOS Hangingstone, Athabasca Oil Hangingstone, and Nexen Long Lake projects;

- Horse River – a river originating in the southwestern portion of the study area, joining the Athabasca River upstream of Fort McMurray, and whose watershed includes the Grizzly Algar Lake Project, JACOS and Athabasca Oil Sands Hangingstone projects, and portions of the Suncor Meadow Creek East, and Connacher Great Divide and Algar projects;

- Steepbank River – joins the Athabasca River from the east and whose watershed includes the Suncor Steepbank and Millennium mines, the Suncor North Steepbank Extension, Oak Point Energy Lewis Pilot Project, and portions of the Suncor in situ Firebag and the Husky in situ Sunrise Thermal projects;

- Muskeg River – flows from the east and drains several oil sands development areas and whose watershed includes the Shell Muskeg River Mine and Expansion, Shell Jackpine Mine and Expansion, Syncrude Aurora North and South mines, and portions of the Suncor in situ Firebag and Fort Hills, Imperial Oil Kearl Lake, Imperial Oil Aspen (in application), and Husky Sunrise projects, and the Hammerstone Muskeg Valley Quarry;

- MacKay River – flows from the west and whose watershed includes the Athabasca Oil Sands Dover West Project, Brion Energy Dover and MacKay River projects, Athabasca Oil Dover West Sands and Clastics Project (in application), Koch Dunkirk Project (in application), Prosper Petroleum Rigel Project (in application), Grizzly Oil Sands Thickwood Project (in application), Marathon Oil Birchwood Project (in application), Suncor MacKay River and Dover projects, Sunshine Oilsands Thickwood and Legend Lake (in application) projects, and portions of the Sunshine Oilsands West Ells, Husky Saleski Carbonate Pilot (in application), and Syncrude Mildred Lake projects;

- Ells River – flows from the west and whose watershed includes portions of the Brion Energy Dover Project, Sunshine Oilsands West Ells and Legend Lake (in application) projects, Prosper

[4] See Figure 1.3-1 for the location of the oil sands development projects listed in this section for each of the watersheds.

Petroleum Rigel Project (in application), Canadian Natural Horizon Mine, and the BP Terre de Grace Project; this river is also the drinking water source for the community of Fort McKay;

- Tar River – flows from the west and whose watershed contains most of the Canadian Natural Horizon Mine, and portions of the BP Terre de Grace Project;
- Calumet River – also flows from the west and whose watershed is partly within the Canadian Natural Horizon Mine; and
- Firebag River – a river flowing from Saskatchewan whose watershed includes the Suncor Fort Hills, Cenovus Telephone Lake Borealis, Value Creation Audet Pilot (in application) projects, most of the Suncor in situ Firebag Project, and portions of the Husky Sunrise Thermal and Imperial Oil Kearl Lake projects.

Other waterbodies monitored under the JOSMP and within existing or proposed oil sands developments include:

- tributaries within watersheds described above such as Muskeg Creek, Jackpine Creek, Stanley Creek, Iyinimin Creek, and Wapasu Creek in the Muskeg River watershed and Birch Creek, Sunday Creek, Unnamed Creek, Sawbones Creek, and Gregoire River in the Christina River watershed;
- smaller tributaries of the Athabasca River (McLean Creek, Poplar Creek, Beaver River, Mills Creek, Fort Creek, Eymundson Creek, Big Creek, and Redclay Creek) that contain parts of a number of oil sands projects, including the Suncor Millennium Mine (McLean Creek), Syncrude Mine, and Suncor Base Mine and Voyageur Upgrader projects (Poplar Creek), Suncor Voyageur South (in application) project (Poplar Creek and Beaver River), Shell Muskeg River Mine, Syncrude Mine, and Suncor Fort Hills projects (Fort Creek and Mills Creek), Teck Resources Frontier Project (in application) (Big Creek and Redclay Creek);
- a minor tributary of the lower Peace River catchment (Alice Creek), which flows into Lake Claire of the Athabasca River Delta;
- specific lakes and wetlands such as Isadore's Lake, Shipyard Lake, McClelland Lake, Kearl Lake, Namur Lake, Gregoire Lake, Gardiner Lake, Christina Lake, and Johnson Lake; and
- a set of lakes for the purpose of assessing lake sensitivity to acidifying emissions.

Finally, there are a number of waterbodies and watercourses that are used as baseline areas for certain monitoring components.

1.4 GENERAL MONITORING AND ANALYTICAL APPROACH

1.4.1 Overall Monitoring Approach

The monitoring approach for the 2015 Program incorporates a combination of both stressor- and effects-based monitoring approaches. The stressor-based approach is derived primarily from EIAs prepared for each of the oil sands projects. EIAs are undertaken in part to evaluate the potential impacts that the proposed project, alone or in combination with other developments, could have on the local and regional environment. To date, EIAs conducted for projects in the Athabasca oil sands region have used primarily a stressor-based approach.

A potential stressor is any factor (e.g., chemicals, temperature, water flow, nutrients, food availability, and biological competition) that either currently exists in the environment and will be influenced by the proposed project or will be potentially introduced into the environment as a result of the proposed project. Using this approach, the impact of a development is evaluated by predicting the potential impact of each identified stressor on valued components of the environment (Munkittrick et al. 2000). Using impact predictions from various EIAs, specific potential stressors have been identified that are monitored to document *baseline* conditions, establish natural variation in those conditions, as well as to identify potential changes related to development. Examples include specific water quality variables and changes in water quantity (RAMP 2009b).

Although the stressor-based impact assessment has been successful, the inherent risk of the approach is that it assumes that all potential stressors can be identified and evaluated. Accordingly, an effects-based approach has been advocated for impact assessments and subsequent monitoring efforts (Munkittrick et al. 2000). This approach focuses on evaluating the performance of biological components of the environment (e.g., fish and benthic invertebrates) because they integrate the potential effects of complex and varied stressors over time. This approach is independent of stressor identification, and focuses on understanding the accumulated environmental state resulting from the summation of all stressors. For example, the current federal Environmental Effects Monitoring (EEM) program for the pulp and paper and metal mining industries incorporates an effects-based monitoring approach (Environment Canada 2010). There is a strong emphasis in the Program on monitoring sensitive biological indicators such as benthic invertebrates and fish populations that reflect and integrate the overall condition of the aquatic environment. By combining both monitoring approaches, a more holistic understanding of potential effects on the aquatic environment related to the development of oil sands projects can be achieved.

1.4.2 Monitoring Components

The 2015 Program focused on the following six components of boreal aquatic ecosystems[5]:

Climate and Hydrology – monitors changes in the quantity of water flowing through rivers and creeks in the study area, lake levels in selected waterbodies, and local climatic conditions. Climate and hydrologic data are collected to facilitate the interpretation of data collected by the other monitoring components by placing them in the context of current hydrologic conditions relative to historical mean and extreme conditions, document stream-specific hydrologic conditions and regional climate to characterize natural variability and to allow detection of regional trends, and quantify and assess the transport and loadings of oil sands contaminants that enter waterbodies. The Climate and Hydrology component focuses on key elements of the hydrologic cycle, including rainfall, snowfall, streamflow, and lake water levels. Climate, streamflow, and lake levels are monitored to develop an understanding of the hydrologic system, including natural variability, short and long-term trends, and potential changes related to development.

[5] The spatial and temporal monitoring of these components has become increasingly harmonized in recent years and this trend was continued in the 2015 Program, with sampling stations for as many components as possible being located in the same location in the watercourses being monitored.

Climate and Hydrology monitoring in the 2015 Program consisted of:

- a total of 46 streamflow stations of which 17 were in watersheds unaffected by oil sands development as of 2015, 13 were in watersheds with less than 5% of the watershed affected by land change due to oil sands development, and 16 were in watersheds with more than 5% of the watershed affected by land change due to oil sands development;
- 12 stations collecting climate data; and
- an area-wide snowcourse survey program.

Water Quality in rivers, lakes, and wetlands – monitoring of water quality is conducted in order to identify anthropogenic and natural factors affecting the quality of streams and lakes in the Athabasca oil sands region, and water quality conditions reflect habitat quality and potential exposure of fish and invertebrates to organic and inorganic chemicals.

Monitoring activities for the Water Quality component in the 2015 Program consisted of:

- discrete sampling conducted at a total of 70 stations sampled either monthly, seasonally (March, May, July, and September), monthly during the open water season (May to September), or during the fall only (September);
- 12 stations[6] sampled in September 2015 that were also sampled for the Benthic Invertebrate Communities component;
- 15 stations sampled in September 2015 that were also sampled for the Fish Populations component; and
- deployment of 16 water quality data sondes from either May or July 2015 to late October 2015, prior to freeze-up.

In addition, the Water Quality component in the 2015 Program conducted a special study to investigate relationships between TSS and turbidity using data obtained from the data sondes. An assessment of sediment loading was conducted using these TSS relationships and discharges generated from the Climate and Hydrology component.

Benthic Invertebrate Communities and **Sediment Quality** in rivers, lakes, and wetlands – Benthic invertebrate communities are a commonly-used indicator of aquatic environmental conditions and are included as a monitoring component because they integrate biologically relevant variations in water, sediment, and habitat quality, they are limited in their mobility, and they reflect local conditions. Benthic invertebrate communities can thus be used to identify point sources of inputs or disturbance. The short life span of benthic invertebrates (typically about one year) allows them to integrate the physical and chemical aspects of water quality and sediment quality over annual time periods and provide early warning of possible changes to fish communities (e.g., Kilgour and Barton 1999). Based on known tolerances of benthic taxa, it is possible to re-create the environmental conditions by determining which animals are present (Rooke and Mackie 1982). Sediment quality is monitored in conjunction with benthic

[6] Includes one water quality station (CLR-2) that was discontinued after April 2015, then subsequently sampled to support the interpretation of benthic invertebrate community data (see Section 3.1.2.1).

invertebrate communities as it provides a link between physical and chemical habitat conditions and the benthic invertebrate communities.

For the 2015 Program, benthic invertebrate communities were sampled at 35 river reaches, four channels of the ARD, and nine lakes within the Athabasca oil sands region. Of these stations, sediment sampling was conducted at the 27 locations in river reaches that had depositional habitats, as well as the four channels of the ARD, and nine lakes.

Fish Populations in rivers as biological indicators of ecosystem integrity and a highly-valued resource in the Athabasca oil sands region. In 2015, emphasis was placed on monitoring the composition of wild fish communities, as well as the health of specific sentinel fish species selected as monitors of local aquatic habitats. These data will assist in providing a baseline against which future changes in fish populations will be assessed, as well as an opportunity to be compared current data to historical studies to evaluate possible changes over time.

The core elements of the Fish Populations component in the 2015 Program were:

- fish community monitoring and fish habitat assessments in tributaries (referred to in previous years as “fish assemblage monitoring”) – focuses on characterizing fish assemblages on the basis of total abundance, taxonomic richness, diversity, and an assemblage tolerance index, in areas downstream of development relative to fish assemblages upstream of development; and

- wild fish health monitoring (referred to in previous years as “sentinel fish species monitoring”) in the Athabasca River and select tributaries – monitoring potential effects of stressors on populations of fish species that have limited movement relative to the location of the potential stressors.

Two additional studies were undertaken for the Fish Populations component in 2015:

- pilot program for the status of fish in the Athabasca River – evaluation of the feasibility of monitoring fish populations of the mainstem Athabasca River using the provincial approach to sampling key sportfish species; and

- expanded fish community study – evaluation of whether original fish community sampling methods are adequate to describe the fish community in a given area, and to refine the field methods for future surveys.

Acid-Sensitive Lakes – monitors water quality in regional lakes in order to assess potential changes in water quality as a result of acidification. The Acid-Sensitive Lakes (ASL) component was initiated in 1999 to conduct annual monitoring of water chemistry in regional lakes to determine long-term changes in these lakes in response to acid deposition on these lakes and their catchment basins. Fifty lakes were monitored under the ASL component in the 2015 Program, in six physiographic regions: Stony Mountains; Birch Mountains; West of Fort McMurray; Northeast of Fort McMurray; Canadian Shield; and Caribou Mountains. These lakes are unaffected by oil sands development except potentially through deposition.

1.4.3 Definition of Terms

The analysis for each component is based on a selection of sampling stations and monitoring years to be used in the analysis for each watershed/river basin. For the analysis, the sampling stations and monitoring years are categorized into combinations of spatial and temporal treatments and controls, as described below:

- ***Test*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of oil sands developments; data collected from these locations are designated as *test* for the purposes of data analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but simply that data collected from these locations are being tested against *baseline* conditions to assess potential changes; and
- ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2015) or were (prior to 2015) upstream of all oil sands developments; data collected from these locations are designated as *baseline* for the purposes of data analysis, assessment, and reporting.

The terms *test* and *baseline* depend solely on location of the aquatic resource in relation to the location of oil sands development to allow for long-term comparison of trends between *baseline* and *test* stations.

1.4.4 Overall Analytical Approach for 2015

The monitoring design of the 2015 Program was consistent with the monitoring design of both the RAMP and the JOSMP as described in the RAMP Technical Design and Rationale document (RAMP 2009b).

The overall analytical approach for the 2015 Program report is a weight-of-evidence approach that builds on analytical approaches used in previous years by the RAMP and described in the RAMP Technical Design and Rationale (RAMP 2009b) (Figure 1.4-1). Key features of the overall analytical approach are as follows.

First, the analysis for each monitoring component uses a set of measurement endpoints (Table 1.4-1) representing the health and integrity of valued environmental resources within the component. These are the same measurement endpoints that were used in the historical RAMP 2004 to 2013 Technical Reports (RAMP 2005; RAMP 2006; RAMP 2007; RAMP 2008; RAMP 2009a; RAMP 2010; RAMP 2011; RAMP 2012; RAMP 2013; and RAMP 2014), and in the previous JOSMP 2014 Technical Report (JOSMP 2015).

Second, the analysis of results for 2015 compared to previous monitoring years is conducted for the Athabasca River and ARD, as well as at the watershed/river basin level to assess temporal trends.

Third, a set of criteria are used for determining whether or not there has been a change in the values of the measurement endpoints: (i) at *test* stations; and (ii) compared to *baseline* range of natural variability (Table 1.4-1).

Fourth, the magnitude of these changes in the values of the measurement endpoints is summarized and locations or watersheds with moderate or high levels of change become candidate sites for additional studies to identify the causes of the changes being measured.

Figure 1.4-1 Overall analytical approach for 2015.

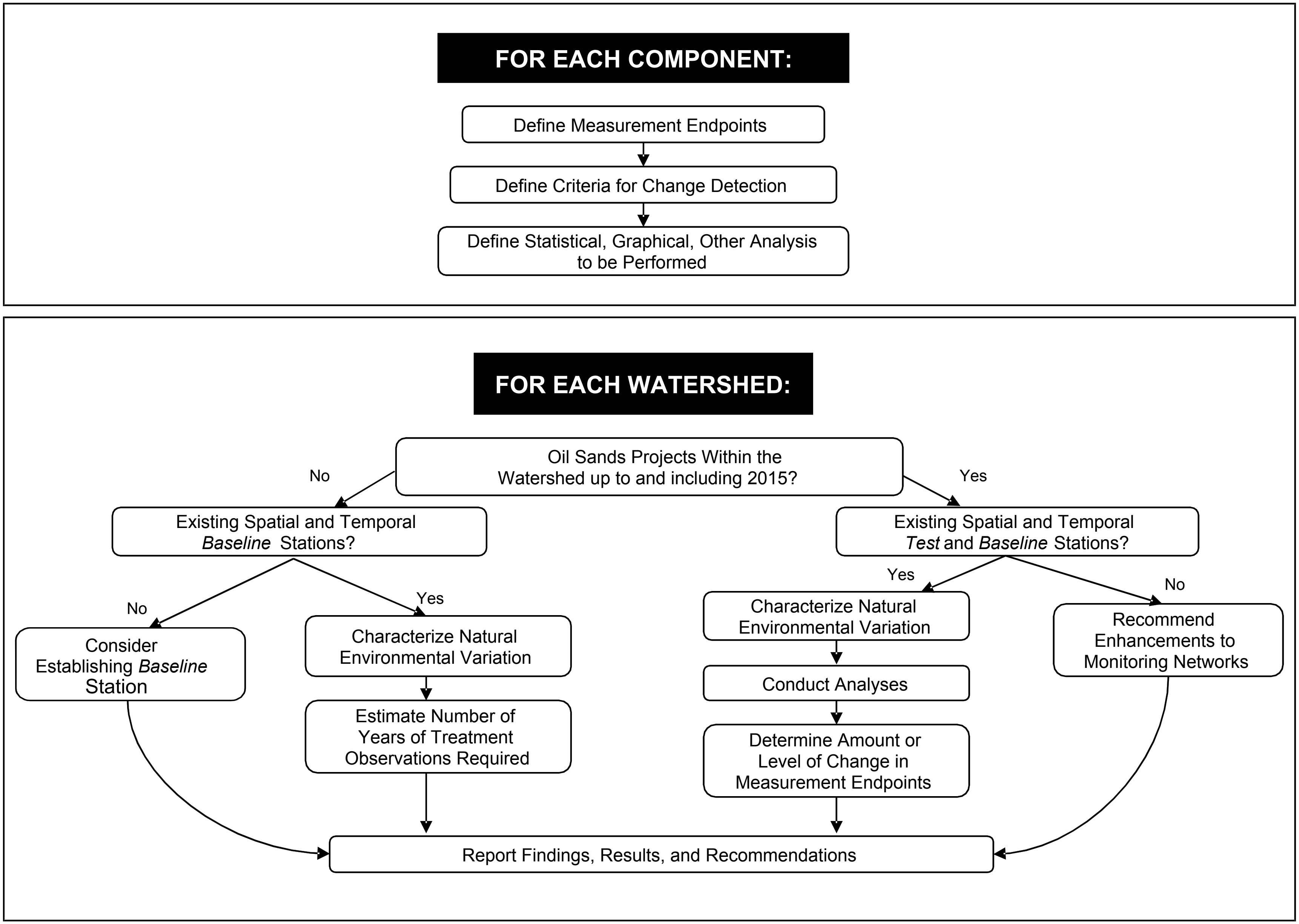


Table 1.4-1 Measurement endpoints and criteria for determination of change used in the 2015 analysis.

Component	Measurement Endpoints Used in 2015 Program Report[1]	Criteria for Determining Change Used in 2015 Program Report
Climate and Hydrology	Mean open-water season discharge Mean winter discharge Annual maximum daily discharge Open-water season minimum daily discharge	Differences between observed *test* and estimated *baseline* hydrographs (i.e., the hydrograph that would have been observed had oil sands developments not occurred in the drainage, so that changes in water withdrawals, releases, and diversions are accounted for) as follows: Negligible-Low: ± 5% ; Moderate: ± 15%;High: > 15%.
Water Quality	pH Total suspended solids Dissolved phosphorus Total nitrogen and nitrate-nitrite Various ions (sodium, chloride, calcium, magnesium sulphate) Total alkalinity Total dissolved solids, Dissolved organic carbon Total and dissolved aluminum Total arsenic, Total boron Total molybdenum, Total strontium Ultra-trace mercury, Naphthenic acids Various PAH end-points, including: Total PAHs Total parent PAHs, Total alkylated PAHs Naphthalene, Retene Total dibenzothiophenes Overall ionic composition	Comparison to range of regional *baseline* conditions. Comparison to CCME and other water quality guidelines. Calculation of water quality index based on CCME water quality index found at http://www.ccme.ca/ourwork/water.html?category_id=102 , with water quality index scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions 60 to 80: Moderate difference from regional *baseline* conditions Less than 60: High difference from regional *baseline* conditions
Benthic Invertebrate Communities	Abundance Richness (number of taxa) Equitability (measure of diversity) Abundance of EPT (mayflies, stoneflies, caddisflies) Axes of Correspondence Analysis ordination	Exceedance of regional range of *baseline* variability for the selected measurement endpoints based on the mean and standard deviation, with regional range defined as $\overline{X} \pm 2SD$, and statistically significant differences between measurement endpoints in *test* reaches/lakes as compared to *baseline* reaches/lakes or across years; 1. Negligible-Low: no strong statistically significant difference in any measurement endpoint between *test* and *baseline* reaches/lakes, with difference implying a negative change. 2. Moderate: strong statistically significant difference in any one measurement endpoint between *test* and *baseline* reaches/lakes, with low “noise” in the statistical test. 3. High: statistically significant difference in any measurement endpoint between *test* and *baseline* reaches/lakes and either: (i) at least three measurement endpoints outside *baseline* range of natural variation or (ii) at least one measurement endpoint outside *baseline* range of natural variation for three consecutive years.

[1] The measurement endpoints do not include a complete list of variables that were analyzed for water and sediment quality. A complete list can be found in Table 3.1-10, Table 3.1-11, Table 3.1-12, and Table 3.1-20.
CCME is the Canadian Council of Ministers of the Environment. USEPA is the United States Environmental Protection Agency.

Table 1.4-1 (Cont'd.)

Component	Measurement Endpoints Used in 2015 Program Report[1]	Criteria for Determining Change Used in 2015 Program Report
Sediment Quality	Particle size distribution (clay, silt, and sand) Total organic carbon Total hydrocarbons (CCME and BTEX) Metals, Sublethal toxicity Various PAH end-points, including: Total PAHs Total parent PAHs, Total alkylated PAHs Naphthalene, Retene Total dibenzothiophenes Predicted PAH toxicity	Comparison to CCME Interim Sediment Quality Guidelines (ISQG) and other guidelines. Calculation of sediment quality index based on CCME water quality index found at http://www.ccme.ca/ourwork/water.html?category_id=103, with sediment quality index scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions 60 to 80: Moderate difference from regional *baseline* conditions Less than 60: High difference from regional *baseline* conditions
Fish Populations: Wild Fish Health Monitoring	End-points for lethal fish health monitoring: Age Growth Condition Relative gonad size Relative liver size Mixed Function Oxygenase induction activity Incidence of external abnormalities Non-lethal end-points for juvenile (immature) fish: Growth Relative abundance	Comparison to Environment Canada's Environmental Effects Monitoring (EEM) criteria (Environment Canada 2010) where an effect is determined by a difference of ± 10% in condition, ± 25% in age, growth, relative gonad weight, and relative liver weight of fish at the *test* site relative to fish condition at the *baseline* site. 1. Negligible-Low: no exceedance greater than ± 10% in condition, ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site. 2. Moderate: exceedance greater than ± 10% in condition, ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site, but not in two consecutive years of sampling including the current year. 3. High: exceedance greater than ± 10% in condition ± 25% in age, growth, gonad weight, or liver weight of fish at *test* site compared to fish at *baseline* site, and exceedance observed in two consecutive years of sampling including the current year.
Fish Populations: Fish Community Monitoring	Abundance Catch-per-unit effort Richness (number of taxa) Simpson's diversity Assemblage Tolerance Index	Exceedance of regional range of *baseline* variability for the selected measurement endpoints based on the mean and standard deviation, with regional range defined as $\overline{X} \pm 2SD$, and statistically significant differences between measurement endpoints in *test* reaches/lakes as compared to *baseline* reaches or across years; 1. Negligible-Low: no strong statistically significant difference in any measurement endpoint between *test* and *baseline* reaches, with difference implying a negative change. 2. Moderate: strong statistically significant difference in any one measurement endpoint between *test* and *baseline* reaches, with low "noise" in the statistical test. 3. High: statistically significant difference in any measurement endpoint between *test* and *baseline* reaches and either: (i) at least three measurement endpoints outside *baseline* range of natural variation or (ii) at least one measurement endpoint outside *baseline* range of natural variation for three consecutive years. Statistical comparisons were only completed for reaches with three or more years of data. For all other reaches, assessments were conducted solely based on comparisons to the *baseline* range of variability.

[1] The measurement endpoints do not include a complete list of variables that were analyzed for water and sediment quality. A complete list can be found in Table 3.1-10, Table 3.1-11, Table 3.1-12 and Table 3.1-20.
CCME is the Canadian Council of Ministers of the Environment. USEPA is the United States Environmental Protection Agency.

Table 1.4-1 (Cont'd.)

Component	Measurement Endpoints Used in 2015 Program Report[1]	Criteria for Determining Change Used in 2015 Program Report
Acid-Sensitive Lakes	Critical Load of acidity pH Gran alkalinity Base cation concentrations Nitrate plus nitrite concentrations Dissolved organic carbon Dissolved aluminum	Exceedance of Critical Load of acidity of a particular lake by the measured or modeled value of the Potential Acid Input (PAI) to that lake. A statistically significant change in any of the measurement endpoints beyond natural variability, resulting in a reduction of lake pH, Gran alkalinity, Critical Load or base cation concentrations, or an increase in nitrates or aluminum concentrations. For each lake, mean and standard deviation calculated for each of seven measurement endpoints over all the monitoring years. The number of lakes in 2014 within each subregion with endpoint values greater than two standard deviations from the mean is calculated. 1. Negligible-Low: subregion has <2% of endpoint-lake combinations exceeding ± 2SD criterion. 2. Moderate: subregion has 2% to 10 % of endpoint-lake combinations exceeding ± 2SD criterion. 3. High: subregion has > 10% of endpoint-lake combinations exceeding ± 2SD criterion.

[1] The measurement endpoints do not include a complete list of variables that were analyzed for water and sediment quality. A complete list can be found in Table 3.1-10, Table 3.1-11, Table 3.1-12 and Table 3.1-20.

CCME is the Canadian Council of Ministers of the Environment. USEPA is the United States Environmental Protection Agency.

1.5 ORGANIZATION OF THIS REPORT

Together with this Introduction, the 2015 Program Report contains ten sections within which the results of the 2015 Program developed by AEMERA and implemented by Hatfield are presented.

Section 2: Summary of Oil Sands Project Activities in 2015 – This section contains:

- a list of oil sands projects that were either active (operating or under construction), had received approval, or were in the application stage as of 2015;
- a list of oil sands project water withdrawal and release locations; and
- a summary of land change occurring up to 2015 as a result of oil sands development.

This provides a synthesis of information related to development activities that may be influencing aquatic environmental resources within the Athabasca oil sands region.

Section 3: 2015 Monitoring Activities – This section of the report contains concise descriptions of the monitoring program that was conducted in 2015 for each component, and includes:

- an overview of the 2015 Program;
- a description of any other information that was obtained (i.e., information from regulatory agencies, stakeholders, and oil sands operators, knowledge obtained from local communities, and other sources);
- an overview of field methods;
- a description of changes in monitoring network from the 2014 field program;
- a description of the challenges and issues encountered during 2015 and the means by which these challenges and issues were addressed; and
- a summary of the component data that are now available.

Each component section of Section 3 then presents a description of the detailed approach used for analyzing the data, including:

- a description and explanation of the measurement endpoints that were selected;
- a description of the statistical, graphical, or other analyses that were performed on the monitoring data to assess whether or not changes in the selected measurements endpoints have occurred over time and space; and
- a description and explanation of the criteria that were used in assessing whether or not changes in the selected measurement endpoints have occurred.

Section 4: Climatic and Hydrologic Characterization of the Athabasca Oil Sands Region in 2015 – This section of the report describes the 2015 Water Year (WY) (November 1, 2014 to October 31, 2015) and how the 2015 WY compares with previous years with respect to climatic and hydrologic conditions. This information helps set the context for the results, analyses, and assessments presented in Section 5.

Section 5: 2015 Monitoring Results – This is the main results section of the report consisting of four major parts:

- Section 5.1 is the report of 2015 findings for the mainstem Athabasca River;
- Section 5.2 is the report of 2015 findings for the Athabasca River Delta;
- Sections 5.3 to 5.13 are watershed-level reports of the 2015 findings for hydrology, water quality, benthic invertebrate communities and sediment quality, and fish populations; and
- Section 5.14 is the report of 2015 findings for the Acid-Sensitive Lakes component.

Each of these sections presents the results following the analytical approaches contained in each of the component sections of Section 3, as described above. Each section begins with a summary assessment of the overall status of aquatic environmental resources and possible relation to oil sands projects.

Section 6: Special Studies – This section of the report contains summaries of three studies conducted in 2015 in support of the JOSMP that are not part of the regular monitoring program:

- Study to explore relationships between turbidity, total suspended solids, and discharge in tributaries to the Athabasca River;
- Expanded fish community study; and
- Pilot program for evaluating the status of Fish in the Athabasca River.

Section 7: Synthesis of 2015 Results – This section of the report contains a summary of the findings, conclusions, and recommendations from 2015. The recommendations include proposed changes to the monitoring network for consideration in future years based on the results from the 2015 Program.

The main report concludes with **Section 8: References** and **Section 9: Glossary and List of Acronyms**. In addition, the report is supported by a series of technical appendices that present the detailed analytical results and supporting material for each component.

All data are publicly available on the historical RAMP website (www.ramp-alberta.org) and can be accessed directly or through the AEMERA website (www.aemera.org). The database was updated with 2015 provisional data, with finalized data posted following the release of this report in spring 2016.

2.0 SUMMARY OF OIL SANDS PROJECT ACTIVITIES IN 2015

This section provides information on oil sands developments in watersheds of the Athabasca oil sands region that was needed to support the assessment of the 2015 monitoring results. In particular, this information is important for confirming the classification of sampling stations as *baseline* or *test* as development continues to expand over time resulting in changes to these classifications. Three sets of information are presented: development status of oil sands projects (mining and in situ); summary of water withdrawals from and releases to surface water sources; and land change analysis for 2015.

2.1 DEVELOPMENT STATUS OF OIL SANDS PROJECTS

The development status of all oil sands projects in the Athabasca oil sands region as of the end of 2015, is presented in Table 2.2-1. Areas downstream of oil sands developments that have 2015 or earlier as the year of first disturbance in Table 2.2-1 are designated as *test*. Data obtained from sampling stations in these *test* areas are also designated as *test* for the purposes of analysis, assessment, and reporting (Section 1.4.4). Areas that are: (i) upstream of oil sands developments; or (ii) downstream of oil sands developments but either have no specified year of first disturbance or have 2016 or later as the year of first disturbance in Table 2.2-1 are designated as *baseline*. Data obtained from sampling stations in these *baseline* areas are also designated as *baseline* for the purposes of analysis, assessment, and reporting. Additional information provided in Table 2.2-1 is used to interpret the 2015 monitoring results for all monitoring components.

2.2 WATER USE RELATED TO OIL SANDS PROJECTS IN 2015

Oil sands developments obtain water for their operations largely from nearby surface water or groundwater sources. To accurately assess the hydrologic conditions of each watershed for the Climate and Hydrology component, water withdrawal and release data were collected from oil sands projects that were active (i.e., operational or under construction) and incorporated into the hydrologic water balance model outlined in Section 3.2.1.3. The hydrologic water balance model incorporates only water that was withdrawn from one surface waterbody and released directly to another surface waterbody. Any of the following information provided by operators of the active oil sands projects were not included in the water balance calculations: (i) data classified as muskeg dewatering, groundwater extraction, or other processes not affecting natural surface watercourses and waterbodies; (ii) data from cases in which both the withdrawal and release points are located downstream of the corresponding observed *test* monitoring station; and (iii) withdrawals and releases occurring on days when observed *test* monitoring did not occur (e.g., during winter months for open-water monitoring stations, or when data collection was prevented due to unforeseen circumstances). Table 2.2-2 provides a summary of water withdrawals and releases for each active oil sands project in the 2015 Water Year (WY; i.e., November 1, 2014 to October 31, 2015) that were provided by operators of these projects to the authors of this report[1]. The source of water withdrawals and location of discharge points for each active project are provided in Figure 2.2-1.

[1] to ensure consistency with the analysis and reporting in the Climate and Hydrology component

Table 2.2-1 Development status of all oil sands projects in the JOSMP study area as of 2015.

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2015 Status
Athabasca Oil Corp.	Birch Phase 1	100-15-W4M	in situ	12,000	–	–	Announced
	Dover West Carbonates Phase 1 Demonstration	95-18-W4M	in situ	6,000	–	–	Approved
	Dover West Carbonates Phase 2 Demonstration		in situ	6,000	–	–	Application
	Dover West Sands & Clastics Phase 1	92-18-W4M	in situ	12,000	–	–	Application
	Dover West Sands & Clastics Phase 2		in situ	35,000	–	2019	Announced
	Dover West Sands & Clastics Phase 3		in situ	35,000	–	2020	Announced
	Dover West Sands & Clastics Phase 4		in situ	35,000	–	2022	Announced
	Dover West Sands & Clastics Phase 5		in situ	35,000	–	2024	Announced
	Hangingstone HS-1	86,87,88-10,11,12,13-W4M	in situ	12,000	–	2015	Operational
	Hangingstone HS-2A Debottleneck (1 and 2)		in situ	8,000	–	2017	Application
	Hangingstone HS-2B Expansion		in situ	32,000	–	2019	Application
	Hangingstone HS-3		in situ	30,000	–	2021	Application
BlackPearl Resources Inc.	Blackrod Pilot	02-36-076-18-W4M	in situ	800	–	2011	Operational
	Blackrod Phase 1		in situ	20,000	–	–	Application
	Blackrod Phase 2		in situ	30,000	–	–	Application
	Blackrod Phase 3		in situ	30,000	–	–	Application
BP p.l.c	Terre de Grace Pilot – In Situ	95,96,97-13,14-W4M	in situ	10,000	–	–	Approved
	Terre de Grace Phase 1 – In Situ		in situ	40,000	–	–	Announced
	Terre de Grace Phase 2 – In Situ		in situ	40,000	–	–	Announced
Brion Energy Corp.	MacKay River Phase 1	92, 93-12-W4M	in situ	35,000	2010	2015	Construction
	MacKay River Phase 2		in situ	40,000	2010	–	Approved
	MacKay River Phase 3		in situ	40,000	2010	2020	Approved
	MacKay River Phase 4		in situ	35,000	2010	2022	Approved
	Dover Experimental Pilot	87,88,89,90,91-12-W4M	in situ	2,000	–	2017	Approved
	Dover North Phase 1		in situ	50,000	2010	–	Approved
	Dover North Phase 2		in situ	50,000	2010	–	Approved
	Dover North Phase 3		in situ	50,000	2010	2021	Approved
	Dover North Phase 4		in situ	50,000	2010	2023	Approved
	Dover South Phase 5		in situ	50,000	2010	2025	Approved
Canadian Natural Resources Ltd.	Horizon Phase 1	96-11/12-W4M, 96-13-W4M, 97-11-W4M, 97-12-W4M, 97-13-W4M	mine	135,000	2002	2008	Operational
	Horizon Phase 2A		mine	12,000	–	2014	Operational
	Horizon Phase 2B		mine	45,000	–	2016	Construction
	Horizon Phase 3		mine	80,000	–	2017	Construction
	Horizon Phase 4		mine	145,000	–	–	Announced
	Horizon Phase 5		mine	162,000	–	–	Announced
	Horizon Tranche 2		mine	5,000	–	2014	Operational
	Birch Mountain Phase 1	97-19-W4M	in situ	60,000	–	2019	Announced
	Birch Mountain Phase 2		in situ	60,000	–	2023	Announced
	Gregoire Lake Phase 1	86-8-W4M	in situ	60,000	–	–	Announced
	Gregoire Lake Phase 2		in situ	60,000	–	–	Announced
	Gregoire Lake Phase 3		in situ	30,000	–	–	Announced
	Gregoire Lake Phase 4		in situ	30,000	–	–	Announced

Notes: Information in this table was obtained from AER (2015), GOA (2015a, b), OSR (2015), project EIA documents, and company websites.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2015 Status
Canadian Natural Resources Ltd. (Cont'd.)	Grouse Commercial	74-12-W4M	in situ	40,000	–	2020	Application
	Kirby North Phase 1	73,74,75-7,8,9-W4M	in situ	40,000	–	–	On Hold
	Kirby North Phase 2		in situ	60,000	–	–	Approved
	Kirby South Phase 1		in situ	40,000	–	2013	Operational
Cenovus Energy Inc.	East McMurray Phase 1	89-8-W4M	in situ	30,000	–	–	Announced
	Steepbank Phase 1	92-5-W4M	in situ	30,000	–	–	Announced
	Telephone Lake Borealis Phase A	94,95-3-W4M	in situ	45,000	–	–	On Hold
	Telephone Lake Borealis Phase B		in situ	45,000	–	–	Approved
	Christina Lake Phase 1A	75,76-5,6-W4M	in situ	10,000	–	2002	Operational
	Christina Lake Phase 1B		in situ	8,800	–	2008	Operational
	Christina Lake Phase C		in situ	40,000	–	2011	Operational
	Christina Lake Phase D		in situ	40,000	–	2012	Operational
	Christina Lake Phase E		in situ	40,000	2009	2013	Operational
	Christina Lake Optimization (phases C,D,E)		in situ	22,000	–	2015	Construction
	Christina Lake Phase F		in situ	50,000	–	2016	Construction
	Christina Lake Phase G		in situ	50,000	2009	–	On Hold
	Christina Lake Phase H		in situ	50,000	–	–	Application
	Narrows Lake Phase A	76,77-6,7-W4M	in situ	45,000	2010	–	On Hold
	Narrows Lake Phase B		in situ	45,000	2010	–	Approved
	Narrows Lake Phase C		in situ	40,000	2010	–	Approved
	Pelican Lake Pilot	83-21-W4M	in situ	600	–	2011	Operational
	Pelican Upper Grand Rapids Phase A		in situ	10,000	–	–	On Hold
	Pelican Upper Grand Rapids Phase B		in situ	32,000	–	–	Approved
	Pelican Upper Grand Rapids Phase C		in situ	29,000	–	–	Approved
	Pelican Upper Grand Rapids Phase D		in situ	29,000	–	–	Approved
	Pelican Upper Grand Rapids Phase E		in situ	32,000	–	–	Approved
	Pelican Upper Grand Rapids Phase F		in situ	29,000	–	–	Approved
	Pelican Upper Grand Rapids Phase G		in situ	19,000	–	–	Approved
	West Kirby Phase 1	75-8-W4M	in situ	30,000	–	–	Announced
	Winefred Lake Phase 1	76-4-W4M	in situ	30,000	–	–	Announced
Connacher Oil and Gas Ltd.	Great Divide Pod One	82,83-11,12-W4M	in situ	10,000	–	2007	Operational
	Great Divide Algar		in situ	10,000	–	2010	Operational
	Great Divide Expansion 1A		in situ	12,000	–	–	Approved
	Great Divide Expansion 1B		in situ	12,000	–	–	Approved
ConocoPhillips Canada Ltd.	Surmont Phase 1	81,82,83-5,6,7-W4M	in situ	30,000	2001	2007	Operational
	Surmont Phase 2		in situ	118,000	–	2015	Operational
	Surmont Phase 2 Debottleneck		in situ	57,000	–	–	Application
	Surmont Phase 3 – Tranche 1		in situ	45,000	–	2020	Application
	Surmont Phase 3 – Tranche 2		in situ	45,000	–	2021	Application
	Surmont Phase 3 – Tranche 3		in situ	45,000	–	2023	Application
	Surmont Pilot		in situ	1,200	–	1997	Operational

Notes: Information in this table was obtained from AER (2015), GOA (2015a, b), OSR (2015), project EIA documents, and company websites.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2015 Status
Devon Canada Corp.	Jackfish Phase 1	75,76-6,7-W4M	in situ	35,000	2003	2007	Operational
	Jackfish Phase 2		in situ	35,000	2006	2011	Operational
	Jackfish Phase 3		in situ	35,000	2010	2014	Operational
	Jackfish East Expansion	76-5-W4M	in situ	20,000	–	2018	Announced
	Pike 1A	73,74,75-4,5,6,7,8-W4M	in situ	35,000	–	2019	Approved
	Pike 1B		in situ	35,000	–	2020	Approved
	Pike 1C		in situ	35,000	–	–	Cancelled
E-T Energy Ltd.	Poplar Creek Experimental Pilot	90-9-W4M	in situ	1,000	–	2012	Suspended
	Poplar Creek Phase 1		in situ	10,000	–	–	On Hold
	Poplar Creek Phase 2		in situ	40,000	–	–	On Hold
Grizzly Oil Sands ULC	Algar Lake Phase 1	85-12-W4M	in situ	6,000	–	2014	Suspended
	Algar Lake Phase 2		in situ	6,000	–	–	Approved
	May River Phase 1	12-77-9-W4M	in situ	6,000	–	–	Application
	May River Phase 2		in situ	6,000	–	–	Application
	Thickwood Phase 1	90-15-W4M	in situ	6,000	–	–	Application
	Thickwood Phase 2		in situ	6,000	–	–	Application
Harvest Operations Corp.	BlackGold Phase 1	76-7-W4M	in situ	10,000	–	–	On Hold
	BlackGold Phase 2		in situ	20,000	–	–	Approved
Husky Energy Inc.	Saleski Carbonate Pilot	16-31-87-19-W4	in situ	3,000	–	–	Application
	Sunrise Phase 1A	94-97-6,7-W4M	in situ	30,000	–	2015	Operational
	Sunrise Phase 1B		in situ	30,000	–	2015	Construction
	Sunrise Phase 2A		in situ	35,000	–	–	On Hold
	Sunrise Phase 2B		in situ	35,000	–	–	Approved
	Future Phases		in situ	70,000		–	Approved
Imperial Oil Ltd.	Kearl Lake Phase 1	95,96,97-6,7,8-W4M	mine	110,000	2005	2013	Operational
	Kearl Lake Phase 2		mine	110,000	–	2015	Operational
	Kearl Lake Phase 3		mine	80,000	–	–	On Hold
	Kearl Lake Phase 4 Debottleneck		mine	45,000	–	–	On Hold
	Aspen Phase 1	93-7-W4M	in situ	45,000	–	2020	Application
	Aspen Phase 2		in situ	45,000	–	–	Application
	Aspen Phase 3		in situ	45,000	–	–	Application
Ivanhoe Energy Inc.	Tamarack Phase 1	22-90-9-W4M	in situ	20,000	–	–	Application
	Tamarack Phase 2		in situ	20,000	–	–	Application
JACOS	Hangingstone Pilot	84-10,11,12-W4M	in situ	11,000	–	1999	Operational
	Hangingstone Expansion		in situ	20,000	–	2016	Construction
Koch Exploration Canada Corp.	Dunkirk Commercial Demonstration	10-91-18-W4M	in situ	2,000	–	2017	Application
	Dunkirk Phase 1		in situ	30,000	–	2018	Announced
	Dunkirk Phase 2		in situ	30,000	–	–	Announced

Notes: Information in this table was obtained from AER (2015), GOA (2015a, b), OSR (2015), project EIA documents, and company websites.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2015 Status
Laricina Energy Ltd.	Saleski Experimental Pilot	84-19-W4M	in situ	1,800	–	2011	Suspended
	Saleski Phase 1		in situ	10,700	–	–	On Hold
	Saleski Phase 2		in situ	30,000	–	–	On Hold
	Saleski Phase 3		in situ	60,000	–	–	Announced
	Saleski Phase 4		in situ	60,000	–	–	Announced
	Saleski Phase 5		in situ	60,000	–	–	Announced
	Saleski Phase 6		in situ	60,000	–	–	Announced
Marathon Oil Corp.	Birchwood Demonstration	20-91-15-W4M	in situ	12,000	–	–	Application
MEG Energy Corp.	Christina Lake Phase 1 Pilot	76,78-4,6-W4M	in situ	3,000	2004	2008	Operational
	Christina Lake Phase 2A		in situ	22,000	2005	2009	Operational
	Christina Lake Phase 2B		in situ	35,000	2007	2013	Operational
	Christina Lake Phase 3A		in situ	50,000	2008	–	Approved
	Christina Lake Phase 3B		in situ	50,000	2009	–	Approved
	Christina Lake Phase 3C		in situ	50,000	2011	–	Approved
	Surmont Phase 1	81,82-5-W4M	in situ	40,000	2012	–	Application
	Surmont Phase 2		in situ	40,000	2012	–	Application
	Surmont Phase 3		in situ	40,000	2012	–	Application
Nexen/CNOOC Ltd.	Long Lake Phase 1	84,85-6,7-W4M	in situ	72,000	2000	2008	Suspended
	Long Lake South (Kinosis) Phase 1A		in situ	20,000	2006	2014	Suspended
	Long Lake South (Kinosis) Phase 1B		in situ	37,500	2006	–	Approved
	Long Lake Phase 2		in situ	72,000	–	–	Approved
	Long Lake Phase 3		in situ	72,000	–	–	Application
	Long Lake Phase 4		in situ	72,000	–	–	Announced
	Long Lake Phase 5		in situ	72,000	–	–	Announced
	Long Lake Phase 6		in situ	72,000	–	–	Announced
Oak Point Energy Ltd.	Lewis Pilot	93, 94-7-W4M	in situ	1,720	–	–	Approved
Osum Oil Sands Corp.	Sepiko Kesik Phase 1	21-85-18-W4M	in situ	30,000	–	2018	Application
	Sepiko Kesik Phase 2		in situ	30,000	–	2020	Application
Prosper Petroleum Ltd.	Rigel Phase 1	20-96-17-W4M	in situ	10,000	–	2017	Application
PTT Exploration and Production	Mariana – Hangingstone Phase 1	83-10-W4M	in situ	20,000	–	–	On Hold
	Mariana – South Leismer Phase 1	77-10-W4M	in situ	20,000	–	–	On Hold
	Mariana – Thornbury Phase 1	80-12-W4M	in situ	20,000	–	2021	Application
	Mariana – Thornbury Expansion		in situ	20,000	–	–	On Hold
Shell Albian Sands	Muskeg River Mine Commercial	95-10-W4M	mine	155,000	1997	2002	Operational
	Muskeg River Mine Expansion & Debottlenecking	95-8,9-W4M, 94-10-W4M	mine	115,000	2005	–	Approved
	Jackpine Mine Phase 1A	95-8-W4, 95-9-W4	mine	100,000	2002	2010	Operational
	Jackpine Mine Phase 1B		mine	100,000	–	–	Approved
	Jackpine Mine Expansion	96,97-8,9-W4M	mine	100,000	2007	–	Approved
	Pierre River Mine Phase 1	97,98,99-10,11-W4M	mine	100,000	2007	–	Cancelled
	Pierre River Mine Phase 2		mine	100,000	–	–	Cancelled

Notes: Information in this table was obtained from AER (2015), GOA (2015a, b), OSR (2015), project EIA documents, and company websites.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2015 Status
Southern Pacific Resource Corp.	STP-McKay Phase 1	91-14,15-W4M	in situ	12,000	–	2012	Suspended
	STP-McKay Phase 1 Expansion		in situ	6,000	–	2016	Application
	STP-McKay Phase 2A		in situ	12,000	–	2018	Application
	STP-McKay Phase 2B		in situ	6,000	–	2018	Application
Statoil	Corner Phase 1	80-8-W4M	in situ	40,000	–	–	On Hold
	Corner Expansion		in situ	40,000	–	–	On Hold
	Leismer Demonstration	79-10-W4M	in situ	10,000	–	2010	Operational
	Leismer Commercial		in situ	10,000	–	2011	Operational
	Leismer Expansion		in situ	20,000	–	–	Approved
	Leismer Northwest		in situ	20,000	–	–	Disclosed
Suncor Energy Inc.	Millennium Mine	92,93-9-W4M	mine	294,000	–	1967	Operational
	Steepbank Debottleneck Phase 3		mine	4,000	–	2007	Operational
	North Steepbank Mine Extension	92,93-9-W4M	mine	180,000	2006	2012	Operational
	Millennium Debottlenecking	91,92-9-W4M	mine	23,000	–	2008	Operational
	Voyageur South Phase 1	91,92-10-W4M	mine	120,000	–	–	Application
	Chard Phase 1	80-5-W4M	in situ	40,000	–	–	Announced
	Dover BEST Pilot	93-12-W4M	in situ	300	–	2014	Operational
	Dover ESEIEH Pilot		in situ	–	–	2015	Operational
	Firebag Stage 1	93,94,95,96-4,5,6,7-W4M	in situ	35,000	2000	2004	Operational
	Firebag Stage 2		in situ	35,000	–	2006	Operational
	Firebag Cogeneration and Expansion		in situ	25,000	–	2007	Operational
	Firebag Stage 3		in situ	42,500	–	2011	Operational
	Firebag Stage 4		in situ	42,500	–	2012	Operational
	Firebag Stage 5		in situ	62,500	–	–	Approved
	Firebag Stage 6		in situ	62,500	–	–	Approved
	Firebag Stages 3 to 6 Debottlenecking		in situ	23,000	–	–	Application
	Fort Hills Phase 1	96-11-W4M, 97,98-10-W4M	mine	160,000	2001	2017	Construction
	Fort Hills Debottleneck		mine	20,000	–	–	Approved
	Lewis Phase 1	91-7-W4M	in situ	40,000	–	–	Announced
	Lewis Phase 2		in situ	40,000	–	–	Announced
	MacKay River Phase 1	92, 93-12-W4M	in situ	33,000	1998	2002	Operational
	MacKay River Debottleneck		in situ	5,000	–	2014	Operational
	MacKay River Expansion (MR2)		in situ	20,000	2005	–	On Hold
	Meadow Creek East Phase 1	84,85-8,9,10-W4M	in situ	20,000	2001	2020	Approved
	Meadow Creek East Phase 2		in situ	30,000	–	2022	Approved
	Meadow Creek East Phase 3		in situ	30,000	–	–	Approved

Notes: Information in this table was obtained from AER (2015), GOA (2015a, b), OSR (2015), project EIA documents, and company websites.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-1 (Cont'd.)

Operator	Development	Location (Township-Range-Meridian)	Type of Operation	Capacity[1]	Year of Application	Year of First Disturbance	2015 Status
Sunshine Oilsands Ltd.	Legend Lake Phase A1	96-18-W4M	in situ	10,000	–	–	Application
	Legend Lake Phase A2		in situ	30,000	–	–	Announced
	Legend Lake Phase B1		in situ	30,000	–	–	Announced
	Legend Lake Phase B2		in situ	30,000	–	–	Announced
	Thickwood Phase A1	90-18-W4M	in situ	10,000	–	–	Approved
	Thickwood Phase A2		in situ	30,000	–	–	Announced
	Thickwood Phase B		in situ	30,000	–	2021	Announced
	West Ells Phase A1	94,95,96-17,18-W4M	in situ	5,000	–	2015	Operational
	West Ells Phase A2		in situ	5,000	–	–	Approved
	West Ells Phase A3		in situ	30,000	–	–	Announced
	West Ells Phase B		in situ	20,000	–	–	Announced
	West Ells Phase C1		in situ	30,000	–	–	Announced
	West Ells Phase C2		in situ	30,000	–	–	Announced
Surmont Energy Inc.	Wildwood Phase 1	20-82-8-W4M	in situ	12,000	–	–	Application
Syncrude Canada	Mildred Lake and Aurora North Base Mine Stage 1 & 2 Expansion	6-93-10-W4M; 96-9,10,11-W4M	mine	290,700	1973	1978	Operational
	Mildred Lake and Aurora North Stage 3 Expansion	6-93-10-W4M; 96-9,10,11-W4M	mine	116,300	2001	2006	Operational
	Centrifuge Tailings Management	6-15-93-11-W4M	mine	NA	–	2015	Operational
	Aurora South Train 1	94, 95-7,8-W4M	mine	100,000	–	–	Approved
	Aurora South Train 2		mine	100,000	–	–	Approved
	Mildred Lake Mine Extension	6-15-93-11-W4M	mine	184,000	–	2023	Application
Teck Resources Ltd.	Frontier Phase 1A	99-11, 100,101-9,10,11-W4M	mine	85,000	2011	2026	Application
	Frontier Phase 1B		mine	85,000	2011	2027	Application
	Frontier Phase 2		mine	90,000	2011	2037	Application
	Frontier Phase 4 Equinox		mine	39,400	2011	2030	Application
Total E&P Canada Ltd.	Joslyn North Mine Phase 1	94,95,96-11-W4M, 94-12-W4M	mine	100,000	2006	–	On Hold
Value Creation Inc.	Advanced TriStar ATS-1	25-89-8-W4M	in situ	15,000	–	–	Application
	Advanced TriStar ATS-2		in situ	30,000	–	–	Application
	Advanced TriStar ATS-3		in situ	30,000	–	–	Application
	Audet Pilot	98-3-W4M	in situ	12,000	–	–	Application
	DOEx Pilot	29-87-8-W4M	in situ	6,000	–	–	Application

Notes: Information in this table was obtained from AER (2015), GOA (2015a, b), OSR (2015), project EIA documents, and company websites.

[1] Unless otherwise stated, units are in bpd.

Table 2.2-2 Summary of water withdrawals and discharges for active (operating or under construction) oil sands projects, used in the water balance analysis for the 2015 WY.

Operator	Project	Water Withdrawal from a Surface Waterbody		Water Release to a Surface Waterbody	
		Volume (Million m^3)	Location	Volume (Million m^3)	Location
Canadian Natural Resources Ltd.	Kirby	0.031	Christina River watershed	0.039	Christina River watershed
		0.009	Athabasca River watershed	-	-
	Horizon	22.98	Athabasca River	0.150	Calumet River watershed
Imperial Oil Resources	Kearl Lake	29.54	Athabasca River	0.795	Muskeg River watershed
		-	-	0.399	Firebag River watershed
MEG Energy Corp.	Christina Lake	0.031	Christina River watershed	-	-
Nexen	Long Lake	0.015	Christina River watershed	-	-
Shell Canada Energy	Jackpine Mine and Muskeg River Mine	12.27	Athabasca River	1.75	Muskeg River
Statoil Canada Ltd.	Leismer	0.015	Christina River watershed	-	-
Suncor Energy Inc.	North Steepbank Extension	17.51	Athabasca River	3.00	Athabasca River
	MacKay River	0.019	MacKay River watershed	-	-
	Fort Hills	0.237	Athabasca River	0.152	Athabasca River
Syncrude Canada Ltd.	Mildred Lake Mine and Aurora North	38.19	Athabasca River	3.21	Athabasca River
		-	-	1.419	Poplar Creek
		-	-	5.36	Stanley Creek

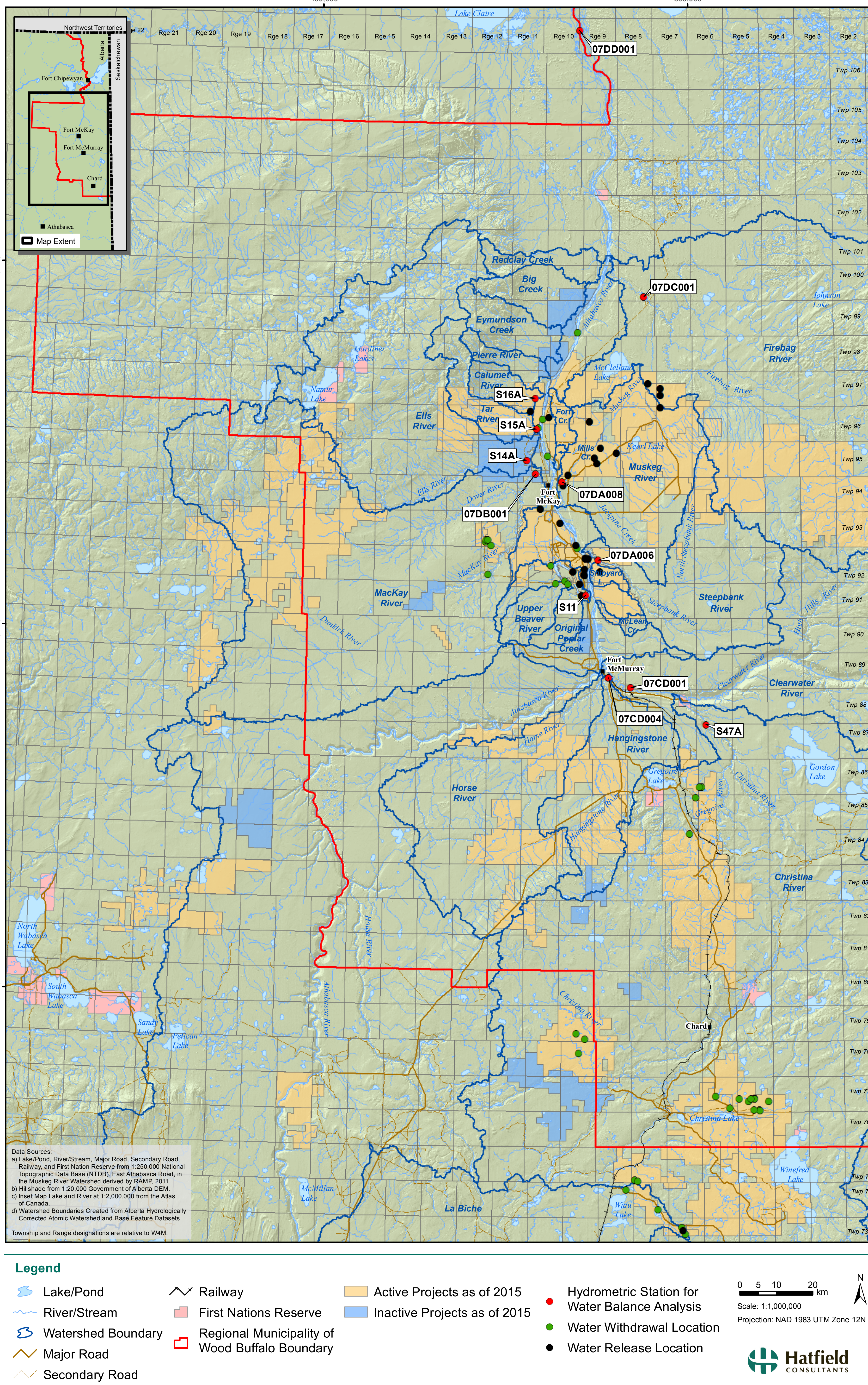
Notes:

Withdrawal and release volumes presented above were those reported to the authors of this report and may not include all withdrawal and release volumes that actually occurred in the 2015 WY in the Athabasca oil sands region.

Withdrawal and release volumes presented above are the final values used in the Chapter 5 water balance analyses and satisfy the following criteria: (i) volumes were classified as withdrawn or released to the environment; (ii) locations of withdrawals and releases occurred within the watershed being assessed; and (iii) withdrawals and releases occurred concurrently with periods of recorded hydrograph data within the analysis watershed.

Values shown were rounded to three decimal places for volumes less than 1 million m^3, and two decimal places otherwise.

Figure 2.2-1 Locations of surface water withdrawals and releases for active oil sands projects, used in the water balance calculations, 2015 WY.



K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_C_WithdrawalRelease_20160329_ss.mxd

2.3 LAND CHANGE AS OF 2015 RELATED TO OIL SANDS ACTIVITIES

Land change due to development activities occurring in 2015 was estimated with satellite imagery in conjunction with more detailed maps provided by a number of oil sands companies. A total of seventy RapidEye 5-m resolution images (42 north of Fort McMurray and 28 south of Fort McMurray) were acquired on June 17, 20, 27, 28 and 29, July 22 and 28, and August 10 and 30, 2015. The July imagery were used to replace the June and August 2015 cloud-covered areas to improve visual quality for interpretation and image classification purposes. A land change classification protocol was developed and applied to the imagery to identify and delineate two types of land change in 2015 from the projects listed in Table 2.2-1. Developed areas where there was no natural exchange of water with the rest of the watershed (e.g., tailings ponds) were designated as hydrologically closed-circuited. Developed areas where there was natural exchange of water with the rest of the watershed (e.g., cleared land) were designated as not hydrologically closed-circuited.

Based on the resolution of the satellite imagery, a development of 0.5 ha was the smallest entity delineated. Details of the land change estimation procedure are provided in Appendix A. Drafts of the land change maps were provided to companies where the classification required further verification, and recommendations for revision of the maps were used to produce the final set of 2015 land change maps.

Land change areas as of 2015 are presented in Figure 2.3-1 and Figure 2.3-2 for north and south of Fort McMurray, respectively. Table 2.3-1 provides a tabular summary of the total area and percent land change in each of the major watersheds of the Athabasca oil sands region, by land change type. Land change as of 2015 was estimated to be approximately 128,486 ha, which was an increase of 4,496 ha from 2014. The total area of land change represented approximately 3.49% of the total area of the watersheds in which these oil sands projects are occurring, compared to 3.47% in 2014. The percentage of the area of watersheds with land change as of 2015 varied from less than 1% for many watersheds (MacKay, Horse, Pierre River, and Upper Beaver watersheds), to 1% to 5% for the Steepbank, Calumet, Firebag, Ells, Christina, and Hangingstone watersheds, to more than 10% for the Muskeg River, Fort Creek, Mills Creek, Tar River, Shipyard Lake, Poplar Creek, and McLean Creek watersheds, as well as for the smaller Athabasca River tributaries between Fort McMurray and the confluence of the Firebag River.

Land change area within the city of Fort McMurray in 2015 was estimated at approximately 7,490 ha, compared to approximately 7,442 ha in 2014. Almost half of this land change was in watersheds of smaller tributaries of the Athabasca River, with the remaining land change occurring in the Clearwater, Hangingstone, and Horse watersheds.

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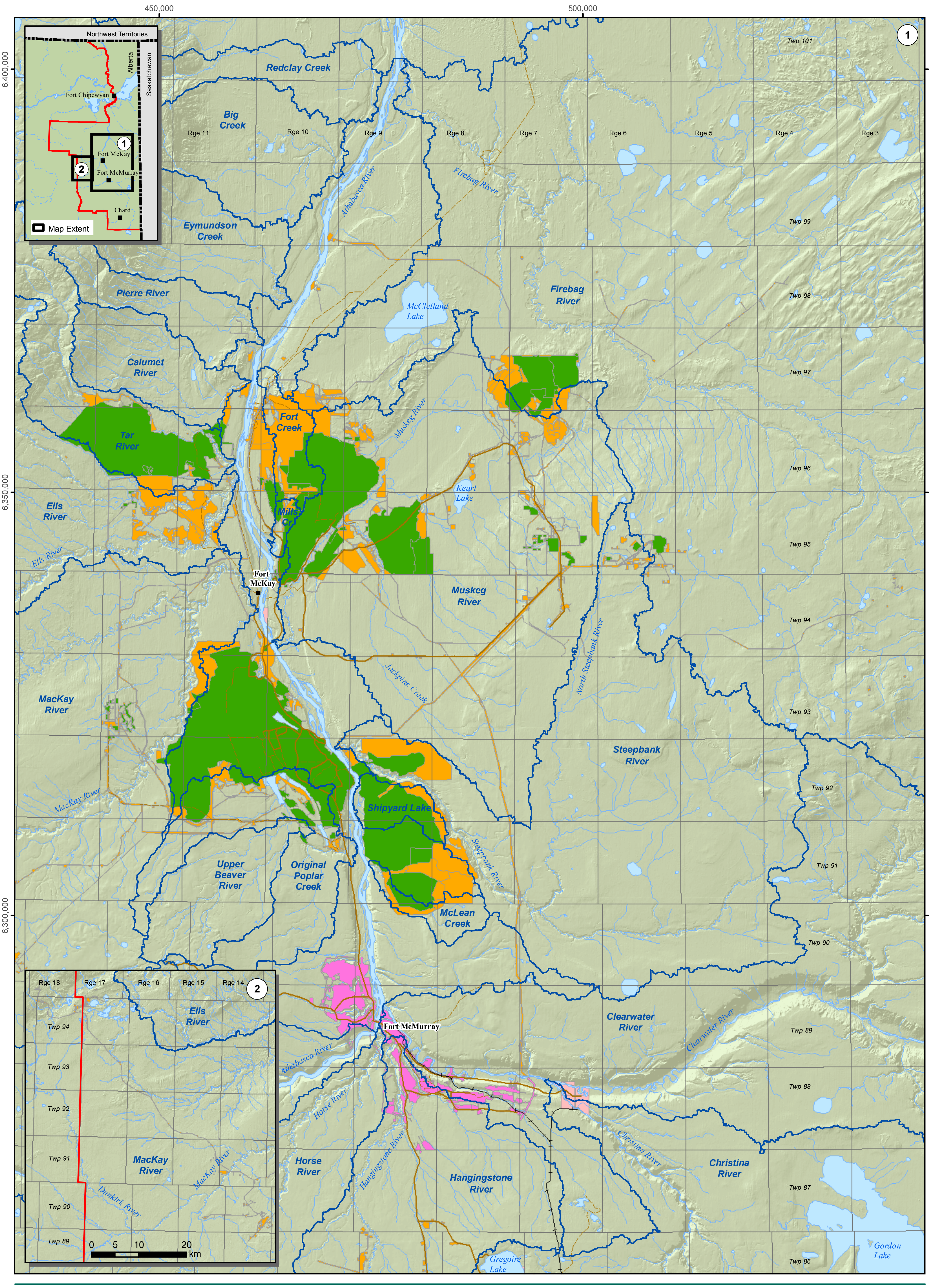
Figure 2.3-1 Land change classes derived from 5-m RapidEye (June, July, and August 2015) multispectral satellite imagery, north of Fort McMurray.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Town of Fort McMurray

Land Change Area as of 2015[e]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, and First Nation Reserve from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed derived by RAMP, 2011.
b) Hillshade from 1:20,000 Government of Alberta DEM.
c) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
d) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
e) Land Change Areas Delineated from 5-m RapidEye (June, July, and August 2015) Multispectral Imagery.

Township and Range designations are relative to W4M.

0 2.5 5 10 km

N

Scale: 1:450,000

Projection: NAD 1983 UTM Zone 12N

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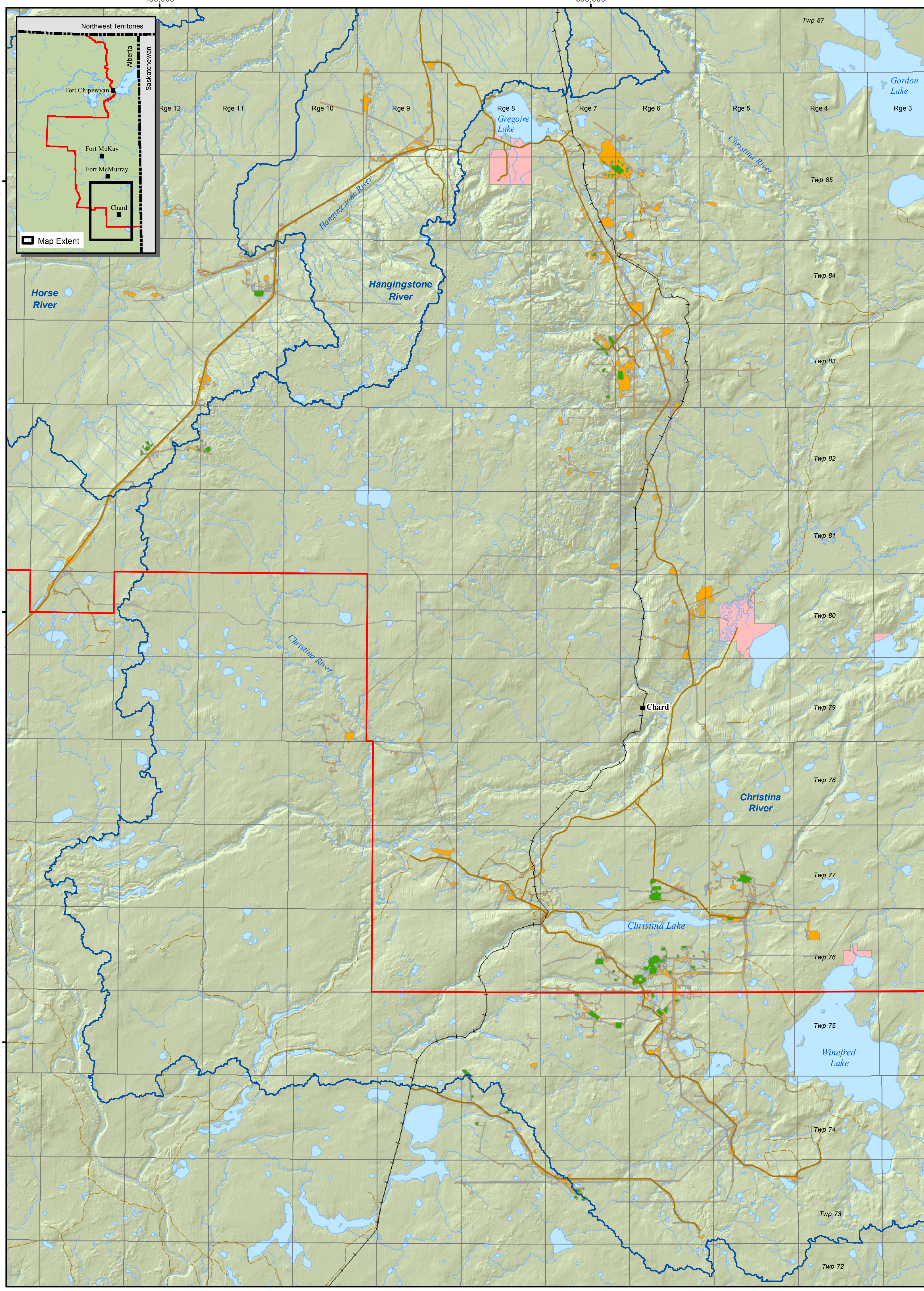
Figure 2.3-2 Land change classes derived from 5-m RapidEye (June, July, and August 2015) multispectral satellite imagery, south of Fort McMurray.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary

Land Change Area as of 2015[e]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

0 2.5 5 10 km

N

Scale: 1:450,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Lake/Pond, River/Stream, Major Road, Secondary Road, Railway, and First Nation Reserve from 1:250,000 National Topographic Data Base (NTDB). East Athabasca Road, in the Muskeg River Watershed derived by RAMP, 2011.
b) Hillshade from 1:20,000 Government of Alberta DEM.
c) Inset Map Lake and River at 1:2,000,000 from the Atlas of Canada.
d) Watershed Boundaries Created from Alberta Hydrologically Corrected Atomic Watershed and Base Feature Datasets.
e) Land Change Areas Delineated from 5-m RapidEye (June, July, and August 2015) Multispectral Imagery.

Township and Range designations are relative to W4M.

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Table 2.3-1 Total area and percent of land change in watersheds of the Athabasca oil sands region related to oil sands development in 2015.

Watershed	Total Watershed Area (ha)	Watershed Area with Land Change (ha)					
		Not-Closed Circuited (ha)		Closed-Circuited (ha)		Watershed Total (ha and %)	
		Area (ha)	Percent	Area (ha)	Percent		
Calumet River	17,523	135	0.77	70	0.40	205	1.17
Christina River[1]	1,340,198	13,269	0.99	1,814	0.14	15,083	1.13
Ells River	270,945	3,621	1.34	360	0.13	3,982	1.47
Firebag River[1]	646,993	3,492	0.54	4,046	0.63	7,539	1.17
Fort Creek	6,640	3,400	51.21	2,192	33.02	5,593	84.23
Hangingstone River	106,572	1,517	1.42	16	0.02	1,533	1.44
Horse River	215,740	1,849	0.86	157	0.07	2,006	0.93
MacKay River	556,871	4,396	0.79	763	0.14	5,160	0.93
McLean Creek	4,643	937	20.17	609	13.12	1,546	33.29
Mills Creek	1,424	206	14.48	723	50.77	929	65.25
Muskeg River[2]	143,304	9,108	6.36	14,786	10.32	23,894	16.67
Original Poplar[3]	28,388	1,716	6.04	3,802	13.39	5,518	19.44
Pierre River	13,824	18	0.13	0	0.00	18	0.13
Shipyard Lake	5,113	726	14.20	3,982	77.87	4,707	92.07
Steepbank River	136,395	4,142	3.04	1,414	1.04	5,556	4.07
Tar River	33,264	1,404	4.22	9,929	29.85	11,333	34.07
Upper Beaver River	18,796	41	0.22	82	0.43	123	0.65
Minor Athabasca River Tributaries[2,4]	135,132	7,860	5.82	25,902	19.17	33,762	24.98
Total	**3,681,765**	**57,836**	**1.57**	**70,650**	**1.92**	**128,486**	**3.49**
Lac La Biche[5]	864,496	641	0.07	101	0.01	742	0.09

[1] The total watershed areas of the Christina River and Firebag River were increased in 2015 to include the portions of the watersheds that were within the province of Saskatchewan.

[2] Land change areas within the Muskeg River and Minor Athabasca River Tributaries watersheds were reduced slightly in 2015 due to the removal of non-oil sands development from the calculation of land change areas (specifically, the Hammerstone Quarry and Fort McKay Industrial Park and access roads).

[3] Original Poplar refers to the Poplar Creek watershed prior to the Beaver Creek diversion, while "Upper Beaver" refers to that part of the Beaver Creek drainage that now drains into Poplar Creek as a result of the Beaver Creek diversion. Drainage boundaries were estimated from maps in Syncrude Canada Ltd. (1977).

[4] Refers to Athabasca River tributaries from upstream of Fort McMurray to the mouth of the Firebag River excluding the watersheds explicitly listed in this table.

[5] The Lac La Biche watershed was added in 2011 given some of the Canadian Natural Kirby project is located within this watershed. This watershed, however, is not part of the Athabasca oil sands region currently monitored under the JOSMP.

3.0 MONITORING ACTIVITIES FOR THE 2015 PROGRAM

This section contains a description of monitoring conducted for the 2015 Program. The description of the monitoring conducted for each component consists of a:

- summary of the monitoring activities conducted in the 2015 Water Year (WY) including associated field methods;
- description of any other information obtained (i.e., information from regulatory agencies, owners and operators of oil sands projects, knowledge obtained from local communities, and other sources);
- description of changes in the monitoring network from the 2014 JOSMP;
- description of the challenges and issues encountered during the 2015 WY and the means by which these challenges and issues were addressed;
- summary of the component data that are now available; and
- description of the approach used for analyzing the data.

Monitoring activities for all components in the 2015 WY were implemented according to the monitoring protocols, field methods, and Standard Operating Procedures (SOPs) contained in the RAMP Technical Design and Rationale (RAMP 2009b). Any changes in monitoring protocols, field methods, and SOPs from those contained in RAMP (2009b) are noted below.

Quality Assurance and Quality Control (QA/QC) procedures were employed throughout and for all aspects of the monitoring conducted in the 2015 WY. Appendix B contains a detailed description of the QA/QC procedures used for monitoring in the 2015 WY.

All 2015 monitoring data collected have been added to the online database, which is currently located at www.ramp-alberta.org and through the AEMERA website (www.aemera.org).

Table 3.1-1 provides an overview of the stations monitored for each component of the JOSMP in the 2015 WY, indicating as well the level of harmonization of monitoring achieved among the various components.

3.1 FIELD DATA COLLECTION

3.1.1 Climate and Hydrology Monitoring Component

3.1.1.1 Overview of 2015 Climate and Hydrology Monitoring Activities

Climate monitoring (Table 3.1-2 and Figure 3.1-1) in the 2015 WY consisted of:

- monitoring climate variables at 10 year-round stations;
- measuring rainfall from May 1 to October 31 at five hydrometric monitoring stations; and
- conducting snowcourse surveys during the months of February, March, and April covering four distinct bio-geographic land cover types in four representative regions of the study area for the 2015 Program.

Hydrology monitoring (Table 3.1-2 and Figure 3.1-2) in 2015 consisted of:

- 40 year-round hydrometric monitoring stations;
- 13 open-water hydrometric monitoring stations;
- three year-round lake/wetland water level monitoring stations;
- monitoring water temperature at 46 of the 53 hydrometric monitoring stations; and
- measuring total suspended solids (TSS) and total dissolved solids (TDS) throughout the open-water season at all hydrometric monitoring stations during each visit.

Appendix C provides specific station information for all climate and hydrology stations in the 2015 program.

3.1.1.2 Field Methods

Field methods described in this section include procedures for streamflow measurements, water level surveys, climate station visits, and snowcourse surveys. Further detail and specific procedures for each procedure can be found in the RAMP Design and Rationale document (RAMP 2009b).

General

Field crews conducted ten field visits in the 2015 WY for the Climate and Hydrology component:

- five field visits during the open-water season at the year-round and open-water stations;
- five field visits during the winter season to all year-round stations; and
- three field visits (in three of the five winter visits) for the regional snowcourse survey.

Streamflow Measurement

Streamflow measurement procedures and standards used for the Climate and Hydrology component were consistent with Water Survey of Canada (WSC 2001), United States Geological Survey (USGS 1982), and BC Ministry of Environment (BC MOE 2009) recommendations and protocols, and are presented in the RAMP Design and Rationale Document (RAMP 2009b). QA/QC procedures are provided in Appendix B of this report.

Standards for velocity-area streamflow measurements are summarized as follows:

- Number of verticals – minimum of 20, or at a spacing of 0.05 m in small streams;
- Where depth was 0.75 m or less, one observation was made at 60% of the depth below the surface;
- Where depth was greater than 0.75 m, velocity was observed once at 20% and once at 80% of the depth;
- Number of velocity readings for a measurement under ice – the same procedures were used for under ice velocity observations as for open-water velocity observations, with the exception that velocity was observed at 50% of the under-ice depth (effective depth) for depths less than 0.75 m;
- Under ice velocity observations conducted at 50% of the effective depth were subject to a velocity correction of 0.88 due to the addition of the ice as a confining layer. Panels measured with two velocity measurements were not subject to any velocity correction; and
- Velocity averaging – at least 40-second averages for the Sontek FlowTracker ADV (Acoustic Doppler Velocimeter), OTT ADC (Acoustic Digital Current meter), and electromagnetic meters (Hach HF950 and Marsh McBirney Flo-Mate 2000).

Table 3.1-1 Overview of the stations monitored for each component of the JOSMP in the 2015 WY.

Waterbody	Monitoring Component						Managing Entity		
	Climate and Hydrology	Water Quality	Benthic Invertebrate Communities	Sediment Quality	Fish Populations		Hatfield	AEMERA	Other
					Wild Fish Health	Fish Community			
Athabasca River									
Athabasca River below Fort McMurray	07DA001	-	-	-	-	-	-	-	H
Athabasca River near Embarras Airport	07DD001	-	-	-	-	-	-	-	H
Athabasca River below Eymundson Creek	S24	-	-	-	-	-	H	-	-
Athabasca River below Pierre River	-	ATR-DD-C, ATR-DD-E, ATR-DD-W	-	-	-	-	W	-	-
Athabasca River above Fort McMurray	-	-	-	-	M2	-	F	-	-
Athabasca River below Beaver River	-	M4	-	-	-	-	W	-	-
Athabasca River above MacKay River	-	M5	-	-	-	-	W	-	-
Athabasca River below Fort MacKay	-	M6	-	-	-	-	W	-	-
Athabasca River below Redclay Creek	-	M8[1]	-	-	M8 (5.8km)[2]	-	F	D	-
Athabasca River above town of Athabasca	-	-	-	-	M0-US	-	F	-	-
Athabasca River below town of Athabasca	-	M0-DS[3]	-	M0-DS[3]	M0-DS	-	W, S, F	-	-
Athabasca River below Fort McMurray STP discharge	-	M3[3]	-	M3[3]	M3	-	W, S, F	-	-
Athabasca River above Muskeg River	-	M4-US[3]	-	M4-US[3]	M4-US	-	W, S, F	-	-
Athabasca River below Muskeg River	-	M4-DS[3]	-	M4-DS[3]	M4-DS	-	W, S, F	-	-
Athabasca River above Ells River	-	-	-	-	M7	-	F	-	-
Athabasca River below Firebag River	-	-	-	-	M8	-	F	-	-
Athabasca River near Athabasca River Delta	-	-	-	-	M9	-	F	-	-
Athabasca River Delta									
Big Point Channel	-	BPC-1	BPC-1	BPC-1	-	-	W, B, S	-	-
Embarras River	-	EMR-2	EMR-2	EMR-2	-	-	W, B, S	-	-
Fletcher Channel	-	FLC-1	FLC-1	FLC-1	-	-	W, B, S	-	-
Goose Island Channel	-	GIC-1	GIC-1	GIC-1	-	-	W, B, S	-	-
Muskeg River Watershed									
Muskeg River near the mouth	-	MU0[1]	MUR-E1	-	-	-	B	W, D	-
Muskeg River near Fort McKay	07DA008	MU1[1]	MUR-D2	MUR-D2	MUR-F2	MUR-F2	B, S, F	W, D	H
Muskeg River above Jackpine Creek	-	MU4[1]	-	-	-	-	-	W, D	-
Muskeg River above Muskeg Creek	S5A	MU5	-	-	-	-	H	W	-
Muskeg River above Stanley Creek	S5	MU6[1]	MUR-D3	MUR-D3	-	-	H, B, S	W, D	-
Muskeg River above Wapasu Creek	-	MU7	-	-	-	-	-	W	-

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[1] Data sonde stations. Note: water quality sampling at station M8 consisted only of a data sonde.

[2] Distance from water quality station (displayed only where distance between stations is greater than 1 km)

[3] for Wild Fish Health Monitoring

[4] for Benthic Invertebrate Communities component

Table 3.1-1 (Cont'd.)

Waterbody	Monitoring Component						Managing Entity		
	Climate and Hydrology	Water Quality	Benthic Invertebrate Communities	Sediment Quality	Fish Populations		Hatfield	AEMERA	Other
					Wild Fish Health	Fish Community			
Muskeg River Watershed (Cont'd.)									
Muskeg River above Wapasu Creek	-	MU8	-	-	-	-	-	W	-
Muskeg River at Imperial Kearl Lake Road	S20	MU9	-	-	-	-	H	W	-
Muskeg River Upland	-	MU10	-	-	-	-	-	W	-
Stanley Creek	-	STC-1	-	-	-	-	W	-	-
Jackpine Creek near the mouth	-	JA1	JAC-D1	JAC-D1	-	JAC-F2	B, S, F	W	-
Jackpine Creek at Canterra Road	S2	TR3.1	-	-	-	-	H	W	-
Jackpine Creek above Shell Jackpine	-	TR3.2	-	-	-	-	-	W	-
Jackpine Creek at East Athabasca Hwy	-	JAC-2[4]	JAC-D2	JAC-D2	-	JAC-F1	W, B, S, F	-	-
Wapasu Creek near the mouth	S10A (5.5 km)[2]	WA1	-	-	-	-	H, D	W	-
Muskeg Creek near the mouth	S22	-	-	-	-	-	H	-	-
Iyinimin Creek above Kearl Lake	S3	-	-	-	-	-	C, H	-	-
Muskeg River at Aurora North/MRM Boundary	S33	-	-	-	-	-	H	-	-
East Jackpine Creek near the 1,300 ft Contour	S37	-	-	-	-	-	H	-	-
Green Stockings Creek at East Athabasca Hwy	S65	-	-	-	-	-	H	-	-
Kearl Lake Outlet	S9	-	-	-	-	-	H	-	-
Kearl Lake	L2	KL1	KEL-1	KEL-1	-	-	C, H, W, B, S	-	-
Aurora Climate Station	C1	-	-	-	-	-	C	-	-
Muskeg River Watershed Snowcourse Survey	CANR Area	-	-	-	-	-	Sn	-	-
Steepbank River Watershed									
Steepbank River adjacent to Millennium Mine	07DA006	ST WSC	-	-	-	-	W	-	H
Steepbank River near the mouth	-	ST1[1]	-	-	-	STR-F1	F	W, D	-
Steepbank River below North Steepbank River	S66	STB RIFF 10[1]	-	-	-	-	H, W, D	-	-
Steepbank River upstream of Millennium Mine	-	STR-2	-	-	-	-	W	-	-
Steepbank River approx. 27 km upstream from mouth	-	STB RIFF 7[1]	-	-	-	-	W, D	-	-
Steepbank Climate Station	C3	-	-	-	-	-	C	-	-
Steepbank River above North Steepbank River	-	-	-	-	-	STR-F2	F	-	-
Tar River Watershed									
Tar River near the mouth	S15A	TAR-1	TAR-D1	TAR-D1	-	-	H, W, B	-	-
Tar River above CNRL Lake	S34	TAR-2A	TAR-E2	-	-	TAR-F2	H, W, B, F	-	-
Horizon Climate Station	C2	-	-	-	-	-	C	-	-
Tar River Watershed Snowcourse Survey	CNRL Area	-	-	-	-	-	Sn	-	-

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1 Data sonde stations. Note: water quality sampling at station M8 consisted only of a data sonde.

2 Distance from water quality station (displayed only where distance between stations is greater than 1 km)

3 for Wild Fish Health Monitoring

4 for Benthic Invertebrate Communities component

Table 3.1-1 (Cont'd.)

Waterbody	Monitoring Component						Managing Entity		
	Climate and Hydrology	Water Quality	Benthic Invertebrate Communities	Sediment Quality	Fish Populations		Hatfield	AEMERA	Other
					Wild Fish Health	Fish Community			
MacKay River Watershed									
Mid Dover River	-	DOV RIFF 4	-	-	-	-	W	-	-
MacKay River near the mouth	07DB001[1] (4.5 km)[2]	MA1	-	-	-	MAR-F1	F	W, D	H
MacKay River at Petro-Canada Bridge	S40	MA2[1]	-	-	-	-	C, H, W, D	-	-
Dover River near the mouth	S53	DC-L[3]	-	-	DC-L	-	H, W, F	-	-
Mid Dover River	-	DC-M[3]	-	-	DC-M	-	W, F	-	-
Upper Dover River	-	DC-U[3]	-	-	DC-U	-	W, F	-	-
Lower MacKay River	-	MR-L[3]	-	-	MR-L	-	W, F	-	-
Mid MacKay River	-	MR-M[3]	-	-	MR-M	-	W, F	-	-
Upper MacKay River	-	MR-U[3]	-	-	MR-U	-	W, F	-	-
Dunkirk River near Fort McKay	S54	-	-	-	-	-	H	-	-
Calumet River Watershed									
Calumet River near the mouth	S16A (2.5km)[2]	CA1	CAR-D1	CAR-D1	-	-	H, W, B, S	-	-
Calumet River upper	-	CAR-2	CAR-D2	CAR-D2	-	-	W, B, S	-	-
Firebag River Watershed									
Firebag River at WSC station	07DC001	FI WSC[1]	-	-	-	-	W, D	-	H
Firebag River near the mouth	-	FI1[1]	FIR-D1	FIR-D1	-	-	B, S	W, D	-
Firebag River upstream of Suncor Firebag	S43	FI2	-	-	-	-	C, H, W	-	-
Johnson Lake	-	JOL-1	JOL-1	JOL-1	-	-	W, B, S	-	-
McClelland Lake	L1	MCL-1	MCL-1	MCL-1	-	-	C, H, W, B, S	-	-
McClelland Lake Outlet above Firebag River	S36	-	-	-	-	-	H	-	-
Firebag River Watershed Snowcourse Survey	MCLL Area	-	-	-	-	-	Sn	-	-
Ells River Watershed									
Ells River at CNRL Bridge	S14A	EL2[1]		-		-	H, W, D	-	-
Ells River near the mouth	-	ELLS RIFF 3	ELR-D1	ELR-D1	-	ELR-F1	B, S, F	W	-
Gardiner Lakes	-	GAL-1	GAL-1	GAL-1	-	-	W, B, S	-	-
Namur Lake	L4 (3.6 km)[2]	NAL-1	NAL-1	NAL-1	-	-	C, H, W, B, S	-	-
Lower Ells River	-	ER-L[3]	-	ER-L[3]	ER-L	-	W, S, F	-	-
Mid Ells River	-	ER-M[3]	-	ER-M[3]	ER-M	-	W, S, F	-	-
Upper Ells River (above Joslyn Creek Diversion)	S45	ER-U[3], ELLS RIFF 5[1]	-	ER-U[3]	ER-U	-	H, W, D, S, F	-	-

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[1] Data sonde stations. Note: water quality sampling at station M8 consisted only of a data sonde.

[2] Distance from water quality station (displayed only where distance between stations is greater than 1 km)

[3] for Wild Fish Health Monitoring

[4] for Benthic Invertebrate Communities component

Table 3.1-1 (Cont'd.)

Waterbody	Monitoring Component						Managing Entity		
	Climate and Hydrology	Water Quality	Benthic Invertebrate Communities	Sediment Quality	Fish Populations		Hatfield	AEMERA	Other
					Wild Fish Health	Fish Community			
Clearwater River Watershed									
Clearwater River at Draper	07CD001	AB07CD0200[1]	-	-	-	-	-	W, D	H
Lower Clearwater River	-	CL2	CLR-D1	CLR-D1	-	-	B, S	W	-
High Hills River near the mouth	S51	HHR-1[1]	HHR-E1	-	-	-	H, W, D, B	-	-
Upper Clearwater River	-	CLR-2[4]	CLR-D2	CLR-D2	-	-	W, B, S	-	-
Clearwater River above Christina River	07CD005	-	-	-	-	-	-	-	H
Fort McMurray A Climate Station	3062696	-	-	-	-	-	-	-	C
Christina River Watershed									
Birch Creek at Hwy 881	S62	BRC-1	BRC-D1	BRC-D1	-	BRC-F1	H, W, B, S, F	-	-
Christina River near the mouth	S47A (11 km)[2]	CH1	CHR-D1	CHR-D1	-	-	H, W, B, S	-	-
Christina Lake	-	CHL-1	CHL-1	CHL-1	-	-	W, B, S	-	-
Lower Middle Christina River	-	CHR-2	CHR-D2	CHR-D2	-	CHR-F2 (5.7km)[2]	W, B, S, F	-	-
Upper Middle Christina River	-	CHR-3	CHR-D3	CHR-D3	-	-	W, B, S	-	-
Christina River above Statoil Leismer	S61	CHR-4	CHR-D4	CHR-D4	-	-	H, W, B, S	-	-
Gregoire Lake	-	GRL-1	GRL-1	GRL-1	-	-	H, W, B, S	-	-
Gregoire River near the mouth	S55	GRR-1	GRR-E1	-	-	-	H, W, B	-	-
Jackfish River below Christina Lake	S56	JAR-1	JAR-E1	-	JAR-F1	JAR-F1	H, W, B, S, F	-	-
Sawbones Creek above Christina Lake	S58	SAC-1	SAC-D1	SAC-D1	SAC-F1	SAC-F1	H, W, B, S, F	-	-
Sunday Creek above Christina Lake	S57 (1.5 km)[2]	SUC-1	SUC-D1	SUC-D1	SUC-F1	SUC-F1	H, W, B, S, F	-	-
Sunday Creek at Hwy 881	S63	SUC-2	SUC-D2	SUC-D2	-	SUC-F2	H, W, B, S, F	-	-
Unnamed Creek east of Christina Lake	S64	UNC-2	UNC-D2	UNC-D2	-	UNC-F2	H, W, B, S, F	-	-
Unnamed Creek south of Christina Lake	S60	UNC-3	UNC-D3	UNC-D3	-	UNC-F3	H, W, B, S, F	-	-
Upper Christina River	-	CHR-2A[4]	CHR-E2A	-	-	-	W, B	-	-
Surmont Creek at Hwy 881	S32	-	-	-	-	-	H	-	-
Surmont Climate Station	C5	-	-	-	-	-	C	-	-
Christina Lake near Winefred Lake Climate Station	3061580	-	-	-	-	-	-	-	C
Christina River near Chard	07CE002	-	-	-	-	-	-	-	H
Christina River Watershed Snowcourse Survey	NEX Area	-	-	-	-	-	Sn	-	-
Hangingstone River Watershed									
Hangingstone River at Fort McMurray	07CD004	HA1	-	-	-	-	W	-	H
Hangingstone River above Fort McMurray	-	HAR-1	HAR-E1	-	HAR-F1	-	W, B, F	-	-
Hangingstone Creek at North Star Road	S31	-	-	-	-	-	C, H	-	-

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[1] Data sonde stations. Note: water quality sampling at station M8 consisted only of a data sonde.

[2] Distance from water quality station (displayed only where distance between stations is greater than 1 km)

[3] for Wild Fish Health Monitoring

[4] for Benthic Invertebrate Communities component

Table 3.1-1 (Cont'd.)

Waterbody	Monitoring Component						Managing Entity		
	Climate and Hydrology	Water Quality	Benthic Invertebrate Communities	Sediment Quality	Fish Populations		Hatfield	AEMERA	Other
					Wild Fish Health	Fish Community			
Pierre River Area									
Unnamed Creek (Big Creek)	S48	UN1	BIC-D1	BIC-D1	-	-	H, W, B, S	-	-
Redclay Creek	S50A (5.3 km)[2]	RCC-1[4]	RCC-E1	-	-	-	H, W, B	-	-
Pierre River near Fort McKay	S44 (2.4 km)[2]	PIR-1[4]	PIR-D1	PIR-D1	-	-	H, W, B, S	-	-
Eymundson Creek near the mouth	S49	EYC-1[4]	EYC-D1	EYC-D1	-	-	H, W, B, S	-	-
Pierre Climate Station	C4	-	-	-	-	-	C	-	-
Miscellaneous Tributaries									
Fort Creek	-	FOC-1	FOC-D1	FOC-D1	-	-	W, B, S	-	-
Horse River	-	HO2	-	-	-	-	W	-	-
Isadore's Lake	L3	ISL-1	ISL-1	ISL-1	-	-	W, B, S	H	-
McLean Creek at the mouth	-	MCC-1	-	-	-	-	W	-	-
Poplar Creek at Hwy 63	S11	PO1	POC-D1	POC-D1	-	-	H, W, B, S	-	-
Shipyard Lake	-	SHL-1	SHL-1	SHL-1	-	-	W, B, S	-	-
Beaver River at the mouth	-	BER-1	-	-	-	-	W	-	-
Upper Beaver River	07DA018	BER-2[4]	BER-D2	BER-D2	-	-	W, B, S	-	H
Alice Creek downstream	-	AC-DS[3]	-	AC-DS[3]	AC-DS	-	W, S, F	-	-
Alice Creek upstream	-	AC-US[3]	-	AC-US[3]	AC-US	-	W, S, F	-	-
Mills Creek at Highway 63	S6	-	-	-	-	-	H	-	-
Mildred Lake Climate Station	3064528	-	-	-	-	-	-	-	C

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1 Data sonde stations. Note: water quality sampling at station M8 consisted only of a data sonde.

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3 for Wild Fish Health Monitoring

4 for Benthic Invertebrate Communities component

Table 3.1-2 Climate and hydrometric stations monitored for the JOSMP in the 2015 WY.

Station	Managing Entity	UTM Coordinates (NAD83, Zone 12)		Operating Season	Variables Measured
		Easting	Northing		
C1 Aurora Climate Station	Hatfield	475229	6344053	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction
C2 Horizon Climate Station	Hatfield	443364	6360510	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction
C3 Steepbank Climate Station	Hatfield	473950	6320500	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction
C4 Pierre Climate Station	Hatfield	460898	6378737	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction
C5 Surmont Climate Station	Hatfield	502542	6230964	all year	air temperature, total precipitation, humidity, solar radiation, snow on the ground, barometric pressure, wind speed and direction
3061580 Christina Lake near Winefred Lake Climate Station	AEP	514357	6164368	all year	air temperature, total precipitation, relative humidity
3062696 Fort McMurray A Climate Station	EC	486307	6278820	all year	air temperature, dew point, relative humidity, barometric pressure, wind speed and direction, total precipitation
3064528 Mildred Lake Climate Station	EC	465587	6321236	all year	air temperature, dew point, relative humidity, wind speed and direction, total precipitation
L1 McClelland Lake	Hatfield	483398	6372186	all year	water level, total precipitation, humidity, air temperature, water temperature
L2 Kearl Lake	Hatfield	484815	6351080	all year	water level, total precipitation, humidity, air temperature, water temperature
L3 Isadore's Lake	Hatfield	463297	6342981	all year[1]	water level, water temperature
L4 Namur Lake	Hatfield	402886	6370260	all year	water level, discharge, water temperature, rainfall
S2 Jackpine Creek at Canterra Road	Hatfield	474971	6344091	all year	water level, discharge, water temperature, TSS/TDS grab sample
S3 Iyinimin Creek above Kearl Lake	Hatfield	489423	6345196	open-water	water level, discharge, rainfall, water temperature, TSS/TDS grab sample
S5 Muskeg River above Stanley Creek	Hatfield	479761	6356759	all year	water level, discharge, water temperature, TSS/TDS grab sample
S5A Muskeg River above Muskeg Creek	Hatfield	476042	6351803	all year	water level, discharge, barometric pressure, water temperature, TSS/TDS grab sample
S6 Mills Creek at Highway 63	Hatfield	463755	6344927	all year[1]	water level, discharge, water temperature
S9 Kearl Lake Outlet	Hatfield	483983	6347020	all year	water level, discharge, water temperature, TSS/TDS grab sample

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1 Station was discontinued on March 31, 2015.

2 Water level was monitored year-round.

3 Station was moved in May 2015 from its original location to 300 m downstream to avoid beaver activity.

4 Station was moved in November of 2015 to avoid construction of pipeline along Northstar Road.

5 Station S46 was discontinued on March 31, 2015; operation of WSC Station 07DD001 began in August 2014.

Table 3.1-2 (Cont'd.)

Station	Managing Entity	UTM Coordinates (NAD83, Zone 12)		Operating Season	Variables Measured
		Easting	Northing		
S10A Wapasu Creek	Hatfield	488573	6358554	all year	water level, discharge, water temperature, TSS/TDS grab sample
S11 Poplar Creek at Highway 63 (formerly 07DA007)	Hatfield	471972	6307825	all year	water level, discharge, water temperature, TSS/TDS grab sample
S14A Ells River at the Canadian Natural Bridge	Hatfield	455738	6344944	all year	water level, discharge, water temperature, TSS/TDS grab sample
S15A Tar River near the mouth	Hatfield	458458	6353439	open-water[2]	water level, discharge, water temperature, TSS/TDS grab sample
S16A Calumet River near the mouth	Hatfield	458096	6362020	open-water[3]	water level, discharge, water temperature, TSS/TDS grab sample
S20 Muskeg River Upland	Hatfield	492230	6354940	open-water[2]	water level, discharge, water temperature, TSS/TDS grab sample
S22 Muskeg Creek near the mouth	Hatfield	480969	6349071	all year	water level, discharge, water temperature, TSS/TDS grab sample
S24 Athabasca River below Eymundson Creek	Hatfield	466305	6372764	all year[1]	water level, discharge, water temperature
S31 Hangingstone Creek at North Star Road	Hatfield	469812	6236089	all year[4]	water level, discharge, water temperature, rainfall, TSS/TDS grab sample
S32 Surmont Creek at Highway 881	Hatfield	490250	6254524	all year	water level, discharge, water temperature, TSS/TDS grab sample
S33 Muskeg River at the Aurora North/Muskeg River Mine Boundary	Hatfield	474878	6350204	all year	water level, discharge, water temperature, TSS/TDS grab sample
S34 Tar River above Horizon Lake	Hatfield	440745	6361662	all year	water level, discharge, water temperature, TSS/TDS grab sample
S36 McClelland Lake Outlet above Firebag River	Hatfield	490635	6384056	all year	water level, discharge, water temperature, TSS/TDS grab sample
S37 East Jackpine Creek near the 1,300 m contour	Hatfield	487850	6325416	open-water	water level, discharge, water temperature, TSS/TDS grab sample
S40 MacKay River at Petro-Canada Bridge	Hatfield	444949	6314178	all year	water level, discharge, water temperature, rainfall, TSS/TDS grab sample
S43 Firebag River upstream of Suncor Firebag	Hatfield	531704	6354796	all year	water level, discharge, water temperature, rainfall, TSS/TDS grab sample
S44 Pierre River near Fort McKay (formerly 07DA013)	Hatfield	460769	6369299	open-water	water level, discharge, water temperature, TSS/TDS grab sample
S45 Ells River above Joslyn Creek Diversion	Hatfield	440325	6342418	all year	water level, discharge, water temperature, TSS/TDS grab sample
S47A Christina River near the mouth	Hatfield	505048	6272065	all year	water level, discharge, water temperature, TSS/TDS grab sample
S48 Big Creek	Hatfield	470817	6389113	open-water[2]	water level, discharge, water temperature, TSS/TDS grab sample
S49 Eymundson Creek near the mouth	Hatfield	465473	6372694	open-water	water level, discharge, water temperature, TSS/TDS grab sample
S50A Redclay Creek	Hatfield	474954	6396094	open-water[2]	water level, discharge, water temperature, TSS/TDS grab sample
S51 High Hills River near the mouth	Hatfield	532571	6290998	all year	water level, discharge, water temperature, TSS/TDS grab sample

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5 Station S46 was discontinued on March 31, 2015; operation of WSC Station 07DD001 began in August 2014.

Table 3.1-2 (Cont'd.)

Station	Managing Entity	UTM Coordinates (NAD83, Zone 12)		Operating Season	Variables Measured
		Easting	Northing		
S53 Dover River near the mouth (formerly 07DB002)	Hatfield	451453	6337017	all year	water level, discharge, water temperature, TSS/TDS grab sample
S54 Dunkirk River near Fort McKay (formerly 07DB003)	Hatfield	395815	6302067	all year	water level, discharge, water temperature, TSS/TDS grab sample
S55 Gregoire River near the mouth	Hatfield	510185	6259986	all year	water level, discharge, water temperature, TSS/TDS grab sample
S56 Jackfish River below Christina Lake (formerly 07CE005)	Hatfield	493753	6169685	all year	water level, discharge, water temperature, TSS/TDS grab sample
S57 Sunday Creek above Christina Lake	Hatfield	506227	6158403	all year	water level, discharge, water temperature, TSS/TDS grab sample
S58 Sawbones Creek above Christina Lake	Hatfield	511444	6167182	open-water[2]	water level, discharge, water temperature, TSS/TDS grab sample
S60 Unnamed Creek South of Christina Lake	Hatfield	511145	6159877	open-water[2]	water level, discharge, water temperature, TSS/TDS grab sample
S61 Christina River above Statoil Leismer	Hatfield	466037	6193791	all year	water level, discharge, water temperature, TSS/TDS grab sample
S62 Birch Creek at Hwy 881	Hatfield	492232	6163213	all year	water level, discharge, water temperature, TSS/TDS grab sample
S63 Sunday Creek at Hwy 881	Hatfield	494283	6157255	all year	water level, discharge, water temperature, TSS/TDS grab sample
S64 Unnamed Creek East of Christina Lake	Hatfield	517384	6163640	open-water[2]	water level, discharge, water temperature, TSS/TDS grab sample
S65 Green Stockings Creek at East Athabasca Hwy	Hatfield	489845	6333039	open-water[2]	water level, discharge, water temperature, TSS/TDS grab sample
S66 Steepbank River below the North Steepbank River	Hatfield	491438	6302625	all year	water level, discharge, water temperature, TSS/TDS grab sample
07DA008/S7 Muskeg River near Fort McKay	WSC	465552	6338804	all year	discharge
07DB001/S26 MacKay River near Fort McKay	WSC	458019	6341008	all year	discharge
07DC001/S27 Firebag River near the mouth	WSC	487914	6389855	all year	discharge
07CE002/S29 Christina River near Chard	WSC	508211	6187940	all year	discharge
07DA006/S38 Steepbank River near Fort McMurray	WSC	475296	6317398	all year	discharge
07DA018/S39 Beaver River above Syncrude	WSC	465560	6311437	all year	discharge
07CD005/S42 Clearwater River above Christina River	WSC	504427	6279666	all year	discharge
07CD001 Clearwater River at Draper	WSC	484367	6282383	all year	discharge
07DA001 Athabasca River below Fort McMurray	WSC	475439	6293000	all year	discharge
07CD004 Hangingstone River at Fort McMurray	WSC	478198	6285038	all year	discharge
07DD001/S46 Athabasca River near Embarras Airport	WSC	470241	6463209	all year[5]	discharge

AEMERA: Alberta Environmental Monitoring, Reporting, and Evaluation Agency: EC: Environment Canada; AEP: Alberta Environment and Parks; WSC: Water Survey of Canada

1 Station was discontinued on March 31, 2015.

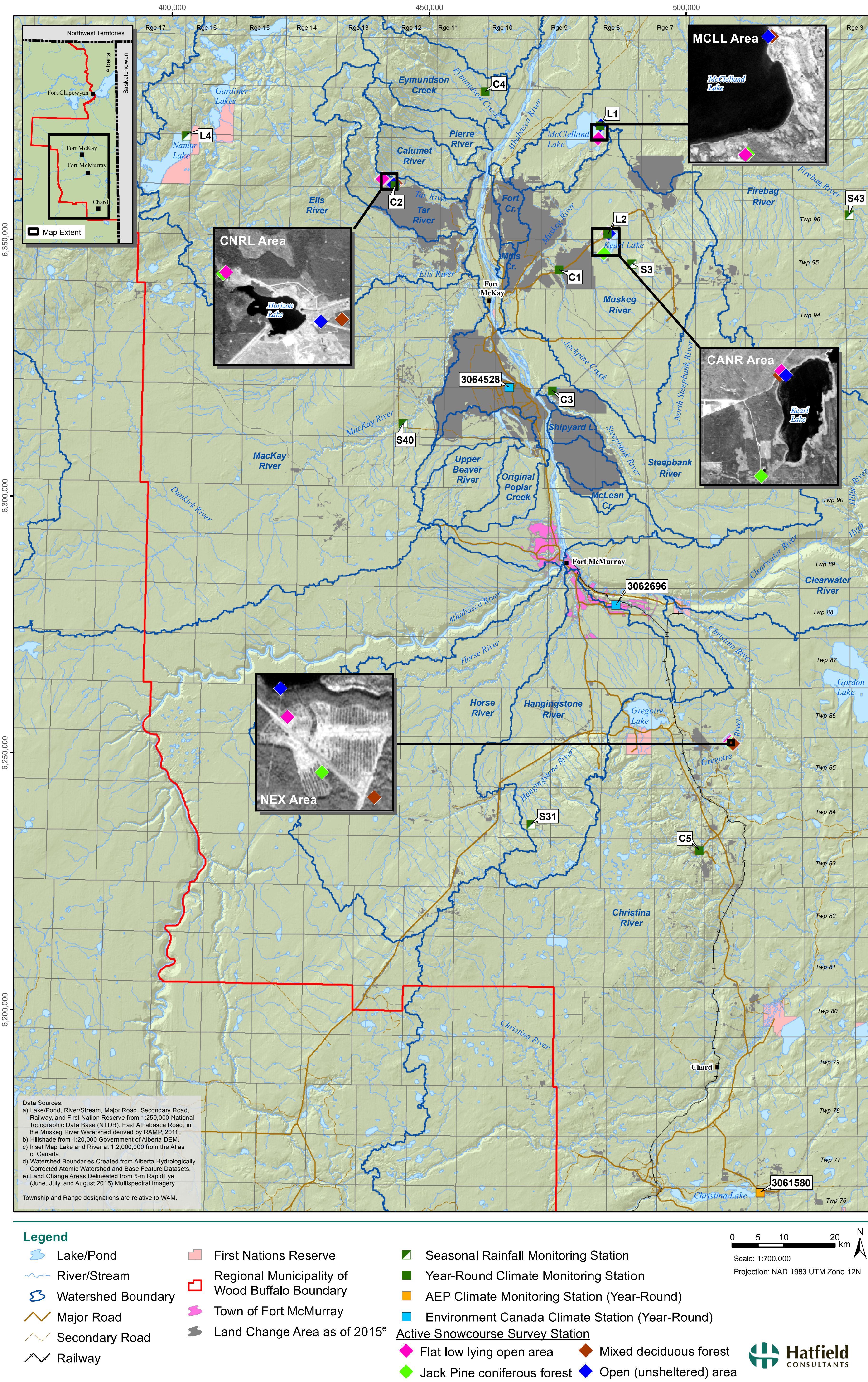
2 Water level was monitored year-round.

3 Station was moved in May 2015 from its original location to 300 m downstream to avoid beaver activity.

4 Station was moved in November of 2015 to avoid construction of pipeline along Northstar Road.

5 Station S46 was discontinued on March 31, 2015; operation of WSC Station 07DD001 began in August 2014.

Figure 3.1-1 Locations of climate stations and snowcourse survey stations monitored for the JOSMP in the 2015 WY.



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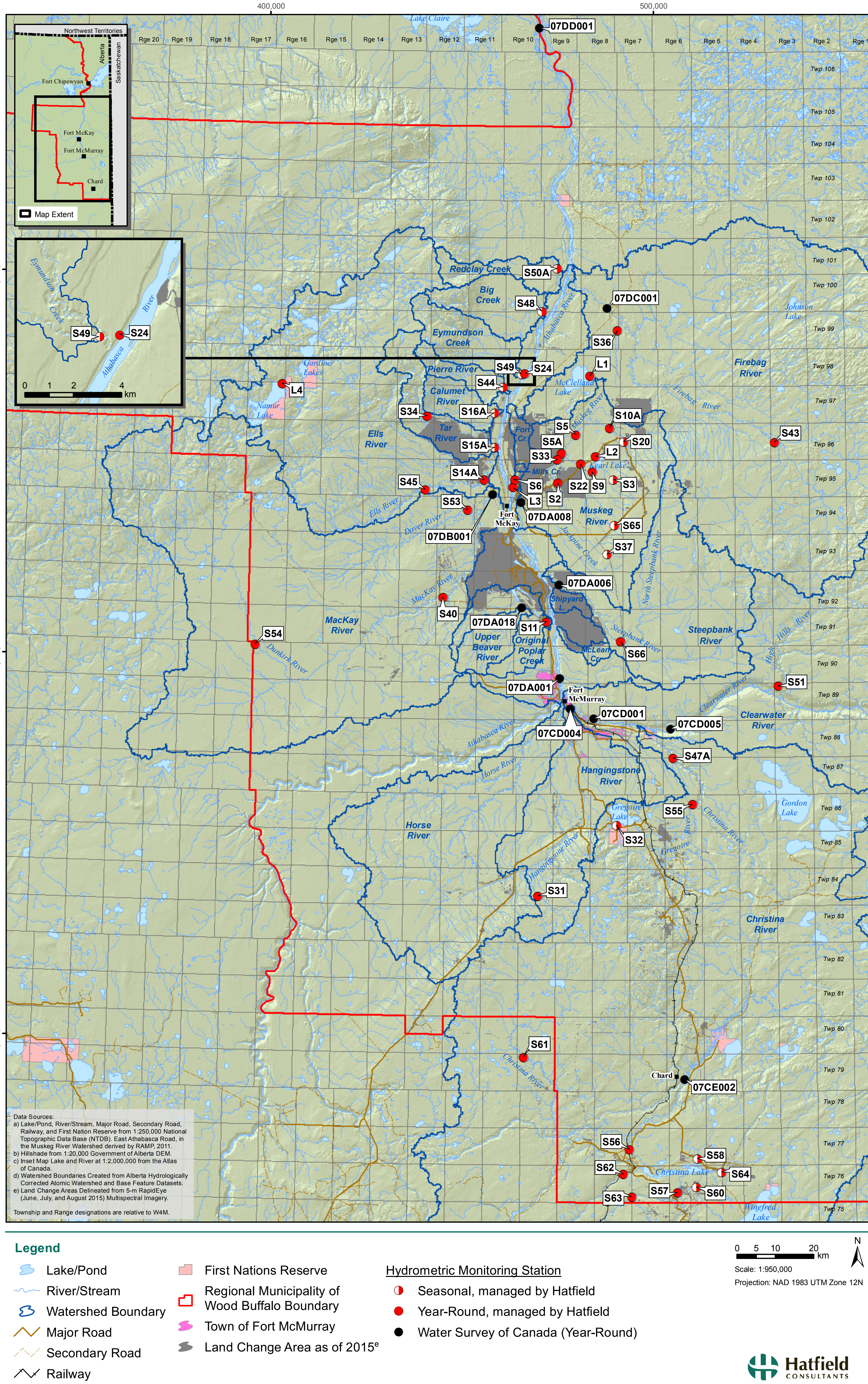
K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_D_Climate_20160330_ss.mxd

Figure 3.1-2 Locations of hydrometric stations monitored for the JOSMP in the 2015 WY.



K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_E_Hydro_20160330_ss.mxd

Standards for Acoustic Doppler Current Profiler (ADCP) streamflow measurements were consistent with standards and procedures set by the Water Survey of Canada (WSC 2014) and were as follows:

- The ADCP was moved across the measurement cross section at a steady pace so that the float velocity did not exceed the velocity of the water in the channel;
- Streamflow was calculated from at least four "good" passes of the cross section. A "good" pass was based on the following criteria: (i) each pass was within 5% of the mean measured discharge; (ii) at least 50% of the total calculated discharge in a pass was measured; (iii) the flow angle was minimal; (iv) the pitch and roll of the measurement platform was less than 5%; and (v) a minimum of ten ensembles were measured at the start and end positions; and
- Under-ice discharge measurements with the ADCP were conducted using at least 20 stationary measurements from holes augered into the river ice. Ice thickness and transducer depth were entered into the ADCP software for each measurement location.

Water Level Surveys

Field crews conducted water level surveys at both hydrometric monitoring stations to reference the continuous water level record to the surface water level. Procedures for conducting the water level survey were derived from standards provided by the British Columbia Ministry of Environment (BC MOE 2009):

- level readings using an automatic level were made to the nearest 0.001 m;
- surveys were made using at least two independent benchmarks; and
- each survey was conducted using two set-ups with a closing error of less than 0.004 m.

Climate Station Visits

Field crews visited climate stations to conduct data logger downloads and preliminary quality assurance to check station function, data reliability, and maintenance needs. Precipitation gauges were inspected to ensure sufficient levels of anti-freeze and hydraulic fluid were present.

Snowcourse Surveys

Snowcourse survey procedures were developed from principles outlined in the British Columbia Ministry of Environment Procedure Manual (Volume 6, Section 9, Subsection 01, Page 5 of 72 of BC MOE [1982]) and included the following:

- 40 snow depths were measured in each of four survey plots in each of the four snowcourse survey areas (Figure 3.1-1), with each survey plot representing one of the four land cover types sampled in each snowcourse survey area: jack pine coniferous forest; mixed deciduous forest; open area; and flat low-lying open area;
- snow depth and the mass of a vertical profile of the snowpack were measured four times in each survey plot and these were used to calculate the average snow water equivalent (SWE) per unit depth of the snowpack for each survey plot;

- forty SWE values were calculated in each survey plot by multiplying individual snow depths by average SWE per unit depth of the snowpack for that survey plot, and a mean SWE value was then calculated for each survey plot; and
- station photos were taken to provide a visual record of ground snow conditions (e.g., patchiness) and any intercepted snow in treed stands.

3.1.1.3 Changes in Monitoring Network from 2014

Discontinued Stations

Monitoring of six stations was discontinued on March 31, 2015 as the stations were not considered to be regional monitoring stations under the scope of the JOSMP (Table 3.1-3). Three of the six stations (S12 Fort Creek at Highway 63, S19 Tar River Lowland Tributary near the mouth, and S25 Susan Lake Outlet) were seasonal stations and were last monitored on October 31, 2014.

Table 3.1-3 Hydrometric stations that were discontinued from the JOSMP in the 2015 WY.

Station	Last Date Monitored
L3 Isadore's Lake	March 31, 2015
S12 Fort Creek at Highway 63	October 31, 2014
S19 Tar River Lowland Tributary near the mouth	October 31, 2014
S24 Athabasca River below Eymundson Creek	March 31, 2015
S25 Susan Lake Outlet	October 31, 2014
S46 Athabasca River near Embarras Airport[1]	March 31, 2015

[1] Monitoring continued at this location through WSC Station 07DD001, which was established in August, 2014.

Modified Stations

The following modifications and field equipment upgrades were made in the 2015 WY to support station function and reliability of data collection:

- Climate sensors were replaced for scheduled calibration at the C2 Horizon Climate Station;
- Barometric pressure sensors were replaced for scheduled calibration at the C2 Horizon, C3 Steepbank, C4 Pierre, and C5 Surmont Climate Stations;
- The HMP-model temperature/relative humidity sensor was replaced for scheduled calibration at Station L1 McClelland Lake;
- A tipping bucket and a pressure transducer were installed near the lake outlet at Station L4 Namur Lake to assist in analysis and discharge estimation;
- Station S16A Calumet River near the mouth was relocated 300 m downstream of its original location in May 2015 to avoid backwater effects caused by beaver activity;
- Station S31 Hangingstone Creek was moved 300 m downstream of its location in November 2015 to avoid pipeline construction;

- A relay station was installed at station S45 Ells River above Joslyn Creek Diversion to help improve the reliability of the telemetry at this station; and
- Pressure transducers were replaced for scheduled calibration at twelve year-round hydrometric stations: L2 Kearl Lake; S2 Jackpine Creek at Canterra Road; S5 Muskeg River above Stanley Creek; S14A Ells River at the Canadian Natural Bridge; S40 MacKay River at Petro-Canada Bridge; S43 Firebag River upstream of Suncor Firebag; S56 Jackfish River below Christina Lake; S60 Unnamed Creek South of Christina Lake; S61 Christina River above Statoil Leismer; S63 Sunday Creek at Hwy 881; S64 Unnamed Creek East of Christina Lake; and S65 Green Stockings Creek at East Athabasca Hwy.

3.1.1.4 Challenges Encountered and Solutions Applied

Wildlife and Environmental Challenges

The following wildlife and environmental challenges were addressed during the 2015 WY:

- The Geonor precipitation gauge at C2 Horizon Climate Station was damaged by ice on December 1, 2014. Data collection was interrupted from December 1 until December 12, 2014, when the precipitation gauge was reinstated;
- The Geonor precipitation gauge at C2 Horizon Climate Station was affected by beetles and other insects becoming trapped in the gauge between June 27 and August 15, 2015. The precipitation data for this period were removed from the analyses. Screens will be installed in all Geonor precipitation gauges in spring 2016 to prevent bugs from entering the gauges;
- Wildlife activity compromised the function of the tipping bucket rain gauge (TBRG) at Station S43 Firebag River Upstream of Suncor Firebag from May 10 to June 15, and August 9 to September 13, 2015. Rainfall data for these periods were not included in the analyses conducted for this report and presented in Section 5, and the data from June 15 to August 9, 2015 was graded as “estimated” due to the potential influence of the TBRG position on data quality. The TBRG was reinstated on each subsequent field visit. The installation of a fence to keep wildlife away from the equipment is being considered as a protective measure;
- Wildlife damaged the pressure transducer at Station S50A Redclay Creek on May 18, 2015. Data collection was interrupted from May 18 until June 16, 2015, when the pressure transducer was replaced;
- Station S66 Steepbank River below the North Steepbank River was damaged by wildlife on August 13, 2015 and October 19, 2015. There was no interruption of data collection on these occasions and the station was repaired on subsequent field visits. A more secure mast and protective fencing will be installed to prevent ongoing wildlife damage; and
- Wildlife activity compromised the function of the TBRG at Station S3 Iyinimin Creek above Kearl Lake from May 8 to June 13, and August 27 to September 14, 2015. Rainfall data for these periods were not included in the analyses conducted for this report and presented in Section 5, and the TBRG was reinstated on each subsequent field visit. The installation of a fence to keep wildlife away from the equipment is being considered as a protective measure.

Data Logger Malfunctions and Attrition

The following data logger malfunctions and equipment challenges were addressed in the 2015 WY:

- A pressure transducer malfunction resulted in unnatural water level fluctuations at Station S14A Ells River at the Canadian Natural Bridge from August 10, 2015 until functionality was restored on September 17, 2015. Water level data were corrected for this period;
- A pressure transducer malfunction resulted in erratic water level data at Station S57 Sunday Creek above Christina Lake from September 20 to October 31, 2015. The anomalous data points were not included in the analyses conducted for this report and presented in Section 5. The issue with the pressure transducer persisted into the 2016 WY until the data logger was replaced on December 8, 2015; and
- Poor light conditions and faulty power supplies caused intermittent data collection for portions of the 2015 WY at stations S22 Muskeg Creek near the Mouth, S31 Hangingstone Creek at North Star Road, S36 McClelland Lake Outlet above Firebag River, S44 Pierre River near Fort McKay (formerly 07DA013), S47A Christina River near the mouth, S58 Sawbones Creek above Christina Lake, S62 Birch Creek at Hwy 881, S63 Sunday Creek at Hwy 881, and S66 Steepbank River below the North Steepbank River. Batteries were either replaced or more batteries added to stations depending on the exact cause of the poor light conditions and components of faulty power supplies were replaced as necessary to reinstate station function.

3.1.1.5 Other Information Obtained

Streamflow data from the WSC were obtained and incorporated into the online RAMP database for stations where data were used for analysis in the report for the 2015 Program. These data were received as provisional and flagged as such in the RAMP database.

The following government operated hydrometric and climate stations were used in the preparation of the 2015 Program report for regional characterization only and; therefore, were not included in the RAMP online database:

- Station 07DA001 Athabasca River below Fort McMurray and Station 07CD004 Hangingstone River at Fort McMurray, which are monitored by WSC;
- Station 3062696 Fort McMurray A and Station 3064528 Mildred Lake, which are monitored by Environment Canada; and
- Station 07CE906 Christina Lake near Winefred Lake, which is monitored by AEP.

3.1.1.6 Summary of Component Data Now Available

Table 3.1-4 summarizes the available climate and hydrology data collected in the 2015 WY and Table 3.1-5 summarizes the climate and hydrology data collected from 1997 to 2014. Additional climate data can be obtained from the following sources: Wood Buffalo Environmental Association (WBEA), Environment Canada (EC), and the Alberta Government using the following links:

- http://www.wbea.org/
- http://www.climate.weatheroffice.gc.ca/Welcome_e.html
- http://www.agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp

Table 3.1-4 Summary of data available for the Climate and Hydrology component of the JOSMP for the 2015 WY, and used in this report.

Catchment and Location	Station	Season			
		Winter	Spring	Summer	Fall
Athabasca River Mainstem					
Athabasca River near Embarras Airport (S46)	S46	2t	3	3	3
Muskeg River Basin					
Aurora Climate Station	C1	g	g	g	g
Kearl Lake	L2	1th	1th	1th	1th
Jackpine Creek at Canterra Road	S2	2t	2t	2t	2t
Iyinimin Creek above Kearl Lake	S3		2ta	2ta	2ta
Muskeg River above Stanley Creek	S5	2t	2t	2t	2t
Muskeg River above Muskeg Creek	S5A	2td	2td	2td	2td
Muskeg River near Fort McKay	07DA008/S7	3	3	3	3
Kearl Lake outlet	S9	2	2t	2t	2t
Wapasu Creek at Canterra Road	S10/S10A	2t	2t	2t	2t
Muskeg River upland	S20		2t	2t	2t
Muskeg Creek near the mouth	S22	2t	2t	2t	2t
Muskeg River at the Aurora/Albian boundary	S33	2t	2t	2t	2t
East Jackpine Creek near the 1300 m contour	S37		2t	2t	2t
North Green Stockings Creek at East Athabasca Highway	S65		2t	2t	2t
Steepbank River Basin					
Steepbank Climate Station	C3	gd	gd	gd	gd
Steepbank River near Fort McMurray	07DA006/S38	3	3	3	3
Steepbank River below North Steepbank River	S66		2t	2t	2t
Firebag River Basin					
McClelland Lake	L1	1th	1th	1th	1th
Firebag River near the mouth	07DC001/S27	3	3	3	3
McClelland Lake Outlet above Firebag River	S36	2t	2t	2t	2t
Firebag River upstream of Suncor Firebag Project	S43	2t	2ta	2ta	2ta
Athabasca River West Tributaries					
Pierre Climate Station	C4	gd	gd	gd	gd
Pierre River near Fort McKay	S44		2t	2t	2t
Big Creek	S48		2t	2t	2t
Eymundson Creek near the mouth	S49		2t	2t	2t
Redclay Creek	S50/S50A		2t	2t	2t
Ells River Basin					
Namur Lake near the outlet	L4/S52	2t	2ta	2ta	2ta
Ells River at CNRL Bridge	S14A	2t	2t	2t	2t
Ells River above Joslyn Creek diversion	S45	2t	2t	2t	2t

Legend
a = rainfall
b = rainfall and snowfall, or total precipitation
c = snowcourse survey
d = barometric pressure
e = air temperature
f = relative humidity
g = air temperature, relative humidity, rainfall and snowfall or total precipitation, wind speed and direction, solar radiation and snow on the ground
h = air temperature, total precipitation and relative humidity
1 = water levels
2 = water levels and discharge
3 = hydrometric data collected by Environment Canada
t = water temperature

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)

Table 3.1-4 (Cont'd.)

Catchment and Location	Station	2015			
		Winter	Spring	Summer	Fall
Mackay River Basin					
MacKay River near Fort McKay	07DB001/S26	3	3	3	3
MacKay River at Petro-Canada Bridge	S40	2t	2ta	2ta	2ta
Dover River near the mouth	S53	2t	2t	2t	2t
Dunkirk River near Fort McKay	S54	2t	2t	2t	2t
Tar River Basin					
Horizon Climate Station	C2	gd	gd	gd	gd
Tar River near the mouth	S15/S15A		2t	2t	2t
Tar River above CNRL Lake	S34	2t	2t	2t	2t
Calumet River Basin					
Calumet River near the mouth	S16/S16A		2t	2t	2t
Poplar River Basin					
Poplar Creek at Highway 63	S11	2t	2t	2t	2t
Beaver River above Syncrude	07DA018/S39	3	3	3	3
Clearwater River Tributaries					
Surmont Climate Station	C5	gd	gd	gd	gd
Christina River near Chard	S29	3	3	3	3
Hangingstone Creek at North Star Road	S31	2t	2ta	2ta	2ta
Surmont Creek at Highway 881	S32	2t	2t	2t	2t
Clearwater River above Christina River	07DC005/S42	3	3	3	3
Christina River near the mouth	S47/S47A	2t	2t	2t	2t
High Hills River near the mouth	S51	2t	2t	2t	2t
Gregoire River near the mouth	S55	2t	2t	2t	2t
Jackfish River below Christina Lake	S56	2t	2t	2t	2t
Sunday Creek above Christina Lake	S57	2t	2t	2t	2t
Sawbones Creek above Christina Lake	S58		2t	2t	2t
unnamed creek south of Christina Lake	S60		2t	2t	2t
Christina River above Statoil Leismer	S61	2t	2t	2t	2t
Birch Creek at Highway 881	S62	2t	2t	2t	2t
Sunday Creek at Highway 881	S63	2t	2t	2t	2t
unnamed creek east of Christina Lake	S64		2t	2t	2t
Snow Course Surveys					
Wide-Area Snowcourse Survey	-	c			

Legend

a = rainfall

b = rainfall and snowfall, or total precipitation

c = snowcourse survey

d = barometric pressure

e = air temperature

f = relative humidity

g = air temperature, relative humidity, rainfall and snowfall or total precipitation, wind speed and direction, solar radiation and snow on the ground

h = air temperature, total precipitation and relative humidity

1 = water levels

2 = water levels and discharge

3 = hydrometric data collected by Environment Canada

t = water temperature

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Table 3.1-5 Summary of data available for the Climate and Hydrology component of the JOSMP from 1997 to 2014, and used in this report. (Page 1 of 2)

see symbol key at bottom

Location	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013				2014			
	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Mainstem																																																																								
Athabasca River below Eymundson Creek (S24)																		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Athabasca River near Embarras Airport (S46)																																																												2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Athabasca River East Tributaries																																																																								
Fort Creek at Highway 63 (S12)														2	2	2		2	2	2		2	2	2														2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t
Isadore's Lake (L3)													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1t	1t	1t	1t	1t	1t	1t	1t	1t	1t	1t	1t
Mills Creek at Highway 63 (S6)		2	2	2		2	2	2		2	2	2		2d	2d	2d		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Susan Lake Outlet (S25)																						2	2	2														2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t
Muskeg River Basin																																																																								
Aurora Climate Station (C1)	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g
Kearl Lake (L2)										1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th
Alsands Drain (S1)		2	2			2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2																																																
Jackpine Creek at Canterra Road (S2)		2	2	2		2	2			2	2			2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Iyinimin Creek above Kearl Lake (S3)		2	2	2		2a	2a	2a		2a	2a	2a						2a	2a	2a		2a	2a	2a		2a	2	2		2	2	2		2a	2a	2		2a	2a	2a		2	2a	2		2a	2a	2a		2	2	2		2a	2a	2a		2a	2a	2a		2ta	2ta	2ta		2ta	2ta	2ta		2ta	2ta	2ta
Blackfly Creek near the Mouth (S4)		2	2	2		2	2	2																																																																
Muskeg River above Stanley Creek (S5)																										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Muskeg River above Muskeg Creek (S5A)		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2d	2d	2d	2d	2d	2d	2d	2d	2d	2d	2d	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td	2td
Muskeg River near Fort McKay (07DA008/S7)													2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2t	4	4	4	2t	4	4	4	4	4	4	4
Stanley Creek near the mouth (S8)											1	1		1	1	1		1	1	1		1	1	1		1	1	1																																												
Kearl Lake Outlet (S9)						2	2	2		2e	2e	2e						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t
Wapasu Creek at Canterra Road (S10/S10A)		2								2	2	2						2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Albian Pond 3 Outlet (S13)														2	2	2		2	2	2		2	2	2																																																
Muskeg River Upland (S20)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t
Shelley Creek near the mouth (S21)																		1	1	1		1	1	1		1	1	1																																												
Muskeg Creek near the Mouth (S22)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Aurora Boundary Weir (S23)																	2	2	2	2	2	2	2	2																																																
Khahago Creek below Black Fly Creek (S28)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2																												
Muskeg River at the Aurora/Albian Boundary (S33)																										2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
East Jackpine Creek near the 1300 m Contour (S37)																																												2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t
North Green Stockings Creek at East Athabasca Highway (S65)																																																																		2t	2t	2t		2t	2t	2t
Muskeg River High Water Gauging			3				3				3				3				3																																																					
Jackpine Creek High Water Gauging			3				3												3																																																					
Steepbank River Basin																																																																								
Steepbank Climate Station (C3)																																																			b	b	b	b	b	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd
Steepbank River near Fort McMurray (07DA006/S38)																																																	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4
Steepbank River below North Steepbank River (S66)																																																																						2t	2t	2t
Firebag River Basin																																																																								
McClelland Lake (L1)			2	2		2	2	2		2	2	2		2	2	2		2	2	2		2a	2a	2a	2a	2a	2a	2	2	2a	2a	2a		2	2	2	1	1b	1b	1bf	1h	1h	1h	1h	1h	1h	1h	1h	1h	1h	1th	1th	1h	1h	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th	1th
Firebag River near the Mouth (07DC001/S27)																					2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4
McClelland Lake Outlet at McClelland Lake (S35)																																														2	2	2		2	2	2																				
McClelland Lake Outlet above Firebag River (S36)																																														2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Firebag River upstream of Suncro Firebag (S43)																																																		2	2	2		2ta	2ta	2ta	2t	2ta	2ta	2ta	2t	2ta	2ta	2ta	2t	2ta	2ta	2ta	2t	2ta	2ta	2ta
Athabasca River West Tributaries																																																																								
Pierre Climate Station (C4)																																																											gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd
Pierre River near Fort McKay (S44)																																																		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t
Big Creek (S48)																																																										2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t
Eymundson Creek near the mouth (S49)																																																										2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t
Red Clay Creek (S50/S50A)																																																										2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t

Legend

a = rainfall
b = rainfall and snowfall, or total precipitation
c = snowcourse survey
d = barometric pressure
e = air temperature
f = relative humidity
g = air temperature, relative humidity, rainfall and snowfall or total precipitation, wind speed and direction, solar radiation and snow on the ground
h = air temperature, total precipitation and relative humidity

1 = water levels
2 = water levels and discharge
3 = high water gauging
4 = hydrometric data collected by Environment Canada
5 = hydrometric data collected by Environment Canada starting on April 1, 2015
t = water temperature

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)

Table 3.1-5 (Cont'd.) (Page 2 of 2)

see symbol key at bottom

Location	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013				2014			
	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Ells River Basin																																																																								
Namur Lake near the Outlet (L4/S52)																																																														2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Ells River above Joslyn Creek (S14)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2																												
Ells River at CNRL Bridge (S14A)																																2	2	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Ells River above Joslyn Creek Diversion (S45)																																																		2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Mackay River Basin																																																																									
MacKay River near Fort McKay (07DB001/S26)																	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4
MacKay River at Petro-Canada Bridge (S40)																																													2	2t	2t	2t	2t	2t	2t	2t	2t	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2ta	2t	2ta	2ta	2ta
Dover River near the mouth (S53)																																																																2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Dunkirk River near Fort McKay (S54)																																																																2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Tar River Basin																																																																									
Horizon Climate Station (C2)																																																g	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd
Tar River near the mouth (S15/S15A)																		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t
Tar River Upland Tributary (S17)																		2	2	2		2	2	2		2	2	2		1	1	1																																										
Tar River Lowland Tributary near the mouth (S19)																		2	2	2		2a	2a	2a		2a	2a	2a		2a	2a	2a		2a	2a	2a	b	2b	2b	2b	b	2b	2b	2b	b	2b	2b	2b	b	2b	2b	2		2a	2a	2a		2a	2a	2a		2ta	2ta	2ta		2ta	2ta	2ta		2ta	2ta	2ta
Tar River above CNRL Lake (S34)																																		2	2	2		2	2	2	2	2	2	2	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Calumet River Basin																																																																									
Calumet River near the mouth (S16/S16A)																		2	2	2		2g	2g	2g	be	2tbe	2tbe	2tbe	e	2be	2be	2tbe	be	be	e																			2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t
Upland Calumet River (S18)																		2	2	2																																																				
Calumet River Upland Tributary (S18A)																						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2																				
Poplar River Basin																																																																									
Poplar Creek at Highway 63 (S11)			2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Beaver River above Syncrude (07DA018/S39)																																													2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4
Clearwater River Tributaries																																																																									
Surmont Climate Station (C5)																																																													gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd	gd
Christina River near Chard (S29)																					2	4a	4a	4a	2	4a	4a	4a	2	4a	4a	4a	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4
Hangingstone River at Highway 63 (S30)																						2	2	2																																																
Hangingstone Creek at North Star Road (S31)																						2	2	2						2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2	2	2		2a	2a	2a		2a	2a	2a		2ta	2ta	2ta	2t	2ta	2ta	2ta	2t	2ta	2ta	2ta
Surmont Creek at Highway 881 (S32)																						2	2	2						2	2	2		2	2	2		2	2	2		2	2	2		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t		2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Clearwater River above Christina River (07DC005/S42)																																																	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4
Christina River near the mouth (S47/S47A)																																																												2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
High Hills River near the mouth (S51)																																																																2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Gregoire River near the mouth (S55)																																																																2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Jackfish River below Christina Lake (S56)																																																																2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Sunday Creek above Christina Lake (S57)																																																																2t	2t	2t	2t	2t	2t	2t	2t	2t	2t	2t
Sawbones Creek above Christina Lake (S58)																																																																2t	2t	2t	2t	2t	2t	2t		2t	2t	2t
Unnamed Creek South of Christina Lake (S60)																																																																				2t	2t	2t		2t	2t	2t
Christina River above Statoil Leismer (S61)																																																																				2t	2t	2t	2t	2t	2t	2t
Birch Creek at Hwy 881 (S62)																																																																				2t	2t	2t	2t	2t	2t	2t
Sunday Creek at HWY 881 (S63)																																																																				2t	2t	2t	2t	2t	2t	2t
Unamed Creek East of Christina Lake (S64)																																																																				2t	2t	2t		2t	2t	2t
Snow Course Surveys																																																																									
Muskeg River Basin Snowcourse Survey		c				c				c				c				c																																																						
Fort Creek Basin Snowcourse Survey														c																																																									
CNRL Area Snowcourse Survey																		c				c				c																																														
Wide-Area Snowcourse Survey																													c				c				c				c				c				c				c				c				c				c				c			

Legend

a = rainfall
b = rainfall and snowfall, or total precipitation
c = snowcourse survey
d = barometric pressure
e = air temperature
f = relative humidity
g = air temperature, relative humidity, rainfall and snowfall or total precipitation, wind speed and direction, solar radiation and snow on the ground
h = air temperature, total precipitation and relative humidity

1 = water levels
2 = water levels and discharge
3 = high water gauging
4 = hydrometric data collected by Environment Canada
5 = hydrometric data collected by Environment Canada starting on April 1, 2015
t = water temperature

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)

3.1.2 Water Quality Monitoring Component

3.1.2.1 Overview of 2015 Water Quality Monitoring Activities

Monitoring activities for the Water Quality component in the 2015 WY included collecting discrete water quality samples for laboratory analyses in conjunction with continuous in situ monitoring of water quality. Continuous water quality monitoring was achieved by a network of data sondes, which was new to the JOSMP in the 2015 WY. The data sonde monitoring network consisted of 16 data sonde stations installed on the Ells, Firebag, High Hills, MacKay, Steepbank, Muskeg, Clearwater, and Athabasca rivers. The stations included three *baseline* and 13 *test* stations, which were operated by either AEMERA or Hatfield.

Table 3.1-6 summarizes the locations and attributes of the data sonde network for the 2015 WY, including the managing entity, nearby hydrology stations, and operating season for each data sonde. Data sondes were deployed in May or July 2015, with most retrieved prior to freeze-up in late October 2015.

Discrete water quality sampling was conducted in eleven sampling campaigns during the 2015 WY. Monthly sampling was generally conducted during all months except April, with larger sampling efforts taking place during seasonal campaigns in winter (March 2 to 6), spring (May 11 to 15, 20 to 21, 25 to 26), summer (July 13 to 16, 20 to 23, 26), and fall (August 27, 28, 31 and September 1 to 4, 8 to 18).

Water quality sampling focused on the lower Athabasca River and its major tributaries as well as regionally-important lakes and wetlands. Water quality samples were collected at a total of 96 stations in 2015:

- 70 water quality stations[1] that were sampled either monthly[2], seasonally (March, May, July, and September), monthly during the open water season (May to September), or during the fall only (September);
- 12 stations [3] at which water quality was sampled in order to harmonize with reaches of the Benthic Invertebrate Communities that were not already harmonized with a water quality station (fall only); and
- 15 stations at which water quality was sampled in order to harmonize with reaches of the Fish Health monitoring in the Fish Populations component that were not already harmonized with a water quality station (fall only).

Table 3.1-7 summarizes the location of the 71 water quality sampling stations monitored in the 2015 WY, the distribution of the sampling effort, managing entity, and water quality variables measured at each station. Sampling intensity was greatest during the fall campaign, with samples collected from all monitoring stations in September 2015. Table 3.1-8 summarizes the location of additional water quality samples collected at stations of the Benthic Invertebrate Communities and Sediment Quality component, as well as reaches of the Wild Fish Health Monitoring program of the Fish Populations component. Figure 3.1-3 provides the locations of data sonde stations and water quality stations sampled in the 2015 WY.

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1 Water quality stations ATR-DD-E, ATR-DD-W, STR-2, and CLR-2 were discontinued in April 2015. Water quality samples were subsequently collected from station CLR-2 in fall 2015 for the Benthic Invertebrate Communities and Sediment Quality component (Table 3.1-7 and Table 3.1-8).

2 A subset of water quality stations has been sampled monthly by RAMP/JOSMP since 2013. The number of stations sampled monthly was expanded in May 2015.

3 including station CLR-2

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Table 3.1-6 Locations and attributes of the data sonde network operated for the JOSMP in the 2015 WY.

Waterbody and Location	Station	AEMERA Nomenclature	Managing Entity	UTM Coordinates (NAD83, Zone 12)		Nearby Hydrometric Station in the JOSMP Network	Nearby WSC or AEP Station	Sonde Data Relayed by Telemetry?	Operating Season	Start of Data Record	End of Data Record	2015			
				Easting	Northing							Winter	Spring	Summer	Fall
Athabasca River															
Athabasca River above Firebag River	M8	AB07DA0980	AEMERA	477415	6398003	n/a	n/a	No	open-water	13-May-15	20-Oct-15			X	X
Clearwater River															
Clearwater River at Draper	CL1	AB07CD0200	AEMERA	484367	6282383	n/a	07CD001	Yes	all year	10-Aug-15	-			X	X
Ells River															
Ells River at the CNRL Bridge	EL2	AB07DA3007	Hatfield	455738	6344943	S14A	n/a	Yes	open-water	23-Jul-15	30-Oct-15			X	X
Ells River above Joslyn Creek	ELLS RIFF 5	AB07DA2999	Hatfield	440330	6342392	S45	n/a	Yes	open-water	21-Jul-15	28-Oct-15			X	X
Firebag River															
Firebag River at WSC station	FI WSC	AB07DC0060	Hatfield	487914	6389855	07DC001	n/a	Yes	open-water	21-Jul-15	29-Oct-15			X	X
Firebag River near the mouth	FI1	AB07DC0110	AEMERA	479595	6398494	n/a	n/a	No	open-water	13-May-15	20-Oct-15			X	X
High Hills River															
High Hills River near the mouth	HHR-1	AB07CD0300	Hatfield	532571	6290998	n/a	07CD901	Yes	open-water	21-Jul-15	28-Oct-15			X	X
MacKay River															
MacKay River near the mouth	MA1	AB07DB0350	Hatfield	444948	6314177	S40	n/a	Yes	open-water	23-Jul-15	30-Oct-15			X	X
MacKay River at Petro-Canada Bridge	MA2	AB07DB0060	AEMERA	458031	6341077	07DB001	n/a	Yes	open-water	30-Jul-15	20-Oct-15			X	X
Muskeg River															
Muskeg River near mouth	MU0	AB07DA0620	AEMERA	463658	6332501	n/a	n/a	Yes	open-water	22-Jul-15	30-Oct-15			X	X
Muskeg River at gauge	MU1	AB07DA0610	AEMERA	465551	6338803	07DA008	n/a	Yes	all year	22-Jul-15	-			X	X
Muskeg River upstream of Stanley Creek	MU4	AB07DA0475	AEMERA	471534	6346782	n/a	n/a	Yes	all year	12-May-15	-			X	X
Muskeg River upstream of Jackpine Creek	MU6	AB07DA0595	AEMERA	479765	6356756	S5	n/a	Yes	all year	12-May-15	-			X	X
Steepbank River															
Steepbank River at the mouth	ST1	AB07DA0260	AEMERA	471276	6320146	n/a	n/a	Yes	open-water	21-Jul-15	24-Sep-15			X	X
Steepbank River below North Steepbank River	STB RIFF 10	AB07DA2720	Hatfield	491438	6302625	S66	07DA910	Yes (07DA910)	open-water	21-Jul-15	28-Oct-15			X	X
Steepbank River, 27km upstream of mouth	STB RIFF 7	AB07DA1010	Hatfield	481845	6315144	n/a	n/a	No	open-water	21-Jul-15	27-Oct-15			X	X

n/a – not applicable

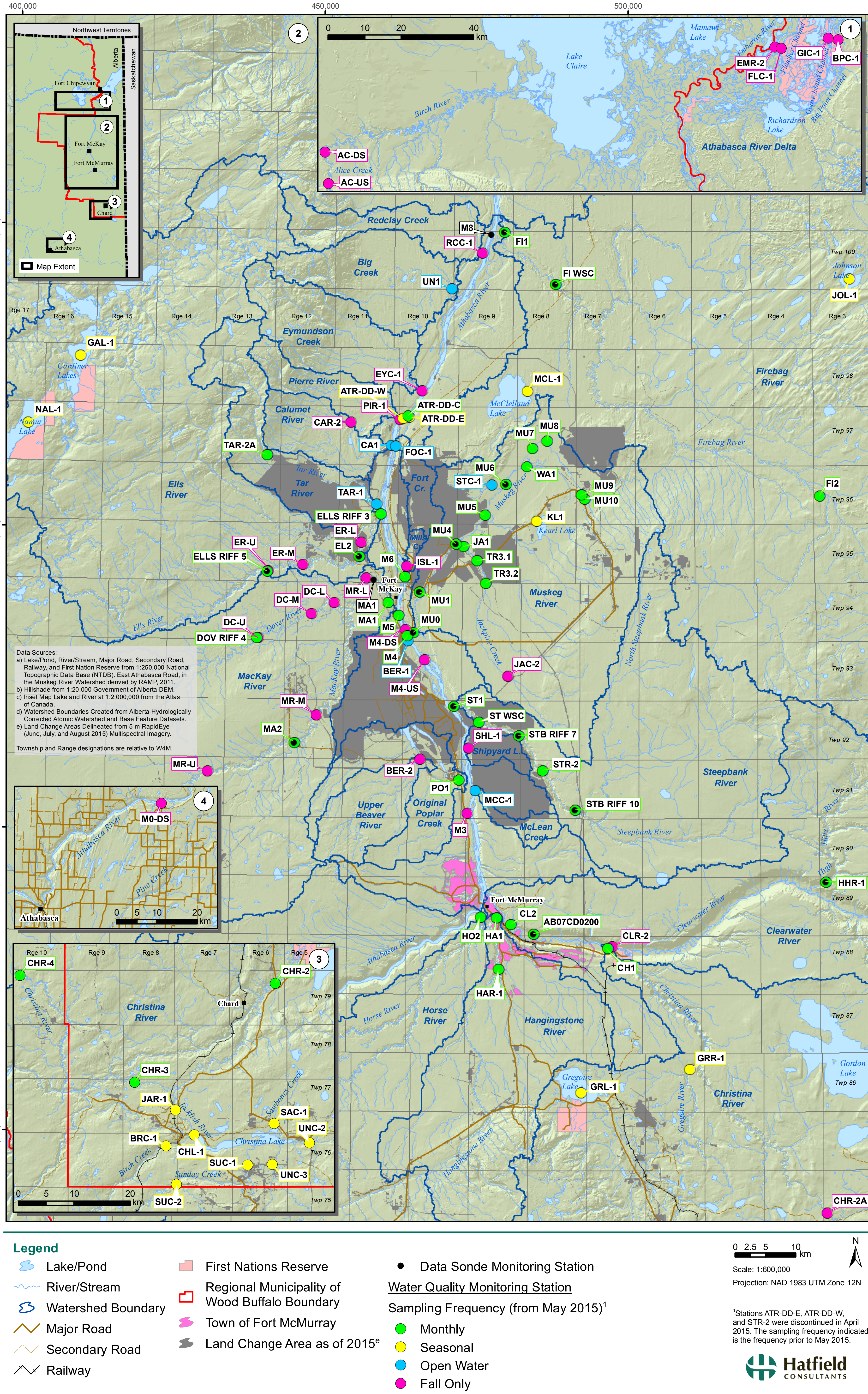
"-" – Data sonde operation continued into the 2016 WY; data sondes MU4 and MU6 operated throughout the 2016 winter season and data sondes CL1 and MU1 were retrieved during freeze-up and redeployed once sufficient ice had formed.

Legend

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Figure 3.1-3 Locations of water quality and data sonde stations monitored for the JOSMP in the 2015 WY.



K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_F_Water_20160330_ss.mxd

Table 3.1-7 Summary of discrete water quality sampling conducted for the JOSMP in the 2015 WY.

Station and Location		AEMERA Nomenclature	UTM Coordinates (NAD83, Zone 12)		Managing Entity	Sampling Frequency (May 2015 Onwards)	Analytical Package	2014		2015									
			Easting	Northing				N	D	J	F	M	A	M	J	J	A	S	O
Athabasca River																			
M4	Athabasca River below Beaver River	AB07DA0400	463529	6331681	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
M5	Athabasca River above MacKay River	AB07DA0679	462069	6335015	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
M6	Athabasca River below Fort MacKay	AB07DA0683	463067	6341490	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
ATR-DD-C	Athabasca River downstream of all development (centre channel)	AB07DA0860	463623	6368049	Hatfield	monthly	1	-	-	-	-	X	-	X	X	X	X	X	X
ATR-DD-E	Athabasca River downstream of all development (east bank)	NP	463808	6367911	Hatfield	quarterly[1]	1	-	-	-	-	X	-	-	-	-	-	-	-
ATR-DD-W	Athabasca River downstream of all development (west bank)	NP	462818	6367661	Hatfield	quarterly[1]	1	-	-	-	-	X	-	-	-	-	-	-	-
Tributaries to the Athabasca River (Southern)																			
Christina River and Tributaries																			
CH1 (CHR-1)	Christina River upstream of Fort McMurray	AB07CE0050	496647	6280031	Hatfield	monthly	1	X	X	X	X	X	-	X	X	X	X	X	X
CHR-2	Christina River upstream of Janvier	AB07CE0030	511698	6192371	Hatfield	monthly	1	X	X	X	X	X	-	X	X	X	X	X	X
CHR-3	Christina River upstream of Jackfish River	AB07CE0005	486512	6174647	Hatfield	monthly	1	-	-	-	-	X	-	X	X	X	X	X	X
CHR-4	Christina River upstream of development	AB07CE0001	466037	6193791	Hatfield	monthly	1	-	-	-	-	X	-	-	X	X	X	X	X
BRC-1	Birch Creek at Hwy 881	AB07CE0010	492165	6163211	Hatfield	quarterly	1	-	-	-	-	X	-	X	-	X	-	X	-
GRR-1	Gregoire River (lower)	AB07CE0100	510152	6259979	Hatfield	quarterly	1	-	-	-	-	X	-	X	-	X	-	X	-
JAR-1	Jackfish River	AB07CE0019	493839	6169627	Hatfield	quarterly	1	-	-	-	-	X	-	X	-	X	-	X	-
SAC-1	Sawbones Creek	AB07CE0060	511453	6167195	Hatfield	quarterly	1	-	-	-	-	X	-	X	-	X	-	X	-
SUC-1	Sunday Creek (inlet to Chistina Lake)	AB07CE0021	506716	6159804	Hatfield	quarterly	1	-	-	-	-	X	-	X	-	X	-	X	-
SUC-2	Sunday Creek (upper)	AB07CE0032	494007	6156324	Hatfield	quarterly	1	-	-	-	-	X	-	X	-	X	-	X	-
UNC-2	Unnamed Creek east of Christina Lake	AB07CE0023	517814	6163718	Hatfield	quarterly	1	-	-	-	-	X	-	X	-	X	-	X	-
UNC-3	Unnamed Creek south of Christina Lake	AB07CE0022	511159	6159892	Hatfield	quarterly	1	-	-	-	-	X	-	X	-	X	-	X	-
Clearwater River and Tributaries																			
AB07CD0200	Clearwater River at Draper	AB07CD0200	484345	6282335	AEMERA	monthly	1	-	-	-	-	-	-	-	-	X	X	X	X
CL2 (CLR-1)	Clearwater River upstream of Fort McMurray	AB07CD0210	480610	6283924	AEMERA	monthly	1	-	-	-	-	-	-	X	X	-	-	-	-
CLR-2	Clearwater River upstream of Christina River	AB07CD0060	496094	6280541	Hatfield	fall only (see Table 3.1-7)	1	X	X	X	X	X	-	-	-	-	-	-	-
HHR-1	High Hills River (mouth)	AB07CD0300	532571	6290998	Hatfield	monthly	1	-	-	-	-	X	-	X	X	X	X	X	X
Hangingstone River																			
HA1 (HAR-1A)	Hangingstone River at Fort McMurray	AB07CD0040	478199	6285028	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
HAR-1	Hangingstone River above Fort McMurray	AB07CD0010	478539	6276489	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
Tributaries to the Athabasca River (Eastern)																			
FOC-1	Fort Creek	AB07DA2760	461549	6363105	Hatfield	open water	1	-	-	-	-	-	-	X	X	X	X	X	-
MCC-1	McLean Creek (mouth)	AB07DA0071	474637	6306051	Hatfield	open water	1	-	-	-	-	-	-	X	X	X	X	X	-
Steepbank River																			
ST1 (STR-1)	Steepbank River (mouth)	AB07DA0260	471119	6320067	AEMERA	monthly	1	-	-	-	-	X[2]	-	X	X	X	X	X	X
ST WSC	Steepbank River adjacent to Millennium Mine	AB07DA1000	475301	6317398	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
STB RIFF 7	Steepbank River approx. 27 km upstream from mouth	AB07DA1010	481848	6315147	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
STR-2	Steepbank River upstream of Suncor Millennium Mine	NP	485838	6309341	Hatfield	monthly[1]	1	X	X	X	X	X	-	-	-	-	-	-	-
STB RIFF 10	Steepbank River below North Steepbank River	AB07DA2720	491258	6302820	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
Muskeg River and Tributaries																			
JA1 (JAC-1)	Jackpine Creek (mouth)	AB07DA0600	472720	6346388	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
MU0 (MUR-1)	Muskeg River (mouth)	AB07DA0620	463643	6332490	AEMERA	monthly	1	X	X	X	X	X	-	-	-	X	X	X	X
MU1	Muskeg River near Fort McKay	AB07DA0610	465553	6338876	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
MU4	Muskeg River above Jackpine Creek	AB07DA0595	471500	6346860	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X

Legend

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids), and PAHs

2 = standard water quality variables, chlorophyll *a* and PAHs

X sampled

NP not provided

"-" not sampled

[1] Sampling frequency prior to May 2015

[2] STR-1 was sampled by Hatfield in March 2015

[3] Sampling was planned; however, samples were unable to be collected as the waterbody was frozen to depth

Table 3.1-7 (Cont'd.)

Station and Location		AEMERA Nomenclature	UTM Coordinates (NAD83, Zone 12)		Managing Entity	Sampling Frequency (May 2015 Onwards)	Analtyical Package	2014		2015									
			Easting	Northing				N	D	J	F	M	A	M	J	J	A	S	O
Muskeg River and Tributaries (Cont'd.)																			
MU5	Muskeg River above Muskeg Creek	AB07DA2754	476270	6351654	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
MU6	Muskeg River above Stanley Creek	AB07DA0475	479793	6356738	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
MU7	Muskeg River above Wapasu Creek	NP	484092	6362703	AEMERA	monthly	1	-	-	-	-	-	-	-	-	X	X	X	-
MU8	Muskeg River above Wapasu Creek	AB07DA0440	486553	6363877	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
MU9	Muskeg River at Imperial Kearl Lake Road	AB07DA0420	492237	6354936	AEMERA	monthly	1	-	-	-	-	-	-	-	-	X	X	-	-
MU10	Muskeg River upland	AB07DA0430	492754	6354303	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
TR3.1	Jackpine Creek at Canterra Road	AB07DA1090	474982	6344048	AEMERA	monthly	1	-	-	-	-	-	-	-	-	X	X	X	X
TR3.2	Jackpine Creek above Shell Jackpine	AB07DA1100	476416	6340374	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
WA1	Wapasu Creek (mouth)	AB07DA1126	483183	6359685	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	-	X
STC-1	Stanley Creek (mouth)	AB07DA0490	477402	6356617	Hatfield	open water	1	-	-	-	-	-	-	X	X	X	X	X	-
Firebag River																			
FI WSC	Firebag River	AB07DC0060	487949	6389846	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
FI1 (FIR-1)	Firebag River (mouth)	AB07DC0110	479595	6398494	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
FI2 (FIR-2)	Firebag River	AB07DC0010	531527	6354782	Hatfield	monthly	1	-	-	-	-	-	-	-	-	X	X	X	X
Tributaries to the Athabasca River (Western)																			
HO2	Horse River	AB07CC0050	475549	6285143	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
PO1 (POC-1)	Poplar Creek at Hwy 63	AB07DA0110	471973	6307829	Hatfield	monthly	1	X	X	X	-[3]	X	-	X	X	X	X	X	X
BER-1	Beaver River	AB07DA1450	463640	6330910	Hatfield	open water	1	-	-	-	-	-	-	X	X	X	X	X	-
CA1 (CAR-1)	Calumet River (mouth)	AB07DA1360	460816	6363196	Hatfield	open water	1	-	-	-	-	-	-	X	X	X	X	X	-
TAR-1	Tar River (mouth)	AB07DA1350	458403	6353397	Hatfield	open water	1	-	-	-	-	-	-	X	X	X	X	X	-
TAR-2A (TAR-2)	Tar River upstream of Canadian Natural Horizon	AB07DA1365	440357	6361662	Hatfield	monthly	1	-	-	-	-	-	-	-	-	X	X	X	X
UN1 (BIC-1)	Unnamed Creek (Big Creek)	AB07DA1270	470811	6389115	Hatfield	open water	1	-	-	-	-	-	-	X	X	X	X	X	-
Ells River																			
ELLS RIFF 3 (ELR-1)	Ells River (mouth)	AB07DA0750	459081	6351861	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
EL2 (ELR-2)	Ells River at CNRL Bridge	AB07DA3007	455548	6344854	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
ELLS RIFF 5 (ELR-3)	Ells River above Joslyn Creek Diversion	AB07DA2999	440330	6342392	Hatfield	monthly	1	-	-	-	-	X	-	X	X	X	X	X	X
MacKay River																			
DOV RIFF 4 (DO1)	Dover River	AB07DB0005	438647	6331358	Hatfield	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
MA1 (MAR-1)	MacKay River (mouth)	AB07DB0060	460352	6337155	AEMERA	monthly	1	-	-	-	-	-	-	X	X	X	X	X	X
MA2 (MAR-2)	MacKay River at Petro-Canada Bridge	AB07DB0350	444779	6314036	Hatfield	monthly	1	X	X	X	X	X	-	X	X	X	X	X	X
Lakes and Wetlands																			
CHL-1	Christina Lake	AB07CE0250	497226	6165178	Hatfield	quarterly	2	-	-	-	-	X	-	X	-	X	-	X	-
KL1 (KEL-1)	Kearl Lake	AB07DA2210	484850	6350577	Hatfield	quarterly	2	-	-	-	-	-	-	X	-	X	-	X	-
MCL-1	McClelland Lake	AB07DA2290	483309	6372106	Hatfield	quarterly	2	-	-	-	-	-	-	X	-	X	-	X	-
JOL-1	Johnson Lake	AB07DD0410	536465	6390715	Hatfield	quarterly	2	-	-	-	-	X	-	X	-	X	-	X	-
GAL-1	Gardiner Lake	AB07DA2030	409600	6378132	Hatfield	quarterly	2	-	-	-	-	X	-	X	-	X	-	X	-
NAL-1	Namur Lake	AB07DA1890	400964	6367082	Hatfield	quarterly	2	-	-	-	-	X	-	X	-	X	-	X	-
GRL-1	Gregoire Lake	AB07CE0120	492150	6256085	Hatfield	quarterly	2	-	-	-	-	X	-	X	-	X	-	X	-
ISL-1	Isadore's Lake	AB07DA0420	463356	6343198	Hatfield	fall only	2	-	-	-	-	-	-	-	-	-	-	X	-
SHL-1	Shipyard Lake	AB07DA3400	473558	6313093	Hatfield	fall only	2	-	-	-	-	-	-	-	-	-	-	X	-
QA/QC																			
Trip and field blanks, split, duplicate							1	X	X	X	X	X	X	X	X	X	X	X	X

Legend

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids), and PAHs

2 = standard water quality variables, chlorophyll *a* and PAHs

X sampled

NP not provided

"-" not sampled

[1] Sampling frequency prior to May 2015

[2] STR-1 was sampled by Hatfield in March 2015

[3] Sampling was planned; however, samples were unable to be collected as the waterbody was frozen to depth

Table 3.1-8 Summary of fall water quality sampling conducted at stations of the Benthic Invertebrate Communities component and reaches of the Wild Fish Health Monitoring program of the JOSMP in the 2015 WY.

Station and Location		AEMERA Nomenclature	UTM Coordinates (NAD83, Zone 12)		Managing Entity	Analytical Package
			Easting	Northing		
Benthic Invertebrate Communities						
BPC-1	Big Point Channel	AB07DD0230	512088	6494156	Hatfield	1
EMR-2	Embarras River	AB07DD0130	494745	6492140	Hatfield	1
FLC-1	Fletcher Channel	AB07DD0131	496561	6491825	Hatfield	1
GIC-1	Goose Island Channel	AB07DD0220	509483	6494586	Hatfield	1
CAR-2	Calumet River upper	AB07DA1345	454122	6367044	Hatfield	1
CHR-2A	Christina River upper	AB07CE0041	532759	6236195	Hatfield	1
CLR-2	Clearwater River upstream of Christina River	AB07CD0060	496094	6280541	Hatfield	1
BER-2	Beaver River	AB07DA1420	465489	6311275	Hatfield	1
JAC-2	Jackpine Creek at East Athabasca Hwy	AB07DA1225	480033	6324995	Hatfield	1
RCC-1	Redclay Creek	AB07DA1295	475878	6395027	Hatfield	1
PIR-1	Pierre River near Fort MacKay	AB07DA1340	462291	6367440	Hatfield	1
EYC-1	Eymundson Creek (mouth)	AB07DA1320	465933	6372234	Hatfield	1
Wild Fish Health Monitoring						
M0-DS	Athabasca River below town of Athabasca	AB07CB0520	383071	6092039	Hatfield	1
M3	Athabasca River below Fort McMurray STP discharge	AB07DA0100	473333	6302300	Hatfield	1
M4-US	Athabasca River above Muskeg River	AB07DA0320	466365	6327730	Hatfield	1
M4-DS	Athabasca River below Muskeg River	AB07DA0640	463147	6332711	Hatfield	1
ER-L	Ells River lower	AB07DA1400	455905	6347163	Hatfield	1
ER-M	Ells River mid	AB07DA3002	446275	6343440	Hatfield	1
ER-U	Ells River upper	AB07DA2999	440421	6342470	Hatfield	1
DC-L	Dover River lower	AB07DB0100	451366	6337142	Hatfield	1
DC-M	Dover River mid	AB07DB0002	447631	6335403	Hatfield	1
DC-U	Dover River upper	AB07DB0005	438803	6331366	Hatfield	1
MR-L	MacKay River lower	AB07DB0081	456656	6341223	Hatfield	1
MR-M	MacKay River mid	AB07DB0340	448485	6318596	Hatfield	1
MR-U	MacKay River upper	AB07DB0360	430477	6309367	Hatfield	1
AC-DS	Alice Creek downstream	AB07KE0301	371865	6454527	Hatfield	1
AC-US	Alice Creek upstream	AB07KE0311	370886	6463164	Hatfield	1
QA/QC						
Trip and field blanks, duplicate						1

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids), and PAHs

3.1.2.2 Summary of Continuous Water Quality Monitoring Field Methods

Continuous monitoring of water temperature (ºC), conductivity (µS/cm), dissolved oxygen (mg/L), turbidity (NTU), and pH was conducted at each station in Table 3.1-6 using either a Hydrolab DS5X or YSI EXO-2 data sonde equipped with multiple sensors. The YSI EXO-2 units recorded water quality at 15-min intervals, while the Hydrolab units logged water quality data at hourly intervals. Table 3.1-9 provides the accuracy and resolution of the data sondes and sensors deployed in the 2015 WY.

Table 3.1-9 Accuracy and resolution of sondes and sensors deployed for the JOSMP in the 2015 WY.

Data Sonde	Sensor	Accuracy (±)	Resolution
Hydrolab DS5X	Temperature	0.1 °C	0.01 °C
	Conductivity	0.5% of reading + 1 µS/cm	0.1 µS/cm
	Dissolved Oxygen	0.2 mg/L	0.01 mg/L
	Turbidity	±1% up to 100 NTU; ±3% from 100-400 NTU; ±5% from 400-3000 NTU	0.1 NTU from 0-400 NTU; 1 NTU for >400 NTU
	pH	0.2	0.01
YSI EXO-2	Temperature	-5 to 35 °C: ±0.01 °C. 35 to 50 °C: ±0.05 °C	0.001°C
	Conductivity	0-1x10^5 µS/cm: ±0.5% of reading or 1 µS/cm, whichever is greater; 1x10^5 to 2x10^5 µS/cm: ±1% of reading	0.1 to 10 µS/cm, range-dependent
	Dissolved Oxygen	0-200%: ±1% reading or 1% air sat., whichever is greater; 200-500%: ±5% reading 0-20 mg/L: ±1% of reading or 0.1 mg/L; 20-50 mg/L: ±5% reading	0.1% air sat; 0.01 mg/L
	Turbidity	0-999 FNU: 0.3 FNU or ±2% of reading, whichever is greater; 1000-4000 FNU: ±5% of reading	0-999 FNU: 0.01 FNU. 1000-4000 FNU: 0.1 FNU
	pH	±0.1 pH units within ±10°C of calibration temperature; ±0.2 pH units for entire temp range	0.01 units

Source: Hach (2006); YSI (2014).

Data sondes were deployed within perforated PVC pipe housings that allowed water to flow past the sensors while protecting the data sondes from damage by moving debris. To minimize fouling and sedimentation effects, the protective housings were equipped with metal cross pieces at the sensor end to raise the probe off the river bed and allow water to flow under the data sonde housing. Both the YSI EXO-2 and Hydrolab DS5X data sondes were also equipped with central wipers that rotated across sensor faces prior to measurement to prevent fouling error caused by accumulations of biological material and sediment. Housings were weighed down in the river and attached to shore using aircraft cable.

Thirteen of the 16 data sondes were connected to external hydrometric stations with telemetry capability for data redundancy and near-real-time data access (Table 3.1-6). At these stations, the data were sent by telemetry to an Aquarius database (Aquarius v.3.6 to 3.10, Aquatic Informatics™), where the data were stored, managed, and published in near-real-time to http://www.ramp-alberta.org. Data from stations without telemetry (i.e., stations FI1, M8, and STB RIFF7) were downloaded during field visits.

Telemetry was a mixture of cellular and satellite (GOES) transmission. Most data sondes were interfaced with existing dataloggers and telemetry systems at hydrometric stations monitored for the JOSMP, or independently by WSC or AEP. New telemetry stations were constructed for data sonde stations MU0 Muskeg River near mouth, MU4 Muskeg River upstream of Stanley Creek, and ST1 Steepbank River at mouth.

Data sonde stations were visited monthly between July and October 2015, when the data sondes were replaced with freshly-calibrated units. Additional monthly visits occurred at the four overwintering data sonde stations (stations CL1, MU1, MU4, and MU6, Table 3.1-6); all other stations were decommissioned in late October 2015, prior to winter freeze-up (Table 3.1-6). Calibrations were conducted in the laboratory prior to field visits, and followed manufacturer-recommended procedures for pH (one-point with pH 7 or 10 standard), conductivity (one-point with 1413 µS/cm standard), turbidity (two-point with 0 and 126 NTU standards), and dissolved oxygen (one-point, 100% saturation) (Hach 2006, YSI 2014).

Data management included calibration drift corrections, identification of data gaps (when sondes were likely buried in sediment), setting grades, and setting approval levels. Appendix B contains a detailed description of the QA/QC data procedures for the data management of the network of data sondes.

Challenges Encountered and Solutions Applied

The following data sonde equipment challenges were addressed in 2015:

- The oxygen sensor at Station HHR-1 malfunctioned in late July 2015, and was replaced in early August;
- The turbidity sensor at Station MU6 began reading zero in late October, and was replaced in early December;
- Low battery voltage occurred at stations ST1, MU0, MU4, and MU6 in fall 2015, when daylight hours declined and solar charging was less effective. While no data were lost as a result of low battery voltage, telemetry capabilities were temporarily turned off to conserve battery power and batteries were replaced during the next available field visit; and
- Data sondes at stations MU6, MA1, HHR-1, and FI1 became buried in sediment at various stages throughout the open-water season. Each data sonde was cleaned or swapped during the next available field visit.

Challenges encountered with co-located hydrometric stations are described in Section 3.1.1.4. Data gaps associated with data sonde equipment challenges are described in Appendix B.

Summary of Continuous Water Quality Data Now Available

All data sonde monitoring stations were new to the JOSMP in 2015. Table 3.1-6 summarizes the available water quality data collected through the data sonde network in the 2015 WY. Data available for these stations include continuous measurements of water temperature, dissolved oxygen, pH, conductivity, and turbidity. Data were presented in near-real time from 12 sites in 2015 (Table 3.1-6), with the time series of water quality made available on http://www.ramp-alberta.org.

3.1.2.3 Summary of Discrete Water Quality Monitoring Field Methods and Sample Analysis

Station locations were identified using GPS coordinates, Alberta Forestry, Lands, and Wildlife Resource Access Maps and where applicable, written descriptions from past RAMP/JOSMP reports. Stations were accessed by foot, boat, helicopter, or Argo.

At all water quality stations, in situ measurements of dissolved oxygen (DO, mg/L), temperature (°C), pH, and conductivity (µS/cm) were collected using a YSI Model 85 multi-probe water meter or a handheld Hanna multimeter (pH, conductivity, and temperature), and a LaMotte portable Winkler titration kit (dissolved oxygen). Single grab samples of water were also collected for laboratory analysis. Grab samples were collected by submerging each sample bottle to a depth of approximately 30 cm, uncapping and filling the bottle, and recapping at depth. The only exceptions to this were samples collected for total hydrocarbons, BTEX analyses, and mercury, which were taken from the water surface to ensure any floating hydrocarbons were collected, and to ensure that the pre-charged preservative stayed in the bottle. The mercury bottles were opened using a clean-hands-dirty-hands technique for sample collection, following guidance from the analytical laboratory.

Samples taken at the mouth of tributaries to the Athabasca River were collected at least 100 m upstream of the confluence where possible, in order to avoid influences of Athabasca River mainstem water on sampled water quality at each station. Similarly, stations located on river mainstems near tributaries were sampled at least 100 m upstream of the tributary confluence.

Sampling methods were modified in winter in response to environmental conditions and to account for and preclude any sampling error or contamination associated with the requisite use of secondary sample transfer vessels and ice augers (all waterbodies sampled during other seasons were free of ice). Water was collected through holes drilled into the river/lake ice using a gas-powered auger. For grab samples, one hole was drilled at the estimated stream thalweg and the hole was thoroughly purged to remove all ice and possible overflow. Samples were collected from as far as possible below the surface of the water.

All water samples were collected, preserved, and shipped according to protocols specified by consulting laboratories without field filtering.

Within the 2015 WY, samples collected by Hatfield from November 2014 to March 2015 were collected under contract to AEP and from May to October 2015 under contract to AEMERA. Until March 2015, all water quality samples were analyzed for standard variables that have been historically sampled by RAMP (Table 3.1-10, Table 3.1-11), with most analyses conducted by ALS Environmental Ltd. (Fort McMurray and Edmonton, Alberta). Analyses of total and dissolved metals (including ultra-trace mercury) and acid-extractable organics (naphthenic acids) were analyzed by Alberta Innovates Technology Futures (AITF) in Vegreville, Alberta, and PAHs were analyzed by AXYS Analytical Services Ltd. in Sidney, British Columbia (BC). Samples collected from regional lakes were also analyzed by ALS for chlorophyll *a*.

From May 2015 onwards, routine analyses were conducted by Maxxam Analytics (Fort McMurray and Edmonton, Alberta), total and dissolved metals, acid-extractable organics (naphthenic acids), and hydrocarbons were conducted by Alberta Innovates Technology Futures (AITF) in Vegreville, Alberta, ultra-trace mercury and methyl mercury (added to the program in May 2015) were analyzed by the Biogeochemical Analytical Services Laboratory (BASL) at the University of Alberta (Edmonton, Alberta), and

PAHs were analyzed by AXYS Analytical Services Ltd in Sidney, BC (Table 3.1-11, Table 3.1-12). Samples collected from regional lakes were also analyzed by Maxxam for chlorophyll *a*.

Details of the analytical chemistry methods and associated detection limits for discrete water quality samples are provided in Table 3.1-10 to Table 3.1-12. Although detection limits could vary between individual analyses based on sample-specific laboratory and quality assurance (QA) data, standard method detection limits were typically applied to all non-detectable data, with the exception of ultra-trace PAHs, for which blank-corrected detection limits were applied.

Blank Correction of Detection Limits for Ultra-trace PAHs

Ultra-trace analysis of PAHs in water was introduced in 2011, with analysis conducted by AXYS Analytical Ltd. (AXYS) using low-resolution mass spectrometry (LRMS) and results for 48 parent and alkylated PAH homologues were reported.

Analytical results from AXYS presented reporting limits (RL, equal to sample-specific detection limits) for each PAH compound (ranging from 0.115 ng/L to 1.95 ng/L); these were calculated for each sample tested based on various internal QA performance assessments undertaken with each analysis. Given that the RLs were variable among tests and measurements in trip blanks exceeded RLs in some cases (typically in different analytical batches), data were subsequently blank-corrected to calculate project-wide, consistent detection limits (DLs) for each PAH compound. This allowed for consistent comparisons of all PAH data collected and consistent calculations of total PAH measures among all stations in the 2015 WY. This blank-correction procedure followed methods developed in conjunction with AXYS for the RAMP 2011 data (RAMP 2012) so that all results measured for a given PAH compound had the same detection limit applied for data from all stations and seasons/months. Project-wide, blank-corrected DLs for each PAH species (or, in the case of alkylated forms, groups of compounds) were generated by calculating DLs for each PAH equal to 3x the standard deviation of concentrations of that compound measured in all project trip blanks.

The RL was adopted as the project-wide DL for cases in which a mean RL was greater than the blank-corrected DL. In most cases, the blank-corrected DL was higher than the mean RL, resulting in the adoption of the blank-corrected DL as the project-wide DL. This resulted in an increase in detection limits for most PAH compounds, by typically less than one order of magnitude. Both PAH-specific RLs and associated, blank-corrected DLs are provided in Table 3.1-12.

A result of applying these blank-corrected detection/reporting limits was an increase in the number of non-detectable concentrations. However, this was necessary to reduce the likelihood of false positives in the dataset of PAH concentrations. Conversely, concentrations of total PAHs were increased by use of this blank-correction method for DLs, given that total PAHs were reported as the sum of all PAH compounds calculated using 1x the project-wide DL, to be conservative (i.e., estimate on the high side) and to be consistent with other summation variables presented in this report (e.g., total PAHs in sediments).

Table 3.1-10 Standard water quality variables measured in support of the JOSMP, November 2014 to March 2015.

Group	Water Quality Variable	Units	Detection Limit	Analytical Method	VMV Code	Lab
Conventional Variables	Conductivity	µS/cm	0.2	APHA 4500-H, 2510, 2320	2041	ALS
	Dissolved Organic Carbon	mg/L	1	APHA 5310 C-Instrumental	6101	ALS
	Hardness (as $CaCO_3$)	mg/L	-	APHA 1030E	10602	ALS
	pH	pH	0.1	APHA 4500-H, 2510, 2320	10301	ALS
	Total alkalinity	mg/L	2	APHA 4500-H, 2510, 2320	10165	ALS
	Total Dissolved Solids	mg/L	12	APHA 2540 C	99558	ALS
	Total Dissolved Solids (Calculated)	mg/L	-	APHA 1030E	203	ALS
	Total Organic Carbon	mg/L	1	APHA 5310 C-Instrumental	6078	ALS
	Total Suspended Solids	mg/L	3	APHA 2540 D	102455	ALS
	True colour	TCU	2	APHA 2120	2021	ALS
General Organics	Benzene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108880	ALS
	CCME Fraction 1 (BTEX)	mg/L	0.1	EPA 5021/8015&8260 GC-MS & FID	107875	ALS
	CCME Fraction 1 (C6-C10)	mg/L	0.1	EPA 5021/8015&8260 GC-MS & FID	107874	ALS
	CCME Fraction 2 (C10-C16)	mg/L	0.25	EPA 3510/CCME PHC CWS-GC-FID	107876	ALS
	CCME Fraction 3 (C16-C34)	mg/L	0.25	EPA 3510/CCME PHC CWS-GC-FID	107878	ALS
	CCME Fraction 4 (C34-C50)	mg/L	0.25	EPA 3510/CCME PHC CWS-GC-FID	107880	ALS
	Ethylbenzene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108916	ALS
	m+p-Xylene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108937	ALS
	Naphthenic acids	mg/L	0.02	GC/MS-ion-trapping, 2011 standard	108338	AITF
	Oilsands extractable	mg/L	0.1	GC/MS-ion-trapping, 2011 standard	108477	AITF
	o-Xylene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108936	ALS
	Toluene	mg/L	0.0005	EPA 5021/8015&8260 GC-MS & FID	108925	ALS
	Total phenolics	mg/L	0.001	AB ENV.06537-COLORIMETRIC	6537	ALS
	Total recoverable hydrocarbons	mg/L	1	APHA 5520 F		ALS
	Xylenes	mg/L	0.00071	EPA 5021/8015&8260 GC-MS & FID	109160	ALS
Major ions	Bicarbonate (HCO_3)	mg/L	5	APHA 4500-H, 2510, 2320	6201	ALS
	Calcium (Ca)	mg/L	0.5	APHA 3030 B&E/EPA SW-846 6020A	104568	ALS
	Carbonate (CO_3)	mg/L	5	APHA 4500-H, 2510, 2320	6301	ALS
	Chloride (Cl)	mg/L	0.5	APHA 4110 B-ION CHROMATOGRAPHY	99494	ALS
	Hydroxide (OH)	mg/L	5	APHA 4500-H, 2510, 2320	8501	ALS
	Ion Balance	%	-	APHA 1030E	118	ALS
	Magnesium (Mg)	mg/L	0.1	APHA 3030 B&E/EPA SW-846 6020A	104587	ALS
	Potassium (K)	mg/L	0.5	APHA 3030 B&E/EPA SW-846 6020A	104599	ALS
	Sodium (Na)	mg/L	1	APHA 3030 B&E/EPA SW-846 6020A	104609	ALS
	Sulphate (SO_4)	mg/L	0.5	APHA 4110 B-ION CHROMATOGRAPHY	98228	ALS
	Sulphide	mg/L	0.0015	APHA 4500 -S E-Auto-Colorimetry	16003	ALS
Nutrients and BOD	Ammonia-N	mg/L	0.05	APHA 4500 NH3-NITROGEN (AMMONIA)	102626	ALS
	Biochemical Oxygen Demand	mg/L	2	APHA 5210 B-5 day Incub.-O2 electrode	8202	ALS
	Nitrate	mg/L	0.05	APHA 4110 B-ION CHROMATOGRAPHY	102647	ALS
	Nitrate+Nitrite	mg/L	0.054	CALCULATION	103392	ALS
	Nitrite	mg/L	0.02	APHA 4110 B-ION CHROMATOGRAPHY	102648	ALS
	Phosphorus, dissolved	mg/L	0.001	APHA 4500-P PHOSPHORUS	15113	ALS
	Phosphorus, total	mg/L	0.001	APHA 4500-P PHOSPHORUS	15406	ALS
	Total Kjeldahl Nitrogen	mg/L	0.2	APHA 4500-NORG (TKN)	7021	ALS
	Total nitrogen	mg/L	-	(Calculated)	-	-
Total Metals	Aluminum	mg/L	0.0002	ICP/MS by DRC-II	103999	AITF
	Antimony	mg/L	0.000001	ICP/MS by DRC-II	80043	AITF
	Arsenic	mg/L	0.000004	ICP/MS by DRC-II	80020	AITF
	Barium	mg/L	0.000004	ICP/MS by DRC-II	80022	AITF
	Beryllium	mg/L	0.000008	ICP/MS by DRC-II	80023	AITF
	Bismuth	mg/L	0.000001	ICP/MS by DRC-II	80024	AITF
	Boron	mg/L	0.0001	ICP/MS by DRC-II	80021	AITF
	Cadmium	mg/L	0.000002	ICP/MS by DRC-II	80026	AITF
	Calcium	mg/L	0.01	ICP/MS by DRC-II	80025	AITF
	Chlorine	mg/L	0.04	ICP/MS by DRC-II	80027	AITF

Table 3.1-10 (Cont'd.)

Group	Water Quality Variable	Units	Detection Limit	Analytical Method	VMV Code	Lab
Total Metals (Cont'd.)	Chromium	mg/L	0.00003	ICP/MS by DRC-II	80029	AITF
	Cobalt	mg/L	0.000002	ICP/MS by DRC-II	80028	AITF
	Copper	mg/L	0.00005	ICP/MS by DRC-II	80030	AITF
	Iron	mg/L	0.0007	ICP/MS by DRC-II	80031	AITF
	Lead	mg/L	0.000003	ICP/MS by DRC-II	80041	AITF
	Lithium	mg/L	0.00005	ICP/MS by DRC-II	80034	AITF
	Manganese	mg/L	0.000005	ICP/MS by DRC-II	80036	AITF
	Mercury	mg/L	0.000008	ICP/MS by DRC-II	80032	AITF
	Mercury, ultra-trace	ng/L	0.08	ICP/MS by DRC-II	74475	AITF
	Molybdenum	mg/L	0.000002	ICP/MS by DRC-II	80037	AITF
	Nickel	mg/L	0.000008	ICP/MS by DRC-II	80039	AITF
	Selenium	mg/L	0.00006	ICP/MS by DRC-II	80044	AITF
	Silver	mg/L	0.000002	ICP/MS by DRC-II	103998	AITF
	Strontium	mg/L	0.000001	ICP/MS by DRC-II	80047	AITF
	Sulphur	mg/L	0.2	ICP/MS by DRC-II	80042	AITF
	Thallium	mg/L	0.0000009	ICP/MS by DRC-II	80053	AITF
	Thorium	mg/L	0.0000009	ICP/MS by DRC-II	80048	AITF
	Tin	mg/L	0.000003	ICP/MS by DRC-II	80046	AITF
	Titanium	mg/L	0.00005	ICP/MS by DRC-II	80049	AITF
	Uranium	mg/L	0.000003	ICP/MS by DRC-II	80054	AITF
	Vanadium	mg/L	0.00001	ICP/MS by DRC-II	80055	AITF
	Zinc	mg/L	0.0001	ICP/MS by DRC-II	80056	AITF
Dissolved Metals	Aluminum	mg/L	0.00013	ICP/MS by DRC-II	103927	AITF
	Antimony	mg/L	0.000008	ICP/MS by DRC-II	103951	AITF
	Arsenic	mg/L	0.000003	ICP/MS by DRC-II	103928	AITF
	Barium	mg/L	0.00005	ICP/MS by DRC-II	103930	AITF
	Beryllium	mg/L	0.000009	ICP/MS by DRC-II	103931	AITF
	Bismuth	mg/L	0.000003	ICP/MS by DRC-II	103932	AITF
	Boron	mg/L	0.00013	ICP/MS by DRC-II	103929	AITF
	Cadmium	mg/L	0.000002	ICP/MS by DRC-II	103934	AITF
	Calcium	mg/L	0.03	ICP/MS by DRC-II	103933	AITF
	Chlorine	mg/L	0.03	ICP/MS by DRC-II	103935	AITF
	Chromium	mg/L	0.0001	ICP/MS by DRC-II	103937	AITF
	Cobalt	mg/L	0.000002	ICP/MS by DRC-II	103936	AITF
	Copper	mg/L	0.00008	ICP/MS by DRC-II	103938	AITF
	Iron	mg/L	0.0006	ICP/MS by DRC-II	103939	AITF
	Lead	mg/L	0.000004	ICP/MS by DRC-II	103949	AITF
	Lithium	mg/L	0.00002	ICP/MS by DRC-II	103942	AITF
	Manganese	mg/L	0.00001	ICP/MS by DRC-II	103944	AITF
	Mercury	mg/L	0.000009	ICP/MS by DRC-II	103940	AITF
	Molybdenum	mg/L	0.000002	ICP/MS by DRC-II	103945	AITF
	Nickel	mg/L	0.000006	ICP/MS by DRC-II	103947	AITF
	Selenium	mg/L	0.00004	ICP/MS by DRC-II	103952	AITF
	Silver	mg/L	0.000001	ICP/MS by DRC-II	103926	AITF
	Strontium	mg/L	0.00007	ICP/MS by DRC-II	103955	AITF
	Sulphur	mg/L	0.2	ICP/MS by DRC-II	103950	AITF
	Thallium	mg/L	0.0000004	ICP/MS by DRC-II	103958	AITF
	Thorium	mg/L	0.0000008	ICP/MS by DRC-II	103956	AITF
	Tin	mg/L	0.000003	ICP/MS by DRC-II	103954	AITF
	Titanium	mg/L	0.00008	ICP/MS by DRC-II	103957	AITF
	Uranium	mg/L	0.000002	ICP/MS by DRC-II	103959	AITF
	Vanadium	mg/L	0.00002	ICP/MS by DRC-II	103960	AITF
	Zinc	mg/L	0.00009	ICP/MS by DRC-II	103961	AITF

Table 3.1-11 PAH variables measured in water samples collected for the JOSMP in the 2015 WY.

Water Quality Variable	Units	Average Reporting Limit	Blank-Corrected Detection Limit	Analytical Method	Lab
Biphenyl	ng/L	0.203	1.827	LR GC/MS	AXYS
C1-Biphenyls	ng/L	0.304	7.253	LR GC/MS	AXYS
C2-Biphenyls	ng/L	0.870	36.553	LR GC/MS	AXYS
Naphthalene	ng/L	0.636	13.550	LR GC/MS	AXYS
C1-Naphthalenes	ng/L	0.588	11.642	LR GC/MS	AXYS
C2-Naphthalenes	ng/L	0.633	6.287	LR GC/MS	AXYS
C3-Naphthalenes	ng/L	0.365	3.221	LR GC/MS	AXYS
C4-Naphthalenes	ng/L	0.349	3.679	LR GC/MS	AXYS
Acenaphthylene	ng/L	0.125	0.372	LR GC/MS	AXYS
Acenaphthene	ng/L	0.211	0.589	LR GC/MS	AXYS
C1-Acenaphthenes	ng/L	0.187	0.433	LR GC/MS	AXYS
Fluorene	ng/L	0.145	0.403	LR GC/MS	AXYS
C1-Fluorenes	ng/L	0.332	6.357	LR GC/MS	AXYS
C2-Fluorenes	ng/L	0.512	2.559	LR GC/MS	AXYS
C3-Fluorenes	ng/L	0.411	4.465	LR GC/MS	AXYS
Phenanthrene	ng/L	0.205	1.736	LR GC/MS	AXYS
Anthracene	ng/L	0.160	0.186	LR GC/MS	AXYS
C1-Phenanthrenes/Anthracenes	ng/L	0.248	1.036	LR GC/MS	AXYS
C2-Phenanthrenes/Anthracenes	ng/L	0.137	1.044	LR GC/MS	AXYS
C3-Phenanthrenes/Anthracenes	ng/L	0.197	0.954	LR GC/MS	AXYS
C4-Phenanthrenes/Anthracenes	ng/L	0.445	3.122	LR GC/MS	AXYS
Retene	ng/L	0.392	0.589	LR GC/MS	AXYS
Dibenzothiophene	ng/L	0.137	0.364	LR GC/MS	AXYS
C1-Dibenzothiophenes	ng/L	0.203	0.553	LR GC/MS	AXYS
C2-Dibenzothiophenes	ng/L	0.268	2.155	LR GC/MS	AXYS
C3-Dibenzothiophenes	ng/L	0.228	2.461	LR GC/MS	AXYS
C4-Dibenzothiophenes	ng/L	0.246	2.637	LR GC/MS	AXYS
Fluoranthene	ng/L	0.095	0.666	LR GC/MS	AXYS
Pyrene	ng/L	0.085	1.304	LR GC/MS	AXYS
C1-Fluoranthenes/Pyrenes	ng/L	0.240	1.183	LR GC/MS	AXYS
C2-Fluoranthenes/Pyrenes	ng/L	0.209	1.500	LR GC/MS	AXYS
C3-Fluoranthenes/Pyrenes	ng/L	0.268	0.885	LR GC/MS	AXYS
C4-Fluoranthenes/Pyrenes[1]	ng/L	0.202	0.184	LR GC/MS	AXYS
Benz[a]anthracene	ng/L	0.088	0.186	LR GC/MS	AXYS
Chrysene	ng/L	0.094	0.238	LR GC/MS	AXYS
C1-Benzo[a]anthracenes/Chrysenes	ng/L	0.101	0.349	LR GC/MS	AXYS
C2-Benzo[a]anthracenes/Chrysenes	ng/L	0.169	0.365	LR GC/MS	AXYS
C3-Benzo[a]anthracenes/Chrysenes[1]	ng/L	0.129	0.203	LR GC/MS	AXYS
C4-Benzo[a]anthracenes/Chrysenes[1]	ng/L	0.110	0.180	LR GC/MS	AXYS
Benzo[b,j,k]fluoranthene	ng/L	0.122	0.145	LR GC/MS	AXYS
Benzo[a]pyrene	ng/L	0.167	0.234	LR GC/MS	AXYS
Benzo[e]pyrene[1]	ng/L	0.163	0.188	LR GC/MS	AXYS
C1-Benzofluoranthenes/Benzopyrenes	ng/L	0.249	0.831	LR GC/MS	AXYS
C2-Benzofluoranthenes/Benzopyrenes	ng/L	0.228	0.723	LR GC/MS	AXYS
Indeno[1,2,3-c,d]-pyrene	ng/L	0.139	0.204	LR GC/MS	AXYS
Dibenz[a,h]anthracene	ng/L	0.177	0.285	LR GC/MS	AXYS
Perylene[1]	ng/L	0.170	0.242	LR GC/MS	AXYS
Benzo[g,h,i]perylene	ng/L	0.123	0.277	LR GC/MS	AXYS

[1] Analyte added to the program in May 2015.

Table 3.1-12 Standard water quality variables measured in support of the JOSMP, May to October 2015.

Group	Water Quality Variable	Units	Detection Limit	Analytical Method	VMV Code	Lab
Conventional Variables	Conductivity	μS/cm	1.0	APHA 22 2510 B	002041	Maxxam
	Dissolved Organic Carbon	mg/L	1.0	MMCW 119 1996	6107	Maxxam
	Hardness (as $CaCO_3$)	mg/L	0.50	Calculation	0010602	Maxxam
	pH	pH	N/A	APHA 22 4500 H+ B	010301	Maxxam
	Total Alkalinity (as $CaCO_3$)	mg/L	0.50	APHA 22 2320 B	1592	Maxxam
	Alkalinity (PP as $CaCO_3$)	mg/L	0.50	APHA 22 2320 B	1593	Maxxam
	Total Dissolved Solids	mg/L	10	APHA 22 2540 C	2004	Maxxam
	Total Dissolved Solids (Calc.)	mg/L	10	Calculation	000201	Maxxam
	Total Organic Carbon	mg/L	1.0	MMCW 119 1996	22214	Maxxam
	Total Suspended Solids	mg/L	1.0	APHA 22 2540 D	2005	Maxxam
	True colour	PtCo units	2.0	APHA 22 2120 C	22213	Maxxam
	Turbidity	NTU	0.10	APHA 22 2130 B	2002	Maxxam
General Organics	Benzene	mg/L	0.0001	NA-006	106092	AITF
	CCME Fraction 1 (BTEX)	mg/L	0.01	Calculation	106091	AITF
	CCME Fraction 1 (C6-C10)	mg/L	0.01	NA-006	-	AITF
	CCME Fraction 2 (C10-C16)	mg/L	0.005	NA-006	106097	AITF
	CCME Fraction 3 (C16-C34)	mg/L	0.02	NA-006	106098	AITF
	CCME Fraction 4 (C34-C50)	mg/L	0.02	NA-006	108342	AITF
	Ethylbenzene	mg/L	0.0001	NA-006	106094	AITF
	m+p-Xylene	mg/L	0.0001	NA-006	106095	AITF
	Naphthenic acids	mg/L	0.08	NA-012	108338	AITF
	Oilsands extractable	mg/L	0.1	NA-012	108477	AITF
	o-Xylene	mg/L	0.0001	NA-006	106096	AITF
	Toluene	mg/L	0.0001	NA-006	106093	AITF
	Total phenolics	mg/L	0.0020	MMCW 154 1996	006537	Maxxam
Major ions	Bicarbonate (HCO_3)	mg/L	0.50	APHA 22 2320 B	1594	Maxxam
	Calcium (Ca), total	mg/L	0.30	EPA 200.7 CFR 2012 m	020005	Maxxam
	Calcium (Ca), dissolved	mg/L	0.30	EPA 200.7 CFR 2012 m	020111	Maxxam
	Carbonate (CO_3)	mg/L	0.50	APHA 22 2320 B	1595	Maxxam
	Chloride (Cl), dissolved	mg/L	1.0	APHA 22 4500-Cl G	2003	Maxxam
	Hydroxide (OH)	mg/L	0.50	APHA 22 2320 B	1596	Maxxam
	Ion Balance	N/A	0.010	Calculation	000111	Maxxam
	Magnesium (Mg), total	mg/L	0.20	EPA 200.7 CFR 2012 m	012005	Maxxam
	Magnesium (Mg), dissolved	mg/L	0.20	EPA 200.7 CFR 2012 m	012111	Maxxam
	Potassium (K), total	mg/L	0.30	EPA 200.7 CFR 2012 m	100774	Maxxam
	Potassium (K), dissolved	mg/L	0.30	EPA 200.7 CFR 2012 m	019111	Maxxam
	Sodium (Na), total	mg/L	0.50	EPA 200.7 CFR 2012 m	011005	Maxxam
	Sodium (Na), dissolved	mg/L	0.50	EPA 200.7 CFR 2012 m	011111	Maxxam
	Sulphate (SO_4), dissolved	mg/L	1.0	APHA 22 4500-SO4 E	1599	Maxxam
	Sulphide	mg/L	0.0019	APHA 22 4500-S2 D	102629	Maxxam
Nutrients and BOD	Ammonia-N	mg/L	0.050	EPA 350.1 R2.0	2007	Maxxam
	Biochemical Oxygen Demand	mg/L	2.0	APHA 22 5210B	8120169	Maxxam
	Nitrate	mg/L	0.0030	APHA 22 4110 B	102647	Maxxam
	Nitrate+Nitrite	mg/L	0.0050	Calculation	102649	Maxxam
	Nitrite, dissolved	mg/L	0.0030	SM 22 4110 B m	102648	Maxxam
	Orthophosphate (P)	mg/L	0.0030	APHA 22 4500-P A,B,F	2014	Maxxam
	Phosphorus, dissolved	mg/L	0.0030	APHA 22 4500-P A,B,F	2010	Maxxam
	Phosphorus, total	mg/L	0.0030	APHA 22 4500-P A,B,F	2013	Maxxam
	Total Kjeldahl Nitrogen	mg/L	0.050	EPA 351.1 R 1978	2009	Maxxam
	Total Kjeldahl Nitrogen, dissolved	mg/L	0.050	EPA 351.1 R 1978	2008	Maxxam
	Total nitrogen	mg/L	0.055	Calculation	007602	Maxxam
Total Metals	Aluminum	mg/L	0.0002	AC-038	103999	AITF
	Antimony	mg/L	0.000001	AC-038	80043	AITF
	Arsenic	mg/L	0.000004	AC-038	80020	AITF
	Barium	mg/L	0.000004	AC-038	80022	AITF
	Beryllium	mg/L	0.000008	AC-038	80023	AITF
	Bismuth	mg/L	0.000001	AC-038	80024	AITF

Table 3.1-12 (Cont'd.)

Group	Water Quality Variable	Units	Detection Limit	Analytical Method	VMV Code	Lab
Total Metals (Cont'd.)	Boron	mg/L	0.0001	AC-038	80021	AITF
	Cadmium	mg/L	0.000002	AC-038	80026	AITF
	Calcium	mg/L	0.01	AC-038	80025	AITF
	Chlorine	mg/L	0.04	AC-038	80027	AITF
	Chromium	mg/L	0.00003	AC-038	80029	AITF
	Cobalt	mg/L	0.000002	AC-038	80028	AITF
	Copper	mg/L	0.00005	AC-038	80030	AITF
	Iron	mg/L	0.0007	AC-038	80031	AITF
	Lead	mg/L	0.000003	AC-038	80041	AITF
	Lithium	mg/L	0.00005	AC-038	80034	AITF
	Manganese	mg/L	0.000005	AC-038	80036	AITF
	Mercury	mg/L	0.000008	AC-038	80032	AITF
	Mercury, ultra-trace	ng/L	0.08	AC-038	74475	AITF
	Molybdenum	mg/L	0.000002	AC-038	80037	AITF
	Nickel	mg/L	0.000008	AC-038	80039	AITF
	Selenium	mg/L	0.00006	AC-038	80044	AITF
	Silver	mg/L	0.000002	AC-038	103998	AITF
	Strontium	mg/L	0.000001	AC-038	80047	AITF
	Sulphur	mg/L	0.2	AC-038	80042	AITF
	Thallium	mg/L	0.0000009	AC-038	80053	AITF
	Thorium	mg/L	0.0000009	AC-038	80048	AITF
	Tin	mg/L	0.000003	AC-038	80046	AITF
	Titanium	mg/L	0.00005	AC-038	80049	AITF
	Uranium	mg/L	0.000003	AC-038	80054	AITF
	Vanadium	mg/L	0.00001	AC-038	80055	AITF
	Zinc	mg/L	0.0001	AC-038	80056	AITF
Dissolved Metals	Aluminum	mg/L	0.00013	AC-038	103927	AITF
	Antimony	mg/L	0.000008	AC-038	103951	AITF
	Arsenic	mg/L	0.000003	AC-038	103928	AITF
	Barium	mg/L	0.00005	AC-038	103930	AITF
	Beryllium	mg/L	0.000009	AC-038	103931	AITF
	Bismuth	mg/L	0.000003	AC-038	103932	AITF
	Boron	mg/L	0.00013	AC-038	103929	AITF
	Cadmium	mg/L	0.000002	AC-038	103934	AITF
	Calcium	mg/L	0.03	AC-038	103933	AITF
	Chlorine	mg/L	0.03	AC-038	103935	AITF
	Chromium	mg/L	0.0001	AC-038	103937	AITF
	Cobalt	mg/L	0.000002	AC-038	103936	AITF
	Copper	mg/L	0.00008	AC-038	103938	AITF
	Iron	mg/L	0.0006	AC-038	103939	AITF
	Lead	mg/L	0.000004	AC-038	103949	AITF
	Lithium	mg/L	0.00002	AC-038	103942	AITF
	Manganese	mg/L	0.00001	AC-038	103944	AITF
	Mercury	mg/L	0.000009	AC-038	103940	AITF
	Molybdenum	mg/L	0.000002	AC-038	103945	AITF
	Nickel	mg/L	0.000006	AC-038	103947	AITF
	Selenium	mg/L	0.00004	AC-038	103952	AITF
	Silver	mg/L	0.000001	AC-038	103926	AITF
	Strontium	mg/L	0.00007	AC-038	103955	AITF
	Sulphur	mg/L	0.2	AC-038	103950	AITF
	Thallium	mg/L	0.0000004	AC-038	103958	AITF
	Thorium	mg/L	0.0000008	AC-038	103956	AITF
	Tin	mg/L	0.000003	AC-038	103954	AITF
	Titanium	mg/L	0.00008	AC-038	103957	AITF
	Uranium	mg/L	0.000002	AC-038	103959	AITF
	Vanadium	mg/L	0.00002	AC-038	103960	AITF
	Zinc	mg/L	0.00009	AC-038	103961	AITF

Changes in Monitoring Network from 2014

A number of changes to the water quality monitoring network relative to 2014 and earlier regional monitoring, particularly the expansion of monthly sampling to a larger number of stations, were made from May 2015 onwards (Table 3.1-7 and Table 3.1-13 compared to Table 3.1-14); these changes were concurrent with AEMERA assuming the management of the JOSMP.

Changes in Analytical Chemistry Methods from 2014

A number of changes were made to the water quality analyses in May 2015, including the suite of consulting laboratories that were responsible for water quality analyses, and the list of variables analyzed for the Program. The detection limits for many water quality variables also changed when Maxxam took over the analysis of routine water, major ions, nutrients, organic carbon, chlorophyll *a*, mercury, and phenols in May 2015.

Water quality variables that were added to the 2015 Program included:

- Routine variables and major ions: carbonate alkalinity, turbidity, total potassium, total calcium, total magnesium, total sodium, dissolved iron, and dissolved manganese as part of ion scan;
- Nutrients and organic carbon: dissolved Kjeldahl nitrogen, total nitrogen, orthophosphate, dissolved nitrite, and dissolved nitrate;
- Mercury: unfiltered and filtered methylmercury, and total and dissolved ultra-low-DL mercury; and
- PAHs: C4-Fluoranthenes/Pyrenes, C3- and C4-Benzo[a]anthracenes/Chrysenes, Benzo[e]pyrene, and Perylene.

The following water quality variables that were removed from the 2015 Program:

- Routine variables: fluoride;
- Nutrients and organic carbon: nitrite and nitrate;
- Trace metals: total and dissolved sulfur;
- Organics: xylenes; and
- No PAHs were removed but some were renamed, including methyl-biphenyl and dimethyl biphenyl (now C1- and C2-biphenyl) and methyl acenaphthalene (now C1-acenaphthalenes).

Target detection limits decreased in 2015 for:

- Routine variables and major ions: total alkalinity, total suspended solids, total dissolved solids, total potassium, carbonate, bicarbonate, hydroxide, dissolved calcium, and dissolved sodium;
- Nutrients and organic carbon: total Kjeldahl nitrogen, nitrate and nitrite, total organic carbon, and dissolved organic carbon; and
- Total mercury (ultra-low DL).

Target detection limits increased in 2015 for:

- Routine variables and major ions: specific conductance/conductivity, sulphide, sulphate, chloride, and dissolved magnesium;
- Nutrients and organic carbon: total phosphorus and total dissolved phosphorus;
- Chlorophyll *a*; and
- Phenols.

Challenges Encountered and Solutions Applied

The following challenges related to the field program and analytical laboratories were encountered by the Water Quality component in the 2015 WY:

- During the February sampling event, *test* station Poplar Creek (PO1) was frozen to depth and no discrete water quality sample could be collected;
- Due to laboratory error, samples collected from *baseline* station MacKay River (MA2) in July 2015 for analysis of PAHs were not analyzed;
- Vegetation growth around *test* station WA1 (Wapasu Creek) in September 2015 prevented sampling crews from landing the helicopter and; therefore, no sample was collected; and
- Due to a miscommunication, Jackpine Creek (JA1) was sampled by both Hatfield and AEMERA in May, June, and July 2015. AEMERA conducted the sampling at this station from August until October 2015.

Other Information Obtained

A special study was also undertaken in 2015 to investigate relationships between TSS and turbidity using data obtained from the data sondes. An assessment of sediment loading was conducted using these TSS relationships and discharges generated from the Climate and Hydrology component. The results of this study are presented in Section 6.1.

Summary of Discrete Water Quality Data Now Available

Table 3.1-13 summarizes the discrete water quality data collected in the 2015 WY and Table 3.1-14 summarizes the discrete water quality data collected from 1997 to 2014.

Table 3.1-13 Summary of discrete water quality data available for the JOSMP in the 2015 WY, and used in this report.

Waterbody and Location	Station	2014		2015									
		N	D	J	F	M	A	M	J	J	A	S	O
Athabasca River													
Athabasca River below Beaver River	M4							1	1	1	1	1	1
Athabasca River above MacKay River	M5							1	1	1	1	1	1
Athabasca River below Fort MacKay	M6							1	1	1	1	1	1
Athabasca River downstream of all development (centre channel)	ATR-DD-C					1		1	1	1	1	1	1
Athabasca River downstream of all development (east bank)	ATR-DD-E					1							
Athabasca River downstream of all development (west bank)	ATR-DD-W					1							
Christina River and Tributaries													
Christina River upstream of Fort McMurray	CH1 (CHR-1)	1	1	1	1	1		1	1	1	1	1	1
Christina River upstream of Janvier	CHR-2	1	1	1	1	1		1	1	1	1	1	1
Christina River upstream of Jackfish River	CHR-3					1		1	1	1	1	1	1
Christina River upstream of development	CHR-4					1			1	1	1	1	1
Birch Creek at Highway 881	BRC-1					1		1		1		1	
Gregoire River (lower)	GRR-1					1		1		1		1	
Jackfish River	JAR-1					1		1		1		1	
Sawbones Creek	SAC-1					1		1		1		1	
Sunday Creek (inlet to Christina Lake)	SUC-1					1		1		1		1	
Sunday Creek (upper)	SUC-2					1		1		1		1	
Unnamed Creek east of Christina Lake	UNC-2					1		1		1		1	
Unnamed Creek south of Christina Lake	UNC-3					1		1		1		1	
Clearwater River and Tributaries													
Clearwater River at Draper	AB07CD0200									1	1	1	1
Clearwater River upstream of Fort McMurray	CL2 (CLR-1)							1	1				
Clearwater River upstream of Christina River	CLR-2	1	1	1	1	1							
High Hills River (mouth)	HHR-1					1		1	1	1	1	1	1
Hangingstone River													
Hangingstone River at Fort McMurray	HA1 (HAR-1A)							1	1	1	1	1	1
Hangingstone River above Fort McMurray	HAR-1							1	1	1	1	1	1

Legend

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids, and PAHs

2 = standard water quality and chlorophyll *a* and PAHs

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Table 3.1-13 (Cont'd.)

Waterbody and Location	Station	2014		2015									
		N	D	J	F	M	A	M	J	J	A	S	O
Tributaries to the Athabasca River (Eastern)													
Fort Creek	FOC-1							1	1	1	1	1	
McLean Creek (mouth)	MCC-1							1	1	1	1	1	
Steepbank River													
Steepbank River (mouth)	ST1 (STR-1)					1		1	1	1	1	1	1
Steepbank River adjacent to Millennium Mine	ST WSC							1	1	1	1	1	1
Steepbank River approx. 27 km upstream from mouth	STB RIFF 7							1	1	1	1	1	1
Steepbank River upstream of Millennium Mine	STR-2	1	1	1	1	1							
Steepbank River below North Steepbank River	STB RIFF 10							1	1	1	1	1	1
Muskeg River and Tributaries													
Jackpine Creek (mouth)	JA1 (JAC-1)							1	1	1	1	1	1
Muskeg River (mouth)	MU0 (MUR-1)	1	1	1	1	1				1	1	1	1
Muskeg River near Fort McKay	MU1							1	1	1	1	1	1
Muskeg River above Jackpine Creek	MU4							1	1	1	1	1	1
Muskeg River above Muskeg Creek	MU5							1	1	1	1	1	1
Muskeg River above Stanley Creek	MU6							1	1	1	1	1	1
Muskeg River above Wapasu Creek	MU7									1	1	1	
Muskeg River above Wapasu Creek	MU8							1	1	1	1	1	1
Muskeg River at Imperial Kearl Lake Road	MU9									1	1		
Muskeg River upland	MU10							1	1	1	1	1	1
Jackpine Creek at Canterra Road	TR3.1							1	1	1	1	1	1
Jackpine Creek above Shell Jackpine	TR3.2							1	1	1	1	1	1
Wapasu Creek (mouth)	WA1							1	1	1	1		1
Stanley Creek (mouth)	STC-1							1	1	1	1	1	
Firebag River													
Firebag River	FI WSC							1	1	1	1	1	1
Firebag River	FI1 (FIR-1)							1	1	1	1	1	1
Firebag River	FI2 (FIR-2)									1	1	1	1
Tributaries to the Athabasca River (Western)													
Horse River	HO2							1	1	1	1	1	1
Poplar Creek at Highway 63	PO1 (POC-1)	1	1	1		1		1	1	1	1	1	1
Beaver River	BER-1							1	1	1	1	1	

Legend

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids, and PAHs

2 = standard water quality and chlorophyll *a* and PAHs

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Table 3.1-13 (Cont'd.)

Waterbody and Location	Station	2014		2015									
		N	D	J	F	M	A	M	J	J	A	S	O
Tributaries to the Athabasca River (Western) (Cont'd.)													
Calumet River (mouth)	CA1 (CAR-1)							1	1	1	1	1	
Tar River (mouth)	TAR-1							1	1	1	1	1	
Tar River upstream of Canadian Natural Horizon	TAR-2A (TAR-2)									1	1	1	1
Unnamed Creek (Big Creek)	UN1 (BIC-1)							1	1	1	1	1	
Ells River													
Ells River at CNRL Bridge	EL2 (ELR-2)							1	1	1	1	1	1
Ells River (mouth)	ELLS RIFF 3 (ELR-1)							1	1	1	1	1	1
Ells River above Joslyn Creek Diversion	ELLS RIFF 5 (ELR-3					1		1	1	1	1	1	1
MacKay River													
Dover River	DOV RIFF 4 (DO1)							1	1	1	1	1	1
MacKay River (mouth)	MA1							1	1	1	1	1	1
MacKay River at Petro-Canada Bridge	MA2 (MAR-2)	1	1	1	1	1		1	1	1	1	1	1
Lakes and Wetlands													
Christina Lake	CHL-1					2		2		2		2	
Kearl Lake	KL1 (KEL-1)							2		2		2	
McClelland Lake	MCL-1							2		2		2	
Johnson Lake	JOL-1					2		2		2		2	
Gardiner Lake	GAL-1					2		2		2		2	
Namur Lake	NAL-1					2		2		2		2	
Gregoire Lake	GRL-1					2		2		2		2	
Isadore's Lake	ISL-1											2	
Shipyard Lake	SHL-1											2	
Stations Sampled for Benthic Invertebrate Communities Component													
Big Point Channel	BPC-1											1	
Embarras River	EMR-2											1	
Fletcher Channel	FLC-1											1	
Goose Island Channel	GIC-1											1	
Calumet River upper	CAR-2											1	
Christina River upper	CHR-2A											1	
Clearwater River upstream of Christina River	CLR-2											1	
Beaver River	BER-2											1	

Legend

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids, and PAHs

2 = standard water quality and chlorophyll *a* and PAHs

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Table 3.1-13 (Cont'd.)

Waterbody and Location	Station	2014		2015									
		N	D	J	F	M	A	M	J	J	A	S	O
Stations Sampled for Benthic Invertebrate Communities Component (Cont'd.)													
Jackpine Creek at East Athabasca Hwy	JAC-2											1	
Redclay Creek	RCC-1											1	
Pierre River near Fort MacKay	PIR-1											1	
Eymundson Creek (mouth)	EYC-1											1	
Stations Sampled for Wild Fish Health Monitoring for Fish Populations Component													
Athabasca River below town of Athabasca	M0-DS											1	
Athabasca River below Fort McMurray STP discharge	M3											1	
Athabasca River above Muskeg River	M4-US											1	
Athabasca River below Muskeg River	M4-DS											1	
Ells River lower	ER-L											1	
Ells River mid	ER-M											1	
Ells River upper	ER-U											1	
Dover River lower	DC-L											1	
Dover River mid	DC-M											1	
Dover River upper	DC-U											1	
MacKay River lower	MR-L											1	
MacKay River mid	MR-M											1	
MacKay River upper	MR-U											1	
Alice Creek downstream	AC-DS											1	
Alice Creek upstream	AC-US											1	

Legend

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids, and PAHs

2 = standard water quality and chlorophyll *a* and PAHs

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Table 3.1-14 Summary of discrete water quality data available for the JOSMP from 1997 to 2014, and used in this report. (Page 1 of 2)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray (grab) [a]	ATR-UFM	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11
Upstream Donald Creek (cross channel)	ATR-DC-CC		1	1	1																				3
(west bank) [b]	ATR-DC-W								1								1				3				1
(east bank) [b]	ATR-DC-E								1								1				3				1
(middle)	ATR-DC-M																1								
Upstream of the Steepbank River (middle)	ATR-SR-M																1								
(west bank)	ATR-SR-W																1				1				1
(east bank)	ATR-SR-E																1				1				1
Upstream of the Muskeg River (middle)	ATR-MR-M																1								
(west bank) [b c]	ATR-MR-W								1								1				1				1
(east bank) [b c]	ATR-MR-E								1								1				1				1
Upstream Fort Creek (cross channel)	ATR-FC-CC-D		1	1	1																				
(west bank) [b c]	ATR-FC-W								1								1				3				1
(east bank) [b c]	ATR-FC-E								1								1				3				1
(middle)	ATR-FC-M																1								
Downstream of all development (cross channel)	ATR-DD-CC																					1	1	1	3
(centre channel)	ATR-DD-C																								
(east bank)	ATR-DD-E																								
(west bank)	ATR-DD-W																								
Upstream of mouth of Firebag River	ATR-FR-CC																								1
Upstream of the Embarras River (cross channel)	ATR-ER									1							1				3				
Embarras River	EMR-1																								
At Old Fort (grab) [d]	ATR-OF													11	11	11	11	11	11	11	11	12	12	12	12
Athabasca River Delta																									
Big Point Channel [e]	ARD-1											1					1				1				
Athabasca River tributaries (Eastern)																									
McLean Creek (mouth)	MCC-1											6	7		6	6	9		6	6	9		6	6	7
(100 m upstream)	MCC-2											6	6												
Steepbank River (mouth)	STR-1	3	1	1	1		1	1	1	1							1				1	1			1
(upstream of Project Millennium)	STR-2																					1			1
(upstream of Nt. Steepbank)	STR-3																								
North Steepbank River (upstream of Suncor Lewis)	NSR-1																						1	1	1
Fort Creek (mouth)	FOC-1														7		7		6	6	7		6	6	7
Muskeg River																									
Mouth [f,i]	MUR-1			1	1	13	13,1	13,1	11,1	13	13,6	13,6	11,7				1				1				1
Upstream of Wapasu Creek	MUR-6								1,2		7	7	7		6	6	9		6	6	7		6	6	7
(1000 m upstream of MUR-6)	MUR-6A																								
Muskeg River Tributaries																									
Alsands Drain (mouth) [f g h]	ALD-1					13	13	13	11	13	13,6	13,6	11,7	4	10	10	10	4	10	10	10	4	10	10	10
Jackpine Creek (mouth) [g]	JAC-1					13	13	13	11	13	13	13	11,1				1				1				1
(upper)	JAC-2																								
Shelley Creek (mouth)	SHC-1								11				11,1												
Muskeg Creek (mouth)	MUC-1								11,2				11,1				1				1				1
Stanley Creek (mouth)	STC-1								11				11,1								1	1	1	1	1
Iyinimin Creek (mouth)	IYC-1																								
Wapasu Creek (Canterra Road Crossing)	WAC-1								11,2	1			11,1												
Athabasca River tributaries (Western)																									
Poplar Creek (mouth) [i]	POC-1																1				1				1
Beaver River (mouth)	BER-1																								
(upper)	BER-2																								
MacKay River (mouth)	MAR-1								1								1				1	1			1
(mid-river, upstream of Suncor Dover)	MAR-2A																								
(upstream of Suncor MacKay) [i]	MAR-2																					1			1
Dunkirk River (Fish program support)	DUR-1																								

Waterbody and Location	Station	2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray (grab) [a]	ATR-UFM	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	11	13	11	13
Upstream Donald Creek (cross channel)	ATR-DC-CC				3				1				1	1			1				1				
(west bank) [b]	ATR-DC-W				1				1				1				1				1	1			1
(east bank) [b]	ATR-DC-E				1				1				1				1				1	1			1
(middle)	ATR-DC-M																								
Upstream of the Steepbank River (middle)	ATR-SR-M																								
(west bank)	ATR-SR-W				1				1				1				1				1				1
(east bank)	ATR-SR-E				1				1				1				1				1				1
Upstream of the Muskeg River (middle)	ATR-MR-M																								
(west bank) [b c]	ATR-MR-W				1				1				1				1				1				1
(east bank) [b c]	ATR-MR-E				1				1				1				1				1				1
Upstream Fort Creek (cross channel)	ATR-FC-CC-D																								
(west bank) [b c]	ATR-FC-W				1																				
(east bank) [b c]	ATR-FC-E				1																				
(middle)	ATR-FC-M																								
Downstream of all development (cross channel)	ATR-DD-CC	1,1	1	1	3	1,1	1	1	3	1,1	1	1	1												
(centre channel)	ATR-DD-C																								
(east bank)	ATR-DD-E									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(west bank)	ATR-DD-W									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Upstream of mouth of Firebag River	ATR-FR-CC				1				1				1				1				1				1
Upstream of the Embarras River (cross channel)	ATR-ER								1																
Embarras River	EMR-1				1																				
At Old Fort (grab) [d]	ATR-OF	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Athabasca River Delta																									
Big Point Channel [e]	ARD-1				1				1																
Athabasca River tributaries (Eastern)																									
McLean Creek (mouth)	MCC-1		6	6	7		6	6	9		7	7	9		6	6	9				9				1
(100 m upstream)	MCC-2																								
Steepbank River (mouth)	STR-1				1				1				1				1				1	1			1
(upstream of Project Millennium)	STR-2				1				1				1				1				1				1
(upstream of Nt. Steepbank)	STR-3					1	1	1	1	*	1	1	1		1	1	1	*	1	1	1				1
North Steepbank River (upstream of Suncor Lewis)	NSR-1	*	1	1	1	*	1	1	1	1	1	1	1				1				1				1
Fort Creek (mouth)	FOC-1		6	6	7										6	6	7				7		6	6	7
Muskeg River																									
Mouth [f,i]	MUR-1				1				1				1				1				1				1
Upstream of Wapasu Creek	MUR-6		6	6	7		6	6	7		6	6	7		6	6	7				7		6	6	7
(1000 m upstream of MUR-6)	MUR-6A																								
Muskeg River Tributaries																									
Alsands Drain (mouth) [f g h]	ALD-1	4	10	10	10	4	10	10	10																
Jackpine Creek (mouth) [g]	JAC-1				1		1	1	1				1				1				1				1
(upper)	JAC-2																								1
Shelley Creek (mouth)	SHC-1																1				1				
Muskeg Creek (mouth)	MUC-1				1	*	1	1	1				1				1				1	1	1	1	1
Stanley Creek (mouth)	STC-1	*	1	1	1	*	1	1	1	*	1	1	1				1				1				1
Iyinimin Creek (mouth)	IYC-1																			1	1				1
Wapasu Creek (Canterra Road Crossing)	WAC-1								1				1				1				1				1
Athabasca River tributaries (Western)																									
Poplar Creek (mouth) [i]	POC-1				1				1				1				1				1				1
Beaver River (mouth)	BER-1			1	1			1	1			1	1				1				1	*			1
(upper)	BER-2																						1	1	1
MacKay River (mouth)	MAR-1				1	1	1	1	1				1				1				1	1	1	1	1
(mid-river, upstream of Suncor Dover)	MAR-2A																								
(upstream of Suncor MacKay) [i]	MAR-2	1	1	1	1				1				1				1				1	1	1	1	1
Dunkirk River (Fish program support)	DUR-1																								

Waterbody and Location	Station	2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray (grab) [a]	ATR-UFM	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13	11	13
Upstream Donald Creek (cross channel)	ATR-DC-CC																								
(west bank) [b]	ATR-DC-W	1			1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3			
(east bank) [b]	ATR-DC-E	1			1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3			
(middle)	ATR-DC-M																								
Upstream of the Steepbank River (middle)	ATR-SR-M																								
(west bank)	ATR-SR-W				1				1				3				3				3				
(east bank)	ATR-SR-E				1				1				3				3				3				
Upstream of the Muskeg River (middle)	ATR-MR-M																								
(west bank) [b c]	ATR-MR-W				1				1				3				3				3				
(east bank) [b c]	ATR-MR-E				1				1				3				3				3				
Upstream Fort Creek (cross channel)	ATR-FC-CC-D																								
(west bank) [b c]	ATR-FC-W																								
(east bank) [b c]	ATR-FC-E																								
(middle)	ATR-FC-M																								
Downstream of all development (cross channel)	ATR-DD-CC																								
(centre channel)	ATR-DD-C																						3	3	3
(east bank)	ATR-DD-E	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
(west bank)	ATR-DD-W	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Upstream of mouth of Firebag River	ATR-FR-CC				1				1				3				3								
Upstream of the Embarras River (cross channel)	ATR-ER																								
Embarras River	EMR-1																								
At Old Fort (grab) [d]	ATR-OF	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Athabasca River Delta																									
Big Point Channel [e]	ARD-1																								
Athabasca River tributaries (Eastern)																									
McLean Creek (mouth)	MCC-1				1				1				3				3				3				3
(100 m upstream)	MCC-2																								
Steepbank River (mouth)	STR-1	1			1	1			1	1			3	3			3	*			3	3			3
(upstream of Project Millennium)	STR-2				1				1				3				3				3		3	3	3
(upstream of Nt. Steepbank)	STR-3				1				1				3				3				3				3
North Steepbank River (upstream of Suncor Lewis)	NSR-1				1				1				3				3				3				3
Fort Creek (mouth)	FOC-1		6	6	7				1				3				3				3				3
Muskeg River																									
Mouth [f,i]	MUR-1				1				1				3				3	3	3	3	3	3	3	3	3
Upstream of Wapasu Creek	MUR-6				1				1				3				3								
(1000 m upstream of MUR-6)	MUR-6A																				3				3
Muskeg River Tributaries																									
Alsands Drain (mouth) [f g h]	ALD-1																								
Jackpine Creek (mouth) [g]	JAC-1				1				2				3				3				3				3
(upper)	JAC-2				1				2				3				3				3				3
Shelley Creek (mouth)	SHC-1				1								*												
Muskeg Creek (mouth)	MUC-1												3				3				3				3
Stanley Creek (mouth)	STC-1				1				1				3				3				3				3
Iyinimin Creek (mouth)	IYC-1								1				3				3				3				3
Wapasu Creek (Canterra Road Crossing)	WAC-1				1				1				3				3				3				3
Athabasca River tributaries (Western)																									
Poplar Creek (mouth) [i]	POC-1				1				1				3				3	3	3	3	3	3	3	3	3
Beaver River (mouth)	BER-1				1				1				3				3				3				3
(upper)	BER-2	1	1	1	1	1	1	1	1				3				3				3				3
MacKay River (mouth)	MAR-1	1	1	1	1				1				3				3				3				3
(mid-river, upstream of Suncor Dover)	MAR-2A	1	1	1	1	1	1	1	1	1	*	3	3	3	3	3	3				3				3
(upstream of Suncor MacKay) [i]	MAR-2	1	1	1	1				1				3				3	3	3	3	3	3	3	3	3
Dunkirk River (Fish program support)	DUR-1				1																				

Note: Monitoring for the Water Quality Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids)
2 = standard water quality variables and chronic toxicity testing (*Pseudokirchneriella subcapitata, Ceriodaphnia dubia, Pimephales promelus*)
3 = standard water quality variables and PAHs
4 = standard water quality variables, chronic toxicity testing, and PAHs
5 = standard water quality for OPTI lakes
6 = thermograph
7 = thermograph and standard water quality variables
8 = thermograph, standard water quality variables, and PAHs
9 = thermograph, standard water quality variables, and chronic toxicity testing
10 = thermograph, standard water quality variables, chronic toxicity testing, and PAHs
11 = AESRD routine water quality variables (conventional variables, major ions, nutrients and total metals)
12 = AESRD routine water quality variables and RAMP standard water quality variables
13 = AESRD routine water quality variables and PAHs
14 = AESRD routine water quality variables and data sonde
15 = AESRD routine water quality variables, PAHs, and data sonde
16 = standard water quality variables and chlorophyll *a*
17 = standard water quality variables, chlorophyll *a*, and PAHs

Footnotes

[a] Two samples collected in winter, but PAHs and several other parameters only measured once
[b] Sample sites were previously labeled ATR-1, 2, and 3 (moving upstream from the Delta)
[c] Samples were collected downstream of tributary in 1998
[d] Monthly sampling for nutrients and conventional variables; quarterly sampling for total and dissolved metals
[e] In 1999, one composite sample was prepared with water from Big Point, Goose Island, Embarras River, and an unnamed side channel
[f] All testing, with the exception of thermographs, was conducted by individual industry
[g] AESRD collected nine samples throughout the year, although only three were analyzed for PAHs
[h] MUR-4 was located upstream of Shelley Creek in 1999
[i] Monthly sampling was initiated in 2013.

* = sampling was scheduled but didn't occur (station was frozen to depth, dry, or couldn't be sampled due to another circumstance)
√ = allowance made for potential TIE
(blue) *Test* (downstream of oil sands developments)
(light green) *Baseline* (upstream of oil sands developments)
(dark green) *Baseline*, but excluded from Regional Baseline calculations because of minor development near the headwaters of the river.

Table 3.1-14 (Cont'd.) (Page 2 of 2)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River tributaries (Western) (Cont'd.)																									
Ells River (mouth)	ELR-1						1	1	1						11	11	11	11					1	1	2
(upstream of Total Joslyn Mine)	ELR-2														11	11	11	14							
(upstream of the Fort MacKay water intake)	ELR-2A																								
(upper)	ELR-3																								
Tar River (mouth)	TAR-1						1	1	1														1	1	2
(upstream of Canadian Natural Horizon)	TAR-2																								
Calumet River (mouth)	CAR-1																						1	1	2
Calumet River (upstrream of Canadian Natural Horizon)	CAR-2																								
Firebag River (mouth)	FIR-1																					1	1	1	1
(upstream of Suncor Firebag)	FIR-2																					1	1	1	1
Pierre River (mouth)	PIR-1																								
Eymundson Creek (mouth)	EYC-1																								
Big Creek (mouth)	BIC-1																								
Red Clay Creek (mouth)	RCC-1																								
Athabasca River tributaries (Southern)																									
Clearwater River (upstream of Fort McMurray)	CLR-1																	3	8	8	8	1	7	7	8
(upstream of Christina River)[i]	CLR-2																	3	8	8	8	1	7	7	8
Christina River (upstream of Fort McMurray)[i]	CHR-1																					1	1	1	3
(upstream of Janvier)	CHR-2																					1	1	1	3
(mid)	CHR-2A																								
(upstream of Jackfish River)	CHR-3																								
(upstream of development)	CHR-4																								
Jackfish River (outlet of Christina Lake)	JAR-1																								
Sunday Creek (inlet to Chistina Lake)	SUC-1																								
Sunday Creek (upstream)	SUC-2																								
Sawbones Creek (inlet to Chistina Lake)	SAC-1																								
Unnamed Creek (east of Christina Lake)	UNC-2																								
Unnamed Creek (south of Christina Lake)	UNC-3																								
Birch Creek	BRC-1																								
Gregoire River	GRR-1																								
Hangingstone River (upstream of Fort McMurray)	HAR-1																								
Hangingstone River (mouth)	HAR-1A																								
Horse River (Fish program support)	HOR-1																								
High Hills River (mouth)	HHR-1																								
Lake Tributaries																									
Mills Creek	MIC-1																								
Wetlands (Lakes)																									
Kearl Lake	KEL-1							16+3	16+3								16+3			16	16				1
Isadore's Lake	ISL-1							16									16			16	16				
Shipyard Lake	SHL-1							16			1	16	1			16	1			16	16			16	16
McClelland Lake	MCL-1																16			1	16				1
Johnson Lake	JOL-1																								
Christina Lake	CHL-1																								
Namur Lake	NAL-1																								
Gregoire Lake	GRL-1																								
Gardiner Lake	GAL-1																								
Additional Sampling (Non-Core Programs)																									
Unnammed Creek north of Ft. Creek (mouth)	UNC-1																1								
Nexen Lakes	-																		5		5		5		5
Potential TIE	-																								√
QA/QC																									
Field and trip blanks, one split and duplicate	-														1	1	1			1	1	1	1	1	1,1

Waterbody and Location	Station	2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River tributaries (Western) (Cont'd.)																									
Ells River (mouth)	ELR-1	1	1	1	2	1	1	1	2	1	1	1	2				1				1				1
(upstream of Total Joslyn Mine)	ELR-2					*	1	1	2	*	1	1	1	*	1	1	1	*	1	1	1				1
(upstream of the Fort MacKay water intake)	ELR-2A																								
(upper)	ELR-3																								
Tar River (mouth)	TAR-1	*	1	1	2	1	1	1	1	*	1	1	1				1				1				1
(upstream of Canadian Natural Horizon)	TAR-2					*	1	1	1	*	1	1	1	*	1	1	2	*	1	1	2				1
Calumet River (mouth)	CAR-1	*	1	1	2	*	1	1	2	*	1	1	2				1				1				1
Calumet River (upstrream of Canadian Natural Horizon)	CAR-2									*	1	1	2	*	1	1	2	1	1	1	2				1
Firebag River (mouth)	FIR-1	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1
(upstream of Suncor Firebag)	FIR-2	1	1	1	1	1	1	1	1	1	1	1	1				1				1				1
Pierre River (mouth)	PIR-1																								
Eymundson Creek (mouth)	EYC-1																								
Big Creek (mouth)	BIC-1																								
Red Clay Creek (mouth)	RCC-1																								
Athabasca River tributaries (Southern)																									
Clearwater River (upstream of Fort McMurray)	CLR-1	1	7	7	8	1	7	7	7	1	7	7	7	1	7	7	7		7	7	7				1
(upstream of Christina River)[i]	CLR-2	1	7	7	8	1	7	7	7	1	7	7	7		6	6	7		6		7				1
Christina River (upstream of Fort McMurray)[i]	CHR-1	1	1	1	3	1	1	1	3	1	1	1	1				1	1			1				1
(upstream of Janvier)	CHR-2	1	1	1	3	1	1	1	3	1	1	1	1				1	1			1				1
(mid)	CHR-2A																	1			1				
(upstream of Jackfish River)	CHR-3																								
(upstream of development)	CHR-4																								
Jackfish River (outlet of Christina Lake)	JAR-1																								
Sunday Creek (inlet to Chistina Lake)	SUC-1																								
Sunday Creek (upstream)	SUC-2																								
Sawbones Creek (inlet to Chistina Lake)	SAC-1																								
Unnamed Creek (east of Christina Lake)	UNC-2																								
Unnamed Creek (south of Christina Lake)	UNC-3																								
Birch Creek	BRC-1																								
Gregoire River	GRR-1																								
Hangingstone River (upstream of Fort McMurray)	HAR-1					*	1	1	1	*	1	1	1	*	1	1	1		1	1	1				1
Hangingstone River (mouth)	HAR-1A																								
Horse River (Fish program support)	HOR-1																								
High Hills River (mouth)	HHR-1																								
Lake Tributaries																									
Mills Creek	MIC-1																								
Wetlands (Lakes)																									
Kearl Lake	KEL-1	1			1			16	16			16	16				16			16	16				16
Isadore's Lake	ISL-1							16	16			16	16			16	16			16	16			16	16
Shipyard Lake	SHL-1			1	1			16	16			16	16			16	16			16	16			16	16
McClelland Lake	MCL-1				1												16				16				16
Johnson Lake	JOL-1																								
Christina Lake	CHL-1																								
Namur Lake	NAL-1																								
Gregoire Lake	GRL-1																								
Gardiner Lake	GAL-1																								
Additional Sampling (Non-Core Programs)																									
Unnammed Creek north of Ft. Creek (mouth)	UNC-1																								
Nexen Lakes	-							5	5		5		5		5		5								
Potential TIE	-				√				√																
QA/QC																									
Field and trip blanks, one split and duplicate	-	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1

Waterbody and Location	Station	2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River tributaries (Western) (Cont'd.)																									
Ells River (mouth)	ELR-1				1				1				3				3				3				3
(upstream of Total Joslyn Mine)	ELR-2				1				1				3				3								
(upstream of the Fort MacKay water intake)	ELR-2A								1	1	*	3	3	3			3								
(upper)	ELR-3																	3	3	3	3	3	3	3	3
Tar River (mouth)	TAR-1		1	1	1				1				3				3				3				3
(upstream of Canadian Natural Horizon)	TAR-2		1	1	1				1				3				3				3				3
Calumet River (mouth)	CAR-1				1				1				3				3				3				3
Calumet River (upstrream of Canadian Natural Horizon)	CAR-2				1				1				3				3				3				3
Firebag River (mouth)	FIR-1				1				1				3				3				3				3
(upstream of Suncor Firebag)	FIR-2				1				1				3				3				3				3
Pierre River (mouth)	PIR-1									*	3	3	3	*	3	3	3	*	3	3	3	*			3
Eymundson Creek (mouth)	EYC-1									*	3	3	3	3	3	3	3	*	3	3	3	*			3
Big Creek (mouth)	BIC-1									*	3	3	3	*	3	3	3	3	3	3	3	3			3
Red Clay Creek (mouth)	RCC-1									*	3	3	3	*	3	3	3	*	3	3	3	3			3
Athabasca River tributaries (Southern)																									
Clearwater River (upstream of Fort McMurray)	CLR-1				1				1				3				3	3			3				3
(upstream of Christina River)[i]	CLR-2				1				1				3				3		3	3	3	3	3	3	3
Christina River (upstream of Fort McMurray)[i]	CHR-1				1				1				3				3	3	3	3	3	3	3	3	3
(upstream of Janvier)	CHR-2				1				1				3				3				3		3	3	3
(mid)	CHR-2A																								
(upstream of Jackfish River)	CHR-3																	3	3	3	3	3	3	3	3
(upstream of development)	CHR-4																	3	3	3	3	3	3	3	3
Jackfish River (outlet of Christina Lake)	JAR-1														3	3	3	3	3	3	3	3	3	3	3
Sunday Creek (inlet to Chistina Lake)	SUC-1														3	3	3	3	3	3	3	3	3	3	3
Sunday Creek (upstream)	SUC-2																	3	3	3	3	3	3	3	3
Sawbones Creek (inlet to Chistina Lake)	SAC-1														3	3	3	3	3	3	3	3	3	3	3
Unnamed Creek (east of Christina Lake)	UNC-2																	3	3	3	3	3	3	3	3
Unnamed Creek (south of Christina Lake)	UNC-3																	3	3	3	3	3	3	3	3
Birch Creek	BRC-1																	3	3	3	3	3	3	3	3
Gregoire River	GRR-1																						3	3	3
Hangingstone River (upstream of Fort McMurray)	HAR-1																				3				3
Hangingstone River (mouth)	HAR-1A																				3				3
Horse River (Fish program support)	HOR-1				1																				
High Hills River (mouth)	HHR-1									1	*	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Lake Tributaries																									
Mills Creek	MIC-1								1				3				3				3				3
Wetlands (Lakes)																									
Kearl Lake	KEL-1				16				16				17				17				17				17
Isadore's Lake	ISL-1				16				16				17				17				17				17
Shipyard Lake	SHL-1				16				16				17				17				17				17
McClelland Lake	MCL-1				1				16				17				17				17				17
Johnson Lake	JOL-1									16	*	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Christina Lake	CHL-1														17	17	17	17	17	17	17	17	17	17	17
Namur Lake	NAL-1																						17	17	17
Gregoire Lake	GRL-1																						17	17	17
Gardiner Lake	GAL-1																						17	17	17
Additional Sampling (Non-Core Programs)																									
Unnammed Creek north of Ft. Creek (mouth)	UNC-1																								
Nexen Lakes	-		5		5						5		5						5		5				
Potential TIE	-																								
QA/QC																									
Field and trip blanks, one split and duplicate	-	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1	1	1	1	1,1

Note: Monitoring for the Water Quality Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend

1 = standard water quality variables (conventional variables, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids)
2 = standard water quality variables and chronic toxicity testing (*Pseudokirchneriella subcapitata, Ceriodaphnia dubia, Pimephales promelus*)
3 = standard water quality variables and PAHs
4 = standard water quality variables, chronic toxicity testing, and PAHs
5 = standard water quality for OPTI lakes
6 = thermograph
7 = thermograph and standard water quality variables
8 = thermograph, standard water quality variables, and PAHs
9 = thermograph, standard water quality variables, and chronic toxicity testing
10 = thermograph, standard water quality variables, chronic toxicity testing, and PAHs
11 = AESRD routine water quality variables (conventional variables, major ions, nutrients and total metals)
12 = AESRD routine water quality variables and RAMP standard water quality variables
13 = AESRD routine water quality variables and PAHs
14 = AESRD routine water quality variables and data sonde
15 = AESRD routine water quality variables, PAHs, and data sonde
16 = standard water quality variables and chlorophyll *a*
17 = standard water quality variables, chlorophyll *a*, and PAHs

Footnotes

[a] Two samples collected in winter, but PAHs and several other parameters only measured once
[b] Sample sites were previously labeled ATR-1, 2, and 3 (moving upstream from the Delta)
[c] Samples were collected downstream of tributary in 1998
[d] Monthly sampling for nutrients and conventional variables; quarterly sampling for total and dissolved metals
[e] In 1999, one composite sample was prepared with water from Big Point, Goose Island, Embarras River, and an unnamed side channel
[f] All testing, with the exception of thermographs, was conducted by individual industry
[g] AESRD collected nine samples throughout the year, although only three were analyzed for PAHs
[h] MUR-4 was located upstream of Shelley Creek in 1999
[i] Monthly sampling was initiated in 2013.
* = sampling was scheduled but didn't occur (station was frozen to depth, dry, or couldn't be sampled due to another circumstance
√ = allowance made for potential TIE
Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)
Baseline, but excluded from Regional Baseline calculations because of minor development near the headwaters of the river.

3.1.3 Benthic Invertebrate Communities and Sediment Quality

3.1.3.1 Overview of Monitoring Activities for the Benthic Invertebrate Communities Component in the 2015 WY

Benthic invertebrate communities were sampled from August 31 to September 18, 2015. A total of 414 samples were collected from 35 river reaches, four delta channels, and nine lakes (Table 3.1-15 and Figure 3.1-4). Stations were accessed by helicopter, boat, or Argo.

As in previous years, sampled habitats were classified as either depositional (dominated by fine sediment deposits and little to negligible flow) or erosional (dominated by rocky substrates and frequent riffle areas). These habitat classes do not change from year to year within a reach and sampling methods are specific to the habitat class, as described below.

Field Methods

Benthic invertebrate communities in depositional habitats were sampled according to standard methods used in previous years (Golder 2003, RAMP 2009b), which were developed from Alberta Environment (1990), Environment Canada (1993), Klemm et al. (1990) and Rosenberg and Resh (1993). An Ekman grab (0.023 m^2, 6” x 6”) was used for benthic invertebrate collections in depositional habitat. Ekman grabs were deployed by hand in water less than 1 m deep and were deployed by rope and messenger when the water was deeper.

Ten replicate Ekman grab samples were collected within pre-established river reaches that were typically 1 km to 2 km long. The exceptions were stations CAR-D2 Calumet River Upper Reach and FOC-D1 Fort Creek Lower Reach; five grab samples were collected at these reaches because the habitat available for sampling at these reaches was considerably shorter (i.e., approximately 400 m in length). Samples were separated by distances of between 100 m and 300 m (as the watercourse flows) to increase independence among samples. Sampling locations within a reach were generally the same as those sampled in previous years where conditions permitted.

Five replicate Ekman grab samples were collected from each of the Athabasca River Delta (ARD) channels, with samples separated by distances of between 50 m and 100 m.

Ten replicate Ekman grab samples were collected from the littoral area of each lake. The depth sampled in lakes was similar to past years and generally between 1 m and 2 m.

Benthic invertebrate communities in erosional reaches (with riffle and/or coarse substrata) were sampled using the CABIN traveling-kick methodology (Environment Canada 2012). Three replicate three-minute traveling-kick samples were collected from each erosional reach using a 400 µm mesh, D-framed net. The length of each erosional reach was defined by approximately 20 times the bankfull width. Sampling focused on riffle habitat; triplicate samples were collected from a single riffle if the single riffle was sufficiently large to contain the effort; multiple (adjacent) riffles were otherwise sampled.

Samples collected with an Ekman grab (i.e., depositional habitat) were sieved in the field using a 250-µm screen, preserved in 10% buffered formalin, and bottled for transport. Samples collected with a kick net were also preserved in 10% buffered formalin, and bottled for transport.

As in previous years, a series of measurements were recorded as supporting information:

- Geographical position – using a hand-held Magellan Global Positioning System (GPS) unit;
- Field water quality measurements – temperature (°C), specific conductivity (µS/cm) and pH were measured with a Hanna hand-held probe (temperature, conductivity, pH), and dissolved oxygen (mg/L) was measured with a LaMotte Winkler titration kit. Hanna pens were calibrated daily, according to the manufacturer's instructions;
- Wetted and bankfull channel widths – measured with an open reel tape measure (erosional stations) or a visual estimate (depositional stations);
- Water depth at each sampling location – measured with a graduated device;
- Water velocity – measured using a Swoffer flowmeter (erosional stations) or determined by measuring the time for a semi-submerged object to travel a known distance (depositional stations);
- General station appearance; and
- An additional Ekman grab sample collected from depositional reaches for analysis of total organic carbon (TOC, as a dry weight percentage) and particle size (% sand, silt and clay, as dry weight).

The following additional information was collected from erosional stations:

- Channel slope – measured with a clinometer;
- Degree of canopy coverage – visual approximation of the percentage of the stream covered by tree canopy as either 0%, 1% to 25%, 51% to 75% or 76% to 100%;
- Macrophyte coverage – visual estimate of the stream bed area covered by macrophyte vegetation;
- Streamside vegetation – list of present and dominant streamside vegetation such as ferns/grasses, shrubs, deciduous trees and coniferous trees;
- Periphyton coverage on substrate – visual estimate of benthic algae (not moss) on rocks;
- Substrate particle size class – visual estimates of dominant substrate size class (0-9) using the modified Wentworth classification system (Cummins 1962);
- Pebble count – measurements of the intermediate axis (cm) of 100 randomly-chosen pebbles in the stream bed;
- Substrate embeddedness – estimate of the embeddedness of ten rocks in the stream bed as being either 100%, 75%, 50%, 25% or not embedded; and
- Surrounding land use – list of present and dominant land uses such as forest, field/pasture, agriculture, residential/urban, logging, mining, commercial/industrial or other.

Table 3.1-15 Benthic Invertebrate Communities stations monitored for the JOSMP in the 2015 WY.

Reach or Station	Location	Habitat[1]	AEMERA Nomenclature	UTM Coordinates (NAD83, Zone 12)			
				Downstream Limit of Depositional Reach / Mid-point of Erosional Reach		Upstream Limit of Depositional Reach	
				Easting	Northing	Easting	Northing
Athabasca River Delta							
GIC-1	Goose Island Channel	depositional	AB07DD0220	509492	6494556	509610	6494021
BPC-1	Big Point Channel	depositional	AB07DD0230	512075	6494073	501575	6493776
FLC-1	Fletcher Channel	depositional	AB07DD0131	496463	6491717	496323	6491506
EMR-2	Embarras River	depositional	AB07DD0130	494741	6492065	494351	6491787
Muskeg River							
MUR-E1	Lower Reach	erosional	AB07DA0620	463884	6332202	-	-
MUR-D2	Middle Reach	depositional	AB07DA0610	466303	6339494	466605	6340509
MUR-D3	Upper Reach	depositional	AB07DA0475	480077	6357943	482144	6359789
Jackpine Creek							
JAC-D1	Lower Reach	depositional	AB07DA0600	471865	6346437	473071	6346324
JAC-D2	Upper Reach	depositional	AB07DA1225	480044	6324997	480780	6324629
Beaver River							
BER-D2	Upper Reach	depositional	AB07DA1420	465480	6311290	465422	6311008
Poplar Creek							
POC-D1	Lower Reach	depositional	AB07DA0110	473047	6308832	472540	6308618
Pierre River							
PIR-D1	Lower Reach	depositional	AB07DA1340	462252	6367481	461819	6368160
Redclay Creek							
RCC-E1	Lower Reach	erosional	AB07DA1295	475783	6395078	-	-
Unnamed Creek (Big Creek)							
BIC-D1	Lower Reach	depositional	AB07DA1270	471617	6387773	470918	6387767
Birch Creek							
BRC-D1	Lower Reach	depositional	AB07CE0010	492047	6163153	491345	6163022
Eymundson Creek							
EYC-D1	Lower Reach	depositional	AB07DA1320	465878	6372237	465450	6372711
Tar River							
TAR-D1	Lower Reach	depositional	AB07DA1350	438838	6353517	458573	6353573
TAR-E2	Upper Reach	erosional	AB07DA1365	440321	6361767	-	-
Ells River							
ELR-D1	Lower Reach	depositional	AB07DA0750	459254	6351513	458613	6351535
Unnamed Creek (east of Christina Lake)							
UNC-D2	Middle Reach	depositional	AB07CE0023	517465	6163752	517874	6163738
Unnamed Creek (Monday Creek)							
UNC-D3	Upper Reach	depositional	AB07CE0022	511124	6159863	510939	6159490
High Hills River							
HHR-E1	Lower Reach	erosional	AB07CD0300	529859	6289433	-	-

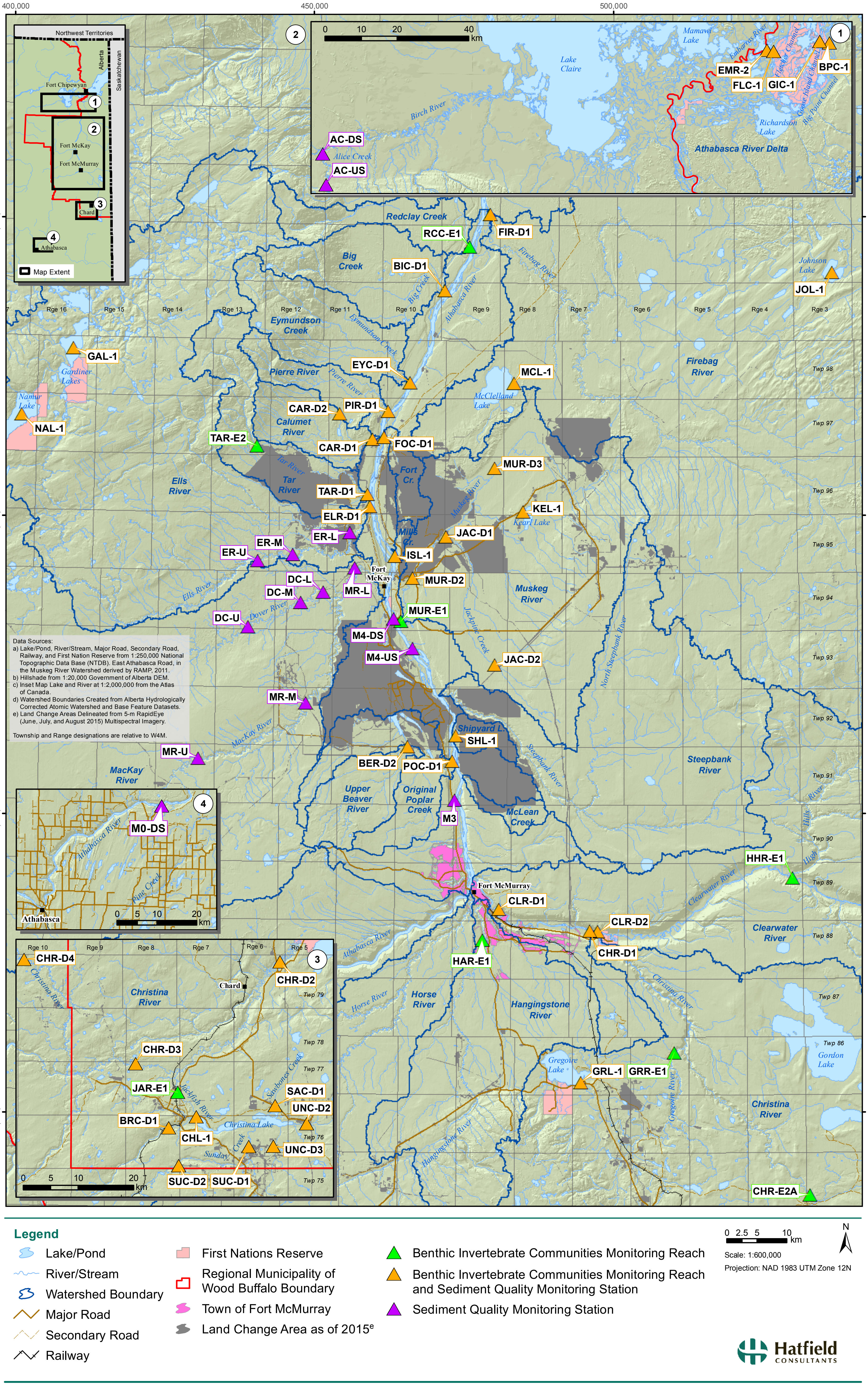
[1] Sediment quality sampling was conducted at depositional reaches and in lakes.
[2] UTM coordinates of first sample in lake.

Table 3.1-15 (Cont'd.)

Reach or Station	Location	Habitat[1]	AEMERA Nomenclature	UTM Coordinates (NAD83, Zone 12)			
				Downstream Limit of Depositional Reach / Mid-point of Erosional Reach		Upstream Limit of Depositional Reach	
				Easting	Northing	Easting	Northing
Fort Creek							
FOC-D1	Lower Reach	depositional	AB07DA2760	461530	6363112	461733	6363060
Jackfish River							
JAR-E1	Lower Reach	erosional	AB07CE0019	493936	6169499	-	-
Christina River							
CHR-D1	Lower Reach	depositional	AB07CD0210	495935	6280318	497733	6278475
CHR-D2	Lower Middle	depositional	AB07CD0060	512330	6193389	511905	6192448
CHR-D3	Upper Middle	depositional	AB07CE0005	486489	6174671	485990	6175255
CHR-D4	Middle Reach	depositional	AB07CE0001	466230	6193842	465867	6193725
CHR-E2A	Upper Reach	erosional	AB07CE0041	532672	6236235		
Clearwater River							
CLR-D1	Lower Reach	depositional	AB07CD0210	479926	6284311	481512	6283398
CLR-D2	Upper Reach	depositional	AB07CD0060	498878	6279874	501153	6279684
Gregoire River							
GRR-E1	Lower Reach	erosional	AB07CE0100	509789	6260002	-	-
Sawbones Creek							
SAC-D1	Lower Reach	depositional	AB07CE0060	511445	6167171	511491	6167890
Sunday Creek							
SUC-D1	Lower Reach	depositional	AB07CE0021	506714	6159803	506273	6159698
SUC-D2	Upper Reach	depositional	AB07CE0032	494275	6157259	494034	6156751
Calumet River							
CAR-D1	Lower Reach	depositional	AB07DA1360	460824	6363196	459608	6362811
CAR-D2	Upper Reach	depositional	AB07DA1345	454024	6366795	454122	6367044
Firebag River							
FIR-D1	Lower Reach	depositional	AB07DC0110	479369	6400426	479397	6398218
Hangingstone Creek							
HAR-E1	Lower Reach	erosional	AB07CD0010	478523	6276478	-	-
Lakes[2]							
CHL-1	Christina Lake	lake	AB07CE0250	497094	6164794	497168	6164528
GAL-1	Gardiner Lake	lake	AB07DA2030	407410	6379522	407934	6379840
GRL-1	Gregoire Lake	lake	AB07CE0120	492067	6254782	491952	6255090
ISL-1	Isadore's Lake	lake	AB07DA0420	463366	6343929	463995	6384612
JOL-1	Johnson Lake	lake	AB07DD0410	530533	6390060	535413	6390244
KEL-1	Kearl Lake	lake	AB07DA2210	485063	6348025	485346	6347701
MCL-1	McClelland Lake	lake	AB07DA2290	481151	6374425	481740	6374667
NAL-1	Namur Lake	lake	AB07DA1890	401326	6370994	401009	6370975
SHL-1	Shipyard Lake	lake	AB07DA3400	473206	6313086	473404	6313575

[1] Sediment quality sampling was conducted at depositional reaches and in lakes.
[2] UTM coordinates of first sample in lake.

Figure 3.1-4 Locations of benthic invertebrate community reaches and sediment quality stations monitored for the JOSMP in the 2015 WY.



Laboratory Methods

ALS Laboratories (Edmonton, Alberta) conducted the chlorophyll *a* analyses for erosional stations and analysis of TOC and particle size distribution for depositional stations.

Dr. Jack Zloty in Summerland, British Columbia performed sorting and taxonomic identifications, as in previous years. Samples were sieved in the laboratory using a 250-μm mesh sieve to remove the preservative and any remaining fine sediments. The material retained by the sieve was elutriated using a flotation technique to separate organic material from sand and gravel, and invertebrates from organic material. Samples containing bitumen were treated with paint thinner to remove hydrocarbons prior to sorting. Inorganic material was scanned under a magnifying lens and any remaining invertebrates were removed before discarding. The remaining organic material was separated into coarse and fine size fractions using a 1-mm sieve. The fine size fraction of large samples was sub-sampled using a modification of the method described by Wrona et al. (1982) in which fine materials were scanned for invertebrates with the aid of a dissecting microscope at a magnification of 6X to 10X. All sorted material was preserved for random checks of removal efficiency. QA/QC procedures related to sample processing for benthic invertebrate communities are discussed in Appendix B.

Each sample was processed individually; the samples were not pooled. Organisms were identified to lowest practical taxonomic levels using up-to-date taxonomic literature, and as per the guidelines in Appendix D.

Changes in Monitoring Network from 2014

The 2015 monitoring network for the Benthic Invertebrate Communities component was the same as the 2014 monitoring network with the exception of the sampling technique used at erosional reaches. Erosional reaches were sampled using Environment Canada's (2012) CABIN protocol in 2015, instead of with a Neil-Hess cylinder, which had been the method of collection since 1998. In addition, a number of reaches previously sampled for the RAMP and/or JOSMP were not sampled by Hatfield (Table 3.1-16) and are not included in the 2015 report.

Challenges Encountered and Solutions Applied

All sampling was undertaken without major issue or incident.

Other Information Obtained

No other information was obtained for this report.

Summary of Component Data Now Available

As of 2015, 4,398 benthic invertebrate community samples have been collected under this program. The distribution of stations and reaches, and the data available for individual locations are presented in Table 3.1-16 for the 2015 WY and in Table 3.1-17 for 1997 to 2014.

Table 3.1-16 Summary of data available for the Benthic Invertebrate Communities component of the JOSMP for the 2015 WY, and used in this report.

Waterbody and Location	Habitat	Reach/Station	2015			
			Winter	Summer	Spring	Fall
Athabasca River Delta						
Athabasca River Delta	depositional	FLC,GIC,BPC				
Embarras River	depositional	EMR-2				
Calumet River						
Lower Reach	depositional	CAR-D1				
Upper Reach	depositional	CAR-D2				
Christina River						
Lower Reach	depositional	CHR-D1				
Middle Reach	erosional	CHR-E2A				
Upper Reach	depositional	CHR-D2				
Upstream of Jackfish River	depositional	CHR-D3				
Upstream of Development	depositional	CHR-D4				
Clearwater River						
Downstream of Christina River	depositional	CLR-D1				
Upstream of Christina River	depositional	CLR-D2				
Ells River						
Lower Reach	depositional	ELR-D1				
Firebag River						
Lower Reach	depositional	FIR-D1				
Fort Creek						
Lower Reach	depositional	FOC-D1				
Gregoire River						
Gregoire River	erosional	GRR-E1				
Hangingstone River						
Lower Reach	erosional	HAR-E1				
High Hills River						
Lower Reach	erosional	HHR-E1				
Jackpine Creek						
Lower Reach	depositional	JAC-D1				
Upper Reach	depositional	JAC-D2				
Muskeg River						
Lower Reach	erosional	MUR-E1				
Middle Reach	depositional	MUR-D2				
Upper Reach	depositional	MUR-D3				
Big Creek						
Lower Reach	depositional	BIC-D1				
Eymundson Creek						
Lower Reach	depositional	EYC-D1				
Pierre River						
Lower Reach	depositional	PIR-D1				
Redclay Creek						
Lower Reach	erosional	RCC-E1				
Tar River						
Lower Reach	depositional	TAR-D1				
Upper Reach	erosional	TAR-E2				

Note: All reaches and stations are JOSMP reaches and stations.

Legend

[1] Data not included in 2015 report

[2] Station sampled by Environment Canada in 2015.

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Table 3.1-16 (Cont'd.)

Waterbody and Location	Habitat	Reach/Station	2015			
			Winter	Summer	Spring	Fall
Beaver River						
Lower Reach	depositional	BER-D2				
Poplar Creek						
Lower Reach	depositional	POC-D1				
Jackfish River						
Lower Reach	erosional	JAR-E1				
Sawbones Creek						
Lower Reach	depositional	SAC-D1				
Sunday Creek						
Lower Reach	depositional	SUC-D1				
Upper Reach	depositional	SUC-D2				
Birch Creek						
Lower Reach	depositional	BRC-D1				
Unnamed Creek south of Christina Lake						
Lower Reach	depositional	UNC-D3				
Unnamed Creek east of Christina Lake						
Lower Reach	depositional	UNC-D2				
Wetlands and Lakes						
Christina Lake	lake	CHL-1				
Gardiner Lake	lake	GAL-1				
Gregoire Lake	lake	GRL-1				
Isadore's Lake	lake	ISL-1				
Johnson Lake	lake	JOL-1				
Kearl Lake	lake	KEL-1				
McClelland Lake	lake	MCL-1				
Namur Lake	lake	NAL-1				
Shipyard Lake	lake	SHL-1				
Locations Not Sampled by Hatfield in 2015[1]						
Athabasca River Delta						
Embarras River	depositional	EMR-1				
Ells River						
Middle Reach	erosional	ELR-E2				
Historical Upper Reach	erosional	ELR-E2A				
Upper Reach	erosional	ELR-E3				
Firebag River						
Upper Reach	erosional	FIR-E2[2]				
MacKay River						
Lower Reach	erosional	MAR-E1[2]				
Middle Reach	erosional	MAR-E2[2]				
Upper Reach	erosional	MAR-E3[2]				
Steepbank River						
Lower Reach	erosional	STR-E1[2]				
Upper Reach	erosional	STR-E2[2]				
Tar River						
Historical Upper Reach	erosional	TAR-E1				

Note: All reaches and stations are JOSMP reaches and stations.

Legend

[1] Data not included in 2015 report

[2] Station sampled by Environment Canada in 2015.

Test (downstream of oil sands developments)   *Baseline* (upstream of oil sands developments)

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Table 3.1-17 Summary of data available for the Benthic Invertebrate Communities Component of the JOSMP from 1997 to 2014, and used in this report. (Page 1 of 2)

see symbol key at bottom

Waterbody and Location	Type	Habitat	Reach / Station	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
				W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F	W S S F
Athabasca River Delta																					
Athabasca River Delta	A	depositional	ATR,FLC,GIC,BPC																		
Embarras River	A	depositional	EMR-1																		
Embarras River	A	depositional	EMR-2																		
Calumet River																					
Lower Reach	A,B[1]	depositional	CAR-D1																		
Upper Reach	A	depositional	CAR-D2																		
Christina River																					
Lower Reach	A	depositional	CHR-D1																		
Middle Reach	A	erosional	CHR-E2A																		
Upper Reach	A	depositional	CHR-D2																		
Upstream of Jackfish River	A	depositional	CHR-D3																	*	
Upstream of Development	A	depositional	CHR-D4																		
Clearwater River																					
Downstream of Christina River	A	depositional	CLR-D1																		
Upstream of Christina River	A	depositional	CLR-D2																		
Ells River																					
Lower Reach	A	depositional	ELR-D1																		
Middle Reach	A	erosional	ELR-E2																		
Historical Upper Reach	A	erosional	ELR-E2A																		
Upper Reach	A	erosional	ELR-E3																		
Firebag River																					
Lower Reach	A	depositional	FIR-D1																		
Upper Reach	A	erosional	FIR-E2																		
Fort Creek																					
Lower Reach	A	depositional	FOC-D1																		
Gregoire River																					
Gregoire River	A	erosional	GRR-E1																		
Hangingstone River																					
Lower Reach	A	erosional	HAR-E1																		
High Hills River																					
Lower Reach	A	erosional	HHR-E1																		
Jackpine Creek																					
Lower Reach	A	depositional	JAC-D1																		
Upper Reach	A	depositional	JAC-D2																		
MacKay River																					
Lower Reach	A	erosional	MAR-E1																		
Middle Reach	A	erosional	MAR-E2																		
Upper Reach	A	erosional	MAR-E3																		
Muskeg River																					
Lower Reach	A	erosional	MUR-E1																		
Middle Reach	A	depositional	MUR-D2																		
Upper Reach	A	depositional	MUR-D3																		
Big Creek																					
Lower Reach	A	depositional	BIC-D1																		
Eymundson Creek																					
Lower Reach	A	depositional	EYC-D1																		
Pierre River																					
Lower Reach	A	depositional	PIR-D1																		
Red Clay Creek																					
Lower Reach	A	erosional	RCC-E1																		
Steepbank River																					
Lower Reach	A	erosional	STR-E1																		
Upper Reach	A	erosional	STR-E2																		

Note: Monitoring for the Benthic Inverebrate Communities Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend:

A = RAMP station

B = Sampled outside of RAMP (data available to RAMP)

[1] sampled outside of RAMP in 2001, became RAMP station in 2002

* sampled in erosional habitat in 2013.

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Baseline, but excluded from Regional Baseline calculations because of minor development near the headwaters of the river.

Table 3.1-17 (Cont'd.) (Page 2 of 2)

see symbol key at bottom

Waterbody and Location	Type	Habitat	Reach / Station
Tar River			
Lower Reach	A[1]	depositional	TAR-D1
Historical Upper Reach	A	erosional	TAR-E1
Upper Reach	A	erosional	TAR-E2
Beaver River			
Lower Reach	A	depositional	BER-D2
Poplar Creek			
Lower Reach	A	depositional	POC-D1
Jackfish River			
Lower Reach	A	erosional	JAR-E1
Sawbones Creek			
Lower Reach	A	depositional	SAC-D1
Sunday Creek			
Lower Reach	A	depositional	SUC-D1
Upper Reach	A	depositional	SUC-D2
Birch Creek			
Lower Reach	A	depositional	BRC-D1
Unnamed Creek south of Christina Lake			
Lower Reach	A	depositional	UNC-D3
Unnamed Creek east of Christina Lake			
Lower Reach	A	depositional	UNC-D2
Wetlands and Lakes			
Christina Lake	A	lake	CHL-1
Gardiner Lake	A	lake	GAL-1
Gregoire Lake	A	lake	GRL-1
Isadore's Lake	A	lake	ISL-1
Johnson Lake	A	lake	JOL-1
Kearl Lake	A	lake	KEL-1
McClelland Lake	A	lake	MCL-1
Namur Lake	A	lake	NAL-1
Shipyard Lake	A	lake	SHL-1
Locations No Longer in Sample Design			
Athabasca River			
Near Fort Creek (east bank)	A	depositional	ATR-B-A1 to A3
(west bank)	A	depositional	ATR-B-A4 to A6
Near Donald Creek (east bank)	A	depositional	ATR-B-B1 to B3
(west bank)	A	depositional	ATR-B-B4 to B6
Suncor near-field monitoring	B	depositional	-
MacKay River			
200 m upstream of mouth	A	erosional	MAR-1
500 m upstream of mouth	A	erosional	MAR-2
1.2 km upstream of mouth	A	erosional	MAR-3
Muskeg River			
50 m upstream of mouth	A	erosional	MUR-1
200 m upstream of mouth	A	erosional	MUR-2
450 m upstream of mouth	A	erosional	MUR-3
Steepbank River			
50 m upstream of mouth	A	erosional	STR-1
150 m upstream of mouth	A	erosional	STR-2
300 m upstream of mouth	A	erosional	STR-3

Note: Monitoring for the Benthic Inverebrate Communities Component was conducted under RAMP until 2013 and is now part of the JOSMP.

Legend:

A = RAMP station

B = Sampled outside of RAMP (data available to RAMP)

[1] sampled outside of RAMP in 2001, became RAMP station in 2002

* sampled in erosional habitat in 2013.

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Baseline, but excluded from Regional Baseline calculations because of minor development near the headwaters of the river.

3.1.3.2 Overview of Monitoring Activities for the Sediment Quality component in the 2015 WY

Sediment samples were collected from August 31 to September 4, 2015 and September 8 to 18, 2015 at the most downstream replicate sampling location in each depositional reach sampled for benthic invertebrate communities (sediment quality stations at a total of 31 depositional reaches sampled for benthic invertebrate communities) and nine lakes (Table 3.1-18, Figure 3.1-4). In addition, during the September sampling campaign, sediment quality was collected at 15 fish health monitoring stations that did not already correspond to a sediment quality sampling station; a description of these stations is provided in Table 3.1-19.

Summary of Field Methods and Sample Shipping and Analysis

Sediment sampling locations were identified using historical GPS coordinates and, when available, station descriptions recorded for benthic invertebrate community sampling locations. Stations were accessed by helicopter, boat, or all-terrain vehicle.

Sediment grabs were collected at each station with an Ekman grab (0.023 m^2, 6” x 6”). Five sealable plastic containers were initially filled from the Ekman grab for chronic toxicity testing and sediment remaining in each grab was deposited in a stainless-steel pan and composited with a stainless steel spoon that was also used to fill sterilized glass jars for chemical analyses. All samples were stored on ice or refrigerated prior to and during shipment to analytical laboratories. Additional sediment samples were collected from each benthic replicate location and placed in sealable plastic bags for particle size and TOC analyses. To minimize potential for sample contamination, pans, spoons, and the dredge were cleaned with Liquinox metal-free soap, rinsed with hexane and acetone, and triple-rinsed with ambient water at each station prior to sampling.

All chemical and physical (e.g., particle size, TOC) analyses were conducted by ALS (Edmonton, Alberta), with the exception of PAHs, which were analyzed by AXYS Analytical Services Ltd. (Sidney, British Columbia). Evaluation of sediment toxicity was undertaken by Maaxam (Edmonton, Alberta). Metals were analyzed using ICP/MS. PAHs were analyzed using a high-resolution GC/MS method.

Sediments were analyzed for the list of sediment quality and toxicity variables shown in Table 3.1-20, consistent with historical RAMP and JOSMP sediment quality programs. Sediment toxicity tests followed published Environment Canada protocols (Environment Canada 2010).

A full list of analytical methods and detection limits for sediment quality variables measured in the 2015 WY is provided in Table 3.1-20.

Changes in Monitoring Network from 2014

Given the sampling rotation for some stations, the following sediment quality stations that were not sampled in 2014 were sampled in the 2015 WY:

- *test* station FIR-D1 (lower reach on the Firebag River) – last sampled in 2013;
- *test* station CAR-D1 (lower reach on the Calumet River) – last sampled in 2012; and
- *baseline* station CAR-D2 (upper reach on the Calumet River) – last sampled in 2012.

Table 3.1-18 Summary of data available for the Sediment Quality component of the JOSMP for the 2015 WY, and used in this report.

Station and Location		AEMERA Nomenclature	UTM Coordinates (NAD83, Zone 12)		2015 WY			
			Easting	Northing	W	S	S	F
Athabasca River								
M0-DS	Athabasca River below town of Athabasca	AB07CB0520	383071	6092039				2
M3	Athabasca River below Fort McMurray STP discharge	AB07DA0100	473333	6302300				2
M4-US	Athabasca River above Muskeg River	AB07DA0320	466365	6327730				2
M4-DS	Athabasca River below Muskeg River	AB07DA0640	463147	6332711				2
Athabasca Delta								
GIC-1	Goose Island Channel	AB07DD0220	509483	6494586				2
BPC-1	Big Point Channel	AB07DD0230	512088	6494156				2
FLC-1	Fletcher Channel	AB07DD0131	496561	6491825				2
EMR-2	Embarras River	AB07DD0130	494745	6492140				2
Tributaries to the Athabasca River (Eastern)								
FOC-D1	Fort Creek	AB07DA2760	461549	6363105				2
FIR-D1	Firebag River (lower reach)	AB07DC0110	479363	6400434				2
Tributaries to the Athabasca River (Western)								
BER-D2	Beaver River (upper reach)	AB07DA1420	465489	6311275				2
CAR-D1	Calumet River (lower reach)	AB07DA1360	459586	6362803				2
CAR-D2	Calumet River (upper reach)	AB07DA1345	454122	6367044				2
ELR-D1	Ells River (lower reach)	AB07DA0750	459254	6351516				2
TAR-D1	Tar River (lower reach)	AB07DA1350	458854	6353551				2
POC-D1	Poplar Creek (lower reach)	AB07DA0110	472958	6308822				2
PIR-D1	Pierre River	AB07DA1340	462291	6367440				2
EYC-D1	Eymundson Creek	AB07DA1320	465933	6372234				2
BIC-D1	Unnamed Creek (Big Creek)	AB07DA1270	471687	6387679				2
Tributaries to the Athabasca River (Southern)								
CLR-D1	Clearwater River (upstream of Fort McMurray)	AB07CD0210	480735	6283997				2
CLR-D2	Clearwater River (upstream of Christina River)	AB07CD0060	496094	6280541				2
CHR-D1	Christina River (upstream of Fort McMurray)	AB07CD0210	495968	6280327				2
CHR-D2	Christina River (upstream of Janvier)	AB07CD0060	512360	6193385				2
CHR-D3	Christina River (upstream of Jackfish River)	AB07CE0005	486208	6174839				2
CHR-D4	Christina River (above Statoil Leismer)	AB07CE0001	466037	6193791				2
SUC-D1	Sunday Creek (lower reach)	AB07CE0021	506716	6159804				2
SUC-D2	Sunday Creek (upper reach)	AB07CE0032	494007	6156324				2
SAC-D1	Sawbones Creek (lower reach)	AB07CE0060	511453	6167195				2
BRC-D1	Birch Creek	AB07CE0010	492190	6163172				2
UNC-D2	Unnamed Creek (east of Christina Lake)	AB07CE0023	517189	6163884				2
UNC-D3	Unnamed Creek (south of Christina Lake)	AB07CE0022	511157	6159818				2
Muskeg River Watershed								
MUR-D2	Muskeg River (middle reach)	AB07DA0610	466300	6339494				2
MUR-D3	Muskeg River (upper reach)	AB07DA0475	480075	6357945				2
JAC-D1	Jackpine Creek (lower reach)	AB07DA0600	471866	6346436				2
JAC-D2	Jackpine Creek (upper reach)	AB07DA1225	480033	6324995				2

Legend

2 - Standard sediment quality variables (carbon, particle size, total hydrocarbons, metals, PAHs, and alkylated PAHs), and toxicity testing (*Chironomus tentans, Hyalella azteca*)

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Table 3.1-19 Summary of fall sediment quality sampling in the 2015 WY for the wild fish health monitoring program of the JOSMP.

Station and Location		AEMERA Nomenclature	UTM Coordinates (NAD83, Zone 12)		2015 WY			
			Easting	Northing	W	S	S	F
Regional Lakes								
CHL-1	Christina Lake	AB07CE0250	497226	6165178				2
GAL-1	Gardiner Lake	AB07DA2030	409600	6378132				2
GRL-1	Gregoire Lake	AB07CE0120	494459	6254984				2
ISL-1	Isadore's Lake	AB07DA0420	463356	6343198				2
JOL-1	Johnson Lake	AB07DD0410	536465	6390715				2
KEL-1	Kearl Lake	AB07DA2210	484850	6350577				2
MCL-1	McClelland Lake	AB07DA2290	483309	6372106				2
NAL-1	Namur Lake	AB07DA1890	400964	6367082				2
SHL-1	Shipyard Lake	AB07DA3400	473558	6313093				2
Tributaries to the Athabasca River (Western)								
AC-DS	Alice Creek downstream	AB07KE0301	371865	6454527				2
AC-US	Alice Creek upstream	AB07KE0311	370886	6463164				2
ER-L	Lower Ells River	AB07DA1400	455905	6347163				2
ER-M	Mid Ells River	AB07DA3002	446275	6343440				2
ER-U	Upper Ells River	AB07DA2999	440421	6342470				2
DC-L	Dover River near the mouth	AB07DB0100	451366	6337142				2
DC-M	Mid Dover River	AB07DB0002	447631	6335403				2
DC-U	Upper Dover River	AB07DB0005	438803	6331366				2
MR-L	Lower MacKay River	AB07DB0081	456656	6341223				2
MR-M	Mid MacKay River	AB07DB0340	448485	6318596				2
MR-U	Upper MacKay River	AB07DB0360	430477	6309367				2

Legend

2 - Standard sediment quality variables (carbon, particle size, total hydrocarbons, metals, PAHs, and alkylated PAHs), and toxicity testing (*Chironomus tentans, Hyalella azteca*)

Test (downstream of oil sands developments)

Baseline (upstream of oil sands developments)

Challenges Encountered and Solutions Applied

All planned sampling was undertaken without major issue or incident.

Other Information Obtained

No additional sediment quality information for the 2015 WY was obtained.

Summary of Component Data Now Available

Table 3.1-18 and Table 3.1-19 summarize the sediment quality data collected in the 2015 WY and Table 3.1-21 summarizes the sediment quality data collected from 1997 to 2014.

Table 3.1-20 Standard sediment quality variables measured for the JOSMP in the 2015 WY.

Group	Sediment Quality Variable	Units	Detection Limit	Analytical Method (VMV code)	Lab
Hydrocarbons and Organic Compounds	2-Bromobenzotrifluoride	%	1	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Benzene	mg/kg	0.005*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 1 (BTEX)	mg/kg	10*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 1 (C6-C10)	mg/kg	10*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 2 (C10-C16)	mg/kg	20*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 3 (C16-C34)	mg/kg	20*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	CCME Fraction 4 (C34-C50)	mg/kg	20*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Ethylbenzene	mg/kg	0.015	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	m+p-Xylene	mg/kg	0.05	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	o-Xylene	mg/kg	0.05	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Toluene	mg/kg	0.05	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Total Hydrocarbons (C6-C50)	mg/kg	20*	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
	Xylenes	mg/kg	0.1	CCME CWS-PHC Dec-2000 - Pub# 1310	ALS
Physical Properties	% Clay	%	0.1	Burt (2009) P46-53	ALS
	% Moisture	%	0.1	Oven dry 105C-Gravimetric (VMV 10042)	ALS
	% Sand	%	0.1	Burt (2009) P46-53	ALS
	% Silt	%	0.1	Burt (2009) P46-53	ALS
	$CaCO_3$ Equivalent	%	0.8	Loeppert and Suarez (1996) P455-456	ALS
	Inorganic Carbon	%	0.1	Loeppert and Suarez (1996) P455-456 (VMV 50303)	ALS
	Texture	-	-	Burt (2009) P46-53	ALS
	Total Carbon by Combustion	%	0.1	Loeppert and Suarez (1996) P. 973-974 (VMV 6075)	ALS
	Total organic carbon	%	0.1	Loeppert and Suarez (1996) P455-456 (VMV 6078)	ALS
Total Metals	Aluminum (Al)	mg/kg	50	EPA 200.2/6020A	ALS
	Antimony (Sb)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Arsenic (As)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Barium (Ba)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Beryllium (Be)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Bismuth (Bi)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Cadmium (Cd)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Calcium (Ca)	mg/kg	100	EPA 200.2/6020A	ALS
	Chromium (Cr)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Cobalt (Co)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Copper (Cu)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Iron (Fe)	mg/kg	50	EPA 200.2/6020A	ALS
	Lead (Pb)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Lithium (Li)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Magnesium (Mg)	mg/kg	20	EPA 200.2/6020A	ALS

[1] PAH toxicity in sediments was estimated using an equilibrium-partitioning method described by Neff et al. (2005).

* Detection limit varied with moisture content in sediment.

Table 3.1-20 (Cont'd.)

Group	Sediment Quality Variable	Units	Detection Limit	Analytical Method (VMV code)	Lab
Total Metals (Cont'd.)	Manganese (Mn)	mg/kg	1	EPA 200.2/6020A	ALS
	Mercury (Hg)	mg/kg	0.05	EPA 200.2/245.1	ALS
	Molybdenum (Mo)	mg/kg	0.1	EPA 200.2/6020A	ALS
	Nickel (Ni)	mg/kg	0.5	EPA 200.2/6020A	ALS
	Phosphorus (P)	mg/kg	50	EPA 200.2/6020A	ALS
	Potassium (K)	mg/kg	50	EPA 200.2/6020A	ALS
	Selenium (Se)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Silver (Ag)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Sodium (Na)	mg/kg	100	EPA 200.2/6020A	ALS
	Strontium (Sr)	mg/kg	1	EPA 200.2/6020A	ALS
	Thallium (Tl)	mg/kg	0.05	EPA 200.2/6020A	ALS
	Tin (Sn)	mg/kg	2	EPA 200.2/6020A	ALS
	Titanium (Ti)	mg/kg	1	EPA 200.2/6020A	ALS
	Uranium (U)	mg/kg	0.05	EPA 200.2/6020A	ALS
	Vanadium (V)	mg/kg	0.2	EPA 200.2/6020A	ALS
	Zinc (Zn)	mg/kg	5	EPA 200.2/6020A	ALS
PAHs	Biphenyl	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Biphenyls	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Biphenyls	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Naphthalene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Naphthalenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Naphthalenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Naphthalenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C4-Naphthalenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Acenaphthylene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Acenaphthene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Acenaphthenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Fluorene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Fluorenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Fluorenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Fluorenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Phenanthrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Anthracene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Phenanthrenes/Anthracenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Phenanthrenes/Anthracenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Phenanthrenes/Anthracenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C4-Phenanthrenes/Anthracenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Retene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS

[1] PAH toxicity in sediments was estimated using an equilibrium-partitioning method described by Neff et al. (2005).

* Detection limit varied with moisture content in sediment.

Table 3.1-20 (Cont'd.)

Group	Sediment Quality Variable	Units	Detection Limit	Analytical Method (VMV code)	Lab
PAHs (Cont'd.)	Dibenzothiophene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Dibenzothiophenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Dibenzothiophenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Dibenzothiophenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C4-Dibenzothiophenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Fluoranthene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Pyrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Fluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Fluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Fluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C4-Fluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benz[a]anthracene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Chrysene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Benzo[a]anthracenes/Chrysenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Benzo[a]anthracenes/Chrysenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C3-Benzo[a]anthracenes/Chrysenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C4-Benzo[a]anthracenes/Chrysenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benzo[b,j,k]fluoranthene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benzo[a]pyrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benzo[e]pyrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C1-Benzofluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	C2-Benzofluoranthenes/Pyrenes	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Indeno[1,2,3-c,d]-pyrene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Dibenz[a,h]anthracene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Perylene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
	Benzo[g,h,i]perylene	mg/kg	Varies[1]	MLA021, based on USEPA methods 1625 and 82701	AXYS
Toxicity	*Chironomus dilutus* - 10d growth	mg/organism	-	Biological test method: test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus Dilutus* or *Chironomus riparius)*, 1997. Environment Canada EPS 1/RM/32.	Maxxam
	Chironomus dilutus - 10d survival	# surviving	-	Biological test method: test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus Dilutus* or *Chironomus riparius)*, 1997. Environment Canada EPS 1/RM/32.	Maxxam
	Hyalella azteca - 14d growth	mg/organism	-	Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*, 1997. Environment Canada EPS 1/RM/33.	Maxxam
	Hyalella azteca - 14d survival	# surviving	-	Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*, 1997. Environment Canada EPS 1/RM/33.	Maxxam

[1] PAH toxicity in sediments was estimated using an equilibrium-partitioning method described by Neff et al. (2005).
* Detection limit varies with moisture content in sediment.

Table 3.1-21 Summary of data available for the Sediment Quality Component of the JOSMP from 1997 to 2014, and used in this report.

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																																																																									
Upstream of Fort McMurray (cross channel)	ATR-UFM																								1				2				1																																								
Upstream of Donald Creek (west bank)[a]	ATR-DC-W				2				2								1				2				1				2				1																																								
(east bank)[a]	ATR-DC-E				2				2								1				2				1				2				1																																								
Upstream of Steepbank River (west bank)	ATR-SR-W																1				2				1				2				1																																								
(east bank)	ATR-SR-E																1				2				1				2				1																																								
Upstream of the Muskeg River (west bank)[a b]	ATR-MR-W								2								1				2				1				2				1																																								
(east bank)[a b]	ATR-MR-E								2								1				2				1				2				1																																								
Upstream of Fort Creek (west bank)[a b]	ATR-FC-W				2				2								1				2				1				2																																														
(east bank)[a b]	ATR-FC-E				2				2								1				2				1				2																																														
Testing inter-site variability (3 composite samples)	-																1								1																																																			
Downstream of all development (west bank)	ATR-DD-W																								1				2				1																																								
(east bank)	ATR-DD-E																								1				2				1																																								
Upstream of mouth of Firebag River (west bank)	ATR-FR-W																								1				2				1																																								
(east bank)	ATR-FR-E																								1				2				1																																								
Upstream of the Embarras River	ATR-ER																3				1				1				2				1				1								1				2				2				2				2				2				2				
Athabasca Delta / Lake Athabasca																																																																									
Delta composite[c]	ARD-1												2																																																												
Big Point Channel	BPC-1												2				2				2				2				2								1								1				2				2				2				2				2				2				2
Goose Island Channel	GIC-1																				2				2				2								1								1				2				2				2				2				2				2				2
Fletcher Channel	FLC-1																				2				2				2								1								1				2				2				2				2				2				2				2
Flour Bay	FLB-1																2																																																								
Extensive Survey (6 sites)	[d]																																				1																																				
Embarras River																																																																									
Embarras River	EMR-1																																				1																								2												
Embarras River	EMR-2																																				1																				2								2				2				2
Athabasca River Tributaries (South of Fort McMurray)																																																																									
Clearwater River (upstream of Fort McMurray)	CLR-1/CLR-D1																				1				2				2																				2												2												2
(upstream of Christina River)	CLR-2/CLR-D2																				1				2				2																				2												2												2
Christina River (upstream of Fort McMurray)	CHR-1																								1				2				2																																								
(upstream of Janvier)	CHR-2																								1				2				2																																								
(benthic reach at mouth)	CHR-D1																																								2				1								2												2								2
(benthic reach at upper Christina River)	CHR-D2																																								2												2												2								2
(upstream of Jackfish River)	CHR-D3																																																																								2
(upstream of development)	CHR-D4																																																																			2				2
Hangingstone River (upstream of Ft. McMurray)	HAR-1																																2				2																																				
Sunday Creek	SUC-D1																																																																2				2				2
Sunday Creek (upstream)	SUC-D2																																																																				2				2
Unnamed Creek 2 (east of Christina Lake)	UNC-D2																																																																				2				2
Unnamed Creek 3 (south of Christina Lake)	UNC-D3																																																																				2				2
Birch Creek	BRC-D1																																																																				2				2
Sawbones Creek	SAC-D1																																																																2				2				2
Athabasca River Tributaries (North of Fort McMurray)																																																																									
McLean Creek (mouth)	MCC-1												2				2				1				2												2																																				
Beaver River	BER-D2																																																2				2				2				2				2				2				2
Poplar Creek (mouth)	POC-1/POC-D1				1																				2								2																2				2				2				2				2				2				2
Steepbank River (mouth)	STR-1				1				1																2												2																																				
(upstream of Suncor Project Millennium)	STR-2																								2												2																																				
(upstream of North Steepbank)	STR-3																																				2																																				
North Steepbank River (upstream of Suncor Lewis)	NSR-1																								2				2				1				1																																				
MacKay River (mouth)	MAR-1				1				1												2				2								2																																								
(upstream of Suncor MacKay)	MAR-2																				1												2																																								

Note: Monitoring for the Sediment Quality Component was conducted under the RAMP until 2013 and is now part of the JOSMP.
Note: the Sediment Quality Component was integrated with the Benthic Invertebrate Community Component in 2006.

Legend

1 = standard sediment quality variables (carbon content, particle size, recoverable hydrocarbons, TEH and TVH, total metals, PAHs and alkylated PAHs)
2 = standard sediment quality variables and toxicity testing
√ = allowance made for potential TIE

Footnotes

[a] Sample stations were previously labeled ATR-1, 2 and 3 (moving upstream from the ARD Delta)
[b] Samples were collected downstream of tributary in 1998
[c] One composite sample was collected from Big Point Goose Island, Embarras and an unnamed side channel in 1999
[d] Stations are BEC, BPC-1, CRC-1, EMR-2, JFC-1
[e] Station was called MUR-D2 (upstream of Stanley Creek) from 2003-2005
[f] Station was called MUR-2 from 2000-2005

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)

Table 3.1-21 (Cont'd.)

See symbol key below.

Waterbody and Location	Station	1997				1998				1999				2000				2001				2002				2003				2004				2005				2006				2007				2008				2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River Tributaries (North of Fort McMurray) (cont'd)																																																																									
Ells River (mouth)	ELR-1								1																2				2				2				1																																		
(benthic reach at mouth)	ELR-D1																																								2				2												2				2				2				2				2
(upstream of Total Joslyn Mine)	ELR-2																																2				1																																		
Tar River (mouth)	TAR-1								1																2				2				1				1																																		
(benthic reach at mouth)	TAR-D1																																								2												2				2				2				2				2				2
(upstream of Canadian Natural Horizon)	TAR-2																																1				1																																		
Calumet River (mouth)	CAR-1																								2								2				2																																		
(benthic reach at mouth)	CAR-D1																																																				2												2								
(upstream of Canadian Natural)	CAR-2																																				2																																		
(benthic reach at upper Calumet)	CAR-D2																																								2												2												2								
Fort Creek (mouth)	FOC-1																1								2																																																
(benthic reach at mouth)	FOC-D1																																								2				2				2								2				2				2				2				2
Big Creek	BIC-D1																																																																					2				2
Pierre River	PIR-D1																																																																					2				2
Eymundson Creek (mouth)	EYC-1																																																																					2				2
Firebag River (mouth)	FIR-1																								2				2				1																																								
(benthic reach at mouth)	FIR-D1																																								2				1												2												2				
(upstream of Suncor Firebag)	FIR-2																												2				1																																								
Muskeg River																																																																										
Mouth	MUR-1				1				1				2				1				1				2				2				2				2																																		
1 km upstream of mouth	MUR-1b																1												1																																												
Upstream of Jackpine Creek	MUR-4				1												1												1																																												
Upstream of Muskeg Creek	MUR-5																1												1																																												
Upstream of Wapasu Creek	MUR-6																1												1																																												
(benthic reach - downstream of Jackpine Creek) [e]	MUR-D2																1												2				2				2				2				2				2				1				1				1				1				2				2
(benthic reach - upstream of Stanley Creek) [f]	MUR-D3																												2				2				2				2				2				2				1				1				1				1				2				2
Muskeg River Tributaries																																																																										
Jackpine Creek (mouth)	JAC-1				1																												2																																								
(benthic reach at mouth)	JAC-D1																																								2				1				2				2				2				2				2				2				2
(benthic reach at upper Jackpine Creek)	JAC-D2																																								2				1				2				2				2				2				2				2				2
Stanley Creek (mouth)	STC-1																												1																																												
Wetlands																																																																										
Kearl Lake (composite)	KEL-1																				1												1								2				2				2				1				1				1				2				2				2
Isadore's Lake (composite)	ISL-1																				1																				2				2				2				1				1				1				2				2				2
Shipyard Lake (composite)	SHL-1																				1				2				1				2								2				2				2				1				1				1				2				2				2
McClelland Lake (composite)	MCL-1																								1				1												2				2				2				1				1				1				2				2				2
Johnson Lake (composite)	JOL-1																																																												1				2				2				2
Christina Lake (composite)	CHL-1																																																																	2				2				2
Gregoire Lake (composite)	GRL-1																																																																									2
Gardiner Lake (composite)	GAL-1																																																																									2
Namur Lake (composite)	NAL-1																																																																									2
Additional Sampling (Non-Core Programs)																																																																										
Potential TIE	-																				√																																																				
QA/QC																																																																										
One split and one duplicate sample	-																1				1				1				1				1				1				1				1				1				1				1				1				1				1				1

Note: Monitoring for the Sediment Quality Component was conducted under the RAMP until 2013 and is now part of the JOSMP.
Note: the Sediment Quality Component was integrated with the Benthic Invertebrate Community Component in 2006.

Legend

1 = standard sediment quality variables (carbon content, particle size, recoverable hydrocarbons, TEH and TVH, total metals, PAHs and alkylated PAHs)
2 = standard sediment quality variables and toxicity testing
√ = allowance made for potential TIE

Footnotes

[a] Sample stations were previously labeled ATR-1, 2 and 3 (moving upstream from the ARD Delta)
[b] Samples were collected downstream of tributary in 1998
[c] One composite sample was collected from Big Point Goose Island, Embarras and an unnamed side channel in 1999
[d] Stations are BEC, BPC-1, CRC-1, EMR-2, JFC-1
[e] Station was called MUR-D2 (upstream of Stanley Creek) from 2003-2005
[f] Station was called MUR-2 from 2000-2005

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)

3.1.4 Fish Populations Component

3.1.4.1 Overview of Monitoring Activities in the 2015 WY

The following monitoring activities were conducted in the 2015 WY for the Fish Populations component:

- Fish community monitoring using fish inventory methods at 16 locations on tributaries of the Athabasca and Clearwater rivers in the study area; and
- Wild fish health surveys at nine locations on the mainstem Athabasca River and at 16 locations on tributaries of the Athabasca River.

Sampling locations are presented in Figure 3.1-5 and common and scientific names for each fish species noted in this report are listed in Appendix E.

3.1.4.2 Summary of Field Methods

Fish Community Monitoring

Fish community monitoring was conducted from September 17 to 25, 2015 on 16 tributary reaches (Figure 3.1-5, Table 3.1-22). The field methods for fish community monitoring were adopted from the United States Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP) for stream monitoring programs throughout the United States (Peck et al. 2006). The procedures described were modified to include appropriate indicators related to the study area and incorporated protocols to collect measurements describing physical habitat, fish community, water and sediment chemistry, and benthic invertebrate communities.

Fish Sampling

The area of each of the 16 tributary reaches sampled was approximately 20 times the wetted width, which was divided into five sub-reaches to assess variability within a reach (based on precision analysis conducted in RAMP [2011]). Tributary reaches were sampled by a two-person field crew using a Smith-Root 12B-POW battery-powered electrofishing unit and one dip net deployed downstream of the anode prior to and during the application of electrical current. Sampling was focused on the shoreline area of the river. The width of the electrofisher pass was approximately 2 m to 3 m from the river bank to a point mid-river, based on what the electrofisher operator could reach. Stunned fish were caught downstream of the current using a dip net with a fine mesh to ensure collection of all sizes classes and species of fish.

Fish collected from each sub-reach were kept in an aerated holding bucket of river water until the completion of all fishing. For each sub-reach, captured fish were measured for length (± 1 mm) and weight (± 0.01 g) and an external assessment was conducted to evaluate the general health of each fish.

Fish Habitat Assessments

Habitat assessments were completed at a transect at each of the downstream and upstream ends of each reach. Habitat assessment methods involved recording a range of variables relating to channel morphology, substrate, water quality, and stream cover similar to that outlined in RAMP (2009b) and Peck et al. (2006).

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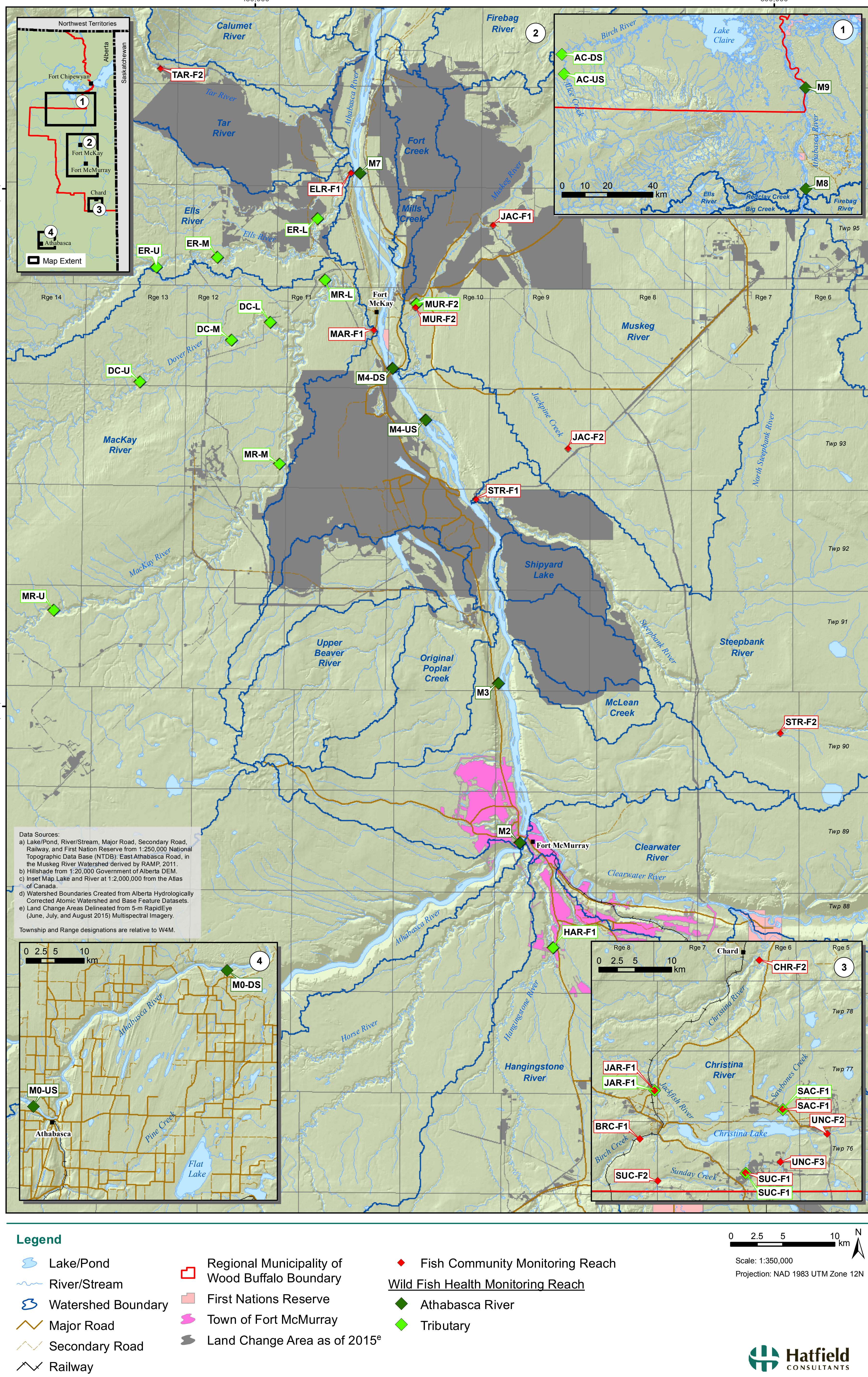
Figure 3.1-5 Location of fish monitoring activities conducted for the JOSMP in the 2015 WY.



K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_H_Fish_20160330_ss.mxd

Table 3.1-22 Locations of reaches surveyed for the fish community monitoring program of the 2015 JOSMP.

Reach	Watercourse	Habitat Type	Reach Designation	UTM Coordinates (NAD83, Zone 12)				Water and Sediment Samples Collected?
				Downstream Boundary		Upstream Boundary		
				Easting	Northing	Easting	Northing	
BRC-F1	Birch Creek	depositional	*baseline*	492005	6163125	491879	6163008	Water and Sediment
CHR-F2	Christina River	depositional	*test*	511819	6192380	511134	6192481	Water and Sediment
ELR-F1	Ells River	depositional	*test*	459063	6351670	459063	6352009	Water and Sediment
JAR-F1	Jackfish River	erosional	*test*	493796	6169761	493825	6169513	Water and Sediment
JAC-F1	Jackpine Creek	depositional	*test*	472805	6346510	472964	6346496	Water and Sediment
JAC-F2	Jackpine Creek	depositional	*baseline*	480284	6324869	480431	6324796	Water and Sediment
MAR-F1	MacKay River	erosional	*test*	461153	6336395	460437	6336773	Water
MUR-F2	Muskeg River	depositional	*test*	466519	6339971	466663	6340158	Water and Sediment
SAC-F1	Sawbones Creek	depositional	*test*	511495	6167203	511548	6167430	Water and Sediment
STR-F1	Steepbank River	erosional	*test*	471194	6320052	471614	6320363	Water
STR-F2	Steepbank River	erosional	*baseline*	500448	6297485	500598	6297453	No
SUC-F1	Sunday Creek	erosional	*test*	506314	6158409	506376	6158269	Water and Sediment
SUC-F2	Sunday Creek	depositional	*baseline*	494288	6157256	494104	6157189	Water and Sediment
TAR-F2	Tar River	erosional	*baseline*	440735	6361657	440525	6361638	Water and Sediment
UNC-F2	unnamed creek east of Christina Lake	depositional	*test*	517580	6163722	517762	6163681	Water and Sediment
UNC-F3	unnamed creek south of Christina Lake	depositional	*test*	511132	6159871	511062	6159654	Water and Sediment

The following information was collected at each transect:

- habitat type (Table 3.1-23);
- wetted width (m);
- maximum depth (m);
- velocity and depth (m/sec) (at 25%, 50%, and 75% of the wetted width);
- overhead and instream cover (%) (Table 3.1-24);
- substrate (dominant and subdominant particle size) (Table 3.1-25);
- bank slope (degrees);
- bank height (m); and
- large and small woody debris (count of debris in length/size classes).

In situ water quality variables including temperature (ºC), dissolved oxygen (mg/L), pH, and conductivity (µS/cm) were measured at the downstream end of each reach using a Hanna hand-held probe (temperature, conductivity, pH) and a LaMotte Winkler titration kit (dissolved oxygen).

Table 3.1-23 Habitat types used for the fish community monitoring program of the 2015 JOSMP (adapted from Peck et al. 2006).

Habitat Type (code)	Description
Plunge pool (PP)	Pool at base of plunging cascade or falls
Trench pool (PT)	Pool-like trench in the centre of the stream
Lateral Scour Pool (PL)	Pool scoured along a bank
Backwater Pool (PB)	Pool separated from main flow off the side of the channel (large enough to offer refuge to small fishes). Includes sloughs (backwater with vegetation), and alcoves (a deeper area off a wide and shallow main channel).
Impoundment Pool (PD)	Pool formed by impoundment above dam or constriction
Pool (P)	Pool (unspecified type)
Run (Ru)	Water moving slowly, with a smooth, unbroken surface. Low turbulence.
Riffle (RI)	Water moving, with small ripples, waves and eddies-waves not broken, surface tension not broken.
Dry Channel (DR)	No water in the channel or flow is submerged under the substrate.

Table 3.1-24 Percent cover rating for instream and overhead cover at each transect used for the fish community monitoring program of the 2015 JOSMP (adapted from Peck et al. 2006).

Code	Percent Cover
0	absent, zero cover
1	sparse, <10%
2	moderate, 10-40%
3	heavy, 40-75%
4	very heavy, >75%

Table 3.1-25 Substrate size class codes used for the fish community monitoring program of the 2015 JOSMP (adapted from Peck et al. 2006).

Code	Description
RS	bedrock (smooth) – larger than a car
RR	bedrock (rough) – larger than a car
RC	asphalt/concrete
XB	large boulder (1000-4000 mm) – metre stick to a car
SB	small boulder (250-1000 mm) – basketball to a metre stick
CB	cobble (64-250 mm) – tennis ball to basketball
GC	coarse gravel (16-64 mm) – marble to tennis ball
GF	fine gravel (2-16 mm) – ladybug to marble
SA	sand (0.06 to 2 mm) – gritty, up to ladybug size
FN	silt/clay – not gritty
HP	hardpan – firm consolidated fine substrate

Wild Fish Health Monitoring

Wild fish health monitoring was undertaken in fall 2015 at nine sites on the Athabasca River and 16 reaches on tributaries of the Athabasca River (Table 3.1-26, Table 3.1-27, and Figure 3.1-5). Trout-perch (*Percopsis omiscomaycus*) was the target fish species at reaches on the Athabasca River, while longnose dace (*Rhinichthys cataractae*), lake chub (*Couesius plumbeus),* or slimy sculpin (*Cottus cognatus*) were targeted on the tributary reaches (Table 3.1-25). The target catch was 20 adult males, 20 adult females, and 100 juvenile (i.e., sexually immature) fish at each reach. Given all target fish were small bodied species, the additional juvenile fish were collected to aid in the analysis of growth (size-at-age) and reproductive performance (Environment Canada 2010).

Fish Sampling

Fish sampling on the Athabasca River was conducted from September 8 to 16, 2015. Sampling was carried out by a three-person field crew using a Coffelt VVP-15 boat electrofisher, with backpack electrofishers and seine nets used as backup sampling methods. Sampling efforts focused on river margins deep enough to be accessible by boat but shallow enough to provide suitable habitat for trout-perch. The boat electrofisher was configured with two anode boom arrays and multiple dropper cables. The boat's hull acted as the cathode. Electrofishing was performed in a downstream direction, and current was applied in 4 s to 5 s bursts at a high frequency (i.e., to catch small-bodied fish) within the designated size. Stunned fish were caught downstream of the current using dip nets with a fine mesh net (6.35 mm mesh size) to ensure collection of all size classes.

Fish sampling on the tributaries of the Athabasca River was conducted between September 25 and October 9, 2015. Sampling efforts were carried out by a two- or four-person field crew using a Smith-Root 12B-POW battery-powered electrofishing unit and three dip nets (or pole seine), which were deployed downstream of the anode prior to and during the application of electrical current. Seine nets and minnow traps were used as supporting methods. Where water levels permitted backpack electrofishing, sampling was conducted from one wetted bank to the other until approximately 40 adult fish greater than 50 mm in length were caught. Stunned fish were caught downstream of the current using dip nets or pole seines with a fine mesh net to ensure collection of all size classes.

All fish were identified to species and brought back in aerated holding containers filled with river water from the specific reach to a contained laboratory facility for dissecting. Each fish was measured for fork length (± 1.0 mm) and weighed (± 0.01 g) using an electronic balance that was calibrated prior to each measurement. The adults were sacrificed and internal organs were removed, and the gonads (± 0.001 g) and liver (± 0.001 g) were weighed. Otoliths were removed and fin clips were taken from each adult fish for ageing. Internal and external pathology examinations were also performed on each fish. The liver tissue was collected, flash frozen in liquid nitrogen and sent to a designated laboratory to conduct Ethoxyresorufin-O-deethylase (EROD) analyses to assess the induction of mixed function oxygenases (MFO) enzymes (Hodson et al. 1991; Gourley and Kennedy 2009). The remaining carcasses were frozen and submitted to Environment Canada for further analysis if required.

Fish Habitat Assessments

Habitat assessments were completed at each reach including measurements of variables relating to channel morphology, substrate, water quality, and stream cover. Water quality variables including temperature (°C), dissolved oxygen (mg/L), and specific conductivity (µS/cm) were measured with a Hanna hand-held probe (temperature, conductivity, pH) and a LaMotte Winkler titration kit (dissolved oxygen). Temperature data loggers (HOBO Water Temp Pro v2) were deployed in late July 2015 at each sampling reach and retrieved during the September 2015 field activities. The loggers recorded hourly temperature to provide information on daily and seasonal temperature fluctuations that may have influenced the growth of the target species.

Water Quality and Sediment Quality Sampling

Water and sediment quality were collected from four and eleven reaches on the mainstem and tributaries, respectively, of the Athabasca River (Table 3.1-26, Table 3.1-27). Samples were collected, preserved, and shipped according to procedures described in Section 3.1.2.3 and Section 3.1.3.2.

Table 3.1-26 Location and general description of each reach sampled for the wild fish health survey on the Athabasca River, using trout-perch (*Percopsis omiscomaycus*), for the 2015 JOSMP.

Reach	Description	UTM Coordinates (NAD83, Zone 12)				Water and Sediment Samples Collected?	Target Numbers Obtained?	
		Upstream Boundary		Downstream Boundary				
		Easting	Northing	Easting	Northing		Adults	Juv.
M0-US	*Baseline* reach upstream of the town of Athabasca not exposed to Pulp and Paper mill discharge or oil sands development.	349607	6068505	352857	6066315	Water	Yes	No
M0-DS	*Baseline* reach downstream of the town of Athabasca and exposed to pulp and paper mill discharge (Poachers Landing)	383071	6092039	383567	6092517	Water and Sediment	Yes	No
M2	*Baseline* reach upstream of Fort McMurray to provide a baseline population not exposed to Sewage Treatment Plant (STP) discharge or oil sands development.	474767	6286349	475394	6286987	No	Yes	No
M3	*Baseline* reach relative to downstream oil sands development, but *test* reach in relation to the upstream STP discharge.	473683	6304170	473333	6302300	Water and Sediment	Yes	No
M4-US	*Test* reach upstream of the Muskeg River confluence to provide exposure to both Suncor/Syncrude operations.	466365	6327730	465087	6329511	Water and Sediment	Yes	No
M4-DS	*Test* reach downstream of the Muskeg River confluence to provide exposure to additional oil sands operations.	463147	6332711	462608	6334422	Water and Sediment	Yes	No
M7	*Test* reach upstream of the Ells River confluence to provide exposure to Shell operations.	460032	6351516	459810	6352032	No	Yes	No
M8	*Test* reach downstream of all tributary watersheds with oil sands developments (downstream of Firebag River confluence).	478578	6402647	478668	6404024	No	Yes	No
M9	*Test* reach downstream of all tributary watersheds with oil sands developments (near the Athabasca River Delta).	478196	6448261	477875	6449601	No	Yes	No

Juv. = Juvenile

Note: Reach lengths varied depending on capture efficiency.

Table 3.1-27 Location of each reach sampled for the wild fish health survey on tributaries to the Athabasca River for the 2015 JOSMP.

Reach	Description	UTM Coordinates (NAD83, Zone 12)		Target Species	Water and Sediment Samples Collected?	Target Numbers Obtained	
		Easting	Northing			Adults	Juv.
ER-L	*Test* reach on the lower Ells River, downstream of oil sand activity.	455711	6347291	*Couesius plumbeus*	Water and Sediment	No	Yes
ER-M	*Test* reach on the mid Ells River, downstream of oil sand activity.	446225	6343223	*Couesius plumbeus*	Water and Sediment	Yes	Yes
ER-U	*Baseline* reach, on the upper Ells River, upstream of oil sand activity.	440285	6342406	*Couesius plumbeus*	Water and Sediment	Yes	Yes
AC-US	*Baseline* reach on Alice Creek	371741	6454284	*Couesius plumbeus*	Water and Sediment	Yes	No
AC-DS	*Baseline* reach on Alice Creek	370982	6462911	*Couesius plumbeus*	Water and Sediment	Yes	No
DC-L	*Baseline* reach on the lower Dover River, upstream of oil sands activity.	451185	6337085	*Couesius plumbeus*	Water and Sediment	Yes	Yes
DC-M	*Baseline* reach on mid Dover River, upstream of oil sand activity.	447671	6335416	*Couesius plumbeus*	Water and Sediment	Yes	No
DC-U	*Baseline* reach on upper Dover River, upstream of oil sand activity.	438655	6331365	*Couesius plumbeus*	Water and Sediment	Yes	Yes
MR-L	*Test* reach on the lower MacKay River downstream of oil sand activity.	456535	6340929	*Rhinichthys cataractae*	Water and Sediment	Yes	No
MR-M	*Test* reach on the mid MacKay River, downstream of oil sand activity.	452194	6323485	*Rhinichthys cataractae*	Water and Sediment	No	No
MR-U	*Baseline* reach on the upper MacKay River, upstream of oil sand activity.	430329	6309362	*Rhinichthys cataractae*	Water and Sediment	Yes	No
JAR-F1	*Test* reach on the Jackfish River, downstream of oil sand activity.	493795	6169789	*Cottus cognatus*	Water	No	No
MUR-F2	*Test* reach on the Muskeg River, downstream of oil sand activity.	465455	6338944	*Couesius plumbeus*	Water and Sediment	No	Yes
SAC-F1	*Test* reach on Sawbones Creek, downstream of oil sand activity.	511445	6167165	None[1]	Water and Sediment	No	No
SUC-F1	*Test* reach on Sunday Creek, downstream of oil sand activity.	440510	6361624	*Cottus cognatus*	Water and Sediment	Yes	No
HAR-F1	*Test* reach on the Hangingstone River, downstream of oil sand activity.	478001	6278899	*Rhinichthys cataractae*	Water	No	Yes

Juv. = Juvenile

Rhinichthys cataractae – longnose dace

Couesius plumbeus – lake chub

Cottus cognatus – slimy sculpin

[1] No fish were caught during the sampling program at SAC-F1; therefore, a target species could not be assigned.

3.1.4.3 Changes in Monitoring Network from 2014

The monitoring activities for the Fish Populations component in the 2015 WY differed from those carried out in 2014 in the following ways:

- wild fish health monitoring was conducted in the 2015 WY and additional reaches were added (Table 3.1-28 and Table 3.1-29);
- fewer fish community reaches were sampled in the 2015 WY than in previous monitoring years (Table 3.1-28 and Table 3.1-29);
- seasonal fish inventories similar to what has been conducted previously by RAMP were not conducted on the Athabasca/Clearwater rivers in the 2015 WY; and
- fish tissue programs were not conducted in the 2015 WY.

3.1.4.4 Challenges Encountered and Solutions Applied

Although fishing effort was maximized to capture the required number of adult fish for wild fish health monitoring, the required numbers of adults and/or juveniles were not obtained at all stations in the 2015 WY (Table 3.1-26 and Table 3.1-27).

3.1.4.5 Other Information Obtained

The following additional information was obtained for the Fish Populations component in the 2015 WY:

- an expanded fish community sampling study was conducted on ten tributaries to the Athabasca River to determine the impact of additional fishing effort and gear types on the number and diversity of fish species caught within a sampling reach; and
- a pilot program was conducted on the Athabasca River to evaluate the feasibility of monitoring fish populations of the mainstem Athabasca River using the Alberta Fisheries approach to sampling key sportfish species.

The results of these studies are presented in Section 6.2 and Section 6.3, respectively.

3.1.4.6 Summary of Component Data Now Available

Table 3.1-28 summarizes the data collected for the Fish Populations component for data collected in the 2015 WY and Table 3.1-29 summarizes the data available for the Fish Populations component from 1997 to 2014.

Table 3.1-28 Summary of data available for the Fish Populations component of the JOSMP for the 2015 WY, and used in this report.

Waterbody and Location	Station	2015			
		Winter	Spring	Summer	Fall
Alice Creek					
Alice Creek (lower reach)	AC-DS				2,3
Alice Creek (upper reach)	AC-US				2,3
Athabasca River					
Downstream of Fort McMurray	3			1	
Downstream of Fort McMurray	4			1	
Downstream of Fort McMurray	6			1	
McLean Creek area	8			1	
McLean Creek area	9			1	
Below Poplar Creek	11			1	
Steepbank River area	16			1	
Below Steepbank River	18			1	
Below Steepbank River	20			1	
Below Muskeg River	24			1	
MacKay River area	25			1	
Below MacKay River	31			1	
Below MacKay River	32			1	
Downstream of development (near Fort Creek)	37			1	
Above the town of Athabasca	M0-US				2
Below of the town of Athabasca	M0-DS				2,3
Above Fort McMurray Sewage Treatment Plant (STP)	M2				2
Between Athabasca STP and Suncor's mines	M3				2,3*
Muskeg River area (upstream)	M4-US				2,3
Below Muskeg River	M4-DS				2,3
Ells River Area (upstream)	M7				2
Downstream of Development (near Firebag River)	M8				2
Downstream of Development (near the ATR. Delta)	M9				2
Athabasca River Tributaries (southern)					
Christina River (upstream of Janvier)	CHR-F2				5
Jackfish River	JAR-F1				2,4
Unnamed Creek (east of Christina Lake)	UNC-F2				4
Unnamed Creek (south of Christina Lake)	UNC-F3				4
Lower Sunday Creek	SUC-F1				2,5
Upper Sunday Creek	SUC-F2				4
Birch Creek	BRC-F1				4
Sawbones Creek	SAC-F1				2,4

Legend

1 = Athabasca River Pilot Study (see Section 6.3)

2 = Wild fish health monitoring: trout-perch (Athabasca River); slimly sculpin (Jackfish, Sunday); lake chub (Ells, Alice, Dover, Muskeg); longnose dace (MacKay, Hangingstone)

3 = Analytical water quality and sediment quality monitoring

4 = Fish community monitoring

5 = Fish community monitoring with additional sampling effort (see Section 6.2)

* Considered at *baseline* reach relative to downstream oil sands development, but *test* reach in relation to the upstream STP discharge.

Baseline (upstream of oil sands developments)

Test (downstream of oil sands developments)

Table 3.1-28 (Cont'd.)

Waterbody and Location	Station	2015			
		Winter	Spring	Summer	Fall
Dover Creek					
Lower Dover Creek	DC-L				2,3
Middle Dover Creek	DC-M				2,3
Upper Dover Creek	DC-U				2,3
Ells River					
Lower Ells River	ELR-F1				5
Lower Ells River	ER-L				2,3
Middle Ells River	ER-M				2,3
Upper Ells River	ER-U				2,3
Hangingstone River					
Hangingstone River	HAR-F1				2
MacKay River					
Lower reach (mouth)	MAR-F1				5
Lower MacKay River	MR-L				2,3
Middle MacKay River	MR-M				2,3
Upper MacKay River	MR-U				2,3
Tar River					
Upper Tar River	TAR-F2				5
Muskeg River					
Lower 35 km below Jackpine Creek confluence	MUR-F2				2,5
Muskeg River Tributaries					
Lower Jackpine Creek	JAC-F1				5
Upper Jackpine Creek	JAC-F2				5
Steepbank River					
Lower Steepbank River	STR-F1				5
Upper Steepbank River	STR-F2				5

Legend

1 = Athabasca River Pilot Study (see Section 6.3)

2 = Wild fish health monitoring: trout-perch (Athabasca River); slimly sculpin (Jackfish, Sunday); lake chub (Ells, Alice, Dover, Muskeg); longnose dace (MacKay, Hangingstone)

3 = Analytical water quality and sediment quality monitoring

4 = Fish community monitoring

5 = Fish community monitoring with additional sampling effort (see Section 6.2)

Baseline (upstream of oil sands developments)

Test (downstream of oil sands developments)

Table 3.1-29 Summary of data available for the Fish Populations Component of the JOSMP from 1997 to 2014, and used in this report.

Waterbody and Location	Site ID	1997				1998				1999				2000				2001				2002			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray	-3																								
Poplar Area	0/1		1	1,5	1,5		1,6	1,5	1,3,6														1		
Steepbank Area	4[a]/5[a]/6		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6
Muskeg Area	10/11		1	1,5	1,5		1,6	1,5	1,3,6									7			6		1		10,6
Tar-Ells Area	16/17		1	1,5	1,5		1,6	1	1,3,6									7					1		
Fort-Calumet Area	19[(a)]																								
CNRL/TrueNorth Area (Fort/Asphalt reaches)																							1		
Reference Area - about 200 km upstream[b]	5/6							1,5	1,3,6																
Reference Area - upstream of Fort McMurray[c]			1																						
Radiotelemetry study region[d]					2		2		2						2	2	2	2	2						
Reference site upstream of Ft. McMurray STP	ATR-1																								3
Reference site between STP and Suncor	ATR-2												1,3												3
Downstream of Suncor's Discharge	ATR-3												1,3												10,3
Below Muskeg River	ATR-4												1,3												10,3
Downstream of Development (near Firebag River)	ATR-5																								
Athabasca River Delta																									
Fletcher, Big Point, Goose Island channels	FLC/BPC/GIC																								
Embarras River	EMR-F2																								
Athabasca River Tributaries (northern)																									
Fort Creek (mouth)	FOC-F1														1,8,5,9	1									
Poplar Creek (mouth)	POC-F1																								
Beaver River (upper)	BER-F2																								
Pierre River (mouth)	PIR-F1														1,8,5,9	1									
Eymundson Creek (mouth)	EYC-F1																								
Red Clay Creek (mouth)	RCC-F1																								
Big Creek (mouth)	BIC-F1																								
Athabasca River Tributaries (southern)																									
High Hills River (mouth)	HH-R/HHR-F1																								
Clearwater River Reach	CR-1																								
Clearwater River Reach	CR-2																								
Clearwater River Reach	CR-3																								
Christina River (mouth)	CHR-F1																								
Christina River (upstream of Janvier)[h]	CHR-F2																								
Christina River (upstream of Jackfish River)	CHR-F3																								
Christina River (upstream of development)	CHR-F4																								
Jackfish River	JAR-F1																								
Unnamed Creek (east of Christina Lake)	UNC-F2																								
Unnamed Creek (south of Christina Lake)	UNC-F3																								
Sunday Creek (lower reach)	SUC-F1																								
Sunday Creek (upper reach)	SUC-F2																								
Birch Creek	BRC-F1																								
Sawbones Creek	SAC-F1																								
Ells River																									
Upper Ells River	ELR-F3												1,3												
Upper Ells River[g,i]	ELR-F2A												1,3												
Middle Ells River	ELR-F2																								
Lower Ells River[g,i]	ELR-F1												1,3												
MacKay River																									
Lower reach (mouth)[i]	MAR-F1		1																				1		
Mid-River (upstream of Suncor MacKay)	MAR-F2																								
Upper MacKay River reach	MAR-F3																								
Horse and Dunkirk rivers	HR-R/DR-R																3				3				
Tar River																									
Lower Tar River	TAR-F1												1,3												
Upper Tar River	TAR-F2												1,3												
Calumet River																									
Lower Calumet River	CAR-F1																								
Upper Calumet River	CAR-F2																								
Firebag River																									
Lower Firebag River	FIR-F1																								
Upper Firebag River	FIR-F2																								
Muskeg River																									
Mouth (within 1 km of confluence with Athabasca River)	MR-E/MUR-F1												1,3						4		3		4		4
Lower 35 km below Jackpine Creek confluence	MUR-F2			1			4						1,3		2,8	2	2	2	2	1	6			1	6
Upper Muskeg River (near Wapasu Creek Confluence)	MUR-F3																						1,4		1,4
Muskeg River Tributaries																									
Jackpine Creek (upper portion of the creek)	JAC-F2																								
Jackpine Creek (accessable areas of lower creek)	JAC-F1														8					1				1	
Muskeg Creek (Canterra road crossing)[e]																							1,4		1,4
Wapasu Creek (mouth or Canterra road)[e]																							1,4		1,4
Steepbank River																									
Steepbank Mine baseline fisheries reach (1995)[f]	AF014			1																					
Lower Steepbank River (current *test* site)	STR-F1/SR-E																								
Lower Steepbank River (original *test* site)	SR-MN												1,3								3				
Baseline site in vicinity of Bitumin Heights (original *baseline* site)	SR-R												1,3				3				3				
Upper Steepbank River (current *baseline* site) (moved in 2009)	SR-R/STR-F2																								
Regionally-Important Lakes																									
Christina Lake	CHL-F1																								
Various lakes in water/air emissions pathway																									

Waterbody and Location	Site ID	2003				2004				2005				2006				2007				2008			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray	-3																								
Poplar Area	0/1						1		1		1		1		1		1		1		1		1	1	1,6
Steepbank Area	4[a]/5[a]/6				6		1		1		1		1,6		1		1		1		1		1	1	1,6
Muskeg Area	10/11				6		1		1		1		1,6		1		1		1		1		1	1	1,6
Tar-Ells Area	16/17						1		1		1		1		1		1		1		1		1	1	1
Fort-Calumet Area	19[(a)]														1		1		1		1		1	1	1
CNRL/TrueNorth Area (Fort/Asphalt reaches)																									
Reference Area - about 200 km upstream[b]	5/6																								
Reference Area - upstream of Fort McMurray[c]																									
Radiotelemetry study region[d]																									
Reference site upstream of Ft. McMurray STP	ATR-1				10															3	3				
Reference site between STP and Suncor	ATR-2				10															3	3				
Downstream of Suncor's Discharge	ATR-3				10															3	3				
Below Muskeg River	ATR-4				10															3	3				
Downstream of Development (near Firebag River)	ATR-5				10,6															3	3				
Athabasca River Delta																									
Fletcher, Big Point, Goose Island channels	FLC/BPC/GIC																								
Embarras River	EMR-F2																								
Athabasca River Tributaries (northern)																									
Fort Creek (mouth)	FOC-F1																								
Poplar Creek (mouth)	POC-F1																								
Beaver River (upper)	BER-F2																								
Pierre River (mouth)	PIR-F1																								
Eymundson Creek (mouth)	EYC-F1																								
Red Clay Creek (mouth)	RCC-F1																								
Big Creek (mouth)	BIC-F1																								
Athabasca River Tributaries (southern)																									
High Hills River (mouth)	HH-R/HHR-F1																								
Clearwater River Reach	CR-1		1		1		1		1,6		1		1		1		1,6		1		1,6		1		1
Clearwater River Reach	CR-2		1		1		1				1				1		1,6		1		1,6		1		1
Clearwater River Reach	CR-3		1	10	1		1				1				1		1,6		1		1,6		1		1
Christina River (mouth)	CHR-F1																								
Christina River (upstream of Janvier)[h]	CHR-F2								1																
Christina River (upstream of Jackfish River)	CHR-F3																								
Christina River (upstream of development)	CHR-F4								1																
Jackfish River	JAR-F1																								
Unnamed Creek (east of Christina Lake)	UNC-F2																								
Unnamed Creek (south of Christina Lake)	UNC-F3																								
Sunday Creek (lower reach)	SUC-F1																								
Sunday Creek (upper reach)	SUC-F2																								
Birch Creek	BRC-F1																								
Sawbones Creek	SAC-F1																								
Ells River																									
Upper Ells River	ELR-F3						4		3		4		3							3	3				
Upper Ells River[g,i]	ELR-F2A						4		3		4		3							3	3				
Middle Ells River	ELR-F2																								
Lower Ells River[g,i]	ELR-F1						4		3		4		3							3	3				
MacKay River																									
Lower reach (mouth)[i]	MAR-F1			10			4																		
Mid-River (upstream of Suncor MacKay)	MAR-F2																								
Upper MacKay River reach	MAR-F3																								
Horse and Dunkirk rivers	HR-R/DR-R								3							3	3								
Tar River																									
Lower Tar River	TAR-F1																								
Upper Tar River	TAR-F2																								
Calumet River																									
Lower Calumet River	CAR-F1																								
Upper Calumet River	CAR-F2																								
Firebag River																									
Lower Firebag River	FIR-F1																								
Upper Firebag River	FIR-F2																								
Muskeg River																									
Mouth (within 1 km of confluence with Athabasca River)	MR-E/MUR-F1		4						3						4	3	3								
Lower 35 km below Jackpine Creek confluence	MUR-F2							1	6							1	6								
Upper Muskeg River (near Wapasu Creek Confluence)	MUR-F3																								
Muskeg River Tributaries																									
Jackpine Creek (upper portion of the creek)	JAC-F2																								
Jackpine Creek (accessable areas of lower creek)	JAC-F1							1																	
Muskeg Creek (Canterra road crossing)[e]																									
Wapasu Creek (mouth or Canterra road)[e]																									
Steepbank River																									
Steepbank Mine baseline fisheries reach (1995)[f]	AF014																								
Lower Steepbank River (current *test* site)	STR-F1/SR-E								3							3	3								
Lower Steepbank River (original *test* site)	SR-MN																								
Baseline site in vicinity of Bitumin Heights (original *baseline* site)	SR-R								3																
Upper Steepbank River (current *baseline* site) (moved in 2009)	SR-R/STR-F2															3	3								
Regionally-Important Lakes																									
Christina Lake	CHL-F1																								
Various lakes in water/air emissions pathway					6				6											6	6				6

Waterbody and Location	Site ID	2009				2010				2011				2012				2013				2014			
		W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F	W	S	S	F
Athabasca River																									
Upstream of Fort McMurray	-3										1	1	1		1	1	1		1	1	1		1	1	1
Poplar Area	0/1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1
Steepbank Area	4[a]/5[a]/6		1	1	1		1	1	1		1	1	1,6		1	1	1		1	1	1		1	1	1
Muskeg Area	10/11		1	1	1		1	1	1		1	1	1,6		1	1	1		1	1	1		1	1	1
Tar-Ells Area	16/17		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1
Fort-Calumet Area	19[(a)]		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1
CNRL/TrueNorth Area (Fort/Asphalt reaches)																									
Reference Area - about 200 km upstream[b]	5/6																								
Reference Area - upstream of Fort McMurray[c]																									
Radiotelemetry study region[d]																									
Reference site upstream of Ft. McMurray STP	ATR-1								3												3				
Reference site between STP and Suncor	ATR-2								3												3				
Downstream of Suncor's Discharge	ATR-3								3												3				
Below Muskeg River	ATR-4								3												3				
Downstream of Development (near Firebag River)	ATR-5								3												3				
Athabasca River Delta																									
Fletcher, Big Point, Goose Island channels	FLC/BPC/GIC																10				10				10
Embarras River	EMR-F2																10				10				10
Athabasca River Tributaries (northern)																									
Fort Creek (mouth)	FOC-F1												10				10				10				10
Poplar Creek (mouth)	POC-F1				10								10				10				10				10
Beaver River (upper)	BER-F2				10								10				10				10				10
Pierre River (mouth)	PIR-F1																				10				10
Eymundson Creek (mouth)	EYC-F1				10																10				10
Red Clay Creek (mouth)	RCC-F1				10																10				10
Big Creek (mouth)	BIC-F1				10																10				10
Athabasca River Tributaries (southern)																									
High Hills River (mouth)	HH-R/HHR-F1												10				3,10				10				10
Clearwater River Reach	CR-1		1	1	1,6		1	1	1		1	1			1	1	1,6		1	1	1		1	1	1
Clearwater River Reach	CR-2		1	1	1,6		1	1	1		1	1			1	1	1,6		1	1	1		1	1	1
Clearwater River Reach	CR-3		1	1	1,6		1	1	1		1	1	1		1	1	1,6		1	1	1		1	1	1
Christina River (mouth)	CHR-F1																10								10
Christina River (upstream of Janvier)[h]	CHR-F2																10								10
Christina River (upstream of Jackfish River)	CHR-F3																10				10				10
Christina River (upstream of development)	CHR-F4																10				10				10
Jackfish River	JAR-F1																10				10				10
Unnamed Creek (east of Christina Lake)	UNC-F2																				10				10
Unnamed Creek (south of Christina Lake)	UNC-F3																				10				10
Sunday Creek (lower reach)	SUC-F1																10				10				10
Sunday Creek (upper reach)	SUC-F2																				10				10
Birch Creek	BRC-F1																				10				10
Sawbones Creek	SAC-F1																10				10				10
Ells River																									
Upper Ells River	ELR-F3								10				10				10				10				10
Upper Ells River[g,i]	ELR-F2A								10				10				10								
Middle Ells River	ELR-F2																10								
Lower Ells River[g,i]	ELR-F1								10				10				10				10				10
MacKay River																									
Lower reach (mouth)[i]	MAR-F1				10								10				10				10				10
Mid-River (upstream of Suncor MacKay)	MAR-F2												10				10				10				10
Upper MacKay River reach	MAR-F3												10				10				10				10
Horse and Dunkirk rivers	HR-R/DR-R			3	3,10												3								
Tar River																									
Lower Tar River	TAR-F1				10								10				10				10				10
Upper Tar River	TAR-F2												10				10				10				10
Calumet River																									
Lower Calumet River	CAR-F1																10								
Upper Calumet River	CAR-F2																10								
Firebag River																									
Lower Firebag River	FIR-F1																				10				
Upper Firebag River	FIR-F2																				10				
Muskeg River																									
Mouth (within 1 km of confluence with Athabasca River)	MR-E/MUR-F1		4	3	3,10				10				10				3,10				10				10
Lower 35 km below Jackpine Creek confluence	MUR-F2				10								10				10				10				10
Upper Muskeg River (near Wapasu Creek Confluence)	MUR-F3												10				10				10				10
Muskeg River Tributaries																									
Jackpine Creek (upper portion of the creek)	JAC-F2				10				10				10				10				10				10
Jackpine Creek (accessable areas of lower creek)	JAC-F1				10				10				10				10				10				10
Muskeg Creek (Canterra road crossing)[e]																									
Wapasu Creek (mouth or Canterra road)[e]																									
Steepbank River																									
Steepbank Mine baseline fisheries reach (1995)[f]	AF014																								
Lower Steepbank River (current *test* site)	STR-F1/SR-E			3	3,10				10				10				3,10				10				10
Lower Steepbank River (original *test* site)	SR-MN																								
Baseline site in vicinity of Bitumin Heights (original *baseline* site)	SR-R																								
Upper Steepbank River (current *baseline* site) (moved in 2009)	SR-R/STR-F2			3	3								10				3,10				10				10
Regionally-Important Lakes																									
Christina Lake	CHL-F1																10				6				
Various lakes in water/air emissions pathway					6				6								6				6				

Legend

1 = Fish inventory
2 = Radiotelemetry; 1997-1998 walleye, lake whitefish (Athabasca River)
2000-2001: longnose sucker, northern pike, Arctic grayling (Athabasca River and Muskeg River)
3 = Wild fish health monitoring (previously called sentinel species monitoring); 1998-1999: longnose sucker (Athabasca River) 2002-2013: trout perch (Athabasca River); slimy sculpin (Muskeg, Steepbank, Dunkirk, Horse, High Hills)
4 = Fish fence: aluminum counting fence (large bodied fish); small-mesh fyke nets (small bodied fish)
5 = Fish habitat association study
6 = Fish tissue monitoring: walleye and lake whitefish (Athabasca River); northern pike (Muskeg River), northern pike (Clearwater River), northern pike, walleye, and lake whitefish (lakes)
7 = Winter fish habitat sampling
8 = Spawning survey
9 = Benthic drift survey
10 = Fish community monitoring (previously called fish assemblage monitoring)

Footnotes

[a] Reaches include east and west banks
[b] Reference area upstream of Fort McMurray; includes a 22 km section extending 1 km upstream of the Duncan Creek Confluence downstream to Iron Point
[c] Reference area upstream of Fort McMurray. It was investigated as a potential reference area for longnose sucker sentinel species monitoring but found to be inadequate due to habitat differences and concerns about longnose sucker mobility.
[d] Radiotelemetry region includes the area 60 km upstream of Fort McMurray to 250 km downstream of Fort McMurray.
[e] small-bodied fish inventory done by fish fence (fyke net) to record fish movements in and out of watercourse. Needed to be done prior to Kearl Project.
[f] Located from 3 to 11 km upstream of the confluence with the Athabasca River.
[g] In 2004 the Ells River was evaluated as a potential reference site for sentinel species (slimy sculpin) monitoring on the Muskeg and Steepbank Rivers. Several sites were sampled but no slimy sculpin were captured. Hence, the site was determined not to be suitable as a reference site for this species.
[h] Reconnaissance inventory carried out in the Christina River upstream and downstream of the Hwy 881 bridge crossing.
[i] In 2004 a fish fence reconnaissance was carried out on the Ells and MacKay rivers.

Test (downstream of oil sands developments)
Baseline (upstream of oil sands developments)

3.1.5 Acid-Sensitive Lakes Component

3.1.5.1 Overview of 2015 Monitoring Activities

The 2015 Acid-Sensitive Lakes (ASL) component consisted of water quality sampling of 50 lakes and ponds within and beyond the study area. The location of each lake is presented in Figure 3.1-6. The 50 lakes are located in six physiographic regions:

- Stony Mountains;
- Birch Mountains;
- West of Fort McMurray;
- Northeast of Fort McMurray;
- Canadian Shield; and
- Caribou Mountains.

The date of sampling and the UTM coordinates for each lake are presented in Table 3.1-30. Each lake is identified by an Alberta Environment and Parks (AEP) number as well as a unique identification number ascribed to each lake by the NO_xSO_x Management Working Group (NSMWG) lake sensitivity mapping program (WRS 2004). The original AEP name of each lake is also included in Table 3.1-30.

The sampling design for the ASL component reflects the natural geographic distribution of lakes within the study area. The 50 lakes represent a majority of the major lakes within the study area that are unaffected by oil sands development except through deposition. There are very few lakes close to the major oil sands developments that are not clearly influenced by the developments themselves. The closest lakes unaffected directly by oil sands development except through deposition are those lakes in the Muskeg River uplands and the area northwest of Fort McMurray, which are well represented in the set of ASL lakes. The set of 50 lakes include a number of smaller lakes that are less than 0.5 km^2 in area. Low alkalinity lakes are represented in the upland areas (Birch Mountains, Stony Mountains). The lakes to the northwest and northeast of the study area in the Caribou Mountains and Canadian Shield are remote from emission sources of NO_xSO_x and were selected as *baseline* lakes.

Summary of Field Methods

Sampling was conducted by AEP in late summer from August 24 to 29, 2015, when chemical conditions were considered to have stabilized. AEP provided the sampling equipment and logistical support for the lake sampling. A float plane was used to access the majority of study lakes while a helicopter with floats was used to reach the smaller lakes. AEP water quality sampling protocols were used as the basis for the field methods (AENV 2006a). Water samples were collected (approximately 10 L of water in total) from the euphotic zone (defined as twice the Secchi disk depth) at a single deep-water site in each major basin of a lake using weighted Tygon tubing. When the euphotic zone extended to the lake bottom, sampling was restricted to depths greater than 1 m above the lake bottom. In shallow lakes (i.e., less than 3 m deep), composite samples were created from five to ten 1-L grab samples collected at

0.5 m depth along a transect dictated by wind direction (upwind to downwind shore). Samples taken from a given lake were then combined to form a single composite sample.

Vertical profiles (1 m intervals) of dissolved oxygen (mg/L), temperature (ºC), conductivity (µS/cm), and pH were measured at the deepest location using a field-calibrated Hydrolab Minisonde 5 water quality meter. Secchi depth was also recorded. Samples for chemical analysis were stored on ice and shipped to the Limnology Laboratory, University of Alberta, Edmonton, within 48 hours of collection, and analyzed for the water quality variables listed in Table 3.1-31. The analytical methods for each water quality variable are described in the online database available at www.ramp-alberta.org.

Subsamples of 150 mL were taken from the composite samples for phytoplankton taxonomy and preserved using Lugol's solution. One or two replicate zooplankton samples were also collected from each lake as vertical hauls through the euphotic zone, using a #20 mesh (63 µm), conical plankton net. Zooplankton samples were preserved in approximately 5% formalin after anaesthetizing in soda water. Plankton samples were archived at AEP and the zooplankton samples were sent to Environment Canada's National Water Research Institute, Saskatoon, for analysis. These data are not presented in this report.

3.1.5.2 Changes in Monitoring Network from 2014

Five lakes from the Caribou Mountains to the northeast of the Athabasca oil sands region that had historically been sampled as *baseline* lakes were sampled in the 2015 WY. These five lakes were not sampled in 2014 because they were considered outside of the JOSMP study area and affected by local hydrologic changes and potential changes associated with forest fires (e.g., change in permafrost extent).

3.1.5.3 Challenges Encountered and Solutions Applied

There were no exceptional challenges encountered in implementing the field activities for the ASL component in the 2015 WY.

Figure 3.1-6 Locations of Acid-Sensitive Lakes monitored for the JOSMP in the 2015 WY.

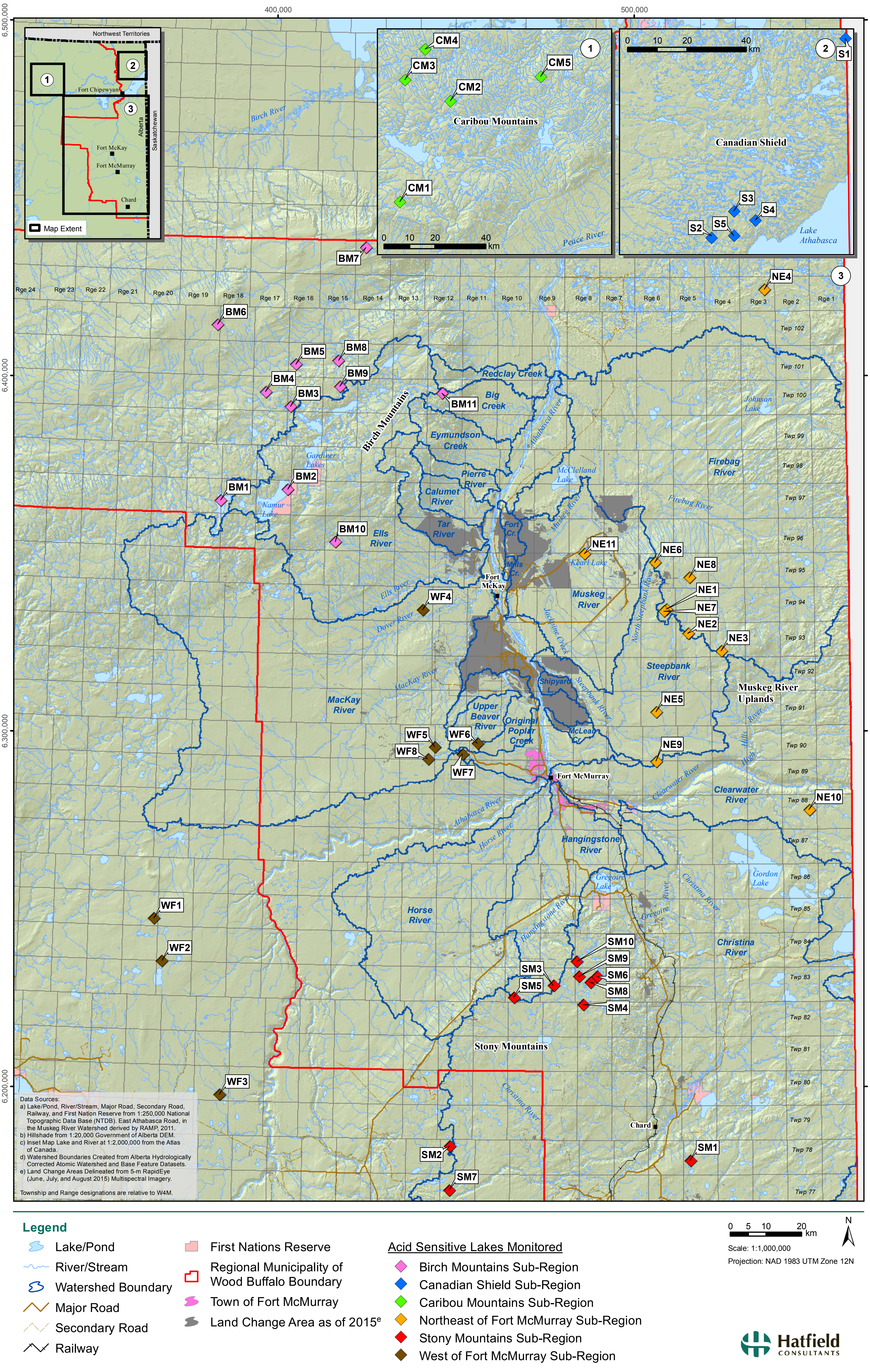


Table 3.1-30 Lakes sampled for the Acid-Sensitive Lakes component of the JOSMP in the 2015 WY.

Lake Identification			Lake Area (km^2)	UTM Coordinates (NAD83, Zone12)		Sampling Date month/day/year
AEP Name	Unique ID[1]	Original Name		Easting	Northing	
Stony Mountains Sub-Region						
SM10	168	A21	1.38	483819	6235130	08/28/15
SM9	169	A24	1.45	484387	6230872	08/28/15
SM6	170	A26	0.71	489502	6230877	08/28/15
SM5	167	A29	1.05	466180	6224950	08/28/15
SM7	166	A86	1.44	448014	6170896	08/28/15
SM8	287	25	2.18	487594	6229281	08/28/15
SM3	289	27	1.83	477248	6228400	08/28/15
SM4	290	28	0.54	487068	6225576	08/28/15
SM2	342	82	1.97	448271	6183205	08/28/15
SM1	354	94	2.50	515689	6179207	08/28/15
Birch Mountains Sub-region						
BM2	436	L18/Namur	43.39	402704	6368016	08/27/15
BM9	442	L23/Otasan	3.44	417321	6396959	08/27/15
BM1	444	L25/Legend	16.80	383849	6364923	08/27/15
BM6	447	L28	1.30	382996	6414339	08/27/15
BM7	448	L29/Clayton	0.65	424694	6435790	08/27/15
BM8	454	L46/Bayard	1.20	416941	6404239	08/27/15
BM4	455	L47	4.37	396500	6395456	08/27/15
BM5	457	L49	2.61	404995	6403111	08/27/15
BM3	464	L60	0.91	403796	6392247	08/27/15
BM10	175	P13	0.38	416003	6353212	08/24/15
BM11	199	P49	2.61	446002	6394961	08/24/15
Northeast of Fort McMurray Sub-Region						
NE1	452	L4 (A-170)	0.61	508990	6334305	08/29/15
NE2	470	L7	0.33	515029	6327465	08/29/15
NE3	471	L8	0.56	524390	6322556	08/29/15
NE4	400	L39/E9/A-150	1.12	536495	6424234	08/29/15
NE5	268	E15	1.87	506092	6305335	08/29/15
NE6	182	P23	0.28	509000	6346712	08/24/15
NE7	185	P27	0.09	508300	6333712	08/24/15
NE8	209	P7	0.15	515399	6343212	08/24/15
NE9	270	4	3.44	506113	6291421	08/29/15
NE10	271	6	4.31	549064	6277789	08/29/15
NE11	418	Kearl	5.34	485939	6349881	08/29/15
West of Fort McMurray Sub-Region						
WF1	165	A42	3.20	365015	6247322	08/27/15
WF2	171	A47	0.47	367321	6235430	08/27/15
WF3	172	A59	2.06	383467	6197733	08/27/15
WF4	223	P94	0.03	440557	6334112	08/25/15
WF5	225	P96	0.21	444002	6295513	08/25/15
WF6	226	P97	0.16	456002	6296463	08/25/15
WF7	227	P98	0.08	451762	6293513	08/25/15
WF8	267	1	2.22	441917	6290884	08/27/15
Caribou Mountains Sub-Region						
CM 1	146	E52/ Fleming	1.60	243692	6522556	08/25/15
CM 5	91	O-1/E55	2.70	298955	6571856	08/25/15
CM 4	97	O-2/E67	0.56	253582	6582654	08/25/15
CM 2	152	E59/Rocky I.	9.53	263546	6562225	08/25/15
CM 3	89	E68 Whitesand	2.46	245596	6570610	08/25/15
Canadian Shield Sub-Region						
S4	473	A301	1.40	525150	6559733	08/25/15
S1	118	L107/Weekes	3.73	555469	6620456	08/26/15
S2	84	L109/Fletcher	1.29	510321	6553552	08/26/15
S5	88	O-10	0.70	518279	6556260	08/26/15
S3	90	R1	0.55	517889	6562197	08/26/15

[1] Derived from the Lake Sensitivity Mapping Program conducted by NSMWG (WRS 2004).

Table 3.1-31 Water quality variables analyzed in lake water sampled for the Acid-Sensitive Lakes component of the JOSMP in the 2015 WY.

pH	bicarbonate	total dissolved nitrogen
turbidity	Gran bicarbonate	ammonia
colour	chloride	nitrite + nitrate
total suspended solids	sulphate	total Kjeldahl nitrogen
total dissolved solids	calcium	total nitrogen
dissolved organic carbon	potassium	total phosphorus
dissolved inorganic carbon	sodium	total dissolved phosphorus
conductivity	magnesium	chlorophyll *a*
total alkalinity (fixed point titration to pH 4.5)	iron	
Gran alkalinity	silicon	

3.1.5.4 Other Information Obtained

AEP collected additional water samples for metals analyses from each lake surveyed during the 2015 WY. These samples were sent to Alberta Innovates Technology Futures (AITF), Vegreville, Alberta for analysis of the total and dissolved fractions of those metals listed in Table 3.1-32. The inorganic mercury concentrations were subjected to low-level (ng/L) analysis. The results of the metals analyses are reported in Appendix F. Samples for low-level methyl mercury were also collected in the 2015 WY; these results area also reported in Appendix F.

Table 3.1-32 Metals analyzed in lake water sampled for the Acid-Sensitive Lakes component of the JOSMP in the 2015 WY.

silver	copper	selenium
aluminum	iron	tin
antimony	mercury	strontium
arsenic	methyl mercury	thorium
barium	lithium	titanium
beryllium	manganese	thallium
bismuth	mercury (low level)	uranium
cadmium	molybdenum	vanadium
cobalt	nickel	zinc
chromium	lead	

3.1.5.5 Summary of Component Data Now Available

The selection of lakes sampled during the seventeen years of the ASL component is summarized in Table 3.1-33.

Table 3.1-33 Summary of lakes sampled for the Acid-Sensitive Lakes component of the JOSMP from 1999 to 2015.

AEP Name	NO_xSO_x GIS No.	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
SM10	168	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM9	169	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM6	170	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM5	167	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM7	166	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM8	287				+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM3	289				+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM4	290				+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM2	342				+	+	+	+	+	+	+	+	+	+	+	+	+	+
SM1	354				+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF1	165	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF2	171	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF3	172	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF4	223				+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF5	225				+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF6	226				+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF7	227				+	+	+	+	+	+	+	+	+	+	+	+	+	+
WF8	267				+	+	+	+	+	+		+	+	+	+	+	+	+
NE1	452	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE2	470	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE3	471	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE4	400	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE5	268		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE6	182				+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE7	185				+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE8	209				+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE9	270				+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE10	271				+	+	+	+	+	+	+	+	+	+	+	+	+	+
NE11	418					+	+	+	+	+	+	+	+	+	+	+	+	+
BM2	436	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM9	442	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM1	444	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM6	447	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM7	448	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM8	454	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM4	455	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM5	457	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM3	464	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM10	175				+	+	+	+	+	+	+	+	+	+	+	+	+	+
BM11	199				+	+	+	+	+	+	+	+	+	+	+	+	+	+
S4	473			+	+	+	+	+	+		+	+	+	+	+	+	+	+
S1	118		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
S2	84	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
S5	88	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+
S3	90	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
CM1	146	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
CM2	152	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
CM3	89		+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
CM4	97	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
CM5	91	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+

3.2 ANALYTICAL APPROACH

A weight-of-evidence approach is used in all components for the analysis of data by applying a number of analytical methods to: (i) interpret results; and (ii) determine whether any changes have occurred due to oil sands development.

The approach used by all components for analyzing the monitoring data consists of a:

- description and explanation of the measurement endpoints that were selected;
- description of the statistical, graphical, or other analyses that were performed on the monitoring data to assess whether or not changes in the selected measurement endpoints have occurred temporally and/or spatially;
- comparison of the monitoring data to published guidelines to assess whether any exceedances in variables measured have occurred;
- comparison of the monitoring data from the 2015 WY to regional *baseline* ranges to assess whether any of the selected measurement endpoints fall outside of natural variability; and
- description and explanation of the criteria that were used to assess whether or not changes in the selected measurement endpoints have occurred.

3.2.1 Climate and Hydrology Monitoring Component

3.2.1.1 Selection of Measurement Endpoints

The following measurement endpoints, previously used by RAMP (RAMP 2009b) and JOSMP (JOSMP 2014), were used in the water balance analysis of the hydrologic data for the 2015 WY:

- Mean open-water season (May 1, 2015 to October 31, 2015) discharge;
- Mean winter (November 1, 2014 to March 31, 2015) discharge;
- Annual maximum daily (November 1, 2014 to October 31, 2015) discharge; and
- Open-water season (May 1, 2015 to October 31, 2015) minimum daily discharge.

These measurement endpoints are used in various oil sands project EIAs (RAMP 2009b) and can be calculated from one year of data. Values for each of these four measurement endpoints were calculated for the *test* and *baseline* hydrographs as discussed below. A percent change in the measurement endpoints between the *test* and *baseline* values was also calculated and used to classify differences between the *baseline* and *test* conditions into **Negligible-Low, Moderate**, or **High**.

3.2.1.2 Temporal Comparisons of Climate and Hydrologic Conditions

Records for the 2015 WY for each hydrometric station were assessed using Exploratory Data Analysis (EDA) (Kundzewicz and Robson 2004) in relation to the historical context (as available) based on past records for the location. Historical values, including daily median, upper quartile, lower quartile, historical maximum, and historical minimum values were calculated and presented graphically.

Observed (*test*) and calculated *baseline* (described below) hydrographs were plotted and described in the context of historical data. The robustness of the historical data was dependent on the period of record available for the specific locations and varied from station to station throughout the study area. As data continue to be collected, the EDA method will provide an increasingly robust analysis of the current year compared to the historical record and will support the use of other methods that incorporate statistical analyses. Where possible, hydrometric monitoring locations with extensive data records were selected to accurately evaluate regional and site-specific trends in hydrologic regimes. The period of record was provided when describing the temporal context of the 2015 WY observations and calculated *baseline* conditions using the EDA approach.

3.2.1.3 Comparison to *Baseline* Conditions

The 2015 hydrologic data were analyzed using a water balance approach consistent with previous analytical methods used in annual reporting from 2004 to 2014. The water balance approach described below is applicable for stations with 2015 WY flow records and associated land use and industrial flow data. The water balance approach thereby provides a consistent approach for the 2015 WY for all watersheds in the study area.

The water balance approach was used to develop *baseline* and *test* hydrographs for each watershed with oil sands development. The *test* hydrographs were developed from recorded water level and flow measurement data while the *baseline* hydrographs were developed using land change information and water withdrawal and release information from oil sands developments in the watershed. This approach identified the influence of development on the 2015 hydrograph. Additional details regarding this analytical approach are found in RAMP (2008) and Appendix C of this report.

The hydrology water balance analysis for the 2015 WY consisted of:

- establishing observed (*test*) hydrographs using water level records and associated stage/discharge relationships that were developed using Aquatic Informatics Aquarius software (Aquarius 3.6, Aquatic Informatics^{TM});
- estimating the 2015 *baseline* hydrographs (described below);
- calculating hydrologic measurement endpoints (Section 3.2.1.1) for both the *baseline* and *test* hydrographs; and
- applying criteria to assess the percentage change in the hydrologic measurement endpoints from estimated (*baseline*) and observed (*test*) hydrographs.

Estimation of 2015 Baseline Hydrograph

The *baseline* hydrographs for the 2015 WY were defined for this analysis as the hydrographs that would have been observed in the 2015 WY had there been no oil sands development in the watershed. Therefore, the *baseline* hydrograph was derived for the purpose of assessing change due to oil sands development, and should not be considered as a fully naturalized hydrograph. The equation provided below describes the method used to calculate the *baseline* hydrographs for the 2015 WY for the hydrometric station located closest to the outlet of each major watershed[4]:

$$Q_{nat} = Q_{obs} + Q_w - Q_r + Q_{HI} - Q_c + Q_{in}$$

where,

- Q_{nat} is the calculated *baseline* or naturalized hydrograph for the 2015 WY;
- Q_{obs} is the *test* hydrograph which was observed in the 2015 WY;
- Q_w are the water withdrawals from the watercourse;
- Q_r are the water releases to the watercourse;
- Q_{HI} is the natural runoff that would have occurred in the watershed, but was intercepted or closed-circuited by oil sands development in the 2015 WY;
- Q_c is the incremental increase in runoff caused by land cleared within the watershed as a result of oil sands development; and
- Q_{in} is the incremental difference in flow to the watershed in question from tributary watersheds that have oil sands development and a water balance calculated (e.g., Athabasca River).

This water balance approach provided an evaluative technique that identified the approximate magnitude of changes in the above measurement endpoints at the mouth of major watercourses. It did not; however, account for changes in runoff timing, watershed responsiveness, or storage properties that could be associated with oil sands development activities. For instance, surface runoff or dewatered volumes that were collected by mines and detained within a water management system (typically including structures such as pits, ditches, and sedimentation ponds) until the water quality met acceptable guidelines for release into surface watercourses and waterbodies were not accounted for within the water balance, given there should be no volumetric changes of released water relative to *baseline* conditions. Water volumes withdrawn (and not returned) from these structures for purposes such as construction and drilling, or dust suppression, would be included given there was a net loss of water released from the mine area. Additionally, surface water volumes diverted into or out of a particular watershed for operational purposes were treated, respectively, as water releases and withdrawals relative to *baseline* conditions.

The water balance excluded influences from groundwater inputs to surface water and did not address changes in watershed responsiveness caused by changes in the watershed. In addition, this approach assumed that areas of land change not closed-circuited would be estimated to have an increased runoff of 20%. This value is based on the following considerations:

[4] The small number of exceptions to this are noted in Section 5, in most cases because of backwater effects from the Athabasca River.

- The Spring Creek study conducted over a 36-year period in the boreal forest area of northern Alberta, which concluded that "the first four years after harvesting indicated minor increases in annual runoff from the Rocky Creek watershed (AENV 2000). Within the study area, land cleared for industrial purposes (and still contributing to flow) are slated to become hydrologically closed-circuited as part of the development process and while these areas are classified as "cleared and contributing" they are generally within the four-year post-harvesting period. The assumption of increasing flow for these areas is consistent with the Spring Creek study.
- While the use of 20% is a generalized assumption, the effect of clearing in most watersheds, related to oil sands development, is (as discussed above, and unlike forestry) a temporary land classification with cleared areas being slated for near-term development. These areas will be incorporated into the closed-circuited areas of the developments as mining plans unfold. In most cases the percentage of the areas of watersheds that were cleared and contributing was relatively small compared to the overall land-cover of the watershed such that this assumption (whether it be from 15 to 25%) would have a minor impact on the overall calculation results when considering the drainage basin as a whole.

3.2.1.4 Classification of Results

The percent difference between the *test* and *baseline* values of the hydrologic measurement endpoints developed through the water balance analyses were used to classify results as follows: ± 5% – **Negligible-Low**; ± 15% – **Moderate**; > 15% – **High**. These ranges were derived from criteria for determining effects on hydrologic measurement endpoints in a number of EIAs prepared for oil sands projects (RAMP 2009b).

3.2.1.5 Longitudinal Change Classification

The water balance assessment described above provides results for an entire watershed based on calculations conducted for the mouth of each watershed. Longitudinal change classification was conducted on watercourses for which a result of **Moderate** and **High** was assigned for any of the measurement endpoints so as to provide additional spatial context for the results of the water balance assessment. For the longitudinal change classification, the same water balance methodology described above was used to define changes to the hydrology at selected locations in the watershed above which land change and water withdrawals and release from development have occurred, both along the river mainstem as well as tributaries of the main river. This classification did not assess the measurement endpoints specifically but rather assessed change based on the introduction of land development at specific locations in the watershed. This assessment allowed the river mainstem and specific developed tributaries to be categorized longitudinally with the level of change as a result of oil sands development. These results were presented in map format showing the length of the river and the sections categorized as **Negligible-Low**, **Moderate**, and **High** compared to the *baseline* situation.

3.2.2 Water Quality Component

The analytical approach for the Water Quality component followed that of previous RAMP and JOSMP reports. The rationale for this approach was described more fully in the RAMP Technical Design and Rationale document (RAMP 2009b) and consists of:

- reviewing and selecting particular water quality variables as water quality measurement endpoints;
- reviewing and selecting criteria to be used in detecting changes in water quality measurement endpoints;
- updating regional *baseline* data ranges for each water quality measurement endpoint; and
- presenting results in tabular and graphical format comparing 2015 concentrations of water quality measurement endpoints to historical concentrations of each endpoint at each station, water quality regional *baseline* conditions, and selected criteria for determining change in water quality.

Innovations or additions to this report relative to reports from previous years includes the inclusion of continuous-monitoring data collected by data sondes in selected watersheds and expanded analysis and reporting of within-year data, given the expansion of monthly water quality sampling in May 2015 by AEMERA relative to previous sampling by RAMP/JOSMP up to March 2015. Given this increased monthly sampling occurred mid-year 2015, and that monthly sampling previously only occurred at a small sub-set of monitoring stations (from 2011 to 2015), most data analysis for the Water Quality component in this report focused on long-term fall datasets available at most stations.

3.2.2.1 Water Quality Measurement Endpoints

The large number of water quality variables measured at each station was reduced to a set of key measurement endpoints that were the primary focus of most of the analysis and reporting. The exception to this is the Water Quality Index (WQI, Section 3.2.2.2, *Water Quality Index*), which used a larger number of water quality variables in accordance with published CCME methods for the WQI (http://www.ccme.ca/ourwork/water.html?category_id=102).

Water quality measurement endpoints used in this report were identical to those used in the previous 2014 JOSMP report (JOSMP 2015), which were chosen based on:

- water quality measurement endpoints used in the EIAs of oil sands projects (RAMP 2009b);
- a draft list of water quality variables of concern in the lower Athabasca region developed by CEMA (2004a);
- water quality variables of interest listed in the RAMP 5-year report (Golder 2003);
- results of correlation analysis of the RAMP 1997 to 2007 water quality dataset indicating significant inter-correlation of various water quality variables, particularly metals (RAMP 2008); and
- water quality variables to assist in interpreting results of the Benthic Invertebrate Communities and the Fish Populations components.

The selected water quality measurement endpoints are:

- *pH* – an indicator of acidity;
- *Conductivity* – basic indicator of overall ion concentration;
- *Total suspended solids (TSS)* – a variable associated with several other measured water quality variables, including total phosphorus, total aluminum, and numerous other metals;
- *Dissolved phosphorus, total nitrogen, and nitrate+nitrite* – indicators of nutrient status. Dissolved phosphorus rather than total phosphorus is included because it is the primary biologically-available species of phosphorus and because total phosphorus levels are strongly associated with TSS (RAMP 2006);
- *Various ions (sodium, chloride, calcium, magnesium, potassium, sulphate)* – indicators of ion balance, which could be affected by discharges or seepages from oil sands development or by changes in the water table and changes in the relative influence of groundwater;
- *Total alkalinity* – an indicator of the buffering capacity and acid sensitivity of waters;
- *Total dissolved solids (TDS) and dissolved organic carbon (DOC)* – indicators of total ion concentrations and dissolved organic matter (particularly humic acids), respectively;
- *Total and dissolved aluminum* – aluminum is mentioned as a variable of interest in some oil sands EIAs, by CEMA, and in the RAMP 5-year report. Total aluminum is found in local bituminous clays and has been demonstrated to be strongly associated with TSS (Golder 2003). Dissolved aluminum more accurately represents biologically available forms of aluminum that may be toxic to aquatic organisms (Butcher 2001);
- *Total boron, total molybdenum, total strontium* – three metals found in predominantly-dissolved form in waters of the Athabasca oil sands region (RAMP 2004), and may be indicators of groundwater influence in surface waters;
- *Total arsenic* and *total mercury (ultra-trace)* – metals of potential importance to the health of aquatic life and human health;
- *Total methyl mercury (ultra-trace)* – a readily bioavailable organo-metalloid cation that is the primary form of mercury taken up by, and potentially accumulated in tissues of, aquatic biota such as fish and benthos;
- *Naphthenic acids* – relatively-labile hydrocarbons associated with oil sands deposits and processing that have been identified as a potential toxicity concern;
- *Total hydrocarbons (CCME fractions + BTEX)* – indicators of the total hydrocarbon content in water, including indicators (fractions) capturing hydrocarbon compounds of different molecular weights (specifically, number of carbon atoms), and concentrations of benzene, toluene, ethylbenzene, and xylene (collectively called BTEX), based on methods presented by CCME (2001) (added in 2011, as an intended replacement for Total Recoverable Hydrocarbons);

- Various PAH measurement endpoints, including:
  - *Total PAHs* – a sum of concentrations of all PAHs measured in a given sample, including parent and alkylated forms;
  - *Total parent PAHs* – a sum of concentrations of all non-alkylated PAHs measured in a given sample;
  - *Total alkylated PAHs* – a sum of concentrations of all alkylated PAHs measured in a given sample;
  - *Naphthalene* – a volatile, low-molecular-weight PAH that may cause toxicity when dissolved in water;
  - *Total dibenzothiophenes* – a sulphonated PAH (parent and alkylated forms) that is associated with bitumen (i.e., petrogenic); and
  - *Retene* – an alkylated phenanthrene generated through decomposition of plant materials (i.e., biogenic rather than petrogenic); and
- Overall ionic composition at each station, assessed graphically using Piper diagrams (Section 3.2.2.3).

3.2.2.2 Assessment of Results

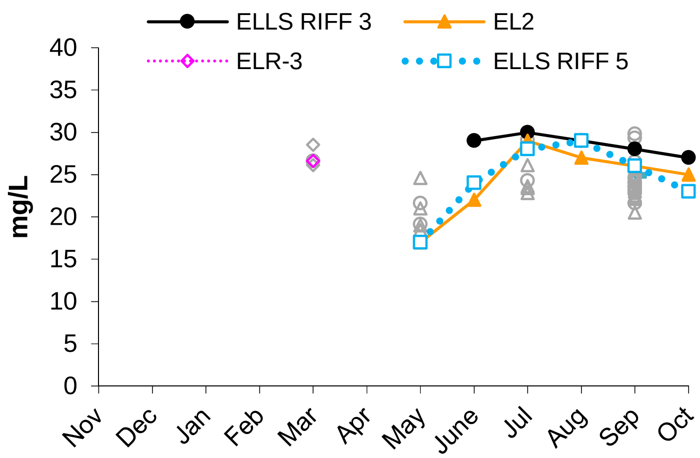
Continuous Water Quality Monitoring Data

Continuously monitored sonde data for dissolved oxygen (mg/L), electrical conductivity (µS/cm), pH (pH units), turbidity (NTU), and water temperature (°C) were presented graphically with daily averaged trend-lines throughout the sampling dates, and compared with corresponding Alberta water quality guidelines where relevant.

Monthly and Seasonal Variations in Water Quality

For stations with monthly data collected in 2015, data for 14 of the 22 selected water quality measurement endpoints were presented graphically in the context of historical variability by presenting available monthly data for each station since 1997 (see example provided in Figure 3.2-1). Although historical RAMP/JOSMP data for these stations predominantly were for September only, seasonal data existed for many stations (a few had recent monthly data). This approach allowed for assessment of historical variability in the concentration of these water quality measurement endpoints against their measured concentration in the 2015 WY. Where possible, stations located upstream and downstream on specific watersheds were presented together to allow assessment of any differences in water quality between upstream and downstream (*test* and *baseline*) stations.

Figure 3.2-1 Example of monthly water quality data for the 2015 WY presented with historical data for a specific station, in this case, for concentrations of calcium in the Ells River watershed.



Note: Color markers indicate data from the 2015 WY and grey marker indicate historical data

Comparison to Historical Concentrations and Published Guidelines

The 2015 value (fall, seasonal, or monthly) of each water quality measurement endpoint was tabulated for each station sampled. Historical variability was presented for each water quality measurement endpoint, represented by minimum, maximum, and median values measured, as well as the number of observations at each station from 1997 to 2015 (fall observations only). In addition, all cases in which concentrations of any water quality variable (i.e., quality measurement endpoints and all other monitored water quality variables) exceeded relevant guidelines in the 2015 WY were reported. Water quality guidelines used to screen data collected for the Water Quality component of the JOSMP are provided in Table 3.2-1.

Temporal Trends

Statistical trend analysis was conducted on specific water quality measurement endpoints (total suspended solids, total dissolved solids, dissolved phosphorus, total nitrogen, total boron, total strontium, calcium, chloride, magnesium, potassium, sodium, sulphate and total arsenic) at those water quality stations for which there were at least seven consecutive years of fall water quality data in order to assess changes in water quality potentially related to oil sands development. A non-seasonal Mann-Kendall test was applied to these data using algorithms developed in the R statistical programming language, and with a level of significance of α=0.05. Concentrations of the measurement endpoints were not discharge-averaged before trend analysis.

Ion Balance

Piper diagrams were used to examine the ion balance at each station to assess temporal and spatial differences in the ionic composition of water in the watershed of interest. Piper diagrams display the relative concentrations of major cations and anions on two separate ternary (triangular) plots, together with a central diamond plot where points from the two ternary plots are projected to describe the overall character, or type of water (Güler et al. 2004), and are commonly applied to groundwater data (see Figure 3.2-2 for an example Piper plot).

An advantage of examining relative ion concentrations is that they generally remain consistent despite changes in dilution by precipitation, allowing year-to-year comparisons of relative ion balance despite inter-annual differences in water flows. Using this approach, changes in groundwater influence or influences on natural surface waters of produced waters (e.g., oil-sands process waters or site-drainage waters), which have higher relative proportions of some cations (i.e., sodium, magnesium or potassium) and anions (i.e., chloride or sulphate) relative to those that generally dominate natural waters (i.e., calcium and carbonate/bicarbonate), may be identified.

Table 3.2-1 Alberta water quality guidelines used to screen data collected for the Water Quality Component of the 2015 JOSMP.

Variables	Units	Short-term (Acute)	Long-term (Chronic)
Conventional Variables			
pH	pH unit	-	6.5-9.0
Dissolved Oxygen	mg/L	5.0 (minimum)	6.5-9.5[a]
Temperature	°C	narrative[b]	narrative[b]
Total Suspended Solids	mg/L	narrative[c]	narrative[c]
Turbidity	NTU	narrative[c]	narrative[c]
Colour	CU	-	20% increase
Total Alkalinity	mg/L	-	20 (minimum)
Major Ions			
Sulphate	mg/L	-	128 to 429[d]
Sulphide (as H_2S)	mg/L	-	0.0019
Chloride	mg/L	640	120
Nutrients			
Ammonia	mg/L	-	0.018 to 190[e]
Nitrate-N	mg/L	124	3
Nitrite-N	mg/L	0.06-0.6[f]	0.02-0.2[f]
Total Nitrogen	mg/L	-	narrative[g]
Total Phosphorus	mg/L	-	narrative[g]
Total Metals			
Arsenic	mg/L	-	0.005
Boron	mg/L	29	1.5
Cadmium	mg/L	0.00011-0.0077[h]	0.00004-0.00037[h]
Chromium III	mg/L	-	0.0089
Chromium VI	mg/L	-	0.0010
Cobalt	mg/L	-	0.0025
Copper	mg/L	0.0009 to 0.062[h]	0.007
Lead	mg/L	-	0.001 to 0.007[h]
Mercury	µg/L	0.013	0.005
Methyl mercury	µg/L	0.002	0.001
Molybdenum	mg/L	-	0.073
Nickel	mg/L	0.037 to 1.52[h]	0.004 to 0.170[h]
Selenium	mg/L	-	0.001
Silver	mg/L	-	0.0001
Thallium	mg/L	-	0.0008
Uranium	mg/L	0.033	0.015
Zinc	mg/L	-	0.03
Dissolved Metals			
Aluminum	mg/L	0.10[i]	0.05[i]
Iron	mg/L	-	0.3
General Organics			
Phenols (mono and dihydric)	mg/L	-	0.004
Oil and Grease	-	narrative[j]	narrative[j]
F1 (C6-C10)	mg/L	-	0.15
F2 (C10-C16)	mg/L	-	0.11
Benzene	mg/L	-	0.04
Ethylebenzene	mg/L	-	0.09
Toluene	mg/L	-	0.0005
Xylene	mg/L	-	0.03
Polycyclic Aromatic Hydrocarbons (PAHs)			
Acenaphthene	µg/L	-	5.8
Acridine	µg/L		4.4
Anthracene	µg/L	-	0.012
Benzo(a)anthracene	µg/L	-	0.018
Benzo(a)pyrene	µg/L	-	0.015
Fluoranthene	µg/L	-	0.04
Fluorene	µg/L	-	3
Naphthalene	µg/L	-	1
Phenanthrene	µg/L	-	0.4
Pyrene	µg/L	-	0.025
Quinoline	µg/L	-	3.4

a: Oxygen values are minima, and are dependent on seasons and life stages, see AESRD (2014) for more information

b: Thermal additions should not alter thermal stratification or turnover dates, exceed maximum weekly average temperature, nor exceed maxium short-term temperature

c: depends on clear/low flow and high flow,see AESRD (2014) for more information

d: Hardness-dependent Guideline: 128 mg/L at hardness 0-30 mg/L, 218 mg/L at hardness 31-75 mg/L, 309 at hardness 76-180 mg/L, and 429 mg/L at hardness 181-250 mg/L

e: Guidelines for total ammonia are temperature and pH dependent; see AESRD (2014) for additional information

f: Guidelines for nitrite are chloride dependent; see AESRD (2014) for additional information

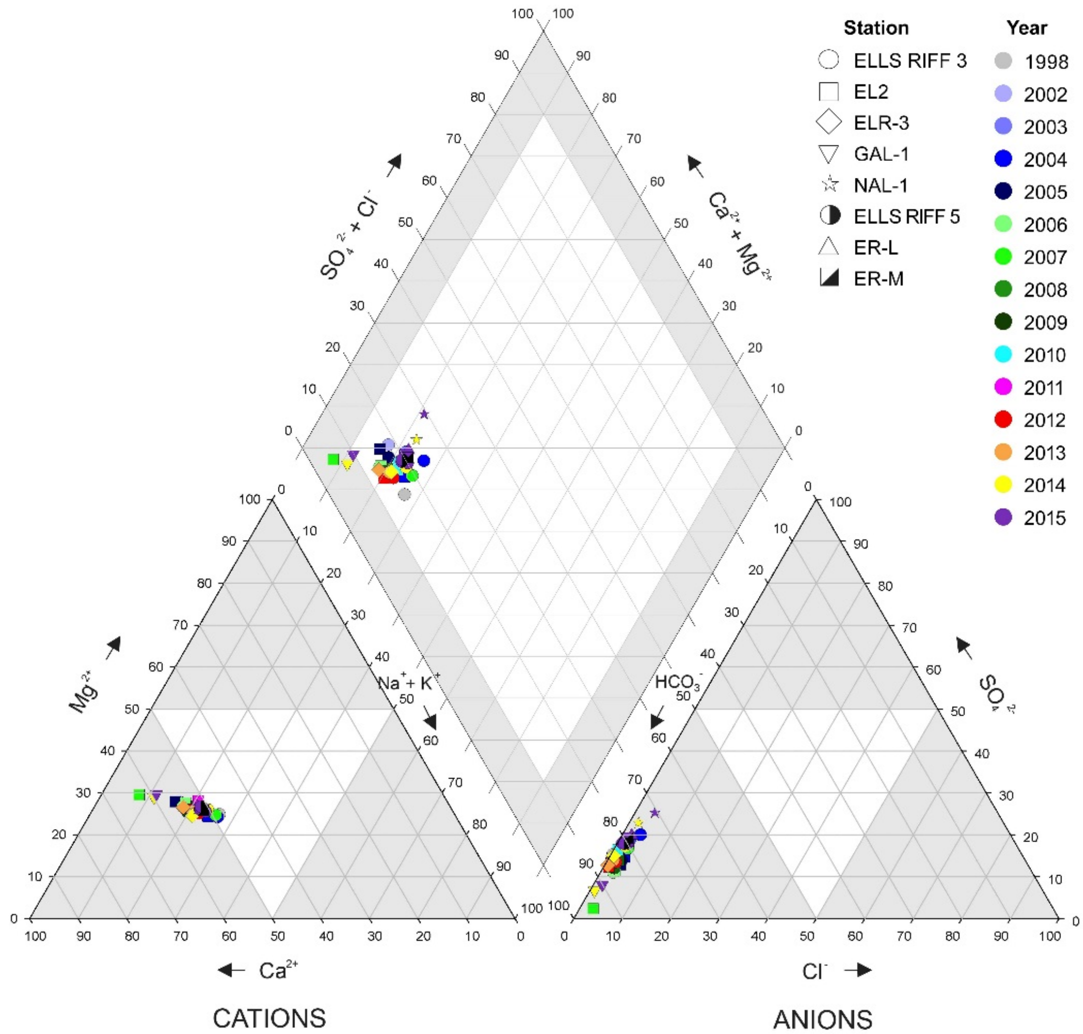
g: Guidelines for total nitrogen and phosphorus are dependent on nature and conditions of ecosystems; see AESRD (2014) for additional information

h: Hardness-dependant. Values given are at hardness levels ranging from 5 to 400 mg/L

i: Value given at pH>=6.5. At pH<6.5, acute guideline is $e^{1.209-2.426*pH+0.286*pH^2}$*1000, and chronic guideline is $e^{1.6-3.327*pH+0.402*pH^2}$*1000

j: Qualitative guidelines based on visual observations, see AESRD (2014) for more information

Figure 3.2-2 Example Piper diagram, illustrating relative ion concentrations in waters from Ells River Watershed, 1998 to 2015.



Comparison to Regional Baseline Concentrations

Development of Regional Baseline Concentrations

Descriptions of regional *baseline* water quality conditions were developed from historical data collected in fall by the RAMP (2002-2013) and the JOSMP (2014, 2015), from *baseline* stations throughout the study area. These ranges of regional natural variability in water quality were used as one method of screening water quality observed at all stations in fall 2015 to assess whether water quality conditions at the time of sampling were similar to, or differed from those typically observed in the region.

This analytical approach is similar to that of the Reference Condition Approach to biomonitoring (Bailey et al. 2004), also used for benthic invertebrate communities in the Benthic Invertebrate Communities component, and incorporates elements of control charting (Morrison 2008), which also is a feature of the analysis of benthic invertebrate communities in the Benthic Invertebrate Communities component as well as the Acid-Sensitive Lakes component. This approach is more fully described in the RAMP Technical Design and Rationale document (RAMP 2009b). It also shares similarities with CCME's prescribed approach for developing site-specific water quality objectives (SSWQOs), which uses the 90th percentile of upstream water quality observations to define benchmarks for assessment of water quality in a given waterbody, typically downstream of some kind of development (CCME 2011). The approach of comparing observed data against a defined range of natural variability also aligns with the Alberta Water Council's (2009) definition of a healthy aquatic ecosystem as "…*an aquatic environment that sustains its ecological structure, processes, functions and resilience within its range of natural variability.*"

In previous years, multivariate data analysis was used to develop descriptions of regional *baseline* water quality that were then applied to water quality measurements from *baseline* and *test* stations. In this approach, fall water quality data from all *baseline* water quality stations from 2002 onwards were pooled using cluster analysis (data collected by RAMP from 1997 to 2001 were excluded from multivariate analysis for cluster derivation due to higher detection limits for metals). Similar approaches to consolidation and analysis of large water quality datasets are common in the water quality assessment literature (e.g., Boyacioglu and Boyacioglu 2010; Astel et al. 2007; Singh et al. 2004; Jones and Boyer 2002; Güler et al. 2004). Details describing the cluster analysis methodology have been reported in previous RAMP technical reports (e.g., RAMP 2011).

For graphical presentation and interpretation of fall 2015 data against regional *baseline* data, the same watershed groups (clusters) were used as in 2014. To preserve clustering of station-data combinations located within specific watersheds, multivariate analysis was not used exclusively to determine cluster membership. For determination of regional ranges of natural variability, stations were grouped together based on cluster analysis and geographical location. This method incorporated both overall patterns determined from cluster analysis with ecological knowledge of the study area. Three "clusters" were determined (stations included in each group of *baseline* data, and 2015 stations compared against these groups are provided in Table 3.2-2):

- Cluster 1: Athabasca River and Delta;
- Cluster 2: Southern Tributaries plus McLean Creek and the Mackay, Ells, Steepbank, and Firebag rivers; and
- Cluster 3: Poplar, Fort, Big, Redclay, and Eymundson Creeks and the Beaver, Tar, Calumet, Pierre, and Muskeg rivers.

Table 3.2-2 Regional *baseline* water quality data groups and station comparisons.

Regional *Baseline* Grouping (Cluster)	*Baseline* Stations Used in Creating Regional Comparison[1]	Stations With Fall 2015 Data Compared Against Regional *Baseline* Range
1. Athabasca River and Delta	ATR-DC-CC (1997-2007), ATR-DC-E (1998-2014), ATR-DC-W (1998-2014), ATR-DC-M (2000), M0-DS (2015)	ATR-DD-C, M4, M5, M6, BPC-1, EMR-2, FLC-1, GIC-1, M3, M4-US, M4-DS
2. Southern Tributaries plus McLean Creek and the MacKay, Ells, Steepbank, and Firebag rivers	CHR-4 (2013-2015), CLR-1 (2001-2009), 2014), DUR-1 (2009), ELR-1 (1998, 2002), ELR-2 (2004-2010), ELR-2A (2010-2012), ELR-3 (2013-2014), FIR-2 (2002-2015), HHR-1 (2011-2015), HOR-1 (2009), MAR-1 (1998-2001), MAR-2 (2002-2014), NSR-1 (2002-2008), PIR-1 (2011-2014), STR-2 (2002-2007), STR-3 (2004-2014), SUC-2 (2013-2015), ELLS RIFF 5 (2015), BRC-1 (2013-2015), DOV RIFF 4 (2015), FI2 (FIR-2) (2002-2015), DC-L (2015), DC-M (2015), DC-U (2015), MR-U (2015)	CH1 (CHR-1), CHR-3, CL2 (CLR-1), ELLS RIFF 3, FI WSC, FI1 (FIR-1), HA1 (HAR-1A), JAR-1, MCC-1, SAC-1, ST WSC, ST1 (STR-1), STB RIFF 10, STB RIFF 7, SUC-1, UNC-2, UNC-3, GRR-1, HO2, HAR-1, CHR-2A, CHR-2, EL2 (ELR-2)
3. Poplar, Fort, Big, Redclay, and Eymundson creeks, and the Beaver, Tar, Calumet, Pierre, and Muskeg rivers	BER-2 (2008-2015) , FOC-1 (2000-2003), JA1 (JAC-1) (1999-2005), JAC-2 (2008-2015), TAR-1 (1998, 2002-2003), CAR-1 (2002-2004), CAR-2 (2005-2015), IYC-1 (2007-2008), MUC-1 (1998-2007), MUR-6 (1998-2007), RCC-1 (2011-2015), SHC-1 (1999), STC-1 (1999-2002), WAC-1 (1998-1999, 2004-2006), TR3.2 (2015), EYC-1 (2011-2015), PIR-1 (2011-2015), UN1 (BIC-1) (2011-2015), TAR-2A (TAR-2) (2004-2015), AC-DS (2015), AC-US (2015)	BER-1, MU0, MU1, MU4, MU5, MU6, MU8, MU10, PO1 (POC-1), STC-1, TR3.1, FOC-1,JA1 (JAC-1), TAR-1, CA1 (CAR-1)

[1] See Table 3.1-13 and Table 3.1-14 for classification of station status by year. Where station status changed from *baseline* to *test* from 1997 to 2015, only *baseline* data were used in the determination of regional water quality characteristics.

To allow for a regional comparison, untransformed data for 14 of the 30 selected water quality measurement endpoints (Section 3.2.2.1) from all *baseline* stations sampled from 1997 to 2015 (fall only) were pooled from each cluster of similar stations. Descriptive statistics describing *baseline* water quality characteristics for all water quality measurement endpoints for each cluster were calculated including the 5th, 25th, 50th (median), 75th, and 95th percentiles for comparison against station-specific data (Table 3.2-3, Table 3.2-4, Table 3.2-5). The historical ranges of *baseline* values for Cluster 1 (Athabasca River mainstem and delta) from 1997 to 2015 were identical to the ranges used in the 2014 analysis because no new *baseline* data were added to the comparative dataset from the 2015 WY (RAMP/JOSMP *baseline* station ATR-DC was discontinued after 2014). The number of observations varied by cluster for each of the selected water quality measurement endpoints. The median rather than the mean was used as an indicator of typical conditions; given water quality data are characteristically positively skewed. Regional *baseline* ranges did not include and were not applied to lakes sampled in 2015, to address concerns expressed by the RAMP 2010 Peer Review (AITF 2011) in combining water quality data from streams and lakes in regional *baseline* ranges.

Table 3.2-3 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2015, Group 1: Athabasca River and Delta.

Measurement Endpoint	Unit	n	Percentiles						
			Minimum	5th	25th	Median	75th	95th	Maximum
Physical Variables									
pH	pH unit	40	7.7	7.85	8.08	8.19	8.21	8.3	8.4
Total suspended solids	mg/L	40	3	3	10	16	23	90	136
Conductivity	µS/cm	40	202	204	235	270	292	313	366
Nutrients									
Total dissolved phosphorus	mg/L	40	0.0025	0.00443	0.007	0.0108	0.017175	0.02805	0.0298
Total nitrogen	mg/L	40	0.05	0.05	0.071	0.1	0.1	0.2653	0.324
Nitrate+nitrite	mg/L	40	0.054	0.240	0.437	0.5	0.692	0.8015	0.901
Dissolved organic carbon	mg/L	40	1.5	2.97	5.82	6.75	9.62	14.1	17.1
Ions									
Sodium	mg/L	40	8	9	10	13	17	21	28
Calcium	mg/L	40	18	19	24	32	34	39	44
Magnesium	mg/L	40	5.49	5.74	7.02	8.5	9.48	11.05	12.3
Potassium	mg/L	38	0.75	0.8	0.86	1	1.19	1.4	1.6
Chloride	mg/L	40	2	2	3	6	17	25	36
Sulphate	mg/L	40	5.67	6.5	11.3	24.2	28.6	35.1	50.2
Total dissolved solids	mg/L	40	40	90	156	169	180	240	282
Total alkalinity	mg/L	40	63	69	84	101	110	120	145
Selected Metals									
Total aluminum	mg/L	41	0.03	0.14	0.436	0.618	1.05	2.23	3.76
Dissolved aluminum	mg/L	41	0.000664	0.0058	0.009	0.0114	0.0233	0.12	1.1
Total arsenic	mg/L	41	0.000424	0.0005	0.00064	0.000849	0.001	0.0017	0.00933
Total boron	mg/L	41	0.0123	0.0157	0.02111	0.0254	0.0318	0.0396	0.045
Total mercury (ultra-trace)	ng/L	30	0.6	1.05	1.2	1.2	1.97	5.5	12.9
Total molybdenum	mg/L	41	0.000179	0.000206	0.00036	0.000618	0.000703	0.0009	0.0011
Total strontium	mg/L	41	0.0897	0.0992	0.135	0.2	0.254	0.289	0.304

Table 3.2-4 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2015, Group 2: southern tributaries plus McLean Creek and the Mackay, Ells, Steepbank, and Firebag rivers.

Measurement Endpoint	Unit	n	Percentiles						
			Minimum	5th	25th	Median	75th	95th	Maximum
Physical Variables									
pH	pH unit	104	7.20	7.60	7.98	8.10	8.27	8.38	8.58
Total suspended solids	mg/L	104	<1	2	3	4	8	28	74
Conductivity	µS/cm	104	80	138	175	215	256	488	576
Nutrients									
Total dissolved phosphorus	mg/L	104	0.00	0.01	0.02	0.03	0.04	0.08	0.12
Total nitrogen	mg/L	103	0.25	0.35	0.53	0.70	1.01	2.00	3.20
Nitrate+nitrite	mg/L	104	0.005	0.005	0.071	0.071	0.1	0.1	0.1
Dissolved organic carbon	mg/L	104	6	8	12	17	26	34	45
Ions									
Sodium	mg/L	103	2	3	5	11	17	29	60
Calcium	mg/L	104	10	12	22	25	32	45	71
Magnesium	mg/L	104	3	4	6	8	10	15	20
Potassium	mg/L	103	0.5	0.5	0.70	0.9	1.1	2.08	3.47
Chloride	mg/L	104	<1	0.5	0.60	1	2.25	29.85	43
Sulphate	mg/L	104	<1	0.51	1.9	5.1	13.7	23.6	36.4
Total dissolved solids	mg/L	104	40	110	136	160	192	330	396
Total alkalinity	mg/L	104	30	45	81	98	126	209	265
Selected Metals									
Total aluminum	mg/L	104	0.011	0.0179	0.0499	0.1265	0.2627	0.7299	3.57
Dissolved aluminum	mg/L	104	0.001	0.0020	0.0053	0.0096	0.0184	0.0389	0.1460
Total arsenic	mg/L	104	0.0001	0.0004	0.0006	0.0007	0.0010	0.0016	0.0026
Total boron	mg/L	104	0.008	0.012	0.023	0.049	0.065	0.133	0.211
Total mercury (ultra-trace)	ng/L	84	0.26	0.62	1.2	1.2	1.73	4.14	5
Total molybdenum	ng/L	104	0.0000	0.0001	0.0002	0.0003	0.0005	0.0008	0.0015
Total strontium	mg/L	104	0.028	0.047	0.069	0.106	0.140	0.253	0.310

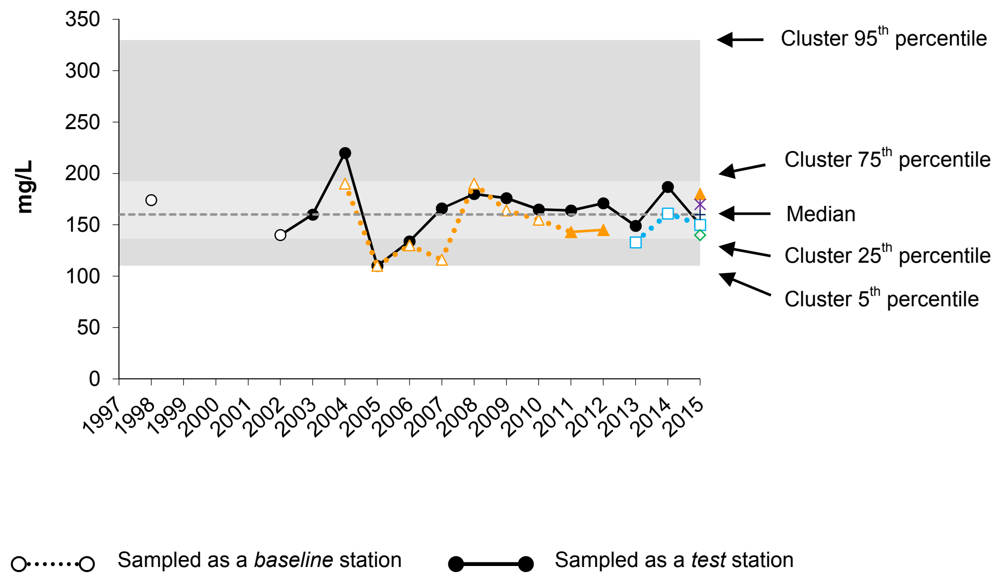
Table 3.2-5 Regional *baseline* values for water quality measurement endpoints, using data from 1997 to 2015, Group 3: Poplar, Fort, Mills, Big, Redclay, and Eymundson creeks and the Beaver, Tar, Calumet, Pierre, and Muskeg rivers.

Measurement Endpoint	Unit	n	Percentiles						
			Minimum	5th	25th	Median	75th	95th	Maximum
Physical Variables									
pH	pH unit	103	7.16	7.41	7.90	8.10	8.23	8.40	8.52
Total suspended solids	mg/L	103	<1	3	3	6	10	50	243
Conductivity	µS/cm	103	136	184	253	350	488	682	1172
Nutrients									
Total dissolved phosphorus	mg/L	103	0.0049	0.0101	0.014	0.021	0.047	0.1158	0.305
Total nitrogen	mg/L	104	0.264	0.400	0.650	0.896	1.113	2.364	5.541
Nitrate+nitrite	mg/L	102	-0.005	-0.005	0.071	0.1	0.1	0.1	0.1
Dissolved organic carbon	mg/L	103	6	10	14	21	27	47	54
Ions									
Sodium	mg/L	103	2	3	9	12	26	71	96
Calcium	mg/L	103	16	21	31	45	55	72	84
Magnesium	mg/L	103	4	7	10	14	17	22	27
Potassium	mg/L	94	0.3	0.5	0.79	1.23	2.02	3.79	5.33
Chloride	mg/L	103	0.5	0.5	1	2	3	22.49	80.2
Sulphate	mg/L	102	<2	2	4	8	34	73	111
Total dissolved solids	mg/L	103	101	151	200	259	327	479	547
Total alkalinity	mg/L	103	29	93	125	185	226	297	354
Selected Metals	mg/L								
Total aluminum		104	0.007	0.015	0.041	0.105	0.310	0.946	4.100
Dissolved aluminum	mg/L	104	0.000	0.002	0.005	0.010	0.020	0.050	0.186
Total arsenic	mg/L	104	0.0001	0.0002	0.0005	0.0010	0.0013	0.0024	0.0050
Total boron	mg/L	104	0.003	0.011	0.038	0.058	0.085	0.211	0.424
Total mercury (ultra-trace)	mg/L	69	0.23	0.67	1.2	1.2	1.8	4.04	10.6
Total molybdenum	ng/L	104	0.00003	0.00005	0.00010	0.00019	0.00063	0.00146	0.00640
Total strontium	mg/L	104	0.050	0.069	0.095	0.153	0.206	0.316	0.435

Comparison of Station-Specific Data to Regional Baseline Ranges

Data for the 14 water quality measurement endpoints selected for this assessment (Table 3.2-3, Table 3.2-4, Table 3.2-5) were presented graphically in the context of relevant regional variability by presenting data for each station for all years of sampling to allow assessment of any temporal trends (see example in Figure 3.2-3). Where possible, stations located upstream and downstream on specific watersheds were presented together to allow assessment of any differences in water quality between upstream and downstream (*test* and *baseline*) stations.

Figure 3.2-3 Example of a comparison of data from a specific watershed against regional *baseline* concentrations and water quality guidelines, in this case, total dissolved solids in the Ells River watershed.



Water Quality Index

Water quality at each monitoring station from fall 2015 was summarized into a single index value, using an approach based on the CCME Water Quality Index. A detailed description of the CCME Water Quality Index and how it is calculated is found at http://www.ccme.ca/ourwork/water.html?category_id=102. Its specific application is described below.

This index was calculated using comparisons of observed water quality against regional *baseline* conditions, calculated and described in Section 3.2.2.3, as the benchmark for comparison, but for a wider set of water quality variables than that used in Section 3.2.2.2, *Comparison to Regional Baseline Concentrations*, described above. Specifically, the concentration of 65 water quality variables (selected based on their frequency of detection in all samples, and including physical properties like TSS, TDS, indicators of ionic composition such as major ions, pH and conductivity, and numerous total and dissolved metals, but not including waterborne PAHs due to the high frequency of non-detectable values) were compared to their 95th percentile of *baseline* concentrations (for the appropriate water quality station cluster see Table 3.2-2) (please see Section 3.2.2.2, *Comparison to Regional Baseline Concentrations* for a description of how these percentiles were calculated for each cluster). The calculation of the Water Quality Index considered three factors: (i) the percentage of variables with values that exceeded regional *baseline* conditions; (ii) the percentage of comparisons that exceeded regional *baseline* conditions; and (iii) the degree to which observed values exceeded regional *baseline* conditions.

Index values were calculated for all *baseline* and *test* stations. Calculation of Water Quality Index values for all stations sampled in fall since 1997 (n=714) yielded index values ranging from 40.7 to 100. It should be noted that historical values for the Water Quality Index calculated for specific observations may change from year to year, given that 95th percentile values for individual variables included in the index may change with addition of new *baseline* data to the data record.

Water Quality Index scores were not calculated for lakes because of concerns raised by the RAMP Peer Review (AITF 2011) regarding combining lakes and streams in regional *baseline* ranges.

3.2.2.3 Classification of Results

Water Quality Index scores were classified using the following scheme:

- 80 to 100: **Negligible-Low** difference compared to regional *baseline* conditions;
- 60 to 80: **Moderate** difference compared to regional *baseline* conditions; and
- Below 60: **High** difference compared to regional *baseline* conditions.

This classification scheme, based on similarity to regional *baseline* conditions, differs somewhat from that used by CCME to classify water quality based on water quality guidelines. Specifically, only three categories were used for this report (versus five used by CCME), to ensure consistency with classification schemes used for other monitoring components of the JOSMP. A classification of a **Negligible-Low** difference from *baseline* corresponds with CCME guideline-based index classes “Good” and “Excellent”; a classification of a **Moderate** difference from *baseline* corresponds with CCME class “Fair”; and a classification of a **High** difference from *baseline* corresponds with CCME classes “Marginal” and “Poor”. Although the CCME index is typically calculated using comparisons against water quality guidelines, it is customized for each station where it is applied to suit local conditions and concerns, and the use of regional norms as benchmarks is an appropriate use of this index (Government of Canada 2008, S. Pappas, Environment Canada, pers. comm. 2009).

3.2.3 Benthic Invertebrate Communities and Sediment Quality

3.2.3.1 Benthic Invertebrate Communities Component

The analytical approach for the Benthic Invertebrate Communities component was based on the analytical approach described in the RAMP Technical Design and Rationale (RAMP 2009b) and consisted of:

- selecting benthic invertebrate community measurement endpoints;
- statistical testing for differences in the values of the measurement endpoints between upstream *baseline* and downstream *test* reaches and in trends over time of the measurement endpoints;
- temporal comparison of the values of the measurement endpoints from reaches and stations designated as *test* to historical conditions for those reaches and stations and to regional *baseline* conditions of reaches and stations of similar habitat conditions (Athabasca River Delta, depositional reaches, erosional reaches, or lakes);
- a discussion of the ecological requirements and environmental tolerances of benthic invertebrate community taxa enumerated in the 2015 WY at reaches and stations using published literature and information; and
- classification of the results of the statistical testing into an overall assessment of the extent of differences in benthic invertebrate communities at a given *test* reach or station compared to: (i) when the reach or station was designated as *baseline*; and (ii) upstream *baseline* reaches (if applicable).

Benthic Invertebrate Community Measurement Endpoints

For each sample, the following benthic invertebrate community measurement endpoints were calculated (Environment Canada 2010):

- Abundance (mean number of individuals per replicate sample);
- Taxon richness (number of distinct taxa);
- Equitability, where

$$\text{Equitability} = \frac{1}{\frac{\sum (p_i)^2}{S}}$$

p is the proportion of S made up of the *i*th species and S is the total number of taxa in the sample; and

- Percent EPT (Ephemeroptera, Plecoptera, Trichoptera).

The data were also ordinated using Correspondence Analysis (CA) to provide a multivariate assessment of spatial and temporal variations in composition of benthic invertebrate communities (see Appendix D for a description of the ordination method). Separate ordinations were carried out for benthic invertebrate communities from the Athabasca River Delta (ARD), lakes, and depositional river reaches[5] because these three types of habitat can be anticipated to produce distinct faunal assemblages and on the basis of previous analyses had demonstrated differences in the composition of benthic invertebrate communities.

The measurement endpoints for benthic invertebrate communities were calculated for each sample and then averaged for each reach or lake.

Statistical Testing for Differences

The benthic invertebrate community dataset for the study area is sufficiently large that there is high power associated with analyses that test for statistical differences in time trends of measurement endpoints or differences in values of measurements between *test* and *baseline* locations, with an error-degrees-of-freedom that is frequently greater than 100. The ability to detect differences is substantive, with the detectable effect sizes much less than the within-reach-standard deviation (SD) (i.e., small differences, Cohen 1977; Kilgour et al. 1998). Differences that are calculated as statistically-significant may therefore be minor, subtle, or otherwise trivial.

The following three factors are considered in evaluating the potential effects of oil sands development on benthic invertebrate communities in order to account for this statistical power and to ensure differences that are identified are meaningful:

- statistical significance in differences in values of measurement endpoints for benthic invertebrate communities from specific hypotheses of change;
- the nature of any statistically-significant differences that are identified; and
- the amount of the variation in the values of the measurement endpoints that is explained by the statistically-significant differences.

[5] Benthic invertebrate community data from erosional habitats were not ordinated in 2015 due to the change in sampling technique.

Each is explained in more detail below.

Determination of Statistically-Significant Differences in Measurement Endpoints for Specific Hypotheses of Change

Variation in benthic invertebrate community measurement endpoints were evaluated using analysis of variance (ANOVA) to statistically compare values of these measurement endpoints in reaches designated as *test* to upstream *baseline* reaches and/or to pre-oil sands development conditions since sampling in the study area began in 1997. When necessary, measurement endpoints were $\log_{10}$-transformed to meet assumptions of normality and homogeneity of variances. Variation in measurement endpoints in the ARD and in lakes were adjusted to account for the influences of the percentage of sand (ARD) and water depth (lakes) (ANOVAs used values adjusted to a common % sand or depth see Appendix E). One-way ANOVAs were first computed for each measurement endpoint with each reach-year or lake-year combination as the factorial variable (as appropriate given the hypothesis being tested). Planned linear orthogonal contrasts (Hoke et al. 1990) were then used to test specific hypotheses related to potential effects potentially associated with oil sands operations. In all cases, the comparisons were tested against the residual error of the overall one-way ANOVA.

The specific hypotheses that were tested varied with the availability of *baseline* and *test* period data in both *test* and *baseline* locations. In cases in which lower *test* reaches (e.g., *test* reach JAC-D1, lower Jackpine Creek) had a corresponding upstream *baseline* reach in the same watershed (e.g., *baseline* reach JAC-D2, upper Jackpine Creek) and when there were data for both reaches in both *baseline* and *test* periods, the testable hypotheses were:

- H_{O1}: No change in the differences of means of measurement endpoints in the *test* reach from *baseline* to *test* periods;
- H_{O2}: No difference in the means of measurement endpoints in the *test* period, between *baseline* and *test* reaches; and
- H_{O3}: No change in the differences of means of measurement endpoints between the *test* and *baseline* reaches in the current year, compared to the differences in the *baseline* period.

In cases in which lower *test* reaches did not have a similar local or upstream *baseline* reach (e.g., *test* reach TAR-D1, lower Tar River) but there was *baseline* and *test* period for the *test* reach, the testable hypotheses were:

- H_{O4}: No difference from *baseline* to *test* periods in means of measurement endpoints; and
- H_{O5}: No change in trend over time in means of measurement endpoints during the *test* period.

Nature of Statistically-Significant Differences

Because of the power of the statistical tests described above, the nature of the statistically-significant differences were examined to determine if the differences were consistent with a negative change in the benthic invertebrate community. The following were the negative changes that were noted:

- decrease in taxa richness;
- decrease in percent EPT;

- increase in equitability;
- change in either the CA Axis 1 or CA Axis 2 scores that professional judgment indicated was potentially a negative change;
- changes in abundance that professional judgment indicated was a potential negative change; and
- excessively high abundance (i.e., in the order of hundreds of thousands of organisms per m^2) if the fauna was dominated by one or a few taxa (Kilgour et al. 2005), and might be consistent with a nutrient enrichment effect (Lowell et al. 2003).

Amount of the Variation Explained by the Statistically-Significant Differences

Prior analysis of the benthic invertebrate community data has suggested that changes were easier to interpret when the change accounted for at least 20% of the variation in the annual means; this additional criterion is used this year to identify meaningful changes. A change that explains 20% of the variation is equivalent to an effect size of 1 standard deviation (i.e., means differ by 1 SD).

Assessment for Erosional Reaches

The analyses described above were used to evaluate Ekman grab data collected for ARD channels, lakes, and depositional reaches. Variations in erosional reaches were not evaluated as above, because of the change in the field methods that occurred in the 2015 WY, and because there was concern that historical data would not be considered comparable (in the strictest sense) to the kick-net data collected in the 2015 WY. The erosional kick-net data from the 2015 WY were, however, compared to historical and "harmonized" Hess data (reach by reach). A data-harmonization procedure was developed (Appendix E) that "translated" the: (i) values of the measurement endpoints from samples from erosional reaches that were collected prior to 2015 with a Neil-Hess cylinder; and (ii) those from erosional reaches collected in the 2015 WY with CABIN kick-net sampling.

Environmental Variables

Environmental variables measured at each reach and station were examined if the criteria for determination of changes in benthic invertebrate communities described above were met.

Temporal Comparisons

A temporal comparison was made of the values of the measurement endpoints from reaches and stations designated as *test* to historical conditions for those reaches and stations and to regional *baseline* conditions of reaches and stations of similar habitat conditions (ARD, depositional reaches, erosional reaches, or lakes)[6].

Results were presented graphically for each of the measurement endpoints (an example is provided in Figure 3.2-4), with trends over time in values of each of the measurement endpoints at a given *test* reach or station compared to an expected normal range in values. The derivation of normal ranges is described below.

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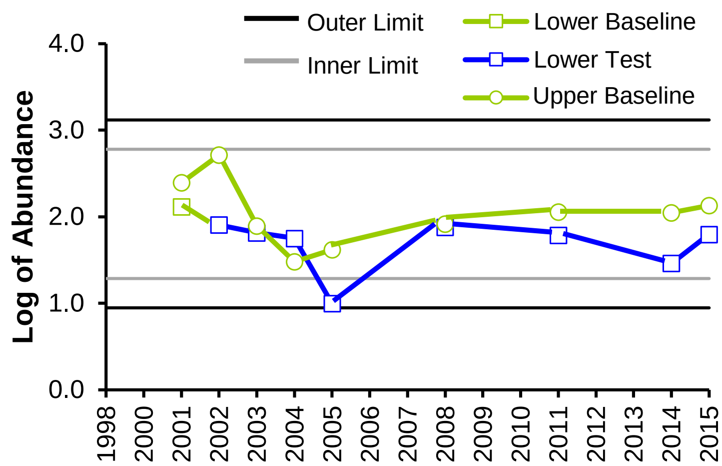
[6] Again, environmental variables measured at each reach and station were examined if temporal comparisons suggested differences between a *test* reach or station and historical conditions or regional *baseline* conditions.

Figure 3.2-4 Example of a time trend chart showing the total abundance (log_{10}) of a benthic invertebrate community in relation to the within-reach range of variability, in this case, for the Clearwater River.



Note: The inner and outer tolerance limits are the confidence region for each of the lower 5th and upper 95th percentiles.

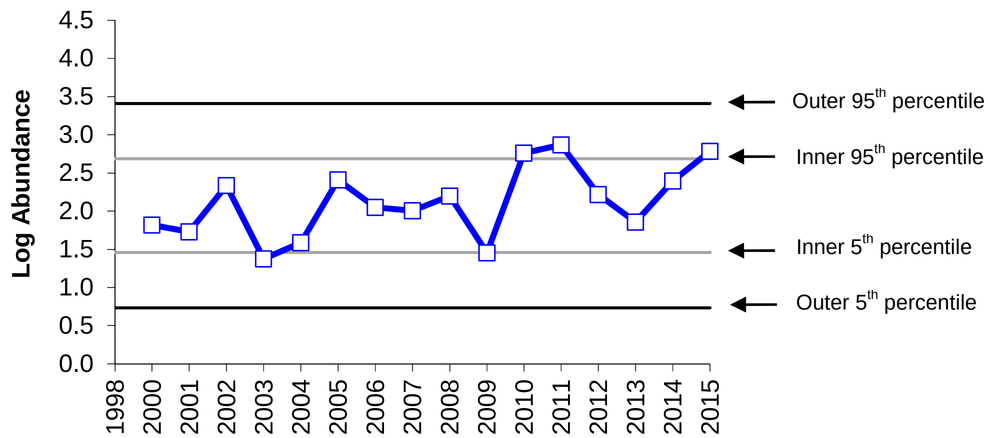
Determination of Normal Ranges

For this analysis, “normal range” is the range of values within which a measurement endpoint might be expected to vary and is represented by the 5th and 95th percentiles of the set of data. Normal range for the assessment of *test* reaches in 2015 were calculated as:

- the within-reach normal range using data from all previous years for a *test* reach or delta channel where more than eight years of data exists;
- the within-reach normal range using data from all previous years for a *test* lake where a regional assessment was not possible; and
- the among-*baseline*-reach normal range using all available data from *baseline* reaches, grouped by erosional or depositional habitat, up to and including 2014.

The within-reach (or lake or channel) normal range was considered first, and an exceedance of limits was followed up with a comparison to regional normal ranges. Inner tolerance limits (Figure 3.2-5) were then calculated for the 5th and 95th percentiles that define the normal range of observations, using the methodology described in Hunt et al. (2001), Smith (2002), and Krishnamoorthy and Mathew (2009). The purpose of the inner tolerance limits for the 5th and 95th percentiles of normal ranges is to identify a range of values of measurement endpoints (between the inner tolerance limits and the 5th and 95th percentile values) that may or may not be unusual but can be flagged as a trigger for further investigation, if required (values inside the inner tolerance limits <u>are not</u> unusual, while values outside the outer tolerance limit clearly <u>are</u> unusual, relative to the “normal range”).

Figure 3.2-5 Example of outer and inner 95th and 5th percentiles representing the normal range for Shipyard Lake.



Comparison to Published Literature

Benthic invertebrate communities (and associated measurement endpoints) at *baseline* reaches vary in relation to local and regional variations in climatic conditions, hydrological influences, and underlying geological conditions. The *baseline* database; therefore, provides (*de facto*) the most appropriate set of regional *baseline* conditions and information against which to assess differences observed at *test* reaches. The literature pertaining to freshwater benthic macro invertebrates; however, has been well developed over the past ~60 years, with the general ecological requirements and tolerances of many taxa encountered in the oil sands region being relatively well described. Some consideration for general tolerances/ requirements, therefore, was taken from Hynes (1970), Plafkin et al. (1989), Klemm et al. (1990), Thorp and Covich (1991), Bode (1996), and Mandeville (2002), among others.

Classification of Results

The criteria used for classifying results of benthic invertebrate communities focused on whether:

1. Measurement endpoints for benthic invertebrate communities at a given *test* location demonstrated a significant change from historical (H_{O1} or H_{O5}) or baseline conditions (H_{O3}), with significance defined as meeting all three of the following conditions: (i) $p<0.05$ in the statistical test; (ii) the effect accounted for a least 20% of the variation in annual means; and (iii) this difference implied a negative change and degrading conditions (see *Nature of Statistically-Significant Differences*, above);

2. Measurement endpoints for benthic invertebrate communities at a given *test* location demonstrated a significant difference from *baseline* locations (H_{O2} or H_{O4}), with significance defined as meeting all three of the conditions described in (1), above; and

3. Values of measurement endpoints for benthic invertebrate communities at a given *test* location exceeded regional *baseline* conditions, i.e., if values of measurement endpoints were lower or greater than the inner tolerance limits for the 5th or 95th percentiles, respectively and if these differences implied a negative change and degrading conditions.

Measured variations were classified as **Negligible-Low**, **Moderate**, or **High** on the basis of these three factors (Table 3.2-6) as follows:

1. If any one or two of the six measurement endpoints for benthic invertebrate communities (abundance, taxa richness, percent EPT taxa, equitability, and CA Axis 1 or CA Axis 2 scores) met the conditions for any one of the three factors, above, measured variations were classified as **Moderate**;
2. If three or more of the six measurement endpoints for benthic invertebrate communities met the conditions for any one of the three factors, above, measured variations were classified as **High**; or
3. Measured variations not meeting either of these criteria were classified as **Negligible-Low**.

Table 3.2-6 Classification of results for the Benthic Invertebrate Communities component of the 2015 JOSMP.

Criterion	Criteria for "Yes"	Classification		
		Negligible-Low	Moderate	High
Statistical significance	For **one or two** measurement endpoints: (i) p<0.05 in the statistical test; (ii) the effect accounted for a least 20% of the variation in annual means; and (iii) this difference implied a negative change and degrading conditions	No	Yes	No
	For **three or more** measurement endpoints: (i) p<0.05 in the statistical test; (ii) the effect accounted for a least 20% of the variation in annual means; and (iii) this difference implied a negative change and degrading conditions	No	No	Yes
Exceed baseline range of variation	**One or two** measurement endpoint means fell beyond the inner tolerance limit for either the 5th or 95th percentile for the normal range of *baseline* variability with these differences implying a negative change and degrading conditions	No	Yes	No
	Three or more measurement endpoint means fell beyond the inner tolerance limit for either the 5th or 95th percentile for the normal range of *baseline* variability with these differences implying a negative change and degrading conditions	No	No	Yes

3.2.3.2 Sediment Quality Component

The analytical approach undertaken for the Sediment Quality component for the 2015 report followed that of previous RAMP reports (RAMP 2014) and the JOSMP 2014 report (JOSMP 2015) and consisted of:

- the review and selection of particular sediment quality variables as measurement endpoints;

- a tabular presentation of the results from the 2015 WY, comparing concentrations of sediment quality measurement endpoints to concentrations previously observed at each station, and sediment quality guidelines where available;
- a graphical presentation of the results from the 2015 WY describing particle-size distribution, TOC, total metals (both absolute and normalized to percent-fines), total hydrocarbons, total PAHs (both absolute and normalized to 1% TOC), and predicted PAH toxicity, using an equilibrium-partitioning approach to assess potential for chronic toxicity from PAH mixtures in sediments described by Neff et al. (2005); and
- the calculation of a Sediment Quality Index.

Selection of Sediment Quality Measurement Endpoints

The large number of sediment quality variables measured at each station was reduced to a set of key measurement endpoints that were the primary focus of most of the analysis and reporting. The exception to this is the Sediment Quality Index (SQI), which used a larger number of sediment quality variables in accordance with the methodology for the index presented in http://www.ccme.ca/ourwork/water.html?category_id=103.

Identical sediment quality measurement endpoints were used in the 2015 report as were used in the previous 2014 JOSMP report (JOSMP 2015) and were selected based on:

- sediment quality measurement endpoints listed in the EIAs of oil sands projects as being potentially affected by oil sands development activities (RAMP 2009b);
- sediment quality variables of interest listed in the RAMP 5-year report (Golder 2003);
- results of correlation analysis of the sediment quality dataset from 1997 to 2004 that identified significant inter-correlation of various sediment quality variables; and
- sediment quality variables that assist in interpreting the results of the Benthic Invertebrate Communities component.

The following sediment quality measurement endpoints were selected:

- *Particle size distribution (clay, silt, and sand)* – sediment particle size is an indicator of depositional regime at a given station, and an important factor affecting organic chemical sorption;
- *Total carbon and total organic carbon* –indicators of the organic matter and inorganic carbon in sediment, including hydrocarbons;
- *Total hydrocarbons (CCME fractions + BTEX)* – indicators of the total hydrocarbon content of sediments, with each indicator (fraction) capturing hydrocarbon compounds of different molecular weights (specifically, number of carbon atoms), and concentrations of benzene, toluene, ethylbenzene, and xylene (collectively called BTEX), based on methods presented by CCME (2001);
- Various *PAH* measurement endpoints, including:

- *Total PAHs* – a sum of concentrations of all PAHs measured in a given sample, including parent and alkylated forms;
- *Total parent PAHs* – a sum of concentrations of all non-alkylated PAHs measured in a given sample;
- *Total alkylated PAHs* – a sum of concentrations of all alkylated PAHs measured in a given sample;
- *Naphthalene* – a volatile, low-molecular-weight PAH that may cause toxicity when dissolved in water;
- *Total dibenzothiophenes* – a sulphonated PAH (parent and alkylated forms) that is associated with bitumen (i.e., petrogenic);
- *Retene* – an alkylated phenanthrene generated through decomposition of plant materials (i.e., biogenic rather than petrogenic); and
- *Predicted PAH toxicity* – an estimate of the cumulative potential for chronic toxicity of all PAHs in a sediment sample, following methods described in Neff et al. (2005). Sediments with a calculated hazard index value greater than 1.0 have the potential to be toxic to aquatic organisms (USEPA 2004). See Appendix D for further details on the calculation of the predicted PAH toxicity;

- *Metals* – With the exception of the sum of total metals, only metals in sediment that exceeded CCME Interim Sediment Quality Guideline (ISQG) values (CCME 2002) were presented, as metals in sediments are not listed in oil sands EIAs as being potentially affected by oil sands development (RAMP 2009b); and
- *Sublethal toxicity* – sublethal toxic effects of whole sediment samples on the survival and growth of the amphipod (seed-shrimp) *Hyalella azteca* (14-day test) and the midge *Chironomus tentans* (10-day test).

Tabular and Graphical Presentation of 2015 Sediment Quality Results

The 2015 sediment quality data for each sediment quality measurement endpoint were tabulated for each station sampled. Historical variability also was presented for each measurement endpoint, represented by minimum, maximum, and median values observed (as well as number of observations) from 1997 to 2014. Concentrations of any sediment quality measurement endpoint and any metal that exceeded relevant guidelines were also reported.

Data for eight of the sediment quality measurement endpoints representative of physical characteristics, and metals and hydrocarbon content (i.e., particle size distribution, carbon content, sum of concentrations of total metals, sum of concentrations of total metals normalized to percent fine sediments, concentration of total PAHs, concentration of total PAHs normalized to 1% TOC, concentrations of CCME hydrocarbon fractions, and PAH Hazard Index), were presented graphically in the context of regional variability, represented by the 5^{th} and 95^{th} percentiles of regional *baseline* values for the measurement endpoints, by presenting data for each station for all years of sampling to allow for the assessment of any temporal trends (Table 3.2-7).

Table 3.2-7 Regional *baseline* values for sediment quality measurement endpoints, using data from 1997 to 2015.

Measurement Endpoint	Unit	n	Percentiles				
			5th	25th	Median	75th	95th
Particle Size Distribution							
% Clay	%	58	0.5	2.16	4.26	7.7	21.33
% Sand	%	58	31.34	70.1	90.75	95.6	99.1
% Silt	%	58	0.33	1.57	5.72	20.75	40.12
Carbon Content							
Inorganic Carbon	%	100	0.04	0.1	0.10	0.17	0.5
Total Organic Carbon	%	102	0.1	0.24	0.65	2.00	16.36
TOC + TIC	%	59	0.14	0.34	0.75	2.16	16.86
Metals							
Total Metals[1]	mg/kg	102	41.7	92.68	162.23	257.05	523.76
Total metals normalized to percent fines	mg/kg	99	472.8	715.5	1162.66	2099.68	7347.2
Total Arsenic	mg/kg	60	0.7	1.7	2.6	3.76	11.28
PAHs							
Total Parent PAHs	mg/kg	58	0.002	0.004	0.011	0.039	0.134
Total Alkylated PAHs	mg/kg	58	0.013	0.026	0.111	0.613	3.576
Total PAHs	mg/kg	101	0.016	0.055	0.1642	1.265	11.745
PAH Hazard Index	mg/kg	100	0.026	0.153	0.308	0.742	2.195
Total PAHs normalized to 1% TOC	mg/kg	101	0.038	0.097	0.255	0.719	5.013
CCME Fractions							
CCME Fraction 1BTEX	mg/kg	75	5	5	10	10	33
CCME Fraction 1	mg/kg	75	5	5	10	10	33
CCME Fraction 2	mg/kg	75	5	15	20	27	123
CCME Fraction 3	mg/kg	75	6	20	35	206	1,990
CCME Fraction 4	mg/kg	75	6	20	23	157	1,100
Total Hydrocarbons (C1-C4)	mg/kg	75	21	60	88	399	3,246

[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

Classification of Results

Sediment quality at each monitoring station from fall 2015 was summarized into a single index value, using an approach based on the CCME Sediment Quality Index. A detailed description of the CCME Sediment Quality Index and how it is calculated is found at http://www.ccme.ca/ourwork/water.html?category_id=103. Its specific application is described below.

This index was calculated using comparisons of observed sediment quality against regional *baseline* conditions described above but for a wider set of water quality variables. Specifically, the concentration of 78 sediment quality variables (selected based on their frequency of detection in all samples, and including all hydrocarbon fractions, 43 specific PAH species, and 28 metals that were commonly detectable in sediment samples) were compared to their 95th percentile of *baseline* concentrations The calculation of the Sediment Quality Index considered three factors: (i) the percentage of variables with values that exceeded regional *baseline* conditions; (ii) the percentage of comparisons that exceeded regional *baseline* conditions; and (iii) the degree to which observed values exceeded regional *baseline* conditions.

Index values were calculated for all *baseline* and *test* stations. Calculation of Sediment Quality Index values for all stations sampled in fall since 1997 (n=449) yielded index values ranging from 25.1 to 100. It should be noted that historical values for the Sediment Quality Index calculated for specific observations may change from year to year, given that 95th percentile values for individual variables included in the index may change with addition of new *baseline* data to the data record.

Sediment Quality Index scores were classified using the following scheme:

- 80 to 100: **Negligible-Low** difference compared to regional *baseline* conditions;
- 60 to 80: **Moderate** difference compared to regional *baseline* conditions; and
- Below 60: **High** difference compared to regional *baseline* conditions.

Sediment quality index scores were not calculated for lakes, following concerns expressed by the 2011 RAMP Peer Review (AITF 2011) regarding combining streams and lakes in the determination of regional *baseline* ranges.

3.2.4 Fish Populations Component

The analytical approach used in 2015 for the Fish Populations component was based on the analytical approach described in the RAMP Technical Design and Rationale document (RAMP 2009b) and consisted of one or more of the following:

- selecting fish population measurement endpoints;
- presenting results in tabular and graphical format comparing 2015 fish population measurements endpoints to historical or *baseline* results for each monitoring activity;
- conducting analysis of covariance (ANCOVA), analysis of variance (ANOVA), a non-parametric Kolmogorov-Smirnov analysis of variance test, or Mann-Kendall trend analysis on measurement endpoints to test for differences in time trends, and/or differences between *baseline* and *test* reaches;
- conducting a power analysis to determine whether sample size was adequate to effectively detect differences in measurement endpoints among reaches;
- comparing results to published literature; and
- selecting and using criteria to assess change in fish population measurement endpoints both spatially and temporally.

3.2.4.1 Fish Community Monitoring

Selection of Measurement Endpoints

Several conventional measurement endpoints of fish communities were calculated using the fish data:

- *Total abundance* – the total number of fish caught in the reach, divided by the lineal length of the reach (No. of fish/m);

- *Catch-per-unit-effort* – the total number of fish caught per 100 seconds of electrofishing;
- *Richness* – the total number of fish species collected per reach. Higher richness values are typically used to infer a "healthier" fish community;
- *Diversity* – this measurement endpoint was computed for each reach following the calculation for Simpson's Diversity (D):

$$D = 1 - \sum (p_i)^2$$

where,

  - p_i is the proportion of the total abundance accounted for by species *i.*

  Higher diversity values are typically used to infer a "healthier" fish assemblage; and

- *Assemblage Tolerance Index (ATI)* – The ATI was developed by Whittier et al. (2007) for stream and river fish assemblages in the western United States to quantify a species' tolerance to an overall human disturbance gradient (Table 3.2-8). For species captured in the Athabasca oil sands region but not assessed by Whittier et al. (2007), a number was assigned based on species similarity to those with calculated values. With this index, lower tolerance values imply a species that is more sensitive to disturbance.

Table 3.2-8 Tolerance values for fish collected during the fish community monitoring program of the 2015 JOSMP (adapted from Whittier et al. 2007).

Common Name	Species Code	Tolerance Value
Arctic grayling	ARGR	2.0
brook stickleback*	BRST	9.4
burbot	BURB	2.0[1]
cisco	CISC	2.5[1]
emerald shiner	EMSH	6.9
finescale dace*	FNDC	7.0
fathead minnow*	FTMN	8.3
goldeye	GOLD	9.3
lake chub*	LKCH	5.5
lake whitefish*	LKWH	2.5[1]
longnose dace*	LNDC	6.2
longnose sucker*	LNSC	4.6
northern redbelly dace*	NRDC	7.0[1]
northern pike	NRPK	7.8
pearl dace*	PRDC	6.7
slimy sculpin*	SLSC	3.0[1]
spoonhead sculpin	SPSC	3.0[1]
spottail shiner*	SPSH	7.7
trout-perch*	TRPR	8.4
walleye	WALL	8.7
white sucker*	WHSC	7.6
yellow perch	YLPR	7.4

* Commonly-caught fish species of Athabasca River tributaries in the Athabasca oil sands region.

[1] Professional judgment based on values for similar species.

Temporal Trends and Spatial Comparisons

Measurement endpoints of fish community monitoring were tabulated and displayed graphically for each reach. Possible changes in fish communities were evaluated by comparing measurement endpoints in reaches designated as *test* to upstream *baseline* reaches and regional *baseline* reaches and/or across years within a reach. When necessary, the measurement endpoints were $\log_{10}$-transformed or ranked to meet assumptions of normality and homogeneity of variances. For reaches where there were three years of data, an one-way analysis of variance (ANOVA) was conducted for each fish community measurement endpoint with each reach-year combination as the factorial variable. The ANOVA used variations within reaches to assess the significance of linear time trends. Linear contrasts were used to carry out the analysis of variance and to test the specific hypothesis. Planned linear orthogonal contrasts (Hoke et al. 1990) were then used to identify differences in time trends between lower *test* reaches and upper *baseline* reaches. In all cases, the comparisons were tested against the residual error of the overall one-way ANOVA.

The nature of statistically-significant differences was examined to determine if the difference was consistent with a negative change in the fish community. A decrease in taxa richness, an increase in ATI and a decrease in diversity would each be considered a negative change or difference. Similar to statistical analyses conducted for the Benthic Invertebrate Communities component, changes are more easily interpreted when the change accounts for at least 20% of the variation in the annual means and this criterion was used this year as an additional screening for identifying meaningful effects. An effect that explains 20% of the variation is equivalent to an effect size of 1 standard deviation; i.e., means differ by 1 SD. Therefore, a statistically-significant difference was considered to have a strong statistical signal when an effect explained 20% of the variation in the annual means.

In cases where there is an upstream *baseline* reach, the hypothesis that was tested was:

- H_{O1}: No difference in time trends in mean values of measurement endpoints between *test* and *baseline* reaches.

In the case when there were no local *baseline* data for a lower *test* reach, the hypothesis that was tested was:

- H_{O2}: No trend over time in mean values of measurement endpoints.

Comparison to Published Literature

There are no conventional “guidelines” *per se* against which to assess observed differences in measurement endpoints of fish communities given *baseline* ranges of variation tend to depend on local or regional climatic, hydrological, and geological conditions. Consequently, *baseline* reach data, data for select reaches from previous RAMP/JOSMP fish community monitoring results (RAMP 2010 to 2014, JOSMP 2015), and published literature of fish surveys conducted within the study area (Golder 2004; AOSERP; FWMIS database) provide the most appropriate set of regional *baseline* conditions and information against which to assess potential change(s) observed in *test* reaches.

Results from the 2015 WY Relative to Regional Baseline Conditions

A temporal comparison was made of the values of the measurement endpoints from reaches designated as *test* to regional *baseline* conditions of reaches. Results were presented graphically for each of the measurement endpoints with trends over time in values of each of the measurement endpoints at a given *test* reach compared to an expected normal range in values. The derivation of normal ranges is described below.

Determination of Normal Ranges

Using the "normal range of variation" of a baseline condition as an ecological criterion implies that some fraction of a baseline dataset is used to define the expected range of values for a given measurement endpoint. The normal range of variation in measurement endpoints for *baseline* reaches were calculated similarly to the ranges for benthic invertebrate communities (see Section 3.2.3.1) (within-reach ranges were not calculated given the small sample size of data available for each reach). The first step was to determine which fish community reaches were similar in habitat conditions in order to group *baseline* reaches according to their similarities. A principal components analysis (PCA) of the physical and chemical habitat data for each of the 53 *baseline* reach x year combinations was conducted to determine how the various habitat attributes covaried, and to select a sub-set of variables that would be used to explore causes of variation in measurement endpoints of fish communities. The PCA was conducted using the habitat variables described in Table 3.2-9.

Table 3.2-9 Habitat variables included in the principal components analysis used to assess covariation and to identify multivariate habitat variables (PC axis), 2015 JOSMP.

maximum water depth	dissolved oxygen concentration
bankfull width	conductivity
wetted channel width	pH
left bank height	water temperature at the time of the sampling
right bank height	instream cover as algae
left bank angle	instream cover as macrophytes
right bank angle	instream cover as large woody debris (LWD)
flow at mid-channel	instream cover as small woody debris (SWD)
depth at mid-channel	instream cover as trees; instream cover as undercut banks
instream cover as boulders	small tree canopy scores for both left and right banks
large tree canopy scores for both left and right banks	understory scores for both left and right banks
canopy LWD scores for both left and right banks	canopy SWD scores for both left and right banks

Data for all habitat variables were scaled by unit variance prior to conducting the PCA to ensure that all data were comparable.

Principal component axes explaining greater than 10% of the total variance in habitat features were carried forward for further interpretation (Jackson 1993). Pearson correlations (i.e., Pearson *r*-values) between individual variables and the "significant" PCA axes that were >|0.6| were considered strongly associated with an axis.

Based on the results of the PCA and Pearson correlations, variables that explained some variability across *baseline* reaches included (see Appendix E for the complete analysis):

- mean bankfull and wetted width;
- depth at mid-channel;
- instream macrophytes;
- instream cover as boulders;
- right bank big tree canopy cover;
- small tree canopy cover for both left and right banks;
- understory shrub cover for both left and right banks;
- SWD for both left and right banks; and
- LWD for both left and right banks.

Spearman rank correlations were calculated between these habitat variables that were highly correlated ($p \leq 0.05$, $r_s \geq |0.271|$) with PCA axes explaining greater than 10% of the total variance in habitat features (as mentioned above) and measurement endpoints (CPUE, total abundance, richness, diversity, and ATI). This step identified which habitat characteristics were driving changes in measurement endpoints at all reaches (see Appendix E for the complete analysis).

Using habitat variables that were significantly correlated with PCA axes and measurement endpoints, a cluster analysis was performed to group reaches of similar habitat variables. Three main groupings of *baseline* and *test* reaches were observed based on mid-channel depth, instream macrophyte coverage, instream boulder coverage, and understory shrub coverage. Therefore, normal ranges of *baseline* variation were calculated by grouping *baseline* reaches using the following characteristics (Table 3.2-10):

- Habitat Cluster 1 – shallow channel with few instream macrophytes, few boulders, and an abundance of understory shrubs;
- Habitat Cluster 2 – deep channel with abundant instream macrophytes, few boulders, and few understory shrubs; and
- Habitat Cluster 3 – shallow channel with few instream macrophytes, an abundance of boulders, and few understory shrubs.

Table 3.2-10 Regional *baseline* fish community data groups and reach comparisons, 2015 JOSMP.

Habitat Cluster	*Baseline* Reaches Used in Creating Regional Comparison[1]	Reaches (2015) Compared Against Regional *Baseline* Range
1. Birch Creek, Upper Ells River, Lower Jackpine Creek, Upper Tar River, Lower Calumet River, Mid MacKay River, Mid Muskeg River, and Lower Steepbank River.	BRC-F1 (2013-2015), ELR-F3 (2013-2014), JAC-F2 (2009-2015), TAR-F2 (2011-2015)	JAC-F1, MUR-F2, STR-F1
2. Upper Muskeg River, Sawbones Creek, Unnamed Creek (east and south of Christina Lake), Beaver River, and Upper Calumet.	BER-F2 (2009-2013), CAR-F2 (2012)	UNC-F2, UNC-F3, SAC-F1
3. Mid Ells River, Christina River, Lower Ells River, Firebag River, Fort Creek, Gregoire River, Lower Jackfish River, Upper and Lower MacKay River, Lower Muskeg River, Poplar Creek, Sunday Creek, Lower Tar River, Big Creek, Eymundson Creek, High Hills River, Pierre River, Redclay Creek, and Mid Steepbank River.	BIC-F1 (2013-2014), CHR-F4 (2013-2014), ELR-F2 (2010-2011), ELR-F2A (2012), EYC-F1 (2013-2014), FIR-F2 (2013), HHR-F1 (2011-2014), MAR-F3 (2011-2014), PIR-F1 (2013-2014), RCC-F1 (2013-2014), STR-F2 (2011-2015), SUC-F2 (2013-2015)	MAR-F1, ELR-F1, CHR-F2, SUC-F1, JAR-F1

[1] See Table 3.1-28 and Table 3.1-29 for classification of reach status by year. Where reach status changed from *baseline* to *test* from 2009 to 2015, only *baseline* data were used in the determination of regional fish habitat characteristics.

The normal range of variability in measurement endpoints for the assessment of *test* reaches in 2015 was calculated as the among-*baseline*-reach range using all available data from *baseline* reaches, grouped by the above classifications, up to and including the current year (Table 3.2-11). As with the Benthic Invertebrate Communities component, Inner tolerance limits were calculated for the 5th and 95th percentiles that define the normal range of observations, using the methodology described in Hunt et al. (2001), Smith (2002), and Krishnamoorthy and Mathew (2009) in order to identify a range of values of measurement endpoints (between the inner tolerance limits and the 5th and 95th percentile values) that may or may not be unusual but can be flagged as a trigger for further investigation, if required.

Table 3.2-11 Regional *baseline* ranges for fish community measurement endpoints for each cluster group for the 2015 JOSMP.

Cluster Group	Measurement Endpoint	Outer Tolerance Limit on the 5th Percentile	5th percentile	Inner Tolerance Limit on the 5th Percentile	Inner Tolerance Limit on the 95th Percentile	95th percentile	Outer Tolerance Limit on the 95th Percentile
1	Mean Abundance (#/m)	0.00	0.01	0.00	0.65	0.73	1.09
	Total Richness	0.00	0.34	0.00	5.18	6.40	9.32
	Mean Diversity	0.00	0.00	0.00	0.68	0.67	1.08
	Mean ATI	0.00	0.60	0.00	6.26	8.20	12.80
	CPUE (No./100 sec)	0.00	0.15	0.00	8.78	10.37	15.44
2	Mean Abundance (#/m)	0.00	0.06	0.00	0.21	0.29	0.62
	Total Richness	0.00	1.60	0.00	4.24	6.50	12.90
	Mean Diversity	0.00	0.03	0.00	0.56	0.62	1.54
	Mean ATI	2.25	6.18	0.00	2.48	8.99	12.40
	Mean CPUE (No./100 sec)	0.00	1.28	0.00	4.80	6.47	13.35
3	Mean Abundance (#/m)	0.00	0.06	0.00	0.45	0.52	0.70
	Total Richness	0.00	2.00	0.00	5.26	8.55	10.50
	Mean Diversity	0.00	0.13	0.00	0.47	0.71	0.96
	Mean ATI	0.00	0.04	0.00	5.24	6.99	10.21
	Mean CPUE (No./100 sec)	0.00	1.37	0.00	5.95	7.36	10.16

Classification of Results

The criteria used for classifying results of fish communities focused on four factors:

1) Whether the measurement endpoints for the fish community significantly differed from the upstream *baseline* reach (if applicable) ($p \leq 0.05$, H_{O1}: No difference in time trends in mean values of measurement endpoints between *test* and *baseline* reaches) and if so, whether it implied a negative change to fish communities at the *test* reach;

2) Whether the measurement endpoints for the fish community significantly changed across years ($p \leq 0.05$, H_{O2}: No trend over time in mean values of measurement endpoints), and if so, whether it implied a negative change to fish communities;

3) Whether the statistically significant trend or difference produced a strong statistical signal (i.e., did the effect account for at least 20% of the variation in the annual means); and

4) Whether or not the measurement endpoints for the fish community at a *test* reach exceeded normal ranges of *baseline* variability;

Measured changes were classified as **Negligible-Low**, **Moderate**, or **High** on the basis of these four factors (Table 3.2-12). There are five measurement endpoints assessed for fish communities (abundance, CPUE, richness, Simpson's Diversity, and the Assemblage Tolerance Index). If any one of those measurement endpoints produced a strong statistical signal implying a negative change to fish communities in 2015 compared to previous years (i.e., factors 1, 2, and 3), and/or if the mean in 2015 fell between the inner and outer tolerance limits or outside the outer tolerance limits for the 5th or 95th percentile for the normal range of *baseline* variability (i.e., factor 4), then the **Moderate** criterion was considered to have been met. This criterion was particularly relevant for the assessment of reaches for which there was at least a three-year data record. Allowing any one of the five measurement endpoints to trigger this criterion assumed that each measurement endpoint represented an attribute of the community that was important. If any three of the key measurement endpoints produced a strong statistical signal (i.e., factors 1, 2, and 3), then the conclusion was that a **High** level of change had been detected. A **High** level of change was also detected if any three measurement endpoint values had fallen outside of the normal range of *baseline* variability within the current year or if a measurement endpoint was outside the normal range of *baseline* variability for three consecutive years (i.e., factor 4).

Table 3.2-12 Classification of results for the fish community monitoring program of the 2015 JOSMP.

Criterion	Criteria for "Yes"	Strong signal[1]?	Classification		
			Negligible-Low	Moderate	High
Statistical significance	A statistically significant trend or difference was observed in **one or two** measurement endpoints that implied a negative change to the fish community.	No	Yes	No	No
		Yes	No	Yes	No
	A statistically significant trend or difference was observed in **three or more** measurement endpoints that implied a negative change to the fish community.	No	Yes	No	No
		Yes	No	No	Yes
Exceed *baseline* range of variation	**One or two** measurement endpoint means fell between the inner and outer tolerance limits or outside the outer tolerance limits for the 5th or 95th percentile for the normal range of baseline variability.	-	No	Yes	No
	Three or more measurement endpoint means fell between the inner and outer tolerance limits or outside the outer tolerance limits for the 5th or 95th percentile for the normal range of baseline variability.	-	No	No	Yes

[1] A statistical signal is considered strong when the effect accounts for at least 20% of the variation in the annual means.

3.2.4.2 Wild Fish Health Monitoring

Selection of Measurement Endpoints

Key measurement endpoints selected for fish health monitoring on the Athabasca River and tributaries of the Athabasca River were based on Environment Canada's Environmental Effects Monitoring (EEM) guidelines developed for the metal mining and pulp and paper sectors (Environment Canada 2010). These measurement endpoints are considered fundamental for interpreting the whole-organism response of the target fish populations sampled at *baseline* and *test* reaches. The measurement endpoints are specific to adult fish and included:

- *Age* – mean age;

- *Growth* – size-at-age;
- *Condition* – describes the relationship between fish length and weight (i.e., how “fat” a fish is), and provides a measure of energy storage;
- *Relative gonad size* – describers the gonad weight relative to body weight, and provides a measure of gonad development and reproductive success for a fish; and
- *Relative liver size* – describes the liver weight relative to body weight, and provides a measure of energy storage.

In addition, supporting measurement endpoints were considered to facilitate the interpretation of results, and included:

- *Mixed function oxygenase (MFO) induction* – supporting variable measured by changes in 7-ethoxyresorufin-O-deethylase (EROD) activity in adult fish. EROD activity is a sensitive indicator of contaminant uptake, which increases in concentration when a fish is exposed to specifically-shaped compounds or contaminants, such as PAHs (Hodson et al. 1991). Accordingly, EROD activity was used as a biomarker for assessing potential exposure of fish to oil sands-related compounds at each sampling reach;
- *Incidence of external health abnormalities* – percentage of abnormalities relative to total number of fish captured, were assessed for all fish caught at a given reach;
- *Growth (size distribution) of juvenile fish* – Length-frequency distributions of juvenile fish compared among reaches provide a measure of relative growth. Size of juvenile fish during their first growing season can be a direct indicator of somatic growth because growth is not complicated by reproductive development; instead, it is solely attributed to environmental conditions (Environment Canada 2010); and
- *Relative abundance of juvenile fish* – percent composition of juvenile fish relative to total catch provides information regarding reproductive performance.

Spatial Comparisons and Temporal Trends

Spatial Comparisons

Athabasca River

For data collected in 2015, spatial differences in measurement endpoints of trout perch from *baseline* and *test* reaches of the Athabasca River were assessed based on the following comparisons:

- *Baseline* reach M0-DS was compared to *baseline* reach M0-US;
- *Baseline* reach M2 was compared to *baseline* reach M0-DS;
- *Test* reach M3 (considered a *test* reach relative to the upstream STP discharge and the town of Fort McMurray) was compared to *baseline* reach M2;
- *Test* reach M4-US was compared to *baseline* reach M3 (considered a *baseline* reach relative to downstream oil sands development);
- *Test* reach M4-DS was compared to *test* reach M4-US;

- *Test* reach M7 was compared to *test* reach M4-DS;
- *Test* reach M8 was compared to *test* reach M7; and
- *Test* reach M9 was compared to *test* reach M8.

All comparisons were made between reaches moving sequentially downstream from the most upstream sampling reach to investigate additive effects of development occurring along the Athabasca River.

Tributaries of the Athabasca River

The sampling design of wild fish health monitoring program for tributaries of the Athabasca River focused largely on broadening the dataset of fish health data within the oils sands region. Many reaches were new to the program in 2015 (*test* and *baseline* reaches), others focused on a new target fish species, while others provided an additional year of data to compliment a previous survey. Accordingly, the following spatial comparisons were evaluated when possible:

- Comparison of measurement endpoints between a *test* reach or reaches vs. an upstream *baseline* reach in the same watershed; and
- Comparison of measurement endpoints among *baseline* reaches in the same watershed to evaluate the extent of *baseline* variability.

To provide context for tributaries only containing one *test* reach without a corresponding upstream *baseline* reach, results were qualitatively compared to regional *baseline* reaches where the same target species was also sampled in 2015.

Data Analysis

Analysis of variance (ANOVA) and an Analysis of Covariance (ANCOVA) were the general tools used to analyze spatial variations in fish measurement endpoints of adult fish ($\alpha = 0.05$). The measurement endpoints were analyzed as described by Environment Canada (2010) and summarized in Table 3.1-13. Analyses were undertaken for each gender separately. When necessary, the measurement endpoints were $\log_{10}$-transformed to meet assumptions of normality and homogeneity of variances.

ANOVA was used to compare age estimates among reaches. Spatial differences in size-at-age (length vs. age), condition (weight vs. length), relative gonad size, and relative liver size of the target fish species among reaches were evaluated using ANCOVA. With the exception of size-at-age and condition, body weight was used as a covariate to adjust for any differences in body size (Table 3.1-13).

An assumption of the ANCOVA model is that the slopes of the regression lines are equal among reaches. Therefore, differences in slopes were tested before the ANCOVA was conducted. Generally, ANCOVA is fairly robust even when slopes are unequal, so slopes were considered different when $p<0.01$ (Paine 1998).

Non-parametric Kolmogorov-Smirnov tests ($\alpha = 0.05$) were used to compare EROD activity between two reaches, where EROD concentration represented the dependent variable and reach the independent variable.

Table 3.2-13 Measurement endpoints for wild fish health monitoring program of the 2015 JOSMP.

Response	Measurement Endpoints	Dependent Variable	Covariate
Survival (Age)	Age	Age	None
Energy use	Growth	Body weight	Age
	Relative gonad size	gonad weight	Body weight
Energy storage	Relative liver size	Liver weight	Body weight
	Condition	Body weight	Fork length

Source: Environment Canada (2010)

The specific spatial comparisons planned for reaches of the Athabasca River (see above) were conducted using the overall ANOVA/ANCOVA models (i.e., all reaches included) with planned orthogonal contrasts (as described in Hoke et al. 1990). However, for spatial comparisons planned for the tributaries of the Athabasca River, a post hoc Tukey's honest significant difference (HSD) test was used to make pair-wise comparisons among more than two reaches.

For instances when qualitative spatial comparisons were made to provide context for *test* reaches without a corresponding upstream *baselin*e reach, relative gonad size, relative liver size and condition were estimated by gonadosomatic index (GSI, 100•[gonad weight/body weight]), liversomatic index (LSI, 100•[liver weight/body weight]) and condition factor (K, 100•[body weight/length^3]), respectively, so that these measurement endpoints could be presented graphically.

Percent change in measurement endpoints between reaches was calculated for each contrast using:

$$PC\ (\%) = \text{Antilog}\ (LSM_T - LSM_B)$$

These percent changes are "back-transformed" from logarithms.

Power analysis was used to determine whether the sample size was adequate to effectively detect differences in measurement endpoints among reaches, assuming a 5% probability of committing a Type I error and a 95% probability of detecting the difference, and the unexplained variability (i.e., the population standard deviation). Power was calculated by re-arranging the following power equation (Green 1989):

$$n = \frac{2(t_\alpha + t_\beta)^2 \sigma^2}{\delta^2}$$

where,

n is the number of fish;

σ is the population standard deviation;

δ is the specified effect size;

t_α is the Students *t* statistic for a two-tailed test with significance level α; and

t_β is the Students *t* statistic for a one-tailed test with significance level β.

The estimated reach standard deviation was the square-root of the pooled mean squared error term from the ANOVA or ANCOVA, separately generated for male and female fish.

Temporal Comparisons

Athabasca River

Historical data collected by RAMP and JOSMP provided an opportunity to evaluate potential temporal differences in measurement endpoints over time. Adult fish sampling on the mainstem of the Athabasca River began in 1999 with sampling taking place at *baseline* reach M3, and *test* reaches M4-US and M4-DS (previously known as *baseline* reach ATR-2 and *test* reaches ATR-3 and ATR-4, respectively). In 2002, *baseline* reach M2 and *test* reach M8 (previously known as *baseline* reach ATR-1 and *test* reach ATR-5) were added to the reaches sampled. In 2015, the *baseline* reaches M0-US and M0-DS, and *test* reaches M7 and M9 were added to those sampled. Therefore, the following temporal comparisons could be made:

1. Each reach with more than three years of data was compared to the historic normal range:
   - *Baseline* reach M2 (2002, 2010, 2013, and 2015);
   - *Baseline* reach M3 (1999,2002, 2010, 2013, and 2015);
   - *Test* reach M4-US (1999,2002, 2010, 2013, and 2015);
   - *Test* reach M4-DS (1999, 2002, 2010, 2013, and 2015); and
   - *Test* reach M8 (2002, 2010, 2013, and 2015).
2. Each of the *test* reaches above as well as *test* reaches M7 (2015) and M8 (2015) were compared to the normal range of values of *baseline* reach M3. *Baseline* reach M3 was used as the reference reach for oil sands operations because it is upstream of oil sands operations and downstream of Fort McMurray's sewage treatment plant (STP).

In order to visualize and assess temporal variations at each reach, data were displayed graphically following the adaptive monitoring framework (AMF) for long-term programs developed by Arciszewski and Munkittrick (2015). Using the AMF, within-reach comparisons are made year to year in order to identify effects despite background noise and natural variability. The trigger for the identification of effects at a reach is the reach-specific running of a historical grand mean (mean of means) ± 2 standard deviations (of the annual means) (i.e., a normal range of variation for annual means). A grand mean using at least three sampling years is (minimally) required to generate a normal range that can be reliably used for interpretation of data falling outside the generated normal range. Three consecutive exceedances of a normal range represents a signal requiring further investigation. The authors state that the probability of incorrectly obtaining three consecutive means falling outside the normal range is 0.0125%. Additionally, it was noted that the focus on reach means is intended to align monitoring results with the goals of a given program, which is often the protection of populations and ecosystems, not preserving individual fish. Changes to population means outside of an expected range is considered a more severe and relevant change than changes to individuals (Arciszewski and Munkittrick 2015). Temporal variations of *test* reaches were then compared to temporal variations at *baseline* reaches to assess potential effects of oil sands development.

The AMF method for visualizing data was applied to age, condition factor (K, 100▪[body weight/length^3]), gonadosomatic index (GSI, 100▪[gonad weight/body weight]) and liversomatic index (LSI, 100▪[liver weight/body weight]). Calculations of K, GSI and LSI are estimates of condition, relative gonad size and relative liver size (i.e., key measurement endpoints), respectively and are more easily presented graphically relative to estimates using ANCOVA. The AMF approach was also applied to length standardized to a common age to visualize growth. Fork length was standardized to a common grand mean age through ANCOVA in which the logarithm of fork length was the dependent variable, and the logarithm of age was the covariable; the ANCOVA was testing for differences in fork length among years within a reach. The ANCOVA was “run” separately for each reach and sex for which there were four or five years of trout perch data. Within each run of the ANCOVA, we assumed no difference in slopes of the relationship between fork length and age. The ANCOVA thus generated separate length-at-age relationships for each year, which were used to compute (for each individual fish) the fork length for a standardized grand mean age (for the reach-by-sex combination in the ANCOVA).

Tributaries of the Athabasca River

Temporal comparisons of measurement endpoints of the target species from tributary reaches were not possible because many of the reaches were sampled for the first time in 2015, and/or new target fish species were selected in 2015 relative previous years.

Comparison to Published Literature

There are many published articles on fish health monitoring for pulpmills and oil sands operations (e.g., Gibbons et al. 1998; Tetreault et al. 2003; Gibbons and Munkittrick 1994), to provide context for the results from the 2015 wild fish health monitoring. Specifically, these studies provide a monitoring framework for interpreting response patterns of fish communities to anthropogenic stress.

Classification of Results

The five effects criteria for determining change in a measurement endpoint for wild fish health are based on the Pulp and Paper Environmental Effects Monitoring (EEM) Program (Environment Canada 2010):

- ± 25% difference in survival (age) of fish among reaches;
- ± 25% difference in growth (size-at-age) in fish among reaches;
- ± 25% difference in gonad size in fish among reaches;
- ± 25% difference in liver size in fish among reaches; and
- ± 10% difference in condition in fish among reaches.
- Two factors are considered when determining the classification of effects as **Negligible-Low**, **Moderate**, or **High** (Table 3.2-14):
- An exceedance of the effects criteria on measurement endpoints (age, growth, relative gonad size, relative liver size, and condition) observed at a *test* reach compared to the *baseline* reach in the current sampling year; and
- An exceedance of the effects criteria at a *test* reach in two consecutive years of sampling, including the current year.

A slight modification was made for comparisons made along the Athabasca River. The design compared between reaches moving sequentially downstream from the most upstream sampling reach to investigate additive effects of development occurring along the Athabasca River. Therefore, each upstream reach was considered *baseline* to the sequential downstream *test* reach.

Table 3.2-14 Classification of results for wild fish health monitoring for the 2015 JOSMP.

Criteria	Criteria for "Yes"	Negligible-Low	Moderate	High
Exceedance of effects criteria in current sampling year	Exceedance of the effects criteria for **one or two** measurement endpoints at a *test* reach compared to the *baseline* reach.	No	Yes	No
	Exceedance of the effects criteria for **three or more** measurement endpoints at a *test* reach compared to the *baseline* reach.	No	No	Yes
Exceedance of effects criteria across sampling years	Exceedance of the effects criteria for any one of the measurement endpoints in two consecutive sampling cycles.	No	No	Yes

3.2.5 Acid-Sensitive Lakes Component

The measurement endpoints for the 2015 ASL component lakes were: pH; Gran alkalinity; Base cation concentrations; Nitrate plus nitrite; Sulphate; Dissolved organic carbon; and Dissolved aluminum.

Gran alkalinity and pH are considered the principal measurement endpoints for the ASL component. Sulphate is included in the list of measurement endpoints but, unlike many lakes in eastern North America sulphate and acidity (H^+) in Alberta lakes are poorly correlated because of the abundance of neutral sulphate compounds in wet and dry deposition (AEP 1990; Lau 1982; Legge 1988; RAMP 2004). Concentrations of sulphate in the ASL component lakes were typically low and despite high rates of deposition in the past were found to be sequestered and immobilized within the individual catchment basins (Whitfield et al. 2010).

3.2.5.1 Temporal Trends

The data analysis focused on the detection and evaluation of potential temporal trends in the ASL measurement endpoints in the study lakes that would indicate incipient acidification of the lakes. In this regard, the following specific data analyses were conducted.

Among-Year Comparisons of Measurement Endpoints using an ANOVA

A one-way Analysis of Variance (ANOVA) was conducted to determine whether there have been any significant changes in mean concentrations of each ASL measurement endpoint in the 50 lakes during the fourteen years of monitoring when all lakes were sampled (2002 to 2015). An ANOVA was run after testing for the homogeneity of the variance of each variable among years. A non-parametric test (Kruskal-Wallis one-way ANOVA) was applied to detect changes in the median concentrations when the variance of measurement endpoint values were found to be non-homogeneous. Tukey's post-hoc test was used to examine individual differences in mean values among years when the ANOVA indicated significant differences. Any observed changes were discussed in relation to acidification, natural variability and other possible causes unrelated to emissions of acidifying substances (e.g., hydrologic events).

Among-Year Comparisons of Measurement Endpoints using the General Linear Model

An ANOVA using the General Linear Model (GLM) was applied to examine trends in measurement endpoints over time in the study lakes. The model regresses the concentration of a measurement endpoint against time in each individual lake and determines the overall significance of the regressions over the 50 lakes. This test is more powerful than the one-way ANOVA for detecting potential changes in a measurement endpoint over time because potential changes are examined in each individual lake rather than in the mean values across lakes. The GLM was applied to the population of 50 lakes as well as subsets of the 50 lakes that included both *baseline* and *test* lakes.

Mann–Kendall Trend Analysis on Measurement Endpoints in Individual Lakes

Potential trends in measurement endpoints were examined in all 50 lakes using a Mann-Kendall trend analysis. Significant trends were examined and discussed in relation to previous hydrologic events and the logical consistencies (or inconsistencies) of these observed trends. The program used for the analysis (MAKESENS) calculates the Mann-Kendall statistic on lakes having fewer than ten years of data. For lakes having at least ten years of data, a normal approximation test was applied to calculate the Z test statistic. To assist in interpreting the results of the trend analyses, control charts were provided of measurement endpoints in those lakes where significant changes occurred in a direction indicative of acidification.

Control Charting of Measurement Endpoints in Lakes Most Likely to Acidify

The pH, Gran alkalinity, sulphate, sum of base cations, nitrates, and dissolved organic carbon were charted in Shewhart control plots for the lakes deemed most at risk to acidification. Five lakes were selected for control charting on the basis of the ratio of the modeled Potential Acid Input to Critical Load (PAI to CL). The higher the ratio in a given lake, the greater the risk for acidification of this lake. The control plots followed standard analytical control chart theory where control limits representing two and three standard deviations were plotted on the graphs with the points and the mean value (Gilbert 1987; Systat 2004). The two and three standard deviations were calculated using all historical data for a lake (1999 to 2015). A trend in the value of a measurement endpoint was determined on the basis of the criteria described below. Given the low probability (1% or less) that these criteria would be violated in a truly random population of a measurement endpoint, there is a high probability of detecting a true trend in a measurement endpoint over time. The visual presentation of the data in control charts permitted the detection of trends before significant changes actually occur.

The following criteria were used to identify a trend or potential risk for acidification using Shewhart control plots (from Systat 2004):

- one year where the value of a measurement endpoint was beyond three standard deviations (on either side);

- nine consecutive years in which values of a measurement endpoint were on one side of central line (mean value);
- six consecutive years in which a measurement endpoint was steadily increasing or decreasing;
- two out of three consecutive years in which values of a measurement endpoint were outside the two standard deviations limit (on one side of the mean). This is a modified version of the first test. This gives an early warning that values of the measurement endpoint may be deviating from normal conditions; and
- four out of five consecutive years in which a measurement endpoint was outside the one standard deviation limit (on one side of the mean). This test is similar to the previous one and may also be considered to be an early warning that values of the measurement endpoint are deviating from normal conditions.

3.2.5.2 Calculation of Critical Loads of Acidity and Comparison to Modeled Potential Acid Input

The critical load of acidity (CL), in units of keq H+/ha/y, is defined as the highest load of acid deposition that will not cause long-term changes in lake chemistry and biology; it represents a measure of a lake's sensitivity to acidification. CLs for the lakes for 2015 conditions were calculated using the Henriksen steady state water chemistry model modified for the effects of organic acids on buffering and acid sensitivity. Details of the model and its assumptions are described below.

The Modified Henriksen Model

The original Henriksen model was modified to account for both the buffering of weak organic anions and the lowering of acid neutralizing capacity (ANC) attributable to strong organic acids. The modified model assumed that DOC, with its associated buffering from weak organic acids (ANC_{org}) and reduction of ANC from strong organic acids (A^{-}_{SA}), was exported from the catchment basin to each lake in the same way that we assume the export of base cations (carbonate alkalinity) to each lake. The modified Henriksen model is:

$$CL= ([BC]^{*}_{0} + ANC_{org} - A^{-}_{SA} - ANC_{lim}) .Q$$

Where,

- $[BC]^{*}_{0}$ is the original base cation concentration before acidification;
- ANC_{lim} is the limiting acid-neutralizing capacity of the lake required to maintain a healthy and functional aquatic ecosystem;
- $ANC_{org} = 0.00680^{*}\ DOC^{(0.8833^{*}pH)}$;
- $A^{-}_{SA} = 6.05\ ^{*}DOC +21.04$; and
- Q is the runoff to each lake from the catchment and lake area.

The modifications of the Henriksen model for organic acids and the empirical relationships for developed for ANC_{org} and A_{-SA} are described in WRS (2006) and RAMP (2009b).

Calculation of Runoff (Q)

The runoff (Q) to each lake, was calculated from the analysis of heavy isotopes of oxygen (^{18}O) and (^{2}H) in each lake conducted, and provided by John Gibson (University of Victoria). With this technique, the natural evaporative enrichment of ^{18}O and ^{2}H in each lake is used to partition water losses between evaporation and liquid outflow and hence derive an estimate of runoff (Gibson 2002; Gibson et al. 2002; Gibson and Edwards 2002; Gibson et al. 2010). This technique utilizes a different set of assumptions from traditional hydrometric methods that extrapolate water yields from one or more gauged catchments to the ungauged lake catchments. Potential inaccuracies in the traditional hydrometric method, especially in low-relief catchments, have previously been recognized in lakes in the oil sands region (WRS 2004). The isotopic technique also permits examination of annual changes in runoff to each lake, which will affect the critical load.

Original Base Cation Concentration ($[BC]_0$)

During the process of acidification of a catchment, base cations are released from the soils to the lake waters. In previous years of applying the Henriksen model (2002 to 2013), it was assumed that base cations have not increased in these lakes as a result of acidic deposition; that is, the current base cation concentrations are equivalent to the original values. This simplifying assumption was adopted for the following two reasons:

- The discrepancy between the original and the current base cation concentrations in a lake is normally calculated by an equation presented in Brakke et al. (1990) based on increases in sulphur concentrations in a lake resulting from aerial deposition. Calculations of Original Base Cation Concentration ($[BC_0]$) using the Brakke et al. (1990) equation indicated that the differences between the current and calculated original base cation concentrations in all 45 lakes were insignificant.
- A study by Whitfield et al. (2010) in which the Magic Model (Model of Acidification of Groundwater in Catchments) was applied to the Athabasca oil sands region concluded that, to date, sulphate deposition levels have resulted in only a limited removal of base cations from the soil.

Despite indications that base cations have not increased in the ASL component lakes, in 2015, $[BC_o]$ was calculated for each lake by applying a modified Brakke et al. (1990) equation. This process was followed in order to be consistent with international methods, and the calculation of $[BC_0]$ followed the equations published in the “Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads” (CLRTAP 2004; Henriksen et al. 2002). $[BC_0]$ was calculated as:

$$[BC_o] = [BC_T] – F(SO_{4,T} - SO_{4,o} + NO_{3,T} - NO_{3,o})$$

Where,

- $[BC_T]$ is the current base cation concentration;
- F is the “F factor” describing the ratio of the change in base cations to the additions of strong acids to each lake from acid deposition;
- $SO_{4,T}$ and $SO_{4,o}$ are the current and original sulphate concentrations in each lake, respectively; and
- $NO_{3,T}$ and $NO_{3,o}$ are the current and original nitrate concentrations in each lake, respectively.

F is defined as:

$$F = \sin(\Pi/2 \cdot Q \cdot [BC_T]/S)$$

where,

- S is the base cation flux when all acid deposition is neutralized in the catchment (F=1); and
- Q and $[BC_T]$ are defined above.

Following Henriksen et al. (2002) and CLRTAP (2004), S was assumed to be 400 meq/m^2/y. Further details on these calculations of CL are presented in Section 5.15 and Appendix F.

Choice of ANC_{lim}

The critical load concept as expressed in the Henriksen model assumes a dose-response relationship between a water quality variable and an aquatic indicator organism. In this case, the water quality variable is the acid-neutralizing capacity (alkalinity) required to maintain a healthy fish population. In applying the Henriksen model in Europe, a critical threshold ANC_{lim} of 20 μeq/L was set to protect brown trout, the most common European salmonid, and to ensure that no toxic acidic episodes occur to this species during the year.

In North America, the effects of acidification on biota have been historically related to pH rather than alkalinity or acid-neutralizing capacity. Research on pH tolerance of a wide range of aquatic organisms has shown that a pH>6 is required to maintain aquatic ecosystem functioning and protect both fish and other organisms (RMCC 1990; Environment Canada 1997; Jeffries and Lam 1993). Within a given region, lake pH has been empirically and theoretically related to alkalinity as an inverse hyberbolic sine function (Small and Sutton 1986) and this relationship has been used to equate the two variables for the purpose of critical load modeling (e.g., Jeffries and Lam 1993). The relationship between pH and alkalinity for the Athabasca oil sands region was derived from a water quality survey conducted on lakes in the ALPAC forest management area (WRS 2001, see Appendix F). Across these lakes, a pH of 6 was associated with an alkalinity of approximately 75 μeq/L. Accordingly, this value was chosen for ANC_{lim} in the Acid Deposition Management Framework for the Athabasca oil sands region (CEMA 2004b) and has been applied in numerous studies (e.g., Gibson et al. 2010).

Comparisons to Modeled PAI

The critical loads for each lake were compared to the modeled rates of the Potential Acid Input (PAI) to each lake catchment calculated for Teck Energy's Frontier Project and published in Davies et al. (2015). The PAI represents the sum of the acidifying nitrogen and sulphur species deposited in each catchment minus the base cation deposition. The ability of nitrates to be assimilated and used as a nutrient by plants within each lake catchment was accounted for by applying the approach adopted by CEMA and AEP, whereby any nitrogen deposition in excess of 10 kg/ha/y and 25% of the first 10 kg/ha/y deposited N were considered acidifying (CEMA 2008; AENV 2007). An "existing conditions" EIA emissions scenario was assumed in the modeling. The PAI predictions reflected new estimates of base cation deposition determined from mixed-bed ion exchange resin collectors deployed for one year (2009 to 2010) at WBEA's Terrestrial Environmental Effects Monitoring (TEEM) study sites in the oil sands region (Fenn et al. 2015). Bulk base cation deposition rates from open study sites were selected for the estimates of

PAI rather than rates measured in "flow-through" sites representing deposition to the forest canopy. The open sites typically displayed lower rates of base cation deposition and; therefore, resulted in higher (more conservative) estimates of PAI. The 2015 PAI modeling also included the deposition of reduced forms of nitrogen (i.e., ammonia and ammonium).

3.2.5.3 Supporting Analyses

The following supporting data analyses were also conducted on the study lakes, the results of which are presented in Appendix F.

Update of the ASL Database, Summary Statistics and Comparisons of ASL Chemistry to Regional Lake Chemistry

The water chemistry data from the 2015 WY and all previous monitoring years combined were tabulated and summarized statistically. Lakes with unusual chemical characteristics were identified based on the 5th and 95th percentiles in the values of the measurement endpoints. The chemical characteristics of the lakes were compared to those of 450 regional lakes reported in the lake sensitivity mapping study produced for the NO_xSO_x Management Working Group (NSMWG, WRS 2004). The following comparisons were conducted to determine how typical the study lakes are of lakes within the oil sands region:

- examination of the range, median, and mean values of key chemical variables for 2015 in the lakes relative to the regional dataset;
- graphical presentation of both datasets in box-plots; and
- statistical comparison of chemical variables between the ASL component lakes and the regional dataset.

Classification of the Lakes using Piper Plots

Piper plots were used to characterize the water in each of the study lakes according to the major chemical constituents. A Piper diagram is a multivariate graphical technique that is used to divide the lakes into four water types on the basis of major cations and anions (Güler et al. 2002; Freeze and Cherry 1979; Back and Hanshaw 1965). The four water types include:

- Type I: Ca^{2+} - Mg^{2+} - HCO_3^-;
- Type II: Na^+ - K^- - HCO_3^-;
- Type III: Na^+- K^- - Cl^- - SO_4^{2-}; and
- Type IV: Ca^{2+} - Mg^{2+} - Cl^- - SO_4^{2-}.

Analysis of Metal Concentrations

The total and dissolved metal fractions in the lakes from 13 years of monitoring by AESRD/AEP (2001, 2003 to 2015) were tabulated and summarized statistically. Lakes having relatively high metal concentrations were identified as those exceeding the 95th percentile concentration for individual metals. Exceedances of the Alberta and CCME surface water quality guidelines were also identified (CEMA 2010;

AESRD 2014). The lakes and physiographic regions having the highest metal concentrations were identified and plotted on regional maps.

Additional analyses were conducted to detect potential changes in metal concentrations attributable to acidification. These analyses included:

- a comparison of selected metals between physiographic regions using an Analysis of Variance (ANOVA);
- a comparison of metal concentrations between *baseline* and *test* lakes using an ANOVA; and
- a Mann Kendall trend analysis on selected metals for all 50 lakes from 2003 to 2015. The metals showing significant increases in individual lakes were plotted in control charts and interpreted as described in Section 3.2.5.2.

3.2.5.4 Classification of Results

A summary of the state of the ASL component lakes in 2015 with respect to the potential for acidification was prepared for each physiographic subregion by examining deviations from the mean chemical concentrations of the measurement endpoints for each lake within each subregion. The measurement endpoint and the relevant trend that is indicative of acidification are as follows: Gran alkalinity (downwards); pH (downwards); sum base cations (upwards); nitrates (upwards); dissolved organic carbon (downwards); sulphate (upwards); and aluminum (upwards).

For each lake, the mean and standard deviation were calculated for each measurement endpoint across all monitoring years. The number of lakes in the 2015 WY within each subregion having measurement endpoint values greater than two standard deviations (SD) (above or below the mean as indicated above) was calculated. The number of exceedances of measurement endpoints greater than 2SDs was expressed as a percentage of the total number of lake-measurement endpoint combinations for each subregion. The results were classified as follows:

- **Negligible-Low** – subregion has less than 2% measurement endpoint-lake combinations exceeding ± 2 SD criterion;
- **Moderate** – subregion has 2% to 10% measurement endpoint-lake combinations exceeding ± 2 SD criterion; and
- **High** – subregion has greater than 10% of measurement endpoint-lake combinations exceeding ± 2 SD criterion.

4.0 CLIMATE AND HYDROLOGIC CHARACTERIZATION OF THE ATHABASCA OIL SANDS REGION IN 2015

4.1 INTRODUCTION

This section summarizes the regional climate and hydrology data and trends for the Athabasca oil sands region for the 2015 Water Year (WY) from November 1, 2014 to October 31, 2015. It also provides a comparison of the 2015 data with long-term historical data that were available for federal and provincial climatic and hydrologic monitoring stations. The information in this section is intended to provide context for the monitoring results in support of the 2015 Joint Oil Sands Monitoring Plan (JOSMP). Data from a number of the Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA) climate and snowpack monitoring stations are also used to provide additional regional context.

4.2 CLIMATE CHARACTERIZATION

The characterization of the climate of the Athabasca oil sands region is based on air temperature, precipitation, and snowpack data to provide both historical and regional context of conditions in the 2015 WY. Long-term context is provided using the Environment Canada (EC) station at the Fort McMurray Airport that has a 70-year historical record (see below), while context on regional variability is provided by climate stations and snow courses monitored by Environment Canada (EC), Alberta Environment and Parks (AEP), and AEMERA (Figure 3.1-1).

Daily precipitation and air temperature data have been collected since 1945 at the Fort McMurray Airport at four stations operated by EC (Table 4.2-1). The combined data record for these stations spans 70 years (1945 to 2015). It is noted that the period of record varies for these stations, as some were decommissioned or moved. However, the data from these stations are considered to be representative of a single location, based on the proximity of the stations being within 1 km of each other and a comparison of overlapping data records that showed minimal variation in precipitation and temperature values between the locations. Therefore, for purposes of the analyses conducted in this report, precipitation and air temperature records from these stations were consolidated into one long-term data series from 1945 to 2015. This data series will be referred hereafter as the Fort McMurray climate data set.

Table 4.2-1 Long-term climate data available from Environment Canada stations operated at the Fort McMurray Airport, AB.

Station Name	Station ID[1]	UTM Coordinate (NAD83 Zone 12)		Elevation (m)	Period of Record	Mean Daily Air Temperature (°C)	Daily Total Precipitation (mm)
		Easting	Northing				
Fort McMurray A	3062693	486715	6278448	369.1	1945 to 2008	✓	✓
Fort McMurray AWOS A	3062700	486307	6278820	369.1	2008 to 2011	✓	✓
Fort McMurray Alberta	3062697	486307	6278820	369.1	2011 to 2015	✓	✓
Fort McMurray CS	3062696	486919	6278571	368.8	1999 to 2015	✓	✓

[1] Unique seven digit station identifier assigned by Environment Canada

4.2.1 Air Temperature

Daily mean air temperatures measured at Fort McMurray Airport for the 2015 WY generally followed the mean historical temperature trend (Figure 4.2-1). Winter air temperatures from November to mid-March were more variable than the remainder of the 2015 WY. These winter fluctuations generally stayed between the range of minimum and maximum historical temperatures with the exceptions of late January and early March when temperatures briefly rose above the historical maximum.

Monthly mean air temperatures in the 2015 WY at the Fort McMurray Airport varied between the historical maximum and historical minimum monthly mean air temperatures for the entire WY (Figure 4.2-2). Air temperatures followed a consistent pattern in the 2015 WY with monthly air temperatures slightly above average for all months except November, February, and September.

Figure 4.2-1 2015 WY daily mean air temperature at Fort McMurray Airport compared to historical values (1945 to 2014).

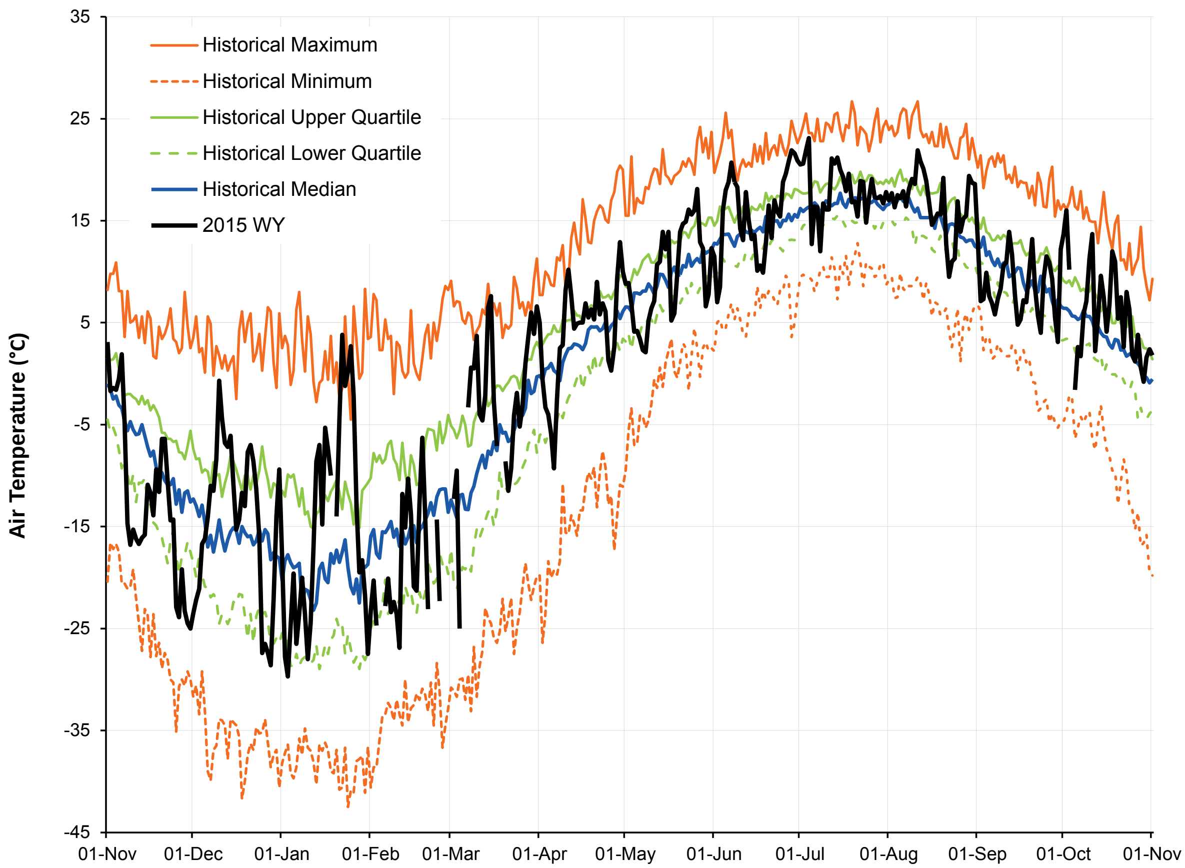
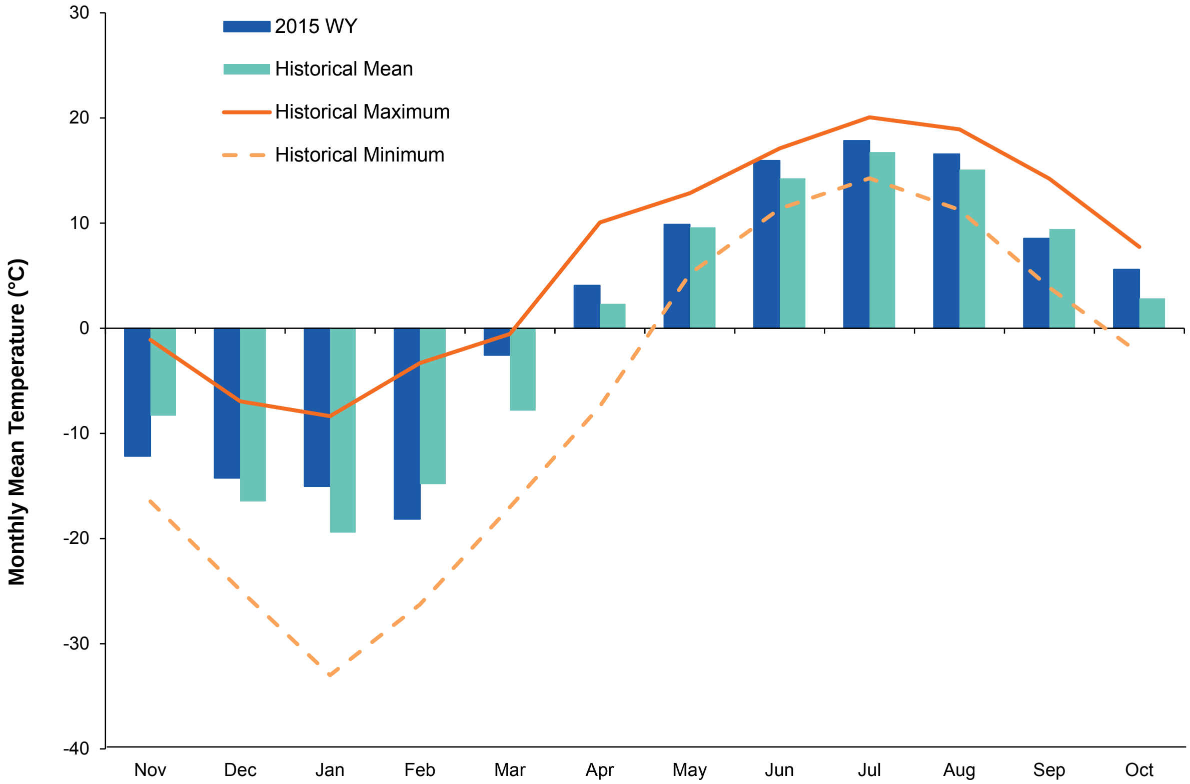


Figure 4.2-2 2015 WY monthly mean air temperatures at Fort McMurray Airport compared to historical values (1945 to 2014).



Note: Daily mean air temperatures for Fort McMurray were averaged for each month for the period 1945 to 2014. These values are compared to monthly means for the 2015 WY.

4.2.2 Precipitation

Long-term WY precipitation measured at Fort McMurray Airport is summarized in Figure 4.2-3. Total precipitation for the 2015 WY was 275.3 mm, which is 37% less than the long-term annual mean value of 436.0 mm and the lowest annual precipitation observed at the Fort McMurray Airport since 1998. The winter period, from November 1, 2014 to March 31, 2015, was drier than average with 53.4 mm of precipitation falling as snow, which was approximately 42% lower than the historical mean for this period. Similarly, total precipitation (assumed to be rainfall) from April 1 to October 31, 2015, was 221.9 mm, approximately 35% lower than the historical mean value for the same period.

Monthly total precipitation was generally below the historical mean for each month, with the exception of February and July (Figure 4.2-4). Additionally, the total precipitation for December was 2.3 mm, which was below the previously-observed historical minimum precipitation. July was the wettest month in the 2015 WY with a total precipitation of 99.7 mm, 29% greater than the historical mean. The July precipitation accounted for 36% of the total precipitation at the Fort McMurray Airport in the 2015 WY.

Figure 4.2-3 Historical annual precipitation at the Fort McMurray Airport, 1945 WY to 2015 WY.

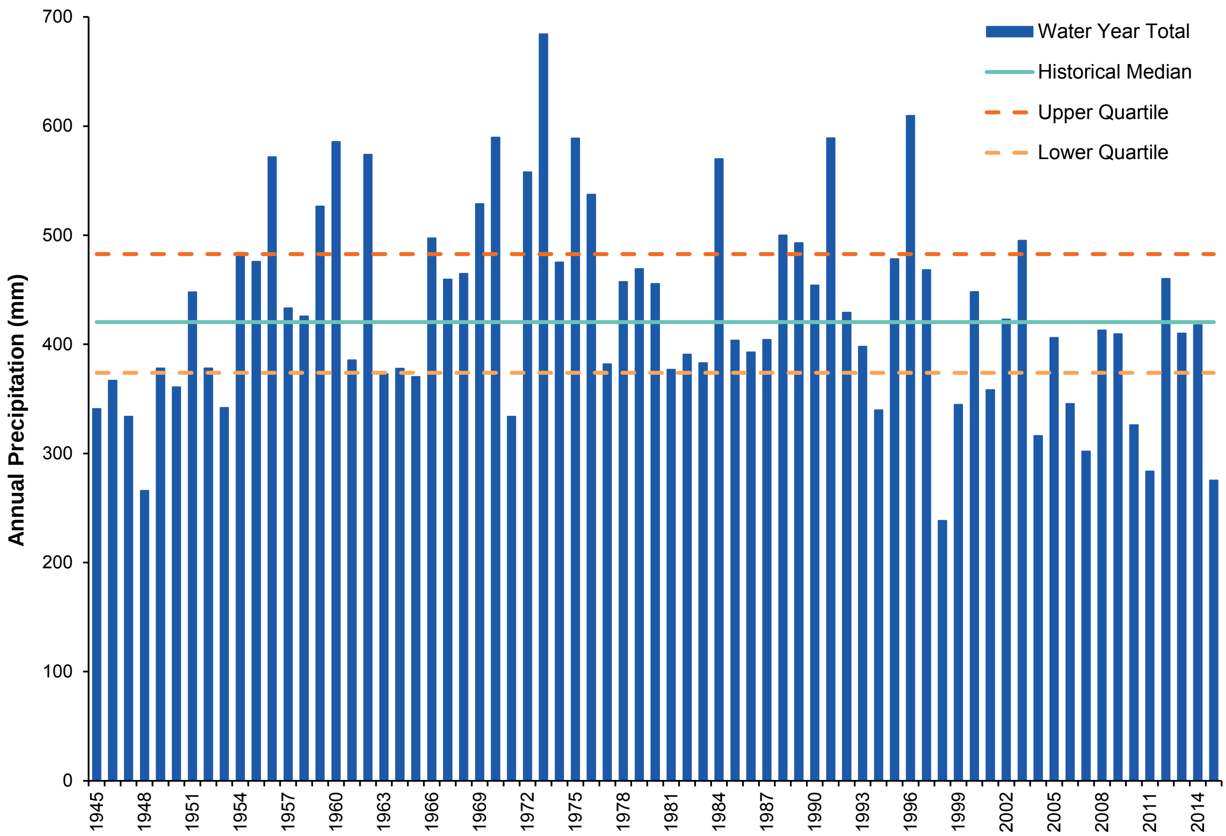
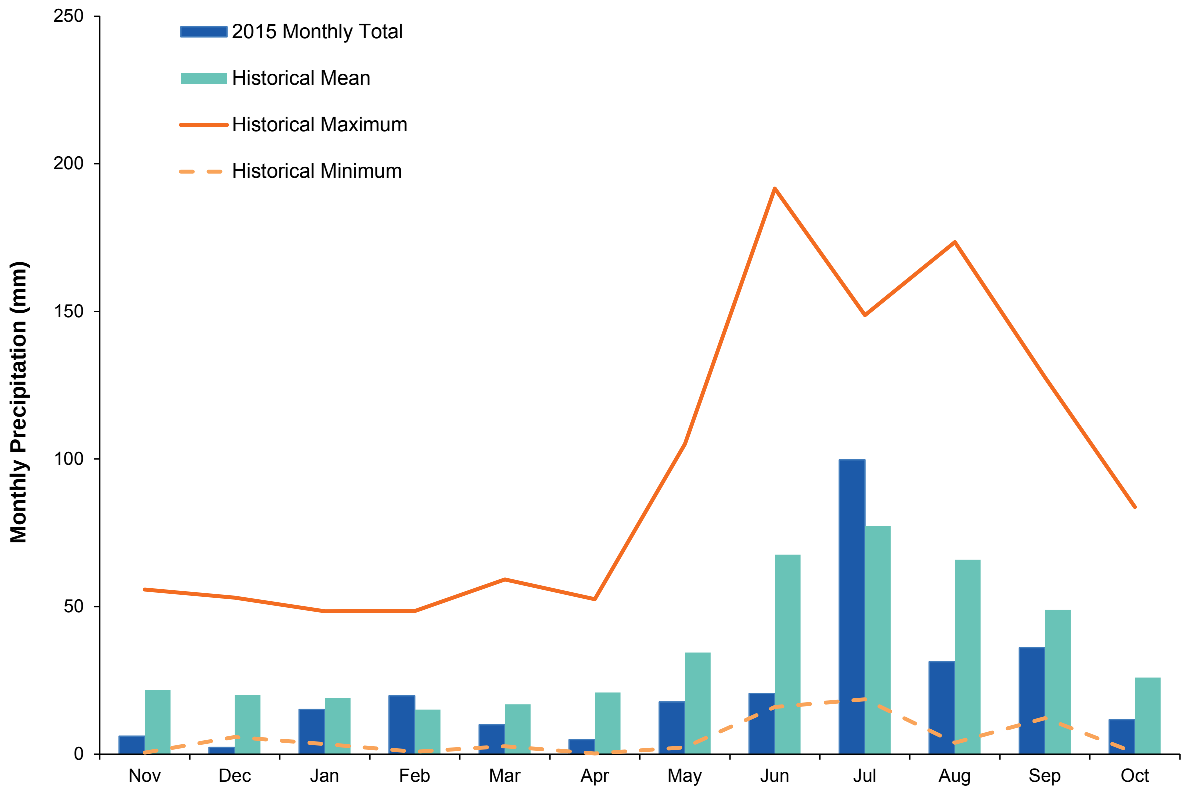


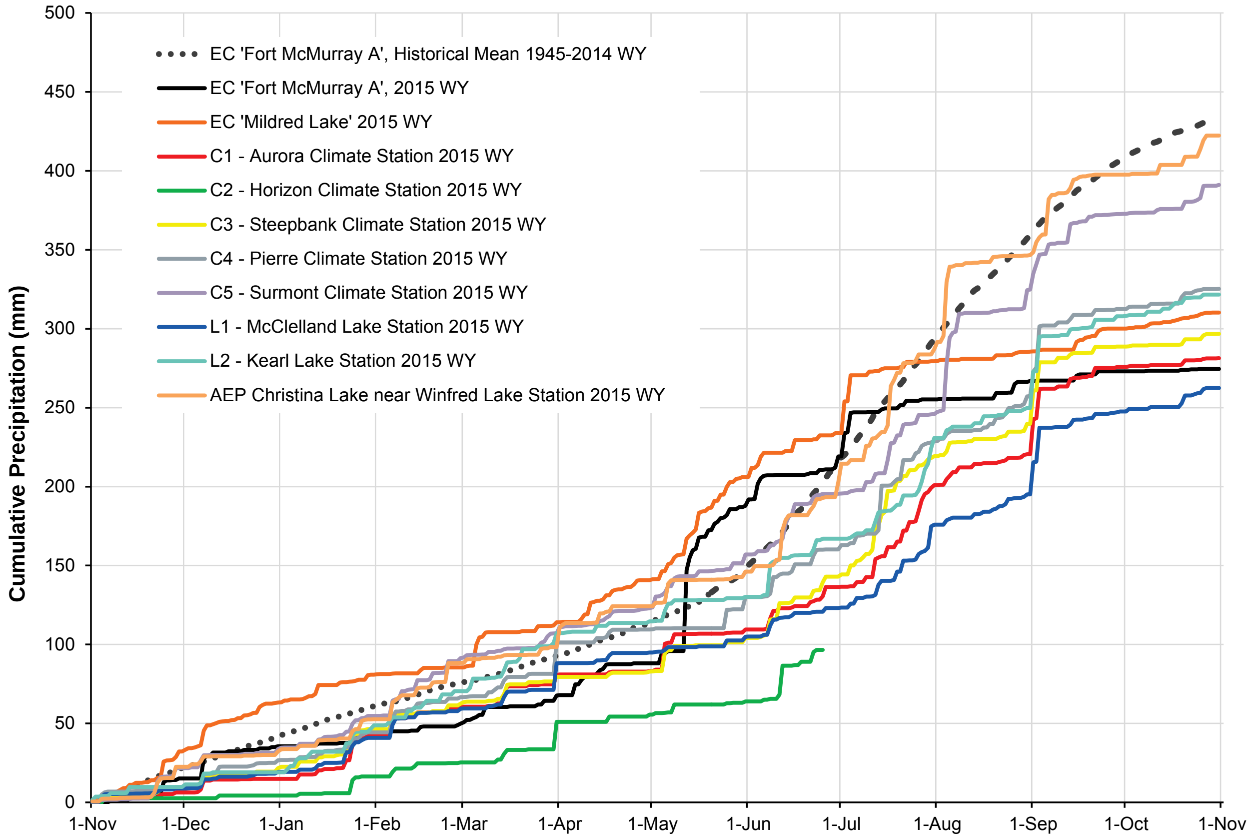
Figure 4.2-4 2015 WY total monthly precipitation at the Fort McMurray Airport compared to historical values (1945 to 2014).



Regional precipitation patterns were characterized using records from the following stations in the Athabasca oil sands region: the EC Mildred Lake station (ID# 3064528); the AEP Christina Lake near Winefred Lake station (ID# 3061580); and stations C1 Aurora, C2 Horizon, C3 Steepbank, C4 Pierre, C5 Surmont, L1 McClelland Lake, and L2 Kearl Lake (Figure 4.2-5). Total precipitation recorded at all these stations for the 2015 WY was lower than the long-term historical mean precipitation at the Fort McMurray Airport (Figure 4.2-5) and cumulative precipitation varied by 171.5 mm across these stations in the 2015 WY.

The two climate stations located south of Fort McMurray (C5 Surmont and AEP Christina Lake near Winefred Lake) recorded the most precipitation in the 2015 WY and the cumulative precipitation record for these stations generally followed the historical Fort McMurray cumulative precipitation trend. There were three instances in the 2015 WY in which the recorded cumulative precipitation at a regional climate station was greater than the historical cumulative precipitation at Fort McMurray Airport: Fort McMurray Airport itself from mid-May to mid-July; Mildred Lake from late-November to late-July; and L2 Kearl Lake from mid-March to mid-May (Figure 4.2-5).

Figure 4.2-5 Cumulative total precipitation at climate stations in the Athabasca oil sands region in 2015.



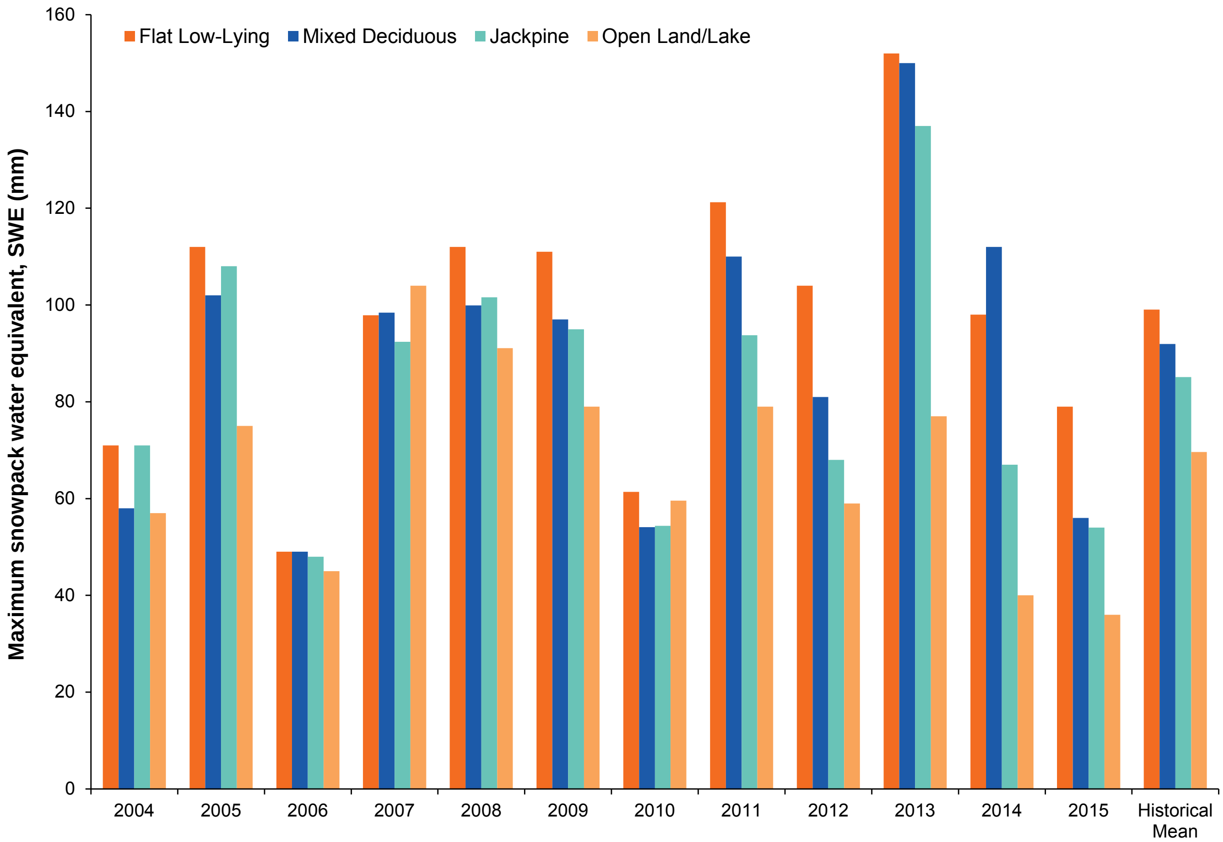
Note: The cumulative total precipitation record at C2 was incomplete due to a data gap from June 27 to August 15, 2015, which prevents cumulative total precipitation from being calculated.

4.2.3 Snowpack

Snowpack data provide context for the amount of water that was stored in snow and contributed to the runoff of the spring freshet. Snowpack amounts (in terms of mm snow water equivalent, [SWE]) were measured at four regional locations during the periods of February 2 to 5, March 4 to 15, and March 31 to April 2, 2015, in each of four land cover types (i.e., flat low-lying, mixed deciduous, jackpine, and open land/lake). These land cover types represent the most common land cover types in the Athabasca oil sands region.

The maximum mean SWE value recorded for each land cover type is presented in Figure 4.2-6 with historical maximum mean SWE values for the period of 2004 to 2014 included for comparison. The maximum mean SWE values in 2015 were highest in the flat low-lying land cover type and decreased in value through the mixed deciduous, jackpine, and open land/lake land cover types, a pattern similar to the historical mean SWE values as well as for the majority of individual years in the data record. In 2015, the maximum mean SWE was lower than the mean of the historical maximum mean in all land cover types. The maximum mean SWE in 2015 for the land/lake land cover type was the lowest when compared to all other land cover types, with 48% less SWE in this land cover type in 2015 than the historical mean maximum SWE (Figure 4.2-6).

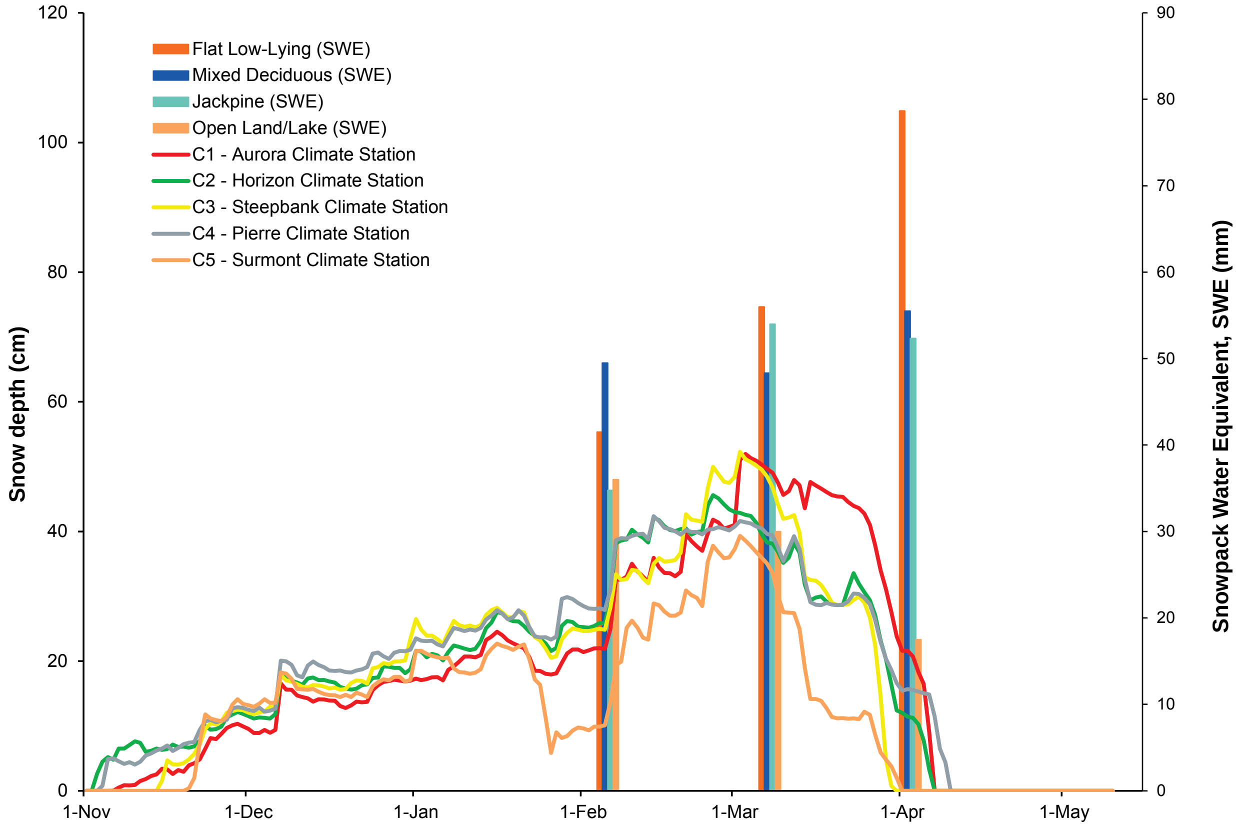
Figure 4.2-6 Maximum mean measured snowpack amounts in the Athabasca oil sands region, 2004 to 2015.



Note: Similarly to previous years, four snowcourses were sampled in each of four land categories (Figure 3.1-1), in February, March, and early April 2015. Snow water equivalent (SWE) values shown here represented the maximum monthly mean values recorded for each land category and year.

Continuous snow depths measured at the C1-Aurora, C2-Horizon, C3-Steepbank, C4-Pierre, and C5-Surmont climate stations correspond with the pattern of SWE measurements conducted in February and March in all land cover types (Figure 4.2-7). The SWE in the mixed deciduous and flat low-lying land cover types increased from the March to April surveys and decreased in the open land/lake and jackpine land-cover types over the same period. The snowpack started melting in late March 2015 and snow depths decreased from early March until spring melt in late March at all climate stations; snow was completely melted by early April (Figure 4.2-7). Detailed information for the 2015 snow surveys conducted at each station is included in Appendix C.

Figure 4.2-7 Comparison of snowpack depth (cm) observed at climate stations and snow water equivalent (SWE, mm) measured in each land category in 2015.



4.3 HYDROLOGIC CHARACTERIZATION

Daily discharge hydrographs were developed for four long-term Water Survey of Canada (WSC) stations and compared to the provisional data from these stations for the 2015 WY. These four stations are located on the Athabasca, Muskeg, MacKay, and Christina rivers (Figure 3.1-2, Table 4.3-1). These stations were chosen because they represent the four primary areas of interest in the Athabasca oil sands region: mainstem Athabasca River (north of Fort McMurray), tributaries of the Athabasca River to the east and west of the Athabasca River mainstem north of Fort McMurray, and south of Fort McMurray, and each station has greater than 30 years of historical data.

Hydrologic variables and runoff for the Athabasca River were compared for the WY, while hydrographs for the Muskeg, MacKay, and Christina river stations were compared for the March to October period as no winter data were collected at these stations during the months of November to February from 1988 to 2000. Table 4.3-1 summarizes the historical and 2015 runoff and minimum/maximum discharges for the four WSC stations.

Table 4.3-1 Summary of 2015 hydrologic variables compared to historical values measured in the Athabasca oil sands region.

Variable	Athabasca River below Fort McMurray (07DA001)	Muskeg River near Fort McKay (07DA008)	MacKay River near Fort McKay (07DB001)	Christina River near Chard (07CE002)
Representative Area	Athabasca River upstream of oil sands development	Eastern tributaries of the Athabasca River	Western tributaries of the Athabasca River	South of Fort McMurray
Effective Drainage Area (km^2)	132,585	1,457	5,569	4,863
Period of Record	1958 to 2015	1974 to 2015	1973 to 2015	1983 to 2015
Runoff Volume (March to October)[1]				
Historical[2] mean (million m^3)	19,536	118.4	426.6	456.9
2015 (million m^3)	13,083	45.5	181.4	205.9
Maximum Daily Discharge (March to October)[1]				
Historical[2] mean (m^3/s)	2527	27.1	113.2	88.1
2015 (m^3/s)	1100	6.4	35.0	25.8
Minimum Daily Discharge (May to October)[3]				
Historical[2] mean (m^3/s)	422	1.0	3.6	6.5
2015 (m^3/s)	282	0.5	2.1	5.8

1 Annual water year (November 1 to October 31) runoff volume and maximum daily discharge provided for the Athabasca River below Fort McMurray (07DA001), while seasonal (March to October) runoff volume and maximum daily flow are provided for the other three stations.

2 The historical mean includes all data up to the end of the 2014 WY.

3 Minimum daily discharge calculated for the open-water season and based on values from May to October for all stations.

4.3.1 Athabasca River

The total annual runoff volume for the 2015 WY at the Athabasca River measured at WSC Station 07DA001, Athabasca River below McMurray, was 13,083 million m^3 (Table 4.3-1). This was approximately 33% less than the historical mean runoff volume of 19,536 million m^3 over the station's 56-year period of record and the lowest annual runoff volume since 2002 (Figure 4.3-1).

Flows generally decreased from November to December 2014 and were similar to historical lower quartile flows over this period, and flows were similar to historical median flows from January to late March 2015 (Figure 4.3-2). The spring freshet started in early April and peaked at 962 m^3/s on April 25, 2015. The maximum recorded daily flow in the 2015 WY was 1100 m^3/s on June 5, 2015, which was approximately 57% lower than the mean historical maximum daily flow of 2544.9 m^3/s. Warm spring temperatures in addition to a low snow pack contributed to the low and early peak freshet and the low and early peak WY flows as compared to the long-term historical patterns of freshet flow (Figure 4.3-2), likely due to a lower than normal snow pack (Section 4.2.3) and warmer than normal spring temperatures (Figure 4.2-2).

After freshet, discharge increased from late May to late June 2015 with the peak WY flow on June 5, 2015. This peak flow coincided with local rainfall events as well as inferred melt conditions from the upper portion of the watershed in the Rocky Mountains. Flows decreased after the early June peak flows and remained near or below the historical minimum flow values until late September when a small increase in flow was recorded in response to rainfall conditions. Flows after this late September event generally remained between historical minimum and historical lower quartile trends for the remainder of the WY. The minimum flow for the 2015 open-water period (May to October) was 282.0 m^3/s recorded on October 31 2015, which was approximately 33% lower than the mean historical minimum daily flow during the open-water period of 422.0 m^3/s (Table 4.3-1).

Figure 4.3-1 Runoff volumes from the Athabasca River 07DA001 station from 1958 to 2015 WY.

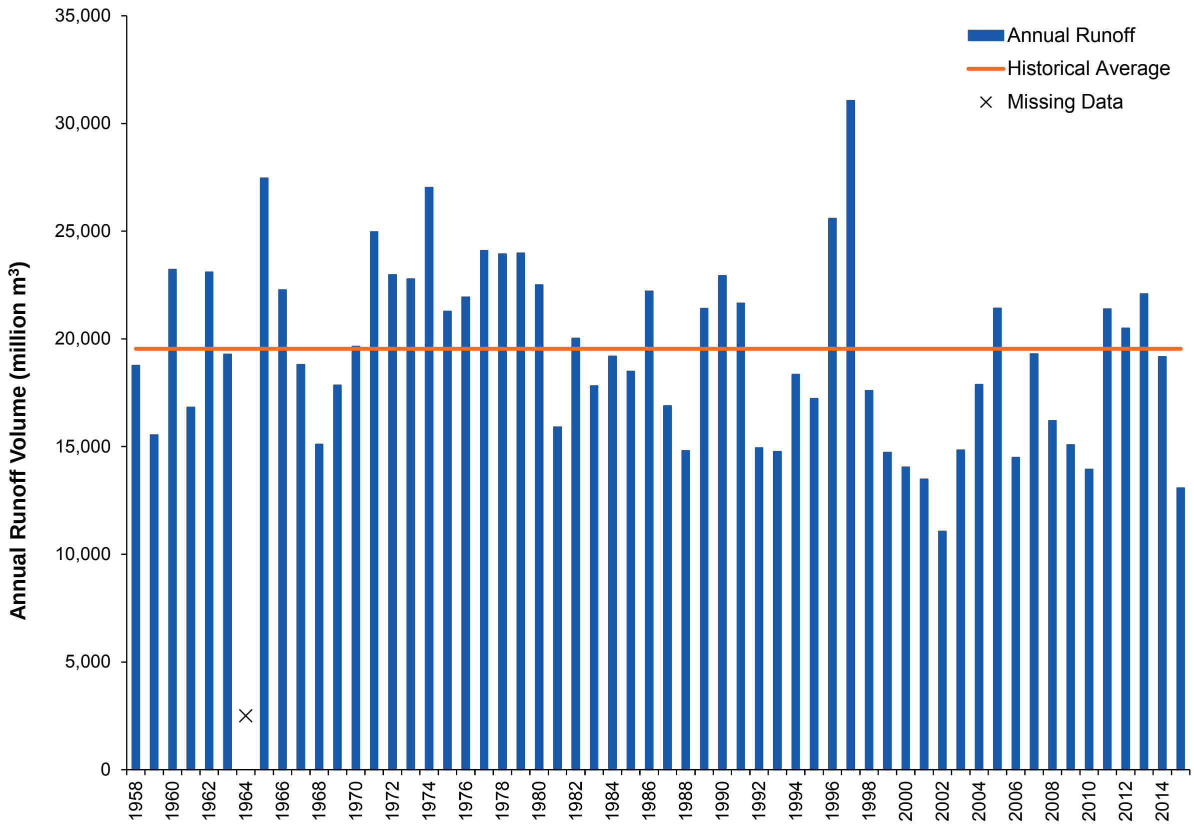
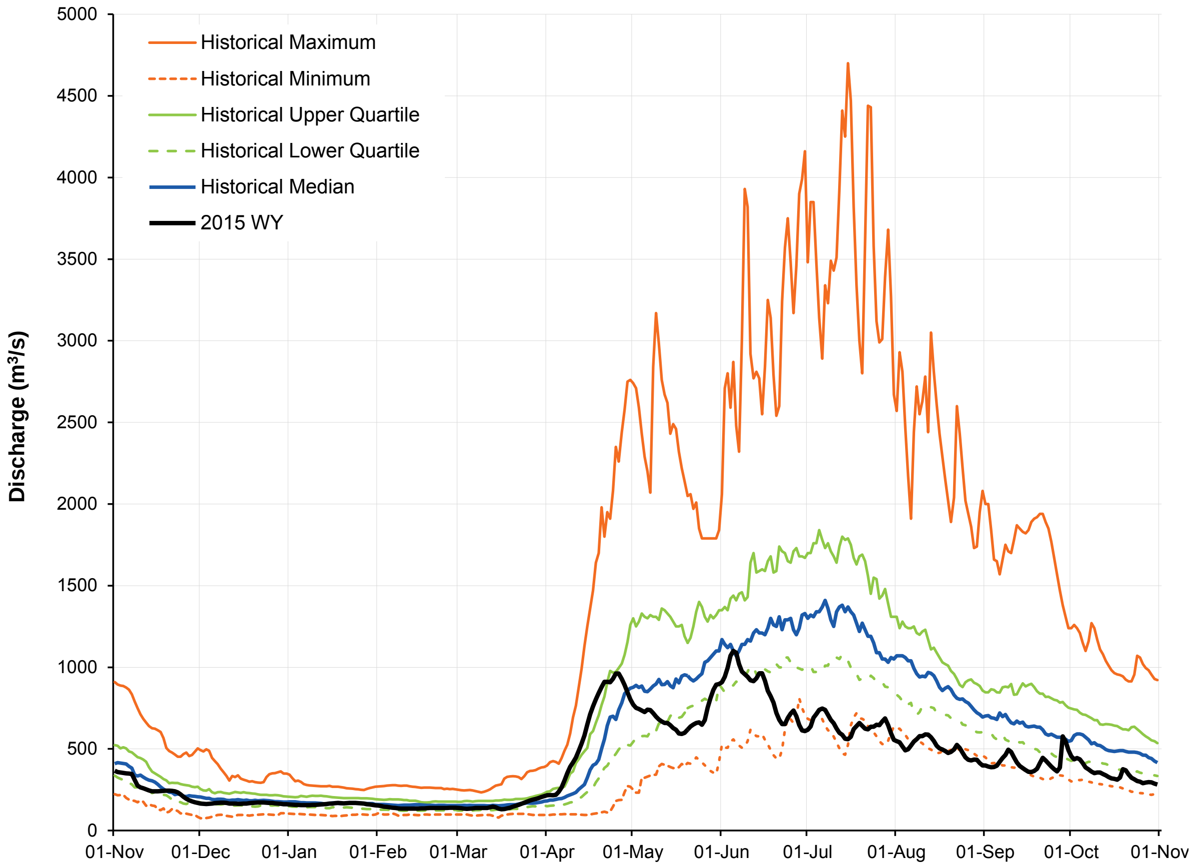


Figure 4.3-2 The 2015 WY Athabasca River (07DA001) hydrograph compared to historical values (1958 to 2015).



4.3.2 Muskeg River

The 2015 seasonal (March to October) runoff volume for the Muskeg River watershed recorded at WSC Station 07DA008, Muskeg River near Fort McKay, was 45.5 million m^3 (Table 4.3-1). This was approximately 62% lower than the long-term mean seasonal runoff volume of 118.4 million m^3, based on the station's 41-year period of record, and the lowest seasonal runoff volume since 1998 (Figure 4.3-3).

Winter flow in the 2015 WY generally remained near the historical median values until late March when warm spring temperatures began to melt the local snow pack and increased flow slightly above the historical median flow (Figure 4.3-4). The spring freshet began in late March 2015 and reached a peak of 5.3 m^3/s on April 21, 2015. This peak flow was greater than the historical median flow on this date but below the historical peak freshet flow; the peak freshet flow also occurred approximately two weeks earlier than historical freshet flows due to a lower than normal snow pack (Section 4.2.3) and warmer than normal spring temperatures (Figure 4.2-2). The peak flow for the 2015 WY was 6.4 m^3/s on May 15, 2015, which was approximately 76% lower than the mean historical maximum daily flow of 27.1 m^3/s.

Flows began to decrease from mid-May and reached historical lower quartile flow values in late May. Flows continued to remain at or below historical lower quartile flows except during two periods of increased rainfall; one from mid-July to mid-August and the other from early September to late

September. The 2015 open-water season (May to October) minimum daily flow of 0.5 m^3/s on August 28 was approximately 50% lower than the historical mean minimum daily flow during the open-water period of 1.0 m^3/s (Table 4.3-1).

Figure 4.3-3 Seasonal (March to October) runoff volumes for the Muskeg River 07DA008 station from 1974 to 2015.

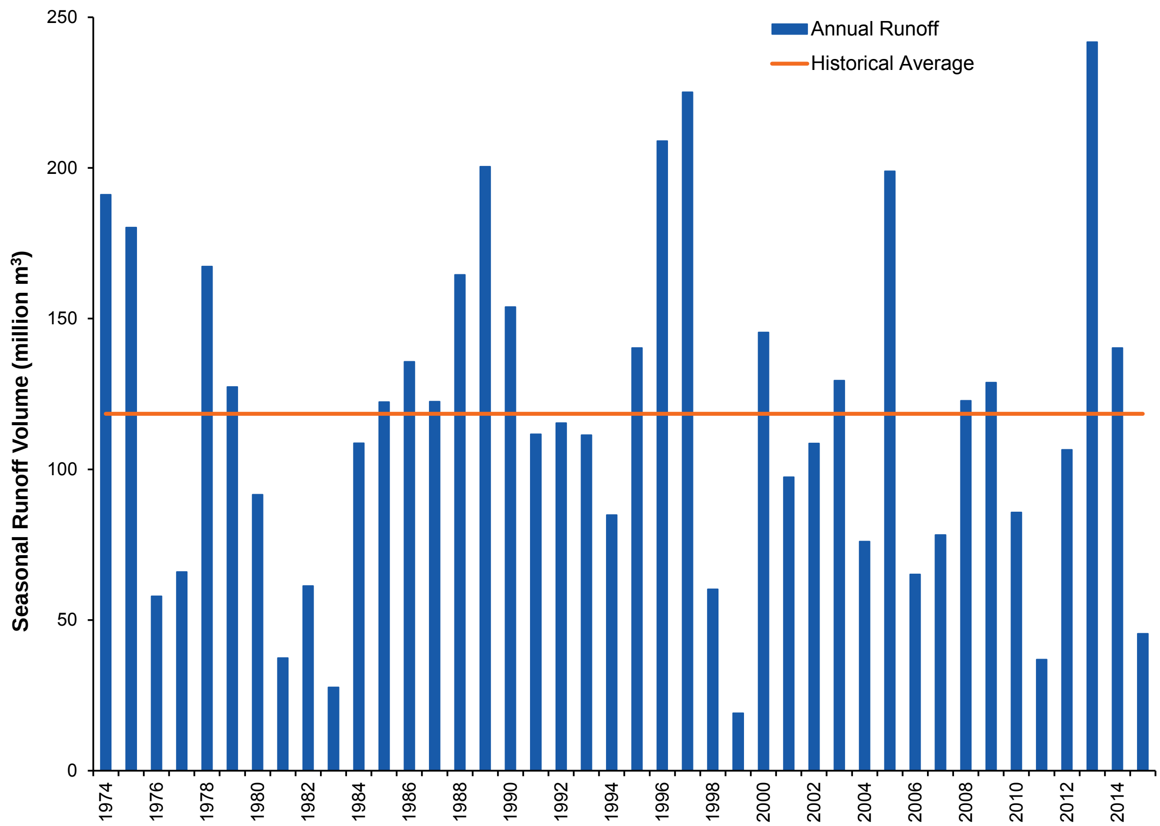
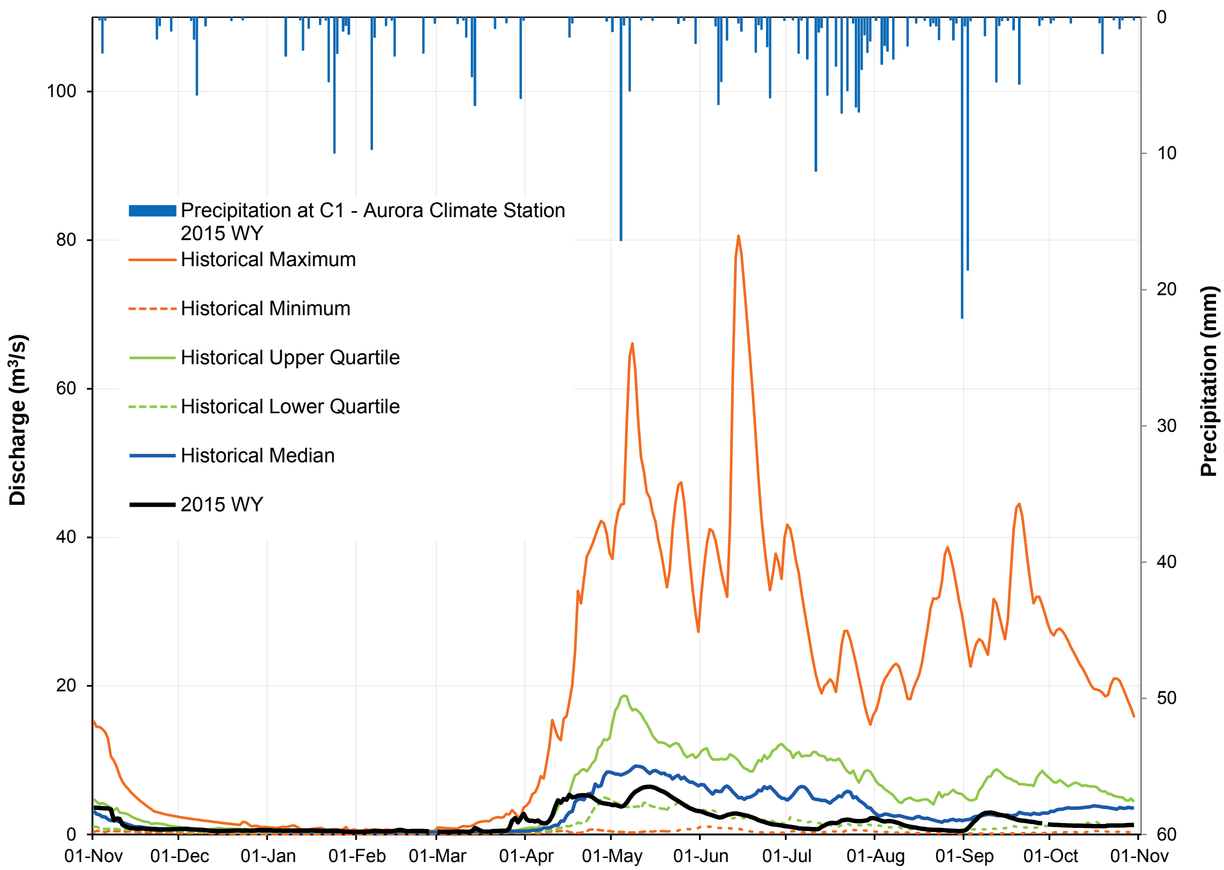


Figure 4.3-4 The 2015 WY Muskeg River (07DA008) hydrograph compared to historical values and 2015 daily precipitation data at the C1 Aurora Climate Station.



4.3.3 MacKay River

The 2015 seasonal (March to October) runoff volume for the MacKay River watershed recorded at WSC Station 07DB001, MacKay River near Fort McKay, was 181.4 million m^3 (Table 4.3-1). This was the lowest seasonal runoff since 2004 and was approximately 57% lower than the long-term mean seasonal runoff volume of 426.6 million m^3, based on a 42-year period of record (Figure 4.3-5, Table 4.3-1).

Winter flows in the 2015 WY generally remained below the historical median flow. An early freshet starting in early April resulted in flows above the historical upper quartile until mid-April (Figure 4.3-6). The spring freshet peaked about two weeks earlier than the historical peak freshet due to a lower than normal snow pack (Section 4.2.3) and warmer than normal spring temperatures (Figure 4.2-2). The peak flow of 27.4 m^3/s on April 27, 2015 was lower than the median historical peak flow of the spring freshet. Following the spring freshet, flows remained within the historical inter-quartile range of flows until a rainfall event generated a peak flow of 35 m^3/s on May 11, 2015. This peak was the maximum daily flow for the 2015 WY; it was also 69% less than the mean historical maximum daily flow of 113.2 m^3/s. Flows then remained near historical lower quartile flows, increasing to near the historical median flow on three occasions in mid-July, early August, and early September. The 2015 open-water season (May to October) minimum daily flow of 2.1 m^3/s occurred on July 11 and was approximately 42% lower than the mean historical minimum daily flow during the open-water period of 3.6 m^3/s.

Figure 4.3-5 Seasonal (March to October) runoff volumes for the Mackay River 07DB001 station from 1973 to 2015.

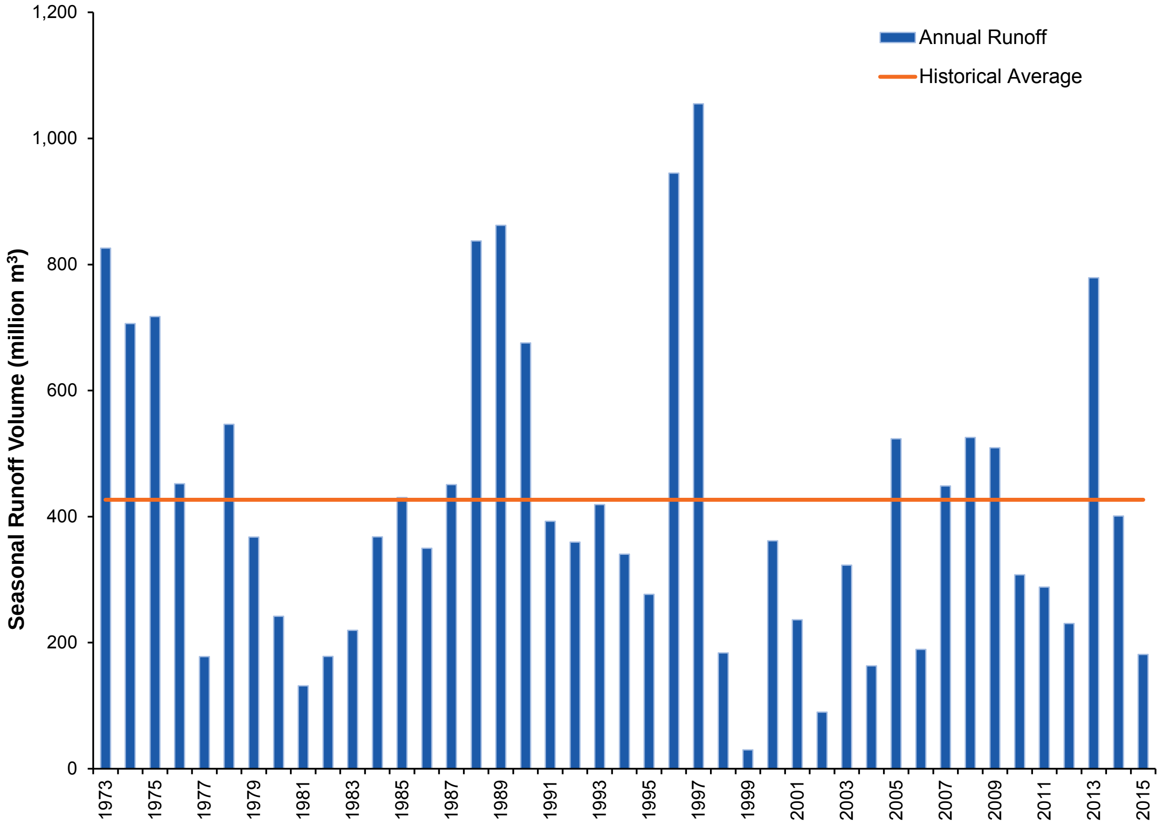
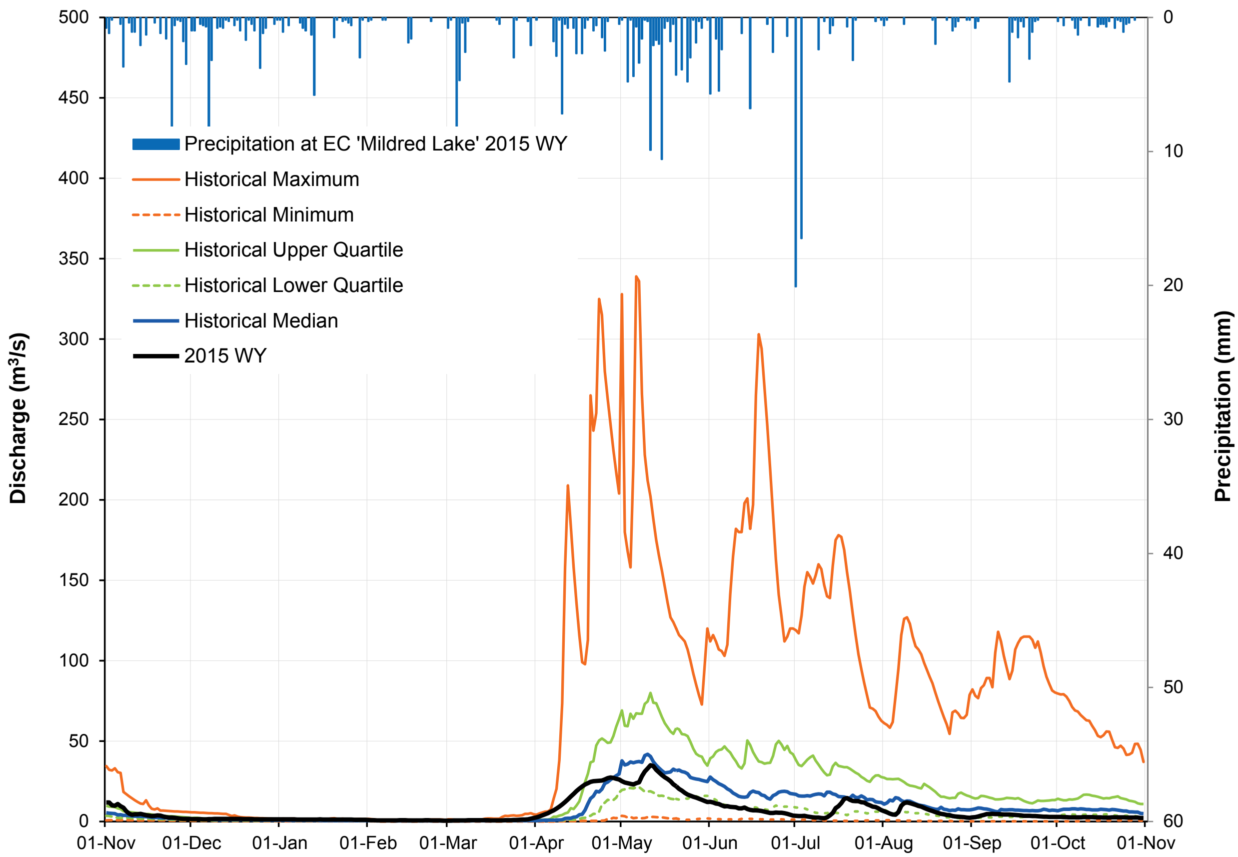


Figure 4.3-6 The 2015 WY MacKay River (07DB001) hydrograph compared to historical values and 2015 daily precipitation data at the EC Mildred Lake climate station.



4.3.4 Christina River

The 2015 seasonal (March to October) runoff volume for the Christina River recorded at WSC station 07CE002, Christina River near Chard, was 205.9 million m^3 (Table 4.3-1). This was approximately 55% lower than the long-term mean seasonal runoff volume of 456.9 million m^3 (Figure 4.3-7). Seasonal runoff recorded at this station for the 2015 WY was the lowest since 1999 and the 2015 WY was the first since 2003 with seasonal runoff volumes below the historical mean seasonal runoff recorded for this station (Figure 4.3-7).

Winter flows generally remained near historical lower quartile flows from November 2014 until mid-April 2015 and then increased above the historical median flow during the spring freshet (Figure 4.3-8). Freshet peaked at 25.8 m^3/s on April 26; this was the maximum daily flow recorded in the 2015 WY, which was approximately71% lower than the mean historical maximum daily flow of 88.1 m^3/s. The timing of the 2015 freshet peak occurred approximately a week earlier than historically due to a low snow pack (Section 4.2.3) and warmer than normal spring temperatures (Figure 4.2-2). Following the peak flow of the spring freshet, flows decreased to below the historical lower quartile in very early June. Flows remained below historical lower quartile flows until rainfall in early August and through the early fall increased flows to greater than historical lower quartile flows for the remainder of the WY. The daily minimum discharge of 5.8 m^3/s for the 2015 open-water season occurred on October 19 2015, which was approximately 11% lower than the historical open-water minimum daily flow of 6.5 m^3/s (Table 4.3-1).

Figure 4.3-7 Seasonal (March to October) runoff volumes for the Christina River 07CE002 station from 1973 to 2015.

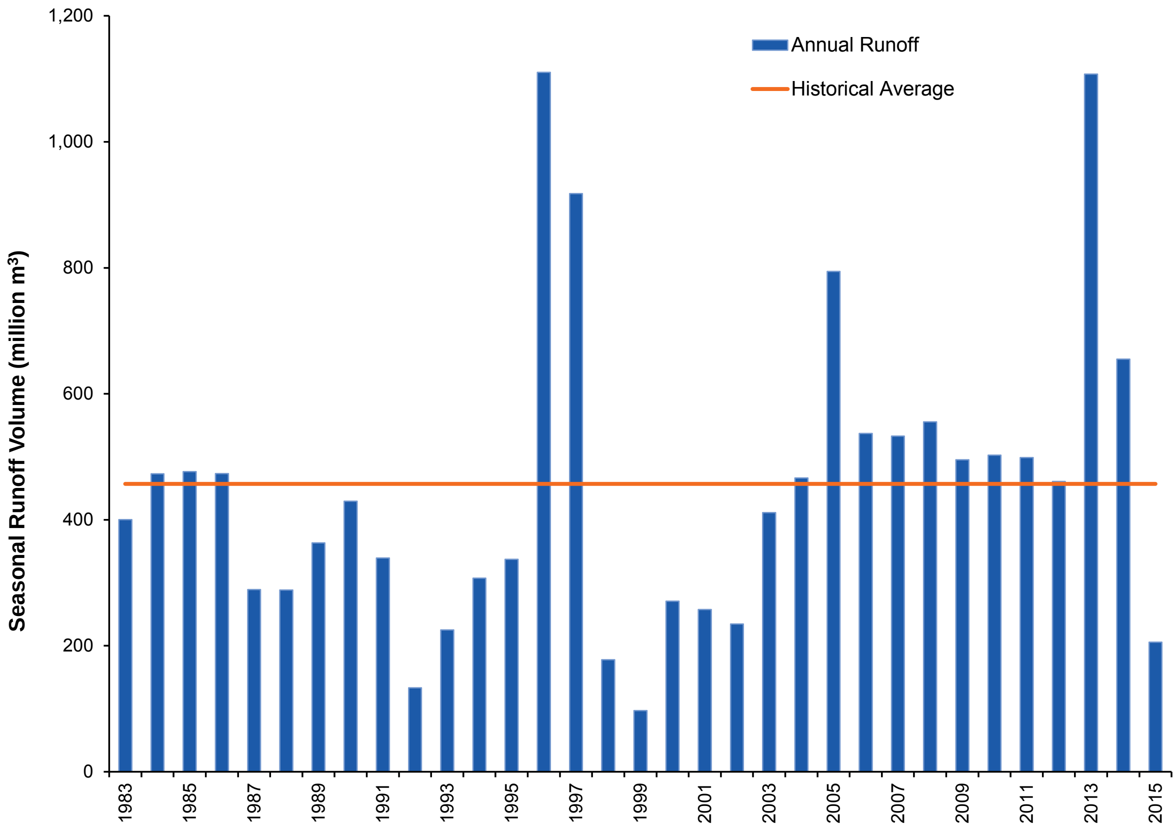
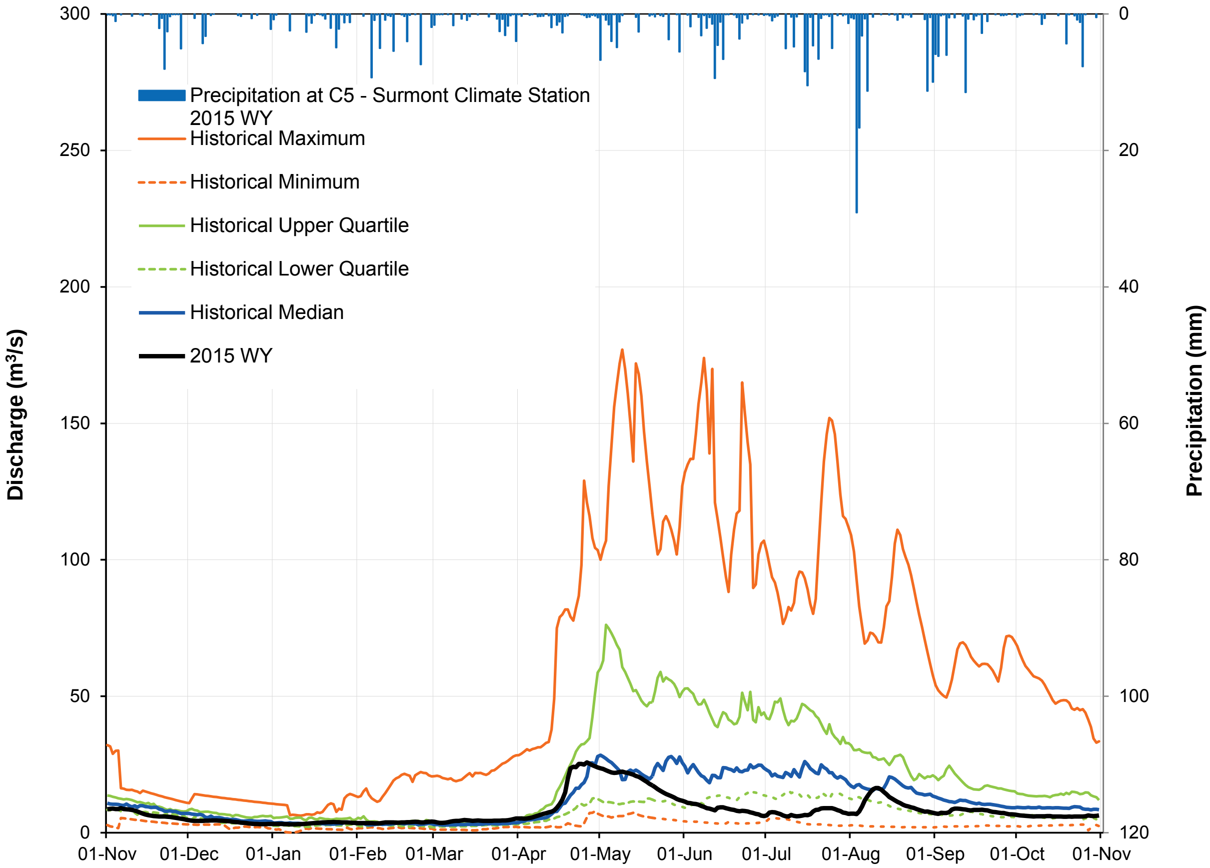


Figure 4.3-8 The 2015 WY Christina River (07CE002) hydrograph compared to historical values and 2015 daily precipitation data at the C5 Surmont climate station.



4.4 SUMMARY

In summary, the climate and hydrology of the Athabasca oil sands region during the 2015 WY (November 1 2014 to October 31 2015) was characterized by the following conditions:

1. Mean daily air temperatures in the 2015 WY were generally between historical minimum and maximum values. Monthly air temperatures were slightly above average for all months except November, February, and September, when mean air temperatures were below historical mean monthly air temperatures.

2. Annual precipitation measured at the Fort McMurray Airport was 275.3 mm, which was 37% lower than the historical mean and the lowest rainfall observed at the Fort McMurray Airport since 1998. Monthly total precipitation was generally low, with total monthly precipitation below the historical mean total monthly precipitation for 10 of the 12 months of the 2015 WY. The wettest months in the 2015 WY were July (99.7 mm total) and September (36.1 mm total), which accounted for 36% and 13% of the total precipitation, respectively, in the 2015 WY. Precipitation falling as snow (November to March) was 42% lower than the long-term mean snowfall, while precipitation as rainfall (April to October) was 35% lower than the long-term mean rainfall.

3. Cumulative precipitation, as measured at ten climate stations throughout the Athabasca oil sands region varied by 171.5 mm in the 2015 WY. Precipitation accumulation as the 2015 WY progressed was generally below the historical progression in mean cumulative precipitation throughout most of the Athabasca oil sands region. Cumulative precipitation briefly rose above the historical cumulative mean at three of these ten climate stations in the 2015 WY: Fort McMurray from mid-May to mid-July; Mildred Lake from late-November to late-July; and L2 Kearl Lake from mid-March to mid-May. Although cumulative precipitation at some of these ten climate stations was occasionally above the historical mean cumulative precipitation, total precipitation did not exceed the historical mean cumulative precipitation (as measured at the Fort McMurray Airport) at any of these stations in the 2015 WY.

4. Measured SWE values in 2015 were greatest in the flat low-lying land cover type, followed in order by the mixed deciduous, jackpine, and open land/lake land cover types; this was similar to historically-measured SWE values. The maximum SWE values in 2015 were all lower than historical mean values for each land cover type. Maximum SWE values in flat low-lying, mixed deciduous, jackpine, and open land/lake land cover types were 20%, 39%, 37% and 48% lower than the historical mean values, respectively, for each land cover type. Melting of the snowpack began in late March in the Athabasca oil sands region in 2015, and snowpack melt was complete by early April.

5. The low precipitation, low snow pack, and warm temperatures that characterize the 2015 WY contributed to early and low freshet peaks, as well as some of the lowest WY runoff volumes observed in recent years. The Athabasca, Muskeg, MacKay and Christina rivers in the 2015 WY had the lowest observed runoff volume (annual runoff volume for the Athabasca River and seasonal runoff volume – March to October – for the Muskeg, MacKay and Christina rivers) since the 2002, 2011, 2004 and 1999 WYs, respectively.

6. The 2015 WY runoff volume for the Athabasca River[1], was 13,083 million m^3, which was 33% lower than the historical mean runoff volume. Seasonal (March to October) runoff volumes for the Muskeg River, MacKay River, and Christina rivers[2] were 62%, 57%, and 55% lower than long-term mean seasonal runoff volumes, respectively.

7. Maximum daily flow values and peak flows throughout the 2015 WY other than the spring freshet were primarily influenced by local rainfall events and, in the case of the Athabasca River, inferred melt conditions from the upper portion of the watershed (i.e., Rocky Mountains) in early June.

[1] As measured at WSC Station 07DA001, Athabasca River below Fort McMurray.

[2] As measured at Muskeg River near Fort McKay (07DA008), MacKay River near Fort McKay (07DB001), and Christina River near Chard (07CE002), respectively.

5.0 2015 MONITORING RESULTS

This chapter consists of two parts. The first part focuses on detailed monitoring results specific to individual watersheds within the Athabasca oil sands region. Monitoring in these watersheds includes the collection of data characterizing hydrology, water quality, benthic invertebrate communities and sediment quality, and fish populations. The second part presents data specific to the Acid-Sensitive Lakes component and focuses on water quality monitoring at 50 lakes located throughout the Athabasca oil sands region and beyond.

For the watershed analyses, Section 5.1 presents 2015 results for the Athabasca River and the Athabasca River Delta (ARD); Sections 5.2 to 5.12 present 2015 watershed results for the major tributaries of the Athabasca River within the Athabasca oil sands region; and Section 5.13 presents the results for miscellaneous aquatic systems that were monitored in 2015. Table 5-1 provides a guide to assist the reader in finding watershed-specific results. The monitoring results for the Acid-Sensitive Lakes component are presented in Section 5.14.

Table 5-1 Page number guide to watersheds and component reports.

	Athabasca River and Delta	Muskeg	Steepbank	Tar	MacKay	Calumet	Firebag	Ells	Clearwater	Christina	Hangingstone	Pierre River Area	Miscellaneous Aquatic Systems	Acid-Sensitive Lakes
Climate and Hydrology	5-9	5-98	5-216	5-246	5-286	5-345	5-380	5-436	5-511	5-555	5-729	-	5-790	-
Water Quality	5-11	5-101	5-217	5-247	5-287	5-347	5-382	5-438	5-512	5-557	5-731	5-762	5-790	-
Benthic Invertebrate Communities	5-13	5-105	5-220	5-249	5-290	5-348	5-384	5-441	5-515	5-562	5-733	5-764	5-790	-
Sediment Quality	5-18	5-112	-	5-251	5-290	5-350	5-388	5-444	5-518	5-576	-	5-766	5-790	-
Fish Populations	5-20	5-114	5-220	5-252	5-291	-	-	5-446	-	5-579	5-734	-	5-790	-

Definitions for Monitoring Status

The Program Report uses the following definitions for monitoring status:

1. ***Test*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of oil sands developments; data collected from these locations are designated as *test* for the purposes of data analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but simply that data collected from these locations are being tested against *baseline* conditions to assess potential changes; and

2. ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2015) or were (prior to 2015) upstream of all oil sands developments; data collected from these locations are designated as *baseline* for the purposes of data analysis, assessment, and reporting.

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5.1 ATHABASCA RIVER AND ATHABASCA RIVER DELTA

Table 5.1-1 Summary of results for the Athabasca River and Athabasca River Delta.

Athabasca River and Delta	Summary of 2015 Conditions																		
	Athabasca River															Athabasca River Delta			
Climate and Hydrology																			
Criteria	07DD001	no station	no station	S24	no station	no station	no station	no station	no station	no station	no station	07DA001	no station	no station	no station	no stations			
Mean open-water season discharge	🟡	-	-	not measured	-	-	-	-	-	-	-	not measured	-	-	-	-	-	-	-
Mean winter discharge	🟡	-	-	not measured	-	-	-	-	-	-	-	not measured	-	-	-	-	-	-	-
Annual maximum daily discharge	🟡	-	-	not measured	-	-	-	-	-	-	-	not measured	-	-	-	-	-	-	-
Minimum open-water season discharge	🟡	-	-	not measured	-	-	-	-	-	-	-	not measured	-	-	-	-	-	-	-
Water Quality																			
Criteria	no station	M8	ATR-DD-W	ATR-DD-C	ATR-DD-E	no station	M6	M5	M4-DS	M4	M4-US	M3	no station	M0-DS	no station	FLC-1	GIC-1	BPC-1	EMR-2
Water Quality Index	-	data sonde only	-	🟡	-	-	🟡	🟡	🟡	🟡	🟡	🟡	-	🟡	-	🟡	🟡	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality																			
Criteria	no station	no station	no station	no station	no station	no station	no station	no station	M4-DS	no station	M4-US	M3	no station	M0-DS	no station	FLC-1	GIC-1	BPC-1	EMR-2
Benthic Invertebrate Communities	-	-	-	-	-	-	-	-	no station	-	no station	no station	-	no station	-	🟡	🟠	🟡	🟡
Sediment Quality Index	-	-	-	-	-	-	-	-	n/a	-	n/a	n/a	-	-	-	n/a	n/a	n/a	n/a
Fish Populations																			
Criteria	M9	M8	no reach	no reach	no reach	M7	no reach	no reach	M4-DS	no reach	M4-US	M3*	M2	M0-DS	M0-US	no reaches			
Fish Communities	No Fish Communities monitoring was conducted in the 2015 WY.																		
Wild Fish Health	🟠	🟤	-	-	-	🟤	-	-	🟠	-	🟡	🟠	🟠	🟠	n/a	-	-	-	-

Legend and Notes

🟡 Negligible-Low — *baseline*
🟠 Moderate — *test*
🟤 High

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

* Wild fish health reach M3 is upstream of all oil sands mining projects and therefore considered a *baseline* station for the purposes of the wild fish health assessment; however, this reach is downstream of the discharge point for the Fort McMurray sewage treatment plant (STP) and can therefore also be considered a *test* reach in relation to the Fort McMurray STP.

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

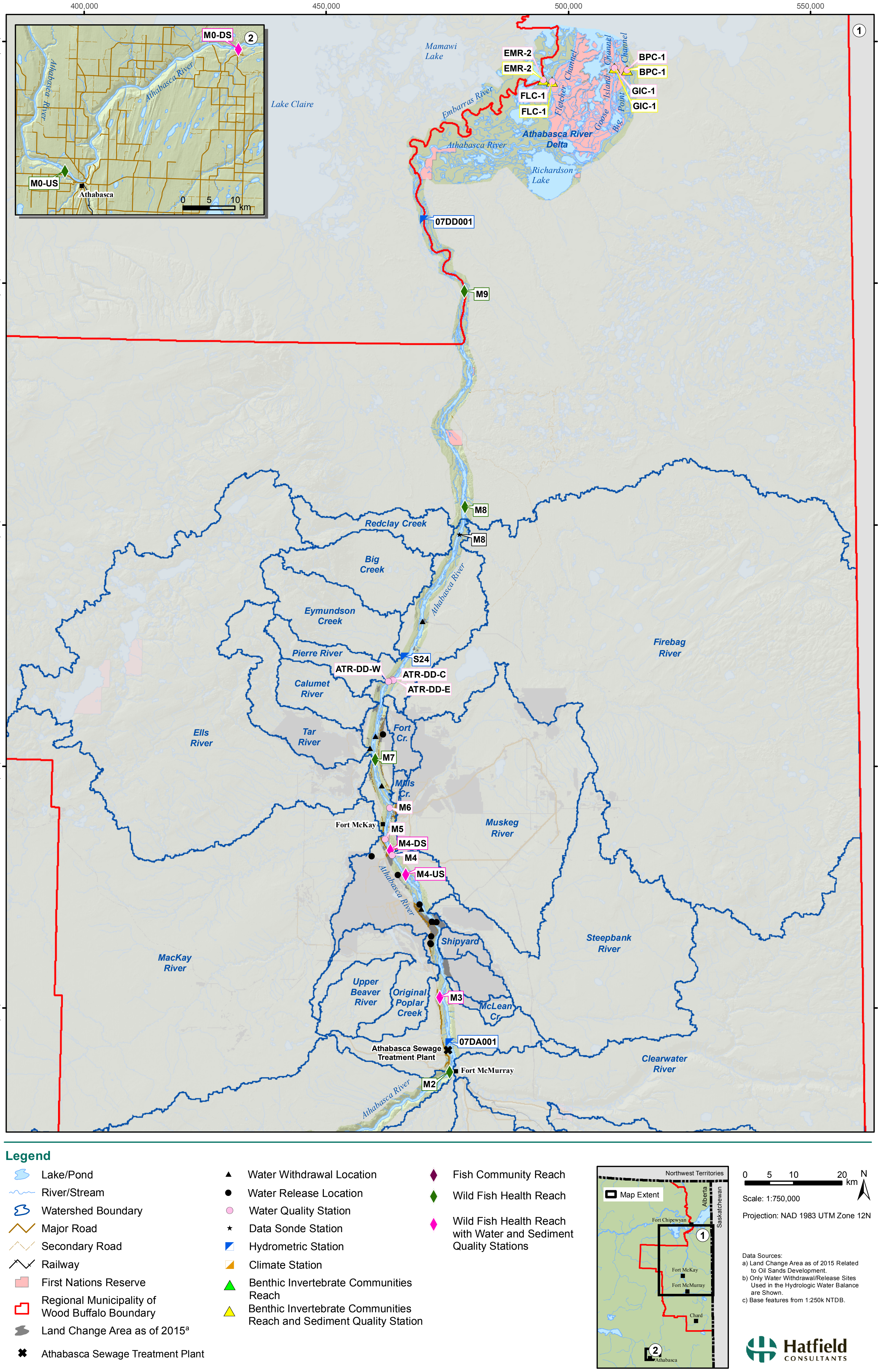
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (Wild Fish Health): Classification for the Athabasca River was based on exceedances of measurement endpoints at each monitoring reach relative to the reach located immediately upstream on the Athabasca River (i.e., considered a "*baseline*" reach for comparison purposes) in an effort to isolate potential effects related to specific influences of interest; see Section 3.2.4.2 for a detailed description of the classification methodology.

Figure 5.1-1 Athabasca River and Athabasca River Delta.



K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_K01_Mainstem_20160322_ss.mxd

Figure 5.1-2 Representative monitoring stations of the Athabasca River and Athabasca River Delta, fall 2015.

Water Quality Station ATR-DD-C: Athabasca River below Pierre River, facing downstream

Water Quality Station M5: Athabasca River above MacKay River, facing upstream

Water Quality Station M4: Athabasca River, below Beaver River, facing downstream

Water Quality, Sediment Quality and Wild Fish Health Station/Reach M3: Athabasca River, below Fort McMurray STP discharge, facing downstream

Benthic, Sediment Quality, and Water Quality Station/Reach FLC-1: Athabasca River Delta – Fletcher Channel

Benthic, Sediment Quality, and Water Quality Station/Reach GIC-1: Athabasca River Delta – Goose Island Channel

Benthic, Sediment Quality, and Water Quality Station/Reach BIC-1: Athabasca River Delta – Big Point Channel

Benthic, Sediment Quality, and Water Quality Station/Reach EMR-2: Athabasca River Delta – Embarras River

5.1.1 Summary of 2015 WY Conditions

Approximately 3.5% (128,486 ha) of the Athabasca oil sands region had undergone land change from oil sands development as of 2015 (Table 2.3-1) and approximately 24.5% (33,762 ha) of the minor Athabasca River tributary watersheds had undergone land change from oil sands development as of 2015 (Table 2.5-2). The Athabasca sewage treatment plant (STP) discharge outlet immediately downstream of Fort McMurray demarcates the *baseline* (upstream) and *test* (downstream) portions of the Athabasca River.

Monitoring activities in the Athabasca River and Athabasca River Delta (ARD) in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components. Table 5.1-1 is a summary of the 2015 assessment for the Athabasca River and ARD, while Figure 5.1-1 provides the locations of the monitoring stations for each monitoring component, reported water withdrawal and discharge locations, and the land change area from oil sands development as of 2015. Figure 5.1-2 contains fall 2015 photos of a number of monitoring stations in the Athabasca River and ARD.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology The mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge in the 2015 WY were 1.1%, 1.8%, 0.7%, and 1.4% lower, respectively, in the Athabasca River observed (*test*) hydrograph than in the estimated (*baseline*) hydrograph. These differences were classified as **Negligible-Low**.

Water Quality Monthly data from 2015 indicate variations across months at all stations for most water quality measurement endpoints, with concentrations of TSS and associated nutrients and metals highest during freshet and concentrations of TDS and associated dissolved constituents highest during low flows in the fall. Water quality guideline exceedances included total phenols at all stations except *baseline* station M0-DS, and sulphide at all Athabasca River mainstem stations, *test* station FLC-1 in the ARD, as well as *baseline* stations M0-US and M0-DS, both of which were monitored to support wild fish health monitoring. These exceedances were common in the Athabasca River and ARD in monitoring conducted in previous years by the RAMP/JOSMP. Differences in water quality in fall 2015 for all stations monitored in the Athabasca River and ARD and regional *baseline* fall conditions were classified as **Negligible-Low**.

Benthic Invertebrate Communities and Sediment Quality The nature of variations in benthic invertebrate communities in the ARD differed for each channel. Variations in key measurement endpoints in Big Point Channel, Fletcher Channel, and Embarras River were classified as **Negligible-Low**. Variations in key measurement endpoints in Goose Island Channel were classified as **Moderate** on the basis of high abundances (> 120,000 individuals per m^2) and the dominance of tubificids.

Concentrations of sediment quality measurement endpoints were below guideline concentrations in fall 2015, with the exception of total arsenic at *test* stations EMR-2, M3, and M4-US, Fraction 3 hydrocarbons at *test* stations GIC-1 and EMR-2, and predicted PAH toxicity at *test* stations BPC-1, EMR-2, M3, M4-DS, and M4-US, and at *baseline* station M0-DS. Sediment quality results for fall 2015 were not classified due to SQI values not being calculated for sediment quality at stations on the Athabasca River mainstem or in the ARD because there were no regional *baseline* concentrations for sediment quality.

Fish Populations (Wild Fish Health) Spatial comparisons for wild fish health reaches on the Athabasca River looked at gradient effects along the Athabasca River. There did not appear to be a simple gradient effect on measurement endpoints of trout perch occurring along the Athabasca River, but rather a concentration of changes in measurement endpoints starting at *test* reach M4-DS, becoming more prominent at *test* reach M7, and then dissipating at *test* reach M9. A similar trend was found in in EROD activity of trout perch. When each monitoring reach was compared to the reach located immediately upstream (i.e., considered a “baseline” reach for comparison purposes in an effort to test for specific influences of interest), the classification of results for wild fish health for *baseline* reaches M0-DS, M2, and M3 were assessed as **Moderate,** *test* reach M4-US was assessed as **Negligible-Low**, *test* reaches M4-DS and M9 were classified as **Moderate**, and *test* reaches M7 and M8 were classified as **High**.

5.1.2 Hydrologic Conditions

Hydrometric monitoring for the Athabasca River in the 2015 WY was conducted at:

- WSC Station 07DD001, Athabasca River at Embarras Airport (formerly JOSMP Station S46); and
- WSC Station 07DA001, Athabasca River below Fort McMurray.

Data from WSC Station 07DD001 were used for the water balance analysis[1].

Historical statistics were calculated using data from JOSMP Station S46 and WSC Station 07DD001. WSC station 07DD001 recorded data annually from 1971 to 1976 and from 2015 onwards, and during open-water months (May to October) from 1977 to 1984. Continuous hydrometric data were collected at Station S46 from August 2011 to October 2014.

The historical flow record for WSC Station 07DD001 is summarized in Figure 5.1-3 and includes the median, interquartile range, and range of flows recorded daily through the water year. Flows of the Athabasca River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically lower than during the open-water season, and generally decrease from November until mid-March. Spring thaw and the resulting increase in flows typically begins in early April. Monthly flows are highest in June at the peak of freshet and often remain elevated in July. The timing of peak flow and the initiation of freshet in the Athabasca River mainstem are often delayed relative to the tributaries of the Athabasca River, due to the large size of the Athabasca River watershed and glacial-fed headwaters forming a significant source of flows in the mainstem. Flows generally recede from late July until the end of October, in response to declining rainfall inputs and eventually river freeze-up.

While flows of the Athabasca River in the 2015 WY were similar to the historical seasonal pattern described above, the magnitude of the flows in the 2015 WY were generally lower than normal, and the timing of peak flow was several weeks earlier than normal (Figure 5.1-3). Flows generally decreased from November to late April, and then increased during spring thaw with an initial peak flow of 915 m^3/s on May 1 that decreased through much of May and then increased to a second, larger peak of 1310 m^3/s on June 7. Discharge then decreased through mid-June, and then decreased more slowly for the remainder of the water year, with the exception of several small periodic increases in flow that were likely responses to precipitation events. The minimum open-water daily flow of 345 m^3/s was recorded on

[1] Data from JOSMP Station S24 Athabasca River below Eymundson Creek were used for the water balance analysis prior to the 2012 WY.

October 29, and was 36% lower than the historical mean minimum daily flow of 543 m^3/s calculated for the open-water period.

Discharge in the winter of 2015 was between the historic lower quartile and the historic minimum flows. The early rise due to spring thaw in late March and April caused flows to be above historical median flows but by early May, discharge was below historical median flows again and typically between the historic lower quartile and the historical minimum flows. Flows were consistently below historical minimum flows from late June through August and then from early September onward above historical minimum flows.

Overall, the annual runoff volume in the 2015 WY was 14,464 million m^3, which was 38% lower than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Athabasca River watershed, at WSC Station 07DD001, is summarized in Table 5.1-2. Key changes in flows and water diversions included:

1. The closed-circuited land area as of 2015 in the minor Athabasca River tributaries, McLean Creek, Shipyard Lake, Horse River, and Beaver River was estimated to be 664.8 km^2 (Table 2.5-1). The loss of flow to the Athabasca River that would have otherwise occurred from this land area was estimated at 62.4 million m^3.

2. As of 2015, the area of land change in the minor Athabasca River tributaries, McLean Creek, Shipyard Lake, Horse River and upper Beaver River that was not closed-circuited was estimated to be 130.0 km^2 (Table 2.5-1). The increase in flow to the Athabasca River that would not have otherwise occurred from this land area was estimated at 2.44 million m^3.

3. Water withdrawals directly from the Athabasca River in the 2015 WY were 120.7 million m^3.

4. Water discharges directly to the Athabasca River in the 2015 WY were 6.4 million m^3.

5. The 2015 WY discharge into the Athabasca River from major tributaries (i.e., Calumet River, Christina River, Ells River, Firebag River, Fort Creek, Hangingstone River, MacKay River, Mills Creek, Muskeg River, Poplar Creek, Steepbank River, and Tar River) was estimated to be 2.96 million m^3 less than the discharge would have been in the absence of oil sands development in those watersheds.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands developments in the 2015 WY was a loss of flow of 177.3 million m^3 at WSC Station 07DD001 on the Athabasca River. The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 1.1%, 1.8%, 0.7%, and 1.4% lower, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.1-3). These differences were classified as **Negligible-Low** (Table 5.1-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis to identify the longitudinal hydrological effects along the Athabasca River was not conducted.

5.1.3 Water Quality

During the 2015 WY water quality samples were taken:

- from the Athabasca River "downstream of development" – center channel (*test* station ATR-DD-C), which was sampled seasonally from May 2014 to March 2015, then monthly from May to October 2015. Previously, ATR-DD had been sampled along its east and west banks (ATR-DD-E and ATR-DD-W) annually or seasonally since the late 1990s until March 2015;
- from three Athabasca River mainstem stations located between the Beaver River and Ells River (*test* stations M4, M5, and M6), established as part of the 2015 Program and sampled from May to October (these locations were sampled by Environment Canada from 2011 to 2014);
- during the benthic invertebrate monitoring component, from four *test* stations in the Athabasca River Delta (ARD): Big Point Channel, BPC-1; Embarrass River, EMR-2; Fletcher Channel, FLC-1; and Goose Island Channel, GIC-1 in September 2015; and
- during the fish health monitoring component, from three *test* stations: M3; M4-US; and M4-DS, as well as from *baseline* station M0-DS in the Athabasca River in September 2015.

Additionally, a data sonde installed at *test* station M8 collected continuous water quality data from May to October 2015 for a subset of water quality variables.

Figure 5.1-4 presents trends in continuous monitoring variables recorded by data sondes at *test* station M8 in the 2015 WY. Monthly and seasonal variations in water quality are summarized in Table 5.1-4 to Table 5.1-7 and Figure 5.1-5. Water quality results from fall 2015 relative to historical fall concentrations are provided in Table 5.1-8 to Table 5.1-11. A summary of water quality guideline exceedances for water quality measurement endpoints is provided in Table 5.1-12. The ionic composition of Athabasca River water measured in 2015 and previous years is presented in Figure 5.1-6, and Figure 5.1-7 to Figure 5.1-9 compare selected water quality measurement endpoints in the Athabasca River and the ARD relative to historical concentrations and regional *baseline* concentrations.

Continuous Monitoring Results from Data Sondes Continuously monitored in situ water quality data indicate that the water temperature increased up to 24°C in summer, then gradually decreased to 5°C in the middle of October (Figure 5.1-4). In contrast to temperature, concentrations of dissolved oxygen were generally higher in fall than in spring and summer, likely related to higher oxygen solubility at lower temperatures, consistent with the steady dissolved oxygen saturation observed over the monitoring period. Concentrations of dissolved oxygen remained within water quality guidelines for the protection of aquatic life throughout the monitoring period. pH levels were alkaline throughout the monitoring period and were also within the guideline range throughout the monitoring period. Specific conductivity was higher in fall than in spring and summer. Turbidity levels were variable, particularly in August and September. Data gaps for data sondes at stations of the Athabasca River are discussed in Appendix B.

Monthly and Seasonal Variations in Water Quality Monthly data collection at Athabasca River mainstem stations began in the 2015 WY. There were temporal variations in concentrations and levels of water quality measurement endpoints but no obvious spatial differences among stations for the same measurement endpoints (Table 5.1-4 to Table 5.1-7, Figure 5.1-5). Concentrations of TSS and associated water quality constituents (i.e., nutrients and a number of total metals) were highest in June and July and lowest in September and October, consistent with seasonal high and low flows in the Athabasca River (Figure 5.1-3). In contrast, concentrations of TDS and associated constituents (i.e., conductivity, alkalinity, and major ions) were lowest in June and highest in October, also consistent with greater available dilution from surface runoff during seasonally high flows in June. Comparison of 2015 monthly data with limited historical data (available only for *test* station ATR-DD-C; Figure 5.1-5) indicate that concentrations and levels of most measurement endpoints fell within the historical monthly ranges with the exception of total arsenic, chloride, and sulphate (Figure 5.1-5).

2015 Fall Results Relative to Historical Concentrations The concentration of total dissolved phosphorus, total nitrogen, magnesium, chloride, sulphate, TDS, total molybdenum, total strontium, total dibenzothiophenes, and total parent and alkylated PAHs were higher at *test* station ATR-DD-C in fall 2015 than fall 2014, which was the first year that water quality was sampled at this *test* station; concentrations and levels of all other water quality measurement endpoints were lower in fall 2015 than fall 2014 (Table 5.1-8). While the concentration of naphthalene was below detection limits in both fall 2015 and fall 2014, the detection limit in fall 2015 was higher than the detection limit in fall 2014. Historical comparisons were not possible for any of the other water quality stations on the Athabasca River and in the ARD as these were sampled for the first time in the 2015 WY; concentrations and levels of all water quality measurement endpoints for these stations are provided in Table 5.1-9 to Table 5.1-11.

Temporal Trends Statistical trend analyses were not conducted on water quality data for stations in the Athabasca River or the ARD area due to insufficient length of the time series in the water quality datasets.

Ion Balance The ionic composition in fall 2015 at *test* station ATR-DD-C was consistent with that observed in fall 2014 and the ionic composition in fall 2015 at the other stations in the Athabasca River and in the ARD were similar to that of *test* station ATR-DD-C with the exception of *test* station M3 and *baseline* station M0-DS both of which had higher proportions of magnesium, calcium, and sulphate and lower proportions of sodium/potassium and chloride (Figure 5.1-6).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Water quality guideline exceedances in 2015 included (Table 5.1-12):

- total phenols at *test* stations ATR-DD-C and M4 in May and July to October; at *test* station M5 in May and July to September; at *test* station M6 in August to October; and all biological monitoring *test* stations (i.e., stations sampled for benthic invertebrate communities and wild fish health) in September (no exceedances occurred at *baseline* station M0-DS); and
- sulphide at *test* station ATR-DD-C in July to August; *test* station M4 in May to August; *test* station M5 in May, July and August; *test* station M6 in June, August, and September; and at biological monitoring *test* station FLC-1 and *baseline* stations M0-US and M0-DS in September.

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints in fall 2015 were within the range of regional *baseline* concentrations at all water quality and biological monitoring stations (Figure 5.1-7 to Figure 5.1-9); with the exception of:

- TSS, with concentration lower than the 5th percentile of regional *baseline* concentration at *test station* ATR-DD-C;

- total dissolved phosphorus, with concentration lower than the 5th percentile of regional *baseline* concentration at *test stations* ATR-DD-C, M3, M4, and M6, and *baseline* station M0-DS;

- total nitrogen, with concentration lower than the 5th percentile of regional *baseline* concentration at *test* station M3 and *baseline* station M0-DS;

- total mercury, with concentration lower than the 5th percentile of regional *baseline* concentration at *test stations* EMR-2, GIC-1, M4-US, and M4-DS, and *baseline* station M0-DS;

- total arsenic, with concentration lower than the 5th percentile of regional *baseline* concentration at *test stations* M5, M6, M4-US, and M4-DS, and *baseline* station M0-DS;

- total strontium and sulphate, with concentrations higher than the 95th percentile of regional *baseline* concentration at *test stations* M3 and *baseline* station M0-DS; and

- total boron and sodium, with concentrations lower than the 5th percentile of regional *baseline* concentration at *baseline station* M0-DS.

Water Quality Index The calculated WQI was 94.7 for *test* station M3 and 100 for all other stations, indicating high consistency with regional *baseline* water quality conditions at all stations monitored in all 2015 on the Athabasca River and in the ARD.

Classification of Fall Results Differences in water quality in fall 2015 for all stations monitored in the Athabasca River and ARD and regional *baseline* fall conditions were classified as **Negligible-Low**.

5.1.4 Benthic Invertebrate Communities and Sediment Quality

5.1.4.1 Benthic Invertebrate Communities

Benthic invertebrate community samples were collected from four depositional channels of the ARD in fall 2015:

- depositional *test* reach BPC-1 in Big Point Channel, sampled from 2002 to 2005 and from 2007 to 2015;

- depositional *test* reach FLC-1 in Fletcher Channel, sampled from 2002 to 2005 and from 2007 to 2015;

- depositional *test* reach GIC-1 in Goose Island Channel, sampled from 2002 to 2005 and from 2007 to 2015; and

- depositional *test* reach EMR-2 in the Embarras River, sampled from 2010 to 2015.

2015 Habitat Conditions Water at *test* reaches BPC-1, GIC-1, FLC-1, and EMR-2 of the ARD in fall 2015 (Table 5.1-13) was moderately deep (1.2 m to 3.3 m) and circum-neutral to slightly alkaline (pH 7.8 to 8.3) with concentrations of dissolved oxygen that ranged from 7.5 mg/L to 7.8 mg/L and conductivity that ranged from 199 µS/cm to 206 µS/cm. The substrate at all *test* reaches was typically dominated by sand or silt. The organic carbon content of the sediments was low (≤2%) at all *test* reaches (Table 5.1-13).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community in fall 2015 included several taxa that are typically associated with good environmental conditions. The benthic invertebrate community at *test* reach BPC-1 in fall 2015 was dominated by tubificid worms (49%) and permanent aquatic forms Bivalvia (*Pisidium* and *Sphaerium;* 27%) and Gastropoda (*Probythinella;* 12%) (Table 5.1-14). Nine chironomid taxa comprised 6% of the total abundance of benthic invertebrates at *test* reach BPC-1 in fall 2015, with *Procladius* being the most abundant. While mayflies and caddisflies were present *test* reach BPC-1 in fall 2015, stoneflies were absent. There were few other flying insects, consisting only of *Gomphus* dragonflies.

The benthic invertebrate community at *test* reach FLC-1 in fall 2015 was dominated by chironomids (58%) with subdominant taxa consisting of tubificid worms (16%) and oligochaete worms *Naididae* (11%) (Table 5.1-15). Chironomids at *test* reach FLC-1 consisted primarily of the genera *Polypedilum*, *Cryptotendipes*, *Paracladopelma* and *Phaenopsectra/Tribelos*. One mayfly genus, *Ametropodidae*, and one caddisfly genus, *Oecetis*, were found at *test* reach FLC-1. *Pisidium* and *Sphaerium* bivalves and *Probythinella* gastropods were present in low relative abundances.

The benthic invertebrate community at *test* reach GIC-1 was dominated by tubificid worms (84%), with subdominant taxa consisting of chironomids (8%) and Bivalvia (7%) (Table 5.1-16). Four chironomid taxa were present in *test* reach GIC-1, with *Phaenopsectra/Tribelos* and *Cryptotendipes* being the most abundant. Mayflies (*Hexagenia limbata*), caddisflies (*Neureclipsis*), and dragonflies (*Gomphus*) were present in low relative abundances in one of the ten replicate samples and *Probythinella* and *Physa* gastropods were present in low relative abundances throughout the sampled reach.

The benthic invertebrate community at *test* reach EMR-2 was dominated by chironomids (37%), tubificid worms (31%) and Bivalvia (23%) (Table 5.1-16). Chironomids were primarily from the genera *Chironomus*, *Pagastiella* and *Cryptotendipes*. Flying insects (Trichoptera: *Oecetis*) were found in all replicates. Bivalves (*Pisidium/Sphaerium*) were present and gastropods were principally *Probythinella* and *Valvata sincera*.

Big Point Channel

Temporal Comparisons[2] CA Axis 2 scores were significantly different in 2015 compared to the mean of all previous years. While this difference accounted for 21% of the variance in annual means (Table 5.1-17) this difference does not imply a negative change or degrading conditions for benthic invertebrate communities at *test* reach BPC-1 in 2015 compared to previous years as the observed variation in CA Axis 2 scores reflected higher relative abundances of Gastropoda and Bivalvia and lower relative abundances of Chironomidae (Figure 5.1-10).

Comparison to Published Literature The composition of the benthic invertebrate community at *test* reach BPC-1 in 2015 was generally what would be expected given a shifting-sand environment (Barton and Smith 1984). The relative abundances of tubificid worms (49%) at *test* reach BPC-1 has been lower in recent years compared to historical results. The dominant chironomid *Procladius* is common in north-temperate waters (Wiederholm 1983) and known to be moderately tolerant of poor water quality

[2] The temporal comparisons of benthic invertebrate community measurement endpoints (Section 3.2.3.1) that were possible for all *test* reaches in the ARD: were changes over time (Hypothesis 5, Section 3.2.3.1); and changes between 2015 values and the mean value of all previous years of monitoring. Only statistically-significant differences are reported.

conditions (Mandeville 2002). EPT taxa, which were absent in 2014, were present in 2015 along with relatively high abundances of permanent aquatic forms such as Bivalvia and Gastropoda, which indicated favourable long-term water quality (Resh and Unzicker 1975; Niemi et al. 1990).

2015 Results Relative to Historical or *Baseline* Conditions Abundance at *test* reach BPC-1 in fall 2015, adjusted to a common % sand composition, exceeded the inner tolerance limit of the 95th percentile for the means of previous years of monitoring in the ARD (Figure 5.1-11); this does not imply a negative change or degrading conditions for benthic invertebrate communities at *test* reach BPC-1 in 2015 compared to previous years because the exceedance was minor and the abundance was well within the range of prior years (Table 5.1-14) Values of all other measurement endpoints of benthic invertebrate communities at *test* reach BPC-1 were within the inner tolerance limits for the 95% region for the means of previous years of monitoring in the ARD.

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities at *test* reach BPC-1 for fall 2015 are classified as **Negligible-Low**:

1. The benthic invertebrate community in fall 2015 included several taxa that are typically associated with relatively good environmental conditions.
2. The significant difference in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means did not imply degrading conditions for benthic invertebrate communities.
3. While values of one of the six measurement endpoints in fall 2015 was beyond the inner tolerance limit of the 95th percentile of the normal range of values of prior years, the excursion outside of normal range did not imply degrading conditions for benthic invertebrate communities.

Fletcher Channel

Temporal Comparisons There was a significant change over time in CA Axis 1 scores for *test* reach FLC-1 (Table 5.1-18). While this difference accounted for 46% of the variance in annual means (Table 5.1-18) this difference does not imply negative trends or degrading conditions for benthic invertebrate communities at *test* reach *FLC-1* as the observed variation in CA Axis 1 scores reflected lower relative abundances of tubificid worms over time at *test* reach FLC-1 (Figure 5.1-10).

Comparison to Published Literature The benthic invertebrate community at *test* reach FLC-1 in 2015 was typical for a shifting-sand riverine environment (Barton and Smith 1984). Shifting sands typically support chironomids, worms, and ceratopogonids, all of which were present in this reach. The dominant forms of chironomids found in the reach included forms common in north-temperate (e.g., *Polypedilum*) (Wiederholm 1983) and forms known to be moderately tolerant of poor water quality conditions (e.g., *Paracladopelma*) (Mandeville 2002). EPT taxa, which were present (although in relatively low abundances) are often difficult to collect in sandy environments (Barton and Smith 1984).

2015 Results Relative to Historical or *Baseline* Conditions Values of all measurement endpoints of benthic invertebrate communities at *test* reach FLC-1 were within the inner tolerance limits of both the 5th and 95th percentiles of the means of all previous years in the ARD (Figure 5.1-11).

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities at *test* reach FLC-1 were classified as **Negligible-Low**:

1. The benthic invertebrate community at *test* reach FLC-1 in 2015 was typical for a shifting-sand riverine environment and included taxa typically associated with a stable benthic invertebrate community.

2. The significant difference in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means did not imply degrading conditions for benthic invertebrate communities.

3. Values of the six measurement endpoints in fall 2015 were within the inner tolerance limit of the 95th percentile of the normal range of values of prior years.

Goose Island Channel

Temporal Comparisons The following statistically-significant differences were measured at *test* reach GIC-1 in fall 2015:

1. Abundance, adjusted to a common % sand composition, was significantly higher in 2015 than the mean of prior years and accounted for 35% of the variance in annual means (Table 5.1-19). As with all channels in the ARD that are monitored for benthic invertebrate communities (Appendix D), abundance is correlated with the proportion of sand in the substrate; abundance at *test* reach GIC-1 in 2015 was substantially higher than the previously-measured maximum abundance at that reach (Table 5.1-16).

2. There was a significant increase in %EPT over time, which accounted for 32% of the variation in annual means.

3. There was a significant decrease CA Axis 1 scores over time, which accounted for 52% of the variation in annual means (Table 5.1-19). The shift in CA Axis 1 scores is likely due to the increase in the relative abundance of tubificid worms in 2015 and the presence of permanent aquatic forms such as bivalves and gastropods (Figure 5.1-10). This difference does not imply a negative change or degrading conditions for benthic invertebrate communities because although Tubificidae is generally considered a group of tolerant worms (Mandeville 2001), permanent aquatic forms indicate favourable long-term water quality (Resh and Unzicker 1975; Niemi et al. 1990).

Comparison to Published Literature The composition of taxa in 2015 was typical for a shifting-sand riverine environment (Barton and Smith 1984), with high relative abundances of worms and lower relative abundances of mayflies and caddisflies. The substrate at *test* reach GIC-1 was primarily silt in 2015, which has been shown for the ARD to lead to higher numbers of organisms generally (Appendix D). High relative abundances of worms (tubificids) have occurred in different channels in years when the channels had silty substrates.

2015 Results Relative to Historical or *Baseline* Conditions Abundance exceeded the inner tolerance limit of the 95th percentile for the means of previous years of monitoring in the ARD (Figure 5.1-11). Abundances were higher in 2015 (greater than 120,000 individuals per m^2) than in previous years (1,800 individuals per m^2 to 36,000 individuals per m^2). Abundances in excess of about 100,000 organisms per m^2 can be an indication of potential degradation (Kilgour et al. 2005) but in this case may also reflect low sand content and high proportions of silt and/or clay (see Table 5.1-13). Values of all other measurement endpoints for *test* reach GIC-1 were within the inner tolerance limits of both the 5th and 95th percentiles for the means of all previous years in the ARD (Figure 5.1-11).

Classification of Results Variations in key measurement endpoints at *test* reach GIC-1 were classified as **Moderate:**

1. The benthic invertebrate community at *test* reach GIC-1 in 2015 was typical for a shifting-sand riverine environment and included taxa typically associated with a stable benthic invertebrate community.
2. One of the three significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.
3. Values of one of the six measurement endpoints in fall 2015 was beyond the inner tolerance limit of the 95th percentile of the normal range of values of prior years, implying possible degrading conditions for benthic invertebrate communities.

Embarras River

Temporal Comparison Results Equitability and %EPT decreased over time at *test* reach EMR-2 (Table 5.1-20) and these changes accounted for 42% and 47% of the variance in annual means, respectively. These differences do not imply negative changes or degrading conditions for benthic invertebrate communities at *test* reach EMR-2; decreases in equitability (i.e., increases in diversity) indicate improving conditions and %EPT in 2015 was visually greater than previous years in the reach (i.e., 2012 to 2014) and well within the range of *baseline* variability (Figure 5.1-11).

Comparison to Published Guidelines The benthic invertebrate community at *test* reach EMR-2 was typical for a shifting-sand environment. The relative abundance of tubificid worms (31%), although lower than in 2014, was higher than in 2010 to 2013. Chironomids were abundant in fall 2015 as were permanent aquatic forms such as bivalves (*Pisidium* and *Sphaerium*) indicating a taxa composition that was typical for rivers in good condition (Hynes 1960; Griffiths 1998).

2015 Results Relative to Historical or *Baseline* Conditions Values of all measurement endpoints of benthic invertebrate communities at *test* reach EMR-2 were within the inner tolerance limits of both the 5th and 95th percentiles of the means of all previous years in the ARD (Figure 5.1-11).

Classification of Results Variations in key measurement endpoints at *test* reach EMR-2 are classified as **Negligible-Low:**

1. The benthic invertebrate community at *test* reach EMR-2 was typical for a shifting-sand environment.
2. None of the significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.

3. Values of the six measurement endpoints in fall 2015 were within the inner tolerance limit of the 95^{th} percentile of the normal range of values of prior years.

5.1.4.2 Sediment Quality

Sediment samples were collected in fall 2015 from the ARD at:

- *test* station BPC-1 in Big Point Channel, sampled from 1999 to 2003, 2005, and from 2007 to 2015;
- *test* station FLC-1 in Fletcher Channel, sampled from 2001 to 2003, 2005, and from 2007 to 2015;
- *test* station GIC-1 in Goose Island Channel, sampled from 2001 to 2003, 2005, and from 2007 to 2015; and
- *test* station EMR-2 in the Embarras River, sampled in 2005, 2010, and from 2012 to 2015.

Sediment quality sampling was also conducted in fall 2015 during the wild fish health monitoring on the Athabasca River at:

- *baseline* station M0-DS (lower reach);
- *test* station M3 (middle reach); and
- *test* stations M4-DS and M4-US (upper reach).

Temporal Trends The following significant ($p<0.05$) temporal trends in concentrations of sediment quality measurement endpoints were measured:

- increasing concentrations of Fraction 4 hydrocarbons at *test* station FLC-1 and *test* station BPC-1;
- decreasing concentrations of Fraction 1 hydrocarbons at *test* station EMR-2;
- increasing concentrations of total parent PAHs at *test* station EMR-2; and
- decreasing concentrations of total parent PAHs at *test* station GIC-1.

Trend analyses could not be conducted for *baseline* station M0-DS or *test* stations M3, M4-DS, and M4-US because fall 2015 was the first year of sampling at these stations.

2015 Results Relative to Historical Conditions Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at the stations in the ARD (Table 5.1-21 to Table 5.1-24, Figure 5.1-12 to Figure 5.1-15) with the following exceptions:

- total dibenzothiophenes at *test* station BPC-1 with a concentration in fall 2015 that was greater than the historical maximum concentration;
- *Hyalella* 14-day survival at *test* station FLC-1, which was lower than fell below the previously-measured minimum survival;

- *Hyalella* 10-day growth and *Chironomus* 10-day growth at *test* station GIC-1, which were lower than previously-measured minimum growth rates; and

- %clay, %total organic carbon, and predicted PAH toxicity at *test* station EMR-2, which were lower than previously-measured minimum values; and

- %silt, Fraction 4 hydrocarbons, and 10-day *Chironomus* survival at *test* station EMR-2, which were greater than previously-measured maximum values.

Table 5.1-25 presents the concentrations and levels of sediment quality measurement endpoints for *baseline* station M0-DS and *test* stations M3, M4-DS, and M4-US (historical comparisons in sediment quality conditions could not be made for these stations because fall 2015 was the first year of sediment sampling at these stations):

- silt and sand co-dominated sediments collected in fall 2015 at *baseline* station M0-DS, *test* station M3, and *test* station M4-US, while sediments collected at *test* station M4-DS were dominated by sand with a smaller portion of silt;

- the concentration of BTEX and Fraction 1 hydrocarbon were non-detectable at *baseline* station M0-DS or at *test* stations M3, M4-DS, and M4-US;

- the concentration of Fraction 2 hydrocarbons were not detectable at *baseline* station M0-DS or at *test* station M4-DS;

- direct sediment toxicity tests indicated high survival of the midge *Chironomus* at *baseline* station M0-DS and *test* station M4-DS and moderate to high survival of *Chironomus* at *test* station M3 and *test* station M4-US; and

- direct sediment toxicity tests indicated high survival of the amphipod *Hyalella* at all four stations.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Measurement endpoints of all sediment quality were below guideline concentrations in fall 2015, with the following exceptions:

- total arsenic at *test* station EMR-2, *test* station M3 and *test* station M4-US;

- Fraction 3 hydrocarbons at *test* station GIC-1 and *test* station EMR-2; and

- predicted PAH toxicity at *test* station BPC-1, *test* station EMR-2, *test* station M3, *test* station M4-DS, and *test* station M4-US, as well as at *baseline* station M0-DS.

2015 Results Relative to Regional *Baseline* Concentrations Results from fall 2015 were not compared to *baseline* ranges of variability because the limited historical sediment quality dataset for the Athabasca River mainstem and the ARD made it impossible to develop regional *baseline* concentrations for sediment quality.

Sediment Quality Index SQI values were not calculated for sediment quality at stations on the Athabasca River mainstem or in the ARD because there were no regional *baseline* concentrations for sediment quality.

Classification of Results Sediment quality results for fall 2015 were not classified due to SQI values not being calculated for sediment quality at stations on the Athabasca River mainstem or in the ARD because there were no regional *baseline* concentrations for sediment quality.

5.1.5 Fish Populations

5.1.5.1 Wild Fish Health

Wild fish health monitoring was conducted in nine reaches of the Athabasca River in fall 2015 using trout perch as the target species:

- *baseline* reach M0-US above the town of Athabasca, which was sampled for the first time in fall 2015;
- *baseline reach* M0-DS at Poachers Landing located downstream of the town of Athabasca and the effluent discharge from the ALPAC pulp mill, which was sampled for the first time in fall 2015;
- *baseline* reach M2 above Fort McMurray (previously designated ATR-1) and the town's sewage treatment plant, which was sampled in fall 2002, 2010, 2013, and 2015;
- *baseline* reach M3[3] below Fort McMurray at Northlands (previously designated ATR-2) and upstream of intensive oil sands mining development, which was sampled in fall 1999, 2002, 2010, 2013, and 2015;
- *test* reach M4-US above the Muskeg River (previously designated ATR-3), which was sampled in fall 1999, 2002, 2010, 2013, and 2015;
- *test* reach M4-DS below the Muskeg River (previously designated ATR-4), which was sampled in fall 1999, 2002, 2010, 2013, and 2015;
- *test* reach M7 above the Ells River, which was sampled for the first time in fall 2015;
- *test* reach M8 below the Firebag River (previously designated ATR-5), which was sampled in fall 2002, 2010, 2013, and 2015; and
- *test* reach M9 near the Athabasca River Delta, which was sampled for the first time in fall 2015.

2015 Habitat Conditions In situ water quality at all sites indicated suitable conditions for trout perch, with concentrations of dissolved oxygen ranging from 7.2 mg/L to 9.8 mg/L, conductivity ranging from 202 µS/cm to 374 µS/cm, pH ranging from 6.36 and 8.52, and temperature ranging from 10.8°C to 15.4°C. The mean water depth at reaches ranged from 0.46 m to 5.20 m. Water velocity varied among reaches and ranged from 0.01 m/s to 0.41 m/s, with the majority of reaches classified as run habitat. The dominant substrate at most reaches was a mixture of cobble and fines or gravel and fines, with the exception of *test* reach M9, with silt and sand as the dominant and sub-dominant substrate, respectively (Table 5.1-26). Mean daily temperatures at reaches decreased from a high of 22°C in August to a low of 9°C in September (Figure 5.1-16).

[3] Although *baseline* reach M3 is upstream of all oil sands mining projects (and therefore considered a *baseline* reach for the purposes of this assessment), it is downstream of the discharge point for the Fort McMurray sewage treatment plant (STP); *baseline* reach M3 can therefore also be considered a *test* reach in relation to the Fort McMurray STP.

Collection and Structure of Target Fish Populations

Summary of Capture Success of Adults and Juveniles The target number of adult trout perch (20 adult fish of each sex) was achieved at all reaches with the exception of *baseline* reach M2 and *test* reach M8 at which 14 and 19 male trout perch were collected, respectively. Although fishing effort was maximized to capture the required number of 100 juvenile trout perch, the target number were not obtained for any of the reaches (Table 5.1-27). A summary of morphometric data for the trout perch caught in the Athabasca River is provided in Table 5.1-27.

Size Distribution Figure 5.1-17 presents the length-frequency distributions for trout perch captured in fall 2015 at each of the nine reaches. A length of 50 mm was used to designate trout perch juveniles on the Athabasca River as 50 mm marks the end of the first peak in the bimodal distributions of length for most reaches (Figure 5.1-17). Length-frequency distributions of juvenile trout perch indicated that juvenile fish at *baseline* reaches M0-US and M0-DS were smaller than those caught at all other reaches (Figure 5.1-17). *Baseline* reaches M0-US and M0-DS had higher frequencies of juvenile fish less than 45 mm, whereas all other reaches had higher frequencies of juvenile fish greater than 45 mm. *Baseline* reaches M0-US and M0-DS in fall 2015 had the highest relative abundance of juvenile trout perch while *baseline* reaches M2 and M3 had the lowest relative abundance of juvenile trout perch (Table 5.1-27).

Incidence of Abnormalities A torn caudal fin was observed on one fish at *baseline* reach M0-DS, and eroded caudal fins were observed on one fish at *test* reach M4-US, three fish at *test* reach M7, and four fish at *test* reach M9 (Table 5.1-27).

Spatial and Temporal Comparison of Measurement Endpoints of Wild Fish Health

A summary of morphometric data for the adult trout perch caught in the Athabasca is provided in Table 5.1-28. The following information provides detailed statistical analyses of the responses of trout perch populations collected at all reaches along the Athabasca River. This information was used to test for spatial and temporal differences in measurement endpoints of trout perch among reaches.

Spatial differences in values of measurement endpoints of trout perch for fall 2015 from *baseline* and *test* reaches of the Athabasca River were assessed with the following comparisons:

- *baseline* reach M0-DS was compared to *baseline* reach M0-US;
- *baseline* reach M2 was compared to *baseline* reach M0-DS;
- *test* reach M3 (relative to the upstream STP discharge and the town of Fort McMurray) was compared to *baseline* reach M2;
- *test* reach M4-US was compared to *baseline* reach M3 (considered a *baseline* reach relative to downstream oil sands mining development);
- *test* reach M4-DS was compared to *test* reach M4-US;
- *test* reach M7 was compared to *test* reach M4-DS;
- *test* reach M8 was compared to *test* reach M7; and
- *test* reach M9 was compared to *test* reach M8.

All comparisons were made between reaches moving sequentially downstream from the most upstream sampling reach to investigate additive effects of development occurring along the Athabasca River.

The following temporal comparisons were made:

- Values of measurement endpoints at each reach with more than three years of data were compared to the historical normal range of measurement endpoint values:
    - *Baseline* reach M2 (2002, 2010, 2013, and 2015);
    - *Baseline* reach M3 (1999, 2002, 2010, 2013, and 2015);
    - *Test* reach M4-US (1999, 2002, 2010, 2013, and 2015);
    - *Test* reach M4-DS (1999, 2002, 2010, 2013, and 2015); and
    - *Test* reach M8 (2002, 2010, 2013, and 2015).
- Each of the *test* reaches above as well as *test* reaches M7 (2015) and M8 (2015) were compared to the normal range of values of *baseline* reach M3. *Baseline* reach M3 was used as the reference reach for oil sands development because it is upstream of oil sands operations and downstream of Fort McMurray's sewage treatment plant (STP).
- Condition, relative gonad size and relative liver size were presented using estimates of condition factor (K), gonadosomatic index (GSI) and liversomatic index (LSI), respectively.

Age – Mean Age and Age Distribution (Survival) Relative age-frequency distributions of trout perch showed age classes ranging from one to four years for the majority of reaches sampled in fall 2015 with the exception of *baseline* reach M0-US and *test* reaches M7, M9, and M4-DS (Figure 5.1-18). Dominant age classes were two and three years at all reaches with most reaches having a dominant age class of three years.

The following statistically-significant differences in the age of trout perch among reaches of the Athabasca River in fall 2015 were identified (Table 5.1-29):

1. Female trout perch were significantly younger at *test* reach M4-US than female trout perch at *baseline* reach M3;
2. Female trout perch were significantly older at *test* reach M4-DS than female trout perch at *test* reach M4-US;
3. Female trout perch were significantly younger at *test* reach M7 than female trout perch at *test* reach M4-DS;
4. Female trout perch were significantly older at *test* reach M8 than female trout perch at *test* reach M7;
5. Male trout perch were significantly younger at *test* reach M8 than male trout perch at *test* reach M7; and
6. Male trout perch were significantly older at *test* reach M9 than male trout perch at *test* reach M8.

An exceedance of the effects criterion (±25% difference in ages of fish between reaches) was measured in female trout perch at *test* reaches M4-DS, M7, and M8; and in male trout perch at *test* reach M9 when compared to their respective upstream reaches (Table 5.1-29).

Mean age of trout perch caught in fall 2015 at all reaches was within the range of ages of trout perch caught in previous surveys and was within the range of ages for fish caught at *baseline* reach M3 (i.e., the reach immediately upstream of all oil sands mining developments) (Figure 5.1-19, Figure 5.1-20).

Growth – Size-at-age (Energy Use) The following statistically-significant differences in weight-at-age of trout perch among reaches of the Athabasca River were measured in fall 2015 (Table 5.1-29):

1. Female trout perch were significantly lighter at a given age at *baseline* reach M0-DS than at *baseline* reach M0-US;
2. Male trout perch were significantly lighter at *baseline* reach M2 than male trout-perch at *baseline* reach M0-DS;
3. Female trout perch were significantly heavier at a given age at *baseline* reach M3 than at *baseline* reach M2;
4. Female and male trout perch were significantly heavier at a given age at *test* reach M4-DS than at *test* reach M4-US;
5. Male trout perch were significantly lighter at a given age at *test* reach M7 than at *test* reach M4-DS;
6. Female and male trout perch were significantly lighter at a given age at *test* reach M8 than at *test* reach M7; and
7. Male trout perch were significantly heavier at a given age at *test* reach M9 than at *test* reach M8.

An exceedance of the effects criterion (±25% difference in growth of fish between reaches) was observed in female trout perch at *baseline* reaches M0-DS and M3 and in male and female trout perch at *test* reaches M4-DS and M8 when compared to their respective upstream reaches (Table 5.1-29).

Mean age-normalized body weight of trout perch caught in fall 2015 at all reaches was within the range of relative body weights of trout perch caught in previous surveys, and was within the range of body weights for fish caught at *baseline* reach M3 (i.e., the reach immediately upstream of all oil sands mining developments) (Figure 5.1-21, Figure 5.1-22), with the following exceptions:

1. Mean age-normalized weight of male trout perch at *baseline* reach M2 was below the estimated normal range;
2. Mean age-normalized weight of male trout perch at *test* reach M4-DS was above the estimated normal range and above the historical normal range at *baseline* reach M3;
3. Mean age-normalized weight of male trout perch at *test* reach M7 was above the historical normal range at *baseline* reach M3; and

4. Mean age-normalized weight of female trout perch at *test* reach M8 was below the historical normal range at *baseline* reach M3.

Relative Gonad Weight (Energy Use) – The following statistically-significant differences in relative gonad weight of trout perch among reaches of the Athabasca River were measured in fall 2015 (Table 5.1-29):

1. Mean gonad size was significantly smaller for female trout perch at *baseline* reach M2 than at *baseline* reach M0-DS;
2. Mean gonad size was significantly larger for female trout perch at *baseline* reach M3 than at *baseline* reach M2;
3. Mean gonad size was significantly smaller for female and male trout perch at *test* reach M7 than at *test* reach M4-DS;
4. Mean gonad size was significantly larger for male trout perch at *test* reach M8 than at *test* reach M7; and
5. Mean gonad size was significantly smaller for female and male trout perch at *test* reach M9 than at *test* reach M8.

The applicable effects criterion (±25% in relative gonad weight of fish between the reaches) was exceeded in female trout-perch at *baseline* reach M2, in male trout perch at *test* reach M8, and in both sexes at *test* reach M7 when compared to their respective upstream reaches (Table 5.1-29).

Mean GSI of trout perch caught in fall 2015 at all reaches was within the range of GSIs of trout perch caught in previous surveys, and was within the range of GSI for fish caught at *baseline* reach M3 (i.e., the reach immediately upstream of all oil sands mining developments)(Figure 5.1-23, Figure 5.1-24), with the following exceptions:

1. GSI of female trout perch at *baseline* reach M2 was lower than the normal range of historical GSI values; and
2. GSIs of female trout perch at *test* reaches M7, M8 and M9 were lower than the historical normal range of GSI at the oil sands *baseline* reach M3.

Relative Liver Weight (Energy Storage) –The following statistically-significant differences in relative liver weight of trout perch among reaches of the Athabasca River were measured in fall 2015 (Table 5.1-29):

1. Mean liver size of female and male trout perch were significantly larger at *baseline* reach M3 than at *baseline* reach M2;
2. Mean liver size of female and male trout perch were significantly smaller at *test* reach M7 than at *test* reach M4-DS;
3. Mean liver size of female and male trout perch were significantly larger at *test* reach M8 than at *test* reach M7; and

4. Mean liver size of female and male trout perch were significantly smaller at *test* reach M9 than at *test* reach M8.

An exceedance of the effects criterion (±25% difference in relative liver weight of fish between reaches) was observed in both sexes of trout perch at *test* reaches M7, M8 and M9 when compared to their respective upstream reaches (Table 5.1-29).

Mean LSI of trout perch caught in fall 2015 at all reaches was within the range of LSIs of trout perch caught in previous surveys, and was within the range of LSI for fish caught at *baseline* reach M3 (i.e., the reach immediately upstream of all oil sands mining developments) (Figure 5.1-25, Figure 5.1-26), with the following exceptions:

1. Mean LSI of female trout perch at *test* reach M8 was below the estimated normal range of historical LSI values;
2. Mean LSI of female and male trout perch at *test* reach M7 was below the historical normal range of *baseline* reach M3; and
3. Mean LSI of female and male trout perch at *test* reach M9 was below the historical normal range of *baseline* reach M3.

Condition (Energy Storage) –The following statistically-significant differences in condition of trout perch among reaches of the Athabasca River were measured in fall 2015 (Table 5.1-29):

1. Condition of female and male trout perch was significantly lower at *baseline* reach M0-DS than at *baseline* reach M0-US;
2. Condition of female and male trout perch was significantly higher at *baseline* reach M2 than at *baseline* reach M0-DS;
3. Condition of female and male trout perch was significantly higher at *test* reach M4-US than at *baseline* reach M3; and
4. Condition of female trout perch was significantly lower at *test* reach M4-DS than at *test* reach M4-US.

None of the above statistical differences in condition of male and female trout perch exceeded the effects criterion (i.e., ±10% in condition of fish between the reaches) (Table 5.1-29).

Condition of trout perch caught in fall 2015 at all reaches was within the range of condition of trout perch caught in previous surveys, and was within the range of condition for fish caught at *baseline* reach M3 (i.e., the reach immediately upstream of all oil sands mining developments) (Figure 5.1-27, Figure 5.1-28), with the following exceptions:

1. Condition of female trout perch at *test* reach M4-US was above the estimated normal range of historical condition values; and
2. Condition of male trout perch at *baseline* reach M2 and *test* reach M4-DS was above the estimated normal range of historical condition values.

Power Analysis to Investigate Influence of Sample Size Power analyses were conducted for comparisons that were not statistically significant for each measurement endpoint using the effects size of ±25% for age, weight-at-age, relative gonad size, and relative liver size, and the effects size of ±10% for condition (Table 5.1-29). Power was relatively high for all comparisons, ranging from 0.62 to 0.99 with the exception of age for female trout perch (power=0.52). Three comparisons did not achieve the desired level of power (>0.90) (Environment Canada 2010): age; growth; and relative gonad size (Table 5.1-29), indicating that the sample size was too low in these cases to detect a significant difference for the target effect sizes. However, it should be noted that some of these comparisons achieved a power near 0.80 and some studies have suggested that a power of 0.80 is adequate (e.g., Cohen 1988).

Exposure – Mixed Function Oxygenase (MFO) Activity The following statistically-significant differences in EROD activity of trout perch among reaches of the Athabasca River in fall 2015 were measured in fall 2015 (Table 5.1-29, Figure 5.1-29):

1. EROD activity of female and male trout perch was significantly higher at *baseline* reach M2 than at *baseline* reach M0-DS.

2. EROD activity of female and male trout perch was significantly higher at *test* reach M4-US than at *baseline* reach M3.

3. EROD activity of female trout perch was significantly higher at *test* reach M7 than at *test* reach M4-DS.

Interpretation of 2015 Responses Measurement endpoints for trout perch in fall 2015 at reaches between *baseline* reach M0-US and *test* reach M4-US were within the historical range of values for each reach and were within the range of values for *baseline* reach M3. Trout perch at *baseline* reaches M0-DS and M2 had significantly lower growth and relative gonad weight, respectively, compared to the respective upstream reaches M0-US and M0-DS, but values were within the historical range of estimates for each reach. Female trout perch at *baseline* reach M3 had significantly higher growth than *baseline* reach M2, but values were within the historical range of estimates for *baseline* reach M3.

Most differences in measurement endpoints occurred downstream of *test* reach M4-US, with values that fell outside the historic normal range of estimates for each respective reach and/or *baseline* reach M3. The following differences in measurement endpoints were observed between stations:

1. *Test* reach M4-DS had significantly older female trout perch and both sexes were heavier than trout perch at upstream *test* reach M4-US; relative weight of male fish at *test* reach M4-DS in 2015 exceeded both the historical range of estimates for that reach and the historical normal range of *baseline* reach M3.

2. *Test* reach M7 had significantly younger female fish and both sexes had lower relative gonad and relative liver weights compared to upstream *test* reach M4-DS, and relative gonad and liver weights were below the historical normal range of *baseline* reach M3.

3. *Test* reach M8 had older female fish and both sexes were significantly lighter with larger relative gonad and liver weights than fish at upper *test* reach M7; relative gonad, liver, and total weights of trout perch at *test* reach M8 were below the historical normal range of *baseline* reach M3.

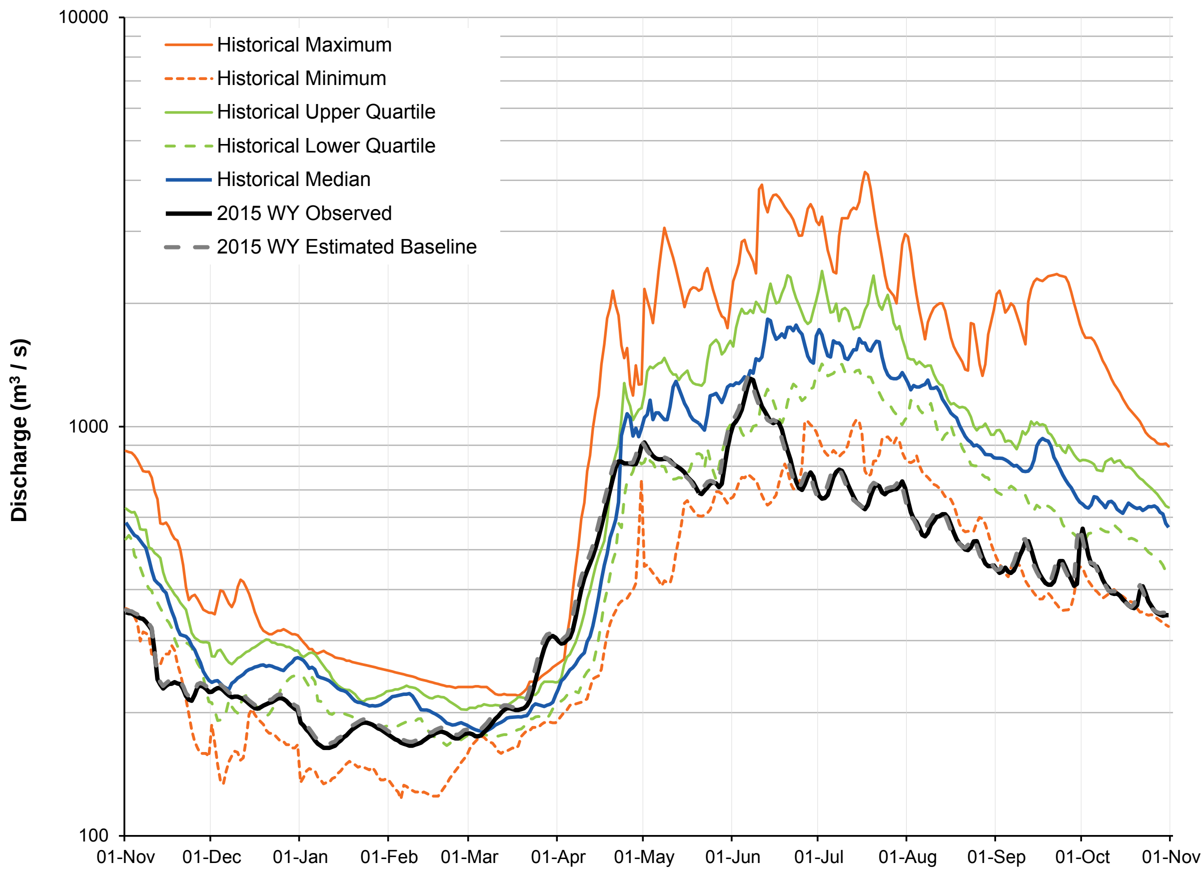
4. Relative gonad and liver weight of female and male fish at *test* reach M9 were below the historical normal range of *baseline* reach M3, and relative liver weight was significantly lower than upper *test* reach M8; male trout perch at *test* reach M9 were also significantly older and lighter than at *test* reach M8.

There did not appear to be a simple gradient effect on measurement endpoints of trout perch occurring along the Athabasca River, but rather a concentration of changes in measurement endpoints starting at *test* reach M4-DS, becoming more prominent at *test* reach M7, and then dissipating at *test* reach M9. A similar trend is occurring in EROD activity of trout perch (Figure 5.1-29). EROD activity in trout perch significantly increases from *baseline* reach M2 compared to upper *baseline* reach M0-DS with a 35 and 10 fold change in EROD activity in female and male trout perch, respectively. This is perhaps because *baseline* reach M2 is the first reach located in the oil sands region and; therefore, is likely influenced by natural background PAHs from oil sand formations. The next significant increase in EROD activity of trout perch occurred at M4-US with a two-fold change in EROD activity in both male in female trout perch relative to reach M3. *Test* reach M4-US is located upstream of the Muskeg River and is located in an area where the formation is more prominent and oil sands operations occur. The final significant increase in EROD activity of trout perch occurred in female fish at *test* reach M7, which is upstream of the Ells River but within the McMurray Formation and immediately downstream of significant oil sands development. Below test reach M7, oil sands development occurs, but currently less intensively than upstream (although some operations are currently being developed or on hold), which may explain the reduction in EROD activity and coincides with fewer exceedances of effects criteria past this point. As well, the oils formation becomes less prominent further downstream on the Athabasca River, which also may contribute to the observed decrease in EROD activity of trout perch and effects observed in measurement endpoints downstream of *test* reach M7.

Classification of Results The significant differences in measurement endpoints for wild fish health that exceeded the Environment Canada effects criteria (Environment Canada 2010) in the Athabasca River in fall 2015 are provided in Table 5.1-30.

The classification of results for wild fish health for *baseline* reaches M0-DS, M2, and M3 were assessed as **Moderate** when compared to upper reaches M0-US, M0-DS, and M2, respectively. *Test* reach M4-US was assessed as **Negligible-Low** when compared to upper reach M3. *Test* reaches M4-DS and M9 were classified as **Moderate** when compared to each respective upstream reach M4-US and M8. *Test* reaches M7 and M8 were classified as **High** when compared to M4-DS and M7, respectively.

Figure 5.1-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Athabasca River near Embarras Airport for the 2015 WY, compared to historical values.



Note: The observed 2015 WY hydrograph was based on Athabasca River at Embarras Airport (WSC Station 07DD001) data. The upstream drainage area is 156,000 km^2. Historical values were calculated for WSC Station 07DD001 from 1971 to 1976 and 2015 (annual coverage), and 1977 to 1984 (coverage from May to October), and JOSMP Station S46 from August 2011 to October 2014.

Table 5.1-2 Estimated water balance at Station 07DD001, Athabasca River at Embarras Airport, 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**14,464.07**	**Observed discharge, obtained from Athabasca River near Embarras, (JOSMP Station S46)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-62.40	Estimated 664.8 km^2 of the Athabasca River watershed is closed-circuited as of 2015 (Table 2.3-1).
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	2.44	Estimated 130.4 km^2 of the Athabasca River watershed with land change from oil sands developments as of 2015 that is not closed-circuited (Table 2.3-1).
Water withdrawals from the Athabasca River near Embarras Airport station, relative to the estimated *baseline* hydrograph	-0.24	Withdrawals by Fort Hills (daily values provided).
	-22.98	Withdrawals by Canadian Natural (daily values provided).
	-29.54	Withdrawals by Imperial (daily values provided).
	-12.27	Withdrawals by Shell (daily values provided).
	-17.51	Withdrawals by Suncor (daily values provided).
	-38.18	Withdrawals by Syncrude (daily values provided).
Water releases into the Athabasca River near Embarras Airport station, relative to the estimated *baseline* hydrograph	3.00	Releases by Suncor (daily values provided).
	3.21	Releases by Syncrude (daily values provided).
	0.15	Releases by Fort Hills (daily values provided).
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	-2.91	Net sum of incremental volume results from the major tributaries as listed in Section 5.2 to Section 5.13[1]
Estimated *baseline* hydrograph (total discharge)	**14,641.30**	**Estimated *baseline* discharge at Athabasca River near Embarras (JOSMP Station S46)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	-177.23	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	-1.21	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

All non-zero values and percentages in this table are presented to two decimal places.

[1] It is assumed that all flow from the Beaver River watershed is controlled through the Poplar Creek Spillway, therefore, the Beaver River watershed is considered hydrologically closed-circuited and only the releases through the Poplar Creek Spillway are considered for the Beaver River watershed. Note, releases in the 2015 WY from the Poplar Creek spillway were estimated using measured discharge from the JOSMP Station S11 Poplar Creek at Highway 63.

Table 5.1-3 Calculated change in hydrologic measurement endpoints for the Athabasca River, 2015 WY.

Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	642.9	650.1	-1.1%
Mean winter discharge	210.7	214.4	-1.8%
Annual maximum daily discharge	1,310.0	1,319.4	-0.7%
Open-water season minimum daily discharge	345.0	350.0	-1.4%

Notes:

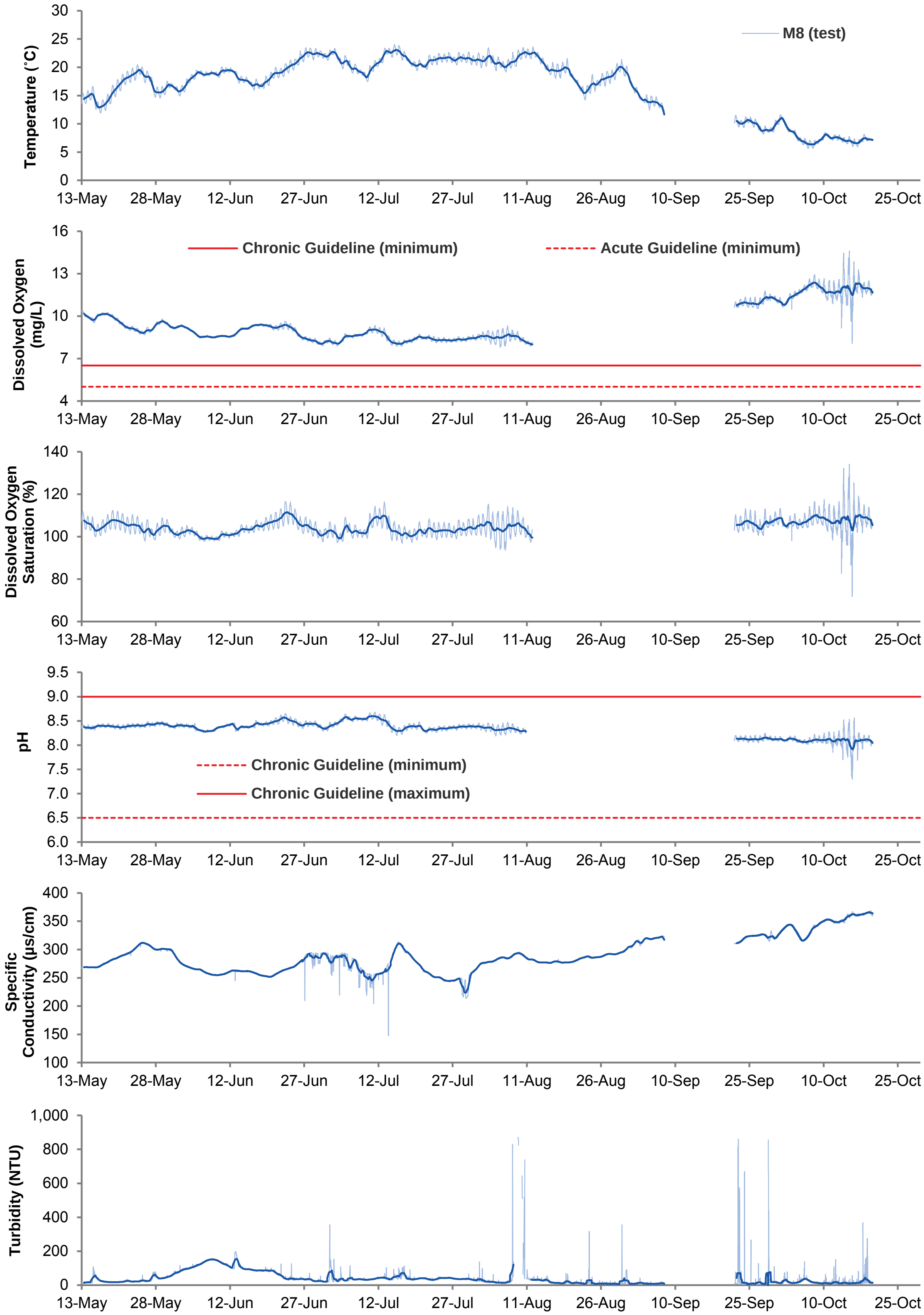
Definitions and assumptions are discussed in Section 3.2.1.

Observed discharge was calculated using data from WSC Station 07DD001

The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. All flows and percentage change values were presented to one decimal place for the sake of clarity.

The open-water season refers to the period from May 1 and October 31 and the winter season refers to the period from November 1 and March 31.

Figure 5.1-4 In situ water quality trends in the Athabasca River recorded by data sonde, May to October 2015.



Notes: Water quality variables were recorded at 15-minute intervals; trend lines are daily averages.

Table 5.1-4 Monthly concentrations of water quality measurement endpoints, Athabasca River centre channel (*test* station ATR-DD-C), March and May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	7	8.04	7.87	Mar	8.18	May
Total suspended solids	mg/L	-	7	17.0	1.3	Sep	96	Jun
Conductivity	µS/cm	-	7	290	240	Sep	415	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	7	0.009	0.004	Sep	0.018	Mar
Total nitrogen	mg/L	-	7	0.360	0.200	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	7	0.016	<0.003	May	0.206	Jun
Dissolved organic carbon	mg/L	-	7	5.9	2.6	Jun	8.4	Mar
Ions								
Sodium	mg/L	-	7	13	7.8	Jul	27.3	Mar
Calcium	mg/L	-	7	30	28	Jul	41.9	Mar
Magnesium	mg/L	-	7	8.8	8.3	Jun, Jul	11.6	Mar
Potassium	mg/L	-	7	0.91	0.81	Jun	1.79	Mar
Chloride	mg/L	120-640	7	10.0	6.7	Jun	21.4	Mar
Sulphate	mg/L	309[b]	7	29	26	Jun	42	Oct
Total dissolved solids	mg/L	-	7	170	150	Jun	245	Mar
Total alkalinity	mg/L	20 (min)	7	98	91	Jun	150	Mar
Selected metals								
Total aluminum	mg/L	-	7	0.483	0.150	Mar	4.19	May
Dissolved aluminum	mg/L	0.05	7	0.0075	0.0044	Oct	0.0205	Jul
Total arsenic	mg/L	0.005	7	0.0006	0.00044	Oct	0.0009	Jun
Total boron	mg/L	1.5-29	7	0.025	0.020	Jun	0.033	Mar
Total molybdenum	mg/L	0.073	7	0.00075	0.00062	Jul	0.00081	Oct
Total mercury (ultra-trace)	ng/L	5-13	7	2.2	0.720	Mar	4.710	Jun
Total methyl mercury	ng/L	1-2	6	0.072	0.036	Oct	0.103	Jun
Total strontium	mg/L	-	7	0.231	0.210	Jul	0.301	Mar
Total hydrocarbons								
BTEX	mg/L	-	7	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	7	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	7	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	7	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	7	<0.02	<0.02	-	<0.25	Mar
Naphthenic acids	mg/L	-	7	0.25	<0.08	-	0.69	May
Oilsands extractable acids	mg/L	-	7	0.50	0.30	Sep	1.70	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	7	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	7	1.370	0.59	Mar	10.00	Jun
Total dibenzothiophenes[c]	ng/L	-	7	29.167	8.17	Mar	40.54	Jun
Total PAHs[c]	ng/L	-	7	179.585	113.88	Mar	339.00	Jun
Total Parent PAHs[c]	ng/L	-	7	23.978	8.71	Mar	37.83	Jun
Total Alkylated PAHs[c]	ng/L	-	7	156.266	105.17	Mar	301.18	Jun
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0045**	<0.001	Mar, Jun	**0.010**	Jul
Sulphide	mg/L	0.0019	2	<0.0019	<0.0019	-	**0.0039**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.1-5 Monthly concentrations of water quality measurement endpoints, Athabasca River below Fort MacKay (*test* station M6), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.11	7.96	Jun	8.19	May
Total suspended solids	mg/L	-	6	30	8	Sep	89	June
Conductivity	µS/cm	-	6	265	240	Jun	340	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.007	0.004	Sep	0.011	July
Total nitrogen	mg/L	-	6	0.41	0.20	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	0.170	Sep
Dissolved organic carbon	mg/L	-	6	5.3	2.7	Jun	8.1	May
Ions								
Sodium	mg/L	-	6	12	8	Jun	17	Oct
Calcium	mg/L	-	6	29	27	Sep	37	Oct
Magnesium	mg/L	-	6	8.4	8.1	Sep	11.0	Oct
Potassium	mg/L	-	6	0.9	0.9	Sep	1.2	May
Chloride	mg/L	120-640	6	8.6	6.2	Jun	12.0	Oct
Sulphate	mg/L	309[b]	6	28	24	Aug	42	Oct
Total dissolved solids	mg/L	-	6	170	130	Jun	220	Oct
Total alkalinity	mg/L	20 (min)	6	95	91	Jun	110	Oct
Selected metals								
Total aluminum	mg/L	-	6	1.00	0.33	Oct	4.11	Jun
Dissolved aluminum	mg/L	0.05	6	0.012	0.005	Oct	0.021	Jul
Total arsenic	mg/L	0.005	6	0.00084	0.00042	Oct	0.0013	Jul
Total boron	mg/L	1.5-29	6	0.025	0.019	Jun	0.043	Jul
Total molybdenum	mg/L	0.073	6	0.0007	0.0006	Jun	0.0011	Jul
Total mercury (ultra-trace)	ng/L	5-13	6	2.08	0.94	Oct	4.31	Jun
Total methyl mercury	ng/L	1-2	6	0.072	0.038	Oct	0.098	Jun
Total strontium	mg/L	-	6	0.231	0.212	Aug	0.365	Jul
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.075	<0.08	Jun, Sep, Oct	0.670	Aug
Oilsands extractable acids	mg/L	-	6	0.50	0.30	Sep	2.00	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	14.00	May
Retene	ng/L	-	6	2.65	0.59	Oct	13.10	Jun
Total dibenzothiophenes[c]	ng/L	-	6	26.88	8.56	Sep	62.51	Jul
Total PAHs[c]	ng/L	-	6	183.91	132.01	Oct	291.79	Jul
Total Parent PAHs[c]	ng/L	-	6	24.26	23.42	Aug	38.20	Jun
Total Alkylated PAHs[c]	ng/L	-	6	159.80	108.36	Oct	264.73	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.005**	0.0028	Jun	**0.008**	Aug
Sulphide	mg/L	0.0019	3	**0.0025**	<0.0019	May, Jul, Oct	**0.0049**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.1-6 Monthly concentrations of water quality measurement endpoints, Athabasca River above MacKay River (*test* station M5), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.16	7.96	Jun	8.21	Oct
Total suspended solids	mg/L	-	6	33	7	Sep	91	Jun
Conductivity	µS/cm	-	6	265	240	Jun	330	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.007	0.004	Sep	0.011	Jun
Total nitrogen	mg/L	-	6	0.34	0.20	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	0.051	Jun
Dissolved organic carbon	mg/L	-	6	5.0	2.1	Jun	8.0	May
Ions								
Sodium	mg/L	-	6	12	8	Jun	16	Oct
Calcium	mg/L	-	6	30	28	Jul	37	Oct
Magnesium	mg/L	-	6	9	8	Jun, Jul	11	Oct
Potassium	mg/L	-	6	0.9	0.8	Jun	1.4	May
Chloride	mg/L	120-640	6	8.8	5.4	Jun	12.0	May
Sulphate	mg/L	309[b]	6	28	26	Jun	42	Oct
Total dissolved solids	mg/L	-	6	160	140	Jun	240	Oct
Total alkalinity	mg/L	20 (min)	6	96	90	Jun	120	Oct
Selected metals								
Total aluminum	mg/L	-	6	1.37	0.29	Oct	4.17	Jun
Dissolved aluminum	mg/L	0.05	6	0.011	0.006	Oct	0.021	Jul
Total arsenic	mg/L	0.005	6	0.00075	0.00042	Oct	0.0010	May
Total boron	mg/L	1.5-29	6	0.024	0.018	Jun	0.030	Oct
Total molybdenum	mg/L	0.073	6	0.0007	0.0006	Jun	0.0008	Oct
Total mercury (ultra-trace)	ng/L	5-13	6	2.22	0.86	Oct	4.91	Jun
Total methyl mercury	ng/L	1-2	6	0.062	0.036	Oct	0.101	Jun
Total strontium	mg/L	-	6	0.233	0.213	Jul	0.290	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.070	<0.08	Jun, Sep, Oct	0.580	May
Oilsands extractable acids	mg/L	-	6	0.50	0.30	Sep	2.00	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	1.76	0.93	Sep	11.10	Jun
Total dibenzothiophenes[c]	ng/L	-	6	22.35	13.17	Sep	54.34	Jul
Total PAHs[c]	ng/L	-	6	170.64	146.49	Sep	253.22	Jun
Total Parent PAHs[c]	ng/L	-	6	24.78	23.65	May	34.33	Jun
Total Alkylated PAHs[c]	ng/L	-	6	146.96	121.92	Sep	224.71	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.006**	0.0030	Jun	**0.011**	Jul
Sulphide	mg/L	0.0019	3	0.0006	<0.0019	Jun, Sep, Oct	**0.0077**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

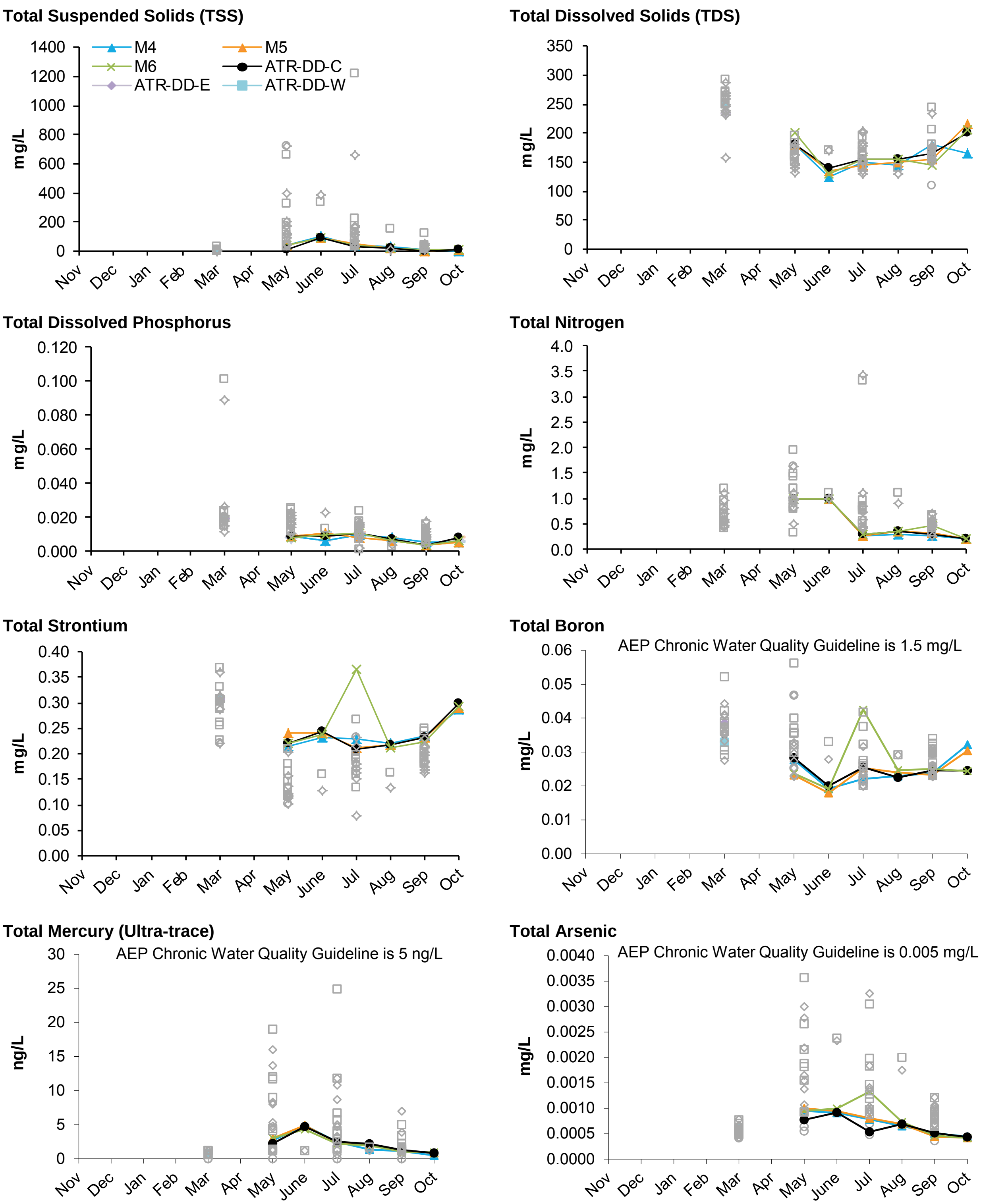
[d] n value refers to number of exceedances in 2015.

Table 5.1-7 Monthly concentrations of water quality measurement endpoints, Athabasca River below Beaver River (*test* station M4), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.16	7.99	Jun	8.18	Jul
Total suspended solids	mg/L	-	6	33.0	6.0	Oct	100	Jun
Conductivity	µS/cm	-	6	265	230	Jun	340	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.007	0.005	Sep, Oct	0.010	Jul
Total nitrogen	mg/L	-	6	0.28	0.200	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	0.051	Jun
Dissolved organic carbon	mg/L	-	6	5.0	4.0	Jun	8.0	May
Ions								
Sodium	mg/L	-	6	10.95	8	Jun	16	Oct
Calcium	mg/L	-	6	29.5	26	Jun	35	Oct
Magnesium	mg/L	-	6	8.6	7.7	Jun	11	Oct
Potassium	mg/L	-	6	0.9	0.7	Jun	1.2	May
Chloride	mg/L	120-640	6	8.2	4.6	Jul	12	May, Oct
Sulphate	mg/L	309[b]	6	28.5	25	Jun	42	Oct
Total dissolved solids	mg/L	-	6	170	130	Jun	210	Oct
Total alkalinity	mg/L	20 (min)	6	95	91	Jun	110	May, Oct
Selected metals								
Total aluminum	mg/L	-	6	1.331	0.283	Oct	3.65	Jun
Dissolved aluminum	mg/L	0.05	6	0.0141	0.0053	Oct	0.0194	Jul
Total arsenic	mg/L	0.005	6	0.0007	0.00045	Oct	0.0010	May
Total boron	mg/L	1.5-29	6	0.023	0.019	Jun	0.032	Oct
Total molybdenum	mg/L	0.073	6	0.00071	0.00062	Jul	0.00085	Oct
Total mercury (ultra-trace)	ng/L	5-13	6	1.920	0.500	Oct	4.890	Jun
Total methyl mercury	ng/L	1-2	6	0.065	0.037	Oct	0.089	Jun
Total strontium	mg/L	-	6	0.231	0.215	May	0.286	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.09	<0.08	Jun, Oct	0.51	May
Oilsands extractable acids	mg/L	-	6	0.45	-0.10	Jun	1.80	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	17.80	Sep
Retene	ng/L	-	6	3.450	0.93	Sep	10.70	Jun
Total dibenzothiophenes[c]	ng/L	-	6	40.367	12.94	Sep	298.45	Oct
Total PAHs[c]	ng/L	-	6	263.251	164.91	Sep	1071.23	Oct
Total Parent PAHs[c]	ng/L	-	6	28.489	23.64	Aug	90.11	Oct
Total Alkylated PAHs[c]	ng/L	-	6	232.684	137.08	Sep	981.12	Oct
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0054**	<0.002	Jun	**0.010**	Jul
Sulphide	mg/L	0.0019	4	**0.0052**	<0.0019	Sep, Oct	**0.450**	Aug

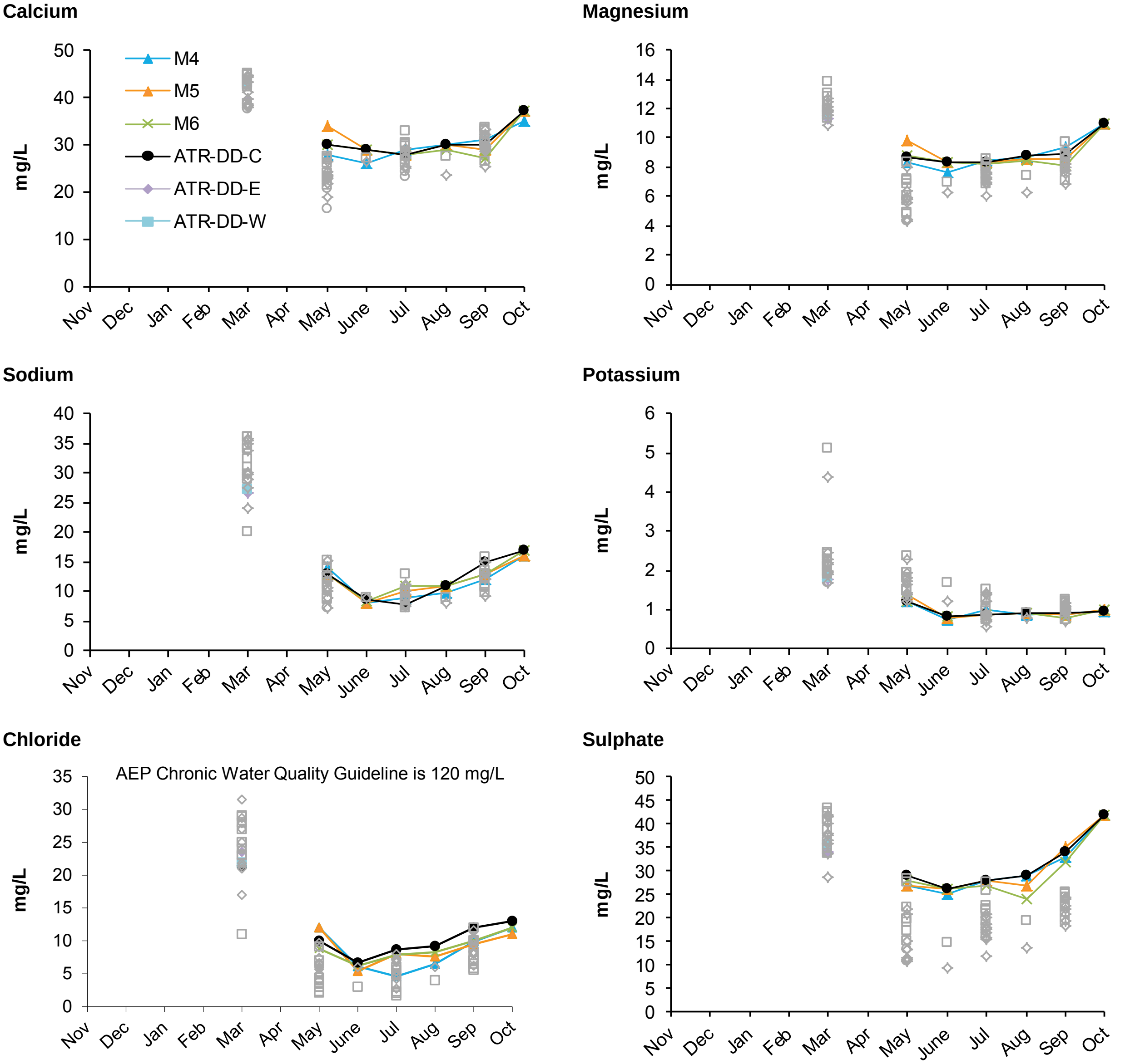
Values in **bold** are above guideline.
[a] Sources for all guidelines are outlined in Table 3.2-1.
[b] based on actual hardness level
[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.
[d] n value refers to number of exceedances in 2015.

Figure 5.1-5 Selected water quality measurement endpoints in the Athabasca River (monthly data) in the 2015 WY.



Non-detectable values are shown at the detection limit.
Colour markers indicate 2015 data and corresponding grey markers indicate historical data.

Figure 5.1-5 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate 2015 data and corresponding grey markers indicate historical data.

Table 5.1-8 Concentrations of water quality measurement endpoints, Athabasca River centre channel (*test* station ATR-DD-C), fall 2015 compared to fall 2014.

Variables	Units	Guidelines[a]	September 2015	September 2014
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	7.97	8.2
Total suspended solids	mg/L	-	1.3	15.9
Conductivity	µS/cm	-	290	300
Nutrients				
Total dissolved phosphorus	mg/L	-	0.004	0.002
Total nitrogen	mg/L	-	0.29	0.27
Nitrate+nitrite	mg/L	3-124	0.041	<0.054
Dissolved organic carbon	mg/L	-	5.2	5.7
Ions				
Sodium	mg/L	-	15	15.6
Calcium	mg/L	-	30	31.6
Magnesium	mg/L	-	8.9	7.9
Potassium	mg/L	-	0.9	1.06
Chloride	mg/L	120-640	12.0	11.7
Sulphate	mg/L	309[b]	34	24
Total dissolved solids	mg/L	-	170	109
Total alkalinity	mg/L	20 (min)	98	105
Selected metals				
Total aluminum	mg/L	-	0.483	0.76
Dissolved aluminum	mg/L	0.05	0.000516	0.0085
Total arsenic	mg/L	0.005	0.000516	0.00067
Total boron	mg/L	1.5-29	0.0246	0.031
Total molybdenum	mg/L	0.073	0.00075	0.00073
Total mercury (ultra-trace)	ng/L	5-13	1.28	1.71
Total methyl mercury	ng/L	1-2	0.079	-
Total strontium	mg/L	-	0.231	0.181
Total hydrocarbons				
BTEX	mg/L	-	<0.01	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.25
Naphthenic acids	mg/L	-	<0.08	0.17
Oilsands extractable acids	mg/L	-	0.30	0.30
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	1,000	<13.55	<7.21
Retene	ng/L	-	0.90	1.64
Total dibenzothiophenes[c]	ng/L	-	39.32	22.3
Total PAHs[c]	ng/L	-	177.06	130.6
Total Parent PAHs[c]	ng/L	-	25.24	14.9
Total Alkylated PAHs[c]	ng/L	-	151.82	115.8

Values in **bold** are above guideline; underlined values are above the fall 2014 values.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.1-9 Concentrations of water quality measurement endpoints, Athabasca River (*test* stations M6, M5, and M4), fall 2015.

Variables	Units	Guidelines[a]	September 2015 Values		
			M6	M5	M4
Physical variables					
pH	pH units	6.5-9.0	8.15	8.15	8.17
Total suspended solids	mg/L	-	8.0	7.3	11
Conductivity	µS/cm	-	280	280	280
Nutrients					
Total dissolved phosphorus	mg/L	-	0.004	0.004	0.005
Total nitrogen	mg/L	-	0.46	0.32	0.26
Nitrate+nitrite	mg/L	3-124	0.17	<0.005	<0.005
Dissolved organic carbon	mg/L	-	5.4	5.0	5.1
Ions					
Sodium	mg/L	-	13	13	12
Calcium	mg/L	-	27	29	31
Magnesium	mg/L	-	8.1	8.6	9.4
Potassium	mg/L	-	0.80	0.85	0.92
Chloride	mg/L	120-640	10	9.5	9.9
Sulphate	mg/L	309[b]	32	35	33
Total dissolved solids	mg/L	-	140	160	180
Total alkalinity	mg/L	20 (min)	97	98	96
Selected metals					
Total aluminum	mg/L	-	0.337	0.30	0.709
Dissolved aluminum	mg/L	0.05	0.00734	0.00724	0.0144
Total arsenic	mg/L	0.005	0.000465	0.000445	0.000512
Total boron	mg/L	1.5-29	0.025	0.023	0.0238
Total mercury (ultra-trace)	ng/L	5-13	1.05	1.16	1.13
Total methyl mercury	ng/L	1-2	0.045	0.048	0.054
Total molybdenum	mg/L	0.073	0.000713	0.00078	0.000659
Total strontium	mg/L	-	0.223	0.231	0.236
Total hydrocarbons					
BTEX	mg/L	-	<0.01	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02	<0.02
Naphthenic acids	mg/L	-	<0.08	<0.08	0.10
Oilsands extractable acids	mg/L	-	0.3	0.3	0.5
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	ng/L	1,000	<13.55	<13.55	17.80
Retene	ng/L	-	3.52	0.93	0.93
Total dibenzothiophenes[c]	ng/L	-	6.91	13.17	12.94
Total PAHs[c]	ng/L	-	113.24	128.63	153.14
Total Parent PAHs[c]	ng/L	-	23.34	24.24	27.43
Total Alkylated PAHs[c]	ng/L	-	89.91	104.39	125.71
Other variables that exceeded Alberta guidelines in 2015					
Total Phenols	mg/L	0.004	**0.0072**	**0.0079**	**0.0062**
Sulphide	mg/L	0.0019	**0.0031**	<0.0019	<0.0019

Values in **bold** are above guideline; sampling began in 2015 and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.1-10 Concentrations of water quality measurement endpoints, Athabasca River at wild fish health reaches (*test* stations M4-DS, M4-US, and M3, and *baseline* station M0-DS), fall 2015.

Variables	Units	Guidelines[a]	September 2015 Values			
			M4-DS	M4-US	M3	M0-DS
Physical variables						
pH	pH units	6.5-9.0	8.14	8.12	8.1	8.28
Total suspended solids	mg/L	-	8.7	7.3	21.0	5.3
Conductivity	µS/cm	-	290	310	300	290
Nutrients						
Total dissolved phosphorus	mg/L	-	0.005	0.006	0.004	0.0030
Total nitrogen	mg/L	-	0.44	0.28	0.200	0.19
Nitrate+nitrite	mg/L	3-124	<0.005	<0.005	0.035	0.032
Dissolved organic carbon	mg/L	-	11.0	7.1	3.7	2.6
Ions						
Sodium	mg/L	-	17	13	9	6.9
Calcium	mg/L	-	30	32	37	35
Magnesium	mg/L	-	9	10	11	11
Potassium	mg/L	-	0.85	0.95	1.0	0.81
Chloride	mg/L	120	10	16	3	1.3
Sulphate	mg/L	309[b]	25	33	41	40
Total dissolved solids	mg/L	-	150	170	170	180
Total alkalinity	mg/L	20 (min)	110	100	110	110
Selected metals						
Total aluminum	mg/L	-	0.369	0.312	0.88	0.253
Dissolved aluminum	mg/L	0.05	0.0109	0.00726	0.01040	0.00643
Total arsenic	mg/L	0.005	0.00049	0.000548	0.0005	0.000424
Total boron	mg/L	1.5-29	0.0333	0.0283	0.018	0.0123
Total molybdenum	mg/L	-	0.0004	0.000634	0.00	0.000759
Total mercury (ultra-trace)	ng/L	5-13	1.71	0.99	1.21	0.92
Total methyl mercury	ng/L	1-2	0.064	0.062	0.066	0.04
Total strontium	mg/L	-	0.201	0.247	0.306	0.304
Total hydrocarbons						
BTEX	mg/L	-	<0.01	<0.01	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02	<0.02	<0.02
Naphthenic acids	mg/L	-	0.26	0.32	< 0.08	< 0.08
Oilsands extractable acids	mg/L	-	0.9	0.8	0.5	0.2
Polycyclic Aromatic Hydrocarbons (PAHs)						
Naphthalene	ng/L	1000	<13.55	<13.55	<13.55	<13.55
Retene	ng/L	-	1.57	0.69	0.94	<0.59
Total dibenzothiophenes[c]	ng/L	-	13.76	34.84	10.18	8.17
Total PAHs[c]	ng/L	-	136.26	200.32	125.72	120.09
Total Parent PAHs[c]	ng/L	-	23.47	26.98	23.76	23.00
Total Alkylated PAHs[c]	ng/L	-	112.79	173.34	101.96	97.10
Other variables that exceeded Alberta guidelines in 2015						
Total phenols	mg/L	0.004	**0.0085**	**0.0041**	**0.0052**	0.0033
Sulphide	mg/L	0.0019	<0.0019	**0.0023**	<0.0019	**0.0023**

Values in **bold** are above guideline; sampling began in 2015 and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.1-11 Concentrations of water quality measurement endpoints, Athabasca River Delta (*test* stations BPC-1, EMR-2, FLC-1, and GIC-1), fall 2015.

Variables	Units	Guidelines[a]	September 2015 Values			
			BPC-1	EMR-2	FLC-1	GIC-1
Physical variables						
pH	pH units	6.5-9.0	8.02	8.0	8.01	8.03
Total suspended solids	mg/L	-	20	14	11	20
Conductivity	µS/cm	-	280	290	290	290
Nutrients						
Total dissolved phosphorus	mg/L	-	0.028	0.008	0.006	0.008
Total nitrogen	mg/L	-	0.26	0.30	0.24	0.27
Nitrate+nitrite	mg/L	3-124	<0.005	<0.005	<0.005	<0.005
Dissolved organic carbon	mg/L	-	5.2	6.5	5	4.9
Ions						
Sodium	mg/L	-	14	14	15	14
Calcium	mg/L	-	31	34	32	31
Magnesium	mg/L	-	8.9	9.4	9	8.8
Potassium	mg/L	-	0.86	0.9	0.87	0.87
Chloride	mg/L	120	14	13	15	15
Sulphate	mg/L	309[b]	29	31	30	29
Total dissolved solids	mg/L	-	180	180	190	180
Total alkalinity	mg/L	20 (min)	96	100	98	96
Selected metals						
Total aluminum	mg/L	-	1.04	0.51	0.616	0.689
Dissolved aluminum	mg/L	0.05	0.00572	0.00368	0.0058	0.00554
Total arsenic	mg/L	0.005	0.000719	0.0009	0.0007	0.000628
Total boron	mg/L	1.5-29	0.0251	0.033	0.0323	0.024
Total mercury (ultra-trace)	ng/L	5-13	1.18	1.03	1.06	1.04
Total methyl mercury	ng/L	1-2	0.059	0.061	0.052	0.053
Total molybdenum	mg/L	0.073	0.000904	0.00091	0.0008	0.000844
Total strontium	mg/L	-	0.219	0.256	0.249	0.218
Total hydrocarbons						
BTEX	mg/L	-	<0.01	<0.01	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02	<0.02	<0.02
Naphthenic acids	mg/L	-	<1.91	<1.64	<1.92	<1.66
Oilsands extractable acids	mg/L	-	<2.4	<2	<2.4	<2.1
Polycyclic Aromatic Hydrocarbons (PAHs)						
Naphthalene	ng/L	1,000	<13.55	<13.55	<13.55	<13.55
Retene	ng/L	-	1.86	1.36	1.22	1.64
Total dibenzothiophenes[c]	ng/L	-	30.31	16.07	9.71	14.20
Total PAHs[c]	ng/L	-	175.82	133.69	119.74	133.44
Total Parent PAHs[c]	ng/L	-	26.45	23.84	23.88	25.68
Total Alkylated PAHs[c]	ng/L	-	149.37	109.86	95.87	107.76
Other variables that exceeded Alberta guidelines in 2015						
Total phenols	mg/L	0.004	**0.0073**	**0.0094**	**0.0069**	**0.0081**
Sulphide	mg/L	0.0019	<0.0019	<0.0019	**0.0023**	<0.0019

Values in **bold** are above guideline; sampling began in 2015 and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.1-6 Piper diagram of fall ion concentrations in the Athabasca River and Athabasca River Delta.

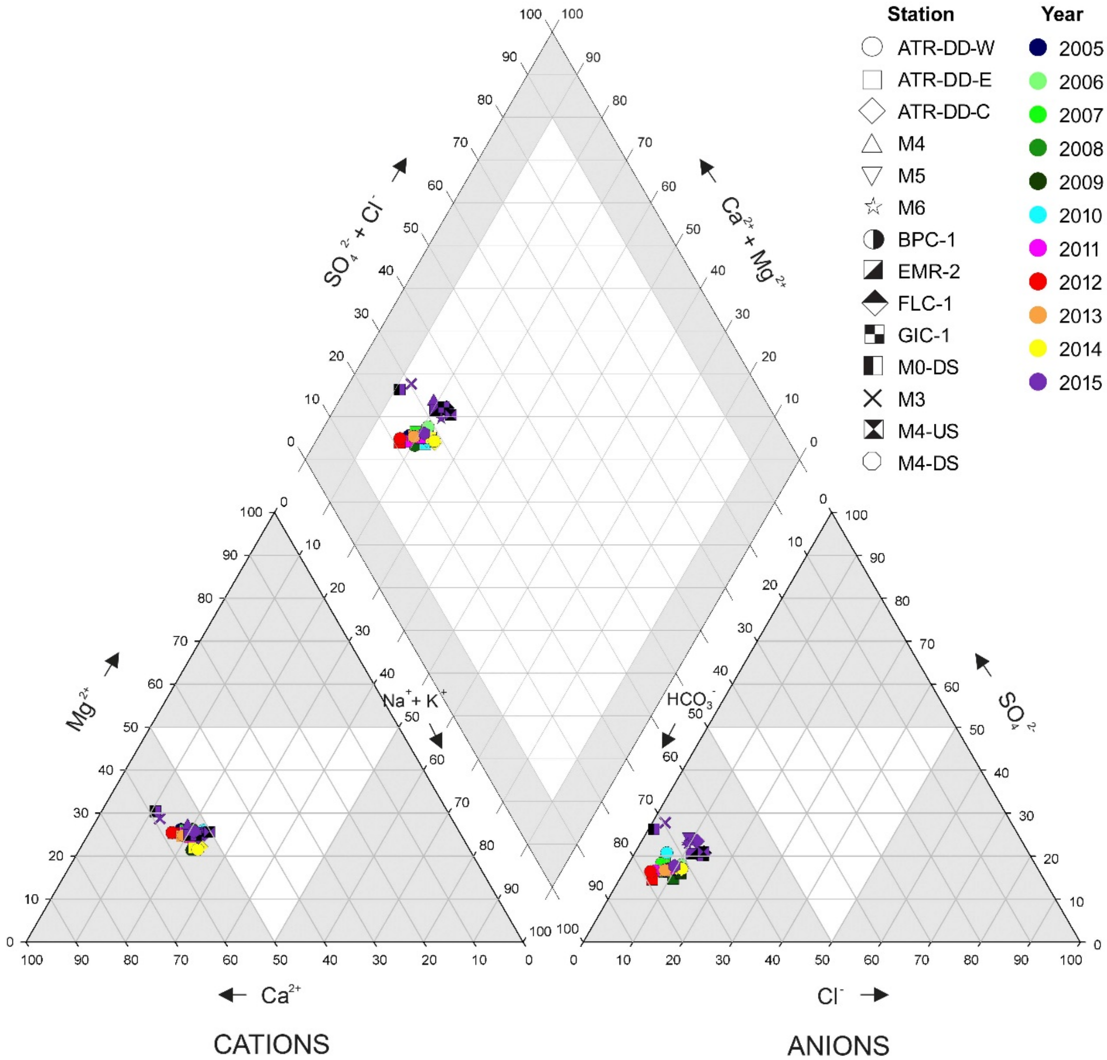
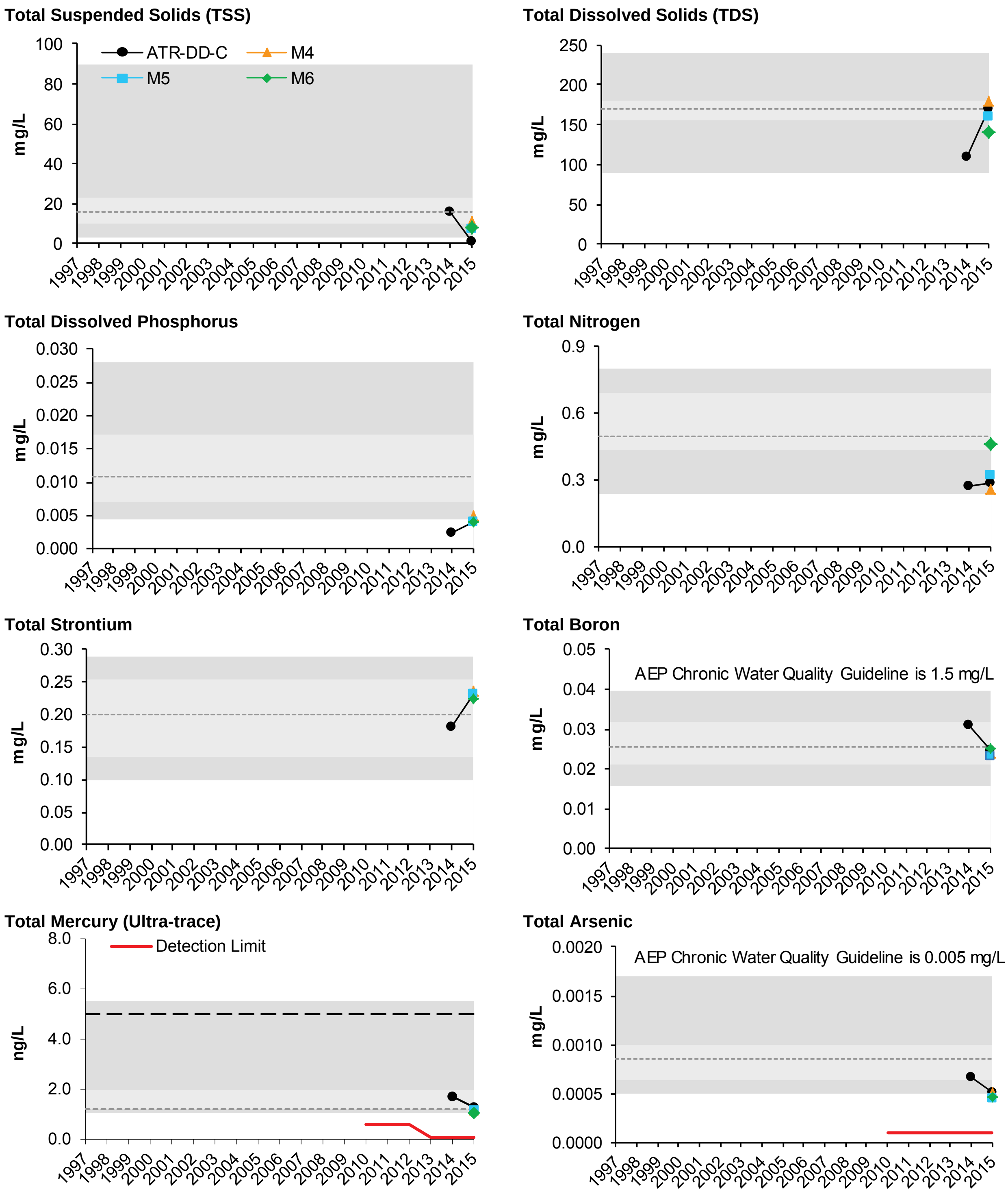


Table 5.1-12 Water quality guideline exceedances in the Athabasca River and Delta, 2015 WY.

Variable	Units	Guideline[a]	March	May	June	July	August	September	October
Athabasca River Centre station (ATR-DD-C)									
Total phenols	mg/L	0.004	<0.001	**0.0041**	<0.002	**0.01**	**0.0081**	**0.0045**	**0.0055**
Sulphide	mg/L	0.0019		<0.0019	<0.0019	**0.0039**	**0.0031**	<0.0019	<0.0019
Athabasca River below Beaver River (M4)									
Total phenols	mg/L	0.004	-	**0.0045**	0.002	**0.0099**	**0.0077**	**0.0062**	**0.0041**
Sulphide	mg/L	0.0019	-	**0.0057**	**0.0065**	**0.007**	**0.0046**	0.0019	0.0019
Athabasca River above MacKay River (M5)									
Total phenols	mg/L	0.004	-	**0.0045**	0.003	**0.011**	**0.0075**	**0.0079**	0.0031
Sulphide	mg/L	0.0019	-	**0.0057**	<0.0019	**0.0077**	**0.0031**	<0.0019	<0.0019
Athabasca River below Fort MacKay (M6)									
Total phenols	mg/L	0.004	-	0.0033	0.0028	0.0037	**0.0082**	**0.0072**	**0.0063**
Sulphide	mg/L	0.0019	-	<0.0019	**0.0049**	<0.0019	**0.0031**	**0.0031**	<0.0019
Athabasca River below town of Athabasca (M0-DS)									
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0023**	-
Athabasca River below Fort McMurray STP discharge (M3)									
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0052**	-
Athabasca River below Muskeg River (M4-DS)									
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0085**	-
Athabasca River above Muskeg River (M4-US)									
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0041**	-
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0023**	-
Big Point Channel (BPC-1)									
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0073**	-
Embarras River (EMR-2)									
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0094**	-
Fletcher Channel (FLC-1)									
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0069**	-
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0023**	-
Goose Island Channel (GIC-1)									
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0081**	-

Values in **bold** are above the guideline.
[a] Sources for all guidelines are outlined in Table 3.2-1.
"-" = not sampled.

Figure 5.1-7 Selected water quality measurement endpoints in the Athabasca River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



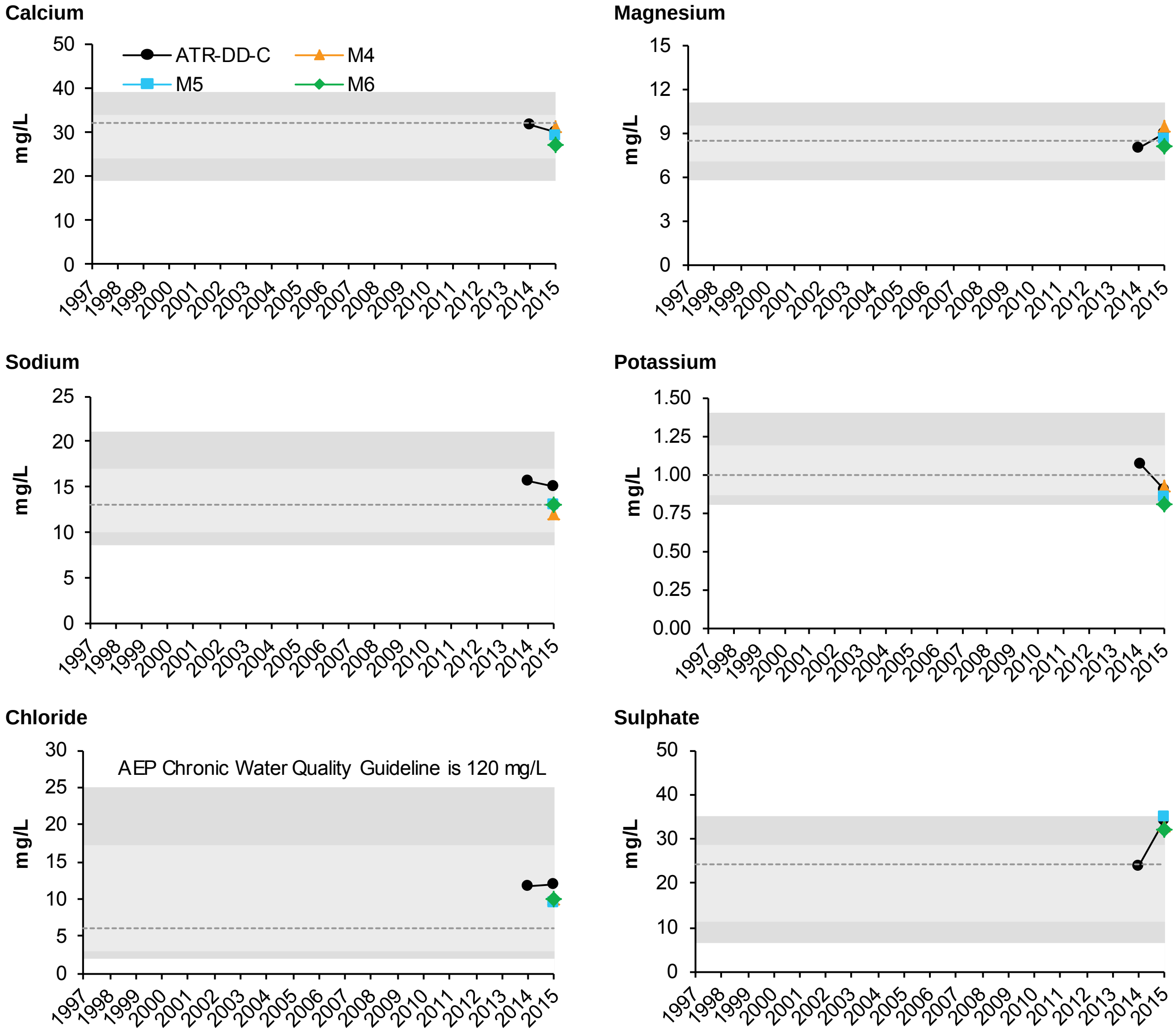
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.1-7 (Cont'd.)



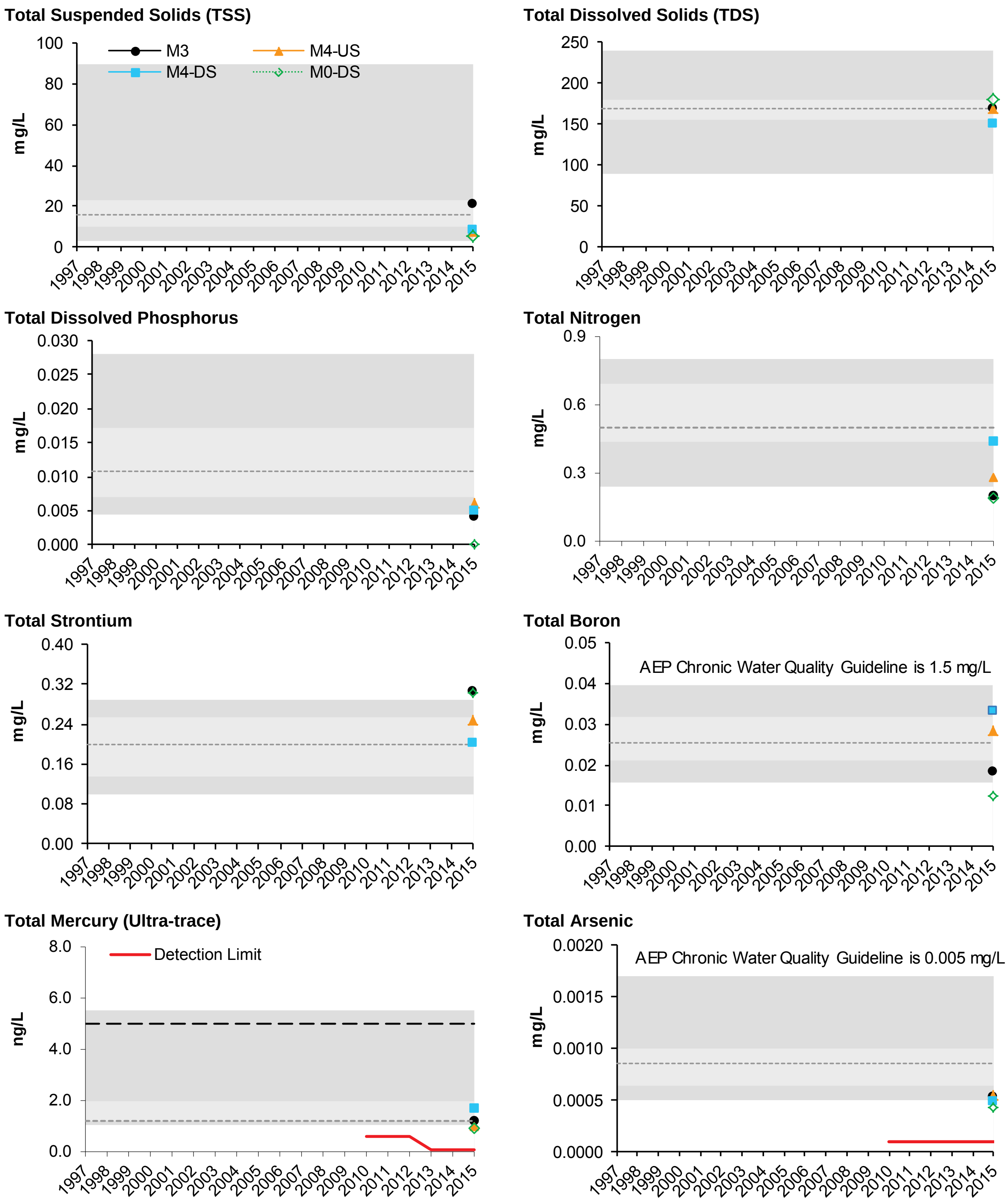
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.1-8 Selected water quality measurement endpoints in the Athabasca River at wild fish health reaches (fall data) relative to regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

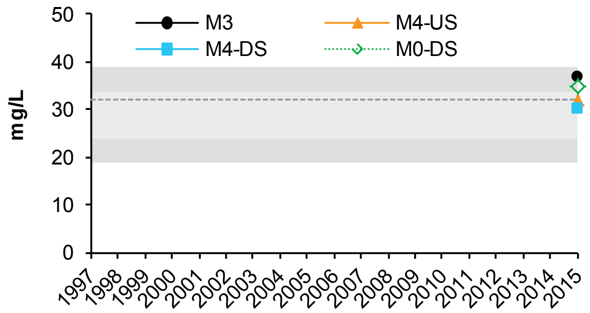
– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

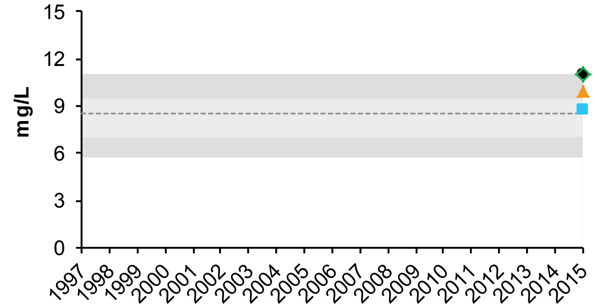
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.1-8 (Cont'd.)

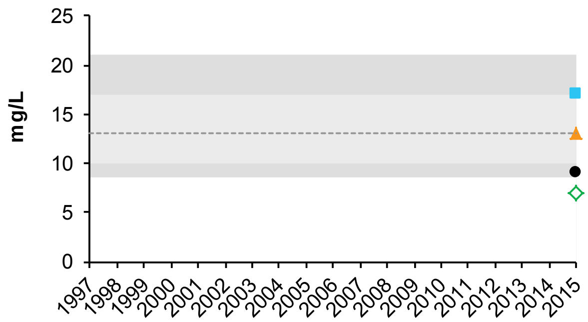
Calcium



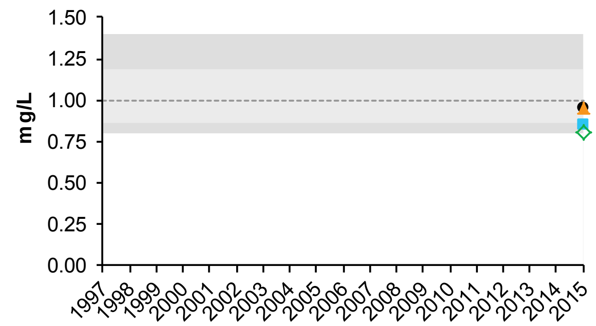
Magnesium



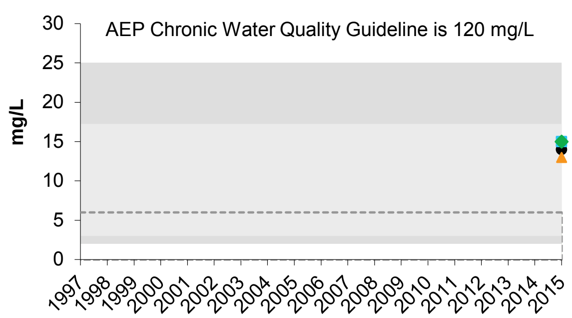
Sodium



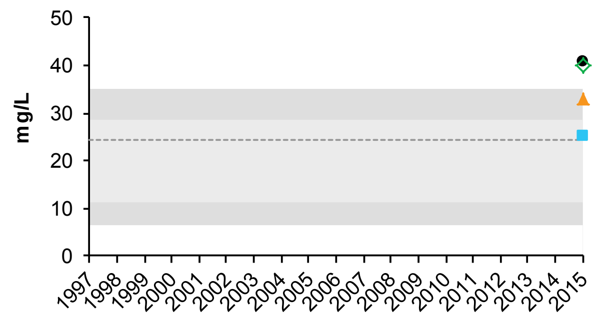
Potassium



Chloride



Sulphate



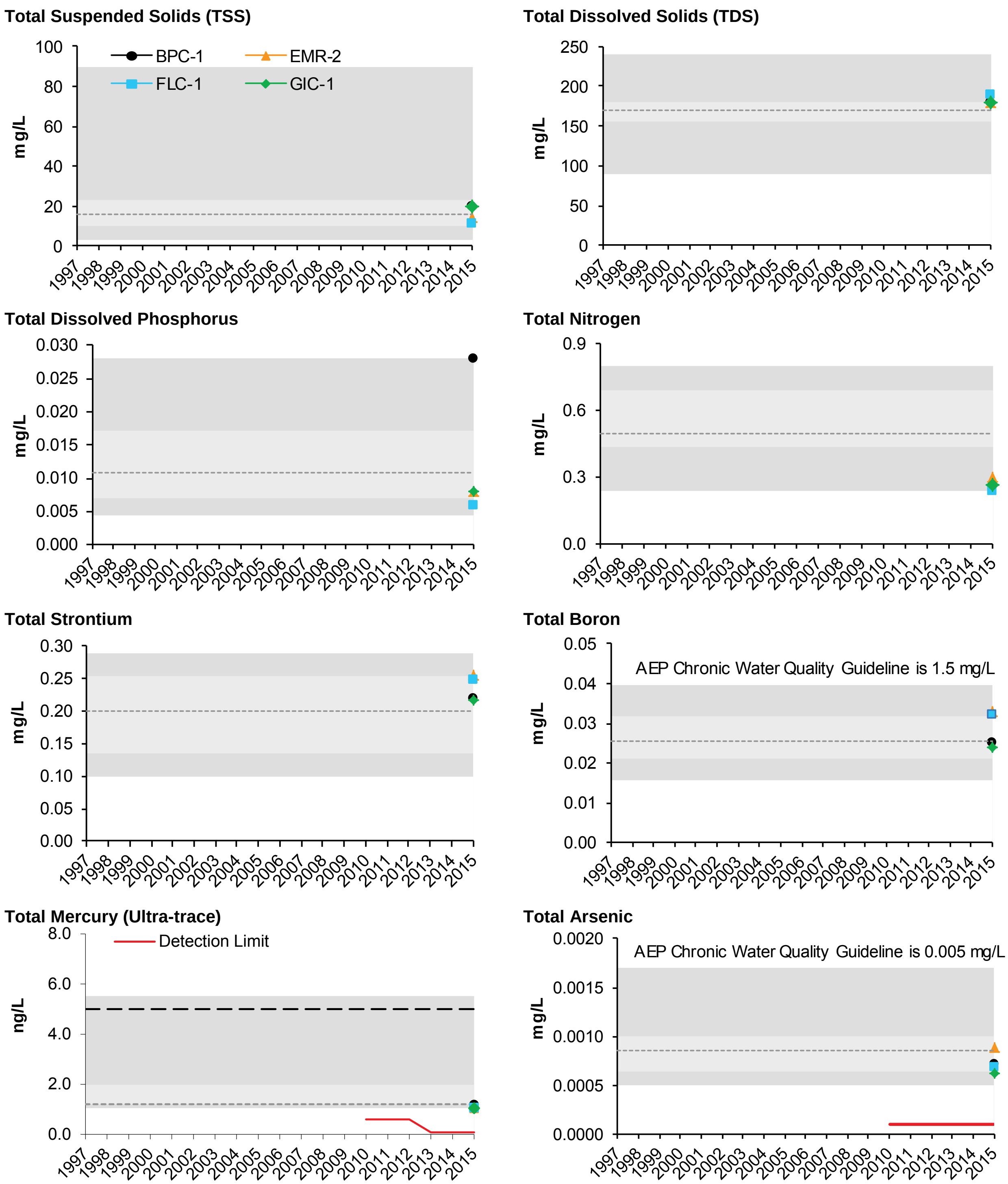
Non-detectable values are shown at the detection limit.

– – – – –   Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.1-9 Selected water quality measurement endpoints in the Athabasca River Delta (fall data) relative to regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

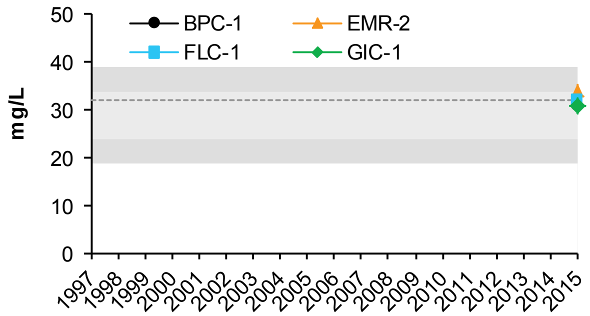
– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

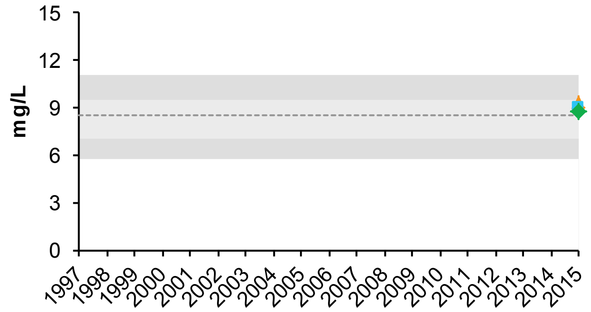
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.1-9 (Cont'd.)

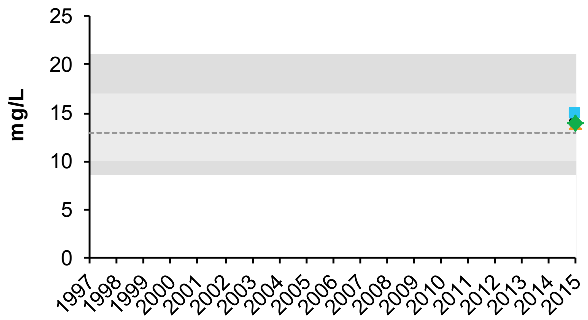
Calcium



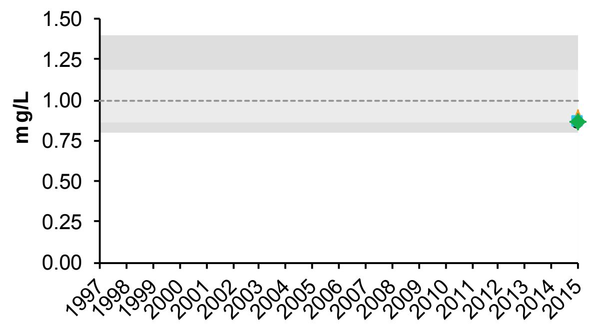
Magnesium



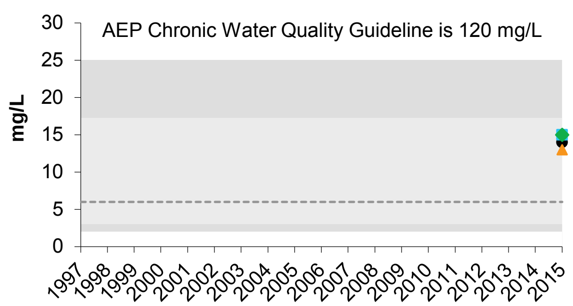
Sodium



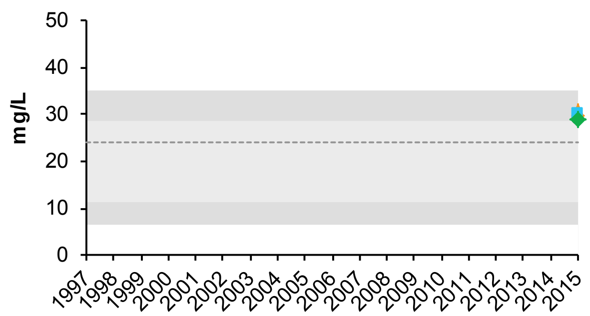
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.1-13 Average habitat characteristics of benthic invertebrate community sampling reaches of the Athabasca River Delta (*test* reaches BPC-1, FLC-1, GIC-1, and EMR-2), fall 2015.

Variable	Units	*Test* Reach BPC-1 (Big Point Channel)	*Test* Reach FLC-1 (Fletcher Channel)	*Test* Reach GIC-1 (Goose Island Channel)	*Test* Reach EMR-2 (Embarras River)
Sample date	-	Aug. 31 – Sep. 1, 2015	Aug. 31, 2015	Sep. 1, 2015	Aug. 31, 2015
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	2.4	2.0	1.2	3.3
Current velocity	m/s	-	-	-	-
Field water quality					
Dissolved oxygen (DO)	mg/L	7.6	7.8	7.5	7.8
Conductivity	µS/cm	201	201	199	206
pH	pH units	7.8	8.3	8.0	7.6
Water temperature	°C	18.9	19.7	18.2	18.6
Sediment composition					
Sand	%	32.6	55.7	14.6	81.5
Silt	%	58.5	37.1	76.9	14.8
Clay	%	8.8	7.2	8.5	3.6
Total organic carbon (TOC)	%	1.4	1.1	2.0	0.9

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.1-14 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community of Big Point Channel (*test* reach BPC-1) of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach BPC-1 (Big Point Channel)		
	2003	2004-2014	2015
Nematoda	<1	<1 to 7	<1
Oligochaeta (cocoon)	-	0 to 2	-
Naididae	1	0 to 7	3
Tubificidae	75	29 to 75	49
Erpobdellidae	-	0 to <1	-
Hydracarina	<1	0 to <1	-
Amphipoda	-	0 to 2	-
Gastropoda	4	0 to 12	12
Bivalvia	10	<1 to 37	27
Ceratopogonidae	1	<1 to 7	1
Chironomidae	6	3 to 64	6
Diptera (misc)	0 to <1	0 to 4	<1
Ephemeroptera	<1	0 to 2	<1
Odonata	<1	0 to <1	-
Plecoptera	-	0 to <1	-
Trichoptera	1	0 to 4	<1
Heteroptera	<1	0 to <1	-
Megaloptera	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	267	36 to 2,359	1,716
Richness	11	6 to 15	14
Equitability	0.17	0.15 to 0.74	0.19
% EPT	1	0 to 19	1

Table 5.1-15 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community of Fletcher Channel (*test* reach FLC-1) of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach FLC-1 (Fletcher Channel)		
	2002	2003-2014	2015
Nematoda	5	0 to 22	-
Oligochaeta (cocoon)	-	0 to 4	-
Naididae	<1	0 to 15	11
Tubificidae	2	10 to 81	16
Hydracarina	-	0 to <1	-
Gastropoda	1	0 to 14	1
Bivalvia	1	<1 to 13	<1
Ceratopogonidae	2	<1 to 14	14
Chironomidae	86	4 to 79	58
Diptera (misc)	0 to <1	0 to <1	-
Ephemeroptera	<1	0 to 2	<1
Odonata	-	0 to <1	-
Plecoptera	-	0 to 1	-
Trichoptera	-	0 to 3	<1
Heteroptera	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	1,034	6 to 2,639	642
Richness	12	4 to 14	15
Equitability	0.20	0.13 to 0.89	0.29
% EPT	1	0 to 6	<1

Table 5.1-16 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities of Goose Island Channel (*test* reach GIC-1) and the Embarras River (*test* reach EMR-2) of the Athabasca River Delta.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Test Reach GIC-1 (Goose Island Channel)			*Test* Reach EMR-2 (Embarras River)		
	2002	2003-2014	2015	2010	2011-2014	2015
Hydra	-	2	-	-	-	-
Turbellaria	-	-	-	-	-	1
Nematoda	5	0 to 2	<1	1	6 to 12	3
Oligochaeta (cocoon)	-	0 to 15	-	-	0 to <1	-
Naididae	-	0 to 8	<1	<1	<1 to 7	<1
Tubificidae	<1	13 to 63	84	1	<1 to 41	31
Lumbriculidae	-	0 to <1	-	-	-	-
Erpobdellidae	-	-	-	-	0 to <1	-
Glossiphoniidae	-	-	-	-	0 to 1	-
Hydracarina	<1	0 to <1	-	<1	0 to <1	-
Amphipoda	-	0 to <1	-	-	-	-
Gastropoda	5	0 to 24	<1	<1	<1-11	2
Bivalvia	13	<1 to 4	7	29	2 to 10	23
Ceratopogonidae	1	1 to 17	1	4	4 to 20	2
Chironomidae	74	13 to 66	8	41	27 to 81	37
Diptera (misc.)	-	0 to 1	-	-	-	-
Ephemeroptera	-	0 to 4	<1	<1	<1 to 10	-
Odonata	<1	0 to 1	<1	-	-	-
Trichoptera	<1	0 to 2	<1	3	<1	1
Benthic Invertebrate Community Measurement Endpoints						
Total abundance per sample	781	41 to 806	2,862	1,022	27 to 1177	1,102
Richness	14	8 to 12	7	23	5 to 14	15
Equitability	0.18	0.24 to 0.52	0.21	0.33	0.24 to 0.56	0.26
% EPT	<1	0 to 4.4	<1	3	<1 to 10	1

Table 5.1-17 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints of Big Point Channel (*test* reach BPC-1) of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2015 vs. Previous Years	Time Trend	2015 vs. Previous Years	
Log of Abundance	0.061	**0.001**	4	13	Abundance higher in 2015 than the mean of all prior years.
Log of Richness	0.496	**0.023**	2	18	Richness higher in 2015 than the mean of all prior years.
Equitability	0.052	0.060	7	7	No change.
Log of EPT	0.064	0.390	7	2	No change.
CA Axis 1	**<0.001**	0.198	16	1	CA Axis 1 scores decreased over time in the channel.
CA Axis 2	**0.038**	**0.011**	13	21	CA Axis 2 scores decreased over time and were lower in 2015 than the mean of previous years.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

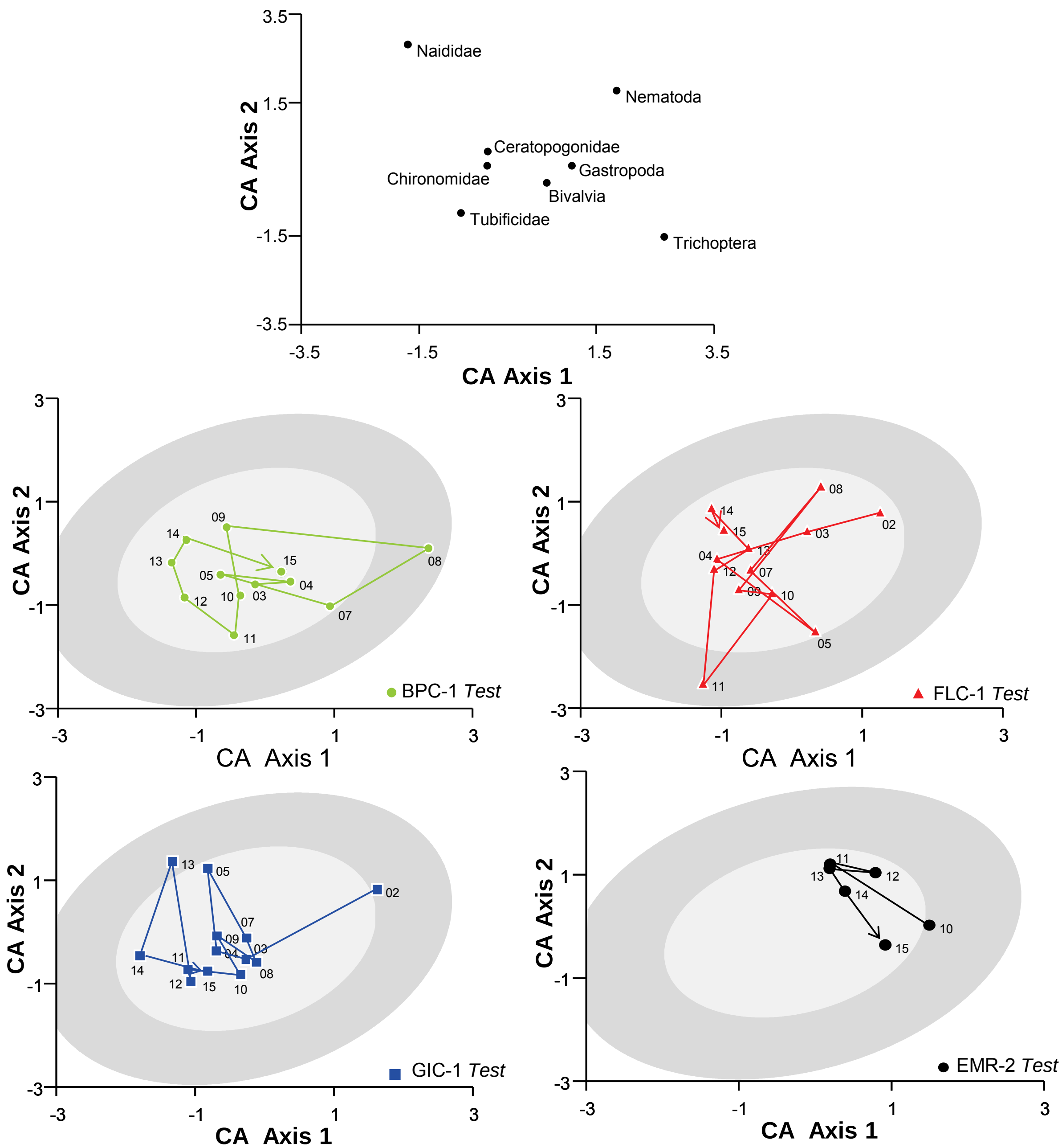
Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

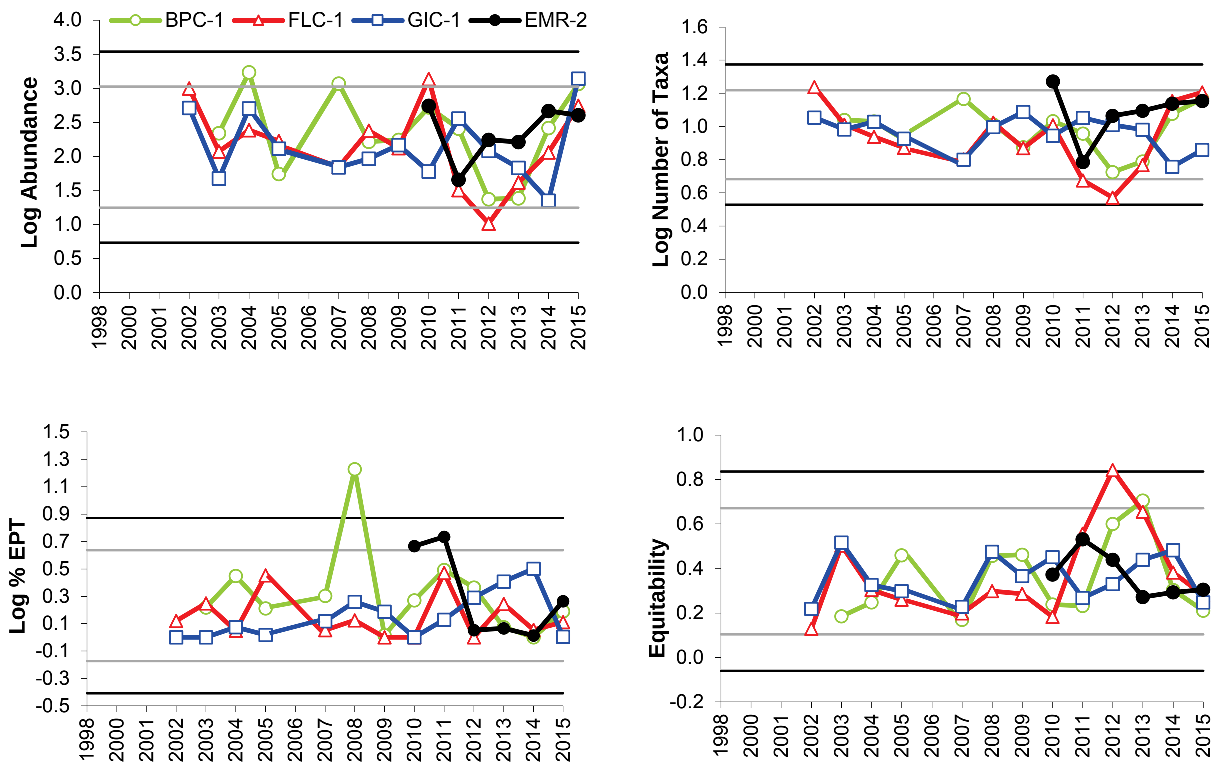
Abundance, richness, and %EPT data were log10(x+1) transformed.

Figure 5.1-10 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional channels of the Athabasca River Delta (*test* reaches BPC-1, FLC-1, GIC-1, and EMR-2).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all ARD reaches, 2002 to 2014.

Figure 5.1-11 Variation in benthic invertebrate community measurement endpoints of the Athabasca River Delta, relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all ARD *test* reaches (2002 to 2014).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed. Values shown are “adjusted” for percent sand, as described in Appendix D.

Table 5.1-18 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints of Fletcher Channel (*test* reach FLC-1) of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2015 vs. Previous Years	Time Trend	2015 vs. Previous Years	
Log of Abundance	**0.024**	**0.025**	9	9	Abundance decreased over time but was higher in 2015 than the mean of previous years.
Log of Richness	0.341	**0.008**	2	17	Richness higher in 2015 than the mean of all prior years.
Equitability	**<0.001**	0.158	17	2	Equitability decreased over time in the channel.
Log of EPT	0.614	0.763	1	1	No change.
CA Axis 1	**<0.001**	0.051	46	5	CA Axis 1 scores decreased over time in the channel.
CA Axis 2	**0.037**	0.376	4	1	CA Axis 2 scores decreased over time in the channel.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Abundance, richness, and %EPT data were log10(x+1) transformed.

Table 5.1-19 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints of Goose Island Channel (*test* reach GIC-1) of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2015 vs. Previous Years	Time Trend	2015 vs. Previous Years	
Log of Abundance	0.643	**<0.001**	0	35	Abundance higher in 2015 than the mean of prior years.
Log of Richness	0.117	0.213	14	9	No change.
Equitability	0.490	0.080	2	10	No change.
Log of EPT	**0.007**	0.191	32	7	Percent of fauna as EPT taxa increased over time in the channel.
CA Axis 1	**<0.001**	0.347	52	1	CA Axis 1 scores decreased over time in the channel.
CA Axis 2	**0.047**	**0.039**	11	12	CA Axis 2 score decreased over time and were lower in 2015 than the mean of prior years.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Abundance, richness, and %EPT data were log10(x+1) transformed.

Table 5.1-20 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints of Embarras River (*test* reach EMR-2) of the Athabasca River Delta.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend	2015 vs. Previous Years	Time Trend	2015 vs. Previous Years	
Log of Abundance	**0.026**	**0.027**	9	9	Abundance increased over time and was higher in 2015 than the mean of previous years.
Log of Richness	**0.040**	**0.011**	3	4	Richness increased over time and was higher in 2015 than the mean of previous years.
Equitability	**0.045**	0.319	42	10	Equitability decreased over time in the channel.
Log of EPT	**0.002**	0.783	47	0	Percent fauna as EPT taxa decreased over time in the channel.
CA Axis 1	**0.032**	0.103	11	6	CA Axis 1 score decreased over time in the channel.
CA Axis 2	**0.009**	**0.035**	9	6	CA Axis 2 score increased over time and were higher in 2015 than the mean of prior years.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Measurement endpoints were adjusted to a common percent sand composition of 50% (see Appendix D).

Abundance, richness, and %EPT data were log10(x+1) transformed.

Table 5.1-21 Concentrations of sediment quality measurement endpoints for Big Point Channel (*test* station BPC-1) of the Athabasca River Delta, fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	1999-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4.1	13	3.4	16.2	32.0
Silt	%	-	49.5	13	5.0	45.0	58.0
Sand	%	-	46.4	13	10.0	38.0	91.7
Total organic carbon	%	-	1.28	13	0.10	1.20	2.24
Total hydrocarbons							
BTEX	mg/kg	-	<20	9	<5	<10	<21
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	9	<5	<10	<21
Fraction 2 (C10-C16)	mg/kg	150[1]	26	9	<5	<20	<29
Fraction 3 (C16-C34)	mg/kg	300[1]	285	9	27	178	**307**
Fraction 4 (C34-C50)	mg/kg	2800[1]	183	9	29	102	199
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0071	13	0.0022	0.0071	0.0240
Retene	mg/kg	-	0.0521	13	0.0159	0.0510	0.0957
Total dibenzothiophenes	mg/kg	-	<u>0.4252</u>	13	0.1041	0.2357	0.3582
Total PAHs	mg/kg	-	1.8883	13	0.5706	1.3575	2.0275
Total Parent PAHs	mg/kg	-	0.1034	13	0.0366	0.1026	0.2086
Total Alkylated PAHs	mg/kg	-	1.7850	13	0.5339	1.2503	1.8792
Predicted PAH toxicity[3]	H.I.	1.0	**1.0837**	13	0.8301	**1.1599**	**2.5896**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	84	12	18	69	90
Chironomus growth - 10d	mg/organism	-	2.15	12	0.89	1.84	4.11
Hyalella survival - 14d	% surviving	-	96	12	66	81	100
Hyalella growth - 14d	mg/organism	-	0.09	12	0.05	0.14	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

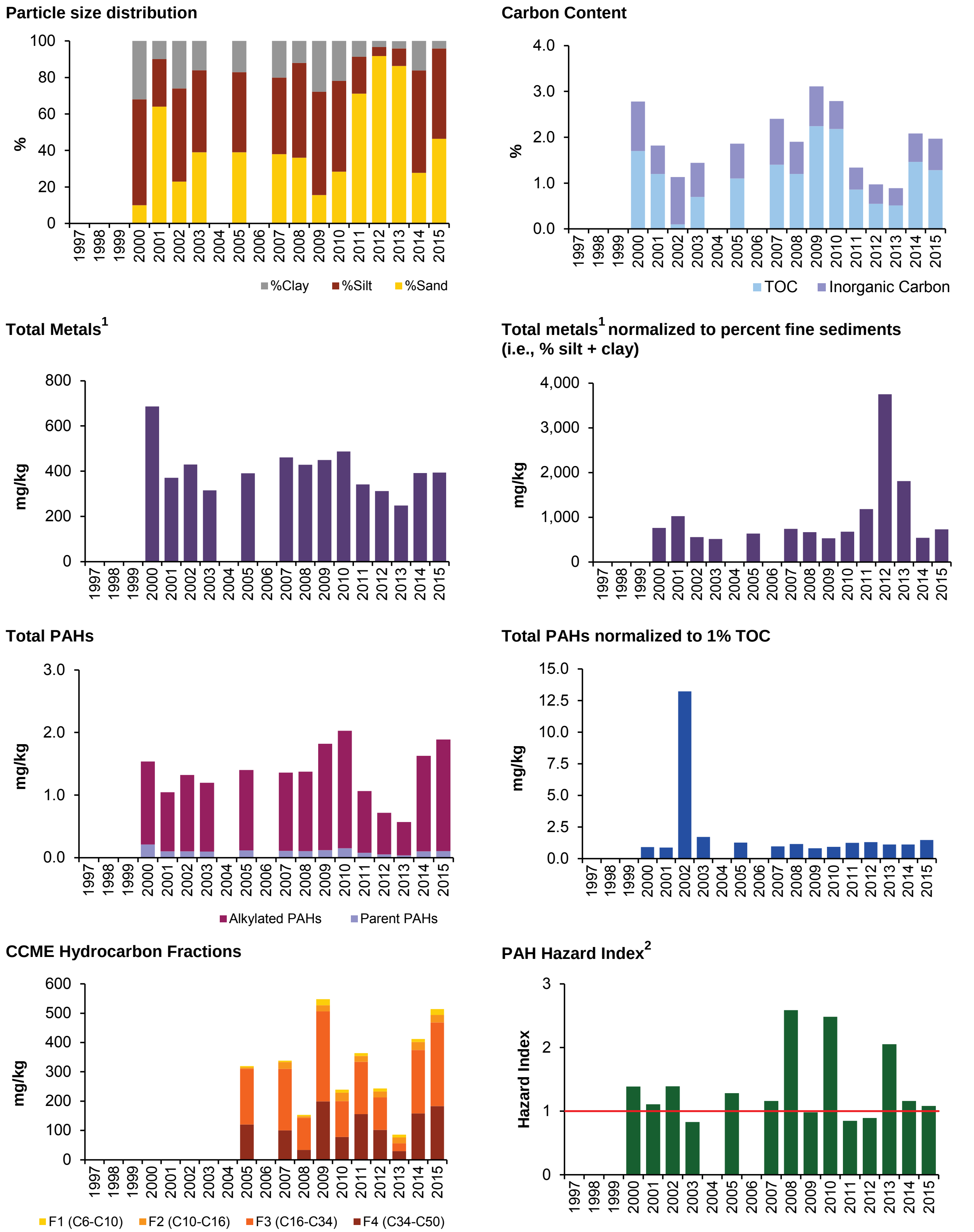
ns = not sampled in 2004 or 2006

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.1-12 Variation in sediment quality measurement endpoints in Big Point Channel, *test* station BPC-1, relative to historical concentrations.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-22 Concentrations of sediment quality measurement endpoints for Fletcher Channel (*test* station FLC-1) of the Athabasca River Delta, fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2001-2014 (fall data only) [ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	9.1	12	3.6	14.8	22.8
Silt	%	-	44.8	12	3.4	40.3	72.0
Sand	%	-	46.1	12	11.0	45.3	93.0
Total organic carbon	%	-	1.32	12	0.58	1.30	2.22
Total hydrocarbons							
BTEX	mg/kg	-	<10	9	<5	<10	30
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	9	<5	<10	**30**
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	9	<5	23	37
Fraction 3 (C16-C34)	mg/kg	300[1]	128	9	68	260	**430**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	78	9	49	187	280
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0044	11	0.0021	0.0070	0.0156
Retene	mg/kg	-	0.0296	12	0.0197	0.0452	0.1570
Total dibenzothiophenes	mg/kg	-	0.1614	12	0.0889	0.1854	0.6860
Total PAHs	mg/kg	-	0.8342	12	0.5859	1.2130	3.2064
Total Parent PAHs	mg/kg	-	0.0601	12	0.0405	0.1000	0.1596
Total Alkylated PAHs	mg/kg	-	0.7742	12	0.5454	1.1130	3.0653
Predicted PAH toxicity[3]	H.I.	1.0	0.4904	12	0.3995	0.8827	**5.3569**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	78	10	34	66	94
Chironomus growth - 10d	mg/organism	-	2.60	10	1.08	2.42	4.26
Hyalella survival - 14d	# surviving	-	<u>76</u>	10	80	90	96
Hyalella growth - 14d	mg/organism	-	0.10	10	0.10	0.22	0.34

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

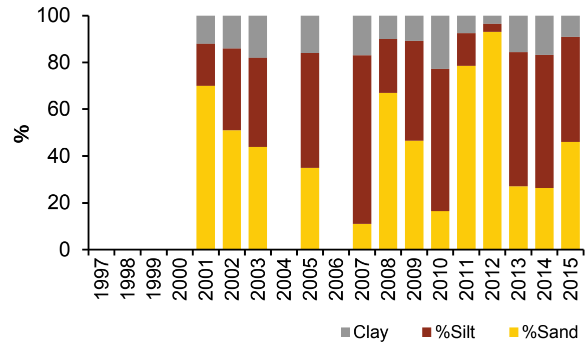
1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

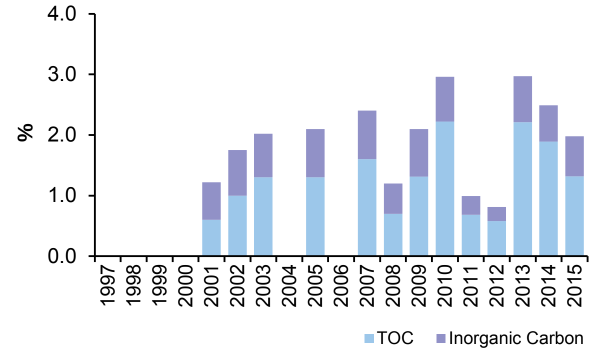
3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.1-13 Variation in sediment quality measurement endpoints in Fletcher Channel, *test* station FLC-1, relative to historical concentrations.

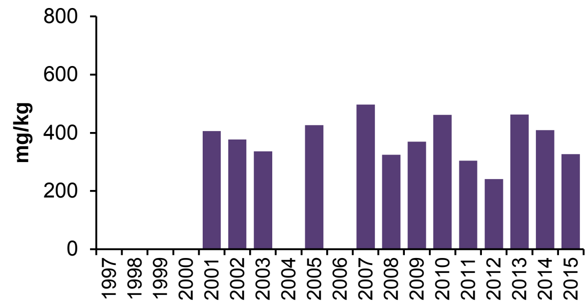
Particle size distribution



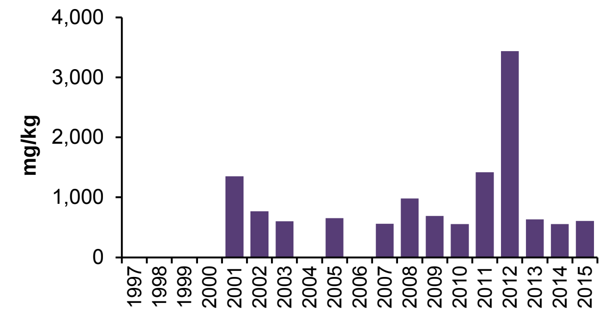
Carbon Content



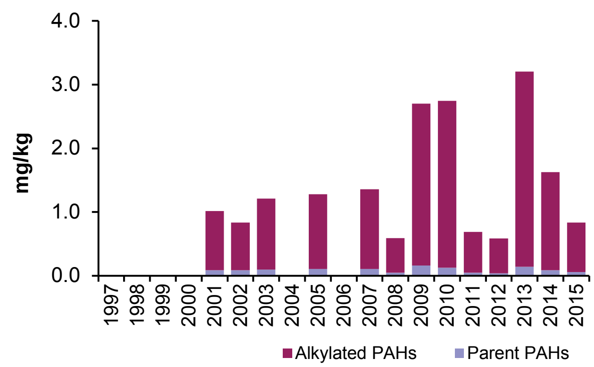
Total Metals[1]



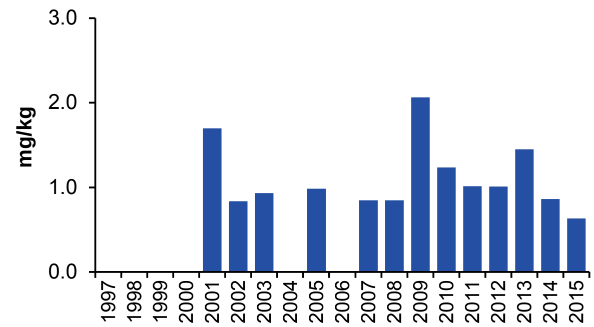
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



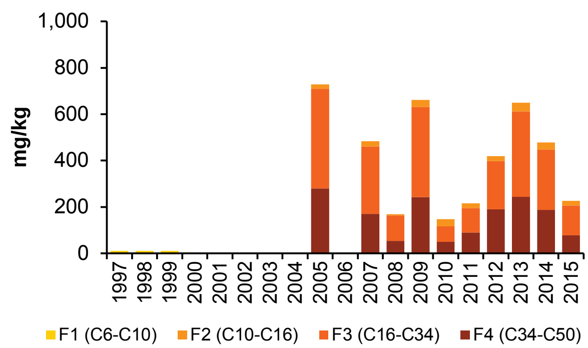
Total PAHs



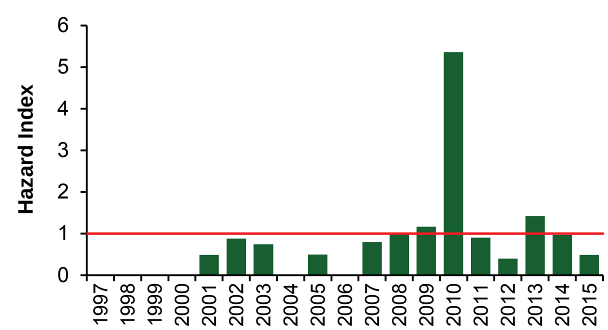
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).
[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-23 Concentrations of sediment quality measurement endpoints for Goose Island Channel (*test* station GIC-1) of the Athabasca River Delta, fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2001-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	7.1	12	2.2	14.6	28.0
Silt	%	-	<u>73.3</u>	12	8.8	46.7	63.7
Sand	%	-	19.6	12	17.0	35.3	89.0
Total organic carbon	%	-	2.01	12	0.47	1.44	2.40
Total hydrocarbons							
BTEX	mg/kg	-	<20	9	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	9	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	26	9	<5	<20	48
Fraction 3 (C16-C34)	mg/kg	300[1]	**305**	9	39	180	**395**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	174	9	46	116	275
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0064	12	<0.0001	0.0063	0.0146
Retene	mg/kg	-	0.0518	12	0.0058	0.0462	0.1160
Total dibenzothiophenes	mg/kg	-	0.3643	12	0.0426	0.2302	0.8249
Total PAHs	mg/kg	-	1.7024	12	0.2942	1.3791	3.1508
Total Parent PAHs	mg/kg	-	0.0925	12	0.0213	0.1102	0.1771
Total Alkylated PAHs	mg/kg	-	1.6099	12	0.2729	1.2674	3.0173
Predicted PAH toxicity[3]	H.I.	1.0	0.9580	12	0.6398	**1.1035**	**1.8850**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>94</u>	9	40	72	84
Chironomus growth - 10d	mg/organism	-	<u>1.21</u>	9	1.34	2.15	4.22
Hyalella survival - 14d	# surviving	-	82	10	70	90	100
Hyalella growth - 14d	mg/organism	-	<u>0.07</u>	10	0.10	0.20	0.30

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

ns = not sampled in 2004 or 2006

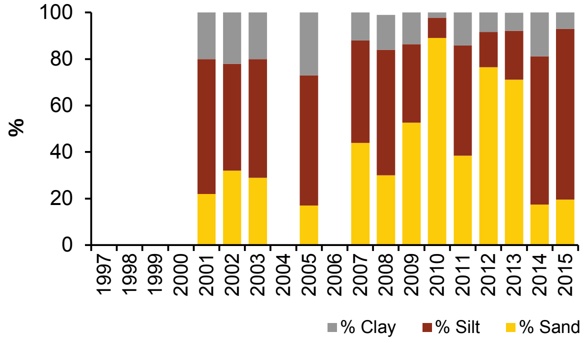
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

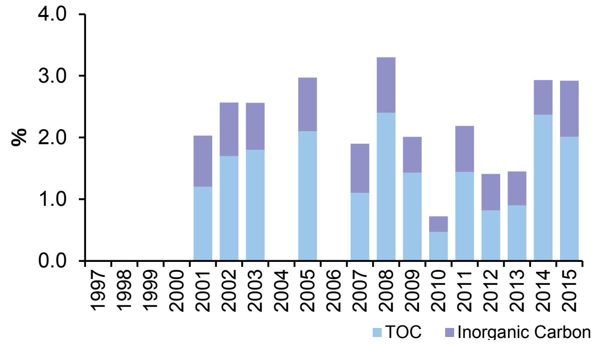
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.1-14 Variation in sediment quality measurement endpoints in Goose Island Channel, *test* station GIC-1, relative to historical concentrations.

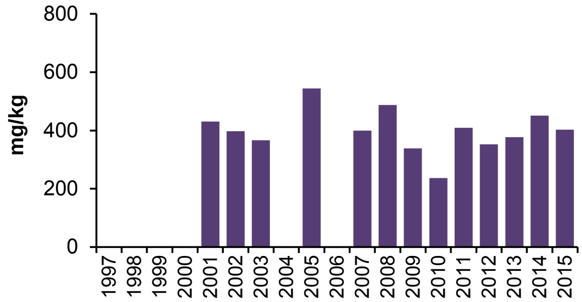
Particle size distribution



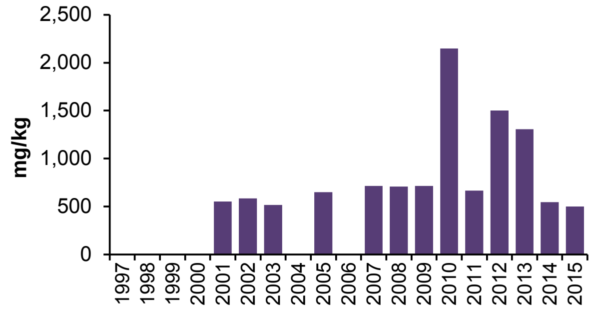
Carbon Content



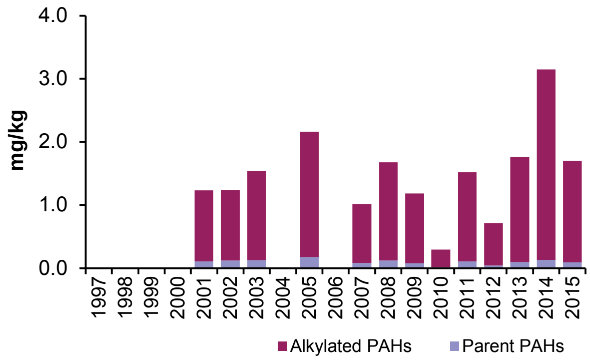
Total Metals[1]



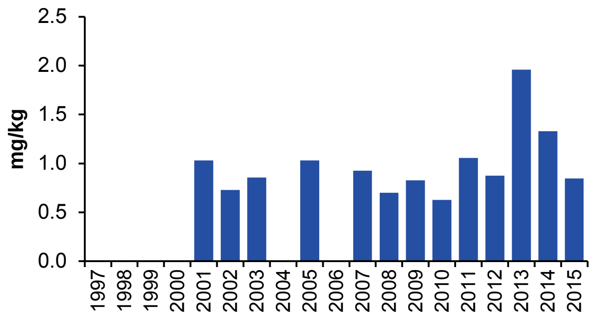
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



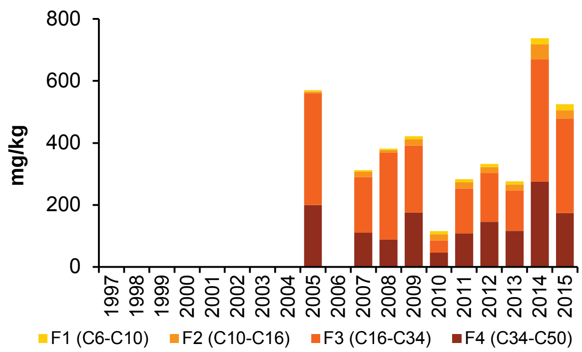
Total PAHs



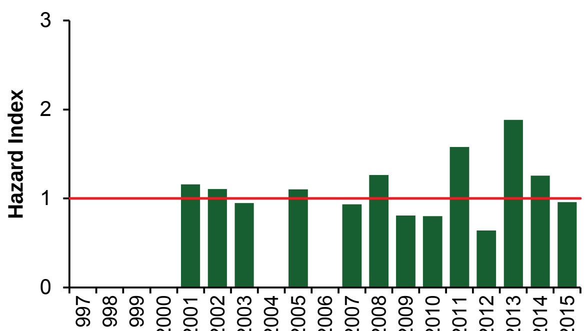
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).
[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-24 Concentrations of sediment quality measurement endpoints for Embarras River (*test* station EMR-2) of the Athabasca River Delta, fall 2015, compared to historical concentrations.

Variables	Units	Guideline	September 2015	2005-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>5.6</u>	5	27.5	32.4	43.0
Silt	%	-	<u>92.9</u>	5	46.8	55.0	67.1
Sand	%	-	1.6	5	1.1	9.3	25.7
Total organic carbon	%	-	<u>2.30</u>	5	2.41	2.58	2.68
Total hydrocarbons							
BTEX	mg/kg	-	<20	5	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	5	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	35	5	<5	<33	54
Fraction 3 (C16-C34)	mg/kg	300[1]	**341**	5	54	279	**390**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<u>211</u>	5	36	174	196
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0098	5	0.0058	0.0126	0.0245
Retene	mg/kg	-	0.1080	5	0.0718	0.1160	0.1390
Total dibenzothiophenes	mg/kg	-	0.5290	5	0.2780	0.4923	0.5774
Total PAHs	mg/kg	-	2.3776	5	2.0864	2.6203	2.6879
Total Parent PAHs	mg/kg	-	0.1378	5	0.1308	0.1671	0.2042
Total Alkylated PAHs	mg/kg	-	2.2398	5	1.9193	2.4238	2.5251
Predicted PAH toxicity[3]	H.I.	1.0	<u>**1.1536**</u>	5	**1.2931**	**1.3436**	**5.9619**
Metals that exceeded CCME guidelines in 2015							
Total Arsenic	mg/kg	5.9	**8.2**	5	**7.0**	**8.1**	**8.9**
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>98</u>	4	28	65	74
Chironomus growth - 10d	mg/organism	-	1.64	4	1.62	1.97	2.45
Hyalella survival - 14d	# surviving	-	94	4	42	87	94
Hyalella growth - 14d	mg/organism	-	0.10	4	0.10	0.20	0.21

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

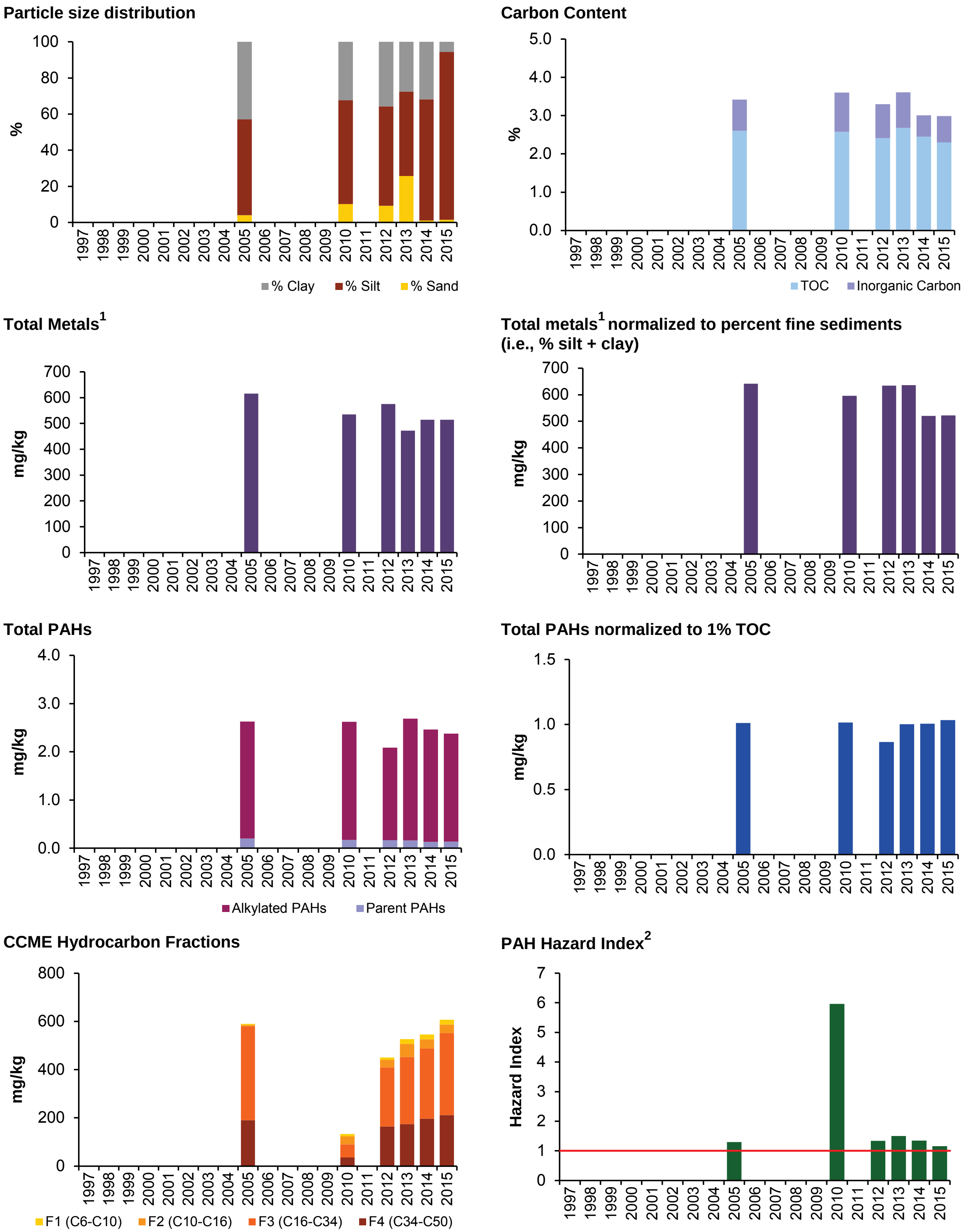
ns = not sampled in 2006 to 2009, or 2011

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.1-15 Variation in sediment quality measurement endpoints in the Embarras River, *test* station EMR-2, relative to historical concentrations.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.1-25 Concentrations of selected sediment quality measurement endpoints, Athabasca River at wild fish health reaches (*test* stations M4-DS, M4-US, and M3, and *baseline* station M0-DS), fall 2015.

Variable	Units	Guideline	September 2015			
			M4-DS	M4-US	M3	M0-DS
Physical variables						
Clay	%	-	6.6	14.1	12.1	19.5
Silt	%	-	17.1	55.2	49.2	54.2
Sand	%	-	76.3	30.7	38.8	26.3
Total organic carbon	%	-	0.89	1.58	1.49	1.41
Total hydrocarbons						
BTEX	mg/kg	-	<10	<20	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<20	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	23	31	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	179	174	129	52
Fraction 4 (C34-C50)	mg/kg	2,800[1]	122	89	71	20
Polycyclic Aromatic Hydrocarbons (PAHs)						
Naphthalene	mg/kg	0.0346[2]	0.0030	0.0063	0.0073	0.0113
Retene	mg/kg	-	0.0368	0.0531	0.0420	0.0674
Total dibenzothiophenes	mg/kg	-	0.5460	0.4146	0.1475	0.0297
Total PAHs	mg/kg	-	1.6597	1.7465	0.8530	0.8029
Total Parent PAHs	mg/kg	-	0.0714	0.1280	0.0802	0.1051
Total Alkylated PAHs	mg/kg	-	1.5883	1.6185	0.7728	0.6978
Predicted PAH toxicity[3]	H.I.	1.0	**1.4592**	**1.7115**	**1.0146**	**2.3528**
Metals that exceeded CCME guidelines in 2015						
Total arsenic	mg/kg	5.9	-	**5.9**	**6.6**	-
Other analytes that exceeded CCME guidelines in 2015						
None	-	-	-	-	-	-
Chronic toxicity						
Chironomus survival - 10d	% surviving	-	92	64	78	94
Chironomus growth - 10d	mg/organism	-	1.91	2.11	2.14	2.07
Hyalella survival - 14d	% surviving	-	94	94	90	98
Hyalella growth - 14d	mg/organism	-	0.16	0.18	0.15	0.14

Values in **bold** indicate concentrations exceeding guidelines.

ns = not sampled in 1999, 2000, 2001, 2008, or 2009

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Table 5.1-26 Average habitat characteristics of wild fish health monitoring reaches in the Athabasca River, fall 2015.

Designation	Reach	Sample Date	Mean Water Depth (m)	Mean Velocity (m/s)	Field Water Quality				Substrate (Dominant/ Subdominant)
					Water Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH	
Baseline	M0-US	Sept. 14, 2015	0.7	0.27	11.8	279	7.2	8.52	silt/cobble
	M0-DS	Sept. 15, 2015	0.6	0.35	10.8	284	8.1	8.50	silt/cobble
	M2	Sept. 8, 2015	0.45	0.25	12.4	289	9.2	7.92	fines/cobble
	M3[1]	Sept. 10, 2015	0.6	0.27	14.4	277	8.2	8.42	fines/gravel
Test	M4-US	Sept. 9, 2015	0.5	0.24	12.4	312	9.2	8.39	fines/gravel
	M4-DS	Sept. 9, 2015	0.5	0.19	14.5	272	9.0	8.34	fines/gravel
	M7	Sept. 14, 2015	0.5	0.08	13.2	374	9.8	6.36	fines/cobble
	M8	Sept. 11, 2015	0.6	0.41	12.4	202	9.0	8.30	fines/cobble
	M9	Sept. 12, 2015	0.5	0.10	15.4	301	8.0	8.36	silt/sand

[1] Although *baseline* reach M3 is upstream of all oil sands mining projects (and therefore considered a *baseline* reach for the purposes of this assessment), it is downstream of the discharge point for the Fort McMurray sewage treatment plant (STP); *baseline* reach M3 can therefore also be considered a *test* reach in relation to the Fort McMurray STP.

Figure 5.1-16 Daily mean temperatures for wild fish health reaches in the Athabasca River, August to September 2015.

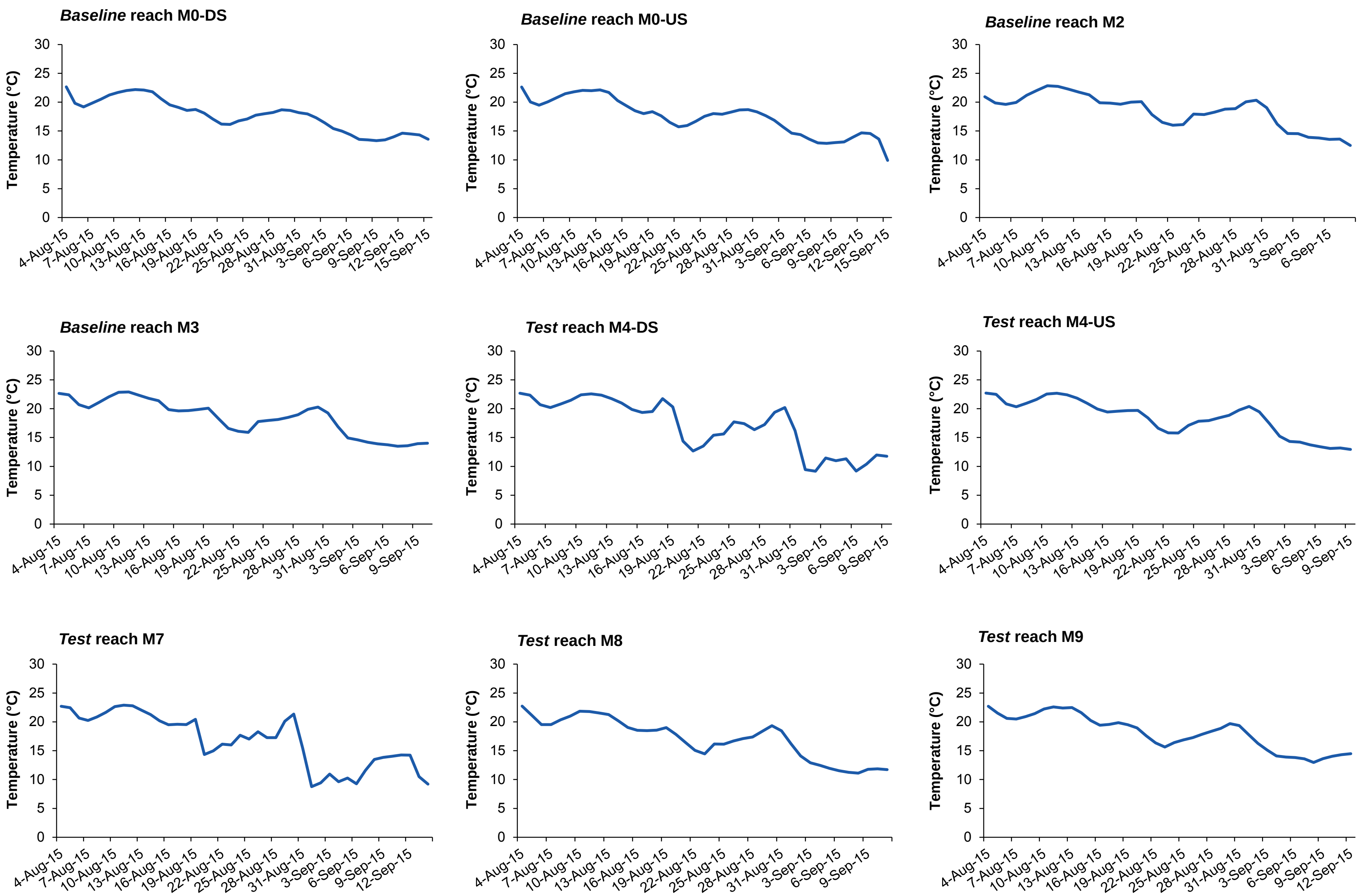


Table 5.1-27 Summary of fish caught and mean length, weight, and relative abundance of juvenile fish at each sampling reach in the Athabasca River, fall 2015.

Reach	Designation	Sample Size		Relative Abundance (%)		Juvenile Measurements		Percentage of External Abnormalities
		Juvenile	Adult	Juvenile	Adult	Average Length (mm)	Mean Weight (g)	
M0-US	*Baseline*	90	50	64	36	42.2	1	0
M0-DS	*Baseline*	96	44	69	31	41.5	0.86	1.0
M2	*Baseline*	15	125	11	89	47.9	1.57	0
M3[1]	*Baseline*	8	132	6	94	49.1	1.46	0
M4-US	*Test*	25	119	17	83	47.4	1.66	1.0
M4-DS	*Test*	29	111	21	79	47.3	1.54	0
M7	*Test*	52	88	37	63	47.2	1.34	2.0
M8	*Test*	81	59	58	42	44.8	1.28	0
M9	*Test*	34	106	24	76	47	1.4	3.0

[1] Although *baseline* reach M3 is upstream of all oil sands mining projects (and therefore considered a *baseline* reach for the purposes of this assessment), it is downstream of the discharge point for the Fort McMurray sewage treatment plant (STP); *baseline* reach M3 can therefore also be considered a *test* reach in relation to the Fort McMurray STP.

Figure 5.1-17 Length-frequency distributions of trout perch in wild fish health reaches of the Athabasca River, fall 2015.

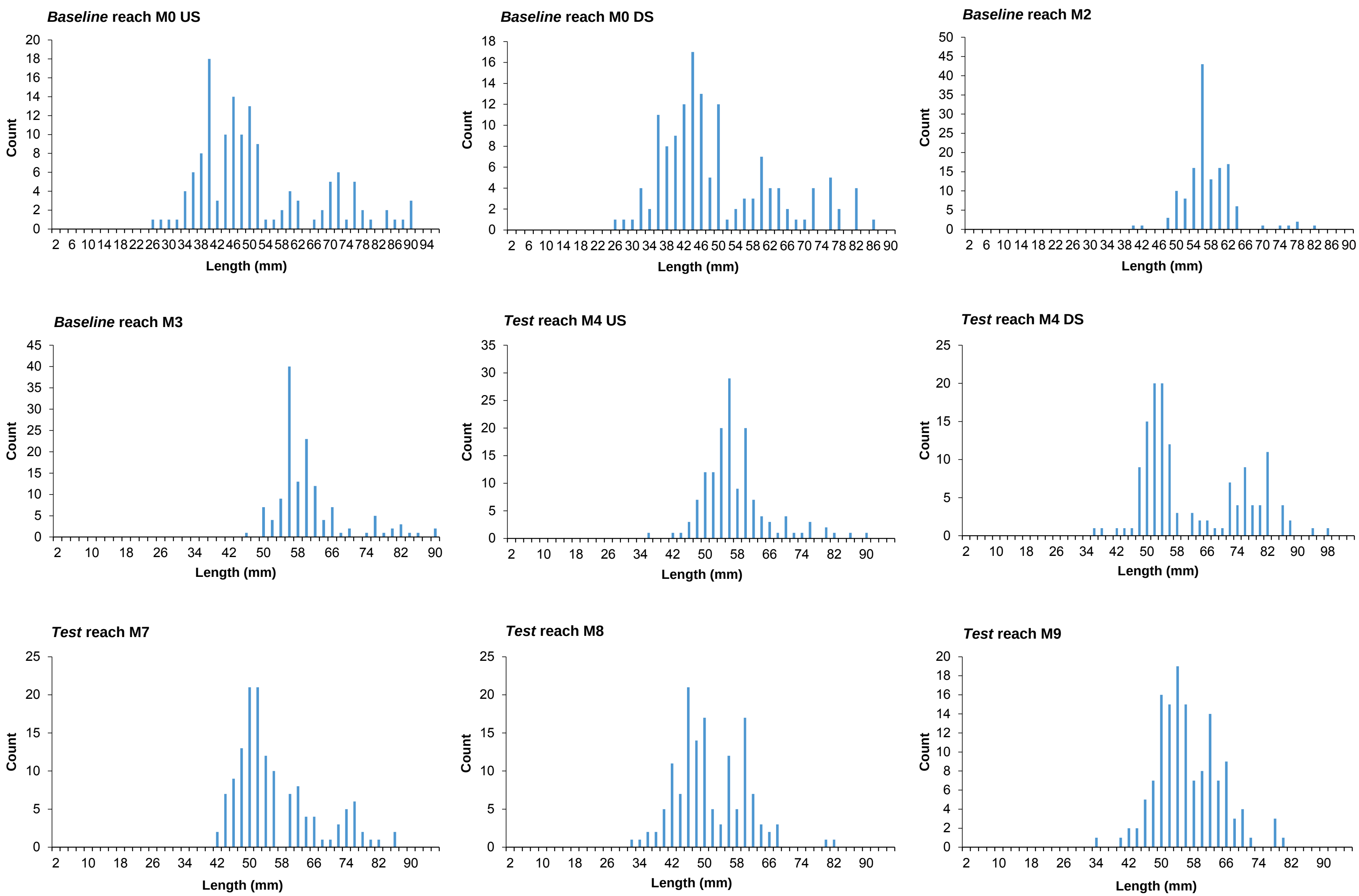


Table 5.1-28 Summary of morphometric data (mean ± SE) for trout perch in reaches of the Athabasca River, fall 2015.

Reach	n	Sex	Age	Length (mm)	Weight (g)	K	GSI	LSI
***Baseline* reaches**								
M0-US	20	F	3.1 ± 1.1	76 ± 10	5.7 ± 1.9	1.24 ± 0.10	5.17 ± 1.28	1.40 ± 0.24
	20[a]	M	2.4 ± 0.6	67 ± 6	3.8 ± 1.0	1.23 ± 0.11	1.43 ± 0.56	1.03 ± 0.24
M0-DS	20	F	2.4 ± 0.6	66 ± 9	3.5 ± 1.6	1.18 ± 0.15	4.29 ± 0.95	1.24 ± 0.28
	20	M	2.6 ± 0.7	69 ± 8	3.8 ± 1.1	1.15 ± 0.13	1.50 ± 0.38	1.14 ± 0.42
M2	20	F	2.6 ± 0.8	65 ± 7	3.6 ± 1.4	1.28 ± 0.07	3.29 ± 1.09	1.13 ± 0.20
	14	M	2.6 ± 0.5	62 ± 4	3.0 ± 0.6	1.25 ± 0.07	1.12 ± 0.21	1.08 ± 0.12
M3*	20	F	2.8 ± 0.6	75 ± 11	5.3 ± 2.1	1.19 ± 0.08	4.16 ± 0.90	1.43 ± 0.15
	20[b]	M	2.6 ± 0.7	66 ± 6	3.4 ± 0.8	1.17 ± 0.10	1.20 ± 0.41	1.22 ± 0.35
***Test* reaches**								
M4-US	20[c]	F	2.4 ± 0.9	66 ± 11	4.0 ± 2.1	1.34 ± 0.09	3.95 ± 1.14	1.34 ± 0.21
	21[d]	M	2.5 ± 0.8	63 ± 7	3.4 ± 1.1	1.30 ± 0.08	1.16 ± 0.32	1.17 ± 0.19
M4-DS	20	F	3.3 ± 1.1	78 ± 10	6.2 ± 2.4	1.22 ± 0.07	4.72 ± 1.06	1.51 ± 0.21
	20[e]	M	2.9 ± 0.6	75 ± 7	5.3 ± 1.2	1.22 ± 0.09	1.41 ± 0.27	1.12 ± 0.12
M7	20	F	1.9 ± 1.1	67 ± 9	3.9 ± 1.6	1.27 ± 0.09	2.61 ± 0.58	0.96 ± 0.19
	20	M	2.8 ± 0.8	72 ± 5	4.6 ± 0.8	1.24 ± 0.11	0.90 ± 0.20	0.77 ± 0.14
M8	20	F	2.4 ± 0.7	62 ± 7	3.2 ± 1.1	1.28 ± 0.06	2.77 ± 0.77	1.30 ± 0.27
	19[f]	M	2.3 ± 0.7	60 ± 4	2.7 ± 0.5	1.26 ± 0.08	1.01 ± 0.35	1.22 ± 0.25
M9	20[g]	F	2.7 ± 0.8	64 ± 5	3.3 ± 0.71	1.23 ± 0.07	2.23 ± 0.35	0.88 ± 0.17
	20	M	2.9 ± 0.5	66 ± 6	3.6 ± 1.0	1.23 ± 0.05	0.84 ± 0.20	0.78 ± 0.13

* Although *baseline* reach M3 is upstream of all oil sands mining projects (and therefore considered a *baseline* reach for the purposes of this assessment), it is downstream of the discharge point for the Fort McMurray sewage treatment plant (STP); *baseline* reach M3 can therefore also be considered a *test* reach in relation to the Fort McMurray STP.

K = condition, GSI = gonadosomatic index, LSI = liversomatic index

[a] sample for age was 19

[b] sample size for length, weight, and K was 23

[c] sample size for EROD was 19

[d] sample size for length, weight, and K was 32

[e] sample size for length, weight, and K was 36

[f] sample size for length, weight, and K was 29

[g] sample size for length, weight, and K is 24

Figure 5.1-18 Relative age-frequency distribution for trout perch at *baseline* reaches M0-US, M0-DS, M2, and M3, and *test* reaches M4-US, M4-DS, M7, M8, and M9 in the Athabasca River, fall 2015.

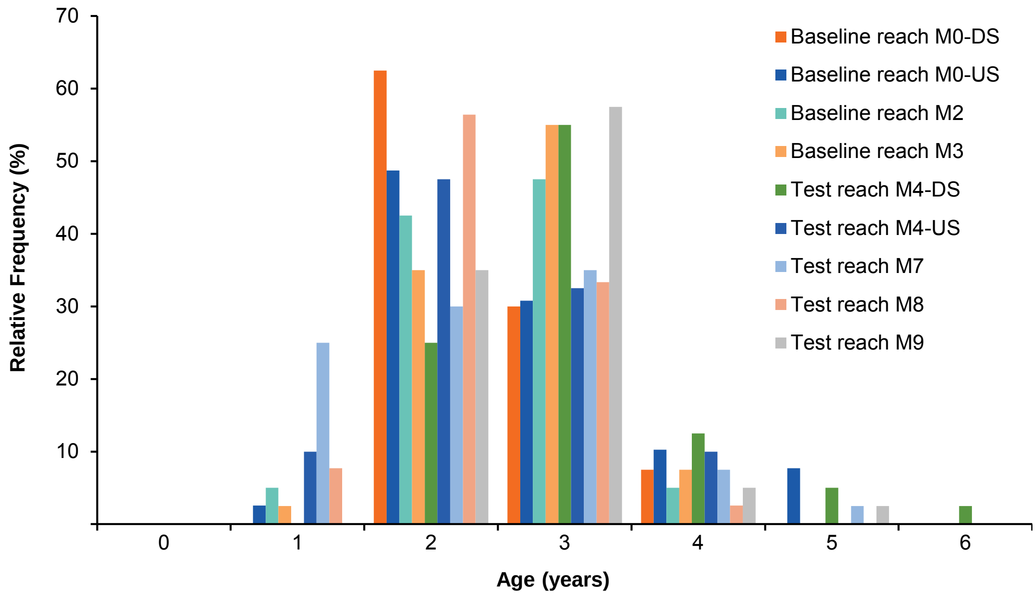


Table 5.1-29 Results of analysis of variance (ANOVA), analysis of covariance (ANCOVA), and Kolmogorov-Smirnov tests for differences in measurement endpoints and EROD activity of adult trout-perch in the Athabasca River, fall 2015.

Analysis	Sex	Comparison	Sample Size	P-value	Direction	Effects Criteria	Percent Difference[1]	Post Hoc[2]
ANOVA								
Age (Survival)								
	Female	M0-DS vs. M0-US	20, 20	0.057	None	±25%	-19.1	*0.52*
		M2 vs. M0-DS	20, 20	0.466	None	±25%	8.4	*0.52*
		M3 vs. M2	20, 20	0.391	None	±25%	10.2	*0.52*
		M4-US vs. M3	20, 20	**0.044**	M4-US < M3	±25%	**-20.2**	-
		M4-DS vs. M4-US	20, 20	**0.002**	M4-DS > M4-US	±25%	**<u>41.3</u>**	-
		M7 vs. M4-DS	20, 20	**<0.001**	M7 < M4-DS	±25%	**<u>-46.7</u>**	-
		M8 vs. M7	20, 20	**0.005**	M8 > M7	±25%	**<u>37.4</u>**	-
		M9 vs. M8	20, 20	0.278	None	±25%	12.7	*0.52*
	Male	M0-DS vs. M0-US	20, 19	0.423	None	±25%	7.2	*0.74*
		M2 vs. M0-DS	14, 20	0.825	None	±25%	2.1	*0.74*
		M3 vs. M2	20, 14	0754	None	±25%	-2.9	*0.74*
		M4-US vs. M3	20, 20	0.755	None	±25%	-2.5	*0.74*
		M4-DS vs. M4-US	20, 20	0.064	None	±25%	16.9	*0.74*
		M7 vs. M4-DS	20, 20	0.554	None	±25%	-4.9	*0.74*
		M8 vs. M7	18, 20	**0.020**	M8 < M7	±25%	**-18.3**	-
		M9 vs. M8	20, 18	**0.003**	M9 > M8	±25%	**<u>29.4</u>**	-
***ANCOVA*[3]**								
Growth – Size-at-age (Energy Use)								
	Female	M0-DS vs. M0-US	20, 20	**<0.001**	M0-DS < M0-US	±25%	**<u>-31.1</u>**	-
		M2 vs. M0-DS	20, 20	0.973	None	±25%	-0.5	*0.65*
		M3 vs. M2	20, 20	**0.002**	M3 > M2	±25%	**<u>35.2</u>**	-
		M4-US vs. M3	20, 20	0.093	M4-US < M3	±25%	-15.1	*0.65*
		M4-DS vs. M4-US	20, 20	**0.010**	M4-DS > M4-US	±25%	**<u>29.4</u>**	-
		M7 vs. M4-DS	20, 20	0.432	None	±25%	-8.0	*0.65*
		M8 vs. M7	20, 20	**<0.001**	M8 < M7	±25%	**<u>-31.5</u>**	-
		M9 vs. M8	20, 20	0.845	None	±25%	1.9	*0.65*
	Male	M0-DS vs. M0-US	20, 19	0.956	None	±25%	-0.5	*0.84*
		M2 vs. M0-DS	14, 20	**0.006**	M2 < M0-DS	±25%	**-19.6**	-
		M3 vs. M2	20, 20	0.072	M3 > M2	±25%	**15.3**	-
		M4-US vs. M3	20, 20	0.129	None	±25%	11.7	*0.84*
		M4-DS vs. M4-US	20, 20	**<0.001**	M4-DS > M4-US	±25%	**<u>47.6</u>**	-
		M7 vs. M4-DS	18, 20	**0.002**	M7 < M4-DS	±25%	**-20.6**	-
		M8 vs. M7	20, 18	**<0.001**	M8 < M7	±25%	**<u>-34.4</u>**	-
		M9 vs. M8	20, 20	0.046	None	±25%	**16.7**	-

Bold values indicate significant difference (p<0.05).

* Data were log-transformed.

1 Percent difference was calculated using ANOVA-adjusted least squared means with upstream reaches as the reference. <u>Underlined</u> values signify instances when significant differences were observed and the effect size exceeded Environment Canada's criterion for 25% for age, weight-at-age, GSI, and LSI, and 10% for condition.

2 Power was calculated when no significant differences were found among reaches. Values in *italics* denote comparisons where power was inadequate and sample size was too low.

3 The results of ANCOVA tests are presented only if slopes of the regression of the variables used in the ANCOVA were not significantly different (p<0.01).

Table 5.1-29 (Cont'd.)

Analysis	Sex	Comparison	Sample Size	P-value	Direction	Effects Criteria	Percent Difference[1]	Post Hoc[2]
ANCOVA[3] (Cont'd.)								
Relative gonad weight (Energy Use)								
	Female	M0-DS vs. M0-US	20, 20	0.814	None	±25%	2.1	*0.79*
		M2 vs. M0-DS	20, 20	**<0.001**	M2 < M0-DS	±25%	**-30.0**	-
		M3 vs. M2	20, 20	**0.046**	M3 > M2	±25%	**18.3**	-
		M4-US vs. M3	20, 20	0.528	None	±25%	5.2	*0.79*
		M4-DS vs. M4-US	20, 20	0.932	None	±25%	0.9	*0.79*
		M7 vs. M4-DS	20, 20	**<0.001**	M7 < M4-DS	±25%	**-34.1**	-
		M8 vs. M7	20, 20	0.111	None	±25%	14.0	*0.79*
		M9 vs. M8	20, 20	**0.005**	M9 < M8	±25%	**-20.9**	-
	Male	M0-DS vs. M0-US	20, 20	0.521	None	±25%	7.9	*0.62*
		M2 vs. M0-DS	14, 20	0.098	None	±25%	-16.2	*0.62*
		M3 vs. M2	20, 14	0.968	None	±25%	-0.2	*0.62*
		M4-US vs. M3	21, 20	0.307	None	±25%	-7.3	*0.62*
		M4-DS vs. M4-US	20, 21	0.475	None	±25%	5.7	*0.62*
		M7 vs. M4-DS	20, 20	**<0.001**	M7 < M4-DS	±25%	**-30.5**	-
		M8 vs. M7	19, 20	**0.020**	M8 > M7	±25%	**28.2**	-
		M9 vs. M8	20, 19	**0.025**	M9 < M8	±25%	**-19.8**	-
Relative liver weight (Energy Storage)								
	Female	M0-DS vs. M0-US	20, 20	0.114	None	±25%	-9.2	0.98
		M2 vs. M0-DS	20, 20	0.149	None	±25%	-8.0	0.98
		M3 vs. M2	20, 20	**<0.001**	M3 > M2	±25%	**23.6**	-
		M4-US vs. M3	20, 20	0.453	None	±25%	-4.3	0.98
		M4-DS vs. M4-US	20, 20	0.191	None	±25%	8.1	0.98
		M7 vs. M4-DS	20, 20	**<0.001**	M7 < M4-DS	±25%	**-34.5**	-
		M8 vs. M7	20, 20	**<0.001**	M8 > M7	±25%	**38.0**	-
		M9 vs. M8	20, 20	**<0.001**	M9 < M8	±25%	**-32.4**	-
	Male	M0-DS vs. M0-US	20, 20	0.254	None	±25%	8.1	0.94
		M2 vs. M0-DS	14, 20	0.488	None	±25%	-4.5	0.94
		M3 vs. M2	19, 14	**0.007**	M3 > M2	±25%	**20.2**	-
		M4-US vs. M3	21, 19	0.343	None	±25%	-7.3	0.94
		M4-DS vs. M4-US	20, 21	0.579	None	±25%	5.0	0.94
		M7 vs. M4-DS	20, 20	**<0.001**	M7 < M4-DS	±25%	**-34.8**	-
		M8 vs. M7	19, 20	**<0.001**	M8 > M7	±25%	**44.5**	-
		M9 vs. M8	20, 19	**<0.001**	M9 < M8	±25%	**-33.3**	0.94

Bold values indicate significant difference (p<0.05).

* Data were log-transformed.

[1] Percent difference was calculated using ANOVA-adjusted least squared means with upstream reaches as the reference. Underlined values signify instances when significant differences were observed and the effect size exceeded Environment Canada's criterion for 25% for age, weight-at-age, GSI, and LSI, and 10% for condition.

[2] Power was calculated when no significant differences were found among reaches. Values in *italics* denote comparisons where power was inadequate and sample size was too low.

[3] The results of ANCOVA tests are presented only if slopes of the regression of the variables used in the ANCOVA were not significantly different (p<0.01).

Table 5.1-29 (Cont'd.)

Analysis	Sex	Comparison	Sample Size	P-value	Direction	Effects Criteria	Percent Difference[1]	Post Hoc[2]
ANCOVA[3] (Cont'd.)								
Condition (Energy Storage)								
	Female	M0-DS vs. M0-US	20, 20	**0.001**	M0-DS < M0	±10%	**-7.5**	-
		M2 vs. M0-DS	20, 20	**<0.001**	M2 > M0-DS	±10%	**8.6**	-
		M3 vs. M2	20, 20	0.068	None	±10%	-4.1	0.98
		M4-US vs. M3	20, 20	**<0.001**	M4-US > M3	±10%	**9.6**	-
		M4-DS vs. M4-US	20, 20	**0.009**	M4-DS < M4-US	±10%	**-6.0**	-
		M7 vs. M4-DS	20, 20	0.610	None	±10%	1.2	0.98
		M8 vs. M7	20, 20	0.874	None	±10%	-0.5	0.98
		M9 vs. M8	24, 20	0.053	None	±10%	-3.4	0.98
	Male*	M0-DS vs. M0-US	20, 20	**0.005**	M0-DS < M0-US	±10%	**-6.2**	-
		M2 vs. M0-DS	14, 20	**0.016**	M2 > M0-DS	±10%	**6.4**	-
		M3 vs. M2	23, 14	**0.050**	M3 > M2	±10%	**-4.7**	-
		M4-US vs. M3	32, 23	**<0.001**	M4-US > M3	±10%	**9.4**	-
		M4-DS vs. M4-US	36, 32	0.490	None	±10%	-1.6	0.99
		M7 vs. M4-DS	20, 36	0.961	None	±10%	0.2	0.99
		M8 vs. M7	29, 20	0.146	None	±10%	-3.6	0.99
		M9 vs. M8	20, 29	0.602	None	±10%	1.2	0.99
EROD Activity								
	Female	M0-DS vs. M0-US	20, 20	0.954	None	-	-	-
		M2 vs. M0-DS	20, 20	**<0.001**	M2 > M0-DS	-	-	-
		M3 vs. M2	20, 20	0.976	None	-	-	-
		M4-US vs. M3	19, 20	**<0.001**	M4-US > M3	-	-	-
		M4-DS vs. M4-US	20, 19	0.196	None	-	-	-
		M7 vs. M4-DS	20, 20	**0.011**	M7 > M4-DS	-	-	-
		M8 vs. M7	20, 20	0.357	None	-	-	-
		M9 vs. M8	20, 20	0.079	None	-	-	-
	Male	M0-DS vs. M0-US	20, 20	0.059	None	-	-	-
		M2 vs. M0-DS	14, 20	**<0.001**	M2 > M0-DS	-	-	-
		M3 vs. M2	20, 20	0.876	None	-	-	-
		M4-US vs. M3	20, 20	**<0.001**	M4-US > M3	-	-	-
		M4-DS vs. M4-US	20, 20	0.134	None	-	-	-
		M7 vs. M4-DS	20, 20	0.134	None	-	-	-
		M8 vs. M7	19, 20	0.345	None	-	-	-
		M9 vs. M8	20, 19	0.199	None	-	-	-

Bold values indicate significant difference ($p<0.05$).

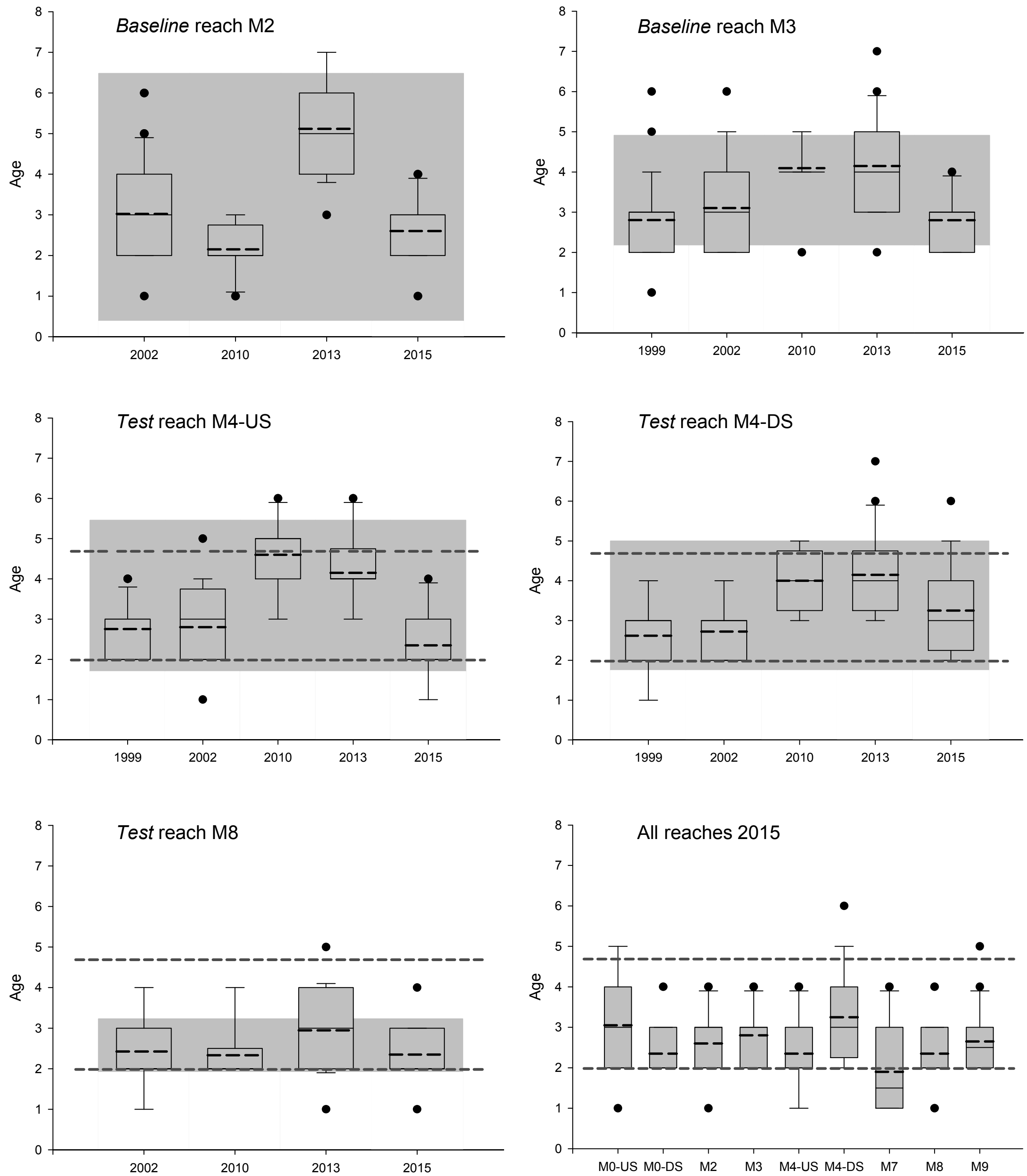
* Data were log-transformed.

[1] Percent difference was calculated using ANOVA-adjusted least squared means with upstream reaches as the reference. <u>Underlined</u> values signify instances when significant differences were observed and the effect size exceeded Environment Canada's criterion for 25% for age, weight-at-age, GSI, and LSI, and 10% for condition.

[2] Power was calculated when no significant differences were found among reaches. Values in *italics* denote comparisons where power was inadequate and sample size was too low.

[3] The results of ANCOVA tests are presented only if slopes of the regression of the variables used in the ANCOVA were not significantly different ($p<0.01$).

Figure 5.1-19 Age of mature female trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.

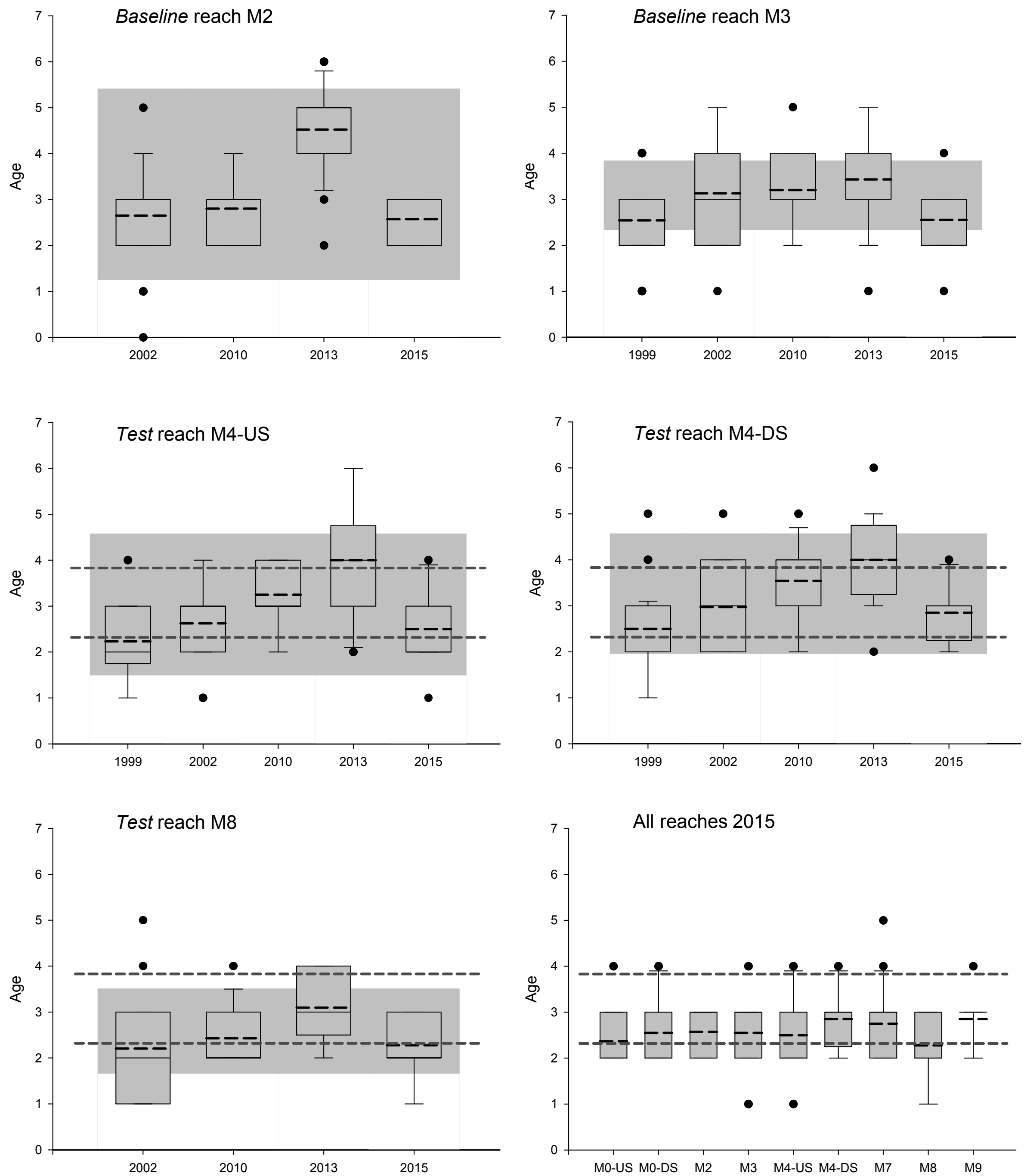


Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of age for female fish, while dotted lines indicate the normal range of age for female fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Figure 5.1-20 Age of mature male trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.

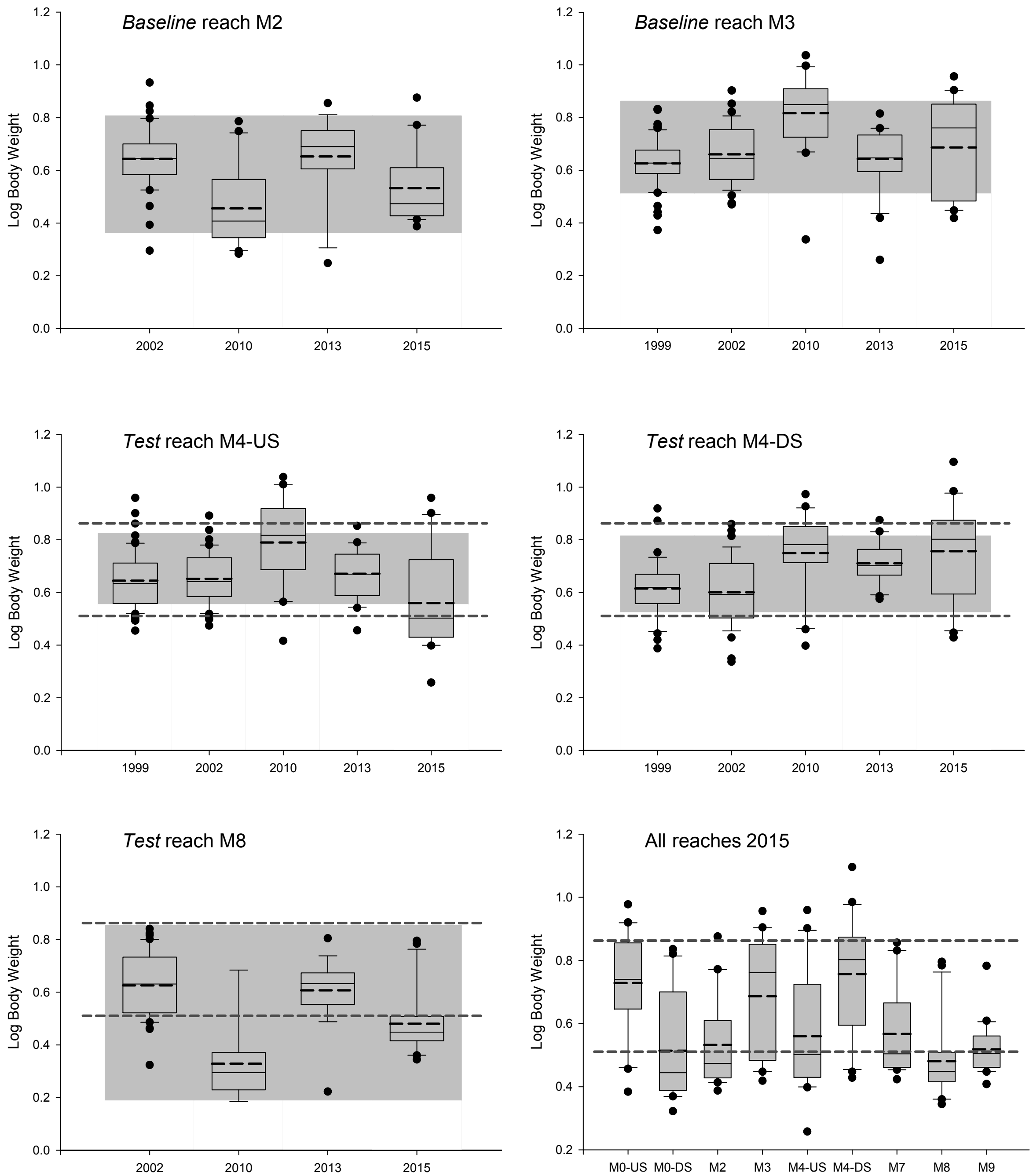


Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of age for male fish, while dotted lines indicate the normal range of age for male fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Figure 5.1-21 Total weight (age-normalized) of mature female trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.



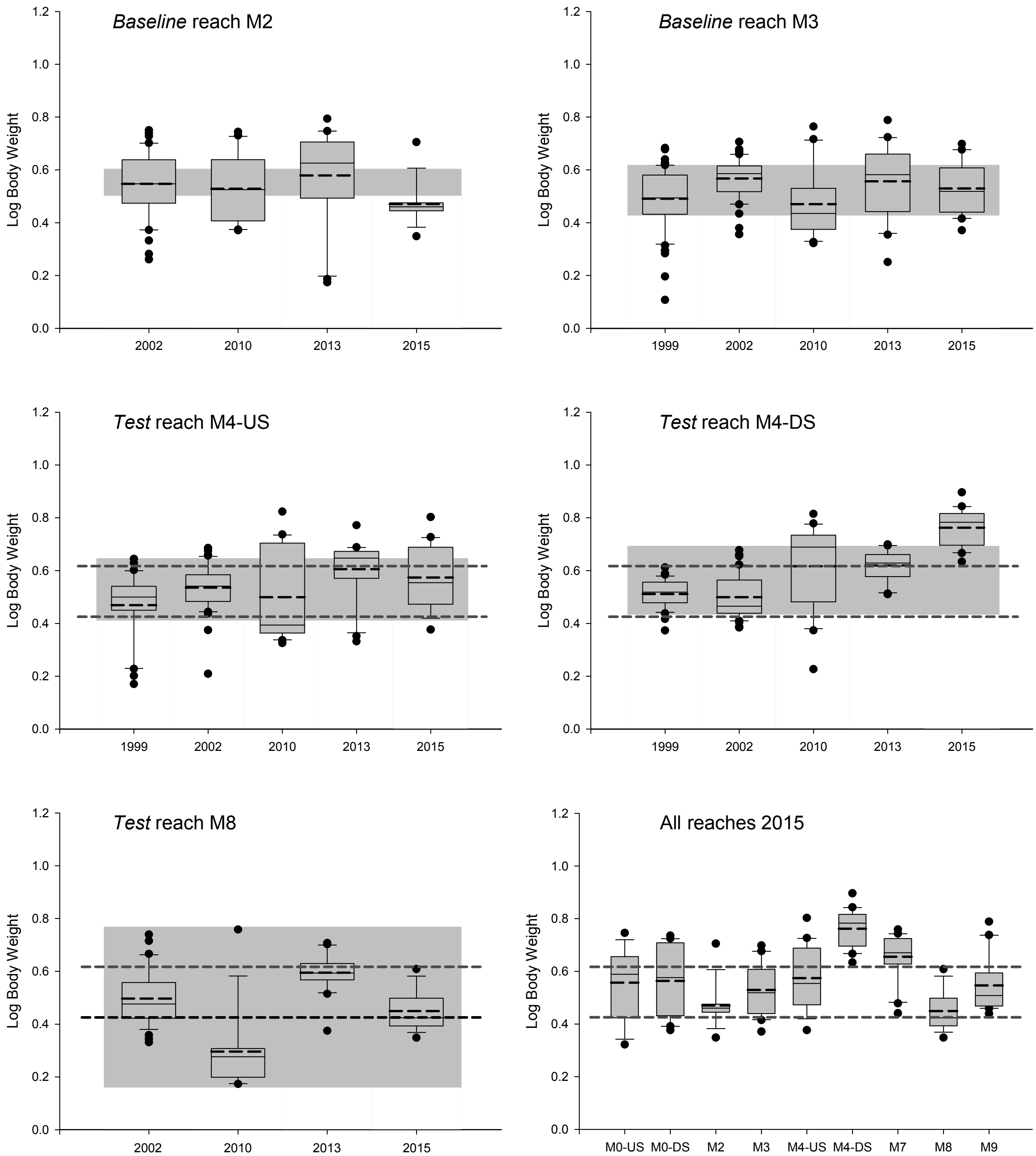
Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of body weight for female fish, while dotted lines indicate the normal range of body weight for female fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Body weight was standardized to a common mean age for each reach.

Figure 5.1-22 Total weight (age-normalized) of mature male trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.



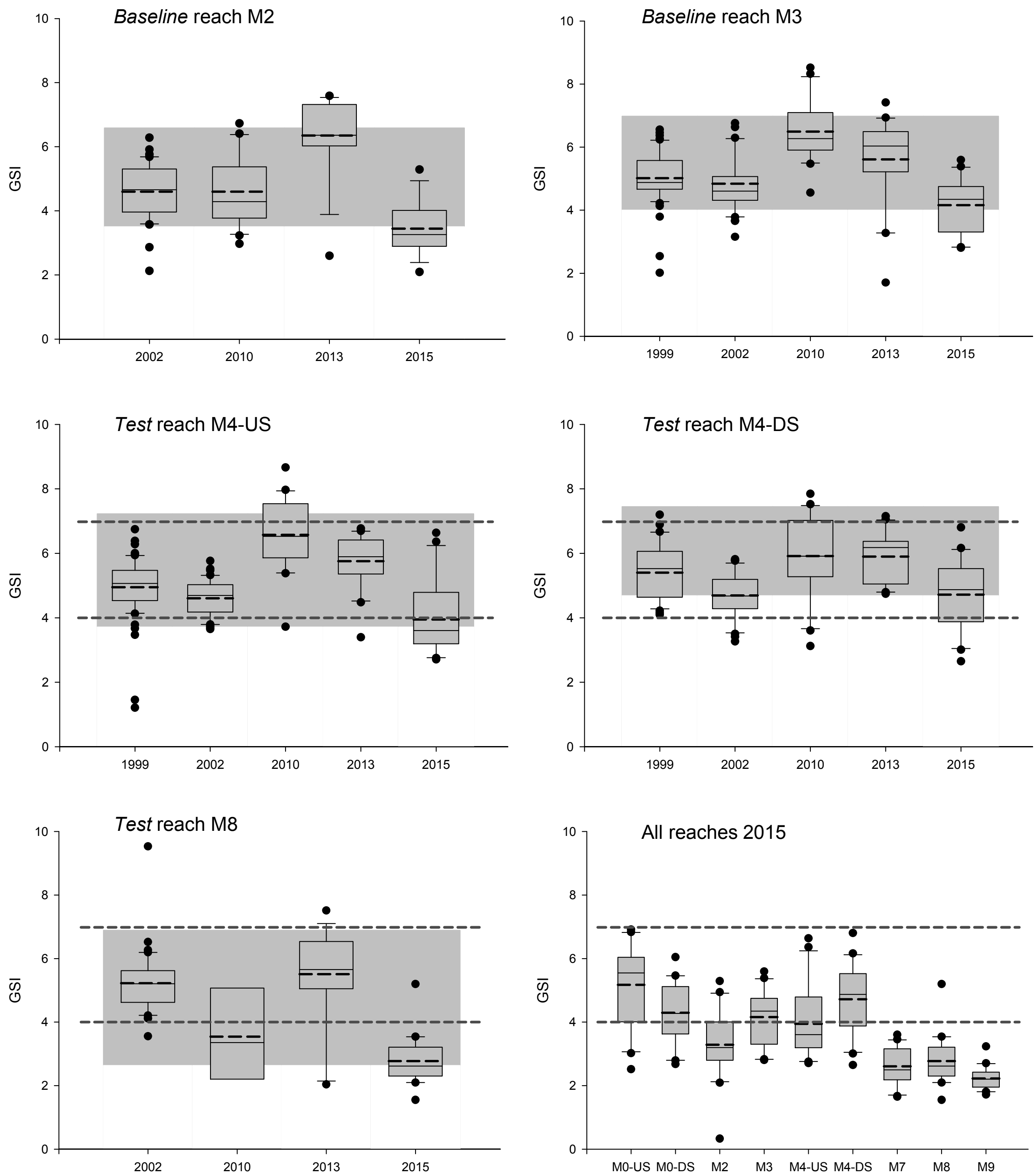
Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of body weight for male fish, while dotted lines indicate the normal range of body weight for male fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Body weight was standardized to a common mean age for each reach.

Figure 5.1-23 GSI of mature female trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.

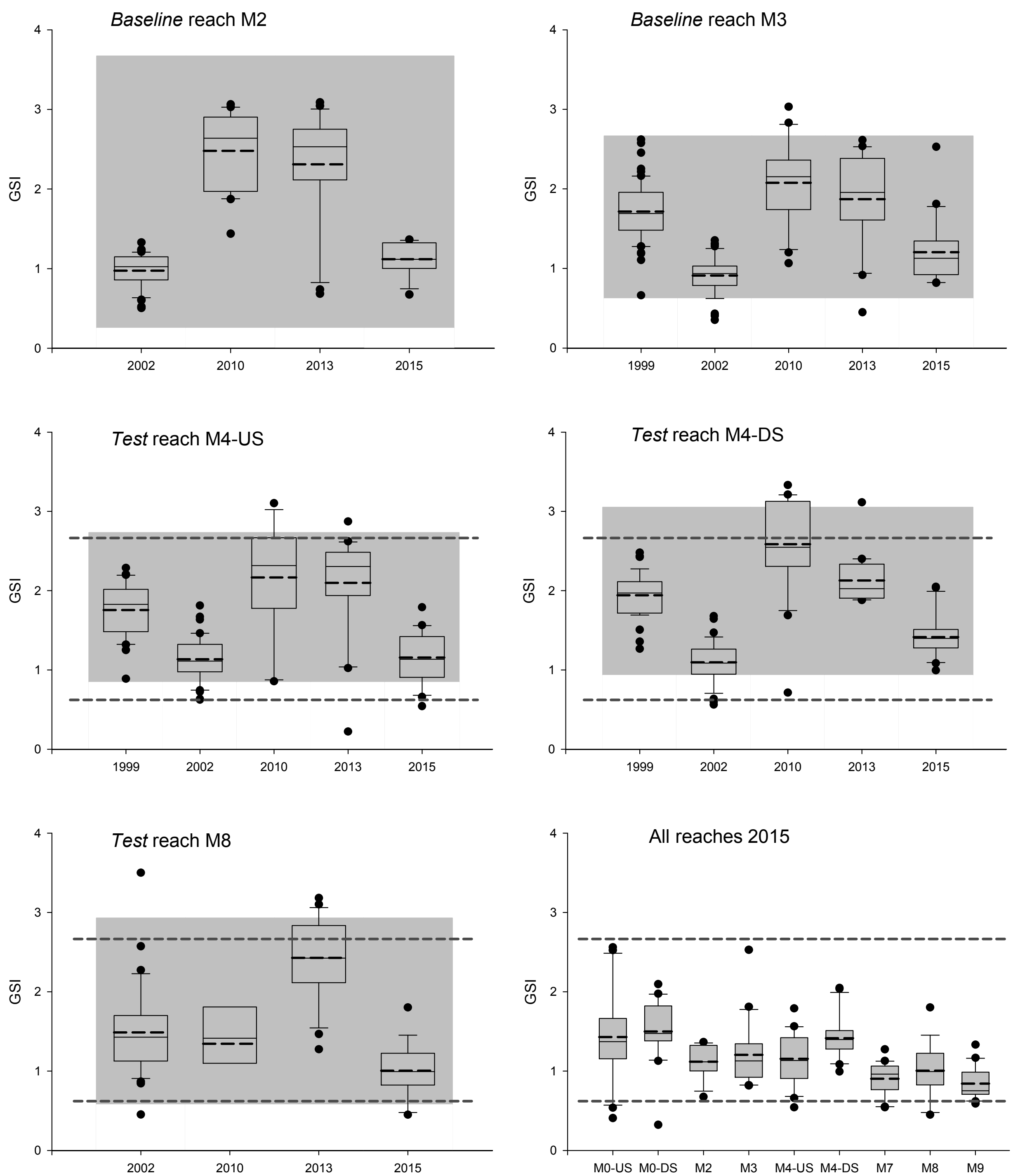


Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of GSI for female fish, while dotted lines indicate the normal range of GSI for female fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Figure 5.1-24 GSI of mature male trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.

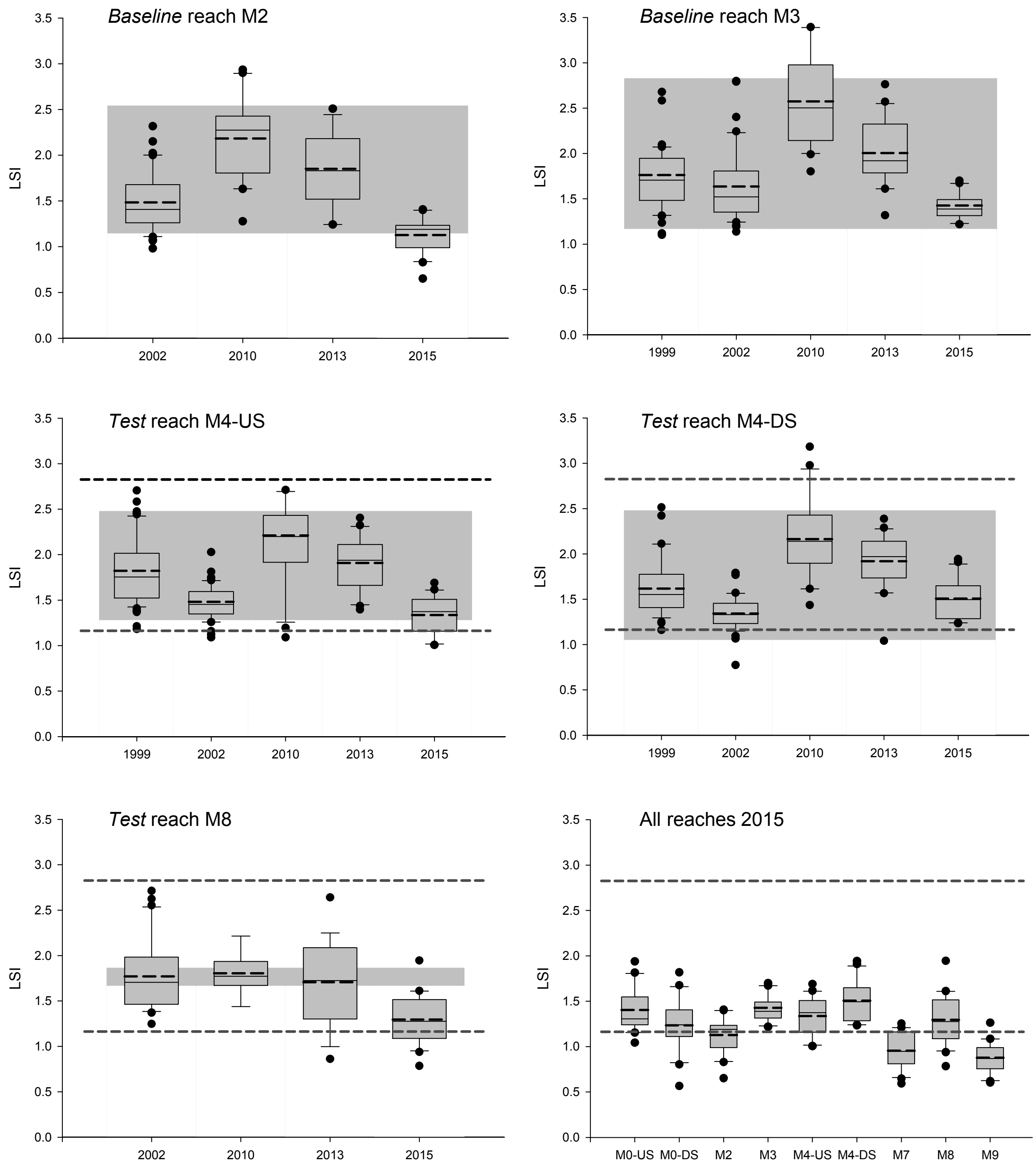


Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of GSI for male fish, while dotted lines indicate the normal range of GSI for male fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Figure 5.1-25 LSI of mature female trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.

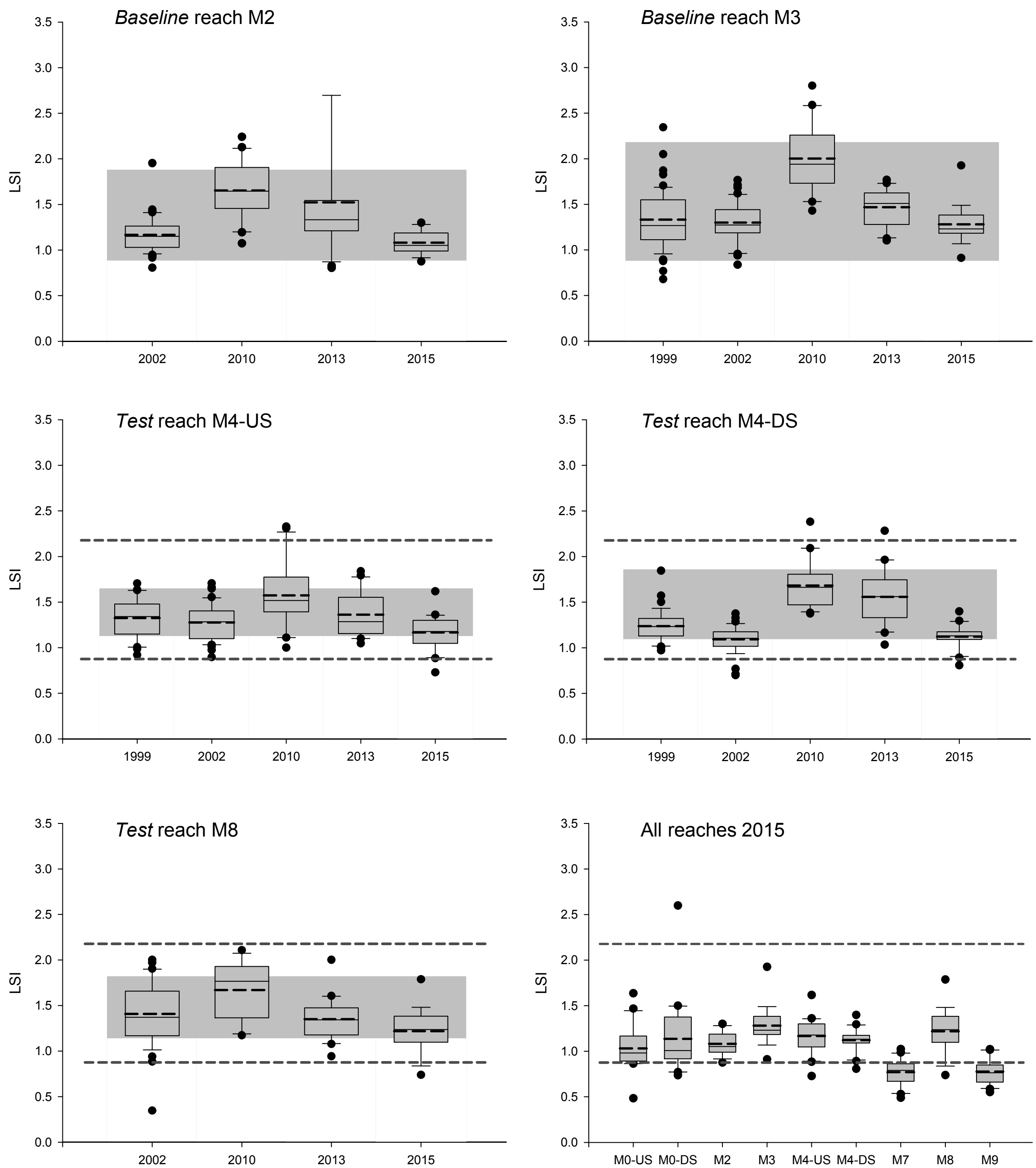


Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of LSI for female fish, while dotted lines indicate the normal range of LSI for female fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Figure 5.1-26 LSI of mature male trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.

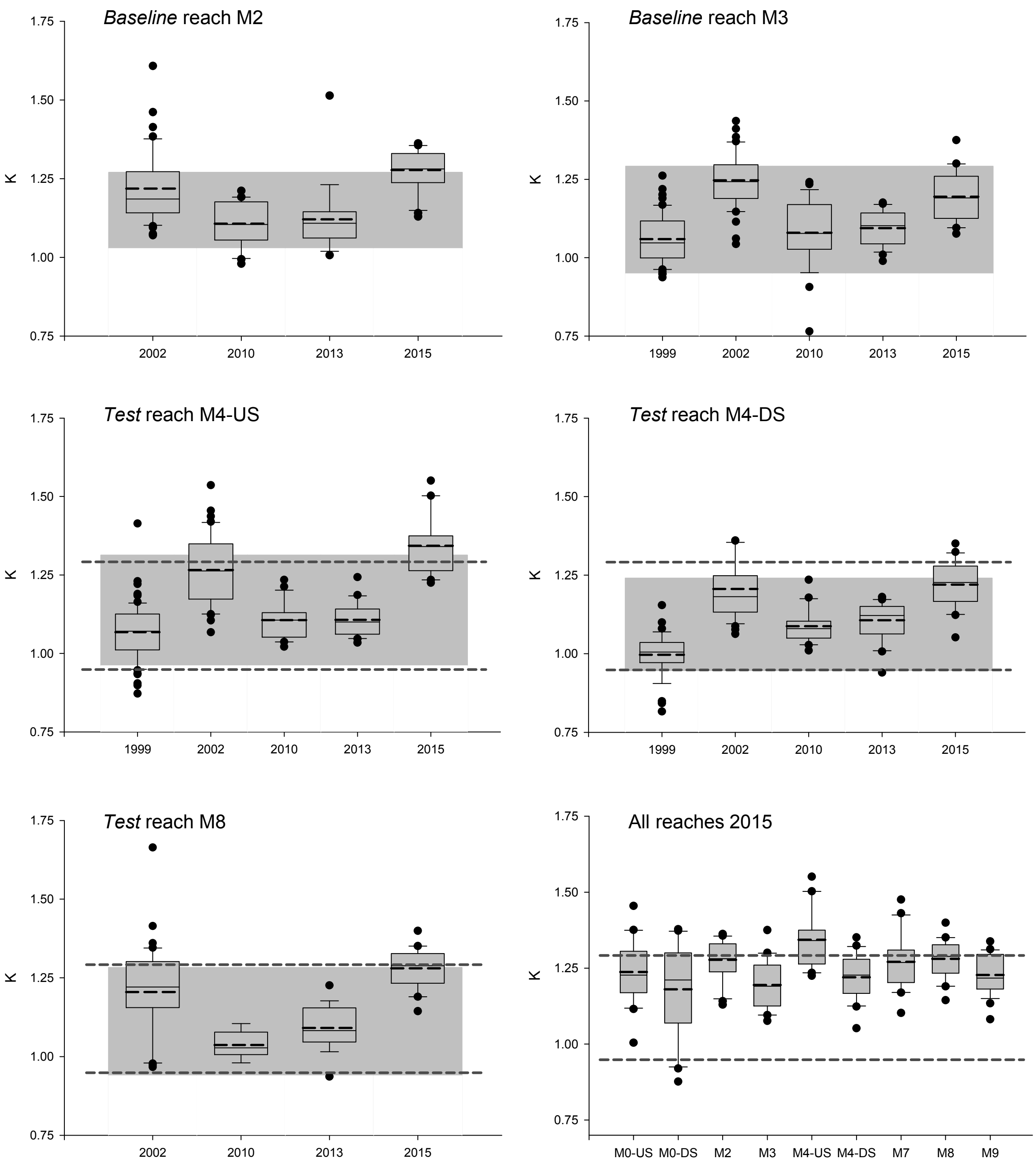


Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of LSI for male fish, while dotted lines indicate the normal range of LSI for male fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Figure 5.1-27 Condition factor (K) of mature female trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.

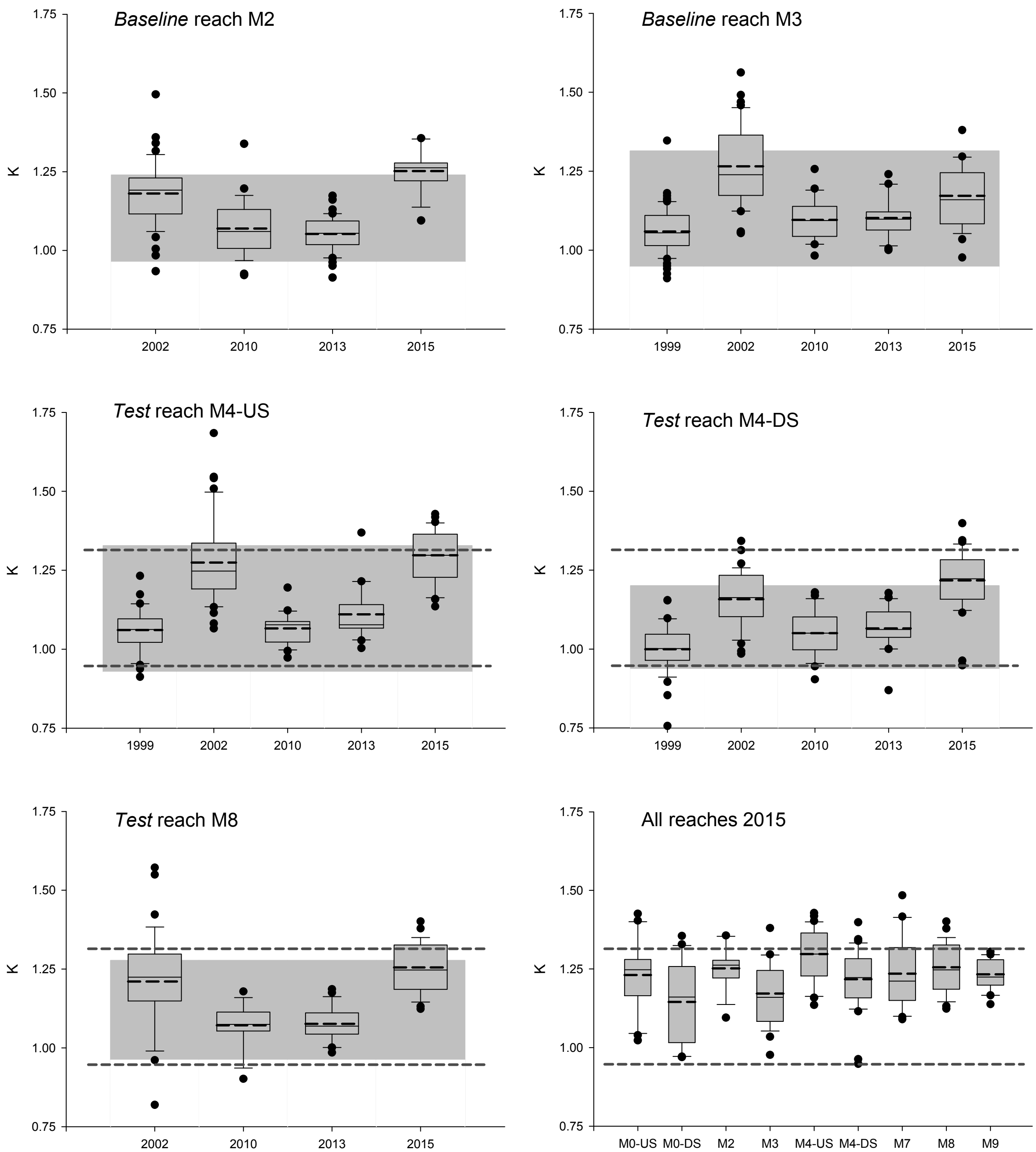


Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of condition for female fish, while dotted lines indicate the normal range of condition for female fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Figure 5.1-28 Condition factor (K) of mature male trout perch in the Athabasca River over time for *baseline* reaches M2 and M3, *test* reaches M4-US, M4-DS, and M8, and all reaches combined.

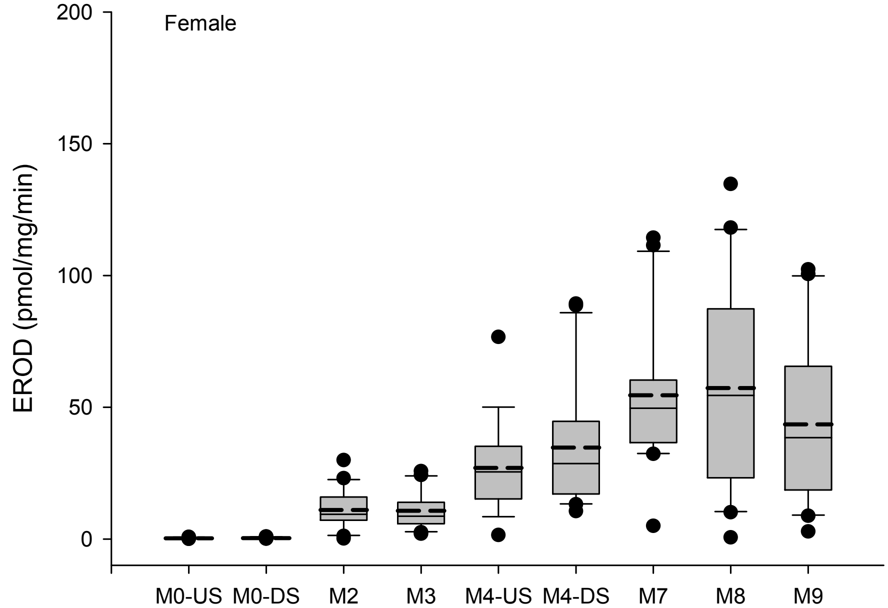


Notes:

Separate plots are presented for reaches that were sampled in previous years (i.e., *baseline* reaches M2 and M3 and *test* reaches M4-US, M4-DS, and M8).

Grey shading indicates the normal range of condition for male fish, while dotted lines indicate the normal range of condition for male fish at *baseline* reach M3 (i.e., the reach immediately upstream of oil sands mining developments).

Figure 5.1-29 EROD activity of mature female and male trout perch at *baseline* reaches M0-US, M0-DS, M2, and M3, and *test* reaches M4-US, M4-DS, M7, M8, and M9 in the Athabasca River, fall 2015.



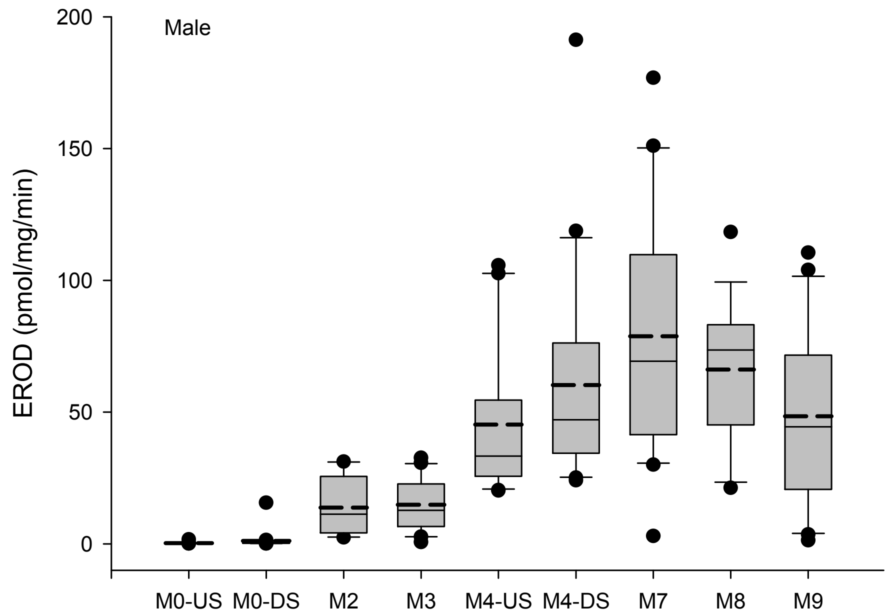


Table 5.1-30 Classification of wild fish health results for all reaches of the Athabasca River, fall 2015.

Reach Comparison	Sex	Age	Growth	Gonad Size	Liver Size	Condition	Assessment
M0-DS vs M0-US	female	0	-	0	0	0	**Moderate**
	male	0	0	0	0	0	
M2 vs. M0-DS	female	0	0	-	0	0	**Moderate**
	male	0	0	0	0	0	
M3 vs. M2	female	0	+	0	0	0	**Moderate**
	male	0	0	0	0	0	
M4-US vs. M3	female	0	0	0	0	0	**Negligible-Low**
	male	0	0	0	0	0	
M4-DS vs. M4-US	female	+	+	0	0	0	**Moderate**
	male	0	+	0	0	0	
M7 vs. M4-DS	female	-	0	-	-	0	**High**
	male	0	0	-	-	0	
M8 vs. M7	female	+	-	0	+	0	**High**
	male	0	-	+	+	0	
M9 vs. M8	female	0	0	0	-	0	**Moderate**
	male	+	0	0	-	0	

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5.2 MUSKEG RIVER WATERSHED

Table 5.2-1 Summary of results for the Muskeg River watershed.

Muskeg River Watershed	Summary of 2015 Conditions																				
	Muskeg River									Jackpine Creek / East Jackpine Creek					Other Creeks					Lakes	
Climate and Hydrology																					
Criteria	no station	07DA008	S33	S5A	S5	no station	no station	S20	no station	no station	S2, C1	no station	no station	S37	S22	S65	no station	S10A	S3	L2	S9
Mean open-water season discharge	-	Negligible-Low	not measured	not measured	not measured	-	-	not measured	-	-	not measured	-	-	not measured	not measured	not measured	-	not measured	not measured	not measured	not measured
Mean winter discharge	-	Moderate	not measured	not measured	not measured	-	-	not measured	-	-	not measured	-	-	not measured	not measured	not measured	-	not measured	not measured	not measured	not measured
Annual maximum daily discharge	-	Negligible-Low	not measured	not measured	not measured	-	-	not measured	-	-	not measured	-	-	not measured	not measured	not measured	-	not measured	not measured	not measured	not measured
Minimum open-water season discharge	-	Negligible-Low	not measured	not measured	not measured	-	-	not measured	-	-	not measured	-	-	not measured	not measured	not measured	-	not measured	not measured	not measured	not measured
Water Quality																					
Criteria	MU0	MU1	MU4	MU5	MU6	MU7	MU8	MU9	MU10	JA1	TR3.1	TR3.2	JAC-2	no station	no station	no station	STC-1	WA1	no station	KL1	no station
Water Quality Index	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low	-	-	-	Negligible-Low	not sampled in fall	-	n/a	-
Benthic Invertebrate Communities and Sediment Quality																					
Criteria	MUR-E1	MUR-D2	no reach	no reach	MUR-D3	no reach	no reach	no reach	no reach	JAC-D1	no reach	no reach	JAC-D2	no reach	no reach	no reach	no reach	no reach	no reach	KEL-1	no reach
Benthic Invertebrate Communities	Negligible-Low	Negligible-Low	-	-	Negligible-Low	-	-	-	-	Negligible-Low	-	-	n/a	-	-	-	-	-	-	Negligible-Low	-
Sediment Quality Index	no station	Negligible-Low	-	-	Negligible-Low	-	-	-	-	Negligible-Low	-	-	Negligible-Low	-	-	-	-	-	-	n/a	-
Fish Populations																					
Criteria	no reach	MUR-F2	no reach	no reach	no reach	no reach	no reach	no reach	no reach	JAC-F1	no reach	no reach	JAC-F2	no reach	no reach	no reach	no reach	no reach	no reach	no reach	no reach
Fish Communities	-	Negligible-Low	-	-	-	-	-	-	-	Negligible-Low	-	-	n/a	-	-	-	-	-	-	-	-
Wild Fish Health	-	n/a	-	-	-	-	-	-	-	no reach	-	-	no reach	-	-	-	-	-	-	-	-

Legend and Notes

Negligible-Low

Moderate

High

baseline

test

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

'-' – not sampled

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional baseline conditions; 60 to 80: Moderate difference from regional baseline conditions; Less than 60: High difference from regional baseline conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (Fish Communities): Classification based on exceedances of measurement endpoints from the regional variation in baseline reaches; see Section 3.2.4.1 for a detailed description of the classification methodology.

Fish Populations (Wild Fish Health): Classification based on exceedances of measurement endpoints from the regional variation in baseline reaches; see Section 3.2.4.2 for a detailed description of the classification methodology.

Figure 5.2-1 Muskeg River watershed.

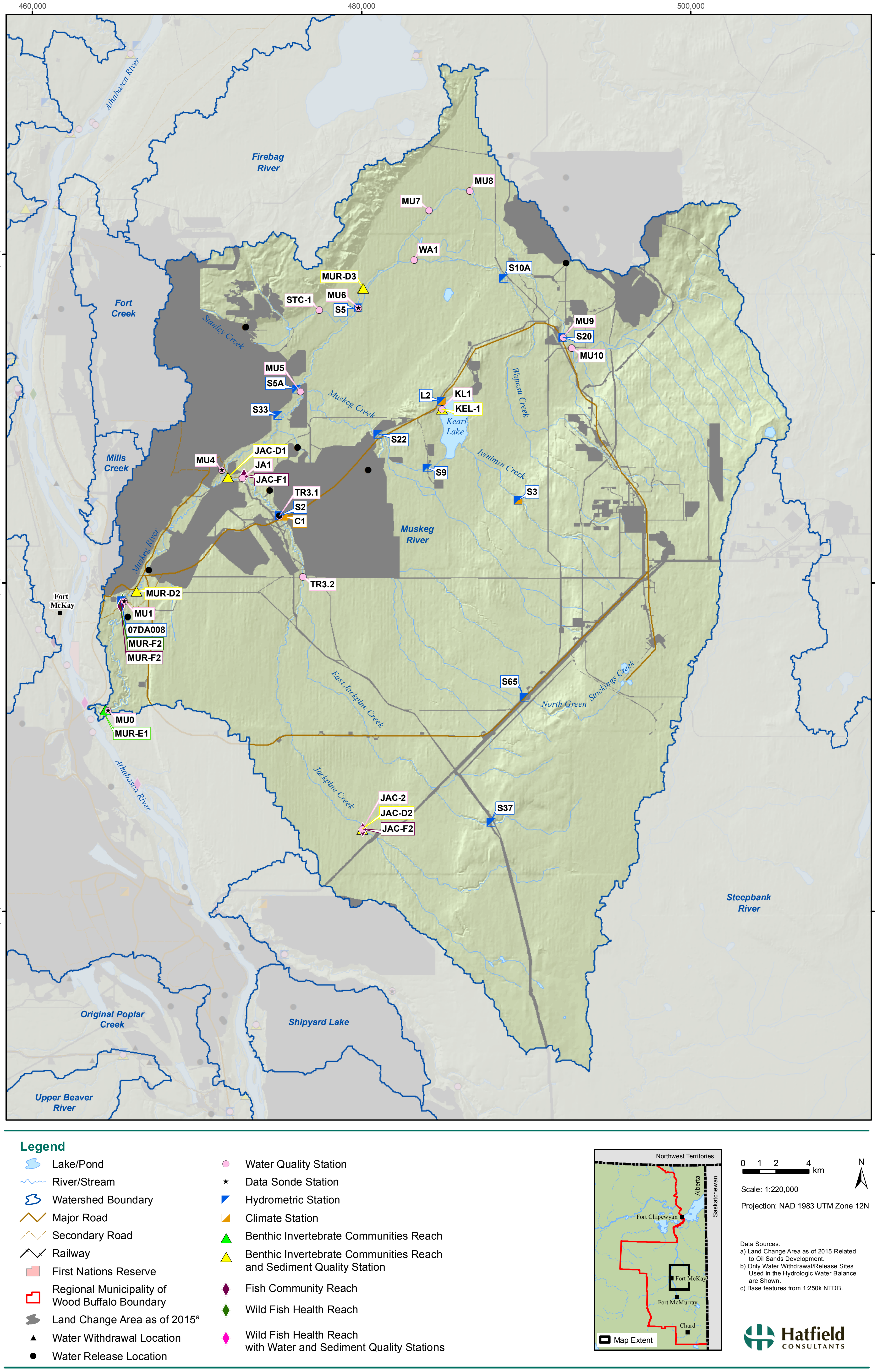


Figure 5.2-2 Representative monitoring stations of the Muskeg River watershed, 2015.

Hydrology Station S33: Muskeg River at the Aurora North Boundary, facing downstream

Hydrology Station S65: Green Stockings Creek, facing upstream

Benthic Invertebrate Communities Reach and Water Quality Station MUR-E1/MU0: Muskeg River near the mouth, facing upstream

Benthic Invertebrate Communities Reach and Water Quality Station MUR-D3/MU6: Muskeg River above Stanley Creek, facing downstream

Benthic Invertebrate Communities and Fish Populations Reach, and Water Quality Station JAC-D2/ JAC-F2/JAC-2: Jackpine Creek, facing downstream

Hydrology and Water Quality Station S2/TR3.1: Jackpine Creek at Canterra Road, facing downstream

Water Quality Station STC-1: Stanley Creek, facing downstream

Benthic Communities Reach and Water Quality Station KEL-1/KL1: Kearl Lake, facing south

5.2.1 Summary of 2015 WY Conditions

Approximately 17% (23,894 ha) of the Muskeg River watershed had undergone land change from oil sands development as of 2015 (Table 2.3-1). The designations of specific areas of the Muskeg River watershed are as follows:

1. The Muskeg River from upstream of Wapasu Creek to the mouth, as well as the lower part of Stanley Creek, Muskeg Creek (including Kearl Lake), Jackpine Creek, and Wapasu Creek drainages in the Husky Sunrise, Shell Muskeg River Mine and Expansion, and Shell Jackpine Mine and Expansion leases are designated as *test*.
2. The remainder of the watershed, including the upper portion of Jackpine Creek, is designated as *baseline*.

Monitoring activities in the Muskeg River watershed in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components. Table 5.2-1 is a summary of the 2015 assessment of the Muskeg River watershed, and Figure 5.2-1 denotes the location of the monitoring stations for each component, reported water withdrawal and discharge locations, and the locations of areas with land change as of 2015. Figure 5.2-2 contains fall 2015 photos of representative monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were +2.1%, +11.1%, -3.8%, and +4.6%, respectively, in the observed *test* hydrograph compared to the estimated *baseline* hydrograph. The differences in mean open-water discharge, annual maximum daily discharge, and open-water minimum daily discharge were classified as **Negligible-Low.** The difference in mean winter discharge was classified as **Moderate.**

The results of a quantitative longitudinal assessment of the Muskeg River suggest that the magnitude of hydrologic impacts changed along length of the river, and depended on the endpoint. Change was generally **Moderate** to **High** between the Muskeg River above Jackpine Creek and S5. Change was generally **Negligible-Low** to **Moderate** upstream of S5. Winter changes were generally higher than endpoints that evaluate annual and open water conditions.

In the 2015 WY, the water level of Kearl Lake generally decreased for most of the water year, but stabilized from July to October, 2015. Lake levels were typically between the historical lower quartile and the historic minima, with brief periods below historic minima in summer.

Water Quality At long-term monitoring stations in the Muskeg River mainstem and its tributaries, water quality was similar to previous years, and concentrations of most water quality measurement endpoints were within the range of *baseline* conditions. Monthly trends in water quality for 2015 at monitoring stations established in 2015 were similar to monthly trends in water quality at the long-term stations. Continuous monitoring data indicated higher concentrations of dissolved oxygen in lower-river stations than at stations located in slower-flowing, lentic stations further upstream on the mainstem. Water quality guideline exceedances for dissolved iron, total phenols, and sulphide were common at many stations, consistent with historical monitoring by RAMP and JOSMP. Differences in water quality conditions at all stations in fall 2015 compared to regional *baseline* water quality conditions were classified as **Negligible-Low**.

Benthic Invertebrate Communities and Sediment Quality Variations in the values of measurement endpoints for benthic invertebrate communities of the Muskeg River at *test* reach MUR-E1, *test* reach MUR-D2, and *test* reach MUR-D3 for fall 2015 were classified as **Negligible-Low**: (i) the benthic invertebrate communities at these reaches in fall 2015 contained fauna typically associated with good environmental conditions; (ii) there were no significant differences in values of benthic invertebrate community measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance that implied degrading conditions for benthic invertebrate communities; and (iii) none of the excursions in values of benthic invertebrate community measurement endpoints in fall 2015 outside of normal ranges implied degrading conditions for benthic invertebrate communities.

Variations in the values of measurement endpoints for benthic invertebrate communities of Jackpine Creek at lower *test* reach JAC-D1 for fall 2015 were classified as **Negligible-Low**: (i) the benthic invertebrate community in fall 2015 contained a rich and diverse fauna, including several taxa that are typically associated with relatively good environmental conditions; (ii) none of the significant differences in values of benthic invertebrate community measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities; and (iii) while the value of one of the six measurement endpoints in fall 2015 (equitability) was beyond the inner tolerance limit of the 95^{th} percentile of the normal range of values of prior years, the excursion did not imply degrading conditions for benthic invertebrate communities.

Variations in the values of measurement endpoints for benthic invertebrate communities of Kearl Lake at *test* station KEL-1 for fall 2015 were classified as **Negligible-Low**. The benthic invertebrate community in fall 2015 contained a diverse fauna and included several taxa that are typically associated with relatively good environmental conditions. None of the significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities. While values of three of the six measurement endpoints in fall 2015 were beyond the inner tolerance limit of the 95^{th} percentile of the normal range of values of prior years, none of these excursions outside of normal ranges implied degrading conditions for benthic invertebrate communities.

Sediment quality measurement endpoints were within the range of regional *baseline* conditions at all stations within the Muskeg River watershed, with the exception of total metals at *test* station MUR-D2, carbon-normalized total PAHs at *test* station MUR-D2 and *baseline* station JAC-D2, and total metals (when normalized to percent fine sediments) at *test* station JAC-D1. Sediment quality at all river stations within the Muskeg River watershed indicated **Negligible-Low** differences from regional *baseline* conditions. SQI values were not calculated for *test* station KEL-1 because lakes were not included in the regional *baseline* calculations.

Fish Populations (Fish Communities) Differences in measurement endpoints for fish communities between *test* reach MUR-F2 and regional *baseline* reaches were classified as **Negligible-Low**, as there were no significant differences implying a negative change in the fish community. The mean values of all measurement endpoints for fish community monitoring at *test* reach MUR-F2 in fall 2015 were within the ranges of regional *baseline* values. Differences in measurement endpoints of the fish community at lower *test* reach JAC-F1 were also classified as **Negligible-Low**. Although there was a significant decrease in abundance at *test* reach JAC-F1, the trend was not strong as it did not explain greater than 20% of the variance in annual means. Although there have been decreases in abundance at *test* reach JAC-F1 since 2010, abundance, CPUE, richness, and diversity were higher in 2015 compared to 2014, which may indicate improving conditions.

Fish Populations (Wild Fish Health) Lake chub was identified as the target species at *test* reach MUR-F2 on the Muskeg River. Because an upstream *baseline* reach on the Muskeg River was not sampled in 2015, quantitative comparisons for assessing potential effects could not be conducted. To provide context to the results for *test* reach MUR-F1, qualitative comparisons of measurement endpoints were made against regional *baseline* reaches in other watersheds where lake chub was monitored in 2015. Measurement endpoints of female lake chub at *test* reach MUR-F2 were relatively similar to measurement endpoints of female lake chub at regional *baseline* reaches with the exception of relative liver size, which were slightly smaller in fish at *test* reach MUR-F2. Temporal comparisons were not possible because 2015 was the first year of fish health monitoring at *test* reach MUR-F1.

5.2.2 Hydrologic Conditions

Muskeg River

Hydrometric monitoring of the Muskeg River watershed in the 2015 WY was conducted at the following locations:

- WSC Station 07DA008 (formerly JOSMP Station S7), Muskeg River near Fort McKay;
- JOSMP Station L2 Kearl Lake;
- JOSMP Station S2 Jackpine Creek at Canterra Road;
- JOSMP Station S3 Iyinimin Creek above Kearl Lake;
- JOSMP Station S5 Muskeg River above Stanley Creek;
- JOSMP Station S5A Muskeg River above Muskeg Creek;
- JOSMP Station S9 Kearl Lake Outlet;
- JOSMP Station S10A Wapasu Creek near the mouth;
- JOSMP Station S20A Muskeg River Upland;
- JOSMP Station S22 Muskeg Creek near the mouth;
- JOSMP Station S33 Muskeg River near the Aurora North/Shell Muskeg River Mine Boundary;
- JOSMP Station S37 East Jackpine Creek near the 1,300 ft. contour; and
- JOSMP Station S65 Greenstockings Creek at the East Athabasca Hwy.

Data from WSC Station 07DA008 and from JOSMP Station L2 are presented below, data from WSC Station 07DA008 were used for the water balance analysis, and data from each JOSMP station in the Muskeg River watershed are provided in Appendix C.

Annual data were collected from 1974 to 1986 and 1999 to 2015 at WSC Station 07DA008 and seasonal data (March to October) were collected from 1987 to 1998.

The historical flow record for WSC Station 07DA008 is summarized in Figure 5.2-3 and includes the median, interquartile range, and range of flows recorded daily through the water year. Flows of the Muskeg River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically lower than during the open-water season and generally decrease from November until early March. Spring thaw and the resulting increase in flows typically occur in late March and April. Monthly flows are highest during May at the peak of freshet and often remain elevated in June and July when total monthly rainfall is at its highest point for the year. Flows then generally recede from late July until the end of October in response to declining rainfall inputs and eventually river freeze-up although short-term increases in discharge are common late in the water year in response to fall precipitation events.

Flows in the Muskeg River in the 2015 WY were similar to the historical seasonal pattern described above but generally were lower in magnitude than average historical flows (Figure 5.2-3). Flows decreased from November 2014 to March 2015 and generally remained close to historical median flows for much of this period (Figure 5.2-3). The increase in flow associated with the spring thaw started in late March and discharge increased and peaked in mid-April and mid-May. The peak annual flow of 6.43 m^3/s, on May 15, was 76% lower than the historical mean annual maximum daily flow of 26.4 m^3/s. Flows then decreased until the minimum open-water daily flow of 0.460 m^3/s on August 31, which was 56% less than the historical mean minimum daily flow of 1.04 m^3/s calculated for the open-water period.

Despite generally low discharge in the 2015 water year, flows were generally within the historic lower quartile range of flows, except for a period in early-to-mid-July, and were never below historical minimum flows. Overall, the annual runoff volume in the 2015 WY was 53.5 million m^3, which was 68% lower than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Muskeg River watershed at WSC Station 07DA008 (formerly JOSMP Station S7) is summarized in Table 5.2-2. Key changes in flows included:

1. The closed-circuited land change area as of 2015 was estimated to be 147.9 km^2 (Table 2.3-1). The loss of flow to the Muskeg River that would have otherwise occurred from this land area was estimated at 5.28 million m^3.

2. As of 2015, the area of land change in the Muskeg River watershed that was not closed-circuited was estimated to be 91.1 km^2 (Table 2.3-1). The increase in flow to the Muskeg River that would not have otherwise occurred from this land area was estimated at 0.65 million m^3.

3. Imperial released 0.80 million m^3 of surface water into the Muskeg River watershed.

4. Syncrude reported a release 5.36 million m^3 of water via the Aurora Clean Water Diversion (CWD). Some of this released water likely froze, evaporated, and flowed as shallow groundwater or through muskeg. To estimate these losses and delays, daily streamflow records from JOSMP hydrometric stations upstream (JOSMP Station S5 Muskeg River above Stanley Creek) and downstream (JOSMP Station S5A Muskeg River above Muskeg Creek) of the CWD were

analyzed. The differences in daily flow volumes between Station S5A and Station S5 were calculated; this represents the maximum possible contribution of the CWD releases to the Muskeg River. It was conservatively assumed that all additional flows at station S5A relative to station S5 originated from the CWD. It was also conservatively assumed that none of the water released from the CWD would have reached the Muskeg River through other pathways. Some of the flow from the CWD likely would have naturally contributed to the Muskeg River, given that some of the CWD flows were diverted surface water, but these flows were not possible to estimate. The results of this calculation suggest that a minimum of 30% of the water released at the CWD did not enter the Muskeg River.

5. Shell released 1.75 million m^3 of surface water, which was passed through ditches and sedimentation ponds into the Muskeg River watershed.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands developments in the 2015 WY was an increase of flow of 1.69 million m^3 at WSC Station 07DA008 (JOSMP Station S7) than the flows were estimated to would have been under *baseline* conditions. The mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge in the 2015 WY for the observed *test* hydrograph were 2.13% greater, 11.07% greater, 0.22% lower, and 4.57% lower, respectively, than for the estimated *baseline* hydrograph (Table 5.2-3). The differences in mean open-water discharge, annual maximum daily discharge, and open-water minimum daily discharge were classified as **Negligible-Low**, and the difference in mean winter discharge was classified as **Moderate** (Table 5.2-1).

The classification of '**Moderate**' for mean winter discharge required a longitudinal classification of effects (Section 3.2.1.5) to be conducted for the Muskeg River. Quantitative water balance assessments were conducted at three locations along the length of the Muskeg River in addition to WSC Station 07DA008: JOSMP Station S5 Muskeg River above Stanley Creek; JOSMP Station S5A Muskeg River above Muskeg Creek; and JOSMP Station S33 Muskeg River at the Aurora North/Muskeg River Mine Boundary. Results from this analysis were used to classify four reaches of the Muskeg River with respect to the values of the measurement endpoints for hydrology (Figure 5.2-4).

Overall, difference in the values of the measurement endpoints between observed *test* conditions and estimated *baseline* conditions was **Moderate** to **High** between Station S5A and Station S5 for all four measurement endpoints as a result of the releases from the CWD and **Negligible-Low** to **Moderate** upstream of Station S5 due to the relatively low watershed disturbance in the upper parts of the watershed. Mean winter discharge and open-water minimum discharge had the greatest difference between observed *test* conditions and estimated *baseline* conditions and the most widespread change over the length of the river. In general, the magnitude of the differences between observed *test* conditions and estimated *baseline* conditions change decreased with increasing distance downstream of Station S5A.

Kearl Lake

Continuous lake level data have been collected at Station L2 Kearl Lake since 1999, with partial records for 1999 to 2001, and 2008. In the 2015 WY, the lake level generally decreased from November 2014 to July 2015; the lake level stabilized from July to October 2015. The maximum water level was recorded at the beginning of the 2015 WY, with a level of 331.834 masl (November 4, 2014) (Figure 5.2-5). The minimum lake level was on August 31, 2015 (331.58 masl). The total range in water level in the 2015 WY was 0.25 m, which was 0.15 m smaller than the mean historical range of 0.4 m.

5.2.3 Water Quality

Water quality samples were taken in the 2015 WY in the Muskeg River watershed from:

- Muskeg River near the mouth (*test* station MU0), sampled monthly from November 2014 to March 2015 and July 2015 to October 2015. *Test* station MU0 (formerly station MUR-1) was sampled for the RAMP/JOSMP in fall only from 1997 to 2012 and monthly starting in 2013;
- Muskeg River at the Water Survey Canada gauge near Fort McKay (*test* station MU1), above Jackpine Creek (*test* station MU4), above Muskeg Creek (*test* station MU5), above Stanley Creek (*test* station MU6), above Wapasu Creek (*test* station MU8), and upland Muskeg River (*test* station MU10), sampled monthly from May 2015 to October 2015;
- Muskeg River above Wapasu Creek (*test* station MU7), sampled monthly from July 2015 to September 2015;
- Muskeg River at Imperial Kearl Lake Road (*test* station MU9), sampled in July and August 2015. *Test* station MU9 (formerly MUR-6A) was initially sampled in 2013 when access limitations required moving station MUR-6 (designated as *baseline* from 1998 to 2007 and *test* from 2008 to 2012) further upstream. Station MUR-6 was renamed MUR-6A after the relocation and remained designated as a *test* station;
- Jackpine Creek near the mouth (*test* station JA1) and 16.5 km upstream of the Muskeg River (*baseline* station TR3.2), sampled monthly from May 2015 to October 2015. *Test* station JA1 (formerly JAC-1) was designated as *baseline* from 1998 to 2005 and *test* from 2006 onwards;
- Jackpine Creek at Canterra Road (*test* station TR3.1), sampled monthly from July 2015 to October 2015;
- Jackpine Creek above Jackpine Mine (*baseline* station JAC-2), sampled in September 2015 to support the benthic invertebrate communities monitoring component. *Baseline* station JAC-2 has been sampled since 2008;
- Wapasu Creek (*test* station WA1), sampled monthly from May 2015 to August 2015 and October 2015[1]. *Test* station WA1 (formerly WAC-1) was sampled in 1998 and 1999 and from 2004 to 2014; it was designated as *baseline* from 1998 to 2006 and as *test* from 2007 onwards;
- Stanley Creek (*test* station STC-1), sampled monthly from May 2015 to September 2015. *Test* station STC-1 was designated as *baseline* from 2001 to 2002 and *test* from 2003 onwards; and

[1] *Test* station WA1 was not sampled in September 2015 as the station was inaccessible at that time.

- Kearl Lake (*test* station KL1), sampled seasonally in May, July, and September 2015. *Test* station KL1 (formerly KEL-1) was designated as *baseline* from 1998 to 2008 and as *test* from 2009 onwards.

Data sondes installed at *test* stations MU0, MU1, MU4, and MU6 collected continuous in situ water quality data from May to October 2015.

Figure 5.2-6 presents trends in continuous monitoring variables recorded by data sondes installed at *test* stations MU0, MU1, MU4, and MU6 in the 2015 WY. Monthly and seasonal variations in water quality are summarized in Table 5.2-4 to Table 5.2-18 and Figure 5.2-7 to Figure 5.2-9. Water quality results from fall 2015 relative to historical fall concentrations are provided in Table 5.2-19 to Table 5.2-24. The ionic compositions of the Muskeg River watershed stations measured in 2015 and previous years are presented in Figure 5.2-10 and Figure 5.2-11. Guideline exceedances for water quality measurement endpoints are presented in Table 5.2-25. Figure 5.2-12 and Figure 5.2-13 compare selected water quality measurement endpoints in the Muskeg River watershed to historical concentrations and regional *baseline* concentrations.

Continuous Monitoring Results from Data Sondes Water temperatures at all four sonde locations were generally similar, peaking at approximately 20°C in mid-August then declining toward 20°C by the end of October. Dissolved oxygen concentrations were highest in the lower Muskeg River and lowest at upper stations, perhaps related to the more lotic nature of the lower river relative to the more lentic character of the upper river (Figure 5.2-6). pH was alkaline at all *test* stations throughout the monitoring period and within the range of water quality guidelines; pH was consistently higher at lower river stations. Apparent step-changes in pH and conductivity at different monitoring locations over the sampling period may represent sonde recalibration events rather than abrupt changes in water quality. Turbidity levels were variable among stations, with high–turbidity events occurring in May to June, mid-July, and early September that may reflect rising flows at these times. Data gaps for data sondes at stations of the Muskeg River are discussed in Appendix B.

Monthly and Seasonal Variations in Water Quality There was relatively moderate seasonal variation in water quality measurement endpoints at the lotic stations within the Muskeg River watershed (Table 5.2-4 to Table 5.2-18, Figure 5.2-7 to Figure 5.2-9). The seasonal variation in water quality measurement endpoints at *test* station KL1 (Kearl Lake) was low relative to that for the lotic stations.

2015 Fall Results Relative to Historical Concentrations No comparisons to historical concentrations could be made for *test* stations MU1, MU4, MU5, MU6, MU7, MU8, MU10, and TR3.1 or *baseline* station TR3.2 because fall 2015 was the first sampling for fall water quality at these stations.

For stations with available historical data, concentrations and levels of water quality measurement endpoints in fall 2015 were within the ranges of previously-measured concentrations with the following exceptions:

- at *test* station JA1, concentrations of retene, total PAHs, and total alkylated PAHs were below previously-measured minimum concentrations;

- at *baseline* station JAC-2, pH levels and concentration of total nitrogen were below previously-measured minimum concentrations and concentrations of chloride and oilsands extractable acids were greater than previously-measured maximum concentrations;
- at *test* station STC-1, concentrations of total suspended solids and nitrate+nitrite were greater than previously-measured maximum concentrations and concentrations of potassium and naphthenic acids were lower than the previously-measured minimum concentration; and
- at *test* station KL1, the concentration of sulphate was non-detectable with a detection limit lower than the previously-measured minimum value and the concentration of oilsands extractable acids exceeded the previously-measured maximum concentration.

Temporal Trends Trend analyses were only possible for *test* stations MU0, JA1, and STC-1 and *baseline* station JAC-2 due to insufficient data for the remaining stations within the Muskeg River watershed. No significant ($p>0.05$) temporal trends in concentrations of water quality measurement endpoints were detected at any of these stations with the exception of sulphate, which exhibited a significant decreasing temporal trend in concentration at *test* station STC-1.

Ion Balance The ionic composition of water at all stations in the Muskeg River watershed was similar to previous years and dominated by calcium and bicarbonate (Figure 5.2-10, Figure 5.2-11). The ionic composition of water in Stanley Creek (*test* station STC-1) has historically shown the greatest variability of all Muskeg River watershed stations (Figure 5.2-11), likely due to influence in some years of site drainage water from Syncrude's Aurora North project through the Clean Water Discharge. In the last eight years, however, the ion balance at *test* station STC-1 has been more stable and consistently dominated by calcium and bicarbonate, with lower concentrations of sulphate and chloride.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of water quality measurement endpoints in the 2015 WY were below guidelines at all stations in the Muskeg River watershed with the following exceptions (Table 5.2-25):

- total phenols (0.004 mg/L) at *test* stations MU0 (July to October), MU1 (June to October), MU4 (June to October), MU5 (June to October), MU6 (June to October), MU7 (July to September), MU8 (June to October), MU9 (July and August), MU10 (June to August and October), JA1 (June to October), TR3.1 (July to October), STC-1 (July to September), KL1 (July and September), and WA1 (June to August and October);
- total phenols (0.004 mg/L) at *baseline* stations TR3.2 (June to October) and JAC-2 (September);
- sulphide (0.0019 mg/L) at *test* stations MU0 (November to January, March to October), MU1 (June to October), MU4 (June to October), MU5 (June to October), MU6 (June to October), MU7 (July to September), MU8 (June to October), MU9 (July and August), MU10 (June to August and October), JA1 (May to October), TR3.1 (July to October), STC-1 (June to September), KL1 (May and September), and WA (June to August and October);
- sulphide (0.0019 mg/L) at *baseline* stations TR3.2 (June to October) and JAC-2 (September);
- dissolved iron (0.3 mg/L) at *test* stations MU0 (November to January), MU1 (May to June, September to October), MU4 (May to June, August to October), MU5 (May to October), MU6

(May to October), MU7 (July to September), MU8 (July to August and October), MU9 (July and August), MU10 (July to September), JA1 (June to August and October), TR3.1 (July to August and October), and WA1 (June to October); and

- dissolved iron (0.3 mg/L) at *baseline* stations TR3.2 (June to October) and JAC-2 (September).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints in fall 2015 were within the range of regional *baseline* concentrations for all stations within the Muskeg River watershed (Table 5.2-19 to Table 5.2-24), with the exception of:

- total suspended solids, with concentrations lower than the 5^{th} percentile of regional *baseline* concentrations at *test* stations MU4, MU5, MU7, MU8, MU10, JA1, and TR3.1 and *baseline* stations JAC-2 and TR3.2;
- total dissolved solids, with concentrations lower than the 5^{th} percentile of regional *baseline* concentrations at *test* stations JA1 and TR3.1;
- dissolved phosphorus, with a concentration lower than the 5^{th} percentile of regional *baseline* concentrations at *test* station MU0;
- total mercury (ultra-trace), with concentrations lower than the 5^{th} percentile of regional *baseline* concentrations at *test* stations MU5, MU7, MU8, and MU10;
- total arsenic, with concentrations lower than the 5^{th} percentile of regional *baseline* concentrations at *test* stations MU5 and STC-1;
- magnesium, with a concentration lower than the 5^{th} percentile of regional *baseline* concentrations at *baseline* station TR3.2;
- sodium and potassium, with concentrations lower than the 5^{th} percentile of regional *baseline* concentrations at *test* station STC-1; and
- sulphate, with concentrations lower than the 5^{th} percentile of regional *baseline* concentrations at *test* stations MU5, MU6, MU7, and STC-1.

Concentrations of water quality measurement endpoints in Kearl Lake (*test* station KL1) were not compared to regional *baseline* concentrations because lakes were not included in the calculation of regional *baseline* conditions given the ecological differences between lakes and rivers.

Water Quality Index In fall 2015, WQI values for all stations within the Muskeg River watershed were 100, indicating no difference from the range of regional *baseline* conditions. A WQI value was not calculated for *test* station KL1 because lakes were not included in the regional *baseline* conditions given the ecological differences between lakes and rivers, or for *test* station WA1 because it was not sampled in fall 2015 due to a lack of access.

Classification of Fall Results In fall 2015, WQI values for all stations within the Muskeg River watershed indicated **Negligible-Low** differences in water quality conditions from regional *baseline* conditions.

5.2.4 Benthic Invertebrate Communities and Sediment Quality

5.2.4.1 Benthic Invertebrate Communities

Muskeg River

Benthic invertebrate communities were sampled in fall 2015 in the Muskeg River at:

- erosional *test* reach MUR-E1, near the mouth of the Muskeg River, sampled since 2000 with a Neil-Hess cylinder and in 2015 with a CABIN kicknet. Values of benthic invertebrate community measurement endpoints for fall 2015 were 'adjusted' per equations in Appendix D to make them comparable to data collected with a Neil-Hess cylinder;
- depositional *test* reach MUR-D2, near the Canterra Road crossing, sampled since 2000; and
- depositional *test* reach MUR-D3, designated as *baseline* from 2002 to 2007 and test from 2008 to 2015.

2015 Habitat Conditions Water at *test* reach MUR-E1 in fall 2015 was shallow (0.2 m), flowing at 0.47 m/s, alkaline (pH 8.3), and with moderate conductivity (246 µS/cm) and high dissolved oxygen concentration (9 mg/L) (Table 5.2-26). Full CABIN-supporting data are provided in Appendix D.

Water at *test* reach MUR-D2 in fall 2015 was deep (1.2 m), flowing at 0.26 m/s, weakly alkaline (pH 7.6), with moderate conductivity (266 µS/cm), and high dissolved oxygen concentration (8.9 mg/L) (Table 5.2-26). The substrate was dominated by sand (90%) with a small amount of silt (8%) and clay (~2%) and low total organic carbon (< 2%).

Water at *test* reach MUR-D3 in fall 2015 was relatively deep (0.8 m), slow moving (0.1 m/s), weakly alkaline (pH 7.2), with moderate conductivity (358 µS/cm) and relatively low dissolved oxygen concentration (6.4 mg/L) (Table 5.2-26). The substrate consisted of sand (57%) and silt (38%) with a small amount of clay (5%) and high total organic content (22%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach MUR-E1 in fall 2015 was dominated by Ephemeroptera (30%), chironomids (20%) and Sphaeriidae (19%), with subdominant taxa consisting of Hydracarina (7%) (Table 5.2-27). Larvae of mayflies were also diverse (11 types) and mostly represented by the genera *Acerpenna*, with *Ephemerella*, *Caenis* and *Amaletus* among others. Chironomids were diverse, dominated by *Thienemannimyia gr.* as well as many other common forms such as *Polypedilum* and *Lopesocladius* (Wiederholm 1983). Larvae of other flying insects such as stoneflies (*Haploperla*, *Acroneuria*, *Pteronarcys, Taeniopteryx*, etc.), caddisflies (*Hydropsyche*, *Lepidostoma*, *Hydroptila*, *Oecetis*, etc.), and dragonflies (*Ophiogomphus*) were found in moderate relative abundances (~3 to 4% each). Permanent aquatic forms such as bivalves (*Lymnaea*, *Gyraulus*) and fingernail and pea clams (*Pisidium* and *Sphaerium*) were also present.

The benthic invertebrate community at *test* reach MUR-D2 in fall 2015 was dominated by chironomids (57%) with subdominant taxa including Gastropoda (6%), Naididae (6%), Ephemeroptera (6%), Ceratopogonidae (5%), and tubificid worms (5%) (Table 5.2-28). Chironomids were primarily of the common forms *Micropsectra*/*Tanytarsus* and *Stempellinella.* Ephemeroptera at the reach were primarily *Caenis* but also included other genera from the families Baetidae (*Acerpenna, Callibaetis*), Baetiscidae

(*Baetisca*), and Leptophlebiidae (*Leptophlebia*). Four genera of Trichoptera were also found, the most common being *Oxyethira*. Larvae of dragonflies Odonata were found at seven replicates and consisted of the genera *Aeshna*, *Ophiogomphus*, and *Enallagma*. Bivalves *(Pisidium, Sphaerium)*. Snails were diverse with eight genera from five families found at the reach, primarily consisting of *Gyraulus*.

The benthic invertebrate community at *test* reach MUR-D3 in fall 2015 was dominated by chironomids (37%), tubificid worms (32%), and bivalves (22%) (Table 5.2-29). Chironomids were made up primarily of the common *Procladius* (61%). Larvae of mayflies (*Leptophlebia* and *Callibaetis*) and a single caddisfly (*Nemotaulius*) were found. Permanent aquatic forms such as Bivalves (*Pisidium, Sphaerium*) and Amphipods (*Gammarus lacustris* and *Hyalella azteca*) were found at the *test* reach. A single snail, *Valvata sincera*, was also found in one replicate sample.

Temporal Comparisons The following temporal comparisons of benthic invertebrate community measurement endpoints at *test* reach MUR-E1 and *test* reach MUR-D2 were conducted:

- a time trend (Hypothesis 1, Section 3.2.3.1); and
- a difference between 2015 measurement endpoint values and all previous years of sampling.

The following temporal comparisons of benthic invertebrate community measurement endpoints at *test* reach MUR-D3 were conducted:

- a difference in mean measurement endpoint values between *baseline* (2002 to 2007) and *test* (2008 to present) periods in the *test* reach (Hypothesis 2, Section 3.2.3.1);
- time trends during the *test* period (Hypothesis 1, Section 3.2.3.1);
- difference in mean measurement endpoint values between 2015 and the mean of all *baseline* years; and
- difference in mean measurement endpoint values between 2015 and the mean of all previous years of sampling for the *test* reach.

None of the temporal comparisons conducted for lower *test* reach MUR-E1 or middle *test* reach MUR-D2 were significant and accounted for more than 20% of the variance in annual means (Table 5.2-30, Table 5.2-31).

The comparisons for *test* reach MUR-D3 that were statistically significant were (Table 5.2-32):

1. There was a significant increase in abundance over time during the *test* period, abundance was significantly higher in fall 2015 than the mean abundance during the *baseline* period and was significantly higher in fall 2015 than the mean abundance of all previous years of monitoring; these accounted for 29%, 22%, and 20%, respectively, of the variance in annual means. None of these significant differences in abundance are indicative of a degrading benthic invertebrate community at *test* reach MUR-D3.

2. There was a significant increase in richness over time during the *test* period, accounting for 34% of the variance in annual means. This significant difference in richness is not indicative of a degrading benthic invertebrate community at *test* reach MUR-D3.

Comparison to Published Literature The benthic invertebrate community at *test* reach MUR-E1 in fall 2015 was diverse with an average of 47 taxa per sample and with several taxa that are considered sensitive to disturbance including mayflies, *Acerpenna* and *Ephemerella*, and the caddisfly *Hydropsyche* (Hynes 1960, Mandeville 2001, Griffiths 1998). Tubificidae, which are generally considered a group of tolerant worms (Mandeville 2001) were present in low relative abundance (1%).

The benthic invertebrate community at middle *test* reach MUR-D2 in fall 2015 was diverse with a mean of 33 taxa per sample and included a number of taxa that are considered relatively sensitive including larvae of flying insects (Mayflies: *Caenis* and *Acerpenna*) (Hynes 1960; Mandeville 2001; Griffiths 1998). The percentage of the fauna as worms was low (<10%) and permanent aquatic forms (amphipod, gastropod, bivalve) were present, indicating good overall water quality (Hynes 1960, Griffiths 1998).

The benthic invertebrate community at upper *test* reach MUR-D3 in fall 2015 reflected typical depositional habitat conditions. The community was dominated numerically by chironomids (37%) and worms (~36% overall). A high relative abundance of worms suggests that the habitat is poor (Hynes 1960; Griffiths 1998). The community however also contained a high abundance of permanent aquatic forms (~2% overall) and EPT taxa were present at the *test* reach, indicating good overall water quality (Hynes 1960; Griffiths 1998).

2015 Results Relative to Historical or Regional *Baseline* Conditions Values of all six benthic invertebrate community measurement endpoints at *test* reach MUR-E1 in fall 2015 were within the inner tolerance limit of the 95th percentile of the normal range of values of prior years (Figure 5.2-15, Figure 5.2-16).

Test reach MUR-D2 has more than eight years of data (2000 to 2015); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach. If there were exceedances of the tolerance limits for this reach, comparisons to the tolerance limits for regional *baseline* reaches were evaluated. Richness and %EPT at *test* reach MUR-D2 in fall 2015 exceeded the inner tolerance limit of the 95th percentile of the normal range of values of prior years (Figure 5.2-17, Figure 5.2-18) and richness exceeded the inner tolerance limit of the 95th percentile of the normal range of values of regional *baseline* data (see normal ranges in Appendix D),. None of these differences are associated with degrading conditions for benthic invertebrate communities.

Values of all six measurement endpoints at *test* reach MUR-D3 in fall 2015 were within the inner tolerance limit of the 95th percentile of the normal range of values of prior years (Figure 5.2-17, Figure 5.2-19).

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities of Muskeg River at *test* reach MUR-E1 for fall 2015 are classified as **Negligible-Low**:

1. The benthic invertebrate community in fall 2015 contained a fauna typically associated with good environmental conditions, with a high relative abundance of EPT taxa, chironomids and permanent aquatic forms such as clams.

2. There were no significant differences in values of benthic invertebrate community measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means for benthic invertebrate communities.

3. None of the values of the six benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limit of the 95th percentile of the normal range of values of prior years.

Variations in the values of measurement endpoints for benthic invertebrate communities of Muskeg River at *test* reach MUR-D2 for fall 2015 are classified as **Negligible-Low**:

1. The benthic invertebrate community in fall 2015 contained a rich fauna with abundant EPT taxa typically associated with relatively good environmental conditions.

2. There were no significant differences in values of benthic invertebrate community measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means for benthic invertebrate communities.

3. While values of two of the six benthic invertebrate community measurement endpoints in fall 2015 were beyond the inner tolerance limit of the 95th percentiles of the normal range of values of prior years, none of these excursions outside of normal ranges implied degrading conditions for benthic invertebrate communities.

Variations in the values of measurement endpoints for benthic invertebrate communities of Muskeg River at *test* reach MUR-D3 for fall 2015 are classified as **Negligible-Low**:

1. The benthic invertebrate community in fall 2015 contained a fauna with a high relative abundance of tubificid worms, consistent with previous years. The presence of EPT taxa and the high relative abundance of permanent aquatic forms such as clams indicates relatively good habitat quality.

2. None of the significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.

3. None of the values of the six measurement endpoints in fall 2015 were beyond the inner tolerance limit of the 5th or 95th percentiles of the normal range of values of *baseline* reaches.

Jackpine Creek

Benthic invertebrate communities were sampled in fall 2015 in Jackpine Creek at:

- depositional *test* reach JAC-D1 sampled since 2002 and designated as *test* since 2006; and
- depositional *baseline* reach JAC-D2 sampled since 2003.

2015 Habitat Conditions Water at lower *test* reach JAC-D1 in fall 2015 was moderately deep (0.51 m), flowing with slow velocity (0.23 m/s), alkaline (pH 8.2), and with moderate conductivity (203 µS/cm) and high dissolved oxygen concentration (9.7 mg/L) (Table 5.2-33). The substrate was dominated by sand (92%) with some silt (6%) and small amounts of clay (< 2%), with low total organic carbon content (1%).

Water at upper *baseline* reach JAC-D2 was moderately deep (0.4 m), flowing with slow velocity (0.33 m/s), weakly acidic (pH 6.8), with moderate conductivity (216 µS/cm), and high dissolved oxygen concentration (9.8 mg/L). The substrate at *baseline* reach JAC-D2 was dominated by sand (86%) with some silt (11%) and small amounts of clay (5%), and low organic carbon content (~1%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach JAC-D1 in fall 2015 was dominated by chironomids (53%) and tubificid worms (27%) (Table 5.2-34). Subdominant taxa consisted of naidid worms (~7%) and gastropods (4%). The most common chironomid taxa at *test* reach JAC-D1 included genera such as *Micropsectra*/*Tanytarsus* and *Paratanytarsus*. EPT taxa were present at the reach, represented by mayflies (Ephemeroptera: *Acerpenna, Caenis, Leptophlebia*), stoneflies (Plecoptera) and caddisflies (Trichoptera: *Oxyethira*). Larvae of flying insects also included the dragonfly *Ophiogomphus*. Permanent aquatic forms such as gastropods (*Ferrissia rivularis,* Lymnaeidae, *Physa*, *Gyraulus*, *Valvata sincera*) and bivalves (*Pisidium*) were found at *test* reach JAC-D1 in eight of the ten replicate samples.

The benthic invertebrate community at *baseline* reach JAC-D2 in fall 2015 was dominated by chironomids (67%). Subdominant taxa included miscellaneous Diptera (11%), Ceratopogonidae (6%) and Coleoptera (4%) (Table 5.2-35). Chironomid taxa composition was dominated by *Micropsectra / Tanytarsus* with *Stempellina*, *Stempellinella*, *Paralauterborniella*, and *Procladius*. Miscellaneous Diptera larvae included members of the families Tabanidae, Tipulidae, Empididae, and Muscidae. Coleoptera larvae included members of the families Elmidae and Haliplidae. Larvae of flying insects included mayflies (*Callibaetis*, *Caenis*, *Ephemerella*, *Leptophlebia*), caddisflies (*Oxyethira*, Leptoceridae) and the dragonfly *Ophiogomphus*. Permanent aquatic forms such as *Gyraulus* gastropods and *Pisidium* clams were found in low relative abundances.

Temporal and Spatial Comparisons The following and temporal comparisons of benthic invertebrate community measurement endpoints at *test* reach JAC-D1 were conducted:

- a difference in values of measurement endpoints between *baseline* reach JAC-D2 and *test* reach JAC-D1 during both *baseline* and *test* periods;
- a difference in mean values of measurement endpoints between *baseline* (i.e., 2002 to 2005) and *test* (2006 to present) periods of *test* reach JAC-D1;
- a change in the difference in mean values of measurement endpoints between *baseline* and *test* reaches, from *baseline* (2002 to 2005) to *test* (2006 to present) periods (Hypothesis 1 in Section 3.2.3.1);
- a trend over time in mean values of measurement endpoints during the *test* period in both *test* and *baseline* reaches;
- a difference in the trends over time in values of measurement endpoints between *baseline* and *test* reaches, during the *test* period;
- changes between 2015 mean values of measurement endpoints and the mean of all *baseline* years; and
- changes between 2015 mean values of measurement endpoints and the mean of all previous years of sampling.

The comparisons for *test* reach JAC-D1 that were statistically significant were (Table 5.2-36):

1. Abundance was higher in the *test* period compared to the *baseline* period, accounting for 31% of the variation in annual means.

2. Richness was higher in the *test* period compared to the *baseline* period, accounting for 39% of the variation in annual means.

3. Equitability was lower in the *test* period compared to the *baseline* period, accounting for 30% of the variation in annual means.

None of these significant differences are indicative of degrading conditions for benthic invertebrate communities at *test* reach JAC-D1.

Comparison to Published Literature The benthic invertebrate community at lower *test* reach JAC-D1 in fall 2015 was typical of a depositional reach. The benthic invertebrate community was dominated by chironomids, however, the percent of fauna as worms was higher in 2015 than in 2014 (Table 5.2-34). Larvae of large flying insects, while sparse, were present in the *test* reach and were represented by members of the groups Ephemeroptera, Plecoptera, Trichoptera and Odonata. Permanent aquatic forms (gastropods and bivalves) were also present indicating a stable, cold-water habitat (Hynes 1960, Griffiths 1998).

The benthic invertebrate community at upper *baseline* reach JAC-D2 in fall 2015 was similar to the lower *test* reach and supported a benthic invertebrate community reflecting a typical depositional river. As with *test* reach JAC-D1, upper *baseline* reach JAC-D2 in fall 2015 supported benthic invertebrate communities rich in chironomids and with EPT taxa, bivalves and gastropods that reflect high water and sediment quality (Hynes 1960, Griffiths 1998).

2015 Results Relative to Historical Conditions *Test* reach JAC-D1 has more than eight years of data (2002 to 2015); therefore, tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach and, if there were exceedances of the tolerance limits, comparisons to the tolerance limits for *baseline* reach JAC-D2 were evaluated. Values of all benthic invertebrate community measurement endpoints for lower *test* reach JAC-D1 were within the inner tolerance limits of the normal range of variation for means from prior years (Figure 5.2-20, Figure 5.2-21), with the exception of equitability, which was lower than the inner tolerance limit for the normal ranges range of variation and which was also within the tolerance limits for *baseline* reach JAC-D2. Lower equitability represents higher benthic invertebrate diversity, which is consistent with improving conditions and this result is therefore not indicative of degrading conditions for benthic invertebrate communities at lower *test* reach JAC-D1.

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities of Jackpine Creek at lower *test* reach JAC-D1 for fall 2015 are classified as **Negligible-Low**:

1. The benthic invertebrate community in fall 2015 contained a rich and diverse fauna, including several taxa that are typically associated with relatively good environmental conditions.

2. None of the significant differences in values of benthic invertebrate community measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.

3. While the value of one of the six measurement endpoints in fall 2015 (equitability) was beyond the inner tolerance limit of the 95th percentile of the normal range of values of prior years, the excursion did not imply degrading conditions for benthic invertebrate communities.

Kearl Lake

Benthic invertebrate communities were sampled in fall 2015 in Kearl Lake (*test* station KEL-1), which was classified as *baseline* from 2001 to 2008, and *test* from 2009 onwards.

2015 Habitat Conditions Water in Kearl Lake in the fall of 2015 had a pH of 7.6, conductivity of 155 µS/cm, and a concentration of dissolved oxygen of 8.1 mg/L (Table 5.2-37). The substrate of Kearl Lake consisted primarily of silt (73%) with some clay (24%), small amounts of sand (3%), and high organic carbon content (35%) (Table 5.2-37).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community in fall 2015 contained a diverse fauna and included several taxa that are typically associated with relatively good environmental conditions. The benthic invertebrate community at *test* station KEL-1 in the fall of 2015 was dominated by Chironomidae (55%) and naidid worms (21%) with subdominant taxa consisting of bivalves (8%) (Table 5.2-38). Dominant chironomids included *Dicrotendipes*, *Tanytarsus,* and *Paratanytarsus*, which are commonly distributed in Holarctic lakes. Bivalves were comprised mainly of two genera: *Pisidium*; and *Sphaerium*. Gastropods were represented by four genera (*Ferrissia rivularis*, *Lymnaea, Gyraulus,* and *Valvata sincera*). Trichoptera (Hydroptilidae, Phryganeidae, and Polycentropodidae), Ephemeroptera (*Caenis*), and Odonata (Aeshnidae, Corduliidae, Libellulidae, Coenagrionidae) were present but in low relative abundances (<1% each).

Temporal Comparisons The temporal comparisons of measurement endpoints for the benthic invertebrate community of Kearl Lake included testing for:

- a difference between *baseline* (2001 to 2008) and *test* (2009 to present) periods;
- a linear time trend in the *test* period (i.e., since 2009);
- a difference between 2015 and the mean of all *baseline* years; and
- a difference between 2015 and all previous years.

Abundance, richness, and %EPT increased over time during the *test* period and were higher in 2015 than the mean of *baseline* years and the mean of all previous years (Table 5.2-39). These changes accounted for between 29 to 45% of the variance in annual means. In addition, equitability decreased over time during the *test* period and this accounted for 30% of the variance in annual means. None of these trends are indicative of degrading conditions for benthic invertebrate communities at Kearl Lake.

Comparison to Published Guidelines The benthic invertebrate community of the *test* station KEL-1 in fall 2015 contained taxa that are relatively typical of shallow lakes. The proportion of worms was lower in 2015 than in 2014, which may suggest improving conditions for other fauna (O'Toole et al. 2008). Chironomids accounted for 55% of the total benthic invertebrates and the species present were a mix of tolerant (e.g., *Chironomus*) and ubiquitous (*Dicrotendipes*, *Polypedilum*) taxa (Broderson and Lindegaard, 1999). The benthic invertebrate community also had a mixture of permanent aquatic forms, such as amphipods and bivalves, as well as larvae of flying insects (Ephemeroptera, Trichoptera, Odonata), which indicate favourable long-term water quality (Resh and Unzicker 1975; Niemi et al. 1990).

2015 Results Relative to Historical Conditions Abundance, richness, and %EPT at *test* reach KEL-1 in fall 2015 exceeded the inner tolerance limit of the 95th percentile of the normal range of values of prior years (Figure 5.2-22, Figure 5.2-23); none of these differences are associated with degrading conditions for benthic invertebrate communities.

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities of Kearl Lake at *test* reach KEL-1 for fall 2015 are classified as **Negligible-Low**:

1. The benthic invertebrate community in fall 2015 contained a diverse fauna and included several taxa that are typically associated with relatively good environmental conditions.
2. None of the significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.
3. While values of three of the six measurement endpoints in fall 2015 were beyond the inner tolerance limit of the 95th percentile of the normal range of values of prior years, none of these excursions outside of normal ranges implied degrading conditions for benthic invertebrate communities.

5.2.4.2 Sediment Quality

Sediment quality was sampled in depositional reaches and in lakes of the Muskeg River watershed at:

- *test* station MUR-D2 on the Muskeg River, sampled in 2000 and from 2003 to 2015;
- *test* station MUR-D3 on the Muskeg River, designated as *baseline* between 2002 and 2007, and as *test* from 2008 onwards;
- *test* station JAC-D1 on Jackpine Creek near the mouth, designated as *baseline* prior to 2006 and as *test* from 2006 onwards;
- *baseline* station JAC-D2 on Jackpine Creek, sampled since 2006; and
- *test* station KEL-1 on Kearl Lake, designated as *baseline* prior to 2008, and as *test* from 2009 onwards.

Temporal Trends The following significant ($p<0.05$) temporal trends in concentrations of sediment quality measurement endpoints were observed:

- decreasing concentrations of total alkylated PAHs, total parent PAHs, total PAHs, and predicted PAH toxicity at *test* station MUR-D2;
- increasing concentrations of Fraction 1 hydrocarbons at *baseline* station JAC-D2; and
- decreasing concentrations of total alkylated PAHs, total PAHs, total PAHs (carbon-normalized), and total arsenic at *test* station KEL-1.

No significant temporal trends were detected in sediment quality at *test* stations MUR-D3 or JAC-D1.

2015 Results Relative to Historical Conditions Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at the Muskeg River mainstem reaches (Table 5.2-40, Figure 5.2-24, Table 5.2-41, Figure 5.2-24) with the following exceptions:

- % sand at *test* stations MUR-D2 and MUR-D3 in fall 2015 greater than previously-measured maximum values;
- % clay and % silt at *test* station MUR-D2 were lower than previously-measured minimum values; a detection limit of 1% for these variables in previous sampling years means that 2015 data are compared to this minimum historical value;
- % clay at *test* station MUR-D3 was lower than the previously-measured minimum value; and
- concentrations of total alkylated PAHs, total parent PAHs, and total PAHs at *test* station MUR-D3 were lower than below previously-measured minimum concentrations.

Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at the Muskeg River tributary reaches (Table 5.2-42, Figure 5.2-26, Table 5.2-43, Figure 5.2-27) with the following exceptions:

- the concentrations of total organic carbon retene, total dibenzothiophenes, total alkylated PAHs, and total PAHs, as well as predicted PAH toxicity at *baseline* station JAC-D2 were greater than the previously-measured maximum concentrations and levels;
- the carbon-normalized concentration of total PAHs at *baseline* station JAC-D2 was lower than the previously-measured minimum concentration;
- *Hyalella* 14-day growth at *test* station JAC-D1 and *baseline* station JAC-D2 was lower than the previously-measured minimum value.

Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at *test* station KEL-1 (Table 5.2-44, Figure 5.2-28) with the following exceptions:

- % sand was lower than the previously-measured minimum value;
- concentrations of total PAHs and total alkylated and total parent PAHs were lower than previously-measured minimum concentrations; and
- the 10-day survival of the midge *Chironomus* was greater than the previously-measured maximum value.

Comparison of Sediment Quality Measurements Endpoints to Sediment Quality Guidelines Concentrations and levels of sediment quality measurement endpoints were below guideline concentrations at *test* stations MUR-D2, MUR-D3, JAC-D1, and KEL-1 and *baseline* station JAC-D2 in fall 2015, with the following exceptions:

- Fraction 3 hydrocarbons at *test* station JAC-D1 and *test* station KEL-1;
- predicted PAH toxicity at *test* station MUR-D2; and
- concentrations of Fraction 1 and 2 hydrocarbons at *test* station KEL-1 that were not detectable, but had a detection limit that exceeded the CCME guidelines.

2015 Results Relative to Regional *Baseline* Conditions In fall 2015, concentrations of all sediment quality measurement endpoints for Muskeg river mainstem and tributary stations were within the ranges of regional *baseline* concentrations (Figure 5.2-24 to Figure 5.2-27, Figure 5.2-28) with the exception of:

- concentration of total metals at *test* station MUR-D2, which was below the 5th percentile of regional *baseline* concentrations;
- concentration of carbon-normalized total PAHs at *test* station MUR-D2 and *baseline* station JAC-D2, which were above the 95th percentile of regional *baseline* concentrations; and
- total metals (when normalized to percent fine sediments) at *test* station JAC-D1, which was below the 5th percentile of regional *baseline* concentrations.

Concentrations of sediment quality measurement endpoints at *test* station KEL-1 were not compared to regional *baseline* concentrations due to the ecological differences between lakes and rivers; Figure 5.2-28 present historical changes in sediment quality measurement endpoints at *test* station KEL-1.

Sediment Quality Index The SQI values for *test* station MUR-D2 and *test* station MUR-D3 were both 100 in fall 2015, and were similar to the SQI values for these stations in 2014 (100 and 98.9%, respectively). Fall 2015 SQI values for *test* station JAC-D1 and *baseline* station JAC-D2 (97.9 and 100, respectively) were also similar to SQI values calculated in 2014 (100 and 100).

An SQI value was not calculated for *test* station KEL-1 because lakes were not included in the regional *baseline* conditions due to ecological differences between lakes and rivers and the lack of *baseline* data for lakes in the region.

Classification of Results Based on the calculated SQI values at *test* stations MUR-D2, MUR-D3, and JAC-D1, and *baseline* station JAC-D2, differences in sediment quality conditions in 2015 to regional *baseline* conditions were classified as **Negligible-Low**.

5.2.5 Fish Populations

Fish community monitoring and wild fish health monitoring were conducted in the Muskeg River watershed in the 2015 WY.

5.2.5.1 Fish Community Monitoring

Muskeg River

Fish community monitoring was conducted on the Muskeg River in fall 2015 at *test* reach MUR-F2. The fish community has been monitored at this reach since 2011, at the same location as the benthic invertebrate community *test* reach MUR-D2.

2015 Habitat Conditions Habitat conditions at *test* reach MUR-F2 for fall 2015 are summarized in Table 5.2-45. *Test* reach MUR-F2 in fall 2015 consisted of riffle habitat with a wetted width and a bankfull width of 19.0 m. The substrate was dominated by coarse gravel with smaller amounts of cobble. Water at *test* reach MUR-F2 had a mean depth of 0.30 m, velocity of 0.33 m/s, pH of 7.99, conductivity of 251 µS/cm, dissolved oxygen concentration of 9.2 mg/L, and a temperature of 8.5˚C. Instream cover consisted of small woody debris, live trees and roots, overhanging vegetation, undercut banks, and boulders.

Relative Abundance of Fish Species A total of 61 fish were caught in fall 2015 at *test* reach MUR-F2 (Table 5.2-46), an increase of 56 individuals compared to the total catch in fall 2014, and the highest catch since sampling began at *test* reach MUR-F2 in 2009. Four species were caught at *test* reach MUR-F2 in fall 2015, with the catch dominated by lake chub (Table 5.2-46).

Temporal and Spatial Comparisons A summary of the values of the fish community measurement endpoints for *test* reach MUR-F2 is provided in Table 5.2-47. No spatial comparisons were possible for the fish community at *test* reach MUR-F2 because a *baseline* reach on the Muskeg River was not monitored in 2015. Temporal comparisons for *test* reach MUR-F2 included testing for changes over time (2011 to 2015) in values of the fish community measurement endpoints (Hypothesis 1, Section 3.2.4.2).

There were statistically significant increases in CPUE, abundance, richness, and diversity over time at *test* reach MUR-F2, indicating a positive change in the fish community (Table 5.2-48). All significant increases explained greater than 20% of the variance in the annual means with the exception of diversity (Table 5.2-48), suggesting a strong statistical signal in the increases in CPUE, abundance, and richness over time.

Comparison to Published Literature Golder (2004) documented similar habitat conditions in the vicinity of *test* reach MUR-F2 to those recorded in fall 2015, consisting of deep slow pools, runs and small sections of riffle habitat, with substrate consisting of gravel and cobble, with some boulders and fine sediment. The low habitat diversity and limited spawning habitat and food supply for this reach of the Muskeg River may be related to the low species richness observed at this reach (Golder 2004). Past studies have documented 21 fish species in the Muskeg River (Golder 2004), compared to a total of 14 fish species captured in the Muskeg River during the historical fish monitoring conducted for the RAMP and JOSMP from 2009 to 2015. Possible reasons for discrepancies in species richness may be due to differences in sampling gear as well as the total amount of the watercourse sampled; fish community monitoring under the JOSMP samples smaller, defined reach lengths compared to the multiple locations and reaches documented as being sampled by Golder (2004).

2015 Results Relative to Regional Baseline Conditions Mean values of all measurement endpoints for fish community monitoring at *test* reach MUR-F2 in fall 2015 were within the inner tolerance limits of the ranges of regional *baseline* values for these measurement endpoints (Figure 5.2-29).

Classification of Results Differences in fish community measurement endpoints between *test* reach MUR-F2 and regional *baseline* conditions were classified as **Negligible-Low:**

1. There were no significant differences implying a negative change in the fish community; and
2. The mean values of all measurement endpoints for fish community monitoring at *test* reach MUR-F2 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints.

Jackpine Creek

Fish community monitoring was conducted on Jackpine Creek in fall 2015 at:

- lower *test* reach JAC-F1, sampled since 2009, in the same location as the benthic invertebrate community *test* reach JAC-D1; and

- upper *baseline* reach JAC-F2, sampled since 2009, in same location as the benthic invertebrate community *baseline* reach JAC-D2.

2015 Habitat Conditions Habitat conditions at lower *test* reach JAC-F1 and upper *baseline* reach JAC-F2 in fall 2015 are summarized in Table 5.2-49. Lower *test* reach JAC-F1 in fall 2015 consisted of riffle habitat with a wetted width of 6.5 m and bankfull width of 9.4 m. Substrate was dominated by fines with smaller amounts of sand. Water at lower *test* reach JAC-F1 had a mean depth of 0.53 m, velocity of 0.22 m/s, pH of 7.59, conductivity of 181 µS/cm, dissolved oxygen concentration of 10.0 mg/L, and a temperature of 8.3 ºC. Instream cover consisted primarily of small woody debris and overhanging vegetation.

Upper *baseline* reach JAC-F2 in fall 2015 consisted of glide habitat and a wetted width of 5.8 m and bankfull width of 8.0 m. Substrate consisted of mostly fines. Water at upper *baseline* reach JAC-F2 in fall 2015 had a mean depth of 0.73 m, velocity of 0.07 m/s, pH of 7.93, conductivity of 223 µS/cm, dissolved oxygen concentration of 9.6 mg/L, and a temperature of 7.0 ºC. Instream cover consisted primarily of macrophytes.

Relative Abundance of Fish Species The total catch of fish in 2015 at lower *test* reach JAC-F1 was higher than the three previous years of sampling, but was lower than two of the earlier years in the monitoring period (2010 and 2011)(Table 5.2-50). Six species were captured in fall 2015, which was double the number of species caught in fall 2014. The total catch of fish was lower in 2015 than in 2014 at upper *baseline* reach JAC-F2 (Table 5.2-50). Six species were captured at upper *baseline* reach JAC-F2 in fall 2015, which was the highest total species richness for this reach since sampling began in 2009 (Table 5.2-50).

Temporal and Spatial Comparisons A summary of the values of the fish community measurement endpoints for lower *test* reach JAC-F1 and upper *baseline* reach JAC-F2 is provided in Table 5.2-47. Values of all measurement endpoints at lower *test* reach JAC-F1 were higher in 2015 compared to 2014, with the exception of ATI; richness and diversity were higher in 2015 compared to 2014 while CPUE, and ATI were lower in 2015 compared to 2014 at upper *baseline* reach JAC-F2 (Table 5.2-47).

Temporal comparisons for lower *test* reach JAC-F1 included testing for changes over time in values of the fish community measurement endpoints from 2010 to 2015 (Hypothesis 1, Section 3.2.4.2). Spatial comparisons consisted of testing for differences in values of fish community measurement endpoints over time between lower *test* reach JAC-F1 and upper *baseline* reach JAC-F2 (Hypothesis 2, Section 3.2.4.2).

There were significant decreases in abundance (indicating a potential negative change in the fish community) and ATI (indicating a potential positive change in the fish community) over time at lower *test* reach JAC-F1 (Table 5.2-51). Differences over time in ATI explained greater than 20% of the variance in annual means suggesting a strong statistical signal in the decrease in ATI, which was a result of a shift in species composition over time from finescale dace and lake chub to slimy sculpin and longnose sucker, both of which are considered more sensitive species (Whittier et al. 2007). By contrast, differences over time in abundance explained less than 20% of the variance in annual means suggesting a weak statistical signal in the decrease in abundance over time. There were no significant differences in values of measurement endpoints between lower *test* reach JAC-F1 and upper *baseline* reach JAC-F2 over time (Table 5.2-51).

Comparison to Published Literature Golder (2004) documented similar habitat conditions in Jackpine Creek consisting of runs and small pools with sand/fine substrate and slow flowing water, which is consistent with observations made in fall 2015. This habitat is likely not suitable for most fish species in the region that require harder substrate and faster flowing water for spawning and rearing (e.g., sculpin species, Arctic grayling, and sucker species) (Bond and Machniak 1977).

Past studies have documented a total of 15 fish species in Jackpine Creek, compared to a total of 14 fish species captured in Jackpine Creek during historical fish monitoring conducted for the RAMP and JOSMP from 2009 to 2015. The total number of fish species documented by the RAMP/JOSMP includes two fish species (finescale dace and trout-perch) that were not documented by Golder (2004) (Table 5.2-50). Possible reasons for discrepancies in species richness may be due to differences in sampling gear as well as the total amount of the watercourse sampled; fish community monitoring under the JOSMP samples smaller, defined reaches relative to the multiple locations and reaches sampled by Golder (2004).

2015 Results Relative to Regional Baseline Conditions Mean values of all measurement endpoints at lower *test* reach JAC-F1 and upper *baseline* reach JAC-F2 were within the inner tolerance limits of regional *baseline* values for these measurement endpoints (Figure 5.2-30).

Classification of Results Differences in measurement endpoints of the fish community at lower *test* reach JAC-F1 were classified as **Negligible-Low**:

1. Although there was a significant decrease in abundance over time at lower *test* reach JAC-F1, the trend did not explain greater than 20% of the variance in annual means.

2. The mean values of all measurement endpoints for fish community monitoring at *test* reach JAC-F1 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints.

5.2.5.2 Wild Fish Health

Wild fish health monitoring was conducted at *test* reach MUR-F2 of the Muskeg River in fall 2015 using lake chub as the target species. No upstream *baseline* reach was sampled in the Muskeg River in 2015. In addition, data gathered during the 2015 program could not be compared with previous wild fish health monitoring conducted in the Muskeg River in 1999, 2001 and 2012, because these historical programs targeted slimy sculpin at erosional reaches located further downstream. In effort to provide some context to data collected at *test* reach MUR-F2, a *qualitative* comparison was made to data collected from the following regional *baseline* reaches where lake chub were also the target species in 2015 for wild fish health monitoring:

- upstream and downstream *baseline* reaches AC-US and AC-DS in Alice Creek;
- upper *baseline* reach ER-U in the Ells River; and
- upper, mid, and lower *baseline* reaches DC-U, DC-M, and DC-L in the Dover River.

Although the *test* reach on the Muskeg River and the regional *baseline* reaches were similar, it was recognized that any comparisons of lake chub from these reaches could be potentially confounded by differences in watersheds related to physical and chemical habitat conditions and biotic factors, and detailed quantitative comparisons were therefore not considered appropriate. As such, the results from the qualitative assessment should also be interpreted with caution.

2015 Habitat Conditions Water quality at *test* reach MUR-F2 was suitable for lake chub, with a concentration of dissolved oxygen of 9.5 mg/L, conductivity of 274 µs/cm, and pH of 7.22 (Table 5.2-52). The water was approximately 0.50 m deep, with a velocity of 0.03 m/s. Substrate consisted of cobble and gravel. Daily water temperatures decreased from a high of 21°C on August 12 to a low of 9°C on September 21 (Figure 5.2-31) and the water temperature measured at the time of sampling was 8.7°C.

Collection and Structure of Target Fish

Summary of Capture Success of Adults and Juveniles While multiple field surveys were conducted at *test* reach MUR-F2 in an attempt to catch the target number of fish (20 of each sex for adults), only 11 adult lake chub were collected and of these, only six adult females and one adult male were appropriately sized for dissection (≥60 mm). The required number of 100 juvenile lake chub was obtained. A summary of morphometric data for the lake chub caught in the Muskeg River is provided in Table 5.2-53. *Test* reach MUR-F2 had the largest proportion of juveniles when compared to regional *baseline* reaches, with *baseline* reach AC-DS having the smallest proportion of juveniles (Table 5.2-53).

Size Distribution Figure 5.2-32 presents the length-frequency distribution of all lake chub captured in fall 2015 at *test* reach MUR-F2 and juvenile lake chub captured at regional *baseline* reaches (a length of 50 mm was used to designate lake chub juveniles on the Muskeg River as 50 mm marks the end of the first peak in the bimodal distribution of length). Given so few adult lake chub were caught at *test* reach MUR-F2, only length-frequency distributions of lake chub juveniles were compared between *test* reach MUR-F2 and regional *baseline* reaches. Length-frequency distributions of lake chub juveniles were relatively similar between *test* reach MUR-F2 and regional *baseline* reaches in 2015 (Figure 5.2-32).

Incidence of Abnormalities 16.7% of the lake chub caught at *test* reach MUR-F2 in fall 2015 were found to have parasites (Table 5.2-53).

Spatial Comparison of Measurement Endpoints of Wild Fish Health

Figure 5.2-33 and the following information provide general comparisons of measurement endpoints for lake chub between *test* reach MUR-F2 and regional *baseline* reaches. Differences in habitat, water quality and substrate conditions between *test* reach MUR-F2 and regional *baseline* reaches (Table 5.2-52) do not allow for direct statistical comparisons and male lake chub were not included in the comparisons due to an insufficient sample size. Relative gonad size, relative liver size and condition were estimated by gonadosomatic index (GSI), liversomatic index (LSI), and condition factor (K), respectively.

Age – Mean Age and Age Distribution (Survival) In 2015, mean age of adult female lake chub was 2.2 years and the mean age of female lake chub captured at *test* reach MUR-F2 in fall 2015 was within the range of mean age of female lake chub captured at regional *baseline* reaches in fall 2015 (Figure 5.2-33). The relative age-frequency distribution of lake chub showed the dominant age class to be less than a year old for the majority of adults (<50 mm) with a sub-dominant age class of four years (Figure 5.2-34).

Growth – Size-at-Age (Energy Use) Growth of female lake chub at *test* reach MUR-F2 was similar to growth of female lake chub from regional *baseline* reaches (Figure 5.2-35).

Relative Gonad Size (Energy Use) – Mean GSI of female lake chub at *test* reach MUR-F2 in fall 2015 (4.91) was lower than the mean GSI of female lake chub captured at all the regional *baseline* reaches in fall 2015 (Figure 5.2-33).

Relative Liver Size (Energy Storage) Mean LSI of adult female lake chub at *test* reach MUR-F2 in fall 2015 (0.71) was lower than the mean LSI of female lake chub captured at all the regional *baseline* reaches in fall 2015 (Figure 5.2-33).

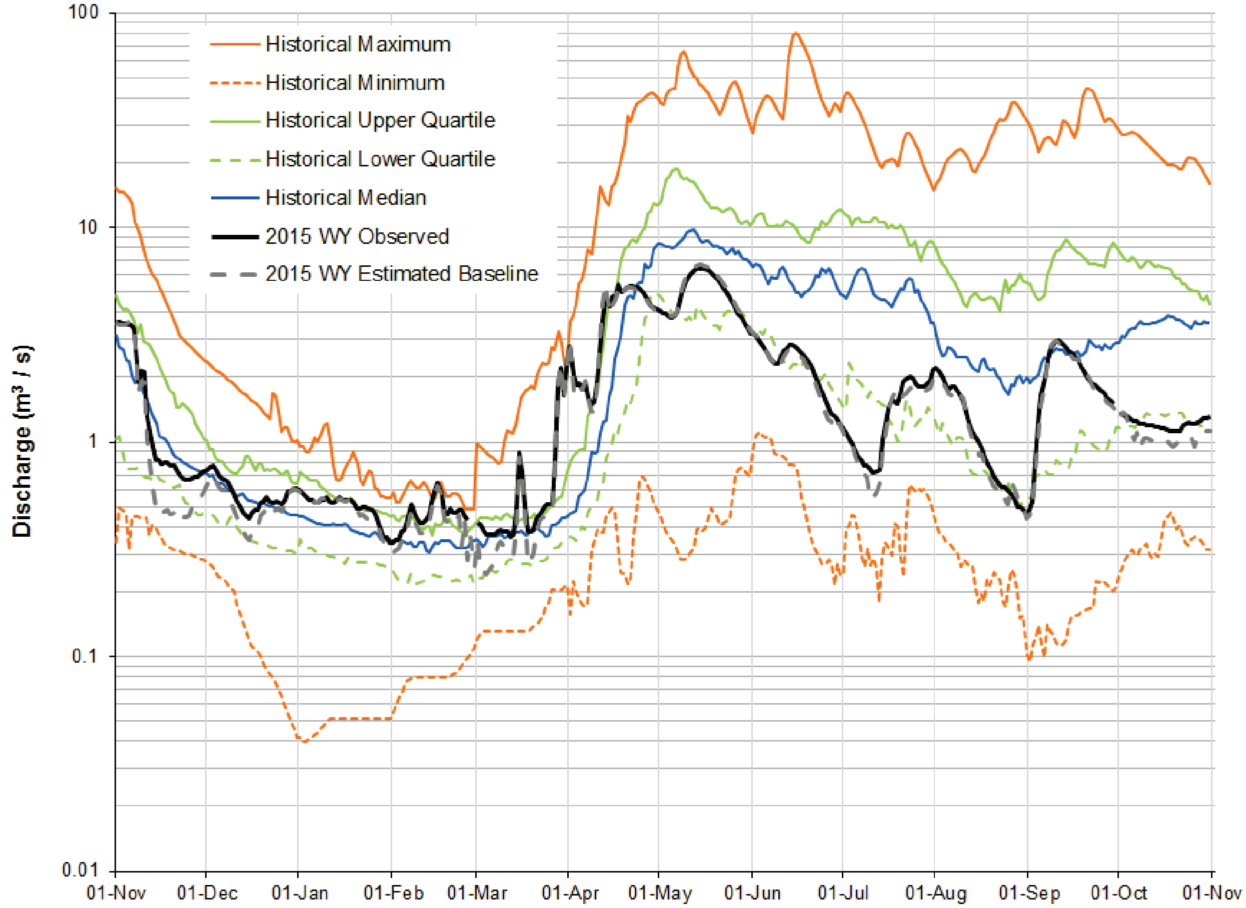
Condition (Energy Storage) Mean condition factor of adult female lake chub at *test* reach MUR-F2 in fall 2015 (1.10) was similar to the mean condition of female lake chub captured at all the regional *baseline* reaches in fall 2015 (Figure 5.2-33).

Exposure – Mixed Function Oxygenase (MFO) Activity Mean EROD activity of adult female lake chub at *test* reach MUR-F2 in fall 2015 (8.20 pmol/min/mm) was two to four-fold greater than the mean EROD activity of female lake chub captured at all the regional *baseline* reaches in fall 2015 (Figure 5.2-36).

Interpretation of 2015 Responses In the absence of temporal data or *baseline* reaches for fish health monitoring in the Muskeg River in 2015, general regional *baseline* comparisons were made to provide context to data collected from *test* reach MUR-F2 in fall 2015. Differences in habitat do exist between MUR-F2 and regional *baseline* reaches and may have influenced the differences in values of fish health measurement endpoints between *test* reach MUR-F2 and regional *baseline* reaches described above. *Test* reach MUR-F2 had a lower velocity than the *baseline* reaches (0.03 m/s vs. 0.05 m/s to 0.25 m/s) (Table 5.2-52). Substrate also varied among reaches; sand, for example, was observed at *test* reach MUR-F2 but was absent from any of the regional *baseline* reaches. Establishment of a *baseline* fish health monitoring reach on the Muskeg River should be considered in future studies so that an effects assessment can be conducted for *test* reach MUR-F2.

Classification of Results Classification of results for fish health at *test* reach MUR-F2 was not possible because a *baseline* reach was not sampled on the Muskeg River in 2015 and comparisons of fish health on the Muskeg River between *test* and *baseline* conditions could therefore not be made.

Figure 5.2-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Muskeg River in the 2015 WY, compared to historical values.



Notes:

The observed 2015 WY hydrograph was based on Muskeg River near Fort McKay, WSC Station 07DA008 (JOSMP Station S7) data. The upstream drainage area is 1,457 km2. Historical daily values from March 1 to October 31 were calculated from data collected from 1974 to 2014, and historical daily values from November 1 to February 28 calculated from data collected from 1974 to 1986 and from 1999 to 2014.

For a more realistic simulation of estimated baseline flows, the Clean Water Diversion releases reported by Syncrude were calculated as the difference in daily flow volumes recorded at JOSMP hydrometric sites S5A and S5 (see text for details).

Table 5.2-2 Estimated water balance at WSC Station 07DA008 (formerly JOSMP Station S7), Muskeg River near Fort McKay, 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**53.671**	**Observed discharge, obtained from Muskeg River near Fort McKay, WSC Station 07DA008 (formerly JOSMP Station S7)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-5.275	Estimated 147.9 km^2 of the Muskeg River watershed is closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.650	Estimated 91.1 km^2 of the Muskeg River watershed with land change from oil sands developments as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Muskeg River watershed, relative to the estimated *baseline* hydrograph	0.000	Water withdrawn by Shell, Imperial, and Suncor for flow augmentation and dust suppression (all values provided daily)
Water releases into the Muskeg River watershed, relative to the estimated *baseline* hydrograph	6.316	Sum of releases into creeks, plus maximum possible contribution of Aurora Clean Water Diversion to Muskeg River, reported as 5.385 million m^3; the maximum possible contribution of Aurora Clean Water Diversion to Muskeg River was assessed as 3.766 million m^3.
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	Not applicable
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**51.980**	**Estimated *baseline* discharge at Muskeg River near Fort McKay, WSC Station 07DA008 (formerly JOSMP Station S7)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	1.691	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	3.247	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

Baseline values shown in the table were likely underestimated, because they were based on the assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

For more realistic winter simulation of estimated baseline flows, the Clean Water Diversion releases were calculated as the difference between flows recorded downstream (at JOSMP hydrometric station S5A) and upstream (at JOSMP hydrometric station S5) of the Aurora North Mine Site. This calculation likely overestimates contributions from the release to Muskeg River, and underestimates the estimated *baseline* hydrograph; however, the process accounts for losses due to flow through shallow groundwater, muskeg, and evaporation.

All non-zero values in this table presented to three decimal places.

Table 5.2-3 Calculated changes in hydrologic measurement endpoints for the Muskeg River watershed, 2015 WY.

Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	2.108	2.153	+2.128%
Mean winter discharge	0.675	0.750	+11.068%
Annual maximum daily discharge	6.684	6.430	-3.796%
Open-water season minimum daily discharge	0.440	0.460	+4.568%

Notes:

Definitions and assumptions discussed in Section 3.2.1.

Observed discharge was calculated from WSC Station 07DA008.

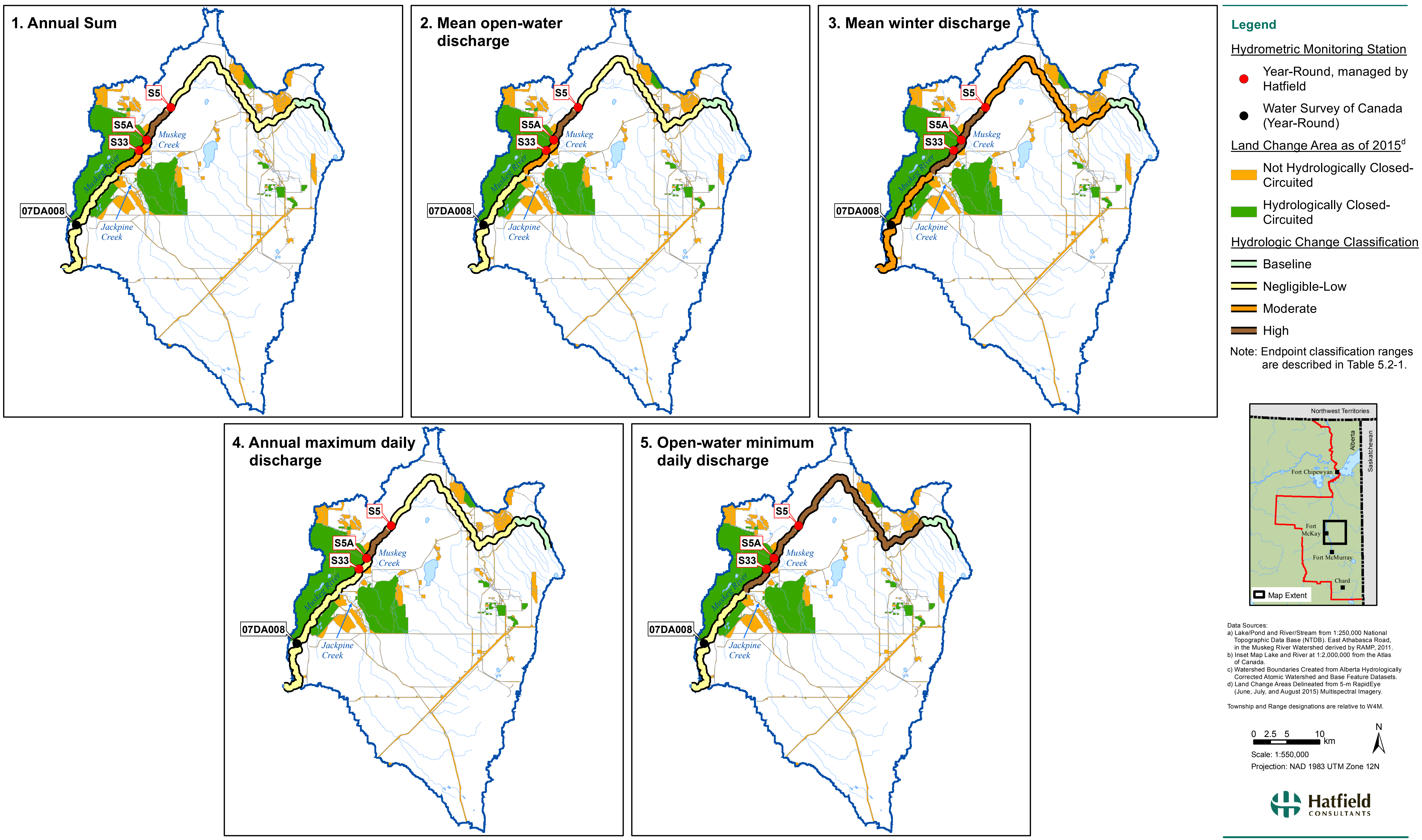
Baseline values shown in the table were likely underestimated because they were based on the assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

For more realistic winter simulation of estimated baseline flows, the Clean Water Diversion releases were calculated as the difference between flows recorded downstream (at JOSMP hydrometric station S5A) and upstream (at JOSMP hydrometric station S5) of the Aurora North Mine Site. This calculation likely overestimates contributions from the release to Muskeg River, and underestimates the estimated *baseline* hydrograph; however, the process accounts for losses due to flow through shallow groundwater, muskeg, and evaporation.

The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. Flow values are presented to three decimal places for the sake of clarity.

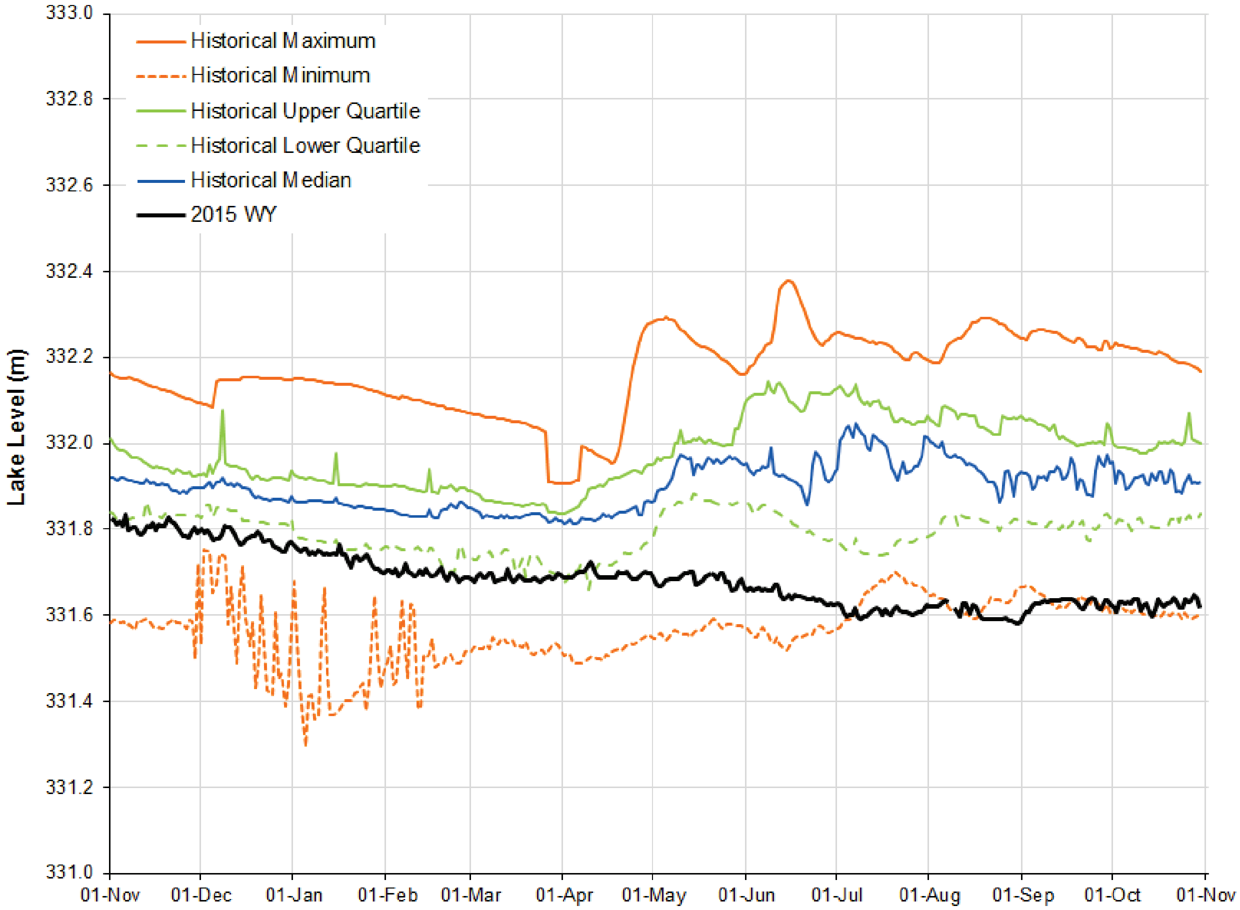
The open-water season refers to the period between May 1 and October 31 and the winter season refers to the period between November 1 and March 31.

Figure 5.2-4 Hydrologic change classification of the Muskeg River, 2015 WY.



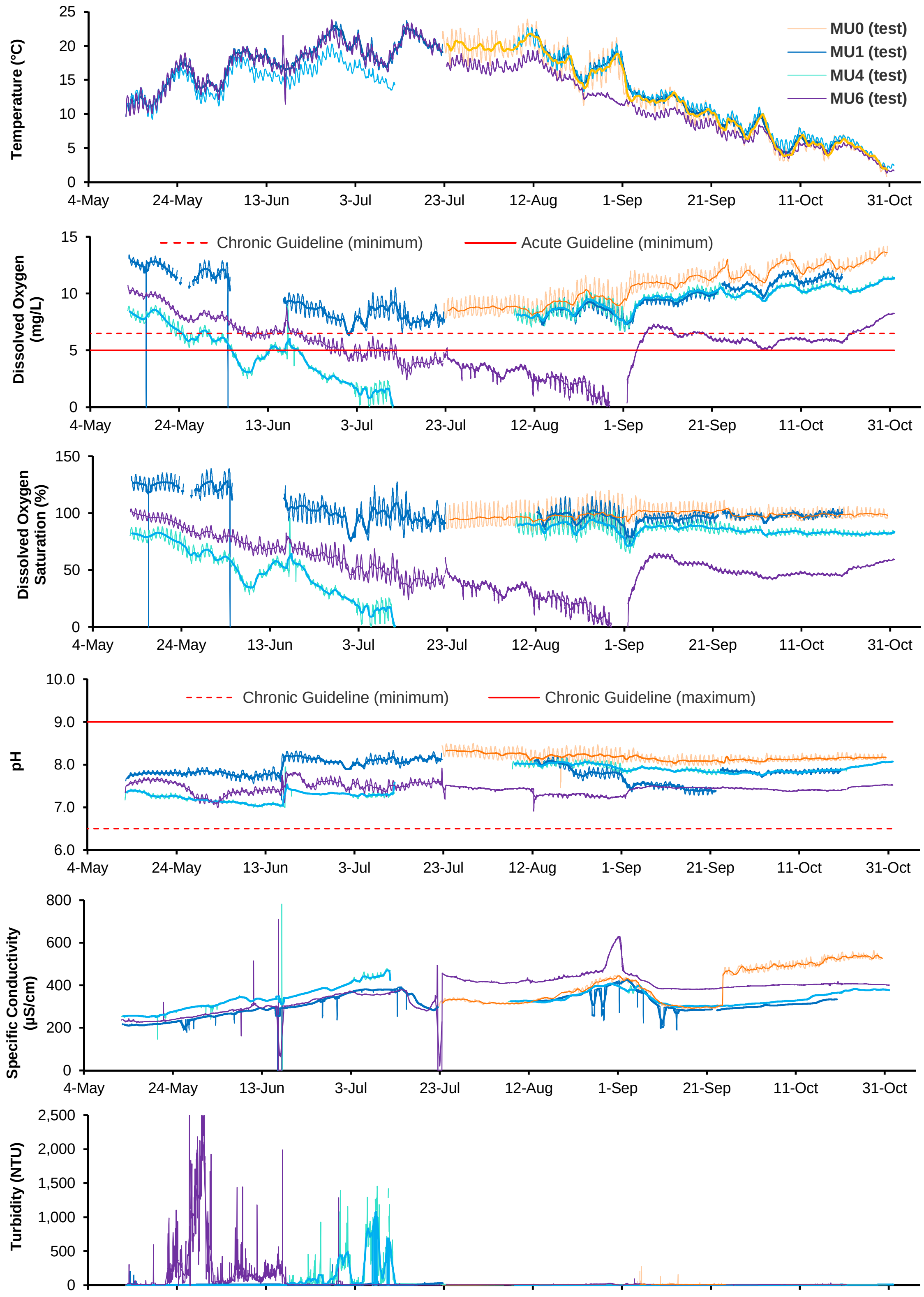
K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_N1_Muskeg_20160329_ss.mxd

Figure 5.2-5 Observed lake levels for Kearl Lake in the 2015 WY, compared to historical values.



Note: Based on 2015 WY data recorded at Kearl Lake, JOSMP Station L2. Historical values were calculated for the period from 1999 to 2014, with periods of missing data present in most years.

Figure 5.2-6 In situ water quality trends in the Muskeg River recorded by data sondes, April to October 2015.



Note: Concentrations and levels of water quality variables were recorded at hourly and 15-minute intervals; trend lines are daily averages.

Table 5.2-4 Monthly concentrations of water quality measurement endpoints, Muskeg River near the mouth (*test* station MU0 [MUR-1]), November 2014 to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	7	8.20	7.66	Mar	8.38	Aug
Total suspended solids	mg/L	-	7	3.00	1.00	Jul, Oct	5.30	Sep
Conductivity	µS/cm	-	7	429	290	Jul	535	Feb
Nutrients								
Total dissolved phosphorus	mg/L	-	7	0.010	0.007	Sep	0.013	Nov
Total nitrogen	mg/L	-	7	0.84	0.64	Oct	1.03	Mar
Nitrate+nitrite	mg/L	3-124	7	0.015	<0.005	-	0.059	Dec
Dissolved organic carbon	mg/L	-	7	22.0	18.7	Feb	27.0	Aug
Ions								
Sodium	mg/L	-	7	16.1	13.0	Sep	18.0	Oct
Calcium	mg/L	-	7	49.0	36.0	Sep	78.8	Feb
Magnesium	mg/L	-	7	13.9	9.0	Sep	16.9	Jan
Potassium	mg/L	-	7	1.52	0.69	Aug	1.64	Jan
Chloride	mg/L	120-640	7	7.77	4.70	Jul	9.90	Feb
Sulphate	mg/L	429[b]	7	11.2	<1.0	Aug	20.0	Nov
Total dissolved solids	mg/L	-	7	250	190	Sep	341	Feb
Total alkalinity	mg/L	20 (min)	7	183	150	Jul, Sep	270	Feb
Selected metals								
Total aluminum	mg/L	-	7	0.035	0.020	Aug	0.071	Nov
Dissolved aluminum	mg/L	0.05	7	0.0025	0.0015	Aug	0.0041	Nov
Total arsenic	mg/L	0.005	7	0.00033	0.00025	Mar	0.00045	Jul
Total boron	mg/L	1.5-29	7	0.054	0.047	Sep	0.062	Feb
Total molybdenum	mg/L	0.073	7	0.00010	0.00007	Jan	0.0002	Nov
Total mercury (ultra-trace)	ng/L	5-13	7	0.74	0.56	Dec, Jan	1.13	July
Total methyl mercury	ng/L	1-2	4	0.094	0.076	Oct	0.11	Aug
Total strontium	mg/L	-	7	0.134	0.109	Sep	0.226	Jan
Total hydrocarbons								
BTEX	mg/L	-	7	<0.10	<0.01	-	<0.10	-
Fraction 1 (C6-C10)	mg/L	0.15	7	<0.10	<0.01	-	<0.10	-
Fraction 2 (C10-C16)	mg/L	0.11	7	**<0.25**	<0.01	-	**<0.25**	-
Fraction 3 (C16-C34)	mg/L	-	7	<0.25	<0.02	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	7	<0.25	<0.02	-	<0.25	-
Naphthenic acids	mg/L	-	7	0.82	0.27	Sep	2.96	Feb
Oilsands extractable acids	mg/L	-	7	2.50	1.20	Jul	6.40	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	7	<13.55	<13.55	-	18.60	Aug
Retene	ng/L	-	7	<0.59	<0.59	-	0.86	July
Total dibenzothiophenes[c]	ng/L	-	7	13.95	<8.17	Feb	18.71	Nov
Total PAHs[c]	ng/L	-	7	143.17	112.43	Mar	151.96	Nov
Total Parent PAHs[c]	ng/L	-	7	22.64	8.87	Mar	29.26	Aug
Total Alkylated PAHs[c]	ng/L	-	7	120.05	101.43	Feb	129.48	Nov
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	0.0018	0.001	Dec-Mar	**0.015**	Jul
Sulphide	mg/L	0.0019	8	**0.0049**	**0.0018**	Dec	**0.0077**	Jul, Aug
Dissolved iron	mg/L	0.3	3	0.27	0.14	Jul	**0.43**	Nov

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-5 Monthly concentrations of water quality measurement endpoints, Muskeg River near Fort McKay (*test* station MU1), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.07	7.91	Sep	8.18	Jul
Total suspended solids	mg/L	-	5	2.0	1.3	Jul, Aug	8.0	Sep
Conductivity	µS/cm	-	5	300	280	Sep	340	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.012	0.012	Jun, Aug, Sep	0.026	Oct
Total nitrogen	mg/L	-	5	0.87	0.73	Jun	1.00	Aug
Nitrate+nitrite	mg/L	3-124	5	0.01	<0.01	-	0.0093	Jul
Dissolved organic carbon	mg/L	-	5	24.0	22.0	Oct	27.0	Aug
Ions								
Sodium	mg/L	-	5	14.0	12.0	Jun	15.0	Oct
Calcium	mg/L	-	5	40.0	34.0	Sep	45.0	Aug, Oct
Magnesium	mg/L	-	5	11.0	9.6	Sep	12.0	Aug, Oct
Potassium	mg/L	-	5	0.87	0.72	Aug	1.30	Jun
Chloride	mg/L	120-640	5	4.0	3.5	Sep	5.4	Oct
Sulphate	mg/L	309[b]	5	2.00	<1.00	-	8.3	Oct
Total dissolved solids	mg/L	-	5	210	190	Sep	220	Aug, Oct
Total alkalinity	mg/L	20 (min)	5	150	140	Jun	170	Oct
Selected metals								
Total aluminum	mg/L	-	6	0.025	0.018	Aug	0.135	May
Dissolved aluminum	mg/L	0.05	6	0.0031	0.0020	Aug	0.0074	May
Total arsenic	mg/L	0.005	6	0.00039	0.00033	May	0.00049	Jul
Total boron	mg/L	1.5-29	6	0.047	0.039	Sep	0.052	Jun
Total molybdenum	mg/L	0.073	6	0.00011	0.00009	Sep	0.00015	Jul
Total mercury (ultra-trace)	ng/L	5-13	6	0.94	0.70	Oct	1.30	May
Total methyl mercury	ng/L	1-2	6	0.092	0.062	May	0.12	Aug, Sep
Total strontium	mg/L	-	6	0.112	0.071	May	0.125	Aug, Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.01	<0.01	-	<0.01	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.75	0.47	Sep	1.82	Jun
Oilsands extractable acids	mg/L	-	6	2.05	1.30	Oct	3.60	Aug
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	16.40	Aug
Retene	ng/L	-	5	0.82	<0.59	Sep, Oct	0.98	Jul
Total dibenzothiophenes[c]	ng/L	-	5	37.8	25.4	Sep	44.7	May
Total PAHs[c]	ng/L	-	5	204.7	159.0	Sep	220.4	Jun
Total Parent PAHs[c]	ng/L	-	5	23.6	23.0	Oct	29.2	Aug
Total Alkylated PAHs[c]	ng/L	-	5	175.5	135.9	Sep	196.5	Jun
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0095**	**0.0062**	Oct	**0.018**	Jul
Sulphide	mg/L	0.0019	5	**0.0093**	**0.007**	Sep	**0.0130**	Oct
Dissolved iron	mg/L	0.3	4	**0.34**	0.18	Jul	**0.78**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-6 Monthly concentrations of water quality measurement endpoints, Muskeg River above Jackpine Creek (*test* station MU4), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	7.98	7.87	Oct	8.19	Jul
Total suspended solids	mg/L	-	5	2.0	<1.0	Sep	2.7	Jun, Jul
Conductivity	µS/cm	-	5	330	290	Jun	380	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.012	0.010	Oct	0.016	Jun
Total nitrogen	mg/L	-	5	0.84	0.76	Oct	1.00	Aug
Nitrate+nitrite	mg/L	3-124	5	0.039	0.006	Sep	0.050	Oct
Dissolved organic carbon	mg/L	-	5	22.0	21.0	Jul, Oct	27.0	Aug
Ions								
Sodium	mg/L	-	5	12.0	12.0	Jun, Aug, Sep	13.0	Jul, Oct
Calcium	mg/L	-	5	44.0	38.0	Jun	48.0	Jul
Magnesium	mg/L	-	5	12.0	11.0	Jun	13.0	Sep, Oct
Potassium	mg/L	-	5	1.10	0.65	Aug	1.60	Jun
Chloride	mg/L	120-640	5	3.5	3.0	Aug	5.0	Oct
Sulphate	mg/L	309[b]	5	3.1	1.80	Aug	13.0	Oct
Total dissolved solids	mg/L	-	5	230	180	Jun	270	Oct
Total alkalinity	mg/L	20 (min)	5	170	140	Jun	190	Oct
Selected metals								
Total aluminum	mg/L	-	6	0.052	0.037	July	0.294	May
Dissolved aluminum	mg/L	0.05	6	0.0033	0.0031	July	0.0064	May
Total arsenic	mg/L	0.005	6	0.00034	0.00028	Oct	0.00041	Aug
Total boron	mg/L	1.5-29	6	0.048	0.039	May	0.051	Oct
Total molybdenum	mg/L	0.073	6	0.00010	0.00008	Oct	0.00011	May
Total mercury (ultra-trace)	ng/L	5-13	6	0.83	0.70	Oct	1.18	May
Total methyl mercury	ng/L	1-2	6	0.086	0.066	July	0.13	Aug
Total strontium	mg/L	-	6	0.113	0.076	May	0.138	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.75	0.33	Sep	1.50	Jul
Oilsands extractable acids	mg/L	-	6	2.75	1.60	Sep, Oct	3.90	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	0.86	<0.59	Sep	1.24	Oct
Total dibenzothiophenes[c]	ng/L	-	5	30.8	18.9	Sep	35.0	Aug
Total PAHs[c]	ng/L	-	5	178.0	142.5	Sep	181.1	Jun
Total Parent PAHs[c]	ng/L	-	5	23.3	21.9	Sep	24.1	Oct
Total Alkylated PAHs[c]	ng/L	-	5	154.5	120.6	Sep	157.9	Jun
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0092**	0.0052	Sep	**0.014**	Jul
Sulphide	mg/L	0.0019	5	**0.0066**	**0.003**	Sep, Oct	**0.0089**	Jun
Dissolved iron	mg/L	0.3	5	**0.39**	0.15	Jul	**0.84**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-7 Monthly concentrations of water quality measurement endpoints, Muskeg River above Muskeg Creek (*test* station MU5), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	7.91	7.85	Jun	8.09	Aug
Total suspended solids	mg/L	-	5	2.7	2.0	Sep	4.0	Jun
Conductivity	µS/cm	-	5	420	340	Jun	440	Jul
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.013	0.011	Oct	0.018	Jun
Total nitrogen	mg/L	-	5	0.98	0.77	Oct	1.10	Aug
Nitrate+nitrite	mg/L	3-124	5	0.048	0.029	Sep	0.094	Aug
Dissolved organic carbon	mg/L	-	5	19.0	18.0	Oct	23.0	Aug
Ions								
Sodium	mg/L	-	5	7.4	7.0	Sep	8.5	Oct
Calcium	mg/L	-	5	61.0	46.0	Jun	71.0	Jul
Magnesium	mg/L	-	5	15.0	12.0	Jun	16.0	Jul, Aug
Potassium	mg/L	-	5	1.10	0.84	Aug	1.30	Oct
Chloride	mg/L	120-640	5	4.4	3.20	July	4.9	Oct
Sulphate	mg/L	309-429[b]	5	1.0	0.67	Aug	1.4	Sep
Total dissolved solids	mg/L	-	5	240	230	Jun	290	Aug
Total alkalinity	mg/L	20 (min)	5	220	180	Jun	240	Jul
Selected metals								
Total aluminum	mg/L	-	6	0.026	0.015	Jul	0.055	Aug
Dissolved aluminum	mg/L	0.05	6	0.0022	0.0017	Oct	0.0029	Jun
Total arsenic	mg/L	0.005	6	0.00025	0.0002	May	0.00057	Jul
Total boron	mg/L	1.5-29	6	0.028	0.013	July	0.0331	Oct
Total molybdenum	mg/L	0.073	6	0.00007	0.00003	Sep	0.00012	Jul
Total mercury (ultra-trace)	ng/L	5-13	6	0.65	0.41	Oct	0.84	Jul
Total methyl mercury	ng/L	1-2	6	0.076	0.039	July	0.09	Jun, Aug
Total strontium	mg/L	-	6	0.119	0.083	May	0.146	Aug
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.67	0.45	Jul, Sep	1.14	Jun
Oilsands extractable acids	mg/L	-	6	2.00	1.30	Oct	3.90	Aug
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	1.04	<0.59	Sep, Oct	2.83	Jun
Total dibenzothiophenes[c]	ng/L	-	5	12.7	9.7	Sep	21.5	Jun
Total PAHs[c]	ng/L	-	5	137.7	129.1	Sep	154.4	Jun
Total Parent PAHs[c]	ng/L	-	5	22.7	22.71	Jul	22.92	Jun
Total Alkylated PAHs[c]	ng/L	-	5	115.0	106.4	Sep	131.4	Jun
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0064**	**0.0055**	Jun	**0.014**	Jul
Sulphide	mg/L	0.0019	5	**0.0088**	**0.0031**	Aug	**0.0150**	Jun
Dissolved iron	mg/L	0.3	6	**0.84**	**0.44**	Jul	**1.82**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-8 Monthly concentrations of water quality measurement endpoints, Muskeg River above Stanley Creek (*test* station MU6), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	7.74	7.55	Oct	7.97	Aug
Total suspended solids	mg/L	-	5	4.0	3.3	Jul, Aug	4.7	Sep, Oct
Conductivity	µS/cm	-	5	420	330	Jun	480	Jul
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.018	0.014	Jul	0.019	Sep
Total nitrogen	mg/L	-	5	<1.00	0.87	Oct	1.20	Jul, Aug
Nitrate+nitrite	mg/L	3-124	5	0.018	0.014	Sep	0.028	Aug
Dissolved organic carbon	mg/L	-	5	21.0	19.0	Sep, Oct	26.0	Aug
Ions								
Sodium	mg/L	-	5	7.4	6.5	Aug	7.9	Oct
Calcium	mg/L	-	5	57.0	45.0	Jun	77.0	Jul
Magnesium	mg/L	-	5	16.0	13.0	Jun	19.0	Jul
Potassium	mg/L	-	5	1.10	0.79	Aug	1.40	Oct
Chloride	mg/L	120-640	5	3.8	2.70	Jul	4.9	Oct
Sulphate	mg/L	309-429[b]	5	1.0	<0.5	Aug	1.4	Sep
Total dissolved solids	mg/L	-	5	270	230	Jun	310	Aug
Total alkalinity	mg/L	20 (min)	5	220	170	Jun	270	Jul
Selected metals								
Total aluminum	mg/L	-	6	0.026	0.012	May	0.034	Aug
Dissolved aluminum	mg/L	0.05	6	0.0023	0.0018	Oct	0.0033	May
Total arsenic	mg/L	0.005	6	0.000289	0.00022	May	0.000383	Aug
Total boron	mg/L	1.5-29	6	0.029	0.026	Jun	0.0356	Jul
Total molybdenum	mg/L	0.073	6	0.00006	0.00004	Jul, Oct	0.00011	May
Total mercury (ultra-trace)	ng/L	5-13	6	0.61	0.48	Oct	0.70	Sep
Total methyl mercury	ng/L	1-2	6	0.087	0.049	May	0.11	Aug
Total strontium	mg/L	-	6	0.132	0.075	May	0.173	Jul
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.67	0.48	Sep	2.02	Jul
Oilsands extractable acids	mg/L	-	6	2.00	1.70	May, Oct	5.30	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	1.26	0.89	Aug	1.39	Jul
Total dibenzothiophenes[c]	ng/L	-	5	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	5	125.9	125.1	Aug	126.1	Oct
Total Parent PAHs[c]	ng/L	-	5	22.7	22.49	Aug	22.73	Jun, Sep, Oct
Total Alkylated PAHs[c]	ng/L	-	5	103.2	102.6	Aug	103.4	Oct
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0072**	**0.0061**	Jun	**0.013**	Jul, Aug
Sulphide	mg/L	0.0019	5	**0.0070**	**0.0037**	Oct	**0.0160**	Jun
Dissolved iron	mg/L	0.3	6	**0.91**	**0.62**	Oct	**1.59**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-9 Monthly concentrations of water quality measurement endpoints, Muskeg River above Wapasu Creek (*test* station MU7), July to September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	3	7.87	7.76	Sep	7.91	Jul
Total suspended solids	mg/L	-	3	6.0	2.0	Sep	6.0	Jul, Aug
Conductivity	µS/cm	-	3	430	420	Sep	430	Jul, Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	3	0.012	0.011	Sep	0.032	Jul
Total nitrogen	mg/L	-	3	1.50	0.82	Sep	1.60	Aug
Nitrate+nitrite	mg/L	3-124	3	0.015	<0.005	Sep	0.016	Jul
Dissolved organic carbon	mg/L	-	3	22	19	Sep	22	Jul, Aug
Ions								
Sodium	mg/L	-	3	6.2	5.8	Aug	6.4	Jul
Calcium	mg/L	-	3	65.0	62	Sep	66.0	Aug
Magnesium	mg/L	-	3	18.0	18.00	Jul-Sep	18.0	Jul, Aug
Potassium	mg/L	-	3	0.9	0.92	Aug	1.4	Sep
Chloride	mg/L	120-640	3	2.4	2.20	Aug	3.9	Sep
Sulphate	mg/L	429[b]	3	1.1	<0.50	Aug	1.9	Sep
Total dissolved solids	mg/L	-	3	250	250	Jul, Sep	290	Aug
Total alkalinity	mg/L	20 (min)	3	230	230	Jul, Sep	240	Aug
Selected metals								
Total aluminum	mg/L	-	3	0.015	0.008	Jul	0.055	Aug
Dissolved aluminum	mg/L	0.05	3	0.0020	0.0013	Sep	0.0022	Jul
Total arsenic	mg/L	0.005	3	0.00041	0.00026	Sep	0.00041	Aug
Total boron	mg/L	1.5-29	3	0.0266	0.0237	Sep	0.0273	Jul
Total molybdenum	mg/L	0.073	3	0.00007	0.00005	Sep	0.00008	Jul
Total mercury (ultra-trace)	ng/L	5-13	3	0.75	0.64	Sep	0.92	Aug
Total methyl mercury	ng/L	1-2	3	0.157	0.101	Sep	0.176	Jul
Total strontium	mg/L	-	3	0.146	0.133	Sep	0.153	Aug
Total hydrocarbons								
BTEX	mg/L	-	3	<0.01	<0.01	Jul-Sep	<0.01	Jul-Sep
Fraction 1 (C6-C10)	mg/L	0.15	3	<0.01	<0.01	Jul-Sep	<0.01	Jul-Sep
Fraction 2 (C10-C16)	mg/L	0.11	3	<0.005	<0.005	Jul-Sep	<0.005	Jul-Sep
Fraction 3 (C16-C34)	mg/L	-	3	<0.02	<0.02	Jul-Sep	<0.02	Jul-Sep
Fraction 4 (C34-C50)	mg/L	-	3	<0.02	<0.02	Jul-Sep	<0.02	Jul-Sep
Naphthenic acids	mg/L	-	3	0.66	0.39	Sep	1.46	Jul
Oilsands extractable acids	mg/L	-	3	2.90	1.80	Sep	4.30	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	3	<13.55	<13.55	Jul, Sep	18.10	Aug
Retene	ng/L	-	3	1.28	0.82	Sep	1.31	Jul
Total dibenzothiophenes[c]	ng/L	-	3	<8.17	<8.17	Jul-Sep	<8.17	Jul-Sep
Total PAHs[c]	ng/L	-	3	125.9	125.1	Jul	135.9	Aug
Total Parent PAHs[c]	ng/L	-	3	22.7	22.5	Jul	30.8	Aug
Total Alkylated PAHs[c]	ng/L	-	3	103.2	102.6	Jul	105.1	Aug
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.012**	**0.008**	Sep	**0.015**	Jul
Sulphide	mg/L	0.0019	3	**0.0085**	**0.0070**	Sep	**0.0093**	Jul
Dissolved iron	mg/L	0.3	3	**0.88**	**0.71**	Sep	**1.24**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-10 Monthly concentrations of water quality measurement endpoints, Muskeg River above Wapasu Creek (*test* station MU8), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	7.75	7.54	Oct	7.78	Jul, Aug
Total suspended solids	mg/L	-	5	2.7	1.0	Sep	8.0	Aug
Conductivity	µS/cm	-	5	390	310	Jun	410	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.016	0.009	Oct	0.023	Jul, Aug
Total nitrogen	mg/L	-	5	0.92	0.75	Sep	1.10	Aug
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.005	Jun-Oct	<0.005	Jun-Oct
Dissolved organic carbon	mg/L	-	5	22.0	19.0	Sep, Oct	24.0	Aug
Ions								
Sodium	mg/L	-	5	7.0	5.4	Jul	7.6	Oct
Calcium	mg/L	-	5	54.0	42.0	Jun	59.0	Jul
Magnesium	mg/L	-	5	17.0	14.0	Jun	19.0	Jul
Potassium	mg/L	-	5	1.20	0.91	Jul	2.10	Oct
Chloride	mg/L	120-640	5	3.3	1.40	Jul	6.3	Oct
Sulphate	mg/L	309-429[b]	5	1.0	0.71	Aug	2.6	Oct
Total dissolved solids	mg/L	-	5	260	210	Jun, Sep	280	Aug
Total alkalinity	mg/L	20 (min)	5	210	170	Jun	220	Jul
Selected metals								
Total aluminum	mg/L	-	6	0.008	0.005	Oct	0.027	Jun
Dissolved aluminum	mg/L	0.05	6	0.0016	0.0013	Sep	0.00186	May
Total arsenic	mg/L	0.005	6	0.000295	0.00022	May	0.000493	Aug
Total boron	mg/L	1.5-29	6	0.020	0.0171	Sep	0.0229	Oct
Total molybdenum	mg/L	0.073	6	0.00007	0.000043	Sep	0.000112	May
Total mercury (ultra-trace)	ng/L	5-13	6	0.83	0.53	May	1.19	Aug
Total methyl mercury	ng/L	1-2	6	0.185	0.061	May	0.441	Aug
Total strontium	mg/L	-	6	0.123	0.067	May	0.133	Aug
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	Jun-Oct	<0.01	Jun-Oct
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	Jun-Oct	<0.01	Jun-Oct
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	Jun-Oct	<0.005	Jun-Oct
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	Jun-Oct	<0.02	Jun-Oct
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	Jun-Oct	<0.02	Jun-Oct
Naphthenic acids	mg/L	-	6	0.29	0.08	Jun	0.71	Jul
Oilsands extractable acids	mg/L	-	6	1.60	0.90	Jun	2.40	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	19.20	Aug
Retene	ng/L	-	5	<0.59	<0.59	Jul, Sep, Oct	1.42	Aug
Total dibenzothiophenes[c]	ng/L	-	5	<8.17	<8.17	-	8.86	Aug
Total PAHs[c]	ng/L	-	5	125.9	125.1	Jun, Jul	139.1	Aug
Total Parent PAHs[c]	ng/L	-	5	22.7	22.49	Jun, Jul	32.23	Aug
Total Alkylated PAHs[c]	ng/L	-	5	103.2	102.6	Jun, Jul	106.9	Aug
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0085**	**0.0061**	Jun	**0.014**	Jul
Sulphide	mg/L	0.0019	5	**0.0085**	**0.0046**	Jul	**0.0150**	Jun
Dissolved iron	mg/L	0.3	3	**0.34**	0.15	May	**0.74**	Aug

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-11 Monthly concentrations of water quality measurement endpoints, Muskeg River at Imperial Kearl Lake Road (*test* station MU9), July and August 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Data	
			July	August
Physical variables				
pH	pH units	6.5-9.0	7.96	8.05
Total suspended solids	mg/L	-	2.0	2.7
Conductivity	µS/cm	-	350	400
Nutrients				
Total dissolved phosphorus	mg/L	-	0.019	0.015
Total nitrogen	mg/L	-	0.83	1.0
Nitrate+nitrite	mg/L	3-124	<0.005	<0.005
Dissolved organic carbon	mg/L	-	21	25
Ions				
Sodium	mg/L	-	3.6	3.6
Calcium	mg/L	-	51	59
Magnesium	mg/L	-	18	20
Potassium	mg/L	-	0.71	0.83
Chloride	mg/L	120-640	<1	<1
Sulphate	mg/L	429[b]	0.58	<0.5
Total dissolved solids	mg/L	-	250	270
Total alkalinity	mg/L	20 (min)	190	220
Selected metals			1.07	0.91
Total aluminum	mg/L	-	0.0212	0.0193
Dissolved aluminum	mg/L	0.05	0.00216	0.002
Total arsenic	mg/L	0.005	0.000565	0.000766
Total boron	mg/L	1.5-29	0.0137	0.0097
Total molybdenum	mg/L	0.073	0.000127	0.000104
Total mercury (ultra-trace)	ng/L	5-13	1.2	1.13
Total methyl mercury	ng/L	1-2	0.27	0.264
Total strontium	mg/L	-	0.0942	0.112
Total hydrocarbons			2.2	1.9
BTEX	mg/L	-	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02
Naphthenic acids	mg/L	-	0.38	0.54
Oilsands extractable acids	mg/L	-	2.2	1.9
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	1,000	<13.55	<13.55
Retene	ng/L	-	<0.59	<0.59
Total dibenzothiophenes[c]	ng/L	-	<8.17	<8.17
Total PAHs[c]	ng/L	-	125.2	125.2
Total Parent PAHs[c]	ng/L	-	22.6	22.5
Total Alkylated PAHs[c]	ng/L	-	102.6	102.6
Other variables that exceeded Alberta guidelines in 2015				
Total phenols	mg/L	0.004	**0.012**	**0.013**
Sulphide	mg/L	0.0019	**0.0062**	**0.012**
Dissolved iron	mg/L	0.3	**0.407**	**0.381**

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] Based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.2-12 Monthly concentrations of water quality measurement endpoints, Muskeg River upland (*test* station MU10), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	7.75	7.56	Oct	7.89	Aug
Total suspended solids	mg/L	-	5	2.0	<1.0	Sep	3.3	Jul, Aug
Conductivity	µS/cm	-	5	350	280	Jun	400	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.012	0.010	Aug	0.019	Jul
Total nitrogen	mg/L	-	5	0.89	0.61	Oct	1.10	Aug
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.005	Jun to Oct	<0.005	Jun to Oct
Dissolved organic carbon	mg/L	-	5	22.0	19.0	Oct	26.0	Aug
Ions								
Sodium	mg/L	-	5	3.6	3.5	Aug	3.7	Jun, Sep
Calcium	mg/L	-	5	50.0	38.0	Jun	58.0	Aug
Magnesium	mg/L	-	5	16.0	14.0	Jun	20.0	Aug
Potassium	mg/L	-	5	0.72	0.69	Jul	0.94	Oct
Chloride	mg/L	120-640	5	1.4	<1.0	Jul	2.1	Oct
Sulphate	mg/L	309[b]	5	0.66	<0.50	Jul, Aug	<1.00	Jun, Sep
Total dissolved solids	mg/L	-	5	220	180	Sep	270	Aug
Total alkalinity	mg/L	20 (min)	5	190	160	Jun	220	Aug
Selected metals								
Total aluminum	mg/L	-	6	0.013	0.007	Aug	0.021	May
Dissolved aluminum	mg/L	0.05	6	0.0022	0.0018	Sep	0.0029	Jun
Total arsenic	mg/L	0.005	6	0.00033	0.00023	May	0.00092	Aug
Total boron	mg/L	1.5-29	6	0.013	0.009	Aug	0.043	Jul
Total molybdenum	mg/L	0.073	6	0.00008	0.00006	Jul	0.00019	May
Total mercury (ultra-trace)	ng/L	5-13	6	0.86	0.64	Sep	1.14	Jul
Total methyl mercury	ng/L	1-2	6	0.147	0.080	May	0.28	Jul
Total strontium	mg/L	-	6	0.088	0.050	May	0.162	Jul
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	May-Oct	<0.01	May-Oct
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	May-Oct	<0.01	May-Oct
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	May-Oct	<0.005	May-Oct
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	May-Oct	<0.02	May-Oct
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	May-Oct	<0.02	May-Oct
Naphthenic acids	mg/L	-	6	0.18	<0.08	Jun, Oct	1.56	Jul
Oilsands extractable acids	mg/L	-	6	1.30	0.70	Sep, Oct	4.10	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	18.20	Aug
Retene	ng/L	-	5	<0.59	<0.59	-	0.81	Aug
Total dibenzothiophenes[c]	ng/L	-	5	<8.17	<8.17	Jun to Oct	8.2	Jun to Oct
Total PAHs[c]	ng/L	-	5	125.9	125.1	Jul	136.2	Aug
Total Parent PAHs[c]	ng/L	-	5	22.7	22.5	Jul	31.3	Aug
Total Alkylated PAHs[c]	ng/L	-	5	103.2	102.6	Jul	104.9	Aug
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0100**	0.0038	Sep	**0.057**	Jul
Sulphide	mg/L	0.0019	3	**0.0070**	**0.0019**	Sep, Oct	**0.0110**	Jun
Dissolved iron	mg/L	0.3	3	0.25	0.12	May	**0.81**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] Based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-13 Monthly concentrations of water quality measurement endpoints, Jackpine Creek near the mouth (*test* station JA1 [JAC-1]), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	7.92	7.88	May	8.12	Aug
Total suspended solids	mg/L	-	6	2.35	<1.00	Sep	4.70	May
Conductivity	µS/cm	-	6	225	140	May	280	Jul
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.013	0.010	Sep	0.019	Jul
Total nitrogen	mg/L	-	6	1.00	0.74	Oct	1.10	Aug
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.005	-	0.045	May
Dissolved organic carbon	mg/L	-	6	27.0	19.0	May	33.0	Aug
Ions								
Sodium	mg/L	-	6	13.0	9.4	May	15.0	Oct
Calcium	mg/L	-	6	26.5	15.0	May	36.0	Jul
Magnesium	mg/L	-	6	7.7	4.8	May	10.0	Jul
Potassium	mg/L	-	6	0.76	0.48	Aug	1.80	May
Chloride	mg/L	120-640	6	2.90	2.50	Jun	3.80	Oct
Sulphate	mg/L	218-309[b]	6	1.6	<1.0	May	5.7	Jul
Total dissolved solids	mg/L	-	6	175	56	May	230	Jul, Aug
Total alkalinity	mg/L	20 (min)	6	110	63	May	150	Jul
Selected metals								
Total aluminum	mg/L	-	6	0.042	0.029	Oct	0.151	May
Dissolved aluminum	mg/L	0.05	6	0.0048	0.0032	Aug	0.0073	May
Total arsenic	mg/L	0.005	6	0.00048	0.00034	May	0.00068	Jul
Total boron	mg/L	1.5-29	6	0.043	0.036	Sep	0.054	Jun
Total molybdenum	mg/L	0.073	6	0.00012	0.00007	Oct	0.0002	Jul
Total mercury (ultra-trace)	ng/L	5-13	6	1.18	0.75	Oct	1.56	May
Total methyl mercury	ng/L	1-2	6	0.152	0.069	May	0.22	Aug
Total strontium	mg/L	-	6	0.103	0.055	May	0.134	Jul
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.64	0.17	Sep, Oct	0.91	Aug
Oilsands extractable acids	mg/L	-	6	2.55	1.10	Oct	4.20	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	0.64	<0.59	Sep, Oct	2.19	May
Total dibenzothiophenes[c]	ng/L	-	6	8.67	<8.17	Aug, Sep	15.23	May
Total PAHs[c]	ng/L	-	6	127.15	125.46	Aug	139.71	May
Total Parent PAHs[c]	ng/L	-	6	22.54	22.36	May	22.73	Sep
Total Alkylated PAHs[c]	ng/L	-	6	104.54	102.87	Aug	117.35	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0088**	0.003	May	**0.016**	Jul
Sulphide	mg/L	0.0019	6	**0.0083**	**0.0044**	Oct	**0.0120**	Jun
Dissolved iron	mg/L	0.3	4	**0.41**	0.15	May	**0.44**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] Based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-14 Monthly concentrations of water quality measurement endpoints, Jackpine Creek at Canterra Road (*test* station TR3.1), July to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	8.00	7.84	Sep	8.10	Jul
Total suspended solids	mg/L	-	4	1.7	<1.0	Oct	2.7	Jul
Conductivity	µS/cm	-	4	235	220	Sep	250	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.016	0.012	Sep	0.024	Jul
Total nitrogen	mg/L	-	4	0.91	0.75	Oct	1.10	Aug
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.005	-	<0.005	-
Dissolved organic carbon	mg/L	-	4	27.0	25.0	Sep	33.0	Aug
Ions								
Sodium	mg/L	-	4	13.0	13.0	Jul-Sep	14.0	Oct
Calcium	mg/L	-	4	29.5	26.0	Sep	35.0	Aug
Magnesium	mg/L	-	4	8.3	7.0	Sep	9.6	Aug
Potassium	mg/L	-	4	0.58	0.48	Jul	0.82	Oct
Chloride	mg/L	120-640	4	2.80	2.50	Jul	3.80	Oct
Sulphate	mg/L	309[b]	4	1.2	0.92	Jul	2.0	Sep
Total dissolved solids	mg/L	-	4	185	150	Sep	220	Aug
Total alkalinity	mg/L	20 (min)	4	115	110	Sep, Oct	130	Aug
Selected metals								
Total aluminum	mg/L	-	4	0.040	0.032	Oct	0.056	Jul
Dissolved aluminum	mg/L	0.05	4	0.0048	0.0042	Aug	0.0050	Jul
Total arsenic	mg/L	0.005	4	0.000556	0.000367	Oct	0.000668	Jul
Total boron	mg/L	1.5-29	4	0.034	0.0275	Oct	0.0393	Aug
Total molybdenum	mg/L	0.073	4	0.00009	0.00007	Oct	0.000127	Jul
Total mercury (ultra-trace)	ng/L	5-13	4	0.91	0.69	Oct	1.06	Jul
Total methyl mercury	ng/L	1-2	4	0.170	0.130	Oct	0.234	Aug
Total strontium	mg/L	-	4	0.102	0.084	Oct	0.118	Aug
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	4	0.51	0.15	Oct	0.94	Jul
Oilsands extractable acids	mg/L	-	4	1.90	1.10	Oct	3.90	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	18.00	Aug
Retene	ng/L	-	4	1.03	<0.59	Sep, Oct	2.01	Aug
Total dibenzothiophenes[c]	ng/L	-	4	9.16	<8.17	Sep	10.83	Aug
Total PAHs[c]	ng/L	-	4	123.0	113.2	Oct	143.2	Aug
Total Parent PAHs[c]	ng/L	-	4	15.7	10.36	Oct	31.67	Aug
Total Alkylated PAHs[c]	ng/L	-	4	107.4	102.7	Oct	111.5	Aug
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0093**	**0.0054**	Sep	**0.017**	Jul
Sulphide	mg/L	0.0019	4	**0.006**	**0.0031**	Aug	**0.016**	Jul
Dissolved iron	mg/L	0.3	3	**0.39**	0.29	Sep	**0.47**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-15 Monthly concentrations of water quality measurement endpoints, Jackpine Creek 16.5 km upstream of the Muskeg River (*baseline* station TR3.2), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	7.82	7.63	Oct	7.92	Jul
Total suspended solids	mg/L	-	5	1.3	<1.0	Sep	2.7	Jul
Conductivity	µS/cm	-	5	220	200	Jun	250	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.016	0.012	Sep	0.026	Jul
Total nitrogen	mg/L	-	5	1.00	0.83	Oct	1.10	Aug
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.005	Jun to Oct	<0.005	Jun to Oct
Dissolved organic carbon	mg/L	-	5	27.0	26.0	Jul, Oct	35.0	Aug
Ions								
Sodium	mg/L	-	5	13.0	11.0	Sep	14.0	Oct
Calcium	mg/L	-	5	24.0	21.0	Sep	35.0	Aug
Magnesium	mg/L	-	5	7.2	6.0	Sep	9.7	Aug
Potassium	mg/L	-	5	0.58	0.46	Jul	0.83	Oct
Chloride	mg/L	120-640	5	2.5	2.00	June	3.6	Oct
Sulphate	mg/L	309[b]	5	0.55	0.53	Aug	<2.00	Sep
Total dissolved solids	mg/L	-	5	170	140	Jun	220	Aug
Total alkalinity	mg/L	20 (min)	5	110	100	Jun, Sep	130	Aug
Selected metals								
Total aluminum	mg/L	-	6	0.044	0.037	Jul	0.090	Oct
Dissolved aluminum	mg/L	0.05	6	0.0059	0.0050	Sep	0.02480	May
Total arsenic	mg/L	0.005	6	0.000502	0.00033	May	0.000714	Jul
Total boron	mg/L	1.5-29	6	0.043	0.0313	Oct	0.0486	Jun
Total molybdenum	mg/L	0.073	6	0.00011	0.000076	Sep	0.000123	May
Total mercury (ultra-trace)	ng/L	5-13	6	1.05	0.76	Oct	1.49	May
Total methyl mercury	ng/L	1-2	6	0.152	0.073	May	0.245	Aug
Total strontium	mg/L	-	6	0.092	0.053	May	0.114	Aug
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.41	0.13	Oct	1.05	Jul
Oilsands extractable acids	mg/L	-	6	2.10	1.10	Oct	3.20	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	May to Oct	<13.55	May to Oct
Retene	ng/L	-	6	0.64	<0.59	Sep, Oct	2.19	May
Total dibenzothiophenes[c]	ng/L	-	6	8.67	<8.17	Aug, Sep	15.23	May
Total PAHs[c]	ng/L	-	6	127.1	125.46	Aug	139.7	May
Total Parent PAHs[c]	ng/L	-	6	22.5	22.36	May	22.73	Sep, Oct
Total Alkylated PAHs[c]	ng/L	-	6	104.5	102.9	Aug	117.3	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0130**	**0.0058**	Sep	**0.018**	Jul
Sulphide	mg/L	0.0019	5	**0.0097**	**0.0044**	Oct	**0.0400**	Jul
Dissolved iron	mg/L	0.3	5	**0.41**	0.15	May	**0.50**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-16 Monthly concentrations of water quality measurement endpoints, Wapasu Creek (*test* station WA1 [WAC-1]), May to August and October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.69	7.44	Oct	7.76	Aug
Total suspended solids	mg/L	-	4	4.7	2	Jun, Oct	22.0	Jul
Conductivity	µS/cm	-	4	300	240	Jun	340	Jul
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.017	0.010	Jun	0.023	Oct
Total nitrogen	mg/L	-	4	1.20	0.79	Oct	1.50	Jul
Nitrate+nitrite	mg/L	3-124	4	0.012	0.007	Jun	0.032	Jul
Dissolved organic carbon	mg/L	-	4	23.0	19.0	Jul	26.0	Aug
Ions								
Sodium	mg/L	-	4	9.2	8.6	Jul	9.4	Jun
Calcium	mg/L	-	4	40.0	30.0	Jun	48.0	Jul
Magnesium	mg/L	-	4	11.5	9.8	Jun	14.0	Jul
Potassium	mg/L	-	4	0.71	0.67	Aug	1.20	Oct
Chloride	mg/L	120-640	4	6.9	5.8	Jul	8.7	Oct
Sulphate	mg/L	309[b]	4	<0.50	<0.50	-	<1.00	Jun
Total dissolved solids	mg/L	-	4	215	180	Jun	230	Jul
Total alkalinity	mg/L	20 (min)	4	150	120	Jun	170	Jul
Selected metals								
Total aluminum	mg/L	-	5	0.027	0.007	Jun	0.088	Jul
Dissolved aluminum	mg/L	0.05	5	0.0033	0.0029	May	0.00406	Jul
Total arsenic	mg/L	0.005	5	0.000405	0.00024	May	0.000666	Jul
Total boron	mg/L	1.5-29	5	0.025	0.0235	Jul	0.0295	May
Total molybdenum	mg/L	0.073	5	0.00008	0.00006	Jun	0.000096	Jul
Total mercury (ultra-trace)	ng/L	5-13	5	0.93	0.56	May	1.45	Jul
Total methyl mercury	ng/L	1-2	5	0.184	0.041	May	0.288	Aug
Total strontium	mg/L	-	5	0.097	0.052	May	0.119	Jul
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	5	0.34	0.13	Jun	0.64	Jul
Oilsands extractable acids	mg/L	-	5	1.80	0.70	Jun	2.20	Jul, Aug
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	3	<13.55	<13.55	Jul, Oct	18.10	Aug
Retene	ng/L	-	3	4.78	<0.59	Oct	7.48	Jul
Total dibenzothiophenes[c]	ng/L	-	3	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	3	131.1	125.91	Oct	138.2	Aug
Total Parent PAHs[c]	ng/L	-	3	22.7	22.49	Jul	30.67	Aug
Total Alkylated PAHs[c]	ng/L	-	3	107.6	103.2	Oct	108.6	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0113**	**0.0069**	Oct	**0.0140**	Jul
Sulphide	mg/L	0.0019	4	**0.0125**	**0.0088**	Oct	**0.0140**	Jul
Dissolved iron	mg/L	0.3	4	**1.40**	0.28	May	**2.00**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-17 Monthly concentrations of water quality measurement endpoints, Stanley Creek (*test* station STC-1), May to September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	7.79	7.70	Jul	7.92	Sep
Total suspended solids	mg/L	-	5	<1.0	<1.0	May, Jun, Aug	15.0	Sep
Conductivity	µS/cm	-	5	340	280	May	370	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.012	0.011	Jun, Sep	0.029	Jul
Total nitrogen	mg/L	-	5	1.00	0.30	Aug	1.20	Sep
Nitrate+nitrite	mg/L	3-124	5	0.006	<0.005	Jun, Aug	0.78	Sep
Dissolved organic carbon	mg/L	-	5	7.8	5.0	Jun	11.0	Sep
Ions								
Sodium	mg/L	-	5	3.1	2.4	Sep	3.7	Jul
Calcium	mg/L	-	5	53.0	40.0	May	59.0	Aug
Magnesium	mg/L	-	5	12.0	10.0	May	14.0	Aug, Sep
Potassium	mg/L	-	5	0.73	0.42	Sep	1.10	May
Chloride	mg/L	120-640	5	<1.0	<1.0	May to Sep	<1.0	May-Sep
Sulphate	mg/L	309-429[b]	5	<1.0	<1.0	Jun, Aug, Sep	4.4	May
Total dissolved solids	mg/L	-	5	220	60	May	230	Aug
Total alkalinity	mg/L	20 (min)	5	180	140	May	200	Aug
Selected metals								
Total aluminum	mg/L	-	5	0.006	0.005	May	0.044	Jul
Dissolved aluminum	mg/L	0.05	5	0.0005	0.00028	Aug	0.0010	Jun
Total arsenic	mg/L	0.005	5	0.000077	0.00006	May, Jun	0.000094	Jul
Total boron	mg/L	1.5-29	5	0.033	0.0232	Sep	0.0452	Jul
Total molybdenum	mg/L	0.073	5	0.00004	0.000024	Aug	0.000049	Jul
Total mercury (ultra-trace)	ng/L	5-13	5	0.49	0.37	Aug	0.69	Sep
Total methyl mercury	ng/L	1-2	5	0.077	0.015	May	0.240	Jun
Total strontium	mg/L	-	5	0.108	0.087	May	0.138	Aug
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	5	0.86	0.29	Sep	1.27	Aug
Oilsands extractable acids	mg/L	-	5	2.90	1.30	Sep	3.50	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	15.30	Sep
Retene	ng/L	-	5	<0.59	<0.59	-	0.95	Jul
Total dibenzothiophenes[c]	ng/L	-	5	<8.17	<8.17	-	10.62	Sep
Total PAHs[c]	ng/L	-	5	126.4	124.8	May	142.0	Sep
Total Parent PAHs[c]	ng/L	-	5	22.5	22.15	May	24.48	Sep
Total Alkylated PAHs[c]	ng/L	-	5	<102.61	<102.61	May to Jul	117.5	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.0086**	<0.002	Jun	**0.011**	Jul
Sulphide	mg/L	0.0019	4	**0.007**	<0.0019	May	**0.033**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.2-18 Seasonal concentrations of water quality measurement endpoints, Kearl Lake (*test* station KL1 [KEL-1]), May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	3	7.91	7.88	Sep	8.08	Jul
Total suspended solids	mg/L	-	3	2.7	2.7	May, Sep	4.0	Jul
Conductivity	µS/cm	-	3	180	150	May	180	Jul, Sep
Nutrients								
Total dissolved phosphorus	mg/L	-	3	0.007	0.004	Jul	0.008	Sep
Total nitrogen	mg/L	-	3	<1.00	0.90	Sep	1.10	Jul
Nitrate+nitrite	mg/L	3-124	3	<0.005	<0.003	May	0.018	Jul
Dissolved organic carbon	mg/L	-	3	21	18	May	22	Sep
Ions								
Sodium	mg/L	-	3	8.9	8.1	May	9.0	Jul
Calcium	mg/L	-	3	19.0	15	May	20.0	Sep
Magnesium	mg/L	-	3	6.7	5.70	May	7.1	Sep
Potassium	mg/L	-	3	0.94	0.92	Jul	0.95	Sep
Chloride	mg/L	120-640	3	1.2	1.00	May	1.7	Sep
Sulphate	mg/L	429[b]	3	<1.0	<1.0	-	<1.0	-
Total dissolved solids	mg/L	-	3	150	120	May	150	Jul, Sep
Total alkalinity	mg/L	20 (min)	3	89	79	May	90	Jul
Selected metals								
Total aluminum	mg/L	-	3	0.009	0.007	Jul	0.014	May
Dissolved aluminum	mg/L	0.05	3	0.0010	0.0007	Sep	0.0015	Jul
Total arsenic	mg/L	0.005	3	0.00030	0.00028	May	0.00031	Jul
Total boron	mg/L	1.5-29	3	0.0426	0.0343	May	0.0481	Sep
Total molybdenum	mg/L	0.073	3	0.00007	0.00004	May	0.00012	Jul
Total mercury (ultra-trace)	ng/L	5-13	3	0.63	0.55	Sep	0.67	Jul
Total methyl mercury	ng/L	1-2	3	0.041	0.038	May	0.055	Sep
Total strontium	mg/L	-	3	0.062	0.053	May	0.064	Jul
Total hydrocarbons								
BTEX	mg/L	-	3	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	3	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	3	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	3	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	3	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	3	0.81	0.47	May	0.97	Jul
Oilsands extractable acids	mg/L	-	3	2.30	2.10	May	2.50	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	3	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	3	<0.59	<0.59	May, Sep	0.76	Jul
Total dibenzothiophenes[c]	ng/L	-	3	8.29	8.25	May	27.08	Jul
Total PAHs[c]	ng/L	-	3	131.6	124.8	May	174.7	Jul
Total Parent PAHs[c]	ng/L	-	3	22.8	22.2	May	23.6	Jul
Total Alkylated PAHs[c]	ng/L	-	3	108.8	102.7	May	151.1	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	2	**0.011**	0.003	May	**0.012**	Sep
Sulphide	mg/L	0.0019	2	**0.0062**	<0.0019	Jul	**0.0089**	May

Values in **bold** are above guideline.

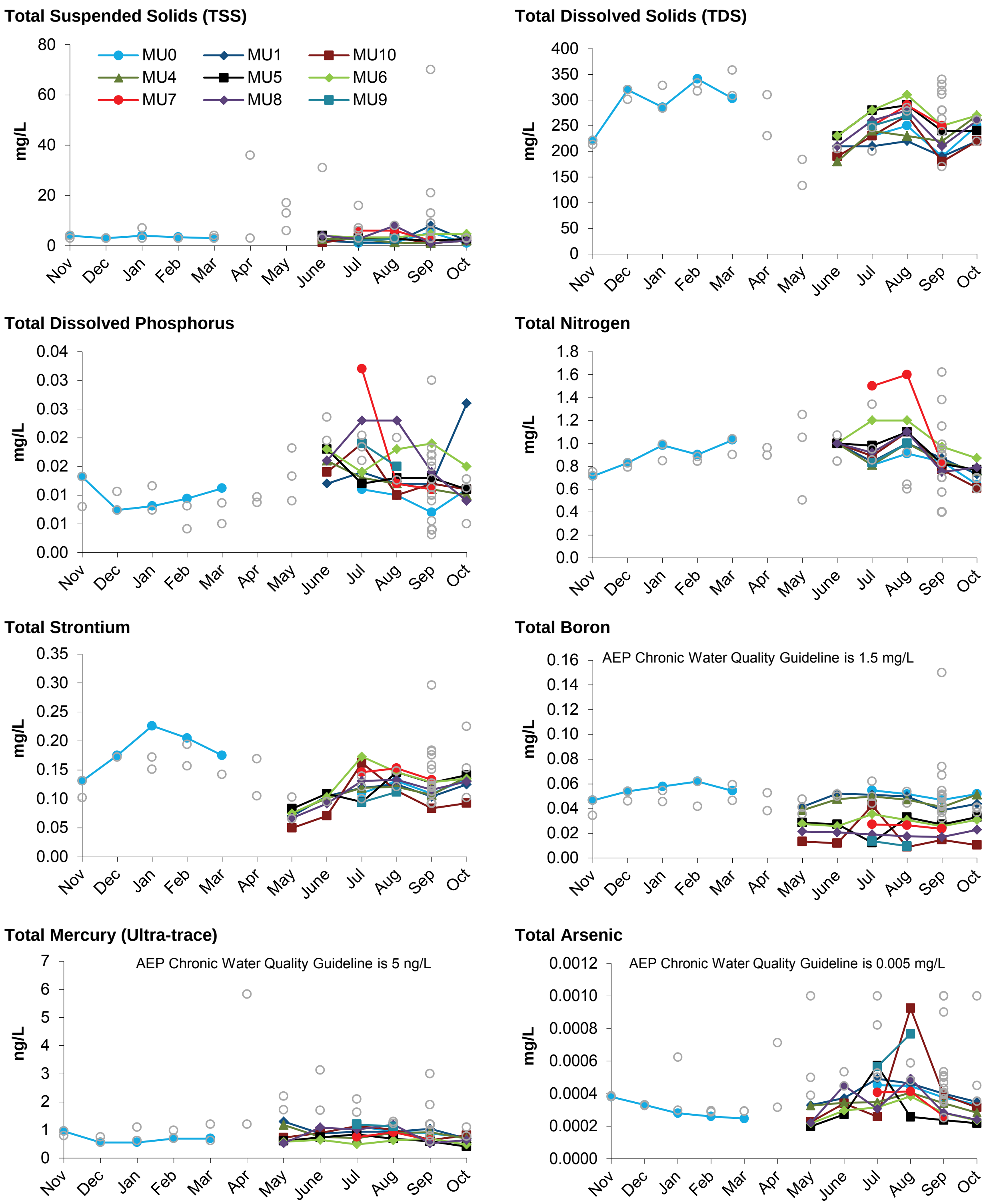
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

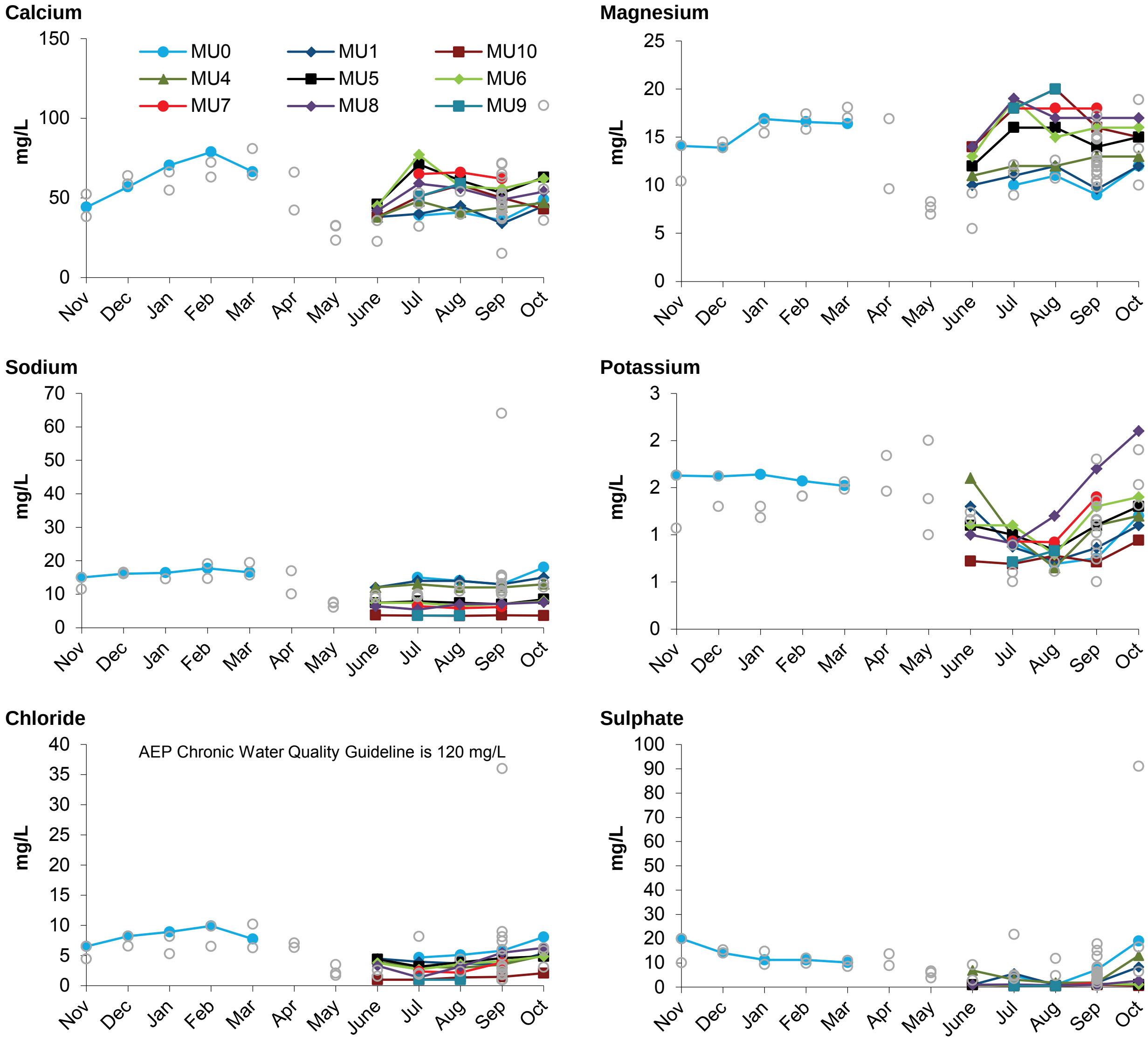
[d] n value refers to number of exceedances in 2015.

Figure 5.2-7 Selected water quality measurement endpoints in the Muskeg River (monthly data) in the 2015 WY.



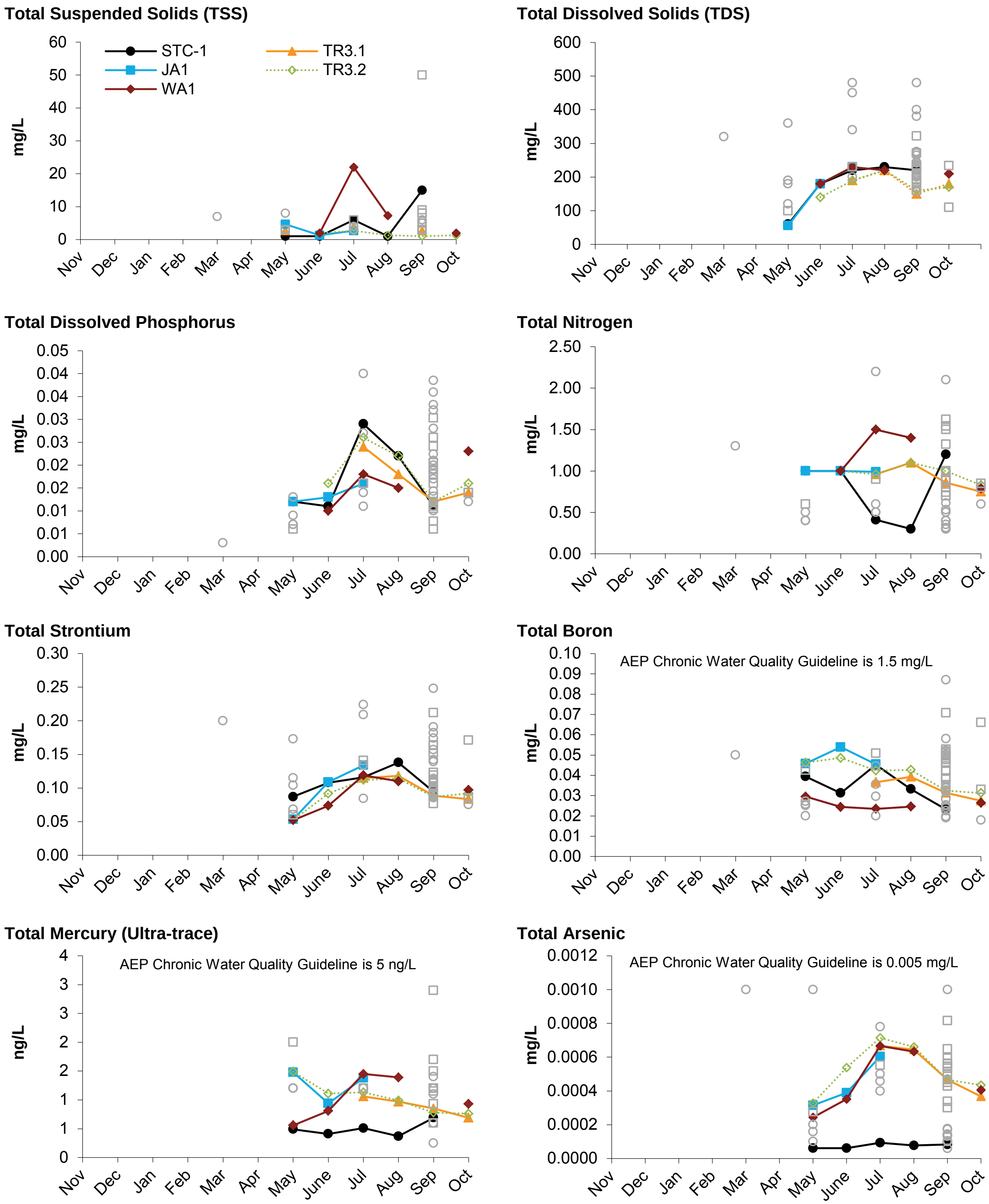
Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.2-7 (Cont'd.)



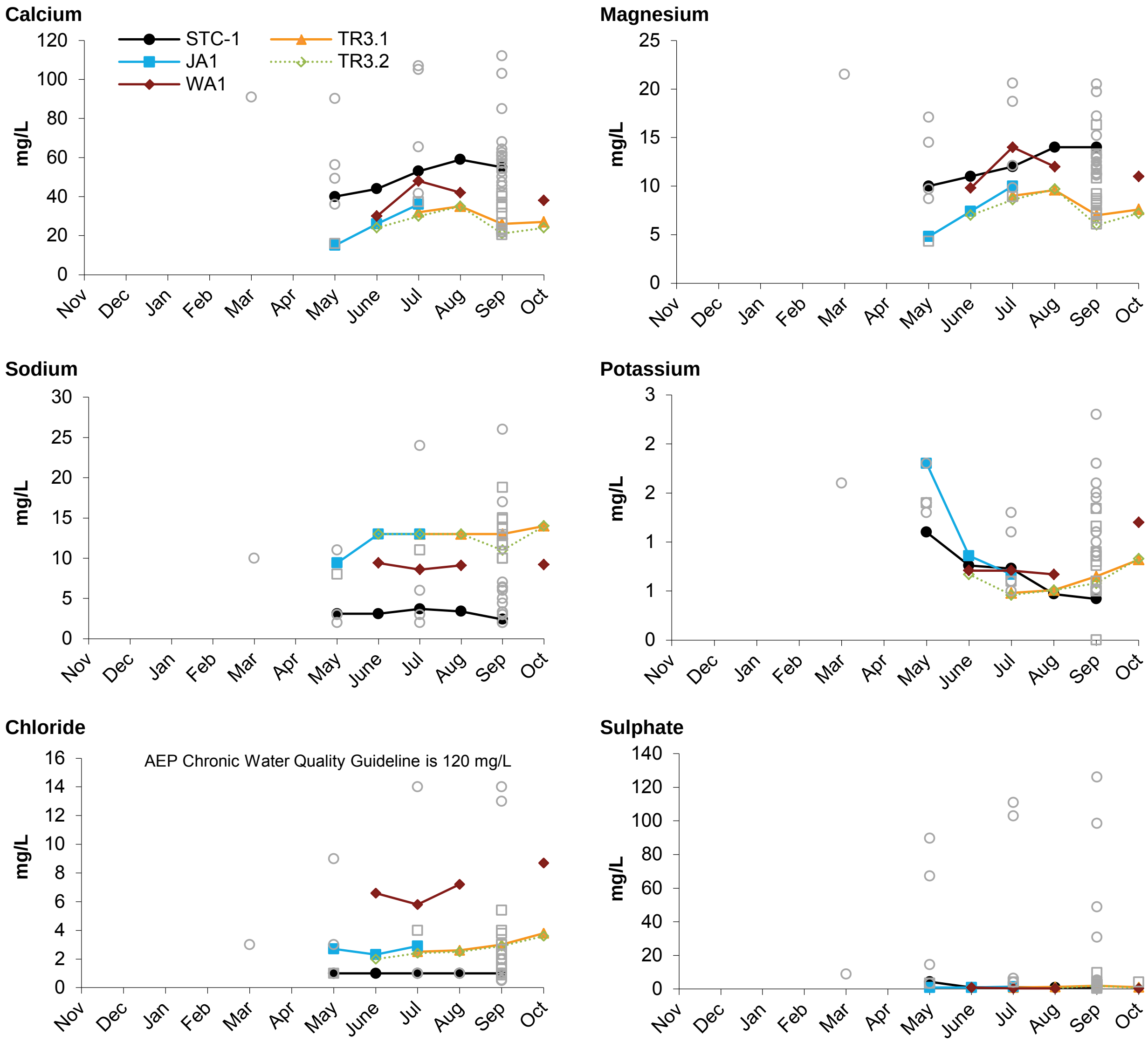
Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.2-8 Selected water quality measurement endpoints in tributaries of the Muskeg River (monthly data) in the 2015 WY.



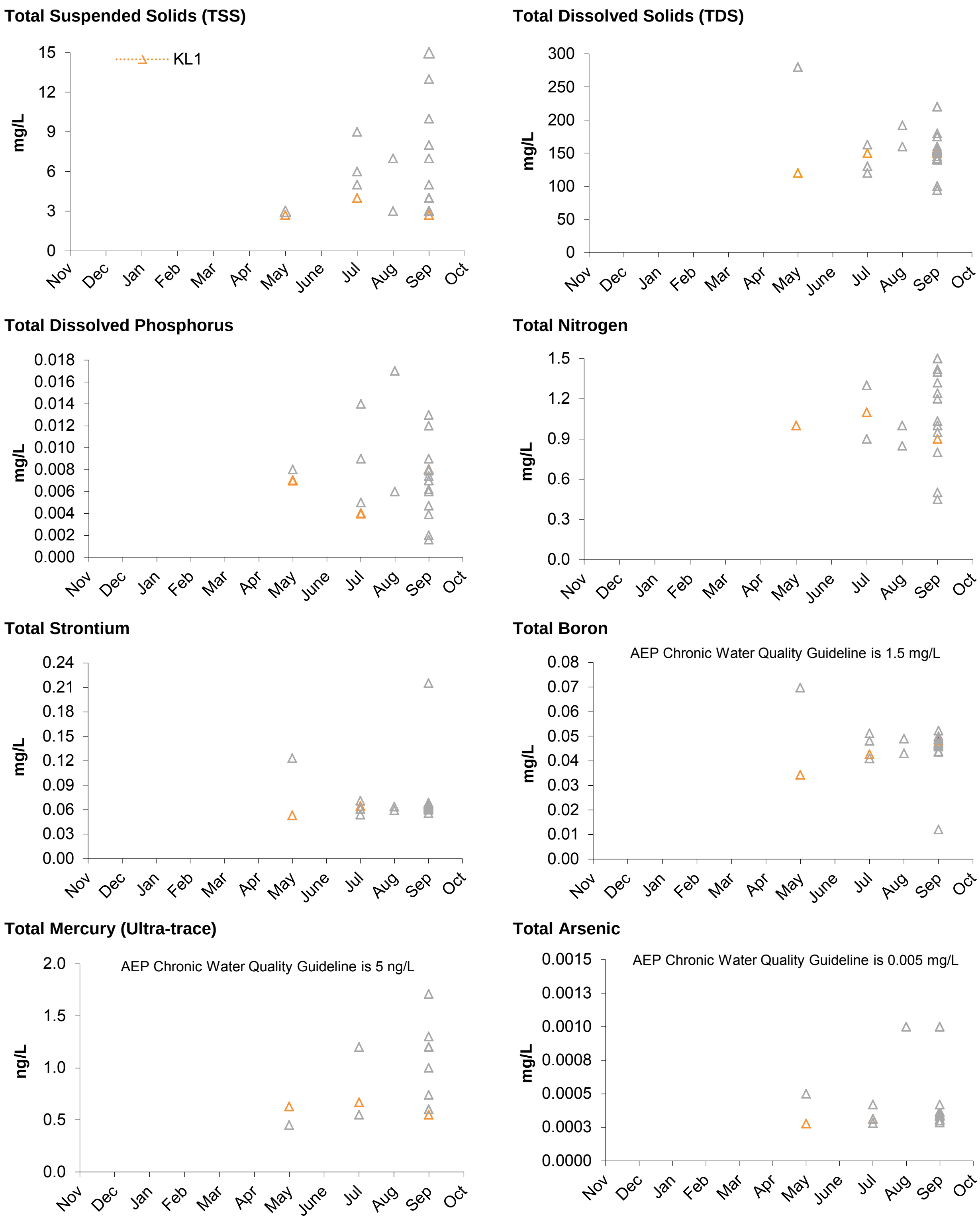
Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.2-8 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

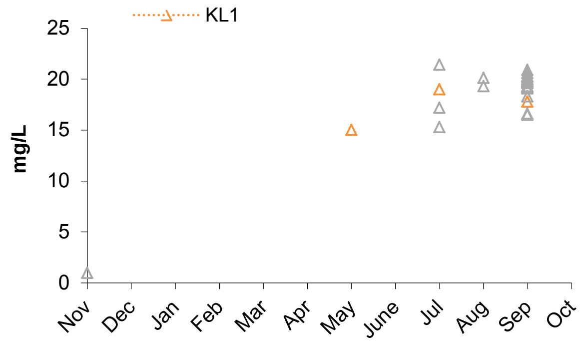
Figure 5.2-9 Selected water quality measurement endpoints in Kearl Lake (seasonal data) in the 2015 WY.



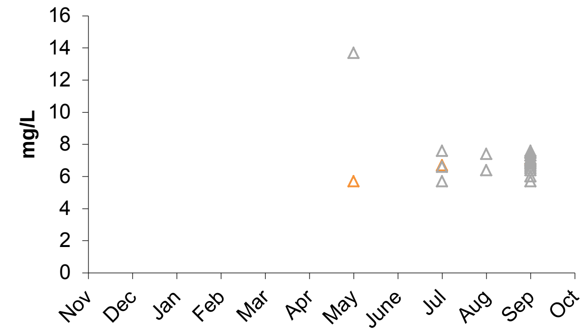
Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.2-9 (Cont'd.)

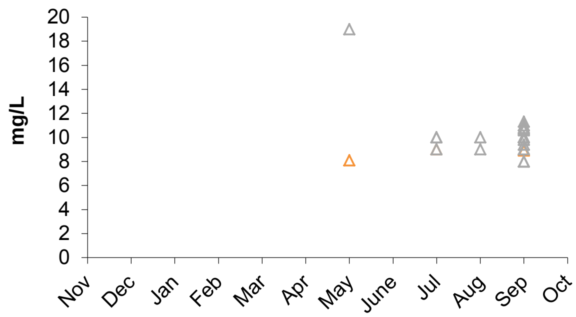
Calcium



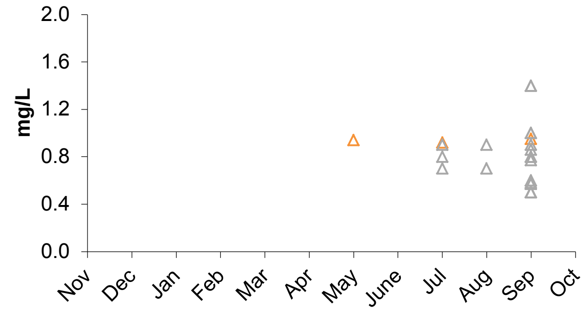
Magnesium



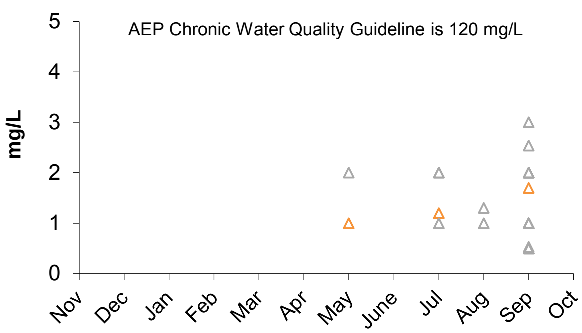
Sodium



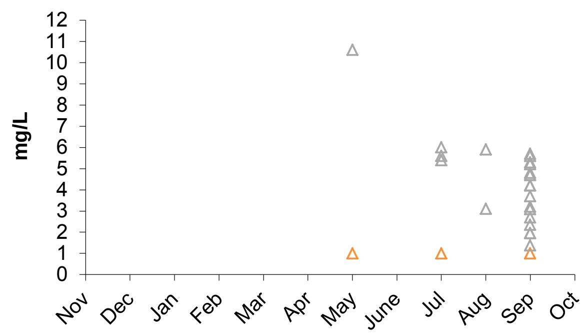
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.2-19 Concentrations of water quality measurement endpoints, Muskeg River near the mouth (*test* station MU0 [MUR-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1997-2014 (fall data only)			
			Value	n	Median	Minimum	Maximum
Physical variables							
pH	pH units	6.5-9.0	8.20	18	8.27	7.40	8.61
Total suspended solids	mg/L	-	5.3	18	3.0	<3.0	70.0
Conductivity	µS/cm	-	320	18	349	220	671
Nutrients							
Total dissolved phosphorus	mg/L	-	0.007	18	0.013	0.003	0.030
Total nitrogen	mg/L	-	0.84	18	0.90	0.40	1.62
Nitrate+nitrite	mg/L	3-124	0.025	18	<0.086	<0.050	<0.100
Dissolved organic carbon	mg/L	-	22.0	18	21.5	15.0	29.0
Ions							
Sodium	mg/L	-	13.0	18	13.0	8.0	64.0
Calcium	mg/L	-	36.0	18	48.7	28.8	108.0
Magnesium	mg/L	-	9.0	18	12.4	7.1	18.9
Potassium	mg/L	-	0.8	18	1.1	0.5	1.9
Chloride	mg/L	120-640	5.8	18	3.2	1.0	36.0
Sulphate	mg/L	309[b]	7.3	18	5.3	0.6	91.0
Total dissolved solids	mg/L	-	190	18	280	170	405
Total alkalinity	mg/L	20 (min)	150	18	179	105	313
Selected metals							
Total aluminum	mg/L	-	0.039	18	0.071	0.021	1.200
Dissolved aluminum	mg/L	0.05	0.0026	18	0.0038	0.0013	0.0300
Total arsenic	mg/L	0.005	0.0004	18	0.0004	0.0003	0.0010
Total boron	mg/L	1.5-29	0.047	18	0.048	0.032	0.150
Total molybdenum	mg/L	0.073	0.0001	18	0.0001	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5-13	0.88	12	1.20	0.60	3.00
Total methyl mercury	ng/L	1-2	0.103	-	-	-	-
Total strontium	mg/L	-	0.109	18	0.127	0.086	0.296
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.270	4	0.655	0.210	1.800
Oilsands extractable acids	mg/L	-	1.700	4	1.435	0.480	2.400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	1.01	0.47	2.15
Total dibenzothiophenes[c]	ng/L	-	17.78	4	18.04	10.17	40.16
Total PAHs[c]	ng/L	-	128.74	4	165.95	101.30	239.33
Total Parent PAHs[c]	ng/L	-	22.76	4	18.93	13.90	23.74
Total Alkylated PAHs[c]	ng/L	-	105.98	4	143.74	87.40	222.15
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**0.0064**	18	**0.0043**	0.0010	**0.0110**
Sulphide	mg/L	0.0019	**0.0054**	18	**0.0045**	0.0015	**0.0220**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.2-20 Concentrations of water quality measurement endpoints at new stations in the Muskeg River (*test* stations MU1, MU4, MU5, MU6, MU7, MU8, and MU10) and in tributaries to the Muskeg River (*test* station TR3.1 and *baseline* station TR3.2), fall 2015.

Measurement Endpoint	Units	Guideline[a]	TR3.1	TR3.2	MU1	MU4	MU5	MU6	MU7	MU8	MU10
Physical variables											
pH	pH units	6.5-9.0	7.84	7.68	7.91	7.96	7.89	7.74	7.76	7.75	7.72
Total suspended solids	mg/L	-	1.3	<1	8	<1	2	4.7	2	<1	<1
Conductivity	µS/cm	-	220	210	280	310	410	400	420	380	350
Nutrients											
Total dissolved phosphorus	mg/L	-	0.012	0.012	0.012	0.011	0.013	0.019	0.011	0.014	0.012
Total nitrogen	mg/L	-	0.86	1	0.87	0.84	0.82	0.97	0.82	0.75	0.77
Nitrate+nitrite	mg/L	3-124	<0.005	<0.005	<0.005	0.006	0.029	0.014	<0.005	<0.005	<0.005
Dissolved organic carbon	mg/L	-	25	27	25	22	19	19	19	19	20
Ions											
Sodium	mg/L	-	13	11	13	12	7	7.1	6.2	7.1	3.7
Calcium	mg/L	-	26	21	34	44	53	56	62	49	50
Magnesium	mg/L	-	7	6	9.6	13	14	16	18	17	16
Potassium	mg/L	-	0.7	0.6	0.9	1.1	1.1	1.3	1.4	1.7	0.7
Chloride	mg/L	120-640	3	2.9	3.5	3.5	4.6	4.1	3.9	5.5	1.5
Sulphate	mg/L	309-429[b]	<2	<2	<2	<2	1.4	1.4	1.9	<1	<1
Total dissolved solids	mg/L	-	150	160	190	220	240	250	250	210	180
Total alkalinity	mg/L	20 (min)	110	100	150	160	210	210	230	200	190
Selected metals											
Total aluminum	mg/L	-	0.0421	0.0449	0.0229	0.0534	0.0171	0.0341	0.0146	0.0106	0.0068
Dissolved aluminum	mg/L	0.05	0.00497	0.00497	0.00306	0.00318	0.002	0.00216	0.00131	0.00133	0.00175
Total arsenic	mg/L	0.005	0.000467	0.000466	0.0004	0.000341	0.000237	0.000281	0.000262	0.000283	0.000391
Total boron	mg/L	1.5-29	0.0314	0.0324	0.0388	0.0413	0.0273	0.0259	0.0237	0.0171	0.0148
Total molybdenum	mg/L	0.073	0.000094	0.000076	0.000091	0.000091	0.000033	0.000058	0.000045	0.000043	0.000068
Total mercury (ultra-trace)	ng/L	5-13	0.85	0.78	1.04	0.92	0.6	0.7	0.64	0.53	0.64
Total methyl mercury	ng/L	1-2	0.162	0.16	0.122	0.091	0.081	0.091	0.101	0.205	0.11
Total strontium	mg/L	-	0.0888	0.0869	0.104	0.107	0.128	0.129	0.133	0.116	0.0838
Total hydrocarbons											
BTEX	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Values in **bold** are above guideline; sampling began in 2015, and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.2-20 (Cont'd.)

Measurement Endpoint	Units	Guideline[a]	TR3.1	TR3.2	MU1	MU4	MU5	MU6	MU7	MU8	MU10
Total hydrocarbons											
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Naphthenic acids	mg/L	-	0.24	0.17	0.47	0.33	0.45	0.48	0.39	0.27	0.14
Oilsands extractable acids	mg/L	-	1.3	1.4	1.5	1.6	1.7	2	1.8	1.5	0.7
Polycyclic Aromatic Hydrocarbons (PAHs)											
Naphthalene	ng/L	1,000	<13.55	<13.55	<13.55	<13.55	<13.55	<13.55	<13.55	<13.55	<13.55
Retene	ng/L	-	<0.59	<0.59	<0.59	<0.59	<0.59	1.26	0.82	<0.59	<0.59
Total dibenzothiophenes[c]	ng/L	-	8.17	8.17	25.38	18.89	9.65	8.17	8.17	8.17	8.17
Total PAHs[c]	ng/L	-	107.19	106.20	140.50	124.58	109.98	106.01	106.67	106.21	106.69
Total Parent PAHs[c]	ng/L	-	22.40	22.40	22.72	22.55	22.40	22.40	22.40	22.40	22.40
Total Alkylated PAHs[c]	ng/L	-	84.78	83.79	117.78	102.04	87.57	83.61	84.26	83.80	84.28
Other variables that exceeded Alberta guidelines in fall 2015											
Total phenols	mg/L	0.004	**0.0054**	**0.0058**	**0.0066**	**0.0052**	**0.0056**	**0.0072**	**0.0077**	**0.0073**	0.0038
Sulphide	mg/L	0.0019	**0.0062**	**0.0077**	**0.0070**	**0.0031**	**0.0054**	**0.0046**	**0.0070**	**0.0093**	<0.0019
Dissolved iron	mg/L	0.3	0.29	**0.31**	**0.33**	**0.39**	**0.82**	**0.96**	**0.71**	0.27	0.22

Values in **bold** are above guideline; sampling began in 2015, and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.2-21 Concentrations of water quality measurement endpoints, Jackpine Creek near the mouth (*test* station JA1 [JAC-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1997-2014 (fall data only)			
			Value	n	Median	Minimum	Maximum
Physical variables							
pH	pH units	6.5-9.0	7.92	16	8.15	7.80	8.33
Total suspended solids	mg/L	-	<1.0	16	4.0	<3.0	50.0
Conductivity	µS/cm	-	220	16	240	183	483
Nutrients							
Total dissolved phosphorus	mg/L	-	0.010	16	0.014	0.006	0.030
Total nitrogen	mg/L	-	0.87	16	0.90	0.70	1.62
Nitrate+nitrite	mg/L	3-124	<0.005	16	<0.1	<0.05	<0.1
Dissolved organic carbon	mg/L	-	25.0	16	25.0	18.6	31.8
Ions							
Sodium	mg/L	-	13.0	16	12.0	10.0	18.8
Calcium	mg/L	-	26.0	16	30.2	20.0	65.6
Magnesium	mg/L	-	7.0	16	8.6	6.1	16.3
Potassium	mg/L	-	0.6	16	0.7	0.5	1.4
Chloride	mg/L	120-640	3.0	16	2.0	0.9	5.6
Sulphate	mg/L	309[b]	<2.0	16	2.8	0.5	9.8
Total dissolved solids	mg/L	-	150	16	208	110	322
Total alkalinity	mg/L	20 (min)	110	16	123	89	249
Selected metals							
Total aluminum	mg/L	-	0.0650	16	0.0609	0.0156	0.6580
Dissolved aluminum	mg/L	0.05	0.0049	16	0.0080	0.0016	**0.1700**
Total arsenic	mg/L	0.005	0.0005	16	0.0006	0.0003	0.0010
Total boron	mg/L	1.5-29	0.036	16	0.047	0.033	0.071
Total molybdenum	mg/L	0.073	0.0001	16	0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5-13	0.82	12	1.20	0.60	2.90
Total methyl mercury	ng/L	1-2	0.161	-	-	-	-
Total strontium	mg/L	-	0.089	16	0.110	0.077	0.212
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.17	4	0.36	0.08	1.40
Oilsands extractable acids	mg/L	-	1.30	4	1.92	0.38	2.90
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<u>0.64</u>	4	3.23	1.37	13.80
Total dibenzothiophenes[c]	ng/L	-	16.29	4	34.70	15.26	136.11
Total PAHs[c]	ng/L	-	<u>119.73</u>	4	204.42	122.83	596.22
Total Parent PAHs[c]	ng/L	-	22.49	4	22.19	14.39	24.59
Total Alkylated PAHs[c]	ng/L	-	<u>97.24</u>	4	181.93	108.44	572.21
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**0.0056**	16	**0.0065**	0.0010	**0.0190**
Sulphide	mg/L	0.0019	**0.0110**	16	**0.0082**	0.0020	**0.1030**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.2-22 Concentrations of water quality measurement endpoints at benthic invertebrate community station, Jackpine Creek above Jackpine Mine (*baseline* station JAC-2), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2008-2014 (fall data only)			
			Value	n	Median	Minimum	Maximum
Physical variables							
pH	pH units	6.5-9.0	<u>7.92</u>	7	8.18	7.98	8.33
Total suspended solids	mg/L	-	2.7	7	10.0	<3.0	243.0
Conductivity	µS/cm	-	250	7	228	202	346
Nutrients							
Total dissolved phosphorus	mg/L	-	0.013	7	0.014	0.007	0.023
Total nitrogen	mg/L	-	<u>0.71</u>	7	0.90	0.72	2.63
Nitrate+nitrite	mg/L	3-124	<0.005	7	<0.071	<0.054	<0.100
Dissolved organic carbon	mg/L	-	23.0	7	25.0	21.1	29.1
Ions							
Sodium	mg/L	-	16.0	7	12.0	10.0	25.5
Calcium	mg/L	-	27.0	7	30.5	22.1	36.9
Magnesium	mg/L	-	8.7	7	8.6	7.2	11.5
Potassium	mg/L	-	0.8	7	0.8	0.5	1.1
Chloride	mg/L	120-640	<u>1.8</u>	7	1.2	<0.5	1.6
Sulphate	mg/L	309[b]	2.8	7	2.0	0.7	4.3
Total dissolved solids	mg/L	-	180	7	183	150	264
Total alkalinity	mg/L	20 (min)	130	7	113	103	187
Selected metals							
Total aluminum	mg/L	-	0.170	7	0.595	0.142	2.840
Dissolved aluminum	mg/L	0.05	0.012	7	0.011	0.006	0.029
Total arsenic	mg/L	0.005	0.0007	7	0.0009	0.0007	0.0016
Total boron	mg/L	1.5-29	0.075	7	0.073	0.045	0.137
Total molybdenum	mg/L	0.073	0.0002	7	0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5-13	1.51	7	1.20	1.00	**8.80**
Total methyl mercury	ng/L	1-2	0.248	-	-	-	-
Total strontium	mg/L	-	0.131	7	0.121	0.096	0.201
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.28	4	0.18	0.05	0.64
Oilsands extractable acids	mg/L	-	<u>1.50</u>	4	0.76	0.42	1.10
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	<1.65	<0.87	<11.10
Total dibenzothiophenes[c]	ng/L	-	8.17	4	9.14	7.09	45.44
Total PAHs[c]	ng/L	-	105.77	4	129.27	86.12	299.06
Total Parent PAHs[c]	ng/L	-	22.40	4	19.78	13.34	22.44
Total Alkylated PAHs[c]	ng/L	-	83.37	4	108.27	72.78	279.05
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**0.0076**	7	0.0059	0.0035	**0.0124**
Sulphide	mg/L	0.0019	**0.0054**	7	**0.0052**	0.0015	**0.0081**
Dissolved iron	mg/L	0.3	**0.464**	7	**0.486**	0.238	**0.709**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.2-23 Concentrations of water quality measurement endpoints, Stanley Creek (*test* station STC-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1997-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.92	14	8.05	7.60	8.46
Total suspended solids	mg/L	-	<u>15</u>	14	<3	<3	6
Conductivity	µS/cm	-	350	14	387	271	760
Nutrients							
Total dissolved phosphorus	mg/L	-	0.011	15	0.020	0.010	0.039
Total nitrogen	mg/L	-	1.2	15	0.4	0.3	2.1
Nitrate+nitrite	mg/L	3-124	<u>0.780</u>	15	<0.100	<0.054	<0.100
Dissolved organic carbon	mg/L	-	11.0	14	8.6	6.0	13.1
Ions							
Sodium	mg/L	-	2.4	14	4.7	2.0	26.0
Calcium	mg/L	-	55.0	14	60.0	45.4	112.0
Magnesium	mg/L	-	14.0	14	12.7	11.1	20.5
Potassium	mg/L	-	<u>0.4</u>	14	1.1	0.5	2.3
Chloride	mg/L	120-640	<1.0	14	1.2	0.5	14.0
Sulphate	mg/L	429[b]	<1.0	14	2.3	0.5	126.0
Total dissolved solids	mg/L	-	220	14	243	200	480
Total alkalinity	mg/L	20 (min)	190	14	206	157	260
Selected metals							
Total aluminum	mg/L	-	0.020	15	0.007	<0.002	0.020
Dissolved aluminum	mg/L	0.05	0.0003	15	0.0010	<0.0003	0.0200
Total arsenic	mg/L	0.005	0.00008	15	0.00014	<0.00006	<0.00100
Total boron	mg/L	1.5-29	0.0232	15	0.0281	0.0180	0.0871
Total molybdenum	mg/L	0.073	0.00003	15	0.00010	0.00001	0.00020
Total mercury (ultra-trace)	ng/L	5-13	0.69	12	<1.20	<0.60	1.40
Total methyl mercury	ng/L	1-2	0.143	-	-	-	-
Total strontium	mg/L	-	0.094	15	0.114	0.075	0.248
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.29</u>	4	0.77	0.51	1.30
Oilsands extractable acids	mg/L	-	1.30	4	1.39	0.91	2.20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	<1.31	<0.41	2.76
Total dibenzothiophenes[c]	ng/L	-	10.62	4	8.43	4.16	35.72
Total PAHs[c]	ng/L	-	126.44	4	143.34	74.12	206.86
Total Parent PAHs[c]	ng/L	-	22.41	4	18.07	13.26	22.55
Total Alkylated PAHs[c]	ng/L	-	104.03	4	122.25	60.87	190.34
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**0.009**	15	0.003	0.001	**0.052**
Sulphide	mg/L	0.0019	**0.0093**	15	**0.004**	**0.002**	**0.013**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.2-24 Concentrations of water quality measurement endpoints, Kearl Lake (*test* station KL1 [KEL-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1997-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.88	16	8.07	7.60	8.30
Total suspended solids	mg/L	-	2.7	16	4.0	<3.0	19.0
Conductivity	µS/cm	-	180	16	176	133	207
Nutrients							
Total dissolved phosphorus	mg/L	-	0.008	16	0.007	0.002	0.013
Total nitrogen	mg/L	-	0.90	16	1.28	0.45	1.92
Nitrate+nitrite	mg/L	3-124	<0.005	16	<0.086	<0.050	<0.100
Dissolved organic carbon	mg/L	-	22.0	16	22.5	9.8	28.2
Ions							
Sodium	mg/L	-	8.9	16	10.0	8.0	11.3
Calcium	mg/L	-	20.0	16	19.7	16.5	20.9
Magnesium	mg/L	-	7.1	16	6.9	5.7	7.6
Potassium	mg/L	-	1.0	16	0.8	0.5	1.4
Chloride	mg/L	120-640	1.7	16	<1.0	<0.5	3.0
Sulphate	mg/L	309[b]	<u><1.0</u>	16	4.0	1.4	5.7
Total dissolved solids	mg/L	-	150	16	155	94	220
Total alkalinity	mg/L	20 (min)	89	16	88	72	105
Selected metals							
Total aluminum	mg/L	-	0.009	16	0.017	0.007	0.130
Dissolved aluminum	mg/L	0.05	0.0007	16	0.0014	0.0010	0.0300
Total arsenic	mg/L	0.005	0.0003	16	0.0004	0.0003	<0.0010
Total boron	mg/L	1.5-29	0.048	16	0.047	0.012	0.052
Total molybdenum	mg/L	0.073	0.00007	16	0.00010	0.00003	0.00090
Total mercury (ultra-trace)	ng/L	5-13	0.55	12	<1.20	<0.60	1.30
Total methyl mercury	ng/L	1-2	0.055	-	-	-	-
Total strontium	mg/L	-	0.062	16	0.065	0.056	0.215
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.81	4	0.19	0.46	1.20
Oilsands extractable acids	mg/L	-	<u>2.30</u>	4	0.42	1.17	2.10
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	12.52	7.21	<15.16
Retene	ng/L	-	<0.59	4	<0.59	<0.41	<2.07
Total dibenzothiophenes[c]	ng/L	-	8.29	4	7.35	5.40	35.35
Total PAHs[c]	ng/L	-	113.80	4	132.83	76.58	206.93
Total Parent PAHs[c]	ng/L	-	22.44	4	19.77	13.26	22.57
Total Alkylated PAHs[c]	ng/L	-	91.36	4	111.18	63.33	188.12
Other variables that exceeded Alberta guidelines in fall 2015							
Total Phenols	mg/L	0.004	**0.012**	16	**0.0051**	0.001	**0.012**
Sulphide	mg/L	0.0019	**0.0062**	16	**0.005**	**<0.002**	**0.010**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.2-10 Piper diagram of fall ion concentrations in the Muskeg River.

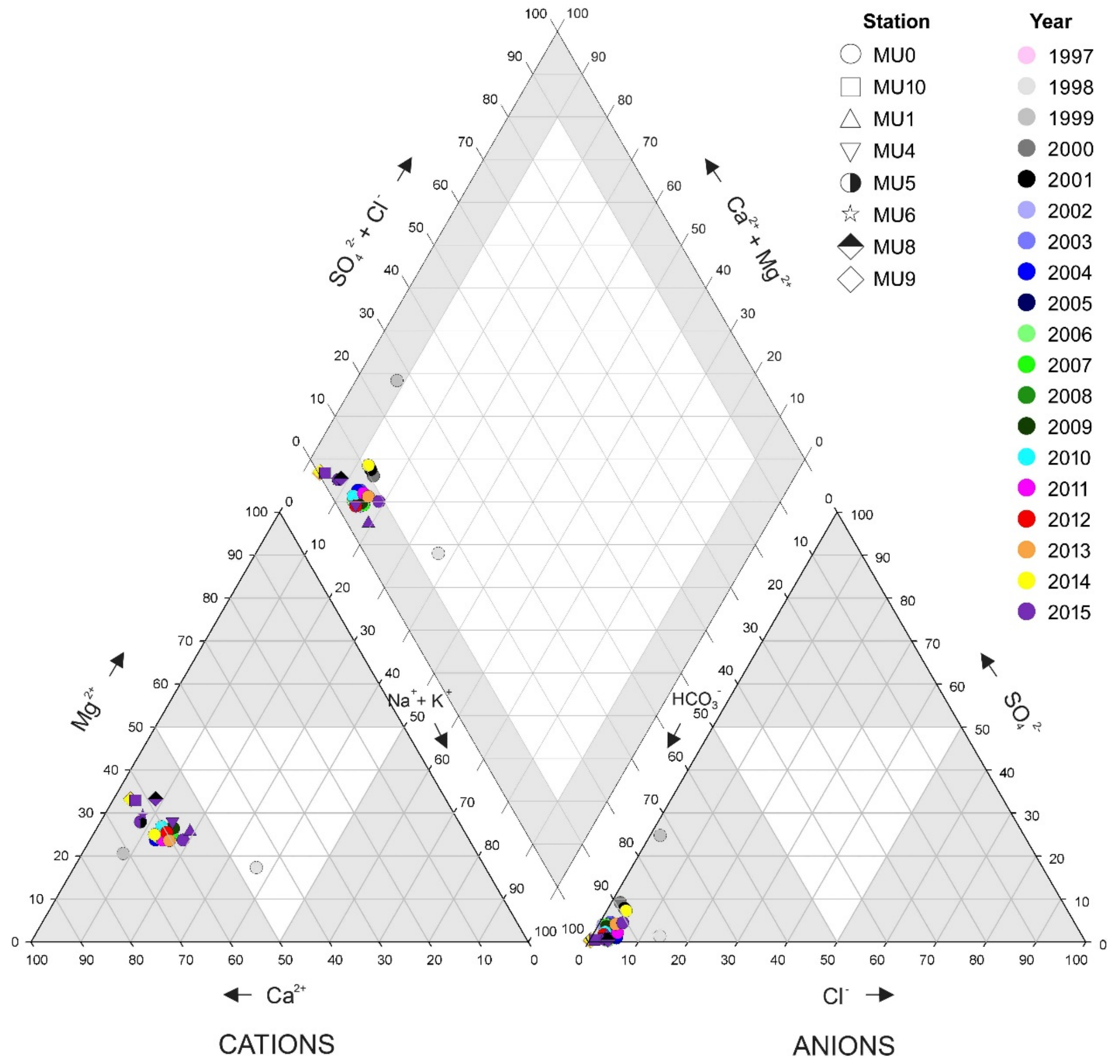


Figure 5.2-11 Piper diagram of fall ion concentrations in tributaries to the Muskeg River and Kearl Lake.

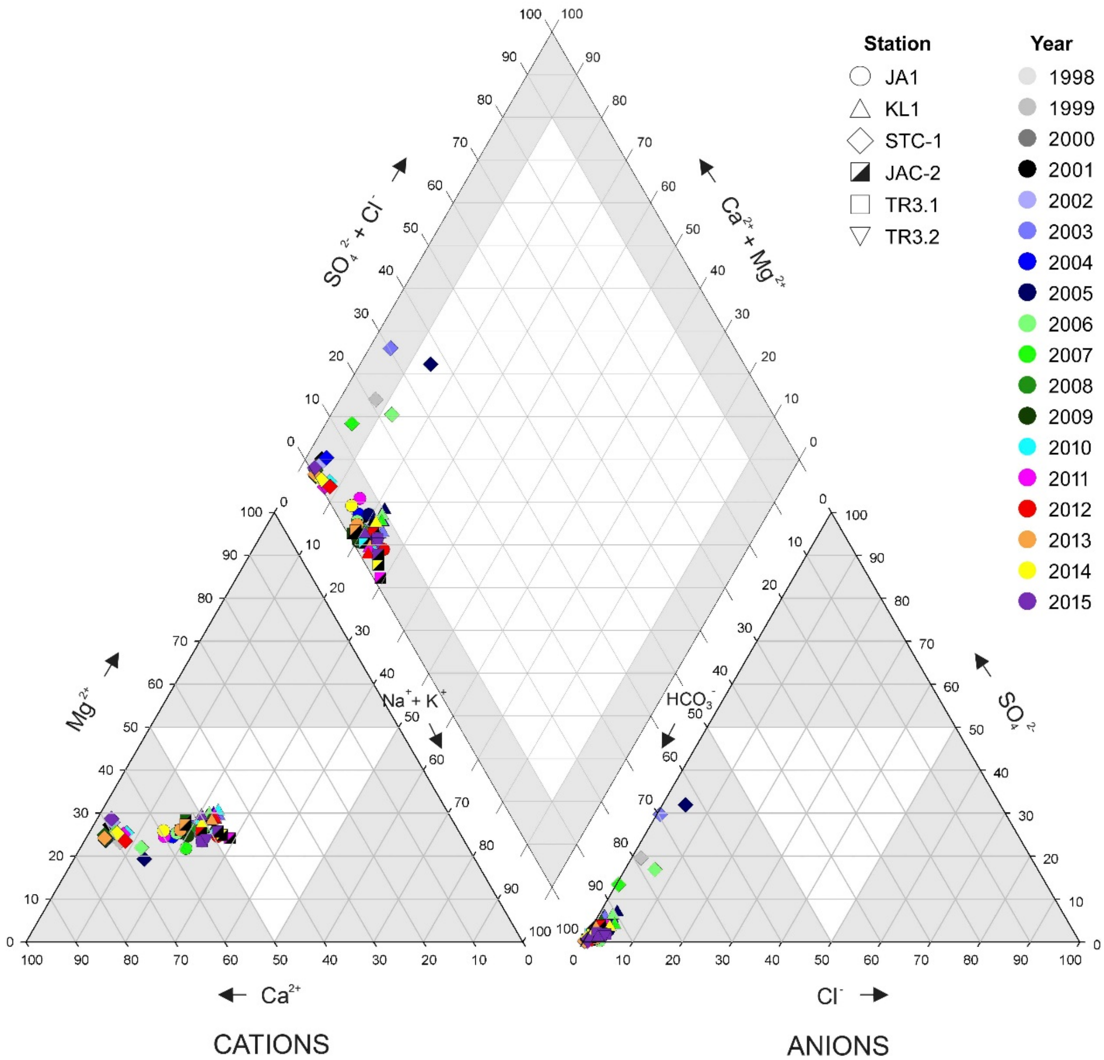


Table 5.2-25 Water quality guideline exceedances in the Muskeg River watershed, 2015 WY.

Variable	Units	Guideline[a]	November	December	January	February	March	May	June	July	August	September	October
Muskeg River mouth (M0)													
Total phenols	mg/L	0.004	0.0018	<0.001	<0.001	<0.001	<0.001	-	-	**0.015**	**0.0093**	**0.0064**	**0.0057**
Sulphide	mg/L	0.0019	**0.0049**	**0.0029**	**0.0036**	0.0018	**0.0031**	-	-	**0.0077**	**0.0077**	**0.0054**	**0.0059**
Dissolved iron	mg/L	0.3	**0.428**	**0.384**	**0.381**	0.213	0.24	-	-	0.135	0.143	0.298	0.274
Muskeg River near Fort McKay (MU1)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0095**	**0.018**	**0.013**	**0.0066**	**0.0062**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.011**	**0.0093**	**0.0085**	**0.007**	**0.013**
Dissolved iron	mg/L	0.3	-	-	-	-	-	**0.363**	**0.777**	0.179	0.246	**0.325**	**0.373**
Muskeg River above Jackpine Creek (MU4)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0092**	**0.014**	**0.011**	**0.0052**	**0.0064**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.0089**	**0.007**	**0.0054**	**0.0031**	**0.0066**
Dissolved iron	mg/L	0.3	-	-	-	-	-	**0.615**	**0.836**	0.152	**0.34**	**0.387**	**0.399**
Muskeg River above Muskeg Creek (MU5)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0055**	**0.014**	**0.012**	**0.0056**	**0.0064**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.015**	**0.01**	**0.0031**	**0.0054**	**0.0088**
Dissolved iron	mg/L	0.3	-	-	-	-	-	**0.853**	**1.82**	**0.442**	**0.865**	**0.817**	**0.459**
Muskeg River above Stanley Creek (MU6)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0061**	**0.013**	**0.013**	**0.0072**	**0.0066**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.016**	**0.0085**	**0.007**	**0.0046**	**0.0037**
Dissolved iron	mg/L	0.3	-	-	-	-	-	**0.75**	**1.59**	**0.859**	**1.23**	**0.962**	**0.623**
Muskeg River above Wapasu Creek (MU7)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	**0.015**	**0.012**	**0.0077**	-
Sulphide	mg/L	0.0019	-	-	-	-	-	-	-	**0.0093**	**0.0085**	**0.007**	-
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	-	**1.24**	**0.881**	**0.714**	-
Muskeg River above Wapasu Creek (MU8)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0061**	**0.014**	**0.011**	**0.0073**	**0.0085**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.015**	**0.0046**	**0.0085**	**0.0093**	**0.0081**
Dissolved iron	mg/L	0.3	-	-	-	-	-	0.153	0.247	**0.414**	**0.735**	0.273	**0.427**

Values in **bold** are above the guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Table 5.2-25 (Cont'd.)

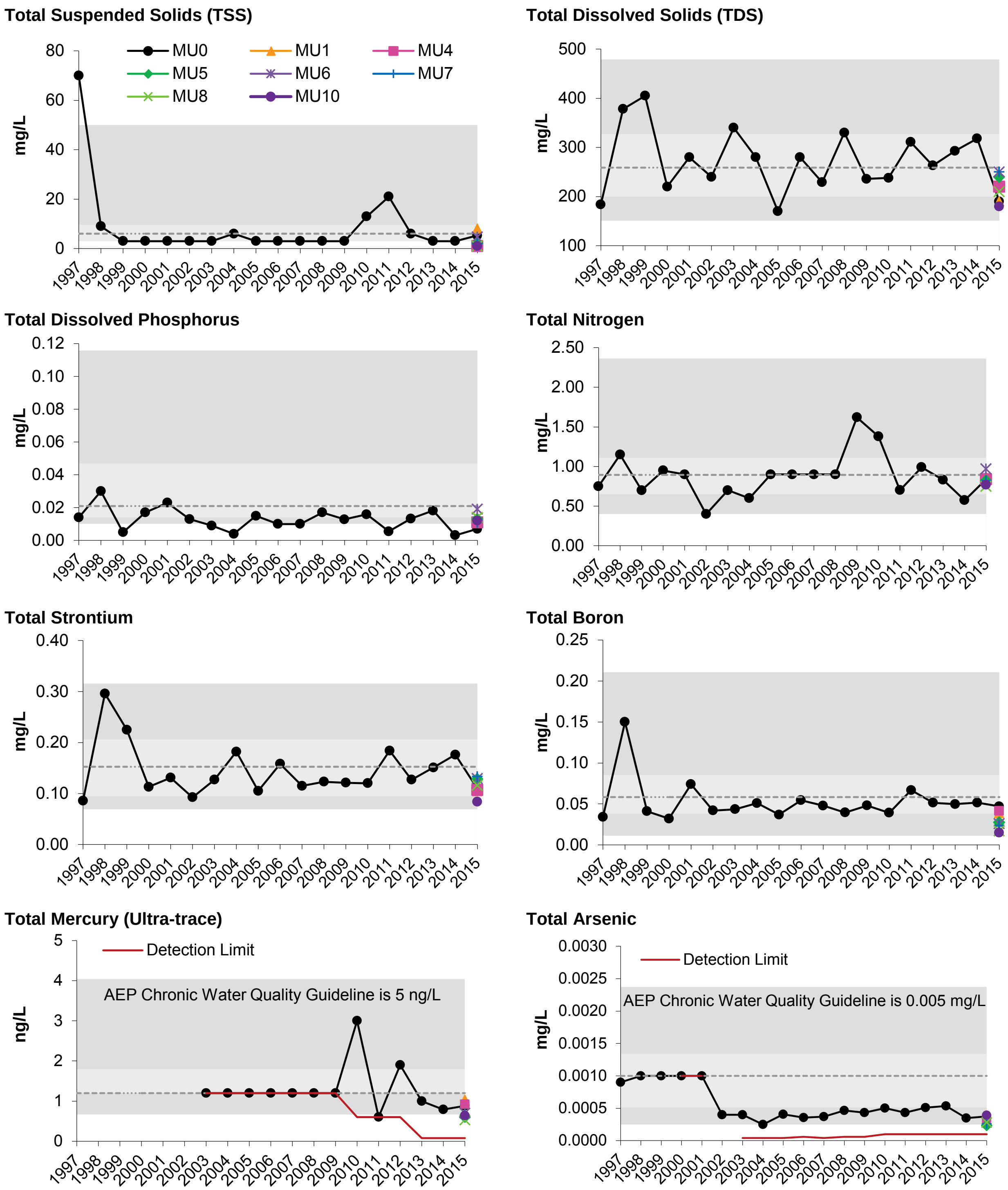
Variable	Units	Guideline[a]	November	December	January	February	March	May	June	July	August	September	October
Muskeg River upland (MU10)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.01**	**0.057**	**0.013**	0.0038	**0.0099**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.011**	**0.007**	**0.0093**	<0.0019	<0.0019
Dissolved iron	mg/L	0.3	-	-	-	-	-	0.116	0.244	**0.808**	**0.73**	**0.216**	0.26
Jackpine Creek mouth (JA1)													
Total phenols	mg/L	0.004	-	-	-	-	-	0.0031	**0.012**	**0.016**	**0.011**	**0.0056**	**0.0065**
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0049**	**0.012**	**0.0081**	**0.0085**	**0.011**	**0.0044**
Dissolved iron	mg/L	0.3	-	-	-	-	-	0.153	**0.439**	**0.436**	**0.391**	0.278	**0.42**
Jackpine Creek at Canterra Road (TR3.1)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	**0.017**	**0.011**	**0.0054**	**0.0075**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	-	**0.016**	**0.0031**	**0.0062**	**0.0059**
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	-	**0.469**	**0.419**	0.286	**0.357**
Jackpine Creek 1.6 km upstream of Muskeg River (TR3.2)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.013**	**0.018**	**0.013**	**0.0058**	**0.0086**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.0097**	**0.04**	**0.016**	**0.0077**	**0.0044**
Dissolved iron	mg/L	0.3	-	-	-	-	-	0.149	**0.458**	**0.496**	**0.488**	**0.308**	**0.358**
Wapasu Creek (WA1)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0096**	**0.014**	**0.013**	-	**0.0069**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.013**	**0.014**	**0.012**	-	**0.0088**
Dissolved iron	mg/L	0.3	-	-	-	-	-	0.278	**0.977**	**2.0**	**1.4**	-	**1.8**
Stanley Creek (STC-1)													
Total phenols	mg/L	0.004	-	-	-	-	-	0.0021	<0.002	**0.011**	**0.0086**	**0.0086**	-
Sulphide	mg/L	0.0019	-	-	-	-	-	<0.0019	**0.0057**	**0.033**	**0.007**	**0.0093**	-
Kearl Lake (KL1)													
Total phenols	mg/L	0.004	-	-	-	-	-	0.003	-	**0.011**	-	**0.012**	-
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0089**	-	<0.0019	-	**0.0062**	-

Values in **bold** are above the guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.2-12 Selected water quality measurement endpoints in the Muskeg River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

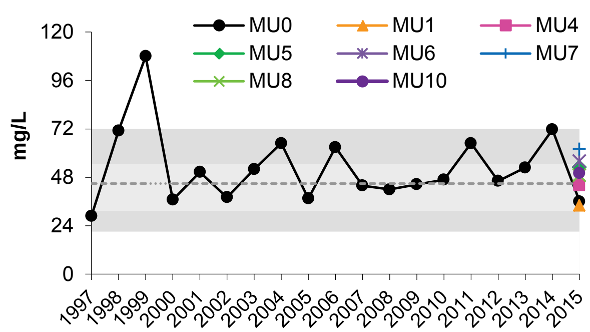
– – – – –   Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

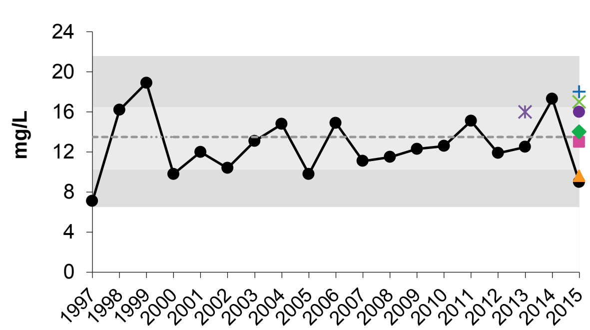
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-12 (Cont'd.)

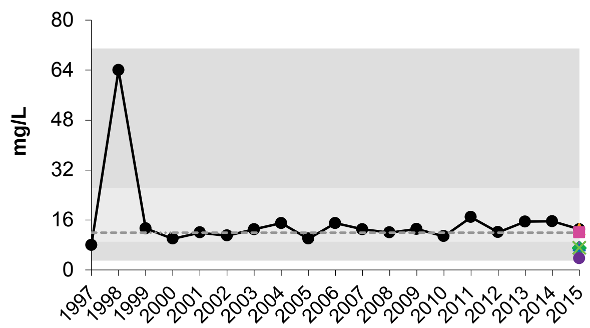
Calcium



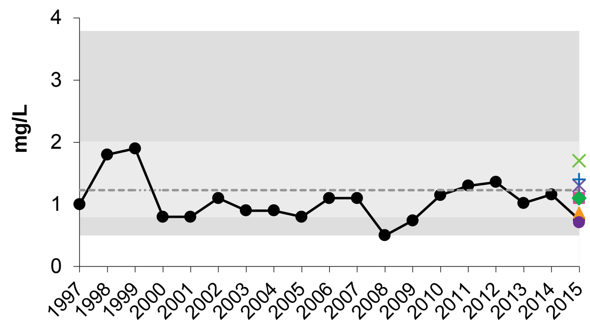
Magnesium



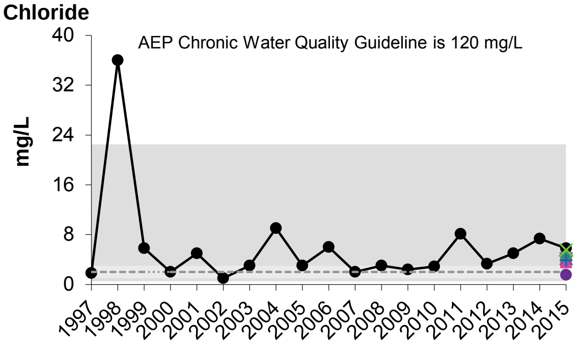
Sodium



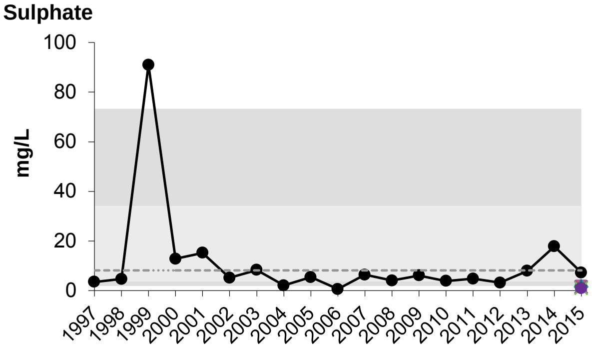
Potassium



Chloride



Sulphate



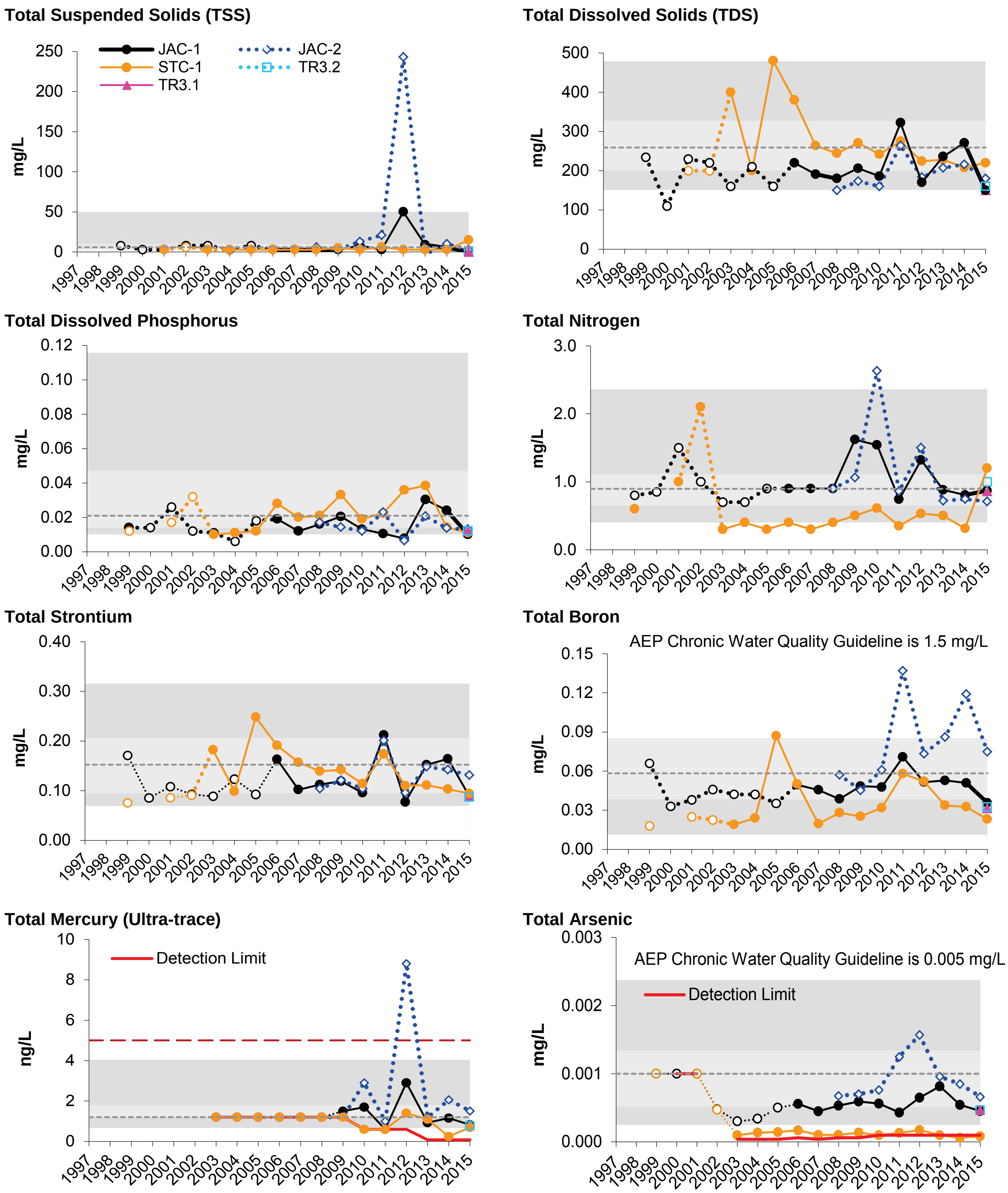
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-13 Selected water quality measurement endpoints in Muskeg River tributaries (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



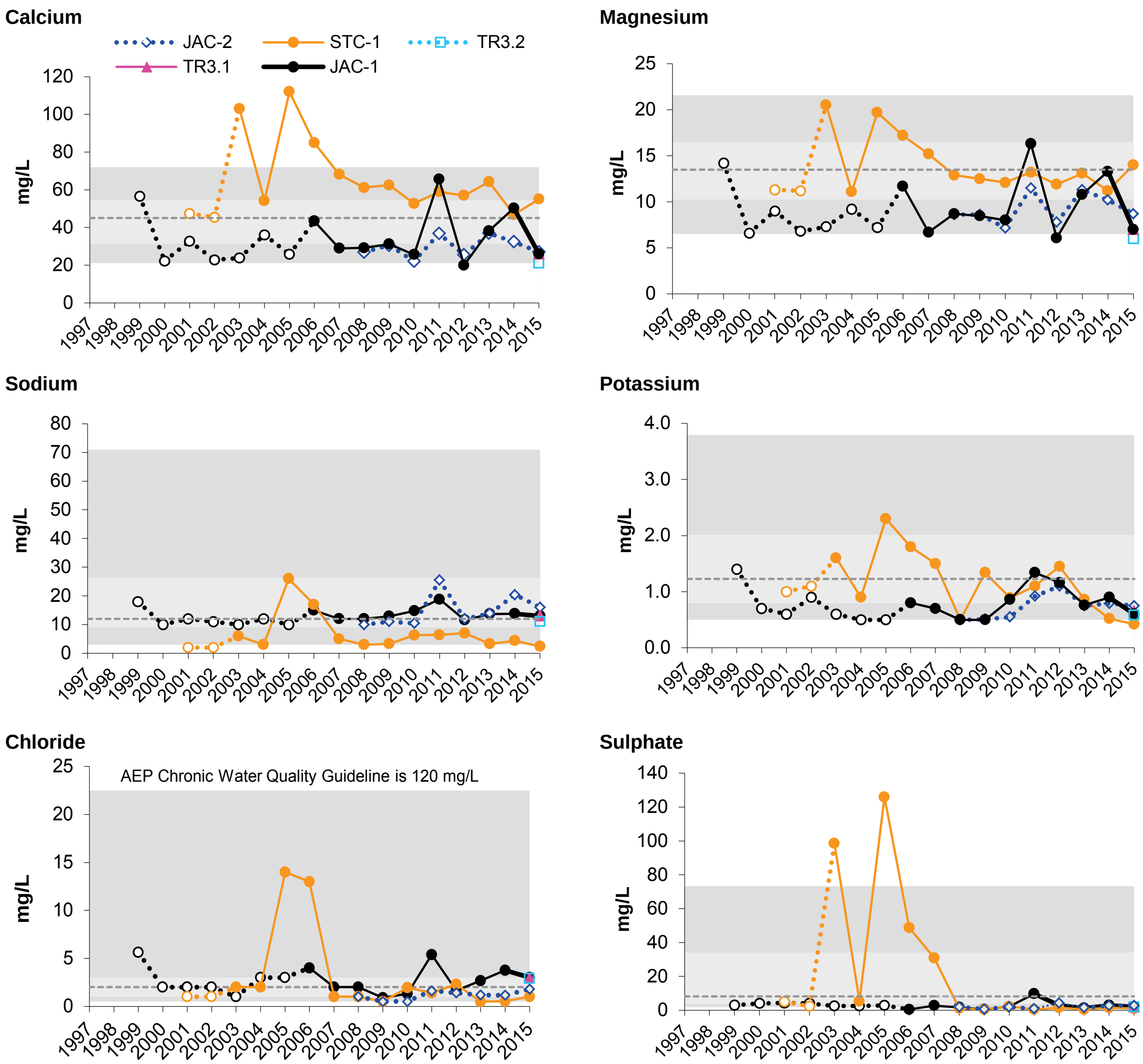
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-13 (Cont'd.)



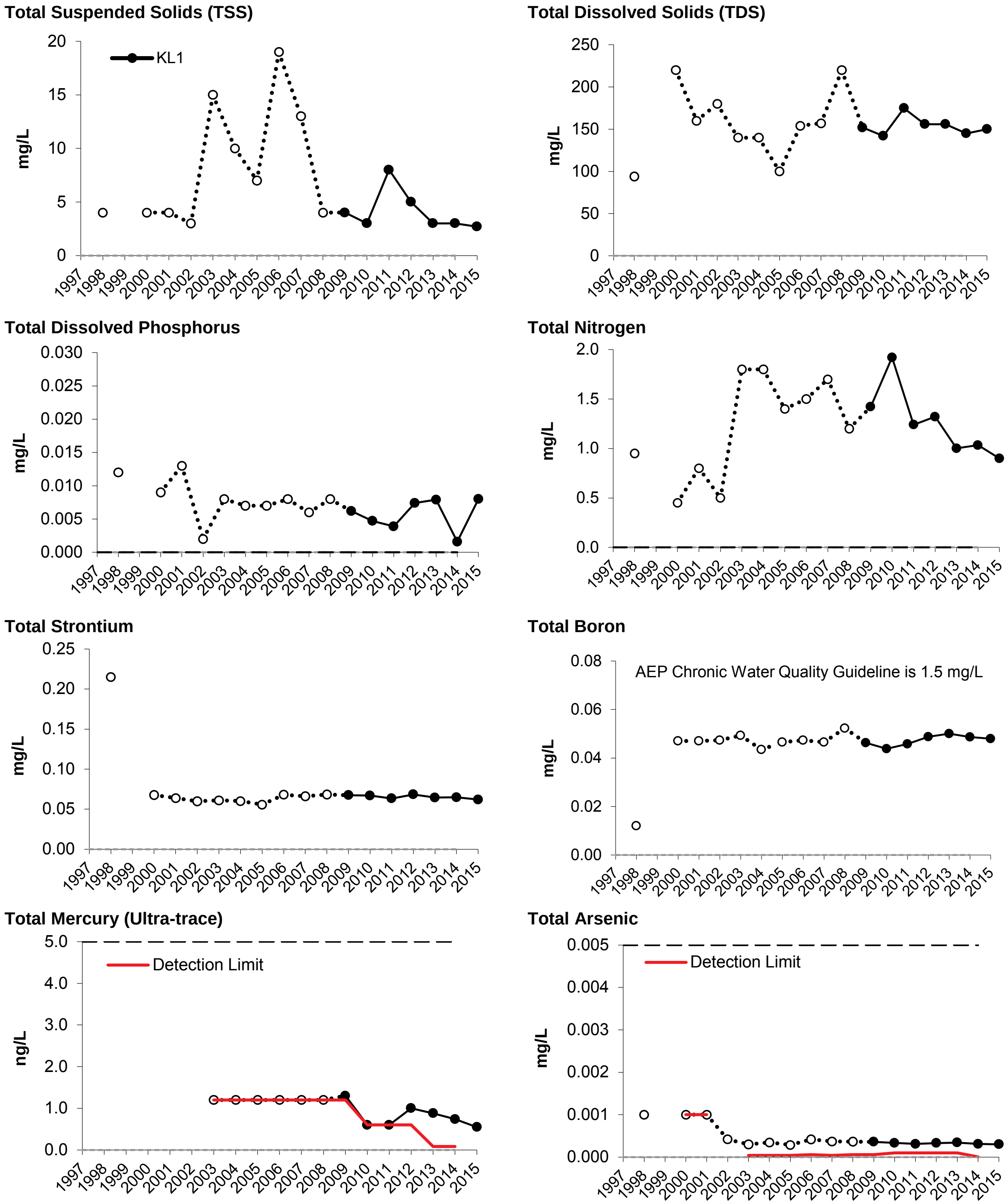
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.2-14 Selected water quality measurement endpoints in Kearl Lake (fall data).

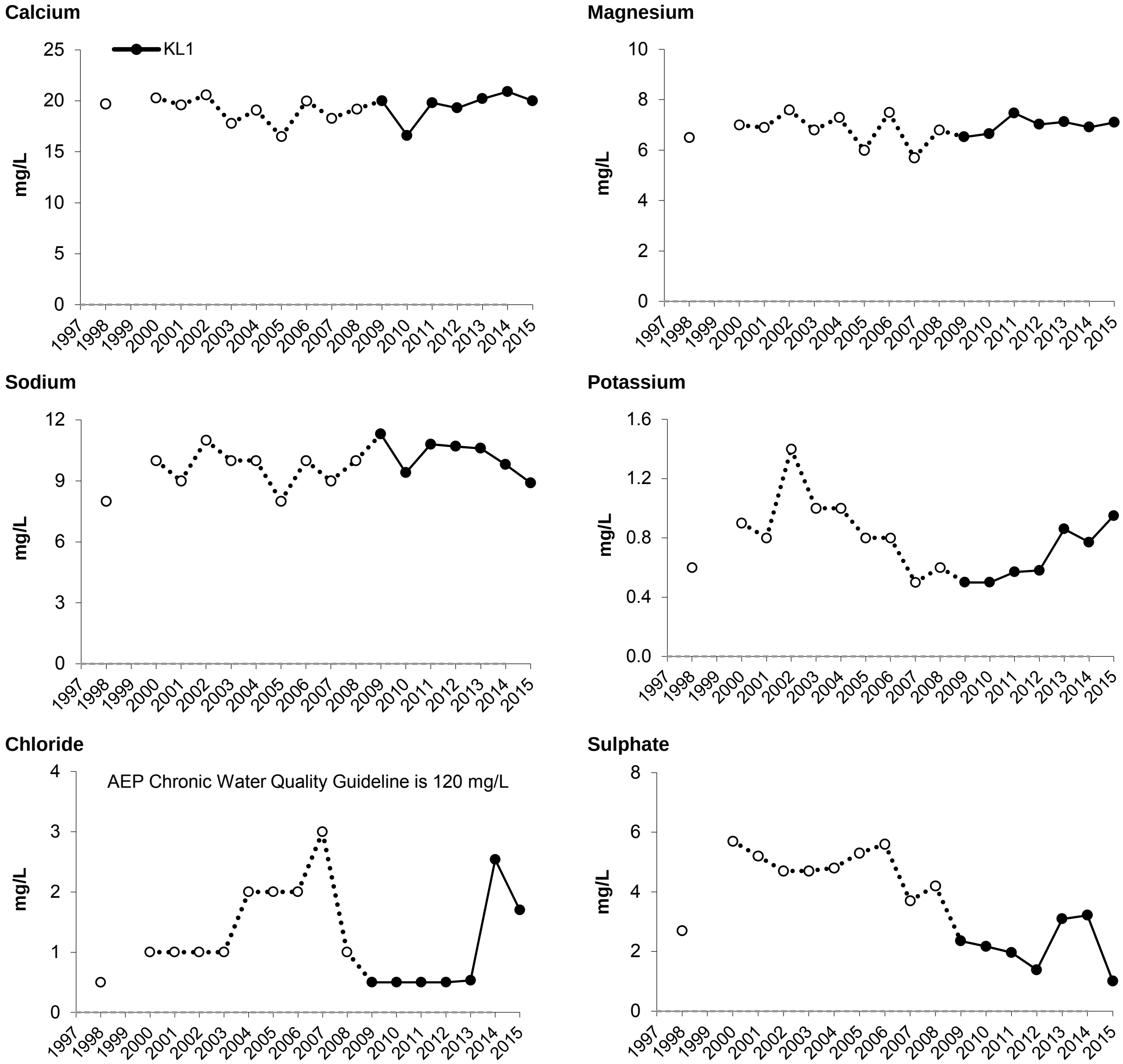


Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Figure 5.2-14 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Table 5.2-26 Average habitat characteristics of benthic invertebrate sampling locations in the Muskeg River (*test* reaches MUR-E1, MUR-D2, and MUR-D3), fall 2015.

Variable	Units	MUR-E1 Lower *Test* Reach	MUR-D2 Middle *Test* Reach	MUR-D3 Upper *Test* Reach
Sample date	-	Sept. 8, 2015	Sept. 14 2015	Sept. 11, 2015
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.2	1.2	0.8
Current velocity	m/s	0.5	0.3	0.1
Field water quality				
Dissolved oxygen (DO)	mg/L	9	8.9	6.4
Conductivity	µS/cm	246	266	358
pH	pH units	8.3	7.6	7.2
Water temperature	°C	12.5	11.7	9.3
Sediment composition				
Sand	%	-	90.2	57.1
Silt	%	-	8.1	38.1
Clay	%	-	1.6	4.8
Total organic carbon (TOC)	%	-	1.4	21.7

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.2-27 Summary of major taxon abundances and measurement endpoints of benthic invertebrate communities in the lower Muskeg River (*test* reach MUR-E1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach MUR-E1		
	1998	2000 to 2014	2015
Hydra	-	0 to <1	<1
Nematoda	2	<1 to 5	<1
Naididae	5	1 to 30	3
Tubificidae	5	0 to 26	1
Planariidae	-	-	<1
Enchytraeidae	<1	0 to 1	-
Lumbriculidae	-	0 to <1	-
Erpobdellidae	-	0 to <1	-
Hirudinea	-	0 to <1	-
Hydracarina	14	0 to 17	7
Amphipoda	-	0 to <1	-
Gastropoda	3	0 to 7	1
Bivalvia	6	0 to 9	19
Ceratopogonidae	1	0 to 26	1
Chironomidae	32	15 to 58	20
Dolichopodidae	-	<1	-
Diptera (misc.)	4	<1 to 22	3
Ephydridae	-	<1	-
Coleoptera	5	<1 to 10	<1
Ephemeroptera	12	5 to 50	30
Odonata	<1	<1 to 2	3
Plecoptera	4	<1 to 8	4
Trichoptera	2	1 to16	4
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	1,487	258 to 3,183	2,004
Richness	60	29 to 43	32
Equitability	0.25	0.13 to 0.38	0.24
% EPT	18	14 to 58	18

Note: All 2015 benthic invertebrate community measurement endpoints, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). All percent abundances of taxa are based on original counts. % EPT as an index in 2015 does not equal the observed percentages in the kick sample, because the index value was adjusted down to be equivalent to what would have been expected with a Neil-Hess cylinder.

Table 5.2-28 Summary of major taxon abundances and measurement endpoints of benthic invertebrate communities in the middle Muskeg River (*test* reach MUR-D2).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach MUR-D2		
	2000	2001 to 2014	2015
Hydra	<1	0 to 4	<1
Nematoda	2	1 to 6	2
Naididae	2	<1 to 11	6
Tubificidae	10	<1 to 31	5
Enchytraeidae	<1	0 to 6	-
Lumbriculidae	1	0 to 7	-
Erpobdellidae	<1	0 to <1	-
Hirudinea	<1	0 to 1	1
Hydracarina	1	<1 to 4	-
Amphipoda	-	0 to 2	<1
Gastropoda	<1	0 to 4	6
Bivalvia	4	0 to 5	3
Ceratopogonidae	1	1 to 28	5
Chironomidae	75	32 to 84	57
Diptera (misc.)	<1	0 to 4	2
Coleoptera	<1	0 to 1	<1
Ephemeroptera	<1	<1 to 6	6
Odonata	<1	0 to <1	<1
Plecoptera	<1	0 to <1	-
Trichoptera	<1	0 to <1	1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	1321	137 to 1300	878
Richness	26	10 to 32	28
Equitability	0.2	0.16 to 0.42	0.4
% EPT	<1	<1 to 6	7

Table 5.2-29 Summary of major taxon abundances and measurement endpoints of benthic invertebrate communities in the upper Muskeg River (*test* reach MUR-D3).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach MUR-D3		
	2002	2003 to 2014	2015
Hydra	-	0 to 3	1
Nematoda	1	0 to 6	1
Naididae	<1	<1 to 7	3
Tubificidae	<1	2 to 26	32
Lumbriculidae	-	0 to 2	-
Erpobdellidae	<1	0 to <1	-
Hirudinea	<1	0 to 3	<1
Hydracarina	<1	0 to 17	-
Amphipoda	<1	<1 to 5	1
Gastropoda	<1	0 to 2	<1
Bivalvia	28	0 to 18	22
Ceratopogonidae	<1	0 to 2	1
Chironomidae	66	27 to 79	37
Diptera (misc.)	<1	0 to 2	<1
Coleoptera	-	0 to 1	<1
Ephemeroptera	-	<1 to 15	2
Odonata	-	0 to <1	-
Plecoptera	-	0 to 1	-
Trichoptera	<1	0 to 1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	218	133 to 389	494
Richness	12	9 to 17	15
Equitability	0.26	0.29 to 0.52	0.34
% EPT	<1	<1 to 16	2

Table 5.2-30 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-E1).

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	**<0.001**	0.054	18	3	Abundance increased over time in the reach.
Log of Richness	0.953	0.747	0	0	No change.
Equitability	**0.003**	0.970	8	0	Equitability decreased over time in the reach.
Log of EPT	0.548	0.079	0	2	No change.
CA Axis 1	**<0.001**	**0.001**	16	3	CA Axis 1 scores decreased over time and were lower in 2015 than the mean of prior years.
CA Axis 2	0.213	0.721	1	0	No change.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Abundance, richness, and %EPT data were log10(x+1) transformed.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for erosional reaches from previous years (1998 to 2014; Appendix D).

Measurement endpoints for *test* reach MUR-E1 in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Table 5.2-31 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-D2).

Measurement Endpoints	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	**<0.001**	0.050	18	4	Abundance decreased over time.
Log of Richness	**<0.001**	**0.002**	9	6	Richness increased over time and was higher in 2015 than the mean of prior years.
Equitability	**0.023**	**0.034**	7	7	Equitability increased over time and was higher in 2015 than the mean of prior years.
Log of EPT	**0.012**	**<0.001**	6	15	EPT increased over time and was higher in 2015 than the mean of prior years.
CA Axis 1	**0.007**	0.196	10	2	CA Axis 1 scores increased over time.
CA Axis 2	**0.045**	**0.003**	4	9	CA Axis 2 scores decreased over time and were lower in 2015 than the mean of prior years.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

2015 CA scores were projected using the taxa scores and eigenvalues calculated taxa abundances at depositional reaches from previous years (1998 to 2014; Appendix D)

Table 5.2-32 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Muskeg River (*test* reach MUR-D3).

Measurement Endpoints	P-value				Variance Explained (%)				Nature of Change(s)
	Control vs. Impact	Linear Time Trend in *Test* Period	2015 vs. *Baseline*	2015 vs. Previous Years	Control vs. Impact	Linear Time Trend in *Test* Period	2015 vs. *Baseline*	2015 vs. Previous Years	
Log of Abundance	0.200	0.012	0.027	0.038	7	29	22	20	Abundance increased in the *test* period and was higher in 2015 than the mean *baseline* and the prior years.
Log of Richness	0.720	<0.001	0.145	0.135	0	34	5	6	Richness increased in the *test* period.
Equitability	0.085	0.004	0.091	0.165	6	18	6	4	Equitability decreased in the *test* period.
Log of EPT	0.413	0.004	0.748	0.572	1	12	0	0	EPT was higher during the *test* period in the upper test reach and increased over time during the *test* period. EPT was higher in 2014 than the means of *baseline* years and the mean of all prior years.
CA Axis 1	0.076	0.869	0.018	<0.001	5	0	10	8	CA Axis 1 scores were lower in 2015 than the mean of prior years.
CA Axis 2	0.011	0.767	0.818	<0.001	12	0	0	0	CA Axis 2 scores were lower in the *test* period, but higher in 2015 than the mean of prior years within the *test* period.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

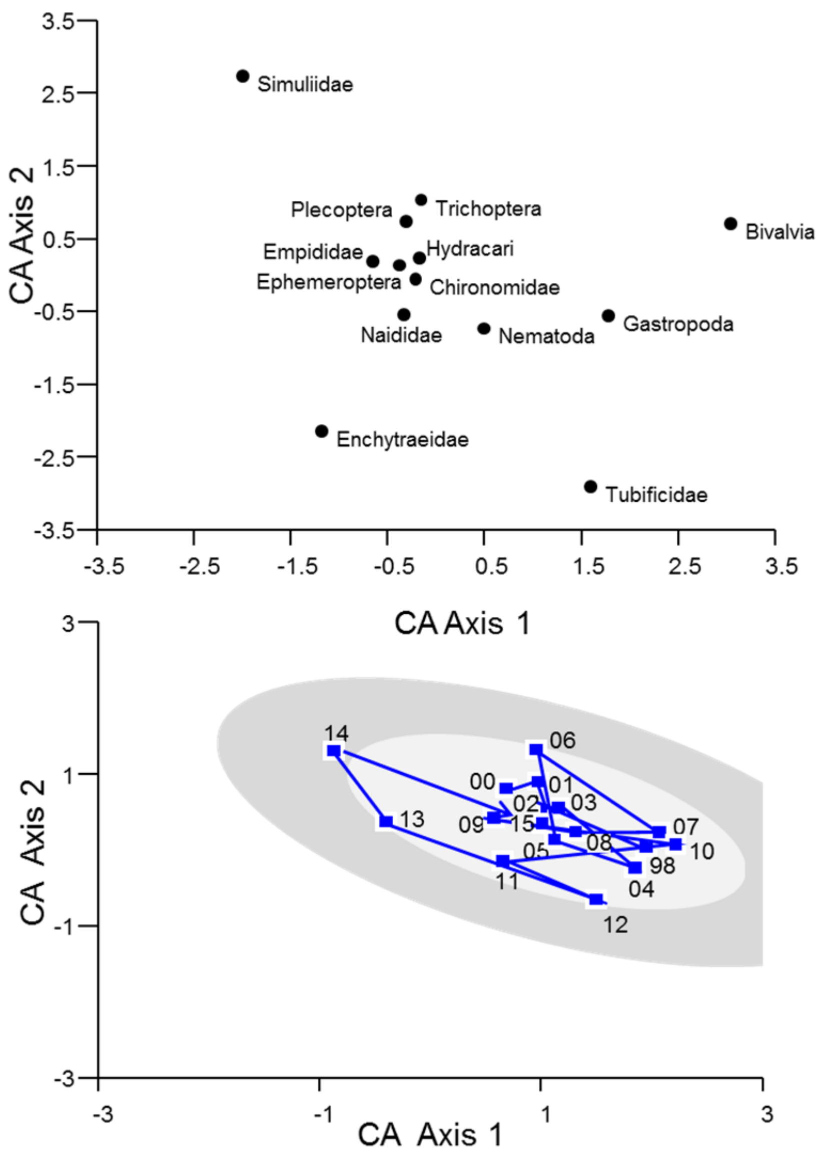
Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed

2015 CA scores were projected using the taxa scores and eigenvalues calculated taxa abundances at depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.2-15 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the lower reach of the Muskeg River (*test* reach MUR-E1).

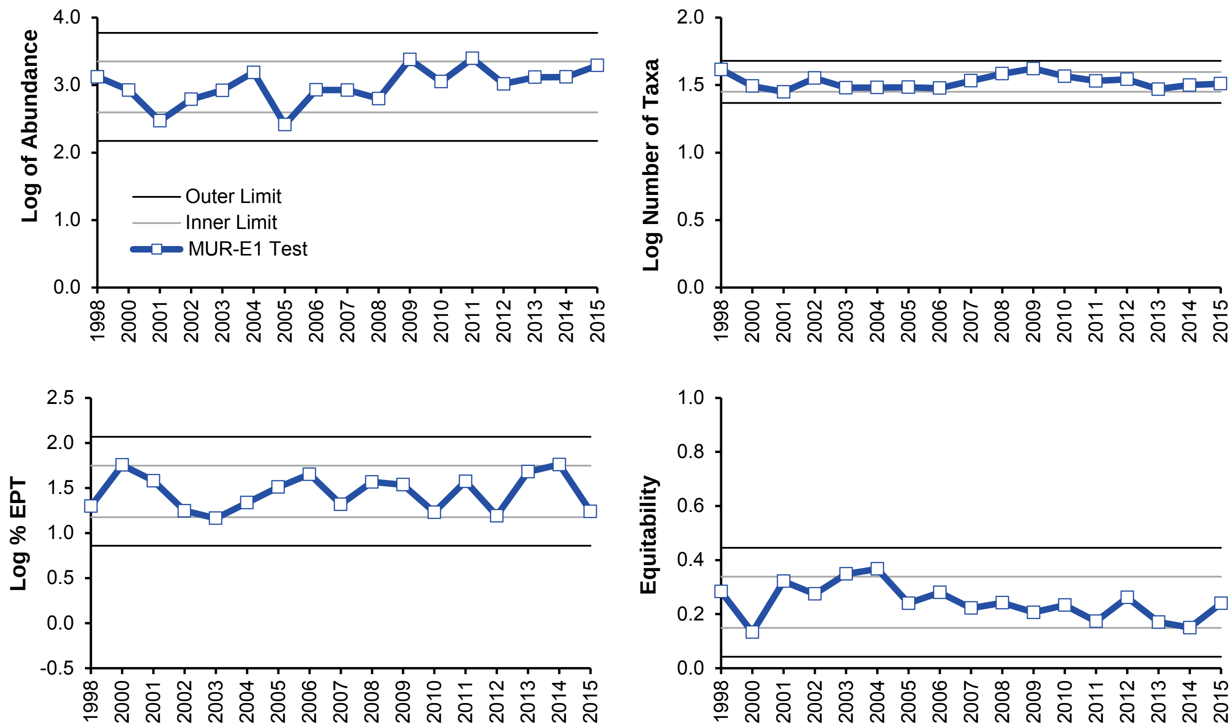


Notes:

The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years (1998 to 2014).

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for erosional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.2-16 Variation in benthic invertebrate community measurement endpoints at lower *test* reach MUR-E1 of the Muskeg River, relative to the historical ranges of variability.



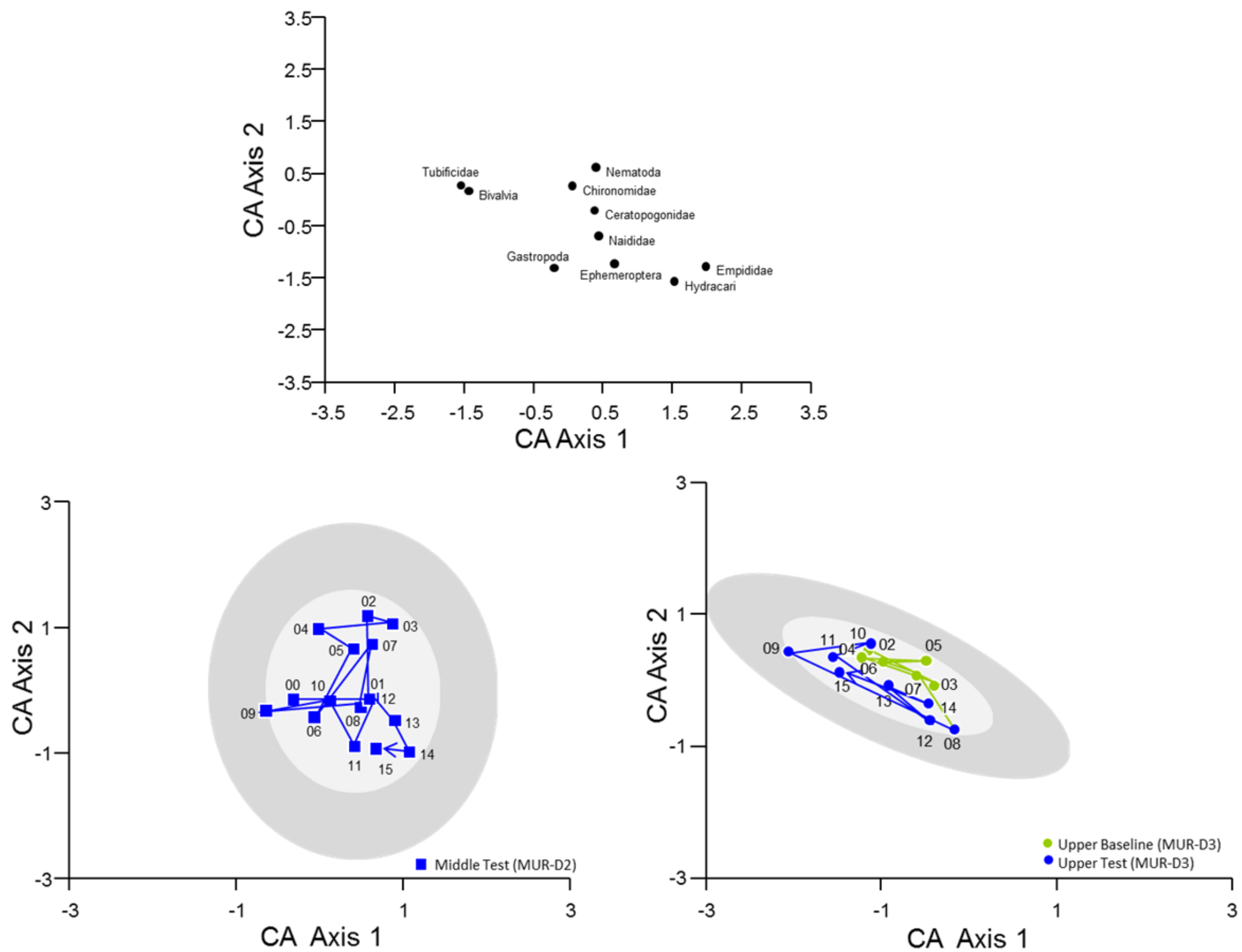
Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at *test* reach MUR-E1 (1998 to 2014).

Abundance, richness, and %EPT data were log10(x+1) transformed before the average was calculated.

Measurement endpoints for *test* reach MUR-E1 in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Figure 5.2-17 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the middle and upper reaches of the Muskeg River (*test* reaches MUR-D2 and MIR-D3).



Notes:

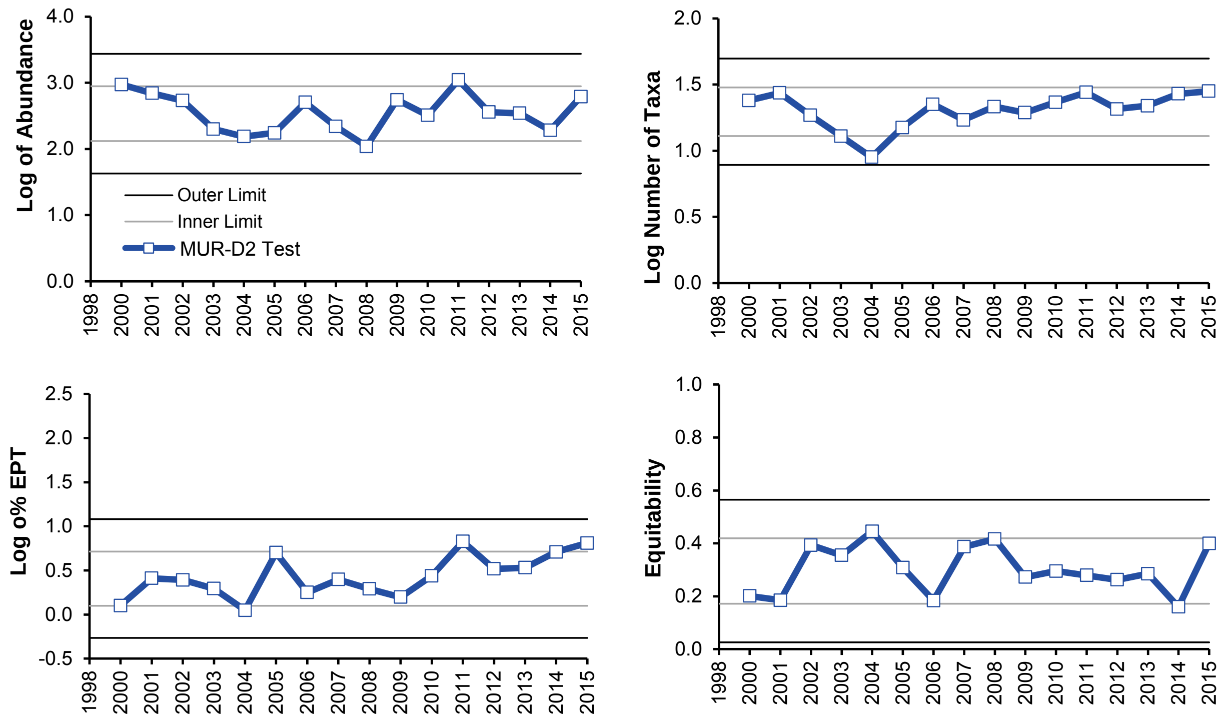
The upper panel is the scatterplot of taxa scores while the lower panels are the scatterplots of sample scores.

The ellipses in the lower panel for MUR-D2 are the inner and outer tolerance limits on the 95th percentile for all previous years (2000 to 2014).

The ellipses in the lower panel for MUR-D3 are the inner and outer tolerance limits on the 95th percentile for regional *baseline* depositional reaches.

2015 CA scores were projected using the taxa scores and eigenvalues calculated taxa abundances at depositional reaches from previous years (1998 to 2014; Appendix D)

Figure 5.2-18 Variation in benthic invertebrate community measurement endpoints at middle *test* reach MUR-D2 of the Muskeg River, relative to the historical ranges of variability.

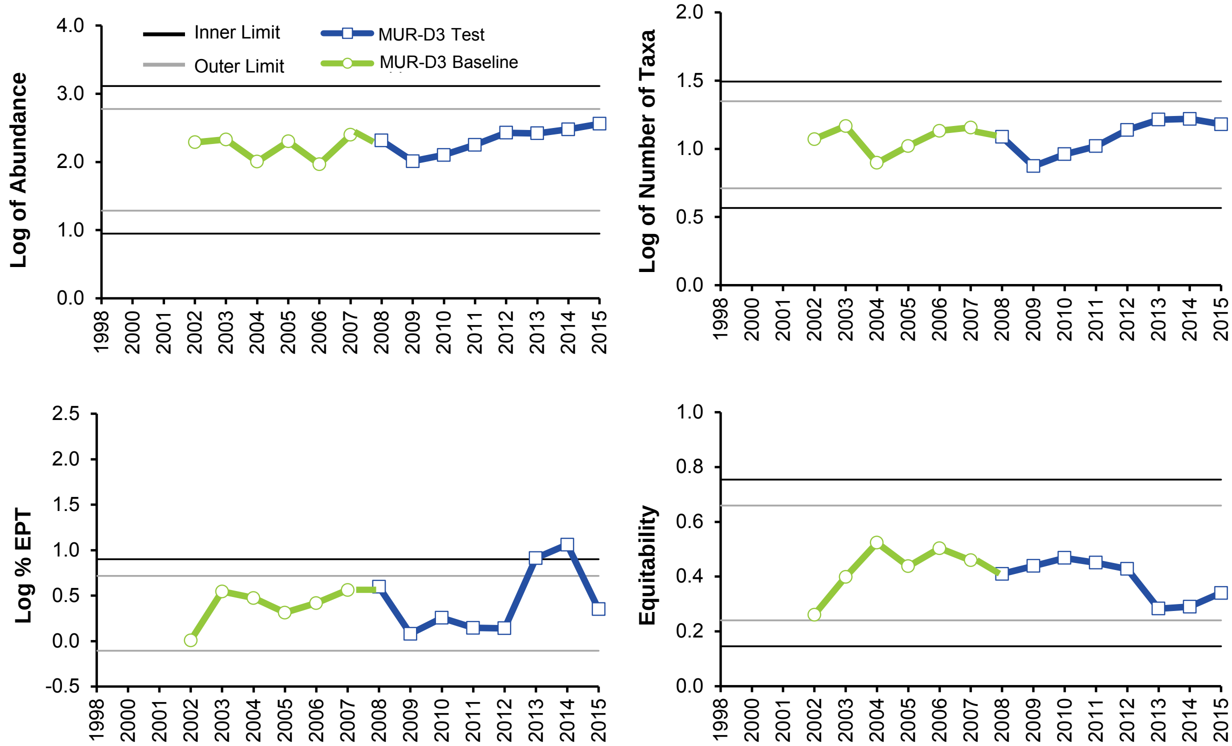


Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at *test* reach MUR-D2 (2000 to 2014).

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed before the average was calculated.

Figure 5.2-19 Variation in benthic invertebrate community measurement endpoints at upper *test* reach MUR-D3 of the Muskeg River relative to regional *baseline* ranges of variability.



Note:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* depositional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed before the average was calculated.

Table 5.2-33 Average habitat characteristics of benthic invertebrate sampling locations in Jackpine Creek (*test* reach JAC-D1 and *baseline* reach JAC-D2), fall 2015.

Variable	Units	JAC-D1 Lower *Test* Reach	JAC-D2 Upper *Baseline* Reach
Sample date	-	Sept.10, 2015	Sept. 11, 2015
Habitat	-	Depositional	Depositional
Water depth	m	0.5	0.4
Current velocity	m/s	0.2	0.3
Field water quality			
Dissolved oxygen (DO)	mg/L	9.7	9.8
Conductivity	µS/cm	203	216
pH	pH units	8.2	6.8
Water temperature	°C	-	10.3
Sediment composition			
Sand	%	92.2	85.7
Silt	%	6.2	10.6
Clay	%	1.6	5.3
Total organic carbon (TOC)	%	1.05	1.32

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.2-34 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community in lower Jackpine Creek (*test* reach JAC-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach JAC-D1		
	2002	2003 to 2014	2015
Hydra	-	0 to 1	1
Nematoda	5	1 to 11	1
Naididae	<1	0 to 10	7
Tubificidae	<1	<1 to 17	27
Enchytraeidae	<1	0 to 18	-
Hirudinea	-	0 to <1	<1
Hydracarina	1	1 to 8	-
Amphipoda	-	0 to <1	-
Gastropoda	<1	0 to 4	4
Bivalvia	1	0 to 3	1
Ceratopogonidae	2	0 to 16	2
Chironomidae	88	38 to 86	53
Dolichopodidae	-	<1	-
Diptera (misc.)	<1	<1 to 4	<1
Coleoptera	-	0 to <1	-
Ephemeroptera	<1	0 to 7	2
Odonata	<1	0 to <1	-
Plecoptera	-	0 to 1	<1
Trichoptera	<1	<1 to 3	<1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	619	79 to 2053	691
Richness	15	7 to 31	17
Equitability	0.38	0.34 t 0.56	0.30
% EPT	<1	<1 to 4	2.6

Table 5.2-35 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community at the upper reach of Jackpine Creek (*baseline* reach JAC-D2).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline reach JAC-D2		
	2003	2004 to 2014	2015
Hydra	-	0 to <1	-
Nematoda	6	<1 to 6	1
Oligochaeta	-	<1 to 10	-
Naididae	3	0 to 9	<1
Tubificidae	2	1 to 13	2
Enchytraeidae	1	<1 to 5	-
Hydracarina	<1	0 to 18	-
Gastropoda	-	0 to 1	<1
Bivalvia	<1	0 to 13	2
Ceratopogonidae	1	2 to 31	6
Chironomidae	67	3 to 82	67
Diptera (misc.)	1	0 to 17	11
Coleoptera	6	1 to 7	4
Ephemeroptera	<1	1 to 19	3
Odonata	-	0 to <1	-
Plecoptera	<1	0 to <1	-
Trichoptera	<1	1 to 7	<1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	105	61 to 521	623
Richness	12	10 to 25	17
Equitability	0.59	0.42 to 0.61	0.35
% EPT	2	<1 to 21	3.4

Table 5.2-36 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Jackpine Creek (*test* reach JAC-D1).

Measurement Endpoint	P-value							Variance Explained (%)							Nature of Change(s)
	Control vs. Impact	Before vs After	BACI	Time Trend in *Test* Period	Difference in Time Trend (*test*)	2015 vs. *Baseline*	2105 vs. Previous Years	Control vs. Impact	Before vs After	BACI	Time Trend in *Test* Period	Difference in Time Trend (*test*)	2015 vs. *Baseline*	2105 vs. Previous Years	
Log of Abundance	**<0.001**	**<0.001**	0.301	0.898	**0.021**	**<0.001**	**0.023**	12	31	1	0	3	9	3	Abundance was higher in the lower *test* reach and higher during the *test* period in both reaches.
Log of Richness	0.393	**<0.001**	0.203	0.994	0.099	0.245	0.607	1	39	2	0	3	1	0	Richness was higher during the *test* period of the reach.
Equitability	**0.001**	**<0.001**	0.285	0.969	**<0.001**	**0.004**	0.084	12	30	1	0	16	9	3	Equitability was lower in the *test* reach than in the upper *baseline* reach and lower in the *test* period of the lower reach. Equitability decreased over time and was lower in 2015 than the mean of upper *baseline* years.
Log of EPT	**<0.001**	**0.002**	0.585	0.418	0.354	0.961	0.306	13	8	0	1	1	0	1	EPT was lower in the *test* reach than the upper *baseline* reach, but higher during the *test* period of the lower reach.
CA Axis 1	0.270	0.320	0.532	0.253	**0.032**	**0.001**	**0.002**	1	1	0	2	6	13	12	CA Axis 1 scores increased over time in the upper *baseline* reach and decreased over time in the lower *test* reach. CA Axis 1 scores in 2015 were lower in the *test* reach than previous years and than the *baseline* reach.
CA Axis 2	0.994	**<0.001**	0.200	**0.029**	0.079	0.096	0.128	0	19	1	3	2	2	1	CA Axis 2 scores were higher during the period when the lower reach was considered to be *baseline* (2002 to 2004).

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

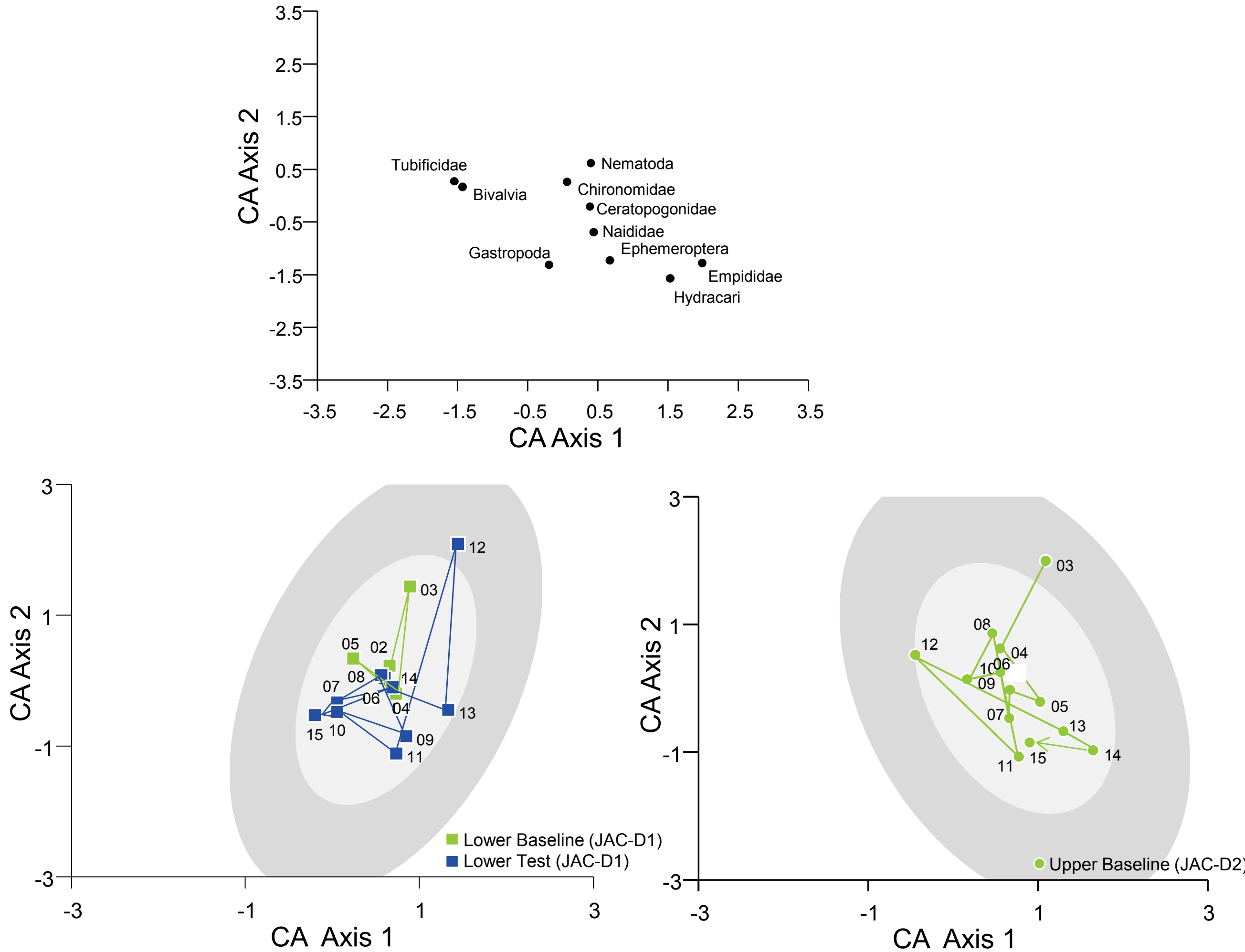
Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.2-20 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower and upper reaches of Jackpine Creek (*test* reach JAC-D1 and *baseline* reach JAC-D2).

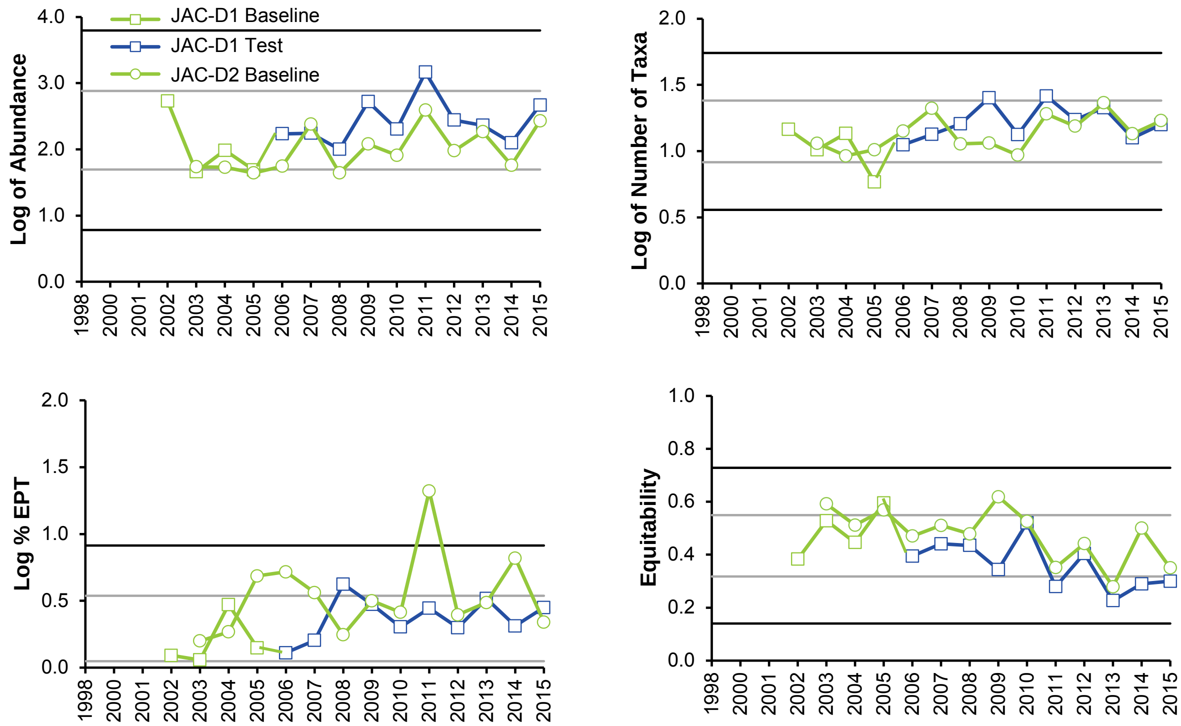


Notes:

The upper panel is the scatterplot of taxa scores while the lower panels are the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years (2002 to 2014).

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.2-21 Variations in benthic invertebrate community measurement endpoints at lower *test* reach JAC-D1 and upper *baseline* reach JAC-D2 of Jackpine Creek relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at *test* reach JAC-D1 (2002 to 2014).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.2-37 Average habitat characteristics of benthic invertebrate community sampling locations in Kearl Lake, fall 2015.

Variable	Units	KEL-1 *Test* Station
Sample date	-	September 3, 2015
Habitat	-	Depositional
Water depth	m	1.9
Field water quality		
Dissolved oxygen (DO)	mg/L	8.1
Conductivity	µS/cm	155
pH	pH units	7.57
Water temperature	°C	12.9
Sediment composition		
Sand	%	2.5
Silt	%	73.0
Clay	%	24.4
Total organic carbon (TOC)	%	35.3

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates

Table 5.2-38 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in Kearl Lake.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Station KEL-1		
	2001	2002 - 2014	2015
Hydra	-	<1	<1
Nematoda	-	0 to 5	2
Naididae	-	<1 to 36	21
Tubificidae	-	0 to 8	2
Enchytraeidae	-	<1	-
Lumbriculidae	-	0 to <1	-
Hirudinea	0 to <1	0 to <1	<1
Hydracarina	<1	0 to 16	-
Amphipoda	13	<1 to 58	<1
Gastropoda	1	0 to 2	1
Bivalvia	4	4 to 31	8
Ceratopogonidae	-	0 to 1	1
Chironomidae	6	13 to 46	55
Diptera (misc)	1	0 to <1	<1
Coleoptera	-	-	<1
Ephemeroptera	<1	0 to 2	7
Odonata	-	0 to <1	<1
Trichoptera	2	0 to 2	1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	18	41 to 401	1,008
Richness	7	7 to 18	23
Equitability	0.92	0.13 to 0.77	0.38
% EPT	3	<1 to 2	8

Table 5.2-39 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Kearl Lake.

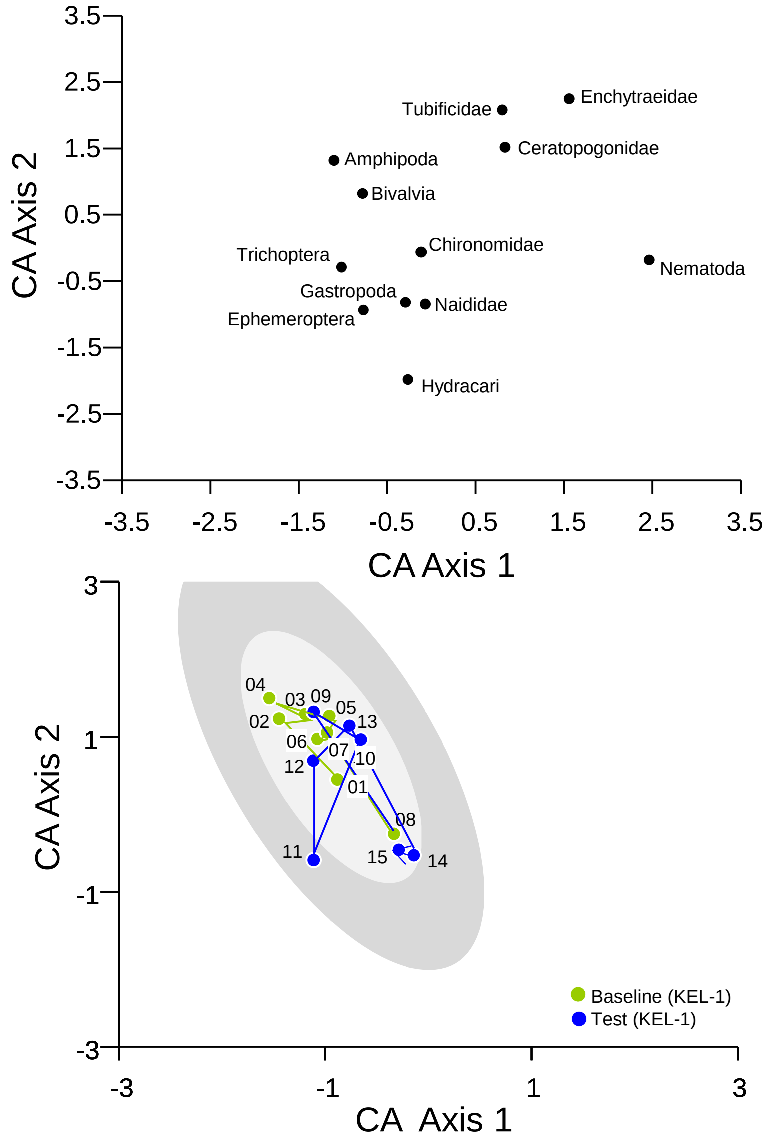
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Before vs. After	Time Trend in *Test* Period	2015 vs. *Baseline*	2015 vs. Previous Years	Before vs. After	Time Trend in *Test* Period	2015 vs. *Baseline*	2015 vs. Previous Years	
Log of Abundance	0.059	**<0.001**	**<0.001**	**<0.001**	2	36	29	31	Abundance increased over time during the *test* period and was higher in 2015 than the mean in the *baseline* period and the mean of all prior years.
Log of Richness	**<0.001**	**<0.001**	**<0.001**	**<0.001**	19	44	35	30	Richness was higher during the *test* period. Richness increased over time in the *test* period and was higher in 2015 than the average of the *baseline* period and the average of all prior years.
Equitability	0.246	**<0.001**	0.056	0.070	1	30	3	3	Equitability decreased over time during the *test* period.
Log of EPT	0.456	**<0.001**	**<0.001**	**<0.001**	1	34	35	45	Percent of the fauna as EPT taxa increased during the *test* period, was higher in 2015 than the mean in the *baseline* period and the mean of all prior years.
CA Axis 1	**0.002**	**<0.001**	**0.001**	**0.003**	16	0	18	14	CA Axis 1 scores were higher during the *test* period. CA Axis 1 scores increased over time in the *test* period and were higher in 2015 than the mean of the *baseline* period and the mean of all prior years.
CA Axis 2	**<0.001**	**0.006**	**0.039**	0.172	15	9	5	2	CA Axis 2 scores were higher during the *test* period. CA Axis 2 scores increased over time in the *test* period and were higher in 2015 than the mean of the *baseline* period.

Bold values indicate significant variation as per the specified contrast ($p < 0.05$). Significance contributes to the classification of results per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

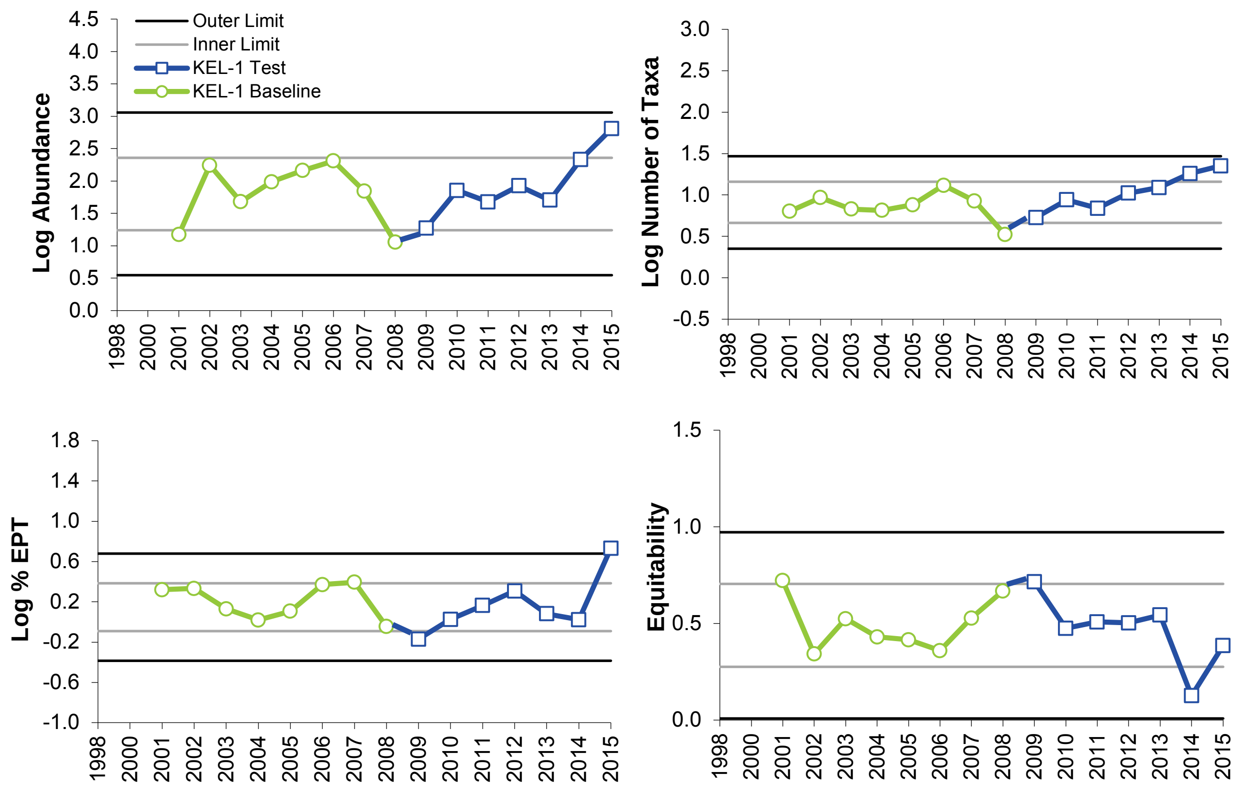
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.2-22 Ordination (Correspondence Analysis) of benthic invertebrate communities of lakes in the oil sands region, showing Kearl Lake.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.2-23 Variations in benthic invertebrate community measurement endpoints in Kearl Lake (KEL-1) relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from 2001 to 2014.

Values were adjusted to a common depth of 2 m (see Appendix D).

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed before the average was calculated

Table 5.2-40 Concentrations of selected sediment quality measurement endpoints in the Muskeg River (*test* station MUR-D2), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2000-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>0.6</u>	11	<1.0	5.6	12.0
Silt	%	-	<u>0.5</u>	11	<1.0	16.0	32.0
Sand	%	-	<u>98.8</u>	11	60.0	79.0	98.6
Total organic carbon	%	-	0.14	12	0.13	2.75	29.60
Total hydrocarbons							
BTEX	mg/kg	-	<10	11	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	11	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	11	<5	67	**180**
Fraction 3 (C16-C34)	mg/kg	300[1]	187	11	50	**856**	**2,900**
Fraction 4 (C34-C50)	mg/kg	2800[1]	164	11	43	743	2,100
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0009	13	0.0004	0.0016	0.0200
Retene	mg/kg	-	<0.0096	13	0.0021	0.1440	0.3140
Total dibenzothiophenes	mg/kg	-	0.1982	13	0.0532	2.8398	11.0401
Total PAHs	mg/kg	-	1.3594	13	0.4039	8.0100	30.4399
Total Parent PAHs	mg/kg	-	0.0662	13	0.0144	0.2489	0.6761
Total Alkylated PAHs	mg/kg	-	1.2932	13	0.3895	7.8604	29.7638
Predicted PAH toxicity[3]	H.I.	1.0	**1.0638**	13	0.7306	**1.3806**	**3.9966**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	48	9	26	70	88
Chironomus growth - 10d	mg/organism	-	1.79	9	0.68	2.11	4.28
Hyalella survival - 14d	% surviving	-	94	9	80	86	100
Hyalella growth - 14d	mg/organism	-	0.18	9	0.11	0.30	0.37

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

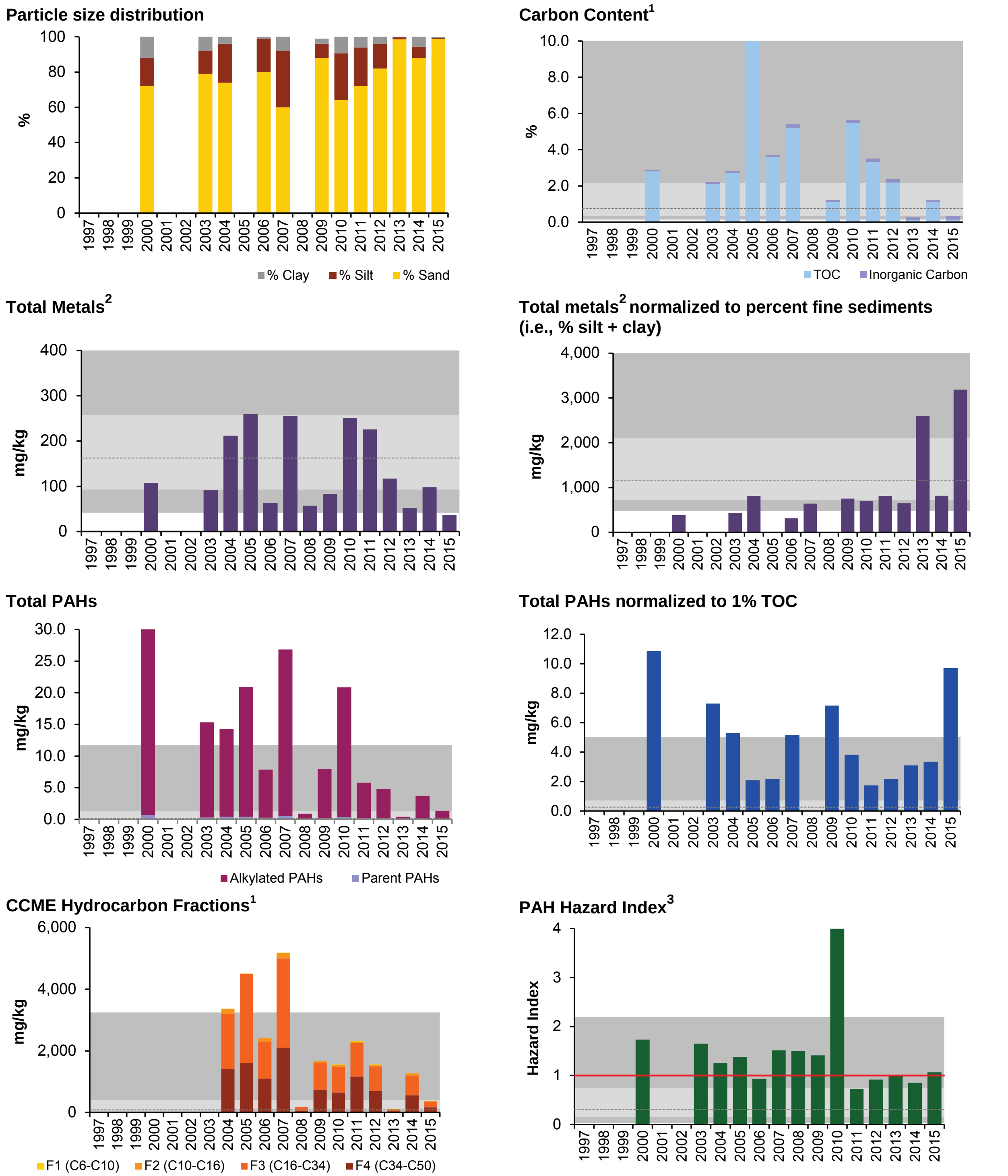
ns = not sampled in 2001 or 2002

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.2-24 Variation in sediment quality measurement endpoints in the Muskeg River, *test* station MUR-D2, relative to historical concentrations and to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.2-41 Concentrations of selected sediment quality measurement endpoints in the Muskeg River (*test* station MUR-D3), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2003-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2.7	11	4.5	6.6	47.0
Silt	%	-	7.0	11	6.0	11.5	29.0
Sand	%	-	90.4	11	26.0	80.0	85.1
Total organic carbon	%	-	4.76	12	1.70	16.30	29.60
Total hydrocarbons							
BTEX	mg/kg	-	<20	11	<5	<10	<80
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	11	<5	<10	**<80**
Fraction 2 (C10-C16)	mg/kg	150[1]	<30	11	<5	27	130
Fraction 3 (C16-C34)	mg/kg	300[1]	182	11	52	**712**	**2,600**
Fraction 4 (C34-C50)	mg/kg	2800[1]	110	11	56	305	1,800
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0006	12	0.0004	0.0052	0.0145
Retene	mg/kg	-	0.0658	12	0.0155	0.3440	2.3300
Total dibenzothiophenes	mg/kg	-	0.0546	12	0.0419	0.1187	0.1899
Total PAHs	mg/kg	-	0.3438	12	0.3786	1.0697	3.1058
Total Parent PAHs	mg/kg	-	0.0152	12	0.0179	0.0476	0.3397
Total Alkylated PAHs	mg/kg	-	0.3285	12	0.3486	0.9428	3.0537
Predicted PAH toxicity[3]	H.I.	1.0	0.3082	12	0.0253	0.3152	**1.2248**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	94	8	30	67	95
Chironomus growth - 10d	mg/organism	-	1.64	8	1.28	1.9	2.95
Hyalella survival - 14d	% surviving	-	90	8	70	83	95
Hyalella growth - 14d	mg/organism	-	0.15	8	0.11	0.25	0.36

Values in **bold** indicate concentrations exceeding guidelines.

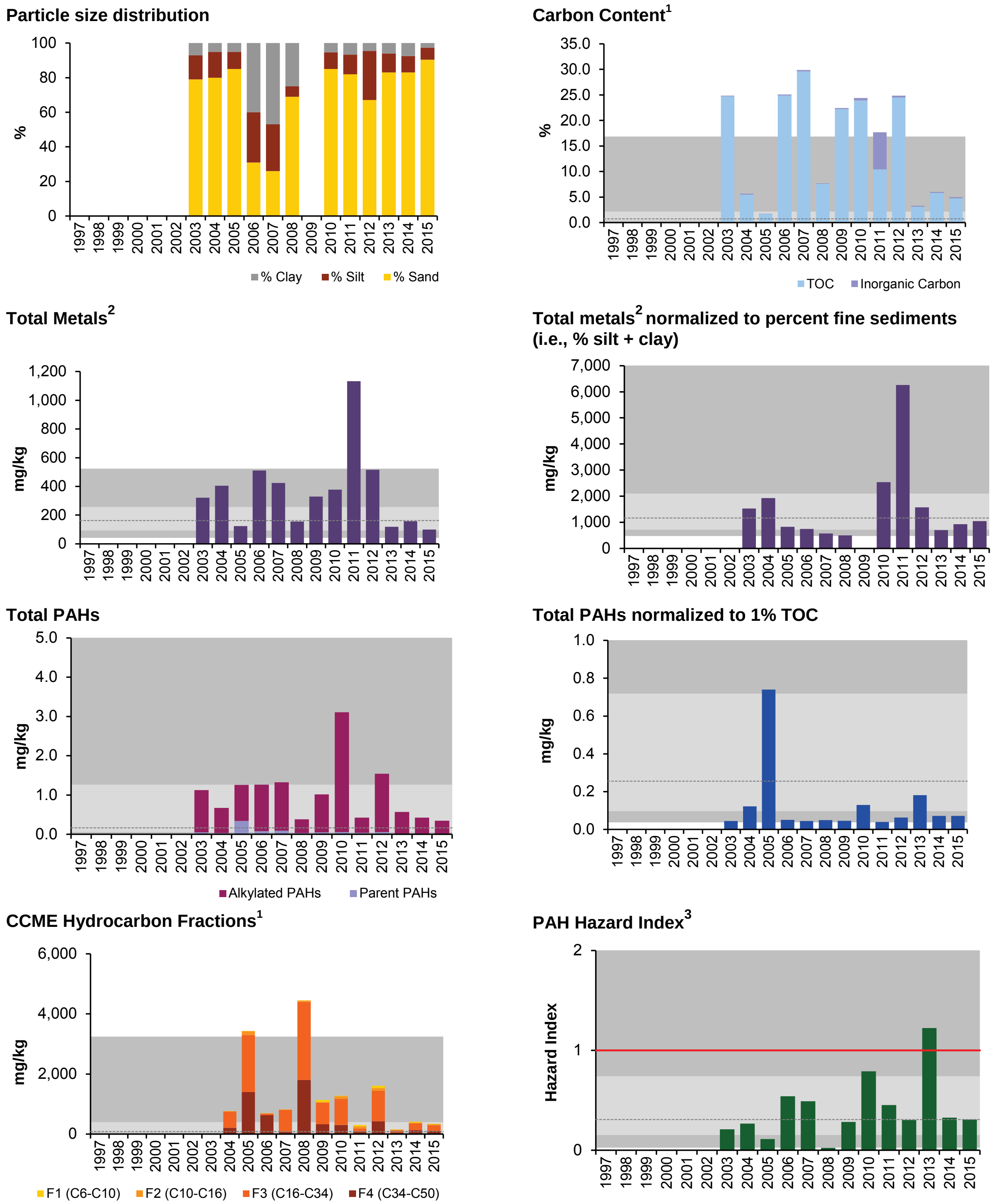
Values underlined indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.2-25 Variation in sediment quality measurement endpoints in the Muskeg River, *test* station MUR-D3, relative to historical concentrations and to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.2-42 Concentrations of selected sediment quality measurement endpoints in Jackpine Creek near the mouth (*test* station JAC-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	1997-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	0.6	11	0.1	3.0	18.7
Silt	%	-	1.2	11	0.3	11.0	19.9
Sand	%	-	98.2	11	74.5	84.0	99.3
Total organic carbon	%	-	0.80	11	0.20	1.10	3.57
Total hydrocarbons							
BTEX	mg/kg	-	<10	10	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	10	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<40	10	13	<20	71
Fraction 3 (C16-C34)	mg/kg	300[1]	**734**	10	101	**408**	**790**
Fraction 4 (C34-C50)	mg/kg	2800[1]	621	10	137	501	820
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0008	11	0.0003	0.0009	0.0030
Retene	mg/kg	-	0.0316	10	0.0072	0.0239	0.9510
Total dibenzothiophenes	mg/kg	-	1.2159	11	0.1047	0.4440	1.6392
Total PAHs	mg/kg	-	3.9889	11	0.4129	1.3500	4.4924
Total Parent PAHs	mg/kg	-	0.1063	11	0.0155	0.0440	0.1360
Total Alkylated PAHs	mg/kg	-	3.8826	11	0.3911	1.3060	4.3754
Predicted PAH toxicity[3]	H.I.	1.0	0.8154	11	0.2138	0.3264	**1.5964**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	88	9	56	78	96
Chironomus growth - 10d	mg/organism	-	2.03	9	1.15	2.43	3.4
Hyalella survival - 14d	% surviving	-	94	9	70	94	100
Hyalella growth - 14d	mg/organism	-	0.16	9	0.14	0.27	0.40

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

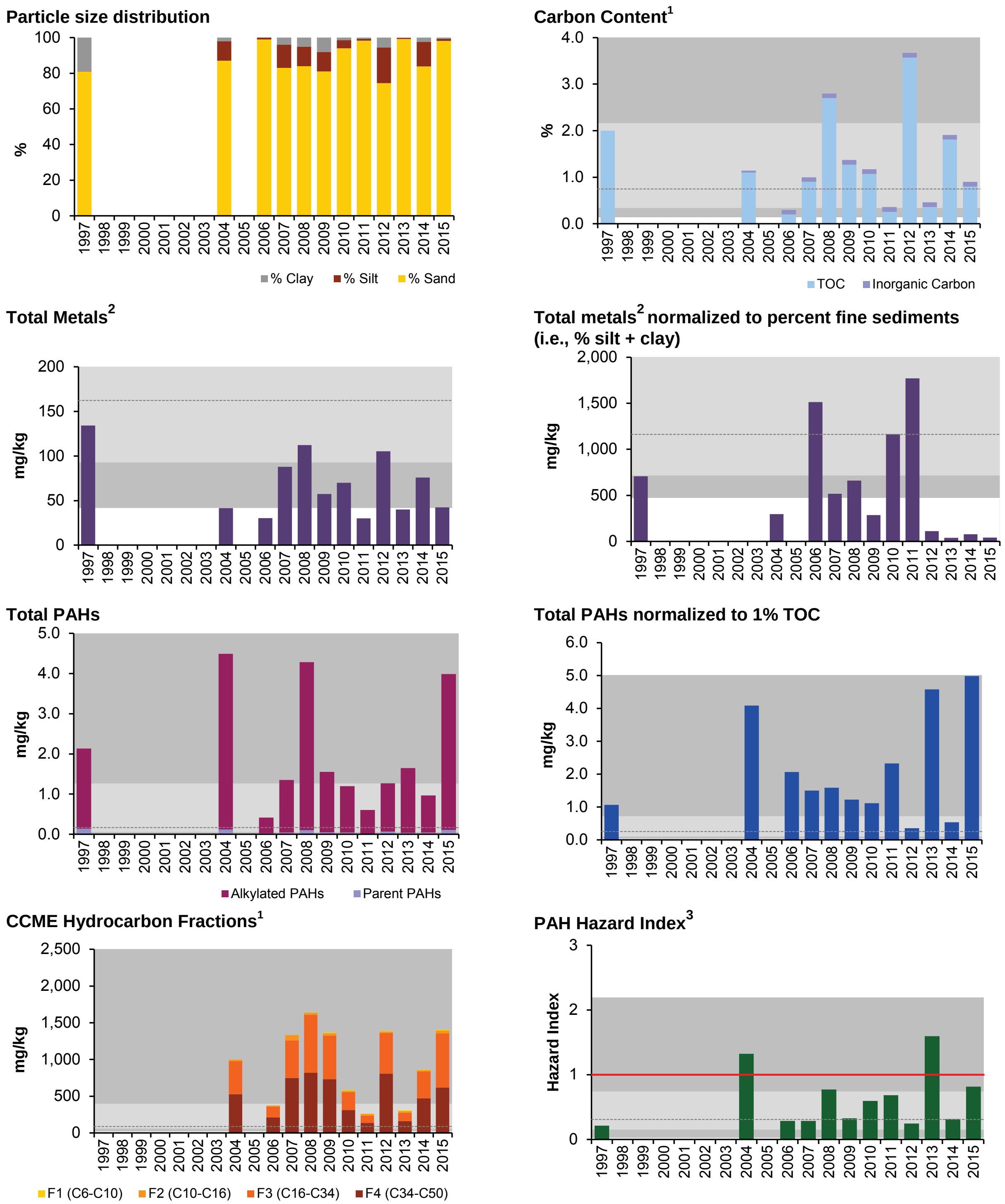
ns = not sampled in 1998 to 2003, and 2005

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.2-26 Variation in sediment quality measurement endpoints in Jackpine Creek near the mouth, *test* station JAC-D1, relative to historical concentrations and to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.2-43 Concentrations of selected sediment quality measurement endpoints in Jackpine Creek above Jackpine Mine (*baseline* station JAC-D2), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2006-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	11.2	8	<1.0	6.0	13.0
Silt	%	-	23.2	8	<1.0	10.8	23.1
Sand	%	-	65.7	8	66.0	82.6	99.0
Total organic carbon	%	-	5.82	9	0.10	1.00	2.06
Total hydrocarbons							
BTEX	mg/kg	-	<30	9	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<30	9	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<30	9	<5	<20	<27
Fraction 3 (C16-C34)	mg/kg	300[1]	<30	9	10	54	190
Fraction 4 (C34-C50)	mg/kg	2800[1]	<30	9	<5	48	160
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0009	8	0.0003	0.0007	0.0041
Retene	mg/kg	-	0.0701	8	0.0010	0.0125	0.0331
Total dibenzothiophenes	mg/kg	-	0.0297	8	0.0019	0.0066	0.0164
Total PAHs	mg/kg	-	0.2178	8	0.0143	0.0968	0.2002
Total Parent PAHs	mg/kg	-	0.0183	8	0.0037	0.0082	0.0203
Total Alkylated PAHs	mg/kg	-	0.1995	8	0.0106	0.0886	0.1803
Predicted PAH toxicity[3]	H.I.	1.0	0.6884	8	0.1351	0.2221	0.3563
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	76	8	46	76	96
Chironomus growth - 10d	mg/organism	-	1.97	8	0.80	2.31	4.17
Hyalella survival - 14d	% surviving	-	95	8	80	92	98
Hyalella growth - 14d	mg/organism	-	0.13	8	0.25	0.30	0.56

Values in **bold** indicate concentrations exceeding guidelines.

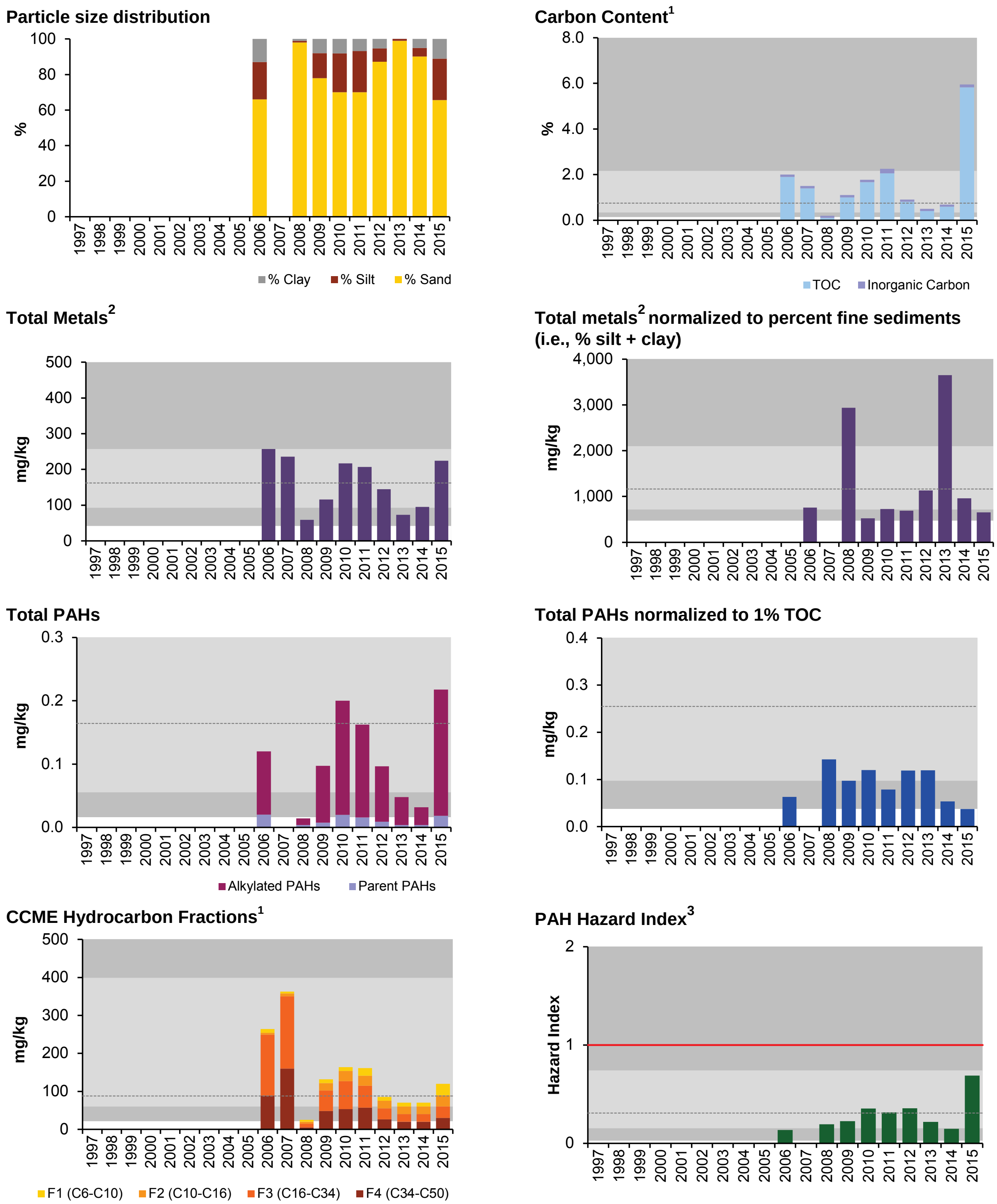
Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.2-27 Variation in sediment quality measurement endpoints in Jackpine Creek above Jackpine Mine, *baseline* station JAC-D2, relative to historical concentrations and to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.2-44 Concentrations of selected sediment quality measurement endpoints in Kearl Lake (*test* station KEL-1), fall 2015, compared to historical concentrations.

Variables	Units	Guideline	September 2015	2001-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	11.9	9	1.0	10.3	58.0
Silt	%	-	87.3	9	4.0	44.7	87.6
Sand	%	-	<u>0.7</u>	9	3.5	23.0	93.0
Total organic carbon	%	-	33.40	11	5.04	34.40	38.10
Total hydrocarbons							
BTEX	mg/kg	-	<170	10	<5	<120	<1,000
Fraction 1 (C6-C10)	mg/kg	30[1]	**<171**	10	<5	**<120**	**<1,000**
Fraction 2 (C10-C16)	mg/kg	150[1]	**<210**	10	<5	**<180**	**530**
Fraction 3 (C16-C34)	mg/kg	300[1]	**666**	10	230	**584**	**3,600**
Fraction 4 (C34-C50)	mg/kg	2800[1]	352	10	81	388	2,500
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0079	7	0.0065	0.0141	**0.0361**
Retene	mg/kg	-	0.0223	11	0.0156	0.0418	0.1130
Total dibenzothiophenes	mg/kg	-	0.0379	11	0.0256	0.0443	0.0866
Total PAHs	mg/kg	-	<u>0.4604</u>	11	0.5092	0.8633	1.4596
Total Parent PAHs	mg/kg	-	<u>0.0780</u>	11	0.0783	0.1170	0.3449
Total Alkylated PAHs	mg/kg	-	<u>0.3823</u>	11	0.4205	0.7052	1.3436
Predicted PAH toxicity[3]	H.I.	1.0	0.1028	11	0.0311	0.1415	0.9241
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	<u>92</u>	7	70	88	90
Chironomus growth - 10d	mg/organism	-	1.62	7	1.16	1.45	2.33
Hyalella survival - 14d	% surviving	-	84	7	74	90	96
Hyalella growth - 14d	mg/organism	-	0.13	7	0.12	0.25	0.31

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

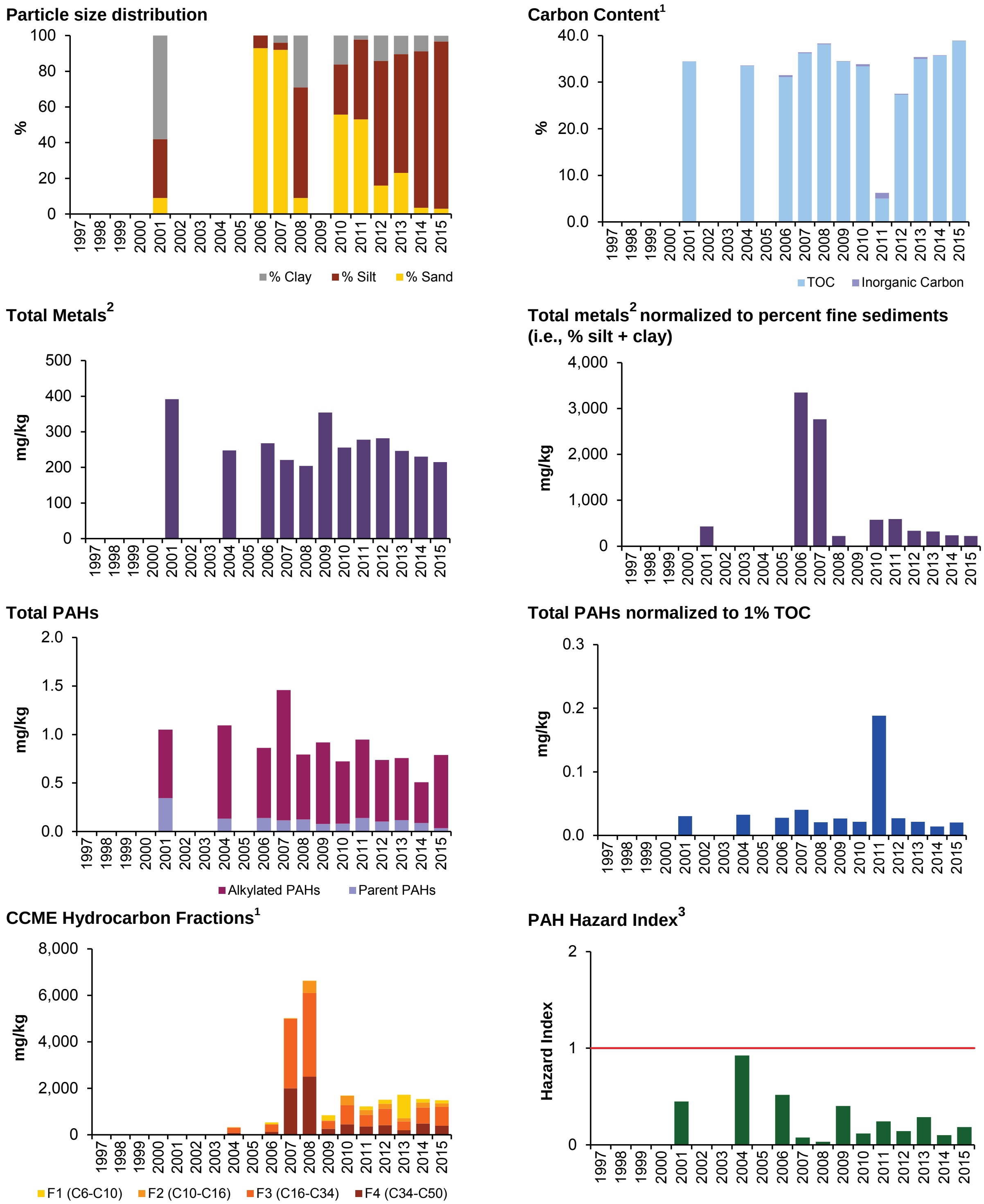
ns = not sampled in 2002, 2003, and 2005

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.2-28 Variation in sediment quality measurement endpoints in Kearl Lake, *test* station KEL-1, relative to historical concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.2-45 Average habitat characteristics of fish community monitoring reach MUR-F2 in the Muskeg River, fall 2015.

Variable	Units	MUR-F2 Mid *Test* Reach
Sample date		Sept. 22, 2015
Habitat type	-	riffle
Maximum depth	m	0.52
Mean depth	m	0.30
Bankfull channel width	m	19.0
Wetted channel width	m	19.0
Substrate		
Dominant	-	coarse gravel
Subdominant	-	cobble
Instream cover		
Dominant	-	small woody debris, boulders, live trees/roots, overhanging vegetation, undercut banks
Subdominant	-	-
Field water quality		
Dissolved oxygen	mg/L	9.2
Conductivity	µS/cm	251
pH	pH units	7.99
Water temperature	^{0}C	8.5
Water velocity		
Left bank velocity	m/s	0.67
Left bank water depth	m	0.52
Centre of channel velocity	m/s	0.05
Centre of channel water depth	m	0.10
Right bank velocity	m/s	0.27
Right bank water depth	m	0.32
Riparian cover – understory (<5 m)		
Dominant	-	woody shrubs and saplings
Subdominant	-	overhanging vegetation

Table 5.2-46 Total number and percent composition of fish species captured in reaches of the Muskeg River, 2009 to 2015.

Common Name	Code	Total Species Catch															Percent of Total Catch														
		MUR-F1						MUR-F2					MUR-F3				MUR-F1						MUR-F2					MUR-F3			
		2009	2010	2011	2012	2013	2014	2011	2012	2013	2014	2015	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	2011	2012	2013	2014	2015	2011	2012	2013	2014
brook stickleback	BRST	3	5	1	-	-	-	-	-	-	-	-	33	1	-	-	5.2	5.4	1.4	0	0	0	0	0	0	0	0	84.6	100	0	0
burbot	BURB	1	-	-	-	8	9	-	-	-	-	-	-	-	-	-	1.7	0	0	0	29.6	21.4	0	0	0	0	0	0	0	0	0
finescale dace	FNDC	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	0	16.1	0	0	0	0	0	0	0	0	0	0	0	0	0
lake chub	LKCH	4	8	1	-	2	-	-	-	2	3	46	-	-	-	-	6.9	8.6	1.4	0	7.4	0	0	0	20.0	60.0	75.4	0	0	0	0
longnose dace	LNDC	-	10	7	1	-	-	-	-	-	-	-	-	-	-	-	0	10.8	9.9	16.7	0	0	0	0	0	0	0	0	0	0	0
longnose sucker	LNSC	5	4	49	-	3	6	-	-	1	-	5	-	-	-	-	8.6	4.3	69.0	0	11.1	14.3	0	0	10.0	0	8.20	0	0	0	0
northern pike	NRPK	-	-	-	1	1	-	2	-	1	1	-	-	-	-	1	0	0	0	16.7	3.7	0	66.7	0	10.0	20.0	0	0	0	0	25.0
pearl dace	PRDC	-	35	2	-	-	-	-	-	2	-	-	2	-	-	-	0	37.6	2.8	0	0	0	0	0	20.0	0	0	5.1	0	0	0
slimy sculpin	SLSC	43	11	5	1	7	23	-	-	-	-	-	-	-	-	-	74.1	11.8	7.0	16.7	25.9	54.8	0	0	0	0	0	0	0	0	0
spoonhead sculpin	SPSC	1	3	-	1	1	1	-	-	-	-	-	-	-	-	-	1.7	3.2	0	16.7	3.7	2.4	0	0	0	0	0	0	0	0	0
trout-perch	TRPR	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	0	0	0	0	0	0	0	0	0	0	1.64	0	0	0	0
walleye	WALL	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0
white sucker	WHSC	-	2	5	-	3	2	1	-	4	1	9	-	-	1	3	0	2.2	7.0	0	11.1	4.8	33.3	0	40.0	20.0	14.8	0	0	100	75.0
yellow perch	YLPR	-	-	-	2	2	1	-	-	-	-	-	-	-	-	-	0	0.0	0	33.3	7.4	2.4	0	0	0	0	0	0	0	0	0
sucker sp. *	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
unknown sp. *	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	0	0	0	0	0	0	0	0	0	0	0	10.3	0	0	0
Total Count		**58**	**93**	**71**	**6**	**27**	**42**	**3**	**0**	**10**	**5**	**61**	**39**	**1**	**1**	**4**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**-**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**7**	**9**	**8**	**5**	**8**	**6**	**2**	**0**	**5**	**5**	**3**	**3**	**1**	**1**	**2**	**7**	**9**	**8**	**5**	**8**	**6**	**2**	**0**	**5**	**3**	**4**	**3**	**1**	**1**	**2**
Electrofishing effort (secs)		**2,051**	**4,623**	**1,267**	**1,526**	**2,274**	**2,296**	**1,178**	**1,841**	**1,853**	**1,853**	**1,765**	**1,297**	**1,763**	**1,551**	**1,310**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

* not included in total species richness count

Table 5.2-47 Summary of fish community measurement endpoints (± 1SD) for reaches along the Muskeg River and Jackpine Creek, 2009 to 2015.

Reach	Designation	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
			Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MUR-F1	Lower *test* reach	2009	0.15	-	7	-	-	0.43	-	3.65	-	2.78	-
		2010	0.19	0.08	9	4.10	2.38	0.64	0.29	6.10	0.51	3.89	2.01
		2011	0.28	0.09	8	3.80	1.10	0.47	0.13	5.15	0.39	5.64	1.87
		2012	0.03	0.02	5	1.20	0.84	0.20	0.27	6.05	2.13	0.40	0.27
		2013	0.05	0.04	8	3.40	2.07	0.53	0.32	5.07	1.89	1.19	0.97
		2014	0.09	0.04	6	3.00	0.71	0.54	0.16	3.29	0.46	1.83	0.89
MUR-F2	Mid *test* reach	2009	0.00	-	1	-	-	0.00	-	2.00	-	0.11	-
		2011	0.01	0.02	2	0.60	0.89	0.10	0.22	7.75	0.07	0.23	0.35
		2012	0.00	-	0	0.00	-	0.00	-	0.00	-	0.00	-
		2013	0.01	0.01	5	2.00	1.22	0.30	0.27	6.90	1.14	0.54	0.31
		2014	0.01	0.00	3	0.80	0.45	0.00	-	6.60	1.27	0.38	0.27
		2015	0.19	0.18	4	2.60	0.55	0.47	0.24	5.91	0.50	4.38	4.05
MUR-F3	Upper *test* reach	2011	0.16	0.10	3	1.40	0.55	0.14	0.22	9.06	0.58	2.99	1.84
		2012	0.00	0.01	1	0.20	0.45	0.00	-	9.40	-	0.06	0.14
		2013	0.00	0.01	1	0.20	0.45	0.00	-	7.60	-	0.06	0.14
		2014	0.01	0.01	2	0.60	0.55	0.00	-	7.67	0.12	0.23	0.24
JAC-F1	Lower *test* reach	2009	0.02	-	3	-	-	0.57	-	6.41	-	0.32	-
		2010	0.65	0.59	8	3.90	2.38	0.53	0.29	7.72	0.51	4.31	4.01
		2011	1.03	1.04	6	2.80	0.84	0.20	0.20	5.74	0.35	17.15	21.14
		2012	0.01	0.01	1	0.40	0.55	0.00	-	3.00	-	0.13	0.17
		2013	0.05	0.02	2	1.40	0.55	0.18	0.24	3.24	0.36	0.76	0.34
		2014	0.05	0.02	3	1.60	0.55	0.29	0.26	3.97	1.14	0.91	0.46
		2015	0.26	0.16	6	3.4	1.34	0.60	0.14	4.55	0.49	3.15	1.95
JAC-F2	Upper *baseline* reach	2009	0.42	-	4	-	-	0.48	-	6.56	-	4.36	-
		2010	0.10	-	5	-	-	0.69	-	7.85	-	4.51	-
		2011	0.69	0.62	4	2.80	0.84	0.50	0.16	8.18	0.61	10.43	10.88
		2012	0.02	0.02	2	0.60	0.55	0.00	-	6.80	2.25	0.30	0.33
		2013	0.12	0.10	3	1.80	0.84	0.19	0.21	8.26	1.72	2.25	1.72
		2014	0.21	0.10	4	2.60	1.14	0.35	0.26	6.19	0.58	5.01	2.42
		2015	0.18	0.10	6	3.00	0.71	0.62	0.07	7.21	0.72	2.22	1.18

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

SD = standard deviation across sub-reaches within a reach

* unknown species not included in the calculation

Table 5.2-48 Results of analysis of variance (ANOVA) testing for temporal differences in fish community measurement endpoints for *test* reach MUR-F2 in the Muskeg River (2011 to 2015).

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change
Abundance	**0.002***	33%	Increasing over time
Richness	**0.002**	31%	Increasing over time
Diversity	**0.03**	16%	Increasing over time
ATI	0.11	8%	No change
CPUE	**<0.001**	42%	Increasing over time

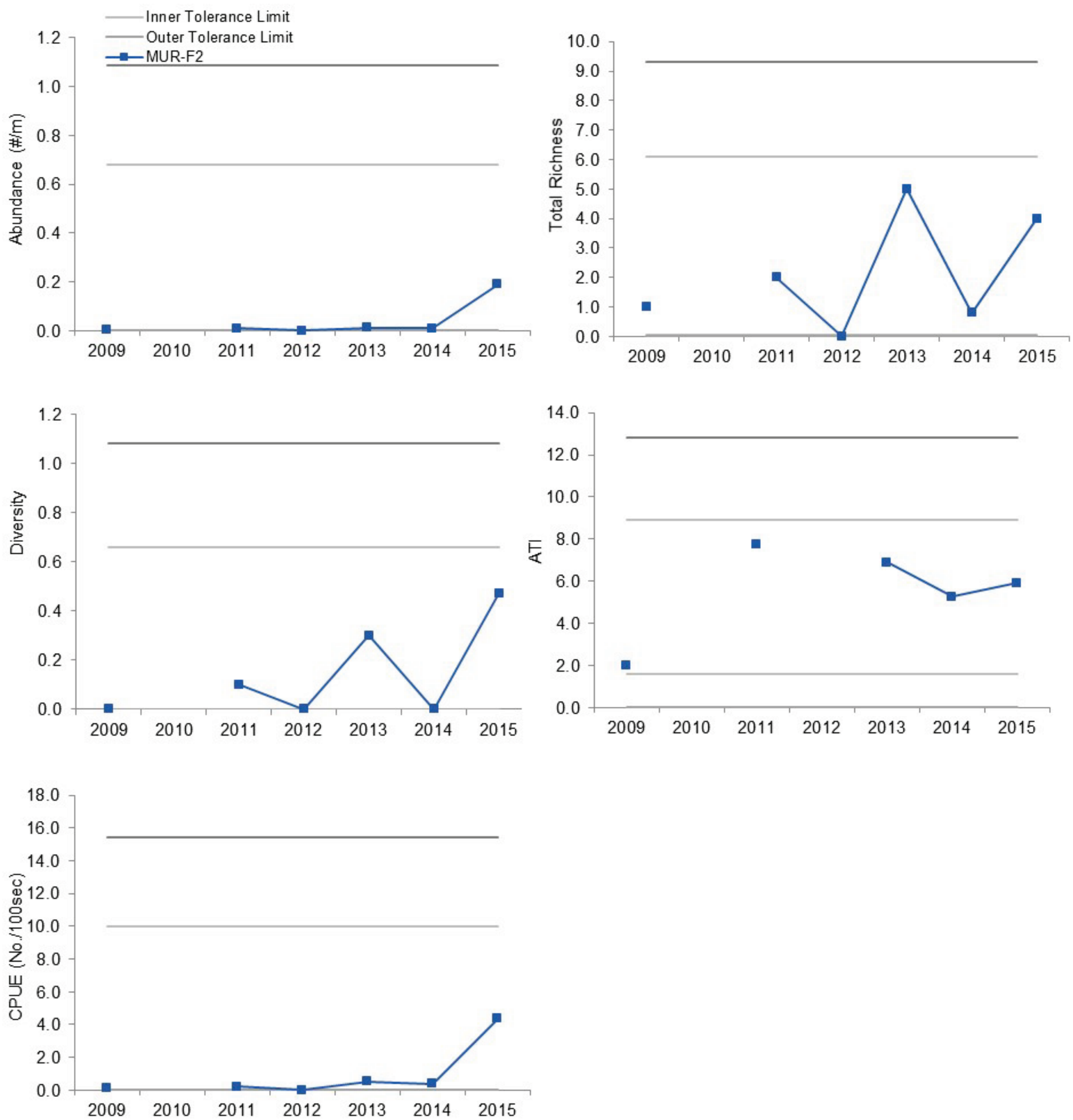
Bold values indicate significant difference (p≤0.05).

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

* data were log-transformed to meet assumptions of ANOVA

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Figure 5.2-29 Variation in fish community measurement endpoints for *test* reach MUR-F2 in the Muskeg River from 2009 to 2015 relative to regional *baseline* conditions (cluster 1).



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using baseline data from cluster 1 (see Table 3.2-10).

A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Table 5.2-49 Average habitat characteristics of fish community monitoring reaches of Jackpine Creek, fall 2015.

Variable	Units	JAC-F1 Lower *Test* Reach	JAC-F2 Upper *Baseline* Reach
Sample date	-	Sept 22, 2015	Sept 23, 2015
Habitat type	-	riffle	glide
Maximum depth	m	0.64	0.95
Mean depth	m	0.53	0.73
Bankfull channel width	m	9.4	8.0
Wetted channel width	m	6.5	5.80
Substrate			
Dominant	-	fines	fines
Subdominant	-	sand	-
Instream cover			
Dominant	-	SWD, filamentous algae	macrophytes
Subdominant	-	macrophytes, LWD, overhanging vegetation	filamentous algae, undercut banks, overhanging vegetation
Field water quality			
Dissolved oxygen	mg/L	10.0	9.6
Conductivity	µS/cm	181	223
pH	pH units	7.59	7.93
Water temperature	^{0}C	8.3	7.0
Water velocity			
Left bank velocity	m/s	0.20	0.06
Left bank water depth	m	0.38	0.40
Centre of channel velocity	m/s	0.25	0.07
Centre of channel water depth	m	0.58	0.68
Right bank velocity	m/s	0.20	0.09
Right bank water depth	m	0.42	0.80
Riparian cover – understory (<5 m)			
Dominant	-	overhanging vegetation	overhanging vegetation
Subdominant	-	woody shrubs and saplings	woody shrubs and saplings

Table 5.2-50 Total number and percent composition of fish species captured in reaches of Jackpine Creek, 2009 to 2015.

Common Name	Code	Total Species Catch														Percent of Total Catch													
		JAC-F1							<u>JAC-F2</u>							JAC-F1							<u>JAC-F2</u>						
		2009	2010	2011	2012	2013	2014	2015	2009	2010	2011	2012	2013	2014	2015	2009	2010	2011	2012	2013	2014	2015	2009	2010	2011	2012	2013	2014	2015
Arctic grayling	ARGR	-	-	-	-	-	-	1	-	-	-	-	-	-	-	0	0	0	0	0	0	2.5	0	0	0	0	0	0	0
brook stickleback	BRST	-	19	2	-	-	-	-	14	29	36	1	16	7	10	0	11.4	1.3	0	0	0	0	23.7	47.5	35.0	25.0	44.4	10.9	37.0
finescale dace	FNDC	-	75	-	-	-	-	-	-	12	-	-	-	1	1	0	44.9	0	0	0	0	0	0	19.7	0	0	0	1.6	3.7
lake chub	LKCH	1	-	138	-	-	2	4	40	10	-	3	18	50	6	14.3	0	89.6	0	0	14.3	10.3	67.8	16.4	0	75.0	50.0	78.1	22.3
Longnose dace	LNDC	-	-	-	-	-	-	4	-	-	-	-	-	-	-	0	0	0	0	0	0	10.3	0	0	0	0	0	0	0
longnose sucker	LNSC	2	3	5	-	2	-	9	-	-	-	-	-	-	3	28.6	1.8	3.2	0	16.7	0	48.7	0	0	0	0	0	0	11.1
northern pike	NRPK	-	1	-	-	-	-	-	-	-	-	-	-	-	-	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0
northern redbelly dace	NRDC	-	-	-	-	-	-	-	-	-	2	-	-	-	5	0	0	0	0	0	0	0	0	0	1.9	0	0	0	18.5
pearl dace	PRDC	-	21	-	-	-	-	-	3	9	50	-	-	-	-	0	12.6	0	0	0	0	0	5.1	14.8	48.5	0	0	0	0
slimy sculpin	SLSC	-	23	2	2	10	9	9	-	-	-	-	-	-	-	0	13.8	1.3	100	83.3	64.3	23.1	0	0	0	0	0	0	0
trout-perch	TRPR	-	9	5	-	-	-	-	-	-	-	-	-	-	-	0	5.4	3.2	0	0	0	0	0	0	0	0	0	0	0
white sucker	WHSC	4	16	2	-	-	3	2	2	1	15	-	2	6	2	57.1	9.6	1.3	0	0	21.4	5.1	3.4	1.6	14.6	0	5.6	9.4	7.4
Total Count		**7**	**167**	**154**	**2**	**12**	**14**	**39**	**59**	**61**	**103**	**4**	**36**	**64**	**27**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**3**	**8**	**6**	**1**	**2**	**3**	**6**	**4**	**5**	**4**	**2**	**3**	**4**	**6**	**3**	**8**	**6**	**1**	**2**	**3**	**6**	**4**	**5**	**4**	**2**	**3**	**4**	**6**
Electrofishing effort (secs)		**2,221**	**3,863**	**1,052**	**1,590**	**1,564**	-	**1,242**	**1,352**	**4,183**	**973**	**1,316**	**1,564**	-	**1,211**	-	-	-	-	-	-	-	-	-	-	-	-	-	-

<u>Underline</u> denotes a *baseline* reach.

Table 5.2-51 Results of analysis of variance (ANOVA) testing for differences in fish community measurement endpoints for reaches of Jackpine Creek.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*Test* Reach JAC-F1)	*Test* Reach JAC-F1 vs. *Baseline* Reach JAC-F2	Time Trend (*Test* Reach JAC-F1)	*Test* Reach JAC-F1 vs. *Baseline* Reach JAC-F2	
Abundance	**0.008***	0.53*	17%	0%	Decreasing over time.
Richness	0.15	0.88	3%	0%	No change.
Diversity	0.92*	0.17*	0%	2%	No change.
ATI	**<0.001**	0.82*	52%	0%	Decreasing over time.
CPUE (No./100 sec)	0.12	0.27*	4%	1%	No change.

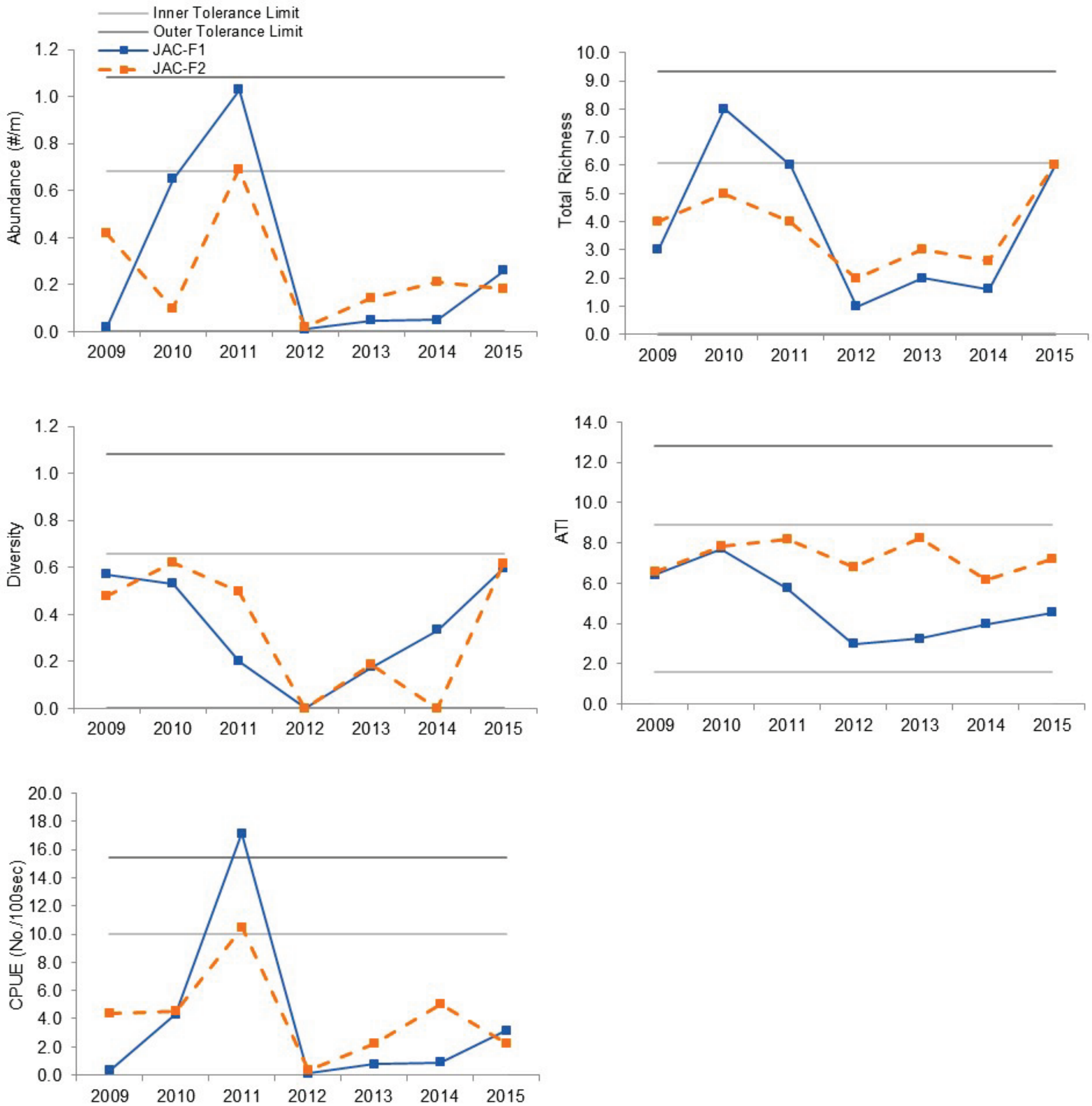
Bold values indicate significant difference (p≤0.05).

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

* indicates data were log-transformed to meet assumptions of ANOVA.

Shading denotes significant differences with >20% variance, which is considered a strong signal in spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Figure 5.2-30 Variation in fish community measurement endpoints for reaches of Jackpine Creek from 2009 to 2015 relative to regional *baseline* conditions (cluster 1).



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data for cluster 1 (see Table 3.2-10).

A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Table 5.2-52 Average habitat characteristics of wild fish health monitoring *test* reach MUR-F2 of the Muskeg River, compared to habitat characteristics of regional *baseline* reaches, fall 2015.

Watercourse	Units	MUR-F2 *test* reach	Regional *Baseline* Reaches					
			ER-U Upper *baseline* reach	AC-U Upper *baseline* reach	AC-L Lower *baseline* reach	DC-U Upper *baseline* reach	DC-M Mid *baseline* reach	DC-L Lower *baseline* reach
Sample date	-							
Mean water depth	m	0.5	0.5	0.45	0.6	0.5	0.4	0.38
Mean velocity	m/s	0.03	0.25	0.05	0.25	0.1	0.1	0.1
Field water quality								
Water temperature	°C	8.7	3.2	8.45	11.6	3.6	6.6	7
Conductivity	μS/cm	274	174	133	163	463	427	466
Dissolved oxygen (DO)	mg/L	9.5	10.8	9.9	9	10.1	9.5	10.9
pH	pH units	7.22	7.05	6.91	7.65	8.09	7.08	7.47
Substrate	-	gravel/cobble/sand	fines/cobble	cobble	silt/gravel	cobble/gravel	cobble/gravel/fines	cobble/gravel

Figure 5.2-31 Daily mean temperatures for wild fish health *test* reach MUR-F2, August to September 2015.

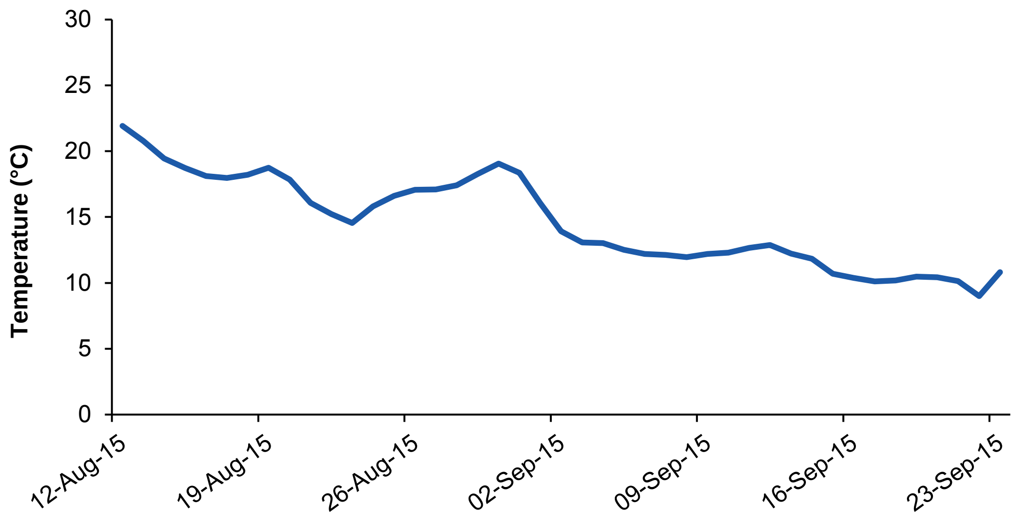


Table 5.2-53 Summary of morphometric data for adult and juvenile lake chub caught at *test* reach MUR-F2 and regional *baseline* reaches, fall 2015.

Group	Reach	Designation	Sample Size		Relative Abundance (%)		Juvenile Measurements		Percentage of External Abnormalities
			Juvenile	Adult	Juvenile	Adult	Mean Length (mm)	Mean Weight (g)	
Test	MUR-F2	*test* reach	103	11	90	10	40.9	0.74	16.70
Regional *Baseline*	AC-US	upper *baseline* reach	97	59	62	38	41.2	0.76	0
	AC-DS	lower *baseline* reach	18	70	20	80	44.4	1.11	1.10
	DC-U	upper *baseline* reach	100	59	63	37	32.6	0.44	7.55
	DC-M	mid *baseline* reach	99	53	65	35	33.7	0.45	5.92
	DC-L	lower *baseline* reach	100	74	57	43	38.94	0.65	9.77
	ER-U	upper baseline reach	104	61	63	37	44.1	0.91	1.82

Figure 5.2-32 Length-frequency distribution of juvenile lake chub in wild fish health *test* reach MUR-F2 compared to regional *baseline* reaches, fall 2015.

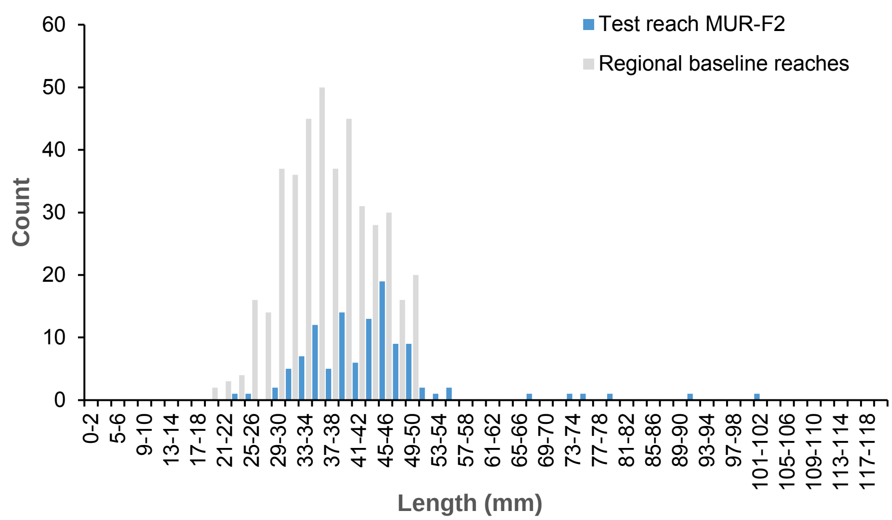


Figure 5.2-33 Measurement endpoints between female lake chub from *test* reach MUR-F2 and female lake chub from regional *baseline* reaches, fall 2015.

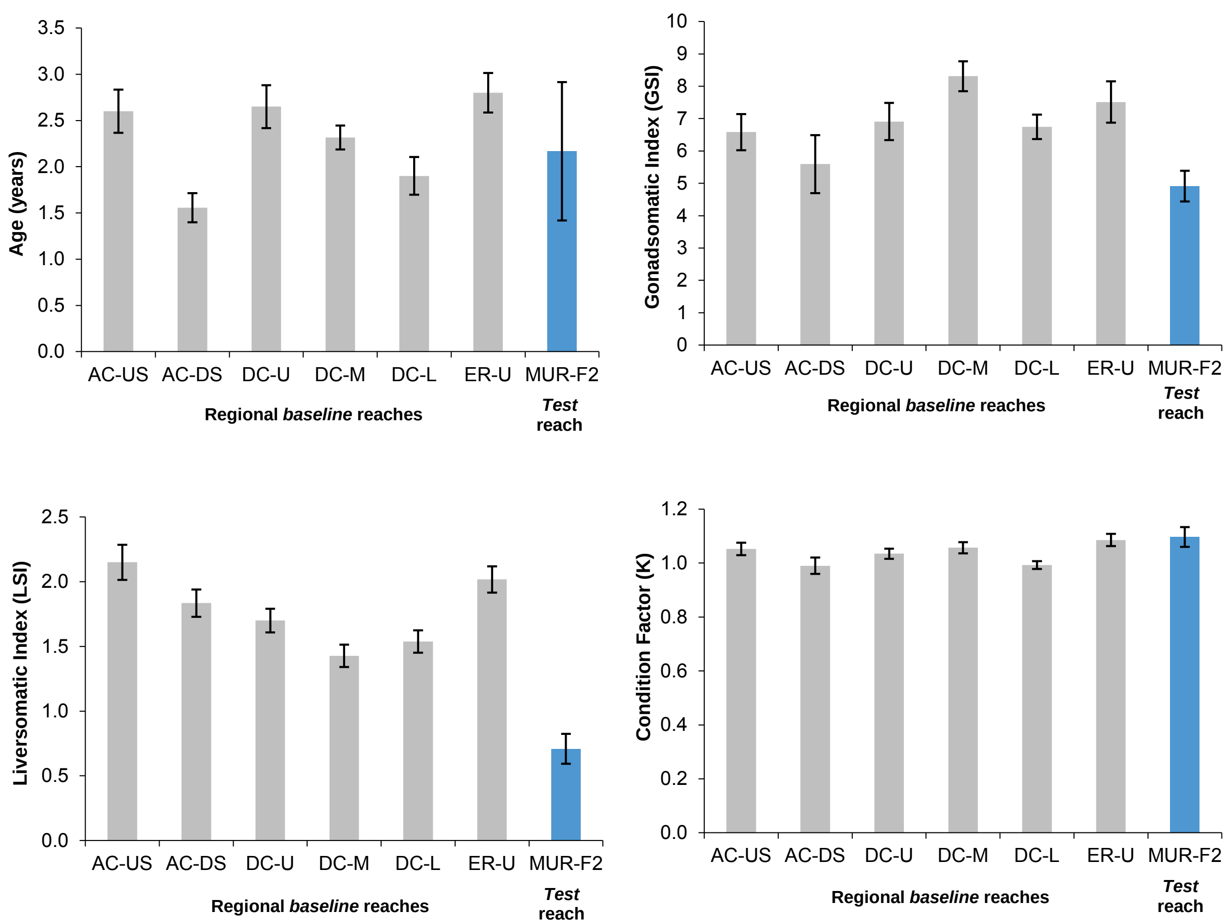


Figure 5.2-34 Relative age-frequency distribution for lake chub captured at *test* reach MUR-F2, fall 2015.

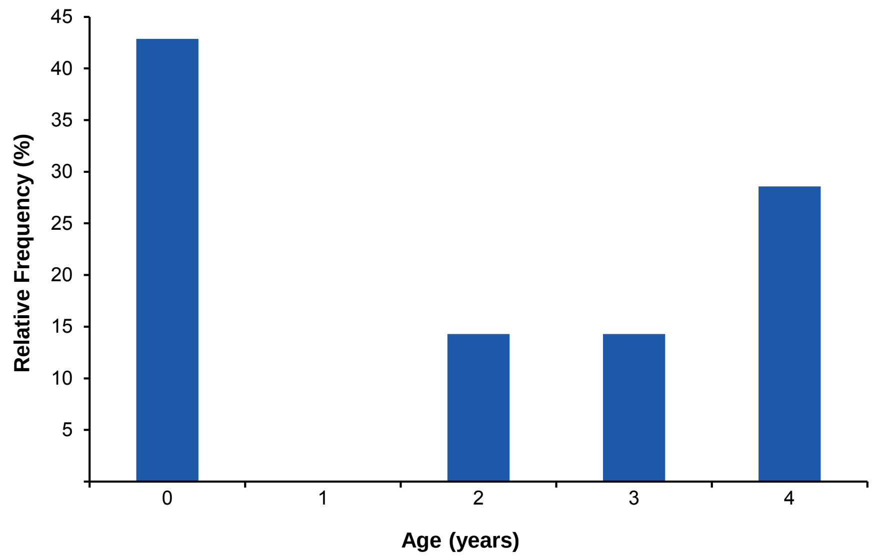


Figure 5.2-35 MUR-F2 female lake chub growth in relation to regional *baseline* reaches females, fall 2015.

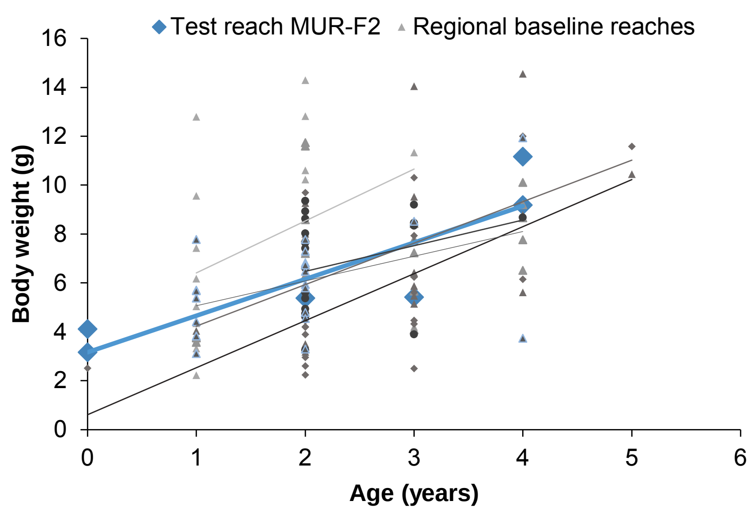
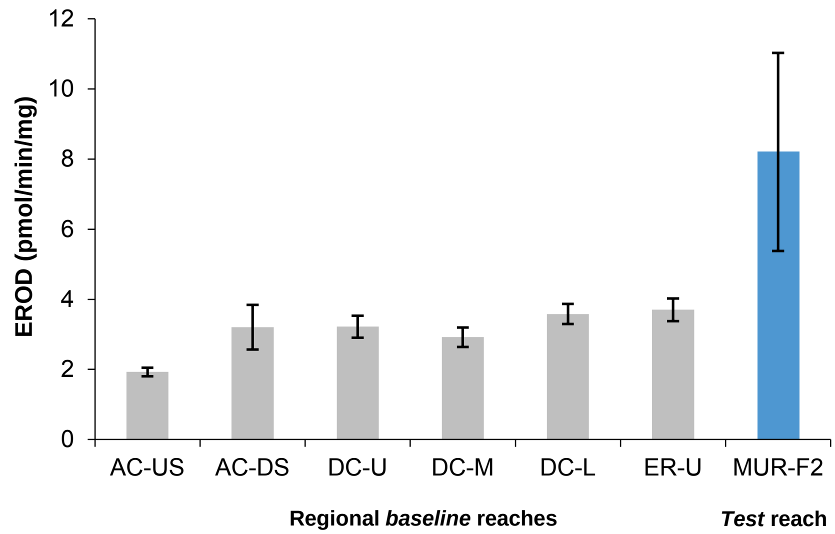


Figure 5.2-36 Mean EROD activity (± 1SE) between female lake chub from *test* reach MUR-F2 and female lake chub from regional *baseline* reaches, fall 2015.



5.3 STEEPBANK RIVER WATERSHED

Table 5.3-1 Summary of results for the Steepbank River watershed.

Steepbank River Watershed	Summary of 2015 Conditions					
Climate and Hydrology						
Criteria	**C3**	**07DA006**	no station	no station	**S66**	no station
Mean open-water season discharge	climate station - n/a	○	-	-	not measured	-
Mean winter discharge	climate station - n/a	○	-	-	not measured	-
Annual maximum daily discharge	climate station - n/a	○	-	-	not measured	-
Minimum open-water season discharge	climate station - n/a	○	-	-	not measured	-
Water Quality						
Criteria	**ST1**	**ST WSC**	**STB RIFF 7**	**STR-2**	**STB RIFF 10**	no station
Water Quality Index	○	○	○	○	○	-
Benthic Invertebrate Communities and Sediment Quality						
No Benthic Invertebrate Communities Component or Sediment Quality Component activities were conducted in the 2015 WY.						
Fish Populations						
Criteria	**STR-F1**	no reach	no reach	no reach	no reach	**STR-F2**
Fish Communities	●	-	-	-	-	n/a
Wild Fish Health	No Wild Fish Health monitoring was conducted in the 2015 WY.					

Legend and Notes

○ Negligible - Low
◐ Moderate
● High

baseline
test

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (Fish Communities): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.1 for a detailed description of the classification methodology.

Figure 5.3-1 Steepbank River watershed.

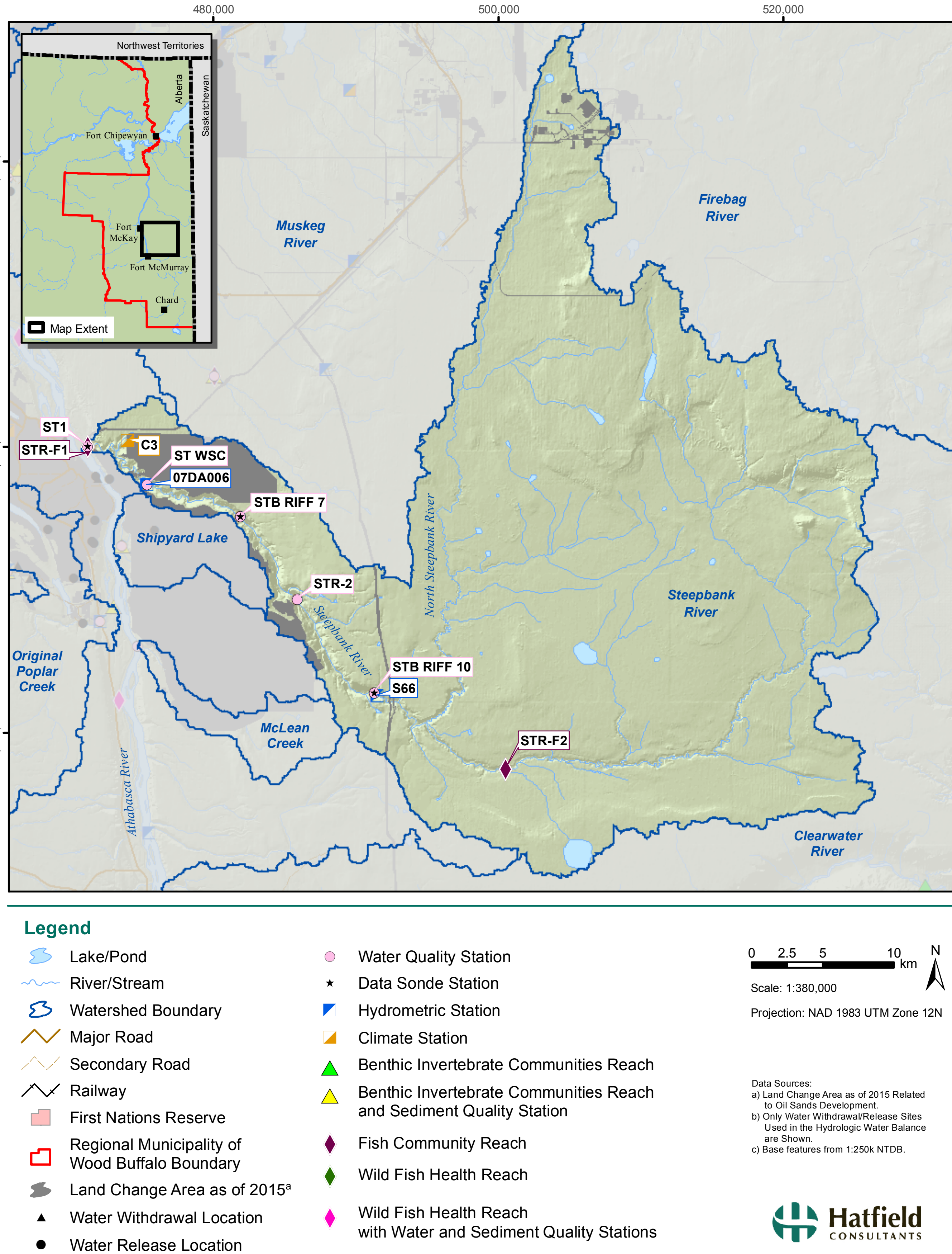


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Figure 5.3-2 Representative monitoring stations of the Steepbank River watershed, fall 2015.

Water Quality Station STB RIFF 7, mid Steepbank River, facing downstream

Hydrology Station S66 and Water Quality Station STB RIFF 10, Steepbank River below North Steepbank River, facing downstream

Fish Community Reach STR-F1 and Water Quality Station ST1 near Steepbank River mouth, facing downstream

Fish Community Reach STR-F2, upper Steepbank River, facing downstream

5.3.1 Summary of 2015 WY Conditions

Approximately 4% (5,556 ha) of the Steepbank River watershed had undergone land change as of 2015 from oil sands development (Table 2.3-1); much of this land change is concentrated in the lower portion of the watershed. The designations of specific areas of the watershed for 2015 are as follows:

1. The Steepbank River watershed downstream of the Suncor oil sands developments, including the North Steepbank River, is designated as *test* (Figure 5.3-1).
2. The remainder of the watershed is designated as *baseline*.

Monitoring activities in the Steepbank River watershed in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, and Fish Populations components. Table 5.3-1 is a summary of the 2015 assessment for the Steepbank River watershed, while Figure 5.3-1 provides the location of the monitoring stations for each component, reported water withdrawal and discharge locations, and the locations of the areas with land change as of 2015. Figure 5.3-2 contains fall 2015 photos of representative monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology The 2015 WY, mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.44% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low.**

Water Quality There were clear temporal variations in water quality measurement endpoints at individual stations across months. Concentrations of nutrients and metals showed temporal trends similar to the particulates (TSS), while major ions followed trends with dissolved solids. Generally, water quality measurement endpoints in 2015 fell within historical monthly ranges of available historical data. Continuous water quality data indicated consistently high dissolved oxygen and typically low turbidity at all monitoring stations. There were **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2015 for all stations. Water quality guideline exceedances included dissolved iron, total phenols, and sulphide at all stations except *test* station STR-2 for total phenols (sampled in winter only). These exceedances are consistent with historical monitoring by the RAMP and JOSMP.

Fish Populations (Fish Communities) Differences in measurement endpoints of the fish community at lower *test* reach STR-F1 were classified as **High** as three of the five measurement endpoints (abundance, richness, and CPUE) decreased significantly over time and these trends showed a strong statistical signal; however, mean abundance, richness, and CPUE were higher in 2015 than 2014, which may indicate that conditions are improving for fish communities in the lower Steepbank River.

5.3.2 Hydrologic Conditions

Hydrometric monitoring for the Steepbank River watershed in the 2015 WY was conducted at WSC Station 07DA006 (formerly JOSMP Station S38), Steepbank River near Fort McMurray and JOSMP Station S66, Steepbank River below North Steepbank River. Data from the WSC Station were used for the water balance analysis presented below. Details for each of these stations can be found in Appendix C.

Seasonal data from March to October have been collected every year at WSC Station 07DA006 (JOSMP Station S38) since 1974, with some data also available for 1972 and 1973. Continuous annual hydrometric data have been collected from 1974 to 1986 and from 2009 to 2015.

The historical flow record for WSC Station 07DA006 (JOSMP Station S38) is summarized in Figure 5.3-3 and includes the median, interquartile, and range of flows recorded daily through the water year. Flows of the Steepbank River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically much lower than during the open-water season and generally decrease from November until early March. Spring thaw and the resulting increase in flows typically occurs in late March and April. Monthly flows are highest in May, at the peak of freshet, and remain elevated in June and July when total monthly rainfall is highest. Flows then generally recede from late July until the end of October in response to declining rainfall inputs and eventually river freeze-up.

Flows in the Steepbank River in the 2015 WY were similar to the historical seasonal pattern described above (Figure 5.3-3) but the annual runoff volume in the 2015 WY was 89.9 million m^3, which was 44% lower than the mean historical annual runoff volume based on the available period of record. In addition, peak annual flow occurred later than normal (mid-July) in response to rainfall (recorded at the nearby Steepbank Climate Station).

Flows generally decreased from November to early January and remained lower than the historical median until mid-March, when runoff increased until the middle of May due to spring thaw. Flows remained below the historical lower quartile from late April until mid-July, and decreased until the lowest open-water daily flow of 1.4 m^3/s on July 11. This lowest open-water daily flow was 17% lower than the historical mean open-water minimum daily flow of 1.65 m^3/s. Flows then increased in mid-July to a peak annual flow of 17.1 m^3/s on July 17, which was 54% lower than the historical mean annual maximum flow of 37.4 m^3/s. Flows then decreased and remained below the historical median for the remainder of the WY with the exception of an increase in early September due to a recorded rainfall event.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Steepbank River watershed at WSC Station 07DA006 (JOSMP Station S38) is summarized in Table 5.3-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2015 in the Steepbank River watershed was estimated to be 14.1 km^2 (Table 2.3-1). The loss of flow to the Steepbank River that would have otherwise occurred from this land area was estimated at 0.968 million m^3.

2. As of 2015, the area of land change in the Steepbank River watershed that was not closed-circuited was estimated to be 41.4 km^2 (Table 2.3-1). The increase in flow to the Steepbank River that would not have otherwise occurred from this land area was estimated at 0.567 million m^3.

No industry withdrawals or releases of water were reported in the Steepbank River watershed in the 2015 WY; all other potential changes in surface water flows (described in Section 3.2.1) were assumed to be insignificant.

The estimated cumulative effect of oil sands development on flows of the Steepbank River in the 2015 WY was a decrease in flow of 0.401 million m^3 at WSC Station 07DA006 (JOSMP Station S38). The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.44% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.3-3). These differences were classified as **Negligible-Low** (Table 5.3-1). A spatial analysis (Section 3.2.1.5) was not required to identify the longitudinal hydrological effects along the Steepbank River given that the differences in values of all measurement endpoints between observed *test* and estimated *baseline* conditions were classified as **Negligible-Low**.

5.3.3 Water Quality

Water quality samples were taken in the 2015 WY in the Steepbank River watershed from:

- the Steepbank River near its mouth (*test* station ST1, previously called STR-1), which was sampled seasonally by RAMP in 1997 and 1998, in fall in 2000 and 2001 by RAMP, in winter and fall by RAMP/JOSMP from 2002 to 2014, March 2015, and then monthly from May to October 2015;

- the Steepbank River downstream of the confluence with the North Steepbank River (*test* station STR-2), designated as *baseline* from 2002 to 2007 and *test* since 2008, sampled in fall from 2002 to 2013 and monthly from April 2014 to March 2015; and
- three Steepbank River stations between the Steepbank River mouth and the confluence of North Steepbank River (*test* stations ST WSC, STB RIFF 7, and STB RIFF 10), established as part of the JOSMP in 2015 and sampled monthly from May to October 2015.

In addition, data sondes were installed and collected continuous water quality data at *test* stations ST1, STB RIFF 7, and STB RIFF 10 from July to October 2015 for a subset of water quality field variables.

Figure 5.3-4 presents trends in continuous monitoring variables recorded by data sondes at *test* stations ST1, STB RIFF 7, and STB RIFF 10 in the 2015 WY. Monthly variations in water quality in the Steepbank River are summarized in Table 5.3-4 to Table 5.3-8 and Figure 5.3-5. Water quality results from fall 2015 relative to historical fall concentrations (if available) are provided in Table 5.3-9 to Table 5.3-10. The ionic composition of Steepbank River water measured in 2015 and previous years is presented in Figure 5.3-6. Guideline exceedances for water quality measurement endpoints are presented in Table 5.3-11 and Figure 5.3-7 compares selected water quality measurement endpoints collected in fall in the Steepbank River relative to regional *baseline* concentrations.

Continuous Monitoring Results from Data Sondes Continuous monitoring results from data sondes from July to October 2015 exhibited similar trends for measured water quality variables at all three *test* stations (Figure 5.3-4). Water temperatures at all stations peaked at approximately 20°C in mid-August then declined steadily toward 0°C by the end of October. DO concentrations were inversely correlated to water temperature, which was related to higher oxygen solubility at lower temperatures. DO saturation remained near 100% at all stations throughout the monitoring period, with greater within-day fluctuations at *test* station ST1, in the lower reaches of the river. Levels of pH were within the alkaline range at all *test* stations throughout the monitoring period and within water quality guideline ranges; pH was consistently higher at lower *test* station ST1 than at *test* stations STB RIFF 7 and STB RIFF 10. Specific conductivity increased from July to August and reached maximum values for the monitoring period at the beginning of September. The decrease in specific in conductivity at all stations in early September coincided with an increase in river flows at that time (Figure 5.3-3). Conductivity generally decreased with distance from the river mouth over the monitoring period. Turbidity was generally low at all stations, with an increase at all stations in early September coinciding with increased flows and a short increase in turbidity at lower *test* station ST1 in mid-September. Data gaps for data sondes at stations of the Steepbank River are discussed in Appendix B.

Monthly Variations in Water Quality There were clear temporal variations in the concentration of water quality measurement endpoints at individual stations across months (Figure 5.3-5). Trends in concentrations of nutrients and metals were similar to trend in concentration of TSS, while trends in concentrations of major ions were similar to trends in concentration of total dissolved solids. Generally, concentrations of water quality measurement endpoints in 2015 were within historical monthly ranges of available historical data (Figure 5.3-5).

2015 Fall Results Relative to Historical Concentrations No historical comparisons were possible for three new *test* stations, ST WSC, STB RIFF 7, and STB RIFF 10 (all sampled for the first time in the 2015 WY), and *test* station STR-2 (not sampled in fall 2015; Table 5.3-9). Concentrations of water quality measurement endpoints at *test* station ST1 in fall 2015 were within historical fall concentrations with the exception of naphthenic acids, retene, total dibenzothiophenes, total parent PAHs, and total alkylated PAHs, all of which had concentrations that were lower than previously-measured minimum concentrations (Table 5.3-10).

Temporal Trends There were no significant ($p>0.05$) temporal trends in fall concentrations of all water quality measurement endpoints at *test* station ST1. Trend analyses were not conducted for other Steepbank River stations due to an insufficient length of data record at these stations.

Ion Balance In fall 2015, the ionic composition of all stations in the Steepbank River watershed was dominated by calcium and bicarbonate ions (Figure 5.3-6). Ionic composition of water at *test* station ST1 has been consistent since monitoring began in 1997.

Comparison of Water Quality Measurement Endpoints to AEP Guidelines The following water quality guideline exceedances were measured in the 2015 WY (Table 5.3-11):

- dissolved iron at *test* stations ST1 (June to October), STR-2 (November, December), ST WSC (May and July to October), STB RIFF 7 (May and July to October), and STB RIFF 10 (May to October);
- total phenols at *test* stations ST1 (June to October), ST WSC (June to October), STB RIFF 7 (July to October), and STB RIFF 10 (June to October); and
- sulphide at *test* stations ST1 (June, July, September, and October), STR-2 (November and December), ST WSC (June, July, September, and October), STB RIFF 7 (May to September), and STB RIFF 10 (May to September).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints in fall 2015 at *test* stations ST1, ST WSC, STB RIFF 7, and STB RIFF 10 were within regional *baseline* concentrations (Figure 5.3-7) and concentrations of all water quality measurement endpoints were near median concentrations of regional *baseline* data at all stations with the exception of TSS concentrations at *test* stations ST1 and STB RIFF 10, which were lower than the 5^{th} percentile of regional *baseline* concentrations.

Water Quality Index WQI values were 100 for all stations in the Steepbank River watershed, indicating **Negligible-Low** difference from the regional *baseline* range of concentrations in fall 2015.

Classification of Results Differences in water quality in fall 2015 at water quality monitoring stations compared to regional *baseline* water quality conditions were classified as **Negligible-Low** for all stations in the Steepbank River watershed.

5.3.4 Fish Populations

5.3.4.1 Fish Community Monitoring

Fish community monitoring was conducted in the Steepbank River in fall 2015 at:

- lower *test* reach STR-F1, which has been sampled since 2009; and
- upper *baseline* reach STR-F2, which has been sampled since 2011.

2015 Habitat Conditions Habitat conditions at lower *test* reach STR-F1 and upper *baseline* reach STR-F2 for fall 2015 are summarized in Table 5.3-12. Lower *test* reach STR-F1 in fall 2015 had a glide habitat with a wetted width of 12.7 m and a bankfull width of 28.9 m. Substrate consisted of rough bedrock with sand. Water at lower *test* reach STR-F1 had a mean depth of 0.79 m, a velocity of 0.28 m/s, pH of 6.28, conductivity of 237 µS/cm, dissolved oxygen of 9.4 mg/L, and temperature of 9.6ºC. Instream cover consisted primarily of small and large woody debris, live trees and roots, and overhanging vegetation.

Upper *baseline* reach STR-F2 in fall 2015 had riffle habitat, with a wetted width of 14.2 m and a bankfull width of 18.4 m. Substrate consisted of cobble with small proportions of coarse gravel. Water at upper *baseline* reach STR-F2 had a mean depth of 0.34 m, a velocity of 0.51 m/s, pH of 7.96, conductivity of 194 µS/cm, dissolved oxygen of 9.6 mg/L, and temperature of 8.1˚C. Instream cover consisted primarily of small woody debris with some macrophytes, large woody debris, live trees/roots, overhanging vegetation, and undercut banks.

Relative Abundance of Fish Species The fish community at lower *test* reach STR-F1 in fall 2015 was similar to the fish community observed in fall 2014 and dominated by slimy sculpin with trout-perch as the subdominant species (Table 5.3-13). The total catch of fish species at upper *baseline* reach STR-F2 decreased in 2015 compared to 2014, but exhibited a similar species composition with slimy sculpin being the dominant species.

Temporal and Spatial Comparisons Abundance, richness, assemblage tolerance index (ATI), and CPUE were higher and diversity lower at lower *test* reach STR-F1 in 2015 compared to 2014 (Table 5.3-14).

Temporal comparisons for lower *test* reach STR-F1 included testing for changes over time (2010 to 2015, Hypothesis 1, Section 3.2.4.2). Spatial comparisons for lower *test* reach STR-F1 included testing for differences from upper *baseline* reach STR-F2 over time (Hypothesis 2, Section 3.2.4.2).

There were significant decreases over time in abundance, richness, diversity, ATI, and total CPUE at lower *test* reach STR-F1 (Table 5.3-14, Table 5.3-15). Differences in values of all measurement endpoints with the exception of diversity explained greater than 20% of the variance of annual means. The decrease over time in the ATI value at *test* reach STR-1 is a result of the recent increase in abundance of slimy sculpin and burbot, both of which are both considered sensitive species (Whittier et al. 2007). There were no significant differences between lower *test* reach STR-F1 and upper *baseline* reach STR-F2 (Table 5.3-15).

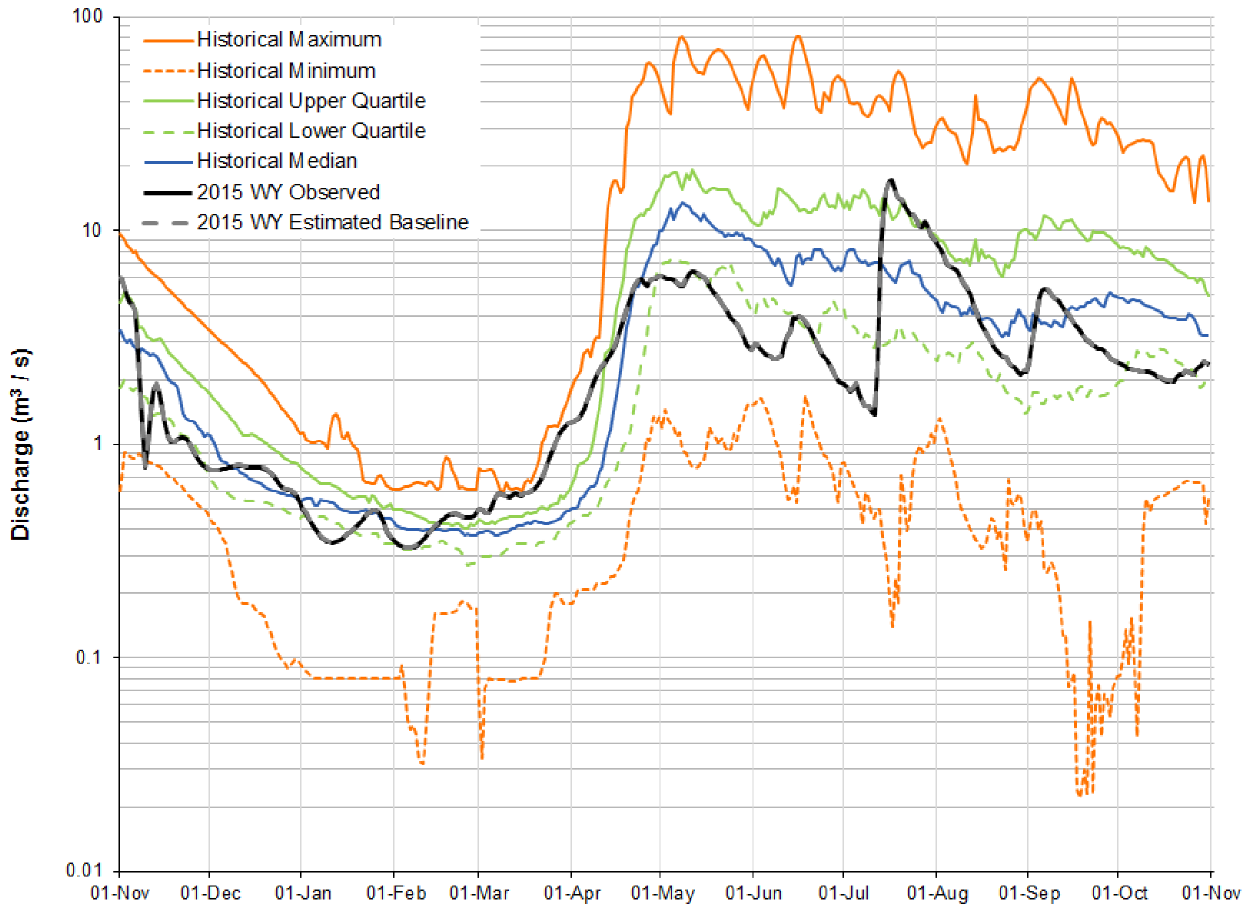
Comparison to Published Literature Golder (2004) documented different habitat conditions than those observed by the RAMP and JOSMP from 2009 to 2015. Habitat conditions in the lower Steepbank River were poor prior to 2004 due to beaver activity, low habitat heterogeneity and predominance of fine substrate (Golder 2004). Habitat conditions at *test* reach STR-F1 in recent years have consisted of riffles and runs, with increasing amounts of embedded substrate over time. Likewise, habitat conditions at upper *baseline* reach STR-F2 in recent years have consisted of run and riffle habitat with cobble and smaller proportions of small boulders. Beaver impoundments have not been documented during fish community monitoring by the RAMP or JOSMP in the Steepbank River.

Past studies indicate a total of 24 fish species recorded in the Steepbank River watershed (Golder 2004), while the total number of fish species recorded by the RAMP/JOSMP between 2009 and 2015 is 16 species. Possible reasons for discrepancies in species richness may be due to differences in sampling gear, as well as the total amount of the watercourse sampled; fish community monitoring under JOSMP samples a smaller, defined reach length relative to the multiple locations and reaches documented in Golder (2004).

2015 Results Relative to Regional *Baseline* Conditions All mean values of all measurement endpoints in 2015 at both lower *test* reach STR-F1 and upper *baseline* reach STR-F2 were within the inner tolerance limits for the normal range of *baseline* conditions with the exception of total richness at upper *baseline* reach STR-F2 that was between the upper and inner tolerance limits for the normal range of *baseline* conditions (Figure 5.3-8).

Classification of Results Differences in measurement endpoints of the fish community at lower *test* reach STR-F1 were classified as **High** as three of the five measurement endpoints (abundance, richness, and CPUE) significantly decreased over time and trends showed a strong statistical signal. It is important to note that mean abundance, richness, and CPUE were higher in the lower Steepbank River in 2015 than in 2014, which may be indicative of improving conditions in recent years.

Figure 5.3-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Steepbank River in the 2015 WY, compared to historical values.



Note:

Observed 2015 WY hydrograph based on Steepbank River near Fort McMurray, WSC Station 07DA006 (JOSMP Station S38) data. The upstream drainage area is 1,320 km^2. Historical daily values from March 1 to October 31 were calculated from data collected from 1972 to 2014, and historical daily values from November 1 to February 28 were calculated from data collected from 1972 to 1986 and from 2009 to 2014.

Table 5.3-2 Estimated water balance at WSC Station 07DA006 (formerly JOSMP Station S38), Steepbank River near Fort McMurray, 2015 WY.

Observed *test* hydrograph (total discharge)	**89.944**	**Observed discharge from Steepbank River near Fort McMurray, WSC Station 07DA006 (formerly JOSMP Station S38)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.968	Estimated 14.1 km^2 of the Steepbank River watershed is closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.567	Estimated 41.4 km^2 of the Steepbank River watershed with land change as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Steepbank River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Steepbank River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**90.345**	**Estimated *baseline* discharge at Steepbank River near Fort McMurray, WSC Station 07DA006 (formerly JOSMP Station S38)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	-0.401	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	-0.444	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

Based on Steepbank River near Fort McMurray, WSC Station 07DA006, 2015 WY data.

All non-zero values in this table are presented to three decimal places.

Table 5.3-3 Calculated change in hydrologic measurement endpoints for the Steepbank River watershed, 2015 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	4.416	4.396	-0.44%
Mean winter discharge	0.844	0.841	-0.44%
Annual maximum daily discharge	17.176	17.100	-0.44%
Open-water season minimum daily discharge	1.376	1.370	-0.44%

Notes:

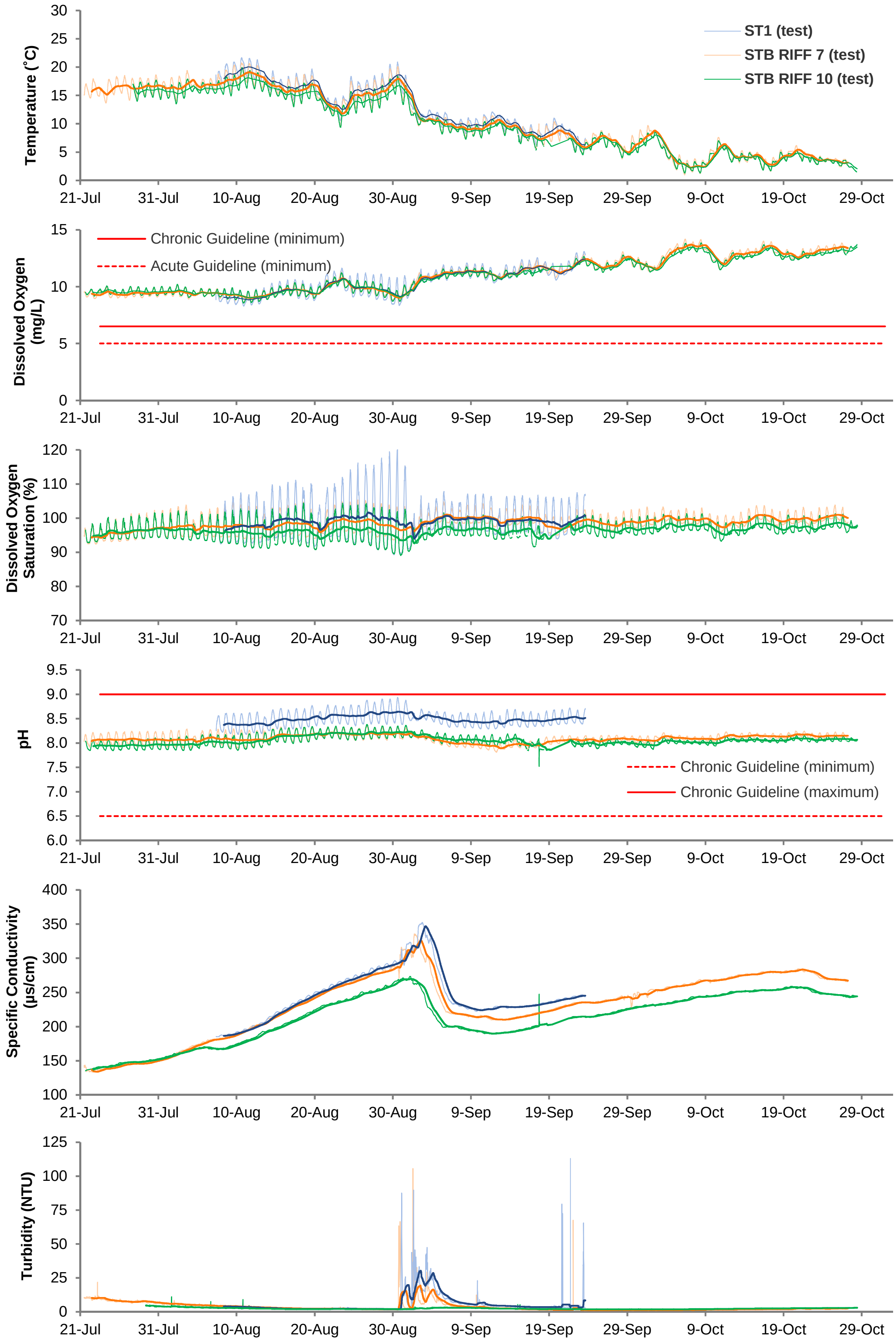
Definitions and assumptions are discussed in Section 3.2.1.

Observed discharge volume was calculated from data for the 2015 WY from WSC Station 07DA006.

The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. Flows and percentage change values are presented to three decimal places for the sake of clarity.

The open-water season refers to the period from May 1 to October 31 and the winter season refers to the period from November 1 to March 31.

Figure 5.3-4 In situ water quality trends in the Steepbank River recorded by data sondes, July to October 2015.



Note: Concentrations and levels of water quality variables were recorded at 15-minute intervals; trend lines are daily averages.

Table 5.3-4 Monthly concentrations of water quality measurement endpoints, mouth of Steepbank River (*test* station ST1 [STR-1]), March to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.24	7.92	Jul	8.28	Sep
Total suspended solids	mg/L	-	6	4.1	1.3	Sep	160.0	Jul
Conductivity	µS/cm	-	6	235	150	Jul	627	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.027	0.008	Mar	0.031	Aug
Total nitrogen	mg/L	-	5	0.82	0.52	Oct	1.00	Jul
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.005	-	0.008	Jul
Dissolved organic carbon	mg/L	-	6	21.5	10.2	Mar	28.0	Aug
Ions								
Sodium	mg/L	-	6	13.0	7.1	Jul	39.4	Mar
Calcium	mg/L	-	6	27.5	20.0	Jul	66.6	Mar
Magnesium	mg/L	-	6	8.8	6.3	Jul	20.5	Mar
Potassium	mg/L	-	6	0.8	0.55	Jul	2.28	Mar
Chloride	mg/L	120-640	6	2.6	1.7	Jul	6.2	Mar
Sulphate	mg/L	309[b]	7	8.0	5.1	Sep	13.0	Mar
Total dissolved solids	mg/L	-	6	180.0	130.0	Jul	368.0	Mar
Total alkalinity	mg/L	20 (min)	6	120.0	68.0	Jul	338.0	Mar
Selected metals								
Total aluminum	mg/L	-	7	0.116	0.058	Sep	1.060	Jul
Dissolved aluminum	mg/L	0.05	7	0.0074	0.0009	Mar	0.0214	Jul
Total arsenic	mg/L	0.005	7	0.0006	0.00038	Mar	0.001	Jul
Total boron	mg/L	1.5-29	7	0.07	0.043	Jul	0.236	Mar
Total molybdenum	mg/L	0.073	7	0.00026	0.00016	Jul	0.00058	Mar
Total mercury (ultra-trace)	ng/L	5-13	7	1.54	0.67	Mar	3.38	Jul
Total methyl mercury	ng/L	1-2	6	0.11	0.067	May	0.19	Aug
Total strontium	mg/L	-	7	0.12	0.073	Jul	0.31	Mar
Total hydrocarbons								
BTEX	mg/L	-	7	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	7	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	7	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	7	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	7	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	7	0.53	0.16	Sep	0.73	Aug
Oilsands extractable acids	mg/L	-	7	2.30	0.80	Oct	3.10	Aug
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	16.90	Aug
Retene	ng/L	-	6	1.52	0.62	Mar	9.65	Jul
Total dibenzothiophenes[c]	ng/L	-	6	56.72	11.68	Mar	328.87	Jul
Total PAHs[c]	ng/L	-	6	244.64	125.86	Mar	947.42	Jul
Total Parent PAHs[c]	ng/L	-	6	28.04	9.26	Mar	36.48	Jul
Total Alkylated PAHs[c]	ng/L	-	6	216.60	116.61	Mar	910.93	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0080**	<0.001	Mar	**0.016**	Jul
Sulphide	mg/L	0.0019	4	**0.0034**	<0.0015	Mar	**0.007**	Sep
Dissolved iron	mg/L	0.3	5	**0.4270**	0.019	Mar	**0.705**	Oct

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.3-5 Monthly concentrations of water quality measurement endpoints, Steepbank River adjacent to Millennium Mine (*test* station ST WSC), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.14	7.93	Jul	8.21	Oct
Total suspended solids	mg/L	-	6	3.4	2.0	Aug, Sep	22.0	Jul
Conductivity	µS/cm	-	6	225	140	Jul	290	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.024	0.013	May, Jun	0.035	Oct
Total nitrogen	mg/L	-	6	0.86	0.52	Oct	<1	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	<0.005	-
Dissolved organic carbon	mg/L	-	6	21.0	16.0	May	27.0	Aug
Ions								
Sodium	mg/L	-	6	11.0	6.4	Jul	18.0	Oct
Calcium	mg/L	-	6	28.0	20.0	Jul	33.0	Oct
Magnesium	mg/L	-	6	8.5	6.1	Jul	11.0	Oct
Potassium	mg/L	-	6	0.8	0.47	Jul	1.40	May
Chloride	mg/L	120-640	6	2.1	1.3	Jul	2.6	Oct
Sulphate	mg/L	309[b]	6	3.1	1.9	May	3.9	Sep
Total dissolved solids	mg/L	-	6	165	60.0	May	200	Jun
Total alkalinity	mg/L	20 (min)	6	115	70	Jul	150	Oct
Selected metals								
Total aluminum	mg/L	-	6	0.129	0.051	Jun	0.774	Jul
Dissolved aluminum	mg/L	0.05	6	0.0085	0.0030	Jun	0.0186	Jul
Total arsenic	mg/L	0.005	6	0.0006	0.00050	May	0.0008	Jul
Total boron	mg/L	1.5-29	6	0.066	0.034	Jul	0.093	Jun
Total molybdenum	mg/L	0.073	6	0.00022	0.00015	Jul	0.00029	Jun
Total mercury (ultra-trace)	ng/L	5-13	6	1.38	1.01	Oct	2.83	Jul
Total methyl mercury	ng/L	1-2	6	0.101	0.057	May	0.163	Aug
Total strontium	mg/L	-	6	0.116	0.069	Jul	0.133	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.53	<0.08	Oct	1.08	Aug
Oilsands extractable acids	mg/L	-	6	1.50	0.50	Oct	2.40	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	1.10	0.84	Oct	17.30	Jul
Total dibenzothiophenes[c]	ng/L	-	6	36.43	22.37	Sep	97.82	Jul
Total PAHs[c]	ng/L	-	6	195.98	166.05	Aug	341.67	Jul
Total Parent PAHs[c]	ng/L	-	6	23.88	22.86	May	49.10	Sep
Total Alkylated PAHs[c]	ng/L	-	6	160.0	143.14	Aug	316.67	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0078**	0.0027	May	**0.016**	Jul
Sulphide	mg/L	0.0019	4	**0.0042**	**0.0024**	May	**0.010**	Aug
Dissolved iron	mg/L	0.3	5	**0.407**	0.221	Jun	**0.72**	Oct

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.3-6 Monthly concentrations of water quality measurement endpoints, Steepbank River approximately 27 km upstream of mouth (*test* station STB RIFF 7), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.08	7.84	Jul	8.22	Oct
Total suspended solids	mg/L	-	6	5.7	1.3	Oct	23.0	Jul
Conductivity	µS/cm	-	6	225	140	Jul	280	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.024	0.013	Jun	0.036	Oct
Total nitrogen	mg/L	-	6	0.86	0.53	Oct	<1	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	0.022	Jun
Dissolved organic carbon	mg/L	-	6	20.5	16.0	May	26.0	Aug
Ions								
Sodium	mg/L	-	6	11.0	6.3	Jul	18.0	Oct
Calcium	mg/L	-	6	28.5	20.0	May, Jul	33.0	Oct
Magnesium	mg/L	-	6	8.7	6.1	Jul	11.0	Oct
Potassium	mg/L	-	6	0.8	0.46	Jul	1.40	May
Chloride	mg/L	120-640	6	1.5	<1	Jul	2.0	Oct
Sulphate	mg/L	309[b]	6	2.9	<1	May, Jun	3.9	Sep
Total dissolved solids	mg/L	-	6	160	60.0	May	180	Jun, Aug
Total alkalinity	mg/L	20 (min)	6	115	70	Jul	150	Oct
Selected metals								
Total aluminum	mg/L	-	6	0.1024	0.0637	Jun	0.7810	Jul
Dissolved aluminum	mg/L	0.05	6	0.009	0.0034	Jun	0.018	Jul
Total arsenic	mg/L	0.005	6	0.0006	0.00048	May	0.00085	Jul
Total boron	mg/L	1.5-29	6	0.068	0.035	Jul	0.091	Jun
Total molybdenum	mg/L	0.073	6	0.00022	0.00015	Jul	0.00031	Jun
Total mercury (ultra-trace)	ng/L	5-13	6	1.63	0.95	Oct	2.71	Jul
Total methyl mercury	ng/L	1-2	6	0.097	0.057	May	0.179	Aug
Total strontium	mg/L	-	6	0.116	0.070	Jul	0.131	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.50	<0.08	Oct	0.79	Aug
Oilsands extractable acids	mg/L	-	6	1.65	0.40	Oct	2.00	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	0.93	0.60	Oct	11.00	Jul
Total dibenzothiophenes[c]	ng/L	-	6	11.86	9.51	May	26.95	Jul
Total PAHs[c]	ng/L	-	6	132.71	126.14	May	171.81	Jul
Total Parent PAHs[c]	ng/L	-	6	22.77	22.17	May	23.70	Oct
Total Alkylated PAHs[c]	ng/L	-	6	109.7	103.98	May	148.80	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0063**	0.0029	Jun	**0.014**	Jul
Sulphide	mg/L	0.0019	5	**0.0047**	<0.0019	Oct	**0.0077**	Aug
Dissolved iron	mg/L	0.3	5	**0.389**	0.257	Jun	**0.71**	Oct

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.3-7 Monthly concentrations of water quality measurement endpoints, Steepbank River above Millennium Mine (*test* station STR-2), November 2014 to March 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.14	8.00	Nov	8.21	Jan
Total suspended solids	mg/L	-	5	4.5	3.3	Jan	26.9	Nov
Conductivity	µS/cm	-	5	561	272	Nov	600	Feb
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.016	0.012	Mar	0.038	Dec
Total nitrogen	mg/L	-	5	0.64	0.537	Feb	0.75	Nov
Nitrate+nitrite	mg/L	3-124	5	0.19	<0.05	Nov	0.31	Mar
Dissolved organic carbon	mg/L	-	5	11.1	9.7	Mar	27.5	Nov
Ions								
Sodium	mg/L	-	5	34.2	14.2	Nov	40.0	Mar
Calcium	mg/L	-	5	66.1	34.2	Nov	68.9	Mar
Magnesium	mg/L	-	5	19.6	9.9	Nov	21.1	Mar
Potassium	mg/L	-	5	2.0	0.83	Nov	2.15	Mar
Chloride	mg/L	120-640	5	1.7	1.0	Nov	2.1	Feb
Sulphate	mg/L	309[b]	5	8.9	4.3	Nov	10.0	Mar
Total dissolved solids	mg/L	-	5	347.0	188.0	Nov	366.0	Mar
Total alkalinity	mg/L	20 (min)	5	299.0	149.0	Nov	346.0	Mar
Selected metals								
Total aluminum	mg/L	-	5	0.080	0.03410	Nov	0.123	Mar
Dissolved aluminum	mg/L	0.05	5	0.0019	0.0009	Mar	0.0115	Nov
Total arsenic	mg/L	0.005	5	0.0005	0.00041	Mar	0.0007	Nov
Total boron	mg/L	1.5-29	5	0.24	0.082	Nov	0.259	Feb
Total molybdenum	mg/L	0.073	5	0.00059	0.00035	Dec	0.0030	Nov
Total mercury (ultra-trace)	ng/L	5-13	5	0.64	0.59	Mar	1.56	Nov
Total methyl mercury	ng/L	1-2	0	-	-	-	-	-
Total strontium	mg/L	-	5	0.30	0.119	Nov	0.36	Jan
Total hydrocarbons								
BTEX	mg/L	-	5	<0.1	<0.1	-	<0.1	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.1	<0.1	-	<0.1	-
Fraction 2 (C10-C16)	mg/L	0.11	5	**<0.25**	**<0.25**	-	**<0.25**	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.25	<0.25	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.25	<0.25	-	<0.25	-
Naphthenic acids	mg/L	-	5	0.36	<0.02	Dec	1.40	Feb
Oilsands extractable acids	mg/L	-	5	1.50	0.50	Dec	2.40	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	1.11	0.92	Feb	1.50	Nov
Total dibenzothiophenes[c]	ng/L	-	5	<8.17	<8.17	-	8.65	Jan
Total PAHs[c]	ng/L	-	5	126.88	111.96	Mar	128.57	Jan
Total Parent PAHs[c]	ng/L	-	5	22.61	9.03	Mar	22.98	Jan
Total Alkylated PAHs[c]	ng/L	-	5	104.26	102.64	Nov	105.60	Jan
Other variables that exceeded Alberta guidelines in 2015[d]								
Sulphide	mg/L	0.0019	2	<0.0015	<0.0015	-	**0.0048**	Nov
Dissolved iron	mg/L	0.3	2	0.0587	0.0182	Mar	**0.763**	Dec

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.3-8 Monthly concentrations of water quality measurement endpoints, Steepbank River below North Steepbank River (*test* station STB RIFF 10), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.00	7.77	Jul	8.18	Jun
Total suspended solids	mg/L	-	6	2.7	1.3	Sep	11.0	Jul
Conductivity	µS/cm	-	6	200	130	Jul	260	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.029	0.015	May	0.037	Oct
Total nitrogen	mg/L	-	6	0.85	0.55	Oct	<1	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	0.021	Sep
Dissolved organic carbon	mg/L	-	6	21.5	14.0	May	29.0	Aug
Ions								
Sodium	mg/L	-	6	9.1	5.4	Jul	14.0	Oct
Calcium	mg/L	-	6	24.0	18.0	May	28.0	Oct
Magnesium	mg/L	-	6	7.4	5.7	Jul	8.8	Oct
Potassium	mg/L	-	6	0.7	0.43	Jul	1.40	May
Chloride	mg/L	120-640	6	1.1	<1	-	1.4	Aug, Sep
Sulphate	mg/L	309[b]	6	1.6	<1	May, Jun	2.6	Oct
Total dissolved solids	mg/L	-	6	160	110.0	May	190	Oct
Total alkalinity	mg/L	20 (min)	6	105	66	Jul	140	Oct
Selected metals								
Total aluminum	mg/L	-	6	0.064	0.0185	Jun	0.249	Jul
Dissolved aluminum	mg/L	0.05	6	0.0092	0.0030	Jun	0.0183	Jul
Total arsenic	mg/L	0.005	6	0.0006	0.00048	May	0.00077	Aug
Total boron	mg/L	1.5-29	6	0.058	0.030	Jul	0.088	Oct
Total molybdenum	mg/L	0.073	6	0.00022	0.00015	Jul	0.00027	Jun
Total mercury (ultra-trace)	ng/L	5-13	6	1.36	0.89	Oct	2.25	Jul
Total methyl mercury	ng/L	1-2	6	0.094	0.049	May	0.193	Aug
Total strontium	mg/L	-	6	0.098	0.062	May	0.115	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.61	<0.08	Oct	0.73	Aug
Oilsands extractable acids	mg/L	-	6	1.65	0.20	Oct	2.30	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	16.50	Aug
Retene	ng/L	-	6	1.48	0.91	Oct	4.49	Jul
Total dibenzothiophenes[c]	ng/L	-	6	<8.17	<8.17	-	8.71	Sep
Total PAHs[c]	ng/L	-	6	128.51	124.77	May	137.97	Oct
Total Parent PAHs[c]	ng/L	-	6	23.42	22.15	May, Jun	26.08	Aug
Total Alkylated PAHs[c]	ng/L	-	6	104.2	102.61	May	113.61	Oct
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0065**	0.0028	May	**0.015**	Jul
Sulphide	mg/L	0.0019	5	**0.0043**	<0.0019	Oct	**0.0085**	Aug
Dissolved iron	mg/L	0.3	6	**0.421**	0.339	May	**0.77**	Oct

Values in **bold** are above guideline.

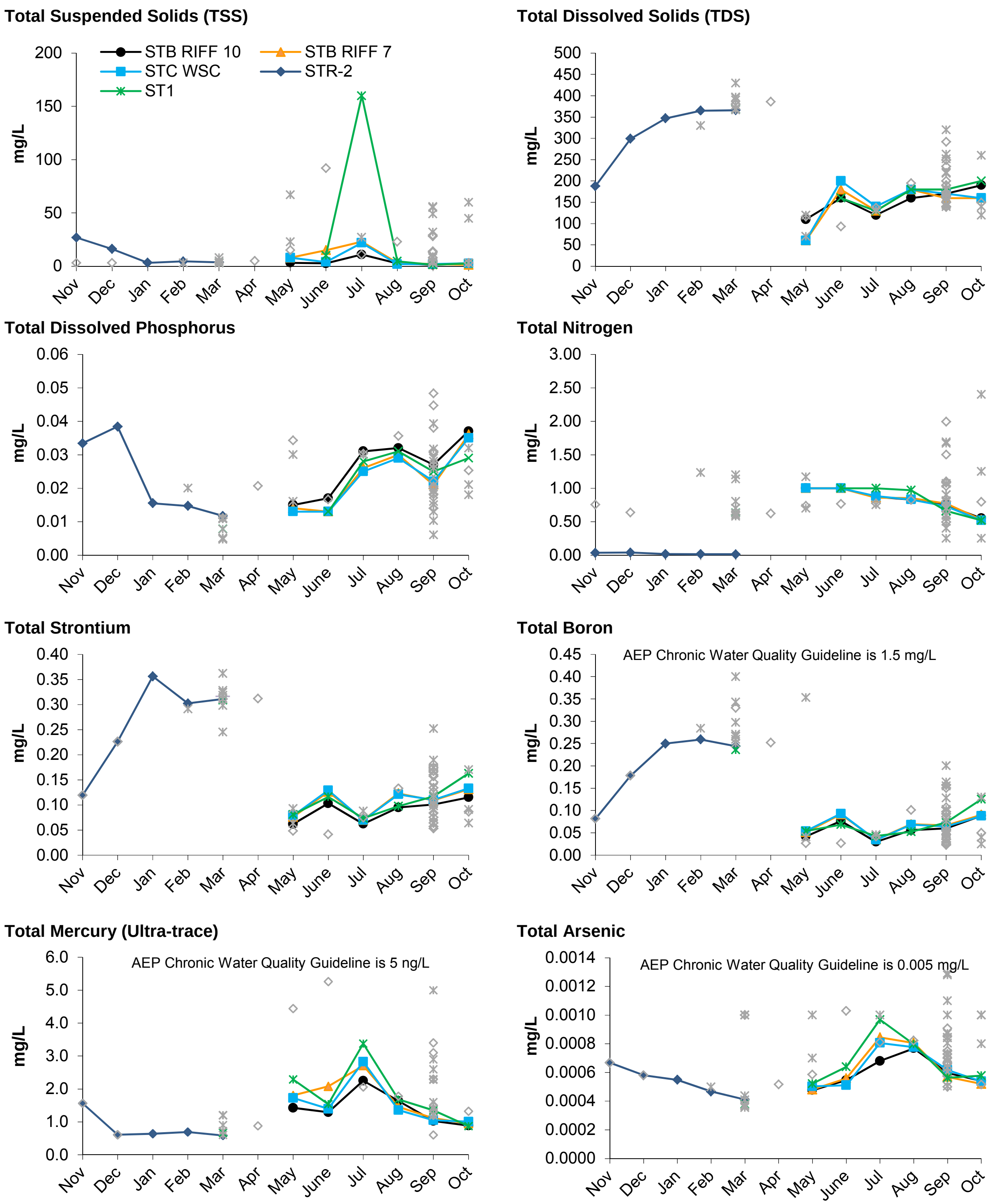
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

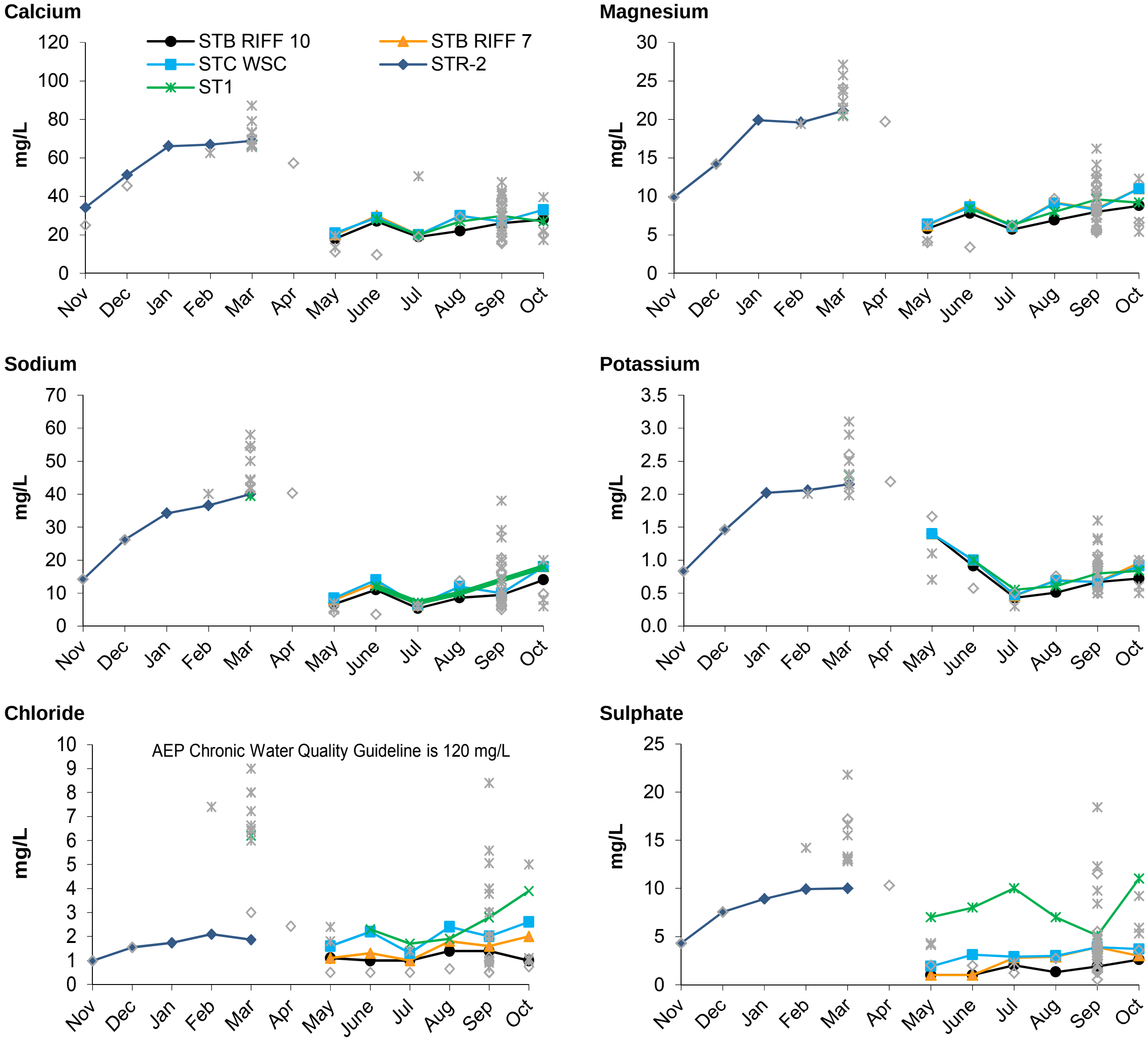
[d] n value refers to number of exceedances in 2015.

Figure 5.3-5 Selected water quality measurement endpoints in the Steepbank River (monthly data) in the 2015 WY.



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.3-5 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.3-9 Concentrations of water quality measurement endpoints at Steepbank River stations (*test* stations STB WSC, STB RIFF 7, and STB RIFF 10), fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value		
			STB WSC	STB RIFF 7	STB RIFF 10
Physical variables					
pH	pH units	6.5-9.0	8.13	8.04	8.04
Total suspended solids	mg/L	-	2.0	2.0	1.30
Conductivity	µS/cm	-	220	220	210
Nutrients					
Total dissolved phosphorus	mg/L	-	0.022	0.021	0.03
Total nitrogen	mg/L	-	0.73	0.77	0.75
Nitrate+nitrite	mg/L	3-124	<0.005	<0.005	0.021
Dissolved organic carbon	mg/L	-	23	23	23
Ions					
Sodium	mg/L	-	10.0	10.0	9.5
Calcium	mg/L	-	27	27	26
Magnesium	mg/L	-	8.3	8.4	8.0
Potassium	mg/L	-	0.67	0.67	0.67
Chloride	mg/L	120-640	2.0	1.6	0.7
Sulphate	mg/L	309[b]	3.9	3.9	1.9
Total dissolved solids	mg/L	-	170	160	170
Total alkalinity	mg/L	20 (min)	110	110	110
Selected metals					
Total aluminum	mg/L	-	0.123	0.096	0.040
Dissolved aluminum	mg/L	0.05	0.008	0.008	0.009
Total arsenic	mg/L	0.005	0.001	0.001	0.001
Total boron	mg/L	1.5-29	0.064	0.067	0.060
Total molybdenum	mg/L	0.073	0.00019	0.00019	0.00021
Total mercury (ultra-trace)	ng/L	5-13	1.05	1.11	1.03
Total methyl mercury	ng/L	1-2	0.111	0.11	0.113
Total strontium	mg/L	-	0.11	0.109	0.101
Total hydrocarbons					
BTEX	mg/L	-	<0.01	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02	<0.02
Naphthenic acids	mg/L	-	0.10	0.17	0.17
Oilsands extractable acids	mg/L	-	1.1	1.2	1.1
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	ng/L	1,000	39.20	<13.55	14.80
Retene	ng/L	-	0.88	0.85	1.53
Total dibenzothiophenes[c]	ng/L	-	22.37	16.39	8.71
Total PAHs[c]	ng/L	-	197.9	133.7	137.8
Total Parent PAHs[c]	ng/L	-	48.8	23.0	24.6
Total Alkylated PAHs[c]	ng/L	-	149.1	110.7	113.2
Other variables that exceeded Alberta guidelines in fall 2015					
Dissolved iron	mg/L	0.3	**0.47**	**0.43**	**0.47**
Sulphide	mg/L	0.0019	**0.0054**	**0.0062**	**0.0062**
Total phenols	mg/L	0.004	**0.010**	**0.012**	**0.010**

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.3-10 Concentrations of water quality measurement endpoints, mouth of Steepbank River (*test* station ST1 [STR-1]), fall 2015, compared to historical concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1997-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.28	17	8.20	7.70	8.60
Total suspended solids	mg/L	-	1.3	17	8.0	<3.0	60.0
Conductivity	µS/cm	-	240	17	234	141	516
Nutrients							
Total dissolved phosphorus	mg/L	-	0.025	17	0.019	0.006	0.039
Total nitrogen	mg/L	-	0.66	17	0.800	0.250	2.40
Nitrate+nitrite	mg/L	3-124	<0.005	17	<0.071	<0.050	<0.100
Dissolved organic carbon	mg/L	-	23	17	23	10	30
Ions							
Sodium	mg/L	-	14	17	11.0	6.00	38.0
Calcium	mg/L	-	30	17	30.0	17.2	50.3
Magnesium	mg/L	-	9.6	17	8.60	5.40	16.2
Potassium	mg/L	-	0.8	17	0.80	0.50	1.6
Chloride	mg/L	120-640	2.8	17	2.00	<0.70	8.40
Sulphate	mg/L	309[b]	5.1	17	4.70	2.45	18.4
Total dissolved solids	mg/L	-	180	17	182	120	320
Total alkalinity	mg/L	20 (min)	130	17	120	63	263
Selected metals							
Total aluminum	mg/L	-	0.058	17	0.188	0.040	2.79
Dissolved aluminum	mg/L	0.05	0.007	17	0.0135	<0.0044	**0.0987**
Total arsenic	mg/L	0.005	0.0006	17	0.0008	<0.0005	0.0013
Total boron	mg/L	1.5-29	0.073	17	0.057	0.025	0.200
Total molybdenum	mg/L	0.073	0.00022	17	0.00023	0.00015	0.00050
Total mercury (ultra-trace)	ng/L	5-13	1.35	12	<1.50	<1.20	5.00
Total methyl mercury	ng/L	1-2	0.108	-	-	-	-
Total strontium	mg/L	-	0.117	17	0.114	0.063	0.252
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.16</u>	4	0.43	0.19	0.88
Oilsands extractable acids	mg/L	-	1.1	4	1.18	0.52	2.20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.210	<15.16
Retene	ng/L	-	<u>0.9</u>	4	8.36	1.540	53.70
Total dibenzothiophenes[c]	ng/L	-	<u>41.4</u>	4	263.6	89.17	1,678
Total PAHs[c]	ng/L	-	<u>178.4</u>	4	852.8	325.4	4,775
Total Parent PAHs[c]	ng/L	-	<u>23.8</u>	4	33.82	27.69	97.42
Total Alkylated PAHs[c]	ng/L	-	<u>154.6</u>	4	819.0	297.7	4,677
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.492**	17	**0.373**	0.187	**0.719**
Sulphide	mg/L	0.0019	**0.007**	17	**0.0060**	<0.0015	**0.0410**
Total phenols	mg/L	0.004	**0.0053**	17	**0.006**	0.001	**0.013**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.3-6 Piper diagram of fall ion concentrations in the Steepbank River watershed.

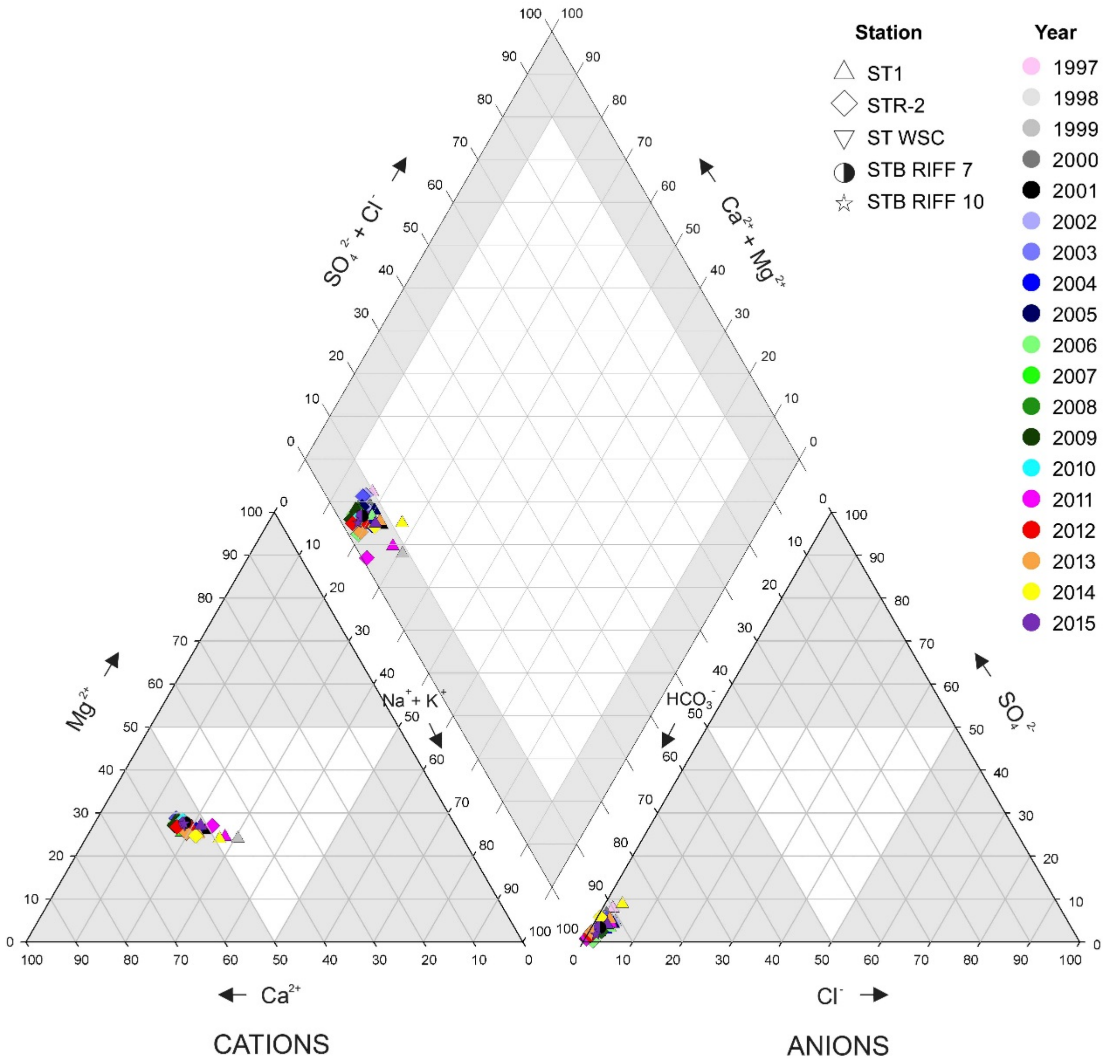


Table 5.3-11 Water quality guideline exceedances in the Steepbank River watershed, 2015 WY.

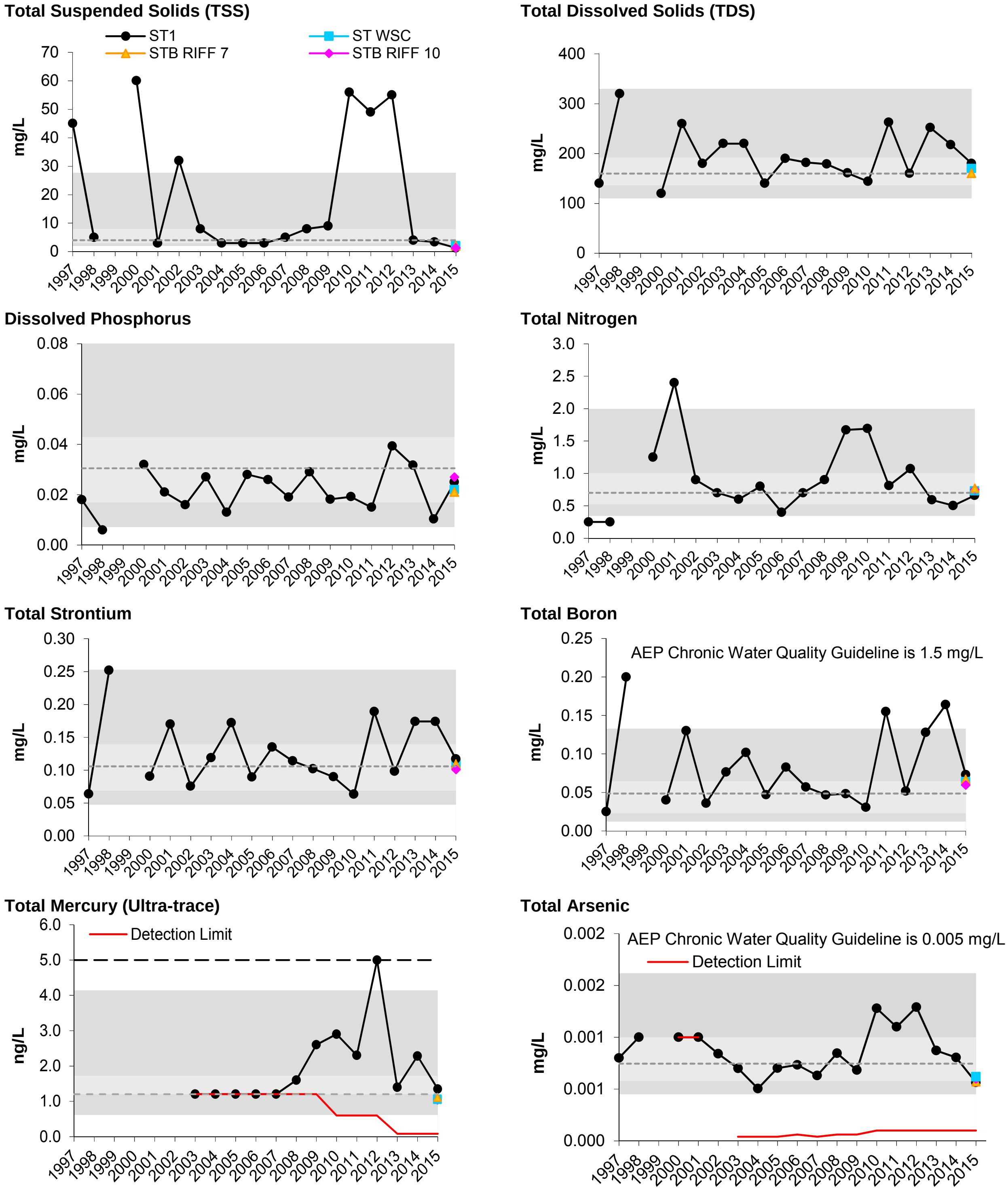
Variable	Units	Guideline[a]	November	December	January	February	March	May	June	July	August	September	October
Steepbank River mouth (ST1 [STR-1])													
Total phenols	mg/L	0.004	-	-	-	-	<0.001	-	**0.0089**	**0.016**	**0.011**	**0.0053**	**0.007**
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015	-	**0.0041**	**0.0039**	<0.0019	**0.007**	**0.0029**
Dissolved iron	mg/L	0.3	-	-	-	-	0.0194	**0.303**	0.276	**0.427**	**0.488**	**0.492**	**0.705**
Steepbank River adjacent to Millennium Mine (ST WSC)													
Total phenols	mg/L	0.004	-	-	-	-	<0.001	-	**0.0089**	**0.016**	**0.011**	**0.0053**	**0.007**
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015	-	**0.0041**	**0.0039**	<0.0019	**0.007**	**0.003**
Dissolved iron	mg/L	0.3	-	-	-	-	0.0194	**0.303**	0.276	**0.427**	**0.488**	**0.492**	**0.705**
Steepbank River approx. 27 km upstream of mouth (STB RIFF 7)													
Total phenols	mg/L	0.004	-	-	-	-	-	0.003	0.0029	**0.014**	**0.0072**	**0.012**	**0.0053**
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0032**	**0.0024**	**0.0062**	**0.0077**	**0.0062**	0.0019
Dissolved iron	mg/L	0.3	-	-	-	-	-	**0.328**	0.257	**0.344**	**0.619**	**0.433**	**0.714**
Steepbank River above Millennium Mine (STR-2)													
Sulphide	mg/L	0.0019	**0.0048**	**0.0022**	<0.0015	<0.0015	<0.0015	-	-	-	-	-	-
Dissolved iron	mg/L	0.3	**0.669**	**0.763**	0.0587	0.0267	0.0182	-	-	-	-	-	-
Steepbank River below North Steepbank River (STB RIFF 10)													
Total phenols	mg/L	0.004	-	-	-	-	-	0.0028	**0.0056**	**0.015**	**0.0067**	**0.01**	**0.0063**
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0024**	**0.0024**	**0.007**	**0.0085**	**0.0062**	<0.0019
Dissolved iron	mg/L	0.3	-	-	-	-	-	**0.339**	**0.372**	**0.355**	**0.658**	**0.47**	**0.773**

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.3-7 Selected water quality measurement endpoints in the Steepbank River (fall data) relative to historical and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

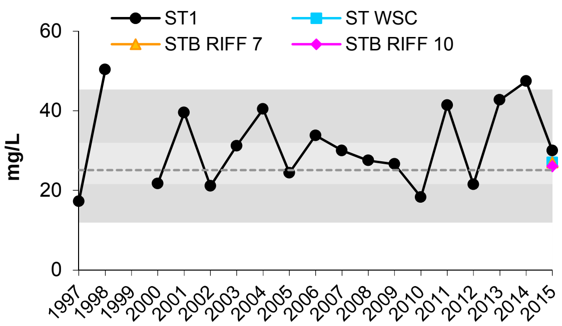
– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

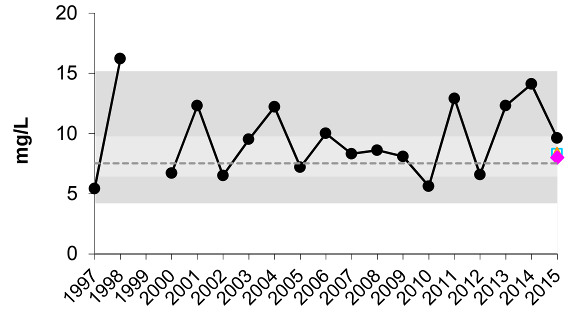
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.3-7 (Cont'd.)

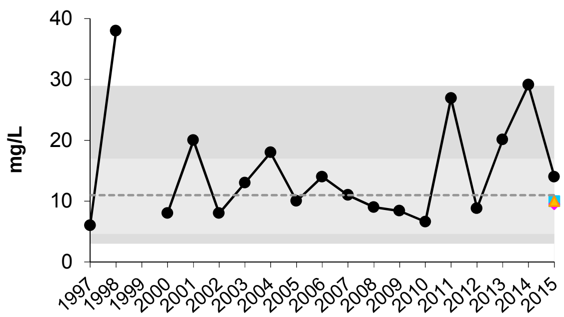
Calcium



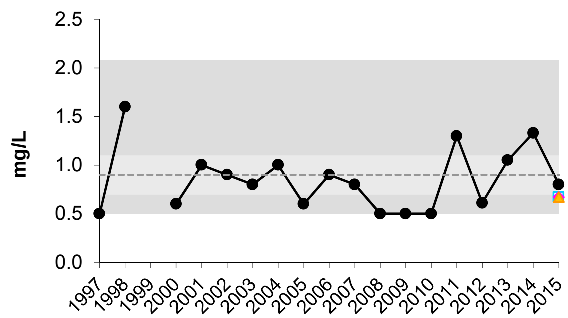
Magnesium



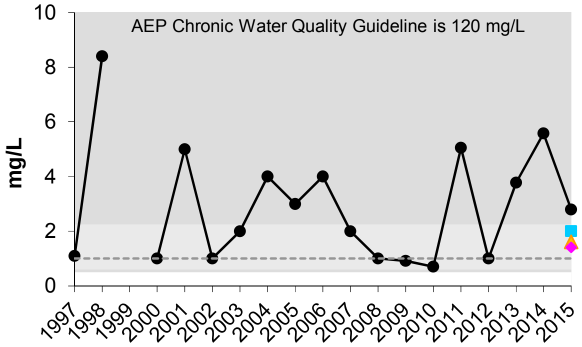
Sodium



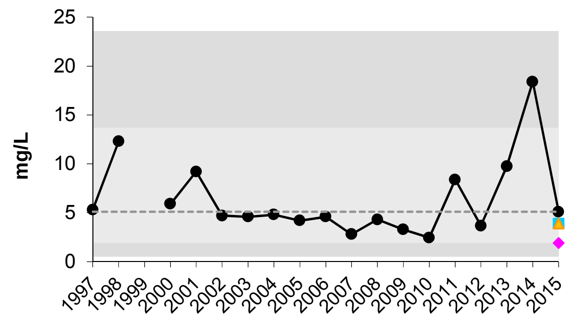
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.3-12 Average habitat characteristics of lower *test* reach STR-F1 and upper *baseline* reach STR-F2 in the Steepbank River, fall 2015.

Variable	Units	STR-F1 Lower *Test* Reach	STR-F2 Upper *Baseline* Reach
Sample date	-	Sept. 19, 2015	Sept. 19, 2015
Habitat type	-	glide	riffle
Maximum depth	m	1.00	0.48
Mean depth	m	0.79	0.34
Bankfull channel width	m	28.9	18.4
Wetted channel width	m	12.7	14.2
Substrate			
Dominant	-	sand	cobble
Subdominant	-	rough bedrock	coarse gravel
Instream cover			
Dominant	-	small and large woody debris, live trees/roots, overhanging vegetation	small woody debris
Subdominant	-	-	macrophytes, large woody debris, live trees/roots, overhanging vegetation, undercut banks
Field water quality			
Dissolved oxygen	mg/L	9.4	9.6
Conductivity	µS/cm	237	194
pH	pH units	6.28	7.96
Water temperature	^{0}C	9.6	8.1
Water velocity			
Left bank velocity	m/s	0.19	0.12
Left bank water depth	m	0.50	0.12
Centre of channel velocity	m/s	0.64	0.67
Centre of channel water depth	m	0.89	0.46
Right bank velocity	m/s	0.00	0.73
Right bank water depth	m	0.78	0.31
Riparian cover – understory (<5 m)			
Dominant	-	woody shrubs and saplings	woody shrubs and saplings
Subdominant	-	overhanging vegetation	overhanging vegetation

Table 5.3-13 Total number and percent composition of fish species captured in reaches of the Steepbank River, 2009 to 2015.

Common Name	Code	Total Species Catch												Percent of Total Catch											
		STR-F1							<u>STR-F2</u>					STR-F1							<u>STR-F2</u>				
		2009	2010	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2009	2010	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Arctic grayling	ARGR	-	-	-	-	-	-	-	-	-	1	6	-	0	0	0	0	0	0	0	0	0	2.2	3.5	0
brook stickleback	BRST	-	-	-	-	-	-	-	5	1	-	-	-	0	0	0	0	0	0	0	6.3	50.0	0	0	0
burbot	BURB	-	8	-	-	6	3	-	-	-	-	-	-	0	3.8	0	0	42.9	17.6	0	0	0	0	0	0
lake chub	LKCH	2	-	-	3	-	-	1	5	1	3	8	3	6.1	0	0	30.0	0	0	6	6.3	50.0	6.5	4.6	5.2
lake whitefish	LKWH	-	-	-	-	-	-	-	1	-	-	-	-	0	0	0	0	0	0	0	1.3	0	0	0	0
longnose dace	LNDC	1	63	2	2	1	-	1	9	-	3	13	2	3.0	30.0	7.7	20.0	7.1	0	6	11.4	0	6.5	7.5	3.4
longnose sucker	LNSC	2	-	1	1	2	3	2	3	-	3	25	4	6	0	3.8	10.0	14.3	17.6	11.8	3.8	0	6.5	14.5	6.9
northern pike	NRPK	-	-	-	1	-	1	-	-	-	-	-	-	0	0	0	10.0	0	5.9	0	0	0	0	0	0
northern redbelly dace	NRDC	16	-	-	-	-	-	-	1	-	-	-	-	48.5	0	0	0	0	0	0	1.3	0	0	0	0
pearl dace	PRDC	2	64	-	-	-	-	-	-	-	-	-	1	6.1	30.5	0	0	0	0	0	0	0	0	0	2
slimy sculpin	SLSC	2	60	8	2	2	10	9	35	-	29	87	32	6.1	28.6	30.8	20.0	14.3	58.8	52.9	44.3	0	63.0	50.3	55.2
spoonhead sculpin	SPSC	-	3	3	-	-	-	-	-	-	-	-	-	0	1.4	11.5	0	0	0	0	0	0	0	0	0
trout-perch	TRPR	1	7	-	-	1	-	4	20	-	7	22	14	3.0	3.3	0	0	7.1	0	24	25.3	0	15.2	12.7	24.1
walleye	WALL	1	-	-	-	1	-	-	-	-	-	5	-	3.0	0	0	0	7.1	0	0	0	0	0	2.9	0
white sucker	WHSC	1	4	12	1	-	-	-	-	-	-	7	2	3.0	1.9	46.2	10.0	0	0	0	0	0	0	4.0	3.4
yellow perch	YLPR	-	1	-	-	1	-	-	-	-	-	-	-	0	0.5	0	0	7.1	0	0	0	0	0	0	0
unknown sp. *		5	-	-	-	-	-	-	-	-	-	-	-	15.2	0	0	0	0	0	0	0	0	0	0	0
Total Count		**33**	**210**	**26**	**10**	**14**	**17**	**17**	**79**	**2**	**46**	**173**	**58**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**9**	**8**	**5**	**6**	**7**	**4**	**5**	**8**	**2**	**6**	**8**	**7**	**9**	**8**	**5**	**6**	**7**	**4**	**5**	**8**	**2**	**6**	**8**	**7**
Electrofishing effort (secs)		**3,652**	**4,977**	**1,326**	**1,948**	**1,772**	**1,765**	**1,517**	**1,309**	**1,712**	**2,269**	**2,606**	**1,868**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

* Not included in total species richness count.

<u>Underline</u> denotes *baseline* reach.

Table 5.3-14 Summary of fish community measurement endpoints (± 1SD) for *test* reach STR-F1 and *baseline* reach STR-F2 in the Steepbank River, 2009 to 2015.

Reach	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Lower *test* reach STR-F1	2009	0.25	-	10	9.00	-	0.13	-	6.92	-	0.90	-
	2010	0.42	0.23	8	3.70	0.95	0.57	0.13	5.42	0.81	4.38	2.60
	2011	0.10	0.07	5	2.60	1.14	0.43	0.29	5.07	1.46	1.96	1.32
	2012	0.04	0.03	6	2.00	1.58	0.38	0.36	5.44	1.28	0.51	0.40
	2013	0.02	0.02	7	2.20	1.30	0.37	0.35	4.25	1.45	0.90	0.83
	2014	0.05	0.02	4	2.20	1.10	0.39	0.35	3.37	0.53	0.96	0.33
	2015	0.07	0.07	5	1.8	1.1	0.25	0.34	4.16	1.10	1.13	1.31
Upper *baseline* reach STR-F2	2011	0.32	0.18	8	4.20	1.30	0.59	0.09	6.02	2.08	5.80	2.82
	2012	0.01	0.01	2	0.40	0.55	0.00	0.00	7.45	2.76	0.12	0.16
	2013	0.18	0.04	6	3.40	1.14	0.51	0.16	4.32	0.64	2.03	0.50
	2014	0.38	0.16	8	4.40	0.89	0.60	0.10	5.10	1.82	4.48	1.93
	2015	0.21	0.10	7	2.60	1.82	0.33	0.30	5.10	2.38	3.25	1.62

* Unknown species not included in the calculation.

SD = standard deviation across sub-reaches within a reach

Table 5.3-15 Results of analysis of variance (ANOVA) testing for differences in fish community measurement endpoints for *test* reach STR-F1 and *baseline* reach STR-F2 of the Steepbank River.

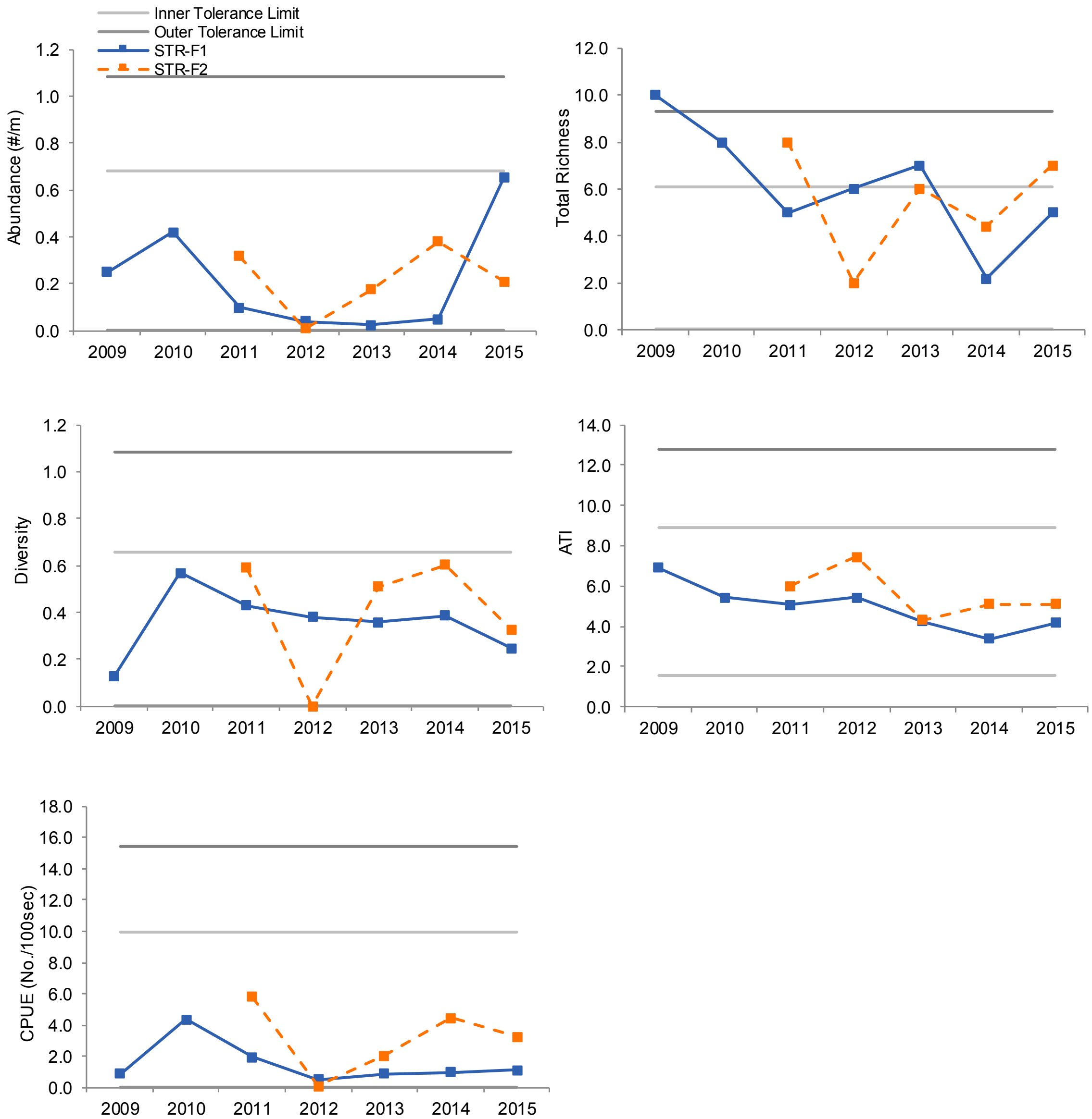
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend (*Test* Reach STR-F1)	*Test* Reach STR-F1 vs. *Baseline* Reach STR-F2	Time Trend (*Test* Reach STR-F1)	*Test* Reach STR-F1 vs. *Baseline* Reach STR-F2	
Abundance	**<0.001***	0.09*	40%	4%	Decreasing over time.
Richness	**0.003**	0.21	22%	1%	Decreasing over time.
Diversity	**0.04***	0.22*	10%	1%	Decreasing over time.
ATI	**0.002**	0.64*	24%	0%	Decreasing over time.
CPUE	**<0.001***	0.32*	33%	<1%	Decreasing over time.

Bold values indicate significant difference (p≤0.05).

* Data were log-transformed to meet assumptions of ANOVA.

Shading denotes significant differences with >20% variance, which is considered a strong signal in spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Figure 5.3-8 Variation in fish community measurement endpoints for the Steepbank River from 2009 to 2015 relative to regional *baseline* conditions.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data from cluster 1 (see Table 3.2-10).

A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Although *baseline* reach STR-F2 was not part of *baseline* cluster 1, the data were graphed to provide comparison to *test* reach STR-F1.

5.4 TAR RIVER WATERSHED

Table 5.4-1 Summary of results for the Tar River watershed.

Tar River Watershed	Summary of 2015 Conditions		
Climate and Hydrology			
Criteria	**S15A**	**C2**	**S34**
Mean open-water season discharge	🟤	climate station – n/a	not measured
Mean winter discharge	not measured	climate station – n/a	not measured
Annual maximum daily discharge	🟤	climate station – n/a	not measured
Minimum open-water season discharge	🟤	climate station – n/a	not measured
Water Quality			
Criteria	**TAR-1**	no station	**TAR-2A**
Water Quality Index	🟡	-	🟡
Benthic Invertebrate Communities and Sediment Quality			
Criteria	**TAR-D1**	no reach	**TAR-E2**
Benthic Invertebrate Communities	🟠	-	n/a
Sediment Quality Index	🟡	-	no station
Fish Populations			
Criteria	no reach	no reach	**TAR-F2**
Fish Communities	-	-	n/a
Wild Fish Health	No Wild Fish Health monitoring was conducted in the 2015 WY.		

Legend and Notes

🟡 Negligible - Low

🟠 Moderate

🟤 High

baseline

test

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

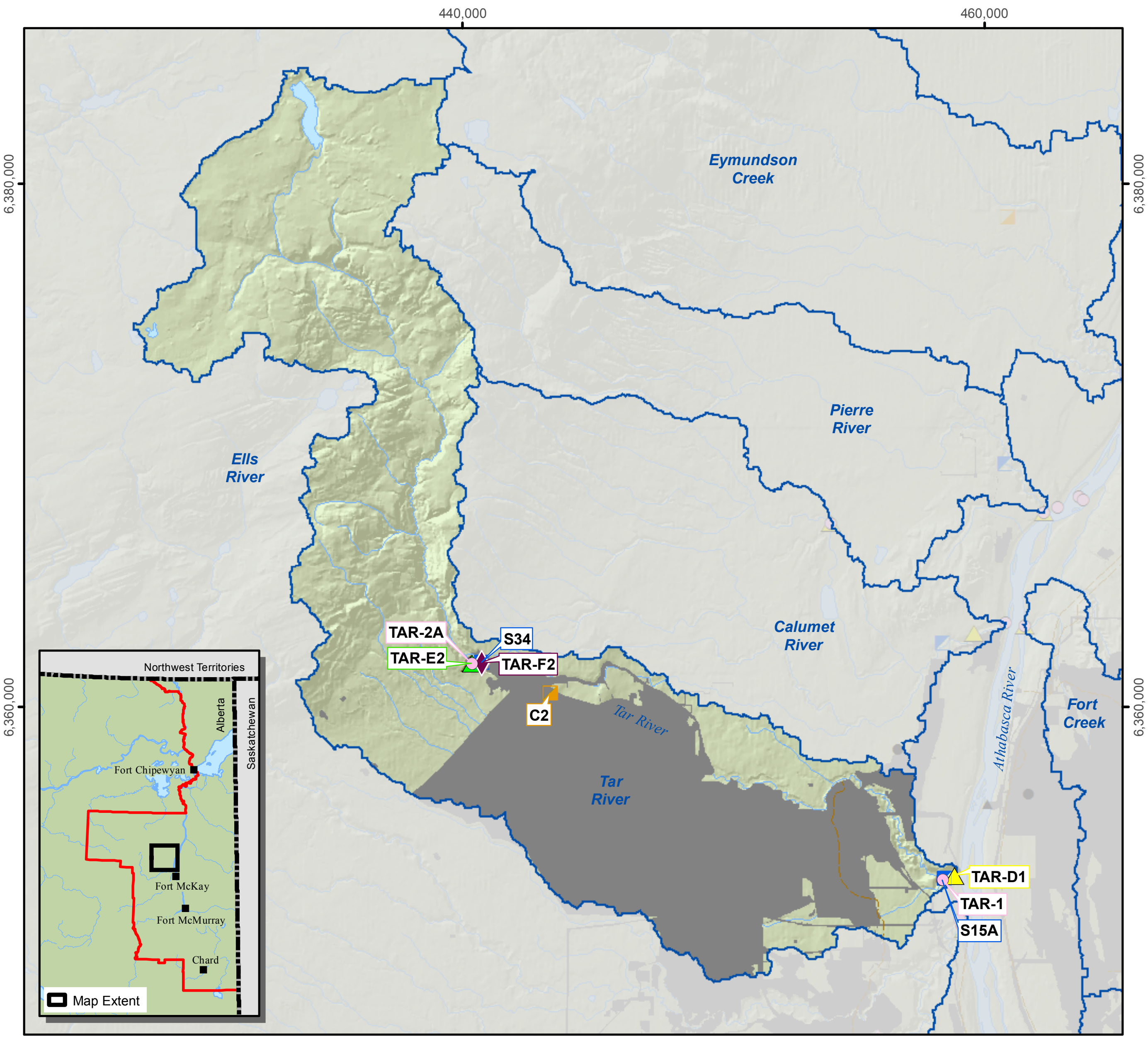
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (Fish Communities): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.1 for a detailed description of the classification methodology.

Figure 5.4-1 Tar River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]
- Water Withdrawal Location
- Water Release Location
- Water Quality Station
- Data Sonde Station
- Hydrometric Station
- Climate Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Community Reach
- Wild Fish Health Reach
- Wild Fish Health Reach with Water and Sediment Quality Stations

0 1 2 4 6 km

N

Scale: 1:240,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

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Figure 5.4-2 Representative monitoring stations of the Tar River watershed, fall 2015.

Benthic Invertebrate Communities Reach TAR-D1: Tar River near the mouth, facing downstream

Hydrology Station S15A, facing downstream

Hydrology Station S34: Tar River above Horizon Lake, facing downstream

Benthic Invertebrate and Fish Communities Reach TAR-E2/TAR-F2: Tar River above Horizon Lake, facing upstream

5.1.1 Summary of 2015 WY Conditions

Approximately 34% (11,333 ha) of the Tar River watershed had undergone land change from oil sands development as of 2015 from (Table 2.3-1). The designations of specific areas of the watershed are as follows (Figure 5.4-1):

1. The Tar River watershed downstream of the Canadian Natural Horizon Project operations is designated as *test*.
2. The remainder of the watershed is designated as *baseline*.

Monitoring activities in the Tar River watershed in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components. Table 5.4-1 is a summary of the 2015 assessment for the Tar River watershed, while Figure 5.4-1 provides the locations of the monitoring stations for each component, reported project water withdrawal and discharge locations, and the locations of the areas with land change as of 2015. Figure 5.4-2 provides fall 2015 photos of representative monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology The 2015 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 29.06% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph for the Tar River at JOSMP Station S15A, Tar River near the mouth. These differences were classified as **High**. The amount of development in the Tar River watershed increases downstream of JOSMP Station S34, Tar River above Horizon Lake and differences in the values of the three hydrologic measurement endpoints between *test* and *baseline* cases were assessed as **Negligible-Low** for approximately 7 km downstream of Station S34, **Moderate** for the next 7 km downstream, and **High** for the remainder of the Tar River to its confluence with the Athabasca River.

Water Quality There were no obvious monthly trends in most of the water quality measurement endpoints at *test* station TAR-1 and *baseline* station TAR-2A from May to October 2015. Relative to historical seasonal data, all water quality measurement endpoints were within historical ranges except some ions at *test* station TAR-1, which were higher than previous observations in May 2015, likely due to historically low flows in the river. Water quality variables with concentrations that exceeded AEP water quality guidelines included dissolved iron, total phenols, and sulphides. Guideline exceedances of dissolved iron and sulphides were more frequent at *test* station TAR-1 than at *baseline* station TAR-2A; these results are consistent with results of historical monitoring under the RAMP and JOSMP. The ionic composition of water at both stations was consistent with historical observations and most water quality measurement endpoints at *test* station TAR-1 and *baseline* station TAR-2A in fall 2015 were within the range of previously-measured concentrations and were consistent with regional *baseline* concentrations. WQI values calculated using fall 2015 data indicated **Negligible-Low** differences in water quality from regional *baseline* ranges at both Tar River stations.

Benthic Invertebrate Communities and Sediment Quality Variations in the values of measurement endpoints for benthic invertebrate communities of the Tar River at *test* reach TAR-D1 for fall 2015 are classified as **Moderate**. The benthic invertebrate community at *test* reach TAR-D1 in fall 2015 did not contain taxa typically associated with good environmental conditions. In particular, Ephemeroptera were missing from the benthic invertebrate community in fall 2015 and have not been present at *test* reach TAR-D1 since 2012, indicating a compromised community and degraded conditions. In addition, two benthic invertebrate community measurement endpoints had significant differences in values between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means and which implied degrading conditions for benthic invertebrate communities.

There have been significant increases in concentrations of Fraction 1, 2, 3, and 4 hydrocarbons at *test* station TAR-D1 over the period of the monitoring record; no statistically-significant temporal trends were detected in concentrations of the other sediment quality variables at this station. Concentrations of the heavier hydrocarbon fractions (Fraction 3 and 4) at *test* station TAR-D1 in fall 2015 exceeded previously-measured maximum concentrations for the fall season. Concentrations of naphthalene, retene, and total parent PAH values in fall 2015 were below previously-measured minimums. Concentrations of measurement endpoints of sediment quality were below guideline concentrations in fall 2015 at *test* station TAR-D1 with the exception of predicted PAH toxicity, which exceeded the potential chronic toxicity threshold; the PAH hazard index in fall 2015 was similar to that observed in fall 2014 and has exceeded the potential chronic toxicity threshold since 2006. All sediment quality measurement endpoints at *test* station TAR-D1 in fall 2015 were within regional *baseline* concentrations. The calculated SQI for *test* station TAR-D1 in fall 2015 was 97.9, similar to the SQI calculated in 2014 of 100, and higher than the SQI value of 67.0 calculated for this station in fall 2013. Differences in sediment quality conditions in 2015 between *test* station TAR-D1 and regional *baseline* conditions were classified as **Negligible-Low**.

Fish Populations (Fish Communities) Reach TAR-F2 was a *baseline* reach in fall 2015; therefore, no classification of results could be assessed under the Environment Canada effects criteria guideline. Mean values of all measurement endpoints were higher at *baseline* reach TAR-F2 in 2015 compared to 2014. There were no significant changes in measurement endpoints over time with the exception of abundance, which has significantly decreased over time. However, differences in abundance explained less than 20% of the variance in annual means, suggesting that no strong statistical signal existed in the decline in abundance. Mean values of all measurement endpoints for *baseline* reach TAR-F2 were within the inner tolerance limits of the normal range of variability for *baseline* conditions.

5.1.2 Hydrologic Conditions

Hydrometric monitoring for the Tar River watershed in the 2015 WY was conducted at JOSMP Station S15A, Tar River near the mouth and JOSMP Station S34, Tar River above Horizon Lake. Data from the JOSMP Station S15A were used for the water balance analysis and are presented below. Details for each of these stations are provided in Appendix C.

Hydrometric data from the open-water period (May to October) have been collected every year at JOSMP Station S15A since 2007. Data were also collected annually at WSC Station 07DA015, Tar River near Fort MacKay from 1975 to 1977, and during the open-water period at JOSMP Station S15 from 2001 to 2006. The combination of these data records provides the historical context for JOSMP Station S15A.

The historical flow record for JOSMP Station S15A is summarized in Figure 5.4-3 and includes the median, and interquartile range of flows. Flows of the Tar River are typical for a northern environment; the available historical data indicate that flows are typically highest during spring freshet in May and lower for the other open-water months. Winter flows were only recorded for two to three years in the 1970s at Station 07DA015 and summary statistics in winter should therefore not be interpreted as necessarily indicative of typical flow conditions.

Hydrometric monitoring in the 2015 WY began in the third week of April, shortly after ice-out. Flows were below the historical median in late April and continued to decrease to below the historical minimum flow, with the minimum open-water daily flow recorded on June 10 at 0.04 m^3/s being 76% lower than the historical mean minimum daily flow of 0.16 m^3/s. Discharge then increased before reaching an open-water peak flow of 1.32 m^3/s on June 15, which was 79% lower than the historical mean open-water maximum daily flow of 6.3 m^3/s. Flows then decreased, to below historical lower quartile flows for the remainder of the WY with the exception of mid-August, mid-September and end of October, which generally correlated with rainfall events recorded at the JOSMP C2 Horizon weather station.

Overall, the runoff volume in the 2015 WY open-water period was 4.49 million m^3, which was 65% lower than the mean historical open-water runoff volume of 12.9 million m^3 based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Tar River watershed at JOSMP Station S15A is summarized in Table 5.4-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2015 was estimated to be 99.3 km^2 (Table 2.3-1). The loss of flow to the Tar River that would have otherwise occurred from this land area was estimated at 2.28 million m^3.
2. As of 2015, the area of land change in the Tar River watershed that was not closed-circuited was estimated to be 14.0 km^2 (Table 2.3-1). The increase in flow to the Tar River that would not have otherwise occurred from this land area was estimated at 0.065 million m^3.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the open-water period of the 2015 WY was a loss of flow of 2.217 million m^3 in the Tar River near the mouth (JOSMP Station S15A). The 2015 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were all 29.0% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.4-3). These differences were classified as **High** (Table 5.4-1) and; therefore, a longitudinal classification of change was conducted for the Tar River (Section 3.2.1.5); the results of this analysis are presented in Figure 5.4-4. Differences in the values of the three hydrologic measurement endpoints between *test* and *baseline* cases upstream of JOSMP Station S34, Tar River above Horizon Lake, were classified as *baseline* because no oil sands development had occurred upstream of this location as of 2015. The amount of development in the Tar River watershed increases downstream of JOSMP station S34 and differences in the values of the three hydrologic measurement endpoints between *test* and *baseline* cases were assessed as **Negligible-Low** for approximately 7 km downstream of Station S34, **Moderate** for the next 7 km downstream, and **High** for the remainder of the river to its confluence with the Athabasca River.

5.1.3 Water Quality

During the 2015 WY (i.e., November 2014 to October 2015), water quality samples were taken:

- monthly from May to September at the Tar River near its mouth (*test* station TAR-1), designated as *baseline* from 1998 to 2003 and *test* from 2004 onwards and sampled seasonally up to and including 2014; and
- monthly from July to October at the upper Tar River (*baseline* station TAR-2A), sampled seasonally up to and including 2014.

Monthly variations in the Tar River water quality are summarized in Table 5.4-4, Table 5.4-5, and Figure 5.4-5. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations are provided in Table 5.4-6 and Table 5.4-7. The ionic composition of water in the Tar River watershed is presented in Figure 5.4-6. Guideline exceedances for water quality measurement endpoints are presented in Table 5.4-8 and Figure 5.4-7 shows a comparison of selected water quality measurement endpoints in the Tar River relative to historical regional *baseline* concentrations.

Monthly Variations in Water Quality Monthly trends in concentrations of water quality measurement endpoints were not apparent at *test* station TAR-1 and *baseline* station TAR-2A (Table 5.4-4, Table 5.4-5, Figure 5.4-5). Relative to previous seasonal sampling at these stations, the concentrations of most water quality variables were similar at *test* station TAR-1 and *baseline* station TAR-2A (Figure 5.4-5), although ion concentrations at *test* station TAR-1 were slightly higher in May than historically observed, likely related to historically low river flows observed during May and June 2015.

2015 Fall Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints in fall 2015 were within previously-measured concentrations (Table 5.4-6, Table 5.4-7) with the following exceptions:

- *test* station TAR-1: oilsands extractable acids and naphthalene, with concentrations that exceeded previously-measured maximum concentrations at *test* station TAR-1 (waterborne naphthalene and oilsands extractable acids have only been measured at current, ultra-trace detection limits since 2011 and that historical comparisons of 2015 data for these water quality variables are to data from 2011 to 2014 only); and pH, total dibenzothiophenes, total parent PAHs and total alkylated PAHs, with levels and concentrations below previously-measured minima; and
- *baseline* station TAR-2A: naphthenic acids, with a concentration that exceeded the previously-measured maximum concentration; and total mercury, with a concentration below the previously-measured minimum concentration at *baseline* station TAR-2A.

Temporal Trends There were no significant temporal trends in the fall concentrations of water quality measurement endpoints at either *test* station TAR-1 or *baseline* station TAR-2A.

Ion Balance The ionic composition of water in fall 2015 at both *test* station TAR-1 and *baseline* station TAR-2A was similar to historical measurements of ionic composition (Figure 5.4-6).

Comparison of Water Quality Measurement Endpoints to AEP Guidelines The following water quality guideline exceedances were measured in the 2015 WY (Table 5.4-8):

- dissolved iron at *test* station TAR-1 (all sampling months) and *baseline* station TAR-2A (July and August);
- total phenols at *test* station TAR-1 (all sampling months) and *baseline* station TAR-2A (all sampling months); and
- sulphide at *test* station TAR-1 (all sampling months) and *baseline* station TAR-2A (September).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints at *test* station TAR-1 and *baseline* station TAR-2A in fall 2015 were within historical concentrations and regional *baseline* concentrations with the exception of TSS, total nitrogen, and total mercury concentrations at *baseline* station TAR-2A, which had concentrations that were lower than the 5th percentile of regional *baseline* concentrations (Figure 5.4-7).

Water Quality Index The WQI value for *test* station TAR-1 (100) and *baseline* station TAR-2A (97.4) showed a **Negligible-Low** difference from regional *baseline* conditions.

Classification of Results Differences in water quality observed in fall 2015 in the Tar River watershed indicated a **Negligible-Low** difference from regional *baseline* conditions.

5.1.4 Benthic Invertebrate Communities and Sediment Quality

5.1.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 at:

- depositional *test* reach TAR-D1, designated as *baseline* in 2002 and 2003 and as *test* from 2004 to 2015 (the reach was not sampled in 2007 and 2008); and
- erosional *baseline* reach TAR-E2, sampled since 2009 with a Neil-Hess cylinder and in 2015 with a CABIN kicknet. The *baseline* reach in the upper watershed was situated at TAR-E1 from 2003 to 2006. The study reach was "moved" further upstream due to increased oil sand development in the watershed. Values of benthic invertebrate community measurement endpoints for fall 2015 were "adjusted" to make them as comparable as possible to data collected with a Neil-Hess cylinder and therefore to data from previous years (see Appendix D).

2015 Habitat Conditions Depositional *test* reach TAR-D1 was shallow (0.2 m) and flowing with moderate velocity (0.4 m/s), and the water was alkaline (pH 8.0) and had moderate conductivity (326 μS/cm) (Table 5.4-9). The substrate was primarily sand (94.5%), with small amounts of silt (2.7%) and clay (2.8%), and low total organic carbon (<1%; Table 5.4-9).

Erosional *baseline* reach TAR-E2 was shallow (0.3 m) and flowing with slow velocity (0.2 m/s), and the water was alkaline (pH 8.2) and had moderate conductivity (310 μS/cm) (Table 5.4-9). The substrate was dominated by gravel. Full CABIN supporting data for *baseline* reach TAR-E2 are provided in Appendix D.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach TAR-D1 in fall 2015 was dominated by Chironomids (98%) (Table 5.4-10). Chironomids were primarily comprised of *Saetheria*, and *Rheosmittia*/ *Lopesocladius*. EPT taxa were not present in the lower *test* reach TAR-D1 in 2015. Permanent aquatic forms were represented by a single Hydracarina, while larvae of aquatic insects were represented by a single member of Lepidoptera (Noctuidae).

The benthic invertebrate community of *baseline* reach TAR-E2 in fall 2015 was dominated by caddisflies (27%), mayflies (24%), and stoneflies (24%) (Table 5.4-11). Subdominant taxa included chironomids (13%) and Hydracarina (8%). Caddisflies included *Glossossoma*, *Lepidostoma* and members of the family Hydropsychidae (e.g., *Hydropsyche*). Mayflies were comprised primarily of *Baetis* and members of the family Heptageniidae. Three stonefly genera were present, *Haploperla*, *Zapada*, *Pteronarcella*. A variety of chironomids were present, mainly *Rheotanytarsus* with *Eukiefferiella*, *Orthocladius*, *Cricotopus*, *Tvetenia*, and *Neoplasta*. Permanent aquatic forms were sparse and included a single *Pisidium* clam and the amphipod *Hyalella*.

Temporal Comparisons The following temporal comparisons of benthic invertebrate community measurement endpoints for *test* reach TAR-D1 were conducted:

- difference in measurement endpoints from before (2002 to 2003) to after (2004 to present) the reach was designated *test* (Hypothesis 1, Section 3.2.3.1);
- trend over time in measurement endpoints for the period that the reach was designated as *test* (Hypothesis 2, Section 3.2.3.1);
- difference between 2015 values and the means of measurement endpoints of all *baseline* years (2002 and 2003) in the lower reach (i.e., TAR-D1); and
- difference between 2015 values and the means of measurement endpoints of all previous sampling years at *test* reach TAR-D1.

The temporal comparisons that statistically significant were (Table 5.4-12, Figure 5.4-8):

1. Abundance and richness were significantly lower during the *test* period than during *baseline* years at *test* reach TAR-D1, accounting for 38% and 40% of the variance in annual means, respectively.
2. Richness was significantly lower at *test* reach TAR-D1 in 2015 compared to the mean richness of *baseline* years, accounting for 23% of the variance in annual means.

These significant differences are generally indicative of degrading conditions for benthic invertebrate communities in the lower Tar River.

Comparison to Published Literature The percent of the benthic invertebrate community as worms at *test* reach TAR-D1 was low in 2015 (2%) relative to 2014 (>25%) and 2013 (>69%). High relative abundance of worms in previous years suggested that the habitat at *test* reach TAR-D1 was in poor condition (Hynes 1960, Griffiths 1998). Permanent aquatic forms (e.g., *Hydracarina*) were present in 2015 but in low relative abundances. EPT taxa which have been present in the past at *test* reach TAR-D1 were absent in 2015, as they were in 2013 and 2014. The decrease in abundance and taxa richness, and the absence of EPT taxa in 2015 is consistent with a conclusion that *test* reach TAR-D1 in fall 2015 presented degraded habitat and that the community was compromised.

The benthic invertebrate community of *baseline* reach TAR-E2 contained taxa in fall 2015 that is typical of good environmental conditions. The benthic invertebrate community was dominated by EPT taxa, including larvae of mayflies, stoneflies and caddisflies, which indicate favourable long-term water quality (Resh and Unzicker 1975; Niemi et al. 1990). Caddisflies included the net spinner *Hydropsyche* and the scrapper *Glossossoma*, both of which are common in north-temperate locales (Wiggins 1977). Chironomids were diverse and included forms known to represent fair to good water quality (Mandeville 2002), such as *Rheotanytarsus* which tends to be present in rocky streams with good flows (Merritt and Cummins 1996).

2015 Results Relative to Regional Historical Variability Values of all benthic invertebrate community measurement endpoints for *test* reach TAR-D1 were within the inner tolerance limits of the 95th percentile of the normal range of *baseline* reaches (Figure 5.4-8; Figure 5.4-9).

Values of all benthic community measurement endpoints in fall 2015 at *baseline* reach TAR-E2 were similar to that observed in prior years. There was a slight increase in taxa richness and equitability, and a slight decrease in %EPT taxa in fall 2015 (Figure 5.4-10). CA Axis scores were similar to observations in 2014 (Figure 5.4-11).

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities of the Tar River at *test* reach TAR-D1 for fall 2015 are classified as **Moderate**. The benthic invertebrate community at *test* reach TAR-D1 in fall 2015 did not contain taxa typically associated with good environmental conditions. In particular, Ephemeroptera were missing from the benthic invertebrate community in fall 2015 and have not been present at *test* reach TAR-D1 since 2012, indicating a compromised community and degraded conditions. In addition, two benthic invertebrate community measurement endpoints had significant differences in values between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means and which implied degrading conditions for benthic invertebrate communities.

5.1.4.2 Sediment Quality

Sediment quality was sampled in fall 2015 from the Tar River near its mouth (*test* station TAR-D1). This station was designated as *baseline* between 1998 and 2003 and *test* from 2004 onwards.

Temporal Trends There have been significant ($p<0.05$) increases in concentrations of Fraction 1, 2, 3, and 4 hydrocarbons at *test* station TAR-D1 over the period of the monitoring record; no statistically-significant temporal trends were detected in concentrations of the other sediment quality variables at *test* station TAR-D1.

2015 Results Relative to Historical Conditions Sediments at *test* station TAR-D1 in fall 2015 were predominantly sand (95.1%) with smaller concentrations of clay (2.8%) and silt (2.1%) (Table 5.4-13, Figure 5.4-12). The proportion of sand exceeded the previously-measured maximum value while clay and silt compositions were below previously-measured minimum values (Table 5.4-13).

Concentrations of the heavier hydrocarbon fractions (Fraction 3 and 4) at *test* station TAR-D1 in fall 2015 exceeded previously-measured maximum concentrations for the fall season (Table 5.4-13), likely indicating the presence of bitumen in the sediments. Concentrations of naphthalene, retene, and total parent PAH values in fall 2015 were below previously-measured minimums for the fall season (Table 5.4-13). The PAH hazard index in fall 2015 (1.2) was similar to that observed in fall 2014 and has exceeded the potential chronic toxicity threshold of 1.0 since 2006.

Survival was 100% for both the midge *Chironomus* and the amphipod *Hyalella* in the direct sediment toxicity tests, with the *Chironomus* survival value exceeding the previously-measured maximum, and growth rates of *Chironomus* and *Hyalella* at *test* station TAR-D1 remained between the previously-measured ranges of growth rate.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of measurement endpoints of sediment quality were below guideline concentrations in fall 2015 at *test* station TAR-D1 with the exception of predicted PAH toxicity, which exceeded the potential chronic toxicity threshold (Table 5.4-13).

2015 Results Relative to Historical Concentrations and Regional *Baseline* Concentrations All sediment quality measurement endpoints at *test* station TAR-D1 in fall 2015 were within regional *baseline* concentrations (Figure 5.4-12).

Sediment Quality Index The calculated SQI for *test* station TAR-D1 in fall 2015 was 97.9, similar to the SQI calculated in 2014 of 100, and higher than the SQI value of 67.0 calculated for this station in fall 2013.

Classification of Results Based on the calculated SQI value, differences in sediment quality conditions in 2015 between *test* station TAR-D1 and regional *baseline* conditions were classified as **Negligible-Low**. Sediment quality conditions between *test* station TAR-D1 and regional *baseline* conditions were classified as **Moderate** in 2013 and **Negligible-Low** in 2014.

5.1.5 Fish Populations

5.1.5.1 Fish Community Monitoring

Fish community monitoring was conducted on the Tar River in fall 2015 at upstream *baseline* reach TAR-F2. This reach has been sampled since 2011 and is in the same location as benthic invertebrate community *baseline* reach TAR-E2.

2015 Habitat Conditions Habitat conditions at *baseline* reach TAR-F2 for fall 2015 are summarized in Table 5.4-14. *Baseline* reach TAR-F2 in fall 2015 had run and riffle habitat with a wetted width of 6.8 m and a bankfull width of 8.3 m. Substrate consisted of cobble with small amounts of fine gravel. Water at *baseline* reach TAR-F2 was shallow with a mean depth of 0.20 m, velocity of 0.19 m/s, pH of 8.15, conductivity of 311 µS/cm, concentration of dissolved oxygen of 10.8 mg/L, and a temperature of 4.2 ˚C. Instream cover consisted primarily of small woody debris.

Relative Abundance of Fish Species The total catch of fish species at *baseline* reach TAR-F2 in fall 2015 was similar to 2014 and was comprised almost entirely of slimy sculpin with fewer numbers of longnose sucker (Table 5.4-15).

Temporal and Spatial Comparisons Mean values of all measurement endpoints were higher at *baseline* reach TAR-F2 in 2015 compared to 2014 (Table 5.4-16).

Temporal comparisons were conducted at *baseline* reach TAR-F2 between 2011 and 2015 to test for changes over time in measurement endpoints (Hypothesis 1, Section 3.2.4.4). No spatial comparisons were performed because no other reaches in the Tar River watershed were sampled in 2015.

There were no significant changes in fish community measurement endpoints over time with the exception of abundance, which generally decreased since 2011 (Table 5.4-16; Table 5.4-17), although abundance was higher in 2015 relative to 2014. Differences in abundance explained less than 20% of the variance in annual means, indicating that there was no strong statistical signal associated with the decline in abundance.

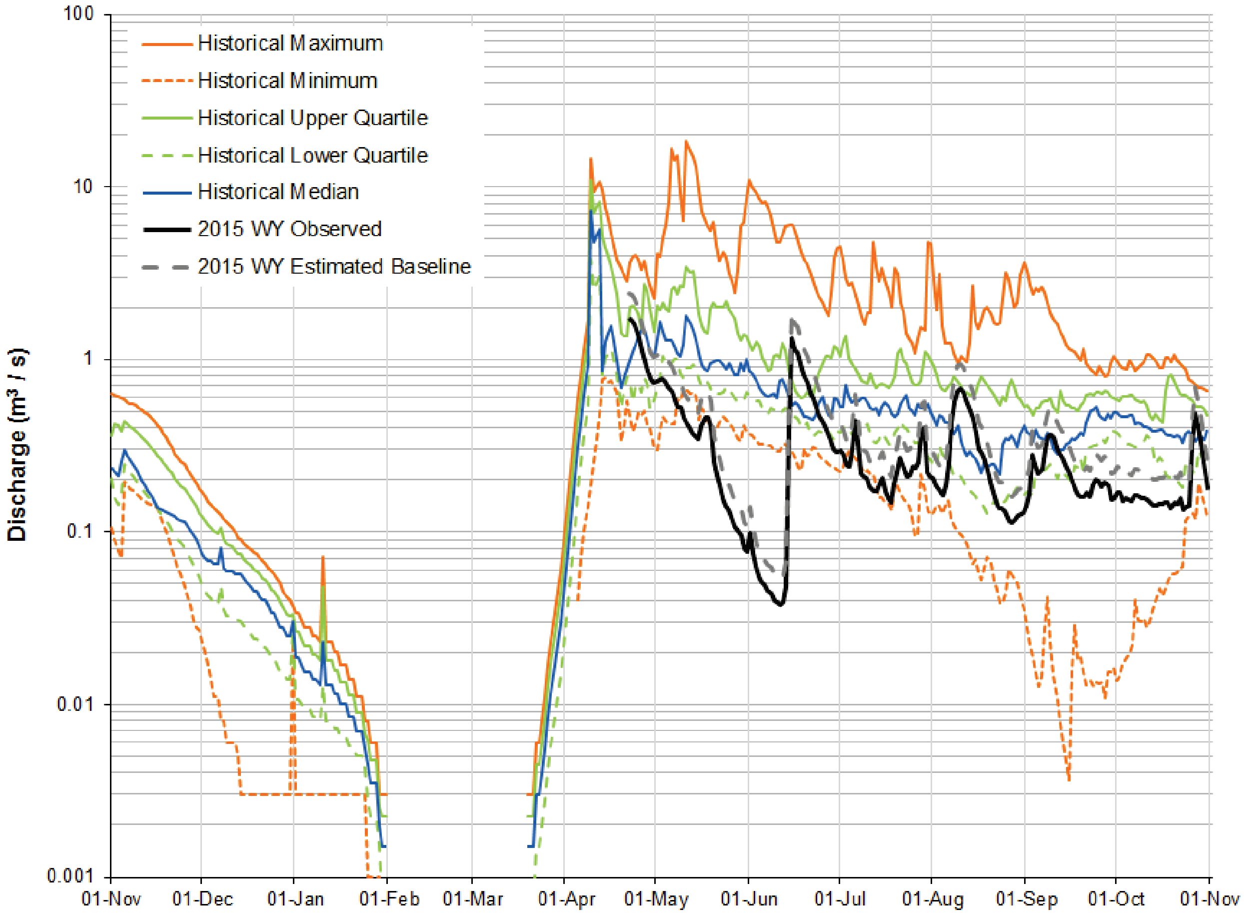
Comparison to Published Literature Habitat conditions documented by Golder (2004) were similar to conditions observed from 2009 to 2015 at *baseline* reach TAR-F2. Golder (2004) documented better fish habitat with a combination of riffles, runs, and pools and a higher proportion of coarser substrate near upper *baseline* reach TAR-F2 in comparison to lower reaches.

Past studies indicate a total of 11 fish species occur in the Tar River (Golder 2004). The results of the fish community sampling in fall 2015, when combined with historical fish monitoring conducted by RAMP/JOSMP in the Tar River watershed, brings the total number of fish species that have been observed between 2009 and 2015 to nine. This includes seven additional species that were not previously documented including finescale dace, lake whitefish, longnose dace, northern redbelly dace, and northern pike at lower *test* reach TAR-F1 (monitored from 2009 to 2014), and brassy minnow and fathead minnow at upper *baseline* reach TAR-F2 (Table 5.4-15).

2015 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints for *baseline* reach TAR-F2 were within the inner tolerance limits of the normal range of variability for *baseline* conditions (Figure 5.4-13).

Classification of Results Only one reach (*baseline*) of the Tar River was monitored in fall 2015 and no classification of results could be therefore be assessed under the Environment Canada effects criteria guideline, which specify the requirement for a *test* and a *baseline* station (Environment Canada 2010).

Figure 5.4-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Tar River in the 2015 WY, compared to historical values.



Note: The observed 2015 WY hydrograph is based on data for the 2015 WY for Tar River near the mouth (JOSMP Station S15A) daily mean open-water data. The upstream drainage area is 332 km^2. Historical values were calculated for the open-water period at WSC Station 07DA015 (1975 to 1977), JOSMP Station S15 (2001 to 2006), and JOSMP Station S15A (2007 to 2014).

Table 5.4-2 Estimated water balance at Tar River near the mouth (JOSMP Station S15A), 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**5.413**	**Observed discharge, obtained from Tar River near the mouth, Station S15A**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-2.282	Estimated 99.3 km^2 of the Tar River watershed is closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.065	Estimated 14.0 km^2 of the Tar River watershed with land change as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Tar River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Tar River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**7.630**	**Estimated *baseline* discharge at Tar River near the mouth, JOSMP Station S15A**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	-2.217	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	-29.061	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph

Notes:

Definitions and assumptions discussed in Section 3.2.1.

Observed volume of water discharged was calculated using data from the 2015 WY for May 1 to October 31, 2015 for Tar River near the mouth, JOSMP Station S15A.

All non-zero values in this table presented to three decimal places.

Table 5.4-3 Calculated change in hydrologic measurement endpoints for the Tar River watershed, 2015 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.398	0.282	-29.061
Mean winter discharge	not measured	not measured	not measured
Open-water maximum daily discharge	2.427	1.722	-29.061
Open-water season minimum daily discharge	0.054	0.038	-29.061

Notes:

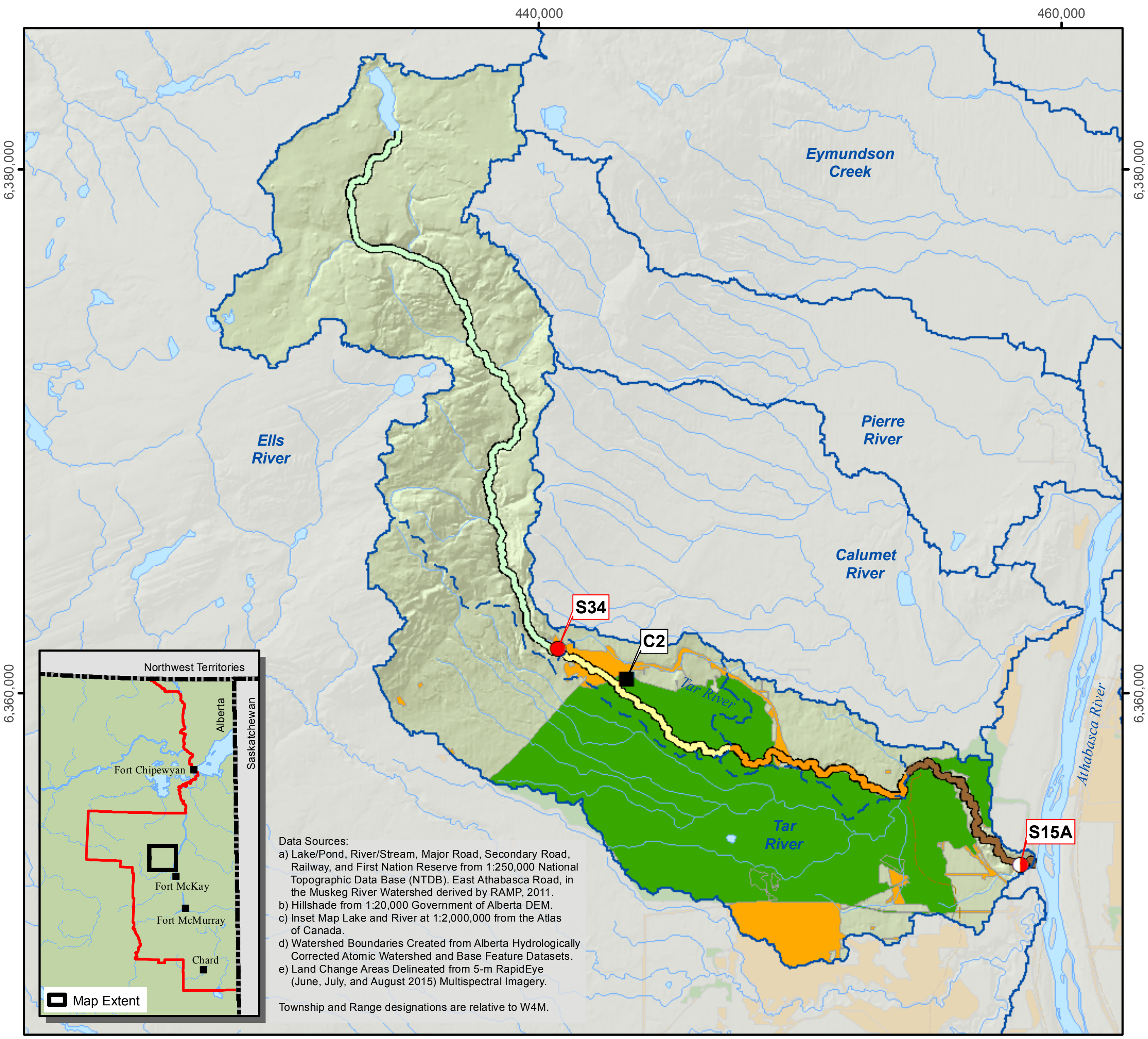
Definitions and assumptions discussed in Section 3.2.1.

Discharge statistics were calculated using data from the 2015 WY for May 1 to October 31, 2015 for Tar River near the mouth, JOSMP Station S15A.

The relative change for each measurement endpoint was calculated using observed and baseline flow values, which were estimated to several decimal places. Flow values are presented to three decimal places for the sake of clarity.

The open-water season refers to the period from May 1 and October 31 and the winter season refers to the period from November 1 and March 31.

Figure 5.4-4 Hydrologic change classification of the Tar River, 2015 WY.



Legend

Lake/Pond
River/Stream
Watershed Boundary
Sub-Watershed Boundary
Secondary Road
Regional Municipality of Wood Buffalo Boundary

Land Change Area as of 2015[e]

Not Hydrologically Closed-Circuited
Hydrologically Closed-Circuited

Hydrometric Monitoring Station

Seasonal, managed by Hatfield
Year-Round, managed by Hatfield

Climate Monitoring Station

Year-Round

Hydrologic Change Classification

Baseline
Negligible-Low
Moderate
High

0 1 2 4 6 km
N
Scale: 1:240,000
Projection: NAD 1983 UTM Zone 12N

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Table 5.4-4 Monthly concentrations of water quality measurement endpoints, mouth of Tar River (*test* station TAR-1), May to September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.05	7.86	Jun	8.13	Jul
Total suspended solids	mg/L	-	5	12.0	3.3	Jul	35.0	May
Conductivity	µS/cm	-	5	350	280	Aug	410	May
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.023	0.008	May	0.034	Sept
Total nitrogen	mg/L	-	5	0.61	0.53	Jun, Jul	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.003	May	<0.005	-
Dissolved organic carbon	mg/L	-	5	16.0	15.0	Jul, Sep	16.0	May, Jun, Aug
Ions								
Sodium	mg/L	-	5	16.0	13.0	Jun, Aug	23.0	May
Calcium	mg/L	-	5	41.0	32.0	Jun	49.0	May
Magnesium	mg/L	-	5	13.0	9.5	Jun	15.0	May
Potassium	mg/L	-	5	2.0	1.90	Jun	2.40	May
Chloride	mg/L	120-640	5	4.1	1.70	Aug	8.0	May
Sulphate	mg/L	309[b]	5	40.0	37.00	Aug	64.0	May
Total dissolved solids	mg/L	-	5	230	200	June, Aug	270	May
Total alkalinity	mg/L	20 (min)	5	140	100	Jun	140	May, Jul, Sep
Selected metals								
Total aluminum	mg/L	-	5	0.457	0.1570	Jul	2.730	May
Dissolved aluminum	mg/L	0.05	5	0.0130	0.0091	Jul	0.0172	Aug
Total arsenic	mg/L	0.005	5	0.0016	0.00098	Jun	0.00185	Aug
Total boron	mg/L	1.5-29	5	0.069	0.055	Jun	0.077	May
Total molybdenum	mg/L	0.073	5	0.00105	0.00085	May	0.00109	Jul, Aug
Total mercury (ultra-trace)	ng/L	5-13	5	1.95	1.50	July	3.37	May
Total methyl mercury	ng/L	1-2	5	0.099	0.072	May	0.156	Aug
Total strontium	mg/L	-	5	0.176	0.149	Aug	0.188	May
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	5	0.79	0.32	Sept	1.47	May
Oilsands extractable acids	mg/L	-	5	2.10	1.00	Jun	3.80	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	49.70	Jul
Retene	ng/L	-	5	1.46	1.17	Jul	11.60	Sept
Total dibenzothiophenes[c]	ng/L	-	5	87.88	60.81	Jun	430.35	May
Total PAHs[c]	ng/L	-	5	372.68	276.35	Jun	1,184.7	May
Total Parent PAHs[c]	ng/L	-	5	39.97	29.21	Jun	66.29	Jul
Total Alkylated PAHs[c]	ng/L	-	5	327.4	247.14	Jun	1,144.7	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0069**	0.0046	May	**0.0092**	Sept
Sulphide	mg/L	0.0019	5	**0.0062**	0.0039	Sept	**0.0120**	May
Dissolved iron	mg/L	0.3	5	**0.636**	0.373	Jul	**0.79**	Sept

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.4-5 Monthly concentrations of water quality measurement endpoints, Tar River above Horizon Mine (*baseline* station TAR-2A [TAR-2]), July to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	8.20	8.00	Sept	8.29	Aug
Total suspended solids	mg/L	-	4	3.0	<1.0	Oct	73.0	Jul
Conductivity	µS/cm	-	4	350	340	Aug	380	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.023	0.016	Oct	0.041	Aug
Total nitrogen	mg/L	-	4	0.38	0.280	Oct	0.590	Jul
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.005	-	<0.005	-
Dissolved organic carbon	mg/L	-	4	11.5	9.4	Oct	13.0	Aug
Ions								
Sodium	mg/L	-	4	12.0	10.0	Jul	15.0	Oct
Calcium	mg/L	-	4	45.5	40.0	Oct	48.0	Jul
Magnesium	mg/L	-	4	13.5	13.0	Aug, Oct	14.0	Jul, Sep
Potassium	mg/L	-	4	1.4	1.20	Sep, Oct	1.70	Jul
Chloride	mg/L	120-640	4	1.1	<1.0	Jul, Oct	1.2	Aug, Sep
Sulphate	mg/L	309[b]	4	36.5	36.00	Jul, Aug	39.0	Oct
Total dissolved solids	mg/L	-	4	235	220	Oct	260	Jul
Total alkalinity	mg/L	20 (min)	4	150	150	Jul-Sep	160	Oct
Selected metals								
Total aluminum	mg/L	-	4	0.116	0.0708	Oct	1.510	Jul
Dissolved aluminum	mg/L	0.05	4	0.0289	0.0111	Oct	0.0405	Jul
Total arsenic	mg/L	0.005	4	0.0012	0.00089	Oct	0.00185	Jul
Total boron	mg/L	1.5-29	4	0.068	0.056	Sept	0.090	Oct
Total molybdenum	mg/L	0.073	4	0.00156	0.00140	Oct	0.00168	Jul
Total mercury (ultra-trace)	ng/L	5-13	4	1.05	0.63	Sept	4.70	Jul
Total methyl mercury	ng/L	1-2	4	0.080	0.035	Oct	0.142	Jul
Total strontium	mg/L	-	4	0.169	0.166	Aug, Sep	0.202	Oct
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	4	0.33	<0.08	Oct	0.44	Jul
Oilsands extractable acids	mg/L	-	4	0.95	0.10	Oct	2.20	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	<0.59	<0.59	-	2.96	Jul
Total dibenzothiophenes[c]	ng/L	-	4	8.17	8.17	-	8.20	Jul
Total PAHs[c]	ng/L	-	4	126.37	125.10	Aug	134.64	Jul
Total Parent PAHs[c]	ng/L	-	4	22.74	22.49	Aug	23.10	Jul
Total Alkylated PAHs[c]	ng/L	-	4	103.6	102.61	Aug	111.54	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0088**	**0.0046**	Oct	**0.0110**	Jul
Sulphide	mg/L	0.0019	1	<0.0019	<0.0019	-	**0.0029**	Oct
Dissolved iron	mg/L	0.3	2	0.2360	0.0639	Oct	**0.3870**	Aug

Values in **bold** are above guideline.

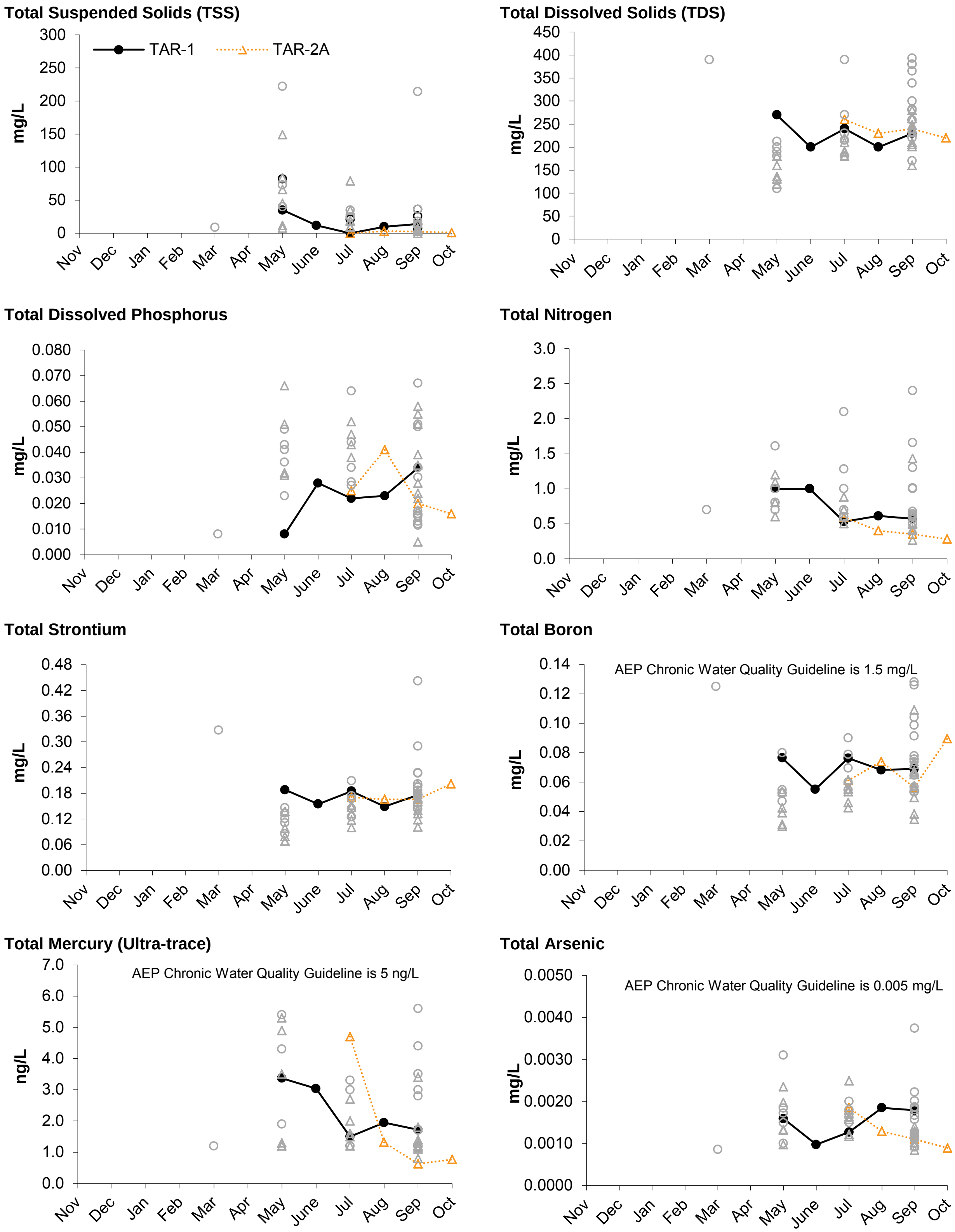
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

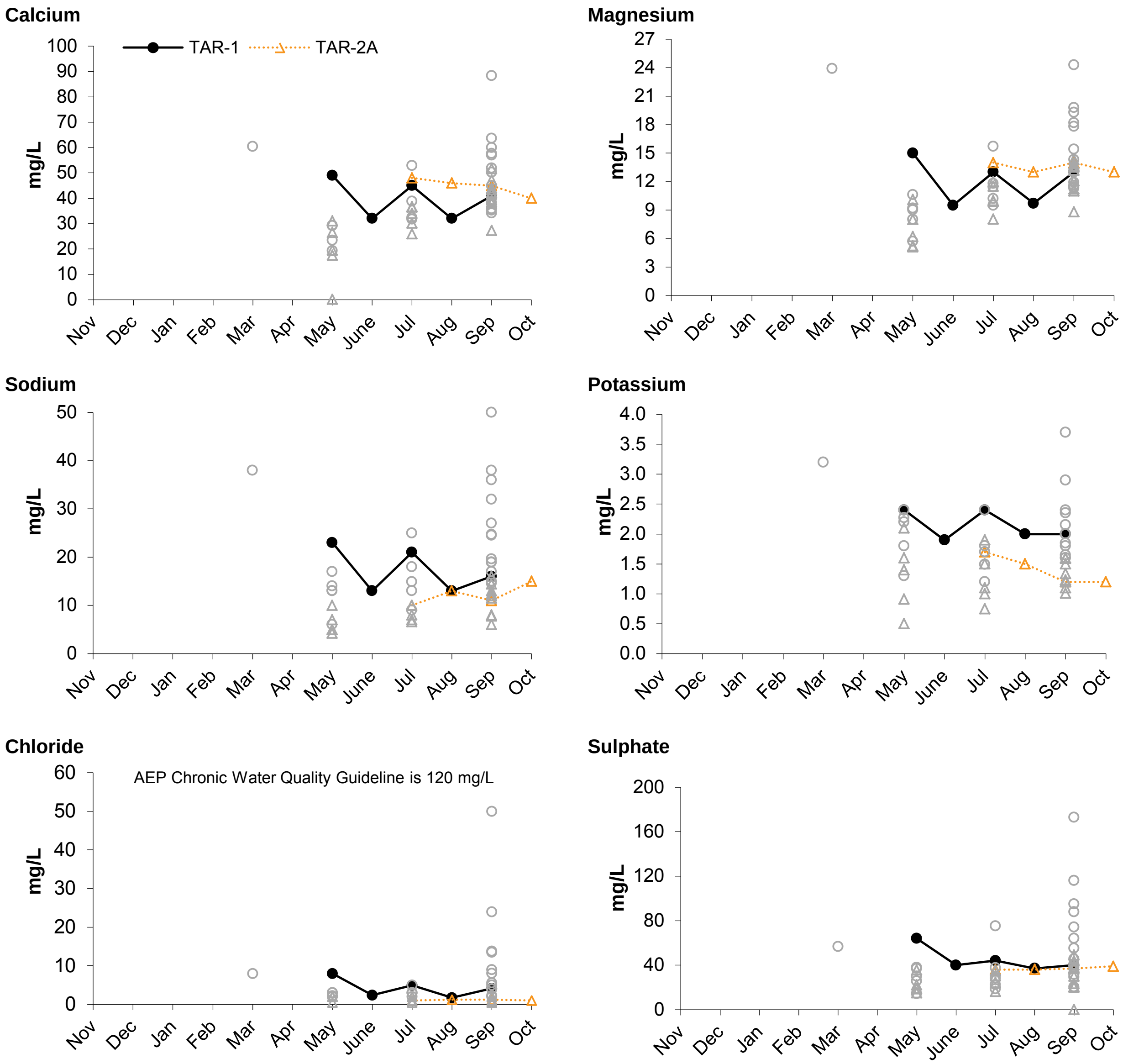
[d] n value refers to number of exceedances in 2015.

Figure 5.4-5 Selected water quality measurement endpoints in the Tar River (monthly data) in the 2015 WY.



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.4-5 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.4-6 Concentrations of water quality measurement endpoints, mouth of Tar River (*test* station TAR-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1998-2014 (Fall Data Only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	<u>8.05</u>	14	8.20	8.09	8.50
Total suspended solids	mg/L	-	14.00	14	16.5	6.0	372
Conductivity	µS/cm	-	350.00	14	432	302	875
Nutrients							
Total dissolved phosphorus	mg/L	-	0.03	14	0.017	0.012	0.125
Total nitrogen	mg/L	-	0.57	14	0.84	0.50	4.30
Nitrate+nitrite	mg/L	3-124	<0.005	14	<0.10	<0.050	**3.50**
Dissolved organic carbon	mg/L	-	15.00	14	17.6	12.0	22.6
Ions							
Sodium	mg/L	-	16.00	14	24.6	14.6	50.0
Calcium	mg/L	-	41.00	14	49.1	38.0	88.5
Magnesium	mg/L	-	13.00	14	14.9	11.3	24.3
Potassium	mg/L	-	2.00	14	2.1	1.6	6.6
Chloride	mg/L	120-640	4.10	14	5.28	1.70	50.0
Sulphate	mg/L	309[b]	40.00	14	50.4	20.4	173
Total dissolved solids	mg/L	-	230.00	14	315	170	590
Total alkalinity	mg/L	20 (min)	140.00	14	148	121	221
Selected metals							
Total aluminum	mg/L	-	0.457	14	0.775	0.167	16.6
Dissolved aluminum	mg/L	0.05	0.013	14	0.015	0.005	**0.057**
Total arsenic	mg/L	0.005	0.002	14	0.0017	0.0009	0.0037
Total boron	mg/L	1.5-29	0.069	14	0.077	0.053	0.145
Total molybdenum	mg/L	0.073	0.0011	14	0.00096	0.00037	0.00200
Total mercury (ultra-trace)	ng/L	5-13	1.72	12	2.25	<1.20	**27.00**
Total methyl mercury	ng/L	1-2	0.103	-	-	-	-
Total strontium	mg/L	-	0.176	14	0.191	0.143	0.442
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	0.4
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.32	4	0.50	0.06	0.78
Oilsands extractable acids	mg/L	-	<u>2.10</u>	4	1.41	0.47	2.00
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<u>31.60</u>	4	<11.44	<7.21	<15.16
Retene	ng/L	-	11.60	4	3.065	2.210	18.50
Total dibenzothiophenes[c]	ng/L	-	<u>66.88</u>	4	101.73	68.28	419.3
Total PAHs[c]	ng/L	-	<u>362.65</u>	4	520.0	363.9	1,664
Total Parent PAHs[c]	ng/L	-	50.64	4	40.28	23.04	100.4
Total Alkylated PAHs[c]	ng/L	-	<u>312.02</u>	4	479.7	340.9	1,564
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.79**	14	**0.348**	0.004	**0.947**
Sulphide	mg/L	0.0019	**0.0039**	14	**0.007**	**<0.002**	**0.023**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.4-7 Concentrations of water quality measurement endpoints, Tar River above Horizon Mine (*baseline* station TAR-2A [TAR-2]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2004-2014 (Fall Data Only)[b]			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.00	10	8.26	8.00	8.40
Total suspended solids	mg/L	-	2.70	10	5.00	<3.00	8.00
Conductivity	µS/cm	-	350	10	337	233	393
Nutrients							
Total dissolved phosphorus	mg/L	-	0.02	10	0.032	0.005	0.058
Total nitrogen	mg/L	-	0.35	10	0.50	0.26	1.43
Nitrate+nitrite	mg/L	3-124	<0.005	10	<0.086	<0.054	<0.100
Dissolved organic carbon	mg/L	-	11.00	10	13.0	8.0	15.8
Ions							
Sodium	mg/L	-	11.00	10	12.0	6.0	16.0
Calcium	mg/L	-	45.00	10	44.8	31.4	53.0
Magnesium	mg/L	-	14.00	10	13.2	8.8	14.3
Potassium	mg/L	-	1.20	10	1.23	1.01	1.60
Chloride	mg/L	120-640	1.20	10	0.75	<0.50	2.00
Sulphate	mg/L	309[b]	37.0	10	37.4	20.0	49
Total dissolved solids	mg/L	-	240.0	10	233.5	160	280
Total alkalinity	mg/L	20 (min)	150.0	10	157.5	100	162
Selected metals							
Total aluminum	mg/L	-	0.140	11	0.158	0.073	0.7
Dissolved aluminum	mg/L	0.05	0.036	11	0.025	0.008	**0.052**
Total arsenic	mg/L	0.005	0.001	11	0.0012	0.0008	0.0014
Total boron	mg/L	1.5-29	0.056	11	0.065	0.035	0.109
Total molybdenum	mg/L	0.073	0.0015	11	0.00138	0.00083	0.00164
Total mercury (ultra-trace)	ng/L	5-13	<u>0.63</u>	11	<1.20	0.80	3.40
Total methyl mercury	ng/L	1-2	0.072	-	-	-	-
Total strontium	mg/L	-	0.166	11	0.167	0.101	0.199
Total hydrocarbons							
BTEX	mg/L	-	<0.01	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	3	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	3	<0.25	<0.25	0.4
Fraction 4 (C34-C50)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.36</u>	4	0.10	<0.02	0.26
Oilsands extractable acids	mg/L	-	1.10	4	0.75	0.34	1.20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	0.59	4	<0.64	<0.41	<2.07
Total dibenzothiophenes[c]	ng/L	-	8.17	4	6.36	4.13	35.3
Total PAHs[c]	ng/L	-	109.80	4	133.6	74.1	203
Total Parent PAHs[c]	ng/L	-	22.42	4	17.87	13.26	25.8
Total Alkylated PAHs[c]	ng/L	-	87.38	4	111.1	60.8	187
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.35**	9	**0.45**	0.11	**0.82**
Total phenols	mg/L	0.004	**0.0075**	9	0.0040	0.0020	**0.0210**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.4-6 Piper diagram of fall ion concentrations in the Tar River watershed.

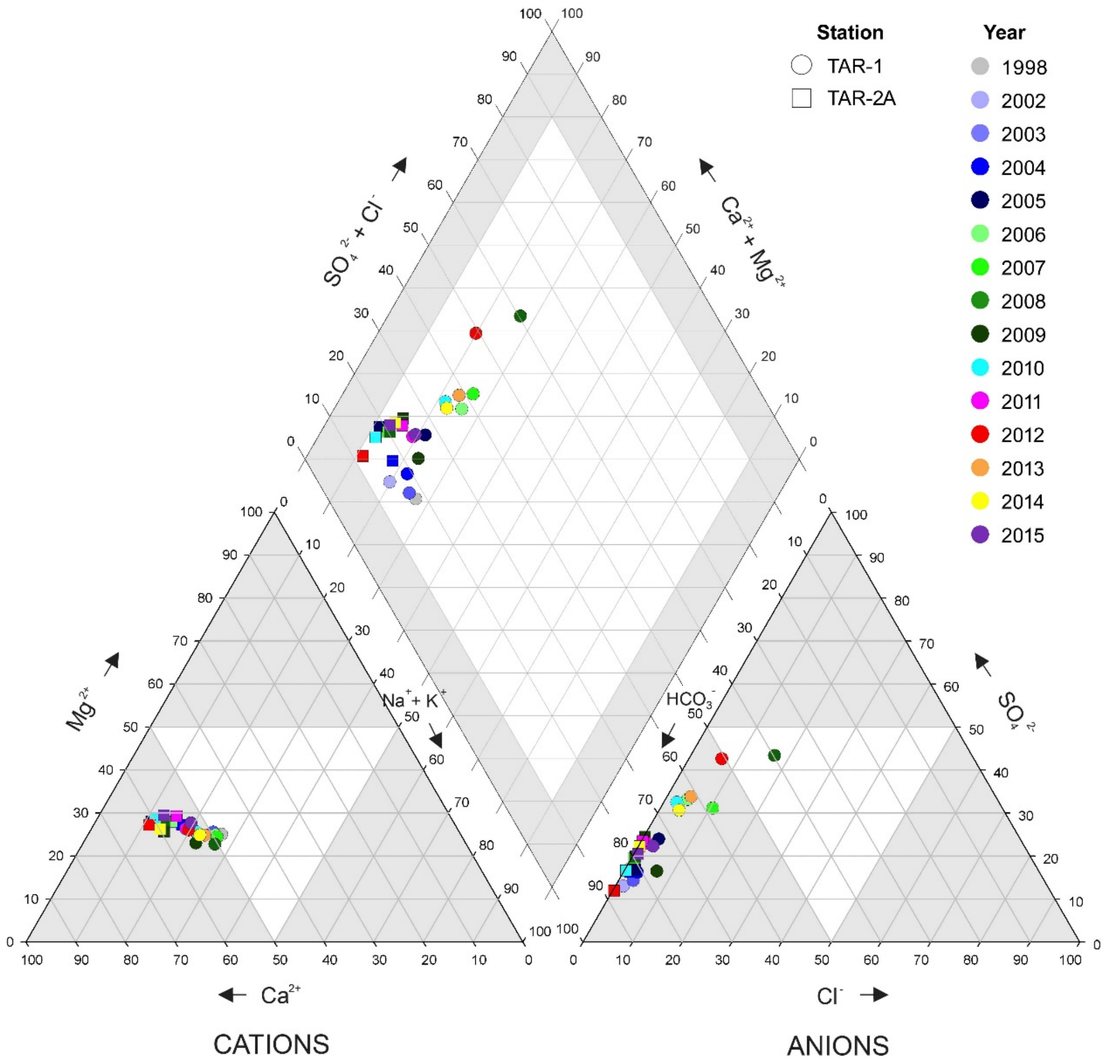


Table 5.4-8 Water quality guideline exceedances in the Tar River watershed, 2015 WY.

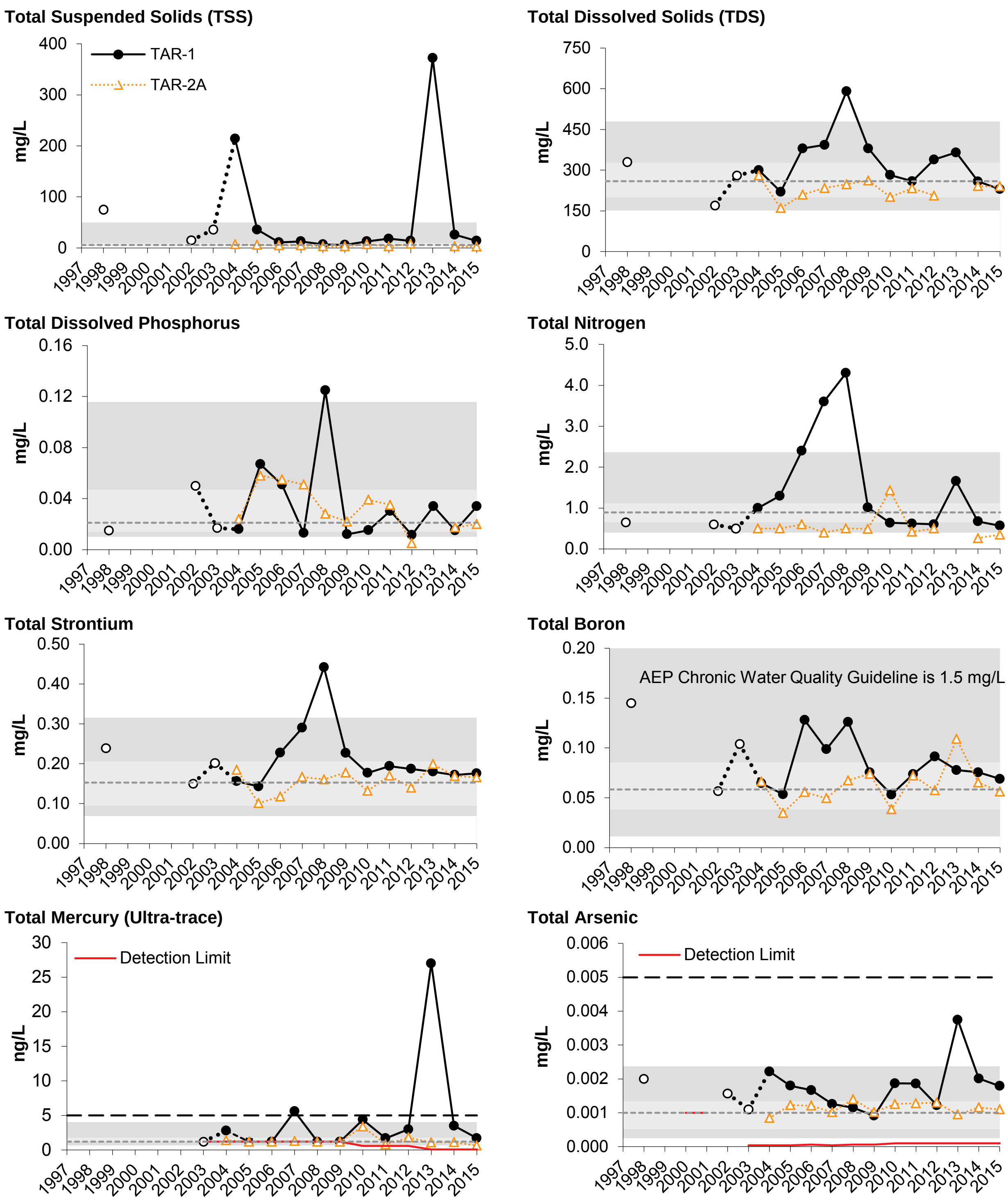
Variable	Units	Guideline[a]	May	June	July	August	September
Tar River mouth (TAR-1)							
Total phenols	mg/L	0.004	**0.0046**	**0.0076**	**0.0069**	**0.0055**	**0.0092**
Sulphide	mg/L	0.0019	**0.012**	**0.0065**	**0.0054**	**0.0062**	**0.0039**
Dissolved iron	mg/L	0.3	**0.636**	**0.708**	**0.373**	**0.584**	**0.79**
Tar River upstream (TAR-2A)							
Total phenols	mg/L	0.004	-	**0.011**	**0.01**	**0.0075**	**0.0046**
Sulphide	mg/L	0.0019	-	<0.0019	<0.0019	<0.0019	**0.0029**
Dissolved iron	mg/L	0.3	-	0.127	**0.387**	**0.345**	0.0639

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.4-7 Concentrations of selected water quality measurement endpoints in the Tar River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



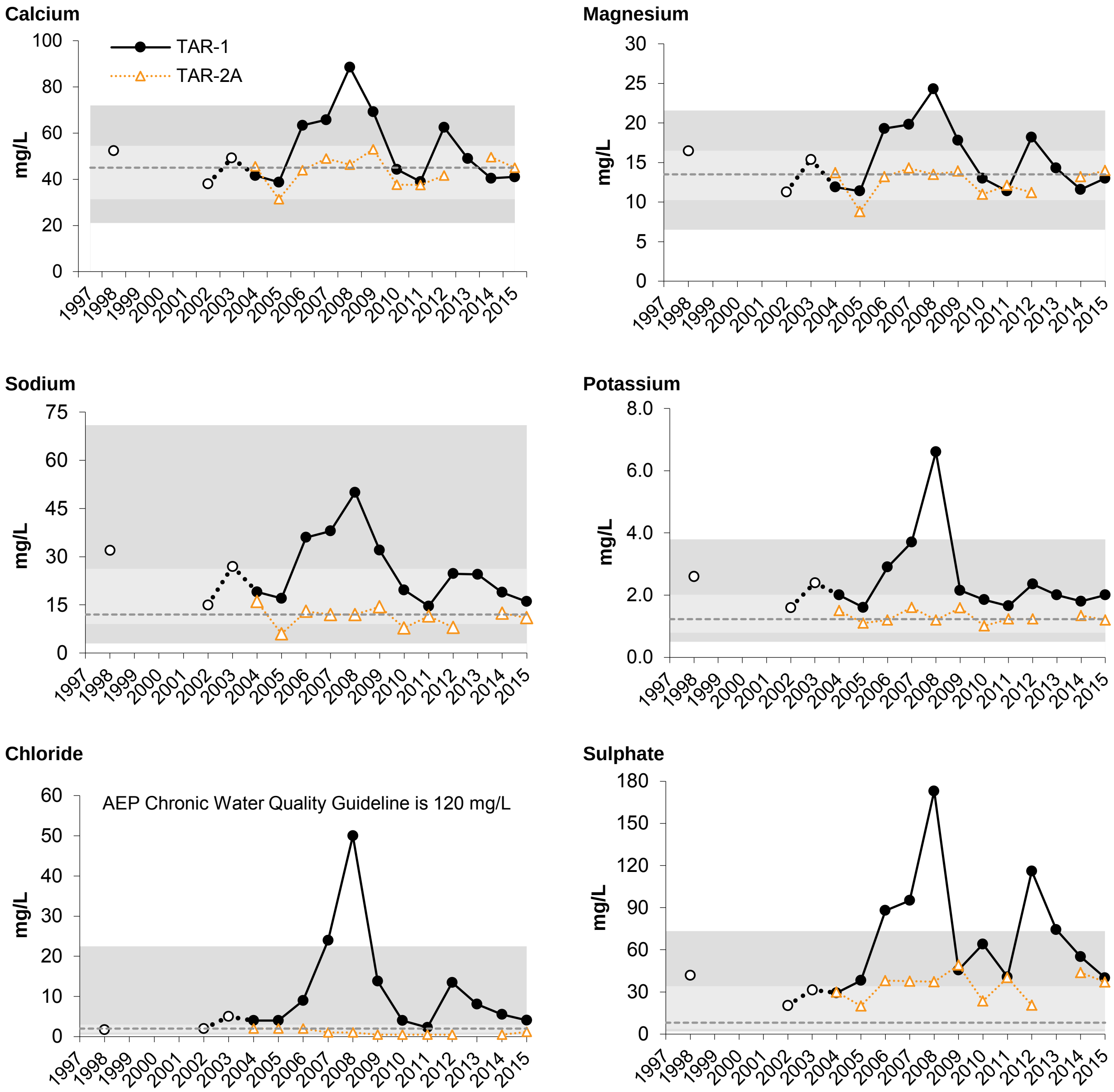
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.4-7 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.4-9 Average habitat characteristics of benthic invertebrate community sampling locations in the Tar River (*test* reach TAR-D1 and *baseline* reach TAR-E2), fall 2015.

Variable	Units	TAR-D1 Lower *Test* Reach	TAR-E2 Upper *Baseline* Reach
Sample date	-	Sept. 16, 2015	Sept.10, 2015
Habitat	-	Depositional	Erosional
Water depth	m	0.15	0.3
Current velocity	m/s	0.4	0.2
Field water quality			
Dissolved oxygen (DO)	mg/L	10.8	9.6
Conductivity	µS/cm	326	310
pH	pH units	8.0	8.2
Water temperature	°C	9.0	11.9
Sediment composition			
Sand	%	94.5	-
Silt	%	2.7	-
Clay	%	2.8	-
Total organic carbon (TOC)	%	0.30	-

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.4-10 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in the lower Tar River (*test* reach TAR-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach TAR-D1		
	2002	2003 to 2013	2015
Nematoda	2	0 to 4	-
Naididae	<1	0 to 4	<1
Tubificidae	7	1 to 69	2
Enchytraeidae	-	0 to 5	-
Erpobdellidae	<1	0 to <1	-
Hirudinea	-	-	-
Hydracarina	<1	0 to 2	<1
Amphipoda	<1	-	-
Gastropoda	<1	0 to 2	-
Bivalvia	1	0 to 2	-
Ceratopogonidae	1	0 to 16	<1
Chironomidae	86	<1 to 90	98
Diptera (misc.)	1	0 to 37	<1
Coleoptera	<1	0 to <1	-
Ephemeroptera	<1	0 to 1	-
Lepidoptera	-	-	<1
Odonata	<1	0 to <1	-
Plecoptera	<1	0 to <1	-
Trichoptera	<1	0 to <1	-
Collembola	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	1562	9 to 559	127
Richness	22	3 to 18	4.7
Equitability	0.27	0.27 to 0.73	0.34
% EPT	<1	0 to 2	0

Table 5.4-11 Summary of major taxa abundances and measurement endpoints for the benthic invertebrate community in the upper Tar River (*baseline* reach TAR-E2).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach TAR-E2		
	2009	2010 to 2013	2015
Nematoda	<1	<1 to 2	-
Oligochaeta	-	<1	-
Naididae	<1	<1 to 2	<1
Tubificidae	<1	1 to 2	1
Amphipoda	-	-	<1
Enchytraeidae	6	1 to 4	-
Lumbriculidae	-	0 to <1	-
Erpobdellidae	-	-	-
Hydracarina	4	8 to 15	8
Ceratopogonidae	-	0 to <1	-
Chironomidae	28	18 to 50	13
Diptera (misc.)	27	0 to 14	4
Coleoptera	-	<1	-
Ephemeroptera	1	18 to 40	24
Plecoptera	15	3 to 21	24
Trichoptera	16	8 to 17	27
Lepidoptera	-	<1	-
Odonata	-	-	<1
Bivalvia	-	-	<1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	187	368 to 921	274
Richness	25	23 to 32	30
Equitability	0.33	0.29 to 0.37	0.41
% EPT	56	5 to 52	31

Note: All 2015 benthic invertebrate community measurement endpoints, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). All percent abundances of taxa are based on original counts. % EPT as an index in 2015 does not equal the observed percentages in the kick sample, because the index value was adjusted down to be equivalent to what would have been expected with a Neil-Hess cylinder.

Table 5.4-12 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach TAR-D1.

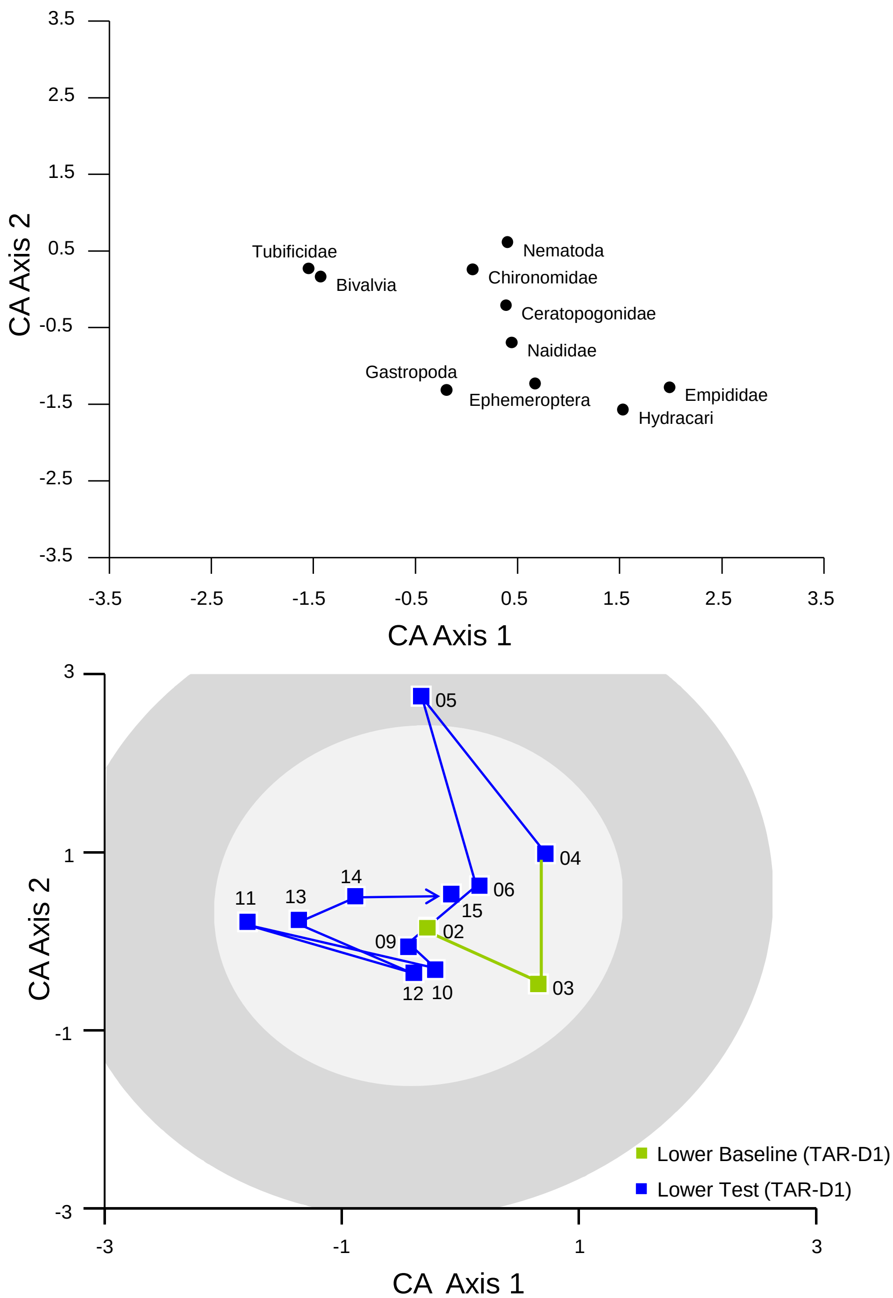
Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Before vs. After	Time Trend in *Test* Period	2015 vs. *Baseline*	2105 vs. Previous Years	Before vs. After	Time Trend in *Test* Period	2015 vs. *Baseline*	2105 vs. Previous Years	
Log of Abundance	**<0.001**	0.093	**<0.001**	0.419	38	2	9	0	Abundance was lower during the *test* period in the reach.
Log of Richness	**<0.001**	0.145	**<0.001**	0.066	40	1	23	2	Richness was lower during the *test* period in the reach and was lower in 2015 than the mean of *baseline* years.
Equitability	0.052	**0.020**	0.758	0.085	8	11	0	6	Equitability was higher in the *test* reach.
Log of EPT	0.661	0.053	0.283	0.108	1	14	4	9	No change.
CA Axis 1	**0.003**	**0.001**	0.480	0.226	14	19	1	2	CA 1 axis scores were higher in the *test* reach and increased over time in *test* reach.
CA Axis 2	**0.023**	**0.006**	0.181	0.966	13	19	4	0	CA 2 axis scores were higher in the *test* reach and increased over time in *test* reach.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.4-8 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of the Tar River (*test* reach TAR-D1).

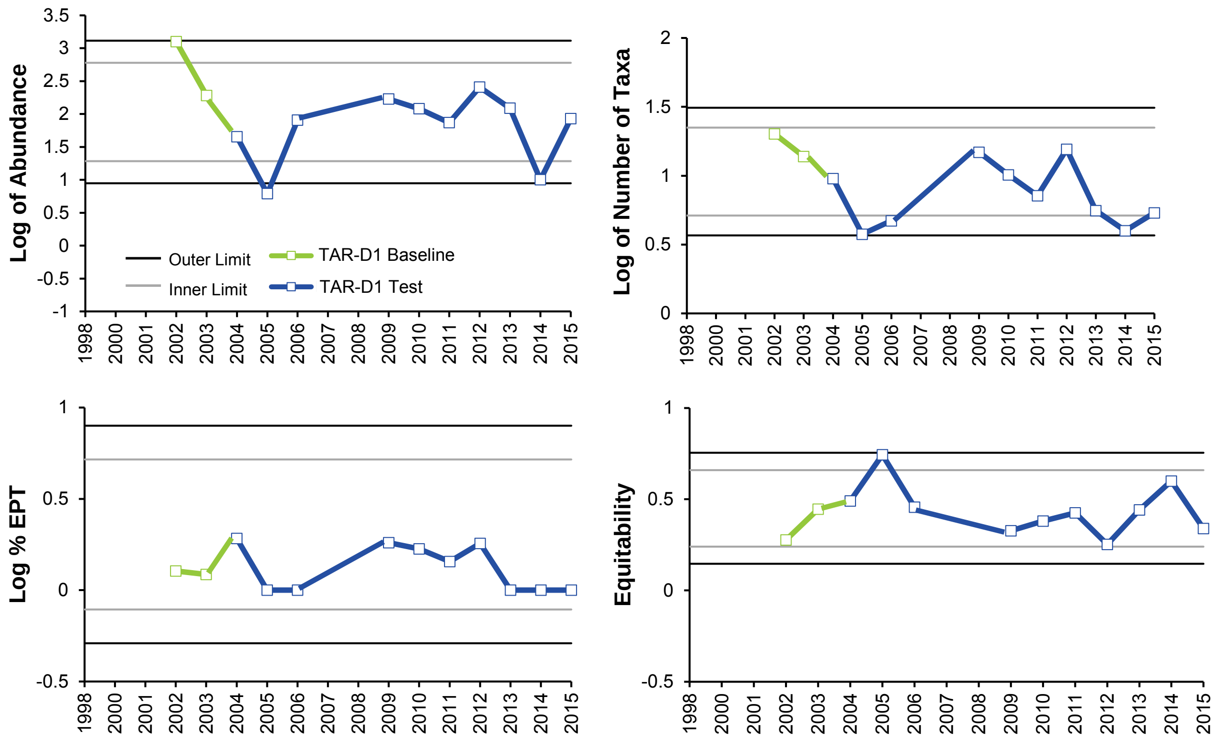


Notes:

The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for baseline depositional reaches (1998 to 2014).

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances at depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.4-9 Variation in benthic invertebrate community measurement endpoints at lower *test* reach TAR-D1 of the Tar River relative to historical ranges of variability.

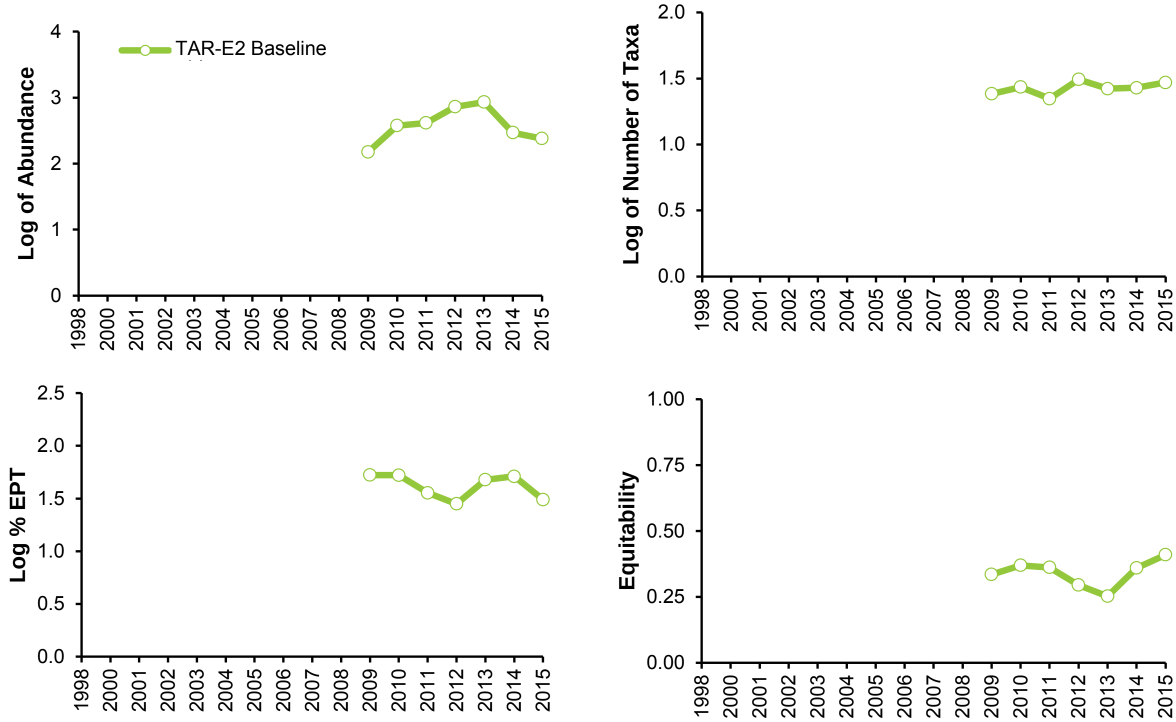


Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from regional baseline depositional reaches (up to 2014).

Abundance, richness and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Figure 5.4-10 Variation in benthic invertebrate community measurement endpoints at upper *baseline* reach TAR-E2 of the Tar River.

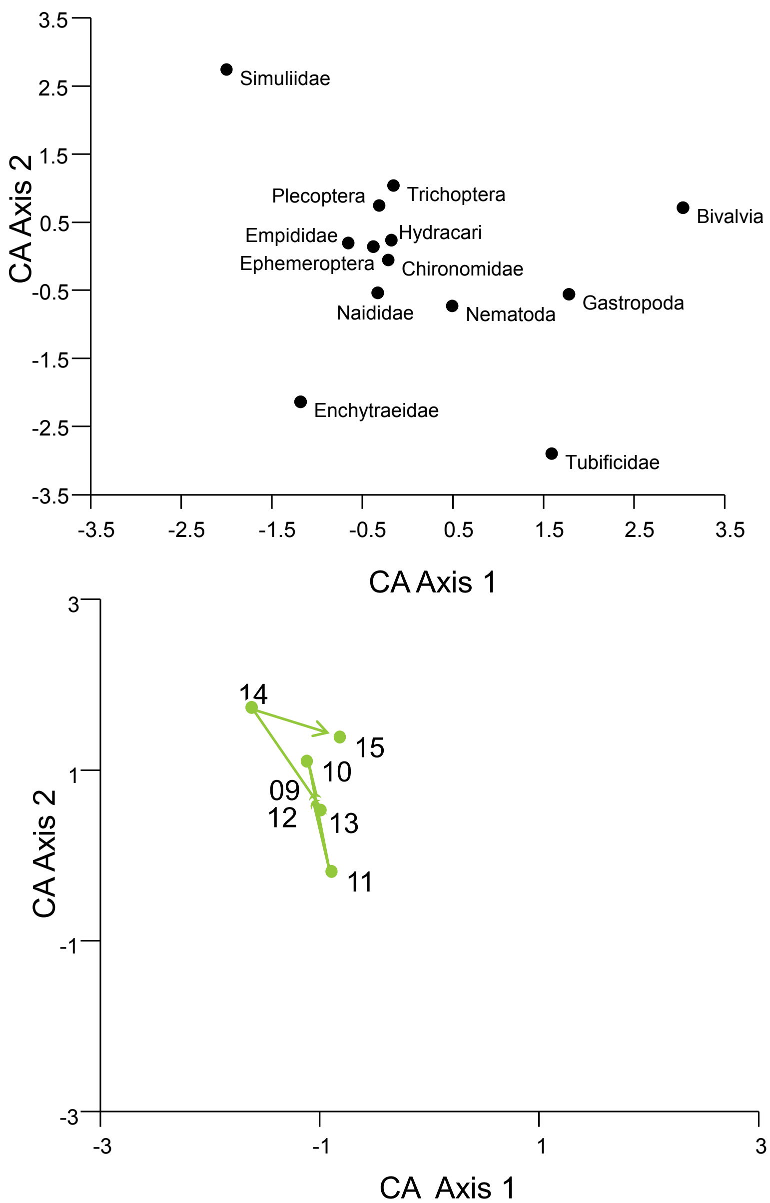


Notes:

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Measurement endpoints for *baseline* reach TAR-E2 in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Figure 5.4-11 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the upper reach of the Tar River (*baseline* reach TAR-E2).



Note: 2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances at erosional reaches from previous years (1998 to 2014; Appendix D).

Table 5.4-13 Concentrations of selected sediment measurement endpoints, Tar River (*test* station TAR-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	1998-2014 (fall data only)ns			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>2.8</u>	12	3.0	13.5	29.2
Silt	%	-	<u>2.1</u>	12	3.0	16.5	67.1
Sand	%	-	<u>95.1</u>	12	11.7	70.0	94.0
Total organic carbon	%	-	0.37	12	0.30	1.29	6.30
Total hydrocarbons							
BTEX	mg/kg	-	<10	9	<5	<10	<30
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	9	<5	<10	<30
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	9	13	29	105
Fraction 3 (C16-C34)	mg/kg	300[1]	<u>91</u>	9	220	**340**	**860**
Fraction 4 (C34-C50)	mg/kg	2800[1]	<u>70</u>	9	119	256	483
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0006</u>	12	0.0007	0.0043	0.0150
Retene	mg/kg	-	<u>0.0046</u>	11	0.0116	0.0687	2.1900
Total dibenzothiophenes	mg/kg	-	0.2357	12	0.1521	0.9433	6.2555
Total PAHs	mg/kg	-	0.7994	12	0.6243	3.3597	19.1394
Total Parent PAHs	mg/kg	-	<u>0.0299</u>	12	0.0473	0.1101	0.4486
Total Alkylated PAHs	mg/kg	-	0.7695	12	0.5220	3.1901	18.6908
Predicted PAH toxicity[3]	H.I.	1.0	**1.2283**	12	0.2063	**2.1189**	**4.4035**
Metals that exceed CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	<u>100</u>	9	10	70	98
Chironomus growth - 10d	mg/organism	-	1.49	9	0.90	2.00	4.00
Hyalella survival - 14d	% surviving	-	100	9	66	88	100
Hyalella growth - 14d	mg/organism	-	0.13	9	0.10	0.21	0.56

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

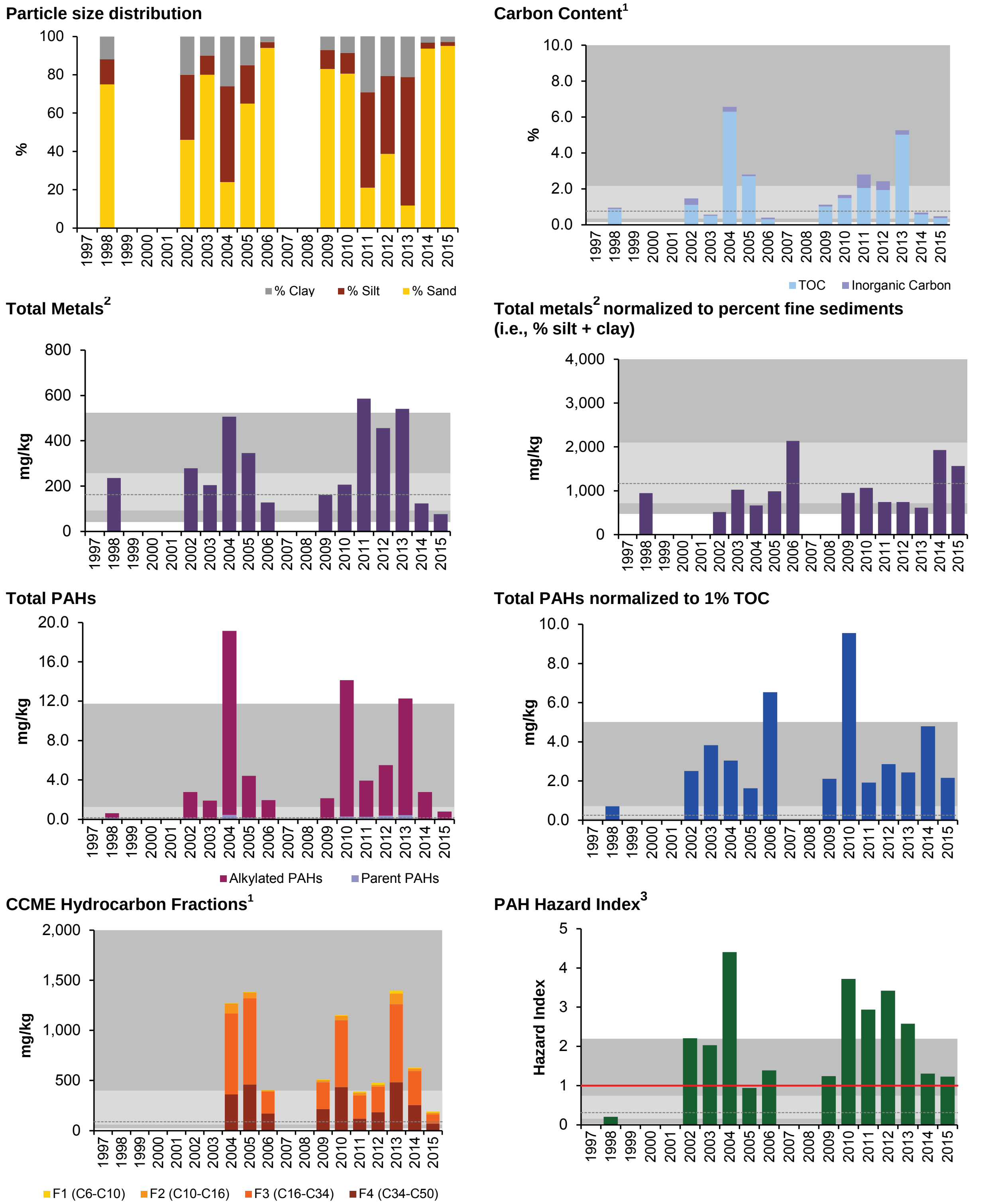
ns = not sampled in 1999, 2000, 2001, 2007, or 2008

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.4-12 Concentrations of selected sediment quality measurement endpoints in the Tar River watershed at *test* station TAR-D1 (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.4-14 Average habitat characteristics of fish community upper *baseline* reach TAR-F2, fall 2015.

Variable	Units	TAR-F2 Upper *Baseline* Reach
Sample date	-	Sept 23, 2015
Habitat type	-	riffle
Maximum depth	m	0.22
Mean depth	m	0.20
Bankfull channel width	m	8.3
Wetted channel width	m	6.8
Substrate		
Dominant	-	cobble
Subdominant	-	fine gravel
Instream cover		
Dominant	-	small woody debris
Subdominant	-	-
Field water quality		
Dissolved oxygen	mg/L	10.8
Conductivity	µS/cm	311
pH	pH units	8.15
Water temperature	^{0}C	4.2
Water velocity		
Left bank velocity	m/s	0.20
Left bank water depth	m	0.18
Centre of channel velocity	m/s	0.15
Centre of channel water depth	m	0.21
Right bank velocity	m/s	0.22
Right bank water depth	m	0.21
Riparian cover – understory (<5 m)		
Dominant	-	overhanging vegetation, woody shrubs and saplings
Subdominant	-	-

Table 5.4-15 Total number and percent composition of fish species captured in reaches of the Tar River, 2009 to 2015.

Common Name	Code	Total Species Catch										Percent of Total Catch									
		TAR-F1					TAR-F2					TAR-F1					TAR-F2				
		2009	2011	2012	2013	2014	2011	2012	2013	2014	2015	2009	2011	2012	2013	2014	2011	2012	2013	2014	2015
arctic grayling	ARGR	-	-	-	-	-	1	2	1	-	-	0	0	0	0	0	0.9	1.6	0.9	0	0
brook stickleback	BRST	2	2	-	-	-	-	-	-	-	-	18.2	3.9	0	0	0	0	0	0	0	0
brassy minnow	BRMN	-	-	-	-	-	-	1	-	-	-	0	0	0	0	0	0	0.8	0	0	0
burbot	BURB	-	-	-	10	3	-	-	-	-	-	0	0	0	13.5	10.7	0	0	0	0	0
fathead minnow	FTMN	-	-	-	-	-	-	-	7	-	-	0	0	0	0	0	0	0	6.3	0	0
finescale dace	FNDC	-	5	1	-	-	-	-	-	-	-	0	9.8	7.1	0	0	0	0	0	0	0
lake chub	LKCH	4	26	-	33	16	5	-	8	-	-	36.4	51.0	0	44.6	57.1	4.7	0	7.1	0	0
lake whitefish	LKWH	-	-	-	-	1	-	-	-	-	-	0	0	0	0	3.6	0	0	0	0	0
longnose dace	LNDC	-	1	-	-	-	-	-	-	-	-	0	2.0	0	0	0	0	0	0	0	0
longnose sucker	LNSC	-	4	3	5	-	-	7	-	-	5	0	7.8	21.4	6.8	0	0	5.7	0	0	5.7
northern pike	NRPK	1	1	-	5	1	-	-	-	-	-	9.1	2.0	0	6.8	3.6	0	0	0	0	0
northern redbelly dace	NRDC	-	-	-	1	-	-	-	-	-	-	0	0	0	1.4	0	0	0	0	0	0
slimy sculpin	SLSC	-	-	2	1	-	101	113	96	85	82	0	0	14.3	1.4	0	94.4	92.6	85.7	100	94.3
trout-perch	TRPR	-	8	1	2	-	-	-	-	-	-	0	15.7	7.1	2.7	0	0	0	0	0	0
walleye	WALL	-	-	-	-	4	-	-	-	-	-	0	0	0	0	14.3	0	0	0	0	0
white sucker	WHSC	4	4	7	17	3	-	-	-	-	-	36.4	7.8	50.0	23.0	10.7	0	0	0	0	0
Total Count		**11**	**51**	**14**	**74**	**28**	**107**	**122**	**112**	**85**	**87**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**4**	**8**	**5**	**8**	**6**	**3**	**4**	**4**	**1**	**2**	**4**	**8**	**5**	**8**	**6**	**3**	**4**	**4**	**1**	**2**
Electrofishing effort (secs)		**1,552**	**743**	**1,905**	**1,786**	**1,529**	**1,043**	**1,526**	**1,347**	**1,270**	**1,022**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

* Not included in total species richness count.

Underline denotes a *baseline* reach.

Table 5.4-16 Summary of fish community measurement endpoints for upper *baseline* reach TAR-F2 of the Tar River, 2011 to 2015.

Reach	Year	Abundance		Richness			Diversity		ATI		CPUE	
		Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TAR-F2	2011	0.71	0.24	3	1.60	0.55	0.10	0.13	3.13	0.22	10.36	3.94
	2012	0.83	0.20	5	2.20	0.84	0.15	0.11	3.16	0.20	7.98	2.05
	2013	0.45	0.08	4	2.80	0.45	0.24	0.11	3.46	0.34	8.33	1.59
	2014	0.28	0.09	1	1.00	0.00	0.00	-	3.00	0.00	6.68	2.17
	2015	0.58	0.16	2	1.4	0.55	0.11	0.15	3.11	0.15	8.70	2.69

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

SD = standard deviation across sub-reaches within a reach.

Table 5.4-17 Results of analysis of variance (ANOVA) testing for differences in fish community measurement endpoints for *baseline* reach TAR-F2 of the Tar River.

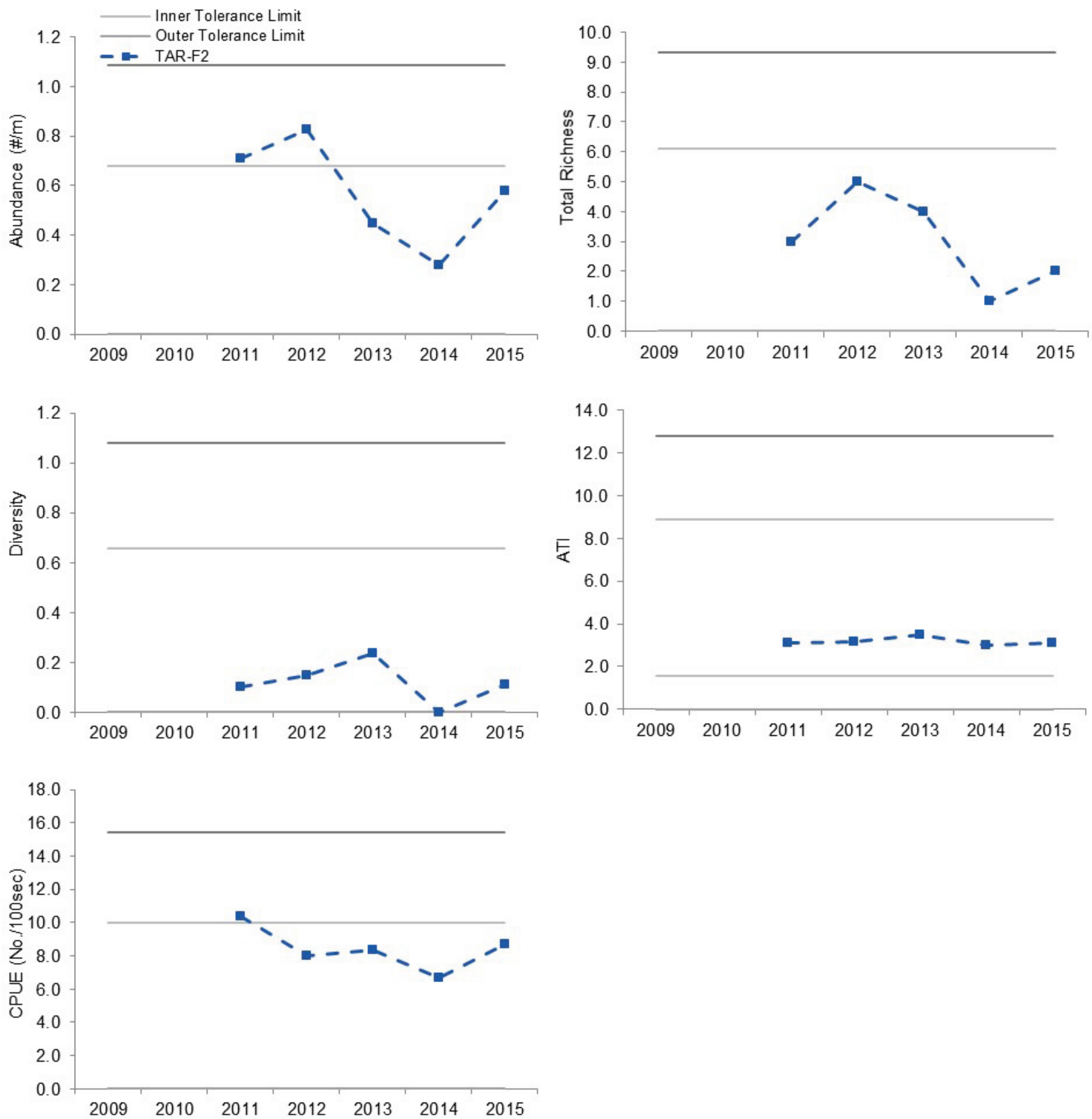
Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
Abundance	**0.02**	19%	Decreasing over time
Richness	0.17	4%	No change
Diversity	0.50	0%	No change
ATI	0.60*	0%	No change
CPUE (No./100 sec)	0.30*	1%	No change

Bold values indicate significant difference (p≤0.05).

* data were log-transformed to meet assumptions of ANOVA

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Figure 5.4-13 Variation in fish community measurement endpoints for upper baseline reach TAR-F2 from 2009 to 2015 relative to regional *baseline* conditions.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using baseline data from cluster 1 (Table 3.2-10).
A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

5.5 MACKAY RIVER WATERSHED

Table 5.5-1 Summary of results for the MacKay River watershed.

MacKay River Watershed	Summary of 2015 Conditions									
	MacKay River					Tributaries to the MacKay River				
Climate and Hydrology										
Criteria	**07DB001**	no station	no station	**S40**	no station	**S53**	no station	no station	no station	**S54**
Mean open-water season discharge	🟡	-	-	not measured	-	not measured	-	-	-	not measured
Mean winter discharge	🟡	-	-	not measured	-	not measured	-	-	-	not measured
Annual maximum daily discharge	🟡	-	-	not measured	-	not measured	-	-	-	not measured
Minimum open-water season discharge	🟡	-	-	not measured	-	not measured	-	-	-	not measured
Water Quality										
Criteria	**MA1**	**MR-L**	**MR-M**	**MA2**	**MR-U**	**DC-L**	**DC-M**	**DC-U**	**DOV RIFF 4**	no station
Water Quality Index	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	-
Benthic Invertebrate Communities and Sediment Quality										
Criteria	no reach	**MR-L**	**MR-M**	no reach	**MR-U**	**DC-L**	**DC-M**	**DC-U**	no reach	no reach
	No Benthic Invertebrate Communities monitoring was conducted in the 2015 WY.									
Sediment Quality Index	-	🟡	🟡	-	🟡	🟡	🟡	🟡	-	-
Fish Populations										
Criteria	**MAR-F1**	**MR-L**	**MR-M**	no reach	**MR-U**	**DC-L**	**DC-M**	**DC-U**	no reach	no reach
Fish Communities	🟡	no reach	no reach	-	no reach	no reach	no reach	no reach	no reach	-
Wild Fish Health	no reach	🟠	🟡	-	n/a	n/a	n/a	n/a	-	-

Legend and Notes

🟡 Negligible - Low

🟠 Moderate

🟤 High

baseline

test

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

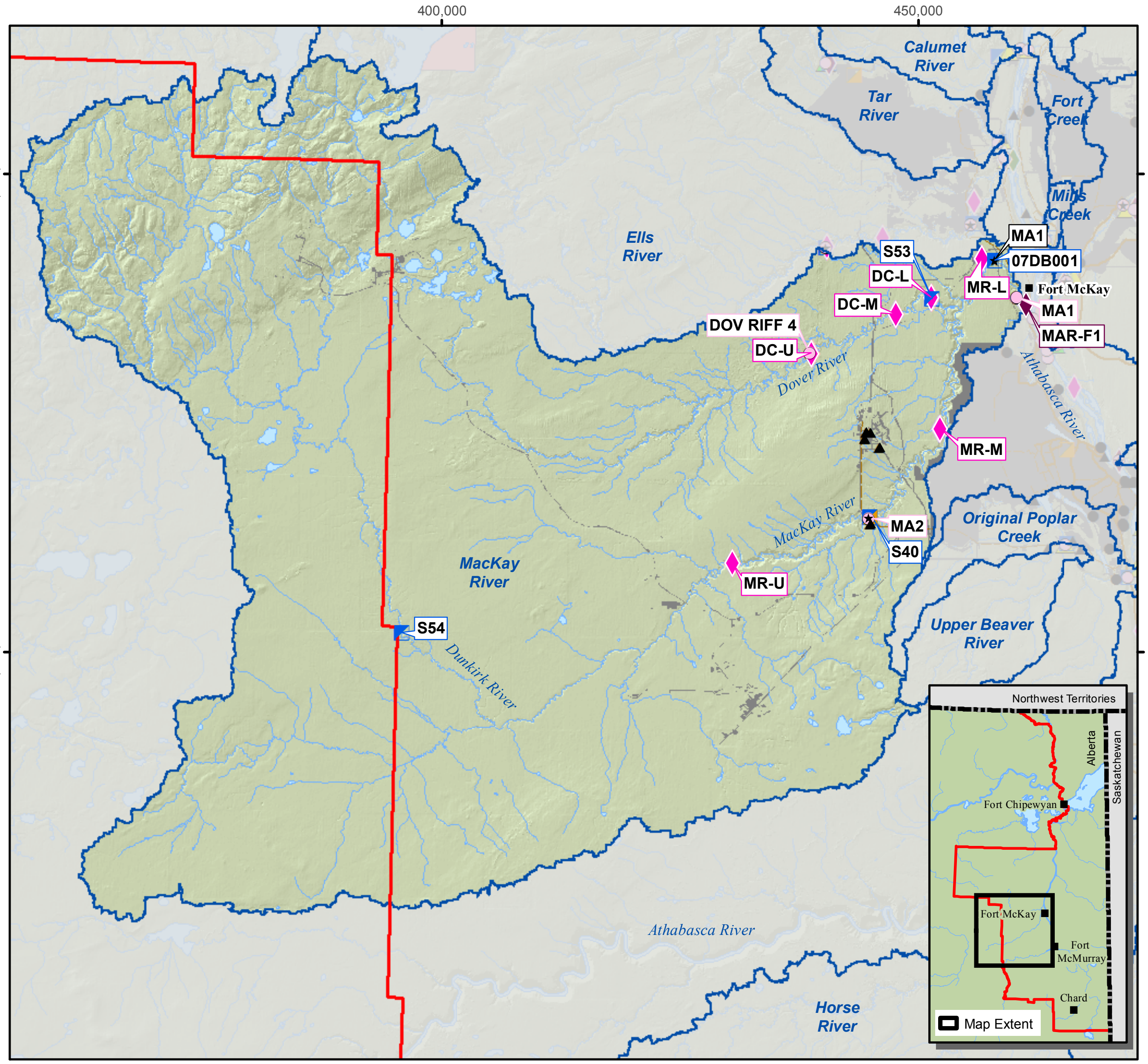
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (Fish Communities): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.1 for a detailed description of the classification methodology.

Fish Populations (Wild Fish Health): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.2 for a detailed description of the classification methodology.

Figure 5.5-1 MacKay River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]
- Water Withdrawal Location
- Water Release Location
- Water Quality Station
- Data Sonde Station
- Hydrometric Station
- Climate Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Community Reach
- Wild Fish Health Reach
- Wild Fish Health Reach with Water and Sediment Quality Stations

0 5 10 20 km

N

Scale: 1:675,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

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Figure 5.5-2 Representative monitoring stations of the MacKay River watershed, fall 2015.

Hydrology and Water Quality Station S40/MA2: MacKay River at the Petro-Canada Bridge, facing upstream

Hydrology Station S53: Dover River near the mouth, facing downstream

Hydrology Station S54: Dunkirk River, facing upstream

Water Quality Station DOV RIFF 4: mid Dover River, facing downstream

Fish Health Reach MR-U: upper MacKay River, facing upstream

Fish Health Reach DC-U: upper Dover River, facing downstream

5.5.1 Summary of 2015 WY Conditions

Approximately 1% (5,160 ha) of the MacKay River watershed had undergone land change from oil sands development as of 2015 (Table 2.3-1). The designations of specific areas of the watershed are as follows:

1. The MacKay River watershed downstream of the Suncor MacKay River in situ operations and the part of Syncrude's Mildred Lake operations in the MacKay River watershed (Figure 5.5-1) are designated as *test*.
2. The remainder of the watershed is designated as *baseline*, recognizing that the Southern Pacific in situ operation has some minor land change near the headwaters of the watershed.

Monitoring activities in the MacKay River watershed in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, Sediment Quality, and Fish Populations components. Table 5.5-1 is a summary of the 2015 assessment of the MacKay River watershed, while Figure 5.5-1 provides the locations of the monitoring stations for each component, locations of reported project water withdrawal and discharge locations from oil sands operations, and the locations of areas with land change as of 2015. Figure 5.5-2 provides fall 2015 photos of monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.009%, 0.021%, 0.016%, 0.021% higher, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality There was generally low monthly variation in concentration of water quality measurement endpoints between May and October in the 2015 WY. Dover River stations generally showed higher concentrations of dissolved ions than MacKay River stations. Concentrations of all water quality measurement endpoints in fall 2015 at *test* station MA1 and *baseline* station MA2 were within previously-measured concentrations with the exception of total parent PAHs at *baseline* station MA2, with a measured concentration in fall 2015 that exceeded the previously-measured maximum concentration. The only significant trends in fall concentrations of water quality measurement endpoints were decreases in arsenic and sulphate at *test* station MA1. Concentrations of all water quality measurement endpoints in fall 2015 were within the range of historical fall concentrations and regional fall *baseline* concentrations with the exception of a number of major ions at the Dover River stations with concentrations that exceeded the 95th percentile of regional *baseline* concentrations and TSS at several stations with concentrations that were below the 5th percentile of regional *baseline* concentrations. The WQI ranged from 98.7 to 100 at *test* stations and from 81.6 to 100 at *baseline* stations in the Mackay River watershed in fall 2015, indicating **Negligible-Low** differences in fall 2015 from regional *baseline* water quality conditions.

Sediment Quality Sediment quality at *baseline* stations DC-L, DC-M, DC-U, and MR-U, and *test* stations MR-L and MR-M exhibited **Negligible-Low** differences from regional *baseline* conditions. All measurement endpoints of sediment quality were below guideline concentrations at all stations of the Dover River and the upper stations of the MacKay River (*test* station MR-M and *baseline* station MR-U). With the exception of total PAHs (absolute and carbon-normalized) and the PAH hazard index level at *test* station MR-L, all sediment quality measurement endpoints were within the ranges of regional *baseline* conditions for stations within the MacKay River watershed. Temporal trend analyses could not be conducted for *baseline* stations DC-L, DC-M, DC-U, and MR-U, or *test* stations MR-L and MR-M, because sampling was initiated in 2015.

Fish Populations (Fish Communities) Differences in measurement endpoints of the fish community at *test* reach MAR-F1 were classified as **Negligible-Low**. There were no significant changes in measurement endpoints over time and mean values of most measurement endpoints for fish community monitoring at *test* reach MAR-F1 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints. Species richness was above the regional *baseline* range, indicating a positive change

Fish Populations (Wild Fish Health) The classification of effects for lower *test* reach MR-L is assessed as **Moderate** because an exceedance of the effects criteria associated with significant differences was observed in one of five measurement endpoints at *test* reach MR-L compared to *baseline* reach MR-U. The classification of effects for mid *test* reach MR-M is assessed as **Negligible-Low** as it does not differ from the *baseline* reach. Reaches of the Dover River consisted solely of *baseline* reaches in fall 2015, therefore, no classification of results could be assessed under the Environment Canada effects criteria guideline.

5.5.2 Hydrologic Conditions

Hydrometric monitoring for the MacKay River watershed in the 2015 WY was conducted at:

- WSC Station 07DB001 (formerly JOSMP Station S26), MacKay River near Fort McKay;
- JOSMP Station S40, MacKay River at the Petro-Canada Bridge;
- JOSMP Station S53, Dover River near the mouth; and
- JOSMP Station S54, Dunkirk River near Fort McKay.

Data from WSC Station 07DB001 were used for the water balance analysis for the Mackay River watershed and are presented below; data for each of the JOSMP stations are presented in Appendix C.

Seasonal data from March to October have been collected every year since 1973 at WSC Station 07DB001 (formerly JOSMP Station S26), with some data also collected in 1972. Winter data (November to February) were collected from 1973 to 1986 and from 2002 to 2014; the discharge record was annual and continuous during these years.

The historical flow record for WSC Station 07DB001 is summarized in Figure 5.5-3 and includes the median, interquartile, and range of flows recorded daily through the water year. Flows of the MacKay River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically lower than during the open-water season and generally decrease from November until early March. Spring thaw and the resulting increase in flows typically occurs in late March and April. Monthly flows are highest during May at the peak of freshet and often remain elevated in June and July when total monthly rainfall is at its highest point for the year. Flows then generally recede from late July until the end of October in response to declining rainfall inputs and eventually river freeze-up.

While flows in the 2015 WY measured at WSC Station 07DB001 were similar to the historical seasonal pattern described above, overall runoff volumes in the 2015 WY were lower than typical historical volumes. Flows decreased from November 2014 to late March 2015 and generally remained above or close to historical upper quartile flows (Figure 5.5-3). An increase in flow due to spring thaw occurred several weeks earlier than usual, resulting in early April flows that were higher than the historical upper quartile flow. The annual peak flow of 35 m^3/s was recorded on May 11, which was 68% lower than the historical mean annual maximum daily flow of 109.7 m^3/s. Flows decreased to below the historical median flow in May and remained consistently lower than the historical median, at times lower than the historical lower quartile flow, for the remainder of the WY. Several small peaks in flow were measured in the summer in response to rainfall events. The minimum open-water daily flow of 2.1 m^3/s was recorded on July 11, which was 43% lower than the historical mean minimum daily flow of 3.6 m^3/s calculated for the open-water period.

Overall, the annual runoff volume in the 2015 WY was 204 million m^3, which was 50% lower than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the MacKay River watershed, at WSC Station 07DB001 (formerly JOSMP Station S26) is summarized in Table 5.5-2. Key changes in flows and water diversions in the 2015 WY included:

1. The closed-circuited land change area as of 2015 was estimated to be 7.6 km^2 (Table 2.3-1). The loss of flow to the MacKay River that would have otherwise occurred from this land area was estimated at 0.279 million m^3.
2. As of 2015, the area of land change in the MacKay River watershed that was not closed-circuited was estimated to be 44.0 km^2 (Table 2.3-1). The increase in flow to the MacKay River that would not have otherwise occurred from this land area was estimated at 0.321 million m^3.
3. In the 2015 WY, Suncor Mackay River/Dover withdrew approximately 0.019 million m^3 (19,480 m^3) of water from the MacKay River watershed.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands developments in the 2015 WY was an increase in flow of 0.023 million m^3 at WSC Station 07DB001. The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.009%, 0.021%, 0.016%, 0.021% higher, respectively, in the observed *test* hydrograph than compared to the estimated *baseline* hydrograph (Table 5.5-3). These differences were classified as **Negligible-Low** (Table 5.5-1). A spatial analysis to identify the longitudinal hydrological effects along the MacKay River was not conducted because all measurement endpoints were classified as **Negligible-Low**.

5.5.3 Water Quality

Water quality samples were taken in the 2015 WY from:

- the MacKay River near its mouth (*test* station MA1, previously called MAR-1, designated *baseline* to 2001 and *test* thereafter), first sampled in fall 1998 and every year until 2014 except 1999, and monthly sampling in the 2015 WY from May 2015;

- the MacKay River upstream of the Suncor MacKay River Dover in situ developments (*baseline* station MA2, previously called MAR-2), sampled in fall every year from 2002 to 2014. Monthly water quality sampling was also conducted at this station in 2013 and 2014. Data were collected in the 2015 WY for all months except April;
- the Dover River upstream station (*baseline* station DOV RIFF 4), newly established in 2015 and sampled in the 2015 WY from May to October; and
- *test* stations MR-L and MR-M, and *baseline* station MR-U in the MacKay River, and *baseline* stations DC-L, DC-M, and DC-U in the Dover River, all sampled in September 2015 to support wild fish health monitoring activities.

Data sondes installed at *test* station MA1 and *baseline* station MA2 collected continuous water quality data from July to October 2015 for a subset of water quality variables.

Figure 5.5-4 presents in situ water quality trends in the MacKay River as recorded by data sondes in the 2015 WY. Monthly and seasonal variations in water quality are summarized in Table 5.5-4 to Table 5.5-6 and Figure 5.5-5. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations are provided in Table 5.5-7 to Table 5.5-10. The ionic composition of water in the MacKay River watershed is presented in Figure 5.5-6. Guideline exceedances for water quality measurement endpoints are presented in Table 5.5-11. A comparison of concentrations of selected water quality measurement endpoints in the Mackay River in fall 2015 relative to historical concentrations and regional *baseline* concentrations is provided in Figure 5.5-7.

Continuous Monitoring Results from Data Sondes Trends in concentration of dissolved oxygen at *test* station MA1 and upstream *baseline* station MA2 were similar, with both stations exhibiting daily fluctuations in concentration of dissolved oxygen (Figure 5.5-4), perhaps due to the wide, shallow nature of the river at these two stations. Water temperatures were highest in July (approximately 23°C) and gradually decreased to near 0°C at the end of October. Levels of pH at both stations were alkaline range, and generally higher at *test* station MA1 from late July to mid-September, when the upper bound water quality guideline of 9.0 was exceeded on a number of occasions. Conductivity was also higher at *test* station MA1 than at *baseline* station MA2 throughout the monitoring period. Turbidity was generally low, but increased mid-August at *baseline* station MA2 in mid-August, concurrent with increased flow that was likely related to precipitation events (Figure 5.5-3). Data gaps for data sondes at stations of the MacKay River are discussed in Appendix B.

Monthly Variations in Water Quality There was generally low monthly variation in concentration of water quality measurement endpoints between May and October with the exception of *baseline* station MA2 (Table 5.5-4 to Table 5.5-6, Figure 5.5-5). There were higher concentrations of TDS, alkalinity and associated major ions in winter at *baseline* station MA2 and lower concentrations of these measurement endpoints during spring when flows were higher. Dover River stations generally showed higher concentrations of dissolved ions, including boron and strontium, than MacKay River stations, suggesting a great influence of groundwater in Dover River waters. Monthly concentrations of water quality measurement endpoints at *test* station MA1 and *baseline* station MA2 in the 2015 WY were similar to historical concentrations (Figure 5.5-5).

2015 Fall Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints in fall 2015 at *test* station MA1 and *baseline* station MA2 were within previously-measured concentrations (Table 5.5-7, Table 5.5-8) with the exception of total parent PAHs at *baseline* station MA2, with a measured concentration in fall 2015 that exceeded the previously-measured maximum concentration. Water quality at *baseline* station DOV RIFF 4 and the six wild fish health monitoring stations in the MacKay River watershed was measured for the first time in the 2015 WY and it was therefore not possible to make historical comparisons for these stations (Table 5.5-9 to Table 5.5-10). At the stations on the MacKay River that were sampled for water quality to support wild fish health monitoring, lower *test* station MR-L exhibited higher concentrations of TDS, major ions and PAHs than mid *test* station MR-M and upper *baseline* station MR-U (Table 5.5-9). Water quality was similar at all the stations on the Dover River that were sampled for water quality to support wild fish health monitoring (Table 5.5-10).

Temporal Trends Significant ($p<0.05$) decreasing trends in fall concentrations of arsenic and sulphate were detected over time at *test* station MA1 (1998 to 2015). No significant trends in fall concentrations of water quality measurement endpoints were detected at *baseline* station MA2. Trend analyses were not conducted for the other water quality monitoring stations in the Mackay River due to insufficient length of the times series of available water quality data.

Ion Balance In fall 2015, the ionic composition of water in the Mackay River watershed was dominated by calcium and bicarbonate and consistent with previous years with the exception of a higher dominance of sodium and potassium and chloride at *test* station MA1 in 1998 (Figure 5.5-6).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Water quality guideline exceedances in the 2015 WY were (Table 5.5-11):

- dissolved iron at *test* stations, MA1 (May to October), MR-L (September), and MR-M (September), and baseline stations, MA2 (November to October), DOV RIFF 4 (May to October), MR-U (September), DC-L (September), DC-M (September), and DC-U (September);
- total silver (January) and total zinc (February) at *baseline* station MA2;
- total phenols at *test* stations, MA1 (June to October), MR-L (September), and MR-M (September), and *baseline* stations, MA2 (July to October), DOV RIFF 4 (June to October), MR-U (September), DC-L (September), DC-M (September), and DC-U (September); and
- sulphide at *test* stations, MA1 (June to October), MR-L (September), and MR-M (September), and baseline stations, MA2 (November to October), DOV RIFF 4 (May to October), MR-U (September), DC-L (September), DC-M (September), and DC-U (September).

2015 Fall Results Relative to Regional *Baseline* Concentrations The concentration of all water quality measurement endpoints in fall 2015 were within the range of historical fall concentrations and regional fall *baseline* concentrations (Figure 5.5-7), with the following exceptions:

- TSS, with a concentration below the 5^{th} percentile of regional baseline concentrations at *test* stations MA1 and MR-L and *baseline* stations DC-M, and DC-U;

- TDS, with a concentration exceeding the 95th percentile of regional baseline concentrations at *baseline* station DC-M;

- total boron and total strontium, with concentrations exceeding the 95th percentile of regional baseline concentrations at *baseline* stations DOV RIFF 4, DC-L, DC-M, and DC-U;

- sodium, with a concentration exceeding the 95th percentile of regional *baseline* concentrations at *baseline* stations DC-L, DC-M, and DC-U;

- magnesium, with a concentration exceeding the 95th percentile of regional *baseline* concentrations at *baseline* stations DOFF RIFF 4 and DC-M; and

- sulphate, with a concentration exceeding the 95th percentile of regional *baseline* concentrations at *baseline* station DC-L.

Water Quality Index The WQI ranged from 98.7 to 100 at *test* stations and from 81.6 to 100 at *baseline* stations in the Mackay River watershed in fall 2015, indicating **Negligible-Low** differences in fall 2015 from regional *baseline* water quality conditions.

Classification of Fall Results Differences in water quality in the Mackay River watershed in fall 2015 and regional *baseline* fall conditions were classified as **Negligible-Low**.

5.5.4 Benthic Invertebrate Communities and Sediment Quality

5.5.4.1 Sediment Quality

Sediment quality sampling was initiated in fall 2015 to support the wild fish health monitoring activities in the MacKay River watershed at:

- *baseline* stations DC-L (lower reach), DC-M (middle reach), and DC-U (upper reach) in the Dover River; and

- *test* stations MR-L (lower reach) and MR-M (middle reach), and *baseline* station MR-U (upper reach) in the MacKay River.

Temporal Trends No trend analyses for sediment quality could be conducted for any of the stations sampled in fall 2015 because 2015 was the first year of sampling at these stations.

2015 Results Relative to Historical Conditions Comparisons to historical ranges in concentrations of measurement endpoints were not possible for any of the stations sampled in fall 2015 because 2015 was the first year of sampling at these stations.

Sediments in fall 2015 at *test* stations MR-L and MR-M and *baseline* station MR-U were predominantly sand (81.5%, 96.8%, and 93.6%, respectively) (Table 5.5-12). BTEX and Fraction 1 hydrocarbons were not detectable at *test* station MR-L (Table 5.5-12) and with the exception of Fraction 3 hydrocarbons at *baseline* station MR-U, total hydrocarbon concentrations were not detectable at either *test* station MR-M or *baseline* station MR-U. Survival was 84% or greater for both the midge *Chironomus* and the amphipod *Hyalella* at all three MacKay River stations in the direct sediment toxicity tests.

Sediment in fall 2015 at *baseline* stations DC-L, DC-M, and DC-U in the Dover River were also predominantly sand (93.6%, 99.1%, and 93.4%, respectively) (Table 5.5-13). BTEX, Fraction 1, and Fraction 2 total hydrocarbons were not detectable at any of the three stations in fall 2015 and Fraction 3 and 4 hydrocarbons were not detectable at *baseline* stations DC-L or DC-M (Table 5.5-13). In the direct sediment toxicity tests, survival was 92% or greater for the amphipod *Hyalella* at all sediment quality stations in the Dover River and 74%, 84%, and 94% for the midge *Chironomus* at *baseline* station DC-M, DC-U, and DC-L, respectively.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of sediment quality measurement endpoints were below guideline concentrations at stations in the Dover River and the MacKay River with the following exceptions:

- Fraction 3 hydrocarbons (994 mg/kg) at *test* station MR-L, which exceeded the CCME guideline of 300 mg/kg;
- predicted PAH toxicity (2.34) at *test* station MR-L, which exceeded the potential chronic toxicity threshold value of 1.0; and
- chrysene (0.0849 mg/kg) at *test* station MR-L, which exceeded the CCME guideline of 0.0571 mg/kg.

2015 Results Relative to Regional *Baseline* Concentrations Concentrations and levels of all sediment quality measurement endpoints at *test* station MR-M and *baseline* station MR-U in the MacKay River were within regional *baseline* concentrations with the exception of total PAHs, carbon-normalized total PAHs and the PAH hazard index, all of which had concentrations and levels greater than the 95th percentile of regional *baseline* values at *test* station MR-L (Figure 5.5-8 to Figure 5.5-10), and all sediment quality measurement endpoints at *baseline* stations DC-L, DC-M, DC-U in the Dover River were within regional *baseline* concentrations in fall 2015 (Figure 5.5-11 to Figure 5.5-13).

Sediment Quality Index Calculated SQI values for the mid *test* station MR-M and upper *baseline* station MR-U for fall 2015 conditions were 100; the calculated SQI for lower *test* station MR-L was 82.7, due to high PAH and hydrocarbon concentrations in fall 2015 relative to regional *baseline* ranges. SQI values for *baseline* stations DC-L, DC-M, and DC-U in the Dover River in fall 2015 were 98.9, 100, and 100, respectively.

Classification of Results Based on the calculated SQI values for all stations within the Mackay and Dover rivers in fall 2015, differences in sediment quality between the sediment quality conditions in fall 2015 and regional *baseline* conditions were classified as **Negligible-Low**.

5.5.5 Fish Populations

5.5.5.1 Fish Community Monitoring

Fish community monitoring was conducted on the MacKay River in fall 2015 at lower *test* reach MAR-F1. Fish community monitoring has been conducted at this reach since 2009, with the exception of 2010.

2015 Habitat Conditions *Test* reach MAR-F1 in fall 2015 had a glide habitat with a wetted width of 45.0 m and a bankfull width of 55.5 m (Table 5.5-14); substrate consisted of coarse gravel with some fine material. Water in fall 2015 had a mean depth of 0.30 m, velocity of 0.26 m/s, pH of 8.05, conductivity of 277 µS/cm, concentration of DO of 6.8 mg/L, and a temperature of 7.6˚C. Instream cover consisted primarily of filamentous algae, small woody debris, and macrophytes.

Relative Abundance of Fish Species The total catch of fish species at *test* reach MAR-F1 was higher in 2015 compared to 2014 (Table 5.5-15), with lake chub as the dominant species. Species richness was also higher in 2015 than in 2014 (Table 5.5-15).

Temporal and Spatial Comparisons Mean values of all measurement endpoints were higher at *test* reach MAR-F2 in 2015 than in 2013 or 2014, with the exception of diversity (Table 5.5-16).

Temporal comparisons for *test* reach MAR-F1 included testing for changes over time in measurement endpoints (Table 5.5-16) (Hypothesis 1, Section 3.2.4.4). No spatial comparisons were performed because no other reaches in the Mackay River watershed were sampled in 2015.

There were no significant changes over time in the values of any of the fish community measurement endpoints at *test* reach MAR-F1 (Table 5.5-17).

Comparison to Published Literature Golder (2004) documented riffle and run habitat, with substrate consisting of sand, gravel, cobble, and boulders in the area of the river where the *test* reach MAR-F1 is located, which is consistent with habitat conditions documented in fall 2015 (Table 5.5-14). This section of the river provides moderate to high fisheries potential (Golder 2004), with previous studies recording a total of 23 fish species in the MacKay River watershed. The results of the fish community sampling in fall 2015, when combined with historical fish monitoring conducted by RAMP/JOSMP in the MacKay River watershed, brings to 17 the total number of fish species that have been observed between 2010 and 2015 (Table 5.5-15). Possible reasons for discrepancies in species richness may be due to differences in sampling gear as well as the total amount of the watercourse sampled; fish community monitoring under JOSMP samples a smaller, defined reach length relative to the multiple locations and reaches documented in Golder (2004).

2015 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints for *test* reach MAR-F1 were within the inner tolerance limits of the 95th percentile of regional *baseline* conditions with the exception of richness, which exceeded the inner tolerance limit of the 95th percentile of *baseline* conditions (Figure 5.5-14).

Classification of Results Differences in measurement endpoints of the fish community at *test* reach MAR-F1 were classified as **Negligible-Low**:

1. There were no significant changes in measurement endpoints over time; and
2. Mean values of all measurement endpoints for fish community monitoring at *test* reach MAR-F1 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints.

5.4.1.1 Wild Fish Health

MacKay River

Wild fish health monitoring was conducted in three reaches of the MacKay River in fall 2015, using longnose dace as the target species:

- upper *baseline* reach MR-U;
- mid *test* reach MR-M; and
- lower *test* reach MR-L.

No temporal comparisons could be made in wild fish health measurement endpoints at these reaches because 2015 was the first year of wild fish health monitoring at these reaches.

2015 Habitat Conditions In situ water quality at all three reaches of the MacKay River indicated suitable conditions for longnose dace with: concentration of dissolved oxygen ranging from 10.4 mg/L to 11.6 mg/L; conductivity ranging from 208 μS/cm to 307 μS/cm; and pH ranging from 6.83 to 7.87. Mean water depth and mean water velocity in fall 2015 were similar in all three reaches, ranging from 0.4 m to 0.5 m for mean depth and 0.3 m/s to 0.5 m/s for mean velocity. The dominant substrate at all three reaches was cobble, with subdominant substrates being either boulders (lower *test* reach MR-L and upper *baseline* reach MR-U), or fines (mid *test* reach MR-M) (Table 5.5-18). Water temperatures ranged from 4.9°C to 8.6°C. Daily mean temperatures decreased from a high of 22°C in August to a low of 5°C in September 2015 (Figure 5.5-15).

Selected measurement endpoints for discrete water quality sampling (as described in Section 3.2.2) at each wild fish heath reach in the MacKay River are provided in Table 5.5-9. Concentrations of water quality variables were generally similar across reaches with the exception of polycyclic aromatic hydrocarbons (PAHs), specifically total dibenzothiophenes, total PAHs, and total alkylated PAHs. PAHs were higher at lower *test* reach MR-L than mid *test* reach MR-M and upper *baseline* reach MR-U, but similar between middle *test* reach MR-M and upper *baseline* reach MR-U. Concentrations of total dibenzothiophenes, total PAHs and total alkylated PAHs were 10, 2.4, and 2.7 times higher, respectively, at lower *test* reach MR-L than at either lower *test* reach MR-L than mid *test* reach MR-M.

Collection and Structure of Target Fish

Summary of Capture Success of Adults and Juveniles The target number of adult longnose dace (20 adult fish of each sex) was achieved at two of the three reaches along the MacKay River (lower *test* reach MR-L and upper baseline reach MR-U), while 20 females and 15 males were collected at mid *test* reach R-M, (Table 5.5-19). The required number of 100 juveniles was not obtained for any of the reaches on the MacKay River (Table 5.5-19). A summary of morphometric data for the longnose dace caught in the MacKay River is provided in Table 5.5-19 and Table 5.5-20.

Size Distribution Figure 5.5-16 presents the length-frequency distribution of all longnose dace captured in fall 2015 at each of the three reaches of the MacKay River. A length class of ≤50 mm was used for juveniles on the MacKay River as 50 mm marks the end of the first peak in the bimodal distribution of length in Figure 5.5-16.

Length-frequency distributions were relatively similar across reaches suggesting juveniles experienced a similar growth rate among reaches in their first growing season (Figure 5.5-16).

In 2015, upper *baseline* reach MR-U had the smallest proportion of juveniles while mid *test* reach MR-M and lower *test* reach MR-L had similar proportions of juveniles (Table 5.5-19). The lower the proportion of juveniles at *baseline* reach MR-U compared to the *test* reaches MR-M and MR-L potentially indicates a greater relative recruitment of longnose dace at the lower *test* reaches.

Incidence of Abnormalities A small percentage of the longnose dace caught in the MacKay River had external abnormalities in fall 2015, which included fin erosion and lesions. Fin erosion was observed on fish at upper *baseline* reach MR-U and lower *test* reach MR-L and lesions were observed on fish at lower *test* reach MR-L (Table 5.5-19).

Spatial Comparison of Measurement Endpoints of Wild Fish Health

A summary of morphometric data for the adult longnose dace caught in the MacKay River is provided in Table 5.5-20. This information was used to test for spatial differences in measurement endpoints of longnose dace among lower *test* reaches MR-M and MR-L and upper *baseline* reach MR-U.

Survival (Age) – Mean Age and Age Distribution The relative age-frequency distribution of longnose dace showed a relatively similar distribution of age classes across reaches. Ages ranged from less than a year to five years at upper *baseline* reach MR-U, less than a year to four years at mid *test* reach MR-M, and one year to four years at lower *test* reach MR-L (Figure 5.5-17). The dominant age class was two years at upper *baseline* reach MR-U and mid *test* reach MR-M, and one year at lower *test* reach MR-L. Female and male longnose dace did not differ in mean age among reaches (Table 5.5-21).

Growth (Energy Use) – Size-at-Age There were no significant differences in growth for either female or male longnose dace among reaches in the MacKay River (Table 5.5-21).

Reproduction (Energy Use) – Relative Gonad Size There were no significant differences in female relative gonad weight among reaches of the MacKay River (Table 5.5-21). Differences in relative gonad weight in male longnose dace could not be evaluated among reaches because slopes were significantly different ($p<0.01$, Figure 5.5-18).

Energy Storage – Relative Liver Size Male longnose dace at lower *test* reach MR-L had significantly smaller relative liver weight than at either mid *test* reach MR-M and upper *baseline* reach MR-U (Table 5.5-21). An exceedance of the effects criterion (±25% difference in relative liver weight of fish between reaches) was observed for male longnose dace at *test* reach MR-L compared to *baseline* reach MR-U and *test* reach MR-M (Table 5.5-21).

Energy Storage – Condition The following statistically-significant differences in condition of longnose dace among reaches of the MacKay River in fall 2015 were measured (Table 5.5-21):

1. Condition of female longnose dace was significantly lower at lower *test* reach MR-L than mid *test* reach MR-M but this difference did not exceed the ±10% effects criterion for condition; and

2. Condition of male longnose dace was significantly lower at *test* reach MR-L than *baseline* reach MR-U but this difference did not exceed the ±10% effects criterion for condition.

Power Analysis to Investigate Influence of Sample Power analyses were conducted for group comparisons that were not statistically significant for each measurement endpoint using the effects size of ±25% for age, weight-at-age, GSI, and LSI, and ±10% for condition (Table 5.5-21). For condition, lengths and weights of the additional fish sexed while searching for the target number of males to dissect were used in an effort to increase power. Power ranged from 0.12 to 0.92. Three comparisons did not achieve the desired level of Power (>0.90) (Environment Canada 2010): age, growth, and LSI, indicating that the sample size was too low to detect a significant difference for an effect size of ±25% for these three measurement endpoints.

Exposure – Mixed Function Oxygenase (MFO) Activity In fall 2015, EROD activity in adult male longnose dace was consistently higher than EROD activity in adult female longnose dace at all reaches of the MacKay River. The following statistically-significant differences in EROD activity in longnose dace among reaches in the MacKay River in fall 2015 were measured (Figure 5.5-19):

1. Female and male longnose dace at lower *test* reach MR-L exhibited significantly higher EROD activity than at upper *baseline* reach MR-U; and

2. Female and male longnose dace at lower *test* reach MR-L exhibited significantly higher EROD activity than at mid *test* reach MR-M.

EROD activity in female and male lake chub at lower *test* reach MR-L was 67% and 111% higher, respectively, than EROD activity in fish at mid *test* reach MR-M. EROD activity in female and male lake chub at lower *test* reach MR-L was a 97% and 111% higher, respectively, than EROD activity in fish at upper *baseline* reach MR-U (Figure 5.5-19).

Interpretation of 2015 Responses There were few significant differences in measurement endpoints of longnose dace among *test* and *baseline* reaches in the MacKay River in fall 2015. An effect was observed in energy storage (relative liver weight) for male longnose dace where male longnose dace at lower *test* reach MR-L had significantly smaller relative liver weight than male fish at mid *test* reach MR-M and upper *baseline* reach MR-U, although similar declines in male condition were minor. A decrease in energy storage can suggest that food resources at the *test* reaches are more limited; however, one would expect condition to follow a similar a similar pattern. Induced EROD activity in longnose dace from the lower *test* reach correlates spatially with the increased exposure of the McMurray Formation in the McKay River and suggests that longnose dace at this location were exposed to bitumen. In addition, concentrations of total dibenzothiophenes, which are sulphonated PAHs associated with bitumen (i.e., petrogenic), were nearly 10 times higher at lower *test* reach MR-L than at mid *test* reach MR-M or upper *baseline* reach MR-U. Further studies would be needed to confirm the effects and responses.

Classification of Results Based on the results of the 2015 survey, the classification of effects for lower *test* reach MR-L is assessed as **Moderate** because an exceedance of the effects criteria associated with significant differences was observed in one of five measurement endpoints at *test* reach MR-L compared to *baseline* reach MR-U. The classification of effects for mid *test* reach MR-M compared to *baseline* reach MR-U is assessed as **Negligible-Low** as there were exceedance of the effects criteria associated with significant differences in any of the five measurement endpoints mid *test* reach MR-M compared to *baseline* reach MR-U.

Dover River

Wild fish health monitoring was conducted in three reaches of the Dover River in fall 2015, using lake chub as the target species:

- upper *baseline* reach DC-U;
- mid *baseline* reach DC-M; and
- lower *baseline* reach DC-L.

No temporal comparisons could be made in wild fish health measurement endpoints at these reaches because 2015 was the first year of wild fish health monitoring at these reaches. In addition, because all reaches are considered *baseline*, spatial comparisons were made to assess natural variability and to develop baseline data for future reach-specific comparisons.

2015 Habitat Conditions In situ water quality indicated suitable conditions for lake chub at all reaches with: concentration of dissolved oxygen ranging from 9.5 mg/L to 10.9 mg/L; conductivity ranging from 427 µS/cm to 466 µS/cm; and pH ranging from 7.08 and 8.09. Mean water velocity across all reaches was 0.10 m/s and mean water depths ranged from 0.38 m to 0.5 m. Water temperatures measured during reach visits ranged from 3.6°C to 7°C (Table 5.5-18). Daily mean water temperature decreased from a high of 22°C in August to a low of 5°C in September (Figure 5.5-20).

Selected measurement endpoints for discrete water quality sampling (as described in Section 3.2.2.2) at each wild fish heath reach along the Dover River are provided in Table 5.5-10. Concentrations of water quality variables were generally similar among reaches with the exception of naphthenic acids, which had higher concentrations of naphthenic acids at lower *baseline* reaches DC-L and DC-M than at upper *baseline* reach DC-U.

Collection and Structure of Sentinel Species Populations

Summary of Capture Success of Adults and Juveniles The target number (20 adult fish of each sex) was reached at all three reaches along the Dover River for female lake chub but not for male lake chub, with from 16 to 19 males caught at the three reaches (Table 5.5-19). The required number of 100 juvenile fish was captured at lower *baseline* reach DC-L and upper *baseline* reach DC-U; 99 juveniles were captured at mid *baseline* reach DC-M (Table 5.5-19). A summary of morphometric data for lake chub caught in the three reaches is provided in Table 5.5-19 and Table 5.5-20.

Size Distribution A length of 50 mm was used to designate lake chub juveniles on the Dover River as 50 mm marks the end of the first peak in the bimodal distribution of length (Figure 5.5-21). Upper *baseline* reach DC-U had the greatest frequency of small individuals followed by mid *baseline* reach DC-M and lower *baseline* reach DC-L, which had the greatest frequency of large individuals (Figure 5.5-21). The greater proportion of larger individuals at the lower reach may indicate that growth rates of juveniles were higher in the lower reaches of the Dover River.

Incidence of Abnormalities Parasites were the most common abnormality observed in fish caught in reaches of the Dover River in fall 2015 (Table 5.5-19). A small percentage of lake chub captured at lower *baseline* reach DC-L also had fin erosion and/or minor lesions (Table 5.5-19).

Spatial Comparison of Measurement Endpoints of Wild Fish Health

A summary of morphometric data for the adult lake chub caught in the Dover River is provided in Table 5.5-20. This information was used to test for spatial differences in measurement endpoints of lake chub among *baseline* reaches DC-U, DC-M, and DC-L.

Survival (Age) – Mean Age and Age Distribution Upper *baseline* reach DC-U had a higher frequency of three year old fish, mid *baseline* reach DC-M had a higher frequency of two year old fish, and *baseline* reach DC-L had a higher frequency of one year old fish (Figure 5.5-22). The following statistically-significant differences in age of lake chub among reaches of the Dover River in fall 2015 were observed (Table 5.5-22):

1. Female lake chub were significantly older at upper *baseline* reach DC-U than lower *baseline* reach DC-L and this difference exceeded the ±25% effects criterion for age;

2. Male lake chub were significantly older at upper *baseline* reach DC-U than mid *baseline* reach DC-M and lower *baseline* reach DC-L and these differences exceeded the ±25% effects criterion for age; and

3. Male lake chub were significantly older at mid *baseline* reach DC-M than lower *baseline* reach DC-L but this difference did not exceed the ±25% effects criterion for age.

Growth (Energy Use) – Size-at-age There were no significant differences in growth among reaches for either female or male lake chub (Table 5.5-22).

Reproduction (Energy Use) – Relative Gonad Size Relative gonad size of female lake chub was significantly smaller at lower *baseline* reach DC-L than at mid *baseline* reach DC-M and upper *baseline* reach DC-U but this difference did not exceed the ±25% effects criterion for gonad size; all other comparisons of relative gonad size were statistically insignificant (Table 5.5-22).

Energy Storage – Relative Liver Size Female fish at upper *baseline* reach DC-U had significantly larger relative liver weight than females at mid *baseline* reach DC-M but this difference did not exceed the ±25% effects criterion for liver size; all other comparisons of energy storage were statistically insignificant (Table 5.5-22).

Energy Storage – Condition Female fish at mid *baseline* reach DC-M had significantly higher condition than females at lower *baseline* reach DC-L but this difference did not exceed the ±10% effects criterion for conditions; all other comparisons of condition were statistically insignificant (Table 5.5-22).

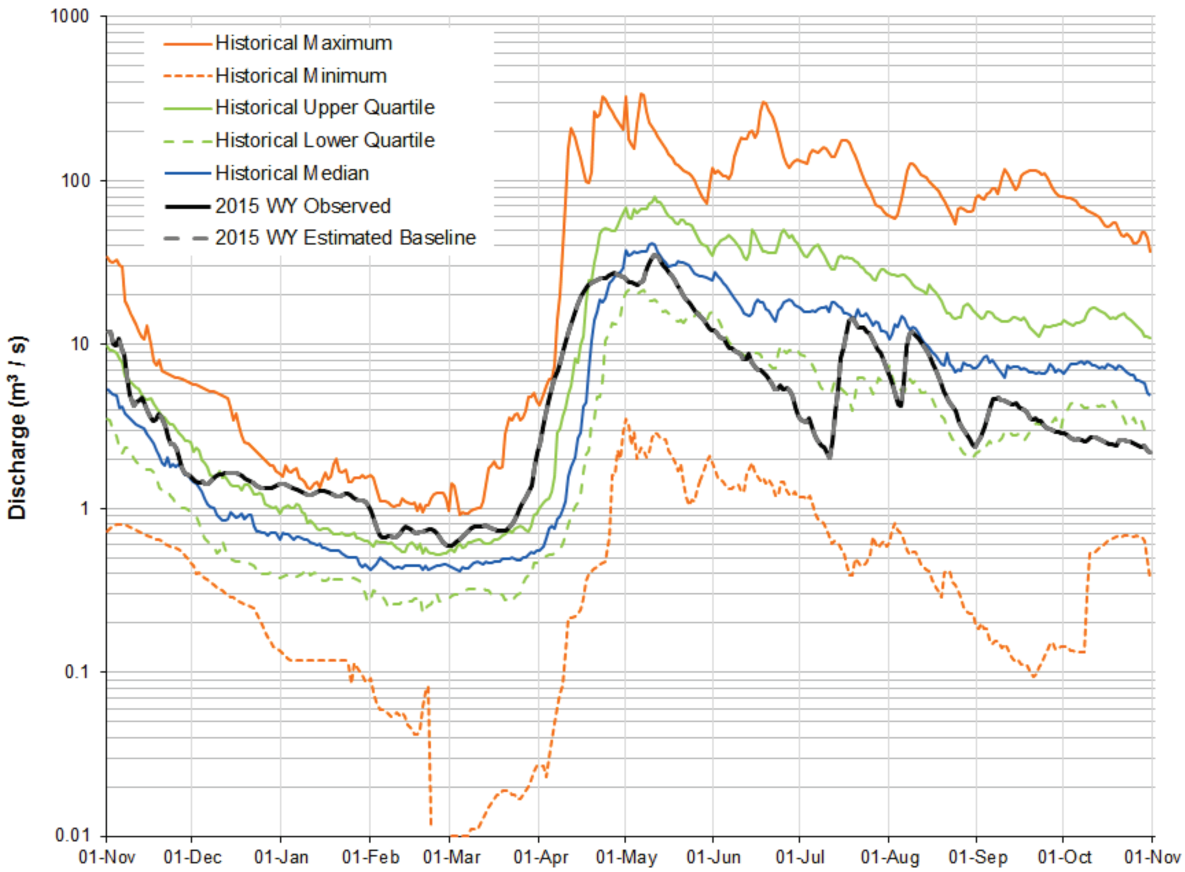
Power Analysis to Investigate Influence of Sample Size Power analyses were conducted for group comparisons that were not statistically significant for each measurement endpoint using the effects size of ±25% for age, weight-at-age, GSI, and LSI, and ±10% for condition (Table 5.5-22). Lengths and weights of the additional fish sexed while searching for the target number of males to dissect were used in an effort to increase power for condition. Power ranged from 0.06 to 0.85 and five comparisons did not achieve the desired level of Power (>0.90) (Environment Canada 2010): age, growth, LSI, GSI, and condition, indicating that the sample size was too low to detect a significant difference for these effects sizes for these measurement endpoints. It should be noted that two of these comparisons (age and GSI) achieved a power near 0.80 and some studies have suggested that a power of 0.80 is adequate (Cohen 1988).

Exposure – Mixed Function Oxygenase (MFO) Activity In 2015, EROD activity in adult male lake chub was consistently higher than EROD activity of adult female lake chub in all reaches of the Dover River and male lake chub at mid *baseline* reach DC-M exhibited significantly lower EROD activity than male lake chub at upper *baseline* reach DC-U (Figure 5.5-19). EROD activity in male lake chub at mid *baseline* reach DC-M was 29% lower than EROD activity in male lake chub at upper *baseline* reach DC-U.

Interpretation of 2015 Responses Results of the fall 2015 wild fish health study indicate that a range of *baseline* variability exists in the Dover River. There were few significant differences in measurement endpoints of lake chub among *baseline* reaches in the Dover River. A difference in age was observed as lake chub were significantly younger at lower *test* reach DC-L than upper *baseline* reaches DC-M and DC-U.

Classification of Results Only *baseline* reaches of the Dover River were monitored in fall 2015 and no classification of results could be therefore be assessed under the Environment Canada effects criteria guideline (Environment Canada 2010).

Figure 5.5-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the MacKay River in the 2015 WY, compared to historical values.



Note: The observed 2015 WY hydrograph was based on MacKay River near Fort McKay, WSC Station 07DB001 (formerly JOSMP Station S26) data. The upstream drainage area is 5,569 km^2. Historical daily values from March 1 to October 31 were calculated from data collected from 1972 to 2014, and historical daily values from November 1 to February 28 calculated from data collected from 1972 to 1987, and from 2002 to 2014.

Table 5.5-2 Estimated water balance at WSC Station 07DB001 (formerly JOSMP Station S26), MacKay River near Fort McKay, 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**203.494**	**Observed discharge, obtained from MacKay River near Fort McKay, WSC Station 07DB001 (formerly JOSMP Station S26)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.279	Estimated 7.6 km^2 of the MacKay River watershed is closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.321	Estimated 44.0 km^2 of the MacKay River watershed with land change from oil sands developments as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the MacKay River watershed, relative to the estimated *baseline* hydrograph	-0.019	Water withdrawals by Suncor Mackay River/Dover (daily values provided)
Water releases into the MacKay River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**203.471**	**Estimated *baseline* discharge at MacKay River near Fort McKay, WSC Station 07DB001 (formerly JOSMP Station S26)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	0.023	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	0.011	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

Notes:

Definitions and assumptions discussed in Section 3.2.1.

Based on data for the 2015 FY for WSC Station 07DB001 MacKay River near Fort McKay.

All non-zero values in this table presented to three decimal places.

Table 5.5-3 Calculated change in hydrologic measurement endpoints for the MacKay River watershed, 2015 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	8.478	8.479	+0.009%
Mean winter discharge	1.870	1.870	+0.021%
Annual maximum daily discharge	34.994	35.000	+0.016%
Open-water season minimum daily discharge	2.050	2.050	+0.021%

Notes:

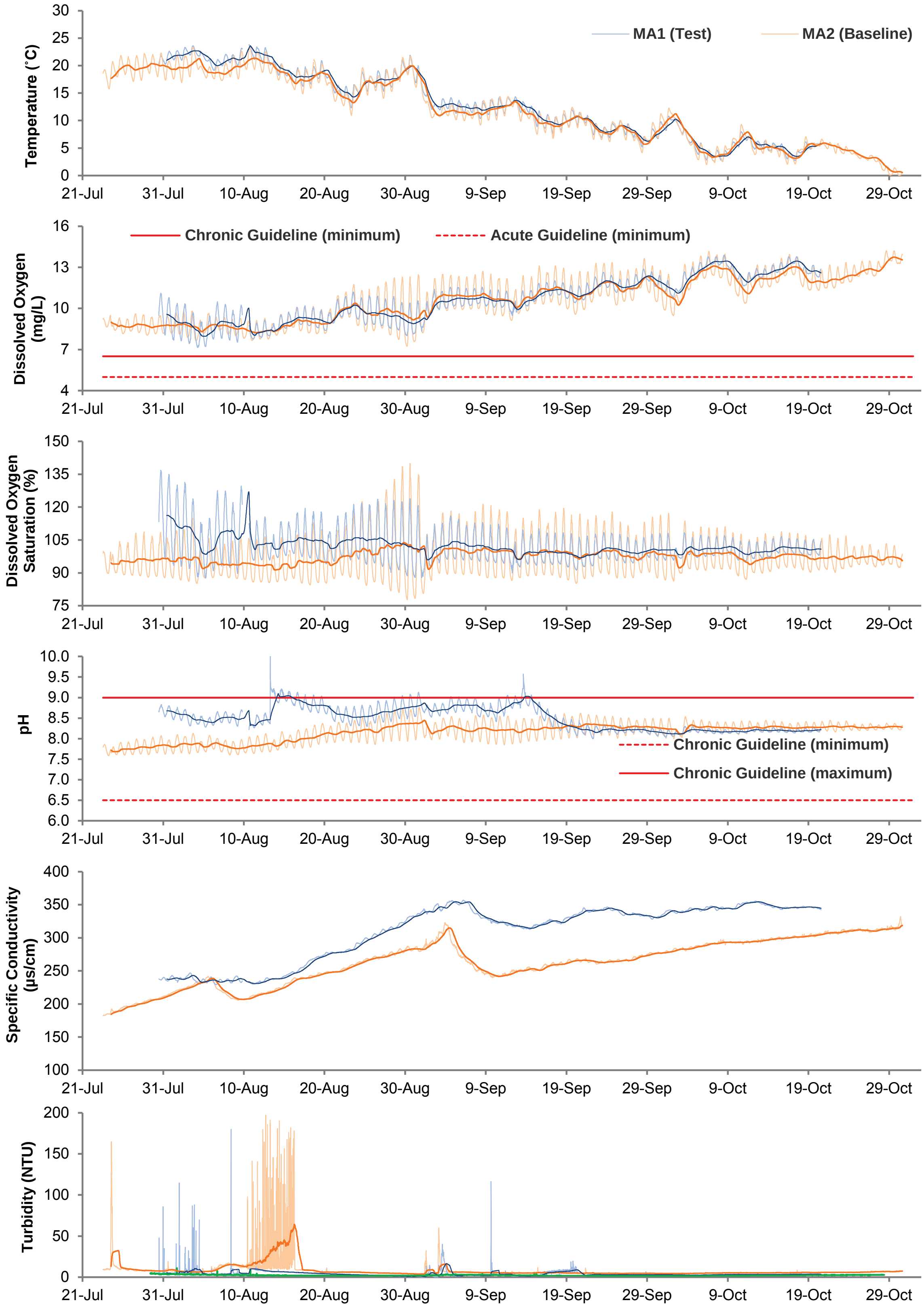
Definitions and assumptions discussed in Section 3.2.1.

Observed discharge was calculated from data from the 2015 WY for WSC Station 07DB001.

The relative change for each measurement endpoint value was calculated using *test* and *baseline* flow values, which were estimated to several decimal places. Flows and percentage change values are presented to three decimal places for the sake of clarity.

The open-water season refers to the period from May 1 and October 31 and the winter season refers to the period from November 1 and March 31.

Figure 5.5-4 In situ water quality trends in the MacKay River recorded by data sondes, July to October 2015.



Note: Water quality variables were recorded at 15-minute intervals; trend lines are daily averages

Table 5.5-4 Monthly concentrations of water quality measurement endpoints, mouth of MacKay River (*test* station MA1 [MAR-1]), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.24	8.00	Jul	8.33	Sep
Total suspended solids	mg/L	-	5	1.30	<1.0	Oct	8.70	Aug
Conductivity	µS/cm	-	5	270	220	Aug	360	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.021	0.016	Jun	0.034	Jul
Total nitrogen	mg/L	-	5	<1.00	0.82	Oct	1.30	Aug
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.005	-	<0.005	-
Dissolved organic carbon	mg/L	-	5	28.0	24.0	Jun	34.0	Aug
Ions								
Sodium	mg/L	-	5	24.0	18.0	Aug	32.0	Oct
Calcium	mg/L	-	5	26.0	21.0	Aug	34.0	Oct
Magnesium	mg/L	-	5	9.30	7.00	Aug	12.00	Oct
Potassium	mg/L	-	5	1.10	0.62	Aug	1.40	Jun
Chloride	mg/L	120-640	5	5.6	3.8	Jul	9.8	Oct
Sulphate	mg/L	309[b]	6	18.0	11.0	Aug	24.0	Oct
Total dissolved solids	mg/L	-	5	210	200	Aug, Oct	220	Jul, Sep
Total alkalinity	mg/L	20 (min)	5	120	100	Aug	160	Oct
Selected metals								
Total aluminum	mg/L	-	6	0.2890	0.0924	Jun	2.5100	May
Dissolved aluminum	mg/L	0.05	6	0.0258	0.01400	Oct	**0.06250**	Jul
Total arsenic	mg/L	0.005	6	0.0009	0.00065	Oct	0.00127	Jul
Total boron	mg/L	1.5-29	6	0.0945	0.0609	May	0.1030	Jul
Total molybdenum	mg/L	0.073	6	0.00031	0.00021	May	0.00038	Oct
Total mercury (ultra-trace)	ng/L	5-13	6	2.27	1.05	Oct	5.62	May
Total methyl mercury	ng/L	1-2	6	0.182	0.161	Oct	0.338	Aug
Total strontium	mg/L	-	6	0.1615	0.0859	May	0.2130	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.41	0.21	Sep	0.64	Aug
Oilsands extractable acids	mg/L	-	6	2.05	1.20	Sep	3.30	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	0.73	<0.59	Jun, Oct	4.86	Jul
Total dibenzothiophenes[c]	ng/L	-	5	80.05	14.76	May	217.99	Aug
Total PAHs[c]	ng/L	-	5	285	160	May	592	Aug
Total Parent PAHs[c]	ng/L	-	5	25.0	23.2	Oct	30.2	Jul
Total Alkylated PAHs[c]	ng/L	-	5	260	135	Jun	562	Aug
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0120**	**0.0068**	Oct	**0.0170**	Jul
Sulphide	mg/L	0.0019	5	**0.0088**	**0.0046**	Jul	**0.0130**	Jun
Dissolved iron	mg/L	0.3	6	**0.5915**	**0.4200**	Sep	**0.8010**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.5-5 Monthly concentrations of water quality measurement endpoints, MacKay River at Petro-Canada Bridge (*baseline* station MA2 [MAR-2]), November 2014 to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	11	7.97	7.82	May	8.36	Aug
Total suspended solids	mg/L	-	11	4.0	2.0	Aug-Oct	25.0	May
Conductivity	µS/cm	-	11	263	130	May	579	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	11	0.034	0.018	Jun	0.064	Jan
Total nitrogen	mg/L	-	11	1.19	0.82	Oct	1.34	Mar
Nitrate+nitrite	mg/L	3-124	11	0.011	<0.003	May	0.482	Mar
Dissolved organic carbon	mg/L	-	11	29.1	26.0	May	43.4	Nov
Ions								
Sodium	mg/L	-	11	19.6	9.8	May	42.9	Mar
Calcium	mg/L	-	11	28.0	14.0	May	62.1	Mar
Magnesium	mg/L	-	11	9.00	5.20	May	20.80	Mar
Potassium	mg/L	-	11	1.06	0.76	Jul	2.35	Mar
Chloride	mg/L	120-640	11	1.80	1.16	Nov	3.17	Mar
Sulphate	mg/L	309[b]	11	14.3	6.2	Jul	62.6	Mar
Total dissolved solids	mg/L	-	11	200	96	May	403	Feb
Total alkalinity	mg/L	20 (min)	11	120	57	May	255	Mar
Selected metals								
Total aluminum	mg/L	-	11	0.2990	0.1840	Oct	1.4500	May
Dissolved aluminum	mg/L	0.05	11	0.02270	0.00541	Feb	0.04960	May
Total arsenic	mg/L	0.005	11	0.00094	0.00076	Oct	0.00111	Mar
Total boron	mg/L	1.5-29	11	0.0902	0.0564	May	0.1720	Mar
Total molybdenum	mg/L	0.073	11	0.00034	0.00017	Jul	0.00070	Mar
Total mercury (ultra-trace)	ng/L	5-13	11	1.65	1.20	Oct	3.91	May
Total methyl mercury	ng/L	1-2	6	0.247	0.144	May	0.461	Aug
Total strontium	mg/L	-	11	0.1470	0.0755	May	0.3500	Mar
Total hydrocarbons								
BTEX	mg/L	-	11	<0.01	<0.01	-	<0.10	-
Fraction 1 (C6-C10)	mg/L	0.15	11	<0.01	<0.01	-	<0.10	-
Fraction 2 (C10-C16)	mg/L	0.11	11	<0.005	<0.005	-	**<0.250**	-
Fraction 3 (C16-C34)	mg/L	-	11	<0.02	<0.02	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	11	<0.02	<0.02	-	<0.25	-
Naphthenic acids	mg/L	-	11	0.64	0.25	Sep, Oct	2.05	Feb
Oilsands extractable acids	mg/L	-	11	1.90	1.10	Aug	3.60	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	9	<13.55	<13.55	-	28.40	Feb
Retene	ng/L	-	10	0.79	<0.59	-	2.50	May
Total dibenzothiophenes[c]	ng/L	-	10	8.17	8.17	-	8.51	Jan
Total PAHs[c]	ng/L	-	10	125	111	Mar	180	Feb
Total Parent PAHs[c]	ng/L	-	10	22.6	8.6	Mar	37.1	Feb
Total Alkylated PAHs[c]	ng/L	-	10	103	98	Nov, Dec	143	Feb
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	11	0.0023	<0.0010	-	**0.0200**	Jul
Sulphide	mg/L	0.0019	11	**0.0097**	**0.0032**	May	**0.0203**	Nov
Dissolved iron	mg/L	0.3	11	**0.6810**	**0.4610**	May	**2.1200**	Jan
Total silver	mg/L	0.0001	11	0.000005	0.000002	Sep, Oct	**0.00145**	Jan
Total zinc	mg/L	0.03	11	0.0029	0.0013	Jun	**0.0447**	Feb

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.5-6 Monthly concentrations of water quality measurement endpoints, Dover River (*baseline* station DOV RIFF 4), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.25	8.04	May	8.32	Sep
Total suspended solids	mg/L	-	6	4.0	2.0	Sep	35.0	May
Conductivity	µS/cm	-	6	410	210	May	520	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.046	0.029	May	0.064	Sep
Total nitrogen	mg/L	-	6	1.05	0.73	Oct	1.20	Jul
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	0.0064	Sep
Dissolved organic carbon	mg/L	-	6	24.5	22.0	Oct	29.0	Aug
Ions								
Sodium	mg/L	-	6	39.5	20.0	May	57.0	Oct
Calcium	mg/L	-	6	38.5	17.0	May	45.0	Sep
Magnesium	mg/L	-	6	14.50	6.80	May	18.00	Oct
Potassium	mg/L	-	6	2.00	1.60	Aug	2.40	May
Chloride	mg/L	120-640	6	4.1	3.1	May	5.5	Oct
Sulphate	mg/L	309[b]	6	19.5	12.0	Aug	27.0	Oct
Total dissolved solids	mg/L	-	6	295	170	May	330	Sep
Total alkalinity	mg/L	20 (min)	6	205	91	May	260	Oct
Selected metals								
Total aluminum	mg/L	-	6	0.2170	0.0925	Jun	1.4300	May
Dissolved aluminum	mg/L	0.05	6	0.01011	0.00579	Oct	0.04370	May
Total arsenic	mg/L	0.005	6	0.00082	0.00063	Oct	0.00108	Jul
Total boron	mg/L	1.5-29	6	0.1710	0.0942	May	0.2090	Sep
Total molybdenum	mg/L	0.073	6	0.00019	0.00017	Aug	0.00023	Jul
Total mercury (ultra-trace)	ng/L	5-13	6	1.75	0.90	Oct	4.54	May
Total methyl mercury	ng/L	1-2	6	0.167	0.120	Oct	0.217	Aug
Total strontium	mg/L	-	6	0.2740	0.1150	May	0.3190	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.68	0.23	Oct	1.40	Jun
Oilsands extractable acids	mg/L	-	6	1.75	0.60	Oct	2.30	Jun
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	3.39	0.99	Oct	12.30	Jun
Total dibenzothiophenes[c]	ng/L	-	6	9.17	8.17	Jun, Oct	11.94	May
Total PAHs[c]	ng/L	-	6	131	126	Oct	144	May
Total Parent PAHs[c]	ng/L	-	6	22.5	22.2	Jun	23.0	Sep
Total Alkylated PAHs[c]	ng/L	-	6	109	103	Oct	122	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	6	**0.0089**	0.0038	May	**0.0120**	Aug
Sulphide	mg/L	0.0019	6	**0.0079**	**0.0065**	May	**0.0120**	Sep
Dissolved iron	mg/L	0.3	6	**0.7410**	**0.5250**	Jul	**0.8930**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

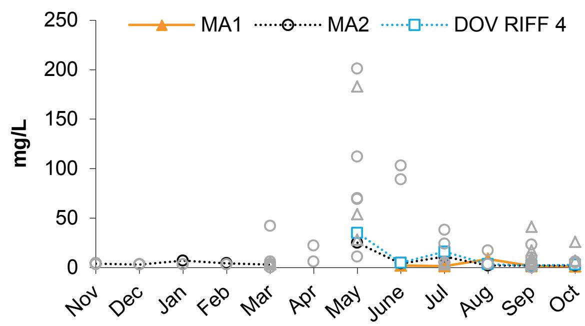
[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

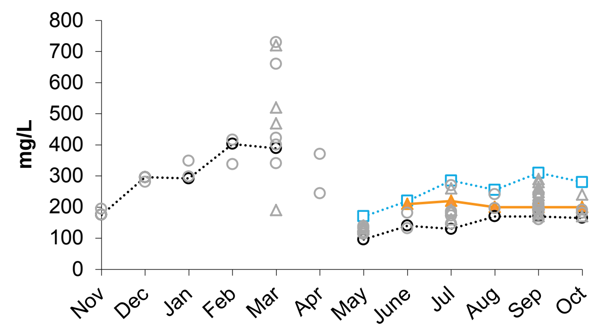
[d] n value refers to number of exceedances in 2015.

Figure 5.5-5 Selected water quality measurement endpoints in the MacKay River watershed (monthly data) in the 2015 WY.

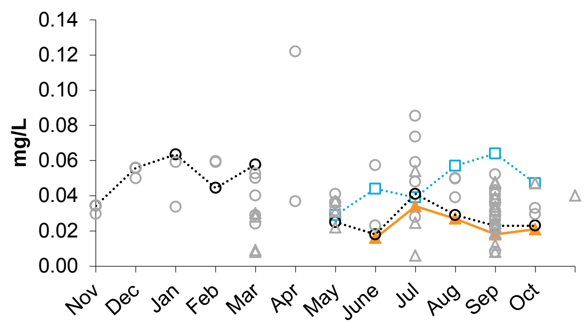
Total Suspended Solids (TSS)



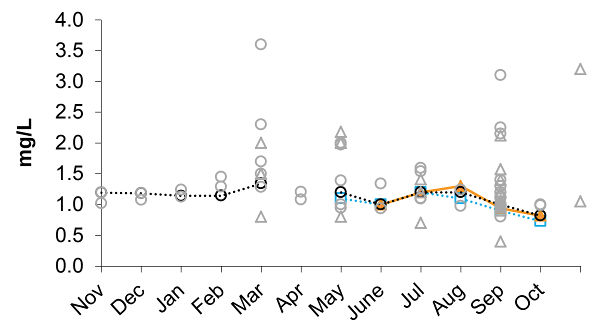
Total Dissolved Solids (TDS)



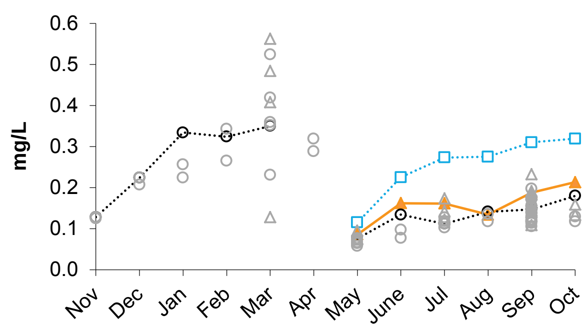
Total Dissolved Phosphorus



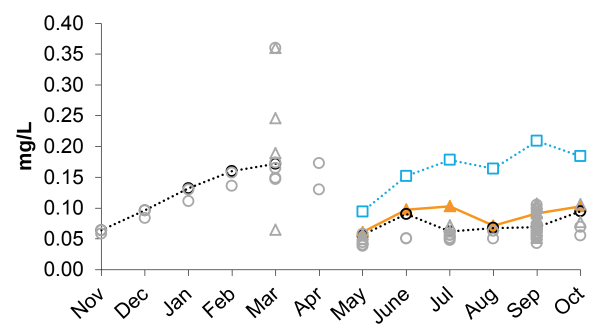
Total Nitrogen



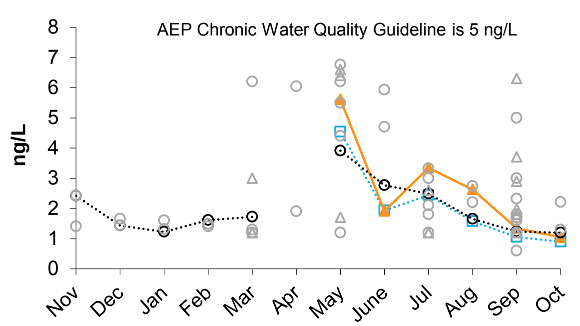
Total Strontium



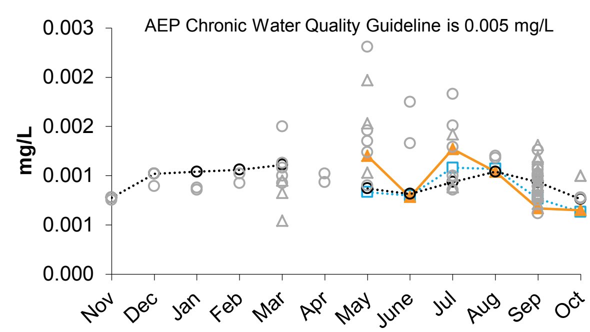
Total Boron



Total Mercury (Ultra-trace)



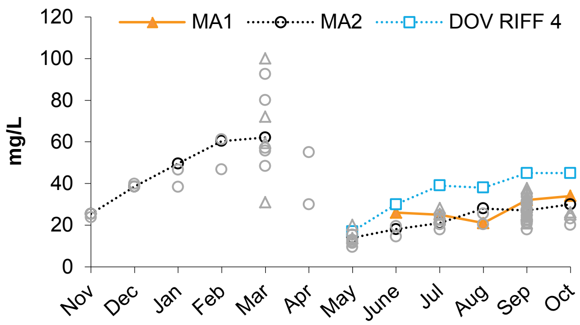
Total Arsenic



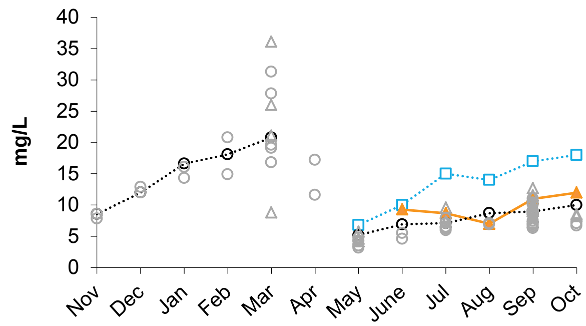
Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.5-5 (Cont'd.)

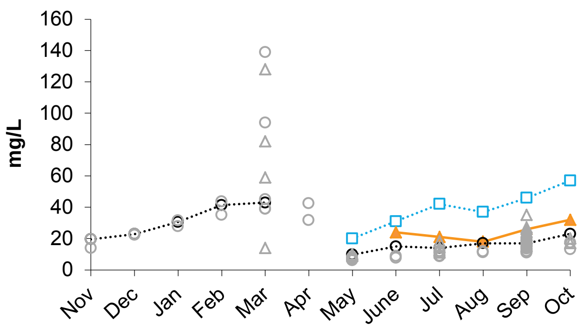
Calcium



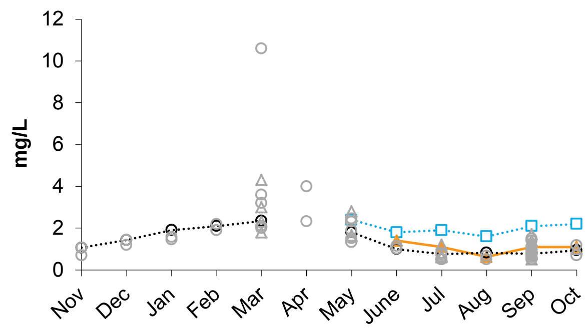
Magnesium



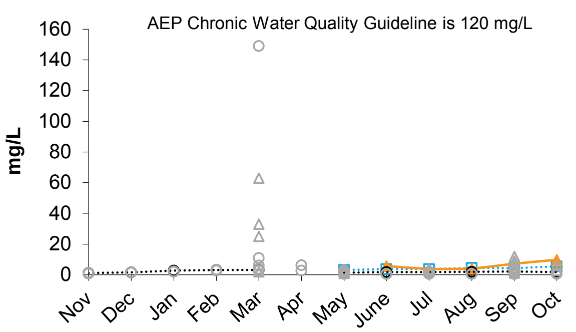
Sodium



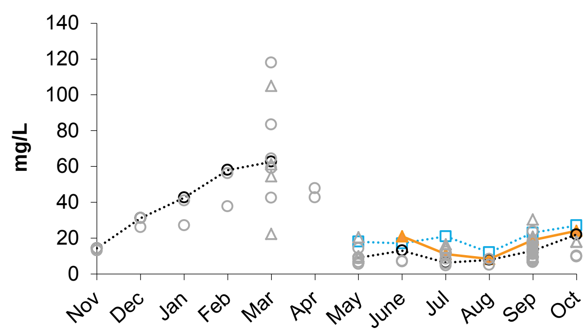
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.5-7 Concentrations of water quality measurement endpoints, mouth of MacKay River (*test* station MA1 [MAR-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1998-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.33	16	8.2	7.6	8.6
Total suspended solids	mg/L	-	1.3	16	6.5	<2.0	41
Conductivity	µS/cm	-	320	16	273	183	576
Nutrients							
Total dissolved phosphorus	mg/L	-	0.018	16	0.025	0.004	0.048
Total nitrogen	mg/L	-	0.94	16	1.07	0.400	3.20
Nitrate+nitrite	mg/L	3	<0.005	16	<0.086	<0.050	<0.100
Dissolved organic carbon	mg/L	-	30.0	16	28.3	20.0	40.0
Ions							
Sodium	mg/L	-	26	16	20.0	15.0	60.0
Calcium	mg/L	-	32	16	27.9	20.8	44.7
Magnesium	mg/L	-	11	16	9.15	7.26	15.90
Potassium	mg/L	-	1.1	16	1.02	0.50	1.70
Chloride	mg/L	120	7.3	16	4.10	1.20	41.2
Sulphate	mg/L	309[b]	19	16	16.0	9.3	35.5
Total dissolved solids	mg/L	-	220	16	226	170	342
Total alkalinity	mg/L	-	140	16	126	80	202
Selected metals							
Total aluminum	mg/L	-	0.111	16	0.219	0.050	1.740
Dissolved aluminum	mg/L	0.05	0.0165	16	0.023	0.007	0.046
Total arsenic	mg/L	0.005	0.00067	16	0.0010	0.00071	0.0013
Total boron	mg/L	1.5-29	0.0914	16	0.082	0.051	0.140
Total molybdenum	mg/L	0.073	0.00033	16	0.00033	0.00015	0.00060
Total mercury (ultra-trace)	ng/L	5-13	1.34	12	<1.2	<1.2	**6.3**
Total methyl mercury	ng/L	1-2	0.181	-	-	-	-
Total strontium	mg/L	-	0.188	16	0.160	0.108	0.287
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.21	4	0.24	0.06	0.77
Oilsands extractable acids	mg/L	-	1.2	4	0.99	0.56	1.20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	-	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	0.7	4	2.06	<0.91	5.55
Total dibenzothiophenes[c]	ng/L	-	80.1	4	59.23	23.95	289.1
Total PAHs[c]	ng/L	-	268.8	4	269.2	131.6	1,028
Total Parent PAHs[c]	ng/L	-	24.3	4	23.72	14.76	30.37
Total Alkylated PAHs[c]	ng/L	-	244.5	4	245.5	116.9	997.8
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.420**	16	**0.527**	0.230	**1.110**
Sulphide	mg/L	0.0019	**0.012**	16	**0.012**	**0.003**	**0.032**
Total phenols	mg/L	0.004	**0.007**	16	**0.006**	0.001	**0.020**

Values in **bold** are above guideline; underlined values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.5-8 Concentrations of water quality measurement endpoints, MacKay River at the Petro-Canada Bridge (*test* station MA2 [MAR-2]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2002-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.28	13	8.2	7.8	8.3
Total suspended solids	mg/L	-	2.0	13	<3.0	<3.0	23.0
Conductivity	µS/cm	-	250	13	228	164	284
Nutrients							
Total dissolved phosphorus	mg/L	-	0.023	13	0.035	0.008	0.052
Total nitrogen	mg/L	-	1.0	13	1.20	0.800	3.10
Nitrate+nitrite	mg/L	3-124	0.011	13	<0.100	<0.054	0.100
Dissolved organic carbon	mg/L	-	29.0	13	31.0	22.0	41.0
Ions							
Sodium	mg/L	-	17	13	15.0	11.0	20.1
Calcium	mg/L	-	27	13	26.2	17.8	34.5
Magnesium	mg/L	-	9.0	13	8.6	6.3	11.0
Potassium	mg/L	-	0.78	13	0.9	0.5	1.5
Chloride	mg/L	120-640	2.1	13	1.0	<0.5	3.0
Sulphate	mg/L	309[b]	13	13	11.00	6.58	23.7
Total dissolved solids	mg/L	-	200	13	200	160	240
Total alkalinity	mg/L	20 (min)	120	13	104	75	128
Selected metals							
Total aluminum	mg/L	-	0.186	13	0.174	0.020	1.080
Dissolved aluminum	mg/L	0.05	0.016	13	0.025	<0.001	0.044
Total arsenic	mg/L	0.005	0.0009	13	0.0010	0.0006	0.0013
Total boron	mg/L	1.5-29	0.069	13	0.058	0.043	0.105
Total molybdenum	mg/L	0.073	0.00032	13	0.00031	0.00013	0.00055
Total mercury (ultra-trace)	ng/L	5-13	1.240	12	1.65	0.60	5.00
Total methyl mercury	ng/L	1-2	0.247	-	-	-	-
Total strontium	mg/L	-	0.147	13	0.139	0.105	0.197
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.25	4	0.25	0.15	0.25
Oilsands extractable acids	mg/L	-	1.3	4	1.00	0.18	1.70
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	14.0	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	1.09	0.743	<2.07
Total dibenzothiophenes[c]	ng/L	-	8.17	4	11.39	4.134	35.33
Total PAHs[c]	ng/L	-	117.40	4	148.0	74.1	205.1
Total Parent PAHs[c]	ng/L	-	<u>22.85</u>	4	18.37	13.26	22.44
Total Alkylated PAHs[c]	ng/L	-	94.55	4	126.8	60.88	188.3
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.540**	13	**0.598**	0.289	**1.240**
Sulphide	mg/L	0.0019	**0.0093**	13	**0.0178**	**0.0048**	**0.03**
Total phenols	mg/L	0.004	**0.0099**	13	**0.009**	0.001	**0.020**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.5-9 Concentrations of water quality measurement endpoints at wild fish health stations in the MacKay River (*test* stations MR-L and MR-M, and *baseline* station MR-U), fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value		
			MR-L	MR-M	MR-U
Physical variables					
pH	pH units	6.5-9.0	8.22	8.08	8.10
Total suspended solids	mg/L	-	<1	4.7	2.0
Conductivity	µS/cm	-	320	270	230
Nutrients					
Total dissolved phosphorus	mg/L	-	0.015	0.018	0.03
Total nitrogen	mg/L	-	0.95	1	0.99
Nitrate+nitrite	mg/L	3-124	<0.005	<0.005	<0.005
Dissolved organic carbon	mg/L	-	27	29	30
Ions					
Sodium	mg/L	-	26	19	15
Calcium	mg/L	-	32	27	26
Magnesium	mg/L	-	11	9.2	8.3
Potassium	mg/L	-	1.2	0.89	0.82
Chloride	mg/L	120-640	8	4.3	1.6
Sulphate	mg/L	309[b]	18	14	8.9
Total dissolved solids	mg/L	-	250	220	180
Total alkalinity	mg/L	20 (min)	140	120	110
Selected metals					
Total aluminum	mg/L	-	0.110	0.132	0.213
Dissolved aluminum	mg/L	0.05	0.0179	0.0267	0.0325
Total arsenic	mg/L	0.005	0.00055	0.0007	0.0008
Total boron	mg/L	1.5-29	0.089	0.070	0.052
Total molybdenum	mg/L	0.073	0.0003	0.0003	0.0003
Total mercury (ultra-trace)	ng/L	5-13	1.07	1.07	1.09
Total methyl mercury	ng/L	1-2	0.147	0.172	0.241
Total strontium	mg/L	-	0.186	0.161	0.131
Total hydrocarbons					
BTEX	mg/L	-	<0.01	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02	<0.02
Naphthenic acids	mg/L	-	0.17	0.18	0.2
Oilsands extractable acids	mg/L	-	1.0	1.0	1.0
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	ng/L	1,000	<13.55	<13.55	<13.55
Retene	ng/L	-	1.08	0.59	0.90
Total dibenzothiophenes[c]	ng/L	-	80.45	8.17	8.17
Total PAHs[c]	ng/L	-	281.61	119.11	119.11
Total Parent PAHs[c]	ng/L	-	24.65	22.73	22.73
Total Alkylated PAHs[c]	ng/L	-	256.96	96.38	96.38
Other variables that exceeded Alberta guidelines in fall 2015					
Dissolved iron	mg/L	0.3	**0.374**	**0.47**	**0.549**
Sulphide	mg/L	0.002	**0.010**	**0.012**	**0.010**
Total Phenols	mg/L	0.004	**0.0065**	**0.008**	**0.008**

Values in **bold** are above guideline; sampling began in 2015 and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.5-10 Concentrations of water quality measurement endpoints at *baseline* station DOV RIFF 4 and wild fish health reaches (*baseline* stations DC-L, DC-M, and DC-U) in the Dover River, fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value			
			DOV RIFF 4	DC-L	DC-M	DC-U
Physical variables						
pH	pH units	6.5-9.0	8.32	8.41	8.37	8.33
Total suspended solids	mg/L	-	2.0	4.0	<1	<1
Conductivity	µS/cm	-	500	500	490	490
Nutrients						
Total dissolved phosphorus	mg/L	-	0.064	0.023	0.032	0.054
Total nitrogen	mg/L	-	0.90	0.92	0.91	0.88
Nitrate+nitrite	mg/L	3-124	0.0064	<0.005	<0.005	<0.005
Dissolved organic carbon	mg/L	-	24	26	26	26
Ions						
Sodium	mg/L	-	46	44	47	45
Calcium	mg/L	-	45	40	45	39
Magnesium	mg/L	-	17	15	17	15
Potassium	mg/L	-	2.1	1.9	2.1	1.9
Chloride	mg/L	120-640	4.3	5.9	5.4	5.5
Sulphate	mg/L	309[b]	23	25	21	22
Total dissolved solids	mg/L	-	330	330	360	320
Total alkalinity	mg/L	20 (min)	250	240	240	250
Selected metals						
Total aluminum	mg/L	-	0.176	0.219	0.07	0.109
Dissolved aluminum	mg/L	0.05	0.008	0.00896	0.0118	0.0115
Total arsenic	mg/L	0.005	0.00077	0.0007	0.0007	0.0006
Total boron	mg/L	1.5-29	0.209	0.211	0.207	0.181
Total molybdenum	mg/L	0.073	0.0002	0.0002	0.0002	0.0002
Total mercury (ultra-trace)	ng/L	5-13	1.060	0.95	0.99	0.98
Total methyl mercury	ng/L	1-2	0.139	0.11	0.14	0.157
Total strontium	mg/L	-	0.31	0.305	0.301	0.293
Total hydrocarbons						
BTEX	mg/L	-	<0.01	<0.01	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02	<0.02	<0.02
Naphthenic acids	mg/L	-	0.29	0.46	0.58	<0.08
Oilsands extractable acids	mg/L	-	1.4	2.2	2.6	1.2
Polycyclic Aromatic Hydrocarbons (PAHs)						
Naphthalene	ng/L	1,000	<13.55	<13.55	<13.55	<13.55
Retene	ng/L	-	1.48	<0.59	<0.59	1.01
Total dibenzothiophenes[c]	ng/L	-	9.28	8.17	7.62	8.36
Total PAHs[c]	ng/L	-	113.54	119.15	119.13	119.35
Total Parent PAHs[c]	ng/L	-	22.64	22.73	22.73	22.81
Total Alkylated PAHs[c]	ng/L	-	90.91	96.42	96.40	96.55
Other variables that exceeded Alberta guidelines in fall 2015						
Dissolved iron	mg/L	0.3	**0.629**	**0.374**	**0.47**	**0.549**
Sulphide	mg/L	0.002	**0.012**	**0.010**	**0.012**	**0.010**
Total phenols	mg/L	0.004	**0.011**	**0.0065**	**0.008**	**0.008**

Values in **bold** are above guideline; sampling began in 2015 and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.5-6 Piper diagram of fall ion concentrations in the MacKay River watershed.

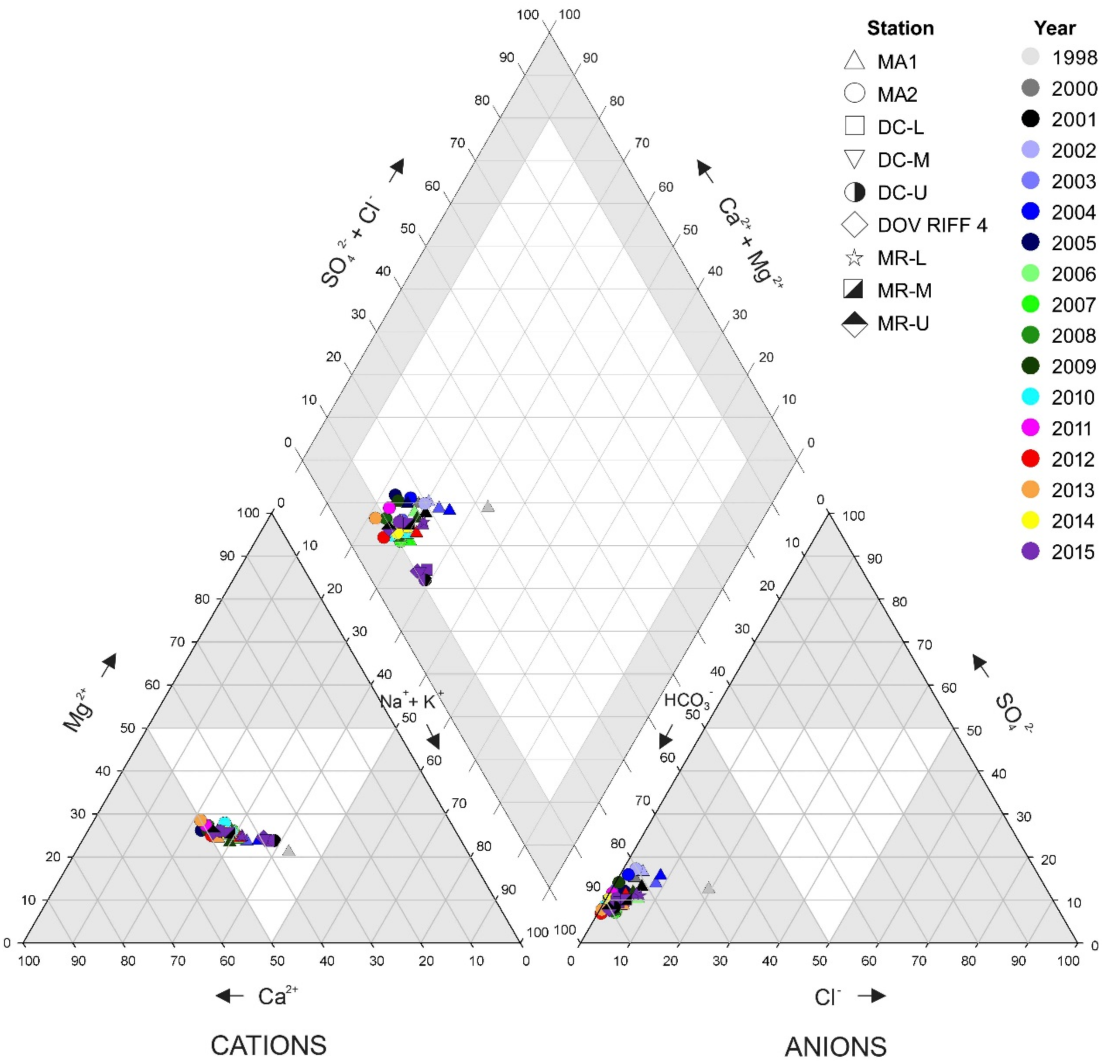


Table 5.5-11 Water quality guideline exceedances in the MacKay River watershed, 2015 WY.

Variable	Units	Guideline[a]	November	December	January	February	March	May	June	July	August	September	October
MacKay River mouth (MA1)													
Dissolved iron	mg/L	0.3	-	-	-	-	-	**0.606**	**0.693**	**0.801**	**0.577**	**0.42**	**0.503**
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.012**	**0.017**	**0.014**	**0.0073**	**0.0068**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.013**	**0.0046**	**0.0062**	**0.012**	**0.0088**
MacKay River upstream (MA2)													
Dissolved iron	mg/L	0.3	**0.922**	**1.39**	**2.12**	**0.878**	**1.39**	**0.461**	**0.674**	**0.563**	**0.617**	**0.54**	**0.681**
Total silver	mg/L	0.0001	0.000005	0.000006	**0.00145**	0.000017	0.000004	0.000007	0.000004	0.000005	0.000003	0.000002	0.000002
Total zinc	mg/L	0.03	0.0019	0.0014	0.0031	**0.0447**	0.0018	0.0039	0.0013	0.0029	0.003	0.0031	0.0013
Total phenols	mg/L	0.004	0.002	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.0039	0.0023	**0.02**	**0.012**	**0.0099**	**0.0058**
Sulphide	mg/L	0.0019	**0.0203**	**0.0102**	**0.0089**	**0.0093**	**0.0117**	**0.0032**	**0.0097**	**0.013**	**0.01**	**0.0093**	**0.0081**
MacKay River lower (MR-L)													
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	-	-	-	**0.374**	-
Sulphide	mg/L	0.002	-	-	-	-	-	-	-	-	-	**0.010**	-
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	-	-	**0.0065**	-
MacKay River middle (MR-M)													
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	-	-	-	**0.47**	-
Sulphide	mg/L	0.002	-	-	-	-	-	-	-	-	-	**0.012**	-
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	-	-	**0.008**	-
MacKay River upper (MR-U)													
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	-	-	-	**0.549**	-
Sulphide	mg/L	0.002	-	-	-	-	-	-	-	-	-	**0.010**	-
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	-	-	**0.008**	-
Dover River upstream (DOV RIFF 4)													
Dissolved Iron	mg/L	0.3	-	-	-	-	-	**0.858**	**0.893**	**0.525**	**0.853**	**0.629**	**0.544**
Total phenols	mg/L	0.004	-	-	-	-	-	0.0038	**0.0042**	**0.011**	**0.012**	**0.011**	**0.0067**
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0065**	**0.0073**	**0.0085**	**0.0085**	**0.012**	**0.0073**

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Table 5.5-11 (Cont'd.)

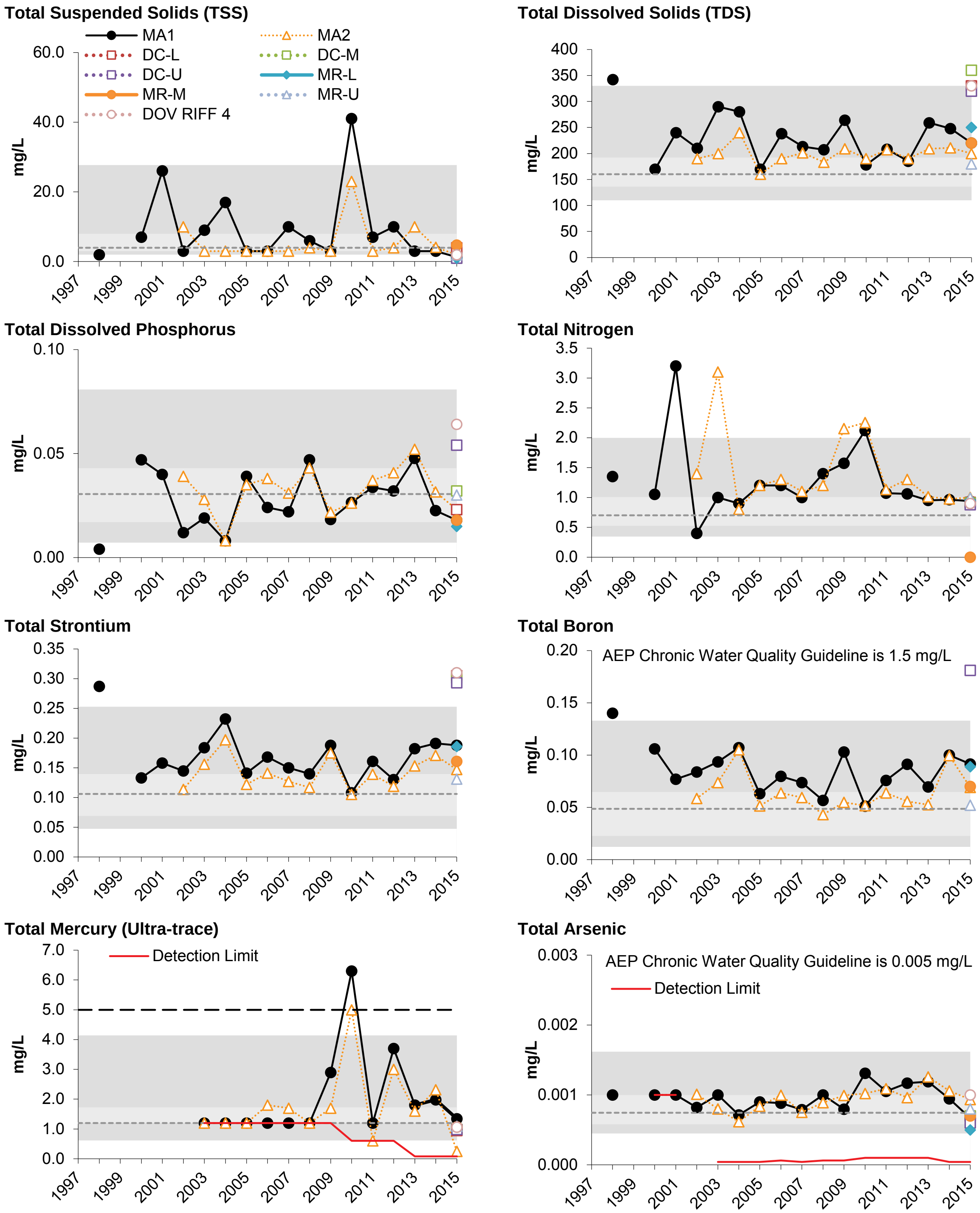
Variable	Units	Guideline[a]	November	December	January	February	March	May	June	July	August	September	October
Dover River lower (DC-L)													
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	-	-	-	**0.374**	-
Sulphide	mg/L	0.002	-	-	-	-	-	-	-	-	-	**0.010**	-
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	-	-	**0.0065**	-
Dover River middle (DC-M)													
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	-	-	-	**0.47**	-
Sulphide	mg/L	0.002	-	-	-	-	-	-	-	-	-	**0.012**	-
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	-	-	**0.008**	-
Dover River upper (DC-U)													
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	-	-	-	**0.549**	-
Sulphide	mg/L	0.002	-	-	-	-	-	-	-	-	-	**0.010**	-
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	-	-	**0.008**	-

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.5-7 Concentrations of selected water quality measurement endpoints in the MacKay River watershed (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



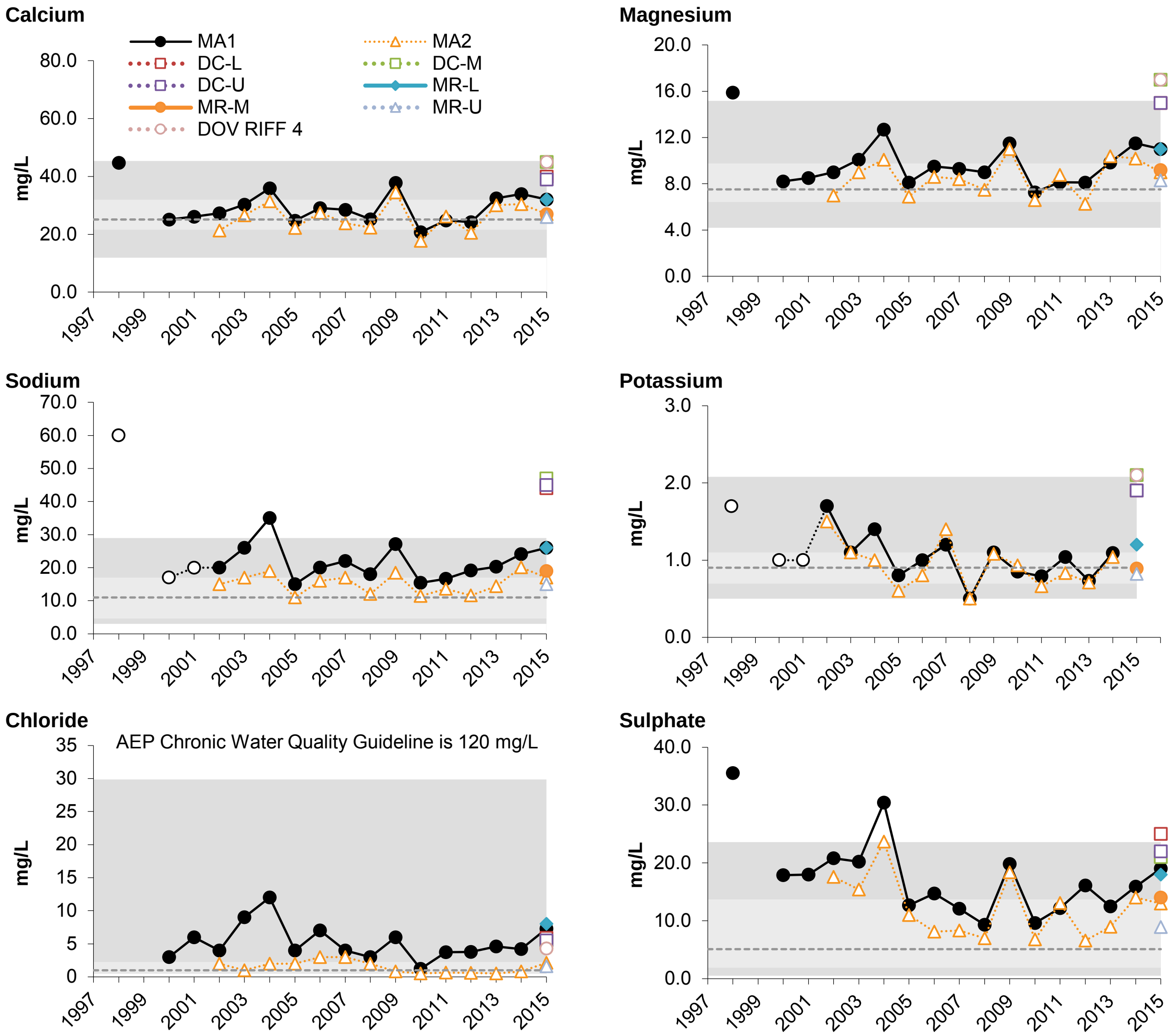
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.5-7 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.5-12 Concentrations of selected sediment quality measurement endpoints, MacKay River at wild fish health reaches (*test* stations MR-L and MR-M, and *baseline* station MR-U), fall 2015.

Variables	Units	Guideline	September 2015		
			MR-L	MR-M	MR-U
Physical variables					
Clay[4]	%	-	7.2	1.2	2.8
Silt[4]	%	-	11.3	2.0	3.6
Sand[4]	%	-	81.5	96.8	93.6
Total organic carbon	%	-	1.29	0.30	0.24
Total hydrocarbons					
BTEX	mg/kg	-	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	115	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	**994**	<20	26
Fraction 4 (C34-C50)	mg/kg	2,800[1]	598	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	mg/kg	0.0346[2]	<0.0007	0.0003	0.0003
Retene	mg/kg	-	0.0824	0.0020	0.0058
Total dibenzothiophenes	mg/kg	-	5.4025	0.0149	0.0161
Total PAHs	mg/kg	-	13.6839	0.0751	0.0930
Total Parent PAHs	mg/kg	-	0.2229	0.0058	0.0071
Total Alkylated PAHs	mg/kg	-	13.4610	0.0693	0.0859
Predicted PAH toxicity[3]	H.I.	1.0	**2.3408**	0.3480	0.4015
Metals that exceeded CCME guidelines in 2015					
None	mg/kg	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015					
Chrysene	mg/kg	0.0571	**0.0849**		
Chronic toxicity					
Chironomus survival - 10d	% surviving	-	84	96	94
Chironomus growth - 10d	mg/organism	-	1.74	1.87	1.88
Hyalella survival - 14d	% surviving	-	98	98	92
Hyalella growth - 14d	mg/organism	-	0.10	0.13	0.15

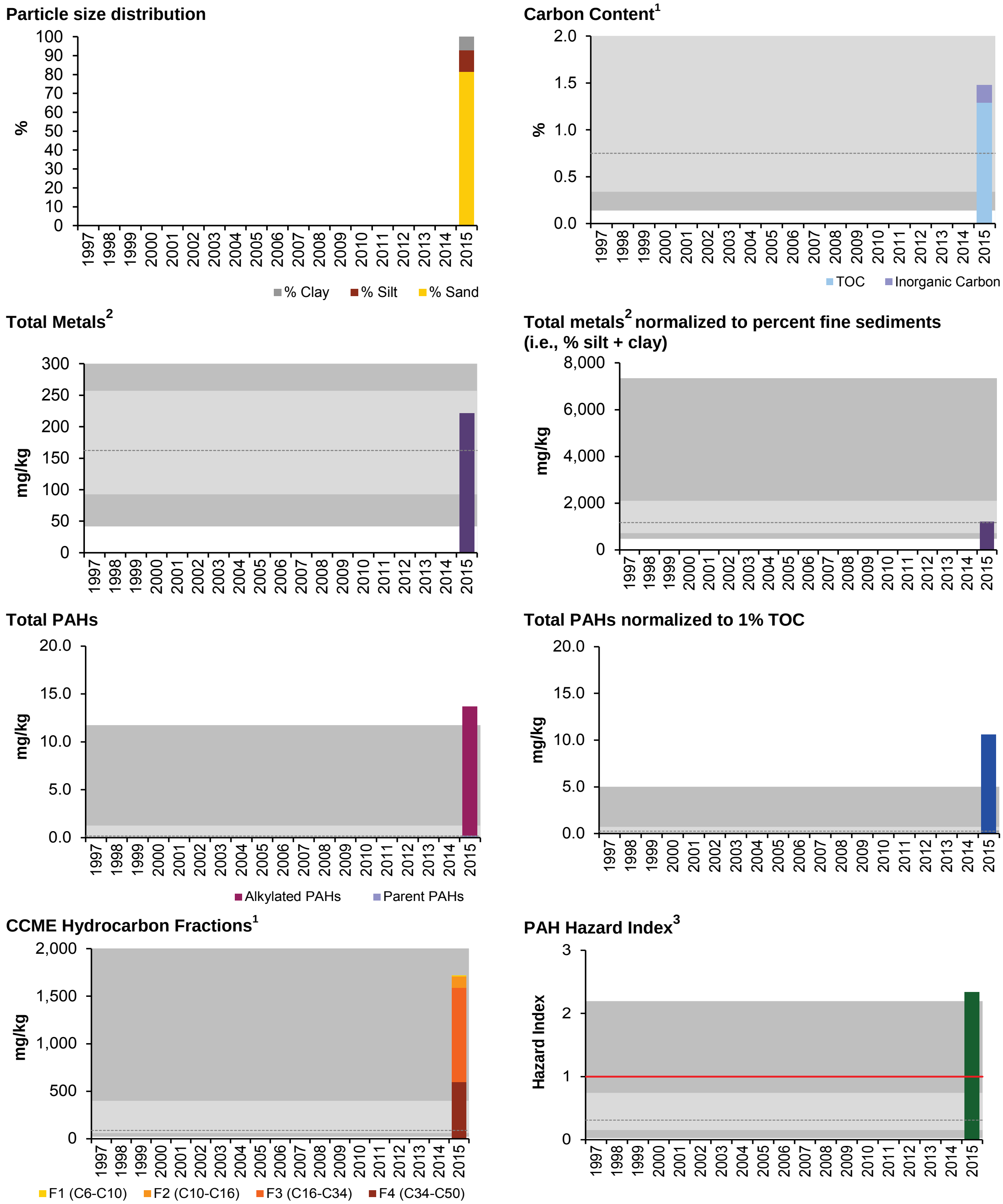
Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.5-8 Concentrations of selected sediment quality measurement endpoints at wild fish health *test* station MR-L, lower MacKay River (fall data) relative to regional *baseline* fall concentrations.



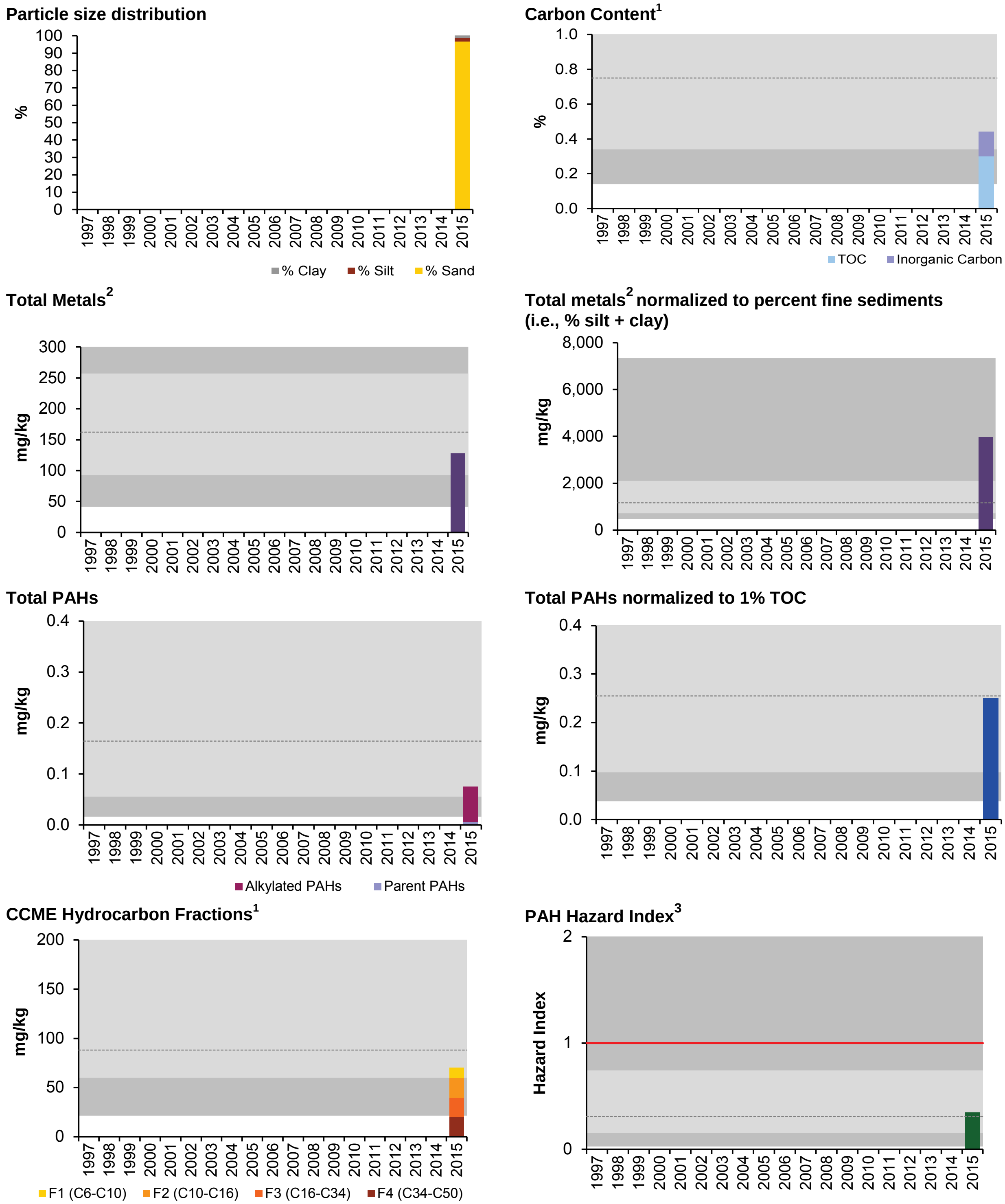
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.5-9 Concentrations of selected sediment quality measurement endpoints at wild fish health *test* station MR-M, mid MacKay River (fall data) relative to regional *baseline* fall concentrations.



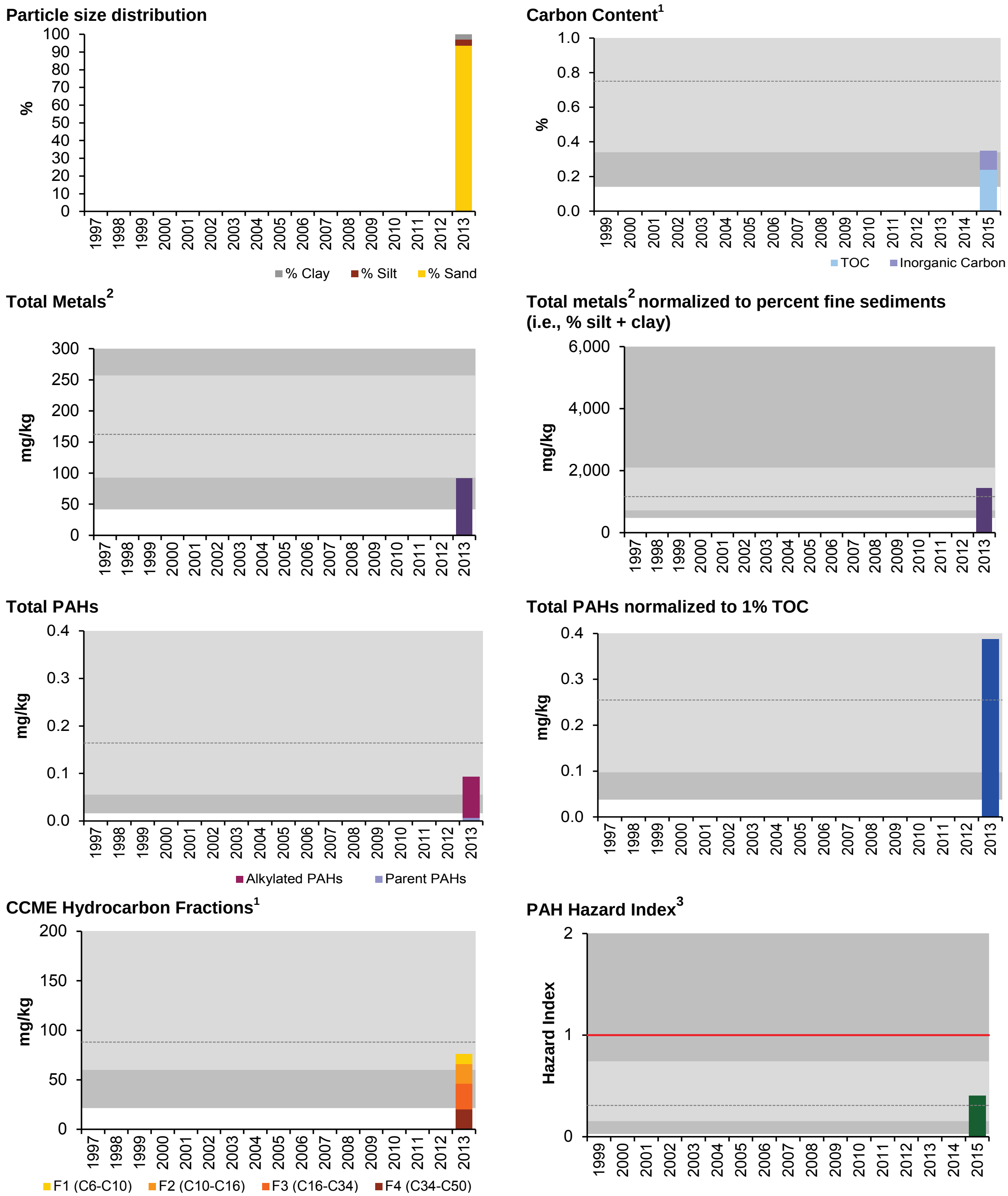
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.5-10 Concentrations of selected sediment quality measurement endpoints at wild fish health *baseline* station MR-U, upper MacKay River (fall data) relative to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Table 5.5-13 Concentrations of selected sediment quality measurement endpoints, Dover River at wild fish health reaches (*baseline* stations DC-L, DC-M, and DC-U), fall 2015.

Variables	Units	Guideline	September 2015		
			DC-L	DC-M	DC-U
Physical variables					
Clay[4]	%	-	2.7	<0.1	2.4
Silt[4]	%	-	3.7	0.8	4.2
Sand[4]	%	-	93.6	99.1	93.4
Total organic carbon	%	-	0.32	0.22	0.55
Total hydrocarbons					
BTEX	mg/kg	-	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	<20	41
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	<20	22
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	mg/kg	0.0346[2]	0.0005	0.0002	0.0005
Retene	mg/kg	-	0.0064	0.0027	0.0040
Total dibenzothiophenes	mg/kg	-	0.0253	0.0060	0.0131
Total PAHs	mg/kg	-	0.1542	0.0259	0.0537
Total Parent PAHs	mg/kg	-	0.0118	0.0023	0.0045
Total Alkylated PAHs	mg/kg	-	0.1423	0.0235	0.0491
Predicted PAH toxicity[3]	H.I.	1.0	0.7243	0.1227	0.1836
Metals that exceed CCME guidelines in 2015					
None	mg/kg	-	-	-	-
Chronic toxicity					
Chironomus survival - 10d	% surviving	-	94	74	84
Chironomus growth - 10d	mg/organism	-	1.87	1.67	2.10
Hyalella survival - 14d	% surviving	-	96	92	98
Hyalella growth - 14d	mg/organism	-	0.15	0.12	0.19

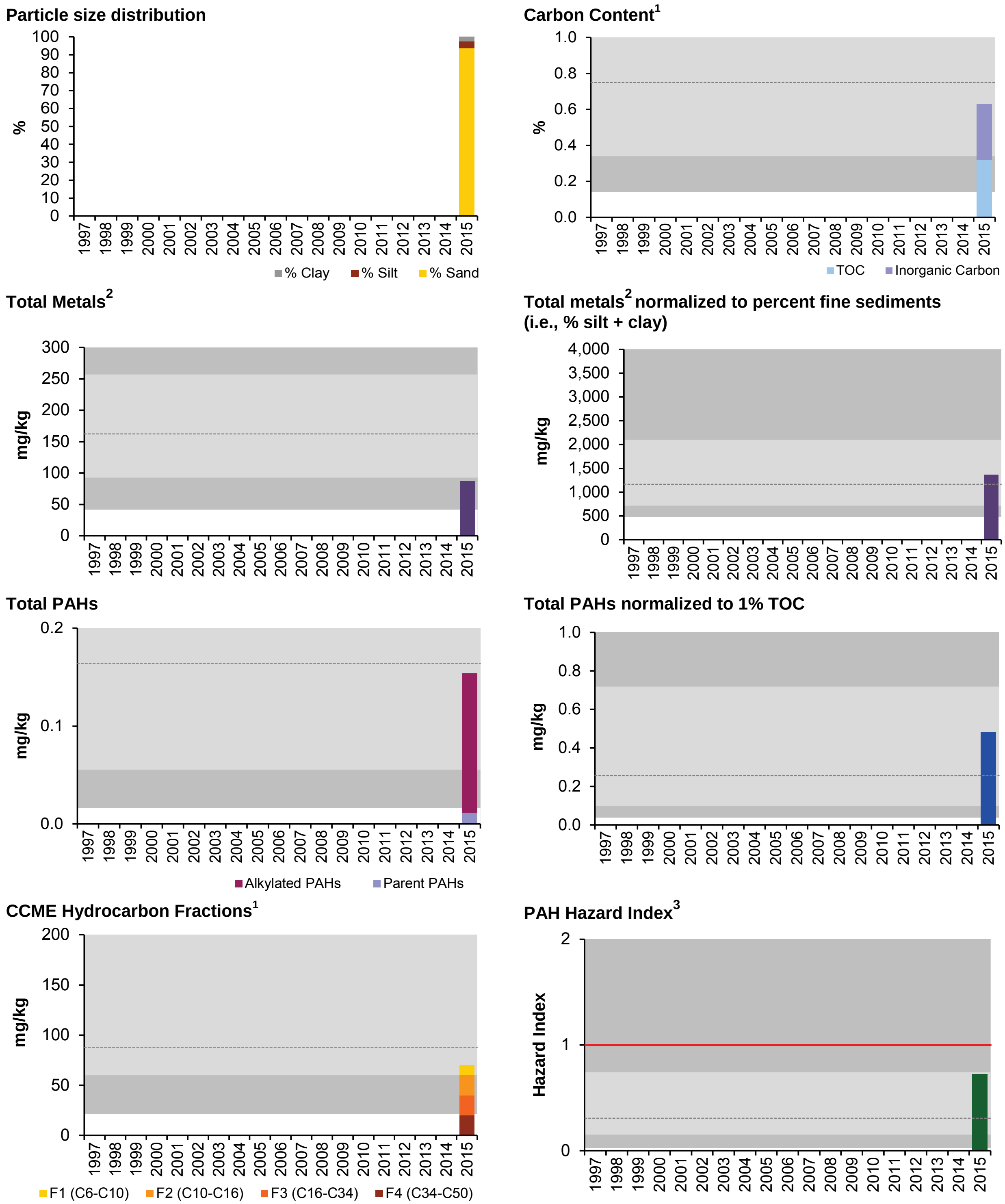
Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.5-11 Concentrations of selected sediment quality measurement endpoints at wild fish health *baseline* station DC-L, lower Dover River (fall data) relative to regional *baseline* fall concentrations.



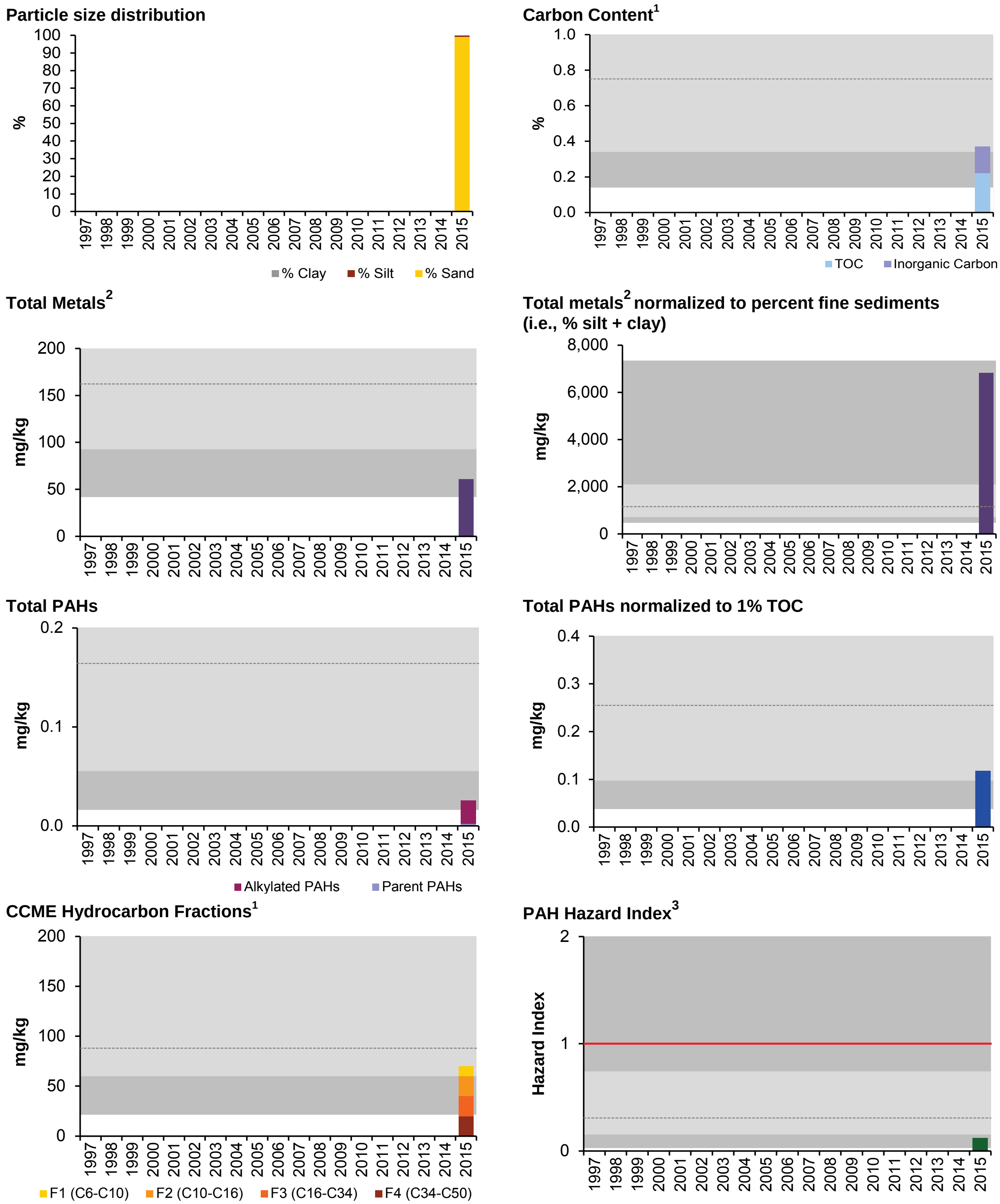
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.5-12 Concentrations of selected sediment quality measurement endpoints at wild fish health *baseline* station DC-M, mid Dover River (fall data) relative to regional *baseline* fall concentrations.



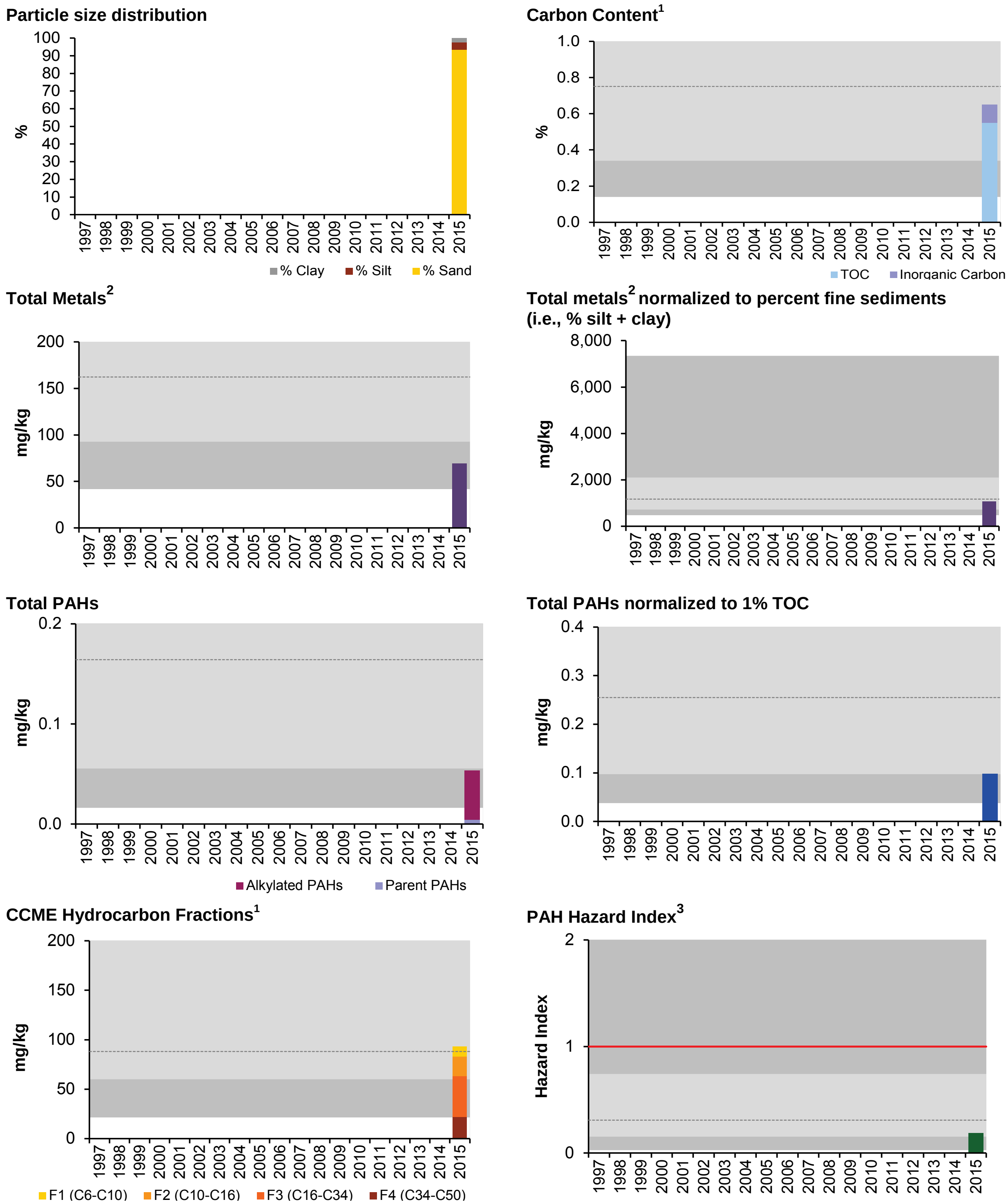
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.5-13 Concentrations of selected sediment quality measurement endpoints at wild fish health *baseline* station DC-U, upper Dover River (fall data) relative to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Table 5.5-14 Average habitat characteristics at fish community monitoring *test* reach MAR-F1 in the MacKay River, fall 2015.

Variable	Units	MAR-F1 Lower *Test* Reach
Sample date	-	Sept. 17, 2015
Habitat type	-	glide
Maximum depth	m	0.50
Mean depth	m	0.30
Bankfull channel width	m	55.5
Wetted channel width	m	45.0
Substrate		
Dominant	-	coarse gravel
Subdominant	-	fines
Instream cover		
Dominant	-	filamentous algae, macrophytes, small woody debris
Subdominant	-	-
Field water quality		
Dissolved oxygen	mg/L	6.8
Conductivity	µS/cm	277
pH	pH units	8.05
Water temperature	^{0}C	7.6
Water velocity		
Left bank velocity	m/s	0.28
Left bank water depth	m	0.20
Centre of channel velocity	m/s	0.39
Centre of channel water depth	m	0.23
Right bank velocity	m/s	0.12
Right bank water depth	m	0.14
Riparian cover – understory (<5 m)		
Dominant	-	woody shrubs and saplings
Subdominant	-	overhanging vegetation

Table 5.5-15 Total number and percent composition of fish species captured in reaches of the MacKay River, 2009 to 2015.

Common Name	Code	Total Species Catch													
		MAR-F1						MAR-F2				MAR-F3			
		2009	2011	2012	2013	2014	2015	2011	2012	2013	2014	2011	2012	2013	2014
brook stickleback	BRST	1	-	1	-	-	-	-	-	-	-	-	-	-	-
burbot	BURB	-	-	-	5	7	-	-	-	-	-	-	-	-	-
flathead chub	FLCH	-	-	1	-	-	-	-	-	-	-	-	-	-	-
finescale dace	FNDC	-	1	-	-	-	-	-	1	-	-	-	-	-	-
goldeye	GOLD	-	-	1	-	-	-	-	-	-	-	-	-	-	-
lake chub	LKCH	1	3	-	-	-	44	22	30	12	17	6	3	1	30
longnose dace	LNDC	-	4	-	-	2	2	21	3	36	45	1	1	11	43
longnose sucker	LNSC	-	1	-	-	-	9	2	1	3	1	1	1	2	-
northern pike	NRPK	1	-	-	-	-	2	-	-	1	-	-	1	-	-
pearl dace	PRDC	-	-	7	-	1	-	-	-	-	-	-	-	-	-
slimy sculpin	SLSC	-	1	-	3	3	-	1	2	4	3	21	12	7	20
spoonhead sculpin	SPSC	9	7	-	-	-	-	-	-	-	-	-	-	-	-
spottail shiner	SPSH	-	-	2	-	2	2	-	-	-	-	-	-	-	-
trout-perch	TRPR	6	10	133	-	4	31	8	5	-	11	9	23	1	1
walleye	WALL	-	-	2	1	2	1	-	-	-	-	-	-	-	-
white sucker	WHSC	-	2	3	-	-	3	-	-	-	6	-	-	-	9
yellow perch	YLPR	-	-	-	1	2	2	-	-	-	-	-	-	-	-
Total		**18**	**29**	**150**	**10**	**23**	**96**	**54**	**42**	**56**	**83**	**38**	**41**	**22**	**103**
Total Species Richness		**5**	**8**	**9**	**4**	**8**	**9**	**5**	**6**	**5**	**6**	**5**	**5**	**5**	**5**
Electrofishing effort (secs)		**2,980**	**1,372**	**2,920**	**3,015**	**2,982**	**2,327**	**1,480**	**2,017**	**2,529**	**2,548**	**1,375**	**1,977**	**2,509**	**2,521**

Common Name	Code	Percent of Total Catch													
		MAR-F1						MAR-F2				MAR-F3			
		2009	2011	2012	2013	2014	2015	2011	2012	2013	2014	2011	2012	2013	2014
brook stickleback	BRST	5.6	0	0.7	0	0	0	0	0	0	0	0	0	0	0
burbot	BURB	0	0	0	50.0	30.4	0	0	0	0	0	0	0	0	0
flathead chub	FLCH	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0
finescale dace	FNDC	0	3.4	0	0	0	0	0	2.4	0	0	0	0	0	0
goldeye	GOLD	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0
lake chub	LKCH	5.6	10.3	0	0	0	45.8	40.7	71.4	21.4	20.5	15.8	7.3	4.5	29.1
longnose dace	LNDC	0	13.8	0	0	8.7	2.1	38.9	7.1	64.3	54.2	2.6	2.4	50.0	41.7
longnose sucker	LNSC	0	3.4	0	0	0	9.4	3.7	2.4	5.4	1.2	2.6	2.4	9.1	0
northern pike	NRPK	5.6	0	0	0	0	2.1	0	0	1.8	0	0	2.4	0	0
pearl dace	PRDC	0	0	4.7	0	4.3	0	0	0	0	0	0	0	0	0
slimy sculpin	SLSC	0	3.4	0	30.0	13.0	0	1.9	4.8	7.1	3.6	55.3	29.3	31.8	19.4
spoonhead sculpin	SPSC	50	24.1	0	0	0	0	0	0	0	0	0	0	0	0
spottail shiner	SPSH	0	0	1.3	0	8.7	2.1	0	0	0	0	0	0	0	0
trout-perch	TRPR	33.3	34.5	88.7	0	17.4	32.3	14.8	11.9	0	13.3	23.7	56.1	4.5	1.0
walleye	WALL	0	0	1.3	10.0	8.7	1.0	0	0	0	0	0	0	0	0
white sucker	WHSC	0	6.9	2.0	0	0	3.1	0	0	0	7.2	0	0	0	8.7
yellow perch	YLPR	0	0	0	10.0	8.7	2.1	0	0	0	0	0	0	0	0
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**5**	**8**	**9**	**4**	**8**	**9**	**5**	**6**	**5**	**6**	**5**	**5**	**5**	**5**
Electrofishing effort (secs)		-	-	-	-	-	-	-	-	-	-	-	-	-	-

Underline denotes *baseline* reach.

Table 5.5-16 Summary of fish community measurement endpoints (± 1SD) for *test* reach MAR-F1 of the MacKay River, 2009 to 2015.

Year	Abundance		Richness			Diversity		ATI		CPUE	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2009	0.04	-	4	4.00	-	0.58	-	5.57	-	3.89	-
2011	0.12	0.05	7	3.80	0.84	0.69	0.06	5.93	0.95	2.09	0.87
2012	0.50	0.30	8	3.00	1.87	0.17	0.19	8.34	0.16	5.19	3.21
2013	0.03	0.04	4	1.40	1.52	0.14	0.31	2.54	1.08	0.33	0.46
2014	0.02	0.01	7	3.00	1.22	0.54	0.31	4.63	1.58	0.71	0.36
2015	0.12	0.08	9	4.20	1.48	0.44	0.27	6..69	0.99	4.15	2.65

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

SD = standard deviation across sub-reaches within a reach

Table 5.5-17 Results of analysis of variance (ANOVA) testing for differences in fish community measurement endpoints for *test* reach MAR-F1 of the MacKay River.

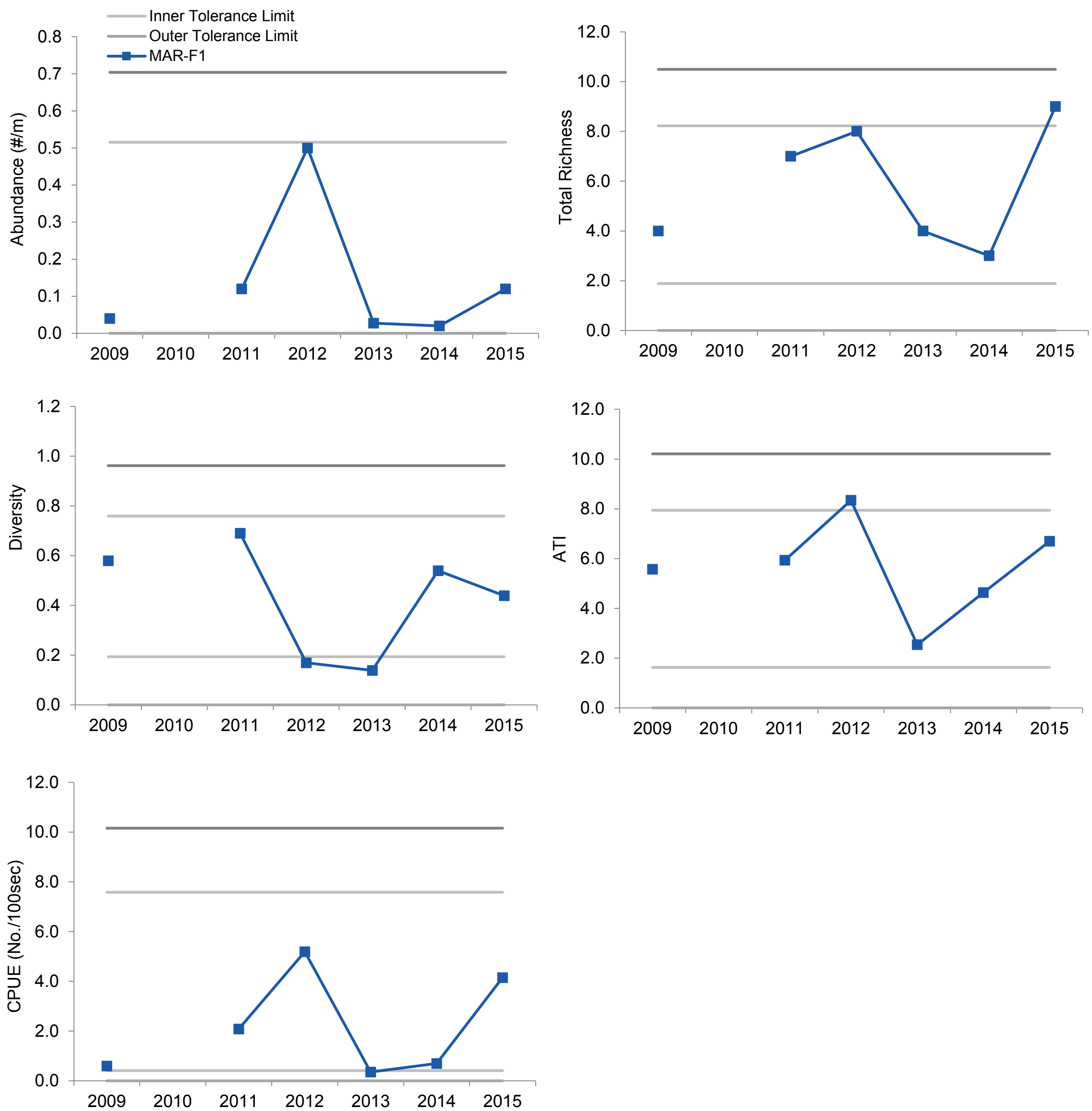
Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
Abundance	0.12*	6%	No change
Richness	0.74	0%	No change
Diversity	0.81*	0%	No change
ATI	0.49	0%	No change
CPUE (No./100 sec)	0.76*	0%	No change

Bold values indicate significant difference (p≤0.05).

***** data were ranked transformed to meet assumptions of ANOVA

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Figure 5.5-14 Variation in fish community measurement endpoints for *test* reach MAR-F1 in the MacKay River from 2009 to 2015 relative to regional *baseline* conditions.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data from cluster 3 (see Table 3.2-10).

A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Table 5.5-18 Average habitat characteristics of wild fish health monitoring reaches in the MacKay River watershed, fall 2015.

Watercourse	Units	MacKay River			Dover River		
		MR-U Upper *baseline* reach	MR-M Middle *test* reach	MR-L Lower *test* reach	DC-U Upper *baseline* reach	DC-M Middle *baseline* reach	DC-L Lower *baseline* reach
Sample date	-	Oct. 6, 2015	Oct. 7, 2015	Oct. 7, 2015	Oct. 7, 2015	Oct. 2, 2015	Oct. 2, 2015
Mean water depth	m	0.43	0.4	0.5	0.5	0.4	0.38
Mean velocity	m/s	0.4	0.3	0.43	0.1	0.1	0.1
Field water quality							
Water temperature	°C	6.7	4.9	8.6	3.6	6.6	7
Conductivity	μS/cm	208	258	307	463	427	466
Dissolved oxygen (DO)	mg/L	11.6	11	10.4	10.1	9.5	10.9
pH		7.87	7.48	6.83	8.09	7.08	7.47
Substrate	-	cobble/ boulder	cobble/sand/ fines	cobble/ boulder	cobble/ gravel	cobble/gravel/ fines	cobble/ gravel

Figure 5.5-15 Daily mean temperatures for wild fish health reaches in the MacKay River, August to September 2015.

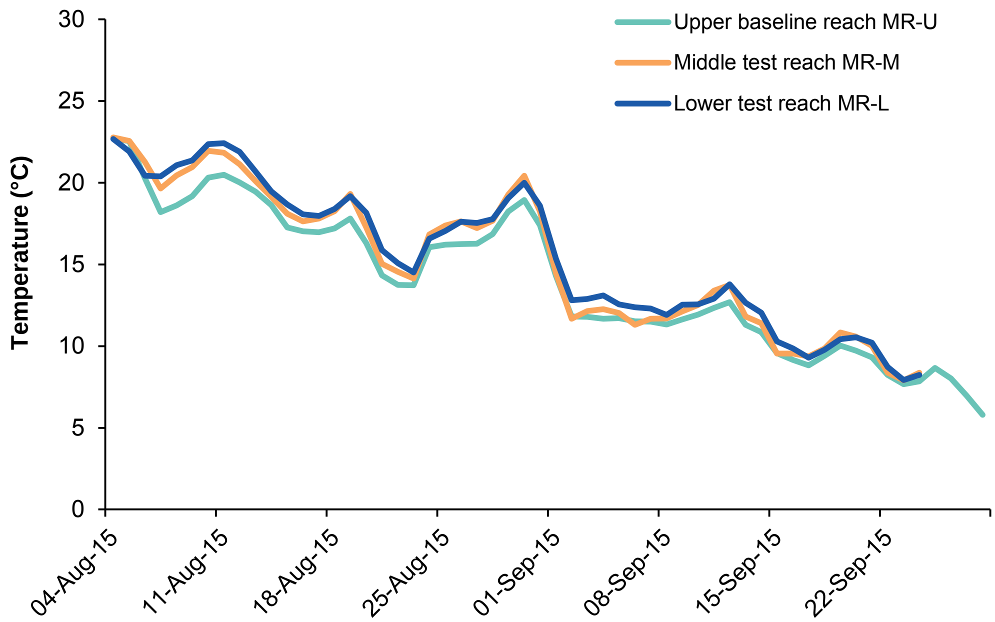


Table 5.5-19 Summary of fish caught and mean length, weight, and relative abundance of juveniles at each sampling reach in the MacKay River watershed, fall 2015.

Watercourse	Species	Reach	Designation	Sample Size		Relative Abundance (%)		Juvenile Measurements		Percentage of External Abnormalities
				Juvenile	Adult	Juvenile	Adult	Mean Length (mm)	Mean Weight (g)	
MacKay River	LNDC	MR-U	upper *baseline* reach	40	76	34.5	65.5	38.8	0.70	1.72
		MR-M	middle *test* reach	46	37	55.4	44.6	38.0	0.72	0
		MR-L	lower *test* reach	84	75	52.8	47.2	40.2	0.71	1.89
Dover River	LKCH	DC-U	upper *baseline* reach	100	59	62.9	37.1	32.6	0.44	7.55
		DC-M	middle *baseline* reach	99	53	65.1	34.9	33.7	0.45	5.92
		DC-L	lower *baseline* reach	100	74	57.5	42.5	38.9	0.65	9.77

LNDC = longnose dace; LKCH = lake chub

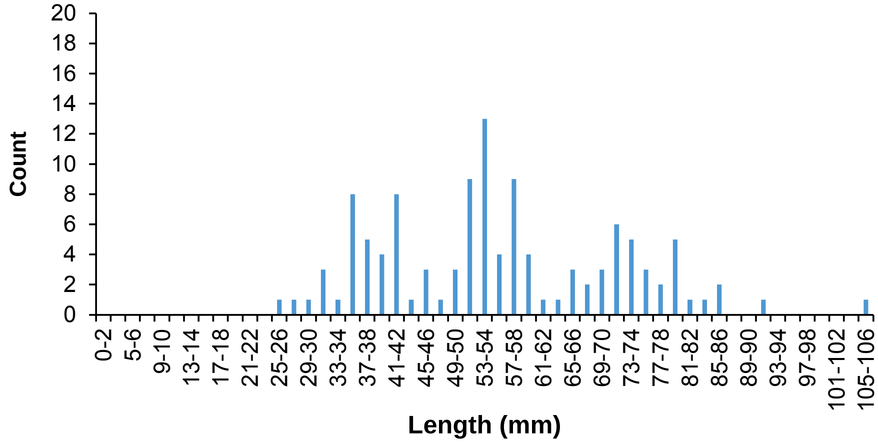
Table 5.5-20 Summary of morphometric data (mean ± 1SE) for adult target species of reaches in the MacKay River Watershed, fall 2015.

Variable	Units	Mackay River (longnose dace)						Dover River (lake chub)					
		MR-U Upper *baseline* reach		MR-M Middle *test* reach		MR-L Lower *test* reach		DC-U Upper *baseline* reach		DC-M Middle *baseline* reach		DC-L Lower *baseline* reach	
N	-	20	20	15	20	20	20	19	20	16	20	19	20
Sex	-	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Age	years	1.8 ± 0.2	2.5 ± 0.2	1.7 ± 0.2	2.0 ± 0.2	1.5 ± 0.1	2.5 ± 0.2	2.5 ± 0.1	2.7 ± 0.2	1.9 ± 0.2	2.3 ± 0.1	1.2 ± 0.2	1.9 ± 0.2
Length	mm	64.75 ± 1.91	78.05 ± 2.14	67.93 ± 1.91	75.80 ± 1.42	65.45 ± 1.02	79.30 ± 1.62	71.00 ± 1.13	79.50 ± 2.86	73.00 ± 2.18	85.75 ± 2.11	71.95 ± 2.10	83.50 ± 2.12
Weight	g	2.82 ± 0.25	5.15 ± 0.57	3.20 ± 0.32	4.93 ± 0.29	2.69 ± 0.11	5.16 ± 0.35	3.64 ± 0.19	5.71 ± 0.69	4.27 ± 0.41	6.80 ± 0.43	3.94 ± 0.39	5.98 ± 0.47
K	-	0.99 ± 0.01	1.03 ± 0.03	0.98 ± 0.02	1.11 ± 0.02	0.95 ± 0.01	1.01 ± 0.02	1.01 ± 0.03	1.03 ± 0.02	1.04 ± 0.02	1.06 ± 0.02	1.00 ± 0.02	0.99 ± 0.01
GSI	-	1.14 ± 0.09	8.66 ± 0.46	1.08 ± 0.09	8.81 ± 0.63	0.72 ± 0.09	7.42 ± 0.51	0.90 ± 0.08	6.91 ± 0.58	0.90 ± 0.07	8.31 ± 0.46	0.87 ± 0.07	6.74 ± 0.38
LSI	-	1.61 ± 0.08	1.87 ± 0.09	1.42 ± 0.13	1.94 ± 0.16	0.82 ± 0.11	1.53 ± 0.18	1.15 ± 0.10	1.70 ± 0.09	1.43 ± 0.11	1.43 ± 0.09	1.26 ± 0.06	1.54 ± 0.09

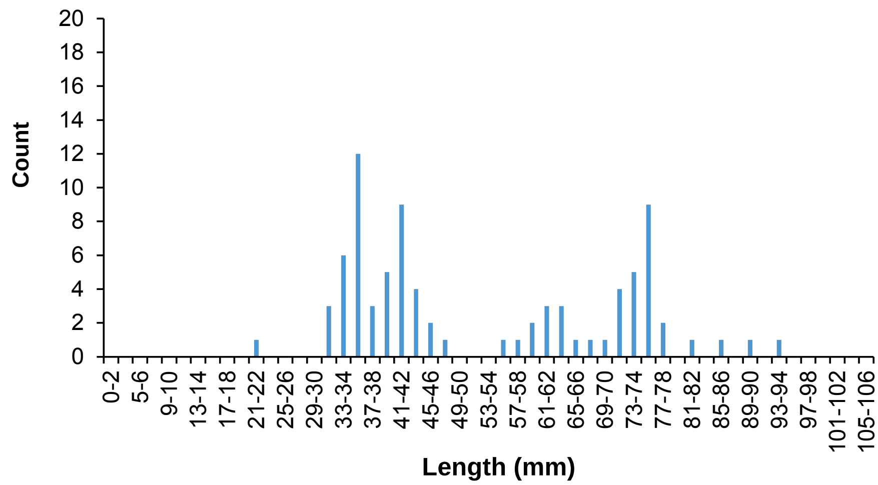
K = condition, GSI = gonadosomatic index, LSI = liversomatic index

Figure 5.5-16 Length-frequency distributions of longnose dace in wild fish health reaches of the MacKay River, fall 2015.

Upper *baseline* reach MR-U



Middle *test* reach MR-M



Lower *test* reach MR-L

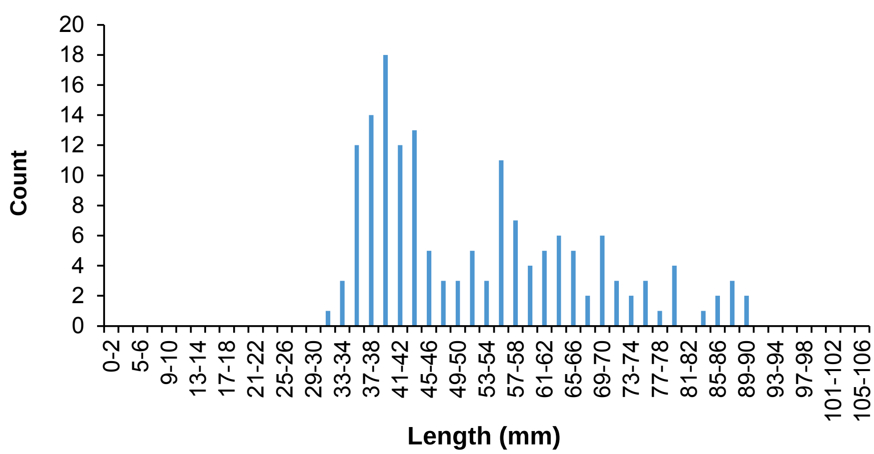


Figure 5.5-17 Relative age-frequency distribution for longnose dace at *baseline* reach MR-U and *test* reaches MR-M and MR-L in the MacKay River watershed, fall 2015.

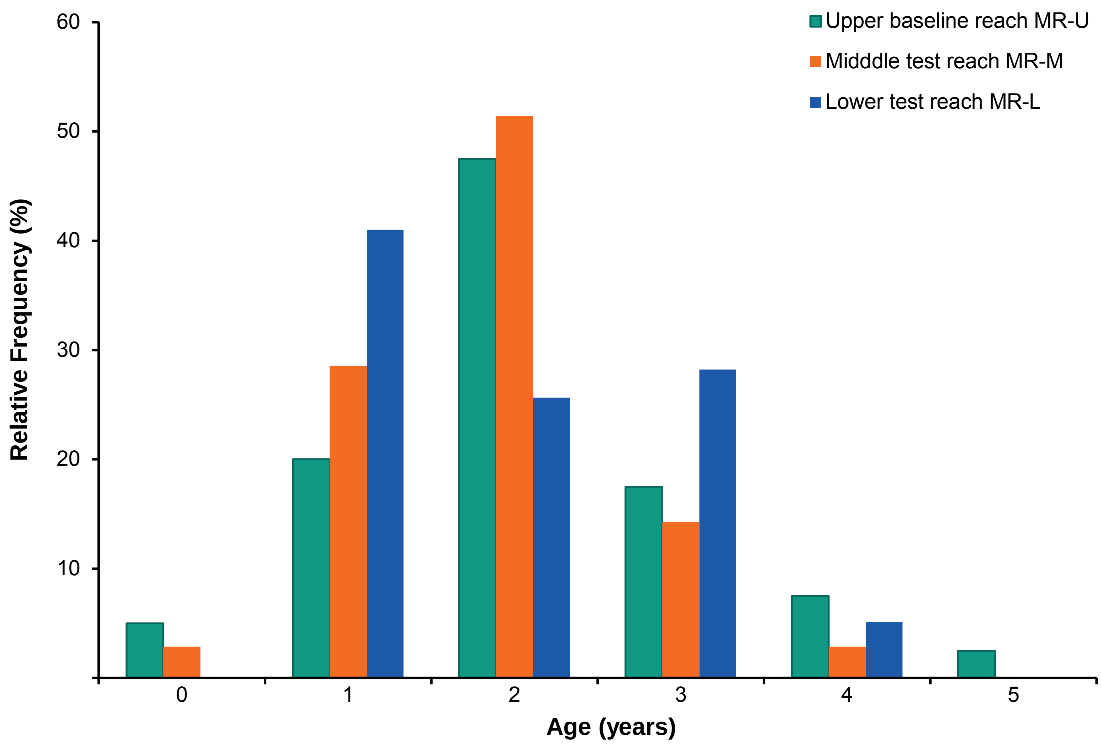


Table 5.5-21 Results of analysis of variance (ANOVA) and analysis of covariance (ANCOVA) for differences in measurement endpoints of longnose dace along the MacKay River (*baseline* reach MR-U and *test* reaches MR-M and MR-L), fall 2015.

Analysis	Sex	Comparison	Actual Sample Size	P-value	Direction	Effects Criteria	% Difference[1]	Post Hoc[2]
ANOVA								
Survival – Age								
	Female	MR-U vs. MR-M	20,20	0.33	None	±25%	-18%	*0.53*
		MR-M vs MR-L	20,20	0.33	None	±25%	23%	*0.53*
		MR-U vs MR-L	20,20	1.00	None	±25%	0%	*0.53*
	Male	MR-U vs. MR-M	20,15	0.95	None	±25%	-5%	*0.41*
		MR-M vs MR-L	15,19	0.75	None	±25%	-12%	*0.41*
		MR-U vs MR-L	20,19	0.50	None	±25%	-16%	*0.41*
ANCOVA[3]								
Growth – Weight-at-age								
	Female	MR-U vs. MR-M	19,20	0.37	None	±25%	12%	*0.88*
		MR-M vs MR-L	20,20	0.94	None	±25%	-3%	*0.88*
		MR-U vs MR-L	19,20	0.56	None	±25%	9%	*0.88*
	Male	MR-U vs. MR-M	20,14	0.54	None	±25%	6%	*0.43*
		MR-M vs MR-L	14,19	0.84	None	±25%	-4%	*0.43*
		MR-U vs MR-L	20,14	0.85	None	±25%	2%	*0.43*
Reproduction – Relative gonad weight								
	Female	MR-U vs. MR-M	19,20	0.70	None	±25%	7%	0.92
		MR-M vs MR-L	20,20	0.08	None	±25%	-18%	0.92
		MR-U vs MR-L	19,20	0.36	None	±25%	-12%	0.92
	Male	MR-U vs. MR-M	18,13	-	-	-	-	-
		MR-M vs MR-L	13,20	-	-	-	-	-
		MR-U vs MR-L	18,20	-	-	-	-	-
Energy Storage – Relative liver weight								
	Female	MR-U vs. MR-M	20,20	0.92	None	±25%	0%	*0.12*
		MR-M vs MR-L	20,20	0.19	None	±25%	-20%	*0.12*
		MR-U vs MR-L	20,20	0.35	None	±25%	-20%	*0.12*
	Male*	MR-U vs. MR-M	20,15	0.51	None	±25%	-15%	-
		MR-M vs MR-L	15,20	**<0.001**	MR-M > MR-L	±25%	-46%	-
		MR-U vs MR-L	20,20	**<0.001**	MR-U > MR-L	±25%	-54%	-
Energy Storage – Condition								
	Female*	MR-U vs. MR-M	20,20	0.10	None	±10%	8%	-
		MR-M vs MR-L	20,22	**0.01**	MR-M > MR-L	±10%	10%	-
		MR-U vs MR-L	20,22	0.68	None	±10%	-3%	-
	Male	MR-U vs. MR-M	22,14	0.43	None	±10%	-3%	-
		MR-M vs MR-L	14,20	0.19	None	±10%	-5%	-
		MR-U vs MR-L	22,20	**0.003**	MR-U > MR-L	±10%	-7%	-

Bold values indicate significant difference ($p<0.05$).

* Data were log-transformed.

1 Percent difference was calculated using ANOVA-adjusted least squared means with upstream reaches as the reference. Underlined values signify instances when significant differences were observed and the effect size exceeded EC's criterion for 25% for age, weight-at-age, GSI, and LSI, and 10% for condition.

2 Power was calculated for the three-way ANOVA when no significant differences were found among reaches. Values in *italics* denote comparisons where power was inadequate and sample size was too low.

3 The results of ANCOVA tests are presented only if slopes of the regression of the variables used in the ANCOVA were not significantly different ($p<0.01$).

Figure 5.5-18 Relationship between body weight (g) and gonad weight (g) of female and male longnose dace at *baseline* reach MR-U and *test* reaches MR-M and MR-L in the MacKay River, fall 2015.

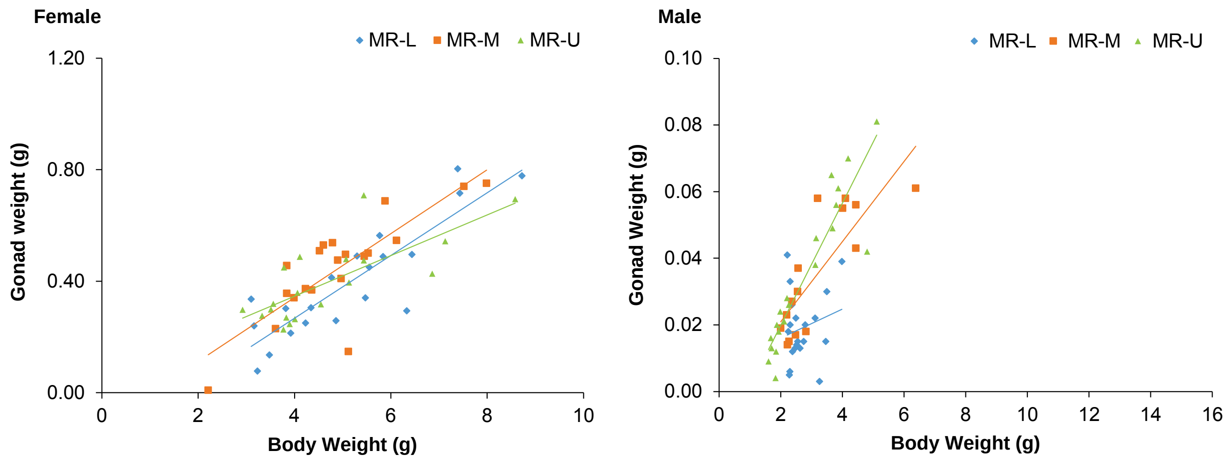
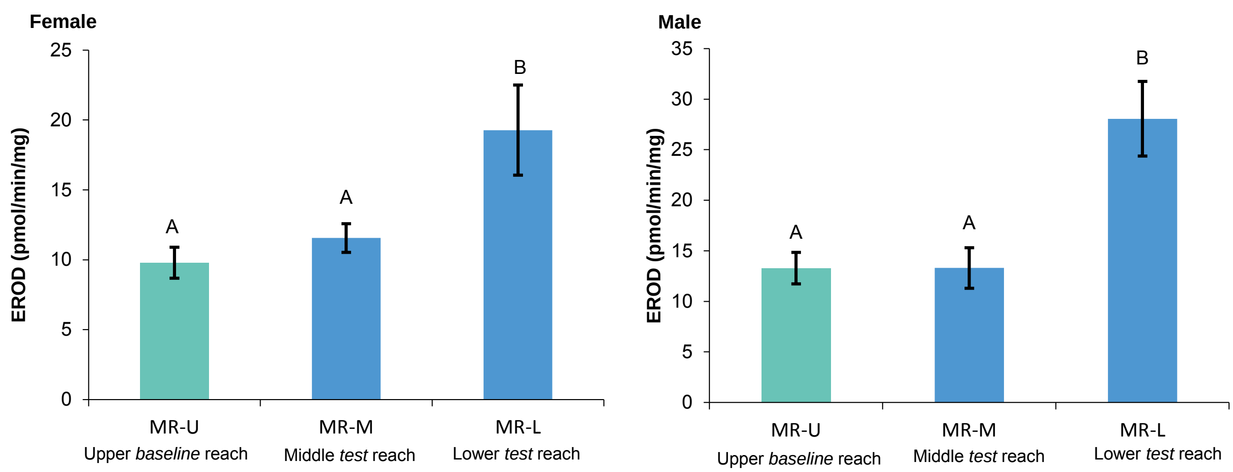


Figure 5.5-19 Mean EROD activity (± 1SE) of female and male longnose dace at *baseline* (MR-U) and test (MR-M and MR-L) reaches on the MacKay River, fall 2015.



Note: Similar letters denote no significant difference between reaches and different letters denote where statistically significant ($p \leq 0.05$) differences exist.

Figure 5.5-20 Daily mean temperatures for wild fish health reaches in the Dover River, August to September 2015.

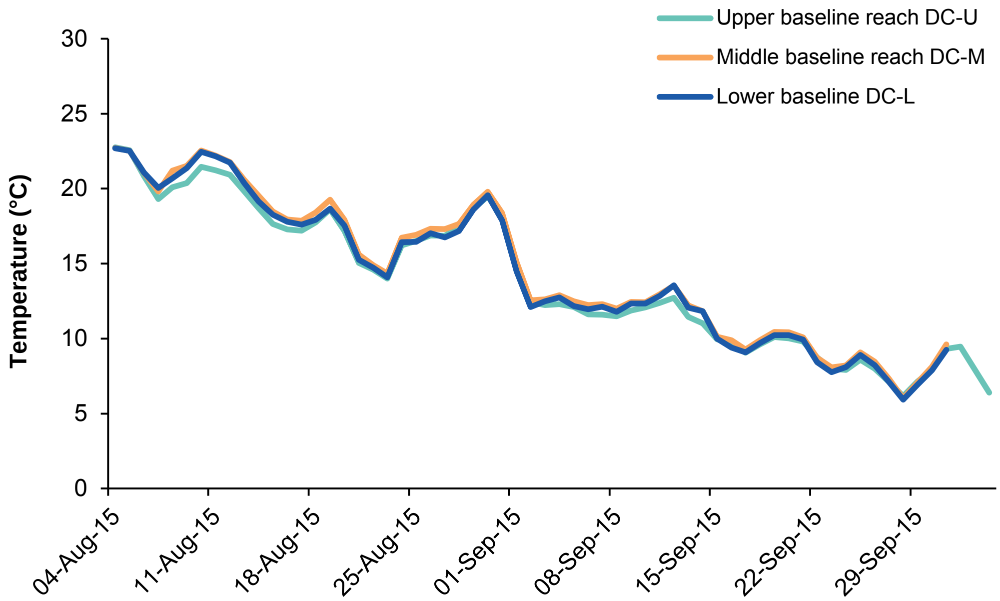
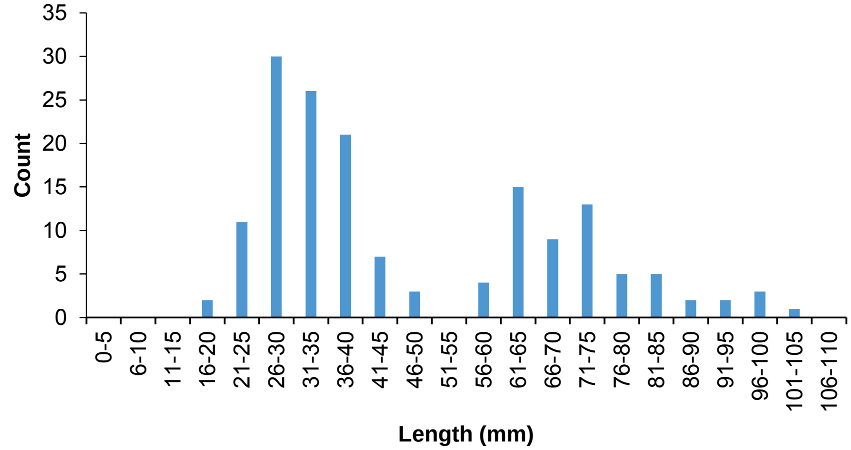
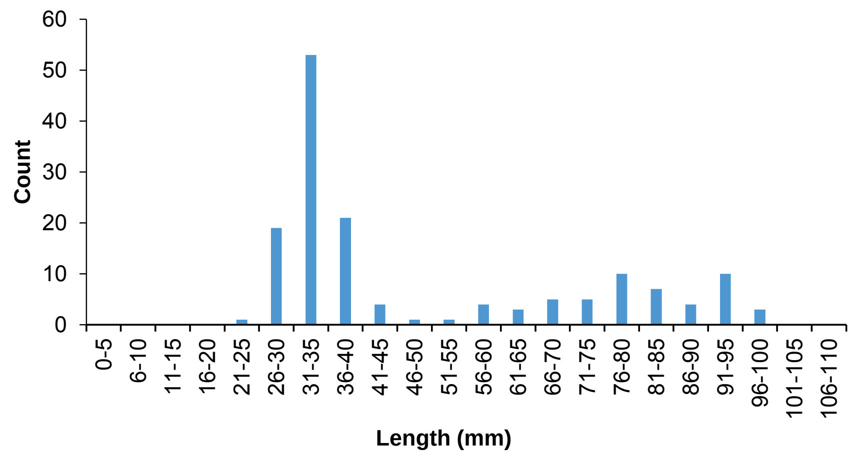


Figure 5.5-21 Length-frequency distributions of lake chub in wild fish health reaches of the Dover River, fall 2015.

Upper *baseline* reach DC-U



Middle *baseline* reach DC-M



Lower *baseline* reach DC-L

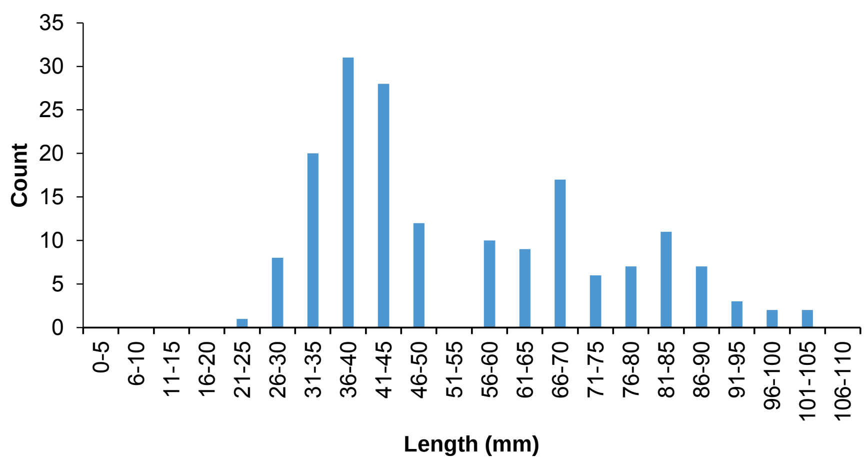


Figure 5.5-22 Relative age-frequency distribution for lake chub at *baseline* reaches of the Dover River, fall 2015.

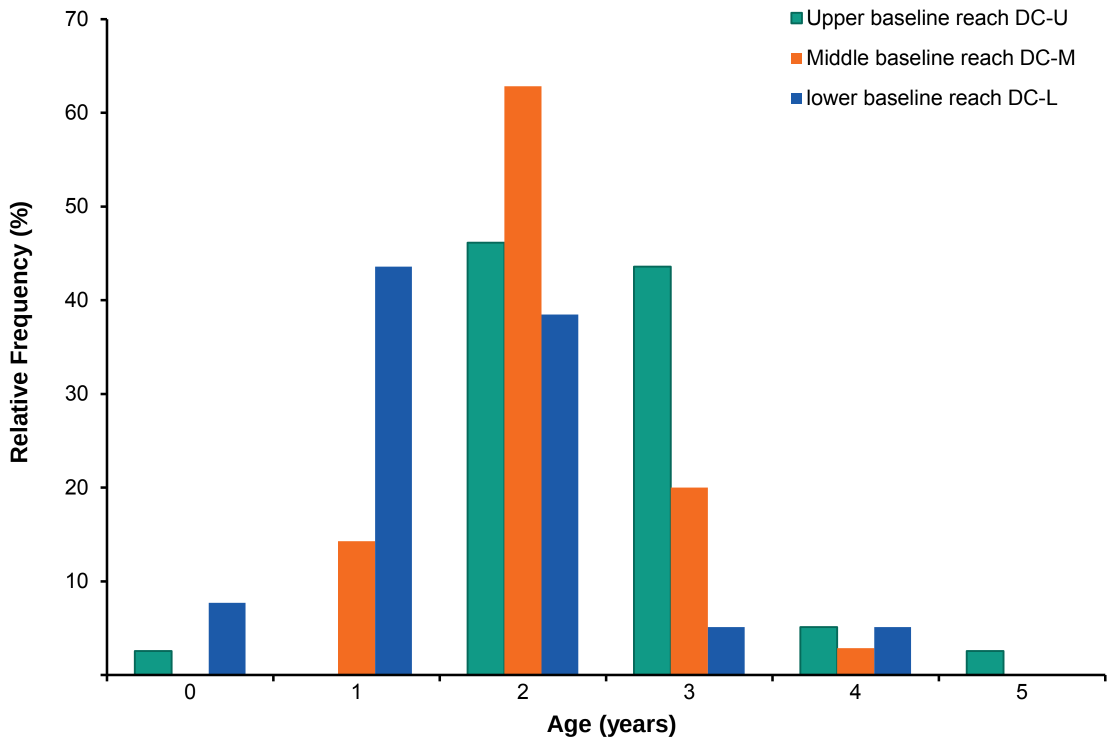


Table 5.5-22 Results of analysis of variance (ANOVA) and analysis of covariance (ANCOVA) for differences in measurement endpoints of lake chub in the Dover River (*baseline* reaches DC-U, DC-M and DC-L), fall 2015.

Analysis	Sex	Comparison	Actual Sample Size	P-value	Direction	Effects Criteria	% Difference[1]	Post Hoc[2]
ANOVA								
Survival – Age								
	Female	DC-U vs. DC-M	20,19	0.17	None	±25%	-17%	*0.81*
		DC-M vs DC-L	19,20	0.24	None	±25%	-18%	*0.81*
		DC-U vs. DC-L	20,20	**0.003**	DC-U > DC-L	±25%	<u>-32%</u>	*0.81*
	Male	DC-U vs. DC-M	19,16	**0.03**	DC-U > DC-M	±25%	-24%	-
		DC-M vs DC-L	16,19	**0.02**	DC-M > DC-L	±25%	<u>-36%</u>	-
		DC-U vs. DC-L	19,19	**<0.001**	DC-U > DC-L	±25%	<u>-51%</u>	-
ANCOVA[3]								
Growth – Weight-at-age								
	Female	DC-U vs. DC-M	20,19	0.06	None	±25%	31%	*0.51*
		DC-M vs DC-L	19,20	0.95	None	±25%	-3%	*0.51*
		DC-U vs. DC-L	20,20	0.14	None	±25%	26%	*0.51*
	Male	DC-U vs. DC-M	19,16	0.11	None	±25%	31%	*0.44*
		DC-M vs DC-L	16,19	0.98	None	±25%	2%	*0.44*
		DC-U vs. DC-L	19,19	0.14	None	±25%	34%	*0.44*
Reproduction – Relative gonad weight								
	Female	DC-U vs. DC-M	19,19	0.94	None	±25%	-2%	-
		DC-M vs DC-L	19,20	**0.02**	DC-M > DC-L	±25%	-14%	-
		DC-U vs. DC-L	19,20	**0.008**	DC-U > DC-L	±25%	-15%	-
	Male	DC-U vs. DC-M	18,16	0.99	None	±25%	0%	*0.85*
		DC-M vs DC-L	16,19	0.93	None	±25%	0%	*0.85*
		DC-U vs. DC-L	18,19	0.91	None	±25%	0%	*0.85*
Energy Storage – Relative liver weight								
	Female	DC-U vs. DC-M	19,20	**0.01**	DC-U > DC-M	±25%	-18%	-
		DC-M vs DC-L	20,20	0.46	None	±25%	11%	-
		DC-U vs. DC-L	19,20	0.09	None	±25%	-9%	-
	Male*	DC-U vs. DC-M	18,16	0.20	None	±25%	17%	*0.19*
		DC-M vs DC-L	16,20	0.50	None	±25%	10%	*0.19*
		DC-U vs. DC-L	18,20	0.78	None	±25%	6%	*0.19*
Energy Storage – Condition								
	Female*	DC-U vs. DC-M	36,36	0.82	None	±10%	1%	-
		DC-M vs DC-L	36,45	**0.02**	DC-M > DC-L	±10%	-5%	-
		DC-U vs. DC-L	36,45	0.08	None	±10%	-4%	-
	Male	DC-U vs. DC-M	19,16	0.23	None	±10%	8%	*0.06*
		DC-M vs DC-L	16,19	0.67	None	±10%	-5%	*0.06*
		DC-U vs. DC-L	19,19	0.68	None	±10%	3%	*0.06*

Bold values indicate significant difference ($p<0.05$).

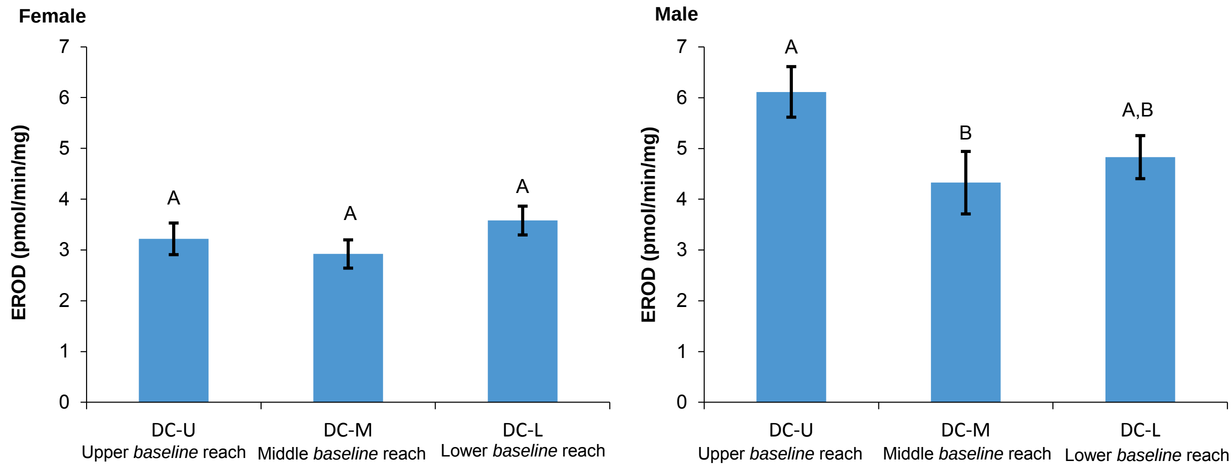
* Data were log-transformed.

[1] Percent difference was calculated using ANOVA-adjusted least squared means with upstream reaches as the reference. <u>Underlined</u> values signify instances when significant differences were observed and the effect size exceeded EC's criterion for 25% for age, weight-at-age, GSI, and LSI, and 10% for condition.

[2] Power was calculated for the three-way ANOVA when no significant differences were found among reaches. Values in *italics* denote comparisons where power was inadequate and sample size was too low.

[3] The results of ANCOVA tests are presented only if slopes of the regression of the variables used in the ANCOVA were not significantly different ($p<0.01$).

Figure 5.5-23 Mean EROD activity (± 1SE) of female and male lake chub at *baseline* reaches of the Dover River, fall 2015.



5.6 CALUMET RIVER WATERSHED

Table 5.6-1 Summary of results for the Calumet River watershed.

Calumet River Watershed	Summary of 2015 Conditions	
Climate and Hydrology		
Criteria	**Station S16A**	no station
Mean open-water season discharge	🟡	-
Mean winter discharge	not measured	-
Annual maximum daily discharge	🟡	-
Minimum open-water season discharge	🟡	-
Water Quality		
Criteria	**CA1**	**CAR-2**
Water Quality Index	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality		
Criteria	**CAR-D1**	**CAR-D2**
Benthic Invertebrate Communities	🟡	n/a
Sediment Quality Index	🟠	🟡
Fish Populations		
No Fish Populations component activities were conducted in the 2015 WY.		

Legend and Notes

🟡 Negligible - Low
🟠 Moderate
🟤 High

baseline
test

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Figure 5.6-1 Calumet River watershed.

Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]
- Water Withdrawal Location
- Water Release Location
- Water Quality Station
- Data Sonde Station
- Hydrometric Station
- Climate Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Community Reach
- Wild Fish Health Reach
- Wild Fish Health Reach with Water and Sediment Quality Stations

0 1 2 4 km N

Scale: 1:140,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_K06_Calumet_20160222_ss.mxd

Figure 5.6-2 Representative monitoring stations of the Calumet River watershed, fall 2015.

Hydrology Station S16A, facing upstream

Water Quality Station CA1, facing downstream

Benthic Invertebrate Communities Reach CAR-D1, facing upstream

Benthic Invertebrate Communities Reach CAR-D2, facing downstream

5.6.1 Summary of 2015 WY Conditions

Approximately 1% (205 ha) of the Calumet River watershed had undergone land change from oil sands development as of 2015 (Table 2.3-1). The designations of specific areas of the watershed are as follows:

1. The Calumet River watershed downstream of Canadian Natural Horizon Project operations is designated as *test*.

2. The remainder of the watershed is designated as *baseline* (Table 5.6-1).

Monitoring activities in the Calumet River watershed in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, and Benthic Invertebrate Communities and Sediment Quality components. Table 5.6-1 is a summary of the 2015 assessment for the Calumet River watershed while Figure 5.6-1 provides the locations of the monitoring stations for each component and the areas with land change as of 2015. Figure 5.6-2 contains fall 2015 photos of representative monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology The 2015 WY mean open-water discharge, maximum daily discharge, and minimum daily discharge were 4.24% higher, 0.25% lower, and 0.25% lower, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**.

Water Quality There were inconsistent trends in concentrations and levels of most of the water quality measurement endpoints at *test* station CA1 from May to September 2015. Temporal trends in concentrations of all major ions except potassium and sulphate were similar to temporal trends in TDS concentration, but temporal trends in concentration of particulate-associated metals were not similar to temporal trends in concentration of TSS. Concentrations of most water quality measurement endpoints were within previously-measured ranges for both stations. Variables that exceeded water quality guidelines included dissolved iron, total phenols, and sulphide at both stations in most sampling months, consistent with historical observations by the RAMP/JOSMP at these locations. Concentrations of all water quality variables were within the regional *baseline* concentrations in fall 2015, with the exception of TSS. Water quality at *test* station CAR-1 and *baseline* station CAR-2 in fall 2015 indicated **Negligible-Low** differences from regional *baseline* conditions.

Benthic Invertebrate Communities and Sediment Quality Variations in measurement endpoints for benthic invertebrate communities at lower *test* reach CAR-D1 are classified as **Negligible-Low.** Although measurement endpoints differed from upper *baseline* reach CAR-D2, none of the differences indicated degrading conditions for benthic invertebrate communities at lower *test* reach CAR-D1. Lower *test* reach CAR-D1 contained a rich and diverse benthic invertebrate community, with various genera of mayflies, stoneflies and caddisflies which indicate good habitat quality.

Sediment at *test* station CAR-D1 in fall 2015 was predominantly sand, whereas sediment at *baseline* station CAR-D2 in fall 2015 was comprised of relatively equal amounts of sand, silt, and clay. Temporal trend analyses were not possible for either station due to the limited years of historical data available. Fraction 2 and 3 hydrocarbons, chrysene, and dibenz(a,h)anthracene exceeded CCME guidelines at *test* station CAR-D1 in fall 2015. Fraction 3 hydrocarbon and total arsenic concentrations exceeded CCME guidelines at *baseline* station CAR-D2. Sediment quality measurement endpoints were within the range of regional *baseline* conditions with the exception of total PAHs (absolute and carbon-normalized) and total hydrocarbons at *test* station CAR-D1 and total metals at *baseline* station CAR-D2, all of which exceeded the 95th percentile of regional *baseline* concentrations. Sediment quality at *test* station CAR-D1 indicated **Moderate** differences from regional *baseline* conditions, while *baseline* station CAR-D2 indicated **Negligible-Low** differences from regional *baseline* conditions.

5.6.2 Hydrologic Conditions

Hydrometric monitoring for the Calumet River watershed in the 2015 WY was conducted at JOSMP Station S16A, Calumet River near the mouth. These data were used for the water balance analysis and are presented below. Additional details for this station can be found in Appendix C.

Continuous hydrometric data have been collected during the open-water period at Station S16A since April 2010. Prior to 2010, hydrometric data were collected from the mouth of the Calumet River at WSC Station 07DA014 from 1975 to 1977, Station S16 for each open-water period from 2001 to 2004, and at the Canadian Natural CR-1 station from 2005 to 2009. Only partial records exist for most historical years and therefore historical statistics, especially for the winter season, should be interpreted with caution for this station.

The historical flow record for JOSMP Station S16A is summarized in Figure 5.6-3 and includes the median, interquartile range, and range of flows recorded daily. Flows of the Calumet River are typical for a northern environment; the available historical data indicate that flows are typically highest during spring freshet and lower for the other open-water months, and that discharge occasionally responds to rainfall-generated runoff events.

Continuous monitoring for the 2015 WY at JOSMP Station S16A, Calumet River near the mouth began on May 3, 2015. Flows for the 2015 WY were generally below historical median flows and were predominately below historical lower quartile flows as well. The peak open-water flow in the 2015 WY was recorded on May 6 (0.37 m^3/s) following a rainfall event, which was recorded at the C2 Horizon weather station. This flow exceeded the historical lower quartile flow, but was below the historical median flow for that date. Flows then decreased to just above the historical minimum values in late June, then fluctuated between the historical minimum and historical lower quartile flows until the minimum open-water daily flow of 0.005 m^3/s was recorded on August 22; this flow was 66% lower than the historical mean minimum daily flow of 0.016 m^3/s calculated for the open-water period. After discharge briefly increased on September 3, flows again remained between the historical lower quartile and the historical minimum flows for the remainder of the 2015 WY.

Overall, the recorded open-water runoff volume in the 2015 WY was 0.703 million m^3. This was 82% lower than the mean historical open-water runoff volume of 3.98 million m^3 based on the available historical record. As mentioned above, only partial records exist for most historical years, so historical statistics should be used with caution for this station.

Differences between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the open water period of the Calumet River at JOSMP Station S16A is summarized in Table 5.6-2.

Key sources of changes in flow for the 2015 WY were:

1. The closed-circuited land change area as of 2015 was estimated to be 0.7 km^2 (Table 2.3-1). The loss of flow to the Calumet River that would have otherwise occurred from this land area was estimated at 0.003 million m^3.

2. The area of land change in the Calumet River watershed as of 2015 that was not closed-circuited was estimated to be 1.4 km^2 (Table 2.3-1). The increase in flow to the Calumet River that would not have otherwise occurred from this land area was estimated at 0.001 million m^3.

3. A total of more than 0.15 million m^3 was released by CNRL-Horizon from a sedimentation pond in 2015 WY; the 0.064 million m^3 of this release that occurred in the open-water season was used in the water balance analysis[1].

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2015 WY was an increase of 0.063 million m^3 at JOSMP Station S16A. The 2015 WY mean open-water discharge, maximum daily

[1] A decision was made to use only the release in the open-water season and not the entire release from the sedimentation pond as this would have resulted in negative flows in the *baseline* hydrograph during certain low flow periods of the 2015 WY.

discharge, and minimum daily discharge were 4.24% higher, 0.25% lower, and 0.25% lower, respectively, in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.6-3). These differences were classified as **Negligible-Low** (Table 5.6-1). A spatial analysis (Section 3.2.1.5) was not required to identify the longitudinal hydrological effects along the Calumet River given that the differences in values of all measurement endpoints between observed *test* and estimated *baseline* conditions were classified as **Negligible-Low**.

5.6.3 Water Quality

Water quality samples were taken in the 2015 WY from:

- the Calumet River near its mouth (*test* station CA1, previously called CAR-1), designated as a *baseline* station from 2002 to 2004 and *test* station from 2005 to 2014. This station was sampled monthly starting from May to September in 2015; and
- the upper Calumet River (*baseline* station CAR-2), sampled in fall since 2005. This station was sampled in September in 2015.

Monthly variations in the water quality of the Calumet River are summarized in Table 5.6-4 and Figure 5.6-4. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations are provided in Table 5.6-5 and Table 5.6-6. The ionic composition of water in the Calumet River watershed compared to historical ion balance is presented in Figure 5.6-5. Guideline exceedances in the 2015 WY for water quality measurement endpoints are presented in Table 5.6-7. Figure 5.6-6 compares selected water quality measurement endpoints in the Calumet River to historical regional *baseline* concentrations.

Monthly Variations in Water Quality Monthly data collected from May to September 2015 at *test* station CA1 showed no consistent seasonal trends in most water quality measurement endpoints (Table 5.6-4). Concentrations of both TSS and TDS were lowest in May and highest in August and September. Temporal trends in concentration of all major ions except potassium and sulphate were similar to temporal trends in TDS concentration, but temporal trends in concentration of particulate-associated metals were not similar to temporal trends in concentration of TSS. Concentrations of PAHs including total dibenzothiophenes, total parent PAHs, and total alkylated PAHs were highest in September and lowest in June. Concentrations of water quality measurement endpoints in the 2015 WY were within historical monthly ranges of concentration (Figure 5.6-4).

2015 Fall Results Relative to Historical Concentrations Water quality measurement endpoints in fall 2015 had similar concentrations to historical results with the following exceptions (Table 5.6-5 and Table 5.6-6):

- *test* station CA1: concentrations of sulphate and oilsands extractable acids exceeded previously-measured maximum concentrations (waterborne oilsands extractable acids have only been measured at current, ultra-trace detection limits since 2011; historical comparisons of 2015 data for oilsands extractable acids are to 2011-2014 data only) and concentration of total dissolved phosphorus was lower than the previously-measured minimum concentration; and

- *baseline* station CAR-2: concentration of oilsands extractable acids exceeded previously-measured maximum concentrations and concentrations of total dissolved phosphorus and total boron were lower than the previously-measured minimum concentrations.

Temporal Trends There were no significant trends ($p>0.05$) in fall concentrations for most water quality measurement endpoints with the exception of an increasing concentration of sulphate at *test* station CA1 since 2011 ($p<0.05$) and a decreasing concentration of total dissolved phosphorus at baseline station CAR-2 since 2011 ($p<0.05$).

Ion Balance The ionic composition of water at *test* station CA1 and *baseline* station CAR-2 has been variable over time, but was within the range of historical observations for both stations in fall 2015 (Figure 5.6-5).

Comparison of Water Quality Measurement Endpoints to Published Guidelines The following water quality guideline exceedances were measured in the Calumet River watershed in the 2015 WY (Table 5.6-7):

- dissolved iron at *test* station CA1 (May, June, and September) and *baseline* station CAR-2 (September);
- total phenols at *test* station CA1 (June-September) and *baseline* station CAR-2 (September); and
- sulphide at *test* station CA1 (May to September) and *baseline* station CAR-2 (September).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality variables were within the regional *baseline* concentrations in fall 2015 with the exception of TSS concentrations, which were higher than the 95th percentile of the regional *baseline* concentrations at *baseline* station CAR-2 (Figure 5.6-6).

Water Quality Index The WQI values for *test* station CA1 (100) and *baseline* station CAR-2 (96.2) indicate a **Negligible-Low** difference from regional *baseline* conditions for both stations.

Classification of Results In fall 2015, water quality at *test* station CA1 and *baseline* station CAR-2 indicated **Negligible-Low** differences from regional *baseline* conditions.

5.6.4 Benthic Invertebrate Communities and Sediment Quality

5.6.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 at:

- depositional *test* reach CAR-D1, sampled from 2002 to 2004 as a *baseline* reach, and then in 2005, 2009, 2012 and 2015 as a *test* reach; and
- depositional *baseline* reach CAR-D2, sampled from 2003 to 2006 and in 2009, 2012 and 2015.

2015 Habitat Conditions Water at *test* reach CAR-D1 in fall 2015 was relatively deep (0.8 m), with a pH of 7.3, a high concentration of dissolved oxygen (9.2 mg/L), and high conductivity (563 µS/cm) (Table 5.6-8). The substrate consisted of silt (40%), sand (31%) and clay (30%). Total organic carbon was low (2.3 %).

Water at *baseline* reach CAR-D2 in fall 2015 was shallow (0.2 m), with a pH of 7.4, high conductivity (522 µS/cm), and high concentration of dissolved oxygen (9.8 mg/L) (Table 5.6-8). The substrate was primarily comprised of sand (87%), with some silt (10%) and some clay (3%). Total organic carbon was moderately high (4%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach CAR-D1 in fall 2015 was dominated by chironomids (69%), with tubificid worms (16%) subdominant (Table 5.6-9). Chironomids were diverse, with dominant genera including common forms such as *Micropsectra/Tanytarsus*, *Stempellinella*, and *Polypedilum* (Wiederholm 1983). Permanent aquatic forms at the *test* reach consisted of Gastropoda (*Physa*, *Gyraulus*), Bivalvia (*Pisidium*) and Amphipoda (*Hyalella azteca*). EPT taxa were present at *test* reach CAR-D1 in fall 2015, including several genera of mayflies (*Callibaetis*, *Caenis*, *Leptophlebia*), stoneflies (*Nemoura*, *Zapada*) and caddisflies (*Cheumatopsyche*, *Hydropsyche*). The dragonfly *Somatochlora* was present in one replicate sample.

The benthic invertebrate community at *baseline* reach CAR-D2 in fall 2015 was dominated by chironomids (80%) with naidids (9%) as the subdominant taxa (Table 5.6-9). Chironomids were diverse at the reach and mostly comprised of *Tanytarsus* with smaller numbers of *Cryptotendipes*, *Dicrotendipes*, *Chironomus*, *Paratanytarsus* and *Stempellinella*. Permanent aquatic forms such as bivalves (*Pisidium*, *Sphaerium*) and gastropods (Lymnaeidae, *Gyraulus, Helisoma*) were present. The amphipod *Hyalella azteca* was present in one replicate. Larvae of flying insects were represented by Ephemeroptera (*Caenis*) and Odonata (*Somatochlora*, *Enallagma*).

Temporal and Spatial Comparisons Temporal and spatial comparisons of measurement endpoints for *test* reach CAR-D1 included testing for:

- a difference in mean values of measurement endpoints between baseline *reach* CAR-D2 and *test* reach CAR-D1 during both *baseline* and *test* periods;
- a difference in mean values of measurement endpoints between *baseline* (i.e., 2002 to 2004) and *test* (2005 to present) periods in the *test* reach CAR-D1;
- a change in the difference in mean values of measurement endpoints between *baseline* and *test* reaches, from *baseline* (2002 to 2004) to *test* (2005 to present) periods (i.e., BACI Hypothesis or Hypothesis 1 in Section 3.2.3.1);
- a linear trend over time in mean values of measurement endpoints during the *test* period in both *test* and *baseline* reaches;
- a difference in the linear trends over time between *baseline* and *test* reaches, during the *test* period;
- changes between 2015 values and the mean of all *baseline* years; and
- changes between 2015 values and the mean of all previous years of sampling.

Abundance and richness were higher in lower *test* reach CAR-D1 than upper *baseline* reach CAR-D2, each accounting each for 35% of the variation in annual means (Table 5.6-10). Abundance and richness in lower *test* reach CAR-D1 in fall 2015 were higher than the mean of all *baseline* values, accounting for 31% and 24% of the variation in annual means, respectively.

Equitability was lower in the lower *test* reach CAR-D1 than upper *baseline* reach CAR-D2, accounting for 51% of the variation in annual means (Table 5.6-10). Equitability in lower *test* reach CAR-D1 in fall 2015 was lower than the mean of all *baseline* values, accounting for 40% of the variation in annual means.

CA Axis 2 scores decreased over time in lower *test* reach CAR-D1 and increased over time in *baseline* reach CAR-D2, accounting for 22% of the variation in annual means (Table 5.6-10). The difference in time trends between the lower and upper reaches corresponded to a shift in taxa composition with a decrease in tubificid and naidid worms in lower *test* reach CAR-D1 (Figure 5.6-7).

Comparison to Published Literature The benthic invertebrate community at lower *test* reach CAR-D1 in fall 2015 was similar to previous years. Diversity was high with many chironomids and the presence of EPT taxa, bivalves, and gastropods which are indicative of a high-quality benthic habitat (Hynes 1960; Griffiths 1998).

The benthic invertebrate community at upper *baseline* reach CAR-D2 in fall 2015 had a more diverse community than in previous years; there was also a marked increase in the percent of fauna as EPT taxa. Dominant fauna in 2015 consisted mainly of tolerant and common chironomid genera (Mandeville 2001).

2015 Results Relative to Regional *Baseline* Conditions The majority of measurement endpoints, with the exception of abundance and equitability, were within the inner tolerance limits for the normal range of regional *baseline* conditions (Figure 5.6-7, Figure 5.6-8). Abundance was higher than the inner tolerance limit for the normal range of regional *baseline* variation, while equitability was lower than the inner tolerance limit. These variations, especially the lower equitability values, were consistent with stable conditions at *test* reach CAR-D1.

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities of the Calumet River at lower *test* reach CAR-D1 are classified as **Negligible-Low**:

1. The benthic invertebrate community in fall 2015 contained a rich and diverse fauna, including several taxa that are typically associated with relatively good environmental conditions.
2. None of the significant increases and decreases in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.
3. While values of three of the six measurement endpoints in fall 2015 were beyond the inner tolerance limit of the 95th percentile of the normal range of values of *baseline* years, none of these excursions outside the normal ranges implied degrading conditions for benthic invertebrate communities.

5.6.4.2 Sediment Quality

Sediment quality was sampled on the Calumet River in fall 2015 at:

- *test* station CAR-D1, sampled in 2005, 2006, 2009, 2012, and 2015; and
- *baseline* station CAR-D2, sampled in 2002, 2004, 2005, 2009, 2012, and 2015.

Temporal Trends Temporal trend analyses were not possible for either *test* station CAR-D1 or *baseline* station CAR-D2 due to the limited years of historical data that were available (n≤6).

2015 Results Relative to Historical Conditions Sediments at *test* station CAR-D1 in fall 2015 were predominantly sand (93.8%) and small proportions of clay (2.0%) and silts (4.2%). The proportion of sand in fall 2015 exceeded the previously-measured maximum value, while the proportions of clay and silt were below previously-measured minimum values (Table 5.6-11, Figure 5.6-9). Sediments at *baseline* station CAR-D2 had relatively equal parts clay (31.7%), silt (34.9%), and sand (33.4%), with all proportions being within previously-measured values (Table 5.6-12, Figure 5.6-10). Total organic carbon concentration in sediments at *test* station CAR-D1 was within the previously-measured range of concentration and below the previously-measured minimum concentration in sediments collected at *baseline* station CAR-D2 (Table 5.6-11, Table 5.6-12).

Concentrations of total hydrocarbons and selected PAHs were within the ranges of previously-measured concentrations at *test* station CAR-D1 with the exception of naphthalene, with a concentration in fall 2015 that was below the previously-measured minimum concentration (Table 5.6-11). Concentrations of BTEX and Fraction 1 hydrocarbons at *baseline* station CAR-D2 were not detectable, but both sediment quality variables had detection limits in 2015 that exceeded the previously-measured maximum values for those variables (Table 5.6-12). Sediment collected at *baseline* station CAR-D2 had concentrations of naphthalene, total parent PAHs, total alkylated PAHs, total PAHs, and a predicted PAH toxicity that were below previously-measured minimum concentrations (Table 5.6-12).

With respect to sediment toxicity tests:

1. Survival of both the midge *Chironomus* (96%) and the amphipod *Hyalella* (98%) both exceeded the previously-measured maximum values at *test* station CAR-D1 (Table 5.6-11).

2. Survival of *Hyalella* (92%) exceeded the previously-measured maximum value and survival of *Chironomus* (48%) was within the previously-measured range at *baseline* station CAR-D2 (Table 5.6-12).

3. *Hyalella* 14-day growth rates were below previously-measured minimum values at both *test* station CAR-D1 and *baseline* station CAR-D2, while 10-day growth rates of the midge *Chironomus* at both *test* station CAR-D1 and *baseline* station CAR-D2 were within previously-measured ranges (Table 5.6-11, Table 5.6-12).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of measurement endpoints for sediment quality at stations within the Calumet River watershed were below guideline concentrations in fall 2015 with the following exceptions (Table 5.6-11, Table 5.6-12):

- Fraction 2 hydrocarbons (185 mg/kg) at *test* station CAR-D1, which exceeded the CCME guideline of 150 mg/kg;

- Fraction 3 hydrocarbons at *test* station CAR-D1 (3,260 mg/kg) and *baseline* station CAR-D2 (944 mg/kg), which exceeded the CCME guideline of 300 mg/kg;

- chrysene and dibenz(a,h)anthracene at *test* station CAR-D1, which exceeded the CCME guidelines of 0.0571 mg/kg and 0.0062 mg/kg, respectively; and

- total arsenic (11.1 mg/kg) at *baseline* station CAR-D2, which exceeded the CCME guideline of 5.9 mg/kg.

The concentration of Fraction 1 hydrocarbons at *baseline* station CAR-D2 was below detection limits, but the detection limit Fraction 1 hydrocarbons in 2015 exceeded the CCME guideline (30 mg/kg).

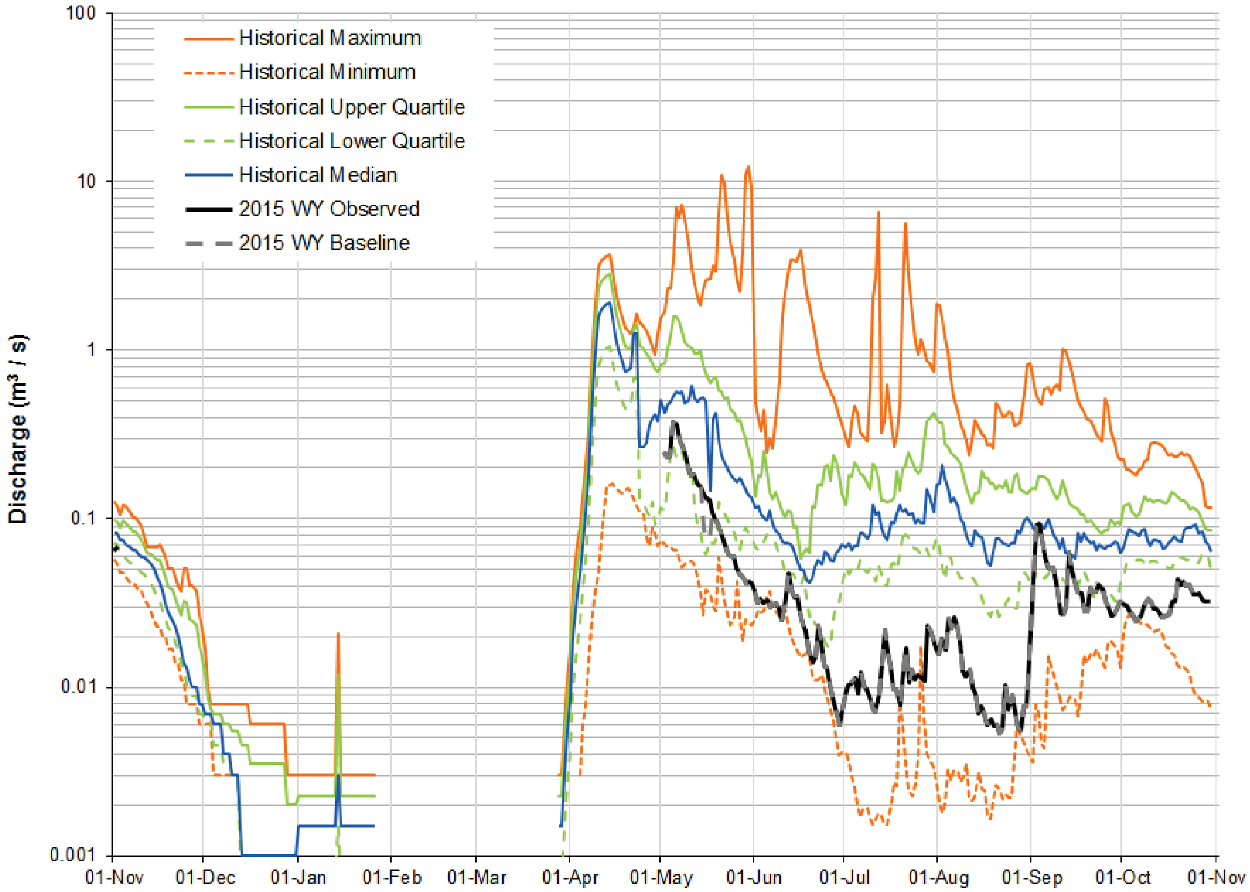
2015 Results Relative to Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints in fall 2015 were within the ranges of regional *baseline* concentrations (Figure 5.6-9, Figure 5.6-10) with the exception of:

- total PAHs, total PAHs when carbon-normalized, and total hydrocarbons at *test* station CAR-D1, which were above the 95th percentile of regional *baseline* concentrations; and
- total metals at *baseline* station CAR-D2, which was above the 95th percentile of regional *baseline* concentrations.

Sediment Quality Index The SQI values calculated in 2015 for *test* station CAR-D1 and *baseline* station CAR-D2 were 68.1 and 84.6, respectively, which were similar to but slightly below values calculated in 2012 (76.0 and 92.2, respectively, 2012 was the most-recent year in which sediments were sampled as these stations). The SQI at *test* station CAR-D1 for 2015 is primarily a result of comparatively high total hydrocarbon and PAH concentrations relative to the range of regional *baseline* values.

Classification of Results Based on the calculated SQI values, differences in sediment quality conditions in 2015 between *test* station CAR-D1 and regional *baseline* conditions were classified as **Moderate**, primarily due high total hydrocarbon and PAH concentrations. Differences in sediment quality conditions in 2015 between *baseline* station CAR-D2 and regional *baseline* conditions were classified as **Negligible-Low**.

Figure 5.6-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Calumet River in the 2015 WY, compared to historical values.



Note: Observed 2015 WY hydrograph is based on Calumet River near the mouth (JOSMP Station S16A) daily mean open-water data. Historical values were calculated from data collected at WSC Station, 07DA014 (1975 to 1977), RAMP Station S16 (2001 to 2004), CNRL Station CR-1 (2005 to 2009), and JOSMP Station S16A (2010 to 2014).

Table 5.6-2 Estimated water balance at Calumet River near the mouth (JOSMP Station S16A), 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**0.703**	**Observed discharge from Calumet River near the mouth (JOSMP Station S16A)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.003	Estimated 0.7 km^2 of the Calumet River watershed is closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.001	Estimated 1.4 km^2 of the Calumet River watershed with land change as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Calumet River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Calumet River watershed, relative to the estimated *baseline* hydrograph	0.064	150,323 m^3 of water into released into the Calumet Watershed from a sedimentation pond, reported by CNRL-Horizon. A decision was made to use only the release in the open-water season (64,000 m^3) and not the entire release from the sedimentation pond as this would have resulted in negative flows in the *baseline* hydrograph during certain low flow periods of the 2015 WY
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**0.641**	**Estimated *baseline* discharge from Calumet River near the mouth, JOSMP Station S16A.**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	0.062	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	9.67	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

All non-zero values in this table presented to three decimal places.

Observed volume of discharged water was calculated using data from May 3 to October 31, 2015 for JOSMP Station S16A.

Table 5.6-3 Calculated change in hydrologic measurement endpoints in the Calumet River watershed, 2015 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.042	0.044	+4.244%
Mean winter discharge	not measured	not measured	not measured
Annual maximum daily discharge	0.373	0.372	-0.254%
Open-water season minimum daily discharge	0.005	0.005	-0.254%

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

Observed discharge was calculated from data for the 2015 WY at JOSMP Station S16A.

The relative change for each measurement endpoint was calculated using observed and baseline flow values, which were estimated to several decimal places. However, for clarity in this table, all flows and percentage change values were presented to three decimal places.

Discharge statistics were calculated using data for May 3 to October 31, 2015 for JOSMP Station S16A, Calumet River near the mouth.

Table 5.6-4 Monthly concentrations of water quality measurement endpoints, mouth of Calumet River (*test* station CA1 [CAR-1]), May to September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.14	8.02	Jun	8.21	May
Total suspended solids	mg/L	-	5	2.0	1.3	May, Jul	21.0	Sep
Conductivity	µS/cm	-	5	590	510	May	690	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.026	0.020	Aug	0.032	Dec
Total nitrogen	mg/L	-	5	1.00	<1	May, Jun	1.20	Jul
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.003	-	<0.005	-
Dissolved organic carbon	mg/L	-	5	29.0	26.0	May	33.0	Jul
Ions								
Sodium	mg/L	-	5	47.0	41.0	May	56.0	Jul
Calcium	mg/L	-	5	59.0	43.0	May	72.0	Aug
Magnesium	mg/L	-	5	19.0	15.0	May	23.0	Aug
Potassium	mg/L	-	5	2.5	2.00	Sep	3.00	May
Chloride	mg/L	120-640	5	18.0	16.0	May	27.0	Aug
Sulphate	mg/L	218-309[b]	5	35.0	16.0	Aug	43.0	May
Total dissolved solids	mg/L	-	5	400.0	350.0	May	450.0	Aug
Total alkalinity	mg/L	20 (min)	5	270.0	200.0	May	330.0	Aug
Selected metals								
Total aluminum	mg/L	-	5	0.0396	0.0194	Aug	0.208	May
Dissolved aluminum	mg/L	0.05	5	0.0021	0.0015	Jul	0.0043	Jun
Total arsenic	mg/L	0.005	5	0.0007	0.00070	Jun	0.0010	Aug
Total boron	mg/L	1.5-29	5	0.13	0.09	Sep	0.144	Jul
Total molybdenum	mg/L	0.073	5	0.00020	0.00015	Sep	0.00029	May
Total mercury (ultra-trace)	ng/L	5-13	5	0.93	0.74	Aug	2.52	Jun
Total methyl mercury	ng/L	1-2	5	0.10	0.09	Jun	0.14	Sep
Total strontium	mg/L	-	5	0.29	0.211	May	0.31	Aug
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Naphthenic Acids	mg/L	-	5	2.18	0.58	Sep	5.16	Aug
Oilsands extractable acids	mg/L	-	5	7.10	3.10	Sep	8.50	Jun
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	0.79	<0.59	Jun	6.59	Sep
Total dibenzothiophenes[c]	ng/L	-	5	43.91	21.54	Jun	360.03	Sep
Total PAHs[c]	ng/L	-	5	232.05	157.76	Jun	987.69	Sep
Total Parent PAHs[c]	ng/L	-	5	25.21	23.66	Jun	43.89	Sep
Total Alkylated PAHs[c]	ng/L	-	5	206.07	134.10	Jun	943.80	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0098**	0.0036	May	**0.015**	Jul
Sulphide	mg/L	0.0019	5	**0.0130**	**0.0097**	Jun	**0.015**	Jul
Dissolved iron	mg/L	0.3	3	**0.3240**	0.175	Jul	**0.808**	May

Values in **bold** are above guideline.

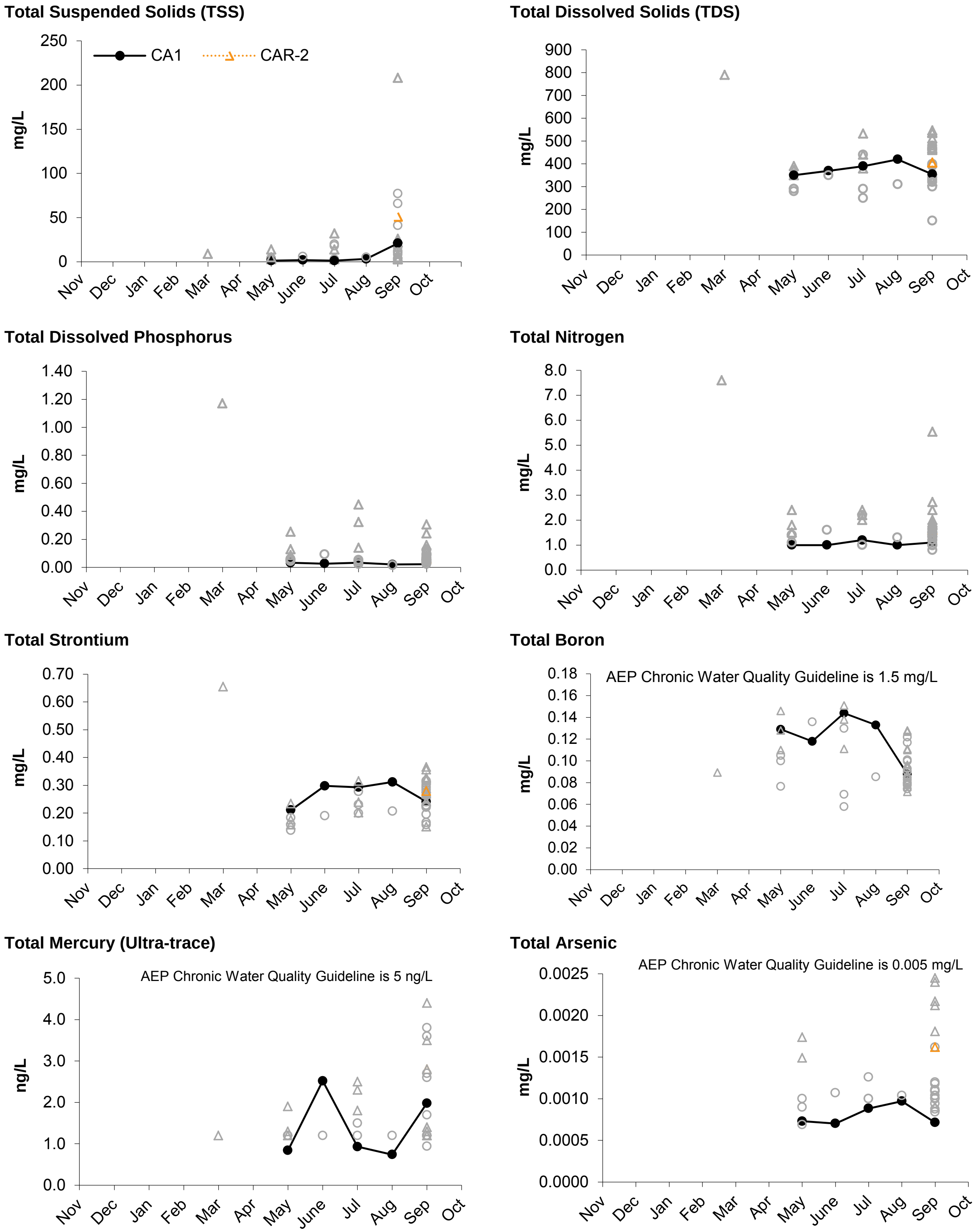
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

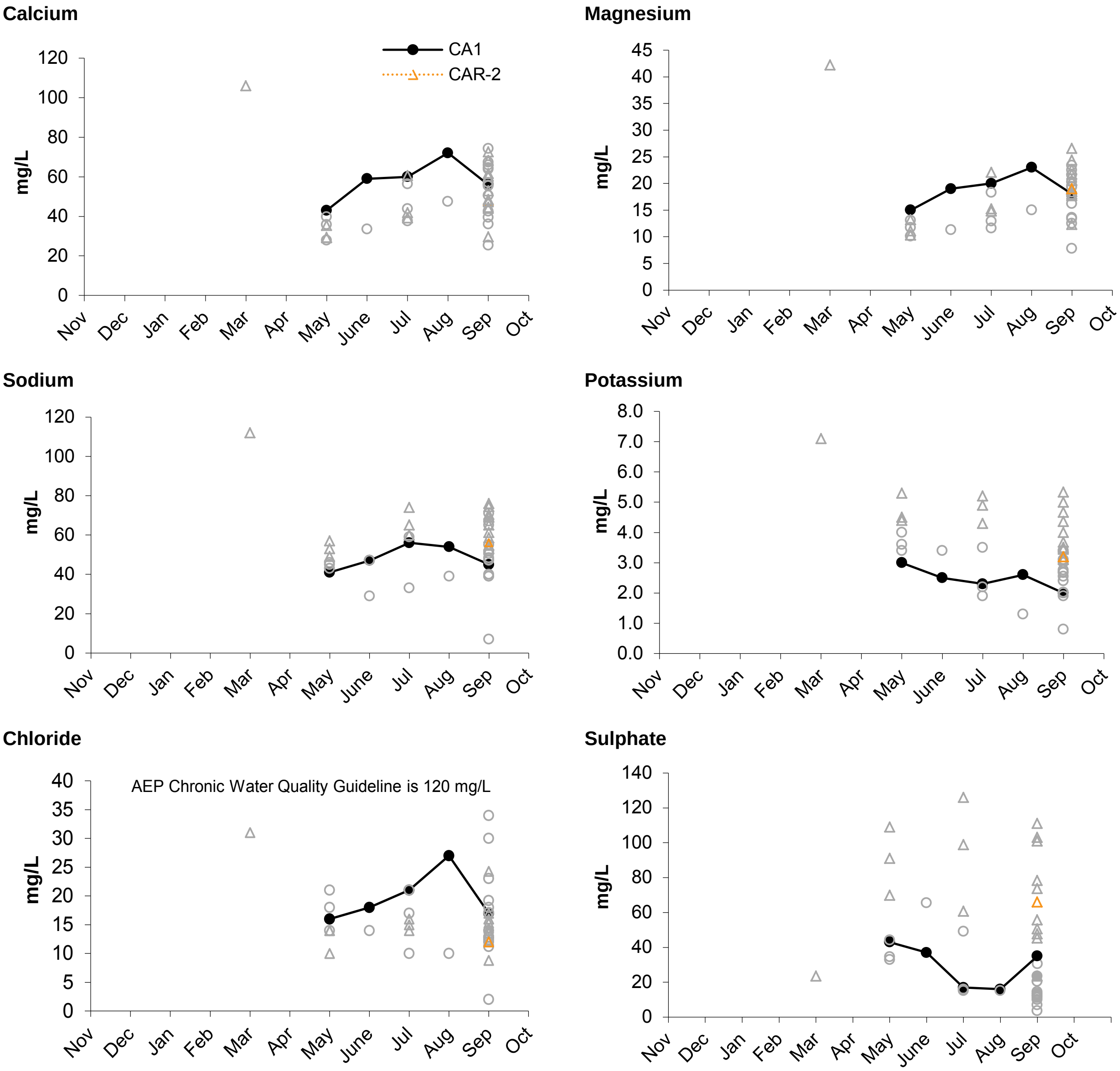
[d] n value refers to number of exceedances in 2015.

Figure 5.6-4 Selected water quality measurement endpoints in the Calumet River (monthly data) in the 2015 WY.



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.6-4 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.6-5 Concentrations of water quality measurement endpoints, Calumet River mouth (*test* station CA1 [CAR-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2002-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.07	13	8.3	8.1	8.6
Total suspended solids	mg/L	-	21	13	11	<3.0	77.1
Conductivity	µS/cm	-	590	13	565	188	702
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.023</u>	13	0.055	0.025	0.122
Total nitrogen	mg/L	-	1.1	13	1.30	0.80	1.54
Nitrate+nitrite	mg/L	3-124	<0.005	13	<0.100	<0.054	<0.100
Dissolved organic carbon	mg/L	-	29.0	13	32.0	22.0	40.7
Ions							
Sodium	mg/L	-	45	13	48.4	7.00	71.0
Calcium	mg/L	-	56	13	55.7	25.3	74.2
Magnesium	mg/L	-	18	13	17.9	7.80	23.4
Potassium	mg/L	-	2.0	13	2.67	0.80	3.4
Chloride	mg/L	120-640	17	13	14.0	2.00	34.0
Sulphate	mg/L	429[b]	<u>35</u>	13	12.6	3.60	30.7
Total dissolved solids	mg/L	-	380	13	394	151	480
Total alkalinity	mg/L	20 (min)	270	13	275	96	337
Selected metals							
Total aluminum	mg/L	-	0.201	13	0.158	0.040	1.28
Dissolved aluminum	mg/L	0.05	0.002	13	0.0036	0.0013	0.0058
Total arsenic	mg/L	0.005	0.001	13	0.0011	0.0008	0.0016
Total boron	mg/L	1.5-29	0.088	13	0.085	0.074	0.122
Total molybdenum	mg/L	0.073	0.0001	13	0.00015	0.00011	0.00030
Total mercury (ultra-trace)	ng/L	5-13	1.980	12	<1.20	<0.94	3.80
Total methyl mercury	ng/L	1-2	0.135	-	-	-	-
Total strontium	mg/L	-	0.24	13	0.23	0.16	0.32
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.26	<0.25	0.45
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.34
Naphthenic acids	mg/L	-	0.58	4	0.86	0.05	2.50
Oilsands extractable acids	mg/L	-	<u>3.1</u>	4	1.96	0.55	2.87
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	6.59	4	9.23	1.11	39.00
Total dibenzothiophenes[c]	ng/L	-	360.03	4	86.07	54.72	1,436.9
Total PAHs[c]	ng/L	-	964.17	4	440.4	245.2	3,715.7
Total Parent PAHs[c]	ng/L	-	43.20	4	27.44	23.56	79.49
Total Alkylated PAHs[c]	ng/L	-	920.97	4	414.0	219.4	3,636.2
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.324**	13	**0.492**	0.273	**0.911**
Sulphide	mg/L	0.0019	**0.013**	13	**0.0119**	**0.0045**	**0.028**
Total phenols	mg/L	0.004	**0.0098**	12	**0.009**	<0.001	**0.016**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.6-6 Concentrations of water quality measurement endpoints, upper Calumet River (*baseline* station CAR-2), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2005-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.92	10	8.1	7.7	8.5
Total suspended solids	mg/L	-	51	10	4.0	<3.0	208
Conductivity	µS/cm	-	590	10	643	494	772
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.060</u>	10	0.118	0.067	0.305
Total nitrogen	mg/L	-	1.6	10	1.9	1.5	5.5
Nitrate+nitrite	mg/L	3-124	0.012	10	<0.071	<0.054	<0.100
Dissolved organic carbon	mg/L	-	46.0	10	47.7	36.1	54.4
Ions							
Sodium	mg/L	-	56	10	67.0	53.0	76.0
Calcium	mg/L	-	48	10	50.7	29.6	72.5
Magnesium	mg/L	-	19	10	20.6	12.3	26.6
Potassium	mg/L	-	3.2	10	3.8	3.1	5.33
Chloride	mg/L	120-640	12	10	14.9	8.82	24.3
Sulphate	mg/L	429[b]	66	10	64.8	23.5	111.0
Total dissolved solids	mg/L	-	470	10	468	323	547
Total alkalinity	mg/L	20 (min)	230	10	236	188	315
Selected metals							
Total aluminum	mg/L	-	0.154	10	0.061	0.020	4.10
Dissolved aluminum	mg/L	0.05	0.013	10	0.012	0.004	0.024
Total arsenic	mg/L	0.005	0.002	10	0.0024	0.0009	0.0050
Total boron	mg/L	1.5-29	<u>0.072</u>	10	0.095	0.076	0.128
Total molybdenum	mg/L	0.073	0.0005	10	0.00056	0.00009	0.00102
Total mercury (ultra-trace)	ng/L	5-13	2.80	10	1.4	<1.2	4.4
Total mercury (ultra-trace)	ng/L	1-2	0.31	-	-	-	-
Total strontium	mg/L	-	0.279	10	0.30	0.15	0.37
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	0.65
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	0.49
Naphthenic acids	mg/L	-	0.64	4	0.48	0.11	1.60
Oilsands extractable acids	mg/L	-	<u>2.6</u>	4	1.20	0.73	1.98
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.4	<7.2	<15.2
Retene	ng/L	-	2.95	4	2.351	0.637	10.80
Total dibenzothiophenes[c]	ng/L	-	8.17	4	6.277	4.514	35.41
Total PAHs[c]	ng/L	-	106.41	4	133.3	76.1	207.1
Total Parent PAHs[c]	ng/L	-	22.40	4	18.32	13.26	22.55
Total Alkylated PAHs[c]	ng/L	-	84.00	4	112.4	62.86	189.7
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.492**	10	**0.475**	0.110	**1.500**
Sulphide	mg/L	0.0019	**0.023**	10	**0.031**	**0.020**	**0.588**
Total phenols	mg/L	0.004	**0.013**	10	**0.013**	**0.008**	**0.041**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.6-5 Piper diagram of fall ion concentrations in Calumet River watershed.

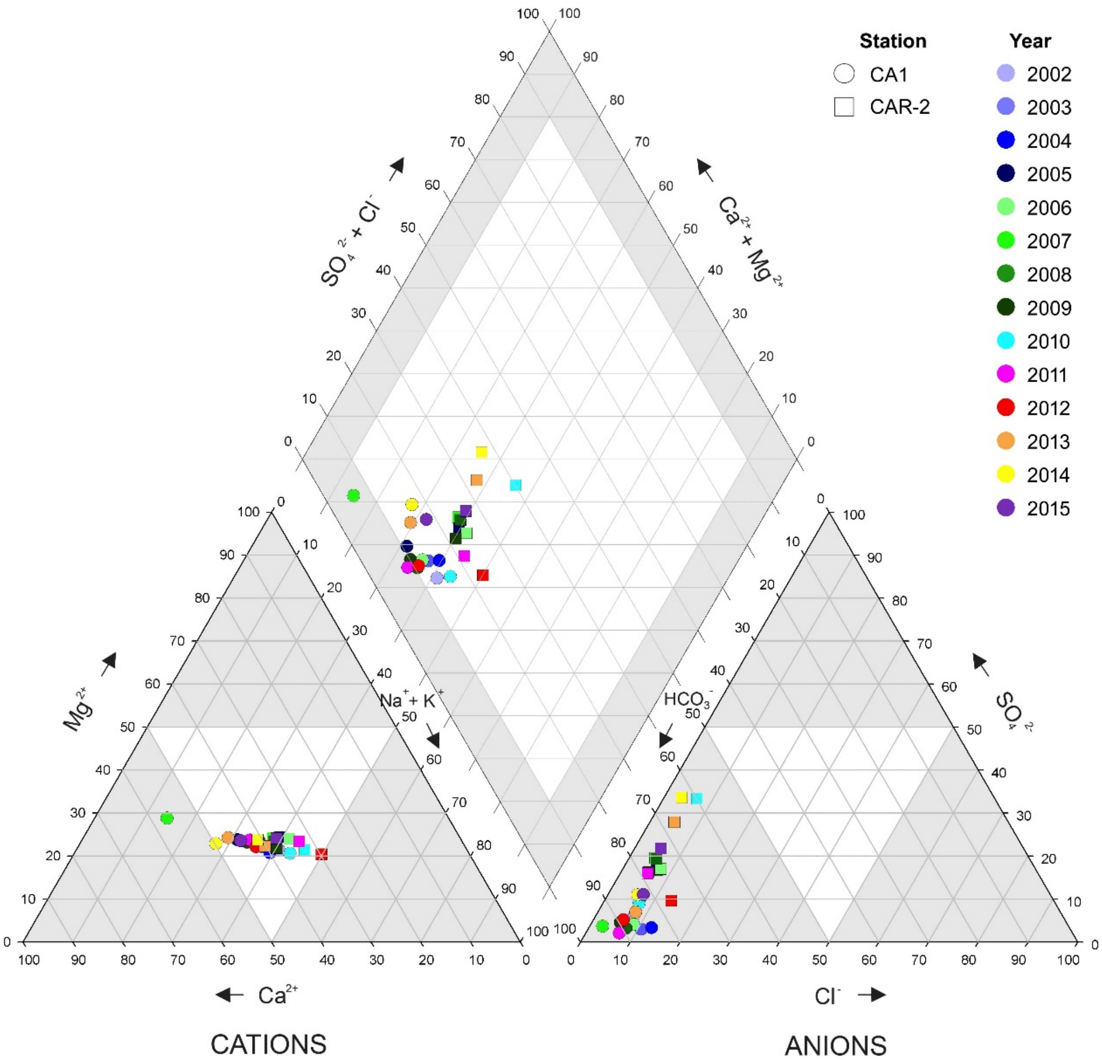


Table 5.6-7 Water quality guideline exceedances in the Calumet River watershed, 2015 WY.

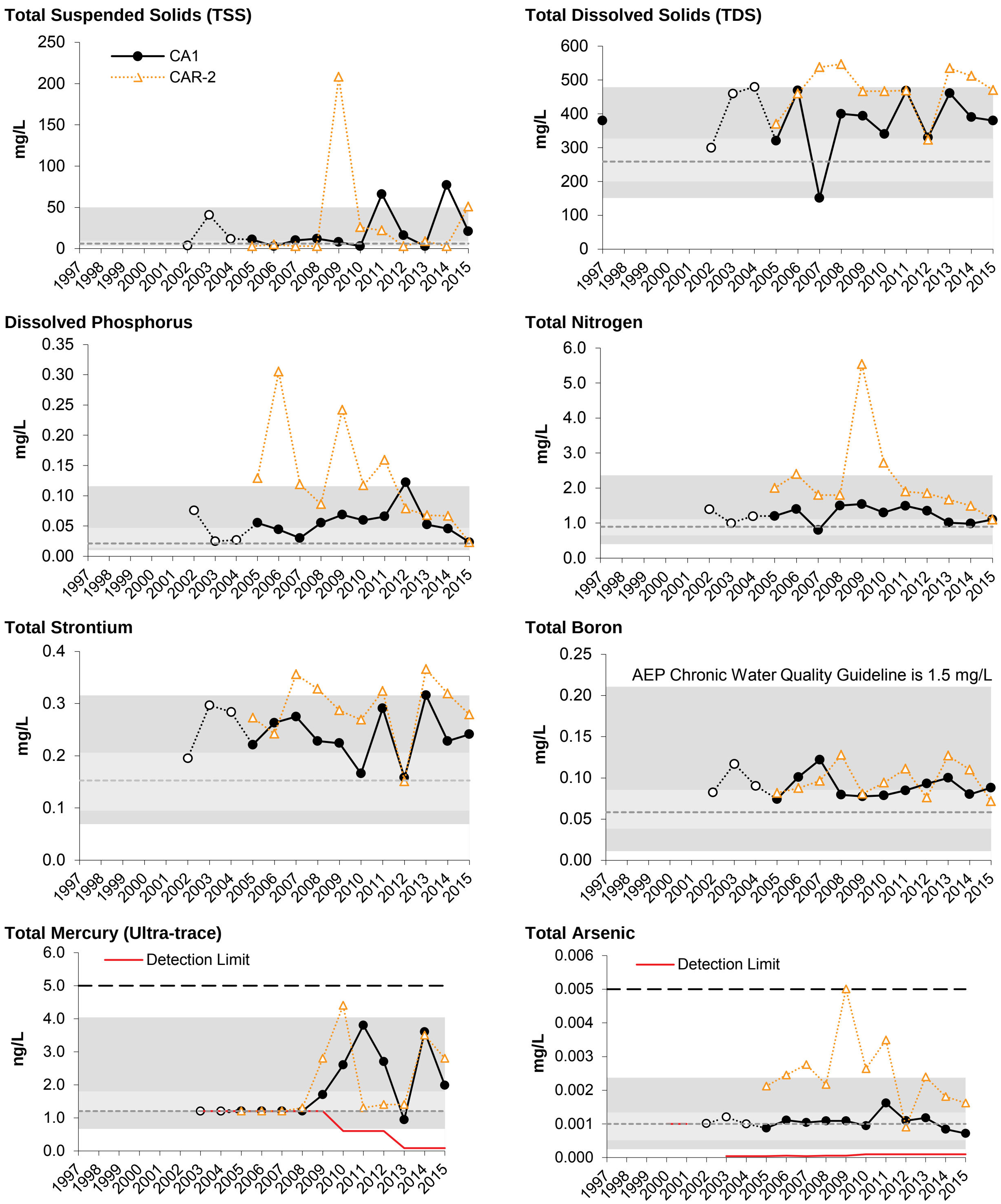
Variable	Units	Guideline[a]	May	June	July	August	September
Calumet River mouth (CA1 [CAR-1])							
Total phenols	mg/L	0.004	0.0036	**0.0075**	**0.015**	**0.013**	**0.0098**
Sulphide	mg/L	0.0019	**0.013**	**0.0097**	**0.015**	**0.012**	**0.013**
Dissolved iron	mg/L	0.3	**0.808**	**0.728**	0.175	0.27	**0.324**
Upper Calumet River (CAR-2)							
Total phenols	mg/L	0.004	-	-	-	-	**0.013**
Sulphide	mg/L	0.0019	-	-	-	-	**0.023**
Dissolved iron	mg/L	0.3	-	-	-	-	**0.492**

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-5.

"-" = not sampled.

Figure 5.6-6 Selected water quality measurement endpoints in the Calumet River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



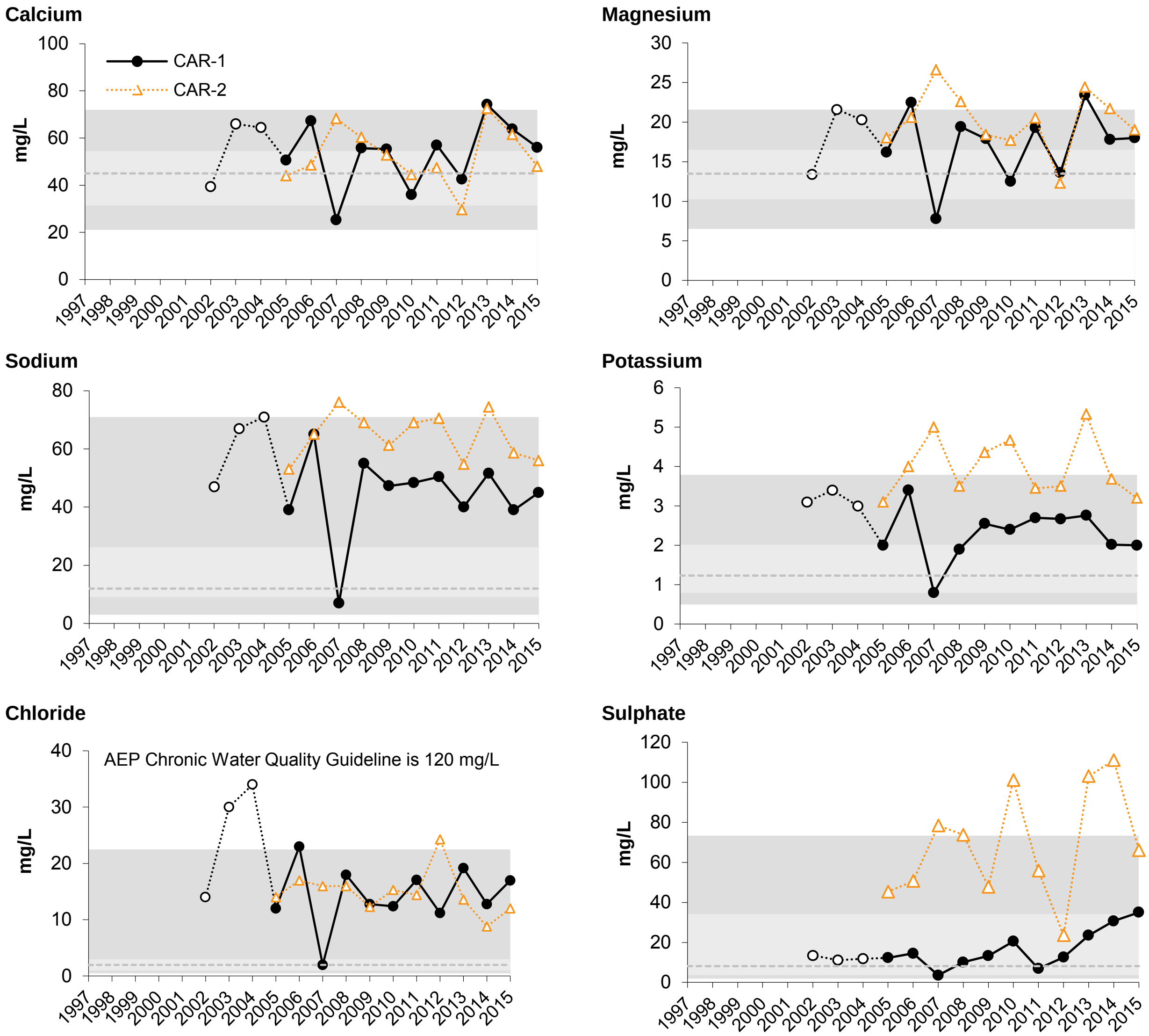
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.6-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.6-8 Average habitat characteristics of benthic invertebrate community sampling locations in the Calumet River (*test* reach CAR-D1 and *baseline* reach CAR-D2), fall 2015.

Variable	Units	CAR-D1 Lower *Test* Reach	CAR-D2 Upper *Baseline* Reach
Sample date	-	Sept. 18, 2015	Sept. 12, 2015
Habitat	-	Depositional	Depositional
Water depth	m	0.8	0.2
Current velocity	m/s	trace	0.31
Field water quality			
Dissolved oxygen (DO)	mg/L	7.0	9.8
Conductivity	µS/cm	563	522
pH	pH units	7.25	7.37
Water temperature	°C	9.5	8.2
Sediment composition			
Sand	%	30.9	87.0
Silt	%	39.8	9.7
Clay	%	29.3	3.3
Total organic carbon (TOC)	%	2.3	4.0

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.6-9 Summary of major taxon abundances measurement endpoints for the benthic invertebrate community in the Calumet River (*test* reach CAR-D1 and *baseline* reach CAR-D2).

Taxon	Percent Major Taxa Enumerated in Each Year					
	Test Reach CAR-D1			*Baseline* Reach CAR-D2		
	2002	2003 to 2012	2015	2003	2004 to 2012	2015
Hydra	-	<1	1	-	-	-
Nematoda	1	<1 to 3	1	4	2 to 49	-
Naididae	<1	<1 to 17	3	9	1 to 6	9
Tubificidae	1	1 to 37	16	-	0 to 2	-
Enchytraeidae	<1	<1 to 1	-	-	-	-
Lumbriculidae	-	<1	-	-	-	-
Hirudinea	-	-	<1	-	-	-
Erpobdellidae	<1	0 to <1	-	0	0 to <1	-
Glossiphoniidae	-	<1	-	-	<1	-
Amphipoda	<1	0 to <1	<1	3	<1 to 2	-
Hydracarina	<1	0 to <1	-	3	0 to 2	-
Gastropoda	<1	0 to 3	1	13	<1 to 5	2
Bivalvia	1	0 to 12	1	1	<1 to 10	<1
Ceratopogonidae	1	<1 to 2	1	3	1 to 4	2
Chironomidae	91	46 to 86	69	54	1 to 67	80
Diptera (misc.)	-	1	1	-	-	<1
Coleoptera	<1	0 to 1	<1	-	0 to 22	-
Odonata	<1	0 to <1	-	<1	<1 to 1	<1
Ephemeroptera	<1	<1 to 2	1	<1	1	2
Plecoptera	<1	0 to 1	<1	-	-	-
Trichoptera	<1	0 to <1	<1	<1	0 to <1	-
Heteroptera	<1	0 to <1	-	-	-	-
Benthic Invertebrate Community Measurement Endpoints						
Total abundance per sample	1,636	366 to 764	3,017	213	43 to 545	782
Richness	20	10 to 20.2	23	11	4 to 14	23
Equitability	0.27	0.32 to 0.38	0.20	0.54	0.45 to 0.69	0.23
% EPT	0.12	0.09 to 1.47	1.33	0.25	0 to 2.55	2.13

Table 5.6-10 Results of analysis of variance (ANOVA) testing for differences in measurement endpoints of benthic invertebrate community in the Calumet River (*test* reach CAR-D1).

Measurement Endpoint	P-value							Variance Explained (%)							Nature of Change(s)
	Control vs. Impact	Before vs. After	BACI	Time Trend in *Test* Period	Difference in Time Trend (*test*)	2015 vs. *Baseline*	2105 vs. Previous Years	Control vs. Impact	Before vs. After	BACI	Time Trend in *Test* Period	Difference in Time Trend (*test*)	2015 vs. *Baseline*	2105 vs. Previous Years	
Log of Abundance	**<0.001**	0.554	0.731	0.903	**0.002**	**<0.001**	**0.011**	35	0	0	0	12	31	8	Abundance was higher in the lower reach, increasing over time. Abundance was higher in 2015 than the mean of the upper *baseline* and the mean of prior years in the lower reach.
Log of Richness	**<0.001**	**0.013**	0.430	0.059	**0.001**	**<0.001**	**0.038**	35	6	1	3	11	24	4	Richness was higher in the lower reach than the upper reach, and higher in the *test* period than the *baseline* period of the lower reach. Richness increased over time and was higher in 2015 than the mean of the upper *baseline* and the mean of prior years in the lower reach.
Equitability	**<0.001**	**0.029**	0.217	0.315	**0.001**	**<0.001**	**0.017**	51	7	2	1	16	40	9	Equitability was lower in the lower reach than the upper reach, and lower in the *test* period than the *baseline* period of the lower reach. Equitability decreased over time and was lower in 2015 than the mean of the upper *baseline* and the mean of prior years in the lower reach.
Log of EPT	0.099	**0.016**	0.083	**0.016**	**0.011**	0.147	0.507	4	10	5	9	11	3	1	EPT was higher in the *test* period of the lower reach, increasing over time.
CA Axis 1	**0.005**	0.108	0.071	0.237	0.164	0.660	0.159	11	3	4	2	2	0	3	CA Axis 1 scores were lower in the *test* reach.
CA Axis 2	**0.017**	0.131	0.244	0.179	**<0.001**	0.094	**<0.001**	7	3	2	2	22	3	16	CA Axis 2 scores were lower in the *test* reach, decreasing over time. CA Axis 2 scores were lower in 2015 than the mean of prior years in the reach.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

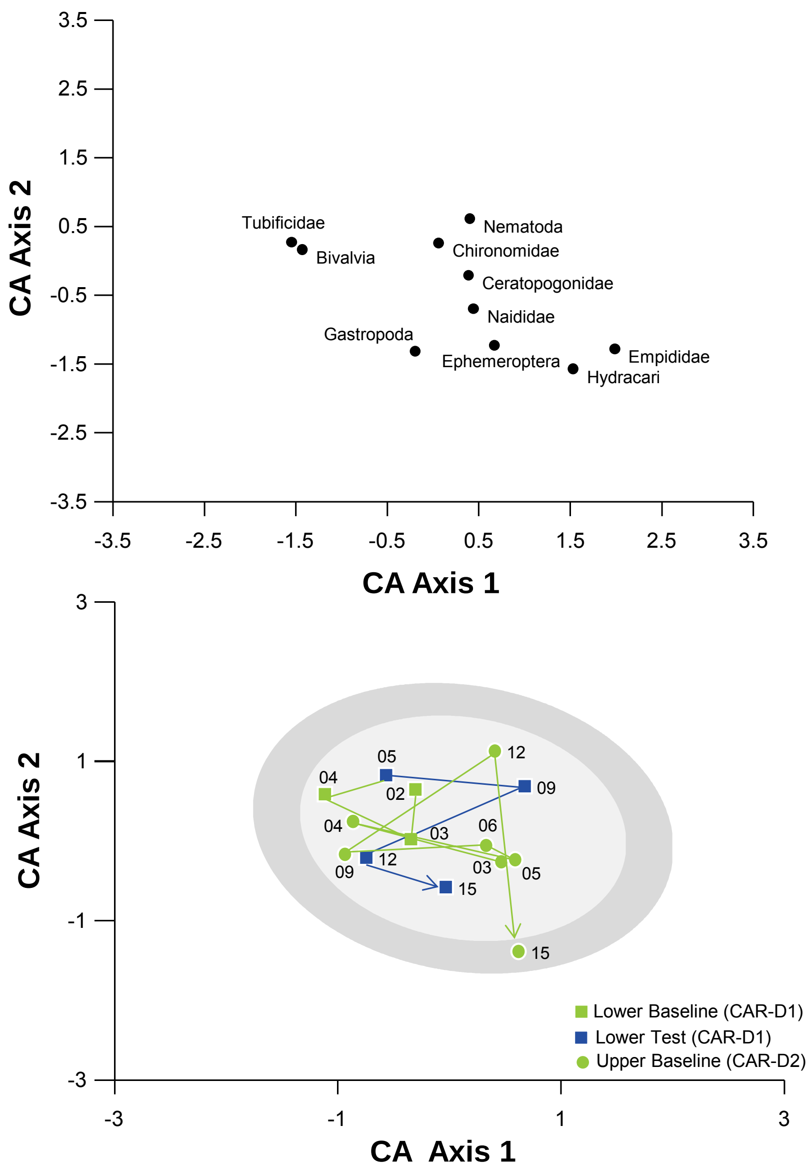
Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.6-7 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower and upper reaches of the Calumet River (*test* reach CAR-D1 and *baseline* reach CAR-D2).

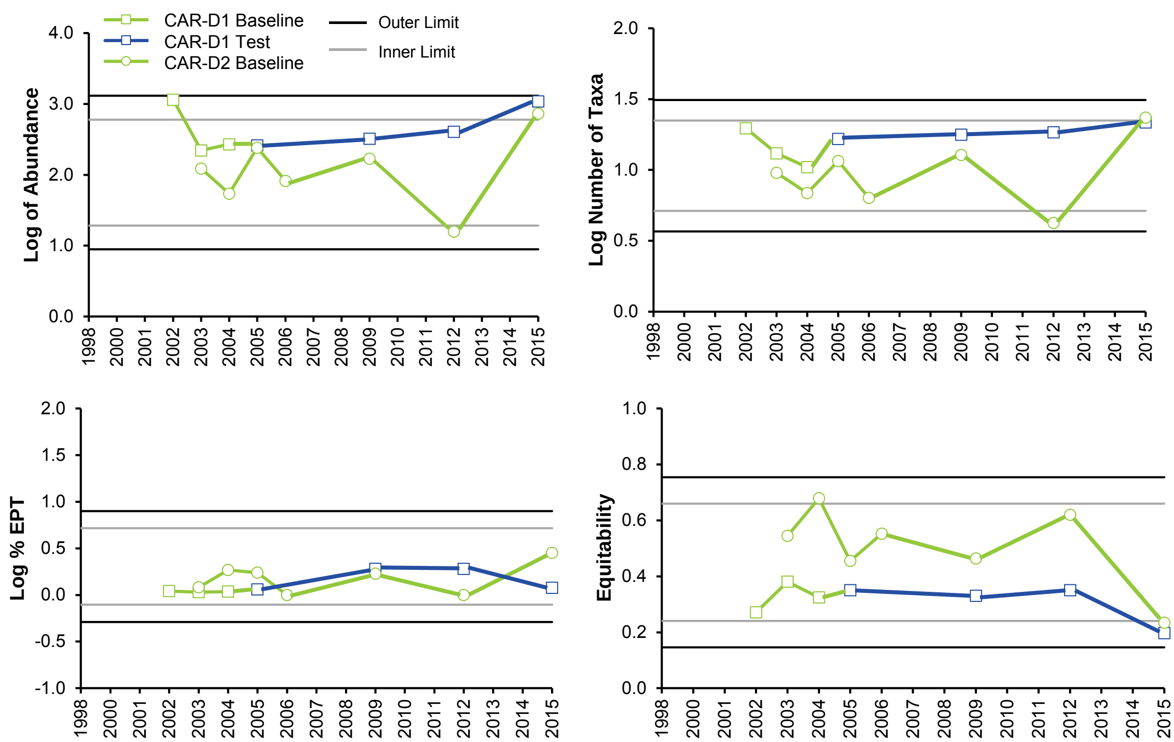


Notes:

The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses are the inner and outer tolerance limits on the 95th percentile for regional *baseline* depositional reaches.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.6-8 Variation in benthic invertebrate community measurement endpoints at lower *test* reach CAR-D1 and upper *baseline* reach CAR-D2 of the Calumet River relative to regional *baseline* ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* depositional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.6-11 Concentrations of selected sediment quality measurement endpoints, Calumet River (*test* station CAR-D1), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2002-2012 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2.0	5	6.0	10.0	21.0
Silt	%	-	4.2	5	7.0	12.3	30.0
Sand	%	-	93.8	5	52.0	70.0	87.0
Total organic carbon	%	-	2.34	5	0.60	2.80	4.10
Total hydrocarbons							
BTEX	mg/kg	-	<10	4	<5	<8	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	4	<5	<8	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	**185**	4	92	**208**	**640**
Fraction 3 (C16-C34)	mg/kg	300[1]	**3,260**	4	**1,730**	**3,125**	**7,200**
Fraction 4 (C34-C50)	mg/kg	2800[1]	2,560	4	1,600	2,630	**5,300**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0014	5	0.0014	0.0036	0.0110
Retene	mg/kg	-	0.1170	5	0.0500	0.1600	0.1810
Total dibenzothiophenes	mg/kg	-	7.1883	5	0.3105	5.5152	9.6810
Total PAHs	mg/kg	-	16.7214	5	1.5416	17.4632	26.9809
Total Parent PAHs	mg/kg	-	0.4453	5	0.1134	0.5714	0.6723
Total Alkylated PAHs	mg/kg	-	16.2761	5	1.4282	16.8918	26.3524
Predicted PAH toxicity[3]	H.I.	1.0	0.7954	5	0.5981	0.7901	**1.9459**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
Chrysene	mg/kg	0.0571	**0.1850**	5	0.0190	**0.1870**	**0.2760**
Dibenz(a,h)anthracene	mg/kg	0.0062	**0.0169**	5	0.0017	**0.0123**	**0.0299**
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	96	4	68	84	90
Chironomus growth - 10d	mg/organism	-	1.59	4	1.27	1.71	1.88
Hyalella survival - 14d	% surviving	-	98	4	70	90	90
Hyalella growth - 14d	mg/organism	-	0.08	4	0.20	0.27	0.28

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

ns = not sampled in 2003, 2006 to 2008, 2010 to 2011, or 2013 to 2014

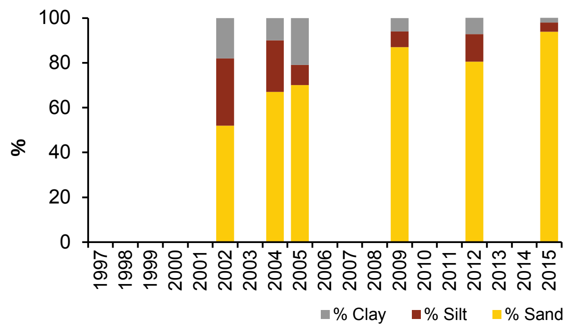
1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

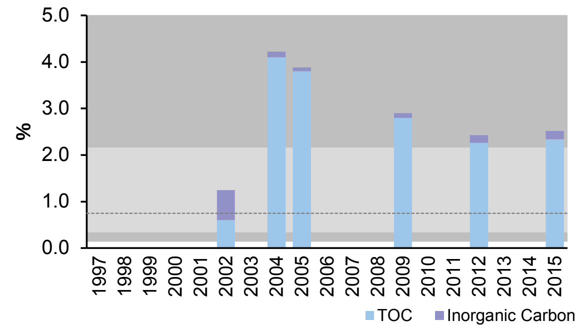
3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.6-9 Variation in sediment quality measurement endpoints in the Calumet River, *test* station CAR-D1, relative to historical concentrations and to regional *baseline* concentrations.

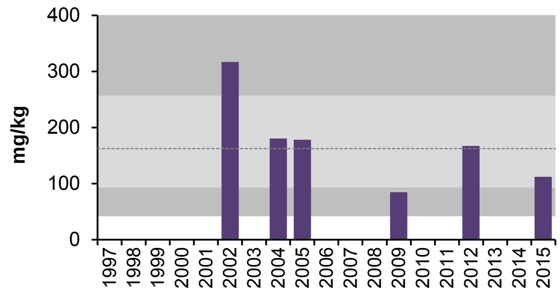
Particle Size Distribution



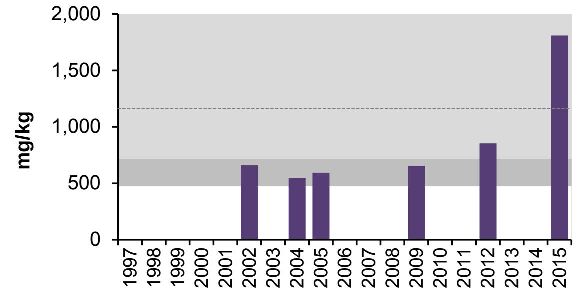
Carbon Content[1]



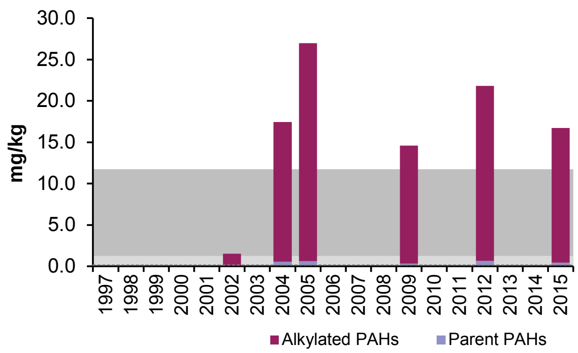
Total Metals[2]



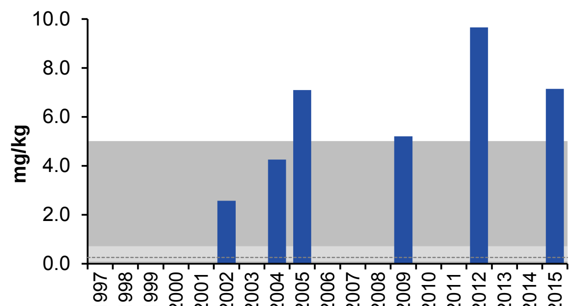
Total metals[2] **normalized to percent fine sediments (i.e., % silt + clay)**



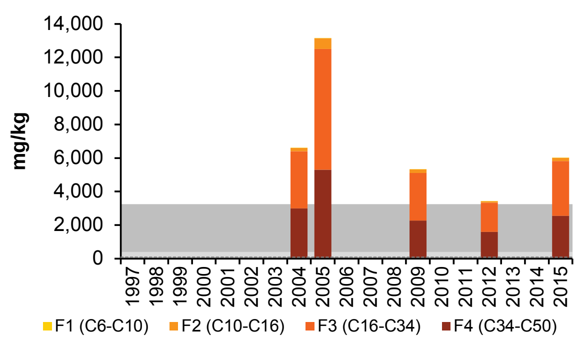
Total PAHs



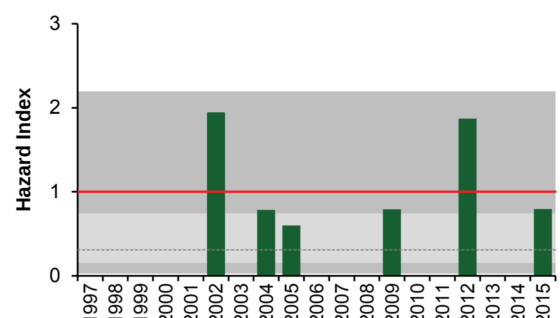
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.6-12 Concentrations of selected sediment quality measurement endpoints, Calumet River (*baseline* station CAR-D2), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2005-2012 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	31.7	4	11.3	20.0	42.0
Silt	%	-	34.9	4	21.8	31.0	53.0
Sand	%	-	33.4	4	5.0	49.0	66.9
Total organic carbon	%	-	<u>2.06</u>	4	7.81	14.25	20.50
Total hydrocarbons							
BTEX	mg/kg	-	<u><100</u>	4	<5	<35	<80
Fraction 1 (C6-C10)	mg/kg	30[1]	**<u><100</u>**	4	<5	**<35**	**<80**
Fraction 2 (C10-C16)	mg/kg	150[1]	<120	4	<5	<47	**230**
Fraction 3 (C16-C34)	mg/kg	300[1]	**944**	4	235	**2,173**	**6,100**
Fraction 4 (C34-C50)	mg/kg	2800[1]	824	4	154	1,594	**4,300**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0007</u>	4	0.0020	0.0098	0.0201
Retene	mg/kg	-	0.0812	4	0.0449	0.2300	0.7450
Total dibenzothiophenes	mg/kg	-	0.0273	4	0.0156	0.0226	0.0414
Total PAHs	mg/kg	-	<u>0.2033</u>	4	0.2525	1.1250	2.6755
Total Parent PAHs	mg/kg	-	<u>0.0122</u>	4	0.0175	0.0558	0.0961
Total Alkylated PAHs	mg/kg	-	<u>0.1911</u>	4	0.2350	1.0538	2.6102
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.0321</u>	4	0.0557	0.1361	0.1874
Metals that exceeded CCME guidelines in 2015							
Total arsenic	mg/kg	5.9	**11.1**	4	3.2	5.5	**12.6**
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	48	4	46	70	86
Chironomus growth - 10d	mg/organism	-	2.50	4	1.28	1.92	2.52
Hyalella survival - 14d	% surviving	-	<u>92</u>	4	58	63	78
Hyalella growth - 14d	mg/organism	-	<u>0.18</u>	4	0.24	0.36	0.44

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

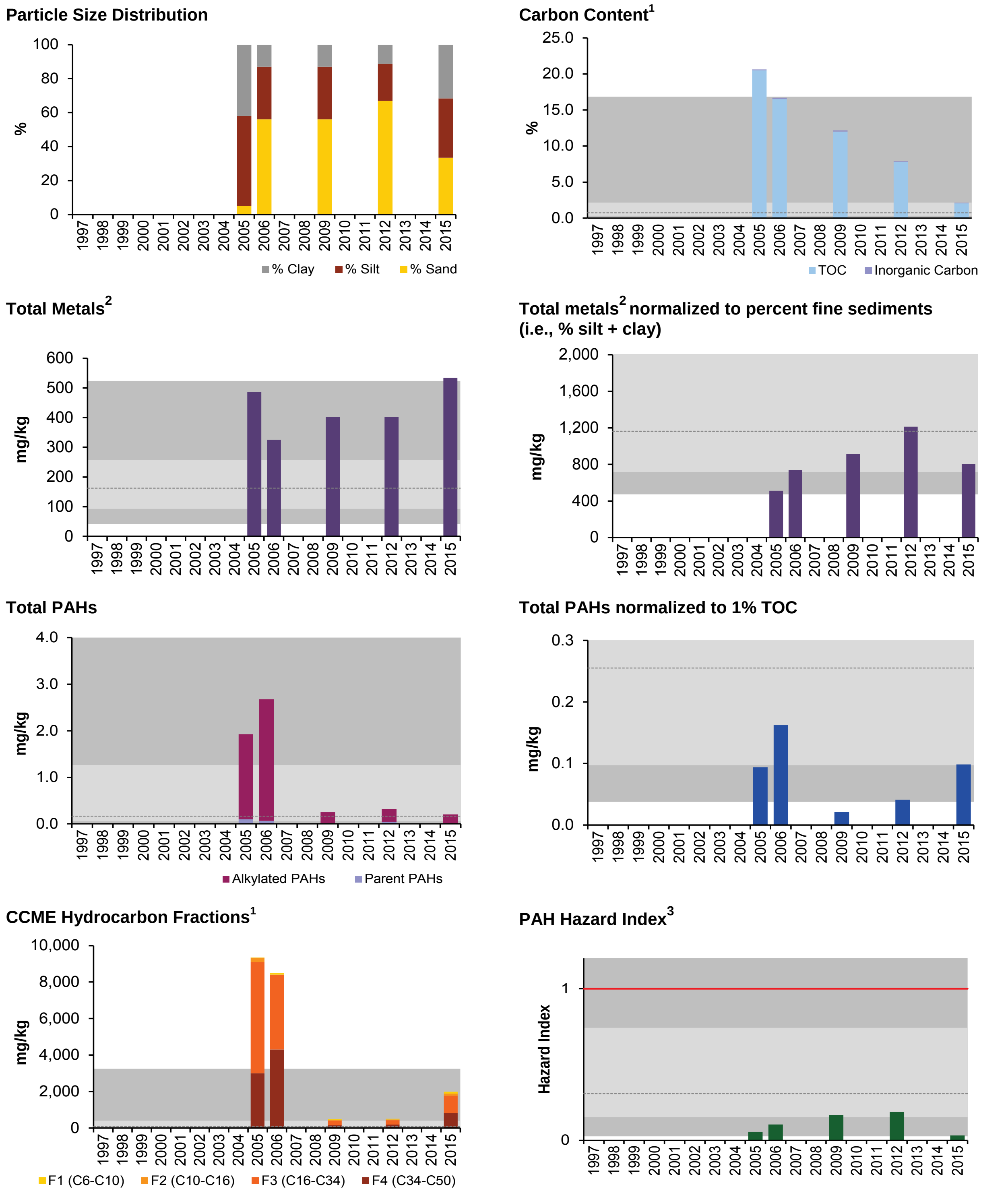
ns = not sampled in 2007, 2008, 2010, or 2011

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.6-10 Variation in sediment quality measurement endpoints in the Ells River, *test* station CAR-D2, relative to historical concentrations and to regional *baseline* concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

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5.7 FIREBAG RIVER WATERSHED

Table 5.7-1 Summary of results for the Firebag River watershed.

Firebag River Watershed	Summary of 2015 Conditions					
	Firebag River			Moose Creek	Lakes	
Climate and Hydrology						
Criteria	no station	**07DC001**	**S43**	**S36**	**L1**	no station
Mean open-water season discharge	-	🟡	not measured	not measured	not measured	-
Mean winter discharge	-	🟡	not measured	not measured	not measured	-
Annual maximum daily discharge	-	🟡	not measured	not measured	not measured	-
Minimum open-water season discharge	-	🟡	not measured	not measured	not measured	-
Climate and Hydrology						
Criteria	**FI1**	**FI WSC**	**FI2**	no station	**MCL-1**	**JOL-1**
Water Quality Index	🟡	🟡	🟡	-	n/a	n/a
Benthic Invertebrate Communities and Sediment Quality						
Criteria	**FIR-D1**	no reach	no reach	no reach	**MCL-1**	**JOL-1**
Benthic Invertebrate Communities	🟠	-	-	-	🟡	n/a
Sediment Quality Index	🟡	-	-	-	n/a	n/a
Fish Populations						
No Fish Populations component activities were conducted in 2015						

Legend and Notes

🟡 Negligible - Low

🟠 Moderate

🟤 High

baseline

test

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

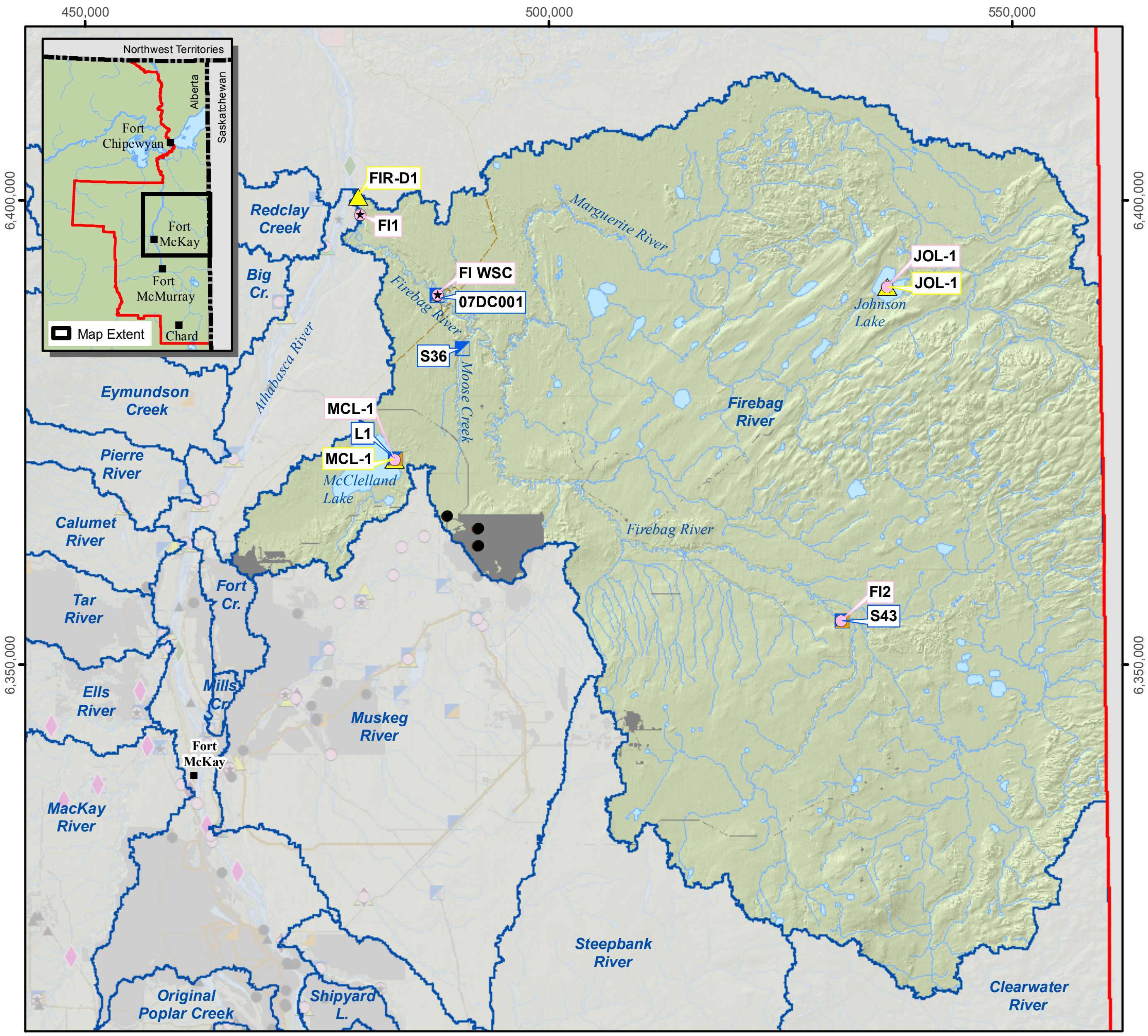
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Figure 5.7-1 Firebag River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]
- Water Withdrawal Location
- Water Release Location
- Water Quality Station
- Data Sonde Station
- Hydrometric Station
- Climate Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Community Reach
- Wild Fish Health Reach
- Wild Fish Health Reach with Water and Sediment Quality Stations

0 5 10 20 km

N

Scale: 1:675,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

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Figure 5.7-2 Representative monitoring stations of the Firebag River watershed, fall 2015.

Hydrology and Water Quality Station 07DC001/ FI WSC: lower Firebag River, facing downstream

Hydrology and Water Quality Station S43/FI2: Firebag River upstream of Suncor Firebag Project, facing upstream

Hydrology Station L1: McClelland Lake, facing northwest

Benthic Invertebrate Communities Reach and Water Quality Station JOL-1: Johnson Lake, facing south

5.7.1 Summary of 2015 WY Conditions

Approximately 1% (7,539 ha) of the Firebag River watershed[1] had undergone land change as of 2015 from oil sands development (Table 2.3-1). The designations of specific areas of the watershed are as follows:

1. The area downstream of the Suncor Firebag and Fort Hills, Imperial Kearl, and Husky Sunrise projects that are in the Firebag River watershed (Figure 5.7-1) is designated as *test*.

2. The remainder of the watershed is designated as *baseline*.

[1] The total area of the Firebag River watershed was increased in 2015 to include the portion of the watershed that is within the province of Saskatchewan.

Monitoring activities in the Firebag River watershed in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, and Benthic Invertebrate Communities and Sediment Quality components. Table 5.7-1 is a summary of the 2015 assessment of the Firebag River watershed while Figure 5.7-1 provides the locations of the monitoring stations for each component, reported water withdrawal and discharge locations for oil sands developments, and the area with land change as of 2015. Figure 5.7-2 provides fall 2015 photos from monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.50%, 0.52%, 0.22%, and 0.56% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences were classified as **Negligible-Low**. Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis was not required to identify the longitudinal hydrological effects along the Firebag River.

The water level recorded at Station L1, McClelland Lake, in winter of the 2015 WY was generally above historic maxima from November 2014 to mid-May 2015, when the annual peak lake level was recorded. Water levels then generally fell for the remainder of the water year. Water levels were above the median historic level until early August, and were between the mean and the lower historic quartile for the remainder of the water year.

Water Quality Water quality of the Firebag River and McClelland and Johnson lakes were similar to measurements in previous years, with similar water quality at upper and lower Firebag River stations and generally consistent monthly trends at all riverine and lacustrine stations. Concentrations of most measurement endpoints and ion balance at all *test* and *baseline* stations fell within the previously measured historical ranges. Concentrations of most water quality measurement endpoints at *test* stations FI1 and FI WSC and *baseline* station FI2 were within the range of regional *baseline* concentrations in fall 2015. Water quality at *test* stations FI1 and FI WSC and *baseline* station FI2 showed **Negligible-Low** differences from regional *baseline* water quality conditions in fall 2015. Water quality guideline exceedances included total mercury at *test* station FI1 (June), and total phenols and sulphide at all *test* and *baseline* stations (almost all seasons). These exceedances were consistent with historical monitoring by RAMP and JOSMP. Concentrations of water quality measurement endpoints for *test* station MCL-1 and *baseline* station JOL-1 were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers.

Benthic Invertebrate Communities and Sediment Quality Variations in measurement endpoints of benthic invertebrate communities at lower *test* reach (FIR-D1) were classified as **Moderate.** Richness decreased to an average of 4.4 taxa per sample, compared to averages of between 6 and 14 reported in previous years, but remained within confidence limits for historical variation. Total abundances, equitability and the percentage of EPT taxa were within the range of values observed in prior years.

Variations in benthic invertebrate community key measurement endpoints in McClelland Lake were classified as **Negligible-Low** as none of the statistically-significant temporal differences in values of benthic invertebrate community key measurement endpoints that accounted for more than 20% of the variation in annual means were indicative of degrading conditions for benthic invertebrate communities. In addition, values of all benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limits for the normal range of variation of previous years. The general composition of the community in terms of relative abundances, presence of fully aquatic forms and presence of generally sensitive taxa, such as the mayfly *Caenis* and two types of caddisflies, suggested that the community of McClelland Lake was in good condition and generally consistent with *baseline* conditions.

The benthic invertebrate community of Johnson Lake in 2015 showed some variation in composition from 2014, with an increase in richness and the presence of EPT taxa, which were not observed in 2013. In addition, the presence of permanent aquatic forms such as amphipods, gastropods and bivalves indicated that Johnson Lake was in good condition in fall 2015.

Sediment quality at *test* station FIR-D1 in fall 2015 indicated **Negligible-Low** differences compared to regional *baseline* conditions, as all fall 2015 sediment quality endpoints were within regional *baseline* ranges. Sediment quality measurement endpoints were not compared to regional *baseline* concentrations for McClelland Lake (MCL-1) or Johnson Lake (JOL-1) because lakes were not included in the calculation of *baseline* concentrations. CCME guidelines were exceeded for Fraction 3 hydrocarbon concentrations at *test* station MCL-1 and *baseline* station JOL-1.

The SQI value for *test* station FIR-D1 indicated **Negligible-Low** differences in sediment quality conditions in fall 2015 compared to regional *baseline* conditions. There were relatively few sediment quality measurement endpoints with fall 2015 concentrations outside the range of previously-measured concentrations and few exceedances of sediment quality guidelines. The concentration all sediment quality measurement endpoints at *test* station FIR-D1 were within regional *baseline* ranges; sediment quality endpoints at *test* station MCL-1 and *baseline* station JOL-1 were not compared to regional *baseline* ranges given the ecological variability between lakes and rivers.

5.7.2 Hydrologic Conditions

Firebag River

Hydrometric monitoring in the Firebag River watershed in the 2015 WY was conducted at the following locations:

- WSC Station 07DC001 (formerly JOSMP Station S27), Firebag River near the mouth;
- JOSMP Station L1, McClelland Lake;
- JOSMP Station S43, Firebag River above Suncor Firebag; and
- JOSMP S36, McClelland Lake Outlet above Firebag River.

Data from WSC Station 07DC001 were used for the water balance analysis and are presented below, as is lake-level time series from JOSMP Station L1; data for JOSMP Stations S43 and S36 are presented in Appendix C.

Seasonal data from March to October have been collected every year at WSC Station 07DC001 (formerly JOSMP Station S27) since 1972, with some partial data available for 1971. Continuous annual hydrometric data have been collected from 1972 to 1986, in 2002, and from 2004 to 2015. The historical flow record for the station is summarized in Figure 5.7-3, and includes the median, interquartile range, and range of flows recorded daily through the water year. Flows of the Firebag River have a typical seasonal runoff pattern characteristic of northern Alberta environments. Flows in winter are typically lower than during the open-water season, and decrease from November until early March. Spring thaw and the resulting increase in flows typically occur in April. Monthly flows are highest in May at the peak of freshet. Flows then recede through June and July, and remain similar from August to October.

Flows in the 2015 FY WSC Station 07DC001 were similar to the historical seasonal pattern described above (Figure 5.7-3). Flows decreased from November to late April and remained slightly higher than the historical median values for most of this period. The increase in flow due to spring thaw occurred at the beginning of April, slightly earlier than the historical timing of the spring freshet. The annual peak flow of 50.8 m^3/s on April 22 was 61% lower than the historical mean annual maximum daily flow of 129.2 m^3/s. Flows were below historical median flows from late April to the end of the WY, and often below the historical lower quartile flows over this period with the exception of three periods of rainfall-generated runoff in June, July, and September as recorded at the Pierre Climate Station, approximately 30 km southwest of WSC Station 07DC001. The minimum open-water daily flow of 13.3 m^3/s on August 31 was 15% lower than the historical mean minimum daily flow of 15.6 m^3/s calculated for the open-water period.

Overall, the annual runoff volume in the 2015 WY was 595 million m^3, which was 28% lower than the mean historical annual runoff volume of 830.5 million m^3 based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Firebag River watershed, at WSC Station 07DC001 (formerly JOSMP Station S27) is summarized in Table 5.7-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2015 was estimated to be 40.5 km^2 (Table 2.3-1). The loss of flow to the Firebag River that would have otherwise occurred from this land area was estimated at 4.04 million m^3.

2. As of 2015, the area of land change in the Firebag River watershed that was not closed-circuited was estimated to be 34.9 km^2 (Table 2.3-1). The increase in flow to the Firebag River that would not have otherwise occurred from this land area was estimated at 0.70 million m^3.

3. In the 2015 WY, Imperial Oil released a total of approximately 0.40 million m^3 (398,865 m^3) of water into the Firebag River watershed.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative hydrologic effect of oil sands development in the 2015 WY in the Firebag River was a loss of flow of 2.94 million m^3 at WSC Station 07DC001. The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.50%, 0.52%, 0.22%, and 0.56% lower in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.7-3). These differences were classified as **Negligible-Low** (Table 5.7-1). Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis to identify the longitudinal hydrological effects along the Firebag River was not required.

McClelland Lake

Continuous lake level data have been collected at JOSMP Station L1 McClelland Lake since 1997 with several periods of missing data over the data record. In the 2015 WY, water level increased from November until mid-April, and then declined for the remainder of the WY (Figure 5.7-4). The lake level throughout the winter period was consistently above historic maximum levels. The peak annual lake level of 294.7 masl (local datum) occurred in mid-April, which was close to the historical timing of the median peak lake level. Lake levels were above the historic upper quartile level until early July and were either at or below historic median daily levels. The water level of McClelland Lake varied by 0.34 m in the 2015 WY.

5.7.3 Water Quality

During 2015 WY (i.e., November 2014 to October 2015), water quality samples were taken from:

- the Firebag River near its mouth (*test* station FI1, previously called FIR-1), first sampled in 2002 and sampled on a monthly basis from May to October in 2015;
- the Firebag River upstream of Suncor's Firebag Project (*baseline* station FI2, previously called FIR-2), first sampled in 2003 and sampled on a monthly basis from July to October in 2015;
- the Firebag River at WSC Station 07DC001 (*test* station FI WSC) newly established in 2015 and sampled monthly from May to October;
- McClelland Lake (*test* station MCL-1), designated as *baseline* station from 2000 to 2009 and *test* station from 2009 onwards. This lake was sampled in May, July, and September in 2015;
- Johnson Lake (*baseline* station JOL-1), sampled seasonally from 2011 to 2015.

In addition, data sondes installed at *test* station FI1 and *test* station FI WSC collected continuous water quality data from May to October and July to October 2015, respectively, for a subset of water quality variables.

Figure 5.7-5 presents in situ water quality trends in the Firebag River as recorded by data sondes in the 2015 WY. Monthly and seasonal variations in water quality are summarized in Table 5.7-4 to Table 5.7-8 and Figure 5.7-6 to Figure 5.7-7. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations are provided in Table 5.7-9 to Table 5.7-13. The ionic composition of water in the Firebag River watershed is presented in Figure 5.7-8. Guideline exceedances for water quality measurement endpoints are presented in Table 5.7-14 and Figure 5.7-9 to Figure 5.7-10 present a comparison of selected water quality measurement endpoints in the Firebag River and lakes relative to historical regional *baseline* concentrations.

Continuous Monitoring Results from Data Sondes Water temperature in the Firebag River increased to 24°C in summer and decreased to 1°C by the end of October (Figure 5.7-5). Dissolved oxygen, pH, conductivity and turbidity data were removed from the beginning of the monitoring period to late July for *test* station FI WSC and from late May to mid-August from for *test* station FI1 due to data-quality issues potentially related to interaction with substrates. From available data, concentrations of dissolved oxygen were generally higher in fall than in spring and summer, likely a result of higher oxygen solubility at low temperatures as demonstrated by steady dissolved oxygen saturation throughout the monitoring period.

Dissolved oxygen concentrations were above the minimum water quality guideline for protection of aquatic life for the entire monitoring period for which data were available. Water at *test* station FI1 and *test* station FI WSC was alkaline throughout the monitoring period and pH levels did not exceed the water quality guideline for the protection of aquatic life at any time during the monitoring period. There was greater variation in specific conductivity at *test* station FI1 compared to *test* station FI WSC. Data gaps for data sondes at stations of the Firebag River are discussed in Appendix B.

Monthly and Seasonal Variations in Water Quality Generally, concentrations of particulates (TSS) and associated water quality constituents (i.e., a number of metals) were highest in May to July and lowest in August to October (Table 5.7-4 to Table 5.7-6, Figure 5.7-6), consistent with seasonal high and low flows (Figure 5.7-3). In contrast, concentrations of TDS and associated constituents (i.e. conductivity, alkalinity, and major ions) were lowest in May to July and highest in August to October, consistent with greater available dilution from surface runoff during seasonally high flows in spring and summer, followed by lower surface runoff in fall. Within-year trends in concentrations of water quality measurement endpoints at the two lake stations, *test* station MCL-1 and *baseline* station JOL-1, were similar to that at the river stations, although less-pronounced (Table 5.7-7, Table 5.7-8); concentrations of both TSS and TDS generally were higher at *baseline* station JOL-1 than at *test* station MCL-1. Comparison of 2015 monthly data with available historical data (Figure 5.7-7) indicate that concentrations and levels of most water quality measurement endpoints fell within the historical monthly ranges.

2015 Fall Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints measured in the Firebag River watershed in fall 2015 were within the range of previously-measured concentrations (Table 5.7-9 to Table 5.7-13) with the following exceptions:

- *test* station FI1: oilsands extractable acids, with a concentration that exceeded the previously-measured maximum concentration, and sulphate and naphthenic acids, with concentrations that were below previously-measured minimum concentrations;
- *baseline* station FI2: total parent PAHs and pH, with concentrations that exceeded previously-measured maximum concentrations, and TDS and total aluminum, with concentrations that were below previously-measured minimum concentration;
- *test* station MCL-1: naphthenic acids, oilsands extractable acids, chloride and sulphide, with concentrations that exceeded previously-measured maximum concentrations; and
- *baseline* station JOL-1: naphthenic acids, oilsands extractable acids, sulphide, and total phenols, with concentrations that exceeded previously-measured maximum concentrations, and pH, total nitrogen, dissolved aluminum, and total arsenic, with concentrations that were below previously-measured minimum concentrations.

No historical comparisons were made for *test* station FI WSC because this station was monitored for the first time in 2015.

Temporal Trends There were significant increases ($p<0.05$) measured in fall concentrations of total boron and magnesium at *test* station MCL-1 and there were no significant trends in fall concentrations of any of the water quality measurement endpoints at *test* station FI1 and *baseline* station FI2. Statistical trend analyses were not conducted on water quality data for *baseline* station JOL-1 or *test* station FI WSC due to insufficient length of the time series in the water quality datasets.

Ion Balance With few exceptions the ionic composition of water measured at all stations and all years (fall) in the Firebag River watershed has been dominated by calcium and magnesium, and by bicarbonate (Figure 5.7-8).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Water quality guideline exceedances in 2015 included (Table 5.7-14):

- total mercury at *test* station FI1 in June;
- total phenols at *test* stations, FI1 (June to August and October), FI WSC (July to October), and MCL-1 (July, September), as well as *baseline* stations, FI2 (July to October) and JOL-1 (July and September); and
- sulphide at *test* stations, FI1 (June and July), FI WSC (May to October), and MCL-1 (September), as well as *baseline* stations, FI2 (July to September) and JOL-1 (March, May, and September).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints at *test* stations FI1 and FI WSC and *baseline* station FI2 in fall 2015 were within regional *baseline* concentrations, with exception of the following water quality measurement endpoints that had concentrations below the 5th percentile of regional *baseline* concentrations (Figure 5.7-9): total arsenic at *test* station FI1; TDS and total strontium at *baseline* station FI2; and TSS, total arsenic, and total mercury at new *test* station FI WSC.

Concentrations of water quality measurement endpoints at lake stations (*test* station MCL-1 and *baseline* station JOL-1) (Figure 5.7-10) were not compared to regional *baseline* conditions because lakes were not included in the regional *baseline* assessment given the ecological differences between lakes and rivers.

Water Quality Index The WQI calculated for *test* stations FI1 (100) and FI WSC (100) and *baseline* station FI2 (98.6) in the Firebag River watershed in fall 2015 indicated **Negligible-Low** differences in fall 2015 water quality conditions compared to regional *baseline* conditions. WQI was not calculated for *test* station MCL-1 and *baseline* station JOL-1 because lakes were not included in the regional *baseline* assessment given the ecological differences between lakes and rivers.

Classification of Results Differences in between water quality in fall 2015 at *test* station FI1, *test* station FI WSC, and *baseline* station FI2 regional *baseline* water quality conditions were **Negligible-Low**.

5.7.4 Benthic Invertebrate Communities and Sediment Quality

5.7.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 at:

- depositional *test* reach FIR-D1, sampled from 2003 to 2007, 2010, 2013 and 2015;
- McClelland Lake (*test* station MCL-1), designated as *baseline* from 2002 to 2009 and *test* from 2010 to 2015; and
- Johnson Lake (*baseline* station JOL-1), sampled since 2011.

Firebag River

2015 Habitat Conditions Water at lower *test* reach FIR-D1 in fall 2015 was slightly alkaline (pH 7.8), with a high concentration of dissolved oxygen (9.3 mg/L), current velocity of 0.44 m/s, and moderate conductivity (200 µS/cm). The substrate was primarily sand (99%), with low total organic carbon (<1%) (Table 5.7-15).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach FIR-Dl in fall 2015 was dominated by chironomids (99%) (Table 5.7-16). Chironomids were not diverse, with five genera of Chironomini present, the most dominant being *Robackia demeijerei*. Permanent aquatic forms such as amphipods, bivalves, gastropods, and larvae of larger flying insects (EPT taxa) were not present at *test* reach FIR-D1 in 2015; however, these groups were present in the reach in 2013.

Temporal Comparisons The temporal comparisons of values of benthic invertebrate community measurement endpoints that were possible given the data available for the Firebag River watershed were: (i) changes over time (Hypothesis 5, Section 3.2.3.1) for lower *test* reach FIR-D1; and (ii) changes between 2015 values at lower *test* reach FIR-D1 and the mean of all previous years of sampling (2003 to 2014) at the reach.

The only one of these temporal comparisons that was statistically significant was richness in lower *test* reach (FIR-D1) that was measured to be significantly lower in fall 2015 than the mean of all prior years, accounting for 31% of the variation in annual means (Table 5.7-17, Figure 5.7-11).

Comparison to Published Literature *Test* reach FIR-D1 had low taxa richness and diversity in fall 2015, both of which tend to occur with degrading conditions (Hynes 1960; Griffiths 1998). The benthic invertebrate community at *test* reach FIR-D1 also did not contain EPT taxa or permanent aquatic forms. The sampled stations had a high sand content, which can naturally limit the types of benthic invertebrates that can reside in the substrate (e.g., Barton and Smith 1984).

2015 Results Relative to Regional *Baseline* Conditions Values of measurement endpoints for *test* reach FIR-D1 in fall 2015 were within the inner tolerance limits for the normal range of regional *baseline* conditions (Figure 5.7-11, Figure 5.7-12) with the exception of richness in fall 2015 that was below the inner tolerance limit of the 5th percentile of the normal range of regional *baseline* conditions (Figure 5.7-12).

Classification of Results Variations in measurement endpoints of benthic invertebrate communities at lower *test* reach (FIR-D1) were classified as **Moderate** because there was a statistically-significant temporal trend in values of one of the benthic invertebrate community measurement endpoints (richness) that explained more than 20% of the variation in annual mean richness, and the same measurement endpoint (richness) was below the inner tolerance limit of the 5th percentile of the normal range of regional *baseline* conditions.

McClelland Lake

2015 Habitat Conditions Water in McClelland Lake at *test* station MCL-1 had a pH of 8.4 and moderate conductivity (222 µS/cm), which was consistent with previous years (Table 5.7-18). Samples were taken at a depth of nearly 2 m. The lake substrate was primarily silt (79%) with small amounts of clay (13%) and sand (8%). The organic content of McClelland Lake sediments was very high (32% TOC).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of McClelland Lake at *test* station MCL-1 in fall 2015 was dominated by chironomids (35%) with subdominant taxa including Tubificidae (18%), Coleoptera (11%) and naidid worms (11%) (Table 5.7-19). Dominant chironomids included *Dicrotendipes* and *Parachironomus*, all of which are very common in north temperate lakes (Wiederholm 1983). Permanent aquatic forms such as bivalve clams (*Pisidium/Sphaerium*), gastropod snails (*Gyraulus, Helisoma,* and *Valvata sincera*), and amphipods (*Gammrus lacustris*, *Hyalella azteca*) were found in McClelland Lake indicating favorable long term water quality. Mayflies (*Callibaetis*, *Caenis*), caddisflies (*Mystacides*, *Oecetis*) and dragonflies Odonata (Corduliidae) were also present.

Temporal Comparisons The following temporal comparisons of benthic invertebrate community measurement endpoints at *test* station MCL-1 were conducted:

- differences between *baseline* (2002 to 2009) and *test* (2010 to present) periods (Hypothesis 2, Section 3.2.3.1);
- variations over time in the *test* period (i.e., 2010 to present);
- differences between 2015 and the mean of all *baseline* years; and
- differences between 2015 and all previous years.

The temporal comparisons for *test* station MCL-1 that were statistically significant were (Table 5.7-20, Figure 5.7-13):

1. There was a significant increase in %EPT over time during the *test* period, accounting for 24% of the variance in annual means.
2. There was a significant decrease in CA Axis 1 scores over time during the *test* period, accounting for 20% of the variation in annual means.
3. CA Axis 2 scores were significantly greater in the *test* period compared to the *baseline* period.

Changes in CA axis scores reflected a shift in taxa composition with higher relative abundances of tubificid worms and dragonflies at *test* station MCL-1 in the *test* period (Figure 5.7-13). None of these statistically-significant comparisons are indicative of degrading conditions for benthic invertebrate communities.

Comparison to Published Literature The benthic invertebrate community of McClelland Lake is relatively typical of a shallow lake environment (Parsons et al. 2010, Pennak 1989). McClelland Lake contained several taxa considered to be permanent aquatic forms such as bivalves, gastropods and amphipods in addition to larvae of flying insects (Ephemeroptera, Trichoptera and Odonata), which indicates favourable long-term water quality (Niemi et al. 1990).

2015 Results Relative to Historical Conditions Values of all benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limits for the normal range of variation of previous years (Figure 5.7-13, Figure 5.7-14).

Classification of Results Variations in benthic invertebrate community key measurement endpoints in McClelland Lake were classified as **Negligible-Low** as none of the statistically-significant temporal differences in values of benthic invertebrate community key measurement endpoints that accounted for more than 20% of the variation in annual means were indicative of degrading conditions for benthic invertebrate communities. In addition, values of all benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limits for the normal range of variation of previous years. The general composition of the community in terms of relative abundances, presence of fully aquatic forms and presence of generally sensitive taxa, such as the mayfly *Caenis* and two types of caddisflies, suggested that the community of McClelland Lake was in good condition and generally consistent with *baseline* conditions.

Johnson Lake

2015 Habitat Conditions Water in Johnson Lake at *baseline* station JOL-1 in fall 2015 was neutral (pH 6.9) with moderate conductivity (152 µS/cm) (Table 5.7-18). Benthic community samples were collected from 1.4 m of water. The substrate of Johnson Lake consisted primarily of silt (68%) with some sand (23%), and a small amount of clay (10%). Total organic carbon in the sediment was high (25%) (Table 5.7-18).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Johnson Lake at *baseline* station JOL-1 in fall 2015 was dominated by chironomids (60%), with subdominant naidid worms (15%) and amphipods (9%) (Table 5.7-19, Figure 5.7-15). Nineteen chironomid genera were present, with *Polypedilum* and *Procladius* being the most abundant. Amphipods included *Hyalella azteca* and *Gammarus lacustris*, both of which are commonly distributed in Canada (Väinölä et al. 2008). Bivalves (*Pisidium*) were present and gastropods were well represented with eight taxa present (Lymnaeidae, *Ferrissia rivularis*, *Stagnicola*, *Physa*, *Gyraulus*, *Helisoma*, *Menetus cooperi*, and *Valvata sincera*). The most abundant gastropods were *Valvata sincera, Gyraulus* and *Ferrissia rivularis.* Mayflies (Ephemeroptera: *Callibaetis*, *Caenis*) were found at one of the replicate stations in Johnson Lake in fall 2015, as well as *Enallagma* damselflies. Two kinds of caddisflies were present in the Lake, the most abundant of which were *Polycentropus*.

Comparison to Published Guidelines The benthic invertebrate community of Johnson Lake at *baseline* station JOL-1 contained a benthic fauna in 2015 that reflected good water quality and lentic conditions. The community contained several permanent aquatic forms such as Amphipoda (9%), fingernail clams (Bivalvia: Pisidiidae) and gastropods, which are consistent with good long-term water quality (Niemi et al. 1990; Pennak 1989). The abundance of worms was relatively low at *baseline* station JOL-1 in fall 2015 and EPT taxa were present as well, albeit in low abundances.

2015 Results Relative to Historical Conditions Mean benthic invertebrate richness in Johnson Lake was higher in 2015 than the mean of prior years (Table 5.7-19). The percentage of fauna as EPT taxa was also higher in 2015 (Table 5.7-19, Figure 5.7-16). The remaining measurement endpoints of benthic invertebrate community were similar to previous years (Figure 5.7-15, Figure 5.7-16).

Classification of Results The benthic invertebrate community of Johnson Lake in 2015 showed some variation in composition from 2014, with an increase in richness and the presence of EPT taxa, which were not observed in 2013. In addition, the presence of permanent aquatic forms such as amphipods, gastropods and bivalves indicate that Johnson Lake was in good condition in fall 2015.

5.7.4.2 Sediment Quality

Sediment quality was sampled in fall 2015 in the same locations as benthic invertebrate communities were sampled:

- *test* station FIR-D1 on the Firebag River, sampled as a *test* station from 2002 to 2004, 2006 to 2007, 2010, 2013, and 2015);
- *test* station MCL-1 on McClelland Lake, designated as *baseline* from 2002 to 2009 and *test* from 2010 to 2015; and
- *baseline* station JOL-1 on Johnson Lake, sampled since 2011.

Temporal Trends The following significant ($p<0.05$) temporal trends in concentrations of sediment quality measurement endpoints were observed in fall 2015: (i) increasing concentrations of Fraction 3 hydrocarbons at *test* station MCL-1; and (ii) decreasing concentrations of total arsenic at *test* station MCL-1. No significant temporal trends in concentrations of sediment quality measurement endpoints were detected for *test* station FIR-D1 from 2002 to 2015, and trend analysis were not possible for *baseline* station JOL-1 due to the limited years of historical data that were available for that station.

2015 Results Relative to Historical Conditions Concentrations and values of sediment quality measurement endpoints at *test* station FIR-D1, *test* station MCL-1, and *baseline* station JOL-1 in fall 2015 were within ranges of previously-measured concentrations and values (Table 5.7-21 to Table 5.7-23, Figure 5.7-17 to Figure 5.7-19) with the exception of:

- %silt, predicted PAH toxicity, and *Chironomus* growth at *test* station FIR-D1, with concentrations and values that were lower than previously-measured minimum concentrations and values;
- *Hyalella* growth at *test* station MCL-1, with a value that was lower than the previously-measured minimum value;
- BTEX and Fraction 1 and Fraction 2 hydrocarbons, with concentrations below detection limits that were themselves above previously-measured maximum concentrations;
- %clay and *Hyalella* growth at *baseline* station JOL-1, with concentrations and values that were lower than previously-measured minimum concentrations and values; and
- %total organic carbon and retene at *baseline* station JOL-1, with concentrations and values that were higher than previously-measured maximum concentrations and values.

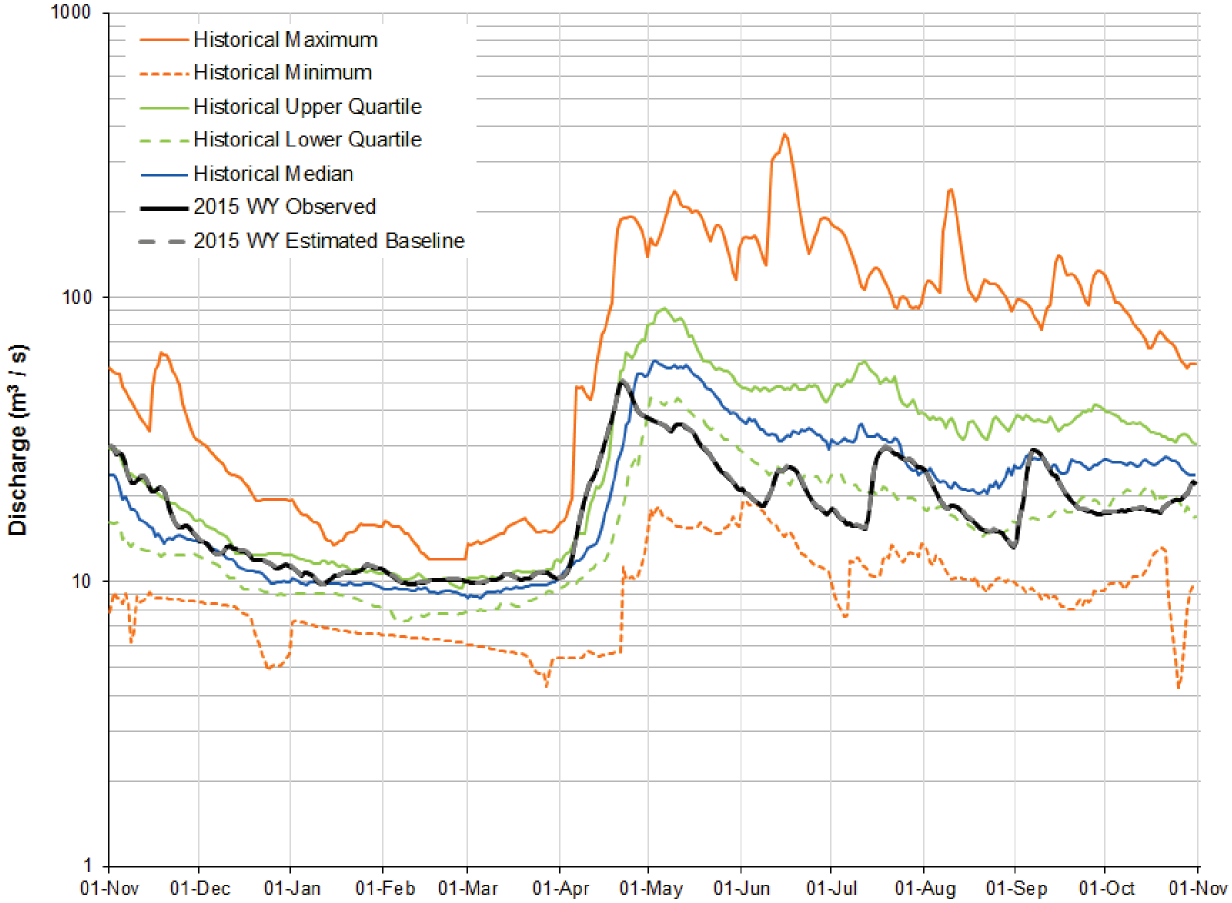
Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations and levels of sediment quality measurement endpoints were below guideline concentrations at *test* stations FIR-D1 and MCL-1 and *baseline* station JOL-1 in fall 2015 with the exception of Fraction 3 hydrocarbons at *test* station MCL-1 and *baseline* station JOL-1 (Table 5.7-22, Table 5.7-23). In addition, the concentrations of Fraction 1 and 2 hydrocarbons at *test* station MCL-1 and Fraction 1 hydrocarbons at *baseline* station JOL-1 were not detectable but their detection limits exceeded applicable CCME guidelines.

2015 Results Relative to Regional *Baseline* Concentrations In fall 2015, concentrations of all sediment quality measurement endpoints were within the ranges of regional *baseline* concentrations at *test* station FIR-D1. Concentrations of sediment quality measurement endpoints in fall 2015 at *test* station MCL-1 or *baseline* station JOL-1 were not compared to regional *baseline* conditions because lakes were not included in the regional *baseline* assessment given the ecological differences between lakes and rivers.

Sediment Quality Index The SQI calculated for *test* station FIR-D1 in fall 2015 was 100, similar to previous values for this location calculated in 2013 (98.3) and 2010 (98.8). SQI was not calculated for *test* station MCL-1 or *baseline* station JOL-1 because lakes were not included in the regional *baseline* assessment given the ecological differences between lakes and rivers.

Classification of Results The SQI value for *test* station FIR-D1 indicated **Negligible-Low** differences in sediment quality conditions in fall 2015 compared to regional *baseline* conditions.

Figure 5.7-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Firebag River in the 2015 WY, compared to historical values.



Note: The observed 2015 WY hydrograph was based on data for the 2015 WY for Firebag River near the mouth, WSC Station 07DC001. The upstream drainage area is 5,988 km^2. Historical daily values from March 1 to October 31 were calculated from data collected from 1972 to 2014, and historical daily values from November 1 to February 28 were calculated from data collected from 1972 to 1986, 2002, and from 2004 to 2014.

Table 5.7-2 Estimated water balance at WSC Station 07DC001 (formerly JOSMP Station S27), Firebag River near the mouth, 2015 WY.

Component	Volume (million m³)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**594.707**	**Observed discharge, obtained from Firebag River near the mouth, WSC Station 07DC001 (formerly JOSMP Station S27)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-4.039	Estimated 40.5 km² of the Firebag River watershed is closed-circuited as of 2015 (Table 2.3-1).
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.697	Estimated 34.9 km² of the Firebag River watershed with land change as of 2015 that is not closed-circuited (Table 2.3-1).
Water withdrawals from the Firebag River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Firebag River watershed, relative to the estimated *baseline* hydrograph	0.399	Releases by Imperial Oil into the Firebag River watershed
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**597.650**	**Estimated *baseline* discharge at Firebag River near the mouth, WSC Station 07DC001 (formerly JOSMP Station S27)**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	-2.943	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	-0.492	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph

Notes:

Definitions and assumptions discussed in Section 3.2.1.

All values in this table are presented to three decimal places.

All non-zero values in this table presented to three decimal places.

Table 5.7-3 Calculated change in hydrologic measurement endpoints for the Firebag River near the mouth, 2015 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m³/s)	Value from *Test* Hydrograph (m³/s)	Relative Change
Mean open-water season discharge	22.026	21.916	-0.503%
Mean winter discharge	13.033	12.965	-0.521%
Annual maximum daily discharge	50.910	50.800	-0.216%
Open-water season minimum daily discharge	13.375	13.300	-0.559%

Notes:

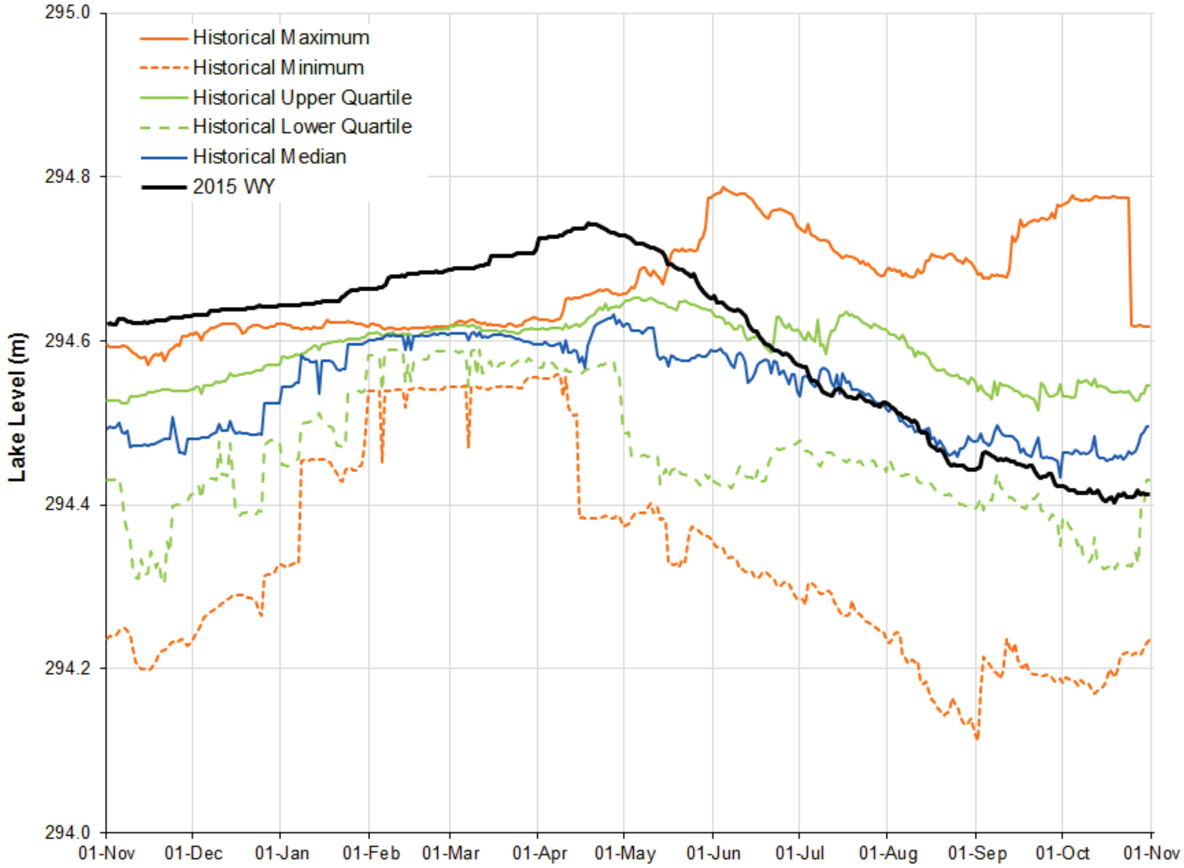
Definitions and assumptions were discussed in Section 3.2.1.

Observed discharge was calculated from data for the 2015 WY for WSC Station 07DC001.

The relative change for each measurement endpoint was calculated using observed and baseline flow values, which were estimated to several decimal places. Flows and percentage change values are presented to three decimal places for the sake of clarity.

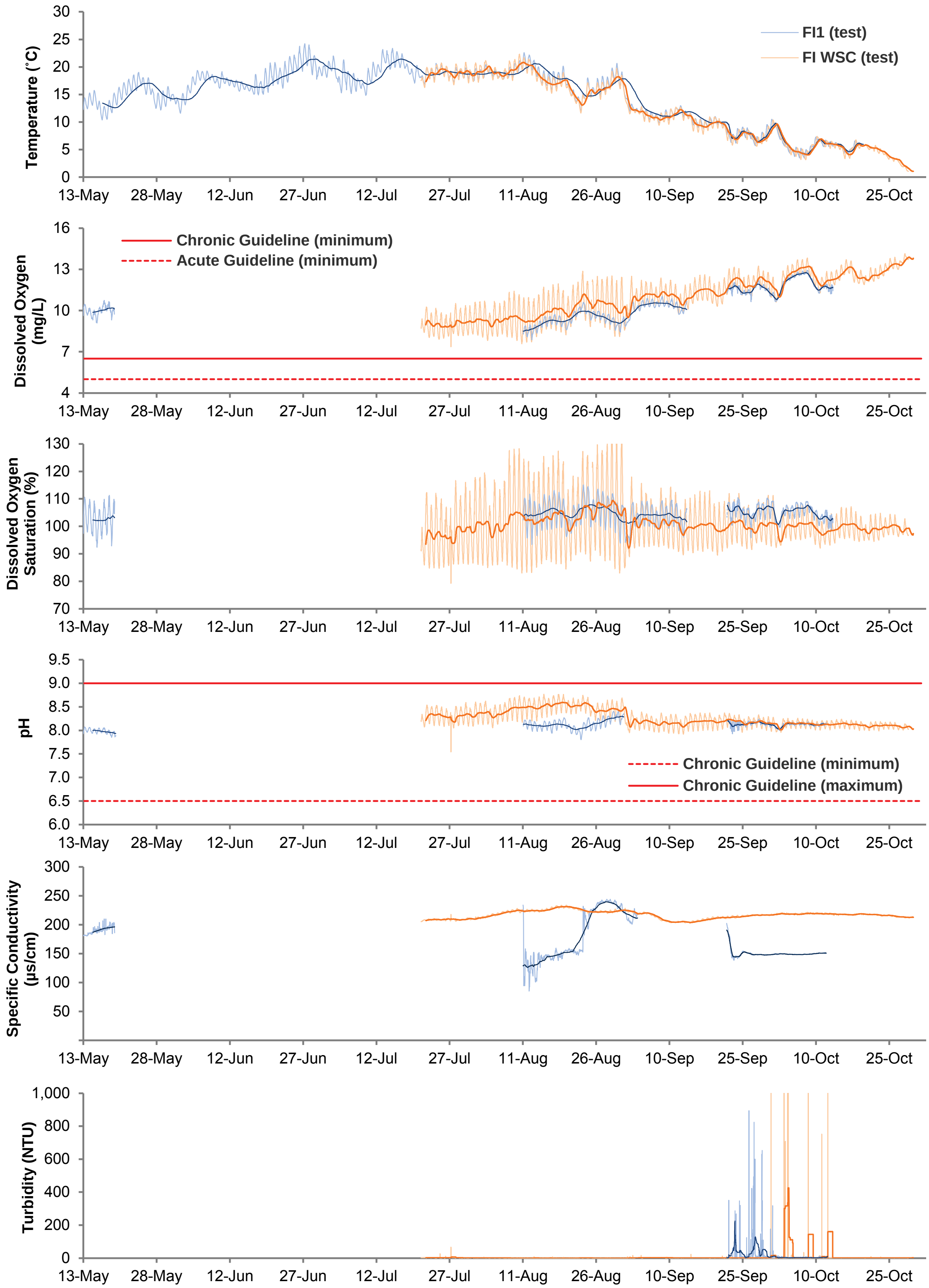
The open-water season refers to the period from May 1 and October 31 and the winter season refers to the period from November 1 and March 31.

Figure 5.7-4 Variation in the water level of McClelland Lake in the 2015 WY, compared to historical values.



Note: Observed 2015 flows based on data for the 2015 for WY McClelland Lake, JOSMP Station L1. Historical statistics were calculated for the period from 1997 to 2014 with numerous periods of missing data over the data record.

Figure 5.7-5 In situ water quality trends in the Firebag River recorded by data sondes, May to October 2015.



Note: Water quality variables were recorded at 15-minute and hourly intervals, and trend lines are daily averages.

Table 5.7-4 Monthly concentrations of water quality measurement endpoints, mouth of Firebag River (*test* station FI1 [FIR-1]), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.03	7.98	Jun	8.16	Sep
Total suspended solids	mg/L	-	5	3.3	1.30	Sep	10.0	Jul
Conductivity	µS/cm	-	5	210	210	-	230	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.018	0.015	Jun	0.023	Jul
Total nitrogen	mg/L	-	5	0.44	0.270	Oct	<1.00	Jun
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.005	-	<0.005	-
Dissolved organic carbon	mg/L	-	4	9.6	7.9	Oct	10.0	Aug
Ions								
Sodium	mg/L	-	5	3.9	3.5	Jul	4.3	Jun
Calcium	mg/L	-	5	30.0	27.0	Jun	31.0	Aug
Magnesium	mg/L	-	5	8.9	8.5	Jun	9.6	Sep
Potassium	mg/L	-	5	0.7	0.63	Jul	0.83	Jun
Chloride	mg/L	120-640	5	2.0	1.00	Jul	2.7	Oct
Sulphate	mg/L	309[b]	5	1.4	<1	Jul, Aug	2.2	Oct
Total dissolved solids	mg/L	-	5	140	120	Jul	160	Oct
Total alkalinity	mg/L	20 (min)	5	110	110	-	120	Oct
Selected metals								
Total aluminum	mg/L	-	6	0.067	0.0477	Sep	0.333	Jul
Dissolved aluminum	mg/L	0.05	6	0.0021	0.0018	Aug	0.0046	May
Total arsenic	mg/L	0.005	6	0.0004	0.00026	Oct	0.00048	Aug
Total boron	mg/L	1.5-29	6	0.019	0.018	Sep	0.024	Oct
Total molybdenum	mg/L	0.073	6	0.00018	0.00016	Sep	0.00021	Jun
Total mercury (ultra-trace)	ng/L	5-13	6	0.86	0.61	Oct	**11.24**	Jun
Total methyl mercury	ng/L	1-2	6	0.053	0.028	Oct	0.079	Aug
Total strontium	mg/L	-	6	0.068	0.052	May	0.078	Aug
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.51	0.17	Sep	0.73	Aug
Oilsands extractable acids	mg/L	-	6	1.50	0.90	Jun, Oct	2.40	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	18.50	Aug
Retene	ng/L	-	6	1.10	<0.59	May, Oct	1.95	Jul
Total dibenzothiophenes[c]	ng/L	-	6	9.80	7.81	May	40.06	Jul
Total PAHs[c]	ng/L	-	6	145.41	66.73	May	234.16	Jul
Total Parent PAHs[c]	ng/L	-	6	23.48	21.35	May	33.37	Aug
Total Alkylated PAHs[c]	ng/L	-	6	117.2	45.38	May	208.77	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0081**	**0.0062**	Oct	**0.0150**	Jul
Sulphide	mg/L	0.0019	2	**0.0025**	<0.0019	Aug, Oct	**0.0073**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.7-5 Monthly concentrations of water quality measurement endpoints, Firebag River at WSC station (*test* station FI WSC), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.04	7.96	Jun	8.27	Sep
Total suspended solids	mg/L	-	6	5.0	1.3	Sep	11.0	May
Conductivity	µS/cm	-	6	210	170	May	230	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.018	0.014	Sep	0.024	Jul
Total nitrogen	mg/L	-	6	0.43	0.26	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	<0.005	-
Dissolved organic carbon	mg/L	-	6	9.4	7.5	Oct	9.8	Jun
Ions								
Sodium	mg/L	-	6	3.5	3.0	May	3.7	Jun
Calcium	mg/L	-	6	29.5	25.0	May	33.0	Aug
Magnesium	mg/L	-	6	8.8	7.6	May	9.7	Aug
Potassium	mg/L	-	6	0.8	0.58	Sep	1.00	May
Chloride	mg/L	120-640	6	1.3	<1	May	1.8	Aug
Sulphate	mg/L	309[b]	6	<1.0	<1.0	-	1.0	May
Total dissolved solids	mg/L	-	6	135	44	May	150	Aug
Total alkalinity	mg/L	20 (min)	6	110	89	May	120	Aug, Oct
Selected metals								
Total aluminum	mg/L	-	6	0.077	0.0171	Aug	0.347	May
Dissolved aluminum	mg/L	0.05	6	0.0021	0.0012	Aug	0.0047	May
Total arsenic	mg/L	0.005	6	0.0003	0.00027	Oct	0.00043	Jul
Total boron	mg/L	1.5-29	6	0.018	0.011	Aug	0.022	Jul
Total molybdenum	mg/L	0.073	6	0.00018	0.00016	Sep	0.00021	Jun
Total mercury (ultra-trace)	ng/L	5-13	6	0.76	0.52	Oct	1.17	May
Total methyl mercury	ng/L	1-2	6	0.052	0.032	Oct	0.069	Aug
Total strontium	mg/L	-	6	0.064	0.053	May	0.074	Jun
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.54	0.17	Sep	0.75	May
Oilsands extractable acids	mg/L	-	6	1.40	0.50	Oct	2.30	May, Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	1.25	0.69	Sep	2.68	May
Total dibenzothiophenes[c]	ng/L	-	6	25.90	9.40	Sep	55.76	May
Total PAHs[c]	ng/L	-	6	177.28	128.89	Sep	235.23	May
Total Parent PAHs[c]	ng/L	-	6	23.70	22.89	Oct	24.78	Jun
Total Alkylated PAHs[c]	ng/L	-	6	153.4	105.88	Sep	210.84	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0059**	<0.002	May	**0.013**	Jul
Sulphide	mg/L	0.0019	6	**0.0056**	**0.0024**	May	**0.0093**	Sep

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.7-6 Monthly concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag Project (*baseline* station FI2 [FIR-2]), July to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	8.14	7.95	Jul	8.58	Sep
Total suspended solids	mg/L	-	4	3.4	2.00	Oct	4.7	Jul
Conductivity	µS/cm	-	4	180	170	Sep	190	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.045	0.037	Oct	0.052	Jul
Total nitrogen	mg/L	-	4	0.43	0.32	Oct	0.49	Aug
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.005	-	<0.005	-
Dissolved organic carbon	mg/L	-	4	7.2	6.1	Jul	9.6	Aug
Ions								
Sodium	mg/L	-	4	3.9	3.5	Jul	4.4	Oct
Calcium	mg/L	-	4	24.0	23.0	Sep, Oct	27.0	Aug
Magnesium	mg/L	-	4	7.3	6.8	Sep	7.8	Aug
Potassium	mg/L	-	4	0.6	0.54	Jul	0.86	Aug
Chloride	mg/L	120-640	4	<1	<1	-	1.3	Aug
Sulphate	mg/L	309[b]	4	<1	<1	-	1.7	Jul
Total dissolved solids	mg/L	-	4	120	100	Sep	140	Aug
Total alkalinity	mg/L	20 (min)	4	95	91	Oct	98	Aug
Selected metals								
Total aluminum	mg/L	-	4	0.011	0.0091	Aug	0.030	Jul
Dissolved aluminum	mg/L	0.05	4	0.0017	0.0013	Jul	0.0020	Oct
Total arsenic	mg/L	0.005	4	0.0005	0.00034	Oct	0.00059	Aug
Total boron	mg/L	1.5-29	4	0.017	0.013	Sep	0.021	Aug
Total molybdenum	mg/L	0.073	4	0.00025	0.00024	Sep	0.00028	Aug
Total mercury (ultra-trace)	ng/L	5-13	4	0.69	0.58	Oct	0.92	Jul
Total methyl mercury	ng/L	1-2	4	0.064	0.044	Jul	0.076	Aug
Total strontium	mg/L	-	4	0.049	0.043	Sep	0.054	Aug
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	4	0.25	<0.08	Oct	0.63	Jul
Oilsands extractable acids	mg/L	-	4	0.80	0.10	Oct	1.60	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	0.63	<0.59	Sep, Oct	11.00	Jul
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	4	125.91	125.10	Aug	144.76	Jul
Total Parent PAHs[c]	ng/L	-	4	22.73	22.49	Aug	28.81	Jul
Total Alkylated PAHs[c]	ng/L	-	4	103.2	102.61	Aug	115.95	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0063**	**0.0045**	Aug	**0.0110**	Jul
Sulphide	mg/L	0.0019	3	**0.0032**	<0.0019	Oct	**0.0054**	Aug

Values in bold are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.7-7 Seasonal concentrations of water quality measurement endpoints, McClelland Lake (*test* station MCL-1), May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	3	8.35	8.34	Sep	8.67	Jul
Total suspended solids	mg/L	-	3	2.0	<1	May	2.0	Jul, Sep
Conductivity	µS/cm	-	3	250	240	Jul	260	May
Nutrients								
Total dissolved phosphorus	mg/L	-	3	0.006	0.004	Jul	0.007	Sep
Total nitrogen	mg/L	-	3	0.95	0.88	Sep	<1.00	May
Nitrate+nitrite	mg/L	3-124	3	<0.005	<0.003	May	<0.005	Jul, Sep
Dissolved organic carbon	mg/L	-	3	14.0	13.0	May	14.0	Jul, Sep
Ions								
Sodium	mg/L	-	3	4.9	4.6	May	5.0	Sep
Calcium	mg/L	-	3	22.0	20.0	Jul	24.0	May
Magnesium	mg/L	-	3	17.0	16.0	May	18.0	Sep
Potassium	mg/L	-	3	2.8	2.70	Jul	3.00	Sep
Chloride	mg/L	120-640	3	1.0	<1	May, Jul	1.70	Sep
Sulphate	mg/L	309[b]	3	<1	<1	-	<1	-
Total dissolved solids	mg/L	-	3	170	160	Sep	180	Jul
Total alkalinity	mg/L	20 (min)	3	140	130	Jul	150	May
Selected metals								
Total aluminum	mg/L	-	3	0.008	0.0033	Jul	0.011	May
Dissolved aluminum	mg/L	0.05	3	0.0002	0.0002	May	0.00025	Jul
Total arsenic	mg/L	0.005	3	0.0002	0.00021	Jul	0.00022	Sep
Total boron	mg/L	1.5-29	3	0.065	0.055	May	0.078	Sep
Total molybdenum	mg/L	0.073	3	0.000006	<0.000002	May	0.000052	Jul
Total mercury (ultra-trace)	ng/L	5-13	3	0.28	0.28	May, Sep	0.40	Jul
Total methyl mercury	ng/L	1-2	3	<0.01	<0.01	May, Jul	0.012	Sep
Total strontium	mg/L	-	3	0.149	0.145	Sep	0.153	May
Total hydrocarbons								
BTEX	mg/L	-	3	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	3	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	3	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	3	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	3	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	3	0.71	0.59	May	0.82	Jul
Oilsands extractable acids	mg/L	-	3	2.00	1.30	May	2.30	Sep
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	3	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	3	0.59	<0.59	May, Sep	3.25	Jul
Total dibenzothiophenes[c]	ng/L	-	3	24.57	8.49	Sep	62.51	Jul
Total PAHs[c]	ng/L	-	3	145.82	133.00	Sep	291.79	Jul
Total Parent PAHs[c]	ng/L	-	3	22.73	22.21	May	27.06	Jul
Total Alkylated PAHs[c]	ng/L	-	3	123.6	110.27	Sep	264.73	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	2	**0.0052**	0.0039	May	**0.010**	Sep
Sulphide	mg/L	0.0019	1	<0.0019	<0.0019	May, Jul	**0.0031**	Sep

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.7-8 Seasonal concentrations of water quality measurement endpoints, Johnson Lake (*baseline* station JOL-1), March May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.92	7.72	Mar	8.11	Jul
Total suspended solids	mg/L	-	4	4.7	2.7	Jul	6.7	Sep
Conductivity	µS/cm	-	4	315	300	Jul	522	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.009	0.006	Jul	0.010	Sep
Total nitrogen	mg/L	-	4	0.97	0.86	Sep	1.84	Mar
Nitrate+nitrite	mg/L	3-124	4	<0.006	<0.003	May	<0.022	Mar
Dissolved organic carbon	mg/L	-	4	13.0	9.4	May	18.9	Mar
Ions								
Sodium	mg/L	-	4	5.3	4.4	Jul	7.3	Mar
Calcium	mg/L	-	4	42.5	36.0	Jul	73.3	Mar
Magnesium	mg/L	-	4	14.5	13.0	May	20.4	Mar
Potassium	mg/L	-	4	1.0	0.40	Jul	2.04	Mar
Chloride	mg/L	120-640	4	5.3	4.40	Jul	6.16	Mar
Sulphate	mg/L	429[b]	4	<1	0.97	Mar	<1.00	-
Total dissolved solids	mg/L	-	4	205	200	May, Jul	333	Mar
Total alkalinity	mg/L	20 (min)	4	170	160	Jul	289	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.006	0.0014	Jul	0.015	Sep
Dissolved aluminum	mg/L	0.05	4	0.0002	<0.00013	Mar, Jul	0.0005	May
Total arsenic	mg/L	0.005	4	0.0002	0.00014	May	0.00033	Mar
Total boron	mg/L	1.5-29	4	0.097	0.066	May	0.112	Sep
Total molybdenum	mg/L	0.073	4	0.00003	0.00001	Jul	0.00009	Mar
Total mercury (ultra-trace)	ng/L	5-13	4	0.65	0.44	May	0.76	Sep
Total methyl mercury	ng/L	1-2	3	0.037	0.020	Jul	0.120	Sep
Total strontium	mg/L	-	4	0.111	0.108	Jul	0.188	Mar
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	4	0.74	0.62	Jul	0.84	May
Oilsands extractable acids	mg/L	-	4	2.80	1.40	Jul	4.50	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	0.66	<0.59	Mar, May	3.56	Sep
Total dibenzothiophenes[c]	ng/L	-	4	8.30	<8.17	Mar, Jul	9.21	May
Total PAHs[c]	ng/L	-	4	125.67	111.22	Mar	163.54	Sep
Total Parent PAHs[c]	ng/L	-	4	22.41	8.60	Mar	22.84	Sep
Total Alkylated PAHs[c]	ng/L	-	4	103.3	102.61	Mar	140.70	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	2	**0.0054**	<0.001	Mar	**0.011**	Sep
Sulphide	mg/L	0.0019	3	**0.0048**	<0.0019	Jul	**0.0088**	Mar

Values in **bold** are above guideline.

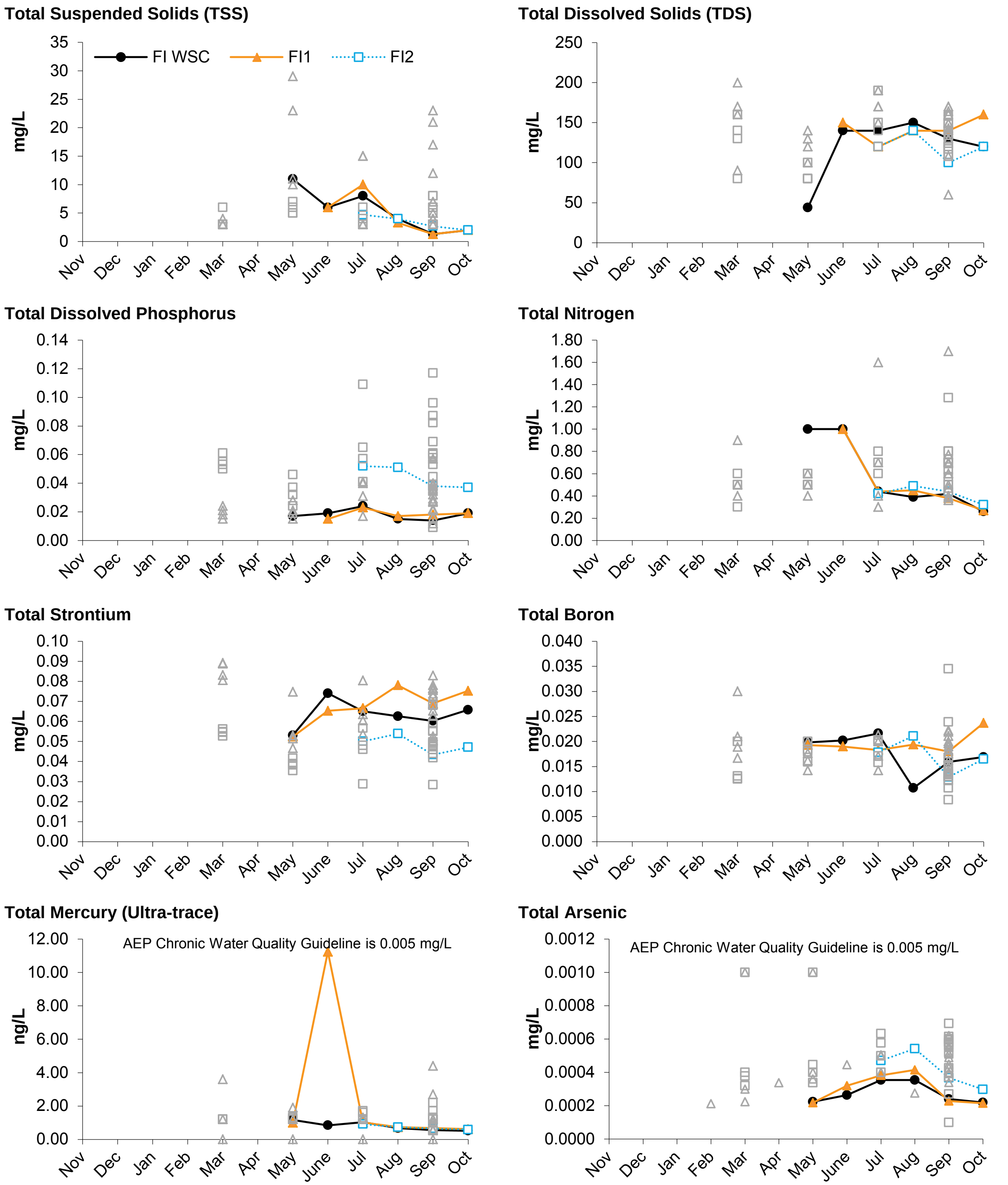
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

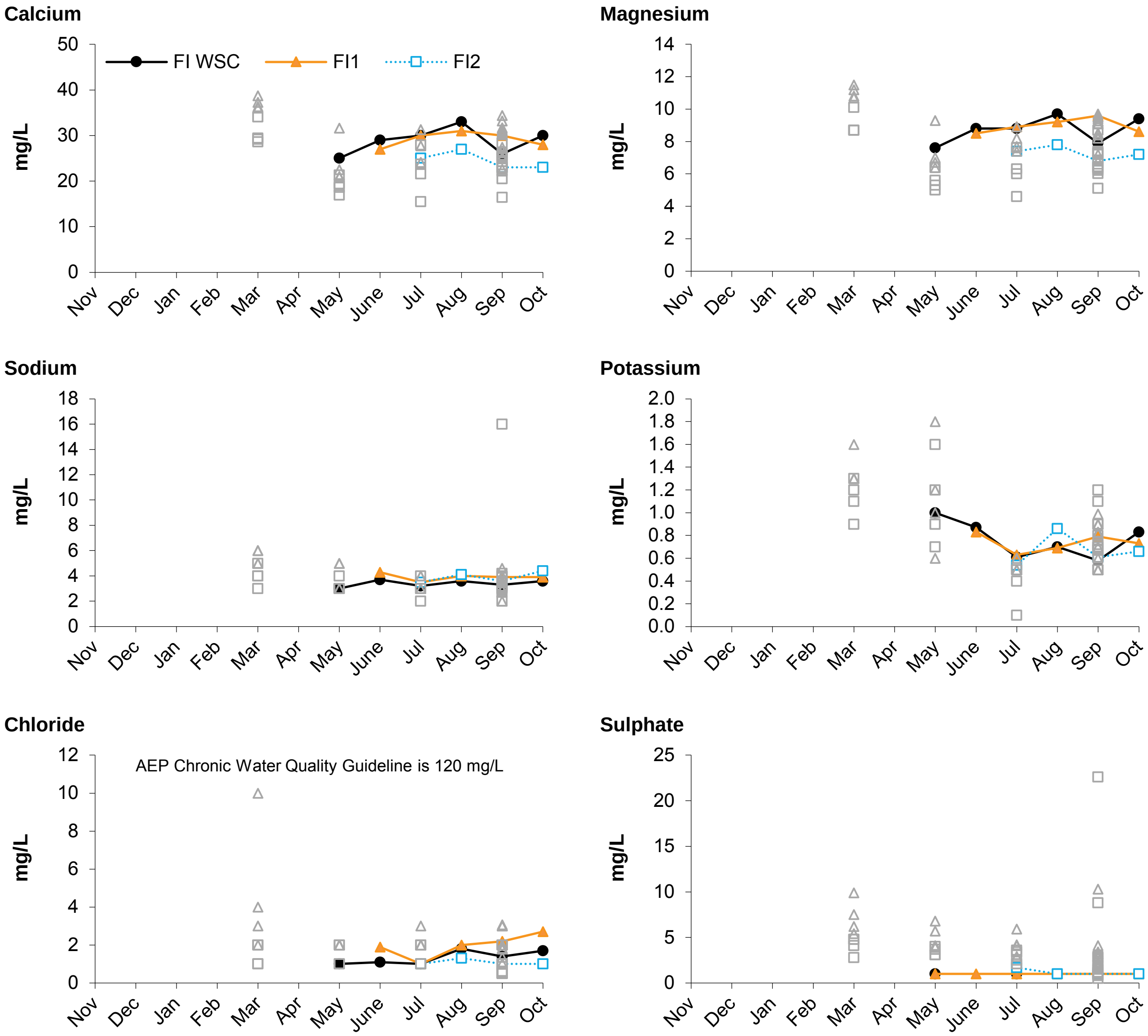
[d] n value refers to number of exceedances in 2015.

Figure 5.7-6 Concentration of selected water quality measurement endpoints in the Firebag River (monthly data) in the 2015 WY.



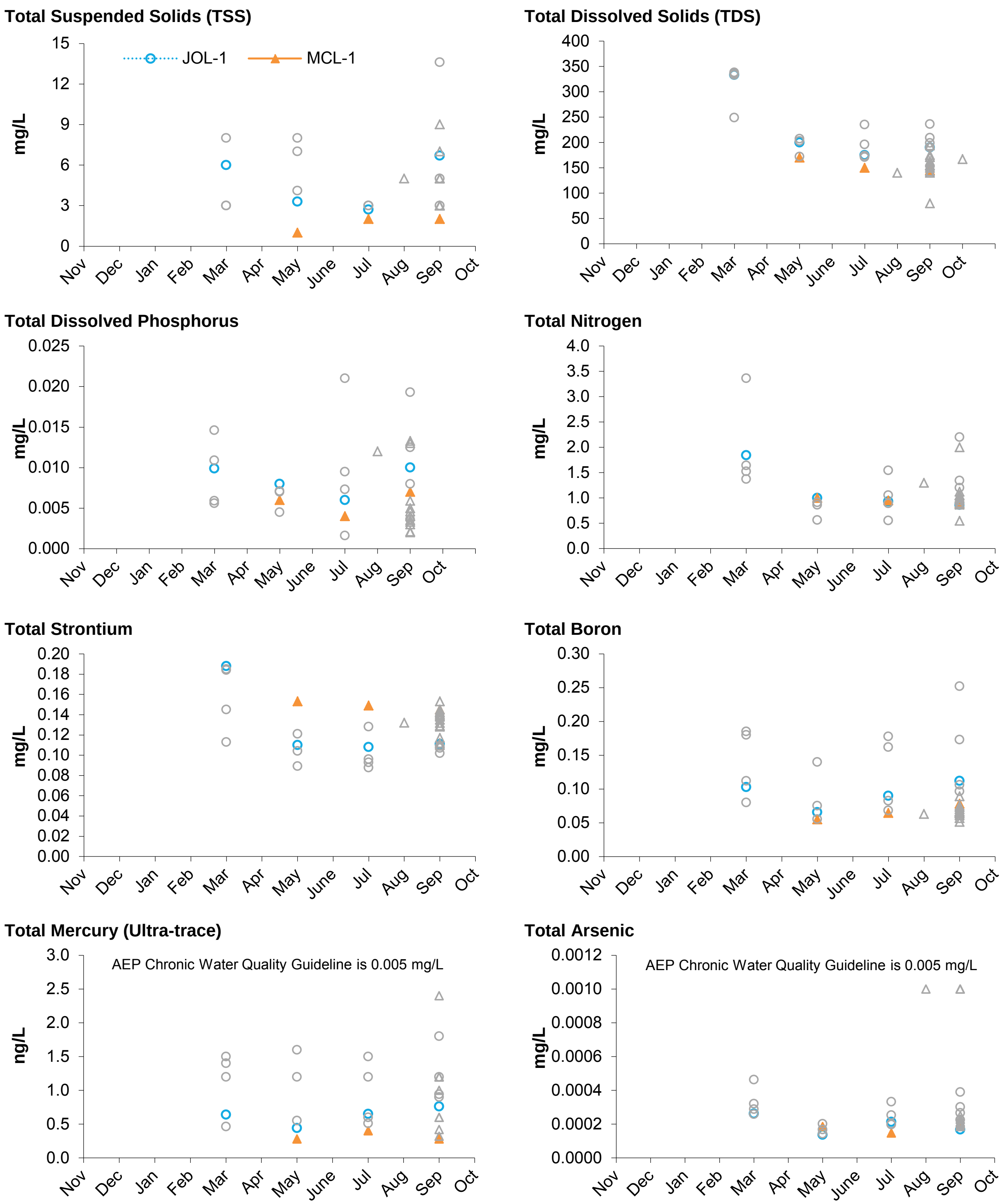
Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.7-6 (Cont'd.)



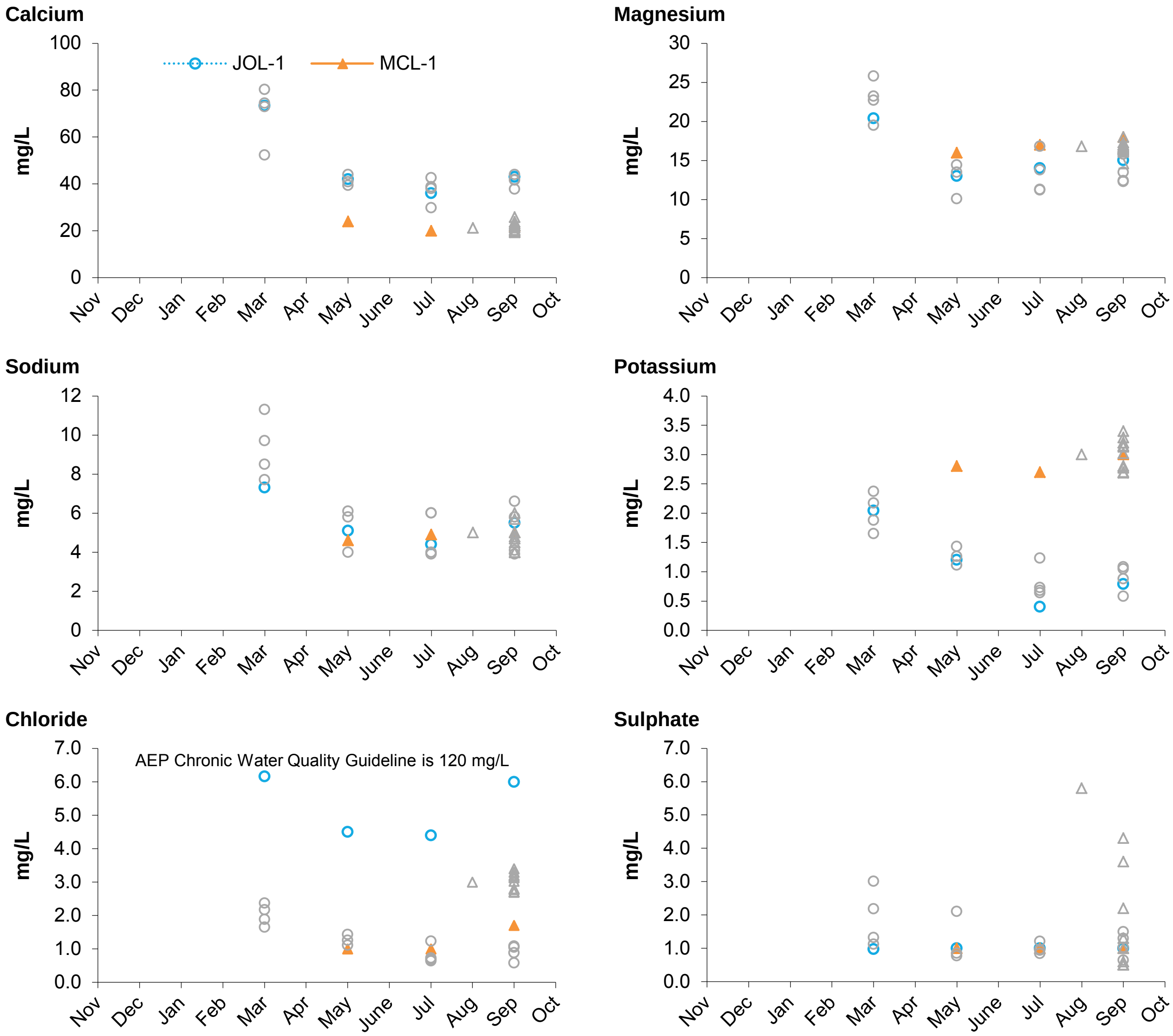
Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.7-7 Concentration of selected water quality measurement endpoints for McClelland Lake and Johnson Lake (seasonal data) in the 2015 WY.



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.7-7 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.7-9 Concentrations of water quality measurement endpoints, mouth of Firebag River (*test* station FI1 [FIR-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	2002-2014 (fall data only)			
				n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.16	13	8.2	7.9	8.5
Total suspended solids	mg/L	-	1.3	13	5.0	<3.0	23
Conductivity	µS/cm	-	210	13	219	171	251
Nutrients							
Total dissolved phosphorus	mg/L	-	0.018	13	0.029	0.012	0.057
Total nitrogen	mg/L	-	0.38	13	0.600	0.361	1.70
Nitrate+nitrite	mg/L	3-124	<0.005	13	<0.100	<0.054	<0.100
Dissolved organic carbon	mg/L	-	9.5	13	13.0	8.0	16.2
Ions							
Sodium	mg/L	-	3.9	13	4.0	2.0	4.6
Calcium	mg/L	-	30	13	30.8	22.6	34.4
Magnesium	mg/L	-	9.6	13	9.1	6.8	9.7
Potassium	mg/L	-	0.79	13	0.8	<0.5	0.99
Chloride	mg/L	120-640	2.2	13	2.0	1.0	3.1
Sulphate	mg/L	309[b]	<u>1.4</u>	13	2.8	1.7	10.3
Total dissolved solids	mg/L	-	140	13	143	60	170
Total alkalinity	mg/L	20 (min)	110	13	110	85	125
Selected metals							
Total aluminum	mg/L	-	0.048	13	0.094	0.033	0.428
Dissolved aluminum	mg/L	0.05	0.002	13	0.0049	0.0015	0.0089
Total arsenic	mg/L	0.005	0.0003	13	0.00045	0.00028	0.00062
Total boron	mg/L	1.5-29	0.018	13	0.018	0.014	0.022
Total molybdenum	mg/L	0.073	0.0002	12	0.00015	0.00011	0.00020
Total mercury (ultra-trace)	ng/L	5-13	0.680	12	<1.20	0.58	4.40
Total methyl mercury	ng/L	1-2	0.044	-	-	-	-
Total strontium	mg/L	-	0.069	12	0.073	0.051	0.083
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.17</u>	4	0.39	0.29	0.67
Oilsands extractable acids	mg/L	-	<u>1.00</u>	4	0.83	0.25	0.89
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.2
Retene	ng/L	-	1.5	4	2.75	0.58	3.43
Total dibenzothiophenes[c]	ng/L	-	8.78	4	11.15	7.724	58.15
Total PAHs[c]	ng/L	-	114.16	4	156.8	85.1	344.1
Total Parent PAHs[c]	ng/L	-	22.66	4	22.88	13.83	24.07
Total Alkylated PAHs[c]	ng/L	-	91.50	4	133.0	71.3	321.8

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.7-10 Concentrations of water quality measurement endpoints, Firebag River at WSC station (*test* station FI WSC), fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value
Physical variables			
pH	pH units	6.5-9.0	8.27
Total suspended solids	mg/L	-	1.3
Conductivity	µS/cm	-	210
Nutrients			
Total dissolved phosphorus	mg/L	-	0.014
Total nitrogen	mg/L	-	0.42
Nitrate+nitrite	mg/L	3-124	0.015
Dissolved organic carbon	mg/L	-	9.6
Ions			
Sodium	mg/L	-	3.3
Calcium	mg/L	-	26
Magnesium	mg/L	-	7.9
Potassium	mg/L	-	0.58
Chloride	mg/L	120-640	1.4
Sulphate	mg/L	309[b]	<1
Total dissolved solids	mg/L	-	130
Total alkalinity	mg/L	20 (min)	110
Selected metals			
Total aluminum	mg/L	-	0.029
Dissolved aluminum	mg/L	0.05	0.002
Total arsenic	mg/L	0.005	0.0003
Total boron	mg/L	1.5-29	0.016
Total molybdenum	mg/L	0.073	0.00016
Total mercury (ultra-trace)	ng/L	5-13	0.56
Total methyl mercury	ng/L	1-2	0.05
Total strontium	mg/L	-	0.060
Total hydrocarbons			
BTEX	mg/L	-	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02
Naphthenic acids	mg/L	-	0.17
Oilsands extractable acids	mg/L	-	0.9
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	1,000	<13.55
Retene	ng/L	-	0.694
Total dibenzothiophenes[c]	ng/L	-	9.2
Total PAHs[c]	ng/L	-	109.4
Total Parent PAHs[c]	ng/L	-	22.7
Total Alkylated PAHs[c]	ng/L	-	86.7
Other variables that exceeded Alberta guidelines in fall 2015			
Sulphide		0.0019	**0.0093**
Total phenols	mg/L	0.004	**0.0073**

Values in **bold** are above guideline; sampling began in 2015 and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.7-11 Concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag Project (*baseline* station FI2 [FIR-2]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	2002-2014 (fall data only)			
				n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	<u>8.58</u>	13	8.1	7.4	8.3
Total suspended solids	mg/L	-	2.7	13	3.0	<3.0	8.0
Conductivity	µS/cm	-	170	13	174	113	261
Nutrients							
Total dissolved phosphorus	mg/L	-	0.038	13	0.060	0.009	0.096
Total nitrogen	mg/L	-	0.44	13	0.700	0.434	1.28
Nitrate+nitrite	mg/L	3-124	<0.005	13	<0.100	<0.054	<0.100
Dissolved organic carbon	mg/L	-	8.0	13	13.1	8.00	17.4
Ions							
Sodium	mg/L	-	3.6	13	3.6	2.0	16
Calcium	mg/L	-	23	13	23.6	16.4	28.4
Magnesium	mg/L	-	6.8	13	6.4	5.1	8.7
Potassium	mg/L	-	0.61	13	0.7	<0.5	1.2
Chloride	mg/L	120-640	<1.00	13	1.00	0.50	2.00
Sulphate	mg/L	309[b]	<1.00	13	1.50	0.810	22.6
Total dissolved solids	mg/L	-	<u>100</u>	13	124	110	158
Total alkalinity	mg/L	20 (min)	92	13	93.0	57.0	114
Selected metals							
Total aluminum	mg/L	-	<u>0.011</u>	13	0.036	0.012	0.082
Dissolved aluminum	mg/L	0.05	0.002	13	0.004	0.001	0.011
Total arsenic	mg/L	0.005	0.0005	13	0.00057	0.00010	0.00062
Total boron	mg/L	1.5-29	0.013	13	0.013	0.008	0.035
Total molybdenum	mg/L	0.073	0.0002	13	0.00018	0.00004	0.00027
Total mercury (ultra-trace)	ng/L	5-13	0.65	12	<1.2	0.53	2.2
Total methyl mercury	ng/L	1-2	0.074	-	-	-	-
Total strontium	mg/L	-	0.043	13	0.049	0.028	0.068
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.12	4	0.23	0.06	0.27
Oilsands extractable acids	mg/L	-	0.8	4	0.95	0.30	0.99
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<8.76	<7.21	<14.1
Retene	ng/L	-	<0.59	4	1.210	0.791	<2.071
Total dibenzothiophenes[c]	ng/L	-	8.2	4	20.57	4.172	35.30
Total PAHs[c]	ng/L	-	105.6	4	178.8	74.1	206.3
Total Parent PAHs[c]	ng/L	-	<u>22.4</u>	4	16.49	13.26	19.21
Total Alkylated PAHs[c]	ng/L	-	83.2	4	160.9	60.9	189.8
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**0.0078**	13	**0.0042**	<0.0010	**0.0154**
Sulphide	mg/L	0.0019	**0.0039**	13	**0.0040**	0.0018	**0.0090**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.7-12 Concentrations of water quality measurement endpoints, McClelland Lake (*test* station MCL-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	2000-2014 (fall data only)			
				n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.34	13	8.5	8.1	8.7
Total suspended solids	mg/L	-	2	13	3.0	<3.0	9.0
Conductivity	µS/cm	-	250	13	245	224	267
Nutrients							
Total dissolved phosphorus	mg/L	-	0.007	13	0.004	0.002	0.013
Total nitrogen	mg/L	-	0.88	13	1.00	0.55	2.00
Nitrate+nitrite	mg/L	3-124	<0.005	13	<0.071	<0.050	<0.100
Dissolved organic carbon	mg/L	-	14.0	13	13.0	11.0	17.0
Ions							
Sodium	mg/L	-	5.0	13	4.8	4.0	6.0
Calcium	mg/L	-	22.0	13	22.0	19.3	25.8
Magnesium	mg/L	-	18.0	13	16.6	14.6	18.0
Potassium	mg/L	-	3.0	13	3.0	2.69	3.4
Chloride	mg/L	120-640	<u>1.7</u>	13	<1.0	<0.50	1.0
Sulphate	mg/L	309[b]	<1.00	13	0.50	<0.50	4.30
Total dissolved solids	mg/L	-	160	13	155	80	194
Total alkalinity	mg/L	20 (min)	140	13	130	122	145
Selected metals							
Total aluminum	mg/L	-	0.0083	13	0.011	0.003	0.026
Dissolved aluminum	mg/L	0.05	0.0002	13	<0.001	<0.001	0.010
Total arsenic	mg/L	0.005	0.0002	13	0.00021	0.00019	<0.0010
Total boron	mg/L	1.5-29	0.0782	13	0.066	0.051	0.089
Total molybdenum	mg/L	0.073	0.000006	13	<0.000030	<0.000003	<0.00010
Total mercury (ultra-trace)	ng/L	5-13	0.280	10	<1.1	<0.3	2.4
Total methyl mercury	ng/L	1-2	0.012	-	-	-	-
Total strontium	mg/L	-	0.145	13	0.135	0.110	0.153
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.71</u>	4	0.36	0.09	0.64
Oilsands extractable acids	mg/L	-	<u>2.3</u>	4	0.84	0.45	1.70
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	13.32	7.21	<15.2
Retene	ng/L	-	<0.59	4	<0.589	<0.407	<2.07
Total dibenzothiophenes	ng/L	-	8.5	4	7.100	4.495	35.30
Total PAHs	ng/L	-	114.6	4	135.2	74.7	221.5
Total Parent PAHs	ng/L	-	22.4	4	20.55	13.26	23.46
Total Alkylated PAHs	ng/L	-	92.2	4	113.3	61.47	200.8
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**0.01**	13	0.0030	<0.0010	**0.0225**
Sulphide	mg/L	0.0019	**<u>0.0031</u>**	13	<0.002	<0.002	<0.003

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.7-13 Concentrations of water quality measurement endpoints, Johnson Lake (*baseline* station JOL-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	2011-2014 (fall data only)			
				n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	<u>7.82</u>	4	8.38	8.24	8.44
Total suspended solids	mg/L	-	6.7	4	4	<3.0	61
Conductivity	µS/cm	-	310	4	309	249	341
Nutrients							
Total dissolved phosphorus	mg/L	-	0.01	4	0.008	0.002	0.019
Total nitrogen	mg/L	-	<u>0.86</u>	4	1.04	0.864	2.20
Nitrate+nitrite	mg/L	3-124	0.0069	4	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	13	4	13.9	12.2	14.6
Ions							
Sodium	mg/L	-	5.5	4	5.3	3.9	6.6
Calcium	mg/L	-	43	4	39.7	22.1	44.0
Magnesium	mg/L	-	15	4	14.7	12.3	16.5
Potassium	mg/L	-	0.79	4	1.07	0.58	2.77
Chloride	mg/L	120-640	6.00	4	3.70	0.50	6.07
Sulphate	mg/L	309[b]	<1.00	4	1.16	0.50	1.49
Total dissolved solids	mg/L	-	210	4	195	175	236
Total alkalinity	mg/L	20 (min)	170	4	160	134	172
Selected metals							
Total aluminum	mg/L	-	0.015	4	0.015	0.011	0.132
Dissolved aluminum	mg/L	0.05	<u>0.00020</u>	4	0.0028	0.0006	0.0158
Total arsenic	mg/L	0.005	<u>0.00019</u>	4	0.00026	0.00020	0.00039
Total boron	mg/L	1.5-29	0.112	4	0.135	0.073	0.252
Total molybdenum	mg/L	0.073	0.00002	4	0.00010	<0.000003	0.00014
Total mercury (ultra-trace)	ng/L	5-13	0.76	4	1.05	0.42	1.80
Total methyl mercury	ng/L	1-2	0.12	-	-	-	-
Total strontium	mg/L	-	0.111	4	0.124	0.107	0.140
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.66</u>	4	0.37	0.11	0.64
Oilsands extractable acids	mg/L	-	<u>2.9</u>	4	1.06	0.45	1.70
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	11.75	7.210	<15.16
Retene	ng/L	-	3.56	4	0.947	0.506	17.30
Total dibenzothiophenes[c]	ng/L	-	8.44	4	6.668	4.134	35.30
Total PAHs[c]	ng/L	-	145.20	4	136.5	75.3	212.0
Total Parent PAHs[c]	ng/L	-	22.51	4	18.65	13.26	24.11
Total Alkylated PAHs[c]	ng/L	-	122.68	4	114.6	62.08	194.4
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	<u>**0.011**</u>	4	**0.00505**	0.002	**0.0063**
Sulphide	mg/L	0.0019	<u>**0.0054**</u>	4	**0.0020**	0.0015	**0.0052**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.7-8 Piper diagram of fall ion concentrations in the Firebag River watershed.

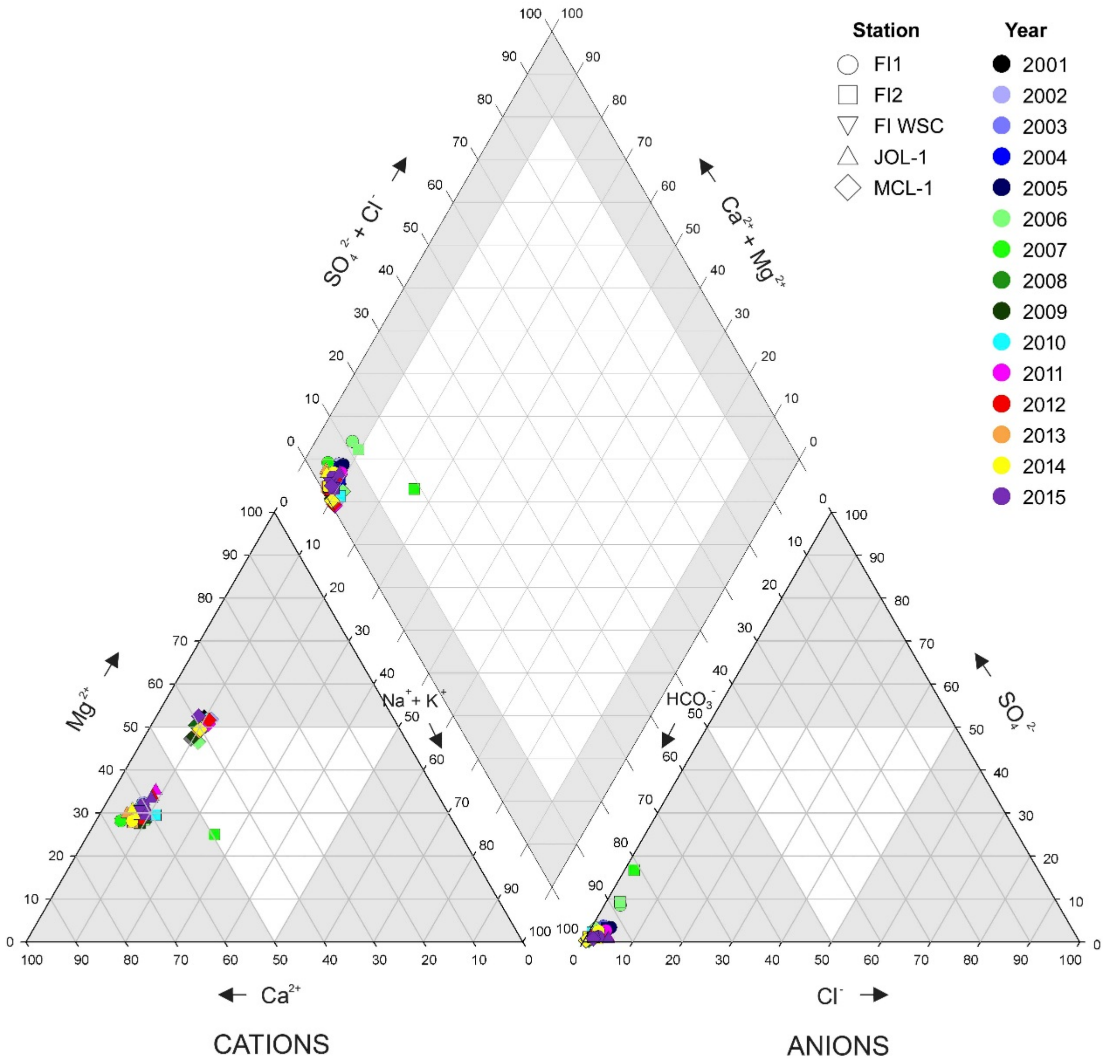


Table 5.7-14 Water quality guideline exceedances in the Firebag River watershed, 2015 WY.

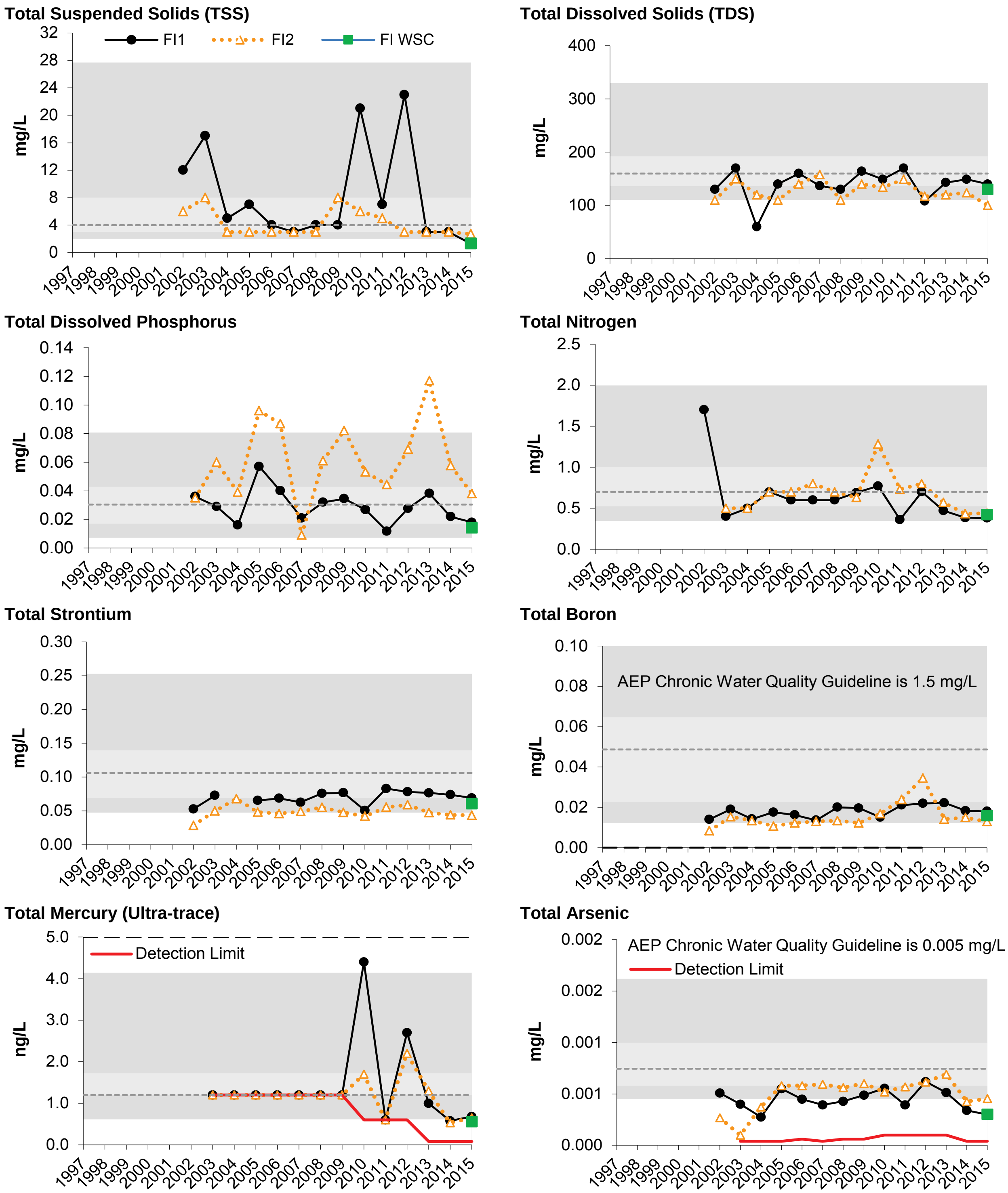
Variable	Units	Guideline[a]	March	May	June	July	August	September	October
Firebag River mouth (FI1)									
Total mercury	ng/L	5-13	-	0.99	**11.24**	1.01	0.73	0.68	0.61
Total phenols	mg/L	0.004	-	-	**0.0079**	**0.015**	**0.0082**	-	**0.0062**
Sulphide	mg/L	0.3	-	-	**0.0073**	**0.0031**	<0.0019	-	<0.0019
Firebag River at WSC station (FI WSC)									
Total phenols	mg/L	0.004	-	<0.002	0.0029	**0.013**	**0.0087**	**0.0073**	**0.0045**
Sulphide	mg/L	0.0019	-	**0.0024**	**0.0073**	**0.0039**	**0.0077**	**0.0093**	**0.0029**
Firebag River above the Suncor Firebag Project (FI2)									
Total phenols	mg/L	0.004	-	-	-	**0.011**	**0.0045**	**0.0078**	**0.0047**
Sulphide	mg/L	0.0019	-	-	-	**0.0024**	**0.0054**	**0.0039**	<0.0019
McClelland Lake (MCL-1)									
Total phenols	mg/L	0.004	-	0.0039	-	**0.0052**	-	**0.01**	-
Sulphide	mg/L	0.0019	-	<0.0019	-	<0.0019	-	**0.0031**	-
Johnson Lake (JOL-1)									
Total phenols	mg/L	0.004	<0.001	0.0035	-	**0.0072**	-	**0.011**	-
Sulphide	mg/L	0.0019	**0.0088**	**0.0041**	-	<0.0019	-	**0.0054**	-

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.7-9 Concentration of selected water quality measurement endpoints in the Firebag River (fall data) relative to historical concentrations and to regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

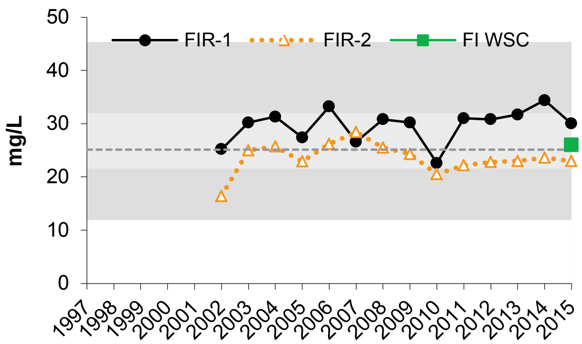
– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

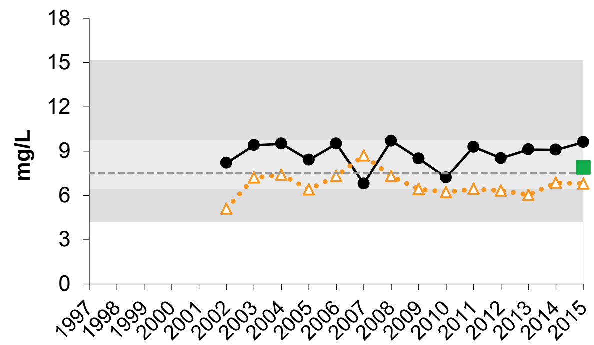
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.7-9 (Cont'd.)

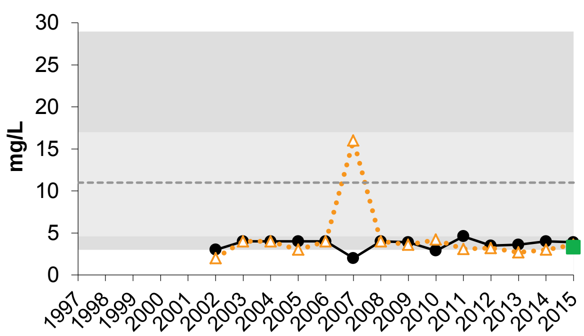
Calcium



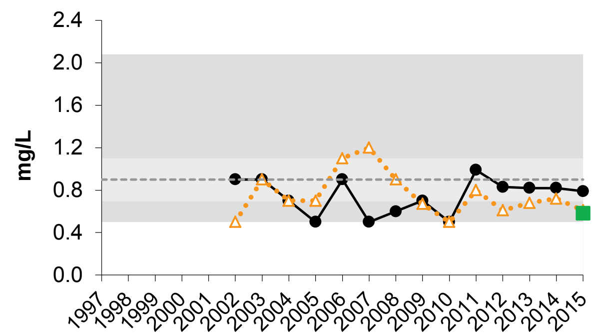
Magnesium



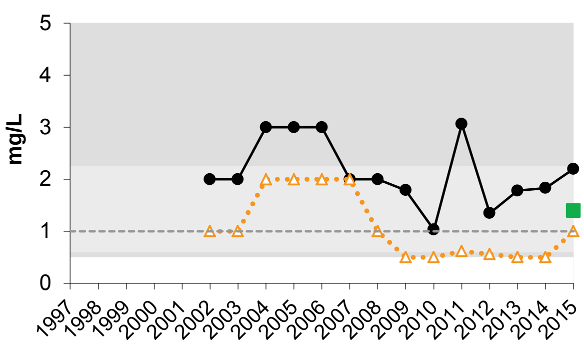
Sodium



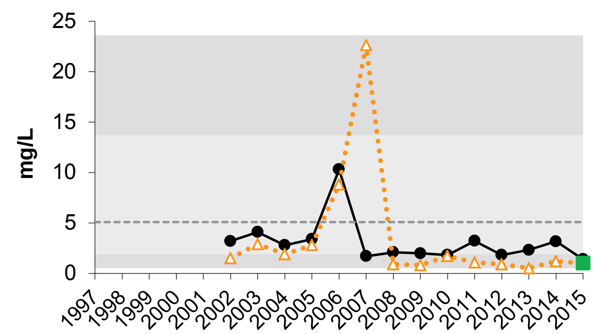
Potassium



Chloride



Sulphate



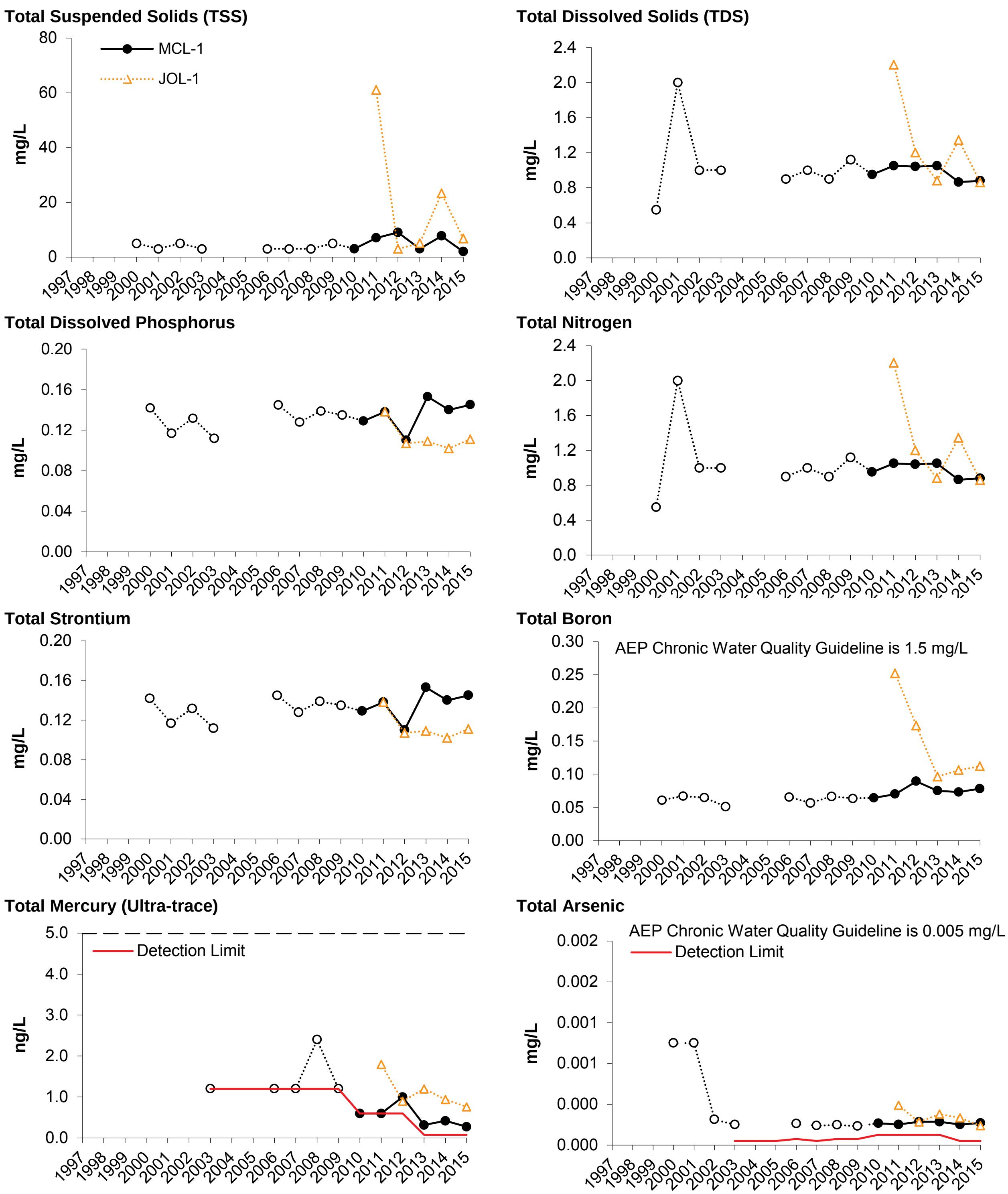
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.7-10 Concentration of selected water quality measurement endpoints in McClelland Lake and Johnson Lake (fall data), relative to historical concentrations.

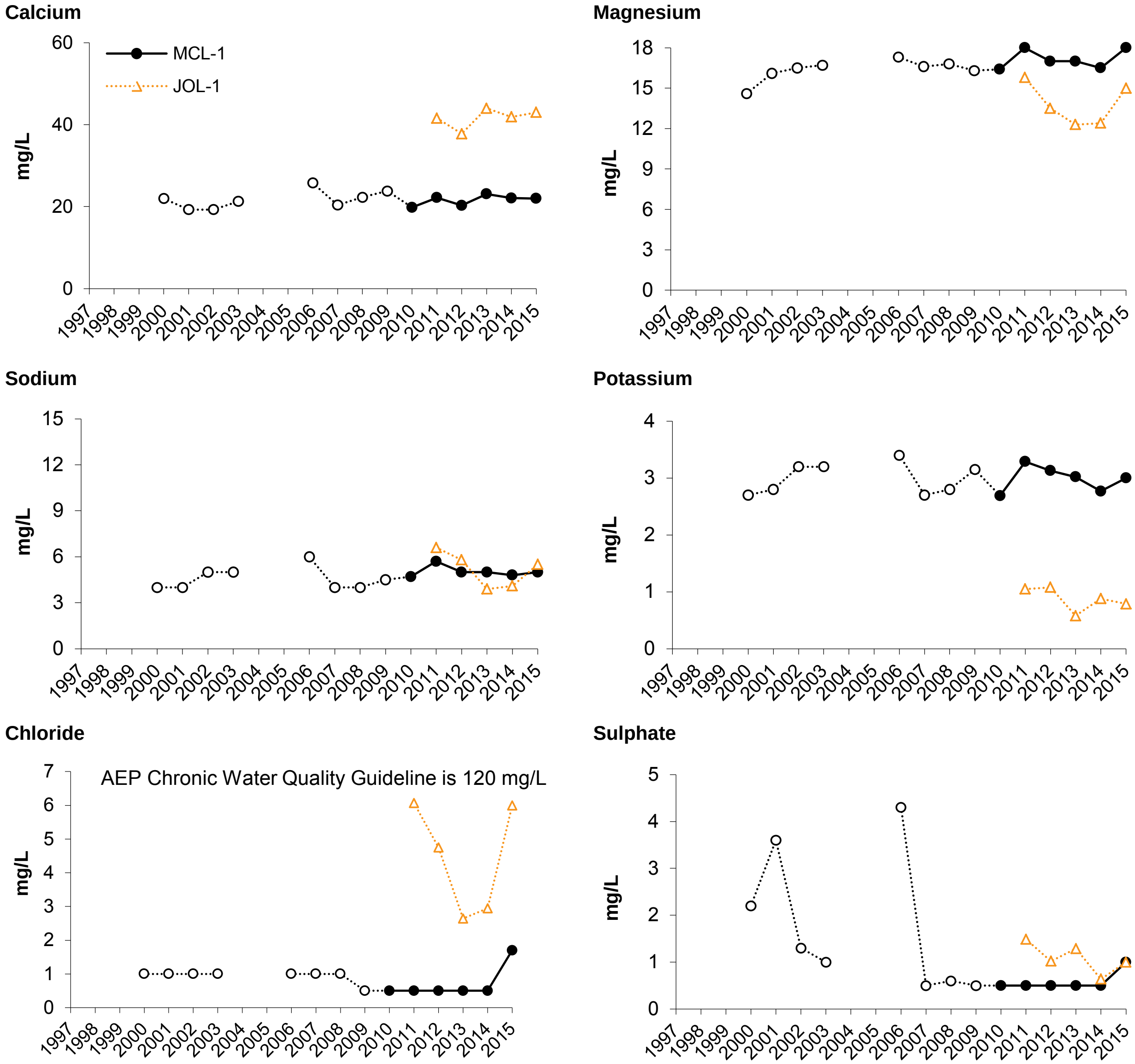


Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Figure 5.7-10 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Table 5.7-15 Average habitat characteristics of benthic invertebrate sampling locations in the Firebag River (*test* reach FIR-D1), fall 2015.

Variable	Units	FIR-D-1 Lower *Test* Reach
Sample date	-	Sept. 17, 2015
Habitat	-	Depositional
Water depth	m	0.26
Current velocity	m/s	0.44
Field water quality		
Dissolved oxygen (DO)	mg/L	9.3
Conductivity	µS/cm	200
pH	pH units	7.8
Water temperature	°C	10.0
Sediment composition		
Sand	%	99.3
Silt	%	0.2
Clay	%	0.5
Total organic carbon (TOC)	%	0.18

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.7-16 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community at the lower Firebag River (*test* reach FIR-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach FIR-D-1		
	2003	2004 to 2013	2015
Nematoda	<1	<1 to 4	<1
Naididae	1	0 to 2	1
Tubificidae	1	6 to 49	-
Enchytraeidae	-	0 to 5	-
Lumbriculidae	-	0 to <1	-
Hydracarina	-	0 to <1	-
Gastropoda	-	0 to <1	-
Bivalvia	-	0 to 14	-
Ceratopogonidae	<1	<1 to 6	<1
Chironomidae	96	17 to 96	99
Diptera (misc.)	<1	1 to 6	-
Ephemeroptera	<1	0 to 3	-
Odonata	<1	0 to 1	-
Plecoptera	<1	0 to <1	-
Trichoptera	-	0 to <1	-
Heteroptera	1	0 to 1	-
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	647	22 to 274	67
Richness	7	6 to 14	4.4
Equitability	0.32	0.34 to 0.53	0.4
% EPT	0	<1 to 20	0

Table 5.7-17 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in the Firebag River (*test* reach FIR-D1).

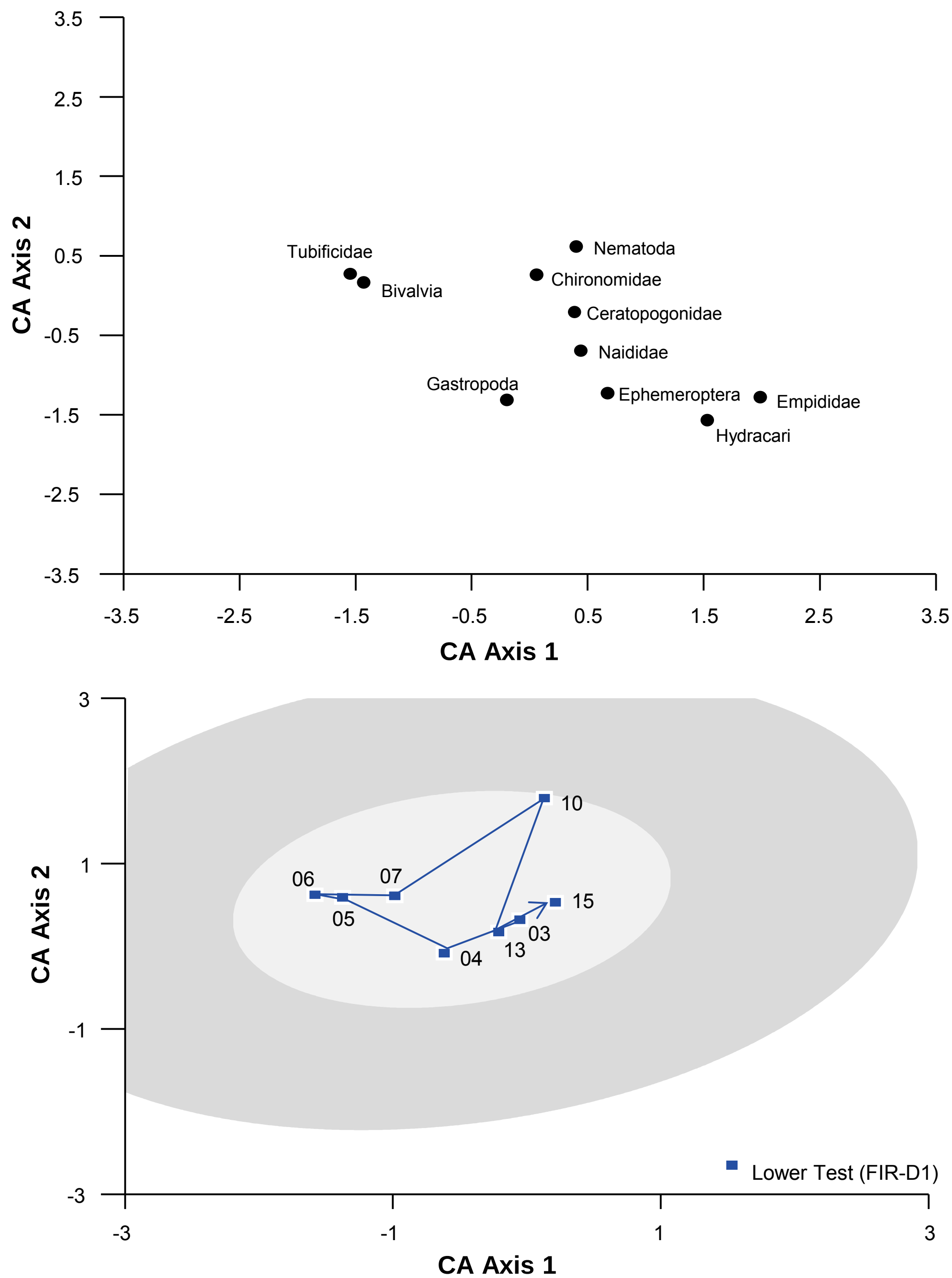
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	0.124	**0.009**	6	17	Abundance was lower in 2015 than the mean of prior years.
Log of Richness	0.310	**0.021**	6	31	Richness was lower in 2015 than the mean of prior years.
Equitability	0.542	0.863	4	0	No change.
Log of EPT	0.106	0.203	11	7	No change.
CA Axis 1	0.053	**0.038**	16	19	CA Axis 1 scores were higher in 2015 than the mean of prior years in the reach.
CA Axis 2	0.113	0.911	11	0	No change.

Bold values indicate significant variation per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

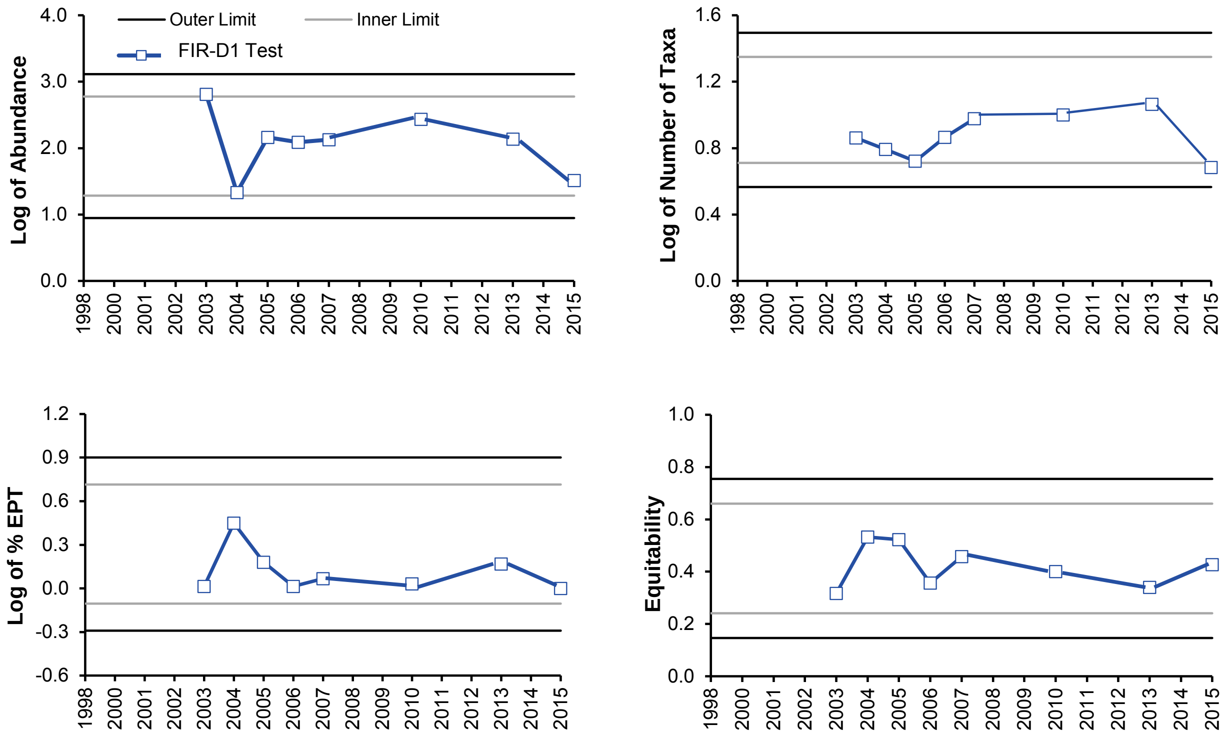
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.7-11 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of the Firebag River (*test* reach FIR-D1).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel for *test* reach FIR-D1 are the inner and outer tolerance limits on the 95th percentile for regional depositional reaches.

Figure 5.7-12 Variation in values of benthic invertebrate community measurement endpoints at lower *test* reach FIR-D1 of the Firebag River relative to regional *baseline* ranges of variability.



Notes:

Tolerance limits for the lower 5th and upper 95th percentiles were calculated using regional depositional *baseline* data (1998 to 2014).

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed before the average was calculated.

Table 5.7-18 Average habitat characteristics of benthic invertebrate sampling locations in McClelland Lake (*test* station MCL-1) and Johnson Lake (*baseline* station JOL-1), fall 2015.

Variable	Units	McClelland Lake *Test* station MCL-1	Johnson Lake *Baseline* station JOL-1
Sample date	-	Sept. 2, 2015	Sept. 2, 2015
Habitat	-	Depositional	Depositional
Water depth	m	1.9	1.4
Field water quality			
Dissolved oxygen (DO)	mg/L	11.2	8.7
Conductivity	µS/cm	222	152
pH	pH units	8.4	6.9
Water temperature	°C	14.5	13.4
Sediment composition			
Sand	%	8.2	22.8
Silt	%	78.8	67.6
Clay	%	13.0	9.7
Total organic carbon (TOC)	%	31.8	25.0

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.7-19 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities, McClelland Lake and Johnson Lake.

Taxon	Percent Major Taxa Enumerated in Each Year					
	McClelland Lake *Test* station MCL-1			Johnson Lake *Baseline* station JOL-1		
	2002	2003 - 2014	2015	2011	2012 - 2014	2015
Hydra	-	<1	-	-	-	<1
Planariidae	-	-	2	-	-	-
Nematoda	1	0 to 5	-	1	<1 to 13	<1
Oligochaeta	-	<1	-	-	-	-
Naididae	14	2 to 17	11	<1	2 to 7	15
Tubificidae	-	0 to 7	18	3	1 to 18	4
Enchytraeidae	-	<1	-	-	-	-
Lumbriculidae	-	0 to 8	-	-	<1	-
Hirudinea	-	<1	1	1	<1 to 2	1
Erpobdellidae	1	0 to <1	-	-	-	-
Hydracarina	1	0 to 12	-	<1	<1 to 2	-
Amphipoda	11	0 to 22	9	37	3 to 25	9
Gastropoda	<1	0 to 22	1	<1	<1 to 3	3
Bivalvia	2	1 to 9	2	19	7 to 31	1
Ceratopogonidae	-	0 to 1	<1	1	0 to 1	1
Chironomidae	58	24 to 91	35	33	23 to 53	60
Diptera (misc.)	-	<1	-	<1	<1	<1
Coleoptera	-	-	-	-	-	<1
Ephemeroptera	1	<1 to 20	11	-	<1	<1
Odonata	-	0 to 1	9	-	0 to <1	<1
Lepidoptera	-	-	-	-	-	<1
Trichoptera	1	0 to 3	<1	<1	0 to <1	1
Benthic Invertebrate Community Measurement Endpoints						
Total abundance per sample	129	469 to 2,409	308	230	170 to 397	313
Richness	11	6 to 24	16	11	10 to 20	18
Equitability	0.51	0.12 to 0.73	0.47	0.44	0.33 to 0.46	0.42
% EPT	2	1 to 24	10	<1	0 to 1	0.8

Table 5.7-20 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in McClelland Lake (*test* station MCL-1).

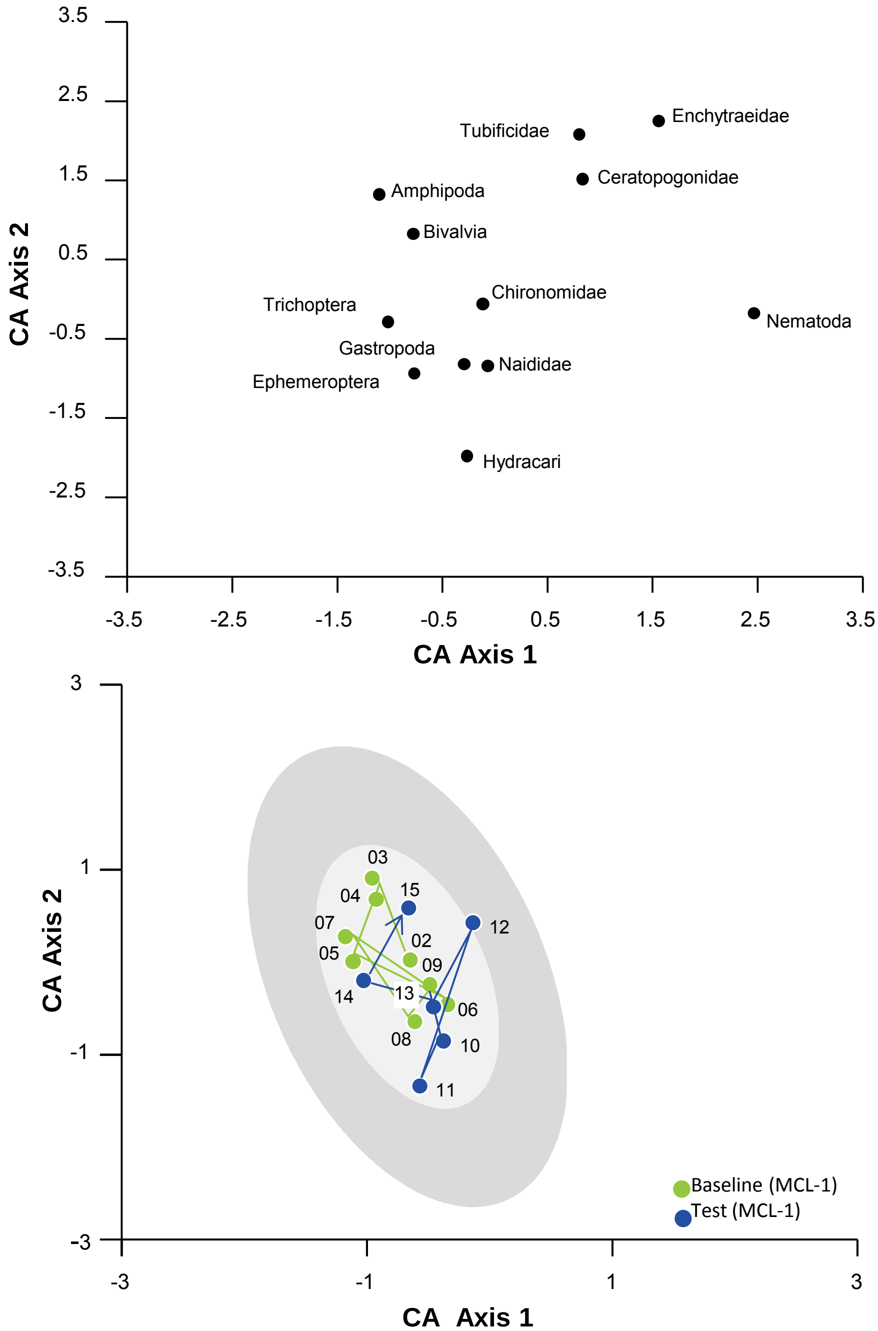
Measurement Endpoint	P-value				Variance Explained				Nature of Changes(s)
	Before vs. After	Time Trend in *Test* period	2015 vs. *Baseline*	2015 vs. Previous Years	Before vs. After	Time Trend in *Test* Period	2015 vs. *Baseline*	2015 vs. Previous Years	
Log of Abundance	**0.009**	**0.005**	0.509	0.930	7	8	0	0	Abundance was higher during the *test* and decreased over time during the *test* period.
Log of Richness	**0.005**	0.788	0.122	0.309	10	0	3	1	Richness was higher during the *test* period.
Equitability	**0.008**	0.914	0.742	0.315	7	0	0	1	Equitability was higher during the *baseline* period.
Log of EPT	**0.001**	**<0.001**	**0.006**	**0.028**	19	24	12	8	The percent fauna as EPT taxa was higher during the *test* period and increased over time during the *test* period. EPT was higher in 2015 than the mean of *baseline* years and the mean of all prior years.
CA Axis 1	**0.018**	**0.011**	0.972	0.541	17	20	0	1	CA Axis 1 scores were higher during the *test* period and decreased over time during the *test* period.
CA Axis 2	**0.001**	0.311	0.052	0.182	24	2	8	4	CA Axis 2 scores were higher during the *test* period.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

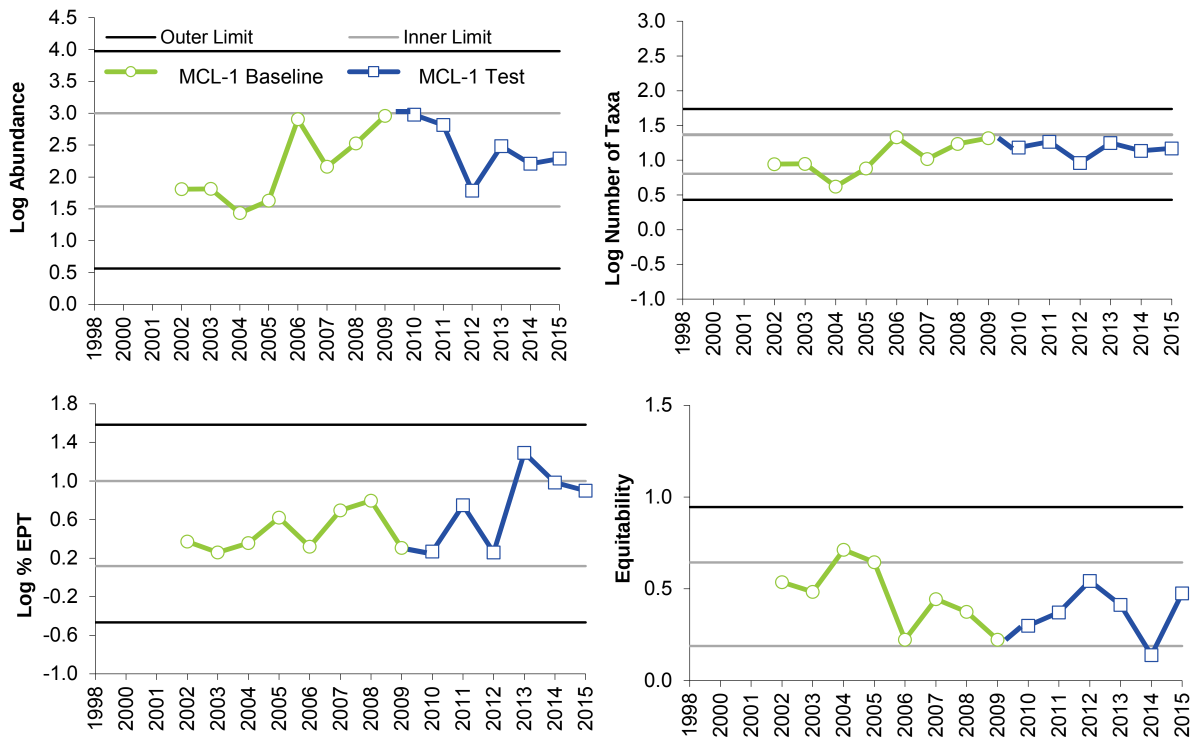
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.7-13 Ordination (Correspondence Analysis) of benthic invertebrate communities of the study lakes, showing McClelland Lake (*test* station MCL-1).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.7-14 Variation in values of benthic invertebrate community measurement endpoints in McClelland Lake (*test* station MCL-1) relative to the historical ranges of variability.

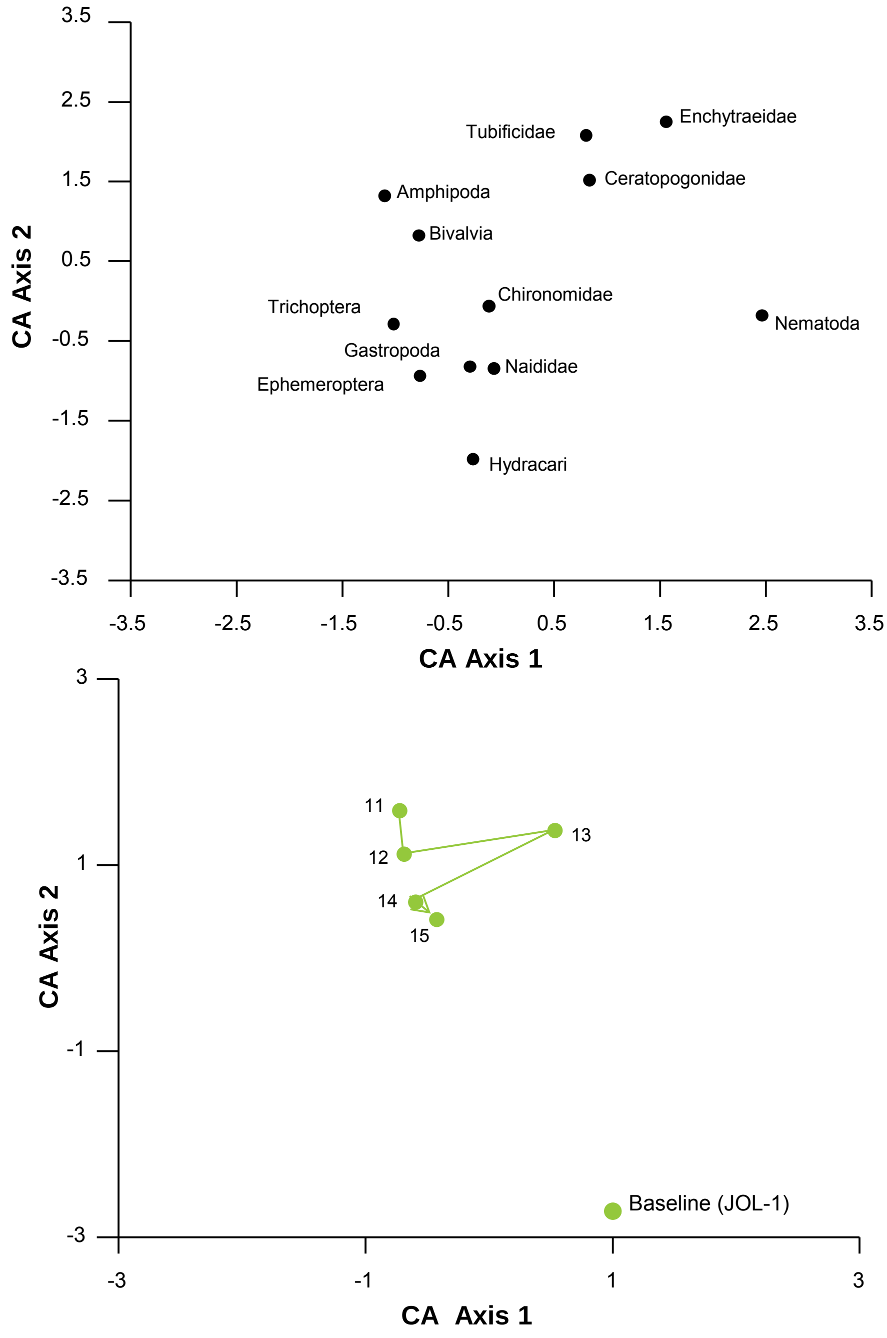


Notes:

Values were adjusted to a common depth of 2 m.

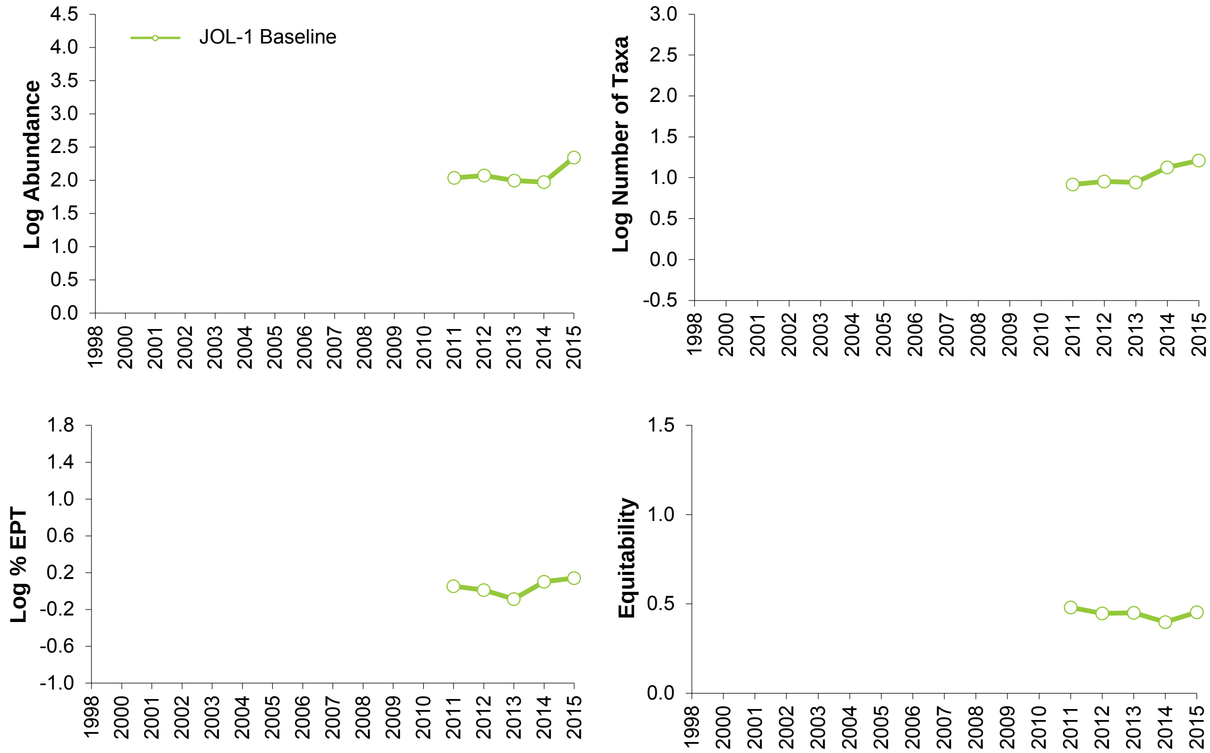
Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Figure 5.7-15 Ordination (Correspondence Analysis) of benthic invertebrate communities of the study lakes, showing Johnson Lake (*baseline* station JOL-1).



Note: The upper panel of is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

Figure 5.7-16 Variation in values of benthic invertebrate community measurement endpoints in Johnson Lake (*baseline* station JOL-1) relative to the historical ranges of variability.



Notes:

Values were adjusted to a common depth of 2 m.

Abundance, richness and %EPT were log10(x+1) transformed before the average was calculated.

Table 5.7-21 Concentrations of sediment quality measurement endpoints, mouth of Firebag River (*test* station FIR-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2002-2013 (fall data only)ns			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	0.5	7	0.1	3.0	8.0
Silt	%	-	<u>0.2</u>	7	0.3	2.0	38.0
Sand	%	-	99.3	7	54.0	93.0	100.0
Total organic carbon	%	-	0.10	7	0.10	0.50	13.20
Total hydrocarbons							
BTEX	mg/kg	-	<10	5	<5	<5	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	5	<5	<5	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	20	5	14	20	40
Fraction 3 (C16-C34)	mg/kg	300[1]	75	5	21	140	**1,900**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	69	5	31	150	1,800
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0009	7	0.0005	0.0016	0.0100
Retene	mg/kg	-	0.0023	7	0.0018	0.0349	9.0600
Total dibenzothiophenes	mg/kg	-	0.0404	7	0.0204	0.1600	2.1234
Total PAHs	mg/kg	-	0.3392	7	0.1692	0.6858	17.1890
Total Parent PAHs	mg/kg	-	0.0190	7	0.0130	0.0428	0.2876
Total Alkylated PAHs	mg/kg	-	0.3202	7	0.1562	0.6429	16.9014
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.1966</u>	7	0.3455	0.8751	**1.4451**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	86	5	70	72	90
Chironomus growth - 10d	mg/organism	-	<u>1.32</u>	5	1.90	2.05	2.73
Hyalella survival - 14d	# surviving	-	88	5	50	90	96
Hyalella growth - 14d	mg/organism	-	0.13	5	0.06	0.23	1.20

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

ns = not sampled in 2005, 2008-2009, 2011-2012, or 2014

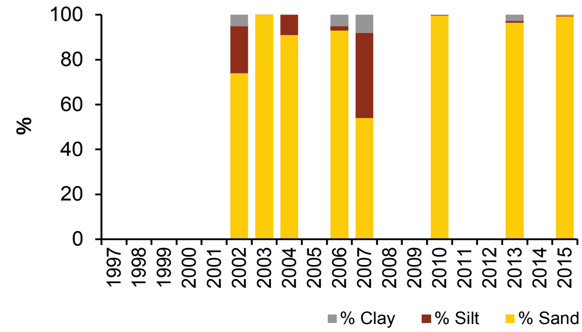
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

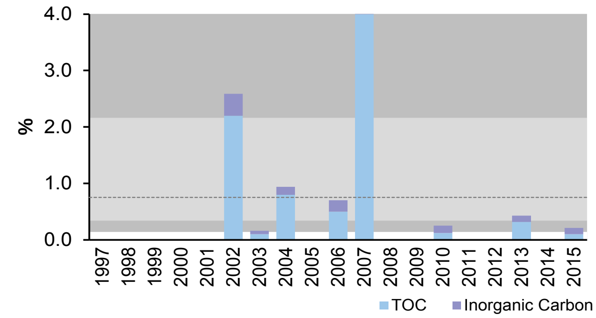
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.7-17 Variation in sediment quality measurement endpoints at the mouth of the Firebag River, *test* station FIR-D1, relative to historical concentrations and regional *baseline* fall concentrations.

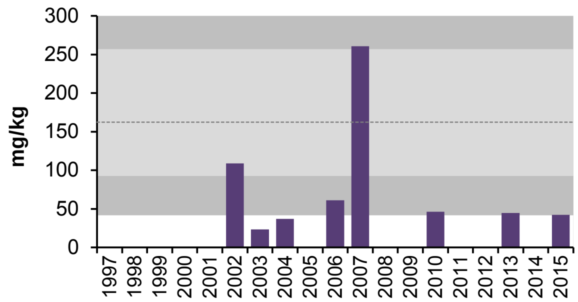
Particle size distribution



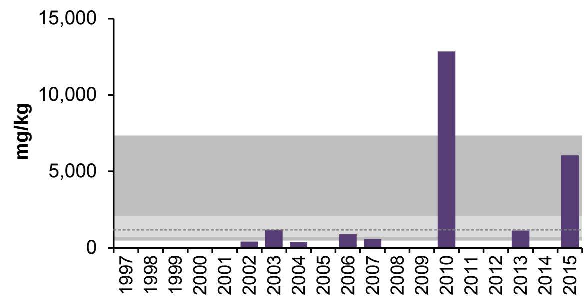
Carbon Content[1]



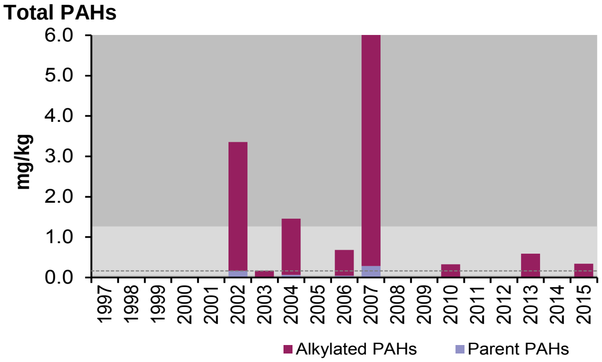
Total Metals[2]



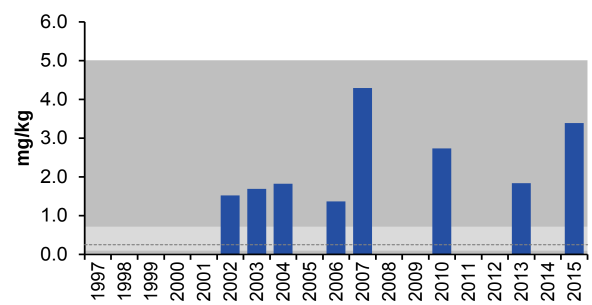
Total metals[2] **normalized to percent fine sediments (i.e., % silt + clay)**



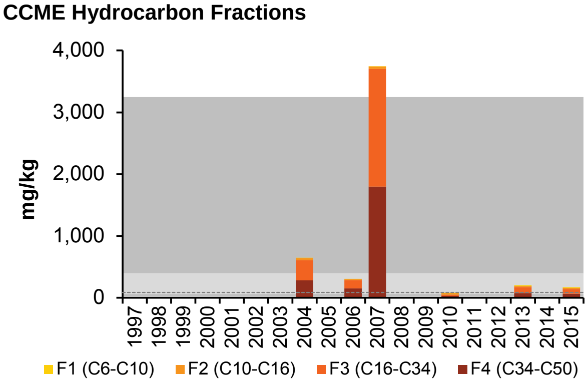
Total PAHs



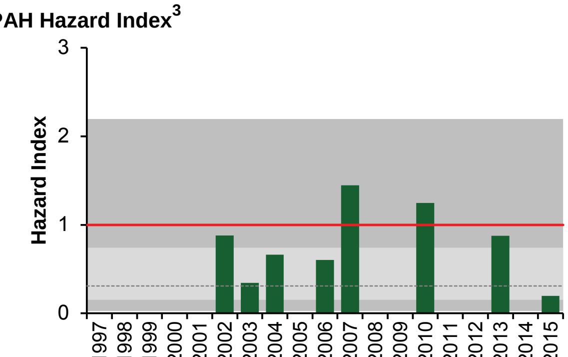
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[3]



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.7-22 Concentrations of sediment quality measurement endpoints, McClelland Lake (*test* station MCL-1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2002-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	11.0	11	0.5	10.1	49.0
Silt	%	-	82.0	11	0.2	23.0	90.6
Sand	%	-	7.0	11	4.0	37.8	99.4
Total organic carbon	%	-	34.00	11	0.40	28.80	35.10
Total hydrocarbons							
BTEX	mg/kg	-	<290	9	<5	<100	<150
Fraction 1 (C6-C10)	mg/kg	30[1]	**<290**	9	<5	**<100**	**<150**
Fraction 2 (C10-C16)	mg/kg	150[1]	**<360**	9	<5	<124	**<288**
Fraction 3 (C16-C34)	mg/kg	300[1]	**1120**	9	<20	**433**	**2900**
Fraction 4 (C34-C50)	mg/kg	2800[1]	618	9	<20	241	2400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0149	8	0.0004	0.0074	0.0241
Retene	mg/kg	-	0.0311	11	0.0013	0.0861	0.1610
Total dibenzothiophenes	mg/kg	-	0.0547	11	0.0020	0.0365	0.3091
Total PAHs	mg/kg	-	0.4274	11	0.0340	0.5641	1.9466
Total Parent PAHs	mg/kg	-	0.0625	11	0.0027	0.0647	0.1389
Total Alkylated PAHs	mg/kg	-	0.3649	11	0.0313	0.4995	1.8077
Predicted PAH toxicity[3]	H.I.	1.0	0.0572	11	0.0387	0.1511	0.7789
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	96	7	74	90	96
Chironomus growth - 10d	mg/organism	-	1.67	7	1.45	1.85	2.12
Hyalella survival - 14d	% surviving	-	90	7	58	80	98
Hyalella growth - 14d	mg/organism	-	0.12	7	0.22	0.31	0.49

Values in **bold** indicate concentrations exceeding guidelines.

ns = not sampled in 2004 or 2005

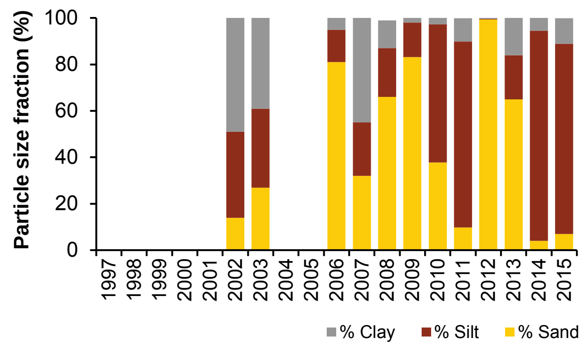
1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

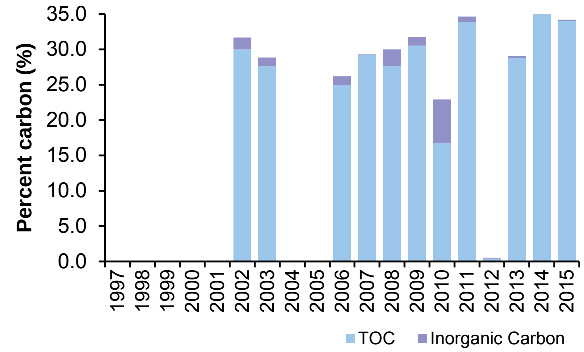
3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.7-18 Variation in sediment quality measurement endpoints in McClelland Lake, *baseline* station MCL-1, relative to historical concentrations.

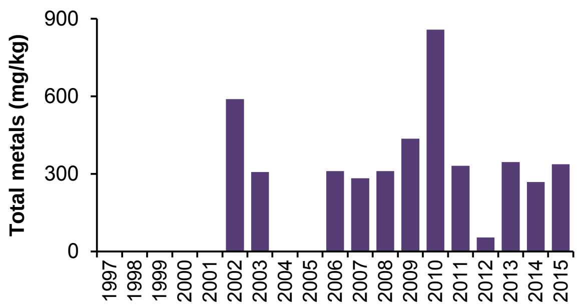
Particle size distribution



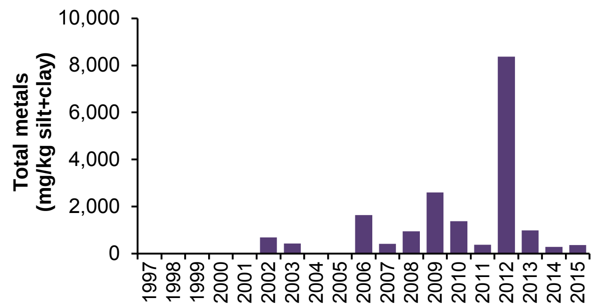
Carbon Content



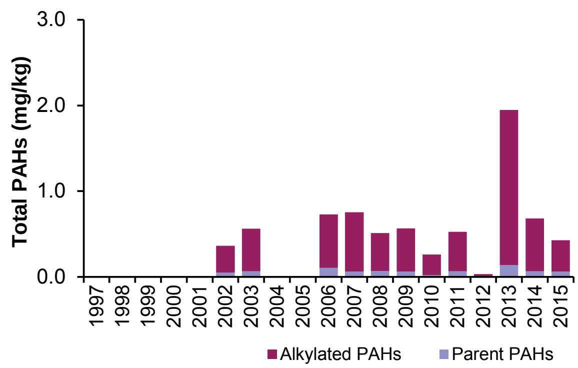
Total Metals[1]



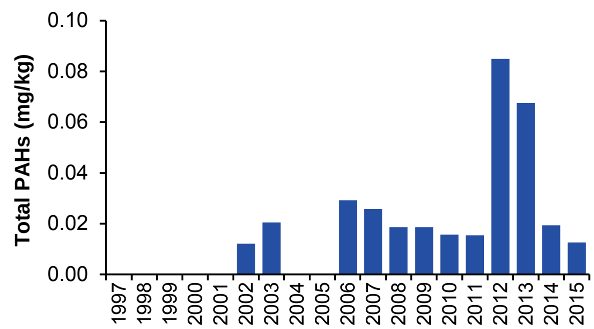
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



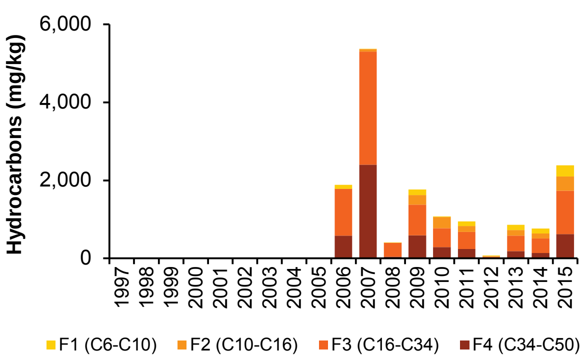
Total PAHs



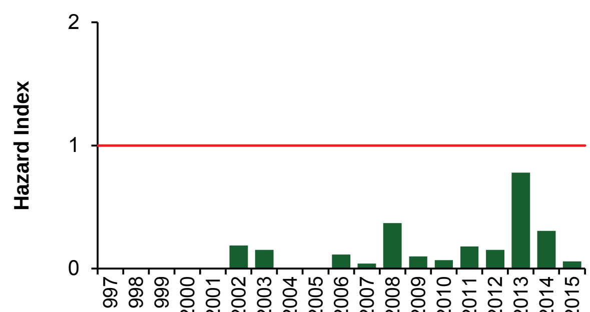
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.7-23 Concentrations of sediment quality measurement endpoints, Johnson Lake (*baseline* station JOL-1), fall 2015, and comparison to historical fall concentrations.

Variables	Units	Guideline	September 2015	2011-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>3.3</u>	4	5.0	8.1	18.1
Silt	%	-	93.7	4	34.1	77.2	94.3
Sand	%	-	3.0	4	0.8	14.7	47.7
Total organic carbon	%	-	<u>38.80</u>	4	19.00	26.00	38.00
Total hydrocarbons							
BTEX	mg/kg	-	<130	4	<90	<110	<160
Fraction 1 (C6-C10)	mg/kg	30[1]	**<130**	4	**<90**	**<110**	**<160**
Fraction 2 (C10-C16)	mg/kg	150[1]	<150	4	<92	<136	**<187**
Fraction 3 (C16-C34)	mg/kg	300[1]	**820**	4	281	**754**	**1300**
Fraction 4 (C34-C50)	mg/kg	2800[1]	387	4	174	327	760
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0039	4	0.0022	0.0052	0.0062
Retene	mg/kg	-	<u>0.5480</u>	4	0.0519	0.1105	0.2190
Total dibenzothiophenes	mg/kg	-	0.0344	4	0.0160	0.0338	0.0495
Total PAHs	mg/kg	-	0.7893	4	0.3321	0.5508	1.0291
Total Parent PAHs	mg/kg	-	0.0353	4	0.0299	0.0382	0.0540
Total Alkylated PAHs	mg/kg	-	0.7540	4	0.2910	0.5182	0.9750
Predicted PAH toxicity[3]	H.I.	1.0	0.1844	4	0.0937	0.1290	0.2951
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	92	4	86	92	96
Chironomus growth - 10d	mg/organism	-	1.90	4	1.17	1.90	1.93
Hyalella survival - 14d	% surviving	-	90	4	76	84	92
Hyalella growth - 14d	mg/organism	-	<u>0.15</u>	4	0.20	0.29	0.37

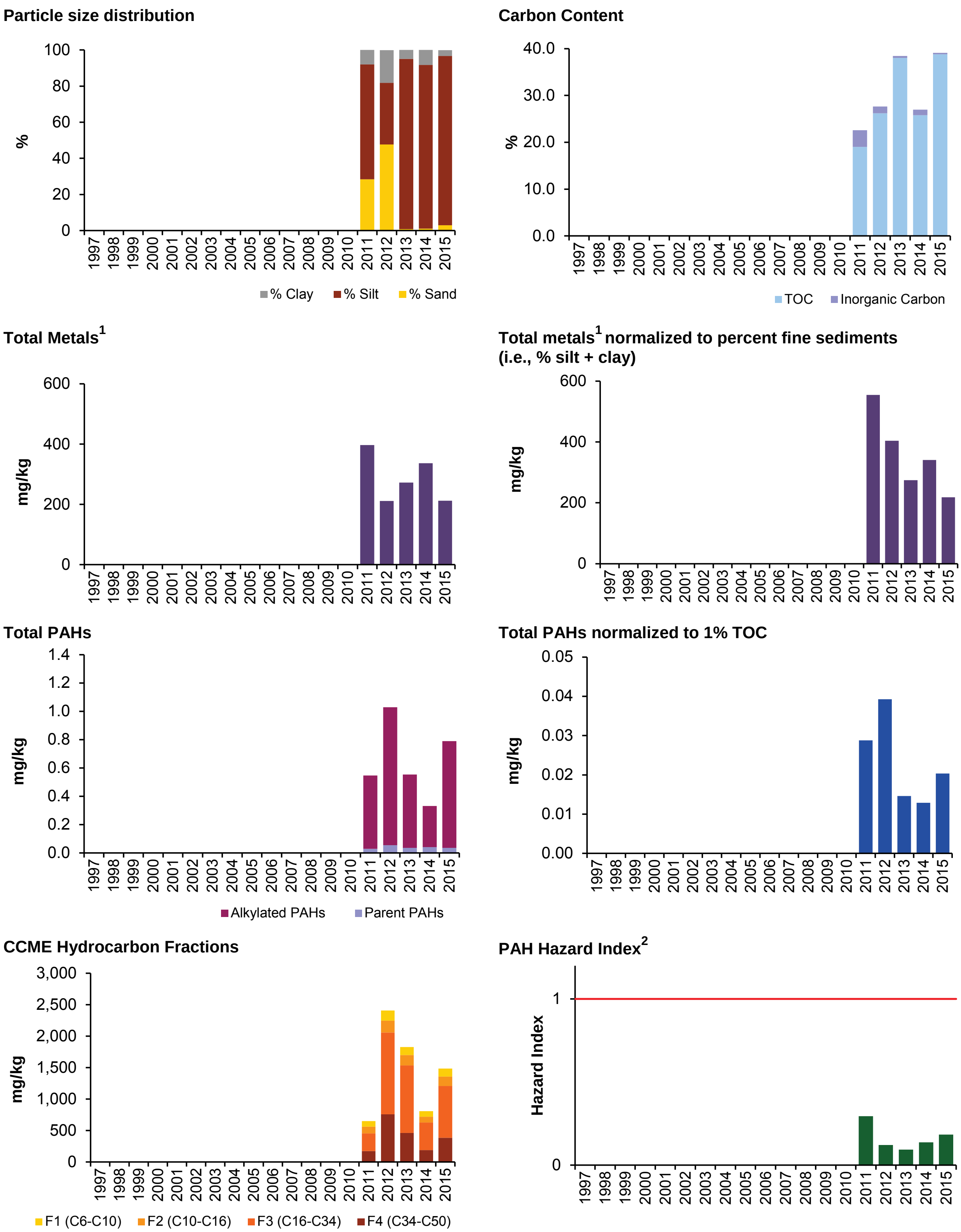
Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.7-19 Variation in sediment quality measurement endpoints in Johnson Lake, *baseline* station JOL-1, relative to historical concentrations.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

5.8 ELLS RIVER WATERSHED

Table 5.8-1 Summary of results for the Ells River watershed.

Ells River Watershed	Summary of 2015 Conditions							
	Ells River						Lakes	
Climate and Hydrology								
Criteria	no station	no station	**S14A**	no station	**S45**	no station	**L4**	no station
Mean open-water season discharge	-	-	Negligible - Low	-	n/a	-	n/a	-
Mean winter discharge	-	-	Negligible - Low	-	n/a	-	n/a	-
Annual maximum daily discharge	-	-	Negligible - Low	-	n/a	-	n/a	-
Minimum open-water season discharge	-	-	Negligible - Low	-	n/a	-	n/a	-
Water Quality								
Criteria	**ELLS RIFF 3**	**ER-L**	**EL2**	**ER-M**	**ELLS RIFF 5**	**ER-U**	**NAL-1**	**GAL-1**
Water Quality Index	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	n/a	n/a
Benthic Invertebrate Communities and Sediment Quality								
Criteria	**ELR-D1**	**ER-L**	no reach	**ER-M**	no reach	**ER-U**	**NAL-1**	**GAL-1**
Benthic Invertebrate Communities	Negligible - Low	no reach	-	no reach	-	no reach	n/a	n/a
Sediment Quality Index	Moderate	High	-	Negligible - Low	-	Negligible - Low	n/a	n/a
Fish Populations								
Criteria	**ELR-F1**	**ER-L**	no reach	**ER-M**	no reach	**ER-U**	no reach	no reach
Fish Communities	Negligible - Low	no reach	-	no reach	-	no reach	-	-
Wild Fish Health	no reach	Moderate	-	Negligible - Low	-	n/a	-	-

Legend and Notes

- Negligible - Low
- Moderate
- High

baseline (green shading)

test (blue shading)

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

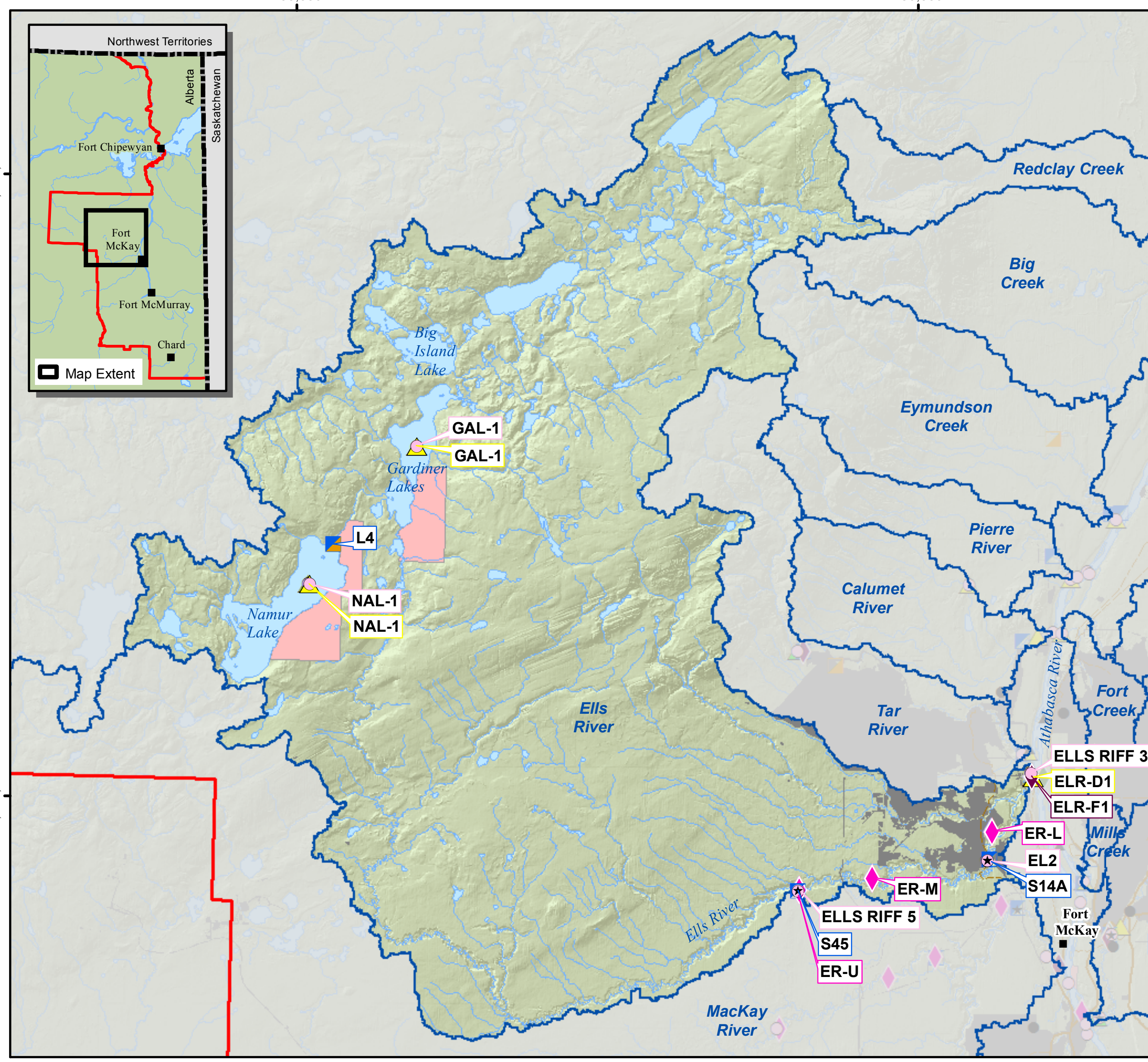
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (Fish Communities): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.1 for a detailed description of the classification methodology. **Fish Populations (Wild Fish Health)**: Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.2 for a detailed description of the classification methodology.

Figure 5.8-1 Ells River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]
- Water Withdrawal Location
- Water Release Location
- Water Quality Station
- Data Sonde Station
- Hydrometric Station
- Climate Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Community Reach
- Wild Fish Health Reach
- Wild Fish Health Reach with Water and Sediment Quality Stations

0 2.5 5 10 km

N

Scale: 1:525,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

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K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_K08_Ells_20160224_ss.mxd

Figure 5.8-2 Representative monitoring stations of the Ells River watershed, fall 2015.

Fish Community Reach ELR-F1 and Benthic Invertebrate Communities and Sediment Quality Reach ELR-D1, facing upstream

Hydrology Station S14A and Water Quality Station EL2: at the Canadian Natural Bridge, facing upstream

Wild Fish Health Reach ER-M, facing upstream

Hydrology Station S45, Water Quality Station ELR-3, and Wild Fish Health Station ER-U, facing downstream

Hydrology Station L4 (Namur Lake)

Benthic Invertebrate Communities and Sediment Quality Station GAL-1: Gardiner Lake, facing east

5.8.1 Summary of 2015 WY Conditions

Approximately 1.5% (3,982 ha) of the Ells River watershed had undergone land change from oil sands development as of 2015 (Table 2.3-1); much of this land change is located in the Joslyn Creek drainage portion of the watershed. The designations of specific areas of the watershed are as follows:

1. The Ells River watershed within and downstream of the currently-deferred Total E&P Joslyn North Mine (Figure 5.8-1) is designated as *test*.

2. The remainder of the watershed is designated as *baseline*.

Monitoring activities in the Ells River watershed in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components. Table 5.8-1 is a summary of the 2015 assessment for the Ells River watershed while Figure 5.8-1 provides the locations of the monitoring stations for each component and the locations of the areas with land change as of 2015. Figure 5.8-2 contains fall 2015 photos of a number of monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.15% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph. These differences are classified as **Negligible-Low**.

Water Quality Concentrations of most water quality measurement endpoints showed variations across months and seasons at both *test* and *baseline* stations. Typically, concentrations of TSS and associated nutrients and metals were highest in May, whereas concentrations of TDS and associated ionic constituents were highest in July and August. The latter constituents also exceeded the previously measured concentrations in some months. Concentrations of most water quality variables at *baseline* Gardiner Lake were higher than at *baseline* Namur Lake.

The 2015 fall data indicate that the differences in water quality between the Ells River and regional *baseline* conditions are **Negligible-Low**. Water quality conditions were consistent with previous years at *test* stations ELLS RIFF 3 and EL2 and typically were within the range of previously-measured concentrations and regional *baseline* conditions. The b*aseline* station ELLS RIFF 5 showed similar water quality to both *test* stations, and was within regional *baseline* conditions in fall 2015 for all key water quality measurement endpoints. Concentrations of water quality measurement endpoints from *baseline* stations GAL-1 and NAL-1 were not compared to regional *baseline* conditions given the ecological differences between lakes and rivers. Water quality guideline exceedances included dissolved iron, total phenols, and sulphide. Exceedances occurred at both *test* and *baseline* stations in all sampling months with relatively higher numbers of variables exceeding relevant guidelines in May (during high flow) and August (during low flow).

Benthic Invertebrate Communities and Sediment Quality Differences in measurement endpoints for the benthic invertebrate community at *test* reach ELR-D1 are classified as **Negligible-Low** because significant increases in CA Axis 1 scores over time were not indicative of degrading conditions. All measurement endpoints were within the inner tolerance limits of the normal range of variation for previous years of sampling, with the exception of %EPT. However, %EPT in fall 2015 was not significantly different than %EPT in previous years, signifying no change in conditions.

The benthic invertebrate communities of both Namur and Gardiner lakes in fall 2015 were consistent with relative high quality benthic habitats, with the presence of Ephemeroptera and Trichoptera taxa and permanent aquatic forms (e.g., bivalves, gastropods).

Sediment quality at *test* station ELR-D1 indicated **Moderate** differences from regional *baseline* conditions, while *test* station ER-L indicated **High** differences from regional *baseline* conditions. For both ELR-D1 and ER-L, these differences from regional *baseline* conditions relates primarily to regionally high concentrations of petroleum hydrocarbons and PAHs. Differences in sediment quality conditions between *test* station ER-M and *baseline* station ER-U and regional *baseline* conditions were classified as **Negligible-Low**. SQI values were not calculated for *baseline* stations NAL-1 and GAL-1 because lakes were not included in the regional *baseline* calculations. Sampling at *baseline* stations GAL-1 and NAL-1 was initiated in 2014; therefore, no historical ranges were available for comparison. No sediment guidelines or threshold values were exceeded at either lake station in 2015.

Fish Populations (Fish Communities) Differences in measurement endpoints for fish community at *test* reach ELR-F1 are classified as **Negligible-Low**. Mean values of all measurement endpoints for fish community monitoring at *test* reach ELR-F1 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints. While there have been statistically-significant decreases in abundance and ATI over time from 2010 to 2015 and these decreases are consistent with a potential negative change in the fish community at *test* reach ELR-F1, less than 20% of the variance in annual means is explained by these decreasing trends.

Fish Populations (Wild Fish Health) The significant differences in measurement endpoints for wild fish health that exceeded the Environment Canada effects criteria in the Ells River in fall 2015 were:

1. Age of female lake chub at lower *test* reach ER-L was 30% lower relative to mid *test* reach ER-M.
2. Age of male lake chub at *test* reach ER-L was 40% lower than *test* reach ER-M and 46% lower than upper *baseline* reach ER-U.

There were no significant differences in measurement endpoints for wild fish health at mid *test* reach ER-M compared to upper *baseline* reach ER-U. The classification of results for wild fish health for lower *test* reach ER-L and mid *test* reach ER-M compared to upper *baseline* reach ER-U are assessed as **Moderate** and **Negligible-Low**, respectively.

5.8.2 Hydrologic Conditions

Hydrometric monitoring for the Ells River watershed in the 2015 WY was conducted at the following locations:

- JOSMP Station S14A, Ells River at the Canadian Natural Bridge;
- JOSMP Station S45, Ells River above the Joslyn Creek Diversion; and
- JOSMP Station L4, Namur.

Data from JOSMP Station S14A, Ells River at the Canadian Natural Bridge, were used for the water balance analysis. Hydrographs, historical statistics, and water balance results for Station S14A are presented below, as are lake level data from Namur Lake (Station L4). Data from all stations monitored in the 2015 WY are presented in Appendix C.

The historical flow record for JOSMP Station S14A is summarized in Figure 5.8-3[1], and includes the median, interquartile, and range of flows recorded daily through the water year. Flows of the Ells River have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are generally much lower than during the open-water season and generally decrease from November until early March. Spring thaw, and the resulting rapid increase in flows, typically occurs in April. Monthly flows are typically highest during May at the peak of freshet and often remain elevated in June and July when total monthly rainfall is highest. Flows generally recede from late July until the end of October in response to declining rainfall inputs and eventual river freeze-up.

Flows of the Ells River in the 2015 WY were generally similar to the historical flow patterns described above, but with a number of key differences. Flows decreased from November to January but were above the historical upper quartile range from mid-February until late April and above historical maximum flows for much of March (Figure 5.8-3). Flows increased throughout much of mid-April due to spring thaw. The timing of peak annual flow was about a month earlier than the median peak annual flow and the magnitude of the peak flow was about 70% lower than the average peak flow. Flows generally declined after the third week in April for the remainder of the water year. The minimum open water flow of 0.98 m^3/s was about 60% lower than historical average open water flow. The annual runoff volume in the 2015 WY was 129 million m^3, which is 43% lower than the mean historical annual runoff volume based on the available period of record.

Differences between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Ells River watershed at JOSMP Station S14A is summarized in Table 5.8-2. The observed *test* and estimated *baseline* hydrographs are presented in Figure 5.8-3. Key changes in flows included:

1. The area of the Ells River watershed in 2015 that was directly influenced by oil sands development activities and was closed-circuited was estimated to be 3.6 km^2 (Table 2.3-1). The loss of flow to the Ells River that would have otherwise occurred from this land area was estimated at 0.192 million m^3.
2. The area of the Ells River watershed in 2015 that was directly influenced by oil sands development activities and was not closed-circuited was estimated to be 36.2 km^2 (Table 2.3-1). The increase in flow to the Ells River that would not have otherwise occurred from this land area was estimated at 0.386 million m^3.

The estimated cumulative effect of oil sands development in the 2015 WY was an increase in flow of approximately 0.194 million m^3 at JOSMP Station S14A[2]. The 2015 WY mean open-water discharge (May to October), mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.15% higher in the observed *test* hydrograph than in the estimated *baseline* hydrograph (Table 5.8-3). These differences are classified as **Negligible-Low** (Table 5.8-1). Given all

[1] The historical flow record was generated from: (i) the continuous annual hydrometric data that have been collected at JOSMP Station S14A every year since 2004; (ii) data collected at this station during the open-water season from 2001 to 2004; and historical continuous annual data that were collected from 1975 to 1986 at WSC Station 07DA017, Ells River near the mouth; this station was located approximately 7.5 km downstream of JOSMP Station S14A and the difference in drainage areas at this station compared to the drainage area at JOSMP Station S14A is small (30 km^2, or 1.2% of the entire Ells River watershed).

[2] JOSMP Station S14A is upstream of some of the oil sands development within the Ells River watershed. The station could not be located downstream of development because of backwater effects from the Athabasca River in the downstream reach of the Ells River. Consequently, this analysis and the results are conservative, with differences between the observed *test* hydrograph and the estimated *baseline* hydrograph expected to be slightly lower at the mouth of the Ells River.

measurement endpoints are classified as **Negligible-Low**, a spatial analysis to identify the longitudinal hydrological effects along the Ells River was not conducted.

Namur Lake

Continuous lake level data have been collected at Station L4 since June of 2012. The water level of Namur Lake increased slightly from November until mid-May in the 2015 WY and then decreased until the end of the water year (Figure 5.8-4). While annual lake level maxima and minima recorded in the 2015 WY were the lowest-recorded in the 3.5 year monitoring record, lake levels from January to June were the highest on record for these months. The frequent exceedance of historical levels is a reflection of the short monitoring record. The highest lake level in the 2015 WY was 98.04 m (local datum), and this level was reached in mid-May. The lowest lake level was recorded at the end of the 2015 WY (97.70 m on October 31); overall, this represents a 0.34 m variation in lake level. Variation in lake level was 0.50 m and 0.29 m in the 2013 WY and 2014 WY, respectively (information from the 2012 WY is not provided, as monitoring began partway through the 2012 WY, in June 2012).

5.8.3 Water Quality

Water quality samples were taken in the 2015 WY from:

- the Ells River near its mouth (*test* station ELLS RIFF 3, previously called ELR-1), established in 1998, sampled annually in the fall from 2002 to 2014, and sampled monthly from May to October 2015;
- the Ells River above its mouth, near the Canadian Natural bridge (*test* station EL2, previously called ELR-2), established in 2004 and sampled as *baseline* station in the fall until 2010, and sampled as a *test* station in the fall 2011 to 2012. Sampling resumed in 2015 and the station was sampled monthly from May to October 2015;
- the Ells River above the Joslyn Creek diversion and upstream of development at hydrology station S45 (*baseline* station ELLS RIFF 5, previously called ELR-3), established in 2013 and sampled seasonally until March 2015, then monthly from May to October 2015;
- Gardiner Lake (*baseline* station GAL-1), a new station established in 2014 and sampled seasonally in 2015 in March, May, July, and September;
- Namur Lake (*baseline* station NAL-1), a new station established in 2014, and sampled seasonally in 2015 in March, May, July, and September; and
- the Ells River *test* stations ER-L and ER-M and *baseline* station ER-U, sampled in September 2015 to support the wild fish health monitoring activities in the Ells River.

In addition, data sondes installed at *test* station EL2 and *baseline* station ELLS RIFF 5 collected continuous water quality data from July to October 2015 for a subset of water quality variables.

Figure 5.8-5 presents in situ water quality trends in the Ells River as recorded by data sondes in the 2015 WY. Monthly and seasonal variations in water quality are summarized in Table 5.8-4 to Table 5.8-8 and Figure 5.8-6 to Figure 5.8-7. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations are provided in Table 5.8-9 to Table 5.8-14. The ionic composition of water in the Ells River compared to historical ion balance is presented in Figure 5.8-8. AEP water quality guideline exceedances for water quality measurement endpoints are presented in Table 5.8-15. Figure 5.8-9 shows a comparison of selected water quality measurement endpoints in the Ells River relative to historical concentrations and regional *baseline* concentrations.

Continuous Monitoring Results from Data Sondes Continuous monitoring results from data sondes indicate that temperature and concentration of dissolved oxygen (DO) exhibited similar trends in the summer and fall at *test* station EL2 and *baseline* station ELLS RIFF 5 (Figure 5.8-5). Water temperature increased up to 25°C in summer and then decreased to near 5°C in late-September. Temperature increased again to 10°C for a short period in early October but decreased thereafter to approximately 0°C at the end of October. In contrast to temperature, DO concentrations were generally higher in fall than in summer, and were likely related to higher oxygen solubility at low temperatures as demonstrated by the steady DO saturation throughout the monitoring period. DO concentrations remained within the water quality guidelines for the protection of aquatic life throughout the monitoring period. Levels of pH, specific conductivity, and turbidity were higher at *test* station EL2 than at *baseline* station ELLS RIFF 5. Levels of pH at both stations were slightly alkaline throughout the monitoring period and there were no exceedances in pH levels of the water quality guideline for the protection of aquatic life. Levels of specific conductivity were higher in summer than in fall. Turbidity was variable, particularly in August and September and gradually settled to around 5 NTU at both stations in October. Data gaps for data sondes at stations of the Ells River are discussed in Appendix B.

Monthly and Seasonal Variations in Water Quality Monthly collection of water quality data in the Ells River started in 2015 and is reported here for the first time. The limited data indicate seasonal variations in water quality measurement endpoints at all Ells River stations (Table 5.8-4 to Table 5.8-6, Figure 5.8-6). Concentrations of particulates (TSS) and associated water quality constituents (e.g., nutrients and many total metals) were higher in May during freshet flows. In contrast, concentrations of TDS and associated constituents (e.g., conductivity, alkalinity, and major ions, with few exceptions) were lowest in May and highest during lower open-water flows in July and August. Comparison of monthly data from 2015 with available historical data (Figure 5.8-6) showed that most measurement endpoints fell within the historical monthly ranges, but some variables were above previously measured concentrations in some months (e.g., TDS, strontium, sodium, and sulphate). Unlike Ells River stations, *baseline* lake stations GAL-1 and NAL-1 did not show obvious seasonal trends (Table 5.8-7, Table 5.8-8, Figure 5.8-7).

2015 WY Fall Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints in fall 2015 were within the range of previously-measured concentrations in the Ells River with the following exceptions (Table 5.8-9 to Table 5.8-11):

- retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs, with concentrations below the previously-measured minima at *test* station ELLS RIFF 3;
- conductivity, magnesium, sulphate, naphthenic acids, oilsands extractable acids, and total parent PAHs, with concentrations higher than the previously-measured maxima at *test* station EL2;
- total nitrogen with concentrations below the previously-measured minima at *test* station EL2 and *baseline* station ELLS RIFF 5:

- total PAHs, and total alkylated PAHs, with concentrations below the previously-measured minima at *test* station EL2; and

- potassium, sulphate, boron, total molybdenum, total strontium, oilsands extractable acids, total phenols, total PAHs, total parent PAHs, and total alkylated PAHs, with concentrations higher than the previously-measured maxima at *baseline* station ELLS RIFF 5.

It should be noted that waterborne PAHs and naphthenic acids and oilsands extractable acids have only been measured at ultra-trace detection limits since 2011, and that historical comparisons of 2015 data for these variables were made to data collected from 2011 to 2014 for *test* station ELLS RIFF 3, from 2011 to 2012 for *test* station EL2 (*test* station EL2 was not sampled in 2013 and 2014), and from 2013 to 2014 for *baseline* stations ELLS RIFF 5.

Water quality at wild fish health reaches (*test* stations ER-L and ER-M and *baseline* station ER-U) was measured for the first time in 2015, so it was not possible to make historical comparisons for these stations (Table 5.8-12). Differences in any water quality measurement endpoints between *test* stations and *baseline* station were not apparent except higher concentrations of PAHs at *test* station ER-L, relative to *test* station ER-M and *baseline* station ER-U.

Baseline lake stations GAL-1 and NAL-1 were first sampled in 2014 and historical comparisons were therefore only possible between 2014 and 2015. In both lakes, concentrations of a range of water quality endpoints including sulphate, TDS, boron, total dibenzothiophenes, total PAHs, total parent PAHs, and total alkylated PAHs were higher in 2015 than in 2014 (Table 5.8-13, Table 5.8-14).

Temporal Trends There were no significant trends ($p<0.05$) in fall concentrations of water quality measurement endpoints at *test* stations ELLS RIFF 3 and EL2. Trend analysis could not be conducted for *baseline* stations ELLS RIFF 5, GAL-1, and NAL-1 due to an insufficient number of sampling years available.

Ion Balance The ionic composition of water in fall 2015 was generally similar at all water quality stations and was dominated by calcium and bicarbonate (Figure 5.8-8). *Baseline* station GAL-1 showed a slightly greater dominance of calcium and bicarbonate, relative to *baseline* station NAL-1 and Ells River stations. The ionic composition of water at *test* station ELLS RIFF 3 has remained consistent since monitoring began in 1998.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Water quality guideline exceedances in the 2015 WY (Table 5.8-15) were:

- dissolved iron at *test* station ELLS RIFF 3 (May) only;

- total phenols at all *test* stations ELLS RIFF 3 (June to October), EL2 (July to October), ER-L (September), ER-M (September), and *baseline* stations ELLS RIFF 5 (July to October), ER-U (September), GAL-1 (May, July, and September) and NAL-1 (July and September); and

- sulphide at all *test* stations ELLS RIFF 3 (June to October), EL2 (June and August to October), ER-L (September), ER-M (September), and *baseline* stations ELLS RIFF 5 (June and August to October), ER-U (September) and GAL-1 (May and September).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints at all *test* and *baseline* stations in fall 2015 were within the range of regional *baseline* concentrations, with the following exceptions (Figure 5.8-9):

- total suspended solids at *test* stations EL2 and ER-M, and *baseline* station ER-U, with concentrations below the 5th percentile of regional *baseline* concentrations;
- total dissolved phosphorous at *test* stations ELLS RIFF 5, EL2, ER-L, and ER-M and *baseline* station ER-U, with concentrations below the 5th percentile of regional *baseline* concentrations; and
- sulphate at *test* station ER-L, with a concentration greater than the 95th percentile of regional *baseline* concentrations.

Concentrations of water quality measurement endpoints at *baseline* stations GAL-1 and NAL-1 were not compared to regional *baseline* concentrations because lakes were not included in the calculations of regional *baseline* conditions (Section 3.2.3.3), given the ecological differences between lakes and rivers.

Water Quality Index WQI values of 98.7 for *test* station ER-L and 100 for all other Ells watershed stations in fall 2015 indicate **Negligible-Low** differences between water quality at all Ells River stations and regional *baseline* conditions.

Classification of Fall Results Differences in water quality in fall 2015 between the Ells River and regional *baseline* fall conditions were classified as **Negligible-Low**, based on high WQI values indicating high similarity with reference *baseline* conditions.

5.8.4 Benthic Invertebrate Communities and Sediment Quality

5.8.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 at:

- depositional *test* reach ELR-D1, which has been sampled since 2003; and
- depositional *baseline* lakes NAL-1 (Namur Lake) and GAL-1 (Gardiner Lake), which have been sampled since 2014.

Ells River

2015 Habitat Conditions Water at *test* reach ELR-D1 in fall 2015 was shallow (0.3 m) and slightly alkaline (pH 7.1), with high DO (9.3 mg/L) and moderate conductivity (265 µS/cm). The substrate was primarily sand (99%), with low total organic carbon (<1%) (Table 5.8-16).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach ELR-DI in fall 2015 was dominated by chironomids (71%) (Table 5.8-16). There were more than 20 genera of chironomids, with *Saetheria* the most abundant. Permanent aquatic forms (Bivalvia: *Pisidium*) and flying insects such as Ephemeroptera (*Acerpenna*, *Caenis*, *Ephemerella*), Plecoptera (*Isoperla*) and Trichoptera (*Oecetis*) were present in the reach in 2015. Gomphidae dragonflies (*Ophiogomphus*) were present at one of the replicates sampled in the reach.

Temporal Comparisons The temporal comparisons of benthic invertebrate community measurement endpoints (outlined in Section 3.2.3.1) that were possible given the data available for the Ells River watershed for *test* reach ELR-D1 were changes over time (Hypothesis 5, Section 3.2.3.1) and changes between 2015 values and the mean of all previous years of sampling (2003 to 2014).

CA Axis 1 scores were significantly higher in 2015 than the mean of previous years and accounted for 44% of the total variance in annual means (Table 5.8-18). The increase in CA Axis 1 scores over time reflects a higher relative abundance of chironomids over time (Figure 5.8-11).

Comparison to Published Literature *Test* reach ELR-D1 had low diversity and a modest percentage of the fauna as worms (14%; Table 5.8-17), which is generally indicative of poor condition (Hynes 1960; Griffiths 1998) and high levels of organic input (Mandeville 2001). However, the benthic invertebrate community in *test* reach ELR-Dl contained EPT taxa including the sensitive mayfly species *Ephemerella* (Mandeville 2001). The high relative abundance of chironomids and the presence of EPT taxa reflect somewhat favourable conditions (Niemi et al. 1990).

2015 Results Relative to Historical or *Baseline* Conditions Abundance, richness and equitability in fall 2015 were within the inner tolerance limits for the range of variability for previous years (Figure 5.8-12)[3]. The percentage of EPT taxa in fall 2015 was above the inner tolerance limits for the range of variability for previous years; this is consistent with habitat quality being good in fall 2015 relative to historical conditions.

Classification of Results Differences in measurement endpoints for the benthic invertebrate community at *test* reach ELR-D1 are classified as **Negligible-Low** because significant increases in CA Axis 1 scores over time were not indicative of degrading conditions. All measurement endpoints were within the inner tolerance limits of the normal range of variation for previous years of sampling, with the exception of %EPT. However, %EPT in fall 2015 was not significantly different than %EPT in previous years, signifying no change in conditions.

Lakes

2015 Habitat Conditions Water in Namur Lake in the fall of 2015 was alkaline (pH 8.0) with low conductivity (65.5 µS/cm) (Table 5.8-19). Benthic invertebrate community samples were collected from 0.5 m of water. The substrate of Namur Lake consisted primarily of sand (98.8%) and total organic carbon content in the sediment of Namur Lake was low (<1%) (Table 5.8-19).

Water in Gardiner Lake in the fall of 2015 was alkaline (pH 7.9) with moderate conductivity (127 µS/cm) (Table 5.8-19). Benthic invertebrate community samples were collected from 0.5 m of water. The substrate of Gardiner Lake consisted primarily of sand (99.8%) and total organic carbon in the sediment of Gardiner Lake was low (<1%) (Table 5.8-19).

Relative Abundance of Benthic Invertebrate Community Taxa in 2015 The benthic invertebrate community of Namur Lake at *baseline* station NAL-1 in fall 2015 was dominated by Chironomidae (62%) with tubificid worms being subdominant (15%) (Table 5.8-20). Chironomids were primarily *Polypedilum* and *Stichtochironomus,* although *Cryptochironomus* were also relatively abundant. Bivalves were

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[3] Because there are more than ten years of data for *test* reach ELR-D1 (2003 to 2015) tolerance limits for the normal range of variation of benthic invertebrate community measurement endpoints were calculated using historical data for this reach.

present and consisted of *Pisidium*. Gastropods were mainly represented by the Lymnaeidae family, although the *Gyraulus* genus was also present. Larvae of flying insects such as mayflies (*Callibaetis, Caenis, Leptophlebia*) and caddisflies (*Oecetis, Molanna*) were found but in relatively low abundance (Table 5.8-20).

The benthic invertebrate community of Gardiner Lake at *baseline* station GAL-1 in fall 2015 was dominated by amphipods (24%), nematodes (24%) and chironomids (21%) (Table 5.8-20). Chironomids were diverse, consisting primarily of the genera *Stichtochironomus, Cryptochironomus,* and *Paratendipes*. Amphipods were present and consisted mostly of *Hyalella azteca*, though a few *Gammarus lacustris* were also present. Other permanent aquatic forms such as bivalves (*Pisidium*) and gastropods (*Lymnaea, Physa, Gyraulus*) were found in *baseline* lake GAL-1. EPT taxa (Ephemeroptera: *Callibaetis, Caenis, Ephemera, Leptophlebia*; Trichoptera: *Mystacides*, *Oecetis*, *Molanna*) were present but in low relative abundances.

Temporal Comparisons One temporal comparison (outlined in Section 3.2.3.1) was made for each lake between 2015 and 2014 at *baseline* stations GAL-1 and NAL-1. ANOVAs were based on adjusted indices of composition where appropriate (Appendix D). In the case of Gardiner and Namur lakes, with only two years of data, the differences in mean endpoint values between years were expressed relative to the within-year standard deviation (i.e., as effect sizes in SD's). Effect sizes <2 SD are generally considered not ecologically large (Kilgour et al. 1998).

All tests for *baseline* reach NAL-1 resulted in non-significant effects (Table 5.8-21). The percentage of EPT taxa was significantly higher in 2015 than in 2014 for *baseline* reach GAL-1, accounting for 20% of the variation in annual means (Table 5.8-22, Figure 5.8-13).

Comparison to Published Guidelines Namur Lake's benthic community had a fauna relatively typical of a shallow lake environment (Parsons et al. 2010, Pennak 1989). Permanent aquatic forms such as bivalves and gastropods were relatively abundant in fall 2015. Larvae of several flying insect groups were found in Namur Lake, consistent with a conclusion that the habitat quality for benthic invertebrate communities in Namur Lake was good.

Gardiner Lake's benthic community contained benthic fauna in 2015 that reflected generally good water quality. Nematodes comprised a relatively high proportion of the fauna in Gardiner Lake in both 2014 and 2015. Nematodes are an unusual group in that their tolerances are not well described, though they generally occur in high abundance in somewhat organic/enriched conditions (Pennak 1989). The presence of Ephemeroptera and Trichoptera taxa and several permanent aquatic forms such as Amphipoda, Bivalvia and Gastropoda were consistent with the conclusion that benthic habitat quality in Gardiner Lake was relatively high (Niemi et al. 1990; Pennak 1989).

Summary of Results The benthic invertebrate communities of both Namur and Gardiner lake in fall 2015 were consistent with relative high quality benthic habitats, with the presence of Ephemeroptera and Trichoptera taxa and permanent aquatic forms (e.g., bivalves, gastropods).

5.8.4.2 Sediment Quality

Sediment samples were collected in fall 2015 from:

- the Ells River near its mouth (*test* station ELR-D1), established in 1998 as a *baseline* station and as a *test* station from 2002 to 2015;
- *test* stations ER-L (lower reach) and ER-M (middle reach) and *baseline* station ER-U (upper reach) in September 2015 to support the wild fish health monitoring activities in the Ells River;
- Gardiner Lake (*baseline* station GAL-1), sampled in 2014 and 2015; and
- Namur Lake (*baseline* station NAL-1), sampled in 2014 and 2015.

Temporal Trends Significant ($p<0.05$) increasing temporal trends in concentrations of Fraction 2, 3, and 4 hydrocarbons were observed at *test* station ELR-D1. Trend analyses could not be conducted on *test* stations ER-L and ER-M, or *baseline* stations NAL-L, GAL-1 and ER-U due to limited years of available data ($n \leq 2$).

2015 Results Relative to Historical Conditions Comparisons to historical ranges were not possible for *test* stations ER-L and ER-M or *baseline* stations ER-U, NAL-1, and GAL-1 because monitoring at these stations only recently commenced (in 2014 or 2015).

At *test* station ELR-D1, sediments in fall 2015 were predominantly sand (93.8%) with lower percent-clay (0.8%) than previously measured (Table 5.8-23, Figure 5.8-14). *Test* stations ER-L and ER-M, and *baseline* station ER-U also were dominated by sand (85.9%, 82.0%, and 92.9%, respectively) (Table 5.8-24, Figure 5.8-15, Figure 5.8-16, Figure 5.8-17). BTEX and Fraction 1 hydrocarbons were not detected at all four stations on the Ells River (Table 5.8-23, Table 5.8-24). Fraction 2 hydrocarbons at *test* station ER-M and Fraction 4 hydrocarbons at *baseline* station ER-U also were non-detectable. All PAH concentrations fell within previously-measured ranges at *test* station ELR-D1 measured (Table 5.8-23). PAH concentrations, specifically alkylated PAHs, were very high at *test* station ER-L (Table 5.8-24). Although *Chironomus* survival at *test* station ELR-D1 was within the previously-measured range, sediment toxicity tests showed low survival of the midge *Chironomus* at both *test* stations ELR-D1 (46%) and ER-L (44%) (Table 5.8-23, Table 5.8-24). Survival of *Chironomus* was high at *test* station ER-M (90%) and *baseline* station ER-U (90%) in fall 2015 (Table 5.8-24). In addition, sediment toxicity tests showed high (≥88%) survival of the amphipod *Hyalella* at all four stations on the Ells River (Table 5.8-23, Table 5.8-24).

Sediments at *baseline* stations NAL-1 and GAL-1 were dominated by sand in fall 2015 (99.9% and 99.8%, respectively) (Table 5.8-25, Table 5.8-26, Figure 5.8-18, Figure 5.8-19). All total hydrocarbon fractions were non-detectable at *baseline* stations NAL-1 and GAL-1. With the exception of naphthalene, PAH concentrations at both *baseline* stations NAL-1 and GAL-1 were below fall 2014 concentrations. Sediment toxicity tests showed moderate-high survival of the midge *Chironomus* (70%) and high survival of the amphipod *Hyalella* (100%) at *baseline* station NAL-1 (Table 5.8-25). In contrast, sediment toxicity tests showed high survival of *Chironomus* (96%) and moderate-high survival of *Hyalella* (76%) at *baseline* GAL-1 (Table 5.8-26).

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Measurement endpoints of sediment quality for stations within the Ells River watershed were below guideline concentrations in fall 2015 (Table 5.8-23 to Table 5.8-26), with the exception of:

- Fraction 2 hydrocarbons at *test* station ELR-D1 (243 mg/kg) and ER-L (548 mg/kg), which exceeded the CCME guideline of 150 mg/kg;
- Fraction 3 hydrocarbons at *test* station ELR-D1 (2,320 mg/kg) and ER-L (3,980 mg/kg), which exceeded the CCME guideline of 300 mg/kg;
- predicted PAH toxicity at *test* station ER-L (1.93), which exceeded the potential chronic toxicity threshold of 1.0;
- chrysene at *test* station ELR-D1 (0.1510 mg/kg), which exceeded the CCME guideline of 0.0571 mg/kg;
- acenaphthene, chrysene, dibenz(a,h)anthracene, phenanthrene, and pyrene at *test* station ER-L, which exceeded their appropriate CCME guidelines; and
- total arsenic at *test* station ER-M (6.8 mg/kg), which exceeded the CCME guideline of 5.9 mg/kg.

2015 Results Relative to Regional *Baseline* Concentrations In fall 2015, concentrations of all sediment quality measurement endpoints for stations within the Ells River watershed were within ranges of regional *baseline* concentrations (Figure 5.8-14, Figure 5.8-15, Figure 5.8-16, Figure 5.8-17) with the following exceptions:

- total PAHs (absolute and carbon-normalized) and CCME total hydrocarbon fractions at *test* stations ELR-D1 and ER-L, which were above the 95th percentile of regional *baseline* concentrations.

No comparisons were made in fall 2015 between *baseline* stations NAL-1 and GAL-1 and regional *baseline* concentrations given that lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers.

Sediment Quality Index The SQI value for *test* station ELR-D1 was 76.8 in fall 2015, relative to fall 2014 (82.1) and fall 2013 (69.3). In fall 2015, SQI values for *test* stations ER-L and ER-M were 51.0 and 98.9, respectively, while the SQI value for *baseline* station ER-U was 100. The low SQI at ER-L relates primarily to high petroleum hydrocarbon and PAH concentrations relative to the range of regional *baseline* values.

SQI values were not calculated for *baseline* stations NAL-1 or GAL-1 because regional *baseline* ranges were not calculated for lakes, due to ecological differences between lakes and rivers and the lack of *baseline* data for lakes in the region.

Classification of Results Based on the calculated SQI value, differences in sediment quality conditions in 2015 between *test* ELR-D1 and regional *baseline* conditions were classified as **Moderate**. Differences in sediment quality conditions in 2015 between *test* station ER-L and regional *baseline* conditions were classified as **High**, primarily due to regionally high hydrocarbon and PAH concentrations. Differences in sediment quality conditions between *test* station ER-M and *baseline* station ER-U and regional *baseline* conditions were classified as **Negligible-Low**.

5.8.5 Fish Populations

In 2015, fish community monitoring and wild fish health monitoring were conducted in the Ells River.

5.8.5.1 Fish Community Monitoring

Fish community monitoring was conducted on the Ells River in fall 2015 at *test* reach ELR-F1. The fish community has been monitored at this reach since 2010, and this reach is at the same location as the benthic invertebrate community and sediment quality *test* reach ELR-D1.

2015 Habitat Conditions Habitat conditions at *test* reach ELR-F1 in fall 2015 are summarized in Table 5.8-27. *Test* reach ELR-F1 in fall 2015 had a glide habitat with a wetted width of 28.0 m and a bankfull width of 37.9 m. Substrate consisted of sand with some fine material. Water at *test* reach ELR-F1 in fall 2015 had a mean depth of 0.48 m, a velocity of 0.27 m/s, pH of 8.00, a conductivity of 213 µS/cm, concentration of DO of 9.5 mg/L, and a temperature of 9.7°C. Instream cover consisted primarily of macrophytes, small woody debris, and live trees and roots with smaller amounts of filamentous algae and large woody debris.

Relative Abundance of Fish Species The total catch of fish species at *test* reach ELR-F1 was higher in fall 2015 than in fall 2014 and was dominated by lake chub and trout-perch (Table 5.8-28). Seven fish species were caught in 2015, which was the highest species richness in fish community sampling in the Ells River since 2012 (Table 5.8-28).

Temporal and Spatial Comparisons Values of all measurement endpoints for fish community monitoring were higher in fall 2015 compared to fall 2014 with the exception of diversity (Table 5.8-29). The increase in ATI in fall 2015 compared to fall 2014 was a result of a greater dominance of trout-perch in fall 2015 (likely leading to lower diversity in fall 2015 than in previous years) than the more sensitive species, slimy sculpin, which was more dominant in fall 2014 (Table 5.8-28; Whittier et al. 2007).

No spatial comparisons were possible for the fish community at *test* reach ELR-F1 in fall 2015 because no upstream *baseline* reach on the Ells River was monitored in fall 2015. The temporal comparison for *test* reach ELR-F1 that was made was to test for changes over time (fall 2010 to fall 2015) in the values of the measurement endpoints (i.e., H_{O2}: No trend over time in mean values of measurement endpoints, Section 3.2.4.1).

The changes over time in abundance and ATI at *test* reach ELR-F1 were statistically-significant (Table 5.8-30). In addition, the trends of both measurement endpoints (i.e., decreasing abundance and decreasing ATI from 2010 to 2015) are consistent with a potential negative change in the fish community at *test* reach ELR-F1. However, less than 20% of the variance in annual means is explained by these decreases over time in abundance and ATI, suggesting there are no strong statistical signals associated with these changes over time (section 3.2.4.1).

Comparison to Published Literature Golder (2004) documented similar habitat conditions consisting primarily of glide habitat dominated by sand and fine sediment in the area of the Ells River where *test* reach ELR-F1 is located, which is consistent with observations made in fall 2015 (Table 5.8-27). Past studies indicate a total of 19 fish species have been recorded in the Ells River watershed (Golder 2004). The results of the fish community sampling in fall 2015, when combined with historical fish monitoring conducted by RAMP/JOSMP in the Ells River watershed, brings the total number of fish species that have been observed between 2010 and 2015 to 16. Possible reasons for discrepancies in species richness may be due to differences in sampling gear as well as the total amount of the watercourse sampled; fish community monitoring under the JOSMP samples a smaller, defined reach length relative to the multiple locations and reaches documented in Golder (2004).

2015 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints for fish community monitoring at *test* reach ELR-F1 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints (Figure 5.8-20).

Classification of Results Differences in measurement endpoints for fish community at *test* reach ELR-F1 are classified as **Negligible-Low**:

1. While there have been statistically-significant decreases in abundance and ATI over time from 2010 to 2015 and these decreases are consistent with a potential negative change in the fish community at *test* reach ELR-F1, less than 20% of the variance in annual means is explained by these decreasing trends.
2. Mean values of all measurement endpoints for fish community monitoring at *test* reach ELR-F1 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints.

5.8.5.2 Wild Fish Health

Wild fish health monitoring was conducted at three reaches in the Ells River in fall 2015, using lake chub as the target species:

- one *baseline* reach in the upper reaches of the Ells River (ER-U);
- one *test* reach mid-watercourse (ER-M); and
- one *test* reach in the lower reaches (ER-L).

Data gathered during the 2015 program could not be compared with previous wild fish health monitoring conducted in the Ells River in 1999, 2000, 2004, 2005, and 2007 because these historical programs used either slimy sculpin or longnose dace, while lake chub was the target fish species in 2015.

2015 Habitat Conditions In situ water quality at all reaches indicated suitable conditions for lake chub, with DO ranging from 10.8 mg/L to 12.1 mg/L; conductivity ranging from 174 µS/cm to 217 µS/cm; and pH ranging from 7.05 to 8.62 (Table 5.8-31). Mean water depth at reaches ranged from 0.45 m to 0.55 m, and mean velocity measured at the upper *baseline* reach ER-U was 0.25 m/s. The dominant and subdominant substrate at the two lower *test* reaches (ER-L and ER-M) were cobble and fines, respectively, while the upper *baseline* reach ER-U had fines and cobble as the dominant and subdominant substrate, respectively. Water temperatures measured during reach visits ranged from 3.2°C to 5.1°C. Daily mean water temperature decreased from a high of 22°C at the beginning of August to 5°C at the end of September (Figure 5.8-21).

Selected measurement endpoints for discrete water quality sampling (as described in Section 3.2.2.2) at each wild fish heath reach along the Ells River are provided in Table 5.8-12. Concentrations of water quality variables were generally similar across all three reaches with the exceptions of total dibenzothiophenes, total PAHs, and total alkylated PAHs with concentrations measured at *test* ER-L that were approximately 6, 1.6, and 1.8 times higher, respectively than at mid *test* reach ER-M and upper *baseline* reach ER-U.

Collection and Structure of Target Fish Populations

Summary of Capture Success of Adults and Juveniles The target number of adult lake chub (20 adult fish of each sex) was achieved at mid *test* reach ER-M and upper *baseline* reach ER-U. At lower *test* reach ER-L the target number of females was achieved but only 16 of 20 males were caught. The required number of 100 juveniles was obtained at all three reaches. A summary of morphometric data for the lake chub caught in the Ells River is provided in Table 5.8-32.

Size Distribution Figure 5.8-22 presents the length-frequency distribution of all lake chub captured in fall 2015 at each of the three reaches. A length of 50 mm was used to designate lake chub juveniles on the Ells River as 50 mm marks the end of the first peak in the bimodal distribution of length in Figure 5.8-22.

Length-frequency distributions of lake chub juveniles were compared among reaches of the Ells River (Figure 5.8-22). Distributions were relatively similar across reaches with the exception of upper *baseline* reach ER-U, which had a greater number of large individuals (i.e., greater than 45 mm) than *test* reaches ER-M and ER-L. This may indicate that lake chub juveniles at upper *baseline* reach ER-U experienced a higher growth rate in their first growing season compared to the two *test* reaches ER-M and ER-L.

The relative abundance of lake chub juveniles in the total catch of lake chub in fall 2015 was similar at all three reaches, indicating a similar recruitment rate of lake chub at the three monitored reaches of the Ells River in fall 2015 (Table 5.8-32).

Incidence of Abnormalities While parasites were found on lake chub at upper *baseline* reach ER-U and mid *test* reach ER-M and fin erosion was observed on lake chub at upper *baseline* reach ER-U and lower *test* reach ER-L in fall 2015, the overall incidence of abnormalities observed on lake chub was low in fall 2015 at all three reaches of the Ells River that were monitored (Table 5.8-32).

Spatial Comparison of Measurement Endpoints of Wild Fish Health

A summary of morphometric data for the adult lake chub caught in the Ells River is provided in Table 5.8-33. The following information provides detailed statistical analyses of the responses of lake chub populations collected at each reach of the Ells River. This information was used to test for spatial differences in measurement endpoints of lake chub among *test* reaches ER-M and ER-L and upper *baseline* reach ER-U.

Age – Mean Age and Age Distribution (Survival) The relative age-frequency distributions of lake chub showed a similar distribution of age classes at mid *test* reach ER-M compared to upper *baseline* reach ER-U, but a generally younger distribution of ages at lower *test* reach ER-L (Figure 5.8-23). Age classes ranged from one year to five years at upper *baseline* reach ER-U, one year to six years in mid *test* reach ER-M, and less than one year to four years at lower *test* reach ER-L. The dominant age class was two years at lower *test* reach ER-L and three years at mid *test* reach ER-M and upper *baseline* reach ER-U.

The following statistically-significant differences in age of lake chub among reaches of the Ells River in fall 2015 were measured (Table 5.8-34):

1. Female lake chub at mid *test* reach ER-M were significantly older than female lake chub at lower *test* reach ER-L.
2. Male lake chub were significantly older at upper *baseline* reach ER-U than at lower *test* reach ER-L.
3. Male lake chub were significantly older at mid *test* reach ER-M than at lower *test* reach ER-L.

The applicable effects criterion (±25% in ages of fish between the reaches) was met in all three cases (Table 5.8-34).

Growth* – Size-at-Age *(Energy Use) There were no statistically-significant differences in relative body weight of either female or male lake chub among the three reaches in the Ells River monitored in fall 2015 (Table 5.8-34).

Relative Gonad Weight (Energy Use) –The following statistically-significant differences in relative gonad weight of lake chub among reaches of the Ells River in fall 2015 were measured (Table 5.8-34):

1. Gonad size was significantly larger for female lake chub at upper *baseline* reach ER-U than at lower *test* reach ER-L.
2. Gonad size was significantly larger for female lake chub at mid *test* reach ER-M than at lower *test* reach ER-L.

However, the applicable effects criterion (±25% in relative gonad weight of fish between the reaches) was not met for either of these two cases (Table 5.8-34).

Relative Liver Weight (Energy Storage) The only statistically-significant difference in relative liver weight of lake chub among reaches in the Ells River in fall 2015 was in female lake chub at mid *test* reach ER-M that had significantly higher relative liver weight to female lake chub at lower *test* reach ER-L (Table 5.8-34); however, no exceedance of the effects criterion was observed in female lake chub. Differences in relative liver weight in male lake chub could not be evaluated among reaches because slopes of liver weight to body weight for adult male lake chub were significantly different among reaches ($p<0.01$) (Figure 5.8-24).

Condition (Energy Storage) There were no statistically-significant differences in condition of either female or male lake chub among the three reaches in the Ells River monitored in fall 2015 (Table 5.8-34).

Power Analysis to Investigate Influence of Sample Size Power analyses were conducted for group comparisons that were not statistically significant for each measurement endpoint using the effects size of ±25% for age, weight-at-age, relative gonad size, and relative liver size, and the effects size of ±10% for condition (Table 5.8-34). Power was relatively high for all comparisons, ranging from 0.60 to 0.99, with the exception of growth for male lake chub ($p<0.50$). There were four comparisons that did not achieve the desired level of power (>0.90) (Environment Canada 2010): growth of males and females; relative gonad size of males; and condition of females (Table 5.8-34), indicating that the sample size was too low in these cases to detect a significant difference for the target effect sizes. However, it should be noted that many of these comparisons achieved a power near 0.80, with the exception of relative weight and relative gonad size for male lake chub, and some studies have suggested that a power of 0.80 is adequate (e.g., Cohen 1988).

Exposure – Mixed Function Oxygenase (MFO) Activity In fall 2015, EROD activity in lake chub was similar between female and male fish and there was a consistent increase in EROD activity in both female and male lake chub from upstream to downstream reaches (Figure 5.8-25). The following statistically-significant differences in EROD activity in lake chub among reaches of the Ells River in fall 2015 were measured (Figure 5.8-25):

1. Female and male lake chub at upper *baseline* reach ER-U exhibited significantly lower EROD activity than female and male lake chub at both lower *test* reaches ER-M and ER-L.

2. EROD activity in female and male lake chub at the lower *test* reach ER-L was significantly higher than EROD activity in female and male lake chub at the mid *test* reach ER-M.

Interpretation of 2015 Responses There were few significant differences in measurement endpoints of lake chub among *test* and *baseline* reaches in the Ells River in fall 2015. Female and male lake chub at lower *test* reach ER-L were significantly younger than lake chub at mid *test* reach ER-M and upper *baseline* reach ER-U. A younger population of fish at lower *test* reach ER-L could be indicative of either an increase in recruitment or an increase in adult mortality (i.e., contaminants, fishing, predation, or the presence of barriers). It is important to note that concentrations of total dibenzothiophenes, which are sulphonated PAHs associated with bitumen (i.e., petrogenic), were nearly six times higher at lower *test* reach ER-L than at mid *test* reach ER-M or upper *baseline* reach ER-U (Table 5.8-12) and there was a consistent increase in EROD activity in both female and male lake chub from upstream to downstream reaches (Figure 5.8-25). Future studies would be needed to investigate effects and responses.

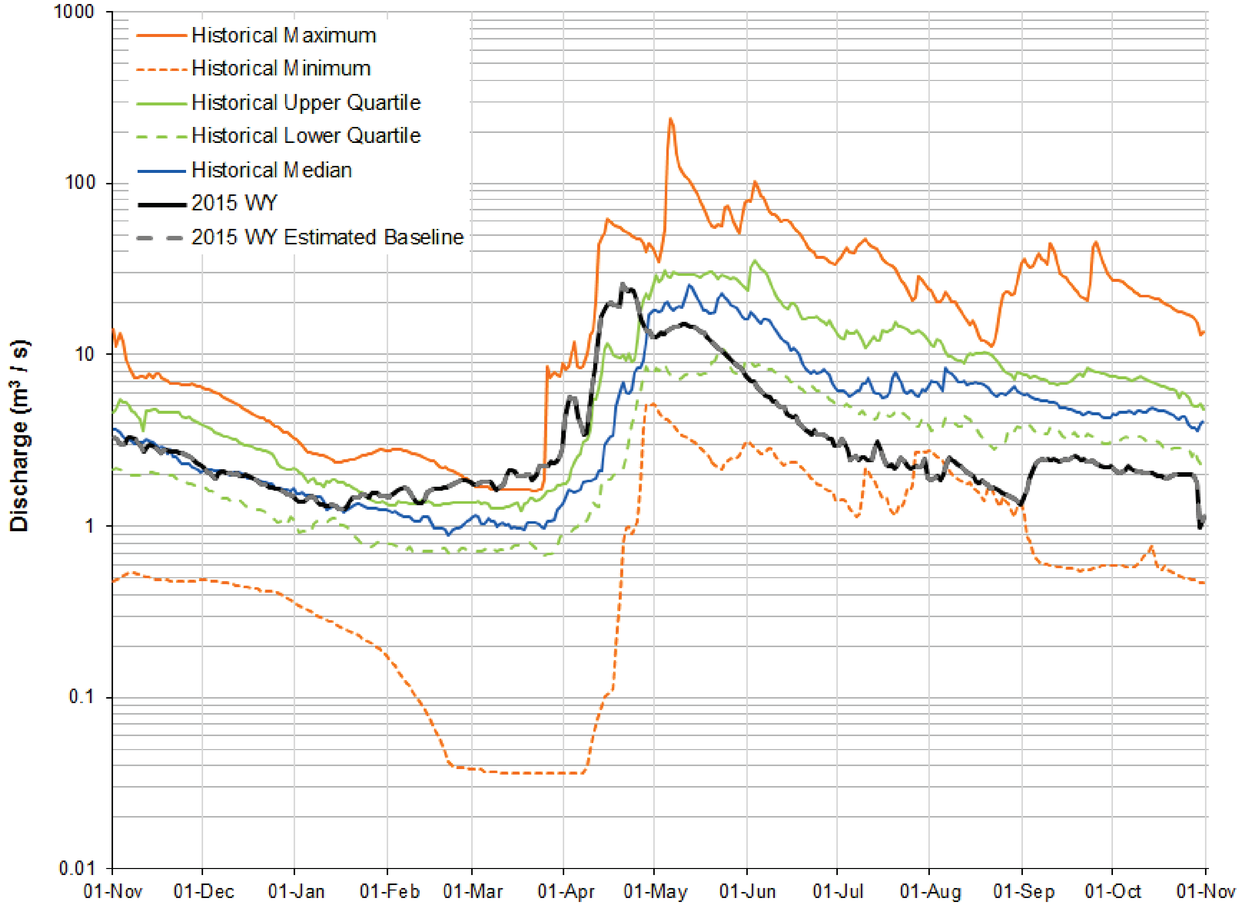
Classification of Results The significant differences in measurement endpoints for wild fish health that exceeded the Environment Canada effects criteria (Environment Canada 2010) in the Ells River in fall 2015 were:

1. Age of female lake chub at lower *test* reach ER-L was 30% lower relative to mid *test* reach ER-M.

2. Age of male lake chub at *test* reach ER-L was 40% lower than *test* reach ER-M and 46% lower than upper *baseline* reach ER-U.

There were no significant differences in measurement endpoints for wild fish health at mid *test* reach ER-M compared to upper *baseline* reach ER-U. The classification of results for wild fish health for lower *test* reach ER-L and mid *test* reach ER-M compared to upper *baseline* reach ER-U are therefore assessed as **Moderate** and **Negligible-Low**, respectively.

Figure 5.8-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Ells River for the 2015 WY, compared to historical values.



Note: The observed 2015 WY hydrograph was based on Ells River at the Canadian Natural Bridge, Station S14A. The upstream drainage area is 2,420 km^2. Historical values were calculated for all months from 1975 to 1986 (WSC Station 07DA017) and from 2004 to 2014 (JOSMP Station S14A); open-water values also incorporated Station S14A data from 2001 to 2003.

Table 5.8-2 Estimated water balance at Ells River at the Canadian Natural Bridge (JOSMP Station S14A), 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**129.118**	**Observed discharge at Ells River at the Canadian Natural Bridge, JOSMP Station S14A**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.192	Estimated 3.6 km^2 of the Ells River watershed is closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.386	Estimated 36.2 km^2 of the Ells River watershed with land change as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Ells River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Ells River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**128.924**	**Estimated *baseline* discharge at Ells River at the Canadian Natural Bridge, JOSMP Station S14A**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	0.194	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	0.150	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

Based on Ells River at the Canadian Natural Bridge, JOSMP Station S14A, 2015 WY data.

All non-zero values in this table are presented to three decimal places.

Table 5.8-3 Calculated change in hydrologic measurement endpoints for the Ells River watershed, 2015 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	4.263	4.270	+0.15%
Mean winter discharge	1.955	1.958	+0.15%
Annual maximum daily discharge	25.688	25.707	+0.15%
Open-water season minimum daily discharge	0.977	0.978	+0.15%

Notes:

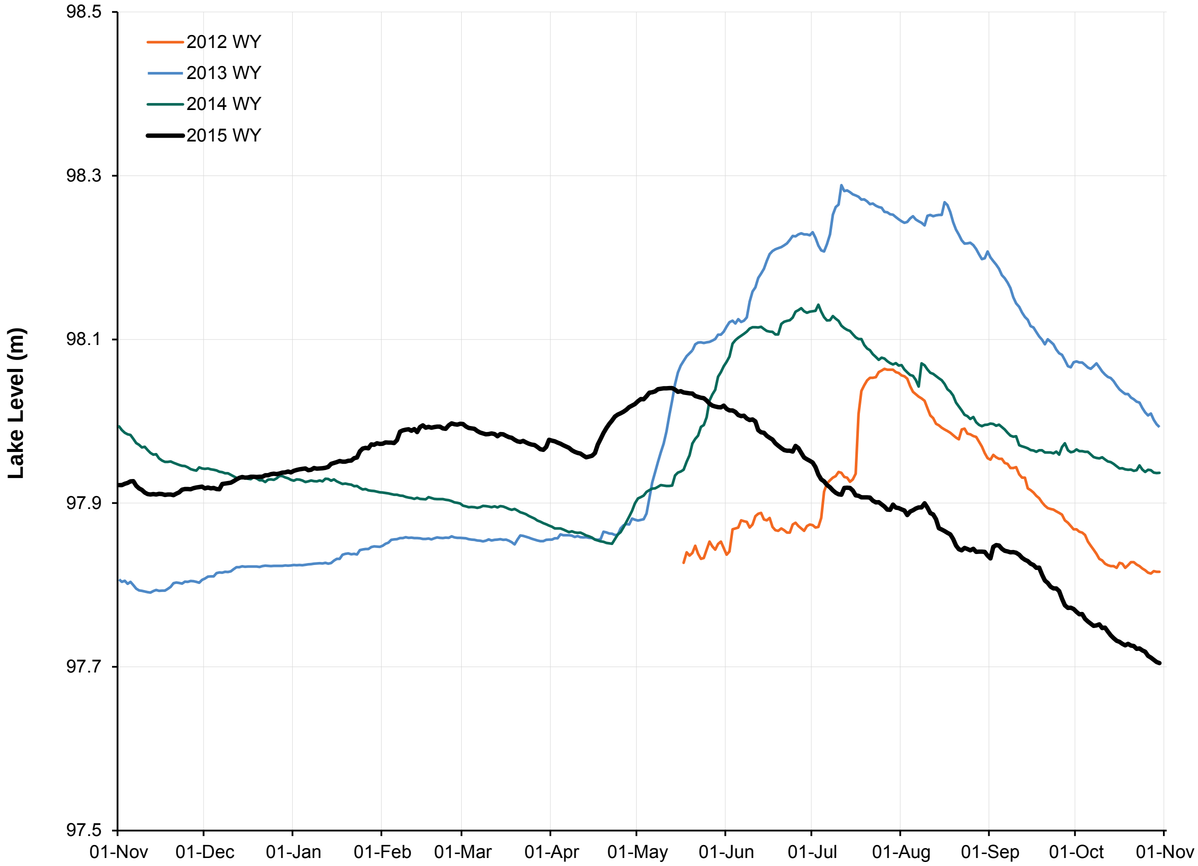
Definitions and assumptions are discussed in Section 3.2.1.

Observed discharge was calculated from JOSMP Station S14A.

The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. Flow values are presented to three decimal places for the sake of clarity.

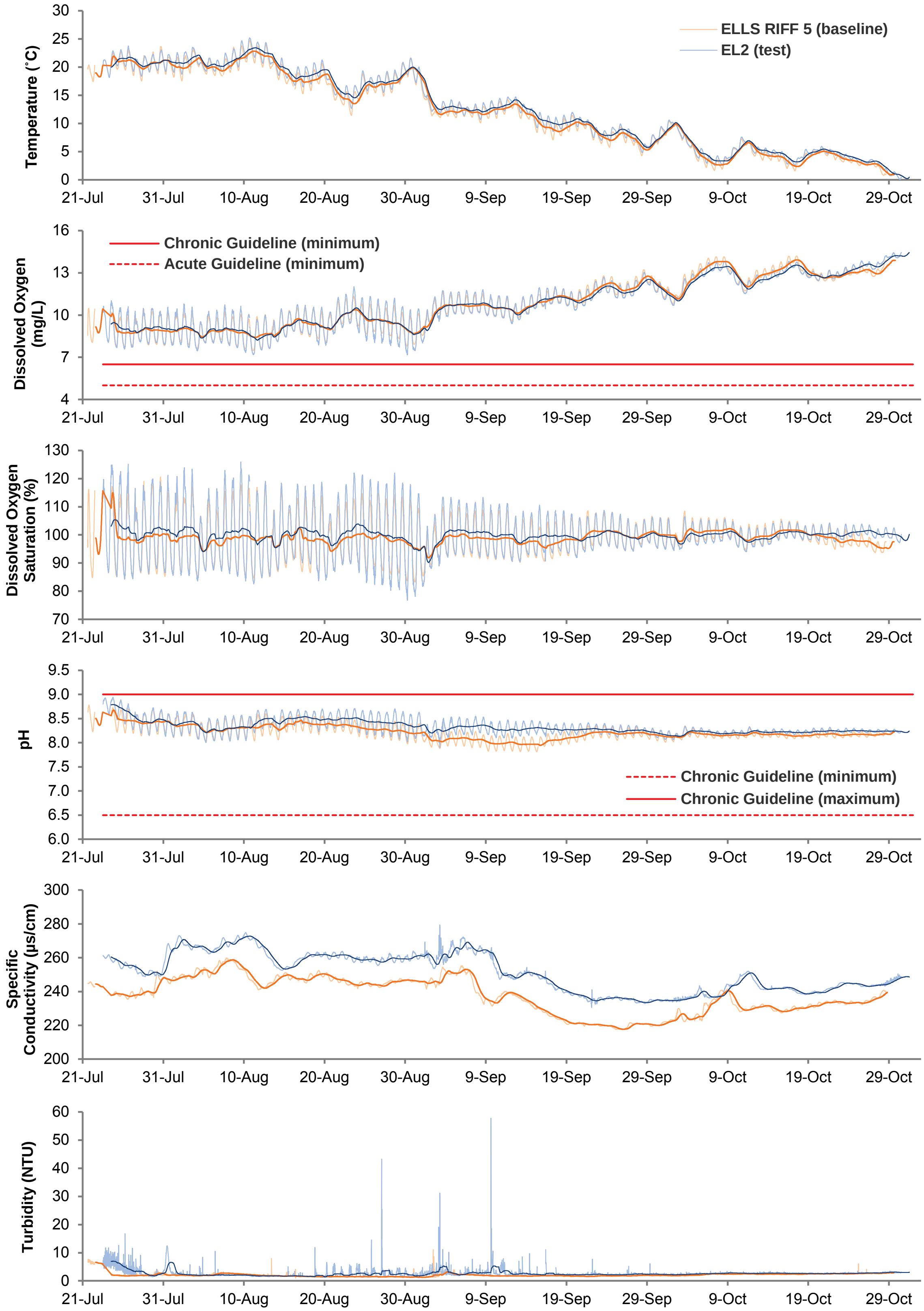
The open-water season refers to the period from May 1 and October 31 and the winter season refers to the period from November 1 and March 31.

Figure 5.8-4 Observed lake levels for Namur Lake, 2012-2015 WY.



Note: Based on 2015 WY data recorded at Namur Lake, JOSMP Station L4. Historical statistics are not calculated due to the short length of the monitoring record. Lake level is expressed in metres above a reach-specific, consistent datum.

Figure 5.8-5 In situ water quality trends in the Ells River recorded by data sondes, July to October 2015.



Note: Water quality variables were recorded at 15-minute intervals; trend lines are daily averages.

Table 5.8-4 Monthly concentrations of water quality measurement endpoints, mouth of Ells River (*test* station ELLS RIFF 3 [ELR-1]), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.16	7.97	May	8.30	Aug
Total suspended solids	mg/L	-	6	2.4	1.3	Oct	56.8	May
Conductivity	µS/cm	-	6	275	240	Sep	310	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.008	0.007	Aug, Oct	0.012	May
Total nitrogen	mg/L	-	5	0.510	<1	May	0.660	Jun
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.005	-	<0.005	-
Dissolved organic carbon	mg/L	-	6	16	12	Oct	18	May
Ions								
Sodium	mg/L	-	5	17	14	Oct	21	Sep
Calcium	mg/L	-	5	29	27	Oct	30	Jul
Magnesium	mg/L	-	5	8.8	8.5	Sep, Oct	9.5	Jul
Potassium	mg/L	-	6	1.4	1.3	May	1.5	Jun
Chloride	mg/L	120-640	6	2.4	1.2	May	3.2	Jul
Sulphate	mg/L	218-309[b]	6	28	19	May	36	Aug
Total dissolved solids	mg/L	-	6	250	111	May	330	Oct
Total alkalinity	mg/L	20 (min)	5	110	100	Jun	120	Jul, Aug
Selected metals								
Total aluminum	mg/L	-	6	0.079	0.065	Sep	2.23	May
Dissolved aluminum	mg/L	0.05	6	0.0060	0.0035	Jul	0.0316	May
Total arsenic	mg/L	0.005	6	0.0008	0.00051	Oct	0.0013	May
Total boron	mg/L	1.5-29	6	0.083	0.054	May	0.108	Aug
Total molybdenum	mg/L	0.073	6	0.00084	0.00056	May	0.00126	Aug
Total mercury ultra-trace	ng/L	5-13	6	1.0	0.82	Sep	4.07	May
Total methyl mercury	ng/L	1-2	6	0.1	0.049	Oct	0.118	Jul
Total strontium	mg/L	-	6	0.139	0.087	May	0.169	Aug
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.56	0.17	Sep	0.94	Jul
Oilsands extractable acids	mg/L	-	6	1.60	1.10	Jun, Sep	2.70	Jul
Polycyclic Aromatic Hydrocarbons PAHs								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	1.30	0.74	Sep	1.57	Jul
Total dibenzothiophenes[c]	ng/L	-	5	64.66	49.13	Oct	116.54	Jun
Total PAHs[c]	ng/L	-	5	276.26	208.70	Oct	374.19	Jun
Total Parent PAHs[c]	ng/L	-	5	26.15	23.50	Oct	27.85	Aug
Total Alkylated PAHs[c]	ng/L	-	5	249.87	185.20	Oct	348.04	Jun
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0071**	**0.0056**	Aug	**0.013**	Jul
Sulphide	mg/L	0.0019	5	**0.0062**	**0.0039**	Sep	**0.009**	Aug
Dissolved iron	mg/L	0.3	1	0.161	0.0439	Jul	**0.33**	May

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.8-5 Monthly concentrations of water quality measurement endpoints, Ells River near the Canadian Natural bridge (*test* station EL2 [ELR-2]), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.08	7.94	May	8.35	Aug
Total suspended solids	mg/L	-	6	2.4	<1	Sep	39	May
Conductivity	µS/cm	-	6	240	160	May	260	Jul, Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.011	0.004	Sep	0.017	May
Total nitrogen	mg/L	-	6	0.705	0.400	Oct	<1	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.005	except Aug	0.009	Aug
Dissolved organic carbon	mg/L	-	6	15	12	Oct	16	May
Ions								
Sodium	mg/L	-	6	12.5	7.2	May	18	Jul, Aug
Calcium	mg/L	-	6	25.5	17	May	29	Jul
Magnesium	mg/L	-	6	7.75	5.3	May	8.8	Jul
Potassium	mg/L	-	6	1.2	1.1	-	1.3	May, Jul
Chloride	mg/L	120-640	6	1.65	<1	May	1.9	Aug, Sep
Sulphate	mg/L	218-309[b]	6	23	17	May	26	Jul
Total dissolved solids	mg/L	-	6	300	56	May	340	Aug
Total alkalinity	mg/L	20 (min)	6	100	63	May	110	Jul, Aug
Selected metals								
Total aluminum	mg/L	-	6	0.067	0.032	Jun	2.150	May
Dissolved aluminum	mg/L	0.05	6	0.0046	0.0016	Jun	0.0296	May
Total arsenic	mg/L	0.005	6	0.0008	0.00049	Oct	0.0011	May
Total boron	mg/L	1.5-29	6	0.076	0.043	May	0.103	Aug
Total molybdenum	mg/L	0.073	6	0.00074	0.00054	May	0.00087	Jul
Total mercury ultra-trace	ng/L	5-13	6	1.1	0.750	Oct	2.46	May
Total methyl mercury	ng/L	1-2	6	0.1	0.038	Oct	0.147	Aug
Total strontium	mg/L	-	6	0.135	0.086	May	0.150	Aug
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 C6-C10	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 C10-C16	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 C16-C34	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 C34-C50	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.53	0.24	Oct	0.92	May
Oilsands extractable acids	mg/L	-	6	1.75	1.20	Oct	2.40	May
Polycyclic Aromatic Hydrocarbons PAHs								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	3.735	<0.59	Sep, Oct	6.47	Jul
Total dibenzothiophenes[c]	ng/L	-	6	114.53	25.99	Oct	417.56	Jul
Total PAHs[c]	ng/L	-	6	369.8	153.5	Oct	987.4	Jul
Total Parent PAHs[c]	ng/L	-	6	25.19	22.86	Oct	31.61	Jul
Total Alkylated PAHs[c]	ng/L	-	6	344.8	130.6	Oct	955.8	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0050**	<0.002	Jun	**0.007**	Oct
Sulphide	mg/L	0.0019	4	**0.0035**	<0.0019	May, Jul	**0.045**	Oct

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.8-6 Monthly concentrations of water quality measurement endpoints, Ells River above Joslyn Creek diversion (*baseline* station ELLS RIFF 5), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Data and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.04	7.72	Mar	8.27	Aug
Total suspended solids	mg/L	-	6	3	<1	Aug, Oct	39	May
Conductivity	µS/cm	-	6	230	150	May	240	Jul, Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.012	0.007	Aug, Sep	0.019	Mar
Total nitrogen	mg/L	-	6	0.705	0.4	Oct	<1	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.005	-	0.271	Mar
Dissolved organic carbon	mg/L	-	6	14	11	Oct	15	Mar
Ions								
Sodium	mg/L	-	6	12	7.3	May	15	Jul, Aug
Calcium	mg/L	-	6	25	17	May	29	Aug
Magnesium	mg/L	-	6	7.55	5.5	May	8.7	Jul, Aug
Potassium	mg/L	-	6	1.3	1.1	Oct	1.4	May, Aug
Chloride	mg/L	120-640	6	<1	<1	-	1.1	Oct
Sulphate	mg/L	218-309[b]	6	20.5	16	Mar	24	Jul
Total dissolved solids	mg/L	-	6	150	120	May, Oct	160	Jun, Jul
Total alkalinity	mg/L	20 (min)	6	96.5	60	May	110	Jun
Selected metals								
Total aluminum	mg/L	-	6	0.067	0.045	Aug	1.630	May
Dissolved aluminum	mg/L	0.05	6	0.003	0.003	Jun	0.027	May
Total arsenic	mg/L	0.005	6	0.001	0.00055	Mar	0.001	Jun
Total boron	mg/L	1.5-29	6	0.069	0.044	Sep	0.086	Jun
Total molybdenum	mg/L	0.073	6	0.00070	0.00047	Sep	0.00089	May
Total mercury ultra-trace	ng/L	5-13	6	0.745	0.620	Sep	3.330	May
Total methyl mercury	ng/L	1-2	6	0.071	0.035	Oct	0.117	Jul
Total strontium	mg/L	-	6	0.128	0.077	Jul	0.141	Jul, Aug
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 C6-C10	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 C10-C16	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 C16-C34	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 C34-C50	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.37	<0.08	Oct	1.03	May
Oilsands extractable acids	mg/L	-	6	2.05	0.20	Oct	3.30	May
Polycyclic Aromatic Hydrocarbons PAHs					6			
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	0.800	<0.59	Sep, Oct	4.93	Jul
Total dibenzothiophenes[c]	ng/L	-	6	8.62	<8.17	Oct	19.45	Jul
Total PAHs[c]	ng/L	-	6	127.9	125.1	Mar	173.6	Jul
Total Parent PAHs[c]	ng/L	-	6	22.62	22.16	Mar	23.91	Jul
Total Alkylated PAHs[c]	ng/L	-	6	105.3	102.6	Mar	149.7	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0046**	<0.001	Mar	**0.0065**	Oct
Sulphide	mg/L	0.0019	5	**0.0024**	<0.0019	May, Jul	**0.0450**	Oct

Values in **bold** are above guideline.

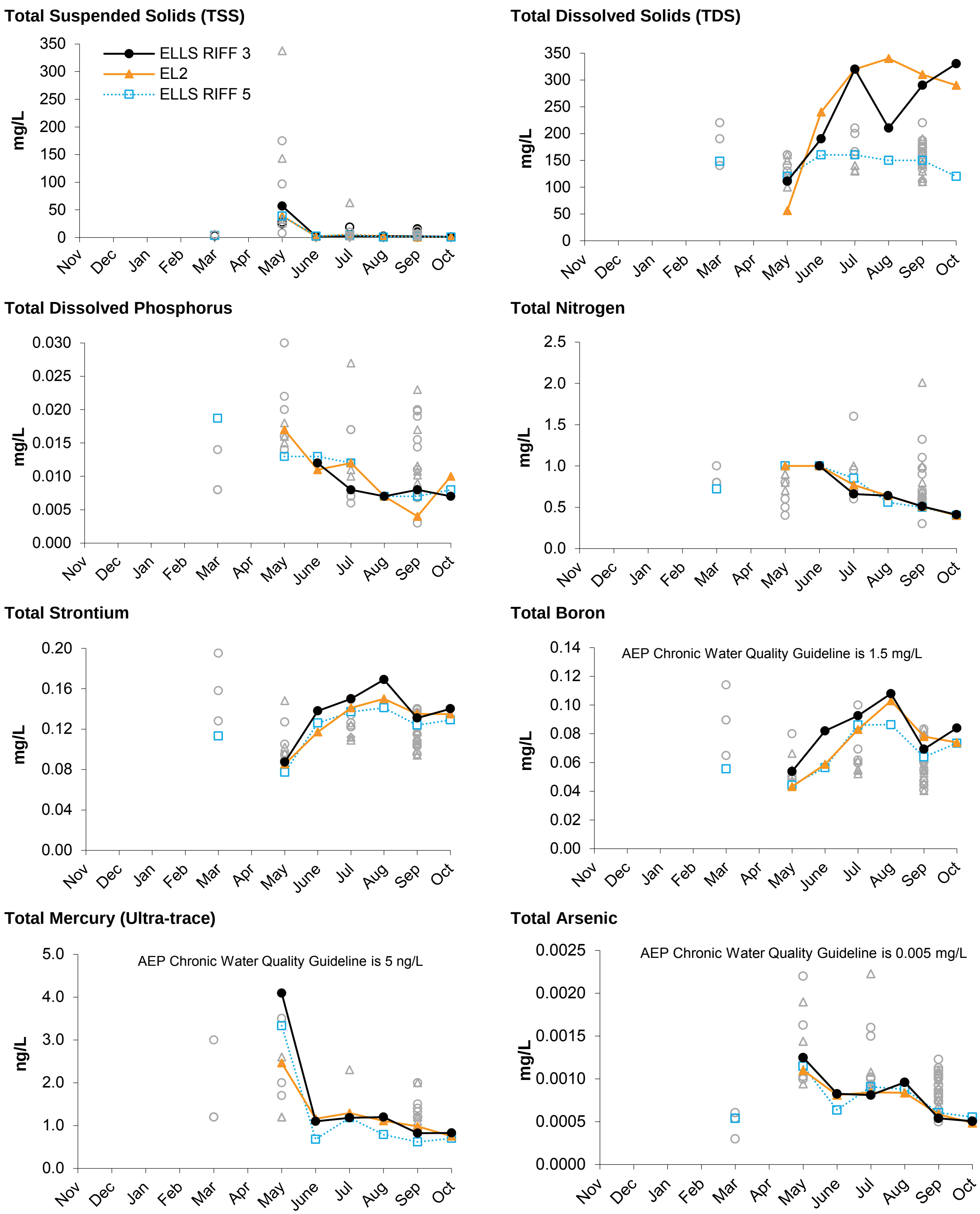
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

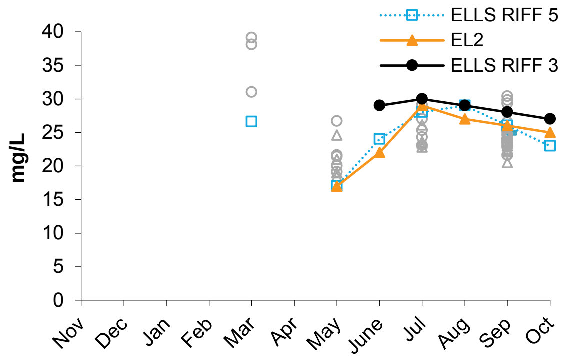
Figure 5.8-6 Selected water quality measurement endpoints in the Ells River (monthly data) in the 2015 WY.



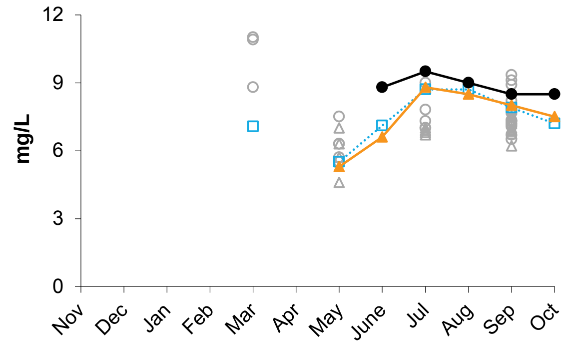
Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.8-6 (Cont'd.)

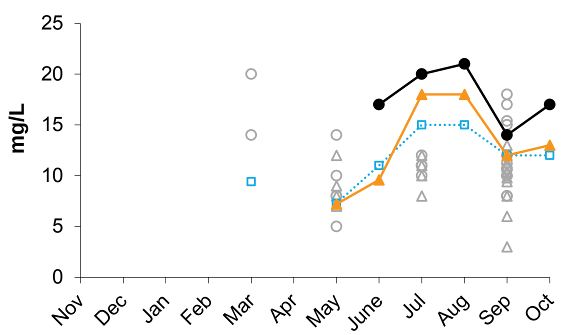
Calcium



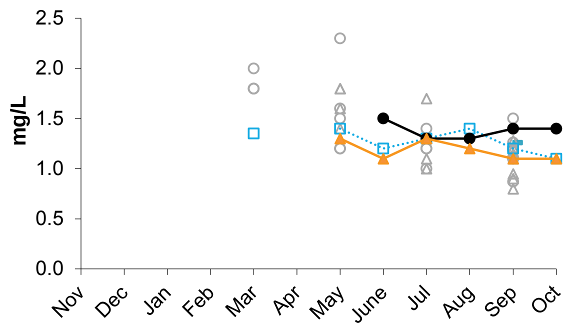
Magnesium



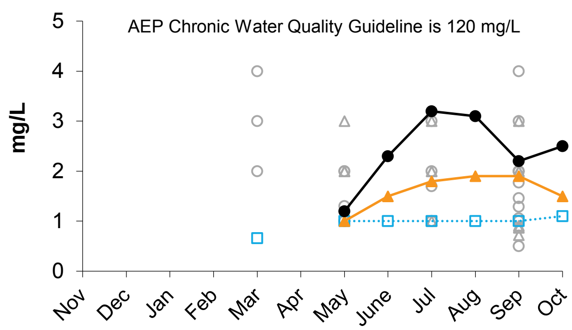
Sodium



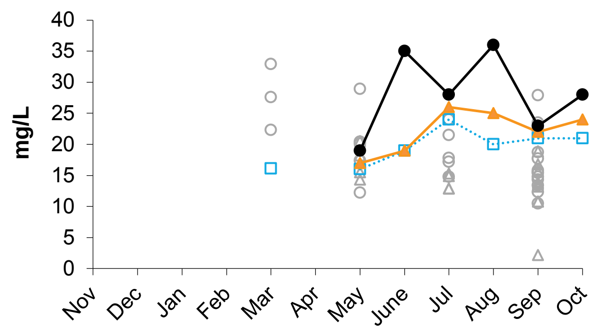
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.8-7 Seasonal concentrations of water quality measurement endpoints, Namur Lake (*baseline* station NAL-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.56	7.06	Mar	7.65	Sep
Total suspended solids	mg/L	-	4	0.15	<1.00	May	2.00	Sep
Conductivity	µS/cm	-	4	71.50	57.0	May	89.20	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0075	0.007	Jul, Sep	0.0213	Mar
Total nitrogen	mg/L	-	4	0.390	0.34	Sep	<1	Jul
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.005	-	0.05	Mar
Dissolved organic carbon	mg/L	-	4	6.65	5.80	May	9.60	Mar
Ions								
Sodium	mg/L	-	4	2.80	2.50	May	3.60	Mar
Calcium	mg/L	-	4	6.95	5.20	May	9.09	Mar
Magnesium	mg/L	-	4	2.25	1.90	May	2.99	Mar
Potassium	mg/L	-	4	1.0	0.9	May	1.4	Mar
Chloride	mg/L	120-640	4	<1.0	<0.5	Mar	<1.0	-
Sulphate	mg/L	309-429[b]	4	8.60	7.60	May	10.00	Mar
Total dissolved solids	mg/L	-	4	60	28	May	64	Sep
Total alkalinity	mg/L	20 (min)	4	25	21	May	34	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.0155	0.0091	Mar	0.017	May
Dissolved aluminum	mg/L	0.05	4	0.001005	<0.00013	Mar	0.0051	May
Total arsenic	mg/L	0.005	4	0.00036	0.000326	May	0.00044	Mar
Total boron	mg/L	1.5-29	4	0.0266	0.0218	May	0.035	Mar
Total molybdenum	mg/L	0.073	4	0.00024	0.00020	May	0.00033	Mar
Total mercury ultra-trace	ng/L	5-13	4	0.470	0.350	Jul	0.950	Sep
Total methyl mercury	ng/L	1-2	3	<0.01	<0.01	May, Jul	0.031	Sep
Total strontium	mg/L	-	4	0.0412	0.0342	May	0.055	Mar
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.01	-
Fraction 1 C6-C10	mg/L	0.15	4	<0.01	<0.01	-	<0.01	-
Fraction 2 C10-C16	mg/L	0.11	4	<0.005	<0.005	-	<0.005	-
Fraction 3 C16-C34	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Fraction 4 C34-C50	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	4	0.37	0.26	Mar	0.46	Sep
Oilsands extractable acids	mg/L	-	4	1.3	1.0	Jul	2.1	Mar
Polycyclic Aromatic Hydrocarbons PAHs								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	<0.59	<0.59	except Jul	1.20	Jul
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	4	128.2	122.1	Mar	147.1	Sep
Total Parent PAHs[c]	ng/L	-	4	22.44	8.77	Mar	24.66	Jul
Total Alkylated PAHs[c]	ng/L	-	4	110.1	102.6	May	124.4	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	2	**0.0053**	<0.001	Mar	**0.011**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.8-8 Seasonal concentrations of water quality measurement endpoints, Gardiner Lake (*baseline* station GAL-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.71	7.42	Mar	8.37	Jul
Total suspended solids	mg/L	-	4	6.60	1.3	May	13.0	Jul
Conductivity	µS/cm	-	4	140	140	May, Jul, Sep	183	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0150	0.006	Jul	0.0157	Mar
Total nitrogen	mg/L	-	4	1.00	0.66	Sep	1.50	Jul
Nitrate+nitrite	mg/L	3-124	4	0.06	<0.005	Jul	0.201	Mar
Dissolved organic carbon	mg/L	-	4	14.0	12.0	Sep	18.4	Mar
Ions								
Sodium	mg/L	-	4	3.5000	3.30	Jul	4.20	Mar
Calcium	mg/L	-	4	17.0000	16.00	May, Jul	23.50	Mar
Magnesium	mg/L	-	4	5.4000	5.00	Jul	7.05	Mar
Potassium	mg/L	-	4	0.9	0.80	Jul	1.16	Mar
Chloride	mg/L	120-640	4	<1	<1	-	<1	-
Sulphate	mg/L	309-429[b]	4	5.75	4.80	Jul	6.23	Mar
Total dissolved solids	mg/L	-	4	105	100	May, Jul	124	Mar
Total alkalinity	mg/L	20 (min)	4	65	63	Jul	86	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.0220	0.0083	Jul	0.040	May
Dissolved aluminum	mg/L	0.05	4	0.0012	0.0005	Jul	0.0043	May
Total arsenic	mg/L	0.005	4	0.00076	0.000756	Mar	0.00106	Sep
Total boron	mg/L	1.5-29	4	0.0301	0.0256	Jul	0.032	Sep
Total molybdenum	mg/L	0.073	4	0.0006	0.0005	May	0.0007	Mar
Total mercury (ultra-trace)	ng/L	5-13	4	0.820	0.570	Jul	1.080	Mar
Total methyl mercury	ng/L	1-2	3	0.021	<0.01	Jul	0.021	May, Sep
Total strontium	mg/L	-	4	0.0723	0.0688	Jul	0.094	Mar
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	4	0.72	0.42	Jul	0.81	Sep
Oilsands extractable acids	mg/L	-	4	2.3	1.8	Mar	3.0	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	Jul, Sep	20.30	Mar
Retene	ng/L	-	4	<0.59	<0.59	Mar, Sep	1.04	Jul
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	4	126.8	124.8	May	136.1	Mar
Total Parent PAHs[c]	ng/L	-	4	22.4537	8.6406	Mar	23.75	Jul
Total Alkylated PAHs[c]	ng/L	-	4	126.8	124.8	May	136.1	Mar
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.0055**	<0.001	Mar	**0.011**	Sep
Sulphide	mg/L	0.0019	2	0.0008	<0.0019	Mar, Jul	**0.0041**	May

Values in **bold** are above guideline.

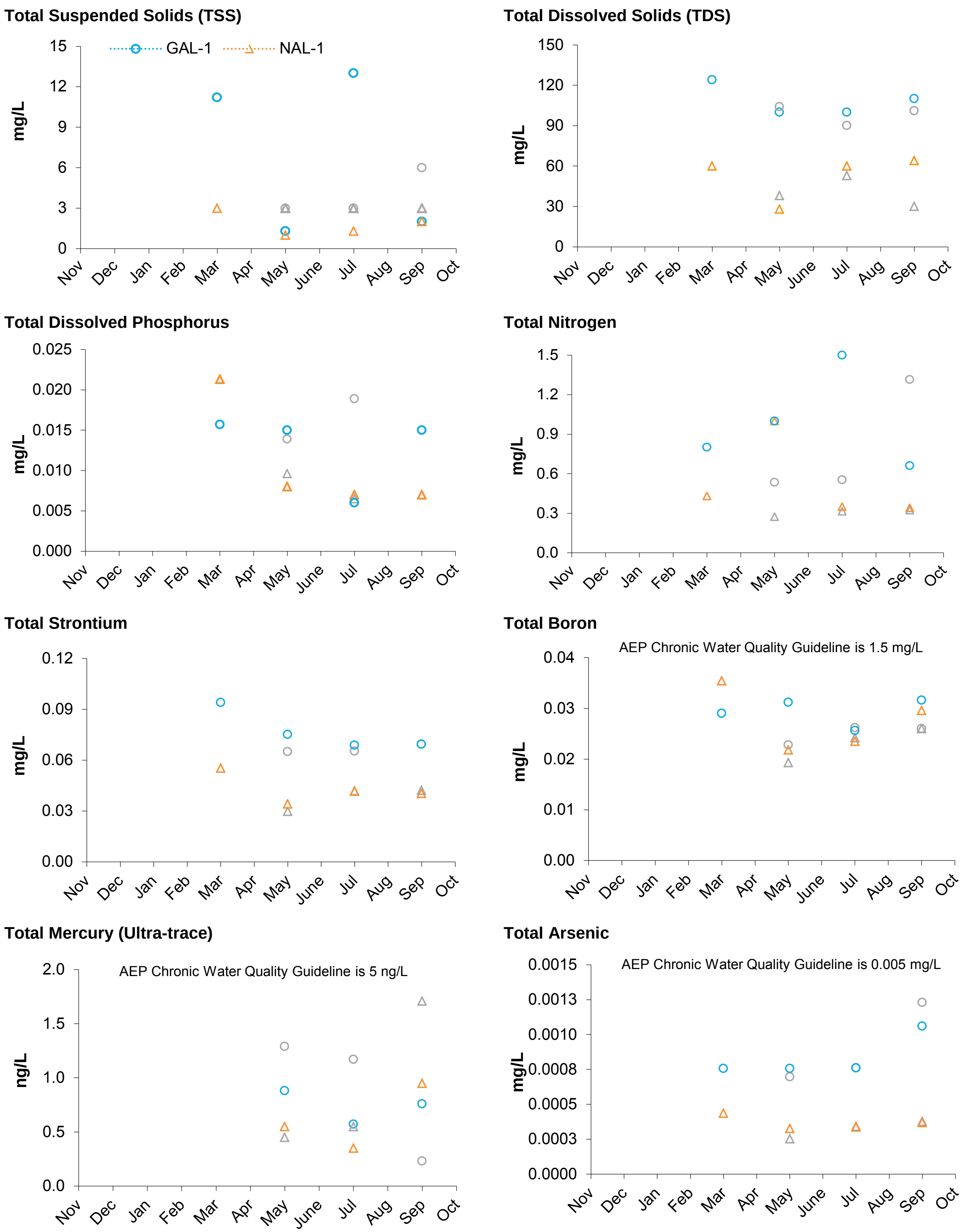
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

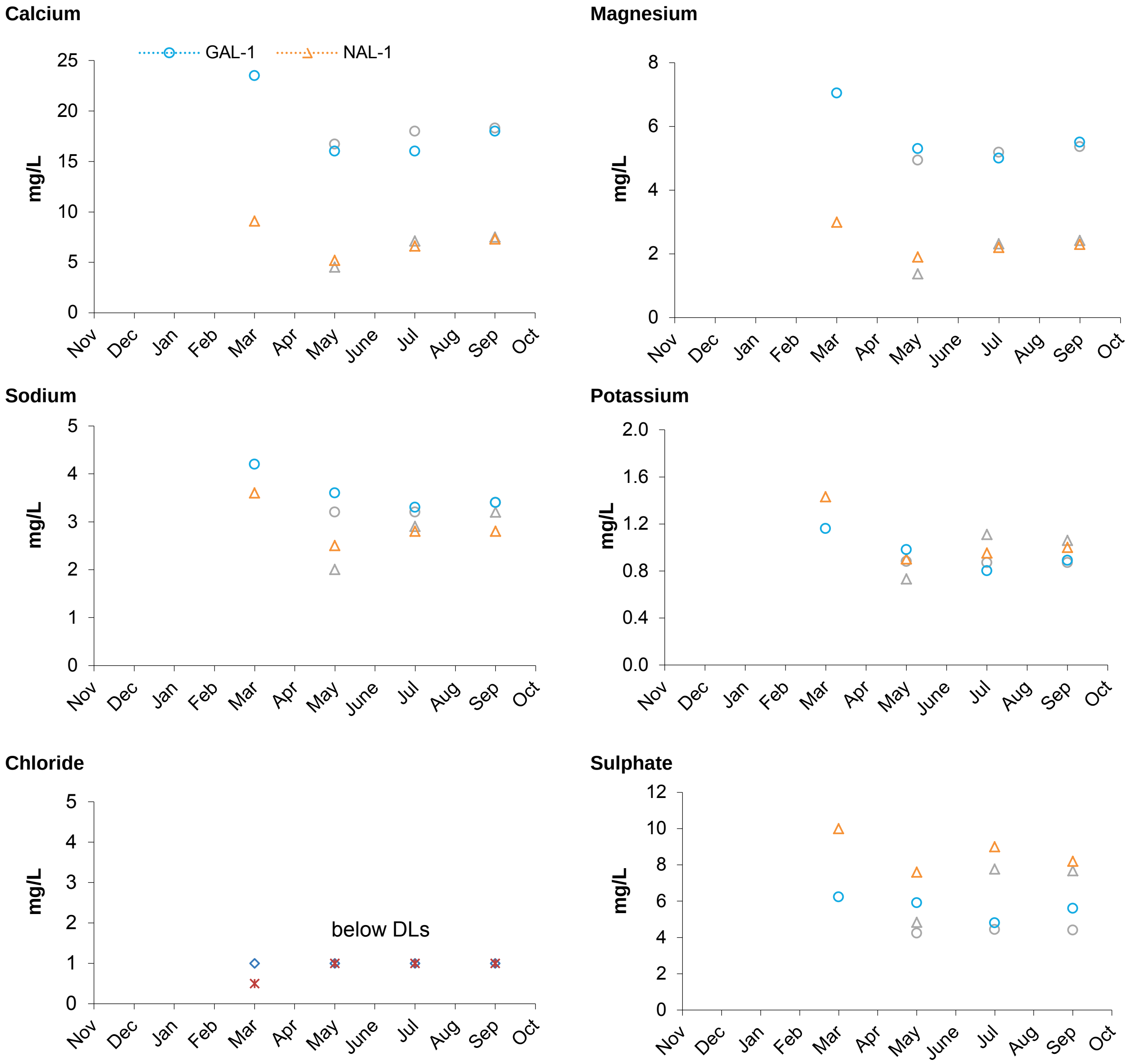
[d] n value refers to number of exceedances in 2015.

Figure 5.8-7 Selected water quality measurement endpoints for Namur Lake and Gardiner Lake (seasonal data) in the 2015 WY.



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.8-7 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.8-9 Concentrations of water quality measurement endpoints, mouth of Ells River (*test* station ELLS RIFF 3 [ELR-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1998-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.15	14	8.2	7.8	8.4
Total suspended solids	mg/L	-	2.0	14	6.5	<3.0	16
Conductivity	µS/cm	-	240	14	227	175	272
Nutrients							
Total dissolved phosphorus	mg/L	-	0.0080	14	0.010	0.003	0.020
Total nitrogen	mg/L	-	0.51	14	0.61	0.30	1.32
Nitrate+nitrite	mg/L	3-124	<0.005	14	<0.086	<0.050	<0.100
Dissolved organic carbon	mg/L	-	13.0	14	15	7	20
Ions							
Sodium	mg/L	-	14	14	11.0	8.0	18.0
Calcium	mg/L	-	28	14	24.8	21.6	30.4
Magnesium	mg/L	-	8.5	14	7.3	6.5	9.34
Potassium	mg/L	-	1.4	14	1.2	0.9	1.5
Chloride	mg/L	120-640	2.2	14	1.9	<0.5	4.0
Sulphate	mg/L	309[b]	23	14	15.7	10.5	27.9
Total dissolved solids	mg/L	-	150	14	166	110	220
Total alkalinity	mg/L	20 (min)	100	14	98	76	117
Selected metals							
Total aluminum	mg/L	-	0.065	14	0.294	0.060	0.673
Dissolved aluminum	mg/L	0.05	0.004	14	0.014	0.005	**0.078**
Total arsenic	mg/L	0.005	0.0005	14	0.0009	<0.0005	0.0012
Total boron	mg/L	1.5-29	0.069	14	0.062	0.041	0.083
Total molybdenum	mg/L	0.073	0.0007	14	0.00070	0.00064	0.00084
Total mercury (ultra-trace)	ng/L	5-13	0.82	12	<1.2	<0.9	2
Total methyl mercury	ng/L	1-2	0.07	-	-	-	-
Total strontium	mg/L	-	0.131	14	0.123	0.095	0.140
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.17	4	0.36	0.07	0.78
Oilsands extractable acids	mg/L	-	1.1	4	0.95	0.43	2.20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<u>0.74</u>	4	4.100	1.730	15.20
Total dibenzothiophenes[c]	ng/L	-	<u>59.63</u>	4	127.4	102.6	238.8
Total PAHs[c]	ng/L	-	<u>232.5</u>	4	499.5	338.0	903.4
Total Parent PAHs[c]	ng/L	-	24.01	4	25.06	18.79	36.30
Total Alkylated PAHs[c]	ng/L	-	<u>208.5</u>	4	474.4	319.2	867.1
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0039**	14	**0.005**	**0.002**	**0.135**
Total phenols	mg/L	0.004	**0.0063**	14	0.004	0.001	**0.011**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.8-10 Concentrations of water quality measurement endpoints, Ells River near the Canadian Natural bridge (*test* station EL2 [ELR-2]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2004-2012 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.16	9	8.2	7.7	8.4
Total suspended solids	mg/L	-	<1	9	4	<3	8
Conductivity	µS/cm	-	<u>240</u>	9	206	164	219
Nutrients							
Total dissolved phosphorus	mg/L	-	0.004	9	0.011	0.004	0.061
Total nitrogen	mg/L	-	<u>0.51</u>	9	0.70	0.55	2.01
Nitrate+nitrite	mg/L	3-124	<0.005	9	<0.1	<0.071	<0.1
Dissolved organic carbon	mg/L	-	13	8	15.3	10.0	20.7
Ions							
Sodium	mg/L	-	12	9	9.8	3.0	13.0
Calcium	mg/L	-	26	9	23	20.5	26
Magnesium	mg/L	-	<u>8.0</u>	9	7	6.2	7.8
Potassium	mg/L	-	1.3	9	1.1	0.8	1.3
Chloride	mg/L	120-640	1.9	9	2.0	0.7	3.0
Sulphate	mg/L	309[b]	<u>22</u>	9	13.6	2.2	18.9
Total dissolved solids	mg/L	-	180	9	145	110	190
Total alkalinity	mg/L	20 (min)	100	9	91	73	110
Selected metals							
Total aluminum	mg/L	-	0.053	9	0.26	0.05	0.74
Dissolved aluminum	mg/L	0.05	0.007	9	0.013	<0.001	0.026
Total arsenic	mg/L	0.005	0.0006	9	0.0008	0.0006	0.0011
Total boron	mg/L	1.5-29	0.078	9	0.05	0.04	0.08
Total molybdenum	mg/L	0.073	0.0007	9	0.0007	0.0006	0.0008
Total mercury (ultra-trace)	ng/L	5-13	0.98	9	<1.2	<0.9	2
Total methyl mercury	ng/L	1-2	0.073	-	-	-	-
Total strontium	mg/L	-	0.135	9	0.11	0.09	0.137
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.46</u>	2	0.075	0.07	0.08
Oilsands extractable acids	mg/L	-	<u>1.6</u>	2	0.69	0.27	1.1
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.44	<9	<14
Retene	ng/L	-	<0.59	2	<1.52	<1	<2
Total dibenzothiophenes	ng/L	-	48.1	2	47.10	44.39	49.81
Total PAHs[c]	ng/L	-	<u>206.3</u>	2	258.36	240.50	276.22
Total Parent PAHs[c]	ng/L	-	<u>23.3</u>	2	19.25	17.58	20.91
Total Alkylated PAHs[c]	ng/L	-	<u>183.0</u>	2	239.11	219.59	258.64
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0062**	8	**0.00485**	**0.003**	**0.014**
Total phenols	mg/L	0.004	**0.0062**	9	**0.0044**	<0.001	**0.025**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.8-11 Concentrations of water quality measurement endpoints, Ells River above Joslyn Creek diversion (*baseline* station ELLS RIFF 5), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2013-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.07	2	8.035	7.98	8.09
Total suspended solids	mg/L	-	<u>2.7</u>	2	3.0	3.0	3.0
Conductivity	µS/cm	-	230	2	212.5	191	234
Nutrients							
Total dissolved phosphorus	mg/L	-	0.007	2	0.0152	0.007	0.016
Total nitrogen	mg/L	-	<u>0.5</u>	2	0.5725	0.571	0.574
Nitrate+nitrite	mg/L	3-124	<0.005	2	0.0625	0.054	0.071
Dissolved organic carbon	mg/L	-	12.0	2	15.1	13.7	16.5
Ions							
Sodium	mg/L	-	12.0	2	10.5	8.7	12.2
Calcium	mg/L	-	26.0	2	26.6	24.5	28.7
Magnesium	mg/L	-	7.9	2	7.5	7.2	7.9
Potassium	mg/L	-	<u>1.3</u>	2	1.1	1.1	1.2
Chloride	mg/L	120-640	<1	2	0.6	0.5	0.7
Sulphate	mg/L	309[b]	<u>21.0</u>	2	14.6	12.1	17.0
Total dissolved solids	mg/L	-	150	2	147	133	161
Total alkalinity	mg/L	20 (min)	98	2	92	85	99
Selected metals							
Total aluminum	mg/L	-	0.0512	2	0.1195	0.0512	0.134
Dissolved aluminum	mg/L	0.05	0.00445	2	0.00647	0.00445	0.00758
Total arsenic	mg/L	0.005	0.000605	2	0.000813	0.000605	0.000816
Total boron	mg/L	1.5-29	<u>0.0639</u>	2	0.0542	0.0488	0.0596
Total molybdenum	mg/L	0.073	<u>0.000651</u>	2	0.000641	0.000639	0.000643
Total mercury (ultra-trace)	ng/L	5-13	0.62	2	0.57	0.26	0.88
Total strontium	mg/L	-	<u>0.124</u>	2	0.112	0.102	0.122
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	<0.25	<0.25	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.24	2	0.345	0.23	0.46
Oilsands extractable acids	mg/L	-	<u>3.3</u>	2	0.885	0.27	1.5
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	11.19	7.21	15.16
Retene	ng/L	-	<0.59	2	0.91	0.59	1.22
Total dibenzothiophenes[c]	ng/L	-	<u>9.4</u>	2	6.6	6.4	6.7
Total PAHs[c]	ng/L	-	<u>133.9</u>	2	90.7	78.9	102.5
Total Parent PAHs[c]	ng/L	-	<u>22.7</u>	2	17.9	13.3	22.4
Total Alkylated PAHs[c]	ng/L	-	<u>111.2</u>	2	72.8	65.6	80.0
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	<u>**0.0078**</u>	2	0.0028	0.002	0.0036

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.8-12 Concentrations of water quality measurement endpoints, Ells River at wild fish health reaches (*test* stations ER-L and ER-M, and *baseline* station ER-U), fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value		
			ER-L	ER-M	ER-U
Physical variables					
pH	pH units	6.5-9.0	7.98	7.98	8.00
Total suspended solids	mg/L	-	1.3	2.7	1.3
Conductivity	µS/cm	-	240	230	230
Nutrients					
Total dissolved phosphorus	mg/L	-	0.005	0.004	0.007
Total nitrogen	mg/L	-	0.44	0.47	0.47
Nitrate+nitrite	mg/L	3-124	<0.005	<0.005	<0.005
Dissolved organic carbon	mg/L	-	13	12	12
Ions					
Sodium	mg/L	-	12	13	12
Calcium	mg/L	-	26	27	26
Magnesium	mg/L	-	7.9	8.3	8.2
Potassium	mg/L	-	1.3	1.4	1.3
Chloride	mg/L	120-640	1.9	1.4	1.4
Sulphate	mg/L	309[b]	24	23	21
Total dissolved solids	mg/L	-	160	170	140
Total alkalinity	mg/L	20 (min)	100	98	98
Selected metals					
Total aluminum	mg/L	-	0.0951	0.112	0.0808
Dissolved aluminum	mg/L	0.05	0.0039	0.00378	0.00367
Total arsenic	mg/L	0.005	0.0005	0.0005	0.0005
Total boron	mg/L	1.5-29	0.056	0.057	0.058
Total molybdenum	mg/L	0.073	0.0006	0.0007	0.0006
Total mercury (ultra-trace)	ng/L	5-13	0.75	0.75	0.74
Total methyl mercury	ng/L	1-2	0.058	0.051	0.045
Total strontium	mg/L	-	0.117	0.115	0.113
Total hydrocarbons					
BTEX	mg/L	-	<0.01	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02	<0.02
Naphthenic acids	mg/L	-	0.38	0.44	0.29
Oilsands extractable acids	mg/L	-	1.9	1.8	1.4
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	ng/L	1,000	<13.55	<13.55	<13.55
Retene	ng/L	-	0.86	<0.59	<0.59
Total dibenzothiophenes[c]	ng/L	-	44.11	<8.17	<8.17
Total PAHs[c]	ng/L	-	194.31	119.51	119.20
Total Parent PAHs[c]	ng/L	-	23.46	22.82	22.84
Total Alkylated PAHs[c]	ng/L	-	170.85	96.68	96.36
Other variables that exceeded Alberta guidelines in fall 2015					
Sulphide	mg/L	0.0019	**0.0031**	**0.0062**	**0.0046**
Total phenols	mg/L	0.004	**0.0082**	**0.0059**	**0.0059**

Values in **bold** are above guideline; sampling began in 2015 and therefore no historical comparisons are possible.
[a] Sources for all guidelines are outlined in Table 3.2-1.
[b] based on actual hardness level
[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.8-13 Concentrations of water quality measurement endpoints, Namur Lake (*baseline* station NAL-1), fall 2015, compared to fall 2014 concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	September 2014 Value
Physical variables				
pH	pH units	6.5-9.0	<u>7.65</u>	7.61
Total suspended solids	mg/L	-	2.0	<3
Conductivity	µS/cm	-	71	73
Nutrients				
Total dissolved phosphorus	mg/L	-	0.0070	0.0345
Total nitrogen	mg/L	-	<u>0.34</u>	0.324
Nitrate+nitrite	mg/L	3-124	<0.005	<0.054
Dissolved organic carbon	mg/L	-	6.1	7.9
Ions				
Sodium	mg/L	-	2.8	3.2
Calcium	mg/L	-	7.3	7.5
Magnesium	mg/L	-	2.3	2.42
Potassium	mg/L	-	1.0	1.1
Chloride	mg/L	120-640	<1	<0.5
Sulphate	mg/L	128[b]	<u>8.2</u>	7.67
Total dissolved solids	mg/L	-	<u>64</u>	30
Total alkalinity	mg/L	20 (min)	24	26
Selected metals				
Total aluminum	mg/L	-	0.016	0.02
Dissolved aluminum	mg/L	0.05	<u>0.001</u>	0.00055
Total arsenic	mg/L	0.005	0.000369	0.000378
Total boron	mg/L	1.5-29	<u>0.030</u>	0.026
Total molybdenum	mg/L	0.073	0.00025	0.000266
Total mercury (ultra-trace)	ng/L	5-13	0.950	1.71
Total methyl mercury	ng/L	1-2	0.031	-
Total strontium	mg/L	-	0.0404	0.0423
Total hydrocarbons				
BTEX	mg/L	-	<0.01	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.25
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.25
Naphthenic acids	mg/L	-	<u>0.46</u>	0.37
Oilsands extractable acids	mg/L	-	1.1	1.2
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	1,000	<u><13.55</u>	<7.2
Retene	ng/L	-	<u><0.59</u>	<0.41
Total dibenzothiophenes[c]	ng/L	-	<u>8.2</u>	4.1
Total PAHs[c]	ng/L	-	<u>147.1</u>	74.5
Total Parent PAHs[c]	ng/L	-	<u>22.7</u>	13.3
Total Alkylated PAHs[c]	ng/L	-	<u>124.4</u>	61.2
Other variables that exceeded Alberta guidelines in fall 2015				
Total phenols	mg/L	0.004	**0.0071**	-

Values in **bold** are above guideline; <u>underlined</u> values are above the fall 2014 values.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.8-14 Concentrations of water quality measurement endpoints, Gardiner Lake (*baseline* station GAL-1), fall 2015, compared to fall 2014 concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	September 2014 Value
Physical variables				
pH	pH units	6.5-9.0	7.86	7.92
Total suspended solids	mg/L	-	2.0	6.0
Conductivity	µS/cm	-	<u>140</u>	136
Nutrients				
Total dissolved phosphorus	mg/L	-	0.015	0.028
Total nitrogen	mg/L	-	0.66	1.31
Nitrate+nitrite	mg/L	3-124	0.040	<0.054
Dissolved organic carbon	mg/L	-	12.0	16.3
Ions				
Sodium	mg/L	-	3.4	3.4
Calcium	mg/L	-	18.0	18.3
Magnesium	mg/L	-	<u>5.5</u>	5.4
Potassium	mg/L	-	0.9	0.9
Chloride	mg/L	120-640	<1	<0.5
Sulphate	mg/L	218[b]	<u>5.6</u>	4.4
Total dissolved solids	mg/L	-	<u>110</u>	101
Total alkalinity	mg/L	20 (min)	<u>65</u>	63
Selected metals				
Total aluminum	mg/L	-	0.020	0.257
Dissolved aluminum	mg/L	0.05	0.001	0.002
Total arsenic	mg/L	0.005	0.001	0.001
Total boron	mg/L	1.5-29	<u>0.032</u>	0.026
Total molybdenum	mg/L	0.073	0.0006	0.0007
Total mercury (ultra-trace)	ng/L	5-13	<u>0.760</u>	0.230
Total methyl mercury	ng/L	1-2	0.021	-
Total strontium	mg/L	-	0.069	0.069
Total hydrocarbons				
BTEX	mg/L	-	<0.01	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.25
Naphthenic acids	mg/L	-	0.81	0.94
Oilsands extractable acids	mg/L	-	<u>2.7</u>	1.90
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	1,000	<u><13.55</u>	<7.21
Retene	ng/L	-	<0.59	2.1
Total dibenzothiophenes[c]	ng/L	-	<u><8.2</u>	4.1
Total PAHs[c]	ng/L	-	<u>127.2</u>	79.8
Total Parent PAHs[c]	ng/L	-	<u>22.8</u>	13.3
Total Alkylated PAHs[c]	ng/L	-	<u>104.4</u>	66.6
Other variables that exceeded Alberta guidelines in fall 2015				
Sulphide	mg/L	0.002	**0.0031**	**0.0039**
Total phenols	mg/L	0.004	**<u>0.011</u>**	**0.0046**

Values in **bold** are above guideline; <u>underlined</u> values are above the fall 2014 values.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.8-8 Piper diagram of fall ion concentrations in the Ells River watershed.

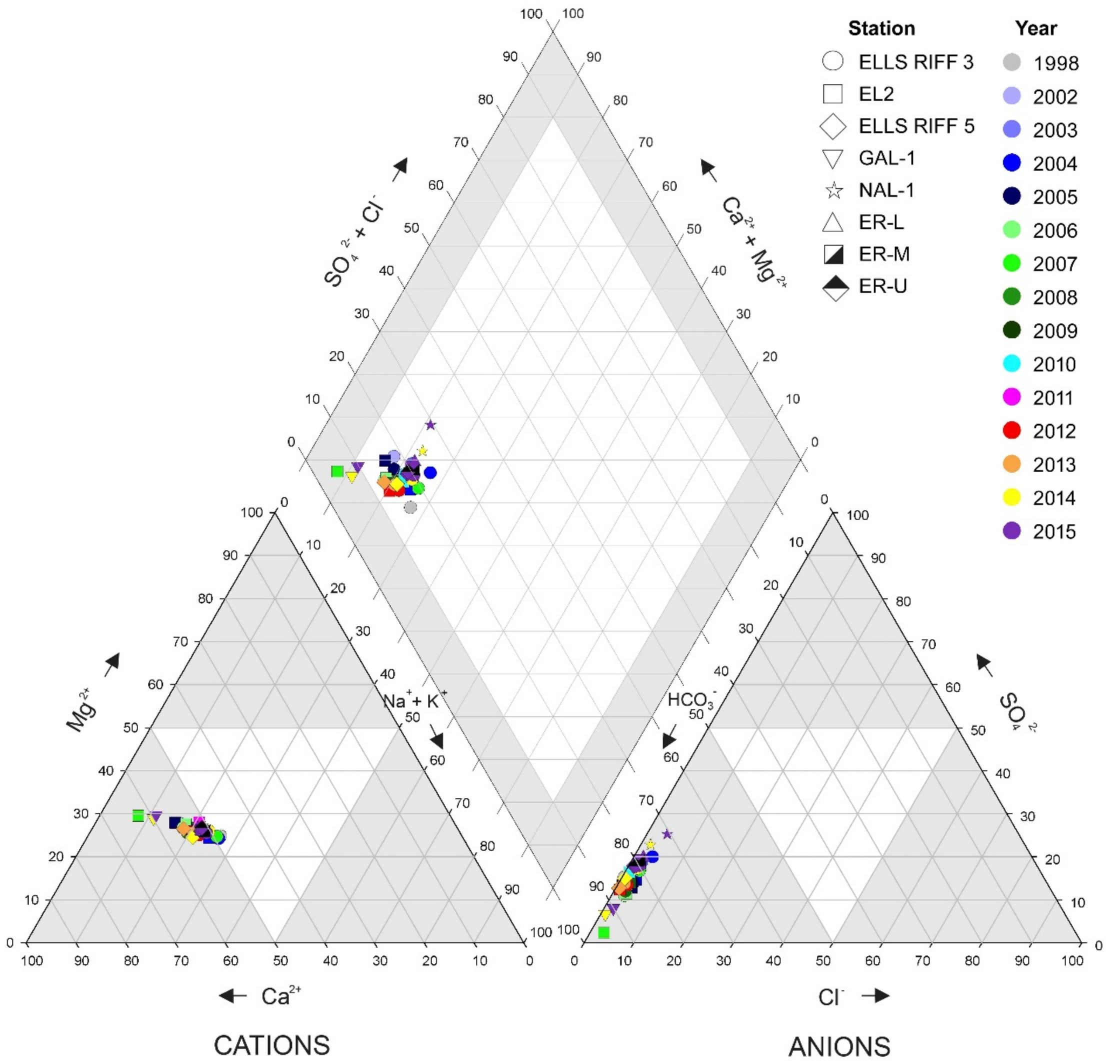


Table 5.8-15 Water quality guideline exceedances in the Ells River watershed, 2015 WY.

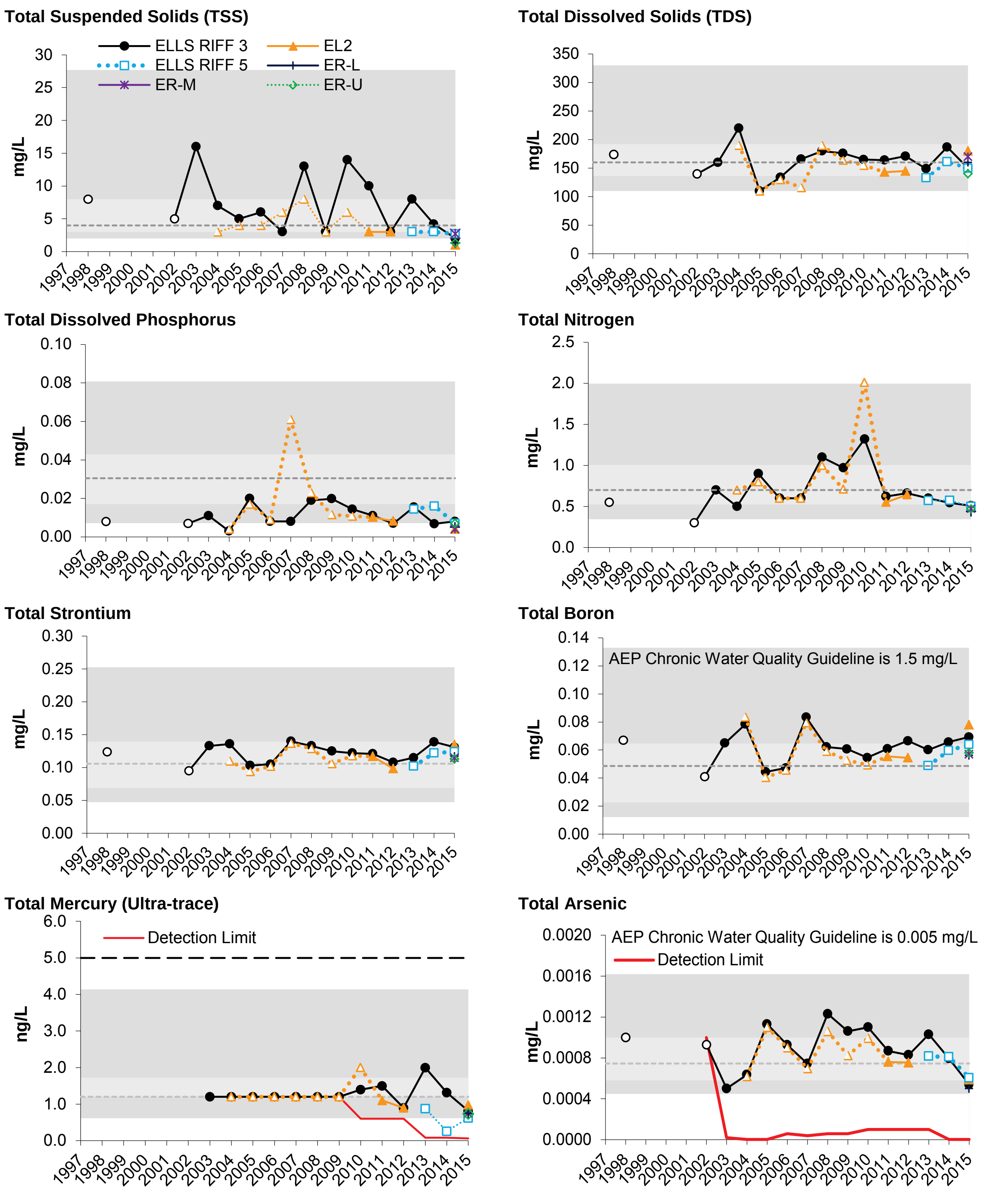
Variable	Units	Guideline[a]	March	May	June	July	August	September	October
Ells River mouth (ELLS RIFF 3)									
Total phenols	mg/L	0.004	-	-	**0.0071**	**0.013**	**0.0056**	**0.0063**	**0.0082**
Sulphide	mg/L	0.0019	-	-	**0.0073**	**0.0062**	**0.0093**	**0.0039**	**0.0051**
Dissolved iron	mg/L	0.3	-	**0.33**	0.162	0.0439	0.164	0.141	0.16
Lower Ells River (ER-L)									
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0031**	-
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0082**	-
Ells River at CNRL Bridge (EL2)									
Total phenols	mg/L	0.004	-	0.0026	<0.002	**0.0053**	**0.0046**	**0.0062**	**0.0065**
Sulphide	mg/L	0.0019	-	<0.0019	**0.0024**	<0.0019	**0.0046**	**0.0062**	**0.045**
Mid Ells River (ER-M)									
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0062**	-
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0059**	-
Upper Ells River (ELLS RIFF 5)									
Total phenols	mg/L	0.004	-	0.0026	<0.002	**0.0053**	**0.0046**	**0.0062**	**0.0065**
Sulphide	mg/L	0.0019	-	<0.0019	**0.0024**	<0.0019	**0.0046**	**0.0062**	**0.045**
Upper Ells River (ER-U)									
Sulphide	mg/L	0.0019	-	-	-	-	-	**0.0046**	-
Total phenols	mg/L	0.004	-	-	-	-	-	**0.0059**	-
Gardiner Lake (GAL-1)									
Total phenols	mg/L	0.004	<0.001	**0.0043**	-	**0.0067**	-	**0.011**	-
Sulphide	mg/L	0.0019	<0.0015	**0.0041**	-	<0.0019	-	**0.0031**	-
Namur Lake (NAL-1)									
Total phenols	mg/L	0.004	<0.001	0.0034	-	**0.011**	-	**0.0071**	-

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.8-9 Selected water quality measurement endpoints in the Ells River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



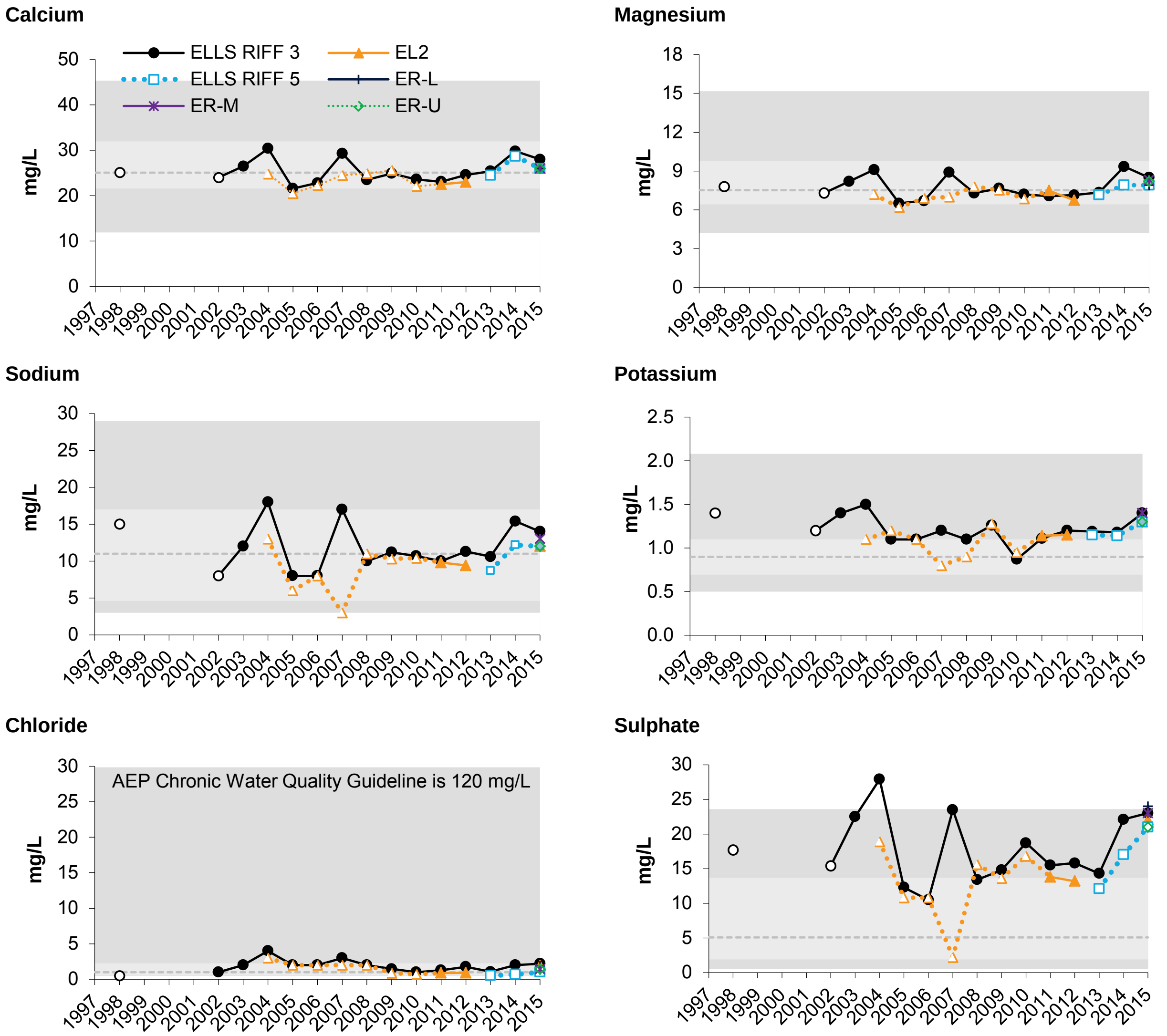
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.8-9 (Cont'd.)



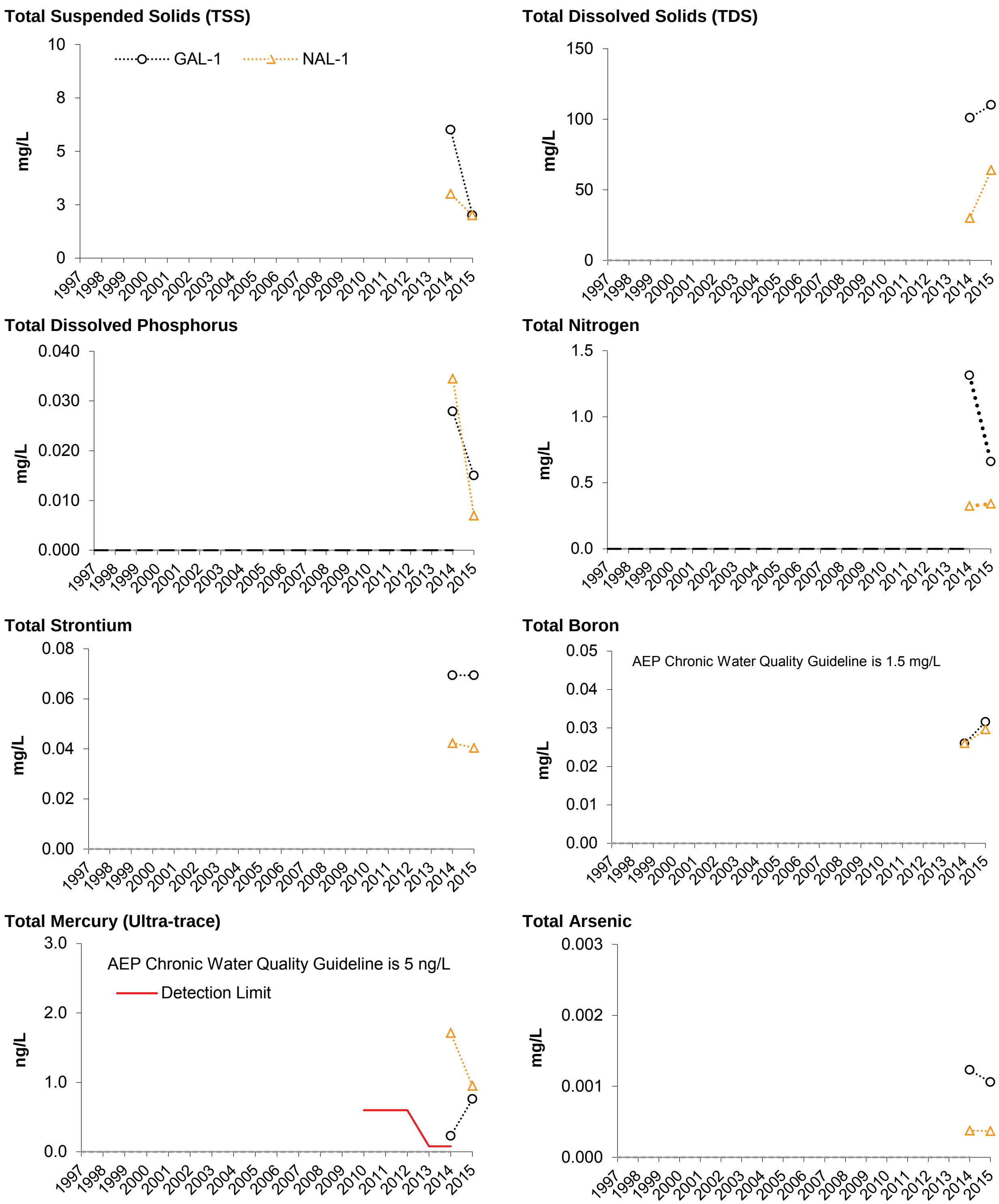
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.8-10 Selected water quality measurement endpoints in Namur Lake and Gardiner Lake (fall data).



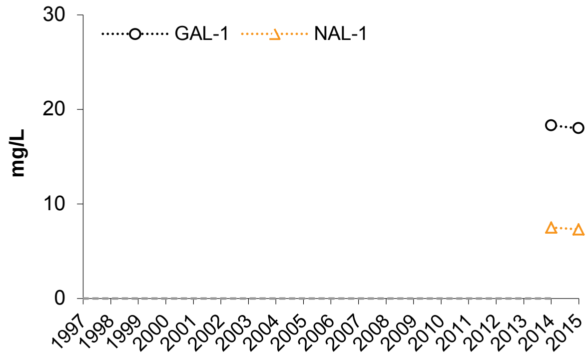
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

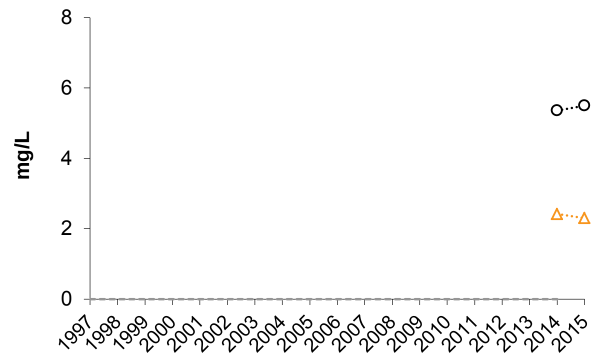
Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Figure 5.8-10 (Cont'd.)

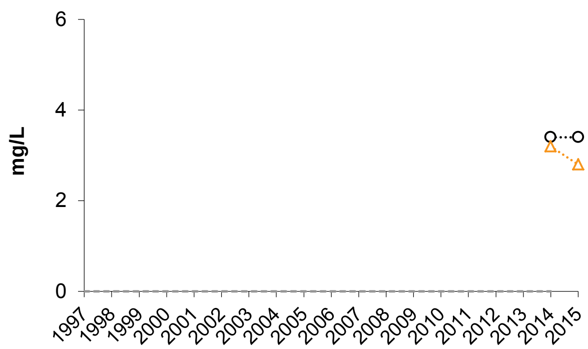
Calcium



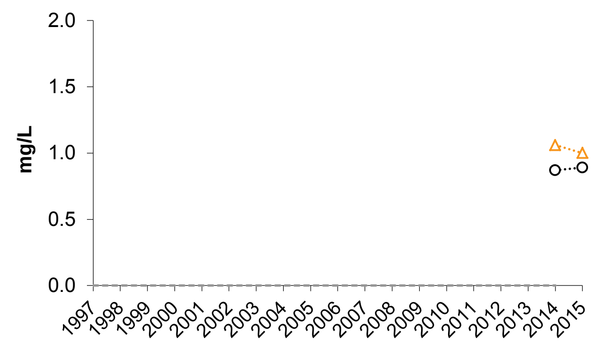
Magnesium



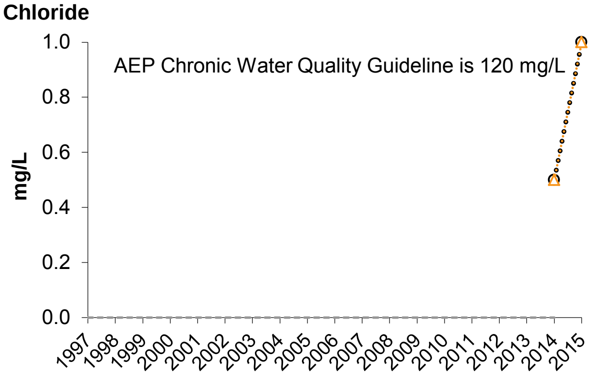
Sodium



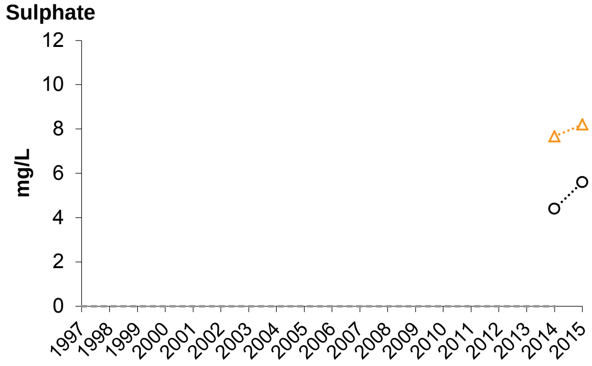
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Table 5.8-16 Average habitat characteristics of the benthic invertebrate sampling location in the Ells River (*test* reach ELR-D1), fall 2015.

Variable	Units	ELR-D1 Lower *Test* Reach
Sample date	-	September 13, 2015
Habitat	-	Depositional
Water depth	m	0.29
Current velocity	m/s	0.85
Field water quality		
Dissolved oxygen (DO)	mg/L	9.3
Conductivity	µS/cm	265
pH	pH units	7.1
Water temperature	°C	10.9
Sediment composition		
Sand	%	99.1
Silt	%	0.58
Clay	%	0.22
Total organic carbon (TOC)	%	0.53

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.8-17 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community at the lower Ells River (*test* reach ELR-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach ELR-D1		
	2003	2004-2014	2015
Nematoda	<1	<1 to 3	1
Naididae	24	2 to 17	8
Tubificidae	52	14 to 62	5
Enchytraeidae	-	0 to <1	-
Hydracarina	<1	0 to 2	-
Gastropoda	<1	0 to 1	-
Bivalvia	<1	0 to 2	<1
Ceratopogonidae	3	0 to 7	6
Chironomidae	19	17 to 76	71
Diptera (misc.)	-	0 to 2	8
Coleoptera	-	0 to <1	-
Ephemeroptera	<1	<1 to 1	1
Odonata	<1	0 to <1	<1
Plecoptera	-	-	<1
Trichoptera	<1	0 to <1	<1
Heteroptera	<1	-	-
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	715	48 to 732	281
Richness	12	4 to 20	13
Equitability	0.38	0.27 to 0.57	0.4
% EPT	1	0 to 1	0.9

Table 5.8-18 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at the lower Ells River (*test* reach ELR-D1).

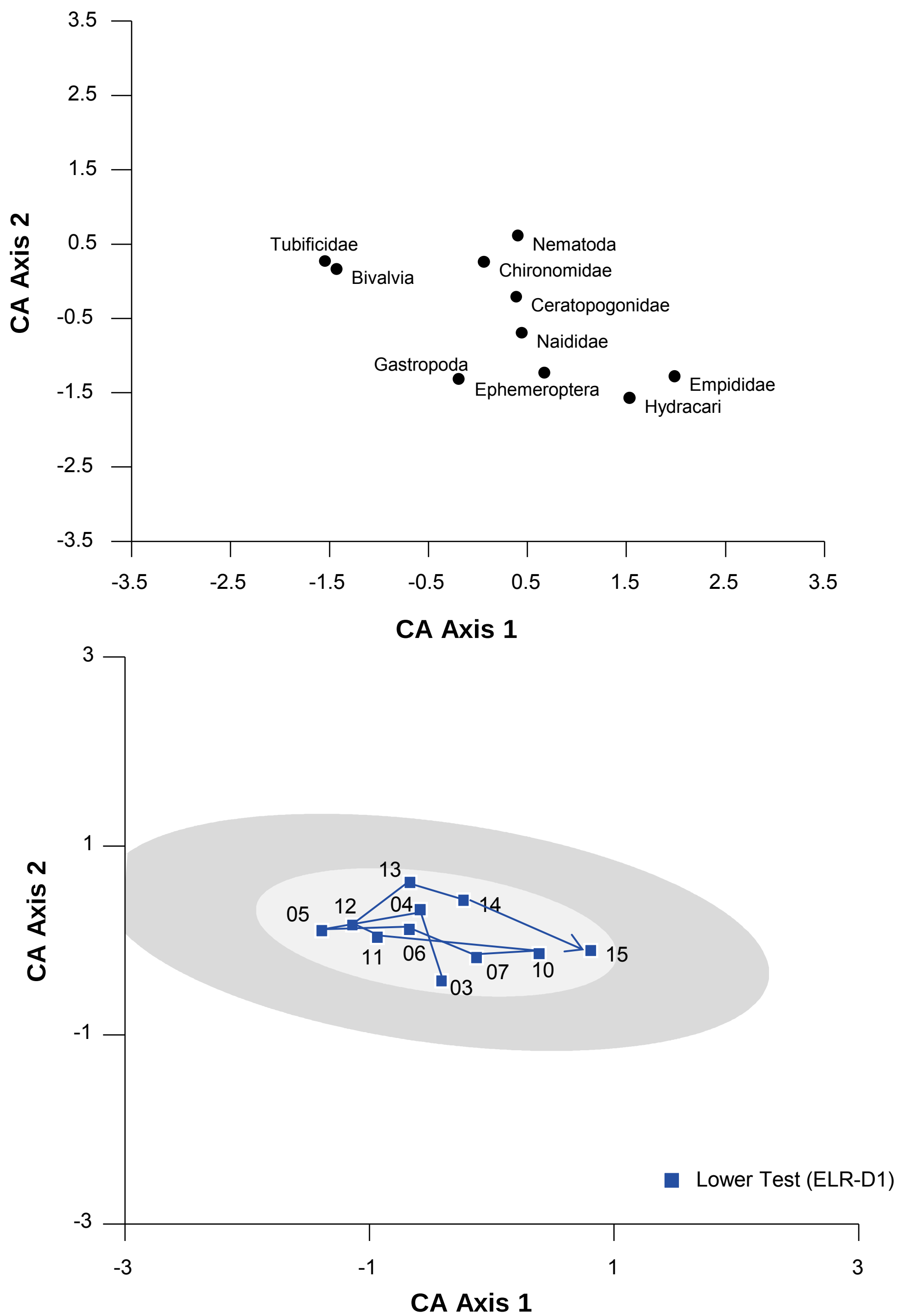
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	**0.011**	0.460	18	1	Abundance decreased over time.
Log of Richness	**0.007**	0.132	12	4	Richness decreased over time.
Equitability	0.892	0.896	0	0	No change.
Log of EPT	0.233	0.060	8	20	No change.
CA Axis 1	**0.005**	**<0.01**	19	44	CA Axis 1 scores increased over time and were higher in 2015 than the mean of prior years in the reach.
CA Axis 2	**0.042**	0.283	14	4	CA Axis 2 scores increased over time.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

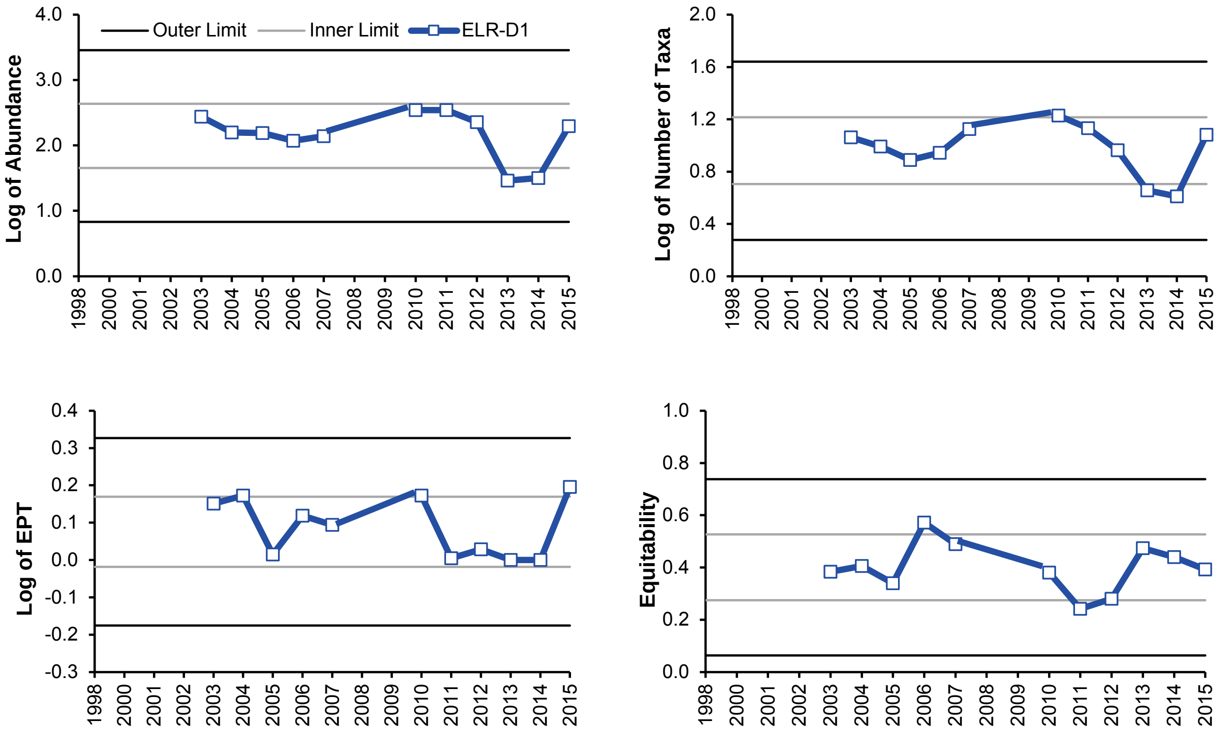
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.8-11 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of the Ells River (*test* reach ELR-D1).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years (2003 to 2014).

Figure 5.8-12 Variation in benthic invertebrate community measurement endpoints at *test* reach ELR-D1 of the Ells River relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at *test* reach ELR-D1 (2003 to 2014).

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed before the average was calculated.

Table 5.8-19 Average habitat characteristics of benthic invertebrate sampling locations in Namur and Gardiner lakes (*baseline* stations NAL-1 and GAL-1), fall 2015.

Variable	Units	Namur Lake *Baseline* station NAL-1	Gardiner Lake *Baseline* station GAL-1
Sample date	-	September 4, 2015	September 4, 2015
Habitat	-	Depositional	Depositional
Water depth	m	0.52	0.54
Field water quality			
Dissolved oxygen (DO)	mg/L	8.0	7.9
Conductivity	µS/cm	65.5	127
pH	pH units	7.12	6.65
Water temperature	°C	13.5	12.9
Sediment composition			
Sand	%	98.8	99.8
Silt	%	0.82	0.1
Clay	%	0.2	0
Total organic carbon (TOC)	%	0.3	0.3

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.8-20 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Namur and Gardiner Lakes.

Taxon	Percent Major Taxa Enumerated in Each Year			
	Namur Lake (*Baseline* station NAL-1)		Gardiner Lake (*Baseline* station GAL-1)	
	2014	2015	2014	2015
Nematoda	29	5	15	24
Oligochaeta	<1	-	<1	-
Naididae	6	1	1	2
Tubificidae	1	15	4	7
Enchytraeidae	2	-	10	-
Lumbriculidae	1	-	<1	-
Hirudinea	<1	<1	<1	<1
Hydracarina	22	-	<1	-
Amphipoda	3	2	3	24
Gastropoda	7	1	<1	2
Bivalvia	6	6	3	7
Ceratopogonidae	<1	4	<1	4
Chironomidae	17	62	61	21
Diptera (misc)	<1	<1	<1	<1
Coleoptera	<1	<1	-	<1
Ephemeroptera	3	1	<1	1
Trichoptera	<1	-	<1	<1
Benthic Invertebrate Community Measurement Endpoints				
Total abundance per sample	820	597	1,190	611
Richness	24	19	21	24
Equitability	0.2	0.2	0.15	0.29
% EPT	6.0	1.5	0.21	1.38

Table 5.8-21 Results of analysis of variance (ANOVA) testing for temporal differences in benthic invertebrate community measurement endpoints at Namur Lake (*baseline* station NAL-1).

Measurement Endpoint	2015 vs. 2014			Nature of Change(s)
	p-value	Variance Explained	Effect Size (SD)	
Log of Abundance	0.884	0	0.3	No change.
Log of Richness	**0.029**	6	0.1	Richness lower in 2015 than in 2014.
Equitability	0.895	0	0.1	No change.
Log of EPT	0.895	0	0.3	No change.

Variance explained in the case of Namur Lake is “total” variance. Variance explained is normally of annual means. When there are only two years, the annual variance explained by the contrast is 100%. Effect sizes were also expressed as the difference in annual means relative to the pooled within-years standard deviation.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.8-22 Results of analysis of variance (ANOVA) testing for temporal differences in benthic invertebrate community measurement endpoints at Gardiner Lake (*baseline* station GAL-1).

Measurement Endpoint	2015 vs. 2014			Nature of Change(s)
	p-value	Variance Explained	Effect Size (SD)	
Log of Abundance	0.117	3	0.3	No change.
Log of Richness	0.237	1	0.1	No change.
Equitability	**0.004**	11	0.1	Equitability higher in 2015 than in 2014.
Log of EPT	**<0.001**	20	0.1	Percent taxa as EPT higher in 2015 than in 2014.

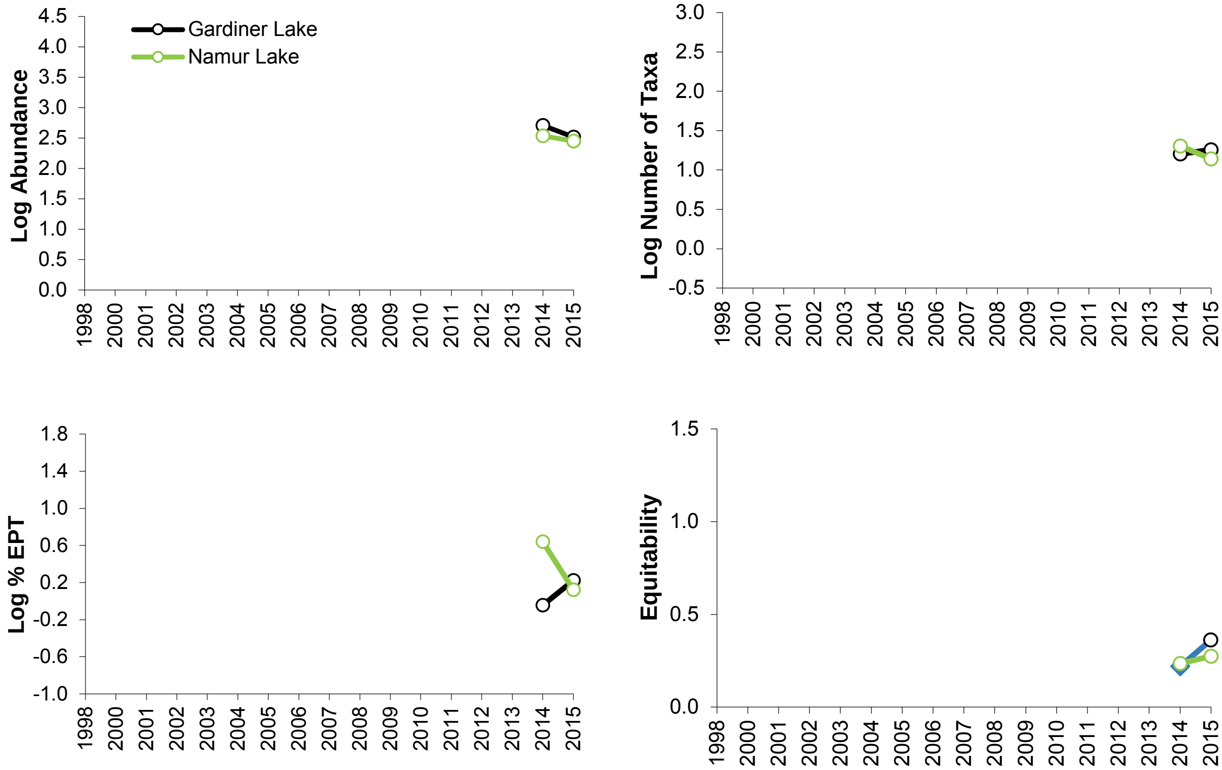
Variance explained in the case of Gardiner Lake is "total" variance. Variance explained is normally of annual means. When there are only two years, the annual variance explained by the contrast is 100%. Effect sizes were also expressed as the difference in annual means relative to the pooled within-years standard deviation.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Note: Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Figure 5.8-13 Variation in benthic invertebrate community measurement endpoints at Gardiner Lake and Namur Lake (*baseline* stations GAL-1 and NAL-1).



Notes:

Values were adjusted to a common depth of 2 m.

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.8-23 Concentrations of selected sediment quality measurement endpoints, Ells River (*test* station ELR-D1), fall 2015 compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	1998-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	0.8	12	1.4	6.7	26.0
Silt	%	-	5.4	12	3.0	13.0	51.0
Sand	%	-	93.8	12	23.0	81.0	95.2
Total organic carbon	%	-	1.71	12	0.40	1.92	2.82
Total hydrocarbons							
BTEX	mg/kg	-	<10	9	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	9	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	**243**	9	73	**187**	**320**
Fraction 3 (C16-C34)	mg/kg	300[1]	**2320**	9	**890**	**1500**	**3000**
Fraction 4 (C34-C50)	mg/kg	2800[1]	1540	9	510	870	1600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0010	12	0.0009	0.0030	0.0094
Retene	mg/kg	-	0.1030	11	0.0670	0.1900	0.7130
Total dibenzothiophenes	mg/kg	-	4.8205	12	1.2776	5.6157	9.8848
Total PAHs	mg/kg	-	13.4045	12	4.8094	16.5095	25.0964
Total Parent PAHs	mg/kg	-	0.3166	12	0.2183	0.4009	0.5713
Total Alkylated PAHs	mg/kg	-	13.0879	12	4.4612	16.1086	24.5252
Predicted PAH toxicity[3]	H.I.	1.0	0.9617	12	**1.1795**	**1.9568**	**3.5029**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
Chrysene	mg/kg	0.0571	**0.1510**	12	**0.0720**	**0.1360**	**0.2260**
Dibenz(a,h)anthracene	mg/kg	0.0062	**0.0090**	12	0.0042	**0.0096**	**0.0130**
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	46	9	38	68	88
Chironomus growth - 10d	mg/organism	-	2.29	9	0.72	2.10	3.74
Hyalella survival - 14d	% surviving	-	94	10	80	90	100
Hyalella growth - 14d	mg/organism	-	0.14	10	0.10	0.17	1.60

Values in **bold** are above guideline; underlined values are outside of historical range.

Values underlined indicate concentrations outside the range of historical observations.

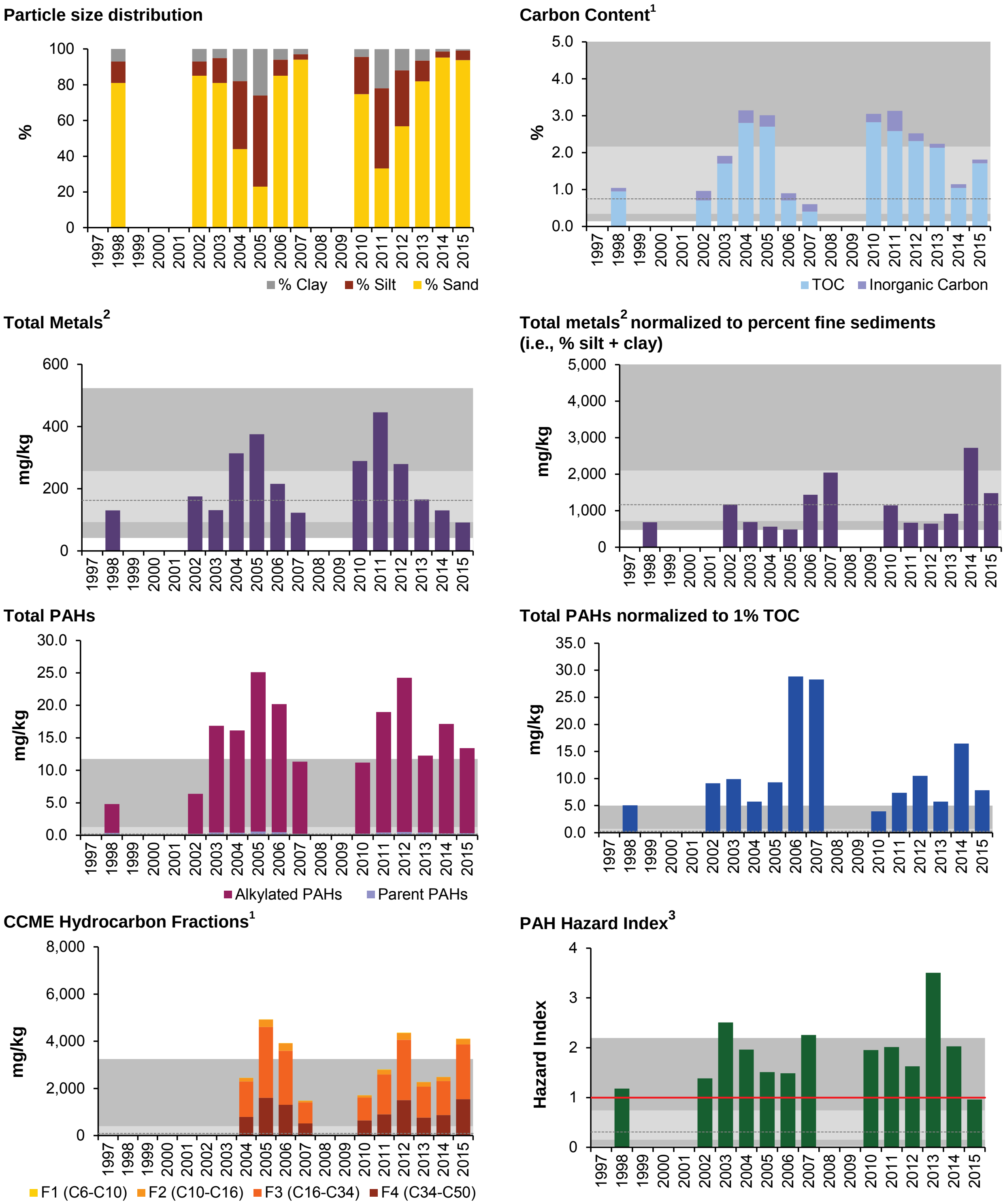
ns = not sampled in 1999, 2000, 2001, 2008, or 2009

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.8-14 Variation in sediment quality measurement endpoints in the Ells River, *test* station ELR-D1 (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.8-24 Concentrations of selected sediment quality measurement endpoints, Ells River at wild fish health reaches (*test* stations ER-L and ER-M, and *baseline* station ER-U), fall 2015.

Variable	Units	Guideline	September 2015		
			ER-L	ER-M	ER-U
Physical variables					
Clay	%	-	4.4	6.8	3.4
Silt	%	-	9.7	11.2	3.7
Sand	%	-	85.9	82.0	92.9
Total organic carbon	%	-	1.81	1.19	0.38
Total hydrocarbons					
BTEX	mg/kg	-	<20	<20	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	<20	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	**548**	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	**3980**	82	30
Fraction 4 (C34-C50)	mg/kg	2,800[1]	2020	42	<20
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene	mg/kg	0.0346[2]	0.0013	0.0008	0.0003
Retene	mg/kg	-	0.1880	0.0733	0.0115
Total dibenzothiophenes	mg/kg	-	19.7380	0.0654	0.0235
Total PAHs	mg/kg	-	43.5089	0.4560	0.1858
Total Parent PAHs	mg/kg	-	0.6958	0.0268	0.0157
Total Alkylated PAHs	mg/kg	-	42.8130	0.4292	0.1702
Predicted PAH toxicity[3]	H.I.	1.0	**1.9324**	0.8886	0.7284
Metals that exceeded CCME guidelines in 2015					
Total arsenic	mg/kg	5.9	-	**6.8**	-
Other analytes that exceeded CCME guidelines in 2015					
Acenaphthene	mg/kg	0.0067	**0.0175**	-	-
Chrysene	mg/kg	0.0571	**0.2950**	-	-
Dibenz(a,h)anthracene	mg/kg	0.0062	**0.0125**	-	-
Phenanthrene	mg/kg	0.0419	**0.0896**	-	-
Pyrene	mg/kg	0.0530	**0.0698**	-	-
Chronic toxicity					
Chironomus survival - 10d	% surviving	-	44	90	90
Chironomus growth - 10d	mg/organism	-	1.18	2.37	2.25
Hyalella survival - 14d	% surviving	-	88	100	98
Hyalella growth - 14d	mg/organism	-	0.07	0.21	0.21

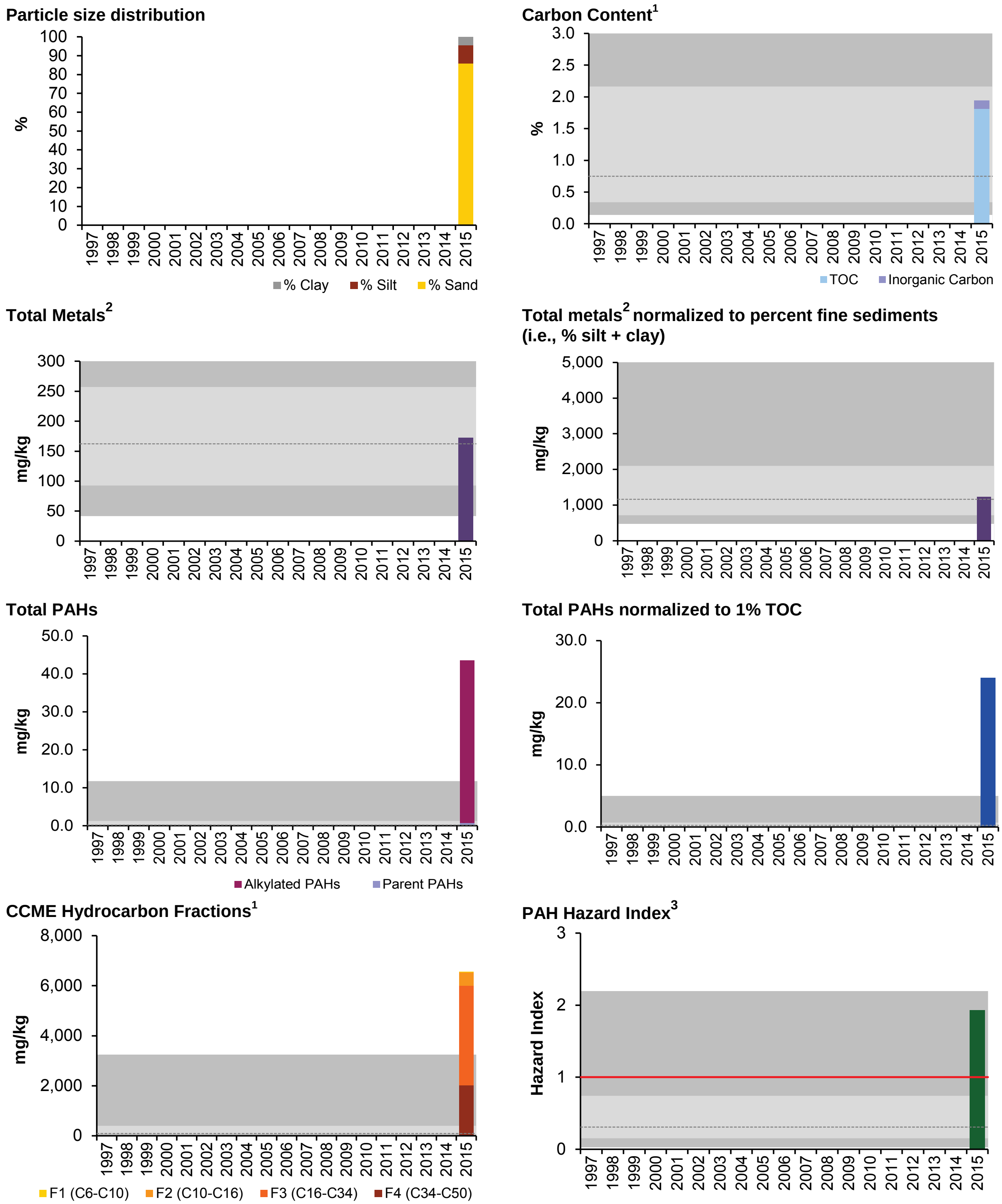
Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.8-15 Variation in sediment quality measurement endpoints at wild fish health *test* station ER-L, lower Ells River (fall data) relative to regional *baseline* fall concentrations.



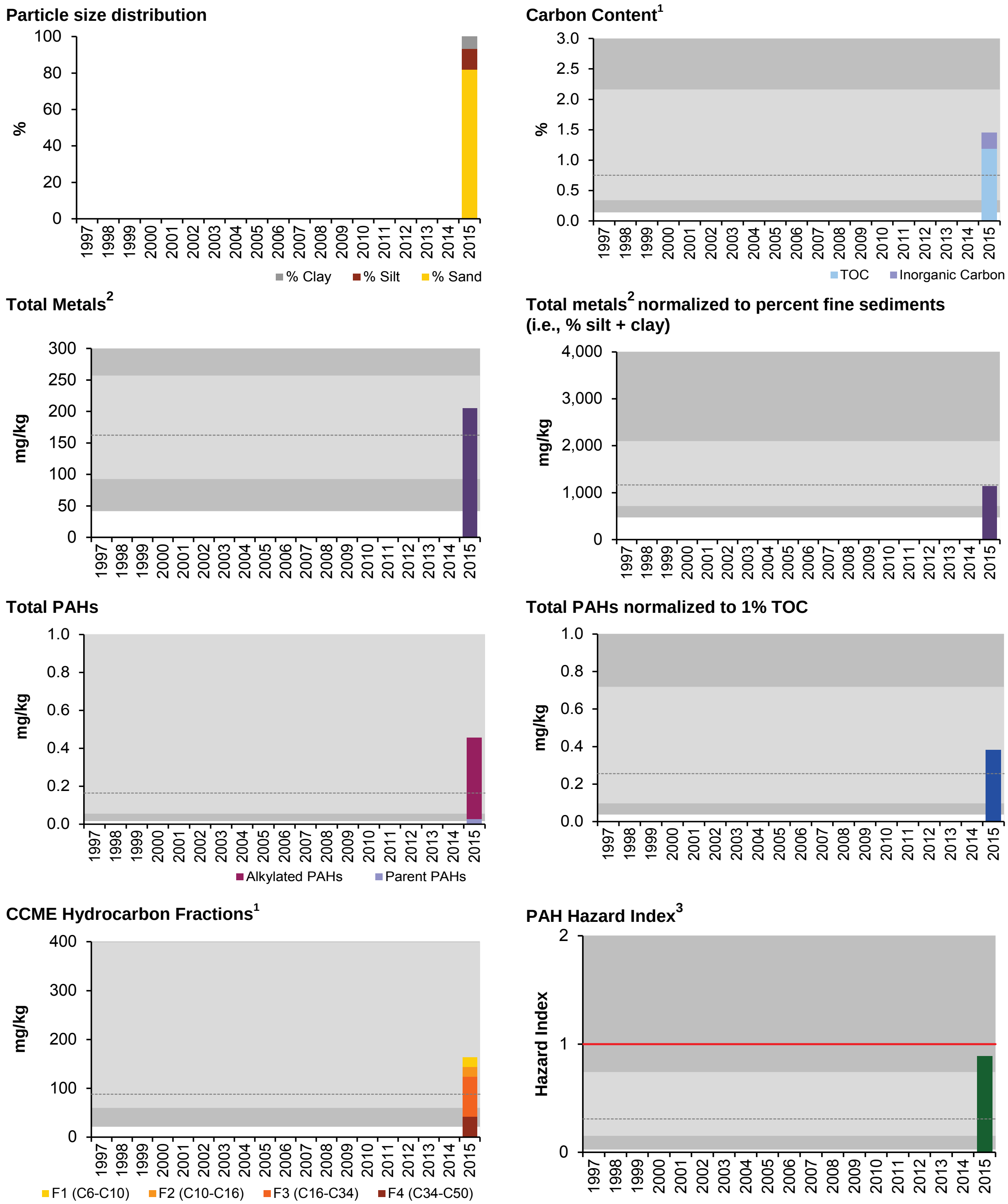
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.8-16 Variation in sediment quality measurement endpoints at wild fish health *test* station ER-M, mid Ells River (fall data) relative to regional *baseline* fall concentrations.



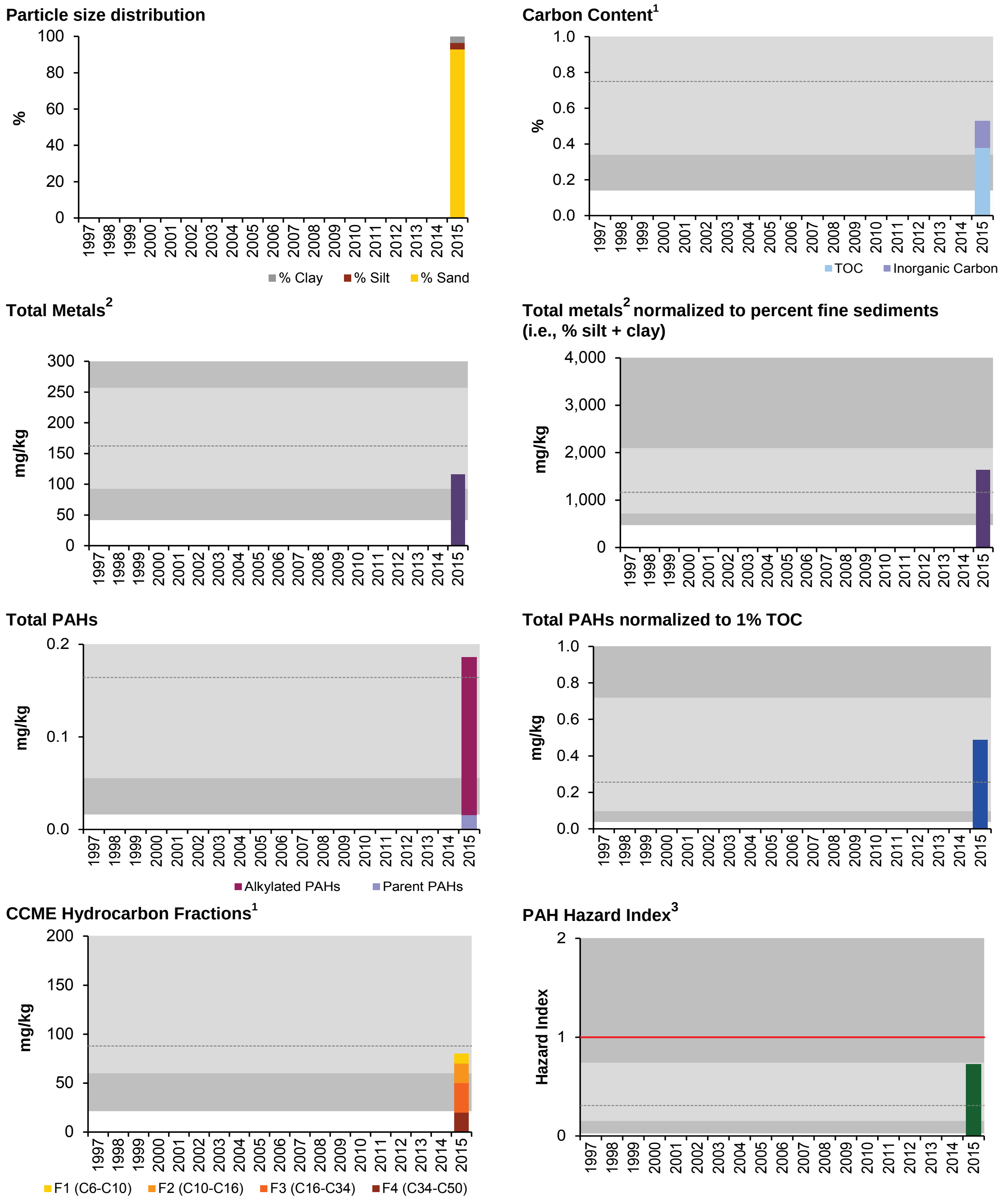
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.8-17 Variation in sediment quality measurement endpoints at wild fish health *baseline* station ER-U in the upper Ells River (fall data) relative to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.8-25 Concentrations of selected sediment quality measurement endpoints, Namur Lake (*baseline* station NAL-1), fall 2015 compared to fall 2014 concentrations.

Variable	Units	Guideline	September 2015	September 2014
			Value	Value
Physical variables				
Clay	%	-	<0.1	0.7
Silt	%	-	<0.1	1.0
Sand	%	-	99.9	98.2
Total organic carbon	%	-	0.19	0.43
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	38
Fraction 4 (C34-C50)	mg/kg	2800[1]	<20	27
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0016	0.0003
Retene	mg/kg	-	0.0006	0.0036
Total dibenzothiophenes	mg/kg	-	0.0007	0.0021
Total PAHs	mg/kg	-	0.0090	0.0319
Total Parent PAHs	mg/kg	-	0.0036	0.0038
Total Alkylated PAHs	mg/kg	-	0.0054	0.0281
Predicted PAH toxicity[3]	H.I.	1.0	0.0376	0.1038
Metals that exceeded CCME guidelines in 2015				
None	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015				
None	-	-	-	-
Chronic toxicity				
Chironomus survival - 10d	% surviving	-	70	83
Chironomus growth - 10d	mg/organism	-	3.13	3.38
Hyalella survival - 14d	% surviving	-	100	98
Hyalella growth - 14d	mg/organism	-	0.17	0.42

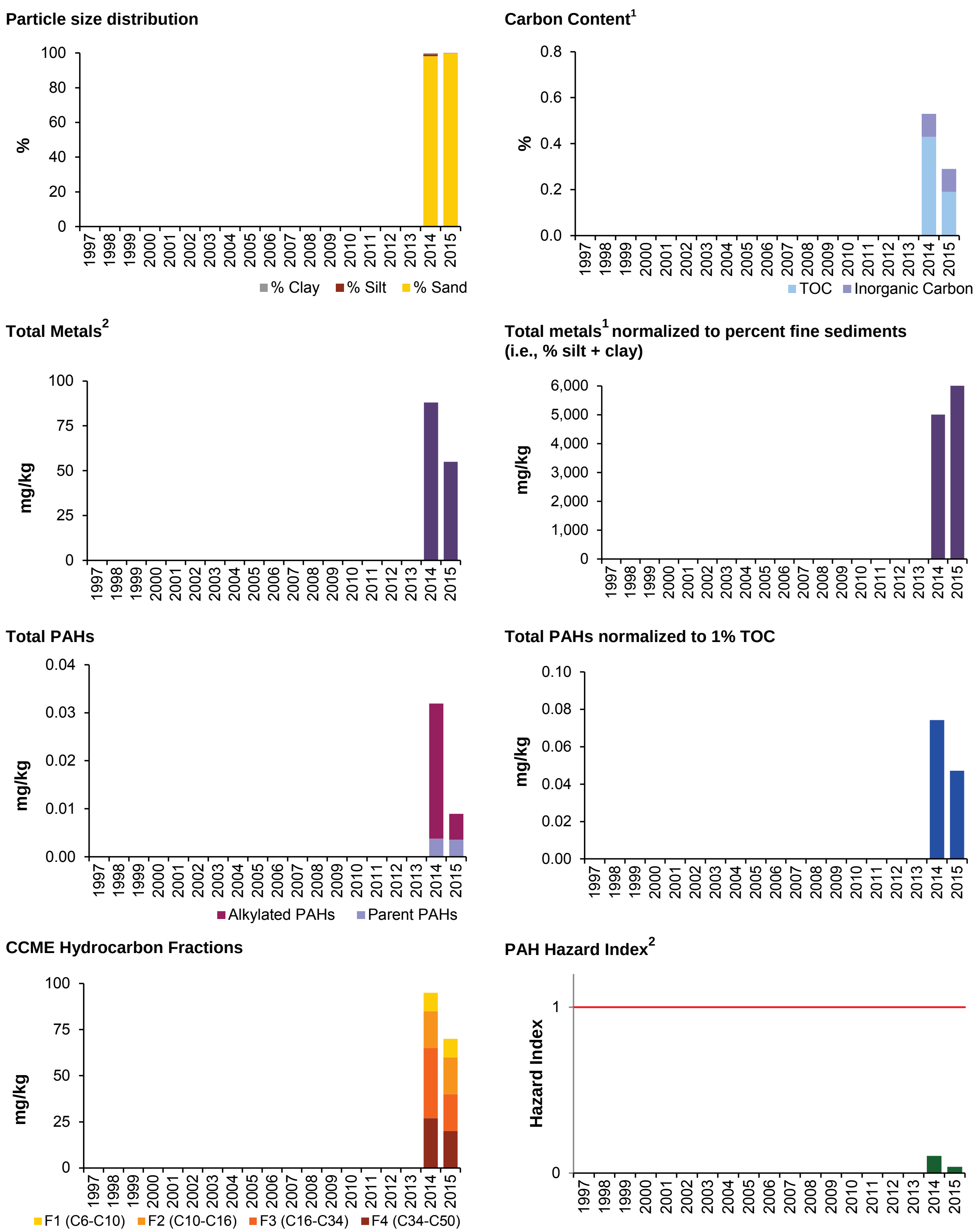
Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.8-18 Variation in sediment quality measurement endpoints in Namur Lake, *baseline* station NAL-1 (fall data).



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.8-26 Concentrations of selected sediment quality measurement endpoints, Gardiner Lake (*baseline* station GAL-1), fall 2015 compared to fall 2014 concentrations.

Variable	Units	Guideline	September 2015	September 2014
			Value	Value
Physical variables				
Clay	%	-	<0.1	2.7
Silt	%	-	<0.1	2.2
Sand	%	-	99.8	95.2
Total organic carbon	%	-	0.35	0.34
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	<20
Fraction 4 (C34-C50)	mg/kg	2800[1]	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0005	0.0003
Retene	mg/kg	-	<0.0001	0.0031
Total dibenzothiophenes	mg/kg	-	0.0006	0.0021
Total PAHs	mg/kg	-	0.0072	0.0270
Total Parent PAHs	mg/kg	-	0.0018	0.0039
Total Alkylated PAHs	mg/kg	-	0.0054	0.0231
Predicted PAH toxicity[3]	H.I.	1.0	0.0297	0.1222
Metals that exceeded CCME guidelines in 2015				
None	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015				
None	-	-	-	-
Chronic toxicity				
Chironomus survival - 10d	% surviving	-	96	87
Chironomus growth - 10d	mg/organism	-	1.99	2.75
Hyalella survival - 14d	% surviving	-	76	92
Hyalella growth - 14d	mg/organism	-	0.16	0.43

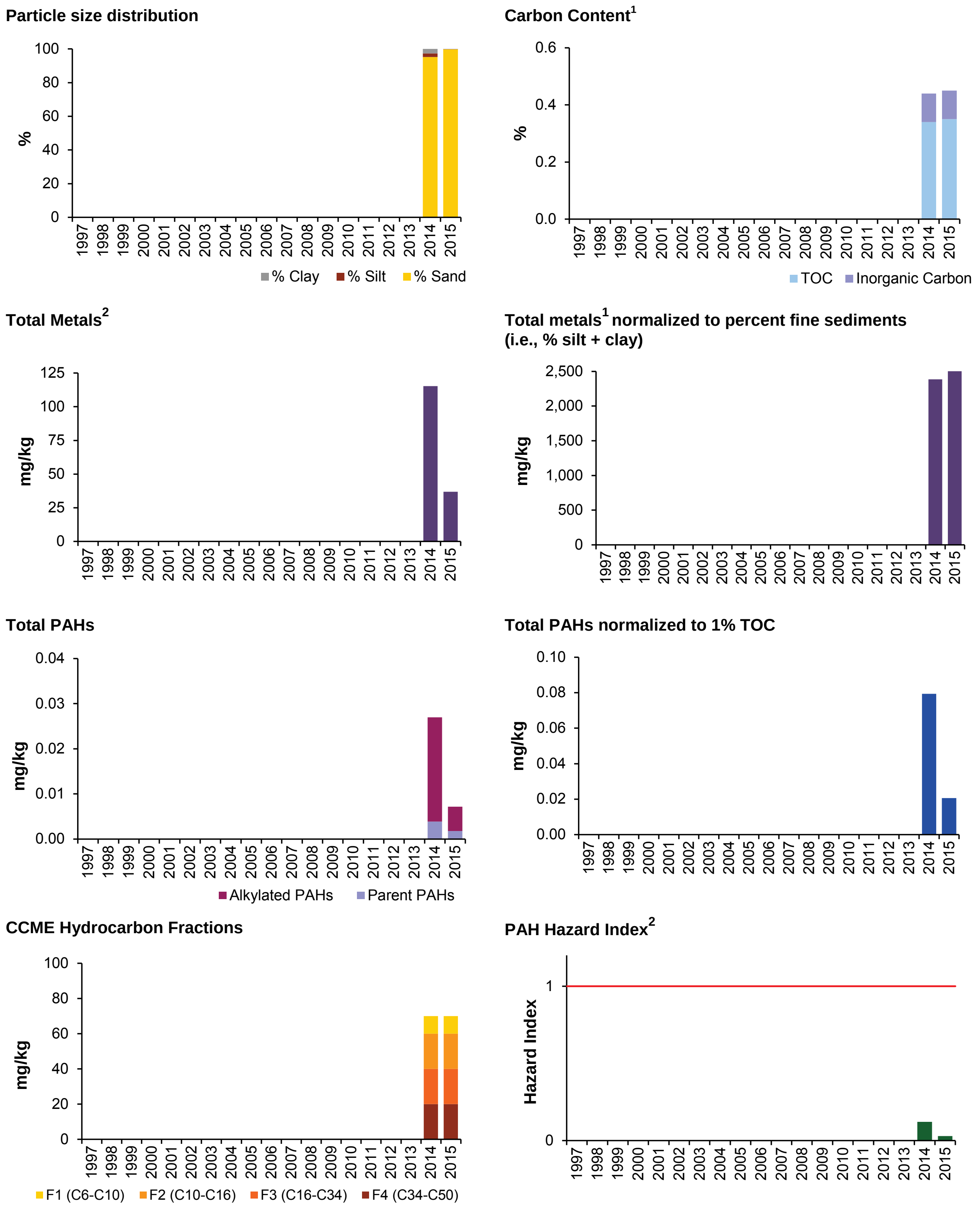
Values in **bold** indicate concentrations exceeding guidelines.

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.8-19 Variation in sediment quality measurement endpoints in Gardiner Lake, *baseline* station GAL-1 (fall data).



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.8-27 Average habitat characteristics at fish community monitoring reach ELR-F1 of the Ells River, fall 2015.

Variable	Units	ELR-F1 Lower *Test* Reach
Sample date	-	Sept 18, 2015
Habitat type	-	glide
Maximum depth	m	0.79
Mean depth	m	0.48
Bankfull channel width	m	37.9
Wetted channel width	m	28.0
Substrate		
Dominant	-	sand
Subdominant	-	fines
Instream cover		
Dominant	-	macrophytes, small woody debris, live trees/roots
Subdominant	-	filamentous algae, large woody debris
Field water quality		
Dissolved oxygen (DO)	mg/L	9.5
Conductivity	µS/cm	213
pH	pH units	8.00
Water temperature	^{0}C	9.7
Water velocity		
Left bank velocity	m/s	0.18
Left bank water depth	m	0.48
Centre of channel velocity	m/s	0.37
Centre of channel water depth	m	0.28
Right bank velocity	m/s	0.25
Right bank water depth	m	0.58
Riparian cover – understory (<5 m)		
Dominant	-	overhanging vegetation, woody shrubs and saplings
Subdominant	-	-

Table 5.8-28 Total number and percent composition of fish species captured in reaches of the Ells River, 2010 to 2015.

Common Name	Code	Total Species Catch												Percent of Total Catch											
		ELR-F1						ELR-F2	ELR-F2A			ELR-F3		ELR-F1						ELR-F2	ELR-F2A			ELR-F3	
		2010	2011	2012	2013	2014	2015	2012	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014	2015	2012	2010	2011	2012	2013	2014
burbot	BURB	-	-	-	5	1	-	-	-	-	-	1	-	0	0	0	29.4	6.7	0	0	0	0	0	0.5	0
fathead minnow	FTMN	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
finescale dace	FNDC	34	-	-	-	-	-	-	160	-	-	1	-	30.6	0	0	0	0	0	0	52.5	0	0	0.5	0
lake chub	LKCH	-	4	5	4	2	57	40	-	1	99	-	23	0	26.7	11.6	23.5	13.3	42.5	34.8	0	1.4	43.6	0	31.9
lake whitefish	LKWH	-	-	9	-	-	-	-	-	-	-	-	-	0	0	20.9	0	0	0	0	0	0	0	0	0
longnose dace	LNDC	2	2	-	-	7	11	16	-	19	18	51	15	1.8	13.3	0	0	46.7	8.2	13.9	0	26.4	7.9	26.4	20.8
longnose sucker	LNSC	-	-	1	-	-	9	-	13	-	25	4	-	0	0	2.3	0	0	6.7	0	4.3	0	11.0	2.1	0
northern pike	NRPK	-	-	-	-	-	2	1	-	-	1	-	-	0	0	0	0	0	1.5	0.9	0	0	0.4	0	0
northern redbelly dace	NRDC	-	-	-	1	-	-	-	-	-	-	-	-	0	0	0	5.9	0	0	0	0	0	0	0	0
pearl dace	PRDC	46	-	7	-	-	-	-	82	43	-	97	-	41.4	0	16.3	0	0	0	0	26.9	59.7	0	50.3	0
slimy sculpin	SLSC	-	-	-	-	4	-	-	-	1	-	4	3	0	0	0	0	26.7	0	0	0	1.4	0	2.1	4.2
spoonhead sculpin	SPSC	-	-	-	3	-	-	-	-	-	-	1	-	0	0	0	17.6	0	0	0	0	0	0	0.5	0
spottail shiner	SPSH	-	1	-	-	-	-	-	-	-	-	-	-	0	6.7	0	0	0	0	0	0	0	0	0	0
trout-perch	TRPR	1	6	18	1	-	36	9	4	6	48	24	28	0.9	40	41.9	5.9	0	26.9	7.8	1.3	8.3	21.1	12.4	38.9
walleye	WALL	-	-	-	-	-	1	-	-	-	-	-	-	0	0	0	0	0	0.75	0	0	0	0	0	0
white sucker	WHSC	12	-	2	3	1	18	49	46	2	36	11	3	10.8	0	4.7	17.6	6.7	13.4	42.6	15.1	2.8	15.9	5.7	4.2
yellow perch	YLPR	15	2	1	-	-	-	-	-	-	-	-	-	13.5	13.3	2.3	0	0	0	0	0	0	0	0	0
sucker sp. *		1	-		-	-	-	-	-	-	-	-	-	0.9	0	0	0	0	0	0	0	0	0	0	0
Total Count		**111**	**15**	**43**	**17**	**15**	**134**	**115**	**305**	**72**	**227**	**193**	**72**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**6**	**5**	**7**	**6**	**5**	**7**	**5**	**5**	**6**	**6**	**9**	**5**	**6**	**5**	**7**	**6**	**5**	**7**	**8**	**5**	**6**	**6**	**9**	**5**
Electrofishing Effort (secs)		**5,258**	**1,307**	**1,979**	**-**	**2,373**	**2,255**	**2,170**	**3,959**	**1,614**	**1,956**	**2,522**	**2,557**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Note: *Baseline* reach ELR-F2A was moved further upstream due to increasing development to a new *baseline* reach (ELR-F3) in 2013.

* not included in total species richness count

Underline denotes a *baseline* reach.

Table 5.8-29 Summary of fish community measurement endpoints (± 1SD) for *test* reach ELR-F1 in the Ells River, 2010 to 2015.

Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
	Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2010	0.37	0.25	7	3.40	1.07	0.58	0.12	7.02	0.21	2.35	1.53
2011	0.06	0.07	6	1.40	1.34	0.30	0.27	6.92	0.65	1.08	1.18
2012	0.14	0.11	7	3.00	1.87	0.38	0.25	7.07	1.54	2.18	1.68
2013	0.04	0.03	6	2.00	1.00	0.32	0.29	4.85	2.34	0.77	0.59
2014	0.04	0.02	5	2.20	0.45	0.81	0.20	4.99	1.20	0.63	0.29
2015	0.24	0.10	7	4.60	0.55	0.62	0.13	6.72	0.62	5.92	2.52

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

SD = standard deviation across sub-reaches within a reach

* unknown species not included in the calculation

Table 5.8-30 Results of analysis of variance (ANOVA) testing for differences in fish community measurement endpoints for *test* reach ELR-F1 of the Ells River.

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change
	Time Trend	Time Trend	
Abundance	**0.04***	9%	Decreasing over time.
Richness	0.46	0%	No change over time.
Diversity	0.22	2%	No change over time.
ATI	**0.05**	9%	Decreasing over time.
CPUE	0.42*	0%	No change over time.

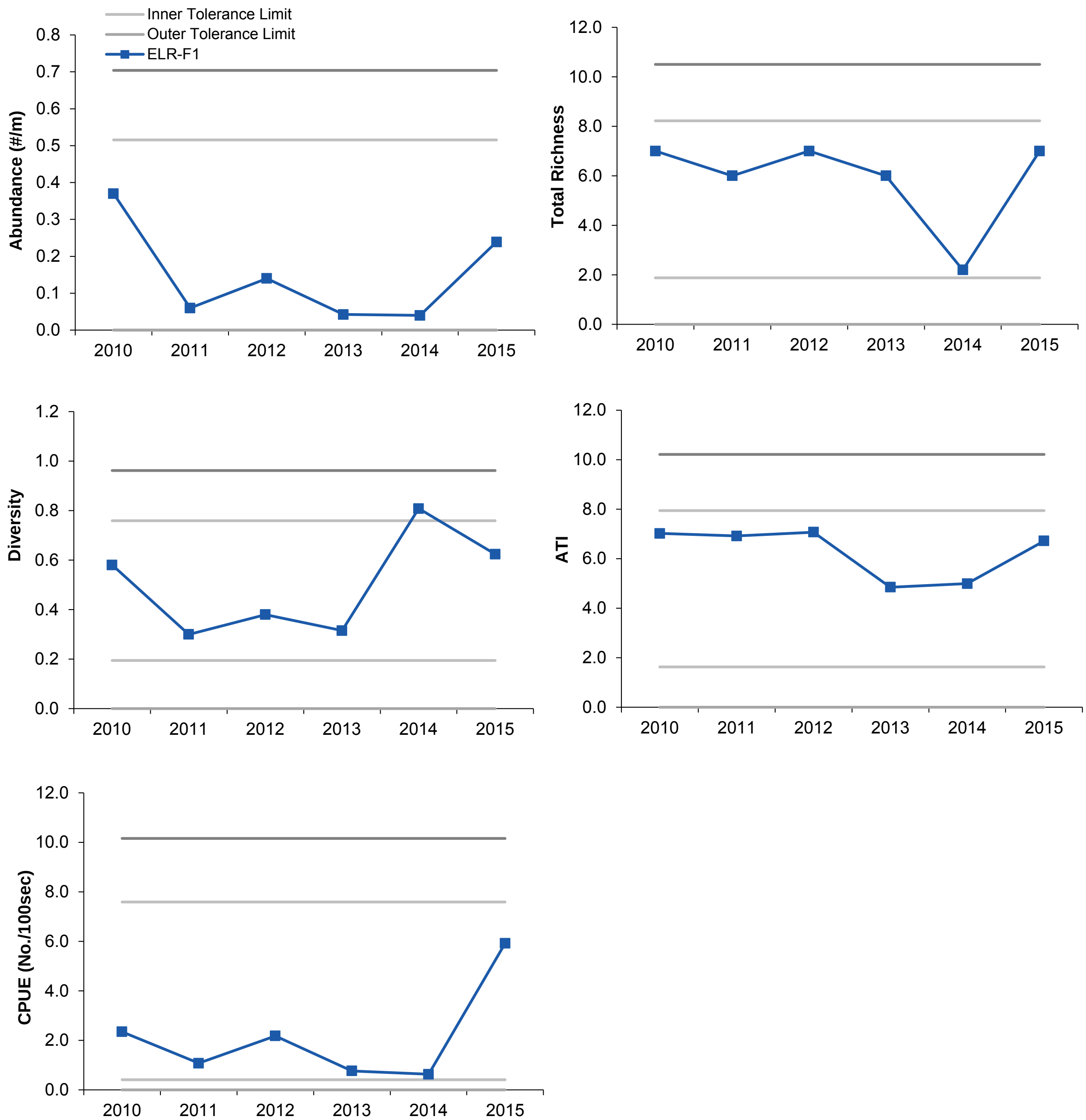
Bold values indicate significant difference (p≤0.05).

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

* data were log-transformed to meet assumptions of ANOVA

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Figure 5.8-20 Variation in fish community measurement endpoints for *test* reach ELR-F1 in the Ells River from 2010 to 2015 relative to regional *baseline* conditions (cluster 3).



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using *baseline* data from cluster 3 (see Table 3.2-10).

A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Table 5.8-31 Average habitat characteristics of wild fish health monitoring reaches in the Ells River, fall 2015.

Variable	Units	ER-L Lower *test* reach	ER-M Middle *test* reach	ER-U Upper *baseline* reach
Sample date	-	October 15, 2015	October 15, 2015	October 15, 2015
Mean water depth	m	0.45	0.55	0.5
Mean velocity	m/s	ns	ns	0.25
Field water quality				
Water temperature	°C	4.9	5.1	3.2
Conductivity	µS/cm	193.67	217	174
Dissolved oxygen (DO)	mg/L	12.1	11.4	10.8
pH	pH units	7.25	8.62	7.05
Substrate	-	cobble/fines	cobble/sand/fines	fines/cobble

ns = not sampled

Figure 5.8-21 Daily mean temperatures for wild fish health reaches in the Ells River, August to October 2015.

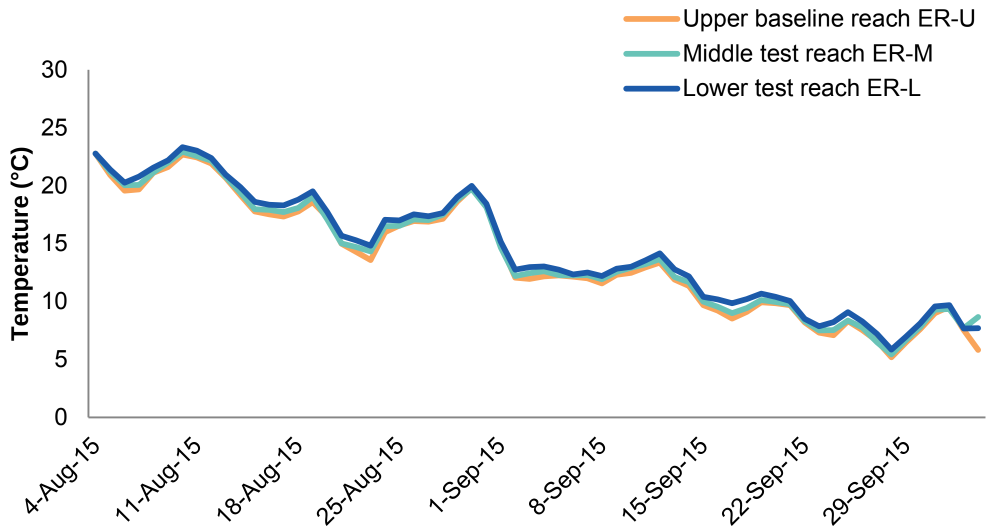
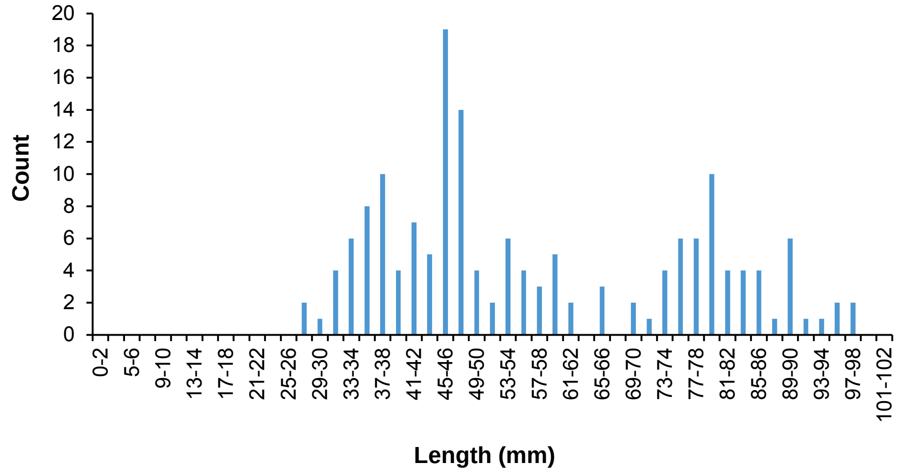


Table 5.8-32 Summary of lake chub caught and mean length, weight, and relative abundance of juveniles in reaches of the Ells River, fall 2015.

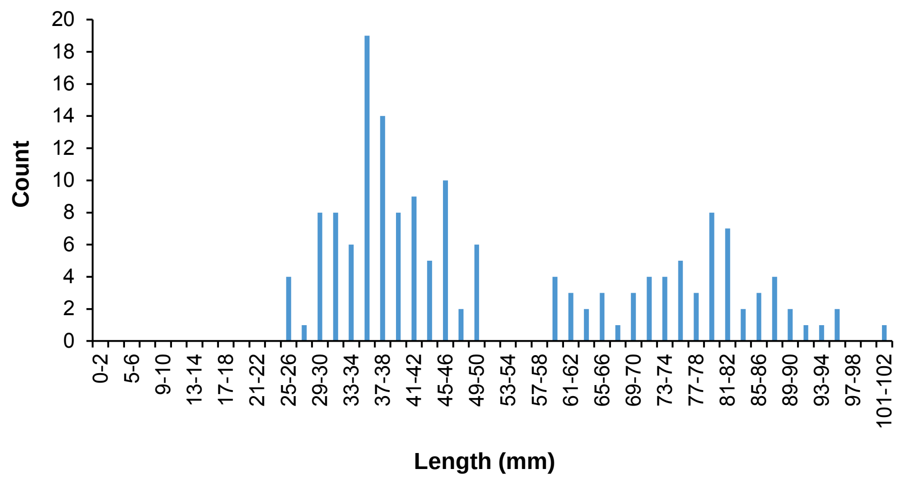
Reach	Designation	Sample Size		Relative Abundance (%)		Juvenile Measurements		Percentage of External Abnormalities
		Juvenile	Adult	Juvenile	Adult	Mean Length (mm)	Mean Weight (g)	
ER-L	lower *test* reach	100	39	71.9	28.1	34.9	0.52	0.61
ER-M	mid *test* reach	104	59	63.8	36.2	38.5	0.58	1.82
ER-U	upper *baseline* reach	104	61	63.0	37.0	44.1	0.91	1.82

Figure 5.8-22 Length-frequency distribution of lake chub in wild fish health reaches of the Ells River, fall 2015.

Upper *baseline* reach ER-U



Mid *test* reach ER-M



Lower *test* reach ER-L

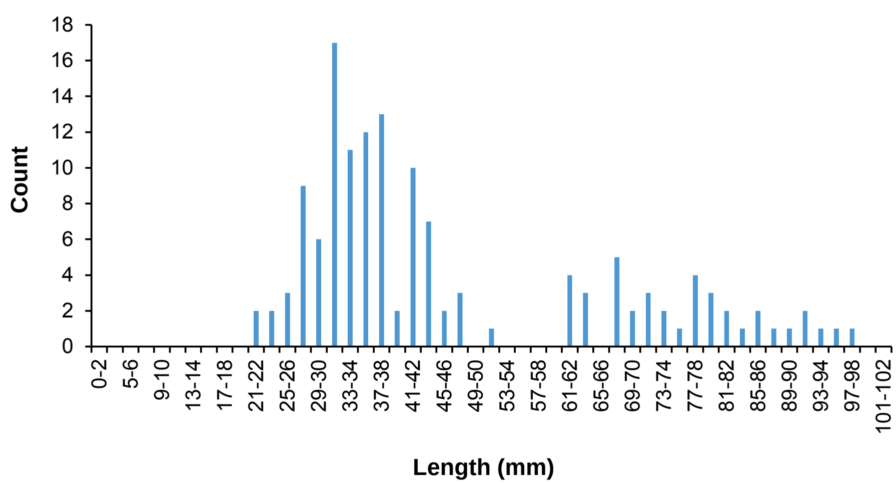


Table 5.8-33 Summary of morphometric data (mean ± 1SE) for lake chub in reaches of the Ells River, fall 2015.

Variable	Units	ER-L lower *test* reach		ER-M mid *test* reach		ER-U upper *baseline* reach	
n	-	16	20	20	20	20	20
Sex	-	Male	Female	Male	Female	Male	Female
Age	years	1.5 ± 0.2	2.2 ± 0.2	2.5 ± 0.2	3.2 ± 0.2	2.8 ± 0.1	2.8 ± 0.2
Length	mm	73.06 ± 2.43	79.90 ± 2.28	75.60 ± 1.17	85.10 ± 1.90	76.95 ± 1.07	86.15 ± 2.72
Weight	g	4.33 ± 0.42	5.66 ± 0.52	4.50 ± 0.19	6.79 ± 0.53	4.77 ± 0.17	7.29 ± 0.70
K	-	1.07 ± 0.02	1.05 ± 0.02	1.03 ± 0.02	1.06 ± 0.02	1.04 ± 0.02	1.09 ± 0.02
GSI	-	0.80 ± 0.10	5.07 ± 0.34	0.90 ± 0.04	7.12 ± 0.47	0.78 ± 0.05	7.51 ± 0.64
LSI	-	1.59 ± 0.09	1.86 ± 0.07	1.44 ± 0.06	2.24 ± 0.18	1.49 ± 0.09	2.02 ± 0.10

K = condition, GSI = gonadosomatic index, LSI = liversomatic index

Figure 5.8-23 Relative age-frequency distributions for lake chub at *baseline* reach ER-U and *test* reaches ER-M and ER-L in the Ells River, fall 2015.

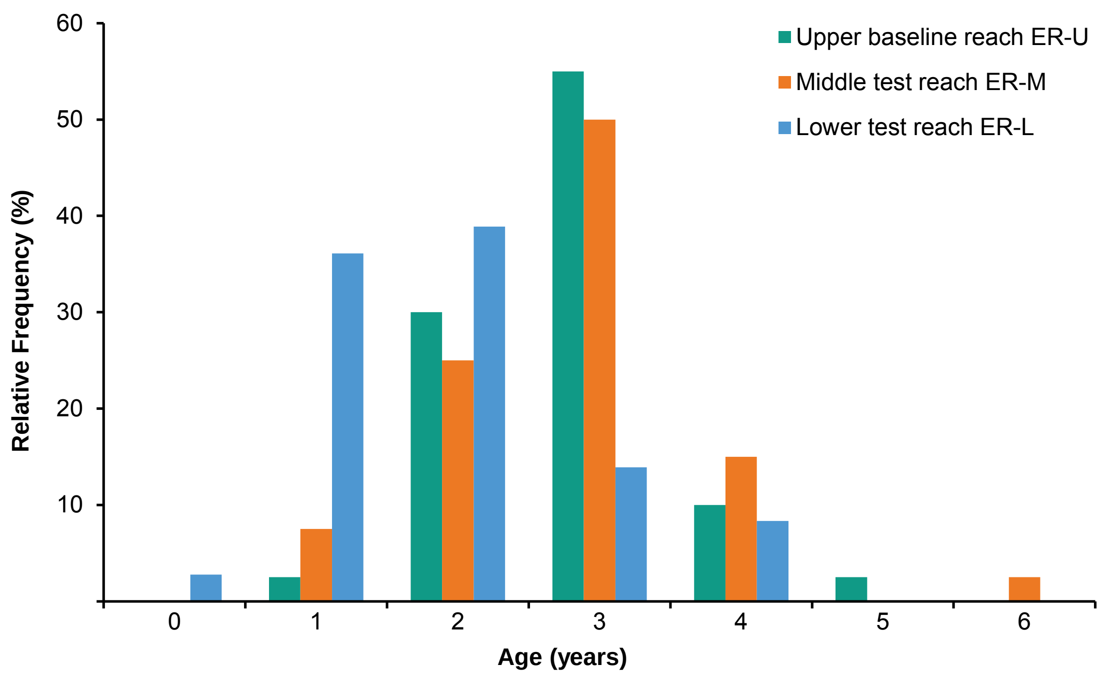


Table 5.8-34 Results of analysis of variance (ANOVA) and analysis of covariance (ANCOVA) for differences in measurement endpoints of lake chub in the Ells River (*baseline* reach ER-U and *test* reaches ER-M and ER-L), fall 2015.

Analysis	Sex	Comparison	Sample Size	P-value	Direction	Effects Criteria	Percent Difference[1]	Post Hoc[2]
ANOVA								
Age (Survival)								
	Female	ER-U vs. ER-M	20,20	0.51	None	±25%	13%	-
		ER-M vs. ER-L	20,20	**0.01**	ER-M > ER-L	±25%	<u>-30%</u>	-
		ER-U vs. ER-L	20,20	0.15	None	±25%	-21%	-
	Male	ER-U vs. ER-M	20,20	0.37	None	±25%	-11%	-
		ER-M vs. ER-L	20,16	**<0.001**	ER-M > ER-L	±25%	<u>-40%</u>	-
		ER-U vs. ER-L	20,16	**<0.001**	ER-U > ER-L	±25%	<u>-46%</u>	-
ANCOVA[3]								
Growth – Weight-at-Age (Energy Use)								
	Female	ER-U vs. ER-M	20,20	0.42	None	±25%	-13%	*0.73*
		ER-M vs. ER-L	20,20	0.99	None	±25%	1%	*0.73*
		ER-U vs. ER-L	20,20	0.49	None	±25%	-12%	*0.73*
	Male*	ER-U vs. ER-M	20,20	0.99	None	±25%	-1%	*0.46*
		ER-M vs. ER-L	20,16	0.28	None	±25%	11%	*0.46*
		ER-U vs. ER-L	20,16	0.40	None	±25%	9%	*0.46*
Relative Gonad Weight (Energy Use)								
	Female*	ER-U vs. ER-M	18,20	0.97	None	±25%	1%	-
		ER-M vs. ER-L	20,19	**0.008**	ER-M > ER-L	±25%	-17%	-
		ER-U vs. ER-L	18,19	**0.02**	ER-U > ER-L	±25%	-16%	-
	Male	ER-U vs. ER-M	19,19	0.08	None	±25%	33%	*0.60*
		ER-M vs. ER-L	19,16	0.99	None	±25%	0%	*0.60*
		ER-U vs. ER-L	19,16	0.13	None	±25%	33%	*0.60*
Relative Liver Weight (Energy Storage)								
	Female*	ER-U vs. ER-M	20,19	0.10	None	±25%	16%	-
		ER-M vs. ER-L	19,20	**0.02**	ER-M > ER-L	±25%	-18%	-
		ER-U vs. ER-L	20,20	0.75	None	±25%	-5%	-
	Male	ER-U vs. ER-M	20,19	-	-	±25%	-	-
		ER-M vs. ER-L	19,15	-	-	±25%	-	-
		ER-U vs. ER-L	20,15	-	-	±25%	-	-
Condition (Energy Storage)								
	Female	ER-U vs. ER-M	27,30	0.64	None	±10%	-3%	*0.87*
		ER-M vs. ER-L	30,22	0.76	None	±10%	3%	*0.87*
		ER-U vs. ER-L	27,22	0.99	None	±10%	0%	*0.87*
	Male	ER-U vs. ER-M	20,20	0.86	None	±10%	-1%	0.98
		ER-M vs. ER-L	20,16	0.14	None	±10%	5%	0.98
		ER-U vs. ER-L	20,16	0.35	None	±10%	4%	0.98

Bold values indicate significant difference ($p<0.05$).

* Data were log-transformed.

[1] Percent difference was calculated using ANOVA-adjusted least squared means with upstream reaches as the reference. <u>Underlined</u> values signify instances when significant differences were observed and the effect size exceeded EC's criterion for 25% for age, weight-at-age, GSI, and LSI, and 10% for condition.

[2] Power was calculated for the three-way ANOVA when no significant differences were found among reaches. Values in *italics* denote comparisons where power was inadequate and sample size was too low.

[3] The results of ANCOVA tests are presented only if slopes of the regression of the variables used in the ANCOVA were not significantly different ($p<0.01$).

Figure 5.8-24 Relationship between body weight (g) and liver weight (g) of female and male lake chub at *baseline* reach ER-U and *test* reaches ER-M and ER-L in the Ells River, fall 2015.

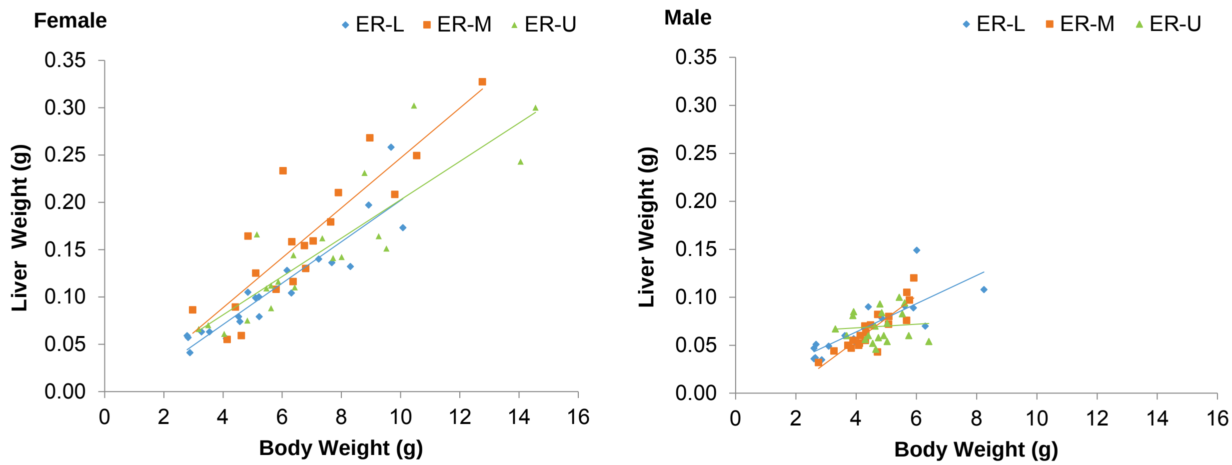
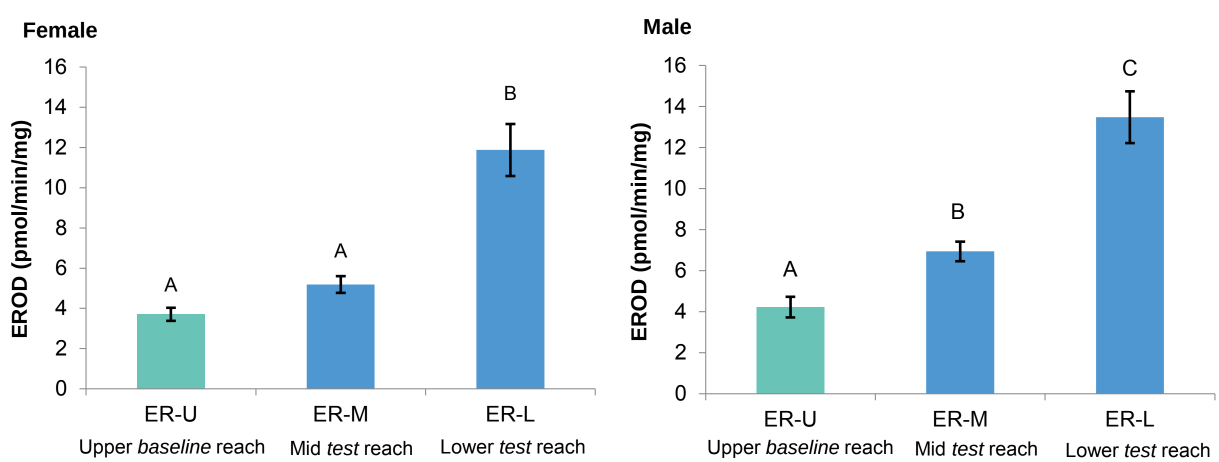


Figure 5.8-25 Mean EROD activity (± 1SE) of female and male lake chub at *baseline* reach ER-U and *test* reaches ER-M and ER-L in the Ells River, fall 2015.



Note: Similar letters denote no significant difference between reaches and different letters denote where statistically significant ($p \leq 0.05$) differences exist.

5.9 CLEARWATER RIVER WATERSHED

Table 5.9-1 Summary of results for the Clearwater River watershed.

Clearwater River Watershed	Summary of 2015 Conditions					
	Clearwater River					High Hills River
Climate and Hydrology						
Criteria	no station	**07CD001**	no station	**07CD005**	**3062696**	**S51**
Mean open-water season discharge	-	🟡	-	not measured	n/a	not measured
Mean winter discharge	-	🟡	-	not measured	n/a	not measured
Annual maximum daily discharge	-	🟡	-	not measured	n/a	not measured
Minimum open-water season discharge	-	🟡	-	not measured	n/a	not measured
Water Quality						
Criteria	**CL2**	**AB07CD0200**	**CLR-2**	no station	no station	**HHR-1**
Water Quality Index	not sampled in fall 2015	🟡	🟠	-	-	🟡
Benthic Invertebrate Communities and Sediment Quality						
Criteria	**CLR-D1**	no reach	**CLR-D2**	no reach	no station	**HHR-E1**
Benthic Invertebrate Communities	🟡	-	n/a	-	-	n/a
Sediment Quality Index	🟡	-	🟡	**-**	-	no station
Fish Populations						
No Fish Populations component activities were conducted in 2015.						

Legend and Notes

- 🟡 Negligible - Low
- 🟠 Moderate
- 🟤 High

baseline

test

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

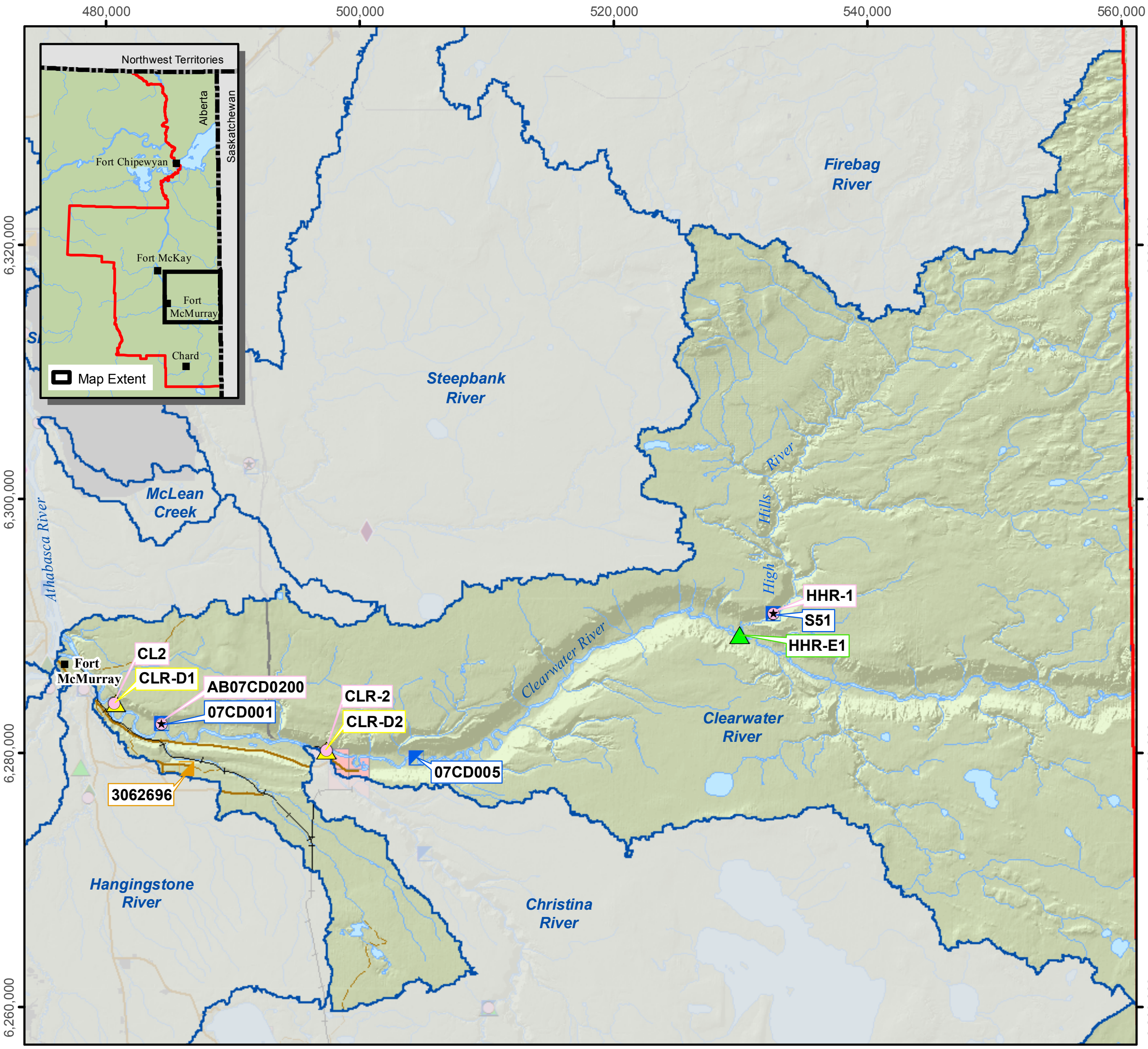
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Figure 5.9-1 Clearwater River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]
- Water Withdrawal Location
- Water Release Location
- Water Quality Station
- Data Sonde Station
- Hydrometric Station
- Climate Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Community Reach
- Wild Fish Health Reach
- Wild Fish Health Reach with Water and Sediment Quality Stations

0 2.5 5 10 km

N

Scale: 1:500,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

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Figure 5.9-2 Representative monitoring stations of the Clearwater River watershed, fall 2015.

Hydrology Station S51: High Hills River near the mouth, facing upstream

Benthic Invertebrate Communities Reach and Water Quality Station CLR-D1/CL2: lower Clearwater River, facing upstream

Benthic Invertebrate Communities Reach and Water Quality Station CLR-D2/CLR-2: upper Clearwater River, facing upstream

Benthic Invertebrate Communities Reach and Water Quality Station HHR-E1/HHR-1: High Hills River near the mouth, facing downstream

5.9.1 Summary of 2015 WY Conditions

There had been no land change in the Clearwater River watershed from oil sands development as of 2015. Given the influence of the Christina River on the Clearwater River and the oil sands development in the Christina River watershed, the designations of specific areas of the Clearwater River watershed are as follows:

1. The Clearwater River downstream of the confluence with the Christina River is designated as *test*.
2. The Clearwater River upstream of the confluence with the Christina River is designated as *baseline*.

Monitoring activities in the Clearwater River watershed were conducted in the 2015 WY for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality components. Table 5.9-1 is a summary of the 2015 assessment of the Clearwater River watershed, while Figure 5.9-1 provides the locations of the monitoring stations for each component. Figure 5.9-2 contains fall 2015 photos of representative monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology Flows decreased from November 2014 to January 2015 and then remained relatively constant until early April. Flows then increased in mid-April in response to spring thaw and reached the annual peak flow on April 20 (147 m^3/s). Flows receded until the minimum open-water daily flow of 54.3 m^3/s on October 25. From mid-April until the end of October, flows were predominately between historical lower quartile flows and historical minimum flows. The assessed hydrologic change classification for the Clearwater River was **Negligible-Low**. This assessed classification of hydrologic change was based on the calculated hydrologic change from the Christina River and then proportionally scaled to the increased watershed size in the Clearwater River.

Water Quality Differences in water quality conditions in fall 2015 compared to regional *baseline* conditions were **Negligible-Low** at *test* station AB07CD0200 and *baseline* station HHR-1, and **Moderate** at *baseline* station CLR-2. There were no significant temporal trends measured in concentrations of water quality measurement endpoints for *baseline* station CLR-2; trend analyses were not conducted for *baseline* station AB07CD0200 or *baseline* station HHR-1 due to an insufficient time series of data available for these stations. The ionic composition of water at all stations in the Clearwater River watershed in fall 2015 was similar to previous years. *Baseline* station CLR-2 was equally dominated by calcium, potassium and sodium as cations, and bicarbonate and chloride as anions. In contrast, *baseline* station HHR-1 was dominated by calcium and bicarbonate and has had an ionic composition that has been more consistent across the monitoring period than the ion composition of the stations on the Clearwater River. Concentrations of most water quality measurement endpoints measured in fall 2015 were within the ranges of regional *baseline* conditions.

Benthic Invertebrate Communities and Sediment Quality Variations in measurement endpoints of benthic invertebrate communities at *test* reach CLR-D1 were classified as **Negligible-Low**. Variations in CA Axis 1 scores at *test* reach CLR-D1 were not related to oil sands development given similar trends were observed at both the *test* and *baseline* reaches**.** The percentage of sensitive EPT taxa was also higher at *test* reach CLR-D1 than at *baseline* reach CLR-D2, indicating that conditions are not degrading in the lower Clearwater River. The benthic invertebrate community of *baseline* reach HHR-E1 contained a benthic fauna that reflected good water and sediment quality. The benthic invertebrate community at *baseline* reach HRR-E1 contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies.

Differences in sediment quality conditions in fall 2015 at *test* station CLR-D1 and *baseline* station CLR-D2 in the Clearwater River watershed compared to regional *baseline* sediment quality conditions were **Negligible-Low**.

5.9.2 Hydrologic Conditions

Hydrometric monitoring for the Clearwater River watershed in the 2015 WY was conducted at the following locations:

- WSC Station 07CD001, Clearwater River at Draper;
- WSC Station 07CD005, Clearwater River above the Christina River; and
- JOSMP Station S51, High Hills River near the mouth.

Data from WSC Station 07CD001 were used to describe the 2015 WY hydrologic conditions of the Clearwater River and are presented below. Data from WSC Station 07CD005 and JOSMP Station S51 are provided in Appendix C.

Continuous hydrometric data have been collected year-round at WSC Station 07CD001 since 1957. The historical flow record is summarized in Figure 5.9-3 and includes the median, interquartile range, and range of flows recorded daily through the WY. Flows of the Clearwater River exhibit a seasonal runoff pattern typical of a northern Alberta environment. Flows during winter are typically lower than in the open-water season and decrease from November until March. Spring thaw and the resulting rapid increase in flows typically occurs in mid-April. Monthly flows are highest in May at the peak of freshet and often remain elevated in June and July when total monthly rainfalls are highest. Flows generally recede after freshet until the end of the water year, in response to declining rainfall inputs and eventual river freeze-up.

Flows at WSC Station 07CD001 in the 2015 WY were similar to the historical seasonal pattern described above except that peak flow was lower than normal and occurred earlier than normal, and less runoff occurred (Figure 5.9-3). Flows decreased from November 2014 to January 2015 and then remained relatively constant until early April. Discharge recorded during this period was between historical upper quartile flows and historical lower quartile flows. Flows then increased in early April in response to spring thaw and reached the annual peak flow on April 20 of 147 m^3/s; this peak was 63% lower than the historical mean annual maximum daily flow of 394 m^3/s. Flows then receded until the minimum open-water daily flow of 54.3 m^3/s on October 25, which was 39% lower than the historical mean minimum daily flow of 89.0 m^3/s calculated for the open-water period. Flows from the end of April until the end of October were predominately between historical lower quartile flows and the historical minimum flows.

The 2015 water year runoff volume recorded at WSC Station 07CD001 was 2,316 million m^3, which was 39% lower than the historical mean water year runoff volume of 3,785 million m^3.

The only oil sands development in the Clearwater River watershed in 2015 was within the Christina River watershed (see Section 5.10). The hydrologic change classification for all the measurement endpoints in the Christina River watershed were **Negligible-Low**. Because the watershed area of the Christina River is approximately 42% of the total Clearwater River watershed the resulting hydrologic change classification in the Clearwater River watershed is also **Negligible-Low** due to the dilution effects in the larger watershed. Based on this assessment of the classification of hydrological change in the Clearwater River watershed no assessment of *test* versus *baseline* hydrologic conditions was necessary.

5.9.3 Water Quality

Water quality samples were taken in the 2015 WY from the:

- Clearwater River upstream of Fort McMurray, but downstream of the confluence of the Christina River (*test* station CL2, previously called CLR-1), sampled since 2001. This station was sampled in May and June in 2015;
- Clearwater River upstream of the confluence with the Christina River (*baseline* station CLR-2), sampled in fall since 2001 and on monthly basis since May 2013. In 2015 WY, this station was sampled monthly from November 2014 to March 2015, and in September 2015 for the benthic invertebrate communities component;

- Clearwater River between *test* station CL2 and *baseline* station CLR-2 (*test* station AB07CD0200), a newly station established in 2015 and sampled monthly from July to October; and
- High Hills River near its mouth, tributary to the Clearwater River (*baseline* station HHR-1), sampled in fall since 2011 and on a seasonal basis in 2014. In 2015, this station was sampled in March and monthly from May to October.

In addition, data sondes installed at *test* station AB07CD0200 and *baseline* station HHR-1 collected continuous water quality data between August and October and July and October, respectively, for a subset of water quality variables.

Figure 5.9-4 presents in situ water quality trends in the Clearwater River watershed as recorded by data sondes in the 2015 WY. Monthly variations in water quality are summarized in Table 5.9-2 to Table 5.9-5 and Figure 5.9-5. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations (if available) are provided in Table 5.9-6 to Table 5.9-8. The ionic composition of water in the Clearwater River watershed is presented in Figure 5.9-6. Guideline exceedances for water quality measurement endpoints are presented in Table 5.9-9 and Figure 5.9-7 presents a comparison of selected water quality measurement endpoints in fall 2015 relative to established regional *baseline* concentrations.

Continuous Monitoring Results from Data Sondes Continuous monitoring results collected between July and October indicate generally similar trends in concentrations and levels of in situ water quality variables at *test* station AB07CD0200 and *baseline* station HHR-1 (Figure 5.9-4). Water temperature decreased over the period of monitoring while concentrations of dissolved oxygen increased, likely a result of higher oxygen solubility at low temperatures as demonstrated by the steady dissolved oxygen saturation levels throughout the monitoring period. Dissolved oxygen concentrations dropped below the water quality guideline for a short period at *baseline* station HHR-1 in the second week of August. Water at both stations was alkaline at both stations and pH remained within water quality guidelines throughout the monitoring period. There was a short-term decrease in pH at *baseline* station HHR-1 at the same time as the decrease in concentration of dissolved oxygen in August. Specific conductivity remained stable throughout the monitoring period and was slightly higher at *test* station AB07CD0200 relative to *baseline* station HHR-1. Turbidity was variable at both stations throughout the monitoring period. Data gaps for data sondes at stations of the Clearwater and High Hills rivers are discussed in Appendix B.

Monthly Variations in Water Quality Monthly data were collected within different time periods of the year at different stations and therefore within-year temporal trends and spatial comparisons could not be established. Monthly concentrations and values of all water quality measurement endpoints were within historical monthly ranges (Table 5.9-2 to Table 5.9-5, Figure 5.9-5) with few exceptions (i.e., TSS at *baseline* station CLR-2 in September, calcium and magnesium at *baseline* station HHR-1 in March).

2015 Fall Results Relative to Historical Concentrations Water quality at *test* station AB07CD0200 was measured for the first time in 2015 and comparisons to historical comparisons were therefore not possible for this station (Table 5.9-6). Concentrations of all water quality measurement endpoints at *baseline* station CLR-2 and *baseline* station HHR-1 in fall 2015 were within the range of previously-measured concentrations (Table 5.9-7, Table 5.9-8) with the following exceptions:

- TSS, total alkalinity, total aluminum, total arsenic, total chromium, total lead, total phenols, and total parent PAHs at *baseline* station CLR-2, with concentrations that exceeded previously-measured concentrations (it should be noted that waterborne PAHs have only been measured at current, ultra-trace detection limits since 2011, and that historical comparisons of 2015 data for these water quality variables are to 2011-2014 data only);

- naphthenic acids, oilsands extractable acids, total parent PAHs, sulphide, and total phenols at *baseline* station HHR-1, with concentrations that exceeded previously-measured maximum concentrations; and
- sulphate, dissolved organic carbon, and total molybdenum at *baseline* station CLR-2, and retene at *baseline* station HHR-1, with concentrations that were lower than previously-measured minimum concentrations.

In addition, the concentration of chloride at *baseline* station HHR-1 was non-detectable but had a detection limit that exceeded the previously-measured maximum concentration.

Temporal Trends There were no significant temporal trends measured in concentrations of water quality measurement endpoints for *baseline* station CLR-2; trend analyses were not conducted for *baseline* station AB07CD0200 or *baseline* station HHR-1 due to an insufficient time series of data available for these stations.

Ion Balance The ionic composition of water at all stations in the Clearwater River watershed in fall 2015 was similar to previous years (Figure 5.9-6). *Baseline* station CLR-2 was equally dominated by calcium, potassium and sodium as cations, and bicarbonate and chloride as anions. In contrast, *baseline* station HHR-1 was dominated by calcium and bicarbonate and has had an ionic composition that has been more consistent across the monitoring period than the ion composition of the stations on the Clearwater River.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Water quality guideline exceedances in 2015 included (Table 5.9-9):

- dissolved iron at *test* station CL2 (May and June) and *baseline* stations, CLR-2 (November to March and September), and HHR-1 (May to October);
- total mercury and total lead at *baseline* station CLR-2 (September);
- total zinc at *baseline* station CLR-2 (February);
- total phenols at *test* stations, CL2 (June) and AB07CD0200 (July to September), and *baseline* stations CLR-2 (November, February, and September) and HHR-1 (May to September); and
- sulphide at *test* stations, CL2 (June) and AB07CD0200 (July to September), and *baseline* stations CLR-2 (November, February, and September) and HHR-1 (May to September).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations and levels of water quality measurement endpoints were within regional *baseline* concentrations in fall 2015 (Figure 5.9-7) with the following exceptions:

- total nitrogen at *test* station AB07CD0200, with concentrations that were lower than the 5^{th} percentile of the regional baseline concentrations;
- chloride at *test* station AB07CD0200, with a concentration that exceeded the 95^{th} percentile of the regional baseline concentration; and
- TSS, total mercury, and chloride at *baseline* station CLR-2, with concentrations that exceeded the 95^{th} percentile of the regional *baseline* concentrations.

Water Quality Index The WQI calculated for fall 2015 at *test* station AB07CD0200 (98.7), *baseline* station CLR-2 (68.9), and *baseline* station HHR-1 (100) indicate **Negligible-Low, Moderate,** and **Negligible-Low** differences, respectively, in water quality conditions in fall 2015 compared to regional *baseline* water quality conditions. The lower WQI for *baseline* station CLR-2 is likely due to the exceedance in concentration in fall 2015 of a number of water quality variables above the 95th percentile of the regional *baseline* concentrations.

Classification of Fall Results Differences in water quality conditions in fall 2015 compared to regional *baseline* conditions were **Negligible-Low** at *test* station AB07CD0200 and *baseline* station HHR-1, and **Moderate** at *baseline* station CLR-2.

5.9.4 Benthic Invertebrate Communities and Sediment Quality

5.9.4.1 Benthic Invertebrate Communities

Clearwater River

Benthic invertebrate communities were sampled in the Clearwater River in fall 2015 at:

- the Clearwater River downstream of the confluence with the Christina River (depositional *test* reach CLR-D1), designated and sampled as a *baseline* reach in 2001, designated and sampled as a *test* reach from 2002 to 2005, 2008, 2011, 2014 and 2015;
- the Clearwater River upstream of the confluence with the Christina River (depositional *baseline* reach CLR-D2), sampled from 2001 to 2005, 2008, 2011, 2014 and 2015.

2015 Habitat Conditions Water at *test* reach CLR-D1 in fall 2015 had a mean depth of 0.85 m, moderate velocity (0.49 m/s), moderate conductivity (263 µS/cm), moderate dissolved oxygen concentration (7.6 mg/L), and pH of 7.75 (Table 5.9-10). The substrate was primarily comprised of sand (86%) with some silt (~11%) and small amounts of clay (3%), with low organic carbon content (<1%).

Water at *baseline* reach CLR-D2 in fall 2015 had a mean depth of 0.25 m, slow velocity (0.25 m/s), moderate conductivity (209 µS/cm), high dissolved oxygen concentration (8.7 mg/L), and a pH of 7.17 (Table 5.9-10). The substrate was mostly sand (84%) with some silt (11%) and small amounts of clay (5%), with low organic carbon content (<1%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of the lower depositional *test* reach CLR-D1 in fall 2015 was dominated by Chironomidae (61%), with Ephemeroptera (13%) as the subdominant taxa (Table 5.9-11). Chironomids consisted primarily of moderately pollution-tolerant forms, such as *Paralauterborniella*, *Polypedilum,* and *Rheosmittia/ Lopesocladius*. Larvae of flying insects included Ephemeroptera (*Ametropus neavei*), Plecoptera (*Taeniopteryx*) and Trichoptera (*Neureclipsis*), as well as *Gomphus* dragonflies. Bivalves, *Pisidium* (fingernail clam) and *Lampsilis radiata* (freshwater mussel), were present at *test* reach CLR-D1 in 2015.

The benthic invertebrate community of the upper depositional *baseline* reach CLR-D2 in fall 2015 was dominated by Chironomidae (45%), Tubificidae (21%), Nematoda (17%) and Bivalvia (10%) (Table 5.9-11). Common forms of chironomids, such as *Micropsectra/Tanytarsus*, *Paralauterborniella*, *Polypedilum* and *Cryptochironomus*, were most abundant. Several Ephemeroptera (*Ametropus neavei*, *Callibaetis*, *Caenis*, *Maccaffertium terminatum*, *Leptophlebia*), and Trichoptera (*Hydroptila*, *Oecetis* and *Neureclipsis*) taxa were found in *baseline* reach CLR-D2. Other permanent aquatic forms included Amphipoda (*Hyalella azteca*), Bivalves (*Pisidium*, *Sphaerium*) and Gastropoda (*Lymnaea*, *Physa*).

Temporal and Spatial Comparisons The following temporal and spatial comparisons of benthic invertebrate community measurement endpoints at *test* reach CLR-D1were conducted:

- a difference in mean values of measurement endpoints between *test* reach CLR-D1 and *baseline* reach CLR-D2 during both *baseline* and *test* periods;
- a difference in mean values of measurement endpoints between *baseline* and *test* periods in both *baseline* and *test* reaches;
- a change in the difference in mean values of measurement endpoints between *baseline* and *test* reaches, from *baseline* to *test* periods (i.e., Hypothesis 1 in Section 3.2.3.1);
- a time trend in mean values of measurement endpoints during the *test* period in both *test* and *baseline* reaches;
- a difference in the time trend of mean values of measurement endpoints between *baseline* and *test* reaches during the *test* period;
- a difference in mean values of measurement endpoints between *baseline* periods and 2015 for the *test* reach; and
- a difference in mean values of measurement endpoints between 2015 and all other years for the *test* reach.

The comparisons for *test* reach CLR-D1 that were statistically significant were (Table 5.9-12, Figure 5.9-8):

1. %EPT was significantly higher at *test* reach CLR-D1 in fall 2015 than the mean of all previous years of monitoring at the *test* reach, accounting for 21% of the variance in annual means. An increase in %EPT is not consistent with degrading conditions.
2. CA axis 1 scores were significantly lower between *baseline* and *test* periods in both *baseline* and *test* reaches, accounting for 30% of the variance in annual means. The higher CA Axis 1 scores in the *baseline* period (2001) reflect a larger relative abundance of bivalves in 2001 (the only *baseline* year). This effect was consistent for both *baseline* and *test* reaches, indicating that the effect was not related to developments in the watershed and are therefore not indicative of degrading conditions for benthic invertebrate communities as a result of oil sands developments.

Comparison to Published Literature The benthic invertebrate community at *test* reach CLR-D1 in fall 2015 was typical of a shifting-sand environment. The community was dominated by chironomids, including forms that are widely-distributed and tolerant of various conditions (e.g., *Polypedilum*). Naidid worms, tubificid worms, and nematodes were present, which indicated low levels of organic input to the reach (Hynes 1960; Griffiths 1998; Mandeville 2001). The community contained representatives of EPT taxa including mayflies (*Ametropus neavei*), stoneflies (*Taeniopteryx*) and caddisflies (*Neureclipsis*), which indicated high water and substrate quality (Mandeville 2001). The relative abundance of Ephemeroptera was higher in 2015 than in all prior years.

The benthic invertebrate community at *baseline* reach CLR-D2 in fall 2015 was similar to that of *test* reach CLR-D1. Chironomidae dominated the fauna in *baseline* reach CLR-D2, with forms that are more common in sand or shifting sands (e.g., *Cryptochironomus*) (Beck 1977; Bode et al. 1996). The community also contained representatives of EPT taxa, including several genera of mayflies and three caddisfly taxa.

2015 Results Relative to Regional *Baseline* Conditions Values of all benthic invertebrate community measurement endpoints for *test* reach CLR-D1 were within the inner tolerance limits of regional *baseline* conditions (Figure 5.9-9).

Classification of Results Variations in measurement endpoints of benthic invertebrate communities at *test* reach CLR-D1 were classified as **Negligible-Low**. Variations in CA Axis 1 scores were not related to oil sands development given similar trends were observed at both the *test* and *baseline* reaches**.** The percentage of sensitive EPT taxa was also higher at *test* reach CLR-D1 than at *baseline* reach CLR-D2, indicating that conditions are not degrading in the lower Clearwater River.

High Hills River

Benthic invertebrate communities were sampled in fall 2015 *baseline* reach HHR-E1 of High Hills River. This erosional reach was sampled from 2011 to 2014 with a Neil-Hess cylinder and in 2015 with a CABIN kicknet. Values of benthic invertebrate community measurement endpoints for fall 2015 were “adjusted” (Appendix D) to make them as comparable as possible to data collected with a Neil-Hess cylinder and therefore to data from 2011 to 2014.

2015 Habitat Conditions Water at *baseline* reach HHR-E1 in fall 2015 was shallow (0.3 m), alkaline (pH 8.3), with a high velocity (1.2 m/s), high dissolved oxygen concentration (10.5 mg/L), and moderate conductivity (205 µS/cm) (Table 5.9-13). The substrate was dominated by gravel. Full CABIN supporting data are provided in Appendix D.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *baseline* reach HHR-E1 in fall 2015 was dominated by mayflies (47%) and caddisflies (30%), with miscellaneous Diptera (7%), Hydracarina (7%), and stoneflies (4%) subdominant (Table 5.9-14). Mayflies were dominated by *Baetis*, *Ephemerella*, and *Rhithrogena*, as well as members from the Ephemerellidae and Heptageniidae families. The percentage of the benthic invertebrate community as worms (Naididae) was lower in fall 2015 compared to previous years. Caddisflies were diverse and numerically dominated by *Lepidostoma*, with *Oecetis*, *Brachycentrus* and *Hydropsyche*. Five stonefly genera were present at the reach; *Zapada*, *Claassenia*, *Skwala*, *Taeniopteryx*. Chironomids consisted primarily of *Tvetenia* and *Rheotanytarsus*. The Empididae fly *Hemerodromia* was relatively abundant. Other flying insects included dragonfly members of the Gomphidae family. Permanent aquatic forms at the reach were represented by the gastropod *Physa*.

Comparison to Published Guidelines The benthic invertebrate community of *baseline* reach HHR-E1 was comprised of benthic fauna that reflected good water and sediment quality. Larvae of flying insects (mayflies, stoneflies, and caddisflies) were diverse and relatively abundant indicating favourable water quality (Resh and Unzicker 1975; Niemi et al. 1990). The dominant forms of chironomids that were found at *baseline* reach HHR-E1 are known to represent fair to good water quality habitats (Mandeville 2002). For example, the chironomid *Rheotanytarsus* tends to be present in rocky streams with good flows (Merritt and Cummins 1996).

2015 Results Relative to Historical Conditions Values of all measurement endpoints in fall 2015 at *baseline* reach HRR-E1 were similar to values from previous years (Figure 5.9-10, Figure 5.9-11) with CA

Axis scores in fall 2015 similar to those in fall 2014, abundance, % EPT and equitability higher in fall 2015 compared to fall 2014 and richness lower in fall 2015 compared to fall 2014.

Summary of Results The benthic invertebrate community of *baseline* reach HHR-E1 contained a benthic fauna that reflected good water and sediment quality. The benthic invertebrate community at *baseline* reach HRR-E1 contained a high diversity of typical riffle fauna including mayflies, stoneflies, and caddisflies.

5.9.4.2 Sediment Quality

Sediment quality samples were collected in fall 2015 from:

- *test* station CLR-D1 on the lower Clearwater River, sampled in 2001 as a baseline reach and 2002, 2003, 2008, 2011, 2014, and 2015 as a *test* reach; and
- *baseline* station CLR-D2 on the Clearwater River, above the Christina River confluence, sampled from 2001 to 2003, 2008, 2011, 2014, and 2015.

Temporal Trends No significant ($p>0.05$) temporal trends in sediment quality measurement endpoints were measured at either *test* station CLR-D1 or *baseline* station CLR-D2 from 2001 to 2015.

2015 Results Relative to Historical Concentrations Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at *test* station CLR-D1 and *baseline* station CLR-D2 (Table 5.9-15, Table 5.9-16, Figure 5.9-12, Figure 5.9-13) with the exception of:

- %silt, %total organic carbon, F2, F3, and F4 hydrocarbons, retene, total dibenzothiophenes, total PAHs, and total alkylated PAHs at *test* station CLR-D1, with concentrations and levels in fall 2015 that exceeded previously-measured maximum concentrations and levels. In addition, concentrations of BTEX and F1 hydrocarbons in fall 2015 at *test* station CLR-D1 were below a detection limit that was greater than previously-measured maximum concentrations for these measurement endpoints; and
- retene, total dibenzothiophenes, and *Hyalella* survival at *baseline* station CLR-D2, with concentrations and levels in fall 2015 that exceeded previously-measured maximum concentrations and levels.

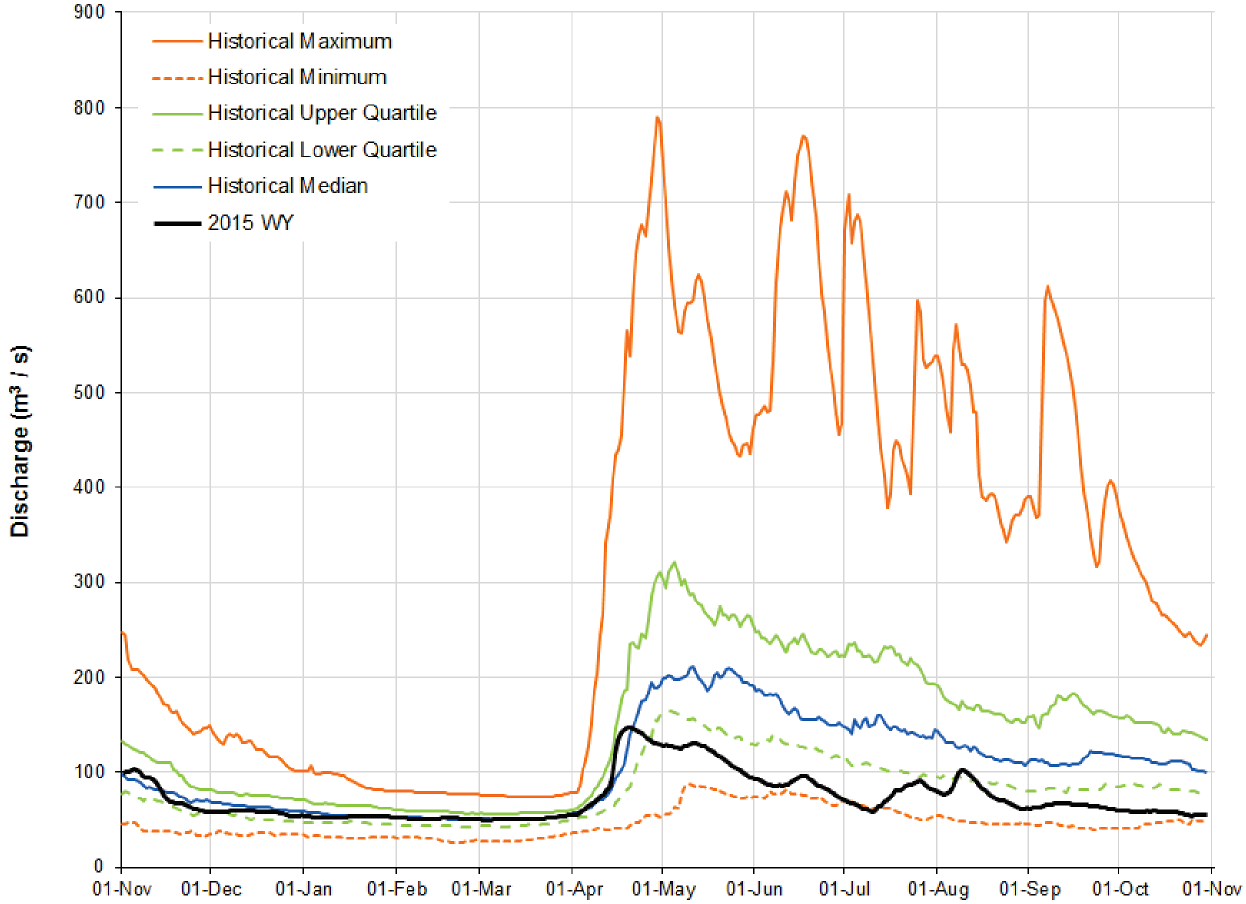
Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of all sediment quality measurement endpoints in fall 2015 at *test* station CLR-D1 and *baseline* station CLR-D2 were below applicable guidelines with the exception of Fraction 3 hydrocarbons at *test* station CLR-D1 (Table 5.9-15).

2015 Results Relative to Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints at *test* station CLR-D1 and *baseline* station CLR-D2 in fall 2015 were within regional *baseline* concentrations (Figure 5.9-12, Figure 5.9-13).

Sediment Quality Index The SQI values calculated for *test* station CLR-D1 and *baseline* station CLR-D2 in fall 2015 were 95.7 and 98.9, respectively.

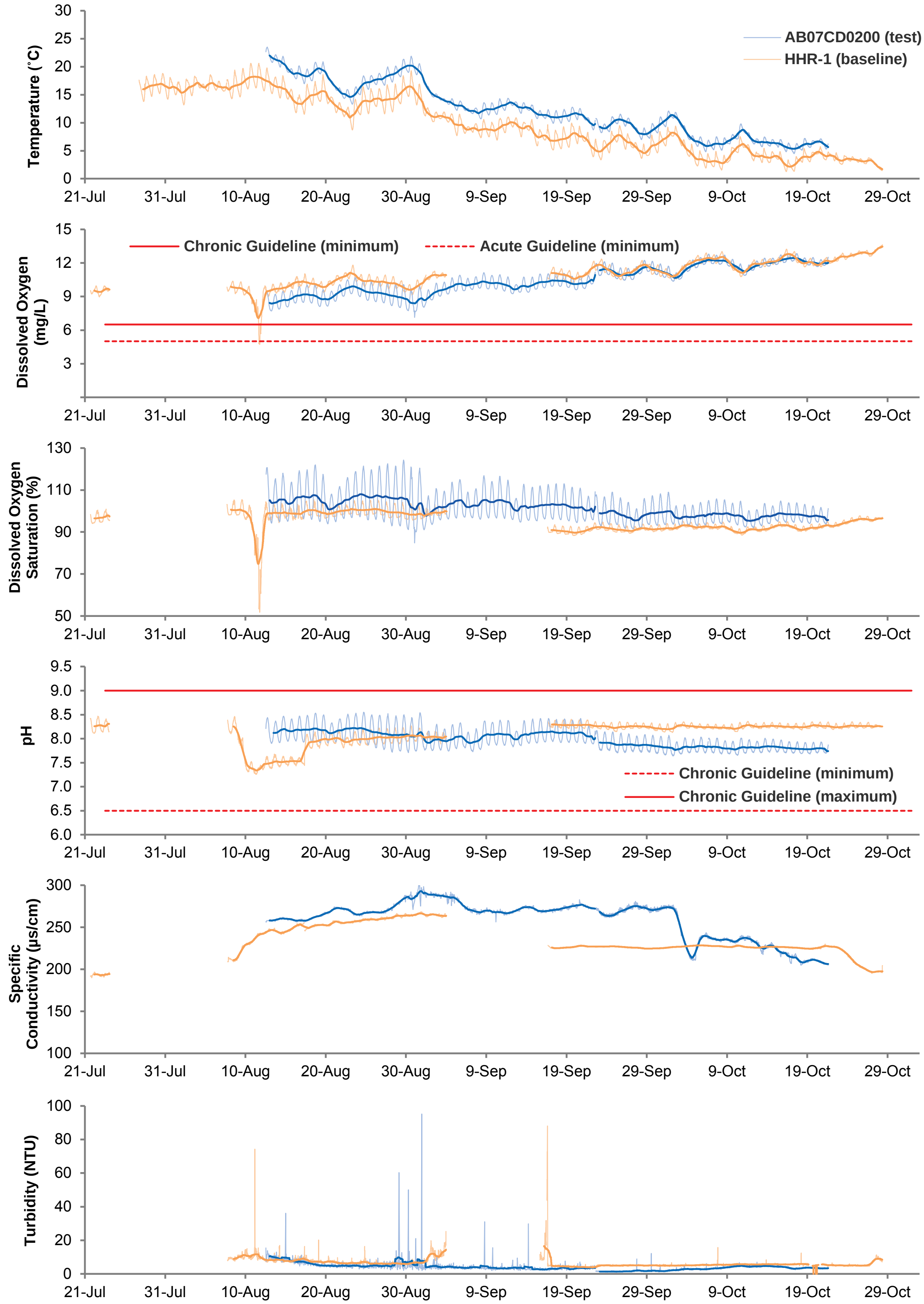
Classification of Results Based on the calculated SQI values, differences in sediment quality conditions in fall 2015 at *test* station CLR-D1 and *baseline* station CLR-D2 in the Clearwater River watershed were **Negligible-Low** compared to regional *baseline* sediment quality conditions.

Figure 5.9-3 Hydrograph for the Clearwater River at Draper for the 2015 WY, compared to historical values.



Note: The observed 2015 WY hydrograph was based on WSC Station 07CD001, Clearwater River at Draper data for November 1, 2014 to October 31, 2015. The upstream gross drainage area is 30,792 km^2. Historical values were calculated for the period from 1958 to 2014.

Figure 5.9-4 In situ water quality trends in the Clearwater River watershed recorded by data sondes, July to October 2015.



Note: Parameters were recorded at 15-minute and hourly intervals; trend lines are daily averages.

Table 5.9-2 Monthly concentrations of water quality measurement endpoints, mouth of Clearwater River (*test* station CL2 [CLR-1]), May to June 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Values	
			May	June
Physical variables				
pH	pH units	6.5-9.0	-	7.92
Total suspended solids	mg/L	-	-	24
Conductivity	µS/cm	-	-	270
Nutrients				
Total dissolved phosphorus	mg/L	-	-	0.01
Total nitrogen	mg/L	-	-	<1
Nitrate+nitrite	mg/L	3-124	-	<0.005
Dissolved organic carbon	mg/L	-	-	9.1
Ions				
Sodium	mg/L	-	-	26
Calcium	mg/L	-	-	20
Magnesium	mg/L	-	-	6.4
Potassium	mg/L	-	-	0.98
Chloride	mg/L	120-640	-	34
Sulphate	mg/L	309[b]	8	8.6
Total dissolved solids	mg/L	-	-	160
Total alkalinity	mg/L	20 (min)	-	79
Selected metals				
Total aluminum	mg/L	-	1.9	1.16
Dissolved aluminum	mg/L	0.05	0.0129	0.013
Total arsenic	mg/L	0.005	0.000794	0.00074
Total boron	mg/L	1.5-29	0.0335	0.0406
Total molybdenum	mg/L	0.073	0.000249	0.000324
Total mercury (ultra-trace)	ng/L	5-13	2.22	1.74
Total methyl mercury	ng/L	1-2	0.047	0.052
Total strontium	mg/L	-	0.0875	0.112
Total hydrocarbons				
BTEX	mg/L	-	<0.01	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02
Naphthenic acids	mg/L	-	0.71	0.1
Oilsands extractable acids	mg/L	-	1.3	1
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	1,000	-	<13.55
Retene	ng/L	-	-	2.5
Total dibenzothiophenes[c]	ng/L	-	-	30.13669
Total PAHs[c]	ng/L	-	-	221.6218
Total Parent PAHs[c]	ng/L	-	-	29.67649
Total Alkylated PAHs[c]	ng/L	-	-	191.9453
Other variables that exceeded Alberta guidelines in 2015[d]				
Total phenols	mg/L	0.004	-	**0.0048**
Sulphide	mg/L	0.0019	-	**0.0041**
Dissolved iron	mg/L	0.3	**0.493**	0.166
Total chromium	mg/L	0.001	**0.00148**	**0.00106**

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.9-3 Monthly concentrations of water quality measurement endpoints, Clearwater River at Draper (*test* station AB07CD0200), July to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	8.07	7.80	Oct	8.11	Aug
Total suspended solids	mg/L	-	4	10.9	4.7	Sep, Oct	19.0	Jul
Conductivity	µS/cm	-	4	265	250	Aug	270	Jul, Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.012	0.010	Sep	0.015	Aug
Total nitrogen	mg/L	-	4	0.39	0.28	Oct	0.61	Aug
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.005	-	0.020	Jul
Dissolved organic carbon	mg/L	-	4	7.4	6.2	Oct	9.9	Aug
Ions								
Sodium	mg/L	-	4	28.5	23.0	Aug	29.0	Jul
Calcium	mg/L	-	4	16.5	16.0	Sep, Oct	18.0	Jul
Magnesium	mg/L	-	4	5.85	5.40	Oct	6.20	Jul
Potassium	mg/L	-	4	0.91	0.85	Oct	0.95	Jul
Chloride	mg/L	120-640	4	36.0	33.0	Aug	37.0	Jul, Oct
Sulphate	mg/L	309[b]	4	7.3	6.5	Aug	7.8	Oct
Total dissolved solids	mg/L	-	4	160	150	Jul	180	Aug
Total alkalinity	mg/L	20 (min)	4	67.0	62.0	Oct	71.0	Aug
Selected metals								
Total aluminum	mg/L	-	4	0.3665	0.1320	Sep	0.5950	Aug
Dissolved aluminum	mg/L	0.05	4	0.00454	0.00269	Sep	0.00745	Jul
Total arsenic	mg/L	0.005	4	0.00057	0.00036	Oct	0.00073	Aug
Total boron	mg/L	1.5-29	4	0.0354	0.0323	Sep	0.0358	Oct
Total molybdenum	mg/L	0.073	4	0.00021	0.00015	Oct	0.00027	Aug
Total mercury (ultra-trace)	ng/L	5-13	4	0.97	0.71	Sep	1.62	Aug
Total methyl mercury	ng/L	1-2	4	0.052	0.030	Oct	0.090	Aug
Total strontium	mg/L	-	4	0.1045	0.1020	Aug	0.1090	Jul
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	4	0.35	<0.08	Oct	0.69	Jul
Oilsands extractable acids	mg/L	-	4	1.3	0.4	Oct	1.9	Aug
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	2.32	0.98	Oct	2.51	Aug
Total dibenzothiophenes[c]	ng/L	-	4	26.01	9.09	Oct	32.97	Sep
Total PAHs[c]	ng/L	-	4	181	129	Oct	222	Jul
Total Parent PAHs[c]	ng/L	-	4	23.7	23.0	Oct	29.3	Jul
Total Alkylated PAHs[c]	ng/L	-	4	157	106	Oct	192	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.0088**	**0.0066**	Oct	**0.0110**	Jul
Sulphide	mg/L	0.0019	3	**0.0023**	<0.0019	Oct	**0.0023**	Jul to Sep

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.9-4 Monthly concentrations of water quality measurement endpoints, upper Clearwater River (*baseline* station CLR-2), November 2014 to September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	7.53	7.32	Mar	7.65	Nov, Sep
Total suspended solids	mg/L	-	6	4.1	<3.0	Nov	340.0	Sep
Conductivity	µS/cm	-	6	245	234	Dec	346	Nov
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.018	0.011	Sep	0.020	Jan
Total nitrogen	mg/L	-	6	0.39	0.29	Dec	1.20	Sep
Nitrate+nitrite	mg/L	3-124	6	0.085	0.005	Sep	0.139	Mar
Dissolved organic carbon	mg/L	-	6	5.40	4.70	Mar	8.30	Nov
Ions								
Sodium	mg/L	-	6	25.5	23.0	Dec, Sep	37.4	Nov
Calcium	mg/L	-	6	14.1	12.8	Dec	18.3	Nov
Magnesium	mg/L	-	6	4.86	4.27	Dec	6.06	Nov
Potassium	mg/L	-	6	0.96	0.88	Dec	0.99	Jan
Chloride	mg/L	120-640	6	36.8	34.1	Dec	55.8	Nov
Sulphate	mg/L	309[b]	6	6.7	6.4	Mar	10.4	Nov
Total dissolved solids	mg/L	-	6	144	137	Feb	177	Nov
Total alkalinity	mg/L	20 (min)	6	57	53	Dec	73	Nov
Selected metals								
Total aluminum	mg/L	-	6	0.1480	0.1090	Feb	6.7000	Sep
Dissolved aluminum	mg/L	0.05	6	0.00515	0.00405	Feb	0.01790	Sep
Total arsenic	mg/L	0.005	6	0.00037	0.00033	Mar	0.00149	Sep
Total boron	mg/L	1.5-29	6	0.0256	0.0250	Mar	0.0391	Nov
Total molybdenum	mg/L	0.073	6	0.00011	0.00008	Sep	0.00014	Nov
Total mercury (ultra-trace)	ng/L	5-13	6	0.62	0.53	Dec	**5.99**	Sep
Total methyl mercury	ng/L	1-2	1	0.521	0.521	Sep	0.521	Sep
Total strontium	mg/L	-	6	0.1009	0.0786	Dec	0.1260	Nov
Total hydrocarbons								
BTEX	mg/L	-	6	<0.10	<0.01	Sep	<0.10	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.10	<0.01	Sep	<0.10	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<**0.250**	<0.005	Sep	<**0.250**	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.25	<0.02	Sep	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.25	<0.02	Sep	<0.25	-
Naphthenic acids	mg/L	-	6	0.26	0.08	Jan	0.62	Feb
Oilsands extractable acids	mg/L	-	6	0.80	0.30	Dec	1.60	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	0.74	<0.59	Nov, Dec	18.20	Sep
Total dibenzothiophenes[c]	ng/L	-	6	8.17	8.17	-	17.89	Sep
Total PAHs[c]	ng/L	-	6	123	111	Mar	199	Sep
Total Parent PAHs[c]	ng/L	-	6	22.6	8.6	Mar	46.3	Sep
Total Alkylated PAHs[c]	ng/L	-	6	102	98	Nov, Dec	153	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	1	<0.001	<0.001	-	**0.009**	Sep
Sulphide	mg/L	0.0019	3	**0.0021**	<0.0015	Jan	**0.0120**	Sep
Dissolved iron	mg/L	0.3	6	**0.4020**	**0.3590**	Dec	**0.6050**	Feb
Total lead	mg/L	0.001[b]	1	0.000069	0.000051	Mar	**0.00317**	Sep
Total zinc	mg/L	0.03	1	0.007	0.005	Dec	**0.139**	Feb

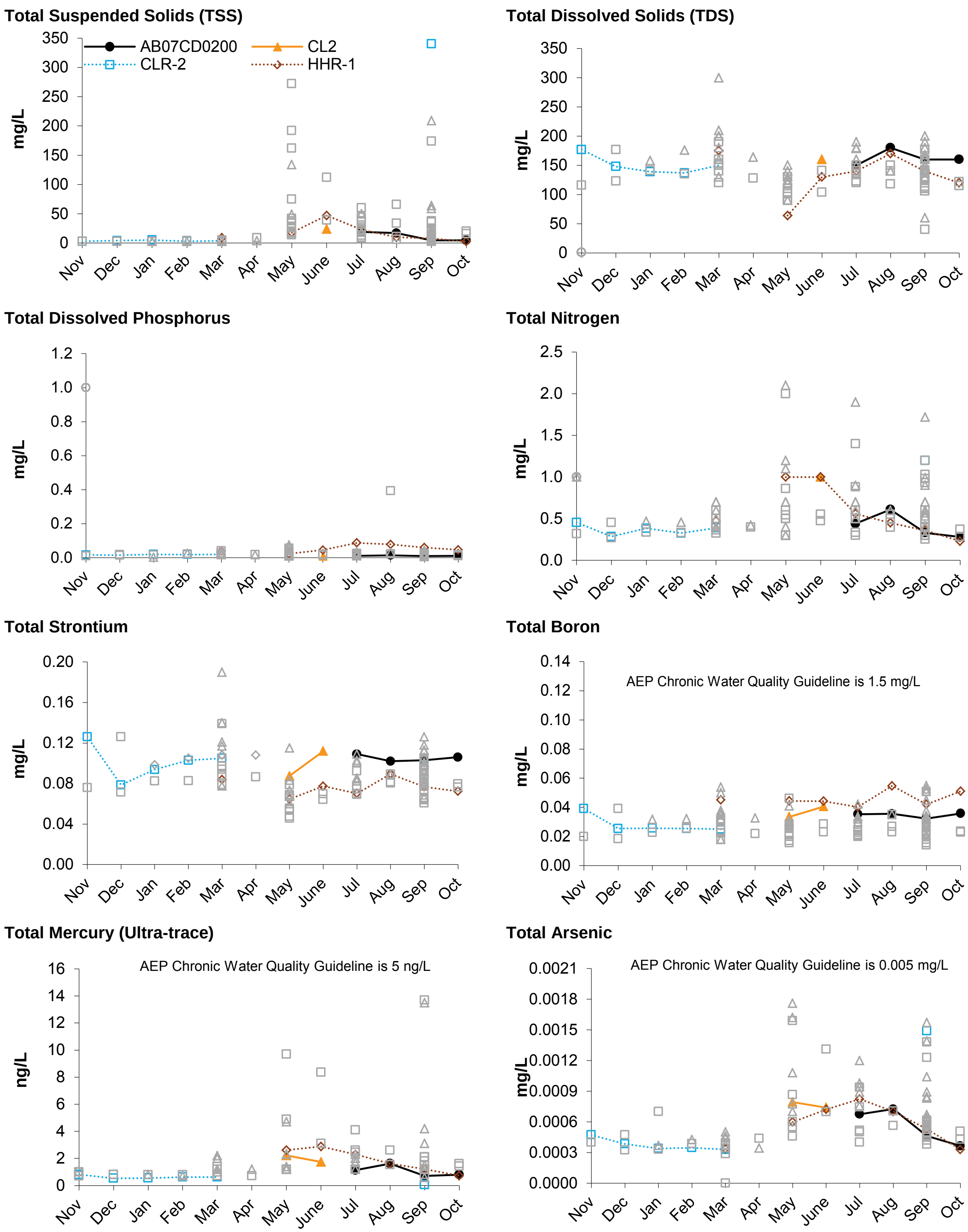
Values in **bold** are above guideline.
[a] Sources for all guidelines are outlined in Table 3.2-1.
[b] based on actual hardness level
[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.
[d] n value refers to number of exceedances in 2015.

Table 5.9-5 Monthly concentrations of water quality measurement endpoints, High Hills River (*baseline* station HHR-1), March to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	7	8.02	7.80	Mar	8.25	Aug
Total suspended solids	mg/L	-	7	10.0	2.7	Oct	47.0	Jun
Conductivity	µS/cm	-	7	220	180	Jun	279	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	7	0.047	0.024	May	0.088	Jul
Total nitrogen	mg/L	-	7	0.47	0.23	Oct	<1.00	May ,Jun
Nitrate+nitrite	mg/L	3-124	7	<0.005	<0.003	May	0.083	Mar
Dissolved organic carbon	mg/L	-	7	11.0	5.4	Mar	13.0	Aug
Ions								
Sodium	mg/L	-	7	8.1	7.2	Jul	9.4	Aug
Calcium	mg/L	-	7	27.0	22.0	Jun	33.3	Mar
Magnesium	mg/L	-	7	8.30	7.10	Jun	10.90	Mar
Potassium	mg/L	-	7	0.74	0.63	Oct	1.30	May
Chloride	mg/L	120-640	7	<1.0	<0.5	Mar	1.4	Aug
Sulphate	mg/L	309[b]	7	3.8	1.9	Sep	6.9	Jun
Total dissolved solids	mg/L	-	7	140	64	May	175	Mar
Total alkalinity	mg/L	20 (min)	7	110	91	Jun	152	Mar
Selected metals								
Total aluminum	mg/L	-	7	0.3770	0.1290	Oct	1.9500	Jun
Dissolved aluminum	mg/L	0.05	7	0.00951	0.00320	Mar	0.02080	Jun
Total arsenic	mg/L	0.005	7	0.00060	0.00033	Oct	0.00082	Jul
Total boron	mg/L	1.5-29	7	0.0444	0.0402	Jul	0.0547	Aug
Total molybdenum	mg/L	0.073	7	0.00035	0.00025	Mar	0.00038	Jul
Total mercury (ultra-trace)	ng/L	5-13	7	1.61	0.72	Oct	2.88	Jun
Total methyl mercury	ng/L	1-2	6	0.125	0.053	Oct	0.175	Aug
Total strontium	mg/L	-	7	0.0768	0.0646	May	0.0895	Aug
Total hydrocarbons								
BTEX	mg/L	-	7	<0.01	<0.01	-	<0.10	-
Fraction 1 (C6-C10)	mg/L	0.15	7	<0.01	<0.01	-	<0.10	-
Fraction 2 (C10-C16)	mg/L	0.11	7	<0.005	<0.005	-	**<0.250**	Mar
Fraction 3 (C16-C34)	mg/L	-	7	<0.02	<0.02	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	7	<0.02	<0.02	-	<0.25	-
Naphthenic acids	mg/L	-	7	0.31	<0.08	Oct	0.64	May
Oilsands extractable acids	mg/L	-	7	1.1	<0.1	Oct	1.7	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	7	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	7	0.92	<0.59	Oct	4.14	Jul
Total dibenzothiophenes[c]	ng/L	-	7	8.17	0.17	-	8.50	Aug
Total PAHs[c]	ng/L	-	7	126.2	125	May	133.0	Jul
Total Parent PAHs[c]	ng/L	-	7	22.9	22.2	May	24.9	Jun
Total Alkylated PAHs[c]	ng/L	-	7	103.2	102.6	May	110.2	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.0046**	<0.0010	Mar	**0.0120**	Jul
Sulphide	mg/L	0.0019	4	**0.0039**	<0.0015	Mar	**0.0065**	Jun
Dissolved iron	mg/L	0.3	5	**0.3660**	0.2420	Mar	**0.5490**	Aug
Total chromium	mg/L	0.001	1	0.00031	0.00003	Oct	**0.00159**	Jun

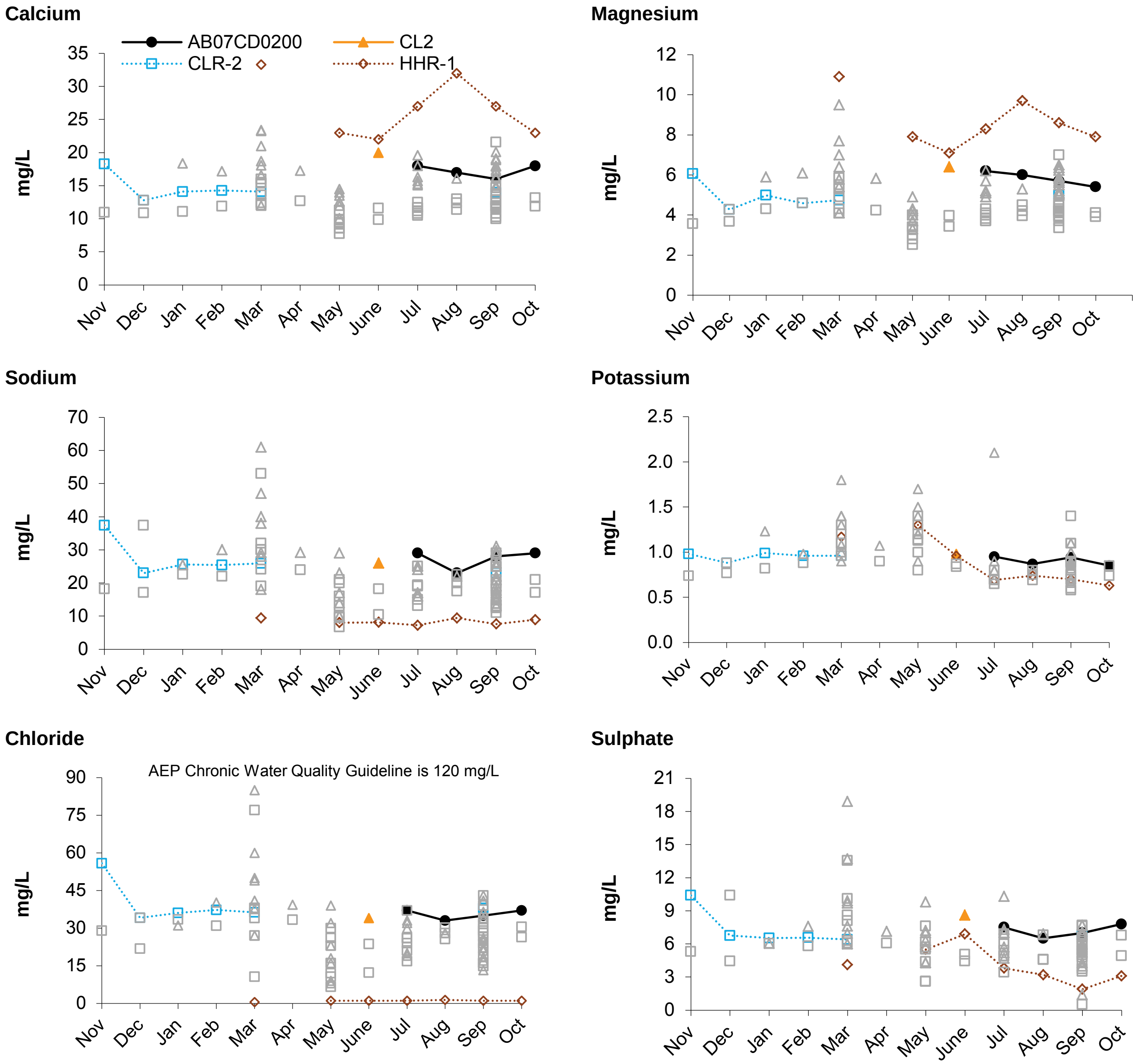
Values in **bold** are above guideline.
[a] Sources for all guidelines are outlined in Table 3.2-1.
[b] based on actual hardness level
[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.
[d] n value refers to number of exceedances in 2015.

Figure 5.9-5 Selected water quality measurement endpoints in the Clearwater River watershed (monthly data) in the 2015 WY.



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.9-5 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.9-6 Concentrations of water quality measurement endpoints, Clearwater River at Draper (*test* station AB07CD0200), fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value
Physical variables			
pH	pH units	6.5-9.0	8.05
Total suspended solids	mg/L	-	4.7
Conductivity	µS/cm	-	260
Nutrients			
Total dissolved phosphorus	mg/L	-	0.01
Total nitrogen	mg/L	-	0.33
Nitrate+nitrite	mg/L	3-124	<0.005
Dissolved organic carbon	mg/L	-	6.6
Ions			
Sodium	mg/L	-	28
Calcium	mg/L	-	16
Magnesium	mg/L	-	5.7
Potassium	mg/L	-	0.94
Chloride	mg/L	120-640	35
Sulphate	mg/L	218[b]	7
Total dissolved solids	mg/L	-	160
Total alkalinity	mg/L	20 (min)	64
Selected metals			
Total aluminum	mg/L	-	0.132
Dissolved aluminum	mg/L	0.05	0.003
Total arsenic	mg/L	0.005	0.00046
Total boron	mg/L	1.5-29	0.032
Total molybdenum	mg/L	0.073	0.0002
Total mercury (ultra-trace)	ng/L	5-13	0.71
Total methyl mercury	ng/L	1-2	0.046
Total strontium	mg/L	-	0.103
Total hydrocarbons			
BTEX	mg/L	-	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02
Naphthenic acids	mg/L	-	0.1
Oilsands extractable acids	mg/L	-	0.8
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	1,000	5.8
Retene	ng/L	-	1.0
Total dibenzothiophenes	ng/L	-	6.7
Total PAHs[c]	ng/L	-	40.0
Total Parent PAHs[c]	ng/L	-	9.9
Total Alkylated PAHs[c]	ng/L	-	30.1
Other variables that exceeded Alberta guidelines in fall 2015			
Sulphide	mg/L	0.0019	**0.0023**

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.9-7 Concentrations of water quality measurement endpoints at benthic invertebrate communities reach, upper Clearwater River (*baseline* station CLR-2), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	2011-2014 (fall data only)			
				n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.65	14	7.9	7.2	8.1
Total suspended solids	mg/L	-	340	14	17	3	174
Conductivity	µS/cm	-	250	14	195	138	253
Nutrients							
Total dissolved phosphorus	mg/L	-	0.011	14	0.018	0.008	0.026
Total nitrogen	mg/L	-	1.2	14	0.45	0.25	1.2
Nitrate+nitrite	mg/L	3-124	0.0051	14	<0.100	<0.054	<0.100
Dissolved organic carbon	mg/L	-	5.5	14	8.15	6.0	24.2
Ions							
Sodium	mg/L	-	23	14	18.0	11.0	29.0
Calcium	mg/L	-	14	14	12.0	10.0	21.6
Magnesium	mg/L	-	5.0	14	4.2	3.4	7.0
Potassium	mg/L	-	0.89	14	0.84	0.50	1.40
Chloride	mg/L	120-640	38	14	27.3	14.8	43.0
Sulphate	mg/L	309[b]	6.8	14	5.4	<0.5	7.7
Total dissolved solids	mg/L	-	140	14	128	40	177
Total alkalinity	mg/L	20 (min)	60	14	49	39	58
Selected metals							
Total aluminum	mg/L	-	6.70	14	0.322	0.102	5.00
Dissolved aluminum	mg/L	0.05	0.018	14	0.008	0.003	**0.185**
Total arsenic	mg/L	0.005	0.0015	14	0.0005	0.0004	0.0014
Total boron	mg/L	1.5-29	0.030	14	0.024	0.014	0.051
Total molybdenum	mg/L	0.073	0.000082	14	0.00012	0.00009	0.00020
Total mercury (ultra-trace)	ng/L	5-13	**5.99**	12	<1.2	0.8	**13.7**
Total methyl mercury	ng/L	1-2	0.521	-	-	-	-
Total strontium	mg/L	-	0.099	14	0.082	0.061	0.103
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.26	4	0.14	0.02	0.39
Oilsands extractable acids	mg/L	-	1.0	4	0.53	0.19	1.20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	18.2	4	5.840	<0.93	37.90
Total dibenzothiophenes	ng/L	-	17.9	4	6.258	4.134	36.18
Total PAHs[c]	ng/L	-	199.5	4	132.6	75.1	318.2
Total Parent PAHs[c]	ng/L	-	46.3	4	20.84	14.28	29.90
Total Alkylated PAHs[c]	ng/L	-	153.2	4	111.8	60.85	288.3
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.4**	13	0.279	0.0955	**0.672**
Total lead	mg/L	0.001	**0.00317**	12	0.000209	0.000083	**0.00292**
Sulphide	mg/L	0.0019	**0.012**	13	**0.004**	**0.002**	**0.013**
Total phenols	mg/L	0.004	**0.0094**	13	0.0039	0.001	**0.007**

Values in **bold** are above guideline; underlined values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.9-8 Concentrations of water quality measurement endpoints, High Hills River (*baseline* station HHR-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	2011-2014 (fall data only) n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.12	4	8.2	8.0	8.4
Total suspended solids	mg/L	-	8	4	23	6.0	55
Conductivity	µS/cm	-	220	4	254	160	266
Nutrients							
Total dissolved phosphorus	mg/L	-	0.06	4	0.053	0.041	0.069
Total nitrogen	mg/L	-	0.36	4	0.416	0.344	0.811
Nitrate+nitrite	mg/L	3-124	<0.005	4	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	11.0	4	12.0	9.1	26.5
Ions							
Sodium	mg/L	-	7.6	4	9.1	5.8	9.3
Calcium	mg/L	-	27	4	32.1	20.9	34.1
Magnesium	mg/L	-	8.6	4	9.58	6.07	10.5
Potassium	mg/L	-	0.70	4	0.77	0.61	0.94
Chloride	mg/L	120-640	<u><1.00</u>	4	<0.50	<0.50	0.62
Sulphate	mg/L	309[b]	<u>1.9</u>	4	3.27	2.07	4.40
Total dissolved solids	mg/L	-	140	4	163	114	174
Total alkalinity	mg/L	20 (min)	110	4	132	81	135
Selected metals							
Total aluminum	mg/L	-	0.283	4	0.84	0.28	3.57
Dissolved aluminum	mg/L	0.05	0.008	4	0.013	0.006	**0.055**
Total arsenic	mg/L	0.005	0.00053	4	0.00076	0.00052	0.00094
Total boron	mg/L	1.5-29	0.042	4	0.056	0.041	0.058
Total molybdenum	mg/L	0.073	<u>0.00033</u>	4	0.00025	0.00024	0.00027
Total mercury (ultra-trace)	ng/L	5-13	1.210	4	2.40	0.70	4.80
Total methyl mercury	ng/L	1-2	0.119	-	-	-	-
Total strontium	mg/L	-	0.077	4	0.089	0.058	0.098
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.40</u>	4	0.18	0.03	0.25
Oilsands extractable acids	mg/L	-	<u>1.10</u>	4	0.40	0.28	0.50
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	13.5	4	8.84	7.210	<15.16
Retene	ng/L	-	<u>0.8</u>	4	3.230	0.910	9.340
Total dibenzothiophenes	ng/L	-	8.2	4	6.258	4.262	35.32
Total PAHs	ng/L	-	126.2	4	130.9	75.9	236.5
Total Parent PAHs	ng/L	-	<u>23.1</u>	4	19.00	13.26	22.93
Total Alkylated PAHs	ng/L	-	103.2	4	109.8	62.60	217.7
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.4**	3	**0.399**	0.25	**0.572**
Sulphide	mg/L	0.0019	<u>**0.0046**</u>	2	**0.0033**	**0.0033**	**0.0033**
Total phenols	mg/L	0.004	<u>**0.0092**</u>	2	**0.005**	**0.005**	**0.0086**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.9-6 Piper diagram of fall ion concentrations in the Clearwater River watershed.

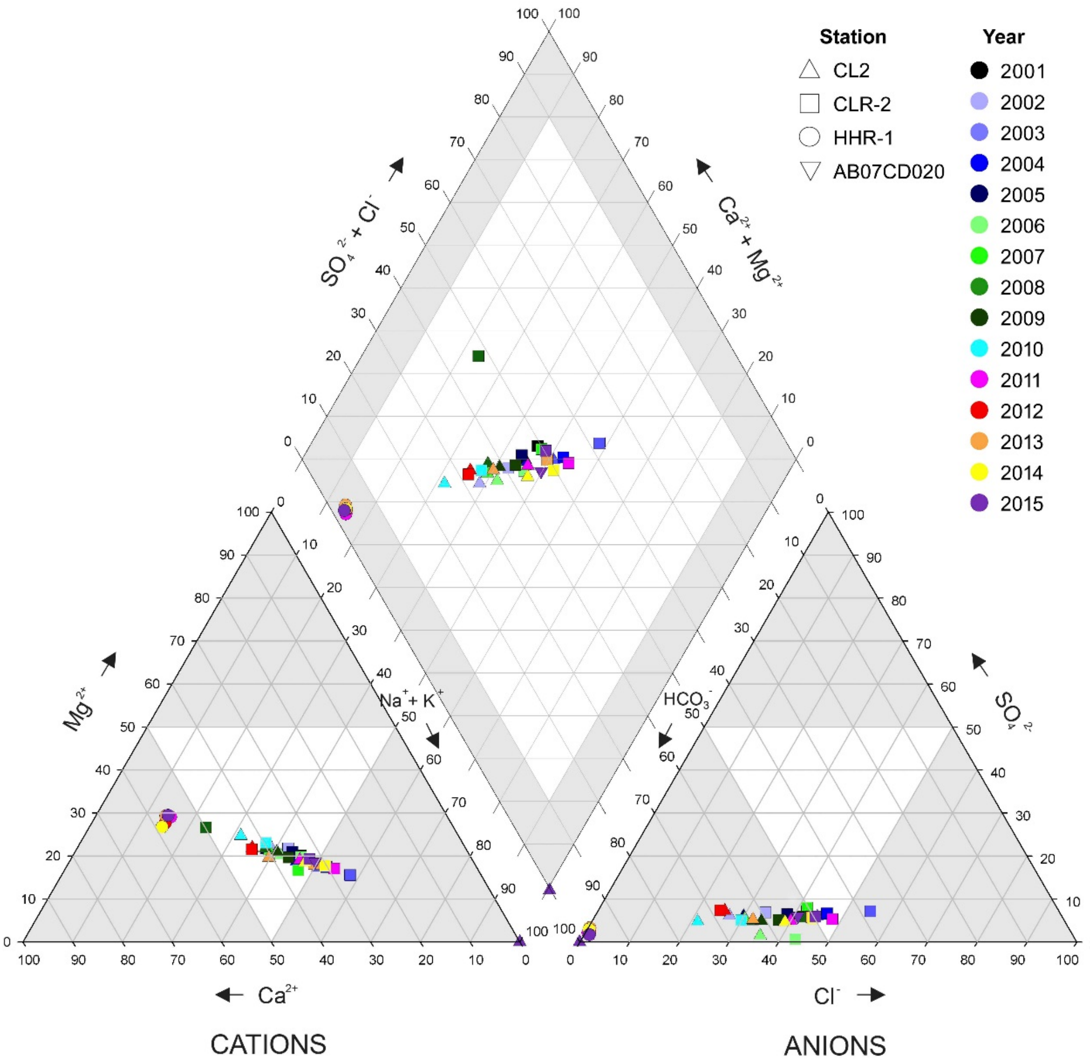


Table 5.9-9 Water quality guideline exceedances in the Clearwater River watershed, 2015 WY.

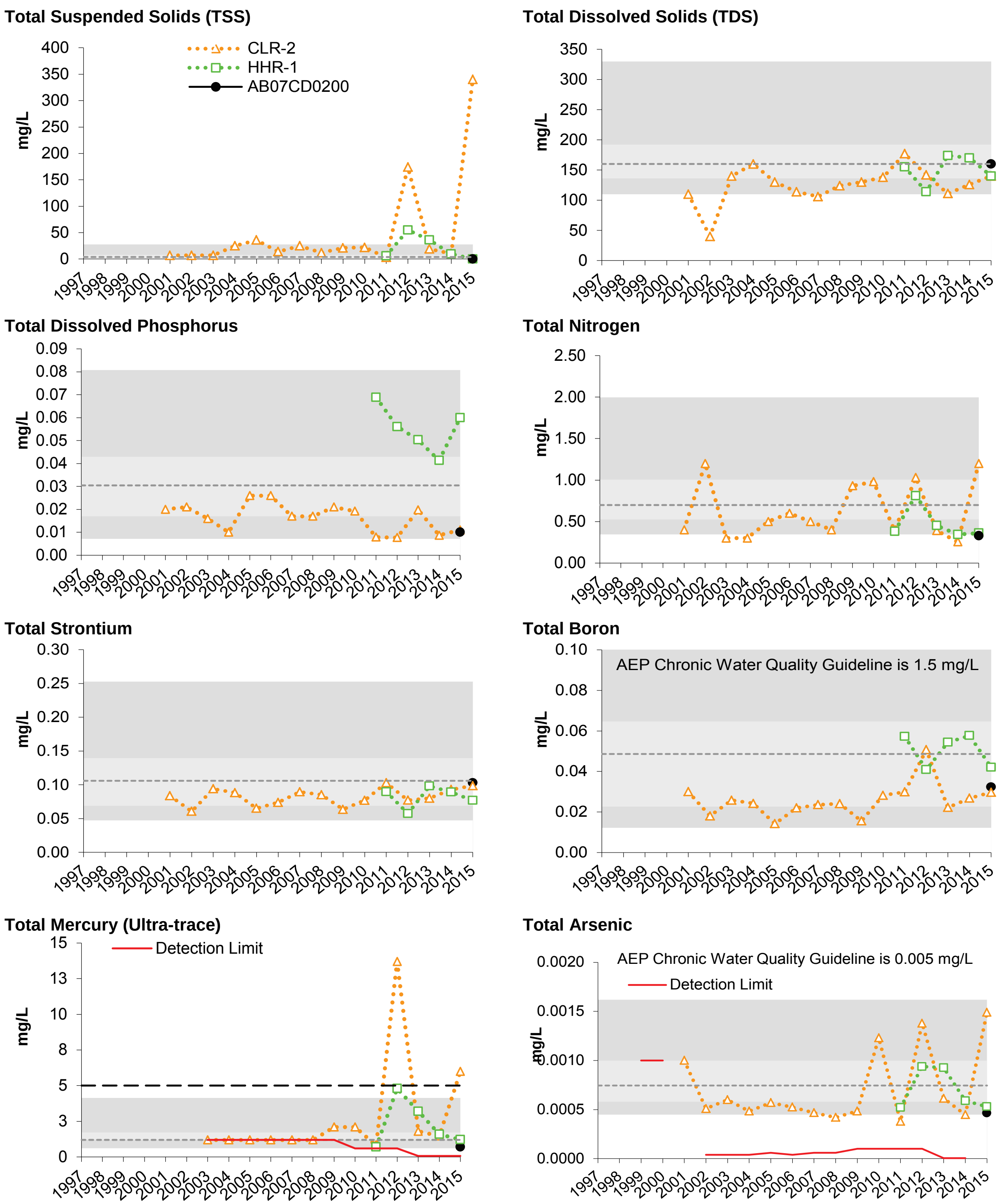
Variable	Units	Guideline[a]	November	December	January	February	March	May	June	July	August	September	October
Lower Clearwater River (CL2)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0048**	-	-	-	-
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.0041**	-	-	-	-
Dissolved iron	mg/L	0.3	-	-	-	-	-	**0.493**	0.166	-	-	-	-
Clearwater River between CL2 and CLR-2 (AB07CD0200)													
Total phenols	mg/L	0.004	-	-	-	-	-	-	-	0.011	**0.0088**	-	**0.0066**
Sulphide	mg/L	0.0019	-	-	-	-	-	-	-	**0.0023**	**0.0023**	**0.0023**	<0.0019
Upper Clearwater River (CLR-2)													
Total phenols	mg/L	0.004	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	-	-	-	-	**0.0094**	-
Sulphide	mg/L	0.0019	**0.0025**	0.0016	<0.0015	**0.0032**	0.0017	-	-	-	-	**0.012**	-
Dissolved iron	mg/L	0.3	**0.401**	**0.359**	**0.391**	**0.605**	**0.439**	-	-	-	-	**0.403**	-
Total mercury	ng/L	5-13	0.81	0.53	0.55	0.62	0.62	-	-	-	-	**5.99**	-
Total lead	mg/L	0.001-0.002	0.000074	0.000073	0.000061	0.000066	0.000051	-	-	-	-	**0.00317**	-
Total zinc	mg/L	0.03	0.007	0.005	0.007	0.139	0.007	-	-	-	-	0.0161	-
High Hills River (HHR-1)													
Total phenols	mg/L	0.004	-	-	-	-	<0.0010	0.0036	0.0028	**0.012**	**0.0058**	**0.0092**	**0.0046**
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015	**0.0024**	**0.0065**	**0.0039**	**0.0062**	**0.0046**	<0.0019
Dissolved iron	mg/L	0.3	-	-	-	-	0.242	**0.366**	**0.361**	**0.451**	**0.549**	**0.391**	**0.327**

Values in **bold** are above the guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

“-“ = not sampled.

Figure 5.9-7 Concentrations of selected water quality measurement endpoints in the Clearwater River watershed (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



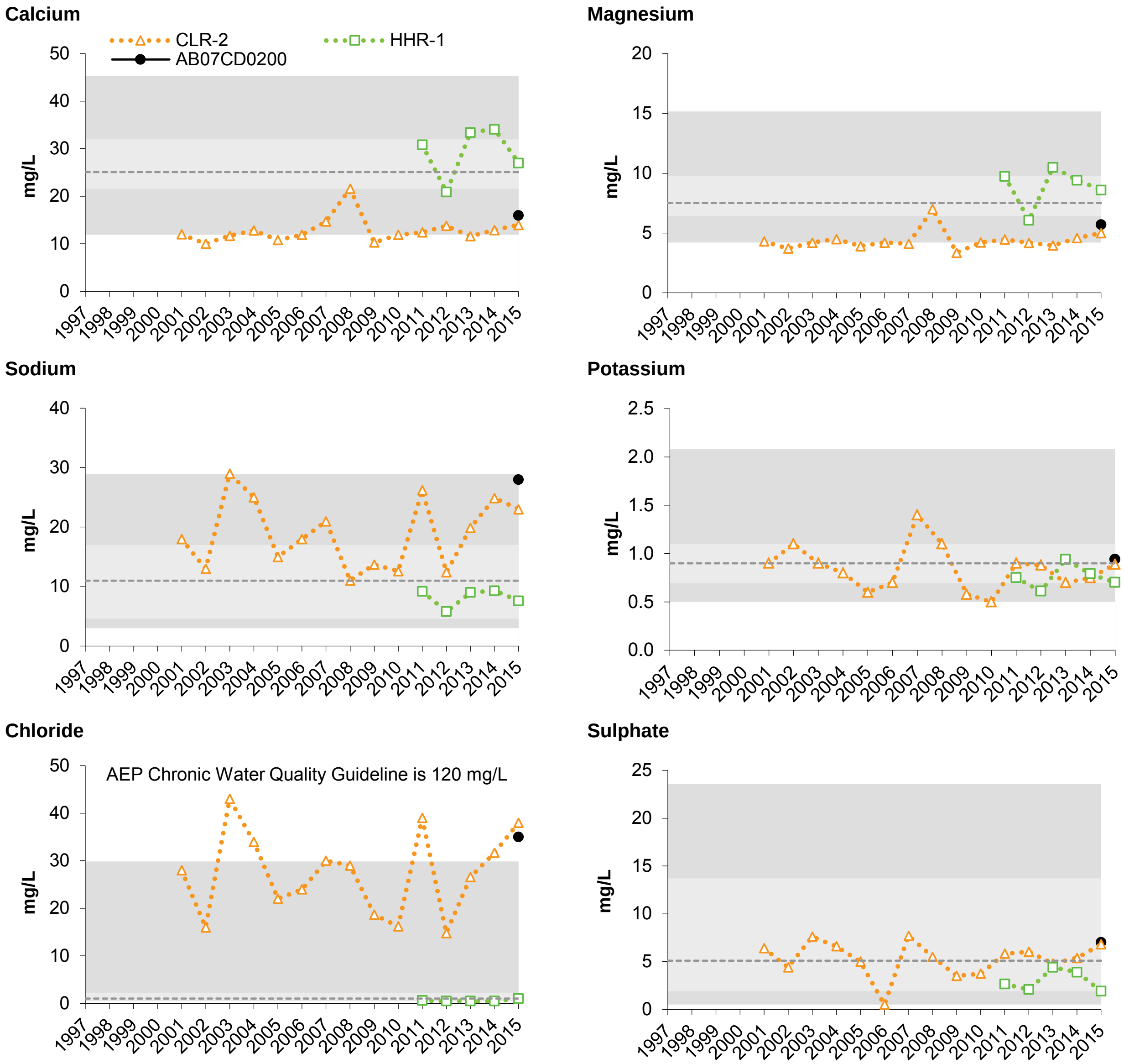
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.9-7 (Cont'd.)



Non-detectable values are shown at the detection limit.
– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.
Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.9-10 Average habitat characteristics of the benthic invertebrate community sampling locations of the Clearwater River (*test* reach CLR-D1 and *baseline* reach CLR-D2), fall 2015.

Variable	Units	CLR-D1 Lower *Test* Reach	CLR-D2 Upper *Baseline* Reach
Sample date	-	Sept. 12, 2015	Sept. 13, 2015
Habitat	-	Depositional	Depositional
Water depth	m	0.85	0.25
Current velocity	m/s	0.49	0.25
Field water quality			
Dissolved oxygen (DO)	mg/L	7.6	8.7
Conductivity	µS/cm	263	209
pH	pH units	7.75	7.17
Water temperature	°C	13.6	12.9
Sediment composition			
Sand	%	86.3	84.3
Silt	%	10.5	10.5
Clay	%	3.1	5.2
Total organic carbon (TOC)	%	0.80	0.49

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.9-11 Summary of major taxon abundances and measurement endpoints for benthic invertebrate communities at the Clearwater River (*test* reach CLR-D1 and *baseline* reach CLR-D2).

Taxon	Percent Major Taxa Enumerated in Each Year					
	Test Reach CLR-D1			*Baseline* Reach CLR-D2		
	2001	2002 to 2014	2015	2001	2002 to 2014	2015
Hydra	-	-	-	-	-	<1
Nematoda	<1	<1 to 17	4	1	<1 to 8	17
Naididae	3	<1 to 5	8	21	<1 to 10	4
Tubificidae	27	5 to 31	8	26	<1 to 45	21
Enchytraeidae	-	0 to 2	-	<1	0 to 1	-
Lumbriculidae	-	0 to <1	-	-	0 to <1	-
Erpobdellidae	-	-	-	-	0 to <1	-
Glossiphoniidae	<1	-	-	<1	0 to <1	-
Hydracarina	<1	0 to <1	-	<1	0 to <1	-
Amphipoda	-	-	-	<1	0 to <1	<1
Gastropoda	<1	0 to <1	-	1	0 to <1	<1
Bivalvia	20	0 to 7	1	11	<1 to 33	10
Ceratopogonidae	1	<1 to 6	3	1	<1 to 4	1
Chironomidae	38	51 to 87	61	34	27 to 87	45
Dolichopodidae	-	-	-	-	0 to <1	-
Diptera (misc.)	<1	0 to 2	<1	<1	0 to 2	1
Coleoptera	-	0 to <1	-	<1	0 to <1	-
Ephemeroptera	<1	<1 to 2	13	1	<1 to 5	1
Odonata	1	0 to 1	<1	<1	0 to 2	<1
Plecoptera	-	0 to 1	-	<1	0 to 1	-
Trichoptera	-	0 to 1	-	<1	0 to 2	<1
Megaloptera	-	-	-	<1	-	-
Heteroptera	<1	-	-	-	0 to <1	-
Lepidoptera	-	0 to <1	-	-	-	-
Benthic Invertebrate Community Measurement Endpoints						
Total abundance per sample	362	34 to 229	218	415	113 to 657	545
Richness	14	6 to 15	6	10	3 to 15	11
Equitability	0.38	0.44 to 0.81	0.60	0.31	0.31 to 0.60	0.40
% EPT	1	<1 to 8	14	0	<1 to 5	2

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Table 5.9-12 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at the lower Clearwater River (*test* reach CLR-D1).

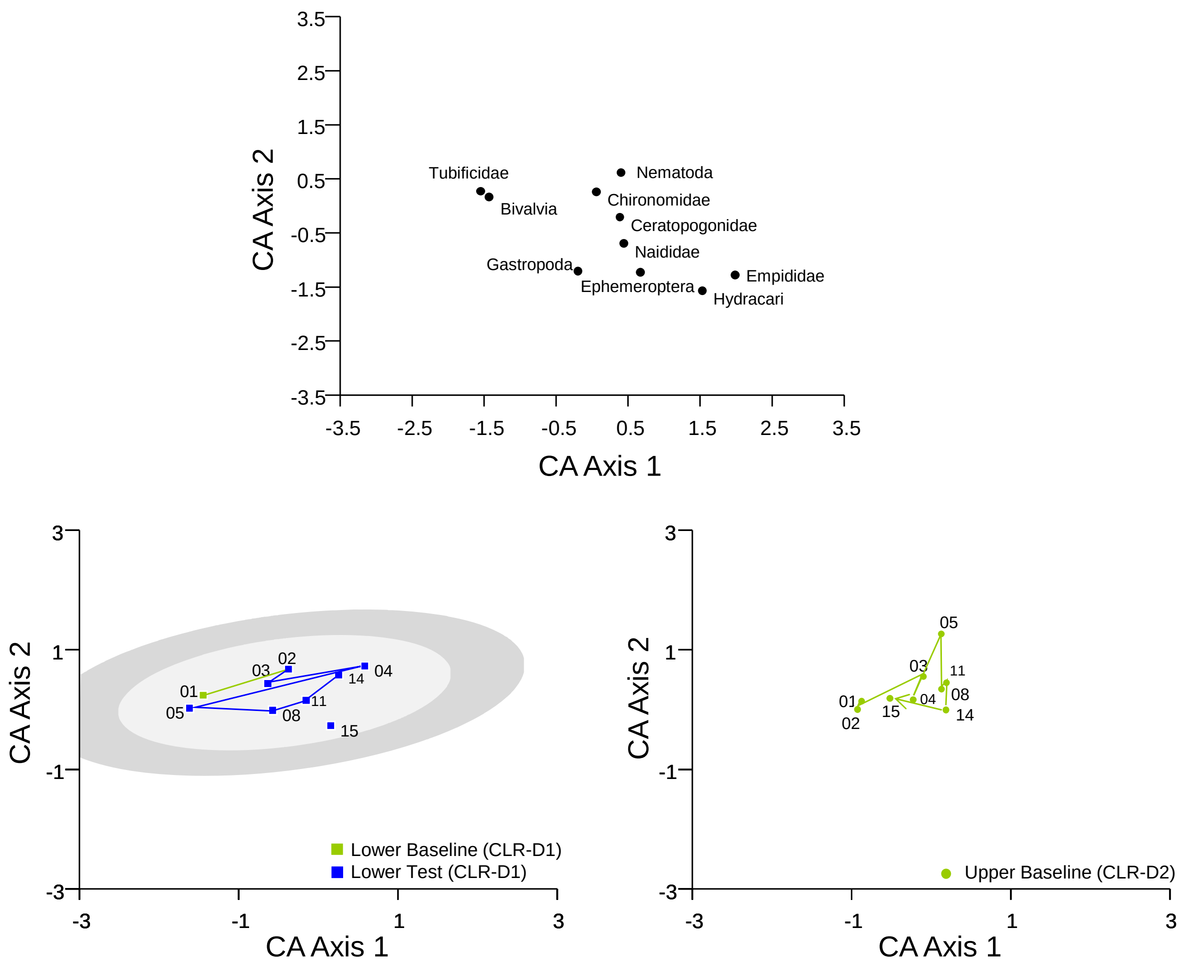
Measurement Endpoint	P-value							Variance Explained (%)							Nature of Change(s)
	Control vs. Impact	Before vs. After	BACI	Time Trend in *Test* Period	Difference in Time Trend (*test*)	2015 vs. *Baseline*	2105 vs. Previous Years	Control vs. Impact	Before vs. After	BACI	Time Trend in *Test* Period	Difference in Time Trend (*test*)	2015 vs. *Baseline*	2105 vs. Previous Years	
Log of Abundance	**0.029**	**0.002**	0.916	0.434	0.952	0.310	0.713	8	16	0	1	0	2	0	Abundance is significantly higher in the upper *baseline* reach and higher during the *baseline* period of the lower reach.
Log of Richness	**0.010**	**0.006**	0.632	0.656	0.386	**0.008**	0.211	7	8	0	0	1	8	2	Richness is significantly higher in the upper *baseline* reach and was higher during the *baseline* period of the lower reach.
Equitability	**0.002**	0.005	0.834	0.335	0.814	0.090	0.891	19	16	0	2	0	6	0	Equitability is significantly higher in the lower *test* reach.
Log of EPT	0.124	0.069	0.341	0.083	0.542	0.053	**0.008**	7	10	3	9	1	11	21	EPT taxa was significantly higher in 2015 than the mean of previous years.
CA Axis 1	**0.011**	**<0.001**	0.329	**0.031**	0.795	0.293	0.072	10	30	2	7	0	2	5	CA Axis 1 scores were higher in the upper *baseline* reach and higher during the *baseline* period in the lower reach. Axis scores decreased at a greater rate in the upper reach.
CA Axis 2	0.687	**0.482**	0.649	0.087	0.260	0.068	0.065	1	2	1	12	5	14	14	CA Axis 2 scores were higher in the upper *baseline* reach.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

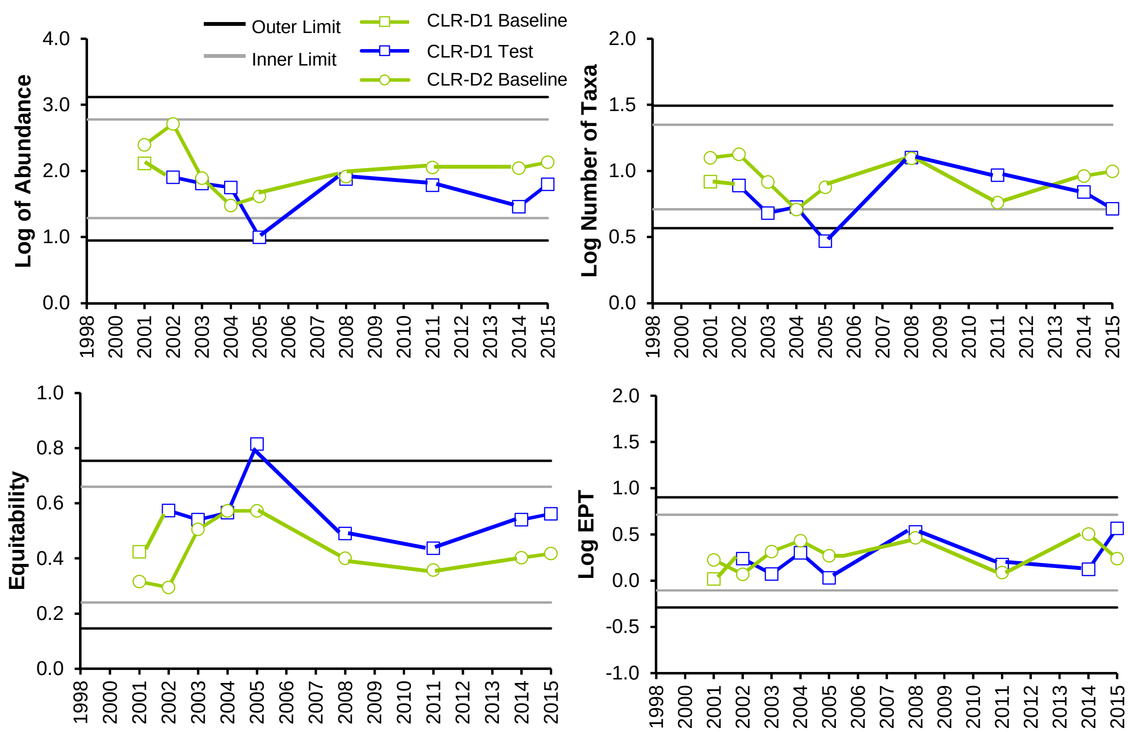
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.9-8 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower and upper reaches of the Clearwater River (*test* reach CLR-D1 and *baseline* reach CLR-D2).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel for *test* reach CLR-D1 are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.9-9 Variation in benthic invertebrate community measurement endpoints at lower *test* reach CLR-D1 and upper *baseline* reach CLR-D2 in the Clearwater River relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years at *test* reach ELR-D1 (2003 to 2014).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.9-13 Average habitat characteristics of the benthic invertebrate community sampling location in the High Hills River (*baseline* reach HHR-E1), fall 2015.

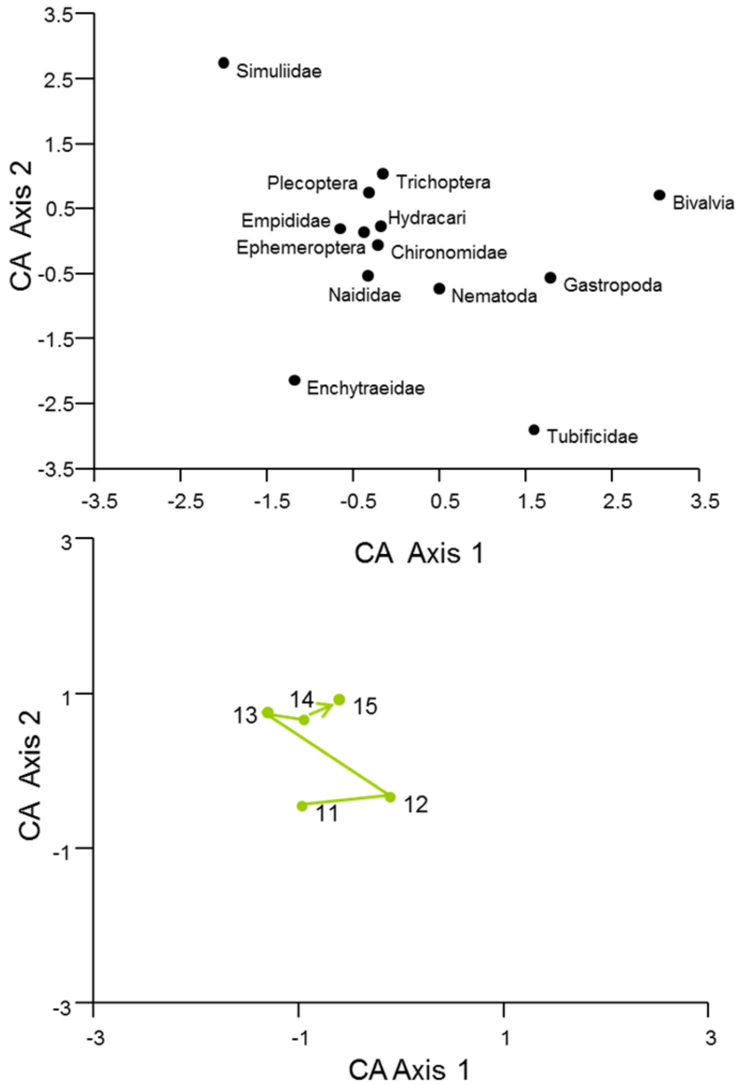
Variable	Units	HHR-E1 *Baseline* reach
Sample date	-	Sept. 9, 2015
Habitat	-	Erosional
Water depth	m	0.3
Current velocity	m/s	1.2
Field water quality		
Dissolved oxygen	mg/L	10.5
Conductivity	µS/cm	205
pH	pH units	8.3
Water temperature	°C	9.5

Table 5.9-14 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community in High Hills River (*baseline* reach HRR-E1), fall 2015.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach HHR-E1		
	2011	2012 to 2014	2015
Nematoda	<1	<1 to 2	-
Naididae	42	10 to 50	1
Tubificidae	-	0 to 2	-
Enchytraeidae	7	1 to 5	-
Hydracarina	5	1 to 5	7
Gastropoda	<1	0 to 4	<1
Bivalvia	-	0 to <1	-
Ceratopogonidae	-	<1 to 3	<1
Chironomidae	13	11 to 23	3
Dolichopodidae	-	0 to <1	-
Psychodidae	<1	-	-
Diptera (misc.)	3	3 to 8	7
Coleoptera	<1	0 to <1	<1
Ephemeroptera	19	14 to 36	47
Odonata	<1	<1	<1
Plecoptera	1	2 to 5	4
Trichoptera	6	7 to 9	30
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	1219	362 to 899	951
Richness	30	28 to 33	26
Equitability	0.17	0.14 to 0.30	0.25
% EPT	27	28 to 46	33

Note: All 2015 benthic invertebrate community measurement endpoints, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). All percent abundances of taxa are based on original counts. % EPT as an index in 2015 does not equal the observed percentages in the kick sample, because the index value was adjusted down to be equivalent to what would have been expected with a Neil-Hess cylinder.

Figure 5.9-10 Ordination (Correspondence Analysis) of benthic invertebrate communities in the High Hills River (*baseline* reach HHR-E1).

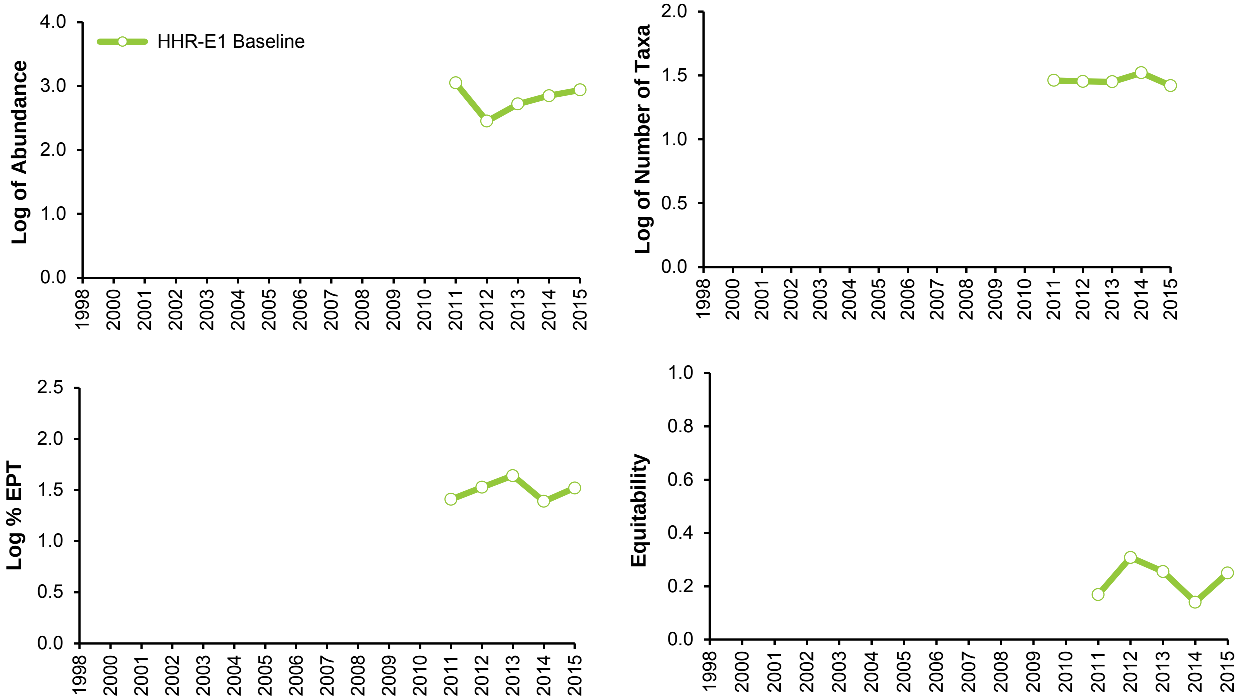


Notes:

The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances at erosional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.9-11 Variation in benthic invertebrate community measurement endpoints at *baseline* reach HHR-E1 in the High Hills River.



Notes:

Abundance, richness, and %EPT data were log10(x+1) transformed before the average was calculated.

Measurement endpoints for *baseline* reach HHR-E1 in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Table 5.9-15 Concentrations of selected sediment quality measurement endpoints, mouth of Clearwater River (*test* station CLR-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2001-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	8.5	6	0.7	2.0	33.0
Silt	%	-	42.8	6	0.7	7.0	29.0
Sand	%	-	48.7	6	38.0	90.0	100.0
Total organic carbon	%	-	1.98	6	0.10	0.21	1.00
Total hydrocarbons							
BTEX	mg/kg	-	<20	3	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	3	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	72	3	<5	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	**540**	3	<5	<20	26
Fraction 4 (C34-C50)	mg/kg	2800[1]	284	3	<7	<20	22
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0015	6	0.0002	0.0009	0.0025
Retene	mg/kg	-	0.1060	6	0.0009	0.0090	0.0473
Total dibenzothiophenes	mg/kg	-	0.7660	6	0.0097	0.0663	0.5204
Total PAHs	mg/kg	-	2.7306	6	0.0705	0.3653	1.8128
Total Parent PAHs	mg/kg	-	0.0853	6	0.0039	0.0290	0.0871
Total Alkylated PAHs	mg/kg	-	2.6453	6	0.0666	0.3363	1.7257
Predicted PAH toxicity[3]	H.I.	1.0	0.8874	6	0.1663	0.6195	**30.9767**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	100	3	50	94	100
Chironomus growth - 10d	mg/organism	-	1.65	3	1.10	1.48	3.53
Hyalella survival - 14d	# surviving	-	90	3	70	90	94
Hyalella growth - 14d	mg/organism	-	0.20	3	0.10	0.34	0.39

Values in **bold** are above guideline; underlined values are outside of historical range.

Values underlined indicate concentrations outside the range of historical observations.

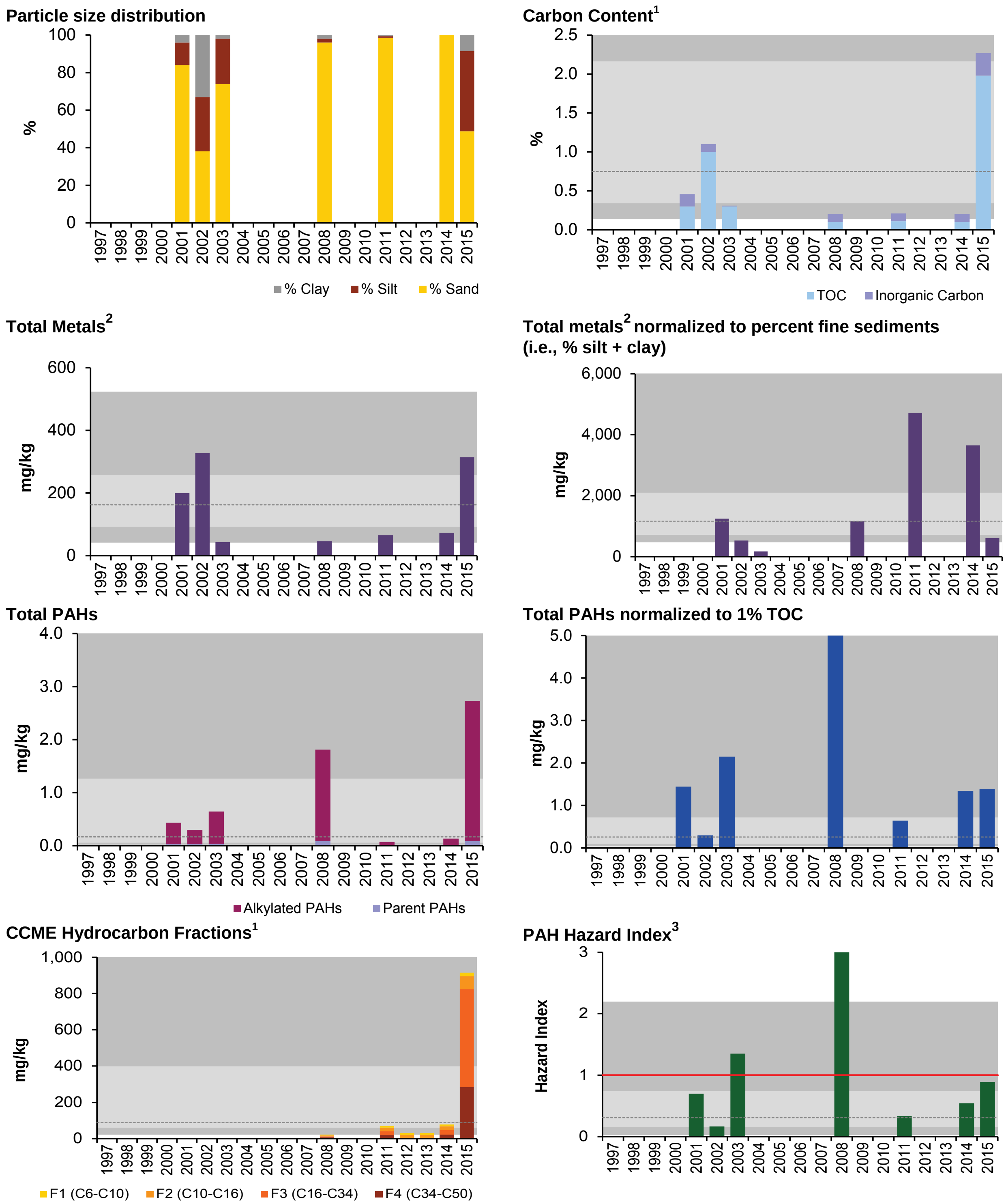
ns = not sampled in 2004-2007, 2009-2010, 2012, or 2013

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.9-12 Variation in selected sediment quality measurement endpoints, Clearwater River (*test* station CLR-D1) relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.9-16 Concentrations of selected sediment quality measurement endpoints, Clearwater River upstream of Christina River (*baseline* station CLR-D2), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2001-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4.6	6	0.4	2.0	12.0
Silt	%	-	12.7	6	0.2	1.5	35.0
Sand	%	-	82.7	6	52.0	97.0	99.5
Total organic carbon	%	-	0.56	6	<0.10	0.19	1.60
Total hydrocarbons							
BTEX	mg/kg	-	<10	3	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	3	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	3	<20	<20	65
Fraction 3 (C16-C34)	mg/kg	300[1]	27	3	<20	<20	**740**
Fraction 4 (C34-C50)	mg/kg	2800[1]	<20	3	<20	<20	450
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0012	6	<0.0001	0.0011	0.0020
Retene	mg/kg	-	<u>0.0080</u>	6	0.0002	0.0022	0.0040
Total dibenzothiophenes	mg/kg	-	<u>0.0058</u>	6	0.0013	0.0017	0.0046
Total PAHs	mg/kg	-	0.0849	6	0.0119	0.0228	0.2007
Total Parent PAHs	mg/kg	-	0.0129	6	0.0011	0.0047	0.0244
Total Alkylated PAHs	mg/kg	-	0.0720	6	0.0086	0.0187	0.1763
Predicted PAH toxicity[3]	H.I.	1.0	0.3275	6	0.0027	0.1251	0.3947
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	84	4	80	91	96
Chironomus growth - 10d	mg/organism	-	2.19	4	1.10	2.07	2.60
Hyalella survival - 14d	% surviving	-	<u>100</u>	4	80	87	98
Hyalella growth - 14d	mg/organism	-	0.18	4	0.10	0.29	0.45

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

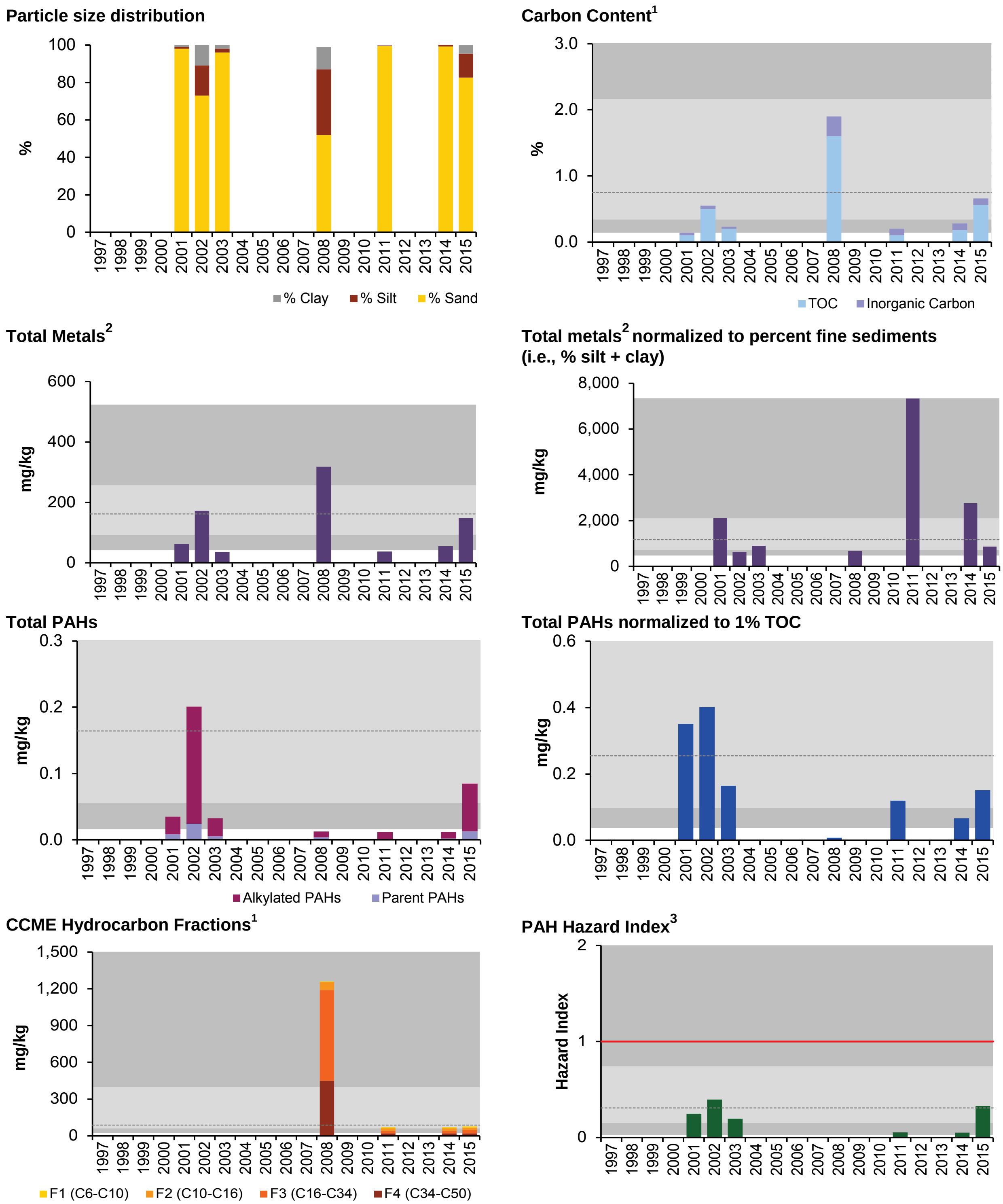
ns = not sampled in 2004-2007, 2009-2010, 2012, or 2013

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.9-13 Variation in selected sediment quality measurement endpoints, Clearwater River (*baseline* station CLR-D2) relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

5.10 CHRISTINA RIVER WATERSHED

Table 5.10-1 Summary of results for the Christina River watershed.

Christina River Watershed	Summary of 2015 Conditions															
	Christina River					Tributaries to Christina Lake						Tributaries to Christina River			Lakes	
Climate and Hydrology																
Criteria	**S47A**	no station	**07CE002**	no station	**S61**	**S58**	**S57**	**S63**	**S64**	**S60**	**S62**	**S56**	**S55**	**C5**	**3061580**	**S32**
Mean open-water season discharge	Negligible - Low	-	not measured	-	not measured	not measured						not measured	not measured	n/a	n/a	not measured
Mean winter discharge	Negligible - Low	-	not measured	-	not measured	not measured						not measured	not measured	n/a	n/a	not measured
Annual maximum daily discharge	Negligible - Low	-	not measured	-	not measured	not measured						not measured	not measured	n/a	n/a	not measured
Minimum open-water season discharge	Negligible - Low	-	not measured	-	not measured	not measured						not measured	not measured	n/a	n/a	not measured
Water Quality																
Criteria	**CH1**	**CHR-2A**	**CHR-2**	**CHR-3**	**CHR-4**	**SAC-1**	**SUC-1**	**SUC-2**	**UNC-2**	**UNC-3**	**BRC-1**	**JAR-1**	**GRR-1**	no station	**CHL-1**	**GRL-1**
Water Quality	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	-	n/a	n/a
Benthic Invertebrate Communities and Sediment Quality																
Criteria	**CHR-D1**	**CHR-E2A**	**CHR-D2**	**CHR-D3**	**CHR-D4**	**SAC-D1**	**SUC-D1**	**SUC-D2**	**UNC-D2**	**UNC-D3**	**BRC-D1**	**JAR-E1**	**GRR-E1**	no station	**CHL-1**	**GRL-1**
Benthic Invertebrate Communities	Moderate	n/a	Negligible - Low	Negligible - Low	n/a	Moderate	High	n/a	Negligible - Low	Negligible - Low	n/a	Moderate	Negligible - Low	-	High	Negligible - Low
Sediment Quality Index	Negligible - Low	no station	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	no station	no station	no station	n/a	n/a
Fish Populations																
Criteria	no reach	no reach	**CHR-F2**	no reach	no reach	**SAC-F1**	**SUC-F1**	**SUC-F2**	**UNC-F2**	**UNC-F3**	**BRC-F1**	**JAR-F1**	no reach	no reach	no reach	no reach
Fish Communities	-	-	Negligible - Low	-	-	[1]	Negligible - Low	n/a	[1]	[1]	[1]	Negligible - Low	-	-	-	-
Wild Fish Health	-	-	no reach	-	-	[2]	[2]	no reach	no reach	no reach	no reach	[2]	-	-	-	-

Legend and Notes

Negligible - Low; Moderate; High; *baseline*; *test*

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

[1] fish community surveys were conducted in fall 2015 but statistical tests and comparisons against regional *baseline* values were not conducted due to the very small numbers of fish caught at these stations both historical and in fall 2015.

[2] statistical tests were not conducted because no *baseline* reaches were sampled in the Christina River watershed for the wild fish health component in 2015 and slimy sculpin were not sampled at any regional *baseline* reach in the 2015 Program.

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

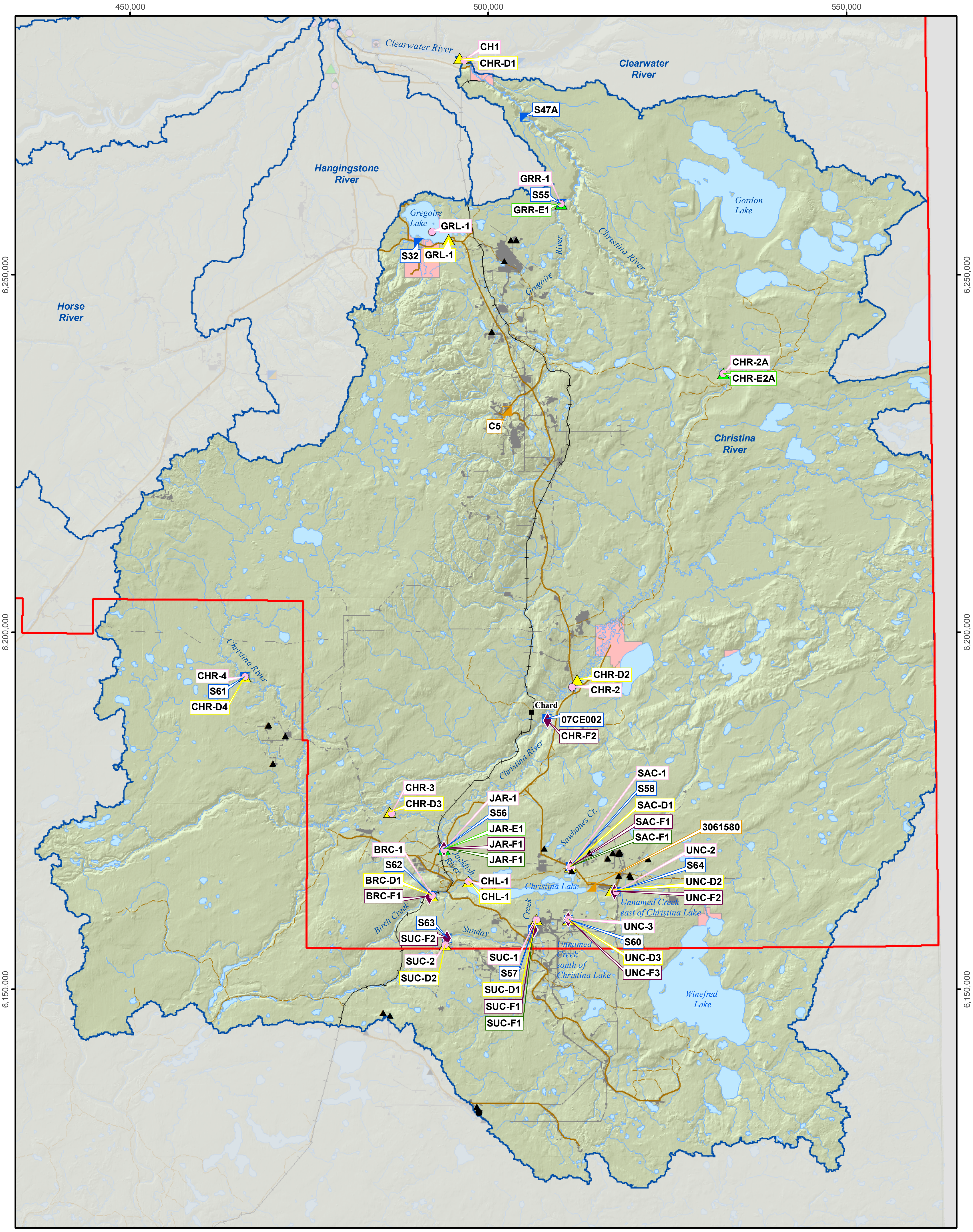
Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (Fish Communities): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.1 for a detailed description of the classification methodology.

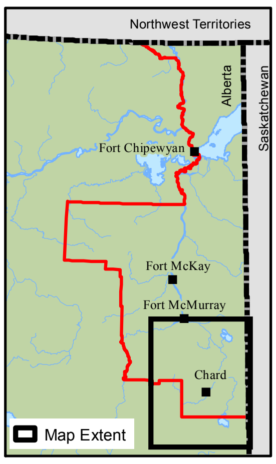
Fish Populations (Wild Fish Health): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.2 for a detailed description of the classification methodology.

Figure 5.10-1 Christina River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]
- Water Withdrawal Location
- Water Release Location
- Water Quality Station
- Data Sonde Station
- Hydrometric Station
- Climate Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Community Reach
- Wild Fish Health Reach
- Wild Fish Health Reach with Water and Sediment Quality Stations



0 2.5 5 10 km

N

Scale: 1:550,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

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Figure 5.10-2 Representative monitoring stations of the Christina River watershed, fall 2015.

Hydrology Station 247A: Christina River near the mouth, facing upstream

Hydrology Station S56: Jackfish River below Christina Lake, facing upstream

Benthic Invertebrate Communities and Sediment Quality Reach/Station CHR-D3: upper middle Christina River, facing upstream

Fish Health and Fish Communities Reach JAR-F1: Jackfish River, facing downstream

Benthic Invertebrate Communities and Sediment Quality Reach Station UNC-D2: Unnamed Creek, facing upstream

Fish Communities Reach SUC-F2: Sunday Creek, facing downstream

Fish Communities Reach UNC-F3: Unnamed Creek south of Christina Lake, facing downstream

Benthic Invertebrate Communities, Water and Sediment Quality Reach/Station GRL-1: Gregoire Lake, facing east

5.10.1 Summary of 2015 WY Conditions

Approximately 1% (15,083 ha)[1] of the Christina River watershed had undergone land change from oil sands development as of 2015 (Table 2.3-1). The designations of specific areas of the Christina River watershed are as follows:

1. The Christina River watershed downstream of the Statoil project near the upper portion of the watershed and the portion of the watershed where Cenovus, MEG Energy, and Devon projects are surrounding Christina Lake are designated as *test*.

2. The tributaries flowing in (e.g., Sawbones and Sunday creeks, downstream of development) and out (Jackfish River) of Christina Lake, as well as Christina Lake itself, are designated as *test*.

3. Gregoire Lake and Gregoire River downstream of the Nexen project are designated as *test*.

4. All other parts of the Christina Lake watershed are designated as *baseline*.

Monitoring activities in the Christina River watershed in the 2015 WY were conducted for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities and Sediment Quality, and Fish Populations components. Table 5.10-1 is a summary of the 2015 assessment of the Christina River watershed, and Figure 5.10-1 denotes the location of the monitoring stations for each component, reported project water withdrawal and discharge locations, and the locations of areas with land change as of 2015. Figure 5.10-2 contains photos of representative monitoring stations in the watersheds.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology Water balance analysis was conducted for JOSMP station S47A (Christina River near the mouth). Overall, the annual 2015 WY runoff volume at this station was 671.5 million m^3, which was 44% lower than average. Water balance analysis showed that differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrographs were +0.05%, +0.06%, +0.06%, and +0.05%, respectively. These differences were classified as **Negligible-Low**.

Water Quality Concentrations of most water quality measurement endpoints in the Christina River and its tributaries exhibited relatively consistent seasonal changes, with total dissolved solids (TDS) and dissolved ions lowest in May during freshet, and higher in months with lower flows. Concentrations of some water quality measurement endpoints (e.g., TDS, boron, sodium, chloride, and sulphate) were generally higher in each month at *test* stations CH1 and GRR-1 than at other *test* and *baseline* stations. Concentrations of naphthalene were unusually high in winter at *test* stations SAC-1 and UNC-3 and *baseline* station BRC-1. Concentrations of most water quality measurement endpoints were within the historical monthly ranges.

Concentrations of water quality measurement endpoints in fall 2015 were within regional *baseline* concentrations with few exceptions, including total dissolved phosphorus, sodium, calcium, chloride, and total boron, which exceeded the 95th percentile of regional *baseline* concentrations at *test* stations CH1 and GRR-1 and *baseline* stations CHR-4 and BRC-1. In contrast, concentrations of total suspended

[1] The total area of the Christina River watershed was increased in 2015 for this report in order to include the part of the watershed that is within the province of Saskatchewan.

solids, total dissolved solids, total boron, total mercury, magnesium, and potassium were lower than the 5th percentile of regional *baseline* concentrations at *test* stations JAR-1, GRR-1, SAC-1, UNC-2, and UNC-3 and at *baseline* stations BRC-1 and SUC-2. The ionic composition of water at all stations in the Christina River watershed in fall 2015 was similar to previous years. Differences in water quality in fall 2015 at all stations in the Christina River and its tributaries compared to regional *baseline* conditions were classified as **Negligible-Low**. WQI values were not generated for *test* stations CHL-1 and GRL-1 because lakes were not included in the regional *baseline* conditions given the ecological differences between lakes and rivers.

Benthic Invertebrate Communities and Sediment Quality Variations in measurement endpoints for benthic invertebrate communities in the Christina River at *test* reach CHR-D1 in fall 2015 were classified as **Moderate**. While the benthic invertebrate community at *test* reach CHR-D1 in fall 2015 included several taxa that are typically associated with relatively good environmental conditions, values of all measurement endpoints for fall 2015 were outside the inner tolerance limits of the normal range of variation from previous years of sampling, including a lower %EPT than previous years. Variations in measurement endpoints for benthic invertebrate communities in the Christina River at *test* reach CHR-D2 in fall 2015 were classified as **Negligible-Low**. The significant difference in CA 1 Axis scores over time that accounted for more than 20% of the variance in annual means did not imply degrading conditions for benthic invertebrate communities and values of all measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of variation from previous years of monitoring. Variations in measurement endpoints for benthic invertebrate communities in the Christina River at *test* reach CHR-D3 in fall 2015 were classified as **Negligible-Low** because no significant changes in values of measurement endpoints at *test* reach CHR-D3 were measured between 2015 and 2014 and values of all measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches. Variations in measurement endpoints for benthic invertebrate communities in the Christina River at test reach CHR-E2A in fall 2015 were not classified because there are only two years of data for reach test CHR-E2A, which were collected eight years apart, during which time the reach changed from *baseline* to *test*.

Differences in values of measurement endpoints for benthic invertebrate communities at locations monitored in fall 2015 in Sunday Creek were classified as **High** because the results of temporal and spatial comparisons contain significant differences in values for three measurement endpoints – richness, equitability, and %EPT – for *test* reach SUC-D1 that explain more than 20% of the variation in annual means.

Variations in values of measurement endpoints of benthic invertebrate communities monitored in fall 2015 in Sawbones Creek were classified as **Moderate** because there were significant differences in values of two measurement endpoints (abundance and %EPT) in the temporal comparisons that accounted for more than 20% of the variance in annual means.

Variations in values of measurement endpoints of benthic invertebrate communities at two unnamed creeks that flow into Christina Lake were classified as **Negligible-Low** because there were no significant variations over time at the monitored reaches and values of all measurement endpoints in fall 2015 for the monitored reaches were within normal ranges for *baseline* reaches.

Variations in the values of measurement endpoints for benthic invertebrate communities of Jackfish River at *test* reach JAR-E1 for fall 2015 were classified as **Moderate**. While the benthic invertebrate community at *test* reach JAR-E1 in fall 2015 contained a benthic fauna that reflected good water and sediment quality, two of the three significant differences in values of measurement endpoints (taxa richness and %EPT) between 2015 and the mean of the prior years that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities. It should be emphasized that values of measurement endpoints for benthic invertebrate communities for 2015 were adjusted to account for the change in sampling gear and this classification should be interpreted with caution.

Variations in the values of measurement endpoints for benthic invertebrate communities of Gregoire River at *test* reach GRR-E1 for fall 2015 were classified as **Negligible-Low**. The benthic invertebrate community of *test* reach GRR-E1 in fall 2015 contained a benthic fauna representative of a healthy erosional river and none of the significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities at *test* reach GRR-E1.

Variations in values of the measurement endpoints of the benthic invertebrate community in Christina Lake in fall 2015 were classified as **High** because there were significant differences in values of all measurement endpoints in the temporal comparisons that accounted for more than 20% of the variance in annual means; however, it is worth noting that the lake in 2015 contained a diverse benthic fauna that included several permanently aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies and caddisflies).

Differences in measurement endpoints of the benthic invertebrate community in Gregoire Lake in fall 2015 were classified as **Negligible-Low** given none of temporal comparisons for benthic invertebrate communities of Gregoire Lake accounted for significant variation.

In fall 2015, concentrations of sediment quality measurement endpoints were generally similar to previous years (where applicable) and were typically within regional *baseline* concentrations at all stations. Differences in sediment quality conditions in fall 2015 at all sediment quality stations in the Christina River watershed were **Negligible-Low** compared to regional *baseline* conditions (sediment quality measurement endpoints were not compared to regional *baseline* concentrations for Christina Lake (CHL-1) or Gregoire Lake (GRL-1) because lakes were not included in the calculation of *baseline* concentrations).

Fish Populations (Fish Communities) Differences in measurement endpoints for *test* reach CHR-F2, *test* reach JAR-F1, and *test* reach SUC-F1 were classified as **Negligible-Low** because: (i) there were no significant changes in values of measurement endpoints for these *test* reaches in either spatial comparisons to *baseline* reaches or in changes over time that implied a negative change in the fish communities at those reaches; and (ii) mean values of all measurement endpoints at these *test* reaches were within the ranges of regional *baseline* values for these measurement endpoints. No spatial or temporal comparisons were conducted for *test* reaches SAC-F1, UNC-F2 or UNC-F3 or for *baseline* reach BRC-F1; reliable statistical analysis was not possible for these *test* reaches because too few fish have been captured at these *test* reaches during the entire monitoring period. Similarly, comparisons of values of fish community measurement endpoints to regional *baseline* values were not made for these *test* reaches.

Fish Populations (Wild Fish Health) Classification of results for wild fish health monitoring in the Christina River watershed in 2015 was not possible because no *baseline* reaches were sampled in the Christina River watershed for the wild fish health component in 2015 and the target fish species, slimy sculpin, was not sampled at any regional *baseline* reach during the 2015 Program.

5.10.2 Hydrologic Conditions

Hydrometric monitoring for the Christina River watershed in the 2015 WY was conducted at the following locations:

- JOSMP Station S47A (formerly JOSMP Station S47), Christina River near the mouth;
- WSC Station 07CE002 (formerly JOSMP Station S29), Christina River near Chard;
- JOSMP Station S32, Surmont Creek at Highway 881;
- JOSMP Station S55, Gregoire River near the mouth;
- JOSMP Station S56 (formerly WSC Station 07CE005), Jackfish River below Christina Lake;
- JOSMP Station S57, Sunday Creek above Christina Lake;
- JOSMP Station S58, Sawbones Creek above Christina Lake;
- JOSMP Station S60, Unnamed Creek south of Christina Lake;
- JOSMP Station S61, Christina River above the Statoil Leismer operation;
- JOSMP Station S62, Birch Creek at Highway 881;
- JOSMP Station S63, Sunday Creek at Highway 881;
- JOSMP Station S64, Unnamed Creek east of Christina Lake; and
- AEP Station 07CE906, Christina Lake near Winefred Lake.

Data from JOSMP Station S47A, Christina River near the mouth, were used for the water balance analysis and are presented below. Lake levels for Christina Lake (Station 07CE906) and discharge data from Jackfish River (Station S56/07CE005) are also provided in this section as these stations record Christina Lake level and outflow prior to entering the Christina River. Data from other JOSMP stations in the Christina River watershed are provided in Appendix C.

The historical flow record for JOSMP Station S47A Christina River near the mouth is summarized in Figure 5.10-3, which includes the median, interquartile range, and range of flows recorded daily through the water year. There was no monitoring station at the Christina River near the mouth from 1967 to 2011 and flows during this period were estimated as the difference between the measured flow at the Clearwater River above the Christina River (WSC Station 07CD005) and the Clearwater River above Draper (WSC Station 07CD001). Hydrometric data were concurrently collected at these WSC stations in the open-water period (May to October) from 1967 to 1975, annually from 1976 to 1996, and seasonally (March to October) from 1997 to 2011. Annual data from JOSMP Station S47A (formerly S47) were used from 2011 to 2014.

Flows of the Christina River near the mouth have a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are typically lower than during the open-water season and decrease from November until early March. Spring thaw and the resulting increase in flow typically begin in March with the peak flow occurring in late April. Flows then recede from late July until the end of October, in response to declining rainfall inputs and eventually river freeze-up.

Flows in the Christina River in the 2015 WY were similar to the historical seasonal pattern described above but were lower in magnitude than average historical flows after mid-April (Figure 5.10-3). Flows decreased from November 2014 to mid-March 2015, remaining close to the historical upper quartile flow during this period. Flows then increased and closely tracked the historical upper quartile flow. The peak flow of 67.2 m^3/s occurred on April 18 and was 63% lower than the historical annual mean maximum flow. Flows then tracked the historical median flow until mid-May when flows decreased until the minimum open-water daily flow of 10.9 m^3/s was recorded on July 12. Minimum open-water flow was 36% lower than the historical mean of 17 m^3/s. Flows then increased in late July and again in mid-August in response to rainfall-generated runoff events recorded at the C5 Surmont weather station; these increases in flow were short-lived and flows rapidly decreased through the remainder of August and tracked near the historical lower quartile flows until the end of the WY.

Overall, the annual runoff volume at JOSMP Station S47A, Christina River near the mouth, in the 2015 WY was 671.5 million m^3, which was 44% lower than the mean historical annual runoff volume of 1,202 million m^3.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Christina River near the mouth (JOSMP Station S47A) is summarized in Table 5.10-2. Key changes in flows and water diversions included:

1. The closed-circuited land change area as of 2015 was estimated to be 18.1 km^2 (Table 2.3-1). The loss of flow to the Christina River that would have otherwise occurred from this land area was estimated at 0.934 million m^3.
2. As of 2015, the area of land change in the Christina River watershed that was not closed-circuited was estimated to be 132.7 km^2 (Table 2.3-1). The increase in flow to the Christina River that would not have otherwise occurred from this land area was estimated at 1.37 million m^3.
3. Total water withdrawals were approximately 0.0910 million m^3 (90,994 m^3) in the 2015 WY.
4. Total releases were 0.0394 million m^3 (39,420 m^3) in the 2015 WY.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands developments in the 2015 WY was an increase in water volume of 0.38 million m^3 in the Christina River at JOSMP Station S47A. The 2015 WY mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were 0.05% greater, 0.06% greater, 0.06% greater, and 0.05% greater, respectively, than for the estimated *baseline* hydrograph (Table 5.10-3). These differences were classified as **Negligible-Low**. Given all measurement endpoints were classified as **Negligible-Low**, a spatial analysis to identify the longitudinal hydrological effects along the Christina River was not conducted.

The water level of Christina Lake in the 2015 WY decreased from November 2015 to the end of March 2015 and remained near the historic lower quartile level throughout this period (Figure 5.10-4). The annual minimum lake level of 553.80 masl occurred on March 26, immediately prior to spring thaw. The lake level increased in early April due to the spring thaw and lake levels from June 3 to August 2 were generally below the recorded historical mean minimum levels. The annual peak level of 554.10 masl occurred on August 14, shortly after rainfall events were recorded at the C5 Surmont weather station. Lake levels decreased after the August peak and again dropped below historical mean minimum levels after September 21. The total annual lake level fluctuation in the 2015 WY was 0.30 m.

Continuous, year-round hydrometric data have been collected at JOSMP Station S56, Jackfish River below Christina Lake since May 2012. From 1982 to 1995, seasonal hydrometric data from March to October were collected at WSC station 07CE005. Overall runoff and peak flows in the 2015 WY were lower than normal at JOSMP Station S56 (Figure 5.10-5). In the early part of the 2015 WY (November 2014 to mid-March 2015), Jackfish River flows varied from historical minimum to historical maximum flows. Flows then increased due to the spring thaw in early April. The annual peak flow of 7.39 m^3/s on May 13 was 86% lower than the historical maximum daily flow of 54.7 m^3/s. Flows then decreased gradually until mid-July and stabilized thereafter, remaining within the historical interquartile range of flows until the end of the WY. The minimum open-water daily flow of 1.46 m^3/s was recorded on July 15 and was 87% higher than the historical mean minimum daily flow of 0.78 m^3/s calculated for the open-water period.

5.10.3 Water Quality

Water quality samples were taken in the 2015 WY on a monthly basis at four stations in the Christina River, on a seasonal basis at eight stations on tributaries to the Christina River, and on a seasonal basis at two lake stations:

- the Christina River near its mouth (lower *test* station CH1, previously called CHR-1), sampled since 2002;
- the Christina River upstream of Janvier (middle *test* station CHR-2), designated as a *baseline* station in 2002 and as *test* station from 2010 onwards;
- the Christina River upstream of Jackfish River (upper *test* station CHR-3), sampled since 2013;
- the Christina River upstream of development (upper *baseline* station CHR-4), sampled since 2013;
- Sawbones Creek (*test* station SAC-1), sampled since 2012;
- Sunday Creek at the inlet into Christina Lake (*test* station SUC-1), sampled since 2012;
- Sunday Creek upstream (*baseline* station SUC-2), sampled since 2013;
- Birch Creek (*baseline* station BRC-1), sampled since 2013;
- unnamed creek east of Christina Lake (*test* station UNC-2), sampled since 2013;
- unnamed creek south of Christina Lake (*test* station UNC-3), sampled since 2013;

- Jackfish River (*test* station JAR-1), sampled since 2012;
- Gregoire River (*test* station GRR-1), sampled since 2014;
- Christina Lake (*test* station CHL-1), sampled since 2012; and
- Gregoire Lake (*test* station GRL-1), sampled since 2014.

An additional station in the Christina River (*test* station CHR-2A) was sampled in fall 2015 to support the Benthic Invertebrate Communities component.

Monthly and seasonal variations in selected water quality measurement endpoints are summarized in Table 5.10-4 to Table 5.10-17 and Figure 5.10-6 to Figure 5.10-8. Water quality results from fall 2015 relative to historical fall concentrations are provided in Table 5.10-18 to Table 5.10-32. The ionic composition of water measured in 2015 and previous years in the Christina River watershed is presented in Figure 5.10-9 to Figure 5.10-11. Guideline exceedances for water quality measurement endpoints are presented in Table 5.10-33 and Figure 5.10-12 to Figure 5.10-14 compare selected water quality measurement endpoints in rivers, streams, and lakes of the Christina River watershed relative to regional *baseline* concentrations.

Monthly/Seasonal Variations in Water Quality With the exception of lower concentration of some metals and ions in May (i.e., boron, strontium, calcium, and magnesium), there were no obvious monthly or seasonal trends in concentration of water quality measurement endpoints in the Christina River. Concentrations of several water quality measurement endpoints (e.g., TSS, TDS, boron, sodium, chloride, and sulphate) in the Christina River were higher at lower *test* station CH1 than at the middle and upper *test* stations (CHR-2 and CHR-3, respectively) and the upper *baseline* station CHR-4 (Table 5.10-4 to Table 5.10-7 and Figure 5.10-6).

Seasonally-sampled tributary stations exhibited higher concentrations of TDS and associated major ions and some metals (i.e., arsenic boron, strontium) in fall relative to spring when concentrations of these water quality measurement endpoints were likely diluted by surface runoff; concentrations of these water quality measurement endpoints were higher *at test* station GRR-1 (Gregoire River) than at other *test* or *baseline* stations. Concentrations of naphthalene were orders of magnitude higher at *test* stations SAC-1 and UNC-3, and *baseline* station BRC-1 in winter than in other seasons (Table 5.10-8 to Table 5.10-15). Concentrations of water quality measurement endpoints were generally higher at *test* station GRL-1 than at *test* station CHL-1 (Table 5.10-16, Table 5.10-17). Comparison of 2015 WY monthly and seasonal data with historical data indicates that concentrations of most of the water quality measurement endpoints were within the historical monthly ranges.

2015 Fall Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints were generally within the range of previously-measured concentrations (Table 5.10-18 to Table 5.10-32). The following water quality measurement endpoints exceeded previously-measured maximum concentrations:

- conductivity, magnesium, chloride, sulphate, total dissolved solids, alkalinity, total molybdenum, and total strontium at *test* station CH1;

- total suspended solids, magnesium, total dissolved solids, naphthenic/oilsands extractable acids, total PAHs, total alkylated PAHs, and total phenols at *test* station CHR-3;
- nitrate+nitrite, naphthenic and oilsands extractable acids, total dibenzothiophenes, sulphides, and total phenols at *baseline* station CHR-4;
- total aluminum, total molybdenum, total ultra-trace mercury, oilsands extractable acids, sulphide at *test* station SAC-1;
- oilsands extractable acids, sulphide, and total phenols at *test* station SUC-1;
- pH, total nitrogen, chloride, total PAHs, total alkylated PAHs, sulphide, and total phenols at *baseline* station SUC-2;
- total suspended solids, total nitrogen, sodium, calcium, magnesium, total aluminum, total PAHs, total alkylated PAHs, sulphide, and total phenols at *baseline* station BRC-1;
- dissolved organic carbon, total ultra-trace mercury, oilsands extractable acids, total PAHs, total alkylated PAHs, and total phenols at *test* station UNC-2;
- total nitrogen, total ultra-trace mercury, total dibenzothiophenes, total PAHs, total alkylated PAHs, and total phenols at *test* station UNC-3;
- sodium, calcium, magnesium, potassium, chloride, total strontium, and sulphide at *test* station JAR-1;
- most nutrients, ions, PAHs, sulphide, and total phenols at *test* station GRR-1 (compared to 2014 data only);
- sodium, calcium, magnesium, potassium, chloride, total boron, total strontium, and total phenols at *test* station CHL-1; and
- most nutrients, ions, metals, PAHs, dissolved iron, sulphide, and total phenols at *test* station GRL-1 (compared to 2014 data only).

The following water quality measurement endpoints fell below previously-measured minimum concentrations:

- total and dissolved aluminum, total ultra-trace mercury, retene, total PAHs, and total alkylated PAHs at *test* station CH1;
- total nitrogen and sulphate at *test* station CHR-3;
- pH, total suspended solids, total dissolved solids, total aluminum, total arsenic, total molybdenum, total ultra-trace mercury at *baseline* station CHR-4;
- pH, conductivity, sodium, calcium, total dissolved solids, total alkalinity, and total boron at *test* station SAC-1;

- pH, conductivity, total dissolved phosphorus, dissolved organic carbon, sodium, potassium, total dissolved solids, total alkalinity, total aluminum, dissolved aluminum, total arsenic, total boron, total molybdenum, and retene at *test* station SUC-1;
- conductivity, total dissolved phosphorus, sodium, calcium, magnesium, potassium, total dissolved solids, total alkalinity, total aluminum, total arsenic, total boron, total molybdenum, total ultra-trace mercury, total strontium, and retene at *baseline* station SUC-2;
- sulphate, dissolved aluminum, total arsenic, total ultra-trace mercury, and naphthenic acids at *baseline* station BRC-1;
- pH, total dissolved phosphorus, total dissolved solids, total aluminum, and naphthenic acids at *test* station UNC-2;
- pH, conductivity, total dissolved phosphorus, calcium, magnesium, potassium, total dissolved solids, total alkalinity, total arsenic, total boron, total molybdenum, and total strontium at *test* station UNC-3;
- pH, total dissolved phosphorus, total nitrogen, dissolved organic carbon, total aluminum, dissolved aluminum, total arsenic, and total boron at *test* station JAR-1; and
- total suspended solids at *test* station CHL-1.

The following water quality measurement endpoints were non-detectable but had detection limits that exceeded the previously-measured maximum values:

- total dibenzothiophenes at *test* station CHR-3;
- chloride and total dibenzothiophenes at *baseline* station CHR-4;
- chloride at *test* station SAC-1;
- total dibenzothiophenes and sulphate at *baseline* station SUC-2;
- chloride and total dibenzothiophenes at *baseline* station BRC-1;
- total dibenzothiophenes at *test* station UNC-2;
- chloride at *test* station UNC-3;
- oilsands extractable acids at *test* station CHL-1; and
- naphthenic acids, oilsands extractable acids, and naphthalene at *test* station GRL-1 (compared to 2014 data only).

Historical comparisons were not made for *test* station CHR-2A because this station was sampled for the first time in 2015.

Temporal Trends There were no significant trends ($p>0.05$) in concentrations of any water quality measurement endpoints at either *test* station CH1 or *test* station CHR-2; trend analysis was not conducted for other stations in the Christina River watershed because the length of the times series of available water quality data was insufficient for the statistical tests to be conducted.

Ion Balance The ionic composition of water at all stations in the Christina River watershed in fall 2015 was similar to previous years and dominated by calcium and bicarbonate (Figure 5.10-9 to Figure 5.10-11), particularly at *baseline* station CHR-4. Calcium and bicarbonate have decreased while sodium and chloride have increased over time at *test* station CH1, which may be related to known saline seeps in the Christina River between *test* station CHR-2 and *test* station CHR-1.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations of water quality measurement endpoints in the Christina River watershed in the 2015 WY were below guidelines at all stations with the following exceptions (Table 5.10-33):

- dissolved iron at *test* stations CH1 (November to January, March, and May), CHR-2 (November to December, May, and August to September), CHR-3 (May, June, and August), SAC-1 (March), UNC-2 (March and July), UNC-3 (March), and GRL-1 (September), and *baseline* stations CHR-4 (August to September) and BRC-1 (May);

- total phenols at *test* stations CH1 (August to October), CHR-2 (February and July to October), CHR-3 (June to October), GRR-1 (May, July, and September), JAR-1 (July and September), SAC-1 (July and September), SUC-1 (July and September), UNC-2 (May, July, and September), UNC-3 (May, July, and September), CHL-1 (July and September), and GRL-1 (July and September), and *baseline* stations CHR-4 (July to October) and SUC-2 (May and July);

- sulphide at *test* stations CH1 (November and June to October), CHR-2 (November, May, and July to September), CHR-3 (May to October), GRR-1 (July and September), JAR-1 (May, July and September), SAC-1 (March, May, July, and September), SUC-1 (May, July, and September), UNC-2 (May, July, and September), UNC-3 (May and July), CHL-1 (March, May, and July), and GRL-1 (May, July, and September), and *baseline* stations CHR-4 (July to September), BRC-1 (May, July, and September), and SUC-2 (May, July, and September); and

- naphthalene at *test* stations SAC-1 and UNC-2, both in March.

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints for all stations within the Christina River watershed in fall 2015 were within the range of regional *baseline* concentrations (Figure 5.10-12 to Figure 5.10-14) with the exception of:

- sodium and chloride at *test* station CH1 with concentrations in fall 2015 that exceeded the 95th percentile of regional *baseline* concentrations;

- total dissolved phosphorus at *baseline* station CHR-4 with a concentration in fall 2015 that exceeded the 95th percentile of regional *baseline* concentrations;

- total boron at *test* station GRR-1 with a concentration in fall 2015 that exceeded the 95th percentile of regional *baseline* concentrations;

- calcium at *test* station GRR-1 and *baseline* station BRC-1 with concentrations in fall 2015 that exceeded the 95th percentile of regional *baseline* concentrations;

- total suspended solids at *test* stations JAR-1 and UNC-3 and *baseline* station SUC-2 with concentrations in fall 2015 that were lower than the 5th percentile of regional *baseline* concentrations;
- total dissolved solids at *test* station SAC-1 with a concentration in fall 2015 that was lower than the 5th percentile of regional *baseline* concentrations;
- total boron at *baseline* station SUC-2 with a concentration in fall 2015 that was lower than the 5th percentile of regional *baseline* concentrations;
- total mercury (ultra-trace), with a concentration in fall 2015 that was lower than the 5th percentile of regional *baseline* concentrations at *baseline* station BRC-1;
- magnesium at *test* station SAC-1 with a concentration in fall 2015 that was lower than the 5th percentile of regional *baseline* concentrations; and
- potassium at *test* stations SAC-1 and UNC-2 with concentrations in fall 2015 that were lower than the 5th percentile of regional *baseline* concentrations.

Lakes do not contribute to the regional *baseline* concentration calculations; therefore, lake stations CHL-1 and GRL-1 were not compared to regional *baseline* conditions.

Water Quality Index The WQI values for fall 2015 at all *test* and *baseline* stations in the Christina River watershed were greater than 80, indicating **Negligible-Low** differences in water quality conditions in fall 2015 compared to regional *baseline* water quality conditions. WQI values were not generated for *test* stations CHL-1 and GRL-1 because lakes were included in the regional *baseline* conditions given the ecological differences between lakes and rivers.

Classification of Fall Results Differences in water quality in fall 2015 at all stations in the Christina River and its tributaries compared to regional *baseline* conditions were classified as **Negligible-Low**.

5.10.4 Benthic Invertebrate Communities and Sediment Quality

5.10.4.1 Benthic Invertebrate Communities

Christina River

Benthic invertebrate communities were sampled in fall 2015 at:

- depositional *test* reach CHR-D1 (lower Christina River), sampled from 2002 to 2007, 2009, 2012, 2014, and 2015;
- depositional *test* reach CHR-D2 (middle Christina River), sampled from 2002 to 2006 and 2009 as a *baseline* reach, and sampled in 2012, 2014, and 2015 as a *test* reach;
- depositional *test* reach CHR-D3 (Christina River, upstream of the confluence with the Jackfish River), sampled in erosional habitat in 2013 (using a Neil-Hess cylinder in riffles) and in depositional habitat in 2014 and 2015 (using an Ekman grab);
- depositional *baseline* reach CHR-D4 (upper Christina River), sampled since 2013; and

- erosional *test* reach CHR-E2A, sampled in 2007 as a *baseline* reach using a Neil-Hess cylinder, and in 2015 as a *test* reach using a kicknet. Values of benthic invertebrate community measurement endpoints for fall 2015 were "adjusted" (Appendix D) to make them as comparable as possible to data collected with a Neil-Hess cylinder and therefore to data from 2007.

2015 Habitat Conditions Water at *test* reach CHR-D1 in fall 2015 was 0.2 m deep, slightly alkaline (pH 7.1), with a high concentration of dissolved oxygen (9.5 mg/L), and moderate conductivity (467 µS/cm). The substrate consisted of sand (58%), with smaller amounts of silt (29%) and clay (13%), and low total organic carbon content (1.2%) (Table 5.10-34).

Water at *test* reach CHR-D2 in fall 2015 was 0.5 m deep, alkaline (pH 8.1), with a high concentration of dissolved oxygen (9.5 mg/L), and moderate conductivity (232 µS/cm). The substrate was predominantly sand (99%) with low total organic carbon content (< 1%) (Table 5.10-34).

Water in the *test* reach CHR-D3 in fall 2015 was 0.6 m deep, weakly alkaline (pH 7.1), with moderate to high velocity (0.88 m/s), a high concentration of dissolved oxygen (9.0 mg/L), and moderate conductivity (288 µS/cm). The substrate was predominantly sand (94%) with low total organic carbon content (< 1%) (Table 5.10-34).

Water at *baseline* reach CHR-D4 in fall 2015 was 0.4 m deep, weakly alkaline (pH 7.5), with moderate velocity (0.35 m/s), a high concentration of dissolved oxygen (8.9 mg/L), and moderate conductivity (226 µS/cm). The substrate was predominantly sand (96%) with small amounts of silt (3%) and low organic carbon content (0.5%) (Table 5.10-34).

Water at *test* reach CHR-E2A in fall 2015 was 0.3 m deep, alkaline (pH 8.5), with a high concentration of dissolved oxygen (10.5 mg/L), moderate conductivity (253 µS/cm), and moderate velocity (0.5 m/s) (Table 5.10-34). The dominant substrate in *test* reach CHR-E2A was gravel. Full CABIN supporting data are provided in Appendix D.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach CHR-D1 in fall 2015 was primarily comprised of chironomids (61%) and tubificid worms (28%) (Table 5.10-35). Chironomids were primarily of the genera *Paralauterborniella*, *Micropsectra/Tanytarsus* and *Chironomus.* EPT taxa were present in seven replicate samples and included Ephemeroptera (Baetidae, *Acentrella*, Ephemerellidae, *Tricorythodes*, *Siphloplecton*), Plecoptera (*Isoperla*, *Taeniopteryx*) and Trichoptera (*Brachycentrus*, *Neureclipsis*). Other flying insects (*Gomphus* and *Ophiogomphus* dragonflies) were present in low relative abundances at *test* reach CHR-D1. Permanent aquatic forms were represented by Gastropoda (*Ferrissia rivularis*, *Lymnaea*) and Bivalvia (*Pisidium, Sphaerium*).

The benthic invertebrate community at *test* reach CHR-D2 in fall 2015 was dominated by chironomids (98%). Various other taxa were also present in low relative abundances (~1%) (Table 5.10-35). Chironomids were primarily *Robackia demeijerei*, with similar abundances of *Paracladopelma*, *Polypedilum*, and *Micropsectra/Tanytarsus*. EPT taxa were present in low relative abundances and represented by mayflies (*Ametropus neavei*) and several stoneflies. Permanent aquatic forms were represented by a single bivalve (Pisidiidae) in one replicate sample.

The most common benthic invertebrate taxa at *test* reach CHR-D3 in fall 2015 were Chironomidae (92%) with Naididae being the subdominant taxa (3%). Various other taxa were also present in low relative abundances (~1%) (Table 5.10-36). Chironomids were primarily of the genera *Polypedilum*, *Cladotanytarsus*, *Cryptochironomus*, and *Robackia demeijerei*. Several flying insects (mayflies: *Centroptilum*, *Baetisca*, *Ephemerella*, caddisflies: *Oecetis*) were present in low relative abundances. Permanent aquatic forms were represented by bivalves (*Pisidium* and *Sphaerium*). The benthic invertebrate community at *test* reach CHR-D3 in 2015 was representative of good habitat quality, with mayflies and caddisflies present, and only a small relative abundance of worms.

The benthic invertebrate community at *baseline* reach CHR-D4 in fall 2015 was comprised of chironomids (90%), primarily of the genera *Polypedilum, Cladotanytarsus*, and *Micropsectra/Tanytarsus*. Larvae of large flying insects were sparse and represented by Amphipoda (*Hyalella azteca*), Ephemeroptera (*Caenis*, *Ephemerella*), Plecoptera (Chloroperlidae*, Pteronarcys*), and Trichoptera (*Brachycentrus*, Hydropsychidae, *Cheumatopsyche*, *Hydropsyche*). Bivalves (*Pisidium*) and Gastropoda (*Gyraulus*) were also present in the reach (Table 5.10-36).

The benthic invertebrate community at *test* reach CHR-E2A in fall 2015 was comprised of chironomids (57%) and Ephemeroptera (28%) (Table 5.10-37). Chironomids were primarily of the genera *Polypedilum* and *Micropsectra/Tanytarsus*. Mayflies from eighteen genera were present in the *test* reach, including several genera from the families Baetidae, Ephemerellidae, Heptageniidae and Leptohyphidae. The most dominant mayflies were *Acentrella*, *Acerpenna* and *Acerpenna/Falliceon*. Other permanent aquatic forms included gastropods (*Physa, Gyraulus*) and bivalves (*Pisidiidae*). Several damselfly larvae, *Ophiogomphus*, were also present in each of the three replicate samples.

Temporal Comparisons The following temporal comparisons of benthic invertebrate community measurement endpoints were conducted:

- *test* reaches CHR-D1 and CHR-D2: trends over time during the *test* period (Hypothesis 1, Section 3.2.3.1); and differences between 2015 values and the mean of all previous years of sampling;
- *test* reach CHR-D3: changes between 2015 and 2014 values of the measurement endpoints (2013 values were not included in the analysis, as erosional habitat rather than depositional habitat was sampled at that reach in 2013); and
- *test* reach CHR-E2A: differences between 2007 *baseline* and 2015 *test* values of the measurement endpoints.

Temporal comparisons were not conducted for *test* reach CHR-E2A because that reach has only been sampled for two years (2007 and 2015).

The comparisons for *test* reach CHR-D1 that were statistically significant are as follows (Table 5.10-38, Figure 5.10-15):

1. Abundance and richness were significantly higher in fall 2015 at *test* reach CHR-D1 than the mean of prior years, equitability was significantly lower in fall 2015 than the mean of prior years, and CA Axis 2 scores were significantly lower in 2015 than the mean of prior years. These effects accounted for from 22% to 33% of the variation in annual means, and none of these changes were indicative of degrading conditions.
2. There was a significant increase in richness over time, accounting for 34% of the variation in annual means.

3. There was a significant increase in CA Axis 1 scores over time, accounting for 44% of the variance in annual means. Changes in both CA Axis 1 and CA Axis 2 scores were likely due to a decrease in bivalves (Figure 5.10-15).

There was a significant increase in CA Axis 1 scores over time at *test* reach CHR-D2, accounting for 41% of the variance in annual means (Table 5.10-39, Figure 5.10-15). The increasing trend in CA Axis 1 scores over time reflected a shift in taxa composition with several previously-abundant taxa having low relative abundances in 2015, including Tubificidae, Bivalvia, and Ephemeroptera. Other taxa that were not recorded in 2015 included Enchytraeidae, Hydracarina, Coleoptera, Odonata and Trichoptera.

No significant changes in values of measurement endpoints at *test* reach CHR-D3 were measured between 2015 and 2014 (Table 5.10-40, Figure 5.10-15).

The results of the comparisons for *test* reach CHR-E2A between 2007 *baseline* and 2015 *test* values of the measurement endpoints are as follows (Table 5.10-41):

1. Abundance was significantly higher in 2015 than 2007.

2. Richness and %EPT were significantly lower in 2015 than 2007.

Comparison to Published Guidelines Lower *test* reach CHR-D1 had a low diversity of benthic fauna, which is typical of a sandy-bottomed river (Barton and Smith 1984). The benthic invertebrate community had high relative abundance of tolerant taxa (tubificids), and low percentage of EPT taxa. Sensitive taxa (Ephemeroptera, Plecoptera, Trichoptera, bivalves, and gastropods) were present in low relative abundances (< 1 to 3%). That the reach contained mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) suggests good habitat quality.

The benthic invertebrate community at middle *test* reach CHR-D2 had a low abundance, diversity, richness, and percentage of EPT taxa compared to *test* reach CHR-D1; however, taxa richness at *test* reach CHR-D2 was higher in 2015 than in previous years. Chironomids were diverse at middle *test* reach CHR-D2 in fall 2015, but the overall abundance of worms was lower than at lower *test* station CHR-D1.

The benthic invertebrate community at *test* reach CHR-D3 was less diverse in fall 2015 than in fall 2013, which was likely due to the shift in sampling habitat from erosional to depositional in 2015. Chironomids were not diverse at *test* reach CHR-D3; however, one of the dominant taxa, *Robackia demeijerei*, is considered relatively-sensitive (Mandeville 2002). EPT taxa were found in low relative abundance in 2015, and were lower compared to what was observed in 2013 (EPT taxa are generally less abundant in depositional habitats compared to erosional habitats). Taxa richness was lower than in 2013 and permanent aquatic forms were sparse. Both richness and %EPT were, however, higher in 2015 than 2014.

The benthic invertebrate community at *baseline* reach CHR-D4 was representative of a healthy, sand-bottomed river. The community was dominated by chironomids and the relative abundance of worms was low (~ 5%). EPT taxa were present in low relative abundance and permanent aquatic forms (Amphipoda, Gastropoda, bivalve) were present, consistent with the sand-dominated substrate characteristics of the reach.

The benthic invertebrate community at *test* reach CHR-E2A, sampled in 2015 with a kick net, was diverse with an average of 43 taxa per replicate sample. *Test* reach CHR-E2A contained many EPT taxa, including a number of taxa that are considered sensitive such as mayflies *Acerpenna* and *Ephemerella*, the caddisfly *Hydropsyche,* and the stonefly *Isoperla* (Hynes 1960; Mandeville 2001; Griffiths 1998). Tubificidae, which is generally considered a group of tolerant worms (Mandeville 2001), were not very abundant in 2015 (< 1%).

2015 Results Relative to Historical or Regional *Baseline* Conditions Values of all measurement endpoints for fall 2015 at benthic invertebrate community reaches in the Christina River were within inner tolerance limits of the normal range of variation with the following exceptions (Figure 5.10-16 to Figure 5.10-20):

1. Values of all measurement endpoints for fall 2015 at *test* reach CHR-D1 were outside the inner tolerance limits of the normal range of variation from previous years of sampling.

2. Adjusted %EPT was outside the outer lower tolerance limit of the normal range of variation at *test reach* CHR-E2A. Although values of these measurement endpoints were significantly different in 2015 than the mean at the *baseline* reach in 2007 (Figure 5.10-20), all values were within the range of variability of the regression relationship between Neil-Hess and kicknet data (Figure 5.10-19). There was less variation in values of measurement endpoints in 2015 than in 2007, possibly because ten stations were sampled at this reach in 2007, whereas only three kicknet replicates were collected from a single riffle at this reach in 2015.

Given there were only two years of depositional data for *test* reach CHR-D3, values of measurement endpoints were compared to the regional range of *baseline* variability; all measurement endpoints were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches.

Classification of Results Variations in measurement endpoints for benthic invertebrate communities in the Christina River at *test* reach CHR-D1 in fall 2015 were classified as **Moderate**. While the benthic invertebrate community at *test* reach CHR-D1 in fall 2015 included several taxa that are typically associated with relatively good environmental conditions, values of all measurement endpoints for fall 2015 were outside the inner tolerance limits of the normal range of variation from previous years of sampling, including a lower %EPT than previous years.

Variations in measurement endpoints for benthic invertebrate communities in the Christina River at *test* reach CHR-D2 in fall 2015 were classified as **Negligible-Low**. The significant difference in CA 1 Axis scores over time that accounted for more than 20% of the variance in annual means did not imply degrading conditions for benthic invertebrate communities and values of all measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of variation from previous years of monitoring.

Variations in measurement endpoints for benthic invertebrate communities in the Christina River at *test* reach CHR-D3 in fall 2015 were classified as **Negligible-Low** because no significant changes in values of measurement endpoints at *test* reach CHR-D3 were measured between 2015 and 2014 and values of all measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches.

Variations in measurement endpoints for benthic invertebrate communities in the Christina River at *test* reach CHR-E2A in fall 2015 were not classified. *Test* reach CHR-E2A was sampled in an erosional habitat with a Neil-Hess sampler in 2007 and with a kicknet in 2007 and measurement endpoints in 2015 were adjusted using a conversion factor (from kicknet to Neil-Hess). The comparisons of the data between 2007 and 2015 made above should therefore be made cautiously. In addition, there are only two years of data for reach *test* CHR-E2A, which were collected eight years apart, during which time the reach changed from *baseline* to *test*.

Sunday Creek

Benthic invertebrate communities were sampled in fall 2015 in Sunday Creek at:

- depositional *test* reach SUC-D1 (lower Sunday Creek), sampled since 2012; and
- depositional *baseline* reach SUC-D2 (upper Sunday Creek), sampled since 2013.

2015 Habitat Conditions Water at *test* reach SUC-D1 in fall 2015 was 0.3 m deep, circum-neutral (pH 7.2), with a velocity of 0.25 m/s, concentration of dissolved oxygen of 9.6 mg/L, and conductivity of 269 µS/cm. The substrate consisted almost entirely of sand (90%) with small amounts of silt (8%) and clay (3%), and low total organic carbon (0.7%) (Table 5.10-42).

Water at *baseline* reach SUC-D2 in fall 2015 was 0.4 m deep, circum-neutral pH (6.8), with a velocity of 0.3 m/s, concentration of dissolved oxygen of 10.0 mg/L, and conductivity of 230 µS/cm. The substrate consisted of sand (81%) with some silt (16%) and clay (3%), and low total organic carbon (1.3%) (Table 5.10-42).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach SUC-D1 was dominated by chironomids (64%) (Table 5.10-43). Subdominant taxa included Ceratopogonidae (9%), miscellaneous Diptera (7%), Bivalvia (6%), and tubificid and naidid worms (4% each). Dominant chironomids included the genera *Saetheria*, *Micropsectra*, and *Stempellina*. Diptera included members of the families Dolichopodidae, Tabanidae, Tipulidae, Empididae, Ceratopogonidae, and Tanypodinae. Flying insects (Ephemeroptera: *Baetisca*, *Hexagenia limbata*, Plecoptera, and Trichoptera: *Oecetis*, Odonata: *Ophiogomphus*) were present in *test* reach SUC-D1 in 2015. Permanent aquatic forms such as *Pisidium* clams and *Gyraulus* snails were also present.

The benthic invertebrate community at *baseline* reach SUC-D2 was dominated by chironomids (87%) (Table 5.10-43). Chironomids were diverse and included *Micropsectra, Paralauterborniella*, and *Stempellina*. Mayflies (*Callibaetis, Caenis, Eurylophella, Hexagenia limbata, Leptophlebia* and *Siphloplecton*), and Caddisflies (Limnephilidae) were found in the upper reach of Sunday Creek in fall 2015, along with permanent aquatic forms such as amphipods (*Hyalella azteca*), gastropods (*Ferrissia rivularis, Physa,* and *Gyraulus*), and bivalves (Pisidiidae).

Temporal and Spatial Comparisons Temporal and spatial comparisons of values of measurement endpoints for *test* reach SUC-D1 consisted of:

- differences from *baseline* reach SUC-D2 across years (Hypothesis 2, Sections 3.2.3.1);
- trends over time during the *test* period (i.e., since 2012, Hypothesis 1, Section 3.2.3.1);

- differences between 2015 values and the mean values from all available *baseline* data; and
- differences between 2015 values and the mean values from all previous years of monitoring (2012 to 2014).

The comparisons that were statistically significant are as follows (Table 5.10-44):

1. Abundance and richness were significantly higher across years at *baseline* reach SUC-D2 than at *test* reach SUC-D1, accounting for 24% and 31% of the variance in annual means respectively.
2. Richness at *test* reach SUC-D1 in 2015 was significantly lower than the mean of values at *baseline* reach SUC-D2, accounting for 37% of the variation in annual means.
3. Equitability was significantly higher across years at *test* reach SUC-D1 than at the *baseline* reach SUC-D2, accounting for 51% of the variance in annual means.
4. %EPT taxa was significantly lower in 2015 at *test* reach SUC-D1 than the mean of all years at *baseline* reach SUC-D2 and also significantly lower than the mean of prior years at *test* reach SUC-D1; both accounted for 32% of the variance in annual means.
5. CA Axis 1 scores were significantly higher across years at *test* reach SUC-D1 than at the *baseline* reach SUC-D2, accounting for 23% of the variance in annual means.
6. CA Axis 1 scores in 2015 at *test* reach SUC-D1 were significantly higher than the mean of *baseline* values and significantly lower than the mean of previous years. These effects accounted for 26% and 56% of the variance in annual means, respectively.
7. CA Axis 2 scores were significantly higher at *test* reach SUC-D1 in 2015 than the mean of *baseline* values and also than the mean of previous years at the *test* reach, accounting for 64% and 43% of the variance in annual means, respectively. Differences in axis scores reflected increased in Ceratopogonidae and Bivalvia (Figure 5.10-21).

Comparison to Published Literature The benthic invertebrate community at *test* reach SUC-D1 in fall 2015 was typical of a sand-bottomed creek with the dominant taxa being chironomids, and with mayflies (*Caenis, Baetisca, Hexagenia limbata, Acerpenna*) and clams (*Pisidium*) present. Worms only accounted for a moderate fraction (< 12%) of the community, suggesting good water quality conditions (Hynes 1960, Griffiths 1998).

The benthic invertebrate community at *baseline* reach SUC-D2 was typical of a creek with a soft, sandy substrate. Chironomids were dominant, with common forms that were moderately tolerant of degraded water quality conditions (Mandeville 2001). The benthic invertebrate community at *baseline* reach SUC-D2 also included a variety of worms, in addition to mayflies, caddisflies and fingernail clams, and gastropods, all in low relative abundances.

2015 Results Relative to Regional Baseline Condition All measurement endpoints of benthic invertebrate communities at *test* reach SUC-D1 were within the inner tolerance limits of the normal range of variation for means from the regional *baseline* depositional reaches (Figure 5.10-21, Figure 5.10-22).

Classification of Results Differences in measurement endpoints at *test* reach SUC-D1 were classified as **High** because the results of temporal and spatial comparisons contain significant differences in values for three measurement endpoints – richness, equitability, and %EPT – for *test* reach SUC-D1 that explain more than 20% of the variation in annual means. *Test* reach SUC-D1 in fall 2015 had a benthic invertebrate community with lower abundance and richness and higher equitability than the upper *baseline* reach, indicating that *test* reach SUC-D1 was of lower quality for benthic invertebrate communities than depositional *baseline* reach SUC-D2.

Tributaries of Christina Lake

Benthic invertebrate communities were sampled in fall 2015 in tributaries of Christina Lake at:

- depositional *test* reach SAC-D1 (Sawbones Creek), sampled since 2012;
- depositional *test* reach UNC-D2 (an unnamed creek, east of Christina Lake), sampled since 2013;
- depositional *test* reach UNC-D3 (an unnamed creek, south of Christina Lake), sampled since 2013; and
- depositional *baseline* reach BRC-D1 (Birch Creek), sampled since 2013.

2015 Habitat Conditions Water at *test* reach SAC-D1 in fall 2015 was relatively deep (1.2 m), basic (pH 6.2), with a velocity of 0.2 m/s, a high concentration of dissolved oxygen (7.3 mg/L), and low conductivity (117 µS/cm). The substrate consisted primarily of sand (84%) with small amounts of silt (12%) and clay (4%). Total organic carbon was low (2%) (Table 5.10-45).

Water at *test* reach UNC-D2 in fall 2015 was 0.6 m deep, neutral (pH 7.0), with a high concentration of dissolved oxygen (8.2 mg/L), and moderate conductivity (204 µS/cm). The substrate consisted of sand (62%), with some silt (32%) and clay (7%). Total organic carbon was low (7%) (Table 5.10-45).

Water at *test* reach UNC-D3 in fall 2015 was shallow (0.2 m), slightly basic (pH 6.7), with a high concentration of dissolved oxygen (9.0 mg/L), and moderate conductivity (231 µS/cm). The substrate consisted almost entirely of sand (95%) with small amounts of silt (4%) and clay (1%). Total organic carbon was low (<1%) (Table 5.10-45).

Water at *baseline* reach BRC-D1 in fall 2015 was 0.4 m deep, slightly basic (pH 6.8), had a velocity of 0.2 m/s, a high concentration of dissolved oxygen (9.8 mg/L), and moderate conductivity (338 µS/cm). Substrate consisted primarily of sand (86%) with small amounts of silt (12%) and clay (2%). Total organic carbon was low (<1 %) (Table 5.10-45).

Relative Abundance of Benthic Community Taxa The benthic invertebrate community of *test* reach SAC-D1 in fall 2015 was dominated by chironomids (80%) with subdominant taxa consisting of Naididae (5%), Ephemeroptera (4%), and bivalves (3%) (Table 5.10-46). Dominant chironomids included *Micropsectra/Tanytarsus*, *Paratendipes*, *Polypedilum*, and *Paralauterborniella*. Larvae of Ephemeroptera included *Acerpenna*, *Acerpenna/Falliceon*, *Callibaetis, Ephemerella*, *Eurylophella, Hexagenia limbata*, and *Leptophlebia*. Trichoptera (Limnephilidae), gastropods (*Gyraulus* and *Ferrissia rivularis*) and bivalves (*Pisidium*) were present in low relative abundances.

The benthic invertebrate community of *test* reach UNC-D2 in fall 2015 was dominated by chironomids (74%) with subdominant taxa Tubificidae (9%) (Table 5.10-47). Dominant chironomids included *Polypedilum* and *Paratendipes*. Larvae of mayflies (*Callibaetis*, Ephemerellidae, *Ephemera*, *Hexagenia limbata*, *Leptophlebia*), caddisflies (*Limnephilus/Nemotaulius*, *Phryganea*), dragonflies (*Somatochlora*) were found in low relative abundances (<1%) at UNC-D2 in 2015. Permanent aquatic forms including Amphipoda (*Hyalella azteca* and *Gammarus lacustris*) Gastropoda (Lymnaeidae, *Gyraulus*, *Valvata sincera*) and Bivalves (*Pisidium*, *Sphaerium*) were all found in the unnamed creek east of Christina Lake in fall 2015.

The benthic invertebrate community of test reach UNC-D3 in fall 2015 was dominated by chironomids (72%) with subdominant taxa of Ceratopogonidea (6%) (Table 5.10-47). Dominant chironomids included *Paracladopelma* and *Polypedilum*. Larvae of flying insects consisted of mayflies (*Callibaetis*, *Baetisca*, Ephemerellidae, *Ephemera*, *Hexagenia limbata*, *Siphloplecton*), stoneflies, and caddisflies (*Oxyethira*, *Oecetis*) were present. Permanent aquatic forms including amphipods (*Hyalella azteca*), gastropods (*Lymnaea*, *Physa*, *Gyraulus*), and bivalves (*Pisidium, Sphaerium*) were all found at *test* reach UNC-D3 in fall 2015. The dragonfly Ophiogomphus was found in 5 replicates of the reach.

The benthic invertebrate community of *baseline* reach BRC-D1 in fall 2015 was primarily comprised of chironomids (95%) (Table 5.10-48). Larvae of flying insects (Mayflies: *Leptophlebia*; Stoneflies: *Zapada*; and Caddisflies: *Hesperophylax, Ptilostomis*) were sparse but present at Birch Creek. Chironomids were primarily of the genera *Paratendipes, Paracladopelma, Polypedilum* and *Paralauterborniella*. Permanent aquatic forms included amphipods (*Hyalella azteca*) and the bivalve (Pisidiidae) in a few replicates of the reach.

Temporal and Spatial Comparisons Temporal comparisons of values of benthic invertebrate community measurement endpoints for *test* reaches SAC-D1, UNC-D2, and UNC-D3 consisted of:

- trends over time during the *test* period (Hypothesis 1, Section 3.2.3.1); and
- differences between 2015 values and the mean values of all previous years of sampling.

The comparisons that were statistically significant were as follows (Table 5.10-49):

1. Total abundance significantly decreased over time at *test* reach SAC-D1, and abundance was significantly higher in 2015 than the mean of the three previous years; both accounting for 50% of the variance in annual means.
2. %EPT was significantly lower in 2015 *test* reach SAC-D1 than the mean of prior years, accounting for 93% of the variance in annual means.
3. CA Axis 1 scores were significantly lower in 2015 *test* reach SAC-D1 than the means of prior years, accounting for 91% of the variance in annual means. Increases in both Chironomidae and Ephemeroptera likely accounted for the differences in CA Axis 1 scores (Figure 5.10-23). These changes are not indicative of degrading conditions at *test* reach SAC-D1.

There were no significant variations (i.e., ≥20%) over time at *test* reaches UNC-D2 and UNC-D3 (Table 5.10-50, Table 5.10-51).

Comparison to Published Literature The benthic invertebrate community of test reach SAC-D1 supported a benthic invertebrate community with low relative abundance of worms (~10%), and a reasonably high diversity of benthic fauna for a sandy-bottomed creek. Chironomids were abundant and diverse, while the presence of larvae of large flying insects and permanent aquatic forms indicated relatively high quality habitat (Hynes 1960; Griffiths 1998; Mandeville 2001). In addition, permanent aquatic forms such as clams and snails, and EPT taxa such as mayflies and stoneflies were present, which are indicative of relatively good water conditions.

The benthic invertebrate community of *test* reach UNC-D2 was representative of a depositional, sandy-bottomed river with high diversity of chironomids and low relative abundance of worms (<10%). The presence of permanent aquatic forms (amphipods, bivalves and gastropods) and larvae of large flying insects (mayflies and caddisflies) indicated good habitat quality (Hynes 1960; Griffiths 1998; Mandeville 2001).

The benthic invertebrate community of *test* reach UNC-D3 had a benthic fauna typical of a depositional, sandy-bottomed river with chironomids as the dominant taxa. The presence of larvae of large flying insects (specifically mayflies) and permanent aquatic forms (amphipods, bivalves, and gastropods), indicated good quality habitat (Pennak 1989).

The benthic invertebrate community of *baseline* reach BRC-D1 was representative of a depositional, sand-bottomed river, with a high diversity of chironomids and low relative abundance of worms (Mandeville 2002). Abundance and richness was similar to other depositional reaches on tributaries to Christina Lake (i.e., *test* reach UNC-D2 and *test* reach UNC-D3) in 2015.

2015 Results Relative to Regional Baseline Conditions Values of all measurement endpoints for the three *test* reaches in fall 2015 were within normal ranges for *baseline* reaches with the exception of abundance and richness being higher than the inner tolerance limit for the 95th percentile of regional *baseline* depositional reaches at *test* reach SAC-D1 (Figure 5.10-23 to Figure 5.10-27). These excursions are not considered to be indicative of degrading conditions for benthic invertebrate communities at this reach.

Classification of Results Variations in values of measurement endpoints of benthic invertebrate communities at *test* reach SAC-D1 were classified as **Moderate** because there were significant differences in values of two measurement endpoints (abundance and %EPT) in the temporal comparisons that accounted for more than 20% of the variance in annual means.

Variations in values of measurement endpoints of benthic invertebrate communities at *test* reach UNC-D2 and *test* reach UNC-D3 were classified as **Negligible-Low** because there were no significant variations over time at *test* reaches UNC-D2 and UNC-D3 and values of all measurement endpoints in fall 2015 for these *test* reaches were within normal ranges for *baseline* reaches.

Tributaries of Christina River

Benthic invertebrate communities were sampled in fall 2015 in tributaries of the Christina River at:

- erosional *test* reach JAR-E1 (Jackfish River), sampled since 2012 with a Neil-Hess cylinder and in 2015 with a CABIN kicknet; and
- erosional *test* reach GRR-E1 (Gregoire River), sampled in 2014 with a Neil-Hess cylinder and in 2015 with a CABIN kicknet.

Values of benthic invertebrate community measurement endpoints for fall 2015 were “adjusted” to make them as comparable as possible to data collected with a Neil-Hess cylinder (see Appendix D).

2015 Habitat Conditions Water at *test* reach JAR-E1 in fall 2015 was shallow (0.2 m) and fast moving (0.6 m/s), with alkaline pH (8.1), high dissolved oxygen concentration (8.0 mg/L), and moderate conductivity (178 µS/cm) (Table 5.10-52). The substrate was dominated by small cobble (6.4-12.8 cm).

Water at *test* reach, GRR-E1 in the fall of 2015 was shallow (0.2 m), alkaline (pH 8.6), had a high concentration of dissolved oxygen (9.8 mg/L) and moderate conductivity (368 µS/cm) (Table 5.10-52). The substrate was dominated by coarse sand.

Full CABIN supporting data for *test* reach JAR-E1 and *test* reach GRR-E1 are provided in Appendix D.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* reach JAR-E1 in fall 2015 was dominated by Ephemeroptera (45%), Trichoptera (19%), Chironomidae (11%), and miscellaneous Diptera (11%) (Table 5.10-53). Mayflies were diverse (12 genera) and numerically dominated by *Baetis* and members of the Ephemerellidae family. Trichoptera were primarily *Lepidostoma* and *Hydropsyche*, with *Brachycentrus* and *Hydroptila*. Other flying insects included stoneflies (*Acroneuria*, *Pteronarcys*) and dragonflies (*Ophiogomphus*). Chironomids were diverse and were represented by *Simulium*, *Hemerodromia*, and *Thienemannimyia gr*. Permanent aquatic forms were also present, including Amphipoda (*Hyalella*), Bivalvia (*Pisidium*, *Sphaerium*), and Gastropoda (*Ferrissia*, *Gyraulus*).

The benthic invertebrate community of *test* reach GRR-E1 in fall 2015 was primarily comprised of chironomids (35%), mayflies (23%) and caddisflies (20%) (Table 5.10-54). Subdominant taxa included miscellaneous Diptera (7%), stoneflies (6%) and water mites (6%). Chironomids were diverse and included primarily *Tvetenia*, *Orthocladius*, and *Rheotanytarsus*. Larvae of mayflies were primarily *Ephemerella* and *Baetis* with other members of the Ephemerellidae family. Larvae of stoneflies were primarily *Taeniopteryx,* with *Zapada* and members of the Perlodidae family. Larvae of caddisflies were primarily *Hydroptila*, with *Cheumatopsyche*, *Oecetis,* and *Hydropsyche*. Other flying insects included the dragonfly *Ophiogomphus*.

Temporal Comparisons Temporal comparisons of values of benthic invertebrate community measurement endpoints for *test* reach JAR-E1 consisted of testing for differences in mean values between 2015 and the mean of the three prior years. The temporal comparisons that were statistically significant were as follows (Table 5.10-55, Figure 5.10-28):

1. Richness was significantly lower in 2015 at *test* reach JAR-E1 than the mean of prior years in the reach, accounting for 52% of the variance in annual means.
2. %EPT was significantly lower in 2015 at *test* reach JAR-E1 than the mean of prior years in the reach, accounting for 76% of the variance in annual means.
3. CA Axis 1 scores were significantly lower in 2015 at *test* reach JAR-E1 than the mean of prior years in the reach, accounting for 98% of the variance in annual means.

Trends of decreasing richness and %EPT were indicative of degrading conditions for benthic invertebrate communities at Jackfish River. Shifts in CA Axis 1 scores may be attributed to decreases in the relative abundance of worms in the reach, which is not indicative of a negative change (Figure 5.10-28).

Temporal comparisons of values of benthic invertebrate community measurement endpoints for *test* reach GRR-E1 consisted of testing for differences in mean values between 2015 and 2014. The following temporal comparisons were statistically significant (Table 5.10-56, Figure 5.10-29, Figure 5.10-30):

1. Abundance was significantly higher in 2015 at *test* reach GRR-E1 than the mean of values for the *test* reach in 2014.

2. Equitability was significantly higher in 2015 at *test* reach GRR-E1 than the mean of values for the *test* reach in 2014.

As there are only two years of data for *test* reach GRR-E1, and given the change in sampling gear in 2015, these differences are not indicative of degrading conditions at the reach.

Comparison to Published Guidelines The benthic invertebrate community of *test* reach JAR-E1 contained a benthic fauna that reflected good water and sediment quality. EPT taxa (mayflies and caddisflies) were abundant as were chironomids indicating a taxa composition typical of good conditions (Hynes 1960, Griffiths 1998). Although the relative abundance of permanent aquatic organisms such as bivalves and gastropods in the reach was low, so was the relative abundance of worms.

The benthic invertebrate community of *test* reach GRR-E1 contained a benthic fauna representative of a healthy erosional river. Larvae of flying insects, including mayflies, caddisflies and stoneflies, were abundant in the reach indicating favourable long-term water quality (Resh and Unzicker 1975; Niemi et al. 1990). The relative abundance of worms was lower in 2015 than in 2014.

Comparison to Baseline Variability Values of all benthic invertebrate community measurement endpoints at *test* reach JAR-E1 in fall 2015 were within the inner tolerance limits of the normal range of values of erosional *baseline* variability (Figure 5.10-31) with the exception of CA Axis 1 and CA Axis 2 scores that exceeded the outer tolerance limit of the 95th percentile of the normal range of values of erosional *baseline* variability (Figure 5.10-28); these exceedances are not associated with degrading conditions for benthic invertebrate communities.

Values of all benthic invertebrate community measurement endpoints at *test* reach GRR-E1 in fall 2015 were within the inner tolerance limits of the normal range of values of erosional *baseline* variability (Figure 5.10-29, Figure 5.10-32).

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities of Jackfish River at *test* reach JAR-E1 for fall 2015 were classified as **Moderate**. While the benthic invertebrate community at *test* reach JAR-E1 in fall 2015 contained a benthic fauna that reflected good water and sediment quality, two of the three significant differences in values of measurement endpoints (taxa richness and %EPT) between 2015 and the mean of the prior years that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities. It should be emphasized that values of measurement endpoints for benthic invertebrate communities for 2015 were adjusted to account for the change in sampling gear and this classification should be interpreted with caution.

Variations in the values of measurement endpoints for benthic invertebrate communities of Gregoire River at *test* reach GRR-E1 for fall 2015 were classified as **Negligible-Low**. The benthic invertebrate community of *test* reach GRR-E1 in fall 2015 contained a benthic fauna representative of a healthy erosional river and none of the significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities at *test* reach GRR-E1.

Christina Lake

Benthic invertebrate communities were sampled in fall 2015 at Christina Lake (CHL-1), which is a *test* lake that has been sampled since 2012.

2015 Habitat Conditions Water in Christina Lake in fall 2015 was deep (>2 m) and alkaline (pH 8.0) with moderate conductivity (200 µS/cm) (Table 5.10-57). The substrate consisted of sand (68%) with some silt (28%), and moderate total organic carbon (3%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of Christina Lake in fall 2015 was dominated by chironomids (44%) and tubificid worms (22%) (Table 5.10-58). Twenty-two chironomid taxa were present in Christina Lake in fall 2015, with *Cladotanytarsus*, *Tanytarsus*, *Procladius* and *Dicrotendipes* the most common. Amphipods of the species *Hyalella azteca* were present, which are commonly distributed throughout Canada (Väinölä et al. 2008). Bivalves (*Pisidium*, *Sphaerium*) were present along with other permanent aquatic forms such as members of the Gastropoda (i.e., members of the Families Planorbidae and Valvatidae). Larvae of flying insects (Ephemeroptera: *Caenis*, *Ephemera*) were present, as were three types of Caddisfly (*Molanna, Agrypnia,* and *Oecetis*).

Temporal Comparisons The temporal comparisons of measurement endpoints for Christina Lake consisted of:

- trends over time (i.e., since 2012) (Hypothesis 7, Section 3.2.2.1); and
- differences between the values of the measurement endpoints in 2015 and the three previous years of sampling.

The temporal comparisons that were statistically significant are as follows (Table 5.10-59):

1. There were significant decreases in richness and %EPT over time and values of both were significantly lower in 2015 than the mean of the prior years of sampling, accounting for from 36% to 88% of the variance in annual means.
2. Equitability was significantly higher in 2015 than the mean of previous years, accounting for 41% of the variance in annual means.
3. There were significant increases in CA Axis 1 and CA Axis 2 scores over time and both were significantly higher in 2015 than the mean of previous years (Figure 5.10-33, Figure 5.10-34), accounting for from 41% to 95% of the variance in annual means. These shifts correspond to increases in tubificid worms and decreases in amphipods at *test* station CHL-1 in fall 2015, indicating degrading conditions for benthic invertebrate communities.

Comparison to Published Guidelines The benthic invertebrate community of Christina Lake was diverse and contained several forms typical of sandy-nearshore lake environments including one kind of amphipod, two genera of fingernail clam, and several kinds of snails (Gastropods) (Table 5.10-58). The presence of several large insects, such as Ephemeroptera and Trichoptera, in Christina Lake indicated that the benthic habitat was in good condition (Hynes 1960; Griffiths 1998).

2015 Results Relative to Historical Conditions The benthic invertebrate community of Christina Lake in fall 2015 was similar to previous years, with the following exceptions (Figure 5.10-33, Figure 5.10-34):

- chironomid abundance in 2015 (44%) was greater than in 2014 (20%), although similar to abundances in 2012 (31%) and 2013 (61%);
- the relative abundance of tubificid worms was higher in 2015;
- richness and %EPT were lower in 2015 than the mean of previous years of sampling;
- abundance, equitability, and CA axis 1 and 2 scores were higher in 2015 than the mean of previous years of sampling; and
- permanent aquatic forms (bivalves, gastropods, and amphipods), and mayflies and caddisflies were present in all years.

Classification of Results Variations in measurement endpoints of the benthic invertebrate community in Christina Lake (*test* reach CHL-1) in fall 2015 were classified as **High** because there were significant differences in values of all measurement endpoints in the temporal comparisons that each accounted for more than 20% of the variance in annual means and all these significant differences implied degrading conditions for benthic invertebrate communities. It is worth nothing that the lake in 2015 contained a diverse benthic fauna that included several permanently aquatic forms (e.g., clams, snails, amphipods), as well as several large aquatic insects (mayflies and caddisflies).

Gregoire Lake

Benthic invertebrate communities were sampled in fall 2015 at Gregoire Lake (GRL-1), which is a *test* lake that was also sampled in fall 2014.

2015 Habitat Conditions Benthic community samples were collected in Gregoire Lake in fall 2015 from an average depth of 1.5 m. The substrate of Gregoire Lake was primarily sand (80%) with some silt (17%) and low levels of total organic carbon (1%) (Table 5.10-60).

Relative Abundance of Benthic Invertebrate Community Taxa in 2015 The benthic invertebrate community of Gregoire Lake (GRL-1) in fall 2015 was dominated by amphipods (20%), nematodes (20%), chironomids (17%) and Naididae (16%) (Table 5.10-61). Chironomids consisted of 11 taxa, with *Cricotopus/Orthocladius* the most abundant, followed by *Cladotanytarsus* and *Strictochironomus*. Gastropods (Lymnaeidae, *Stagnicola*, *Physa* and *Menetus cooperi*) and bivalves (Pisidiidae, *Pisidium*) were also present in fall 2015. EPT taxa (Ephemeroptera: *Callibaetis*, *Caenis*, *Ephemera* and *Leptophlebia*; Trichoptera: *Mystacides, Oecetis* and *Molanna*) were sparse.

Temporal Comparisons The temporal comparisons of measurement endpoints for Gregoire Lake at *test* reach GRL-1 consisted of testing for differences between values of benthic invertebrate community measurement endpoints in 2015 and 2014. Abundance and richness were significantly higher in 2015 than in 2014 at *test* reach GRL-1, but neither explained ≥20% in variance (Table 5.10-62).

Comparison to Published Guidelines The benthic invertebrate community at *test* reach GRL-1 in fall 2015 generally reflected good water quality and lentic (lake-like) conditions. The community contained high relative abundances of permanent aquatic forms such as Amphipoda (20%), Bivalvia, and Gastropoda, and EPT taxa were also present indicating good long-term water quality (Niemi et al. 1990; Pennak 1989).

Classification of Results Differences in measurement endpoints of the benthic invertebrate community at *test* reach GRL-1 in fall 2015 were classified as **Negligible-Low** given none of temporal comparisons for *test* reach GRL-1 accounted for significant variation.

5.10.4.2 Sediment Quality

Sediment quality was sampled in depositional reaches of the Christina River watershed in the same locations as benthic invertebrate community sampling in fall 2015:

- *test* station CHR-D1 on the Christina River, near the mouth, sampled from 2002 to 2004, 2006, 2007, 2009, 2012, 2014, and 2015;
- *test* station CHR-D2 on the Christina River, upstream of Janvier, sampled from 2002 to 2004, 2006, 2009, 2012, 2014, and 2015;
- *test* station CHR-D3 on the Christina River, upstream of the Jackfish River confluence, sampled since 2014;
- *baseline* station CHR-D4 in the Christina River, upstream of development, sampled since 2013;
- *baseline* station BRC-1 on Birch Creek, sampled since 2013;
- *test* station SAC-D1 on Sawbones Creek, sampled since 2012;
- *test* station SUC-D1 on Sunday Creek near the inlet into Christina Lake, sampled since 2012;
- *baseline* station SUC-D2 on Sunday Creek upstream, sampled since 2013;
- *test* station UNC-D2 on an unnamed creek east of Christina Lake, sampled since 2013;
- *test* station UNC-D3 on an unnamed creek south of Christina Lake, sampled since 2013;
- *test* station CHL-1 in Christina Lake, sampled since 2012; and
- *test* station GRL-1 in Gregoire Lake, sampled since 2014.

Temporal Trends The following significant ($p<0.05$) temporal trends in concentrations of sediment quality measurement endpoints were observed[2]:

[2] Trend analyses were only possible for *test* stations CHR-D1 and CHR-D2; due to insufficient length of the time series in the sediment quality datasets for the other *test* and *baseline* stations within the Christina River watershed.

- decreasing concentrations of total PAHs, carbon-normalized PAHs, and total alkylated PAHs at *test* station CHR-D1; and

- decreasing concentrations of total organic carbon, total metals, total PAHs, total parent and total alkylated PAHs, and potential PAH toxicity hazard index at *test* station CHR-D2.

2015 Results Relative to Historical Concentrations Sediment sampling at *test* station CHR-D3 and *test* station GRL-1 was initiated in 2014 and there are therefore insufficient data to enable meaningful historical comparisons for these stations. In addition, with the exception of *test* stations CHR-D1, CHR-D2, and CHR-D3, all sampling in the remaining stations within the Christina River watershed was initiated in either 2012 or 2013 and comparison of fall 2015 conditions to historical ranges for these stations includes data from only two or three years of sampling.

Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at the stations in the Christina River (*test* stations CHR-D1, CHR-D2, and CHR-D3 and *baseline* station CHR-D4) (Table 5.10-63 to Table 5.10-66, Figure 5.10-36 to Figure 5.10-39) with the following exceptions:

- *test* station CHR-D1: Fraction 2 and 4 hydrocarbons, with concentrations in fall 2015 that were lower than the previously-measured minimum concentrations, and *Hyalella* survival that was higher than the previously-measured maximum value;

- *test* station CHR-D2: %clay and % silt, all PAHS, and *Chironomus* growth, with concentrations and values in fall 2015 that were lower than previously-measured minimum concentrations and values, and % sand, that was greater than the previously-measured maximum value; and

- *baseline* station CHR-D4: %silt, %total organic carbon, and *Chironomus* growth, with concentrations and values in fall 2015 that were lower than previously-measured minimum concentrations and values, and total dibenzothiophenes and total parent PAHs with concentrations in fall 2015 that were greater than the previously-measured maximum concentrations.

Table 5.10-66 and Figure 5.10-38 present the concentrations and values of sediment quality measurement endpoints for fall 2015 and fall 2014 for *test* station CHR-D3.

Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at the stations on the tributaries to the Christina River (*baseline* station BRC-D1, *test* station SAC-D1, *test* station SUC-D1, *baseline* station SUC-D2, *test* station UNC-D2, and *test* station UNC-D3) (Table 5.10-67 to Table 5.10-72, Figure 5.10-40 to Figure 5.10-45) with the following exceptions:

- *baseline* station BRC-D1: concentrations and values of all sediment quality endpoints were either lower in fall 2015 than previously-measured minimum concentrations and values or higher than higher than previously-measured maximum concentrations and values with the exception of %clay and predicted PAH toxicity;

- *test* station SAC-D1: all PAH measurement endpoints with the exception of naphthalene, with concentrations in fall 2015 that were lower than previously-measured minimum concentrations, and *Chironomus* survival that was higher in fall 2015 than its previously-measured maximum value;

- *test* station SUC-D1: concentrations and values of all sediment quality endpoints were either lower in fall 2015 than previously-measured minimum concentrations and values or higher than higher than previously-measured maximum concentrations and values with the exception of naphthalene, predicted PAH toxicity, and *Chironomus* growth;

- *baseline* station SUC-D2: %clay, %silt, and %total organic carbon, all PAH measurement endpoints with the exception of naphthalene, *Chironomus* growth, and *Hyalella* growth with concentrations and levels in fall 2015 that were lower than previously-measured minimum concentrations and values, and %sand and *Chironomus* survival, with concentrations and levels in fall 2015 that were higher than higher than previously-measured maximum concentrations and values;

- *test* station UNC-D2: concentrations of all PAH measurement endpoints with the exception of retene and total parent PAHs, and *Hyalella* growth with concentrations and levels in fall 2015 that were lower than previously-measured minimum concentrations and values, and *Chironomus* survival, which was higher in fall 2015 than its previously-measured maximum value; and

- *test* station UNC-D3: %clay, %total organic carbon, all PAH measurement endpoints with the exception of naphthalene and retene, *Chironomus* growth, and *Hyalella* growth, with concentrations and levels in fall 2015 that were lower than previously-measured minimum concentrations and values, and naphthalene with a concentration in fall 2015 that was greater than its previously-measured maximum concentration.

Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at *test* station CHL-1 on Christina Lake and *test* station GRL-1 on Gregoire Lake (Table 5.10-73, Figure 5.10-46) with the following exceptions:

- *Chironomus* growth and *Hyalella* growth at *test* station CHL-1 with values in fall 2015 that were lower than previously-measured minimum values; and

- %silt at *test* station CHL-1 that in fall 2015 was higher than previously-measured maximum value;

Table 5.10-74 and Figure 5.10-47 present the concentrations and values of sediment quality measurement endpoints for fall 2015 and fall 2014 for *test* station GRL-1 on Gregoire Lake.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Measurement endpoints of sediment quality were below guideline concentrations in fall 2015, with the exception of predicted PAH toxicity, at *test* station CHR-D1, and total arsenic at *baseline* station BRC-D1 (7.9 mg/kg). The concentration of Fraction 1 hydrocarbons in fall 2015 at *test* station GRL-1 was not detectable, but had a detection limit that exceeded the CCME guideline.

2015 Results Relative to Regional *Baseline* Concentrations In fall 2015, concentrations of all sediment quality measurement endpoints were within the ranges of regional *baseline* concentrations (Figure 5.10-36 to Figure 5.10-45) with the following exceptions:

- concentrations of total PAHs at *baseline* station SUC-D2 and *test* stations CHR-D2, CHR-D3, and UNC-D3, which were below the 5th percentile of regional *baseline* concentrations;

- concentration of total PAHs (when carbon-normalized) at *test* station CHR-D3, which was below the 5th percentile of regional *baseline* concentrations;

- predicted PAH toxicity at *test* stations CHR-D2 and CHR-D3 and *baseline* station SUC-D2, which were below the 5th percentile of regional *baseline* concentrations;

- concentrations of total metals at *baseline* station BRC-D1 and *test* station UNC-D3, which were below the 5th percentile of regional *baseline* concentrations; and

- concentrations of total metals (when normalized to percent fine sediments) at *test* stations CHR-D2 and CHR-D3 and *baseline* station CHR-D4, which were above the 95th percentile of regional *baseline* concentrations.

Sediment quality measurement endpoints were not compared to regional *baseline* concentrations for *test* station CHL-1 or *test* station GRL-1 because lakes were not included in the calculation of *baseline* concentrations, given the ecological differences between lakes and rivers.

Sediment Quality Index SQI values in fall 2015 at all sediment quality stations in the Christina River watershed were 97.9 or greater, indicating **Negligible-Low** differences compared to regional *baseline* conditions.

SQI values were not calculated for *test* station CHL-1 or *test* station GRL-1 because lakes were not included in the regional *baseline* calculations.

Classification of Results Differences in sediment quality conditions in fall 2015 at all sediment quality stations in the Christina River watershed were **Negligible-Low** compared to regional *baseline* conditions.

5.10.5 Fish Populations

In 2015, fish community monitoring and wild fish health monitoring were conducted in the Christina River watershed at reaches on the Christina River, tributaries to the Christina River, and Christina Lake.

5.10.5.1 Fish Communities

Christina River

Fish community monitoring was conducted on the Christina River in fall 2015 at *test* reach CHR-F2. The fish community was monitored at this reach in 2012 and 2014, at the same location as the benthic invertebrate community and sediment quality *test* reach CHR-D2.

2015 Habitat Conditions Habitat conditions at *test* reach CHR-F2 for fall 2015 are summarized in Table 5.10-75. *Test* reach CHR-F2 consisted of riffle habitat with a wetted width of 42.0 m and a bankfull width of 43.0 m. Substrate consisted mostly of coarse gravel and fine gravel. Water at *test* reach CHR-F2 had a mean depth of 0.34 m, a velocity of 0.64 m/s, pH of 8.58, conductivity of 235 µS/cm, a dissolved oxygen concentration of 10.1 mg/L, and a temperature of 9.4˚C. Instream cover consisted of large and small woody debris, live trees and roots, undercut banks, boulders, and filamentous algae.

Relative Abundance of Fish Species Four fish species were caught at *test* reach CHR-F2 in fall 2015, the same species richness as in 2014, but a lower species richness than in 2012 (Table 5.10-76). The total catch of fish was higher in 2015 than in 2014 and was dominated by longnose sucker and white sucker (Table 5.10-76).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach CHR-F2 consisted of testing for changes over time in fish community measurement endpoints (Hypothesis 2, 2012, 2014, and 2015). No spatial comparisons were conducted because no other reaches of the Christina River mainstem were sampled in 2015.

There were no significant changes in measurement endpoints over time at *test* reach CHR-F2 with the exception of abundance, which significantly increased over time and explained greater than 20% of the variance in annual means (Table 5.10-77, Table 5.10-78). This increase in abundance over time does not imply a negative change to the fish community at *test* reach CHR-F2.

Comparison to Published Literature Golder (2004) documented similar habitat conditions in the vicinity of *test* reach CHR-F2, with riffle and run habitat with a moderate flow and substrate consisting of sand, gravel, cobble, and boulders (Table 5.10-75). The Christina River provides good refugia for spawning fish migrating from the Clearwater River and therefore has a high potential to support recreational fisheries (Golder 2004). Past studies have documented a total of 20 fish species in the Christina River, compared to a total of 17 species captured in the Christina River during historical fish monitoring conducted for the RAMP/JOSMP from 2012 to 2015 (Table 5.10-76). Possible reasons for discrepancies in species richness may be due to differences in sampling gear as well as the total amount of the watercourse sampled; fish community monitoring under the JOSMP samples smaller, defined reach lengths compared to the multiple locations and reaches documented as being sampled by Golder (2004).

2015 Results Relative to Regional *Baseline* Conditions Mean values of all measurement endpoints at *test* reach CHR-F2 were within the inner tolerance limits of regional *baseline* variability (Figure 5.10-48).

Classification of Results Differences in measurement endpoints for *test* reach CHR-F2 were classified as **Negligible-Low:**

1. There were no significant changes in values of fish community measurement endpoints over time that implied a negative change in the fish community; and

2. Mean values of all fish community measurement endpoints at *test* reach CHR-F2 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints.

Tributaries of Christina River

Fish community monitoring was conducted on the Jackfish River at *test* reach JAR-F1 in fall 2015. The Jackfish River is the outlet of Christina Lake and the fish community has been monitored at this reach since 2012, at the same location as benthic invertebrate community *test* reach JAR-E1.

2015 Habitat Conditions Habitat conditions at *test* reach JAR-F1 for fall 2015 are summarized in Table 5.10-79. *Test* reach JAR-F1 consisted of riffle and glide habitat with a wetted width of 33.8 m and a bankfull width of 36.5 m. Substrate was dominated by coarse gravel with smaller amounts of fine gravel and sand. Water at *test* reach JAR-F1 had a mean depth of 0.39 m, velocity of 0.30 m/s, pH of 8.05, conductivity of 178 µS/cm, dissolved oxygen concentration of 8.6 mg/L, and a temperature of 11.6˚C. Instream cover consisted of macrophytes with small amounts of algae

Relative Abundance of Fish Species The total catch of fish at *test* reach JAR-F1 was lower in 2015 than in 2014 and 2013 and was dominated by burbot (Table 5.10-80). The species richness at *test* reach JAR-F1, consisting of five species, was similar to species richness in 2012 and 2013 (Table 5.10-80).

Temporal and Spatial Comparisons Temporal comparisons for *test* reach JAR-F1 included testing for changes over time in measurement endpoints (Hypothesis 2, 2012 to 2015). No spatial comparisons of measurement endpoints were conducted for *test* reach JAR-F1 because a *baseline* reach on the Jackfish River was not monitored in 2015.

There were no significant changes over time in values of any of the fish community measurement endpoints *test* reach JAR-F1 (Table 5.10-81).

Comparison to Published Literature Baseline information for Jackfish River was limited to data in the AEP Fisheries and Wildlife Management Information System (FWMIS) database (AESRD 2012). Arctic grayling, burbot, longnose sucker, northern pike, slimy sculpin, walleye, and white sucker have previously been documented in Jackfish River. All of these species were captured by JOSMP from 2012 to 2015 as well as two additional species (longnose dace and trout-perch) not documented in the AEP FWMIS (Table 5.10-80).

2015 Results Relative to Regional *Baseline* Conditions Mean values of all measurements in 2015 at *test* reach JAR-F1 were within the inner tolerance limits of the *baseline* range of variability (Figure 5.10-48).

Classification of Results Differences in measurement endpoints for *test* reach JAR-F1 were classified as **Negligible-Low:**

1. There were no significant changes in fish community measurement endpoints over time; and
2. Mean values of all fish community measurement endpoints in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints.

Tributaries of Christina Lake

Fish community monitoring was conducted on tributaries of Christina Lake in fall 2015 at:

- *test* reach SUC-F1, lower Sunday Creek, sampled since 2012;
- *baseline* reach SUC-F2, upper Sunday Creek, sampled since 2013;
- *test* reach UNC-F2, unnamed creek east of Christina Lake, sampled since 2013;
- *test* reach UNC-F3, unnamed creek south of Christina Lake, sampled since 2013;
- *test* reach SAC-F1, Sawbones Creek, sampled since 2012; and
- *baseline* reach BRC-F1, Birch Creek, sampled since 2013.

2015 Habitat Conditions Habitat conditions for the Christina Lake tributary reaches for fall 2015 are summarized in Table 5.10-82.

Test reach SUC-F1 was comprised of glide habitat with a wetted width of 9.7 m and a bankfull width of 10.0 m. Substrate was primarily cobble with smaller amounts of sand. Water at *test* reach SUC-F1 in fall 2015 had a mean depth of 0.41 m, with a velocity of 0.14 m/s, pH of 7.54, conductivity of 232 µS/cm, dissolved oxygen concentration of 10.0 mg/L, and a temperature of 9.4˚C. Instream cover consisted of small woody debris and boulders.

Baseline reach SUC-F2 was comprised of glide and impoundment pool habitat with a wetted width of 7.55 m and a bankfull width of 8.55 m. Substrate consisted of fine material with smaller amounts of sand. Water at *baseline* reach SUC-F2 in fall 2015 had a mean depth of 0.59 m with a velocity of 0.22 m/s, pH of 7.29, conductivity of 198 µS/cm, dissolved oxygen concentration of 9.2 mg/L, and a temperature of 9.9˚C. Instream cover consisted of large and small woody debris, and macrophytes.

Test reach UNC-F2 was comprised of glide habitat with a wetted width of 8.0 m and a bankfull width of 7.0 m. Substrate consisted of fine material with smaller proportions of sand. Water at *test* reach UNC-F2 in fall 2015 had a mean depth of 0.96 m, velocity of 0.04 m/s, pH of 7.41, conductivity of 177 µS/cm, dissolved oxygen concentration of 8.4 mg/L, and a temperature of 8.2˚C. Instream cover consisted of macrophytes, overhanging vegetation, and small woody debris.

Test reach UNC-F3 was comprised of glide habitat with a wetted width of 4.1 m and a bankfull width of 4.8 m. Substrate consisted of sand with smaller amounts of fines. Water at *test* reach UNC-F3 in fall 2015 had a mean depth of 0.43 m, velocity of 0.03 m/s, pH of 7.62, conductivity of 187 µS/cm, dissolved oxygen concentration of 9.7 mg/L, and a temperature of 10.5˚C. Instream cover consisted of macrophytes with some filamentous algae and overhanging vegetation.

Test reach SAC-F1 was comprised of glide habitat with a wetted and bankfull width of 6.7 m. Substrate consisted of fine material with smaller amounts of sand. Water at *test* reach SAC-F1 in fall 2015 had a mean depth of 1.46 m, velocity of 0.07 m/s, pH of 7.68, dissolved oxygen concentration of 7.8 mg/L, and a temperature of 9.4 ˚C. Instream cover consisted of macrophytes and undercut banks with small amounts of overhanging vegetation, and small woody debris.

Baseline reach BRC-F1 was comprised of glide habitat with a wetted width of 6.53 m and a bankfull width of 9.0 m. Substrate consisted of sand with smaller amounts of fines. Water at *baseline* reach BRC-F1 in fall 2015 had a mean depth of 0.34m, velocity of 0.16 m/s, pH of 7.79, conductivity of 316 µS/cm, dissolved oxygen concentration of 6.7 mg/L, and a temperature of 9.0˚C. Instream cover consisted of overhanging vegetation with some macrophytes, undercut banks, and large woody debris.

Relative Abundance of Fish Species Table 5.10-83 and Table 5.10-84 present a summary of the relative abundance of fish species at the tributaries of Christina Lake:

1. The total catch of fish species at *test* reach SUC-F1 was lower in 2015 compared to 2014 and was dominated by slimy sculpin, which was consistent with previous years.

2. The total catch of fish species was higher at *baseline* reach SUC-F2 compared to *test* reach SUC-F1 and compared to 2014, and was dominated by spottail shiner.

3. One and seven fish were captured at *test* reaches UNC-F2 and UNC-F3, respectively, with catch at both reaches dominated by northern pike;

4. There were no fish captured at *test* reach SAC-F1 in fall 2015. Only one fish has ever been captured at *test* reach SAC-F1 since the RAMP/JOSMP began monitoring this creek (northern pike in 2012);

5. Two fish (slimy sculpin) were captured at *baseline* reach BRC-F1 in fall 2015.

Test reaches UNC-F2, UNC-F3, and SAC-F1, and *baseline* reach BRC-F1 have a large proportion of deep-water habitat, resulting in poor capture efficiency and low spatial coverage of the reach during fish inventories. An effort was made in 2015 to find better fish habitat in these creeks but these creeks have similar habitat conditions along the entire length of the watercourse that was accessible by Argo and boat.

Temporal and Spatial Comparisons Spatial comparisons (Hypothesis 1, Section 3.2.4.1) were conducted between *test* reach SUC-F1 and *baseline* reach SUC-F2 and temporal comparisons (Hypothesis 2, Section 3.2.4.1) were conducted from 2012 to 2015 for *test* reach SUC-F1, and from 2013 and 2015 for *baseline* reach SUC-F2[3]. The following significant comparisons were identified:

1. There were no significant differences in trends over time in values of measurement endpoints between *test* reach SUC-F1 and *baseline* reach SUC-F2 (Table 5.10-85).

2. There were significant increases in abundance, richness, and CPUE at *test* reach SUC-F1 over time and differences in abundance and richness explained greater than 20% of the variation in annual means (Table 5.10-85). These increases do not imply a negative change to the fish community at *test* reach SUC-F1.

3. There were significant increases in abundance and CPUE at *baseline* reach SUC-F2 over time, both of which explained greater than 20% of the variation in annual means (Table 5.10-85). These increases do not imply a negative change to the fish community at *baseline* reach SUC-F2.

Comparison to Published Literature *Baseline* information for the area was limited to data in the AEP FWMIS database (AESRD 2012). Previous studies at Sunday Creek have documented Arctic grayling, brook stickleback, Iowa darter, lake whitefish, northern pike, slimy sculpin, spottail shiner, walleye, spoonhead sculpin, and white sucker. Seven of these ten species and an additional four species not described in the AEP FWMIS database (burbot, longnose sucker, lake chub, and pearl dace) have been captured either at *test* reach SUC-F1 or *baseline* reach SUC-F2 during fish community monitoring for the JOSMP from 2012 to 2015. There was no published information on fish communities in the unnamed creeks where *test* reaches UNC-F2 and UNC-F3 were located.

[3] No other spatial and temporal comparisons were conducted because so few fish have been captured at *test* reaches SAC-F1 (one fish in four years), UNC-F2 (three fish in three years), and UNC-F3 (20 fish in three years), as well as for *baseline* reach BRC-F1 (eleven fish in three years) (Table 5.10-75); the large proportion of deep-water habitat at these reaches results in poor capture efficiency and low spatial coverage of the reach during fish inventories.

2015 Results Relative to Regional *Baseline* Conditions Values of measurement endpoints for *test* reach SUC-F1 and *baseline* reach SUC-F2 for fall 2015 were within the inner tolerance limits for the range of *baseline* variability (Figure 5.10-48)[4].

Classification of Results Differences in measurement endpoints for fish communities at *test* reach SUC-F1 compared to regional *baseline* conditions were classified as **Negligible-Low**:

1. There were no significant changes in values of fish community measurement endpoints at *test* reach SUC-F1, in either spatial comparisons to *baseline* reach SUC-F2 or in changes over time, that implied a negative change in the fish community; and

2. Mean values of all measurement endpoints for fish community monitoring at *test* reach SUC-F1 in fall 2015 were within the ranges of regional *baseline* values for these measurement endpoints.

5.10.5.2 Wild Fish Health

Christina River Tributaries

Wild fish health monitoring was conducted at *test* reach JAR-F1 of the Jackfish River in fall 2015, using slimy sculpin as the target species. 2015 was the first year of wild fish health monitoring at this reach; therefore, no temporal comparisons could be made.

2015 Habitat Conditions In situ water quality at *test* reach JAR-F1 provided suitable conditions for slimy sculpin, with a concentration of dissolved oxygen of 9.6 mg/L; conductivity of 223 µS/cm; and pH of 8.36 (Table 5.10-86). The mean water depth was 0.5 m. Dominant substrates were cobble and boulders. Water temperature measured at the time of sampling was 5.4°C and daily mean water decreased from a high of 24°C on August 10 to a low 7°C on September 28 (Figure 5.10-49).

Collection and Structure of Target Fish

Summary of Capture Success of Adults and Juveniles Twenty female and 19 male slimy sculpin at *test* reach JAR-F1 were captured and, although fishing effort was maximized to capture the required 100 juveniles, no juveniles were captured at the *test* reach JAR-F1. A summary of morphometric data for the slimy sculpin caught in the Jackfish River is provided in Table 5.10-87.

Size Distribution Figure 5.10-50 presents the length-frequency distribution of all slimy sculpin captured in fall 2015 at *test* reach JAR-F1. No juveniles were captured and no bimodal distribution of length was observed in 2015.

Incidence of Abnormalities External parasites were the only abnormality observed on slimy sculpin caught at *test* reach JAR-F1, affecting 3.6% of the captured fish (Table 5.10-87).

Spatial Comparison of Fish Responses

No spatial comparisons were completed in 2015 because no regional *baseline* reach used slimy sculpin as a target species in the 2015 Program, and no other reaches were sampled on the Jackfish River in

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[4] Comparison of values of fish community measurement endpoints to regional *baseline* values were not made for *test* reaches SAC-F1, UNC-F2, and UNC-F3, or for *baseline* reach BRC-F1.

2015. The information provided below is a summary of the morphometric data for the adult slimy sculpin caught in the Jackfish River at *test* reach JAR-F1 in fall 2015 (Table 5.10-88). Relative gonad size, relative liver size and condition were estimated by gonadosomatic index (GSI), liversomatic index (LSI), and condition factor (K), respectively.

Age – Mean Age and Age Distribution (Survival) The mean age of adult female slimy sculpin at *test* reach JAR-F1 in fall 2015 was 1.7 years while the mean age of adult males was 1.5 years (Table 5.10-88). The relative age-frequency distributions of slimy sculpin captured shows the dominant age class to be a year for the majority of adults (>50 mm) and the sub-dominant age class to be four (Figure 5.10-51).

Growth – Size-at-Age (Energy Use) Females were consistently smaller than males of the same age (Figure 5.10-52). The mean weight of the dominant age class of males (one year old) was 6.39 g and the mean weight of the dominant age class of females (one year old) was 4.19 g.

Relative Gonad Weight (Energy Use) The mean GSI of adult female and adult male slimy sculpin at *test* reach JAR-F1 in fall 2015 was 0.89 and 1.50, respectively (Table 5.10-88).

Relative Liver* Weight (*Energy Storage) The mean LSI of adult female and adult male slimy sculpin at *test* reach JAR-F1 in fall 2015 was 1.14 and 0.83, respectively (Table 5.10-88).

Condition (Energy Storage) The mean condition factor of adult female and adult male slimy sculpin at *test* reach JAR-F1 in fall 2015 was 1.05 and 1.08, respectively (Table 5.10-88).

Exposure – Mixed Function Oxygenase (MFO) Activity The EROD activity of adult female and adult male slimy sculpin at *test* reach JAR-F1 in fall 2015 was 11.36 pmol/min/mm and 10.47 pmol/min/mm, respectively (Figure 5.10-53).

Interpretation of 2015 Response Interpretation of the wild fish health data obtained for the Jackfish River in 2015 was not possible as no *baseline* reaches were sampled in the Christina River watershed for the wild fish health component in 2015 and slimy sculpin were not sampled at any regional *baseline* reach during the 2015 Program.

Classification of Results Classification of results for wild fish health monitoring in the Jackfish River in 2015 was not possible because no *baseline* reaches were sampled in the Christina River watershed for the wild fish health component in 2015 and the target fish species, slimy sculpin, was not sampled at any regional *baseline* reach during the 2015 Program.

Christina Lake Tributaries

Wild fish health monitoring was conducted in two reaches on tributaries of Christina Lake in fall 2015, using slimy sculpin as the target species: *test* reach SAC-F1 on Sawbones Creek; and *test* reach SUC-F1 on Sunday Creek. 2015 was the first year of wild fish health monitoring at these reaches; therefore, no temporal comparisons could be made.

2015 Habitat Conditions In situ water quality at *test* reach SAC-F1 (Sawbones Creek) indicated suitable conditions for slimy sculpin, with a dissolved oxygen concentration of 7.6 mg/L; conductivity of 148 µs/cm; pH of 7.54, and water temperature of 5.5°C (Table 5.10-86). The mean water depth was 1.5 m with a water velocity of 0.02 m/s and a substrate dominated by sand. Temperature at time of sampling was

5.5°C (Table 5.10-86) and daily mean water temperatures decreased from a high of 18.6°C on August 14 to a low of 6.7 °C on September 28 (Figure 5.10-49).

Water quality at *test* reach SUC-F1 (Sunday Creek) indicated suitable conditions for slimy sculpin as well, with a dissolved oxygen concentration of 10 mg/L, conductivity of 232 µs/cm, and pH of 7.54. The mean water depth was 0.11 m and water velocity was 0.49 m/s. The substrate consisted of cobble, sands and fines. Temperature at time of sampling was 9.4°C (Table 5.10-86) and daily mean water temperatures decreased from a high of 19°C on August 13 to a low of 6.5 °C on September 29 (Figure 5.10-49).

Collection and Structure of Target Fish

Summary of Capture Success of Adults and Juveniles Despite multiple sampling trips and the use of a variety of gear types, no fish were caught at the *test* reach SAC-F1 (Sawbones Creek) during fall 2015. The target number of slimy sculpin (20 adult fish of each sex) was achieved at *test* reach SUC-F1 (Sunday Creek), but only 80 juveniles were captured, fewer than the target of 100. A summary of morphometric data for the slimy sculpin caught at *test* reach SUC-F1 is provided in Table 5.10-87.

Size Distribution Figure 5.10-50 presents the length-frequency distribution of all slimy sculpin captured in fall 2015 at *test* reach SUC-F1. A length of 50 mm was used to designate slimy sculpin juveniles as 50 mm marks the end of the first peak in the bimodal distribution of length (Figure 5.10-50).

Incidence of Abnormalities No abnormalities were observed on fish caught at *test* reach SUC-F1 in fall 2015 (Table 5.10-87).

Spatial Comparison of Fish Responses

No spatial comparisons were completed in 2015 because no regional *baseline* reach used slimy sculpin as a target species during the 2015 Program and no other reaches were sampled on the Sunday Creek in 2015. The information provided below is a summary of the morphometric data for the adult slimy sculpin caught in the Sunday Creek at *test* reach SUC-F1in fall 2015 (Table 5.10-88). Relative gonad size, relative liver size and condition were estimated by gonadosomatic index (GSI), liversomatic index (LSI), and condition factor (K), respectively.

Age – Mean Age and Age Distribution (Survival) The mean age of adult female slimy sculpin at *test* reach SUC-F1 in fall 2015 was 2.2 years while the mean age of adult males was 1.6 years (Table 5.10-88). The relative age-frequency distributions of slimy sculpin captured shows the dominant age class to be one year for the majority of adults (>50 mm) and the sub-dominant age class to be three year old fish (Figure 5.10-51).

Growth – Size-at-Age (Energy Use) Females were consistently smaller than males of the same age (Figure 5.10-54). The mean weight of the dominant age class of males (one year old) was 4.76 g and the mean weight of the dominant age class of females (one year old) was 2.59 g.

Relative Gonad Weight (Energy Use) The mean GSI of adult female and adult male slimy sculpin at *test* reach SUC-F1 in fall 2015 was 1.51 and 1.63, respectively (Table 5.10-88).

Relative Liver* Weight (*Energy Storage) The mean LSI of adult female and adult male slimy sculpin at *test* reach SUC-F1 in fall 2015 was 1.07 and 0.90, respectively (Table 5.10-88).

Condition (Energy Storage) The mean condition factor of adult female and adult male slimy sculpin at *test* reach SUC-F1 in fall 2015 was 0.95 and 1.04, respectively (Table 5.10-88).

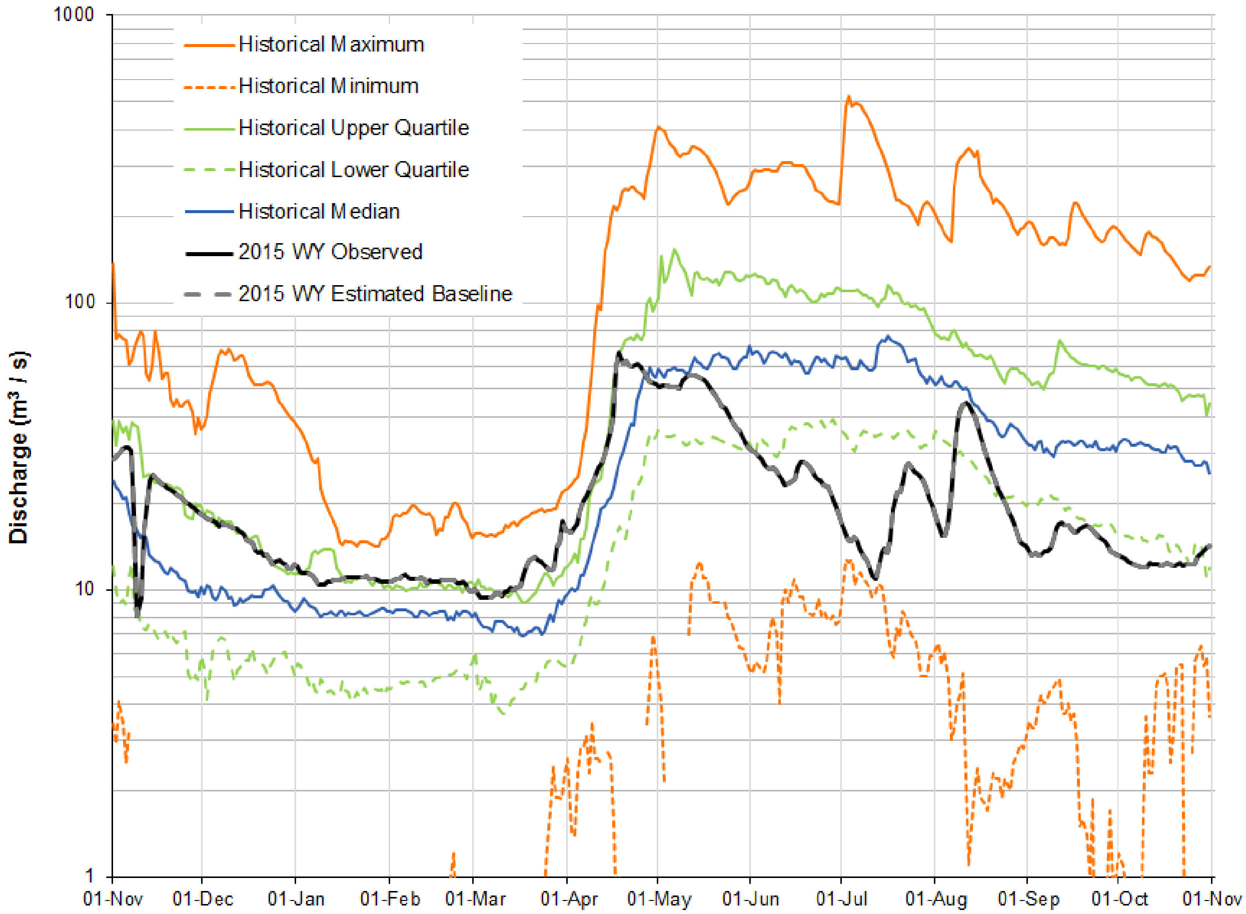
Exposure – Mixed Function Oxygenase (MFO) Activity

The EROD activity of adult female and adult male slimy sculpin at *test* reach SUC-F1 in fall 2015 was 13.93 pmol/min/mm and 15.69 pmol/min/mm, respectively (Figure 5.10-53).

Interpretation of 2015 Response Interpretation of the wild fish health data obtained for Sunday Creek in 2015 was not possible as no *baseline* reaches were sampled in the Christina River watershed for the wild fish health component in 2015 and slimy sculpin were not sampled at any regional *baseline* reach during the 2015 Program.

Classification of Results Classification of results for wild fish health monitoring in the Sunday Creek in 2015 was not possible because no *baseline* reaches were sampled in the Christina River watershed for the wild fish health component in 2015 and the target fish species, slimy sculpin, was not sampled at any regional *baseline* reach during the 2015 Program.

Figure 5.10-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Christina River in the 2015 WY, compared to historical values.



Note: The observed 2015 WY hydrograph was based on Christina River near the mouth, Station S47A. The upstream drainage area is 13,038 km². Historical data included estimated values from 1967 to 2011 and recorded data from 2012 to 2014. The estimated historical data from 1967 to 2011 were calculated from the difference between the measured flow at Clearwater River above Christina River, WSC Station 07CD005, and Clearwater River above Draper, WSC Station 07CD001.

Table 5.10-2 Estimated water balance at JOSMP Station S47A (formerly JOSMP Station S47), mouth of the Christina River, 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**671.541**	**Observed discharge at Christina River near the mouth (JOSMP Station S47A)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.934	Estimated 18.139 km^2 of the Christina River watershed is closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	1.366	Estimated 132.686 km^2 of the Christina River watershed with oil sands developments as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Christina River watershed, relative to the estimated *baseline* hydrograph	-0.091	Water withdrawn by Nexen, Statoil, MEG, and Canadian Natural Kirby.
Water releases into the Christina River watershed, relative to the estimated *baseline* hydrograph	0.039	Water released by Canadian Natural Kirby
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**671.161**	**Estimated *baseline* discharge at Christina River near the mouth, JOSMP Station S47A**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	0.381	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	0.057	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

Observed volume of water discharged was calculated using data for the 2015 WY from November 1 to October 31, 2015 for Christina River near the mouth, JOSMP Station S47A.

All non-zero values in this table presented to three decimal places.

Table 5.10-3 Calculated change in hydrologic measurement endpoints for the mouth of the Christina River, 2015 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	24.074	24.087	+0.054%
Mean winter discharge	14.084	14.093	+0.058%
Annual maximum daily discharge	67.154	67.194	+0.060%
Open-water season minimum daily discharge	10.885	10.891	+0.053%

Notes:

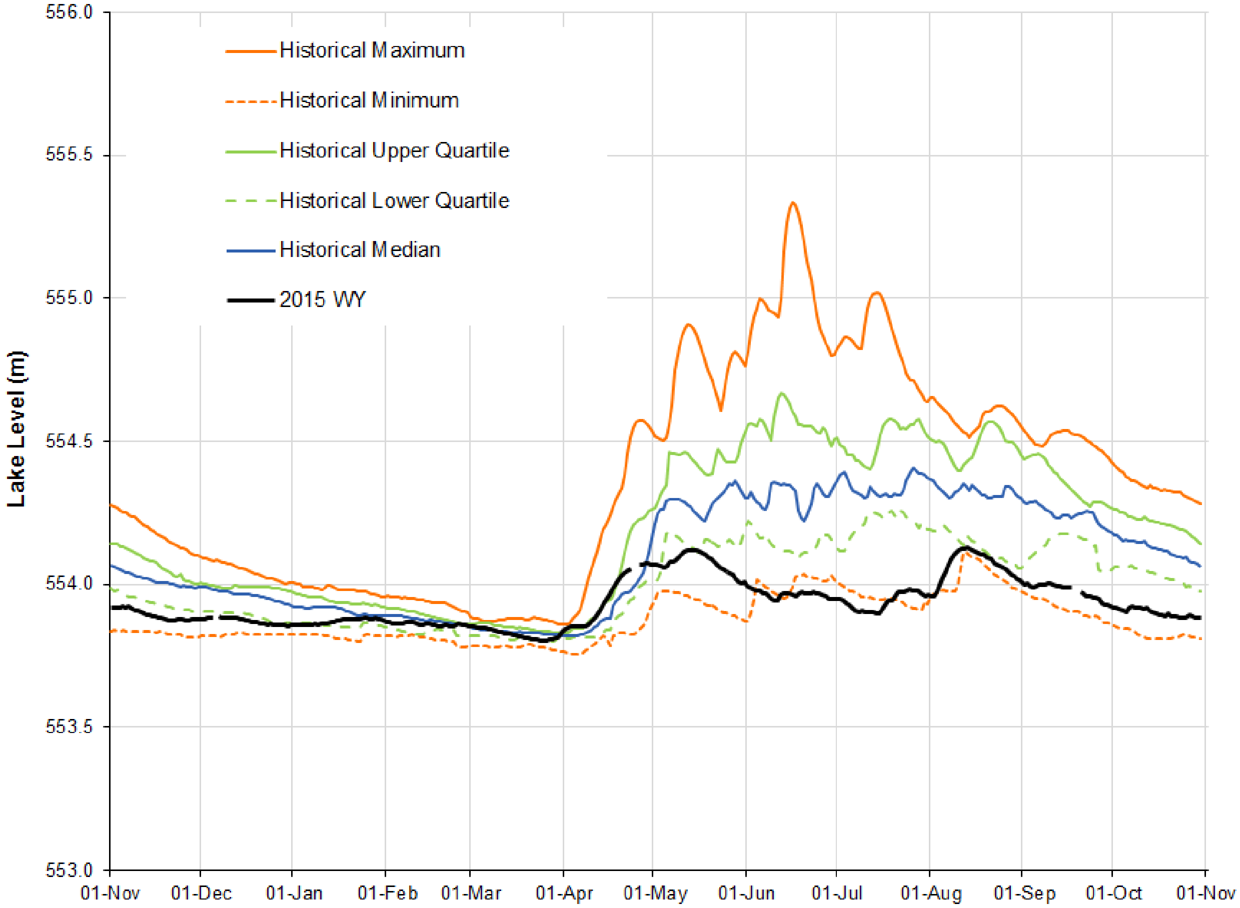
Definitions and assumptions are discussed in Section 3.2.1.

Observed discharge was calculated using data for the 2015 WY from November 1 to October 31, 2015 for Christina River near the mouth, JOSMP Station S47A.

The relative change for each measurement endpoint was calculated using observed and baseline flow values, which were estimated to several decimal places. Flow values are presented to three decimal places for the sake of clarity.

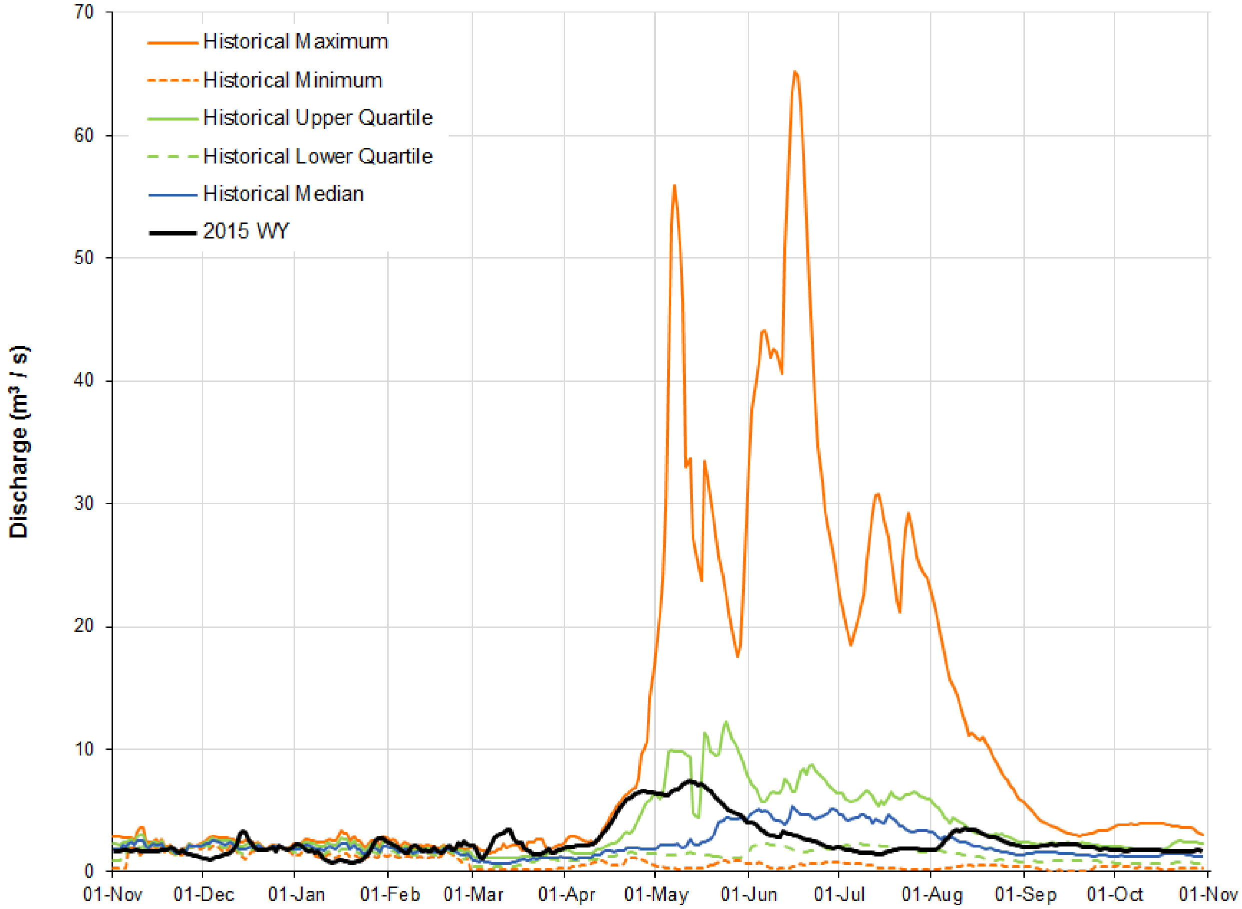
The open-water season refers to the period between May 1 and October 31 and the winter season refers to the period between November 1 and March 31.

Figure 5.10-4 Observed lake levels for Christina Lake near Winfred Lake in the 2015 WY, compared to historical values.



Note: Based on 2015 WY data recorded at Christina Lake near Winfred Lake WSC Station 07CE906. Historical values were calculated for the period from 2001 to 2014.

Figure 5.10-5 Hydrograph for Jackfish River below Christina Lake for the 2015 WY, compared to historical values.



Note: Based on 2015 WY data recorded at Jackfish River below Christina Lake, JOSMP Station S56. Historical values were calculated for the period from 1982 to 1995 from WSC Station 07CE005 and JOSMP Station S56 for 2014.

Table 5.10-4 Monthly concentrations of water quality measurement endpoints, mouth of Christina River (*test* station CH1 [CHR-1]), March to September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	11	8.03	7.64	Feb	8.56	Jul
Total suspended solids	mg/L	-	11	13.3	<3	Dec	73.0	Jul
Conductivity	µS/cm	-	11	502	260	May	626	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	11	0.015	0.009	Jun, Jul	0.029	Dec
Total nitrogen	mg/L	-	11	0.95	0.55	Oct	1.09	Mar
Nitrate+nitrite	mg/L	3-124	11	<0.005	<0.003	May	0.33	Mar
Dissolved organic carbon	mg/L	-	11	16.1	14.0	May	23.3	Nov
Ions								
Sodium	mg/L	-	11	45.1	20.0	May	71.0	Mar
Calcium	mg/L	-	11	36.2	25.0	May	45.2	Jan
Magnesium	mg/L	-	11	11.1	8.0	May	13.2	Feb
Potassium	mg/L	-	11	1.5	0.95	Aug	1.83	Feb, Mar
Chloride	mg/L	120-640	11	56.0	20.0	May	88.0	Jul
Sulphate	mg/L	218-309[b]	11	13.0	5.8	Aug	23.0	Jul
Total dissolved solids	mg/L	-	11	302.0	180.0	Aug	360.0	Jul
Total alkalinity	mg/L	20 (min)	11	158.0	95.0	May	185.0	Feb
Selected metals								
Total aluminum	mg/L	-	11	0.46	0.119	Sep	2.74	Jul
Dissolved aluminum	mg/L	0.05	11	0.0052	0.0012	Feb	0.019	May
Total arsenic	mg/L	0.005	11	0.0009	0.0008	Mar	0.0016	Jul
Total boron	mg/L	1.5-29	11	0.09	0.05	May	0.112	Oct
Total molybdenum	mg/L	0.073	11	0.00051	0.00035	May	0.00074	Jan
Total mercury (ultra-trace)	ng/L	5-13	11	1.27	0.64	Jan	3.46	Jul
Total methyl mercury	ng/L	1-2	6	0.07	0.03	Oct	0.15	Aug
Total strontium	mg/L	-	11	0.21	0.104	May	0.29	Jan
Total hydrocarbons								
BTEX	mg/L	-	11	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	11	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	11	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	11	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	11	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	11	0.45	0.19	Sep	1.61	Feb
Oilsands extractable acids	mg/L	-	11	1.80	1.00	Sep	2.40	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	11	<13.55	<13.55	-	44.80	Mar
Retene	ng/L	-	11	1.32	<0.59	-	12.00	Jul
Total dibenzothiophenes[c]	ng/L	-	11	10.76	<8.17	Oct	218.92	Jul
Total PAHs[c]	ng/L	-	11	148.18	127.22	Dec	662.09	Jul
Total Parent PAHs[c]	ng/L	-	11	23.81	8.82	Mar	41.82	Feb
Total Alkylated PAHs[c]	ng/L	-	11	139.36	104.18	Oct	630.73	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	0.0027	<0.001	-	**0.012**	Jul
Sulphide	mg/L	0.0019	6	**0.0023**	<0.0015	-	**0.010**	Jun
Dissolved iron	mg/L	0.3	5	0.27	<0.06	Jul	**0.71**	Nov

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-5 Monthly concentrations of water quality measurement endpoints, Christina River upstream of Janvier (*test* station CHR-2), November 2014 to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	11	8.04	7.72	Mar	8.50	Jul
Total suspended solids	mg/L	-	11	6.0	2.70	Oct	15.0	Aug
Conductivity	µS/cm	-	11	307	190	May	402	Jan
Nutrients								
Total dissolved phosphorus	mg/L	-	11	0.017	0.011	Jun	0.028	Nov
Total nitrogen	mg/L	-	11	0.75	0.41	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	11	<0.005	<0.003	May	0.34	Mar
Dissolved organic carbon	mg/L	-	11	14.0	13.0	Oct	19.1	Nov
Ions								
Sodium	mg/L	-	11	11.0	6.5	May	13.6	Jan
Calcium	mg/L	-	11	37.3	21.0	May	51.8	Feb
Magnesium	mg/L	-	11	11.0	7.0	May	14.5	Mar
Potassium	mg/L	-	11	1.5	0.96	Aug	2.05	Feb
Chloride	mg/L	120-640	11	1.0	0.66	Jan	1.4	Oct
Sulphate	mg/L	218-309[b]	11	9.5	2.4	Aug	12.9	Jan
Total dissolved solids	mg/L	-	11	190	140	May	255	Feb
Total alkalinity	mg/L	20 (min)	11	165	95	May	204	Feb
Selected metals								
Total aluminum	mg/L	-	11	0.06	0.017	Jun	0.31	Aug
Dissolved aluminum	mg/L	0.05	11	0.0016	0.0009	Jun	0.006	May
Total arsenic	mg/L	0.005	11	0.0008	0.0006	Mar	0.0012	Aug
Total boron	mg/L	1.5-29	11	0.06	0.04	May	0.071	Feb
Total molybdenum	mg/L	0.073	11	0.00066	0.00044	May	0.00140	Jul
Total mercury (ultra-trace)	ng/L	5-13	11	0.77	0.60	Oct	1.39	Aug
Total methyl mercury	ng/L	1-2	6	0.05	0.03	Oct	0.12	Aug
Total strontium	mg/L	-	11	0.18	0.096	May	0.27	Jan
Total hydrocarbons								
BTEX	mg/L	-	11	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	11	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	11	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	11	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	11	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	11	0.45	0.02	Dec	0.99	Jun
Oilsands extractable acids	mg/L	-	11	1.70	0.40	Dec	2.40	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	11	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	11	<0.59	<0.59	-	2.02	Jun
Total dibenzothiophenes[c]	ng/L	-	11	<8.17	<8.17	-	8.73	Jan
Total PAHs[c]	ng/L	-	11	125.33	111.22	Mar	127.53	Oct
Total Parent PAHs[c]	ng/L	-	11	22.44	8.60	Mar	24.35	Oct
Total Alkylated PAHs[c]	ng/L	-	11	102.61	101.43	Feb	103.18	Jan
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	0.0033	<0.001	-	**0.010**	Jul
Sulphide	mg/L	0.0019	5	<0.0019	<0.0015	-	**0.006**	Aug
Dissolved iron	mg/L	0.3	5	0.14	0.04	Jul	**0.86**	Nov

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-6 Monthly concentrations of water quality measurement endpoints, Christina River upstream of Jackfish River (*test* station CHR-3), March to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	7	8.17	7.92	Mar	8.25	Aug
Total suspended solids	mg/L	-	7	3.3	2.70	Oct	7.3	July
Conductivity	µS/cm	-	7	300	160	May	437	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	7	0.019	0.009	Mar	0.039	Aug
Total nitrogen	mg/L	-	7	0.68	0.44	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	7	<0.005	<0.003	May	0.423	Mar
Dissolved organic carbon	mg/L	-	7	14.0	12.0	Oct	17.0	Aug
Ions								
Sodium	mg/L	-	7	8.3	5.2	May	13.0	July
Calcium	mg/L	-	7	44.0	22.0	May	57.0	Mar
Magnesium	mg/L	-	7	12.0	6.3	May	14.5	Mar
Potassium	mg/L	-	7	1.4	0.97	Aug	2.15	Mar
Chloride	mg/L	120-640	7	<1.0	<0.5	Mar	<1.0	-
Sulphate	mg/L	309-429[b]	7	5.8	<1.0	Aug	11.0	July
Total dissolved solids	mg/L	-	7	200	56	May	266	Mar
Total alkalinity	mg/L	20 (min)	7	160	83	May	237	Mar
Selected metals								
Total aluminum	mg/L	-	7	0.06	0.028	Jun	0.134	May
Dissolved aluminum	mg/L	0.05	7	0.0012	0.00074	Mar	0.011	May
Total arsenic	mg/L	0.005	7	0.0011	0.00075	Mar	0.0014	Aug
Total boron	mg/L	1.5-29	7	0.05	0.030	May	0.071	Mar
Total molybdenum	mg/L	0.073	7	0.00092	0.00049	May	0.00169	July
Total mercury (ultra-trace)	ng/L	5-13	7	0.81	0.52	Mar	1.51	May
Total methyl mercury	ng/L	1-2	6	0.05	0.032	Oct	0.09	May
Total strontium	mg/L	-	7	0.19	0.089	May	0.26	Mar
Total hydrocarbons								
BTEX	mg/L	-	7	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	7	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	7	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	7	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	7	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	7	0.47	<0.08	Oct	0.70	Sep
Oilsands extractable acids	mg/L	-	7	2.30	0.80	Oct	3.20	Jun
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	7	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	7	<0.59	<0.59	-	1.83	July
Total dibenzothiophenes[c]	ng/L	-	7	<8.17	<8.17	-	9.30	May
Total PAHs[c]	ng/L	-	7	125.90	111.22	Mar	127.94	Aug
Total Parent PAHs[c]	ng/L	-	7	22.49	8.60	Mar	25.03	Aug
Total Alkylated PAHs[c]	ng/L	-	7	102.91	102.61	Mar	103.75	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0063**	<0.001	Mar	**0.013**	July
Sulphide	mg/L	0.0019	6	**0.0049**	<0.0015	Mar	**0.011**	Jun
Dissolved iron	mg/L	0.3	3	0.21	0.02	Jul	**1.38**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-7 Monthly concentrations of water quality measurement endpoints, Christina River upstream of development (*baseline* station CHR-4), March to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.04	7.79	Mar	8.16	July
Total suspended solids	mg/L	-	5	6.7	3.30	Oct	15.0	July
Conductivity	µS/cm	-	5	320	160	Aug	422	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.047	0.005	Mar	0.110	Sep
Total nitrogen	mg/L	-	5	0.67	0.58	Oct	0.90	Aug
Nitrate+nitrite	mg/L	3-124	5	0.09	<0.005	July	0.12	Oct
Dissolved organic carbon	mg/L	-	5	14.0	13.0	July	22.0	Aug
Ions								
Sodium	mg/L	-	5	5.6	2.8	Aug	7.4	Jul
Calcium	mg/L	-	5	48.0	23.0	Aug	63.0	Jul
Magnesium	mg/L	-	5	12.0	6.0	Aug	16.0	Jul
Potassium	mg/L	-	5	1.1	0.68	Aug	1.73	Mar
Chloride	mg/L	120-640	5	<1.0	<0.5	Mar	<1.0	-
Sulphate	mg/L	309-429[b]	5	2.6	1.4	Oct	5.9	Jul
Total dissolved solids	mg/L	-	5	200	140	Aug	280	Jul
Total alkalinity	mg/L	20 (min)	5	180	82	Aug	232	Mar
Selected metals								
Total aluminum	mg/L	-	5	0.05	0.015	Mar	0.14	Aug
Dissolved aluminum	mg/L	0.05	5	0.0013	0.0005	July	0.014	Aug
Total arsenic	mg/L	0.005	5	0.0013	0.0009	Mar	0.0017	Aug
Total boron	mg/L	1.5-29	5	0.04	0.023	Aug	0.051	July
Total molybdenum	mg/L	0.073	5	0.00068	0.00046	Aug	0.00122	July
Total mercury (ultra-trace)	ng/L	5-13	5	0.94	0.49	Mar	1.96	Aug
Total methyl mercury	ng/L	1-2	4	0.07	0.054	Oct	0.14	Aug
Total strontium	mg/L	-	5	0.17	0.100	Aug	0.23	July
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	5	0.57	0.09	Oct	0.87	Sep
Oilsands extractable acids	mg/L	-	5	2.40	1.30	Oct	3.70	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	15.80	<13.55	-	89.50	Mar
Retene	ng/L	-	5	0.996	0.598	Oct	2.670	July
Total dibenzothiophenes[c]	ng/L	-	5	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	5	129.11	125.87	July	198.80	Mar
Total Parent PAHs[c]	ng/L	-	5	22.73	8.68	Mar	28.78	Sep
Total Alkylated PAHs[c]	ng/L	-	5	103.18	103.12	Aug	190.12	Mar
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	**0.0098**	<0.001	Mar	**0.011**	July
Sulphide	mg/L	0.0019	3	**0.0039**	<0.0015	Mar	**0.007**	Aug
Dissolved iron	mg/L	0.3	2	0.14	0.08	July	**2.53**	Sep

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-8 Seasonal concentrations of water quality measurement endpoints, Sawbones Creek (*baseline* station SAC-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.33	7.31	Jul	7.68	Mar
Total suspended solids	mg/L	-	4	3.7	2.0	May	7.6	Mar
Conductivity	µS/cm	-	4	101	80	May	159	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0200	0.013	May	0.0540	Mar
Total nitrogen	mg/L	-	4	0.99	0.68	Sep	2.86	Mar
Nitrate+nitrite	mg/L	3-124	4	0.006	<0.003	May	<0.022	Mar
Dissolved organic carbon	mg/L	-	4	20.0	15.0	May	33.7	Mar
Ions								
Sodium	mg/L	-	4	2.7	2.3	May	3.1	Mar
Calcium	mg/L	-	4	13.5	8.8	May	23.7	Mar
Magnesium	mg/L	-	4	4.5	3.5	May	6.3	Mar
Potassium	mg/L	-	4	0.58	<0.3	Jul, Sep	0.92	Mar
Chloride	mg/L	120-640	4	<1.0	<0.5	Mar	<1.0	-
Sulphate	mg/L	218-309[b]	4	<0.5	0.33	Mar	<1.00	May
Total dissolved solids	mg/L	-	4	95	80	May	142	Mar
Total alkalinity	mg/L	20 (min)	4	50	40	May	83	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.107	0.0513	Mar	0.201	Jul
Dissolved aluminum	mg/L	0.05	4	0.0055	0.00475	May	0.0084	Mar
Total arsenic	mg/L	0.005	4	0.00099	0.0006	May	0.00162	Mar
Total boron	mg/L	1.5-29	4	0.011	0.0093	Sep	0.015	Jul
Total molybdenum	mg/L	0.073	4	0.00006	0.000034	May	0.00008	Jul
Total mercury (ultra-trace)	ng/L	5-13	4	1.27	1.06	Jul	1.39	Mar
Total methyl mercury	ng/L	1-2	3	0.06	0.037	May	0.063	Jul
Total strontium	mg/L	-	4	0.044	0.029	May	0.062	Mar
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.50	0.28	Sep	0.71	Mar
Oilsands extractable acids	mg/L	-	4	1.65	1.40	Sep	3.20	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	**1,140**	Mar
Retene	ng/L	-	4	1.15	<0.59	Sep	8.74	May
Total dibenzothiophenes[c]	ng/L	-	4	8.22	<8.17	May, Sep	8.33	Mar
Total PAHs[c]	ng/L	-	4	129.12	125.91	Sep	2,431	Mar
Total Parent PAHs[c]	ng/L	-	4	22.71	22.15	May	69.94	Mar
Total Alkylated PAHs[c]	ng/L	-	4	106.70	103.18	Sep	2,361	Mar
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.005	2	**0.003**	<0.001	Mar	**0.013**	Jul
Sulphide	mg/L	0.0019	4	**0.0040**	**0.0028**	Mar	**0.0049**	Jul
Dissolved iron	mg/L	0.3	1	0.27	0.12	May	**2.74**	Mar

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-9 Seasonal concentrations of water quality measurement endpoints, Sunday Creek at inlet to Christina Lake (*test* station SUC-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	8.03	7.96	May	8.23	Mar
Total suspended solids	mg/L	-	4	6.0	<3	Mar	22.0	Jul
Conductivity	µS/cm	-	4	290	160	May	395	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0135	0.013	Sep	0.017	Jul
Total nitrogen	mg/L	-	4	0.69	0.52	Sep	<1.00	May
Nitrate+nitrite	mg/L	3-124	4	0.011	<0.003	May	0.017	Sep
Dissolved organic carbon	mg/L	-	4	13.0	11.8	Mar	15.0	Jul
Ions								
Sodium	mg/L	-	4	8.8	3.5	May	12.6	Mar
Calcium	mg/L	-	4	37.0	18.0	May	56.0	Mar
Magnesium	mg/L	-	4	12.0	6.7	May	16.7	Mar
Potassium	mg/L	-	4	0.83	0.68	Sep	1.37	Mar
Chloride	mg/L	120-640	4	2.90	1.08	Mar	4.20	Sep
Sulphate	mg/L	218-429[b]	4	1.50	<1.00	May	<2.00	Sep
Total dissolved solids	mg/L	-	4	180	110	May	228	Mar
Total alkalinity	mg/L	20 (min)	4	150	82	May	224	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.234	0.0311	Mar	0.435	Jul
Dissolved aluminum	mg/L	0.05	4	0.0030	0.00122	Mar	0.0074	May
Total arsenic	mg/L	0.005	4	0.00069	0.0005	May	0.00136	Jul
Total boron	mg/L	1.5-29	4	0.027	0.0143	May	0.042	Jul
Total molybdenum	mg/L	0.073	4	0.00028	0.000149	May	0.00043	Jul
Total mercury (ultra-trace)	ng/L	5-13	4	1.10	0.62	Mar	1.33	May
Total methyl mercury	ng/L	1-2	3	0.05	0.032	May	0.104	Jul
Total strontium	mg/L	-	4	0.115	0.046	May	0.148	Mar
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.34	0.24	Sep	0.43	Jul
Oilsands extractable acids	mg/L	-	4	1.80	1.50	May	2.20	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	59.9	Mar
Retene	ng/L	-	4	1.89	0.80	Sep	3.14	Jul
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	4	129.67	125.40	May	201.39	Mar
Total Parent PAHs[c]	ng/L	-	4	22.51	9.99	May	24.13	Jul
Total Alkylated PAHs[c]	ng/L	-	4	106.24	103.11	May	191.40	Mar
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	2	**0.006**	<0.001	Mar	**0.013**	Jul
Sulphide	mg/L	0.0019	2	**0.0021**	<0.0015	Mar	**0.0024**	May

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-10 Seasonal concentrations of water quality measurement endpoints, Sunday Creek upstream (*baseline* station SUC-2), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.95	7.76	Mar	8.12	Sep
Total suspended solids	mg/L	-	4	6.7	<1.0	Sep	9.9	Mar
Conductivity	µS/cm	-	4	205	180	May	311	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0110	0.009	Sep	0.022	Mar
Total nitrogen	mg/L	-	4	0.59	0.49	Sep	1.00	May
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.003	May	0.100	Mar
Dissolved organic carbon	mg/L	-	4	12.5	10.0	May	13.6	Mar
Ions								
Sodium	mg/L	-	4	2.8	2.5	Jul	4.5	Mar
Calcium	mg/L	-	4	26.5	22.0	May	43.6	Mar
Magnesium	mg/L	-	4	8.4	7.8	May	13.9	Mar
Potassium	mg/L	-	4	0.75	0.32	Jul	1.92	Mar
Chloride	mg/L	120-640	4	1.45	1.10	May	2.30	Jul
Sulphate	mg/L	309[b]	4	1.00	0.55	Jul	1.33	Mar
Total dissolved solids	mg/L	-	4	140	120	May	177	Mar
Total alkalinity	mg/L	20 (min)	4	110	93	May	170	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.077	0.0335	Mar	0.165	Jul
Dissolved aluminum	mg/L	0.05	4	0.0027	0.0019	Mar	0.0036	Jul
Total arsenic	mg/L	0.005	4	0.00070	0.0004	May	0.00078	Jul
Total boron	mg/L	1.5-29	4	0.014	0.0119	Sep	0.016	Mar
Total molybdenum	mg/L	0.073	4	0.00018	0.000158	Jul	0.00029	Mar
Total mercury (ultra-trace)	ng/L	5-13	4	1.16	0.80	Sep	1.85	Jul
Total methyl mercury	ng/L	1-2	3	0.05	0.027	May	0.057	Sep
Total strontium	mg/L	-	4	0.058	0.049	May	0.091	Mar
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.37	0.11	Sep	0.42	May
Oilsands extractable acids	mg/L	-	4	1.10	0.60	Sep	1.30	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	1.22	0.74	Sep	1.66	Jul
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	4	125.02	111.23	Mar	125.9	Sep
Total Parent PAHs[c]	ng/L	-	4	22.32	8.62	Mar	22.73	Sep
Total Alkylated PAHs[c]	ng/L	-	4	102.70	102.61	Mar	103.2	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.006**	0.0019	Mar	**0.012**	Jul
Sulphide	mg/L	0.0019	3	**0.0032**	<0.0015	Mar	**0.0041**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-11 Seasonal concentrations of water quality measurement endpoints, Birch Creek (*baseline* station BRC-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	8.03	7.86	Mar	8.29	Sep
Total suspended solids	mg/L	-	4	7.65	3.00	Mar	78.0	July
Conductivity	µS/cm	-	4	385	200	May	412	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0215	0.0117	Mar	0.0320	May
Total nitrogen	mg/L	-	4	0.75	0.47	Sep	0.75	July
Nitrate+nitrite	mg/L	3-124	4	0.086	0.011	May	0.184	Mar
Dissolved organic carbon	mg/L	-	4	9.95	8.40	Mar	11.00	May, Jul
Ions								
Sodium	mg/L	-	4	16.4	6.0	May	18.0	Sep
Calcium	mg/L	-	4	48.0	23.0	May	50.0	Mar
Magnesium	mg/L	-	4	14.0	8.0	May	15.5	Mar
Potassium	mg/L	-	4	1.40	1.10	May	1.81	Mar
Chloride	mg/L	120-640	4	1.00	0.60	Mar	1.40	July
Sulphate	mg/L	309-429[b]	4	3.80	<1.00	May	5.94	July
Total dissolved solids	mg/L	-	4	235	140	May	240	Mar, Jul
Total alkalinity	mg/L	20 min	4	210	110	May	230	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.228	0.008	Mar	0.481	May
Dissolved aluminum	mg/L	0.05	4	0.0040	0.00036	Mar	0.0086	May
Total arsenic	mg/L	0.005	4	0.00121	0.00085	Mar	0.00133	Sep
Total boron	mg/L	1.5-29	4	0.056	0.025	May	0.058	Sep
Total molybdenum	mg/L	0.073	4	0.00099	0.00045	May	0.00102	Sep
Total mercury ultra-trace	ng/L	5-13	4	0.81	0.44	Mar	1.47	May
Total methyl mercury	ng/L	1-2	3	0.06	0.04	May	0.11	July
Total strontium	mg/L	-	4	0.16	0.07	May	0.17	Mar
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 C6-C10	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 C10-C16	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 C16-C34	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 C34-C50	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.40	0.13	Sep	0.55	May
Oilsands extractable acids	mg/L	-	4	1.05	0.60	Sep	1.10	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	405	Mar
Retene	ng/L	-	4	0.67	<0.59	Mar, Sep	4.25	July
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	8.17	-
Total PAHs[c]	ng/L	-	4	131.73	126.30	Sep	1,034	Mar
Total Parent PAHs[c]	ng/L	-	4	27.40	23.12	Sep	31.30	Mar
Total Alkylated PAHs[c]	ng/L	-	4	104.61	102.61	May	1,002	Mar
Other variables that exceeded Alberta guidelines in 2015[d]								
Sulphide	mg/L	0.0019	3	**0.0040**	<0.0015	Mar	**0.0077**	July
Dissolved iron	mg/L	0.3	1	0.13	0.04	Mar	**0.73**	May

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-12 Seasonal concentrations of water quality measurement endpoints, unnamed creek east of Christina Lake (*test* station UNC-2), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.86	7.70	Sep	7.89	Mar
Total suspended solids	mg/L	-	4	2.7	2.0	Jul, Sep	4.3	Mar
Conductivity	µS/cm	-	4	221	180	May	300	Jul
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0173	0.013	Sep	0.021	Jul
Total nitrogen	mg/L	-	4	0.91	0.79	Sep	1.51	Mar
Nitrate+nitrite	mg/L	3-124	4	0.008	<0.003	May	0.023	Mar
Dissolved organic carbon	mg/L	-	4	21.0	16.0	May	30.3	Mar
Ions								
Sodium	mg/L	-	4	7.7	4.6	Sep	15.0	Jul
Calcium	mg/L	-	4	29.0	20.0	May	36.4	Mar
Magnesium	mg/L	-	4	8.7	7.4	May	11.0	Jul
Potassium	mg/L	-	4	0.65	<0.3	Sep	1.24	Mar
Chloride	mg/L	120-640	4	2.64	2.10	May	6.30	Jul
Sulphate	mg/L	309[b]	4	0.89	0.50	Sep	2.00	Jul
Total dissolved solids	mg/L	-	4	155	130	May	210	Jul
Total alkalinity	mg/L	20 (min)	4	114	89	May	150	Jul
Selected metals								
Total aluminum	mg/L	-	4	0.025	0.012	Mar	0.104	May
Dissolved aluminum	mg/L	0.05	4	0.0045	0.0029	Jul	0.0046	Mar
Total arsenic	mg/L	0.005	4	0.00094	0.0006	May	0.00116	Mar
Total boron	mg/L	1.5-29	4	0.020	0.0151	May	0.043	Jul
Total molybdenum	mg/L	0.073	4	0.00026	0.000145	Sep	0.00061	Jul
Total mercury (ultra-trace)	ng/L	5-13	4	1.06	0.91	Mar	1.25	May
Total methyl mercury	ng/L	1-2	3	0.07	0.030	May	0.084	Sep
Total strontium	mg/L	-	4	0.084	0.054	May	0.120	Jul
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.58	0.12	Sep	0.64	May
Oilsands extractable acids	mg/L	-	4	2.05	1.10	Sep	2.20	Mar, May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	1.26	0.59	May, Sep	2.58	Mar
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	4	124.97	111.22	Mar	125.91	Sep
Total Parent PAHs[c]	ng/L	-	4	22.34	8.60	Mar	22.73	Sep
Total Alkylated PAHs[c]	ng/L	-	4	102.63	102.61	Mar	103.18	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.006**	0.0011	Mar	**0.015**	Jul
Sulphide	mg/L	0.0019	3	**0.0032**	**0.0023**	Sep	**0.0073**	Jul
Dissolved iron	mg/L	0.3	1	0.250	0.17	May	**3.04**	Mar

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-13 Seasonal concentrations of water quality measurement endpoints, unnamed creek south of Christina Lake (*test* station UNC-3), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.93	7.80	Jul	7.98	Sep
Total suspended solids	mg/L	-	4	3.5	1.3	Sep	7.3	Jul
Conductivity	µS/cm	-	4	240	170	May	273	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0189	0.013	May	0.037	Jul
Total nitrogen	mg/L	-	4	0.81	0.63	Sep	0.82	Jul
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.003	May	<0.005	Jul, Sep
Dissolved organic carbon	mg/L	-	4	18.9	14.0	May	21.0	Jul
Ions								
Sodium	mg/L	-	4	6.5	4.4	May	9.7	Jul
Calcium	mg/L	-	4	30.5	19.0	May	40.9	Mar
Magnesium	mg/L	-	4	9.9	7.1	May	12.5	Mar
Potassium	mg/L	-	4	0.87	0.53	Sep	1.15	Mar
Chloride	mg/L	120-640	4	<1.0	<1.0	-	1.09	Mar
Sulphate	mg/L	309[b]	4	0.55	<0.5	May	<1.0	May
Total dissolved solids	mg/L	-	4	160	110	May	190	Jul
Total alkalinity	mg/L	20 min	4	135	88	May	152	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.124	0.019	Mar	0.502	Jul
Dissolved aluminum	mg/L	0.05	4	0.0056	0.003	Mar	0.0091	Jul
Total arsenic	mg/L	0.005	4	0.00075	0.0005	May	0.00151	Jul
Total boron	mg/L	1.5-29	4	0.021	0.0151	May	0.032	Jul
Total molybdenum	mg/L	0.073	4	0.00017	0.000119	May	0.00029	Jul
Total mercury ultra-trace	ng/L	5-13	4	1.10	0.96	Sep	1.14	May, Jul
Total methyl mercury	ng/L	1-2	3	0.07	0.030	May	0.110	Jul
Total strontium	mg/L	-	4	0.080	0.045	May	0.094	Jul
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 C6-C10	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 C10-C16	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 C16-C34	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 C34-C50	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.49	0.26	Sep	0.61	Jul
Oilsands extractable acids	mg/L	-	4	1.30	1.00	May	2.10	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	22.83	<13.55	May, Jul	**12,800**	Mar
Retene	ng/L	-	4	<0.59	<0.59	-	2.55	Jul
Total dibenzothiophenes[c]	ng/L	-	4	8.66	<8.17	May, Jul	19.55	Mar
Total PAHs[c]	ng/L	-	4	143.47	124.77	May	34,354	Mar
Total Parent PAHs[c]	ng/L	-	4	31.97	22.15	May	13,254	Mar
Total Alkylated PAHs[c]	ng/L	-	4	111.51	102.61	May	21,100	Mar
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.007**	0.0019	Mar	**0.013**	Jul
Sulphide	mg/L	0.0019	2	**0.0030**	<0.0015	Sep	**0.0065**	Jul
Dissolved iron	mg/L	0.3	1	0.27	0.12	May	**0.73**	Mar

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-14 Seasonal concentrations of water quality measurement endpoints, Jackfish River (*test* station JAR-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.98	7.69	Mar	8.08	Jul
Total suspended solids	mg/L	-	4	2.50	<1	Sep	7.3	May
Conductivity	µS/cm	-	4	200	190	May	207	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0120	0.006	Sep	0.0178	Mar
Total nitrogen	mg/L	-	4	0.62	0.49	Sep	<1	May
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.003	-	0.08	Mar
Dissolved organic carbon	mg/L	-	4	14.5	14.0	May, Sep	17.2	Mar
Ions								
Sodium	mg/L	-	4	6.2	6.1	Sep	6.6	Sep
Calcium	mg/L	-	4	25.5	21.0	May	27.5	Sep
Magnesium	mg/L	-	4	8.0	7.5	May	9.0	Sep
Potassium	mg/L	-	4	0.93	0.84	Jul	1.04	Mar
Chloride	mg/L	120-640	4	1.95	1.29	Mar	2.20	Sep
Sulphate	mg/L	218-309[b]	4	<1.00	<1.00	-	1.25	Mar
Total dissolved solids	mg/L	-	4	145	130	Mar	150	Sep
Total alkalinity	mg/L	20 (min)	4	100	100	May, Jul, Sep	110	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.018	0.0074	Sep	0.056	May
Dissolved aluminum	mg/L	0.05	4	0.0007	0.00057	Jul	0.0010	Sep
Total arsenic	mg/L	0.005	4	0.00059	0.0004	Sep	0.00071	Jul
Total boron	mg/L	1.5-29	4	0.023	0.0123	Sep	0.024	Mar
Total molybdenum	mg/L	0.073	4	0.00024	0.000232	May	0.00025	Sep
Total mercury (ultra-trace)	ng/L	5-13	4	0.79	0.71	Sep	0.89	Jul
Total methyl mercury	ng/L	1-2	4	0.03	0.021	Sep	0.058	Jul
Total strontium	mg/L	-	4	0.08	0.071	May	0.0795	Sep
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.31	0.22	Jul	0.58	May
Oilsands extractable acids	mg/L	-	4	1.25	1.00	Sep	1.90	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	0.96	<0.59	Mar, Sep	1.46	May
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	9.21	May
Total PAHs[c]	ng/L	-	4	125.45	111.22	Mar	128.22	Sep
Total Parent PAHs[c]	ng/L	-	4	22.34	8.60	Mar	22.73	Sep
Total Alkylated PAHs[c]	ng/L	-	4	103.11	102.61	Mar	105.50	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	2	**0.005**	<0.001	Mar	**0.011**	Jul
Sulphide	mg/L	0.0019	3	**0.0031**	0.0018	Mar	**0.0041**	May

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-15 Seasonal concentrations of water quality measurement endpoints, Gregoire River (*test* station GRR-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	8.14	7.74	Mar	8.25	Jul
Total suspended solids	mg/L	-	4	11.50	2.70	Sep	21	Jul
Conductivity	µS/cm	-	4	308	250	May	440	Sep
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.0182	0.010	Sep	0.0310	Jul
Total nitrogen	mg/L	-	4	0.762	0.62	Sep	<1.00	May
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.003	-	0.164	Mar
Dissolved organic carbon	mg/L	-	4	17.0	13.5	May	21.0	Mar
Ions								
Sodium	mg/L	-	4	19.9	12.0	May	28.0	Sep
Calcium	mg/L	-	4	35.5	32.0	May	48.0	Sep
Magnesium	mg/L	-	4	10.0	8.9	May	14.0	Sep
Potassium	mg/L	-	4	1.75	1.50	Jul	2.00	May
Chloride	mg/L	120-640	4	4.70	4.26	Mar	6.90	Sep
Sulphate	mg/L	218-309[b]	4	<1	14.00	Sep	23.00	May
Total dissolved solids	mg/L	-	4	228	130	May	280	Sep
Total alkalinity	mg/L	20 (min)	4	143	110	May	220	Sep
Selected metals								
Total aluminum	mg/L	-	4	0.612	0.150	Sep	1.200	May
Dissolved aluminum	mg/L	0.05	4	0.0131	0.00479	Mar	0.0236	Jul
Total arsenic	mg/L	0.005	4	0.00090	0.00061	Mar	0.00118	Jul
Total boron	mg/L	1.5-29	4	0.110	0.0528	May	0.161	Sep
Total molybdenum	mg/L	0.073	4	0.00088	0.0007	Mar	0.00124	Sep
Total mercury (ultra-trace)	ng/L	5-13	4	1.55	0.70	Mar	2.62	Jul
Total methyl mercury	ng/L	1-2	3	0.09	0.070	May	0.136	Jul
Total strontium	mg/L	-	4	0.17	0.116	May	0.246	Sep
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.50	0.40	May	0.54	Sep
Oilsands extractable acids	mg/L	-	4	2.20	1.70	Sep	2.80	Mar
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	1.19	<0.59	Sep	3.57	Jul
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	9.21	May
Total PAHs[c]	ng/L	-	4	127.50	111.34	Mar	129.99	Jul
Total Parent PAHs[c]	ng/L	-	4	22.74	8.73	Mar	24.07	Sep
Total Alkylated PAHs[c]	ng/L	-	4	104.11	102.61	Mar	107.22	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.007**	<0.001	Mar	**0.0130**	Jul
Sulphide	mg/L	0.0019	2	**0.0016**	<0.0015	Mar	**0.0054**	Sep

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.10-16 Seasonal concentrations of water quality measurement endpoints, Christina Lake (*test* station CHL-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	8.11	7.71	Mar	8.21	Jul
Total suspended solids	mg/L	-	4	2.00	<3	Mar	2.0	May, Jul
Conductivity	µS/cm	-	4	200	190	May	210	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.008	0.007	Sep	0.0191	Mar
Total nitrogen	mg/L	-	4	0.558	0.52	Sep	<1	May
Nitrate+nitrite	mg/L	3-124	4	0.006	<0.003	May	0.096	Mar
Dissolved organic carbon	mg/L	-	4	14.0	13.0	May	17.1	Mar
Ions								
Sodium	mg/L	-	4	6.5	6.4	Mar	6.6	May
Calcium	mg/L	-	4	25.0	22.0	May	28.6	Mar
Magnesium	mg/L	-	4	8.2	7.7	Jul	8.9	Mar
Potassium	mg/L	-	4	1.00	0.90	Jul	1.08	Mar
Chloride	mg/L	120-640	4	1.76	1.50	Sep	2.10	Jul
Sulphate	mg/L	218-309[b]	4	<1.00	<1.00	-	1.28	Mar
Total dissolved solids	mg/L	-	4	123	110	Jul	150	Sep
Total alkalinity	mg/L	20 (min)	4	100	100	May, Jul, Sep	110	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.015	0.005	Mar	0.019	Jul
Dissolved aluminum	mg/L	0.05	4	0.0007	0.00045	Mar	0.0011	Jul
Total arsenic	mg/L	0.005	4	0.00055	0.00049	Jul	0.00059	Sep
Total boron	mg/L	1.5-29	4	0.024	0.0231	May	0.032	Sep
Total molybdenum	mg/L	0.073	4	0.00026	0.00023	May	0.00027	Mar
Total mercury (ultra-trace)	ng/L	5-13	4	0.67	0.51	Sep	0.86	Mar
Total methyl mercury	ng/L	1-2	3	0.02	0.013	Jul	0.017	May
Total strontium	mg/L	-	4	0.08	0.069	May	0.081	Sep
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.45	0.34	May	<1.75	Sep
Oilsands extractable acids	mg/L	-	4	1.85	1.40	Mar	2.30	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	4	0.59	<0.59	-	0.97	Jul
Total dibenzothiophenes[c]	ng/L	-	4	<8.17	<8.17	-	<8.17	-
Total PAHs[c]	ng/L	-	4	126.19	113.16	Mar	135.33	Sep
Total Parent PAHs[c]	ng/L	-	4	22.54	8.67	Mar	23.51	Jul
Total Alkylated PAHs[c]	ng/L	-	4	104.29	102.61	May	112.41	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	2	**0.0061**	<0.001	Mar	**0.0120**	Jul
Sulphide	mg/L	0.0019	3	**0.0028**	<0.0019	Sep	**0.0049**	May

Values in **bold** are above guideline.
[a] Sources for all guidelines are outlined in Table 3.2-1.
[b] based on actual hardness level
[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.
[d] n value refers to number of exceedances in 2015.

Table 5.10-17 Seasonal concentrations of water quality measurement endpoints, Gregoire Lake (*test* station GRL-1), March, May, July, and September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	4	7.57	7.30	Mar	8.02	Jul
Total suspended solids	mg/L	-	4	6.60	4.00	May	180	Sep
Conductivity	µS/cm	-	4	130	120	May	179	Mar
Nutrients								
Total dissolved phosphorus	mg/L	-	4	0.012	0.009	May	0.0180	Sep
Total nitrogen	mg/L	-	4	0.785	0.492	Mar	1.6	Sep
Nitrate+nitrite	mg/L	3-124	4	<0.005	<0.003	May	<0.005	Jul, Sep
Dissolved organic carbon	mg/L	-	4	10.4	8.1	May	13.6	Mar
Ions								
Sodium	mg/L	-	4	4.2	3.8	May	5.9	Mar
Calcium	mg/L	-	4	15.5	13.0	May	22.8	Mar
Magnesium	mg/L	-	4	4.1	3.9	May	6.1	Mar
Potassium	mg/L	-	4	1.15	1.00	Jul	1.68	Mar
Chloride	mg/L	120-640	4	3.80	3.20	May	4.52	Mar
Sulphate	mg/L	218-309[b]	4	<1	13.00	May, Jul, Sep	17.10	Mar
Total dissolved solids	mg/L	-	4	94	64	Jul	104	Mar
Total alkalinity	mg/L	20 (min)	4	49	45	May	66	Mar
Selected metals								
Total aluminum	mg/L	-	4	0.202	0.082	May	0.908	Sep
Dissolved aluminum	mg/L	0.05	4	0.0071	0.00268	Mar	0.0225	Jul
Total arsenic	mg/L	0.005	4	0.00067	0.00045	May	0.00243	Sep
Total boron	mg/L	1.5-29	4	0.025	0.0195	May	0.032	Sep
Total molybdenum	mg/L	0.073	4	0.00047	0.00035	May	0.00068	Sep
Total mercury (ultra-trace)	ng/L	5-13	4	0.90	0.54	May	1.50	Sep
Total methyl mercury	ng/L	1-2	3	0.03	0.014	May	0.210	Sep
Total strontium	mg/L	-	4	0.07	0.059	May	0.084	Mar
Total hydrocarbons								
BTEX	mg/L	-	4	<0.01	<0.01	-	<0.1	Mar
Fraction 1 (C6-C10)	mg/L	0.15	4	<0.01	<0.01	-	<0.1	Mar
Fraction 2 (C10-C16)	mg/L	0.11	4	<0.005	<0.005	-	**<0.25**	Mar
Fraction 3 (C16-C34)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Fraction 4 (C34-C50)	mg/L	-	4	<0.02	<0.02	-	<0.25	Mar
Naphthenic Acids	mg/L	-	4	0.54	0.20	Jul	<1.59	Sep
Oilsands extractable acids	mg/L	-	4	1.60	<2	Sep	2.40	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	4	<13.55	<13.55	-	33.30	Mar
Retene	ng/L	-	4	1.02	<0.59	-	5.09	Jul
Total dibenzothiophenes[c]	ng/L	-	4	8.19	<8.17	-	9.21	May
Total PAHs[c]	ng/L	-	4	133.24	124.77	May	139.25	Sep
Total Parent PAHs[c]	ng/L	-	4	22.58	9.14	Mar	23.26	Sep
Total Alkylated PAHs[c]	ng/L	-	4	113.02	102.61	May	124.29	Mar
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	2	**0.0050**	<0.001	Mar	**0.0120**	Jul
Sulphide	mg/L	0.0019	3	**0.0032**	<0.0015	Mar	**0.0062**	May
Dissolved iron	mg/L	0.3	1	0.04	0.03	Mar	**0.37**	Sep

Values in **bold** are above guideline.

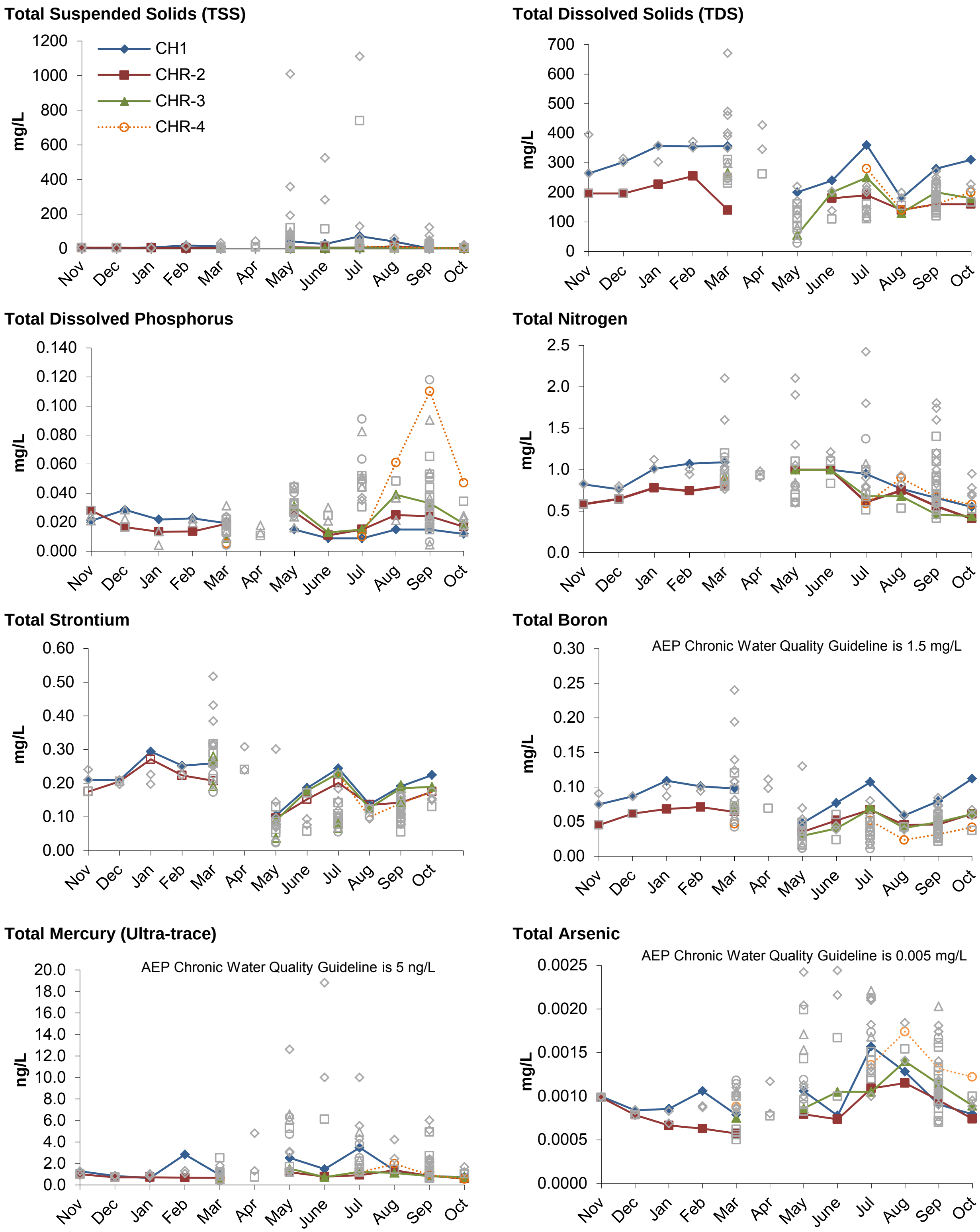
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Figure 5.10-6 Selected water quality measurement endpoints in the Christina River (monthly data) in the 2015 WY.

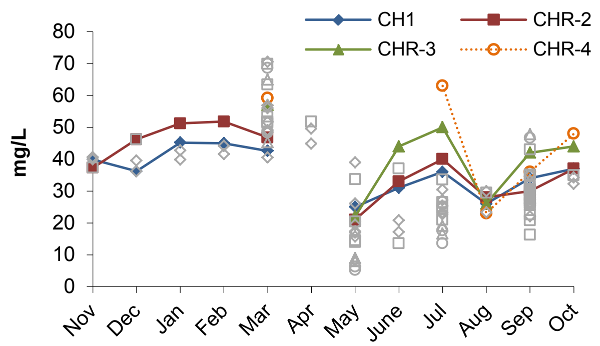


Non-detectable values are shown at the detection limit.

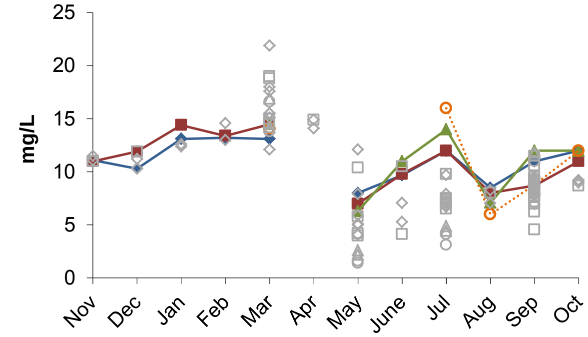
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.10-6 (Cont'd.)

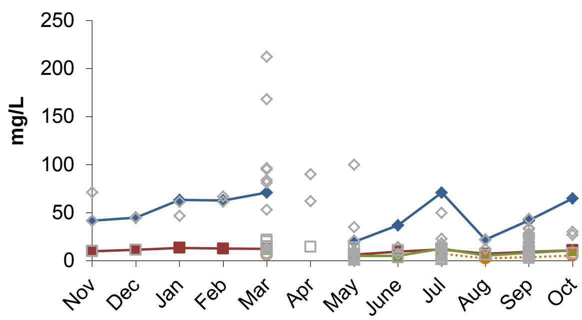
Calcium



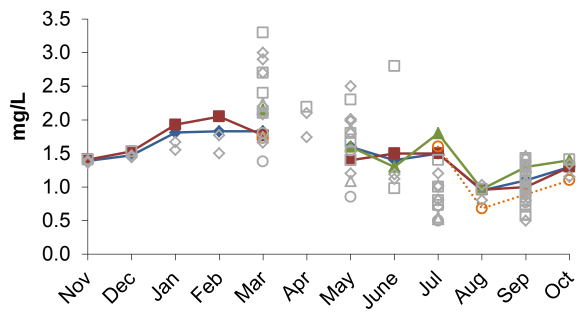
Magnesium



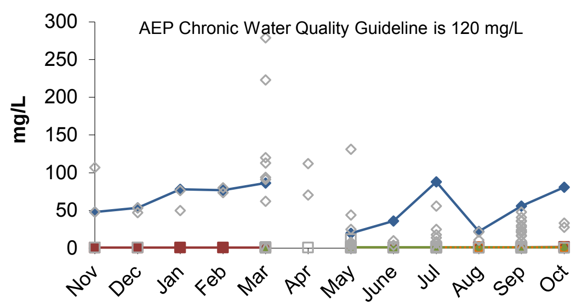
Sodium



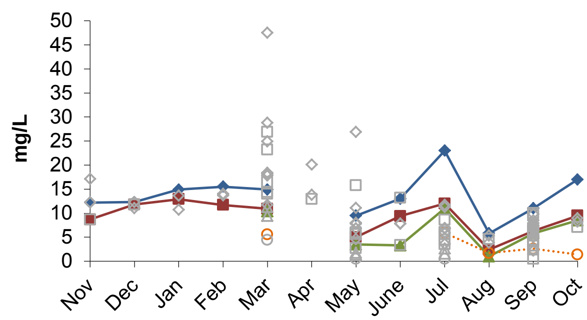
Potassium



Chloride

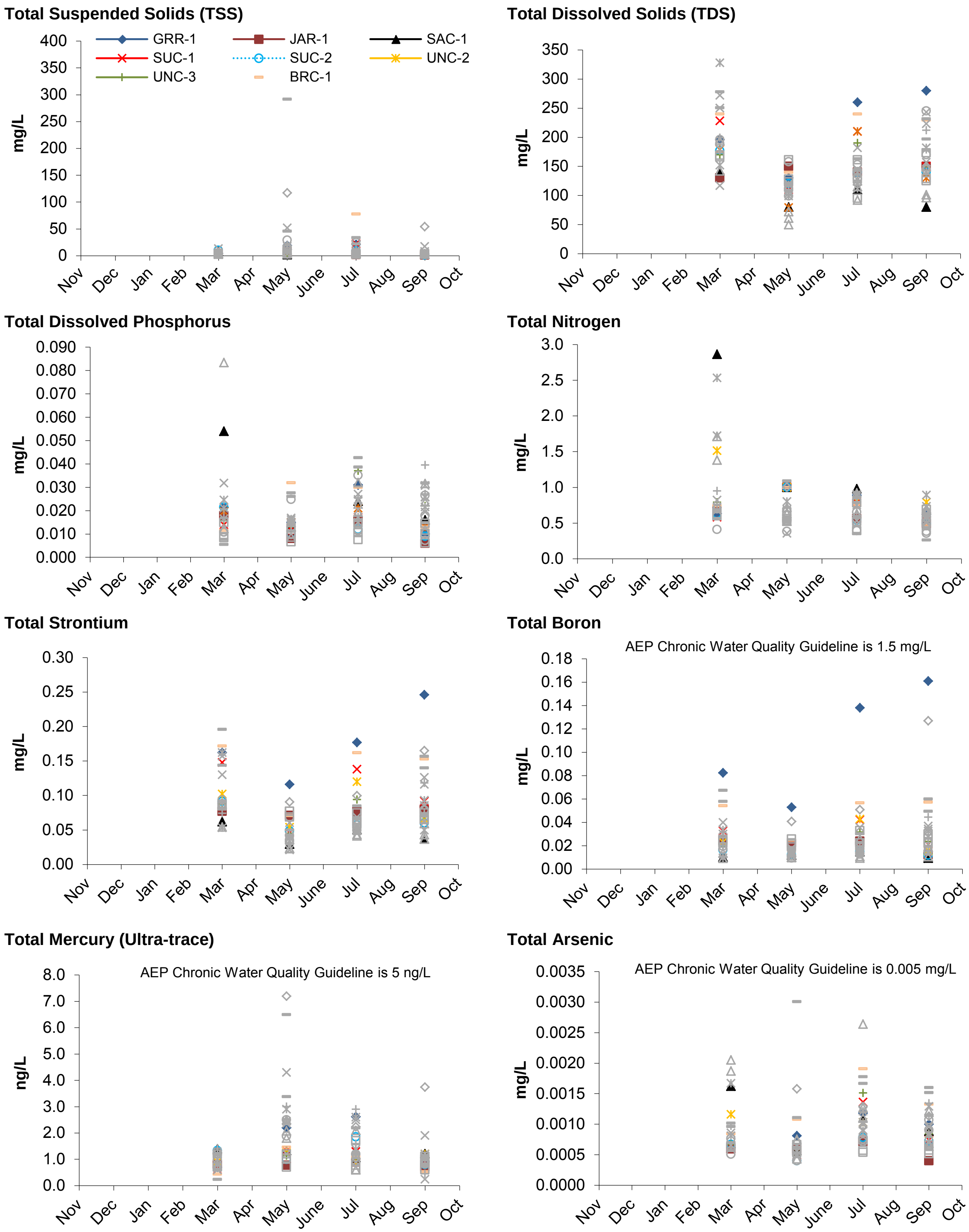


Sulphate



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

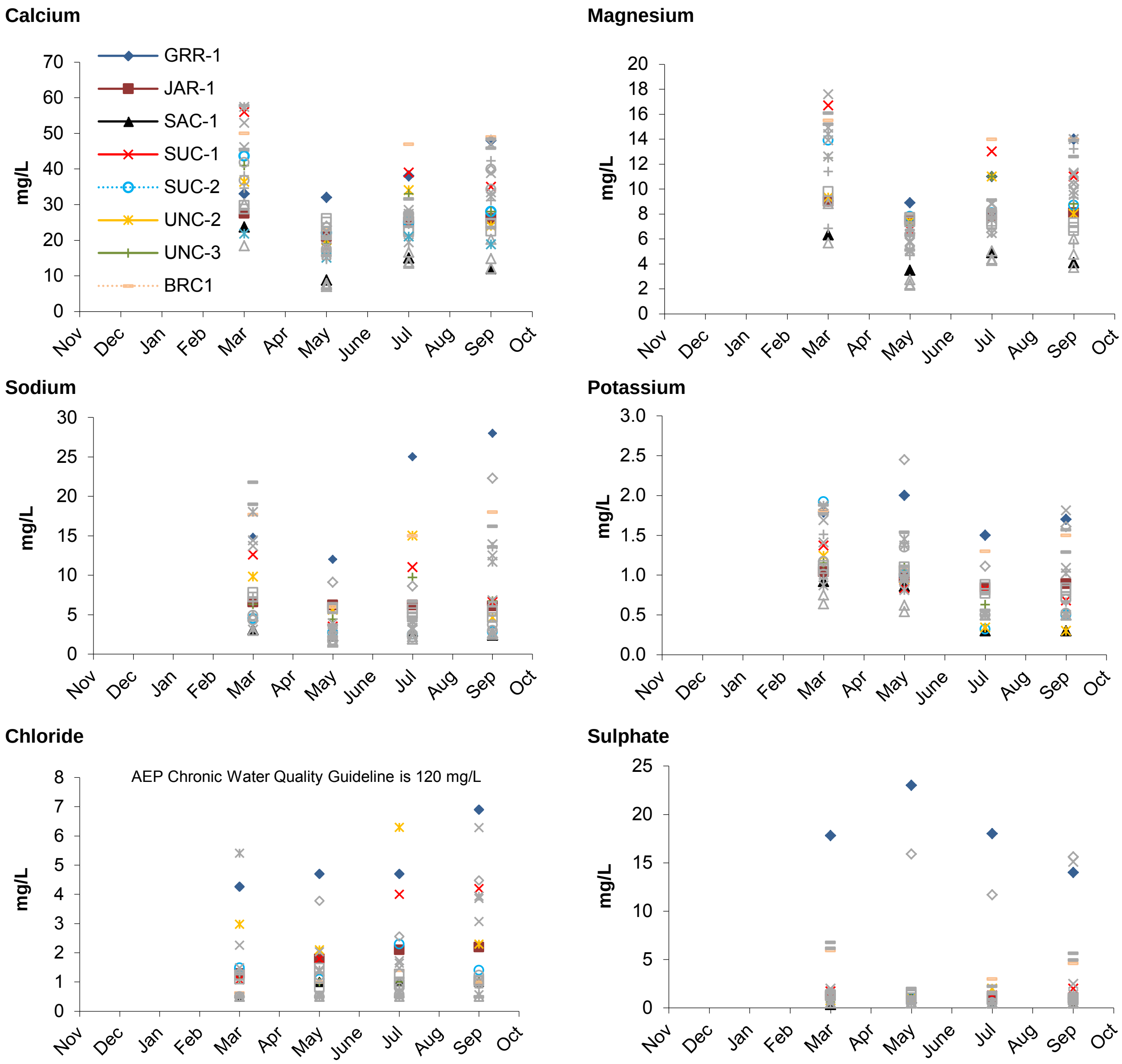
Figure 5.10-7 Selected water quality measurement endpoints in tributaries to the Christina River (seasonal data) in the 2015 WY.



Non-detectable values are shown at the detection limit.

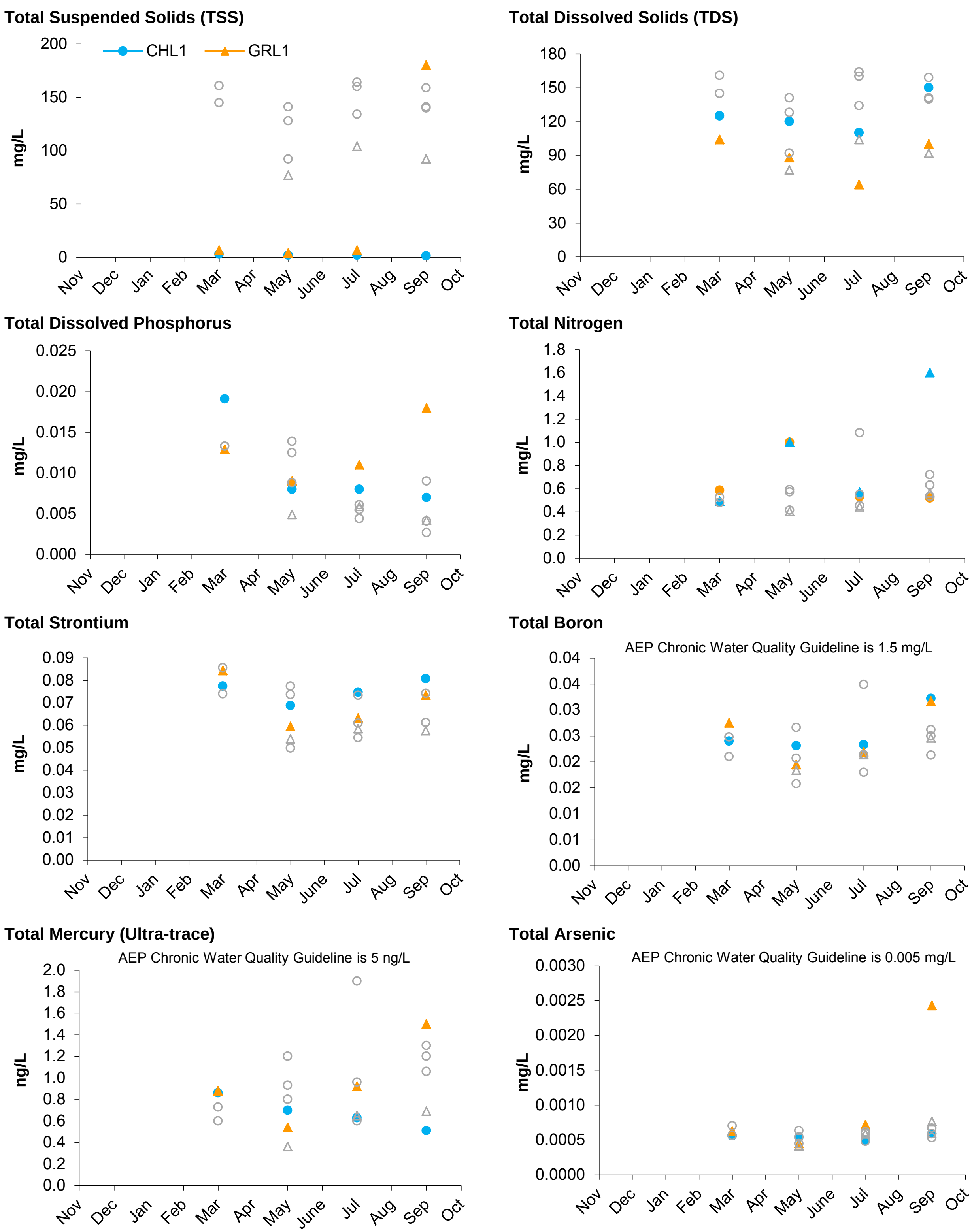
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.10-7 (Cont’d.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

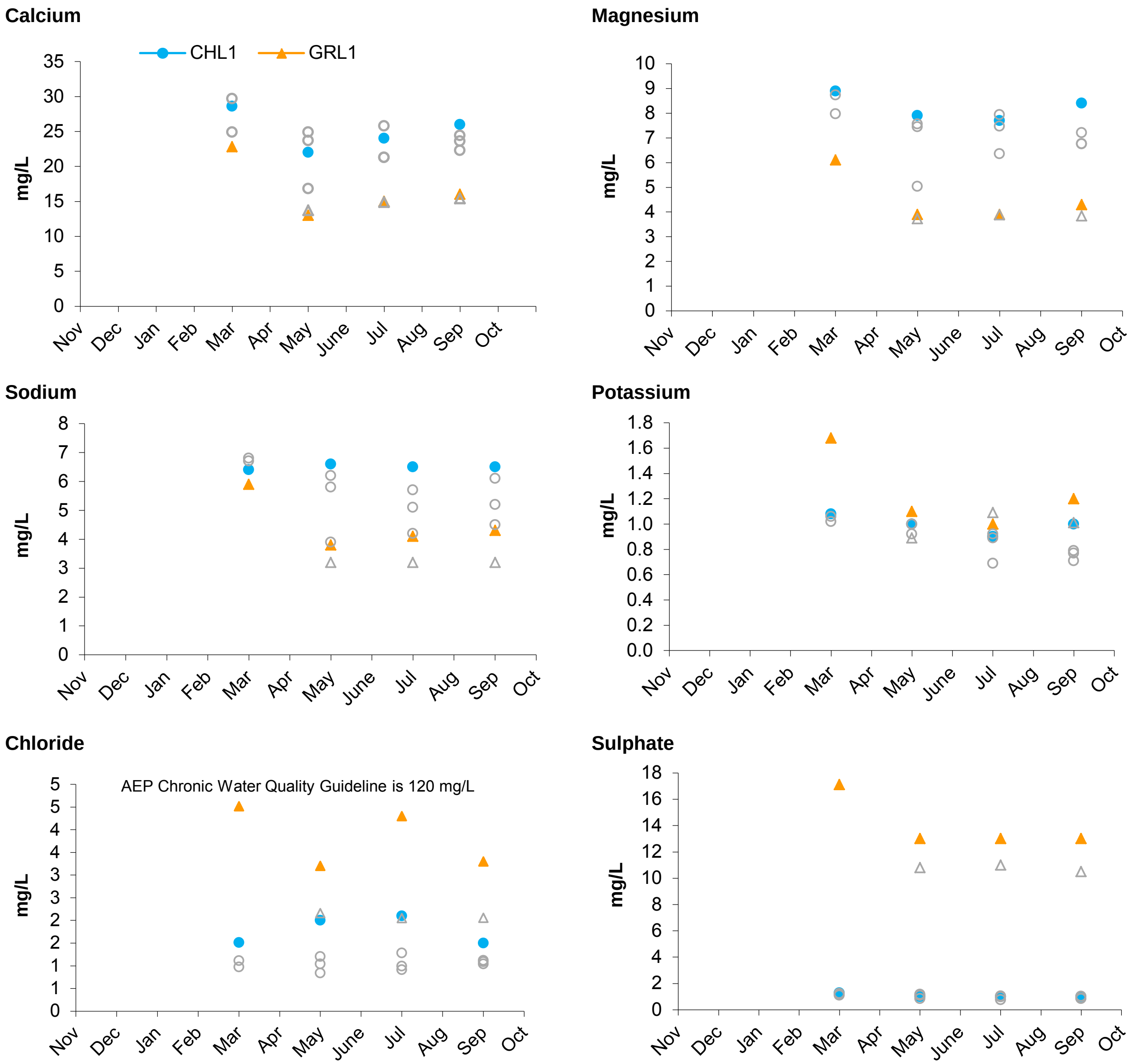
Figure 5.10-8 Selected water quality measurement endpoints in Christina Lake and Gregoire Lake (seasonal data) in the 2015 WY.



Non-detectable values are shown at the detection limit.

Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.10-8 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.10-18 Concentrations of water quality measurement endpoints, mouth of Christina River (*test* station CH1 [CHR-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2002-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.40	13	8.30	8.10	8.40
Total suspended solids	mg/L	-	2.7	13	26	<3	123
Conductivity	µS/cm	-	460	13	295	210	431
Nutrients							
Total dissolved phosphorus	mg/L	-	0.015	13	0.023	0.005	0.054
Total nitrogen	mg/L	-	0.66	13	0.95	0.58	1.80
Nitrate+nitrite	mg/L	3-124	<0.005	13	<0.100	<0.054	<0.100
Dissolved organic carbon	mg/L	-	16	13	19.6	14.0	25.3
Ions							
Sodium	mg/L	-	42	13	25.0	12.8	43.4
Calcium	mg/L	-	34	13	27.3	22.0	35.0
Magnesium	mg/L	-	11	13	8.40	6.96	9.50
Potassium	mg/L	-	1.10	13	1.06	0.50	1.30
Chloride	mg/L	120-640	56	13	24.0	9.5	47.9
Sulphate	mg/L	309[b]	11	13	6.80	2.20	9.80
Total dissolved solids	mg/L	-	280	13	195	140	271
Total alkalinity	mg/L	20 (min)	140	13	112	86	128
Selected metals							
Total aluminum	mg/L	-	0.119	13	0.73	0.24	3.23
Dissolved aluminum	mg/L	0.05	0.005	13	0.010	0.007	0.029
Total arsenic	mg/L	0.005	0.0009	13	0.0011	0.0007	0.0018
Total boron	mg/L	1.5-29	0.080	13	0.054	0.027	0.084
Total molybdenum	mg/L	0.073	0.00051	13	0.00038	0.00016	0.00044
Total mercury (ultra-trace)	ng/L	5-13	0.820	12	1.50	1.20	**6.00**
Total methyl mercury	ng/L	1-2	0.036	-	-	-	-
Total strontium	mg/L	-	0.191	13	0.129	0.078	0.161
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.19	4	0.18	0.02	0.68
Oilsands extractable acids	mg/L	-	1.0	4	0.64	0.37	1.10
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	<2.04	1.66	3.44
Total dibenzothiophenes[c]	ng/L	-	8.4	4	18.03	6.01	52.14
Total PAHs[c]	ng/L	-	111.2	4	151.4	138.5	316.3
Total Parent PAHs[c]	ng/L	-	22.6	4	19.92	14.98	23.48
Total Alkylated PAHs[c]	ng/L	-	88.6	4	129.9	123.5	295.9
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0023**	13	**0.004**	**0.002**	**0.011**
Total phenolics	mg/L	0.004	**0.0082**	13	**0.0046**	0.001	**0.014**

Values in **bold** are above guideline; underlined values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-19 Concentrations of water quality measurement endpoints, lower Christina River (*test* station CHR-2A), fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value
Physical variables			
pH	pH units	6.5-9.0	8.14
Total suspended solids	mg/L	-	4.0
Conductivity	µS/cm	-	270
Nutrients			
Total dissolved phosphorus	mg/L	-	0.016
Total nitrogen	mg/L	-	0.59
Nitrate+nitrite	mg/L	3-124	<0.005
Dissolved organic carbon	mg/L	-	17
Ions			
Sodium	mg/L	-	12
Calcium	mg/L	-	33
Magnesium	mg/L	-	9.8
Potassium	mg/L	-	1.0
Chloride	mg/L	120-640	4.0
Sulphate	mg/L	309[b]	6.2
Total dissolved solids	mg/L	-	180
Total alkalinity	mg/L	20 (min)	140
Selected metals			
Total aluminum	mg/L	-	0.0809
Dissolved aluminum	mg/L	0.05	0.00344
Total arsenic	mg/L	0.005	0.000809
Total boron	mg/L	1.5-29	0.0562
Total molybdenum	mg/L	0.073	0.000567
Total mercury (ultra-trace)	ng/L	5-13	0.99
Total methyl mercury	ng/L	1-2	0.073
Total strontium	mg/L	-	0.135
Total hydrocarbons			
BTEX	mg/L	-	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02
Naphthenic Acids	mg/L	-	0.54
Oilsands extractable acids	mg/L	-	1.6
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	1,000	<13.55
Retene	ng/L	-	<0.59
Total dibenzothiophenes[c]	ng/L	-	8.17
Total PAHs[c]	ng/L	-	113.70
Total Parent PAHs[c]	ng/L	-	22.48
Total Alkylated PAHs[c]	ng/L	-	91.21
Other variables that exceeded Alberta guidelines in fall 2015			
Dissolved iron	mg/L	0.3	**0.345**
Sulphide	mg/L	0.0019	**0.0054**
Total phenols	mg/L	0.004	**0.0092**

Values in **bold** are above guideline; sampling began in 2015, no historical comparisons possible.
[a] Sources for all guidelines are outlined in Table 3.2-1.
[b] based on actual hardness level
[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-20 Concentrations of water quality measurement endpoints, Christina River upstream of Janvier (*test* station CHR-2), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2002-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.09	13	8.20	7.90	8.49
Total suspended solids	mg/L	-	4.0	13	8	<3	30
Conductivity	µS/cm	-	260	13	211	125	325
Nutrients							
Total dissolved phosphorus	mg/L	-	0.024	13	0.033	0.015	0.065
Total nitrogen	mg/L	-	0.56	13	0.800	0.414	1.400
Nitrate+nitrite	mg/L	3-124	<0.005	13	<0.100	<0.054	<0.100
Dissolved organic carbon	mg/L	-	16	13	18.0	13.0	29.2
Ions							
Sodium	mg/L	-	9.2	13	6.6	2.9	11.5
Calcium	mg/L	-	30	13	28.5	16.3	43.0
Magnesium	mg/L	-	8.7	13	8.2	4.6	11.5
Potassium	mg/L	-	1.0	13	1.0	0.58	1.43
Chloride	mg/L	120-640	<1	13	1.00	<0.50	2.00
Sulphate	mg/L	309[b]	6.3	13	5.8	<0.5	10.0
Total dissolved solids	mg/L	-	160	13	152	120	240
Total alkalinity	mg/L	20 (min)	130	13	106	59	162
Selected metals							
Total aluminum	mg/L	-	0.076	12	0.139	0.049	0.511
Dissolved aluminum	mg/L	0.05	0.003	12	0.0096	0.0017	0.0193
Total arsenic	mg/L	0.005	0.001	12	0.0011	0.0007	0.0016
Total boron	mg/L	1.5-29	0.046	12	0.034	0.022	0.060
Total molybdenum	mg/L	0.073	0.0006	12	0.00042	0.00031	0.00081
Total mercury (ultra-trace)	ng/L	5-13	0.840	12	<1.20	<0.60	4.90
Total methyl mercury	ng/L	1-2	0.054	-	-	-	-
Total strontium	mg/L	-	0.142	12	0.108	0.055	0.172
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.18	4	0.31	0.06	0.62
Oilsands extractable acids	mg/L	-	1.0	4	0.72	0.40	1.20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	<1.880	<0.407	<3.760
Total dibenzothiophenes[c]	ng/L	-	<8.17	4	6.258	4.157	35.40
Total PAHs[c]	ng/L	-	106.34	4	128.34	74.24	210.64
Total Parent PAHs[c]	ng/L	-	22.52	4	20.12	13.38	22.93
Total Alkylated PAHs[c]	ng/L	-	83.81	4	105.99	60.86	192.16
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.323**	12	**0.620**	0.0273	**1.960**
Sulphide	mg/L	0.0019	**0.0031**	13	**0.0048**	**<0.0020**	**0.0400**
Total phenols	mg/L	0.004	**0.0080**	13	**0.009**	<0.001	**0.019**

Values in **bold** are above guideline; underlined values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-21 Concentrations of water quality measurement endpoints, Christina River upstream of Jackfish River (*test* station CHR-3), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2013-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.24	2	8.36	8.24	8.48
Total suspended solids	mg/L	-	<u>4.0</u>	2	<3.0	<3.0	<3.0
Conductivity	µS/cm	-	300	2	288	233	342
Nutrients							
Total dissolved phosphorus	mg/L	-	0.033	2	0.05	0.02	0.09
Total nitrogen	mg/L	-	<u>0.46</u>	2	0.59	0.54	0.64
Nitrate+nitrite	mg/L	3-124	<0.005	2	<0.063	<0.054	<0.071
Dissolved organic carbon	mg/L	-	14	2	12.80	3.10	22.50
Ions							
Sodium	mg/L	-	8.3	2	9.00	7.50	10.50
Calcium	mg/L	-	42	2	40.65	33.50	47.80
Magnesium	mg/L	-	<u>12</u>	2	10.59	9.37	11.80
Potassium	mg/L	-	1.3	2	1.27	1.08	1.46
Chloride	mg/L	120-640	<u><1</u>	2	<0.5	<0.5	<0.5
Sulphate	mg/L	309[b]	<u>5.8</u>	2	6.93	5.96	7.90
Total dissolved solids	mg/L	-	<u>200</u>	2	171	155	187
Total alkalinity	mg/L	20 (min)	160	2	152	126	178
Selected metals							
Total aluminum	mg/L	-	0.058	2	0.05	0.04	0.06
Dissolved aluminum	mg/L	0.05	0.001	2	0.01	0.0011	0.02
Total arsenic	mg/L	0.005	0.0011	2	0.0016	0.0011	0.0020
Total boron	mg/L	1.5-29	0.049	2	0.05	0.04	0.06
Total molybdenum	mg/L	0.073	0.001	2	0.0009	0.0009	0.0010
Total mercury (ultra-trace)	ng/L	5-13	0.810	2	1.10	0.69	1.50
Total methyl mercury	ng/L	1-2	0.044	-	-	-	-
Total strontium	mg/L	-	0.185	2	0.17	0.14	0.19
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.70</u>	2	0.44	0.31	0.56
Oilsands extractable acids	mg/L	-	<u>1.6</u>	2	0.65	0.49	0.80
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.19	<7.21	<15.16
Retene	ng/L	-	<0.59	2	0.73	<0.41	1.05
Total dibenzothiophenes[c]	ng/L	-	<u><8.17</u>	2	5.40	4.13	6.67
Total PAHs[c]	ng/L	-	<u>105.90</u>	2	88.29	74.10	102.49
Total Parent PAHs[c]	ng/L	-	22.40	2	17.85	13.26	22.44
Total Alkylated PAHs[c]	ng/L	-	<u>83.50</u>	2	70.44	60.84	80.05
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0054**	2	**0.004**	**<0.002**	**0.007**
Total phenols	mg/L	0.004	**<u>0.0110</u>**	**2**	**0.0080**	**0.0063**	**0.0097**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-22 Concentrations of water quality measurement endpoints, Christina River upstream of development (*baseline* station CHR-4), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2013-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.06	2	8.105	8.1	8.11
Total suspended solids	mg/L	-	4.7	2	18	18	18
Conductivity	µS/cm	-	240	2	274.5	221	328
Nutrients							
Total dissolved phosphorus	mg/L	-	0.11	2	0.0622	0.0064	0.118
Total nitrogen	mg/L	-	0.67	2	0.6615	0.454	0.869
Nitrate+nitrite	mg/L	3-124	0.097	2	0.0665	<0.054	0.079
Dissolved organic carbon	mg/L	-	17	2	20	13.9	26.1
Ions							
Sodium	mg/L	-	3.8	2	4.5	3.5	5.5
Calcium	mg/L	-	36	2	40.65	34.6	46.7
Magnesium	mg/L	-	8.8	2	9.605	8.21	11
Potassium	mg/L	-	0.89	2	0.94	0.77	1.11
Chloride	mg/L	120-640	<1	2	<0.5	<0.5	<0.5
Sulphate	mg/L	309[b]	2.60	2	3.2	2.36	4.04
Total dissolved solids	mg/L	-	160	2	206	186	226
Total alkalinity	mg/L	20 (min)	130	2	141.5	114	169
Selected metals							
Total aluminum	mg/L	-	0.045	2	0.14505	0.0631	0.227
Dissolved aluminum	mg/L	0.05	0.010	2	0.01525	0.0031	0.0274
Total arsenic	mg/L	0.005	0.0013	2	0.0021	0.0017	0.00253
Total boron	mg/L	1.5-29	0.032	2	0.03425	0.0256	0.0429
Total molybdenum	mg/L	0.073	0.0005	2	0.000649	0.0006	0.000709
Total mercury (ultra-trace)	ng/L	5-13	0.940	2	1.725	1.15	2.3
Total methyl mercury	ng/L	1-2	0.074	-	-	-	-
Total strontium	mg/L	-	0.141	2	0.1435	0.124	0.163
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.87	2	0.42	0.38	0.46
Oilsands extractable acids	mg/L	-	2.0	2	0.94	0.48	1.4
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.19	<7.21	<15.16
Retene	ng/L	-	1.00	2	5.966	0.932	11
Total dibenzothiophenes[c]	ng/L	-	<8.17	2	5.40325	4.1341	6.6724
Total PAHs[c]	ng/L	-	109.16	2	94.09735	74.096	114.0992
Total Parent PAHs[c]	ng/L	-	22.40	2	17.8503	13.256	22.4445
Total Alkylated PAHs[c]	ng/L	-	86.76	2	76.24705	60.839	91.6547
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0054**	2	**0.0037**	**0.003**	**0.0048**
Total phenols	mg/L	0.004	**0.011**	2	**0.0069**	0.0039	**0.0099**

Values in **bold** are above guideline; underlined values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-23 Concentrations of water quality measurement endpoints, Sawbones Creek (*test* station SAC-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2012-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.33	3	7.67	7.66	7.84
Total suspended solids	mg/L	-	2.7	3	<3	<3	<3
Conductivity	µS/cm	-	91	3	113	95	143
Nutrients							
Total dissolved phosphorus	mg/L	-	0.016	3	0.024	0.012	0.032
Total nitrogen	mg/L	-	0.68	3	0.681	0.644	0.701
Nitrate+nitrite	mg/L	3-124	<0.005	3	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	20.00	3	20.3	19.8	26.4
Ions							
Sodium	mg/L	-	2.4	3	2.7	2.5	2.7
Calcium	mg/L	-	12	3	14.8	12.1	20.2
Magnesium	mg/L	-	4.10	3	4.77	3.72	6.01
Potassium	mg/L	-	<0.3	3	<0.5	<0.5	<0.5
Chloride	mg/L	120-640	<1.0	3	<0.5	<0.5	<0.5
Sulphate	mg/L	218[b]	<0.5	3	<0.5	<0.5	<0.5
Total dissolved solids	mg/L	-	80	3	101	96	149
Total alkalinity	mg/L	20 (min)	44	3	57.4	47.8	71.2
Selected metals							
Total aluminum	mg/L	-	0.117	3	0.022	0.022	0.046
Dissolved aluminum	mg/L	0.05	0.005	3	0.0057	0.0038	0.0082
Total arsenic	mg/L	0.005	0.001	3	0.0007	0.0006	0.0012
Total boron	mg/L	1.5-29	0.009	3	0.011	0.011	0.019
Total molybdenum	mg/L	0.073	0.0001	3	<0.00010	0.00004	<0.00010
Total mercury (ultra-trace)	ng/L	5-13	1.210	3	1.00	0.95	1.10
Total methyl mercury	ng/L	1-2	0.057	-	-	-	-
Total strontium	mg/L	-	0.037	3	0.043	0.037	0.059
Total hydrocarbons							
BTEX	mg/L	-	<0.01	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	3	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.28	3	0.29	0.05	0.58
Oilsands extractable acids	mg/L	-	1.4	3	0.81	0.30	1.10
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	3	<8.76	<7.21	<15.16
Retene	ng/L	-	<0.59	3	<0.51	<0.41	<0.67
Total dibenzothiophenes[c]	ng/L	-	<8.17	3	6.67	4.13	35.30
Total PAHs[c]	ng/L	-	106.79	3	102.5	74.1	203.4
Total Parent PAHs[c]	ng/L	-	22.40	3	16.42	13.26	22.50
Total Alkylated PAHs[c]	ng/L	-	84.39	3	80.0	60.8	187.0
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0031**	3	**<0.002**	<0.0015	**<0.002**
Total phenols	mg/L	0.004	**0.0079**	3	**0.0070**	**0.0067**	**0.0086**

Values in **bold** are above guideline; underlined values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-24 Concentrations of water quality measurement endpoints, Sunday Creek at the inlet to Christina Lake (*test* station SUC-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2012-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	<u>8.04</u>	3	8.16	8.15	8.24
Total suspended solids	mg/L	-	4.0	3	8.0	<3.0	17.0
Conductivity	µS/cm	-	<u>260</u>	3	310	267	355
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.013</u>	3	0.026	0.019	0.031
Total nitrogen	mg/L	-	0.52	3	0.571	0.503	0.734
Nitrate+nitrite	mg/L	3-124	0.017	3	0.071	<0.054	0.073
Dissolved organic carbon	mg/L	-	<u>14.00</u>	3	18.0	14.4	21.4
Ions							
Sodium	mg/L	-	<u>6.6</u>	3	12.5	6.8	13.9
Calcium	mg/L	-	35	3	38.8	33.4	47.0
Magnesium	mg/L	-	11	3	11.2	10.4	14.0
Potassium	mg/L	-	<u>0.68</u>	3	1.09	1.02	1.81
Chloride	mg/L	120-640	4.2	3	3.86	3.07	6.29
Sulphate	mg/L	309[b]	<2.00	3	2.47	1.12	15.10
Total dissolved solids	mg/L	-	<u>150</u>	3	223	157	243
Total alkalinity	mg/L	20 (min)	<u>130</u>	3	142	135	183
Selected metals							
Total aluminum	mg/L	-	<u>0.100</u>	3	0.239	0.142	0.962
Dissolved aluminum	mg/L	0.05	<u>0.003</u>	3	0.0069	0.0044	0.0150
Total arsenic	mg/L	0.005	<u>0.0007</u>	3	0.0010	0.0009	0.0013
Total boron	mg/L	1.5-29	<u>0.021</u>	3	0.034	0.027	0.037
Total molybdenum	mg/L	0.073	<u>0.0002</u>	3	0.00036	0.00025	0.00059
Total mercury (ultra-trace)	ng/L	5-13	0.900	3	1.20	0.24	1.90
Total methyl mercury	ng/L	1-2	0.053	-	-	-	-
Total strontium	mg/L	-	0.092	3	0.116	0.085	0.126
Total hydrocarbons							
BTEX	mg/L	-	<0.01	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	3	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.24	3	0.28	0.20	0.42
Oilsands extractable acids	mg/L	-	<u>1.6</u>	3	0.75	0.65	1.50
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	3	<8.76	<7.21	<15.16
Retene	ng/L	-	<u>0.80</u>	3	2.63	2.07	5.25
Total dibenzothiophenes[c]	ng/L	-	<8.17	3	12.12	6.67	35.30
Total PAHs[c]	ng/L	-	110.62	3	133.0	103.2	205.8
Total Parent PAHs[c]	ng/L	-	22.40	3	17.81	16.55	22.54
Total Alkylated PAHs[c]	ng/L	-	88.22	3	115.16	80.62	189.26
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**<u>0.0023</u>**	3	**<0.002**	<0.0015	**<0.002**
Total phenols	mg/L	0.004	**<u>0.0095</u>**	3	**0.0057**	0.0036	**0.0060**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-25 Concentrations of water quality measurement endpoints, Sunday Creek upstream (*baseline* station SUC-2), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2013-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	<u>8.12</u>	2	8.03	8.02	8.04
Total suspended solids	mg/L	-	<1	2	<3	<3	<3
Conductivity	µS/cm	-	<u>220</u>	2	257	227	287
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.009</u>	2	0.022	0.018	0.03
Total nitrogen	mg/L	-	<u>0.49</u>	2	0.37	0.35	0.38
Nitrate+nitrite	mg/L	3-124	<0.005	2	<0.0625	<0.054	<0.071
Dissolved organic carbon	mg/L	-	12	2	13.05	11.70	14.40
Ions							
Sodium	mg/L	-	<u>2.8</u>	2	3.35	3.00	3.70
Calcium	mg/L	-	<u>28</u>	2	37.10	34.30	39.90
Magnesium	mg/L	-	<u>8.7</u>	2	10.57	9.83	11.30
Potassium	mg/L	-	<u>0.5</u>	2	0.61	0.52	0.69
Chloride	mg/L	120-640	<u>1.4</u>	2	1.10	0.95	1.24
Sulphate	mg/L	309[b]	<u><1</u>	2	0.73	0.54	0.92
Total dissolved solids	mg/L	-	<u>140</u>	2	157.00	144.00	170.00
Total alkalinity	mg/L	20 (min)	<u>120</u>	2	136.50	125.00	148.00
Selected metals							
Total aluminum	mg/L	-	<u>0.066</u>	2	0.08	0.07	0.08
Dissolved aluminum	mg/L	0.05	0.002	2	0.0042	0.0020	0.0064
Total arsenic	mg/L	0.005	<u>0.0007</u>	2	0.0010	0.0009	0.0011
Total boron	mg/L	1.5-29	<u>0.012</u>	2	0.0189	0.0153	0.0225
Total molybdenum	mg/L	0.073	<u>0.0002</u>	2	0.0003	0.0003	0.0004
Total mercury (ultra-trace)	ng/L	5-13	<u>0.800</u>	2	0.88	0.82	0.94
Total methyl mercury	ng/L	1-2	0.057	-	-	-	-
Total strontium	mg/L	-	<u>0.060</u>	2	0.07	0.07	0.08
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.11	2	0.15	0.13	0.17
Oilsands extractable acids	mg/L	-	0.6	2	0.72	0.43	1.00
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.19	<7.21	<15.16
Retene	ng/L	-	<u>0.74</u>	2	1.17	0.87	1.47
Total dibenzothiophenes[c]	ng/L	-	<u><8.17</u>	2	5.40	4.13	6.67
Total PAHs[c]	ng/L	-	<u>106.04</u>	2	88.89	74.75	103.02
Total Parent PAHs[c]	ng/L	-	22.40	2	18.22	13.91	22.53
Total Alkylated PAHs[c]	ng/L	-	<u>83.64</u>	2	70.67	60.84	80.49
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	<u>**0.0031**</u>	2	<0.0017	<0.0015	**<0.002**
Total phenols	mg/L	0.004	<u>**0.0078**</u>	2	0.0026	0.0011	**0.0041**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-26 Concentrations of water quality measurement endpoints, Birch Creek (*baseline* station BRC-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2013-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.29	2	8.37	8.25	8.48
Total suspended solids	mg/L	-	<u>6.00</u>	2	4.20	<3.00	5.40
Conductivity	µS/cm	-	390	2	372	341	402
Nutrients							
Total dissolved phosphorus	mg/L	-	0.013	2	0.02	0.01	0.03
Total nitrogen	mg/L	-	<u>0.47</u>	2	0.34	0.26	0.42
Nitrate+nitrite	mg/L	3-124	0.062	2	<0.063	<0.054	<0.071
Dissolved organic carbon	mg/L	-	8.9	2	9.75	8.70	10.80
Ions							
Sodium	mg/L	-	<u>18.00</u>	2	14.90	13.60	16.20
Calcium	mg/L	-	<u>49.0</u>	2	47.15	45.90	48.40
Magnesium	mg/L	-	<u>14.0</u>	2	13.25	12.60	13.9
Potassium	mg/L	-	1.5	2	1.43	1.29	1.57
Chloride	mg/L	120-640	<u><1.0</u>	2	<0.5	<0.5	<0.5
Sulphate	mg/L	309[b]	<u>4.6</u>	2	5.31	4.95	5.66
Total dissolved solids	mg/L	-	230	2	215	197	232
Total alkalinity	mg/L	20 (min)	210	2	198	184	211
Selected metals							
Total aluminum	mg/L	-	<u>0.124</u>	2	0.0586	0.0382	0.0790
Dissolved aluminum	mg/L	0.05	<u>0.001</u>	2	0.0037	0.0012	0.0062
Total arsenic	mg/L	0.005	<u>0.0013</u>	2	0.0016	0.0015	0.0016
Total boron	mg/L	1.5-29	0.058	2	0.0549	0.0496	0.0601
Total molybdenum	mg/L	0.073	0.0010	2	0.0010	0.0010	0.0011
Total mercury (ultra-trace)	ng/L	5-13	<u>0.530</u>	2	0.7750	0.7500	0.8000
Total methyl mercury	ng/L	1-2	0.056	-	-	-	-
Total strontium	mg/L	-	0.153	2	0.1485	0.1400	0.1570
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.13</u>	2	0.43	0.19	0.67
Oilsands extractable acids	mg/L	-	0.6	2	0.83	0.45	1.20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.18	<7.21	<15.16
Retene	ng/L	-	<0.59	2	0.57	0.47	<0.67
Total dibenzothiophenes[c]	ng/L	-	<u><8.17</u>	2	5.40	4.13	6.67
Total PAHs[c]	ng/L	-	<u>106.92</u>	2	90.71	75.85	105.57
Total Parent PAHs[c]	ng/L	-	22.79	2	19.99	14.46	25.53
Total Alkylated PAHs[c]	ng/L	-	<u>84.13</u>	2	70.72	61.40	80.05
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**<u>0.0031</u>**	2	<0.00175	**<0.002**	<0.0015
Total phenols	mg/L	0.004	**<u>0.0066</u>**	2	0.002	0.0017	0.0023

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-27 Concentrations of water quality measurement endpoints, unnamed creek east of Christina Lake (*test* station UNC-2), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2013-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	<u>7.70</u>	2	8.10	7.91	8.29
Total suspended solids	mg/L	-	2.0	2	4	<3	5
Conductivity	µS/cm	-	190	2	203	136	269
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.013</u>	2	0.02	0.02	0.03
Total nitrogen	mg/L	-	0.79	2	0.74	0.59	0.89
Nitrate+nitrite	mg/L	3-124	0.010	2	<0.063	<0.054	<0.071
Dissolved organic carbon	mg/L	-	<u>22</u>	2	20.40	19.80	21.00
Ions							
Sodium	mg/L	-	4.6	2	7.15	2.60	11.70
Calcium	mg/L	-	24	2	25.50	18.80	32.20
Magnesium	mg/L	-	8.0	2	7.57	5.61	9.53
Potassium	mg/L	-	<0.3	2	<0.5	<0.5	<0.5
Chloride	mg/L	120-640	2.3	2	2.26	0.57	3.94
Sulphate	mg/L	309[b]	<0.5	2	0.96	<0.5	1.42
Total dissolved solids	mg/L	-	<u>130</u>	2	161	141	182
Total alkalinity	mg/L	20 (min)	97.0	2	100.7	68.4	133.0
Selected metals							
Total aluminum	mg/L	-	<u>0.0242</u>	2	0.0609	0.0578	0.0639
Dissolved aluminum	mg/L	0.05	0.0044	2	0.0045	0.0028	0.0062
Total arsenic	mg/L	0.005	0.0008	2	0.0008	0.0008	0.0008
Total boron	mg/L	1.5-29	0.0158	2	0.0236	0.0147	0.0324
Total molybdenum	mg/L	0.073	0.00015	2	0.0003	<0.0001	0.0004
Total mercury (ultra-trace)	ng/L	5-13	<u>1.200</u>	2	1.0800	1.0600	1.1000
Total methyl mercury	ng/L	1-2	0.084	-	-	-	-
Total strontium	mg/L	-	0.0660	2	0.0713	0.0495	0.0931
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.12</u>	2	0.58	0.35	0.80
Oilsands extractable acids	mg/L	-	<u>1.1</u>	2	0.78	0.76	0.80
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.19	<7.21	<15.16
Retene	ng/L	-	<0.59	2	0.60	<0.407	0.80
Total dibenzothiophenes[c]	ng/L	-	<u><8.17</u>	2	5.40	4.13	6.67
Total PAHs[c]	ng/L	-	<u>107.61</u>	2	89.83	74.10	105.57
Total Parent PAHs[c]	ng/L	-	22.40	2	19.39	13.26	25.53
Total Alkylated PAHs[c]	ng/L	-	<u>85.21</u>	2	70.44	60.84	80.05
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0023**	2	**0.00205**	0.0017	**0.0024**
Total phenols	mg/L	0.004	**<u>0.0081</u>**	2	**0.007**	**0.006**	**0.0080**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-28 Concentrations of water quality measurement endpoints, unnamed creek south of Christina Lake (*test* station UNC-3), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2013-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.98	2	8.10	8.08	8.11
Total suspended solids	mg/L	-	1.3	2	4	<3	5
Conductivity	µS/cm	-	220	2	283	227	339
Nutrients							
Total dissolved phosphorus	mg/L	-	0.022	2	0.03	0.03	0.04
Total nitrogen	mg/L	-	0.63	2	0.59	0.58	0.59
Nitrate+nitrite	mg/L	3-124	<0.005	2	<0.063	<0.054	<0.071
Dissolved organic carbon	mg/L	-	18	2	17	15	18
Ions							
Sodium	mg/L	-	6.7	2	10.10	6.60	13.60
Calcium	mg/L	-	28	2	36.70	31.10	42.30
Magnesium	mg/L	-	8.8	2	11.25	9.29	13.20
Potassium	mg/L	-	0.53	2	0.86	0.66	1.04
Chloride	mg/L	120-640	<1.0	2	0.66	<0.5	0.81
Sulphate	mg/L	309[b]	0.53	2	0.78	<0.5	1.06
Total dissolved solids	mg/L	-	150	2	195	179	212
Total alkalinity	mg/L	20 (min)	120	2	154	127	181
Selected metals							
Total aluminum	mg/L	-	0.0962	2	0.1044	0.0917	0.1170
Dissolved aluminum	mg/L	0.05	0.0064	2	0.0063	0.0037	0.0089
Total arsenic	mg/L	0.005	0.0008	2	0.0012	0.0011	0.0013
Total boron	mg/L	1.5-29	0.0235	2	0.0357	0.0269	0.0445
Total molybdenum	mg/L	0.073	0.0002	2	0.0003	0.0002	0.0004
Total mercury (ultra-trace)	ng/L	5-13	0.9600	2	0.7000	0.4500	0.9500
Total methyl mercury	ng/L	1-2	0.069	-	-	-	-
Total strontium	mg/L	-	0.0726	2	0.0960	0.0739	0.1180
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.26	2	0.38	0.22	0.54
Oilsands extractable acids	mg/L	-	1.6	2	1.27	0.94	1.60
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.19	<7.21	<15.16
Retene	ng/L	-	<0.59	2	0.59	0.51	<0.669
Total dibenzothiophenes[c]	ng/L	-	9.15	2	5.40	4.13	6.67
Total PAHs[c]	ng/L	-	126.74	2	89.87	74.17	105.57
Total Parent PAHs[c]	ng/L	-	22.40	2	19.39	13.26	25.53
Total Alkylated PAHs[c]	ng/L	-	104.34	2	70.48	60.91	80.05
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**0.0089**	2	0.0038	0.0033	**0.0043**

Values in **bold** are above guideline; underlined values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-29 Concentrations of water quality measurement endpoints, Jackfish River (*test* station JAR-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2012-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	<u>7.92</u>	3	8.03	7.97	8.07
Total suspended solids	mg/L	-	<1	3	<3	<3	3
Conductivity	µS/cm	-	200	3	183	175	207
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.0060</u>	3	0.010	0.006	0.015
Total nitrogen	mg/L	-	<u>0.49</u>	3	0.574	0.501	0.691
Nitrate+nitrite	mg/L	3-124	<0.005	3	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	<u>14</u>	3	15.9	15.5	16.1
Ions							
Sodium	mg/L	-	<u>6.1</u>	3	5.4	4.6	5.5
Calcium	mg/L	-	<u>26</u>	3	24.5	22.5	24.7
Magnesium	mg/L	-	<u>8.1</u>	3	6.91	6.67	7.29
Potassium	mg/L	-	<u>0.89</u>	3	0.81	0.73	0.84
Chloride	mg/L	120-640	<u>2.2</u>	3	1.05	1.02	1.06
Sulphate	mg/L	309[b]	<1	3	0.950	0.810	1.010
Total dissolved solids	mg/L	-	150	3	129	125	173
Total alkalinity	mg/L	20 (min)	100	3	91.7	89.3	107.0
Selected metals							
Total aluminum	mg/L	-	<u>0.0074</u>	3	0.022	0.008	0.063
Dissolved aluminum	mg/L	0.05	<u>0.001</u>	3	0.0013	0.0012	0.0053
Total arsenic	mg/L	0.005	<u>0.0004</u>	3	0.0006	0.0005	0.0007
Total boron	mg/L	1.5-29	<u>0.012</u>	3	0.026	0.022	0.030
Total molybdenum	mg/L	0.073	0.00025	3	0.00022	0.00022	0.00023
Total mercury (ultra-trace)	ng/L	5-13	0.710	3	1.00	<0.60	1.11
Total methyl mercury	ng/L	1-2	0.021	-	-	-	-
Total strontium	mg/L	-	<u>0.080</u>	3	0.066	0.065	0.075
Total hydrocarbons							
BTEX	mg/L	-	<0.01	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	3	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.29	3	0.23	0.04	0.52
Oilsands extractable acids	mg/L	-	1.0	3	0.54	0.36	1.60
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	3	<8.76	<7.21	<15.16
Retene	ng/L	-	<0.59	3	<1.14	<0.92	3.85
Total dibenzothiophenes[c]	ng/L	-	8.17	3	6.67	4.13	35.30
Total PAHs[c]	ng/L	-	108.77	3	105.98	77.18	205.63
Total Parent PAHs[c]	ng/L	-	22.40	3	16.59	13.73	22.96
Total Alkylated PAHs[c]	ng/L	-	86.37	3	83.02	63.45	189.03
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	<u>**0.0023**</u>	3	**<0.002**	<0.0015	**<0.002**
Total phenols	mg/L	0.004	**0.0077**	3	0.0035	0.0014	**0.0087**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-30 Concentrations of water quality measurement endpoints, Gregoire River (*test* station GRR-1), fall 2015, compared to fall 2014 concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	September 2014
			Value	Value
Physical variables				
pH	pH units	6.5-9.0	8.23	8.22
Total suspended solids	mg/L	-	2.7	54.0
Conductivity	µS/cm	-	440	346
Nutrients				
Total dissolved phosphorus	mg/L	-	0.01	0.007
Total nitrogen	mg/L	-	0.62	0.474
Nitrate+nitrite	mg/L	3-124	<0.005	<0.054
Dissolved organic carbon	mg/L	-	19	16.3
Ions				
Sodium	mg/L	-	28	22.3
Calcium	mg/L	-	48	39.7
Magnesium	mg/L	-	14	10.3
Potassium	mg/L	-	1.7	1.6
Chloride	mg/L	120-640	6.9	4.48
Sulphate	mg/L	309[b]	14	15.6
Total dissolved solids	mg/L	-	280	245
Total alkalinity	mg/L	20 (min)	220	155
Selected metals				
Total aluminum	mg/L	-	0.15	3.5
Dissolved aluminum	mg/L	0.05	0.00516	0.019
Total arsenic	mg/L	0.005	0.000999	0.001
Total boron	mg/L	1.5-29	0.161	0.127
Total molybdenum	mg/L	0.073	0.00124	0.00086
Total mercury (ultra-trace)	ng/L	5-13	0.9	3.74
Total methyl mercury	ng/L	1-2	0.092	-
Total strontium	mg/L	-	0.246	0.165
Total hydrocarbons				
BTEX	mg/L	-	<0.01	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.25
Naphthenic acids	mg/L	-	0.54	0.37
Oilsands extractable acids	mg/L	-	1.7	1.30
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	1,000	<13.55	7.57
Retene	ng/L	-	<0.59	2.61
Total dibenzothiophenes[c]	ng/L	-	<8.17	4.134
Total PAHs[c]	ng/L	-	127.25	96.95
Total Parent PAHs[c]	ng/L	-	24.07	17.10
Total Alkylated PAHs[c]	ng/L	-	103.18	79.84
Other variables that exceeded Alberta guidelines in fall 2015				
Sulphide	mg/L	0.0019	**0.0054**	**0.0032**
Total phenols	mg/L	0.004	**0.0098**	**0.0047**

Values in **bold** are above guideline; underlined values are above the fall 2014 values.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-31 Concentrations of water quality measurement endpoints, Christina Lake (*test* station CHL-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2012-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.17	3	8.11	8.05	8.17
Total suspended solids	mg/L	-	<u>1.3</u>	3	5.0	3.5	15.0
Conductivity	µS/cm	-	200	3	183	166	206
Nutrients							
Total dissolved phosphorus	mg/L	-	0.007	3	0.004	0.003	0.009
Total nitrogen	mg/L	-	0.52	3	0.631	0.534	0.721
Nitrate+nitrite	mg/L	3-124	<0.005	3	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	14	3	15.2	13.4	16.3
Ions							
Sodium	mg/L	-	<u>6.5</u>	3	5.2	4.5	6.1
Calcium	mg/L	-	<u>26</u>	3	23.6	22.3	24.4
Magnesium	mg/L	-	<u>8.4</u>	3	6.76	6.75	7.21
Potassium	mg/L	-	<u>1.0</u>	3	0.77	0.71	0.79
Chloride	mg/L	120-640	<u>1.50</u>	3	1.09	1.04	1.12
Sulphate	mg/L	309[b]	<1	3	0.870	0.850	1.01
Total dissolved solids	mg/L	-	150	3	141	140	159
Total alkalinity	mg/L	20 (min)	100	3	90.9	86.4	105
Selected metals							
Total aluminum	mg/L	-	0.016	3	0.030	0.014	0.043
Dissolved aluminum	mg/L	0.05		3	0.0013	<0.0010	0.0046
Total arsenic	mg/L	0.005	0.0006	3	0.0006	0.0005	0.0007
Total boron	mg/L	1.5-29	<u>0.032</u>	3	0.025	0.021	0.026
Total molybdenum	mg/L	0.073	0.00026	3	0.00023	0.00021	0.00024
Total mercury (ultra-trace)	ng/L	5-13	0.51	3	1.20	1.06	1.30
Total methyl mercury	ng/L	1-2	0.015	-	-	-	-
Total strontium	mg/L	-	<u>0.081</u>	3	0.061	0.061	0.074
Total hydrocarbons							
BTEX	mg/L	-	<0.01	3	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	3	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	3	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	3	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<1.75	3	0.18	0.11	0.29
Oilsands extractable acids	mg/L	-	<u><2.19</u>	3	0.20	0.12	0.55
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	3	<8.76	<7.21	<15.16
Retene	ng/L	-	<0.59	3	<0.66	<0.51	0.91
Total dibenzothiophenes[c]	ng/L	-	8.2	3	13.15	6.67	35.30
Total PAHs[c]	ng/L	-	135.3	3	106.0	103.3	225.2
Total Parent PAHs[c]	ng/L	-	22.9	3	23.25	13.86	23.74
Total Alkylated PAHs[c]	ng/L	-	112.4	3	92.18	80.05	201.43
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**<u>0.0096</u>**	3	**0.0052**	**0.0048**	**0.0052**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.10-32 Concentrations of water quality measurement endpoints, Gregoire Lake (*test* station GRL-1), fall 2015, compared to fall 2014 concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value	September 2014 Value
Physical variables				
pH	pH units	6.5-9.0	7.47	7.8
Total suspended solids	mg/L	-	180	3.8
Conductivity	µS/cm	-	130	127
Nutrients				
Total dissolved phosphorus	mg/L	-	0.018	0.0042
Total nitrogen	mg/L	-	1.6	0.564
Nitrate+nitrite	mg/L	3-124	<0.005	<0.054
Dissolved organic carbon	mg/L	-	11	10.2
Ions				
Sodium	mg/L	-	4.3	3.2
Calcium	mg/L	-	16	15.4
Magnesium	mg/L	-	4.3	3.84
Potassium	mg/L	-	1.2	1.2
Chloride	mg/L	120-640	3.3	2.06
Sulphate	mg/L	218[b]	13	10.5
Total dissolved solids	mg/L	-	100	92
Total alkalinity	mg/L	20 (min)	49	45
Selected metals				
Total aluminum	mg/L	-	0.908	0.188
Dissolved aluminum	mg/L	0.05	0.011	0.00314
Total arsenic	mg/L	0.005	0.0024	0.000766
Total boron	mg/L	1.5-29	0.032	0.0246
Total molybdenum	mg/L	0.073	0.0007	0.000487
Total mercury (ultra-trace)	ng/L	5-13	1.50	0.69
Total methyl mercury	ng/L	1-2	0.21	-
Total strontium	mg/L	-	0.073	0.0576
Total hydrocarbons				
BTEX	mg/L	-	<0.01	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.25
Naphthenic acids	mg/L	-	≤1.59	0.25
Oilsands extractable acids	mg/L	-	≤2	0.5
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	1,000	≤13.55	<7.2104
Retene	ng/L	-	1.45	<0.4069
Total dibenzothiophenes[c]	ng/L	-	8.22	4.13
Total PAHs[c]	ng/L	-	125.17	74.94
Total Parent PAHs[c]	ng/L	-	22.94	13.26
Total Alkylated PAHs[c]	ng/L	-	102.24	61.68
Other variables that exceeded Alberta guidelines in fall 2015				
Dissolved iron	mg/L	0.3	**0.367**	<0.0006
Sulphide	mg/L	0.0019	**0.0062**	<0.0015
Total phenols	mg/L	0.004	**0.011**	0.001

Values in **bold** are above guideline; underlined values are above the fall 2014 values.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.10-9 Piper diagram of fall ion concentrations in the mainstem stations (*test* stations CHR-1, CHR-2, CHR-2A, CHR-3, and *baseline* station CHR-4) of the Christina River watershed.

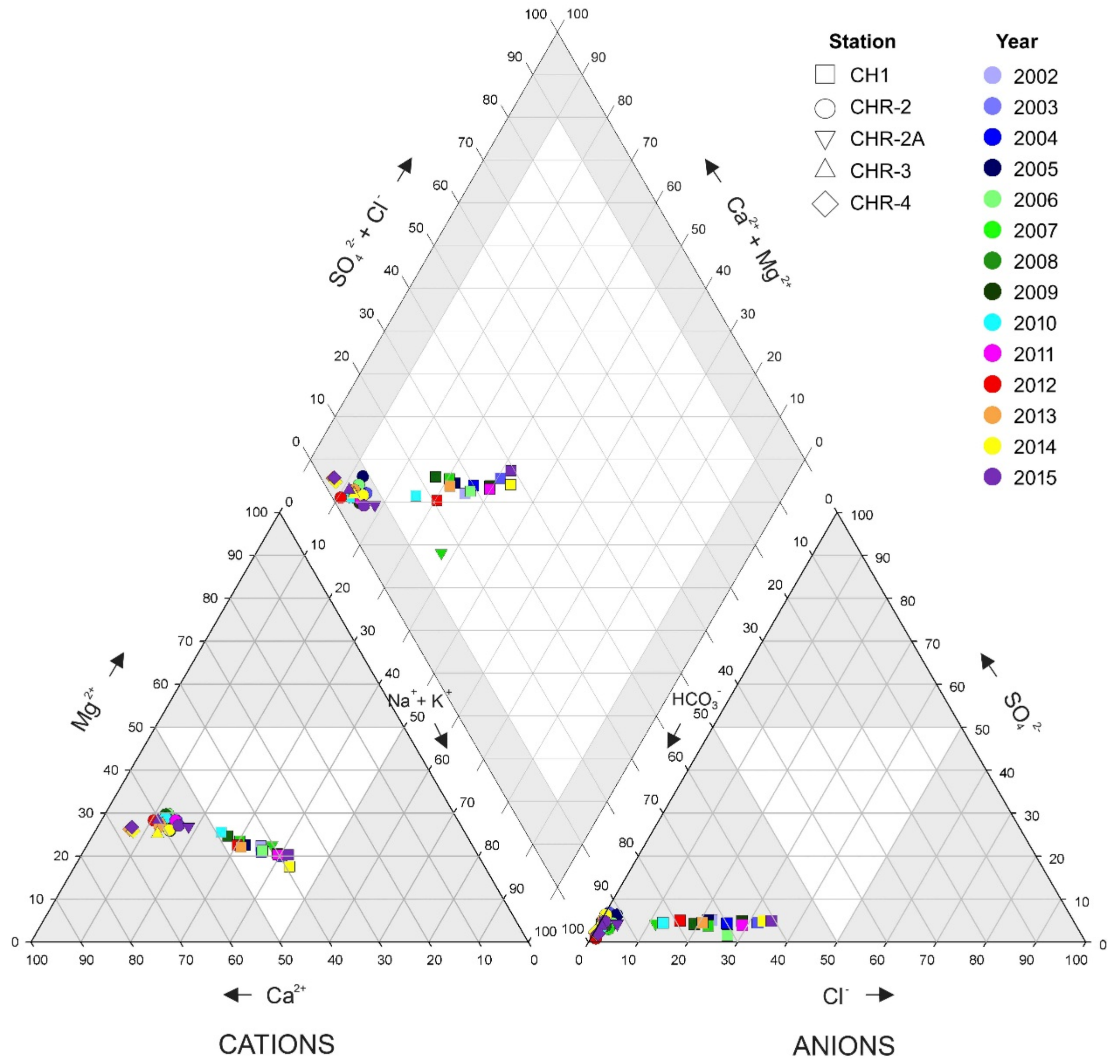


Figure 5.10-10 Piper diagram of fall ion concentrations in tributary stations (*test* stations GRL-1, GRR-1, CHL-1, and JAR-1) of the Christina River watershed.

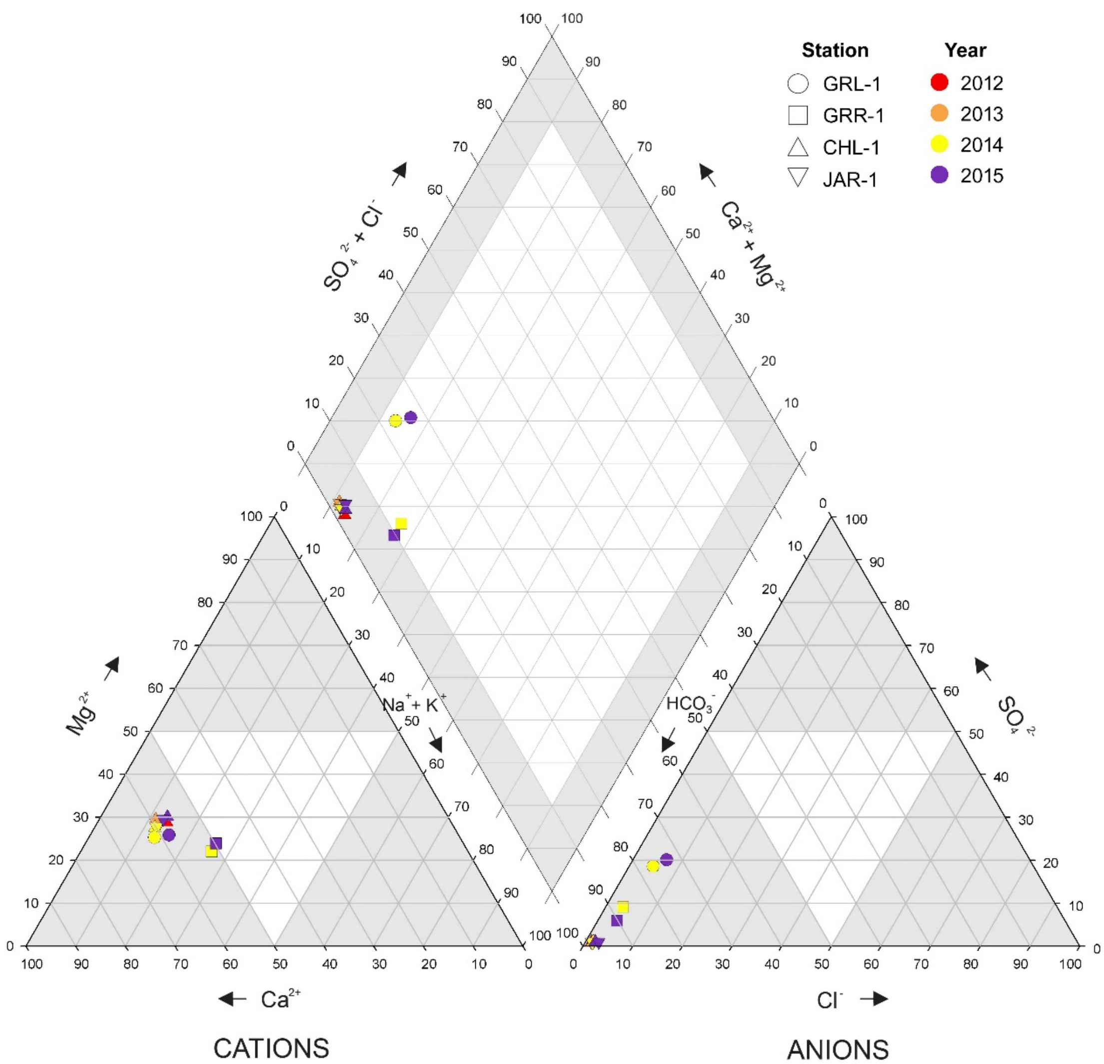


Figure 5.10-11 Piper diagram of fall ion concentrations in tributary stations (*test* stations SAC-1, SUC-1, UNC-2, UNC-3, and *baseline* stations BRC-1 and SUC-2) of the Christina River watershed.

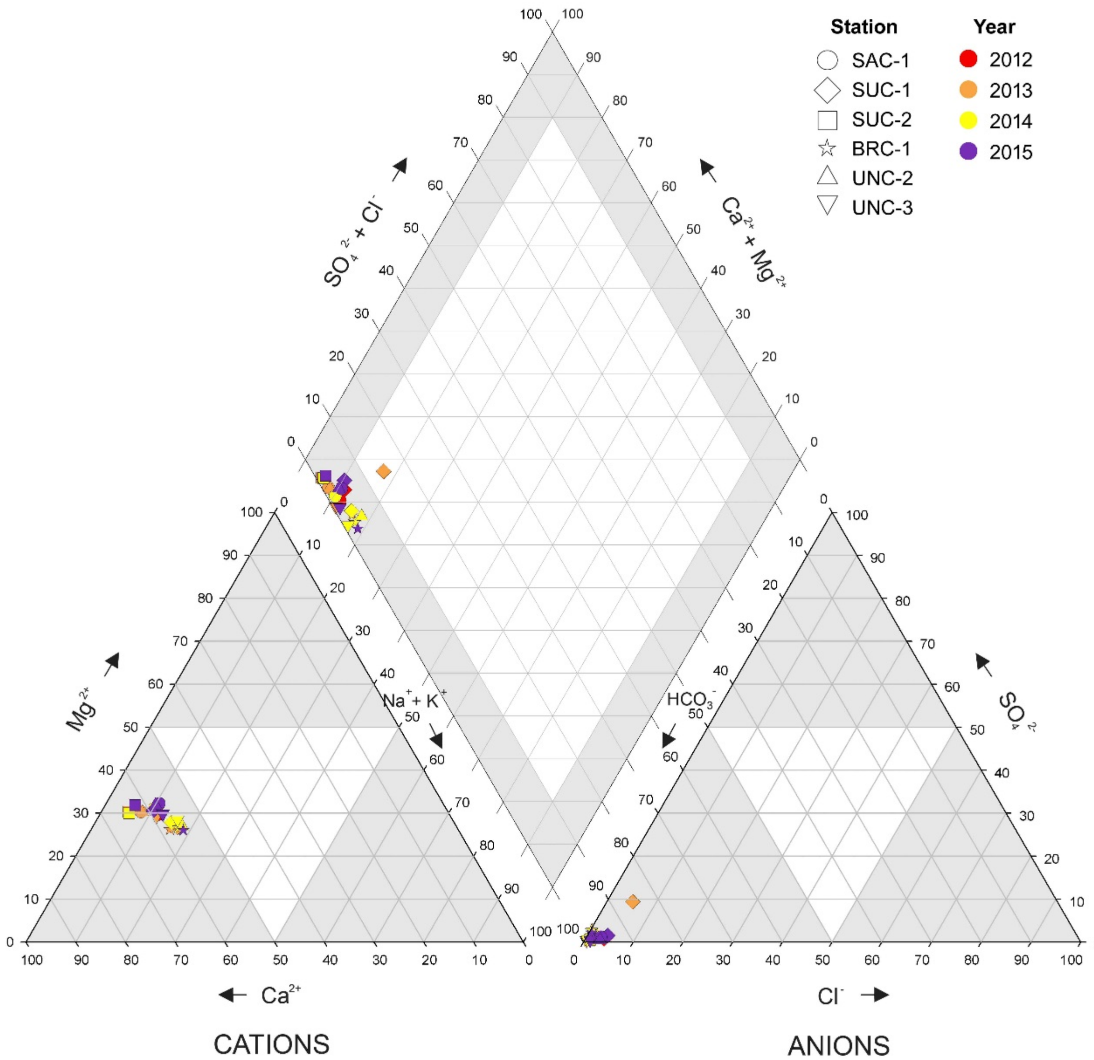


Table 5.10-33 Water quality guideline exceedances in the Christina River watershed, 2015 WY.

Variable	Units	Guideline[a]	November	December	January	February	March	April	May	June	July	August	September	October
Christina River at the mouth (CH1 [CHR-1])														
Total phenols	mg/L	0.004	0.0036	<0.001	<0.001	<0.001	<0.001	-	0.0027	0.0027	0.012	**0.0055**	**0.0082**	**0.0061**
Sulphide	mg/L	0.0019	**0.0041**	<0.0015	<0.0015	<0.0015	<0.0015	-	<0.0019	**0.0097**	**0.0089**	**0.0062**	**0.0023**	**0.0044**
Dissolved iron	mg/L	0.3	**0.708**	**0.68**	**0.391**	0.267	**0.434**	-	**0.44**	0.1	<0.06	0.19	0.16	0.1
Christina River upstream of Janvier (CHR-2)														
Total phenols	mg/L	0.004	0.0019	<0.001	<0.001	**0.0062**	<0.001	-	0.0033	0.002	**0.01**	**0.0057**	**0.008**	**0.0059**
Sulphide	mg/L	0.0019	**0.0022**	<0.0015	<0.0015	<0.0015	<0.0015	-	**0.0041**	<0.0019	**0.0039**	**0.0062**	**0.0031**	<0.0019
Dissolved iron	mg/L	0.3	**0.858**	**0.444**	0.126	0.107	0.102	-	**0.791**	0.0831	0.0369	**0.381**	**0.323**	0.142
Christina River upstream of Jackfish River (CHR-3)														
Total phenols	mg/L	0.004	-	-	-	-	<0.001	-	0.0029	**0.0061**	**0.013**	**0.0079**	**0.011**	**0.0063**
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015	-	**0.0049**	**0.011**	**0.0023**	**0.007**	**0.0054**	**0.0044**
Dissolved iron	mg/L	0.3	-	-	-	-	0.0609	-	**1.38**	**0.755**	0.0236	**0.952**	0.206	0.069
Christina River upstream of development (CHR-4)														
Total phenols	mg/L	0.004	-	-	-	-	<0.001	-	-	-	**0.011**	**0.0098**	**0.011**	**0.0072**
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015	-	-	-	**0.0039**	**0.007**	**0.0054**	<0.0019
Dissolved iron	mg/L	0.3	-	-	-	-	0.139	-	-	-	0.0793	**1.96**	**2.53**	0.106
Birch Creek (BRC-1)														
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015	-	**0.0049**	-	**0.0077**	-	**0.0031**	-
Dissolved iron	mg/L	0.3	-	-	-	-	0.035	-	**0.727**	-	0.19	-	0.0633	-
Gregoire River (GRR-1)														
Total phenols	mg/L	0.004	-	-	-	-	<0.001		**0.0042**	-	**0.013**	-	**0.0098**	-
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015		<0.0019	-	**0.0046**	-	**0.0054**	-
Jackfish River (JAR-1)														
Total phenols	mg/L	0.004	-	-	-	-	<0.001		0.0026	-	**0.011**	-	**0.0077**	-
Sulphide	mg/L	0.0019	-	-	-	-	0.0018		**0.0041**	-	**0.0039**	-	**0.0023**	-
Sawbones Creek (SAC-1)														
Total phenols	mg/L	0.004	-	-	-	-	<0.001		<0.002	-	**0.013**	-	**0.0079**	-
Sulphide	mg/L	0.0019	-	-	-	-	**0.0028**		**0.0049**	-	**0.0049**	-	**0.0031**	-
Dissolved iron	mg/L	0.3	-	-	-	-	**2.74**		0.12	-	0.28	-	0.26	-
Naphthalene	ng/L	1,000	-	-	-	-	**1,140**		<13.55	-	<13.55	-	<13.55	-

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Table 5.10-33 (Cont'd.)

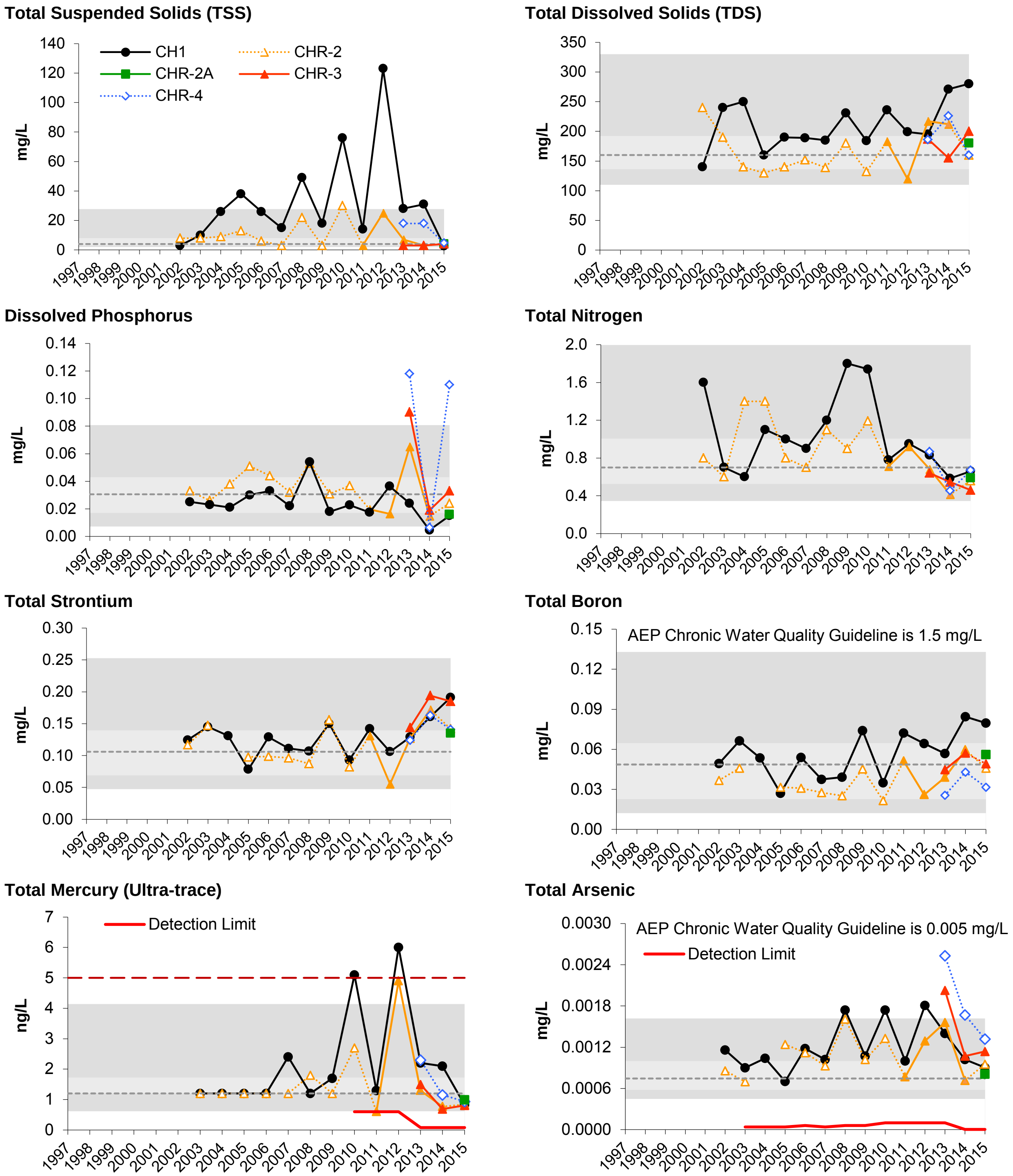
Variable	Units	Guideline[a]	November	December	January	February	March	April	May	June	July	August	September	October
Sunday Creek (SUC-1)														
Total phenols	mg/L	0.004	-	-	-	-	<0.001		0.003	-	**0.013**	-	**0.0095**	-
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015		**0.0024**	-	<0.0019	-	**0.0023**	-
Sunday Creek (SUC-2)														
Total phenols	mg/L	0.004	-	-	-	-	0.0019		**0.0048**	-	**0.012**	-	**0.0078**	-
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015		**0.0032**	-	**0.0041**	-	**0.0031**	-
Unnamed Creek east of Christina Lake (UNC-2)														
Total phenols	mg/L	0.004	-	-	-	-	0.0019		**0.0048**	-	**0.012**	-	**0.0078**	-
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015		**0.0032**	-	**0.0041**	-	**0.0031**	-
Naphthalene	ng/L	1,000	-	-	-	-	**12,800**		13.55	-	13.55	-	32.1	-
Dissolved iron	mg/L	0.3	-	-	-	-	**3.04**		0.17	-	**0.32**	-	0.25	-
Unnamed Creek south of Christina Lake (UNC-3)														
Total phenols	mg/L	0.004	-	-	-	-	0.0019		**0.0046**	-	**0.013**	-	**0.0089**	-
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015		**0.0041**	-	**0.0065**	-	<0.0019	-
Christina Lake (CHL-1)														
Total phenols	mg/L	0.004	-	-	-	-	<0.001		0.0025	-	**0.012**	-	**0.0096**	-
Sulphide	mg/L	0.0019	-	-	-	-	**0.0024**		**0.0049**	-	**0.0031**	-	<0.0019	-
Gregoire Lake (GRL-1)														
Total phenols	mg/L	0.004	-	-	-	-	<0.001	-	<0.002	-	**0.012**	-	**0.011**	-
Sulphide	mg/L	0.0019	-	-	-	-	<0.0015	-	**0.0032**	-	**0.0031**	-	**0.0062**	-
Dissolved iron	mg/L	0.3	-	-	-	-	0.0261	-	0.0291	-	0.0444	-	**0.367**	-

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.10-12 Concentrations of selected water quality measurement endpoints in the Christina River (*test* stations CHR-1, CHR-2A, CHR-2, CHR-3, and *baseline* station CHR-4) (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



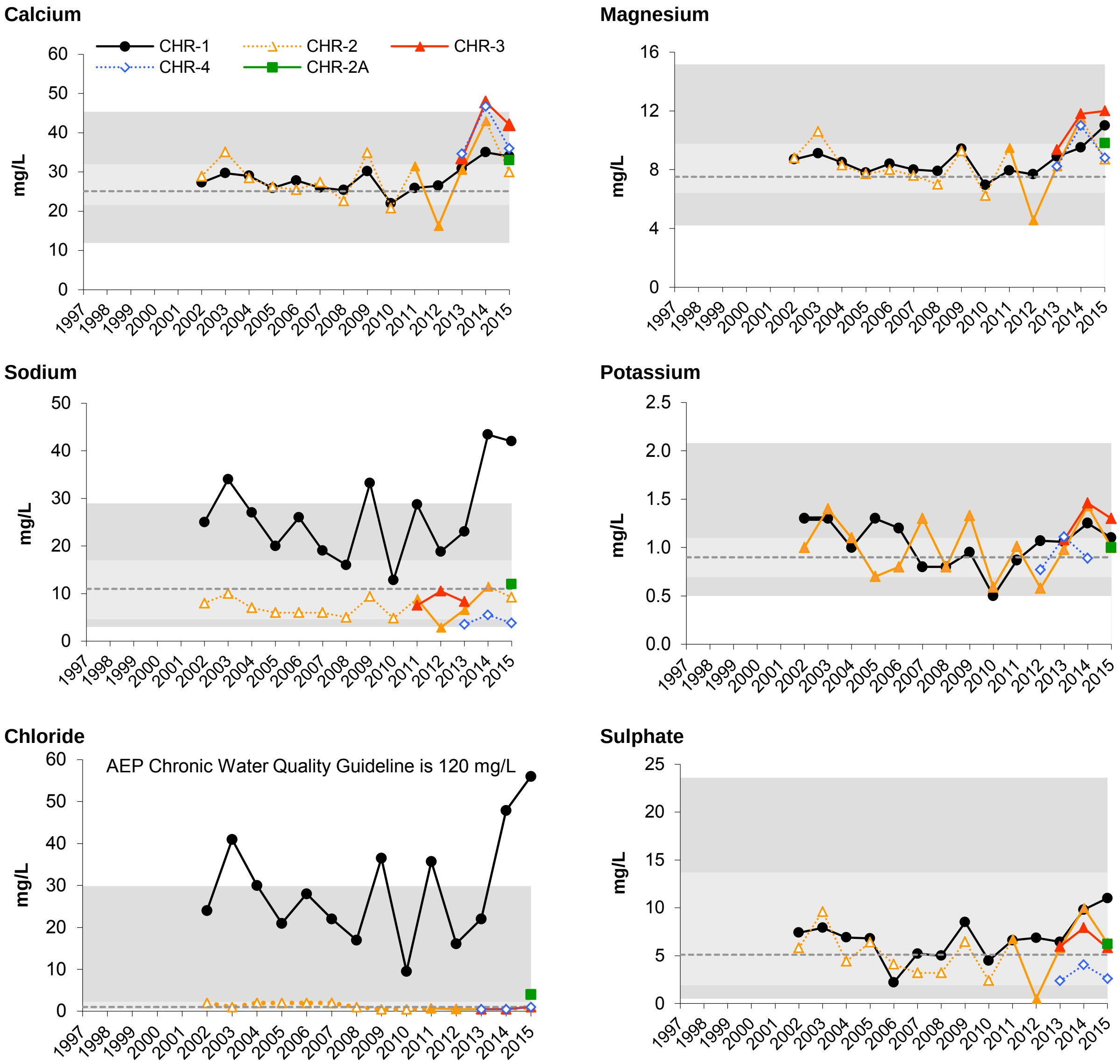
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-12 (Cont'd.)



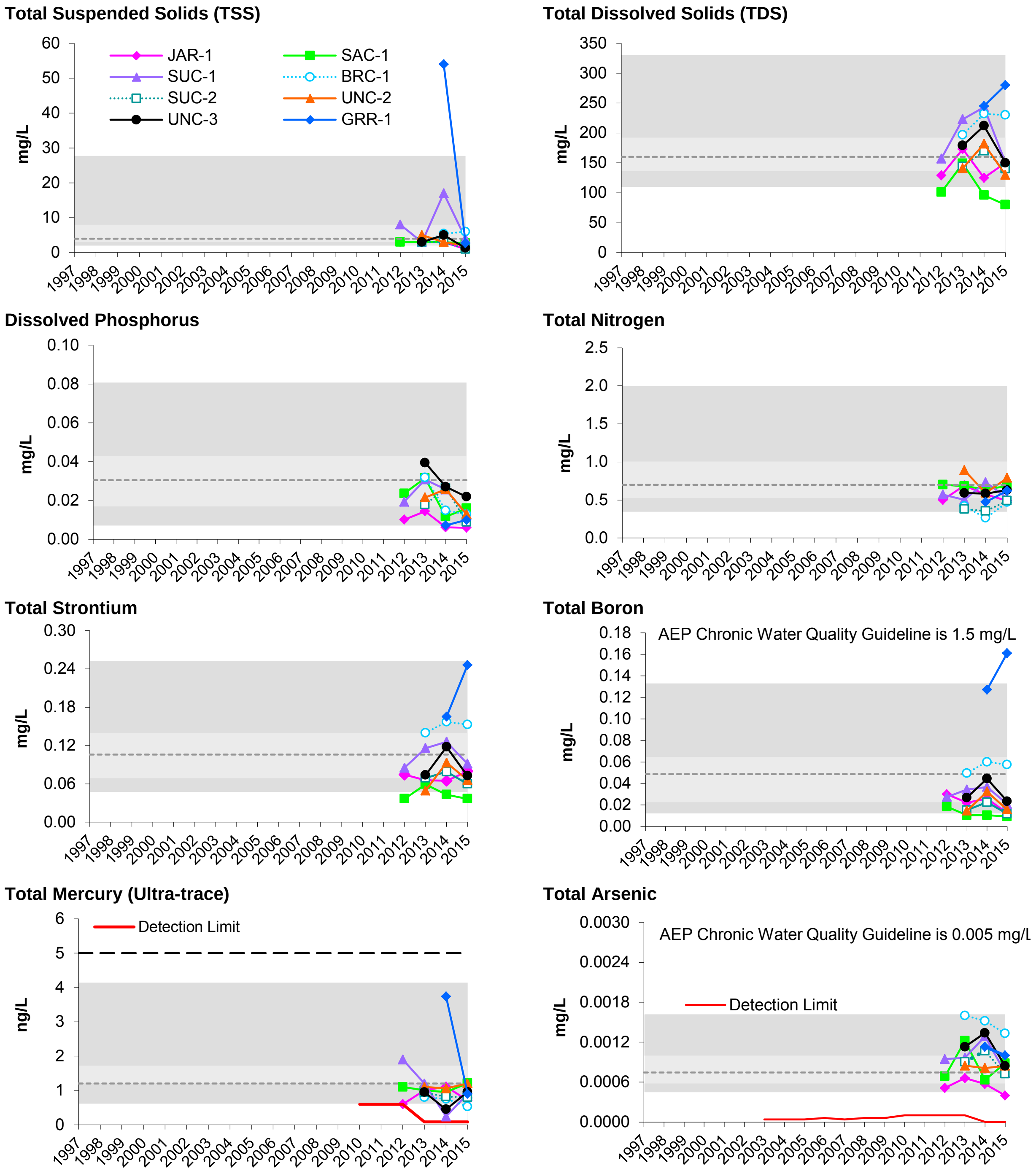
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-13 Concentrations of selected water quality measurement endpoints in the tributary stations (*test* stations JAR-1, SAC-1, SUC-1, UNC-2, UNC-3, and GRR-1, and *baseline* stations BRC-1 and SUC-2) of the Christina River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

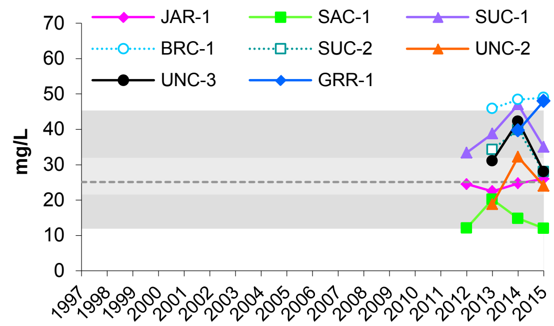
– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

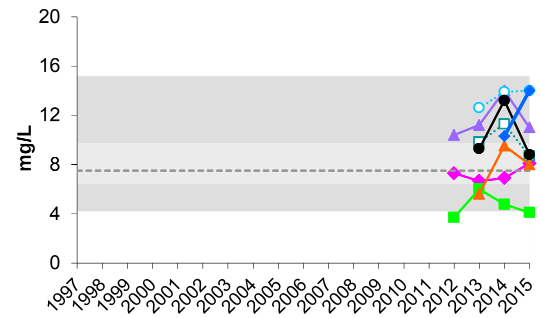
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.10-13 (Cont'd.)

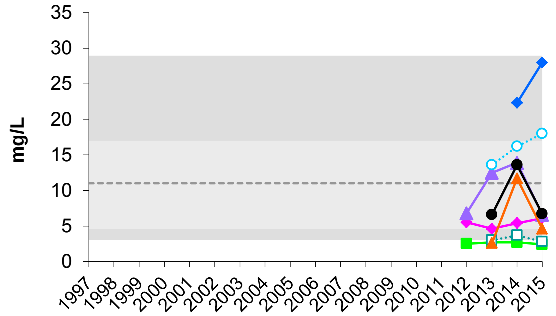
Calcium



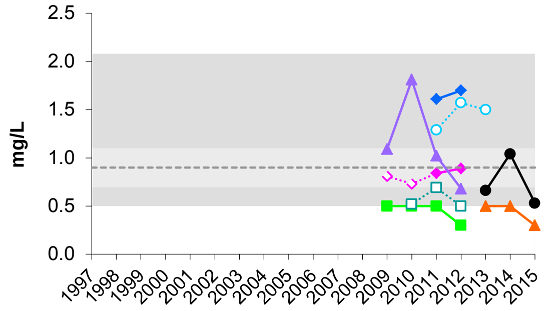
Magnesium



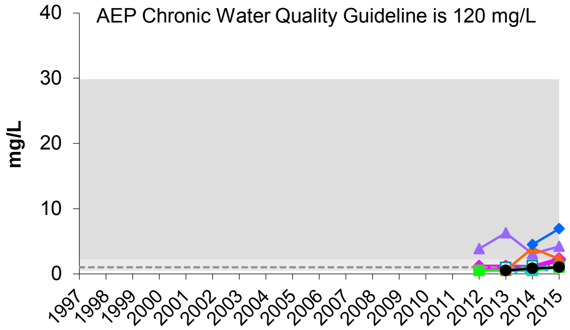
Sodium



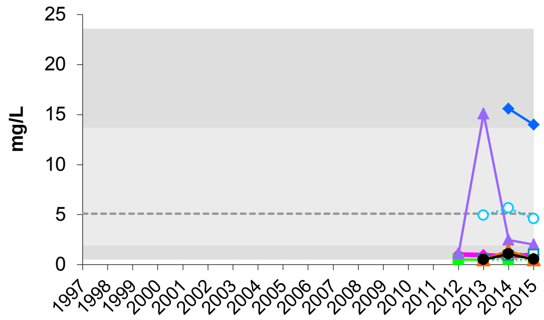
Potassium



Chloride



Sulphate



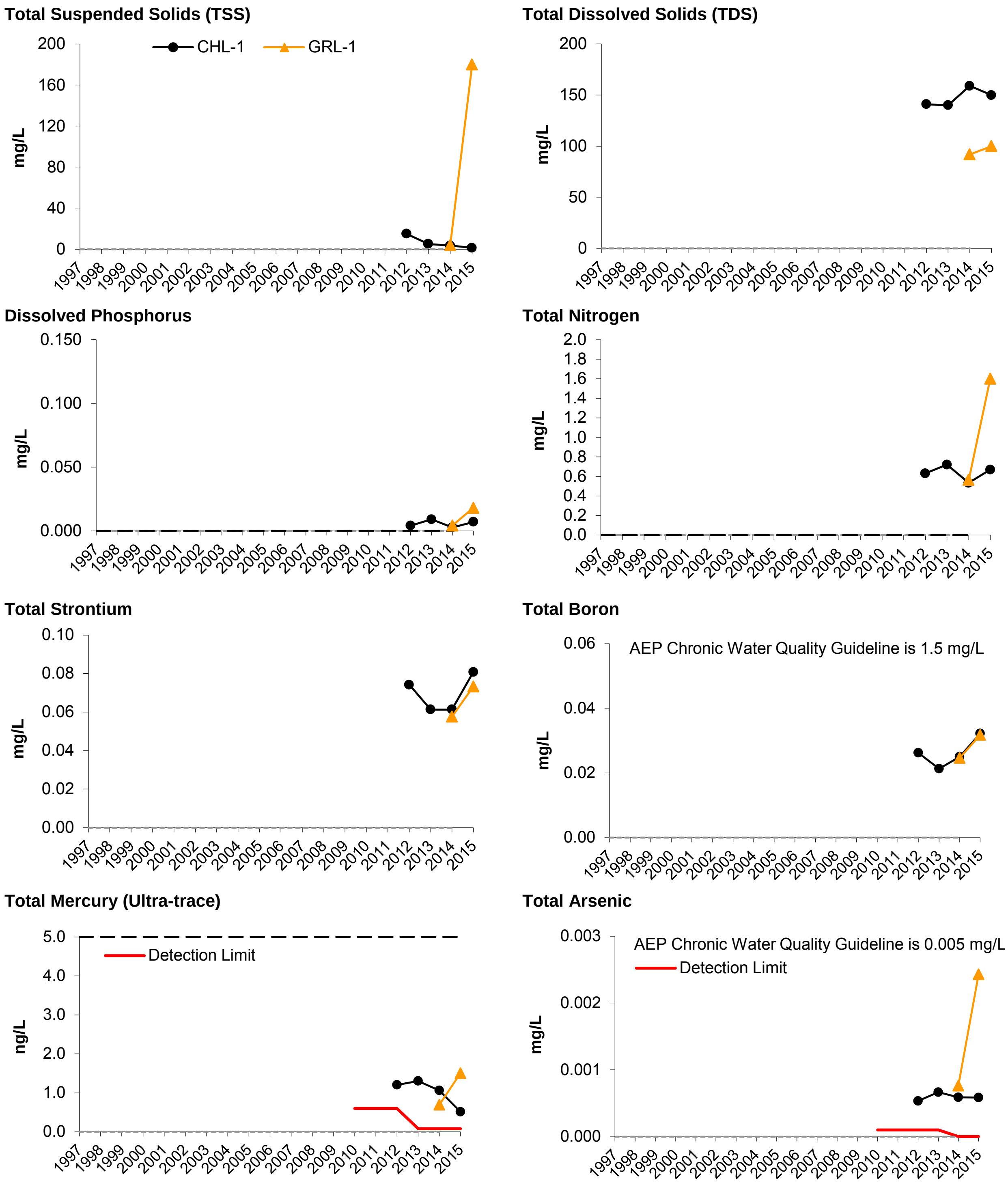
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

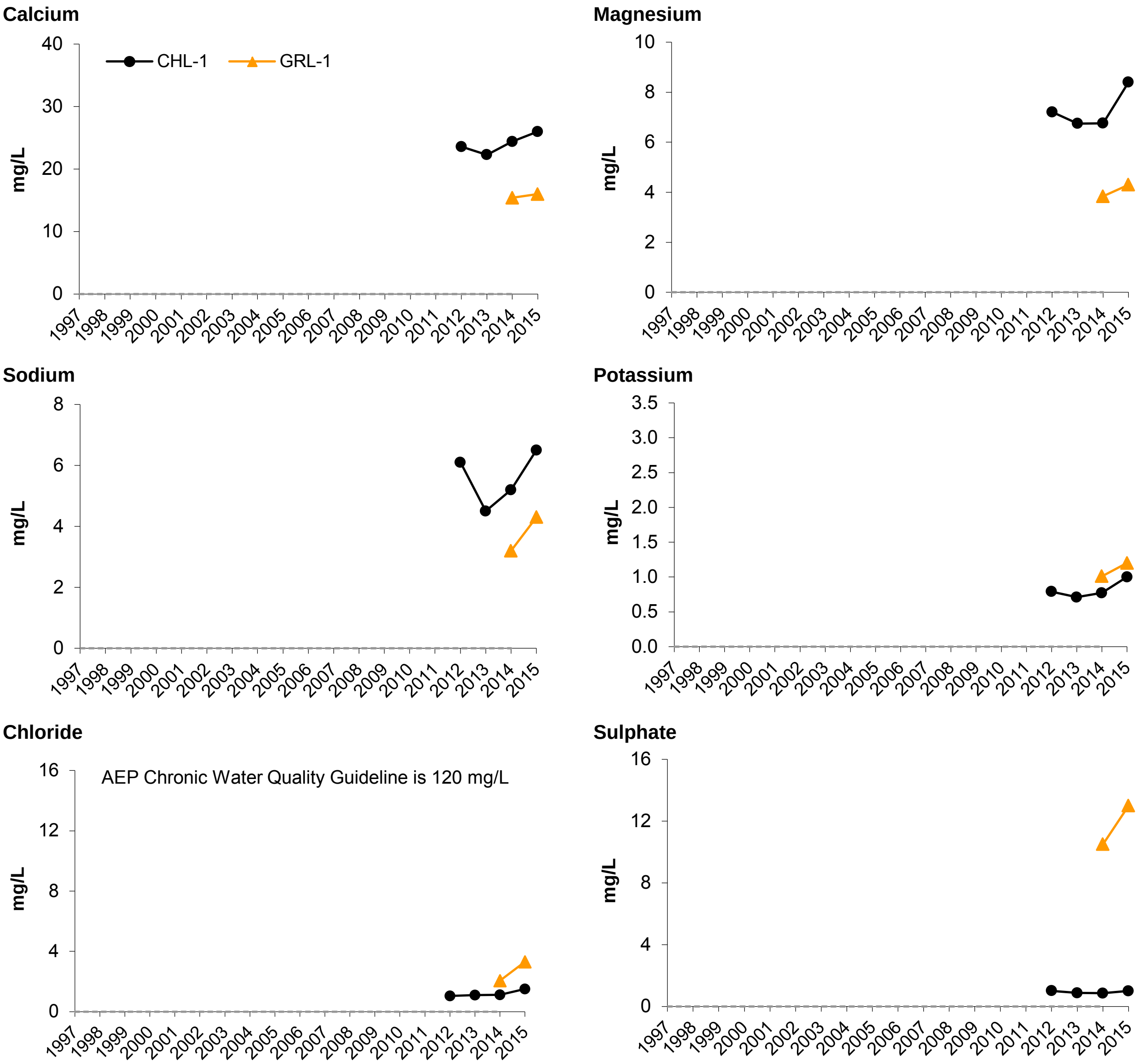
Figure 5.10-14 Concentrations of selected water quality measurement endpoints in Christina Lake (*test* station CHL-1) and Gregoire Lake (*test* station GRL-1) (fall data) relative to historical concentrations.



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Figure 5.10-14 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Table 5.10-34 Average habitat characteristics of benthic invertebrate community sampling locations in the Christina River, fall 2015.

Variable	Units	CHR-D1 Lower *Test* Reach	CHR-D2 Middle *Test* Reach	CHR-E2A Middle *Test* Reach	CHR-D3 Upper *Test* Reach	CHR-D4 Upper *Baseline* Reach
Sample date	-	Sept. 16, 2015	Sept. 18, 2015	Sept. 9, 2015	Sept. 9, 2015	Sept. 9, 2015
Habitat	-	Depositional	Depositional	Erosional	Depositional	Depositional
Water depth	m	0.21	0.47	0.3	0.6	0.4
Current velocity	m/s	1.28	1.32	0.49	0.88	0.35
Field water quality						
Dissolved oxygen (DO)	mg/L	9.5	9.5	10.5	9.0	8.9
Conductivity	µS/cm	467	232	253	288	226
pH	pH units	7.12	8.10	8.46	7.1	7.5
Water temperature	°C	11.6	10.7	12.7	10.8	7.9
Sediment composition						
Sand	%	58.0	99.2	-	94.1	95.9
Silt	%	29.0	0.6	-	4.9	2.9
Clay	%	13.0	0.1	-	0.9	1.1
Total organic carbon (TOC)	%	1.24	0.03	-	0.31	0.52

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.10-35 Summary of major taxa abundances and measurement endpoints for benthic invertebrate communities at the depositional lower *test* reach CHR-D1 and middle *test* reach CHR-D2 of the Christina River.

Taxon	Percent Major Taxa Enumerated in Each Year					
	Lower *Test* Reach CHR-D1			Middle *Test* Reach CHR-D2		
	2002	2003 to 2014	2015	2003	2004 to 2014	2015
Nematoda	1	1 to 8	<1	1	0 to 11	-
Naididae	<1	<1 to 5	2	-	0 to 9	<1
Tubificidae	44	5 to 71	28	23	<1 to 33	<1
Enchytraeidae	-	0 to <1	-	-	0 to 3	-
Lumbriculidae	-	o to <1	-	-	-	-
Erpobdellidae	-	0 to <1	-	-	-	-
Glossiphoniidae	<1	-	-	<1	-	-
Hydracarina	-	0 to <1	-	-	0 to <1	-
Gastropoda	2	0 to 2	1	<1	-	-
Bivalvia	11	0 to 1	1	3	0 to 7	<1
Ceratopogonidae	<1	1 to 8	3	2	0 to 2	<1
Chironomidae	39	15 to 70	61	44	28 to 99	98
Diptera (misc.)	<1	0 to 4	1	<1	0 to 4	-
Coleoptera	-	0 to <1	-	-	0 to <1	-
Ephemeroptera	-	<1 to 1	<1	2	<1 to 6	1
Hemiptera	-	-	<1	-	-	-
Odonata	<1	<1 to 1	<1	<1	0 to <1	-
Plecoptera	<1	<1 to 1	<1	-	0 to 2	<1
Trichoptera	<1	0 to <1	<1	<1	0 to 5	-
Heteroptera	-	0 to <1	-	<1	-	-
Benthic Invertebrate Community Measurement Endpoints						
Total abundance per sample	516	39 to 1024	965	1110	26 to 719	85
Richness	11	7 to 20	18	20	5 to 12	6
Equitability	0.31	0.17 to 0.49	0.25	0.2	0.26 to 0.57	0.52
% EPT	0.5	1 to 6	0.9	2.6	1 to 11	1.4

Table 5.10-36 Summary of major taxa abundances and measurement endpoints for benthic invertebrate communities at the depositional upper *test* reach CHR-D3 and *baseline* reach CHR-D4 of the Christina River.

Taxon	Percent Major Taxa Enumerated in Each Year			
	Upper *Test* Reach CHR-E/D3*		Upper *Baseline* Reach CHR-D4	
	2013 to 2014	2015	2013 to 2014	2015
Nematoda	<1 to 7	1	2 to 3	1
Oligochaeta	<1	-	<1	-
Naididae	1 to 5	3	<1 to 1	1
Tubificidae	<1	2	1 to 6	2
Enchytraeidae	<1 to 1	-	<1	-
Lumbriculidae	-	-	0 to <1	-
Hirudinea	-	<1	<1	<1
Hydracarina	<1 to 1	-	<1 to 5	-
Amphipoda	-	-	-	<1
Gastropoda	0 to <1	-	<1	<1
Bivalvia	<1	1	<1 to 1	1
Ceratopogonidae	1	1	2 to 3	2
Chironomidae	64 to 93	92	79 to 03	90
Diptera (misc)	<1	-	<1	1
Coleoptera	<1 to 1	-	<1	<1
Ephemeroptera	<1 to 8	<1	<1	<1
Odonata	<1	-	-	-
Plecoptera	5	-	0 to <1	<1
Trichoptera	<1 to 6	1	<1	1
Benthic Invertebrate Community Measurement Endpoints				
Total abundance per sample	114 to 440	310	124 to 451	1,618
Richness	10 to 31	14	15	20
Equitability	0.30 to 0.36	0.30	0.19 to 0.37	0.20
% EPT	<1 to 21	0.70	<1 to 1	0.72

* sampled as an erosional habitat in 2013, and as a depositional reach in 2014 and 2015

Table 5.10-37 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate communities at the erosional middle *test* reach CHR-E2A of the Christina River.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Test Reach CHR-E2A	
	2007	2015
Nematoda	1	2
Naididae	9	<1
Tubificidae	1	<1
Enchytraeidae	<1	-
Erpobdellidae	-	-
Hydracarina	2	-
Gastropoda	<1	<1
Bivalvia	3	<1
Ceratopogonidae	<1	<1
Chironomidae	28	57
Dolichopodidae	1	-
Diptera (misc.)	2	<1
Ephydridae	-	-
Coleoptera	3	<1
Anisoptera	1	-
Odonata	-	1
Ephemeroptera	17	28
Plecoptera	3	4
Trichoptera	3	6
Benthic Invertebrate Community Measurement Endpoints		
Total abundance per sample	7,601	1,990
Richness	37	29
Equitability	0.34	0.26
%EPT	23	17.8

Note: All 2015 benthic invertebrate community measurement endpoints, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). All percent abundances of taxa are based on original counts. % EPT as an index in 2015 does not equal the observed percentages in the kick sample, because the index value was adjusted down to be equivalent to what would have been expected with a Neil-Hess cylinder.

Table 5.10-38 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate key measurement endpoints in *test* reach CHR-D1 of the Christina River.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	0.240	**<0.001**	2	33	Abundance was higher in 2015 than the mean of prior years.
Log of Richness	**<0.001**	**<0.001**	34	22	Richness increased over time and was higher in 2015 than the mean of prior years.
Equitability	0.139	**0.019**	13	33	Equitability was lower in 2015 than the mean of prior years.
Log of EPT	0.806	0.192	1	27	No change.
CA Axis 1	**<0.001**	0.209	44	2	CA Axis 1 scores increased over time in the reach.
CA Axis 2	0.741	**0.006**	0	22	CA Axis 2 scores were lower in 2015 than the mean of prior years in the reach.

Bold values indicate significant variation as per the specified contrast ($p < 0.05$). Significance contributes to the classification of results as per Table 3.2-6.

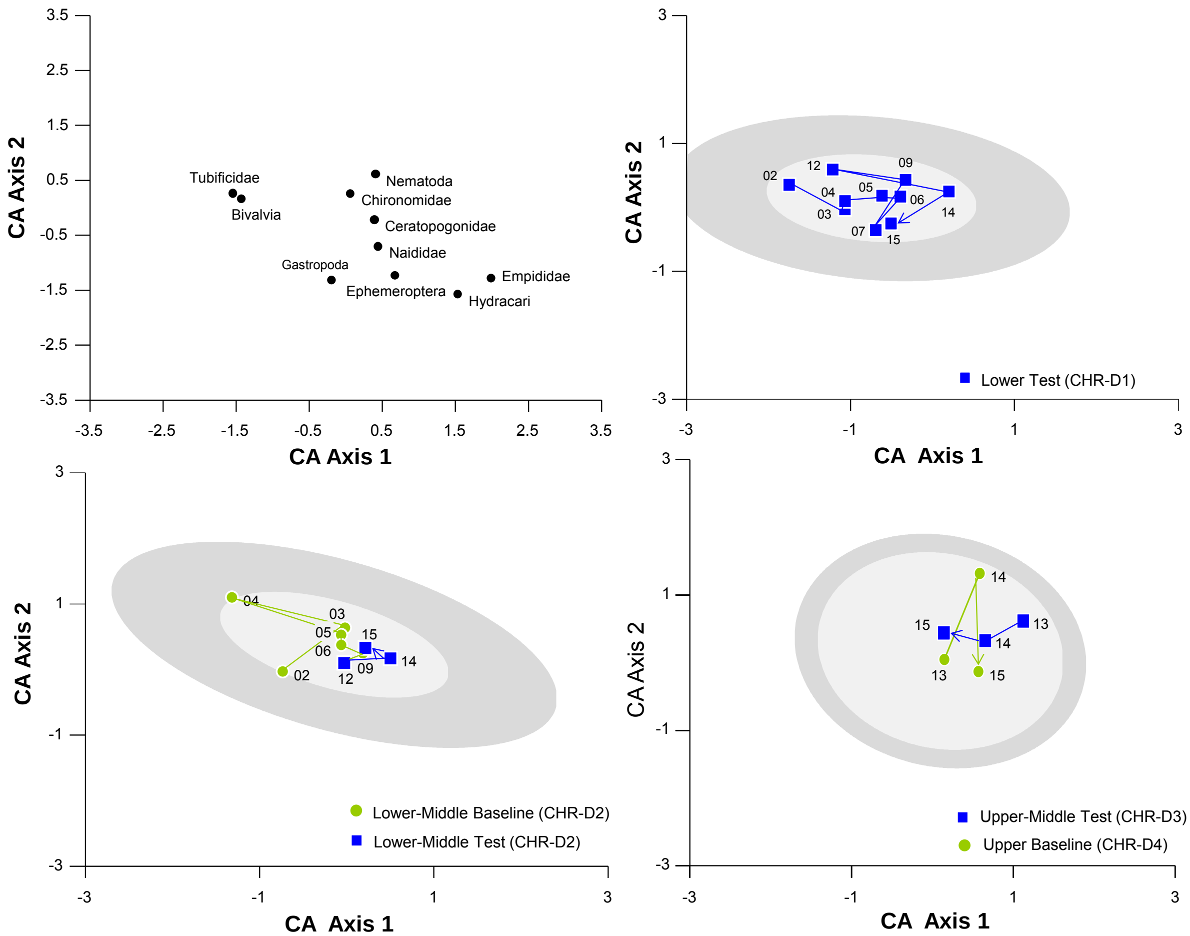
Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.10-15 Ordination (Correspondence Analysis) of depositional reaches, showing the lower *test* reach CHR-D1, middle *test* reach CHR-D2, upper *test* reach CHR-D3, and upper *baseline* reach CHR-D4 of the Christina River.



Notes:

The upper left panel is the scatterplot of taxa scores while the other three panels are scatterplots of sample scores. The ellipses are the inner and outer tolerance limits on the 95th percentile for regional *baseline* depositional reaches.

Sampling at *test* station CHR-D3 was conducted in erosional habitat in 2013 but was shifted to depositional habitat in 2014 and 2015 to be consistent with other reaches of the Christina River.

The 2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances at depositional reaches from previous years (1998 to 2014; Appendix D).

Table 5.10-39 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate key measurement endpoints in *test* reach CHR-D2 of the Christina River.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	**0.001**	0.214	13	2	Abundance decreased over time in the reach.
Log of Richness	**0.044**	0.132	7	4	Richness decreased over time in the reach.
Equitability	**0.023**	0.247	14	3	Equitability increased over time in the reach.
Log of EPT	0.970	0.226	0	8	No change.
CA Axis 1	**<0.001**	0.131	41	5	CA Axis 1 scores increased over time in the reach.
CA Axis 2	0.081	0.770	7	0	No change.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Table 5.10-40 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate key measurement endpoints in *test* reach CHR-D3 of the Christina River.

Measurement Endpoint	2015 vs. 2014			Nature of Change(s)
	P-value	Variance Explained (%)	Effect Size (SDs)	
Log of Abundance	0.055	4.2	0.48	No change.
Log of Richness	0.093	3.1	0.42	No change.
Equitability	0.788	0.1	0.06	No change.
Log of EPT	0.276	1.3	0.26	No change.
CA1	0.064	3.9	0.46	No change.
CA2	0.636	0.2	0.11	No change.

Variance explained in the case of *test* reach CHR-D3 in Christina Rive is “total” variance. Variance explained is normally of annual means. When there are only two years, the annual variance explained by the contrast is 100%. Effect sizes were also expressed as the difference in annual means relative to the pooled within-years standard deviation (SD).

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Notes:

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Table 5.10-41 Results of the t-test for differences in benthic invertebrate key measurement endpoints in *test* reach CHR-E2A of the Christina River.

Measurement Endpoint	2007 *Baseline* Reach (n = 10)		2015 *Test* Reach (n = 3)		P-value	Nature of Difference(s)
	Mean	Variance	Mean	Variance		
Log of Abundance	2.61	0.04	3.28	0.02	**0.002**	Abundance was higher in 2015
Log of Richness	1.54	0.01	1.45	<0.01	**0.028**	Richness was higher in 2007.
Equitability	0.34	<0.01	0.27	0.01	0.124	No difference.
Log of EPT	1.46	0.04	0.97	<0.01	**<0.001**	Percent EPT taxa was higher in 2007
CA1	1.38	0.53	0.99	0.02	0.07	No difference.
CA2	0.82	0.51	0.42	0.82	0.265	No difference.

Bold values indicate significant variation per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

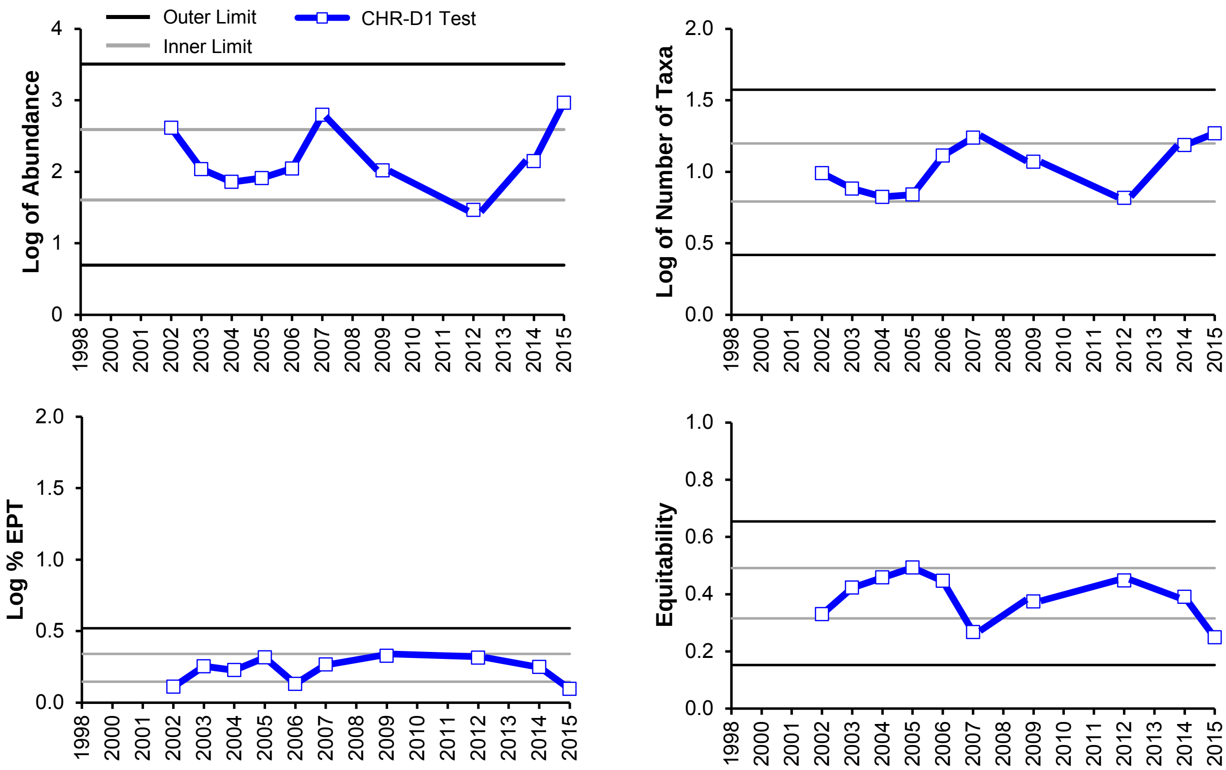
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Notes:

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for erosional reaches from previous years (1998 to 2014; Appendix D).

Measurement endpoints in 2015, with the exception of equitability, are estimates generated with the Neil-Hess to Kicknet relationships (Appendix D).

Figure 5.10-16 Variation in benthic invertebrate community measurement endpoints at *test* reach CHR-D1 in the Christina River relative to the historical ranges of variability.

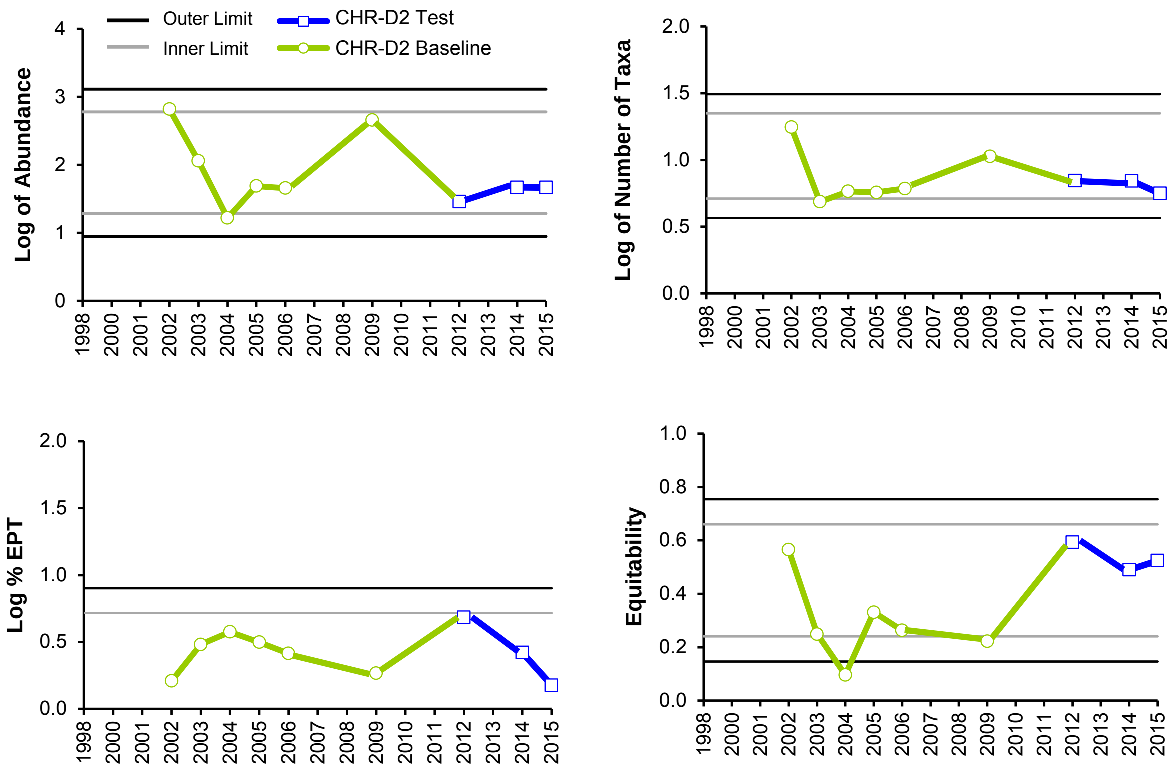


Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from 2002 to 2014 at this reach.

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Figure 5.10-17 Variation in benthic invertebrate community measurement endpoints at *test* reach CHR-D2 in the Christina River relative to the historical ranges of variability.

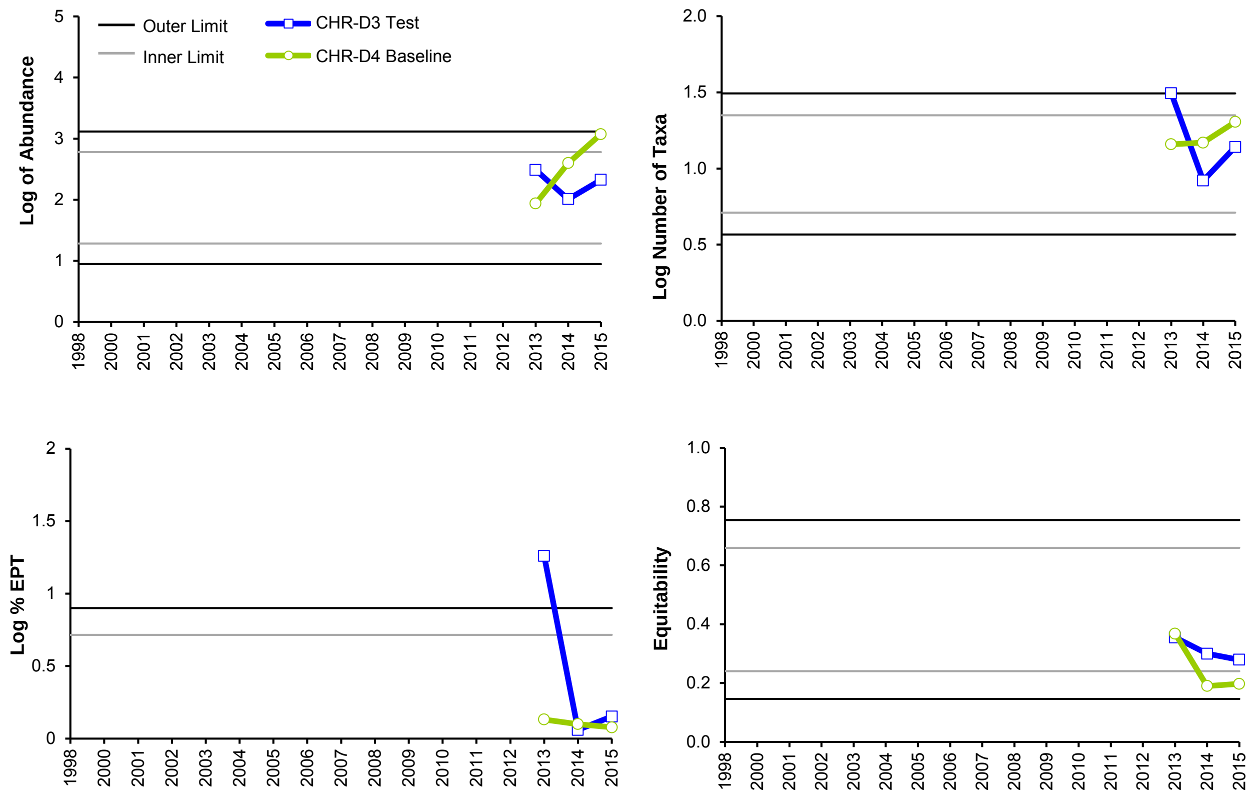


Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from 2002 to 2014 at this reach.

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed before the average was calculated.

Figure 5.10-18 Variation in benthic invertebrate community measurement endpoints at *test* reach CHR-E/D3 and *baseline* reach CHR-D4 in the Christina River relative to the regional *baseline* ranges of variability.

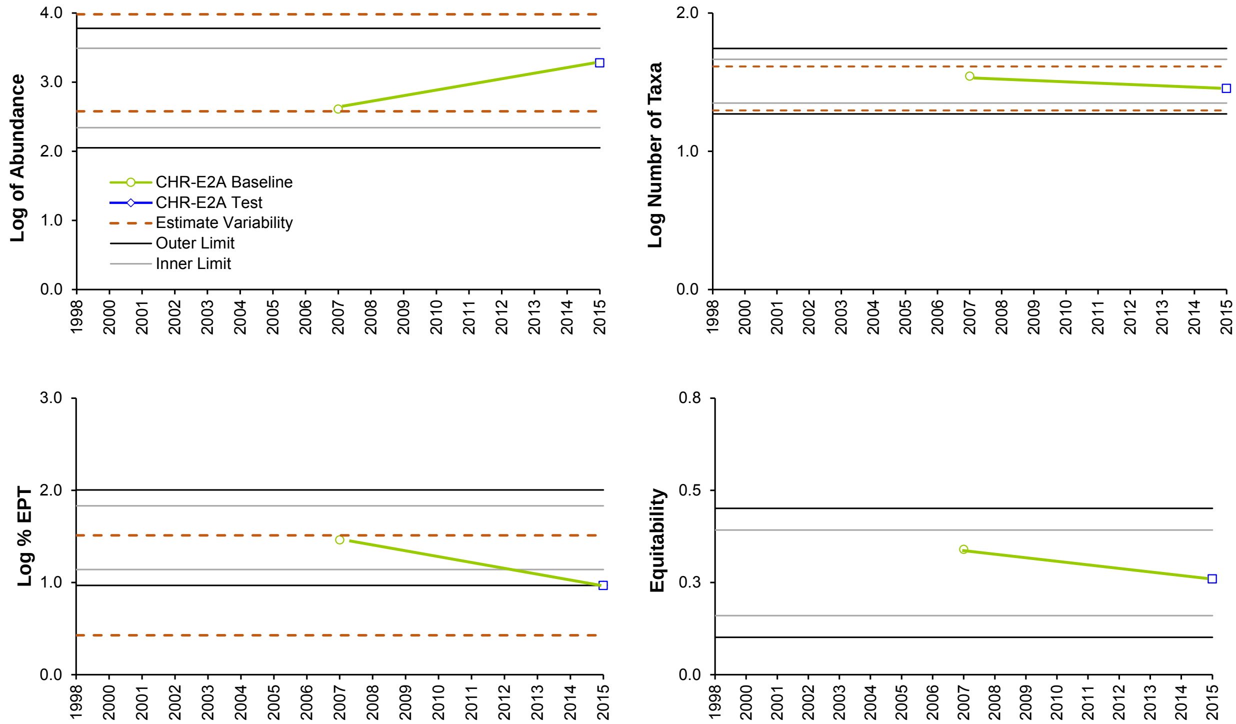


Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* depositional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were log10(x+1) transformed before the average was calculated.

Figure 5.10-19 Variation in benthic invertebrate community measurement endpoints at erosional *test* reach CHR-E2A in the Christina River relative *baseline* reach variability.



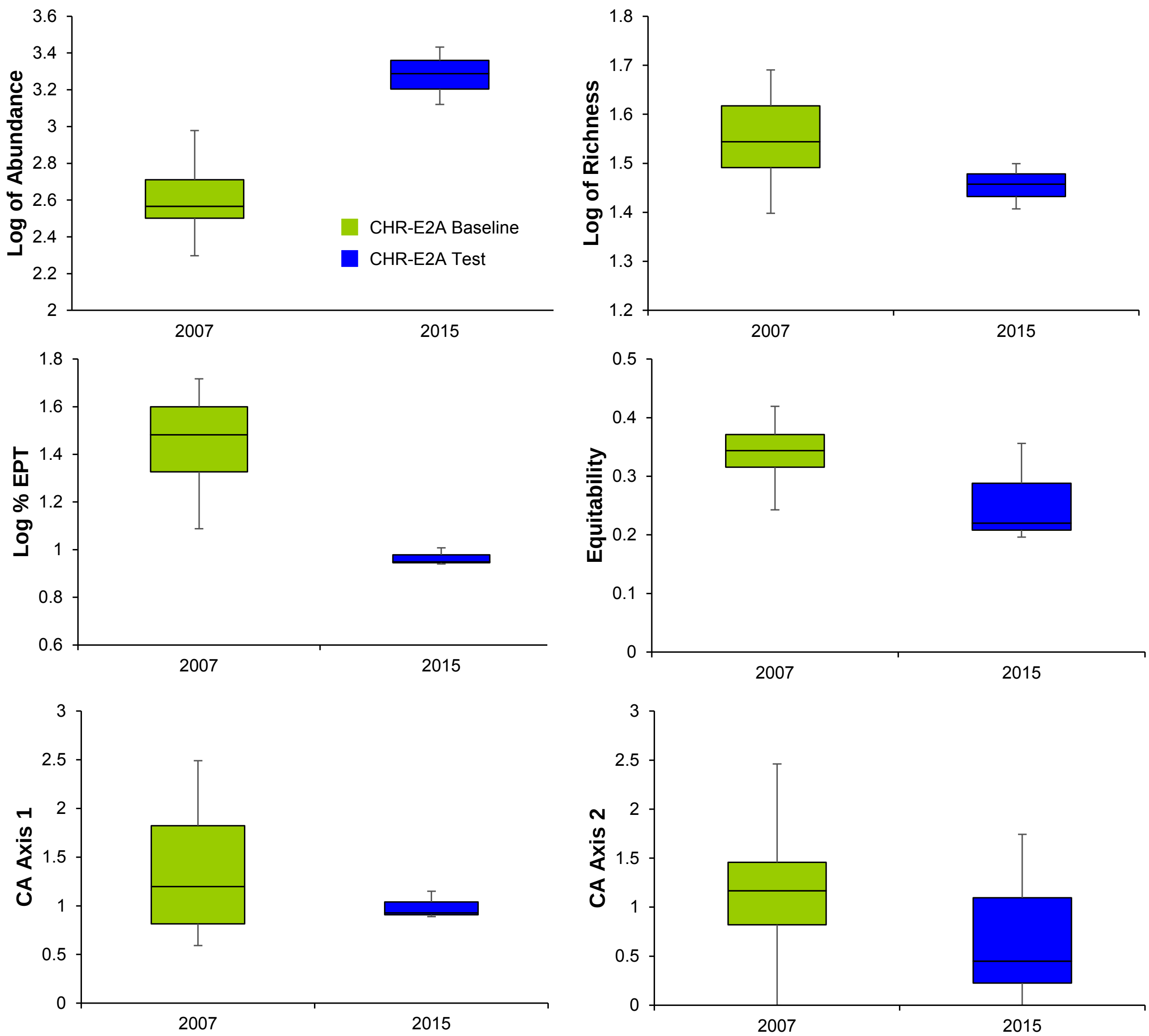
Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed before the average was calculated.

Measurement endpoints for *test* reach CHR-2A in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). The estimate variability represents ± 2SD and was calculated using data from erosional reaches where both Kicknet and Neil-Hess samples were collected (Appendix D).

Figure 5.10-20 Distribution of benthic invertebrate community measurement endpoints at *test* reach CHR-E2A in the Christina River relative to *baseline* reach CHR-E2A.



Notes:

Measurement endpoints for *test* reach CHR-2A in 2015, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.10-42 Average habitat characteristics of benthic invertebrate community sampling locations in Sunday Creek, fall 2015.

Variable	Units	SUC-D1 Lower *Test* Reach	SUC-D2 Upper *Baseline* Reach
Sample date	-	Sept. 14, 2015	Sept. 17, 2015
Habitat	-	Depositional	Depositional
Water depth	m	0.33	0.42
Current velocity	m/s	0.25	0.28
Field water quality			
Dissolved oxygen (DO)	mg/L	9.6	10.0
Conductivity	µS/cm	269	230
pH	pH units	7.2	6.8
Water temperature	°C	11.0	8.5
Sediment composition			
Sand	%	89.6	80.8
Silt	%	7.6	15.9
Clay	%	2.9	3.3
Total organic carbon (TOC)	%	0.69	1.33

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.10-43 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities of Sunday Creek.

Taxon	Percent Major Taxa Enumerated in Each Year				
	Lower *Test* Reach SUC-D1			Upper *Baseline* Reach SUC-D2	
	2012	2013 to 2014	2015	2013 to 2014	2015
Nematoda	<1	3	3	3 to 4	2
Oligochaeta	<1	-	-	0 to <1	-
Naididae	2	1 to 5	4	4 to 6	2
Tubificidae	2	<1 to 1	4	2 to 4	3
Enchytraeidae	-	0 to <1	-	0 to <1	-
Hirudinea	-	-	-	0 to <1	<1
Hydracarina	<1	<1 to 1	-	<1 to 1	-
Amphipoda	-	-	-	0 to <1	<1
Gastropoda	<1	0 to <1	<1	<1 to 1	<1
Bivalvia	2	<1 to 2	6	1 to 3	3
Ceratopogonidae	2	3 to 4	9	4 to 7	1
Chironomidae	80	79 to 87	64	70 to 78	87
Diptera (misc)	7	3 to 5	7	1 to 3	1
Coleoptera	-	-	-	<1	<1
Ephemeroptera	<1	<1 to 2	2	2 to 4	1
Odonata	<1	<1	<1	<1	<1
Plecoptera	-	<1	<1	0 to <1	-
Trichoptera	<1	<1	<1	<1 to 1	<1
Megaloptera	-	-	-		<1
Heteroptera	-	0 to <1	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints					
Total abundance per sample	168	258 to 304	358	454 to 1,429	1,193
Richness	14	16 to 22	16	24 to 26	24
Equitability	0.39	0.30 to 0.30	0.36	0.23 to 0.25	0.19
% EPT	<1	1 to 3	2	3 to 4	0.7

Table 5.10-44 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community endpoints at *test* reach SUC-D1 of Sunday Creek.

Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Control vs. Impact	Time Trend in *Test* Period	2015 vs. *Baseline*	2105 vs. Previous Years	Control vs. Impact	Time Trend in *Test* Period	2015 vs. *Baseline*	2105 vs. Previous Years	
Log of Abundance	**0.014**	0.443	0.064	0.715	24	2	13	1	Abundance was higher in the *baseline* reach.
Log of Richness	**0.002**	0.837	**0.001**	**0.045**	31	0	37	12	Richness was higher in the *baseline* reach and was lower in 2015 than the mean of the *baseline* reach, but higher in 2015 than the mean of previous years in the *test* reach.
Equitability	**0.001**	0.293	0.066	0.985	51	5	15	0	Equitability was higher in the *test* reach.
Log of EPT	0.163	0.090	**0.003**	**0.003**	7	10	32	32	The percentage of taxa as EPT was lower in 2015 than the mean of *baseline* reach and previous years in the *test* reach.
CA Axis 1	**0.011**	**0.033**	**0.007**	**<0.001**	23	16	26	56	CA 1 axis scores were higher in the *test* reach and increased over time in *test* reach. CA 1 axis scores were lower in 2015 in the *test* reach than the mean of *baseline* values and the mean of previous years in the *test* reach.
CA Axis 2	**0.017**	0.275	**<0.001**	**<0.001**	16	3	64	43	CA 2 axis scores increased over time in *test* reach. CA 2 axis scores were higher in 2015 in the *test* reach than the mean of *baseline* values and the mean of previous years in the *test* reach.

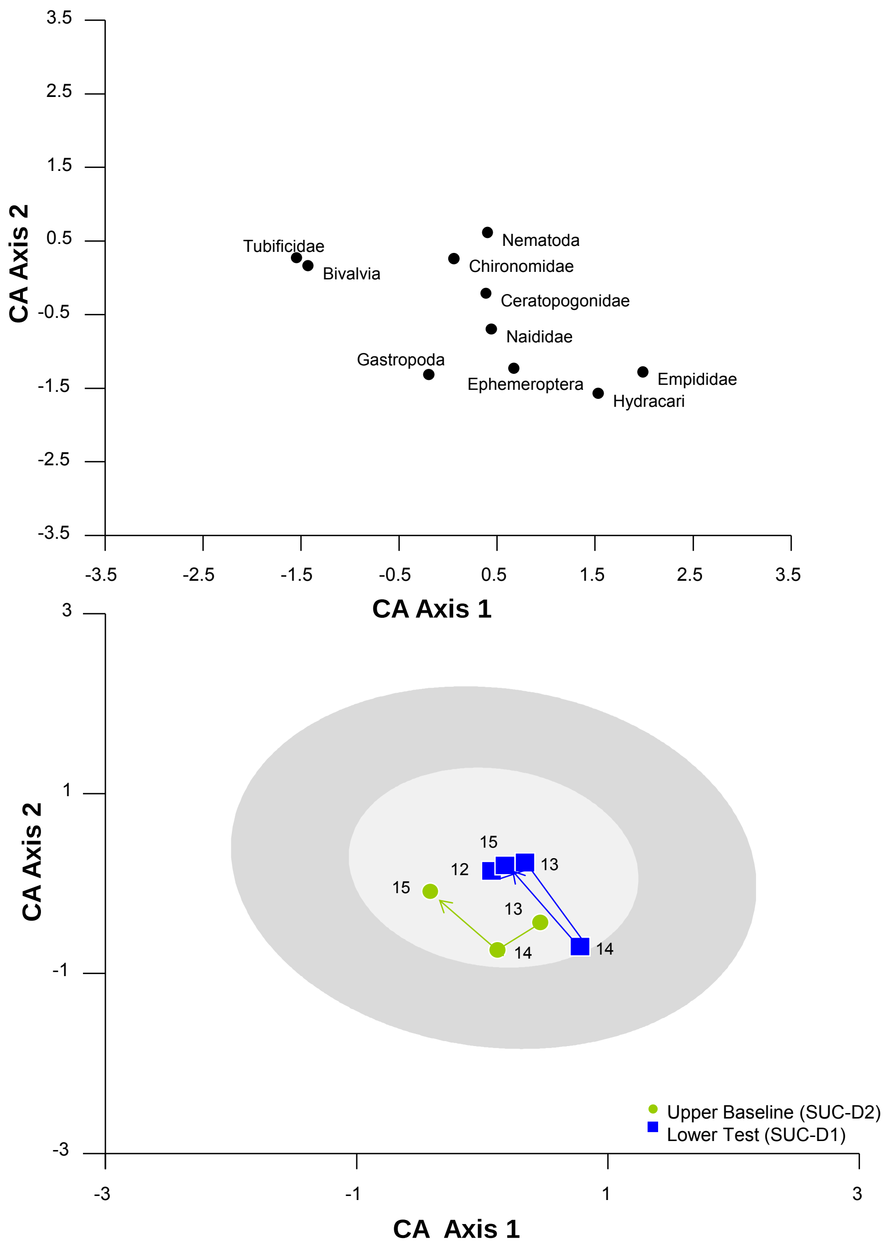
Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Note: 2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.10-21 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing *test* reach SUC-D1 and *baseline* reach SUC-D2.

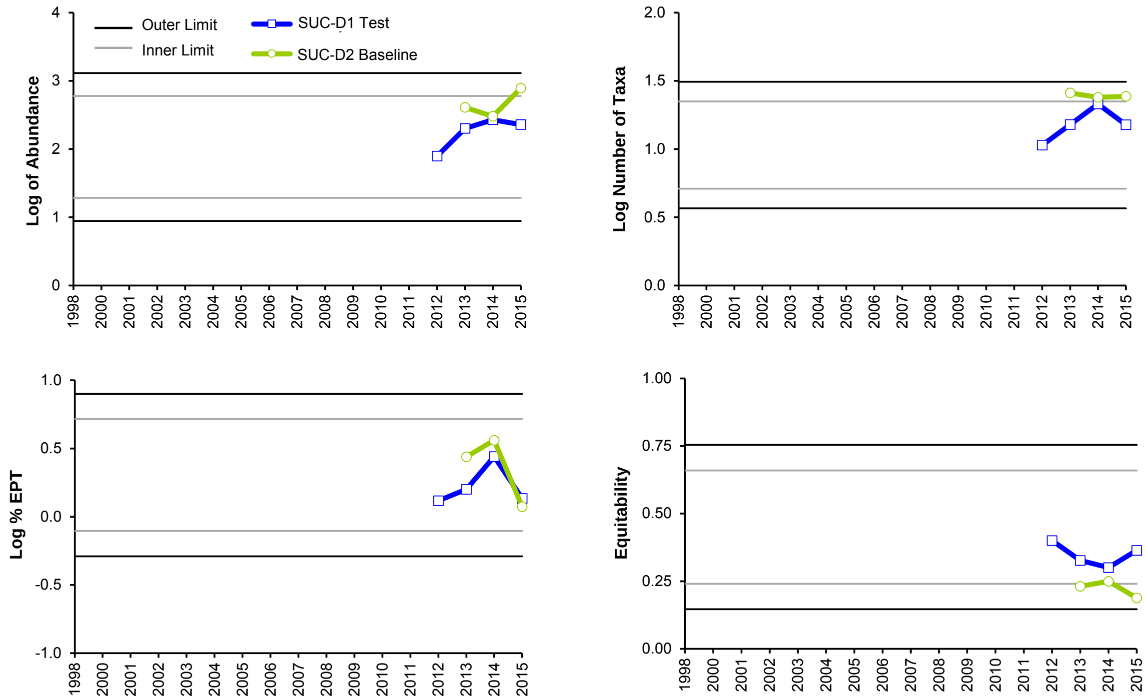


Notes:

The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for depositional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.10-22 Variation in benthic invertebrate community measurement endpoints at *test* reach SUC-D1 and *baseline* reach SUC-D2 of Sunday Creek, relative to regional *baseline* ranges of variation.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* depositional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.10-45 Average habitat characteristics of benthic invertebrate sampling locations in tributaries of Christina Lake, fall 2015.

Variable	Units	SAC-D1 Lower *Test* Reach	UNC-D2 Middle *Test* Reach	UNC-D3 Upper *Test* Reach	BRC-D1 Lower *Baseline* Reach
Sample date	-	Sept. 15, 2015	Sept. 14, 2015	Sept. 15, 2015	Sept. 17, 2015
Habitat	-	Depositional	Depositional	Depositional	Depositional
Water depth	m	1.15	0.61	0.24	0.4
Current velocity	m/s	0.24	0.22	0.22	0.21
Field water quality					
Dissolved oxygen (DO)	mg/L	7.3	8.2	9.0	9.8
Conductivity	µS/cm	117	204	231	388
pH	pH units	6.24	7.0	6.7	6.78
Water temperature	°C	9.1	9.6	10.8	6.2
Sediment composition					
Sand	%	83.7	61.8	95.1	85.6
Silt	%	12.1	31.6	3.7	12.4
Clay	%	4.2	6.6	1.2	2.0
Total organic carbon (TOC)	%	1.9	6.9	0.34	0.59

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.10-46 Summary of major taxon abundances and benthic invertebrate community measurement endpoints at lower *test* reach SAC-D1 in Sawbones Creek.

Taxon	Percent Major Taxa Enumerated in Each Year		
	Lower *Test* Reach SAC-D1		
	2012	2013 to 2014	2015
Hydra	<1	0 to <1	<1
Nematoda	3	4 to 5	1
Naididae	2	1	5
Enchytraeidae	-	<1	-
Tubificidae	2	3 to 5	2
Lumbriculidae	<1	<1	-
Hirudinea	-	-	<1
Erpobdellidae	1	0 to <1	-
Hydracarina	1	1 to 2	-
Amphipoda	<1	<1	<1
Gastropoda	1	<1	1
Bivalvia	1	2	3
Ceratopogonidae	5	7	2
Chironomidae	68	69 to 77	80
Diptera (misc.)	<1	2 to 6	<1
Coleoptera	<1	<1	-
Ephemeroptera	2	1 to 3	4
Odonata	<1	-	<1
Trichoptera	<1	<1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	780	200 to 346	1,127
Richness	31	21 to 22	27
Equitability	0.3	0.3	0.24
% EPT	2	2 to 3	4.5

Table 5.10-47 Summary of major taxon abundances and benthic invertebrate community measurement endpoints at *test* reach UNC-D2 (unnamed creek east of Christina Lake) and *test* reach UNC-D3 (unnamed creek south of Christina Lake).

Taxon	Percent Major Taxa Enumerated in Each Year			
	Test Reach UNC-D2 (east of Christina Lake)		*Test* Reach UNC-D3 (south of Christina Lake)	
	2013 to 2014	2015	2013 to 2014	2015
Hydra	-	-	-	<1
Nematoda	3 to 4	1	1 to 3	2
Naididae	1	5	1 to 7	5
Tubificidae	3 to 5	9	1 to 2	2
Hirudinea	0 to <1	1	<1	<1
Enchytraeidae	<1	-	-	-
Hydracarina	2 to 3	-	<1 to 2	-
Amphipoda	<1 to 1	<1	<1	<1
Gastropoda	0 to <1	<1	<1	1
Bivalvia	1 to 3	3	1	4
Ceratopogonidae	6 to 9	2	2 to 8	6
Chironomidae	77 to 78	74	59 to 75	72
Diptera (misc)	1 to 2	<1	5 to 18	2
Coleoptera	-	<1	0 to <1	<1
Ephemeroptera	<1	1	2 to 5	2
Odonata	-	-	<1	<1
Plecoptera	<1	-	0 to 2	1
Trichoptera	<1 to 1	<1	<1 to 3	1
Benthic Invertebrate Community Measurement Endpoints				
Total abundance per sample	513 to 569	525	150 to 595	522
Richness	19 to 21	16	25 to 26	23
Equitability	0.16 to 0.28	0.39	0.28	0.25
% EPT	1	1	5 to 8	3.5

Table 5.10-48 Summary of major taxon abundances and benthic invertebrate community measurement endpoints at lower *test* reach BRC-D1 in Birch Creek.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Test Reach BRC-D1	
	2013 to 2014	2015
Hydra	-	<1
Nematoda	0 to 8	<1
Naididae	<1 to 2	<1
Tubificidae	<1	1
Enchytraeidae	0 to <1	-
Hydracarina	<1	-
Amphipoda	-	<1
Bivalvia	0 to <1	<1
Ceratopogonidae	<1 to 9	1
Chironomidae	67 to 82	95
Diptera (misc)	13	1
Ephemeroptera	<1 to 2	1
Odonata	<1	-
Plecoptera	<1	-
Trichoptera	0 to 1	<1
Benthic Invertebrate Community Measurement Endpoints		
Total abundance per sample	209 to 739	526
Richness	9	13
Equitability	0.43 to 0.44	0.30
% EPT	1 to 4	1

Table 5.10-49 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach SAC-D1.

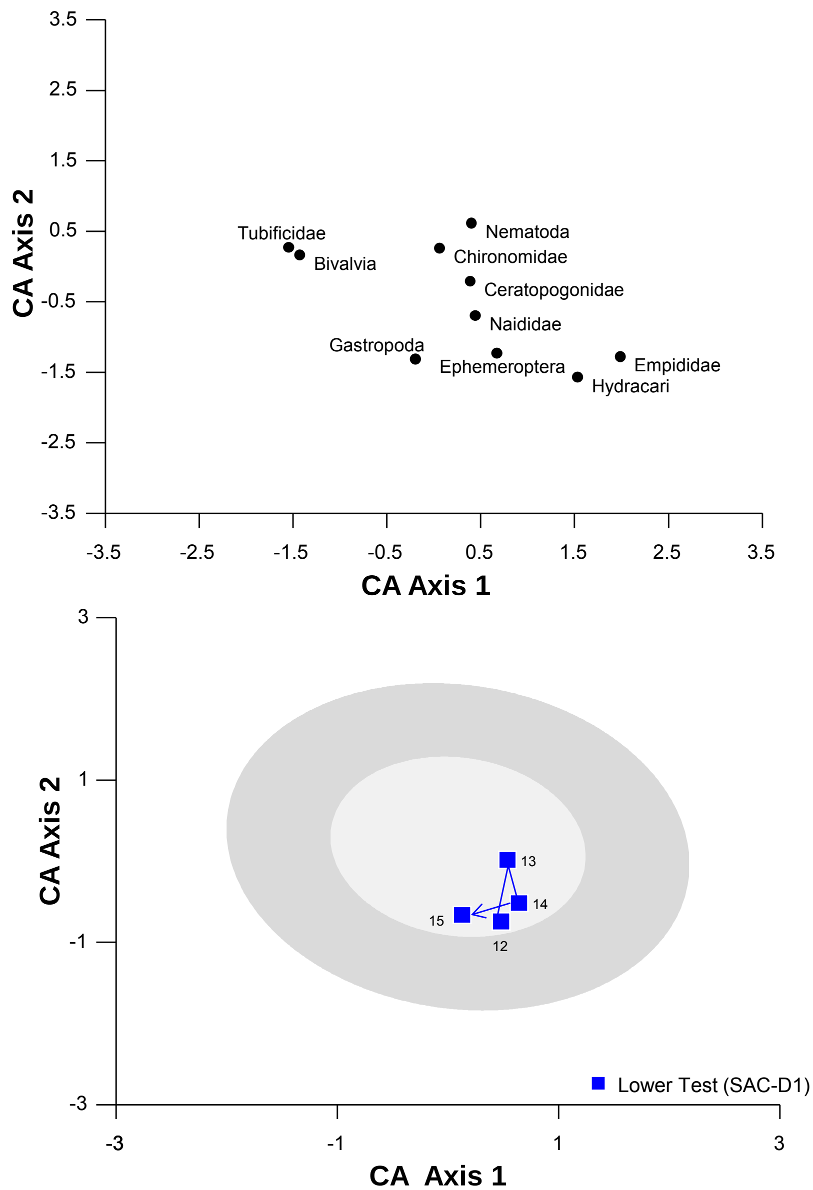
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	**0.003**	**0.004**	50	50	Abundance decreased over time in the reach, but was higher in 2015 than the mean of prior years.
Log of Richness	0.076	0.232	69	30	No change.
Equitability	0.980	0.222	0	100	No change.
Log of EPT	0.776	**0.006**	1	93	Percentage of EPT was lower in 2015 than the mean of prior years.
CA Axis 1	0.579	**0.082**	9	91	CA Axis 1 scores were lower in 2015 than the mean of prior years in the reach.
CA Axis 2	0.452	0.312	7	13	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.10-23 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower *test* reach SAC-D1 of Sawbones Creek.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Table 5.10-50 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach UNC-D2.

Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	0.334	0.175	1	2	No change.
Log of Richness	0.073	0.061	3	4	No change.
Equitability	0.207	**0.032**	2	5	Equitability was higher in 2015 than the mean of prior years.
Log of EPT	0.764	0.426	0	1	No change.
CA Axis 1	0.259	0.244	1	1	No change.
CA Axis 2	0.452	0.312	7	13	No change.

Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.10-51 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at *test* reach UNC-D3.

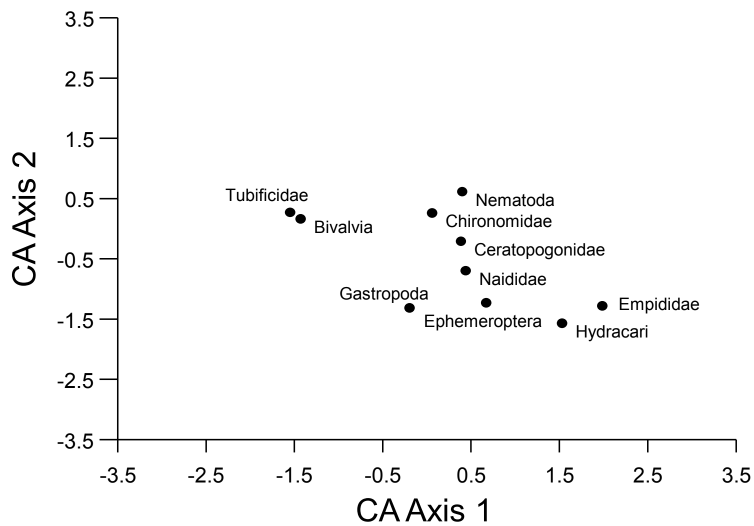
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Time Trend in *Test* Period	2015 vs. Previous Years	Time Trend in *Test* Period	2015 vs. Previous Years	
Log of Abundance	0.848	**0.012**	0	7	Abundance was higher in 2015 than the mean of prior years.
Log of Richness	0.514	0.636	0	0	No change.
Equitability	0.533	0.505	0	0	No change.
Log of EPT	**0.001**	**<0.001**	14	18	Percentage EPT taxa decreased over time and was lower in 2015 than the mean of prior years.
CA Axis 1	0.502	0.677	0	0	No change.
CA Axis 2	**0.018**	0.693	6	0	CA Axis 2 scores decreased over time in the reach

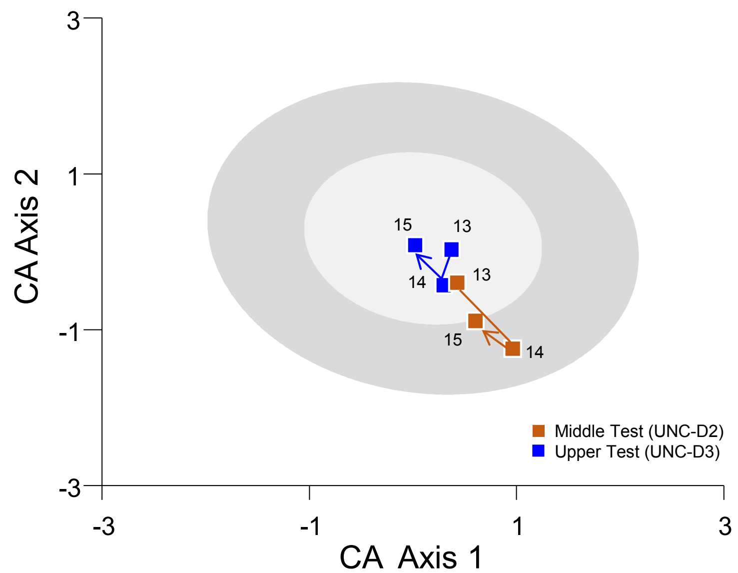
Bold values indicate significant difference ($p<0.05$).

Shading denotes significant differences >20% variance, which is considered a strong signal in the spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-6).

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

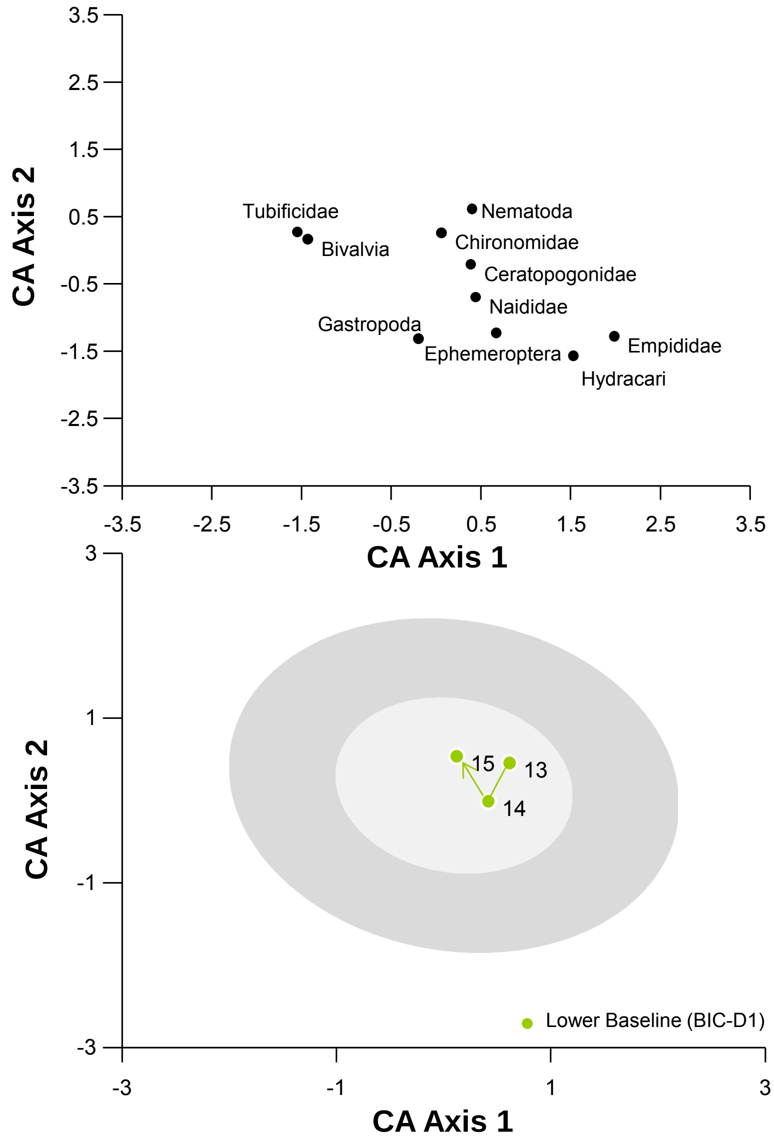
Figure 5.10-24 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the *test* reach UNC-D2 (unnamed creek east of Christina Lake) and *test* reach UNC-D3 (unnamed creek south of Christina Lake).





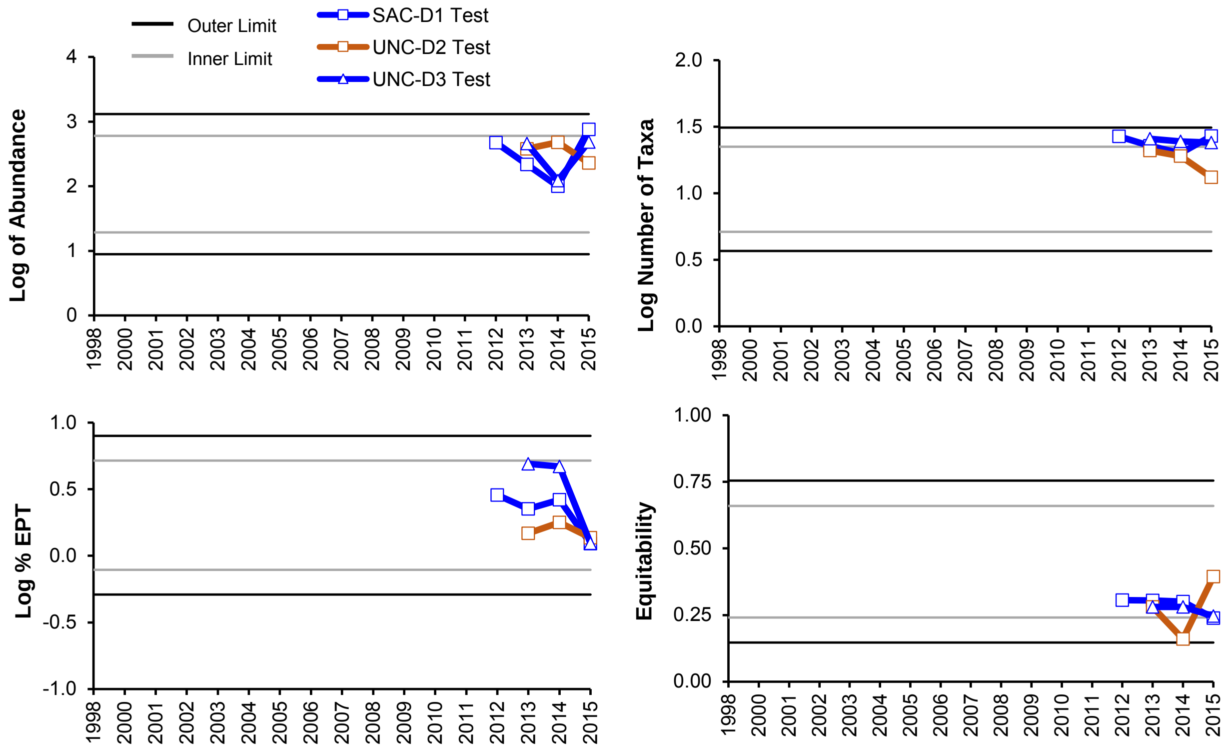
Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Figure 5.10-25 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the *baseline* reach BIC-D1.



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the 5th and 95th percentiles for regional *baseline* depositional reaches.

Figure 5.10-26 Variation in benthic invertebrate community measurement endpoints at *test* reach SAC-D1 of Sawbones Creek, and *test* reaches UNC-D2 and UNC-D3 of Unnamed Creek, relative to regional *baseline* ranges of variability.

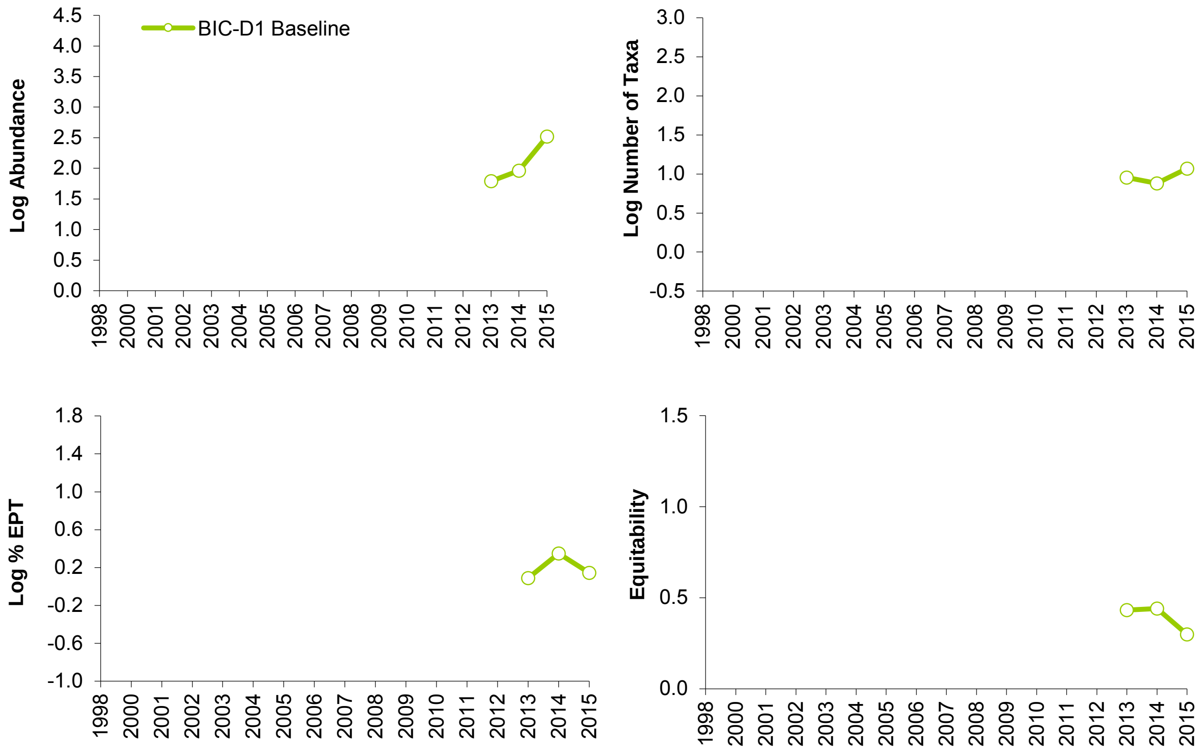


Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Figure 5.10-27 Variation in benthic invertebrate community measurement endpoints at *baseline* reach BIC-D1 of Birch Creek.



Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.10-52 Average habitat characteristics of the benthic invertebrate sampling location in the Jackfish River (*test* reach JAR-E1) and Gregoire River (*test* reach GRR-E1), fall 2015.

Variable	Units	JAR-E1 Lower *Test* Reach	GRR-E1 Lower *Test* Reach
Sample date	-	Sept. 11, 2015	Sept. 9, 2015
Habitat	-	Erosional	Erosional
Water depth	m	0.2	0.2
Current velocity	m/s	0.6	0.3
Field water quality			
Dissolved oxygen (DO)	mg/L	8.0	9.8
Conductivity	µS/cm	178	368
pH	pH units	8.1	8.6
Water temperature	°C	14.3	8.4

Table 5.10-53 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in Jackfish River (*test* reach JAR-E1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach JAR-E1		
	2012	2013 to 2014	2015
Nematoda	1	2 to 5	1
Naididae	2	3 to 4	1
Tubificidae	<1	<1 to 1	-
Enchytraeidae	<1	1	-
Lumbriculidae	<1	-	-
Erpobdellidae	<1	-	-
Hydracarina	11	8 to 9	1
Amphipoda	<1	<1	<1
Gastropoda	1	<1 to 1	1
Bivalvia	<1	<1 to 1	<1
Ceratopogonidae	<1	0 to <1	<1
Chironomidae	23	19 to 33	11
Diptera (misc.)	2	2 to 4	11
Coleoptera	<1	1 to 2	6
Ephemeroptera	29	29 to 39	45
Odonata	<1	<1 to 1	1
Plecoptera	<1	<1 to 1	1
Trichoptera	19	11 to 22	19
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	3,823	4,448 to 6,299	1,670
Richness	38	39 to 43	31
Equitability	0.28	0.27 to 0.28	0.24
% EPT	48	42 to 62	28

Note: All 2015 benthic invertebrate community measurement endpoints, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). All percent abundances of taxa are based on original counts. % EPT as an index in 2015 does not equal the observed percentages in the kick sample, because the index value was adjusted down to be equivalent to what would have been expected with a Neil-Hess cylinder.

Table 5.10-54 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in the Gregoire River (*test* reach GRR-E1).

Taxon	Percent Major Taxa Enumerated in Each Year	
	Test Reach GRR-E-1	
	2014	2015
Nematoda	<1	<1
Naididae	44	3
Hydracarina	1	6
Ceratopogonidae	-	<1
Chironomidae	36	35
Diptera (misc)	1	7
Coleoptera	-	<1
Ephemeroptera	12	23
Odonata	<1	<1
Plecoptera	1	6
Trichoptera	5	20
Benthic Invertebrate Community Measurement Endpoints		
Total abundance per sample	2,275	3,235
Richness	29	31
Equitability	0.13	0.32
% EPT	18	22

Note: All 2015 benthic invertebrate community measurement endpoints, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). All percent abundances of taxa are based on original counts. % EPT as an index in 2015 does not equal the observed percentages in the kick sample, because the index value was adjusted down to be equivalent to what would have been expected with a Neil-Hess cylinder.

Table 5.10-55 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community endpoints in the lower Jackfish River (*test* reach JAR-E1).

Measurement Endpoint	2015 vs. Prior Years		Nature of Change(s)
	P-value	Variance Explained (%)	
Log of Abundance	0.075	48	No change.
Log of Richness	**0.002**	52	Richness was lower in 2015 than the mean of prior years.
Equitability	0.361	80	No change.
Log of EPT	**<0.001**	76	EPT taxa was lower in 2015 than the mean of prior years.
CA1	**0.004**	98	CA Axis 1 scores were lower in 2015 than the mean of prior years.
CA2	0.13	45	No change.

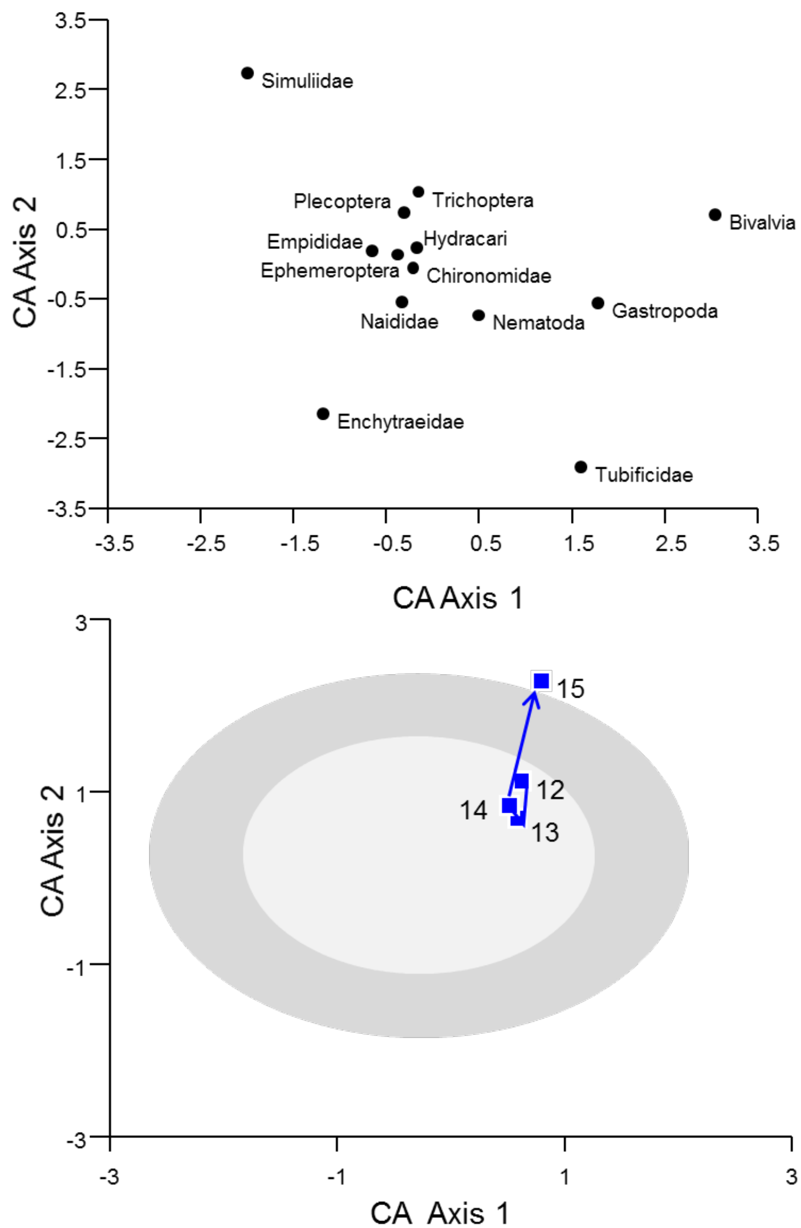
Bold values indicate significant variation per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for >20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Note: 2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for erosional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.10-28 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the lower reach of the Jackfish River (*test* reach JAR-E1).



Notes:

The upper left panel is the scatterplot of taxa scores while the other three panels are scatterplots of sample scores. The ellipses are the inner and outer tolerance limits on the 95th percentile for regional *baseline* erosional reaches.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances at erosional reaches from previous years (1998 to 2014; Appendix D).

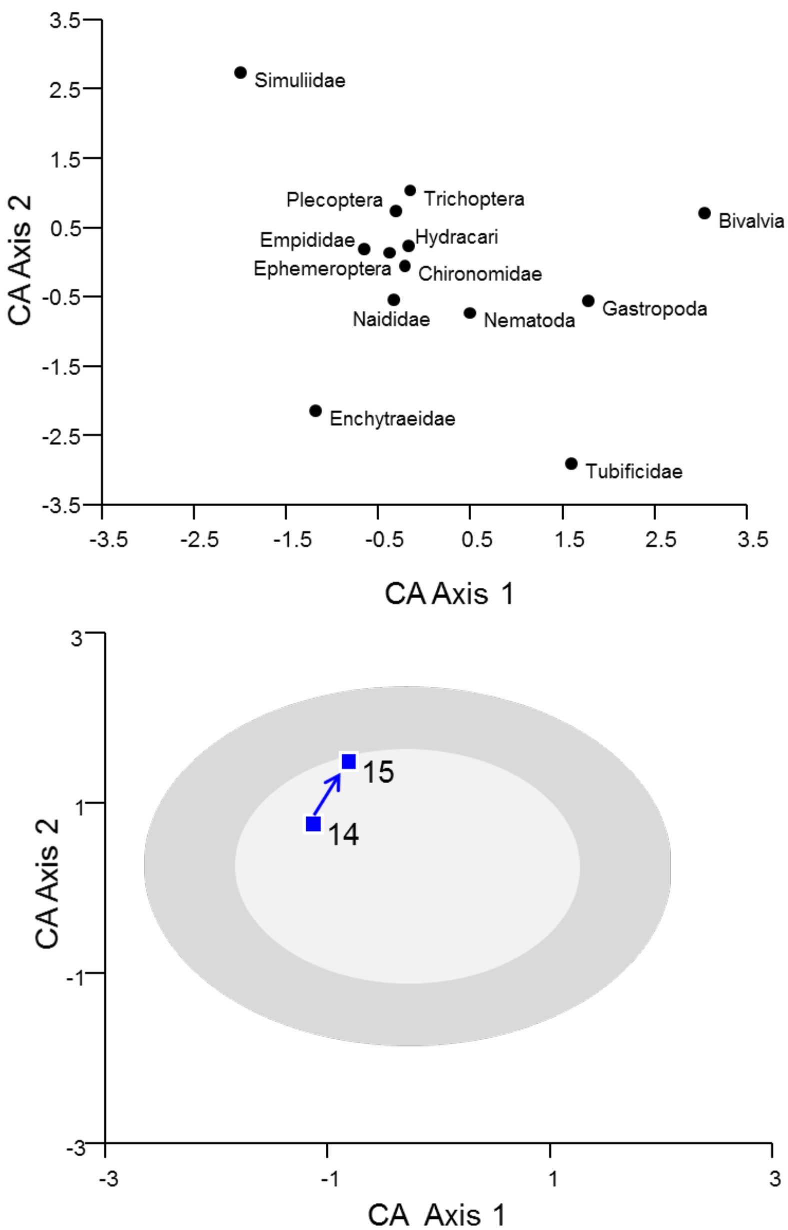
Table 5.10-56 Results of the t-tests for differences in benthic invertebrate community endpoints in the lower Gregoire River (*test* reach GRR-E1).

Measurement Endpoint	2014		2015		P-value	Nature of Difference(s)
	Mean	Variance	Mean	Variance		
Log of Abundance	3.16	0.29	3.5	<0.01	**0.04**	Abundance was higher in 2015 than the mean of prior years.
Log of Richness	1.47	<0.01	1.49	<0.01	0.18	No difference.
Equitability	0.13	<0.01	0.32	<0.01	**<0.001**	Equitability was higher in 2015 than the mean of prior years.
Log of EPT	1.24	0.04	1.33	<0.01	0.09	No difference.
CA1	-1.13	0.06	-0.98	0.07	0.22	No difference.
CA2	0.76	0.12	0.57	0.03	0.13	No difference.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results as per Table 3.2-6.

Note: Measurement endpoints for *test* reach GRR-E1 in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Figure 5.10-29 Ordination (Correspondence Analysis) of benthic invertebrate communities of erosional reaches, showing the lower reach of the Gregoire River (*test* reach GRR-E1).

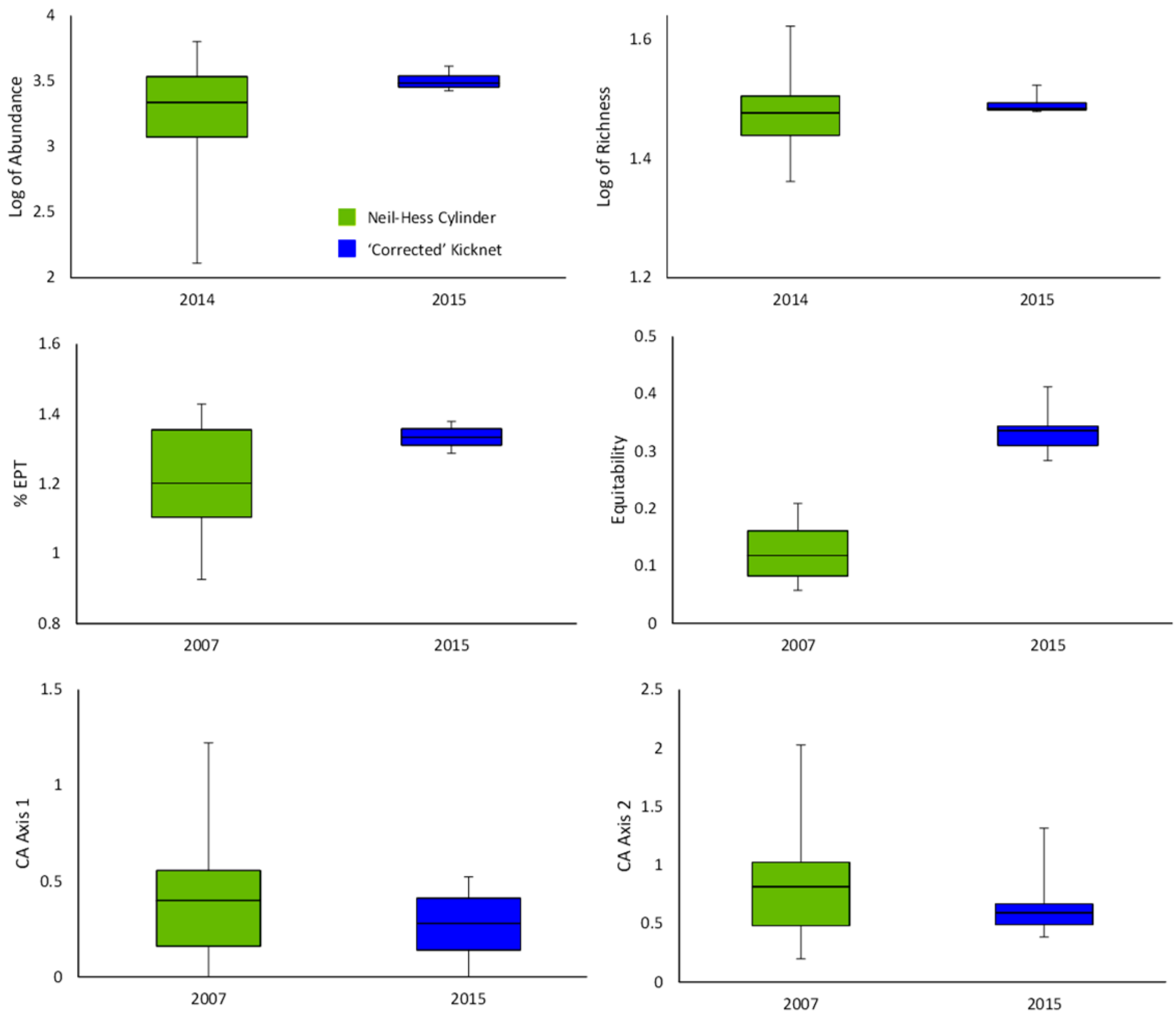


Notes:

The upper panel is the scatterplot of taxa scores while the lower panels is scatterplot of sample scores. The ellipses are the inner and outer tolerance limits on the 95th percentile for regional *baseline* erosional reaches.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances at erosional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.10-30 Distribution of benthic invertebrate community measurement endpoints at *test* reach GRR-E1 in the Gregoire River.



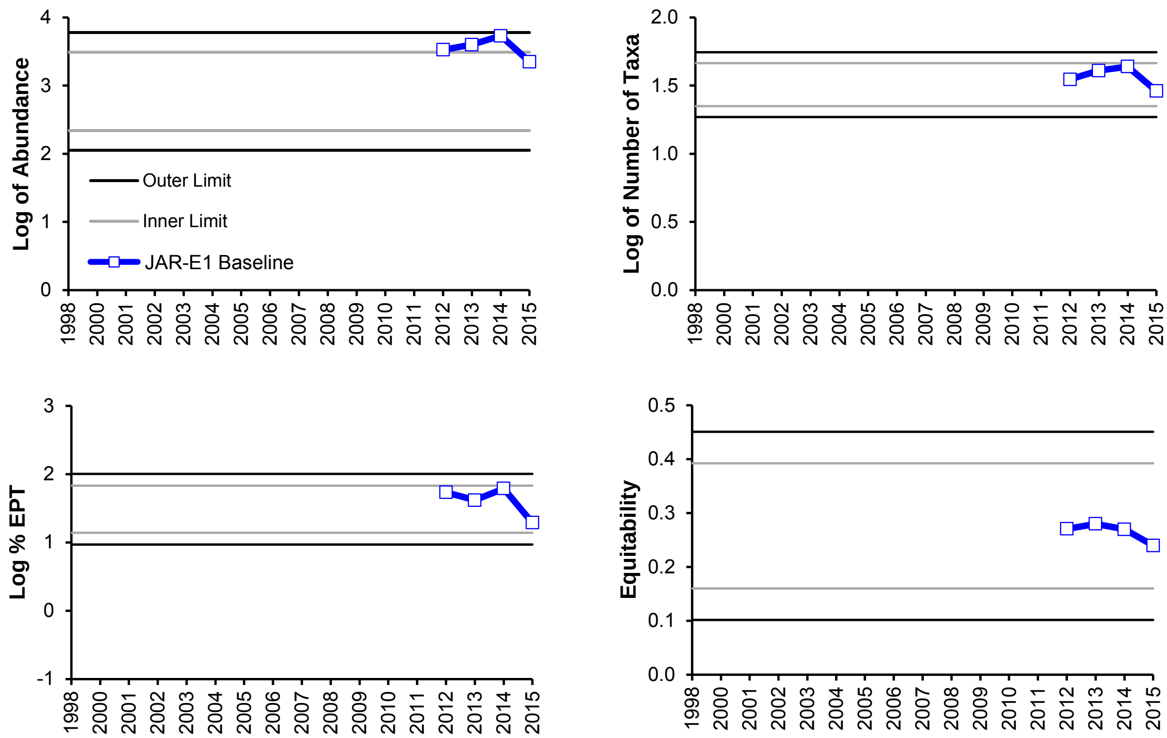
Notes:

Measurement endpoints for *test* reach GRR-E1 in 2015, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances at erosional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.10-31 Variation in benthic invertebrate community measurement endpoints at *test* reach JAR-E1 of the Jackfish River relative to regional *baseline* ranges of variability.



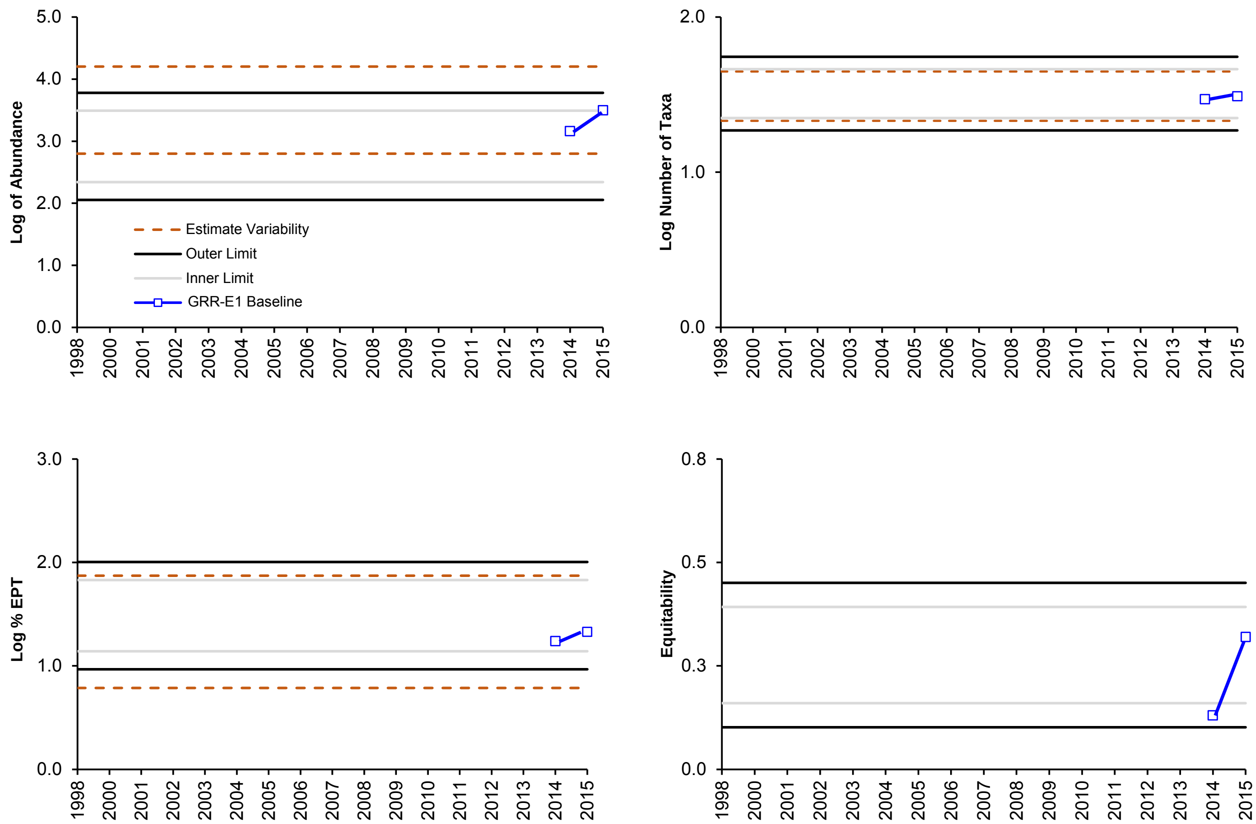
Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Measurement endpoints for *test* reach JAR-E1 in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Figure 5.10-32 Variation in benthic invertebrate community key measurement endpoints at *test* reach GRR-E1 in the Gregoire River relative to *baseline* reach variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed before the average was calculated.

Measurement endpoints for *test* reach GRR-E1 in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). The estimate variability represents ± 2SD and was calculated using data from erosional reaches where both Kicknet and Neil-Hess samples were collected (Appendix D).

Table 5.10-57 Average habitat characteristics of benthic invertebrate sampling locations in Christina Lake, fall 2015.

Variable	Units	CHL-1 *Test* Station
Sample date	-	September 1, 2015
Habitat	-	Depositional
Water depth	m	2.2
Field water quality		
Dissolved oxygen (DO)	mg/L	8.5
Conductivity	µS/cm	200
pH	pH units	8.01
Water temperature	°C	16.9
Sediment composition		
Sand	%	67.8
Silt	%	27.7
Clay	%	4.5
Total organic carbon (TOC)	%	3.0

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.10-58 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community in Christina Lake.

Taxon	Percent Major Taxa Enumerated in Each Year	
	Test Station CHL-1	
	2012-2014	2015
Nematoda	11 to 16	11
Naididae	1 to 13	8
Tubificidae	<1 to 14	22
Enchytraeidae	1 to 5	-
Lumbriculidae	0 to <1	-
Hirudinea	<1	<1
Hydracarina	<1 to 2	-
Amphipoda	11 to 17	5
Gastropoda	1 to 4	<1
Bivalvia	1 to 4	6
Ceratopogonidae	1 to 3	3
Chironomidae	20 to 61	44
Diptera (misc)	0 to <1	-
Coleoptera	0 to <1	-
Ephemeroptera	2 to 6	1
Odonata	<1	-
Trichoptera	<1 to 1	1
Benthic Invertebrate Community Measurement Endpoints		
Total abundance per sample	255 to 638	306
Richness	20 to 33	16
Equitability	0.19 to 0.32	0.41
% EPT	2 to 8	1

Table 5.10-59 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community endpoints in Christina Lake.

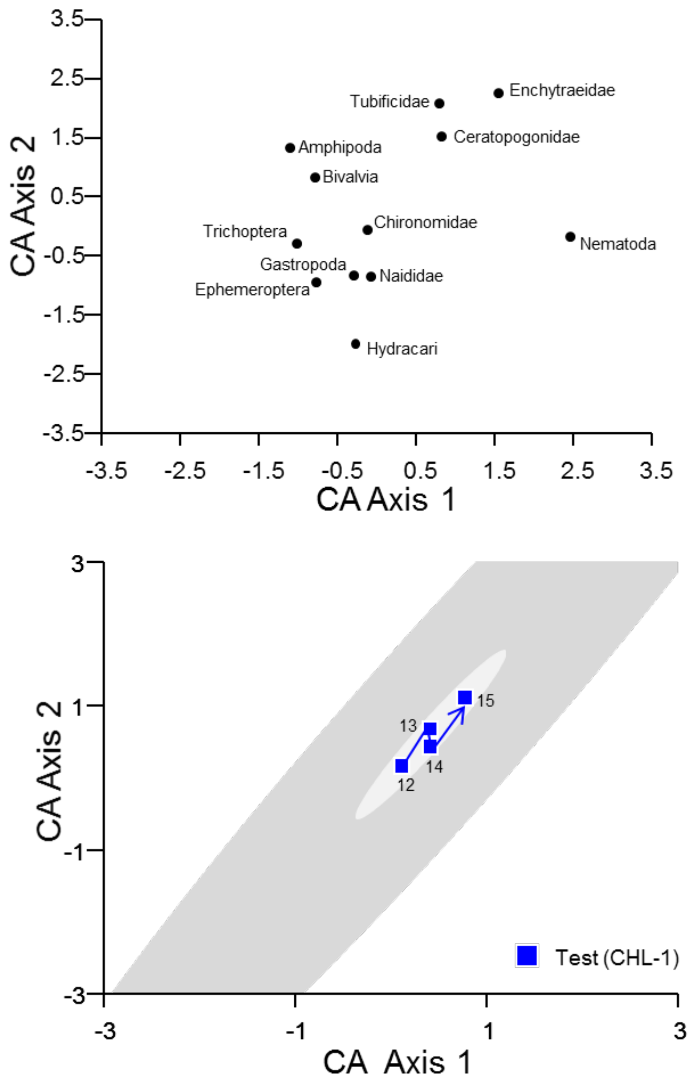
Variable	P-value		Variance Explained (%)		Nature of Effect(s)
	Time Trend	2015 vs. Previous Years	Time Trend	2015 vs. Previous Years	
Log of Abundance	**0.034**	0.468	19	2	Abundance decreased over time in Christina Lake.
Log of Richness	**<0.001**	**0.005**	88	41	Richness decreased over time and was lower in 2015 than the mean of prior years in Christina Lake.
Equitability	0.600	**0.018**	2	41	Equitability was higher in 2015 than the mean of prior years in Christina Lake.
Log of EPT	**0.001**	**0.013**	67	36	Percentage of the fauna as EPT taxa in Christina Lake decreased over time and was lower in 2015 than the mean of prior years.
CA Axis 1	**<0.001**	**<0.001**	84	92	CA Axis 1 scores increased over time and were higher in 2015 than the mean of all prior years.
CA Axis 2	**<0.001**	**<0.001**	41	95	CA Axis 2 scores increased over time and were higher in 2015 than the mean of prior years in the reach.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

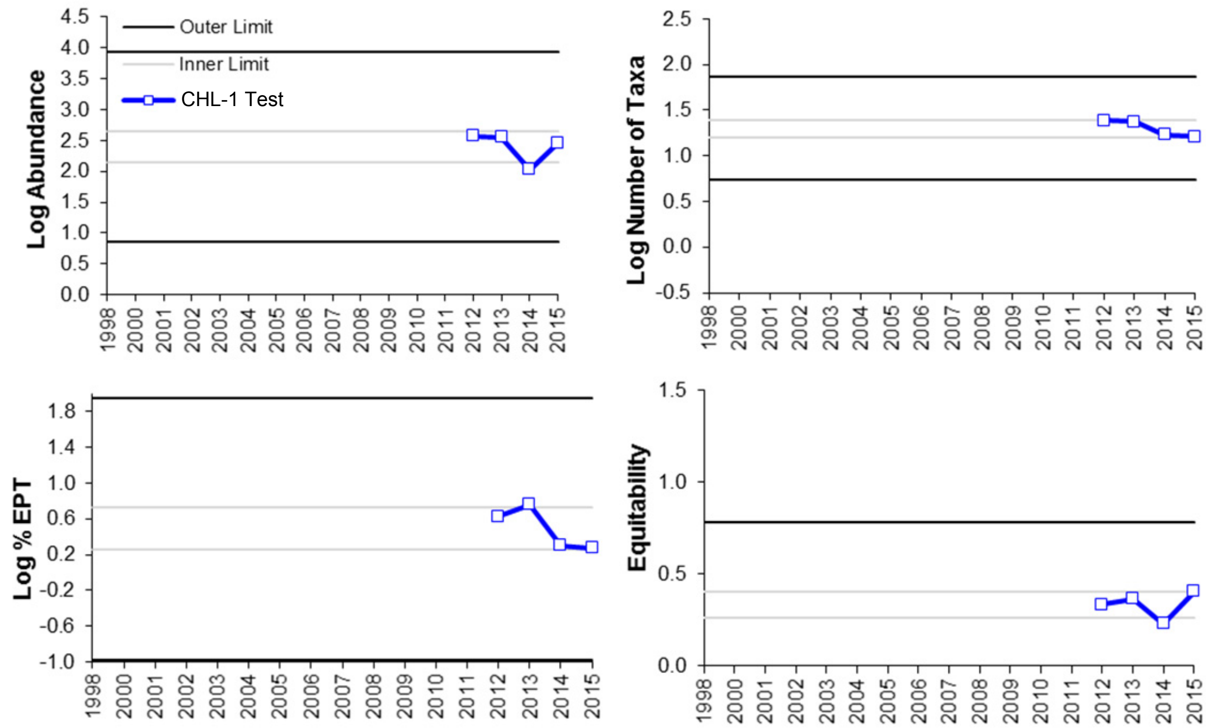
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.10-33 Ordination (Correspondence Analysis) of benthic invertebrate communities of regional lakes, showing Christina Lake.



Note: The upper panel of is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years (2012 to 2014).

Figure 5.10-34 Variation in benthic invertebrate community measurement endpoints at *test* reach CHL-1 of Christina Lake relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from 2012 to 2014.

Values were adjusted to a common depth of 2 m (see Appendix D).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.10-60 Average habitat characteristics of benthic invertebrate sampling locations in Gregoire Lake, fall 2015.

Variable	Units	GRL-1 *Test* Station
Sample date	-	September 1, 2015
Habitat	-	Depositional
Water depth	m	1.5
Field water quality		
Dissolved oxygen (DO)	mg/L	-
Conductivity	µS/cm	-
pH	pH units	-
Water temperature	°C	-
Sediment composition		
Sand	%	80.1
Silt	%	17.3
Clay	%	2.6
Total organic carbon (TOC)	%	1.1

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.10-61 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community at Gregoire Lake (GRL-1).

Taxon	Percent Major Taxa Enumerated in Each Year	
	Test Station GRL-1	
	2014	2015
Hydra	<1	1
Nematoda	7	20
Oligochaeta	<1	-
Naididae	<1	16
Tubificidae	3	9
Enchytraeidae	<1	-
Lumbriculidae	<1	-
Hirudinea	<1	<1
Hydracarina	<1	-
Amphipoda	13	20
Gastropoda	-	3
Bivalvia	11	2
Ceratopogonidae	<1	2
Chironomidae	58	17
Diptera (misc)	<1	-
Coleoptera	<1	<1
Ephemeroptera	2	2
Trichoptera	1	<1
Benthic Invertebrate Community Measurement Endpoints		
Total abundance per sample	243	638
Richness	16	23
Equitability	0.2	0.28
% EPT	3	3

Table 5.10-62 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community endpoints in Gregoire Lake.

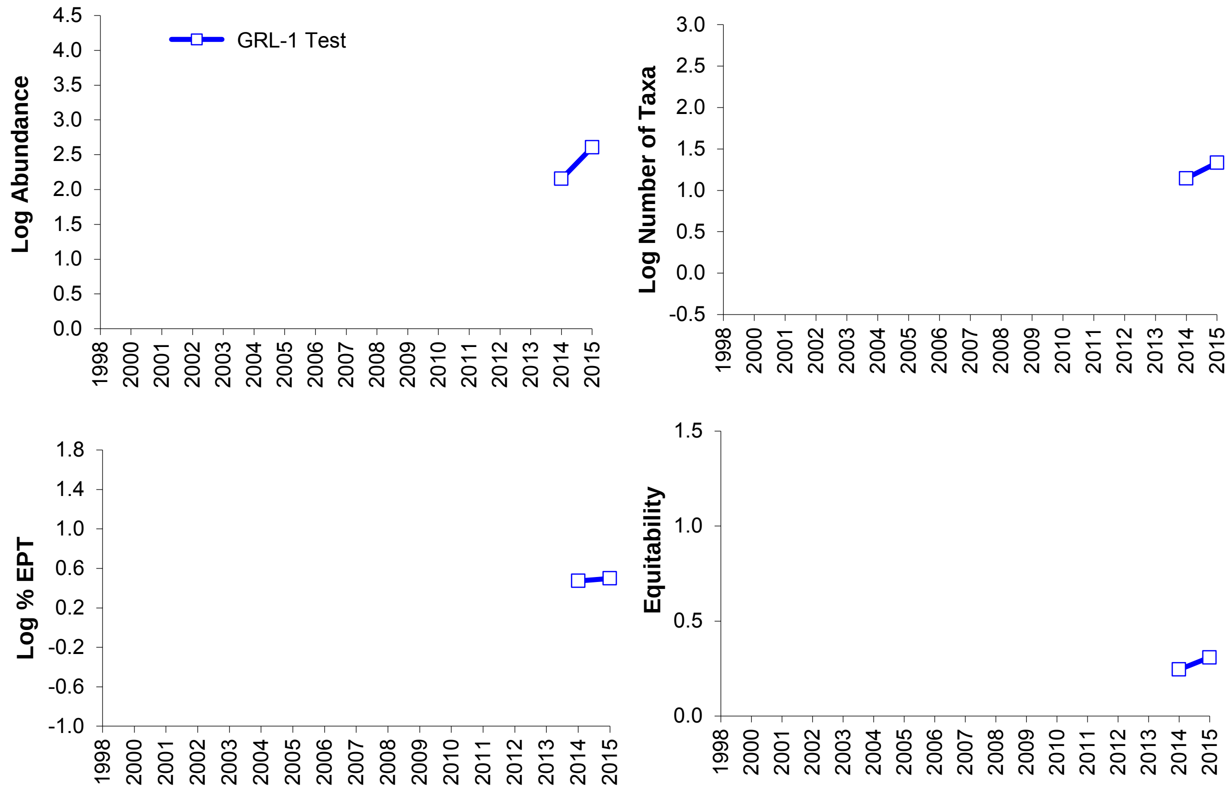
Measurement Endpoint	2015 vs. 2014		Nature of Change(s)
	P-value	Variance Explained (%)	
Log of Abundance	**0.007**	9	Abundance higher in 2015 than in 2014.
Log of Richness	**0.001**	16	Richness higher in 2015 than in 2014.
Equitability	0.067	4	Equitability higher in 2015 than in 2014.
Log of EPT	0.995	0	No change.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.10-35 Variation in benthic invertebrate community measurement endpoints for Gregoire Lake.



Notes:

Values were adjusted to a common depth of 2 m (see Appendix D).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.10-63 Concentrations of selected sediment measurement endpoints, Christina River (*test* station CHR-D1), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2002-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	11.2	8	5.8	10.4	17.0
Silt	%	-	26.3	8	16.0	24.1	38.0
Sand	%	-	62.5	8	54.0	63.8	74.0
Total organic carbon	%	-	1.03	8	0.70	1.06	2.00
Total hydrocarbons							
BTEX	mg/kg	-	<10	6	<5	<10	13
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	6	<5	<10	13
Fraction 2 (C10-C16)	mg/kg	150[1]	<u>26</u>	6	37	55	100
Fraction 3 (C16-C34)	mg/kg	300[1]	207	6	200	**365**	**970**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<u>115</u>	6	130	202	600
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0007	8	0.0004	0.0017	0.0080
Retene	mg/kg	-	0.0314	8	0.0198	0.0439	0.1490
Total dibenzothiophenes	mg/kg	-	0.6256	8	0.2516	0.9098	3.3207
Total PAHs	mg/kg	-	1.7649	8	0.9994	3.2340	11.7490
Total Parent PAHs	mg/kg	-	0.0642	8	0.0449	0.0944	0.3209
Total Alkylated PAHs	mg/kg	-	1.7007	8	0.9545	3.1245	11.4280
Predicted PAH toxicity[3]	H.I.	1.0	**1.4507**	8	0.6472	**1.2415**	**2.7431**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	90	5	86	90	92
Chironomus growth - 10d	mg/organism	-	1.71	5	1.12	2.15	2.69
Hyalella survival - 14d	# surviving	-	<u>98</u>	5	60	90	94
Hyalella growth - 14d	mg/organism	-	0.15	5	0.10	0.23	0.30

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

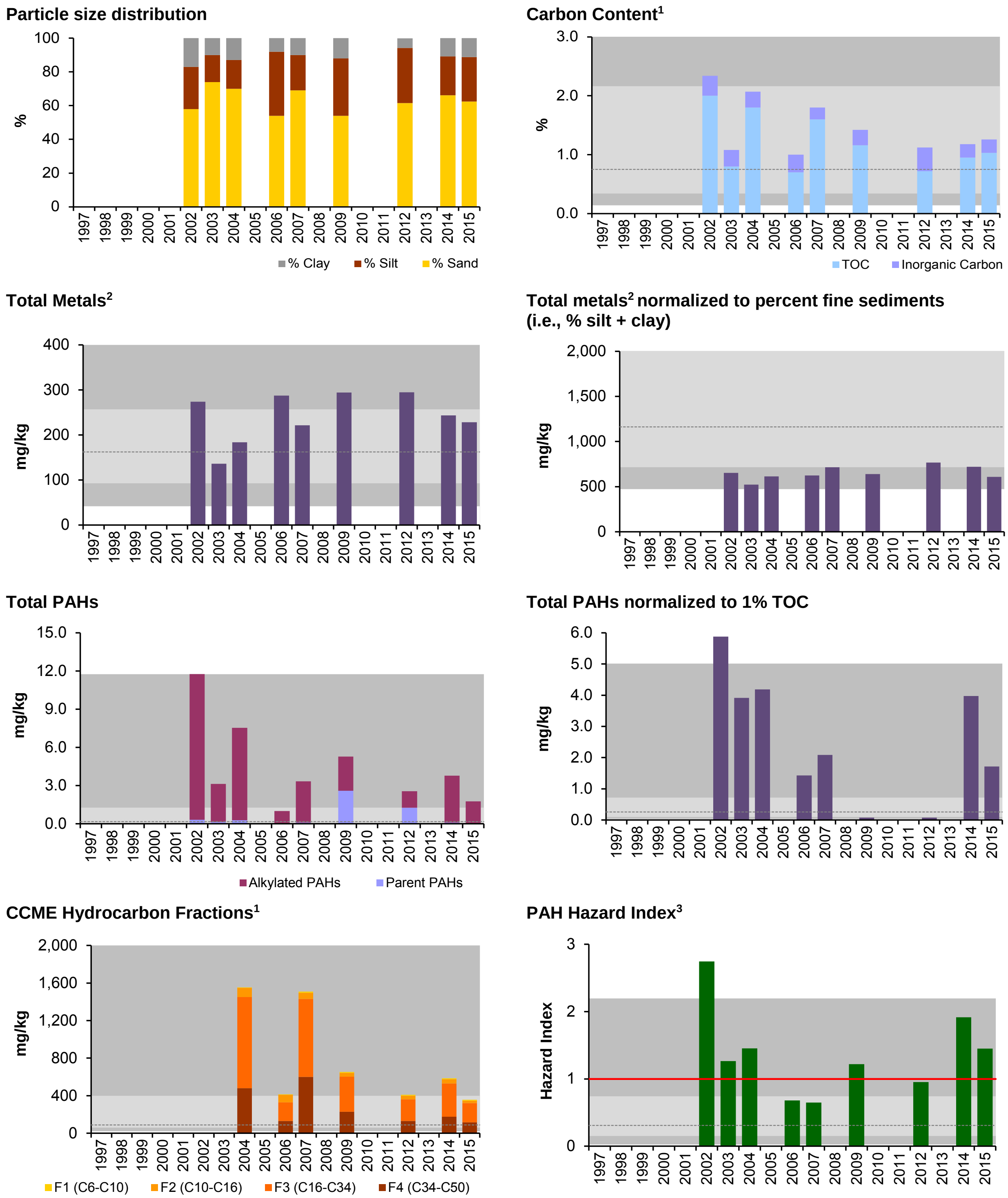
ns = not sampled in 2005, 2008, 2010, 2011, or 2013.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-36 Variation in sediment quality measurement endpoints in the Christina River, *test* station CHR-D1, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-64 Concentrations of selected sediment measurement endpoints, Christina River (*test* station CHR-D2), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2002-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<0.1	7	0.5	3.0	13.0
Silt	%	-	<0.1	7	0.3	2.0	30.0
Sand	%	-	99.9	7	57.0	95.0	99.2
Total organic carbon	%	-	0.10	7	0.10	0.14	1.60
Total hydrocarbons							
BTEX	mg/kg	-	<10	5	<5	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	5	<5	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	5	<5	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	5	<5	20	47
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	5	<5	<20	32
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.00025	7	0.00026	0.0014	0.0030
Retene	mg/kg	-	0.0002	7	0.0006	0.0052	0.0920
Total dibenzothiophenes	mg/kg	-	0.0007	7	0.0013	0.0065	0.0205
Total PAHs	mg/kg	-	0.0060	7	0.0185	0.0698	0.3171
Total Parent PAHs	mg/kg	-	0.0019	7	0.0024	0.0075	0.0338
Total Alkylated PAHs	mg/kg	-	0.0041	7	0.0161	0.0622	0.2833
Predicted PAH toxicity[3]	H.I.	1.0	0.0256	7	0.0830	0.4393	0.5705
Metals that exceeded CCME guidelines in 2015							
None		-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	84	6	50	76	92
Chironomus growth - 10d	mg/organism	-	1.08	6	1.42	2.16	4.30
Hyalella survival - 14d	# surviving	-	94	6	80	98	100
Hyalella growth - 14d	mg/organism	-	0.15	6	0.11	0.30	0.40

Values in **bold** indicate concentrations exceeding guidelines.

Values underlined indicate concentrations outside the range of historical observations.

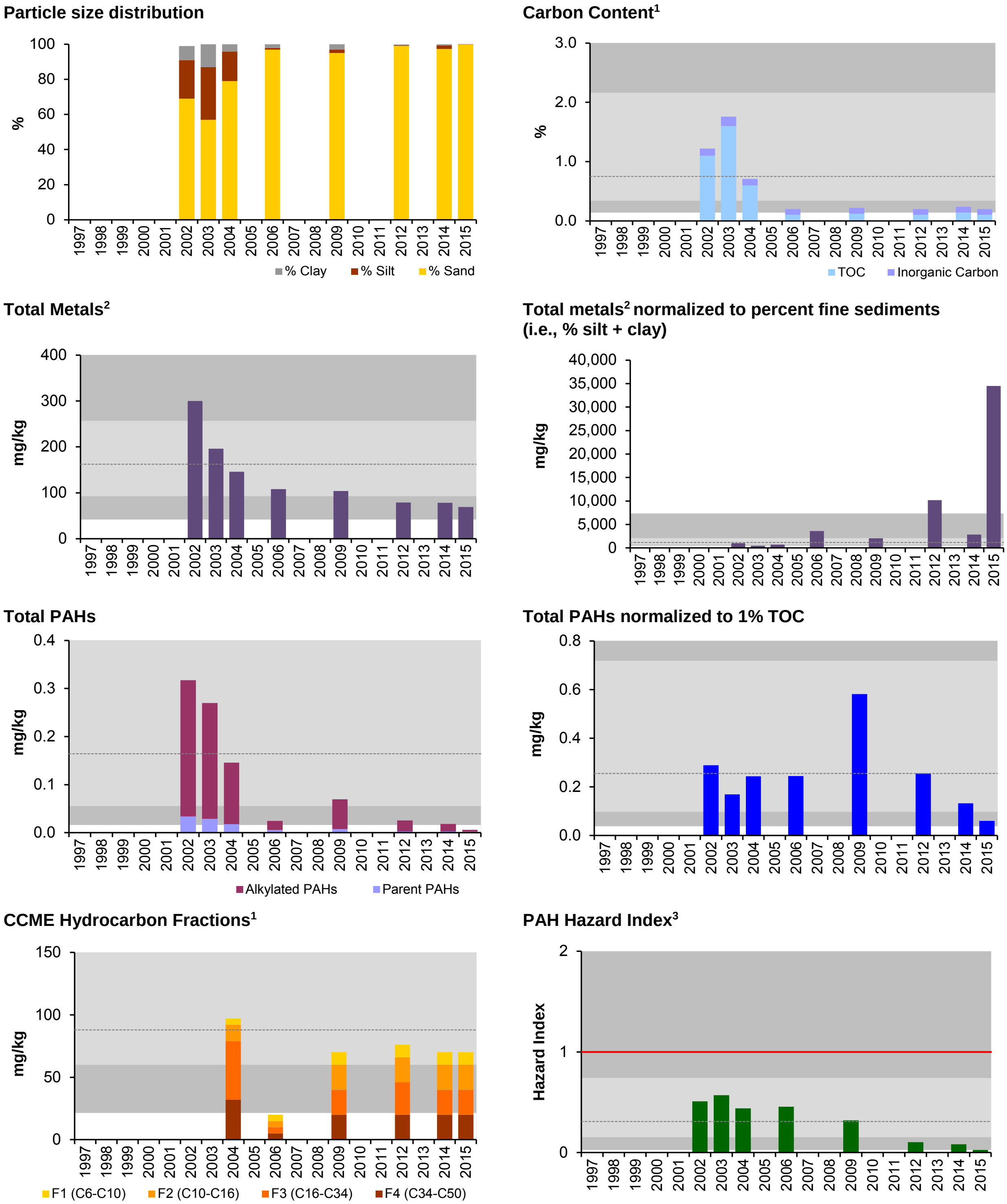
ns = not sampled in 2005, 2007, 2008, 2010, 2011, or 2013.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-37 Variation in sediment quality measurement endpoints in the Christina River, *test* station CHR-D2, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-65 Concentrations of selected sediment measurement endpoints, Christina River (*test* station CHR-D3), fall 2015, compared to fall 2014 concentrations.

Variable	Units	Guideline	September 2015	September 2014
			Value	Value
Physical variables				
Clay	%	-	0.8	0.8
Silt	%	-	0.1	4.0
Sand	%	-	99.0	95.2
Total organic carbon	%	-	0.21	0.60
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	<36
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	<21
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0008	0.0003
Retene	mg/kg	-	0.0002	0.0349
Total dibenzothiophenes	mg/kg	-	0.0004	0.0079
Total PAHs	mg/kg	-	0.0056	0.0820
Total Parent PAHs	mg/kg	-	0.0020	0.0043
Total Alkylated PAHs	mg/kg	-	0.0036	0.0777
Predicted PAH toxicity[3]	H.I.	1.0	0.0236	0.3203
Metals that exceeded CCME guidelines in 2015				
None	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015				
None	-	-	-	-
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	94	74
Chironomus growth - 10d	mg/organism	-	1.62	2.32
Hyalella survival - 14d	# surviving	-	98	90
Hyalella growth - 14d	mg/organism	-	0.16	0.31

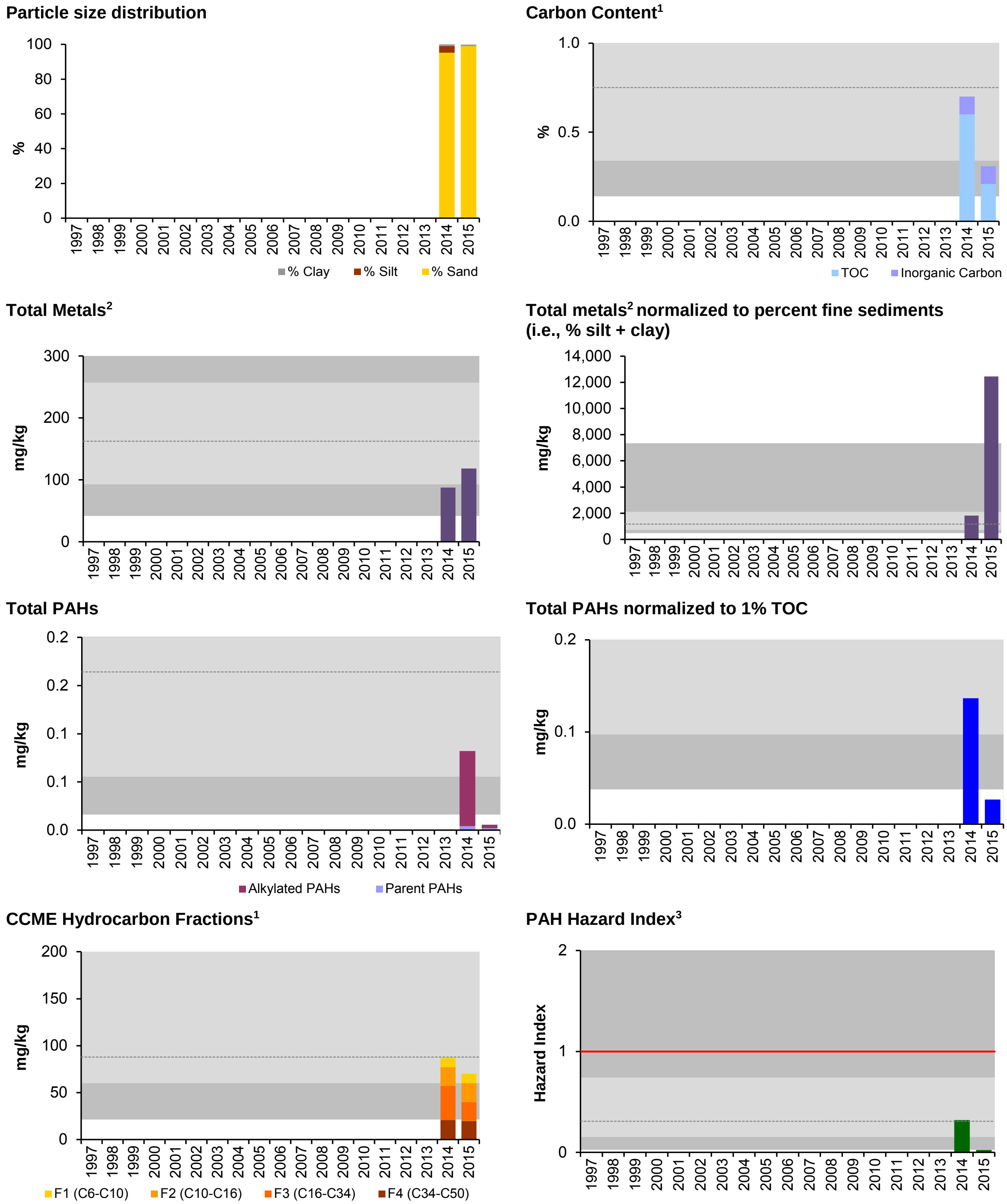
Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-38 Variation in sediment quality measurement endpoints in the Christina River, *test* station CHR-D3, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-66 Concentrations of selected sediment measurement endpoints, Christina River (*baseline* station CHR-D4), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2013-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	1.0	2	0.6	6.8	13.0
Silt	%	-	<u>0.2</u>	2	0.3	15.2	30.0
Sand	%	-	98.8	2	57.0	78.1	99.1
Total organic carbon	%	-	<u>0.17</u>	2	0.21	0.91	1.60
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	2	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	2	<20	<20	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	2	<20	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0009	2	0.0007	0.0008	0.0010
Retene	mg/kg	-	0.0009	2	0.0001	0.0008	0.0015
Total dibenzothiophenes	mg/kg	-	<u>0.0052</u>	2	0.0016	0.0018	0.0019
Total PAHs	mg/kg	-	0.0213	2	0.0162	0.0204	0.0247
Total Parent PAHs	mg/kg	-	<u>0.0034</u>	2	0.0024	0.0027	0.0030
Total Alkylated PAHs	mg/kg	-	0.0178	2	0.0131	0.0177	0.0223
Predicted PAH toxicity[3]	H.I.	1.0	0.0982	2	0.0714	0.0928	0.1141
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>98</u>	2	50	66.5	83
Chironomus growth - 10d	mg/organism	-	<u>1.59</u>	2	2.92	3.61	4.30
Hyalella survival - 14d	# surviving	-	98	2	98	99	100
Hyalella growth - 14d	mg/organism	-	0.17	2	0.11	0.27	0.43

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

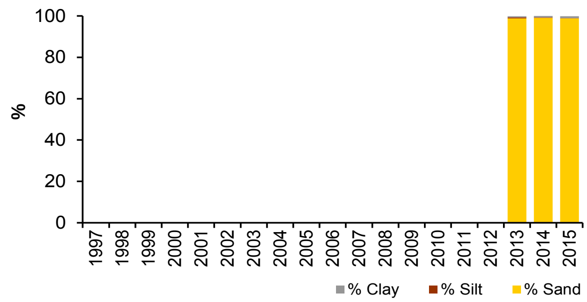
1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

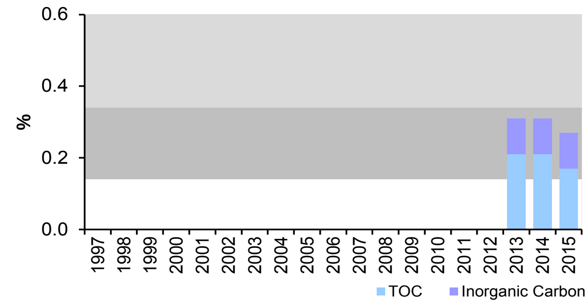
3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-39 Variation in sediment quality measurement endpoints in the Christina River, *baseline* station CHR-D4, relative to historical concentrations and regional *baseline* fall concentrations.

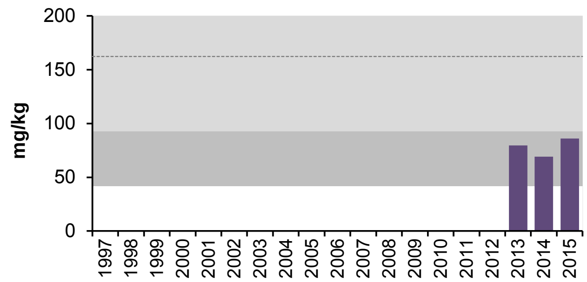
Particle size distribution



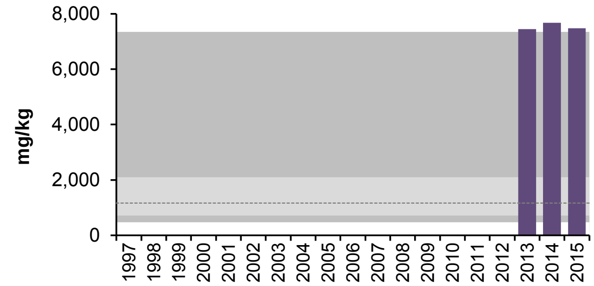
Carbon Content[1]



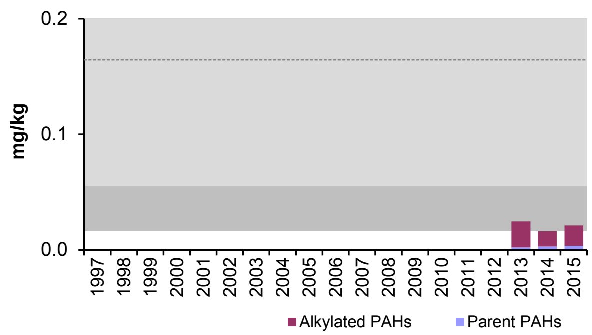
Total Metals[2]



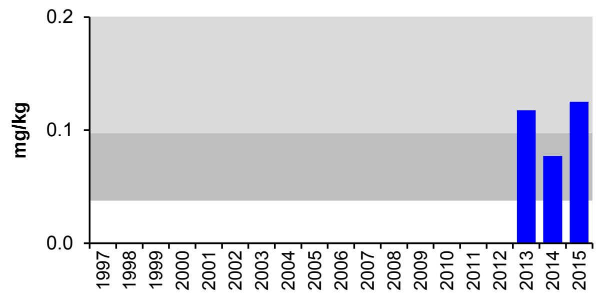
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



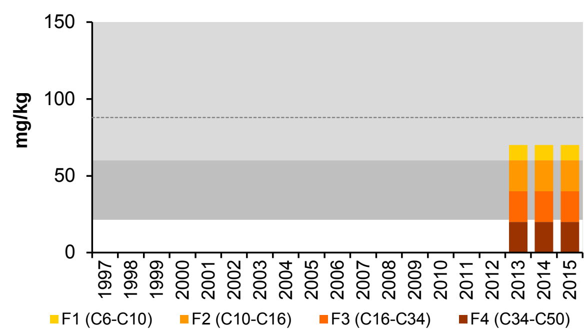
Total PAHs



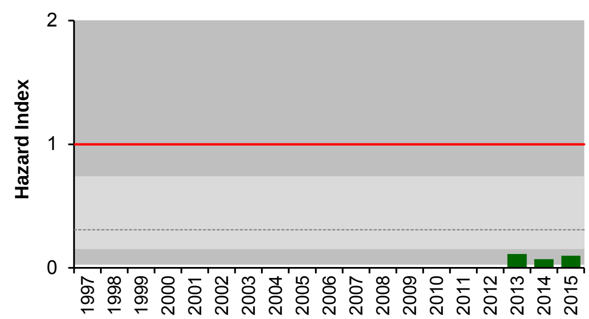
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-67 Concentrations of selected sediment measurement endpoints, Birch Creek (*baseline* station BRC-D1), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2013-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	6.2	2	2.9	6.4	10.0
Silt	%	-	<u>58.1</u>	2	9.0	14.5	20.0
Sand	%	-	<u>35.7</u>	2	70.0	79.1	88.2
Total organic carbon	%	-	<u>2.50</u>	2	0.61	1.06	1.50
Total hydrocarbons							
BTEX	mg/kg	-	<u><20</u>	2	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<u><20</u>	2	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<u><30</u>	2	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<u>130</u>	2	<20	38	56
Fraction 4 (C34-C50)	mg/kg	2800[1]	<u>67</u>	2	<20	22	23
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0016</u>	2	0.0013	0.0015	0.0016
Retene	mg/kg	-	<u>0.0349</u>	2	0.0027	0.0068	0.0109
Total dibenzothiophenes	mg/kg	-	<u>0.0087</u>	2	0.0035	0.0048	0.0061
Total PAHs	mg/kg	-	<u>0.1809</u>	2	0.0439	0.0676	0.0913
Total Parent PAHs	mg/kg	-	<u>0.0646</u>	2	0.0101	0.0143	0.0185
Total Alkylated PAHs	mg/kg	-	<u>0.1164</u>	2	0.0338	0.0533	0.0728
Predicted PAH toxicity[3]	H.I.	1.0	0.2195	2	0.1968	0.2246	0.2525
Metals that exceeded CCME guidelines in 2015							
Total Arsenic	mg/kg	5.9	**<u>7.9</u>**	2	2.5	3.1	3.6
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	<u>-</u>	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	<u>84</u>	2	62	64	66
Chironomus growth - 10d	mg/organism	-	<u>1.93</u>	2	2.82	2.99	3.15
Hyalella survival - 14d	% surviving	-	<u>90</u>	2	92	93	94
Hyalella growth - 14d	mg/organism	-	<u>0.19</u>	2	0.32	0.32	0.32

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

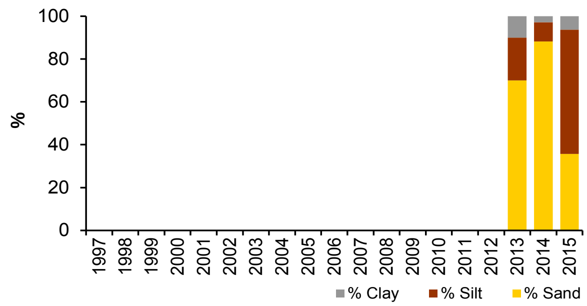
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

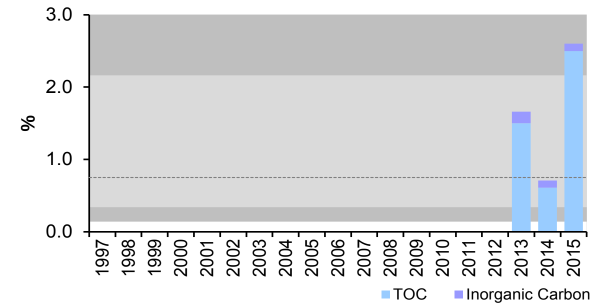
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-40 Variation in sediment quality measurement endpoints in the Birch Creek, *test* station BRC-D1, relative to historical concentrations and regional *baseline* fall concentrations.

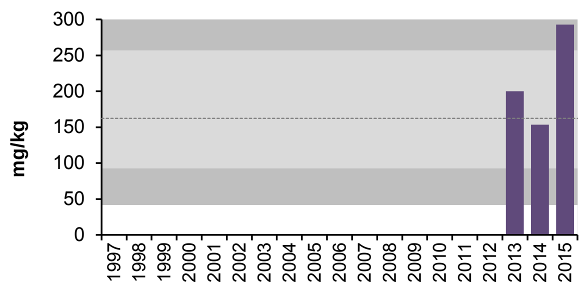
Particle size distribution



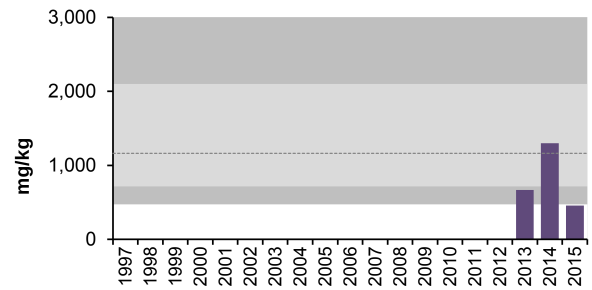
Carbon Content[1]



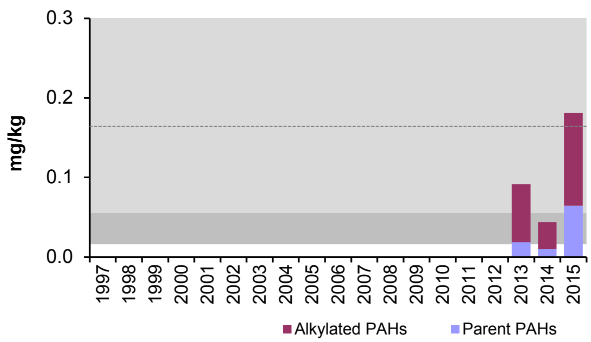
Total Metals[2]



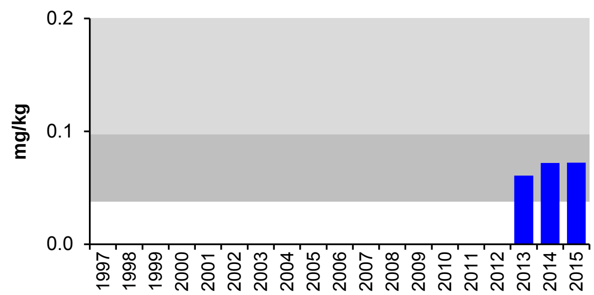
Total metals[2] normalized to percent fine sediments (i.e., % silt + clay)



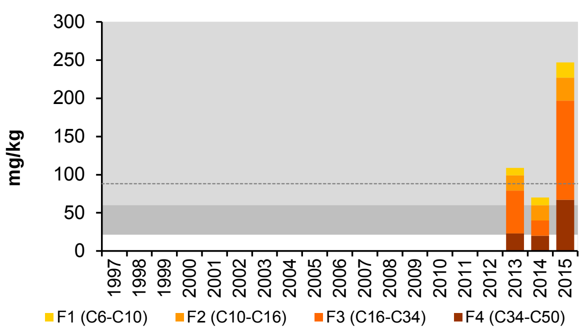
Total PAHs



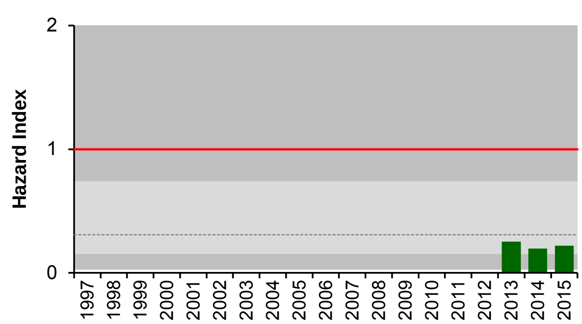
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions[1]



PAH Hazard Index[3]



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-68 Concentrations of selected sediment measurement endpoints, Sawbones Creek (*test* station SAC-D1), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2012-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	6.1	3	5.4	6.0	8.3
Silt	%	-	31.0	3	26.9	36.3	50.3
Sand	%	-	62.9	3	41.4	57.8	67.7
Total organic carbon	%	-	4.99	3	4.08	5.02	5.95
Total hydrocarbons							
BTEX	mg/kg	-	<20	3	<20	<30	<40
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	3	<20	<30	**<40**
Fraction 2 (C10-C16)	mg/kg	150[1]	<35	3	<29	33	57
Fraction 3 (C16-C34)	mg/kg	300[1]	138	3	101	233	249
Fraction 4 (C34-C50)	mg/kg	2,800[1]	105	3	51	131	145
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0013	3	0.0012	0.0012	0.0019
Retene	mg/kg	-	<u>0.1020</u>	3	0.2800	0.8420	1.2000
Total dibenzothiophenes	mg/kg	-	<u>0.0091</u>	3	0.0125	0.0147	0.0172
Total PAHs	mg/kg	-	<u>0.2041</u>	3	0.4983	1.0447	1.3839
Total Parent PAHs	mg/kg	-	<u>0.0150</u>	3	0.0175	0.0252	0.0256
Total Alkylated PAHs	mg/kg	-	<u>0.1891</u>	3	0.4727	1.0272	1.3587
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.2216</u>	3	0.3611	0.7985	**2.4350**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>98</u>	3	56	88	90
Chironomus growth - 10d	mg/organism	-	2.12	3	1.71	2.26	2.58
Hyalella survival - 14d	# surviving	-	90	3	90	96	98
Hyalella growth - 14d	mg/organism	-	0.19	3	0.15	0.23	0.29

Values in **bold** indicate concentrations exceeding guidelines.

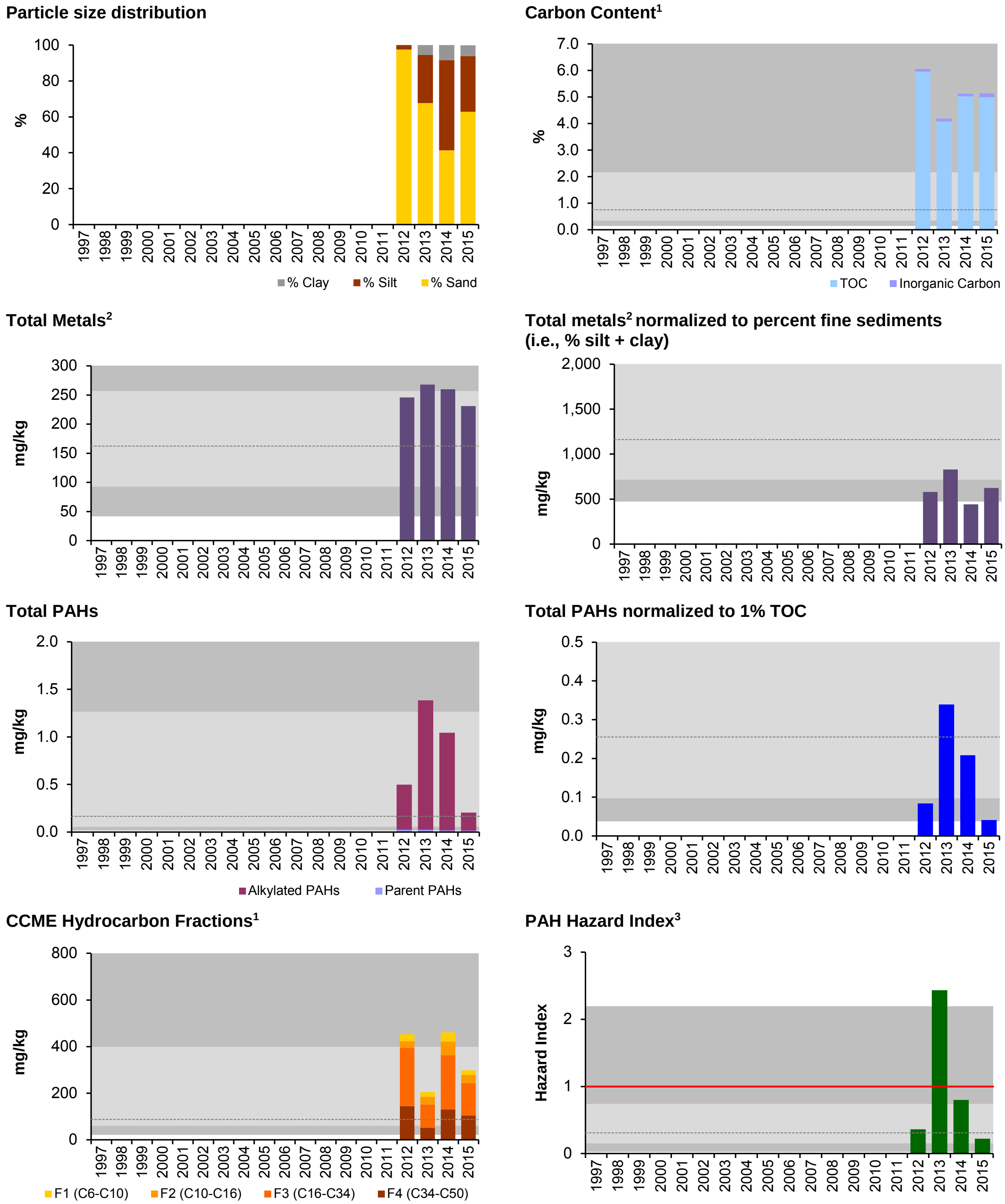
Values <u>underlined</u> indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-41 Variation in sediment quality measurement endpoints in the Sawbones Creek, *test* station SAC-D1, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-69 Concentrations of selected sediment measurement endpoints, Sunday Creek (*test* station SUC-D1), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2012-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5.1	3	1.0	1.1	3.1
Silt	%	-	12.9	3	0.6	0.9	9.6
Sand	%	-	82.1	3	87.4	98.0	98.3
Total organic carbon	%	-	0.93	3	0.13	0.13	0.71
Total hydrocarbons							
BTEX	mg/kg	-	<10	3	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	3	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	3	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	79	3	<20	<20	28
Fraction 4 (C34-C50)	mg/kg	2,800[1]	60	3	<20	<20	22
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0006	3	0.0002	0.0005	0.0006
Retene	mg/kg	-	0.0471	3	0.0010	0.0014	0.0125
Total dibenzothiophenes	mg/kg	-	0.0075	3	0.0013	0.0021	0.0075
Total PAHs	mg/kg	-	0.1066	3	0.0171	0.0275	0.0809
Total Parent PAHs	mg/kg	-	0.0087	3	0.0021	0.0033	0.0079
Total Alkylated PAHs	mg/kg	-	0.0979	3	0.0138	0.0254	0.0730
Predicted PAH toxicity[3]	H.I.	1.0	0.1995	3	0.0759	0.1263	0.3297
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	98	3	54	70	80
Chironomus growth - 10d	mg/organism	-	2.23	3	0.90	1.47	3.88
Hyalella survival - 14d	# surviving	-	100	3	86	86	98
Hyalella growth - 14d	mg/organism	-	0.20	3	0.39	0.45	0.50

Values in **bold** indicate concentrations exceeding guidelines.

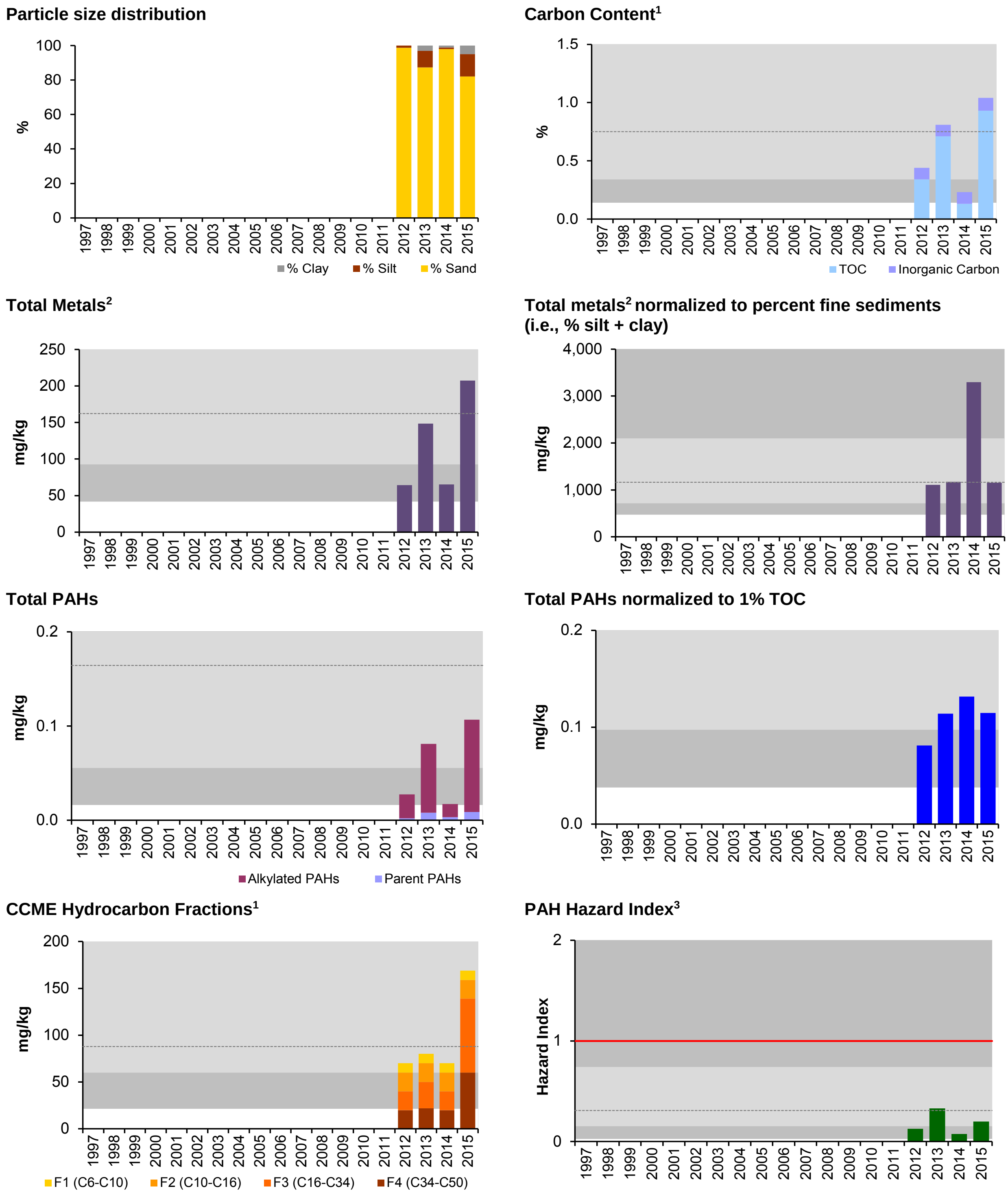
Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-42 Variation in sediment quality measurement endpoints in the Sunday Creek, *test* station SUC-D1, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-70 Concentrations of selected sediment measurement endpoints, Sunday Creek (*baseline* station SUC-D2), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2013-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>0.5</u>	2	2.6	3.1	3.6
Silt	%	-	<u>23.9</u>	2	1.0	2.1	3.2
Sand	%	-	<u>98.9</u>	2	94.2	94.9	95.6
Total organic carbon	%	-	<u><0.10</u>	2	0.12	0.18	0.24
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	2	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	2	<20	<20	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	2	<20	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0004	2	0.0003	0.0009	0.0014
Retene	mg/kg	-	<u>0.0006</u>	2	0.0047	0.0734	0.1420
Total dibenzothiophenes	mg/kg	-	<u>0.0007</u>	2	0.0021	0.0026	0.0032
Total PAHs	mg/kg	-	<u>0.0059</u>	2	0.0294	0.1013	0.1732
Total Parent PAHs	mg/kg	-	<u>0.0017</u>	2	0.0034	0.0035	0.0036
Total Alkylated PAHs	mg/kg	-	<u>0.0042</u>	2	0.0258	0.0978	0.1698
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.0257</u>	2	0.1395	0.5336	0.9278
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	<u>93</u>	2	76	83	90
Chironomus growth - 10d	mg/organism	-	<u>1.45</u>	2	2.30	3.90	5.50
Hyalella survival - 14d	% surviving	-	98	2	94	96	98
Hyalella growth - 14d	mg/organism	-	<u>0.10</u>	2	0.33	0.54	0.74

Values in **bold** indicate concentrations exceeding guidelines.

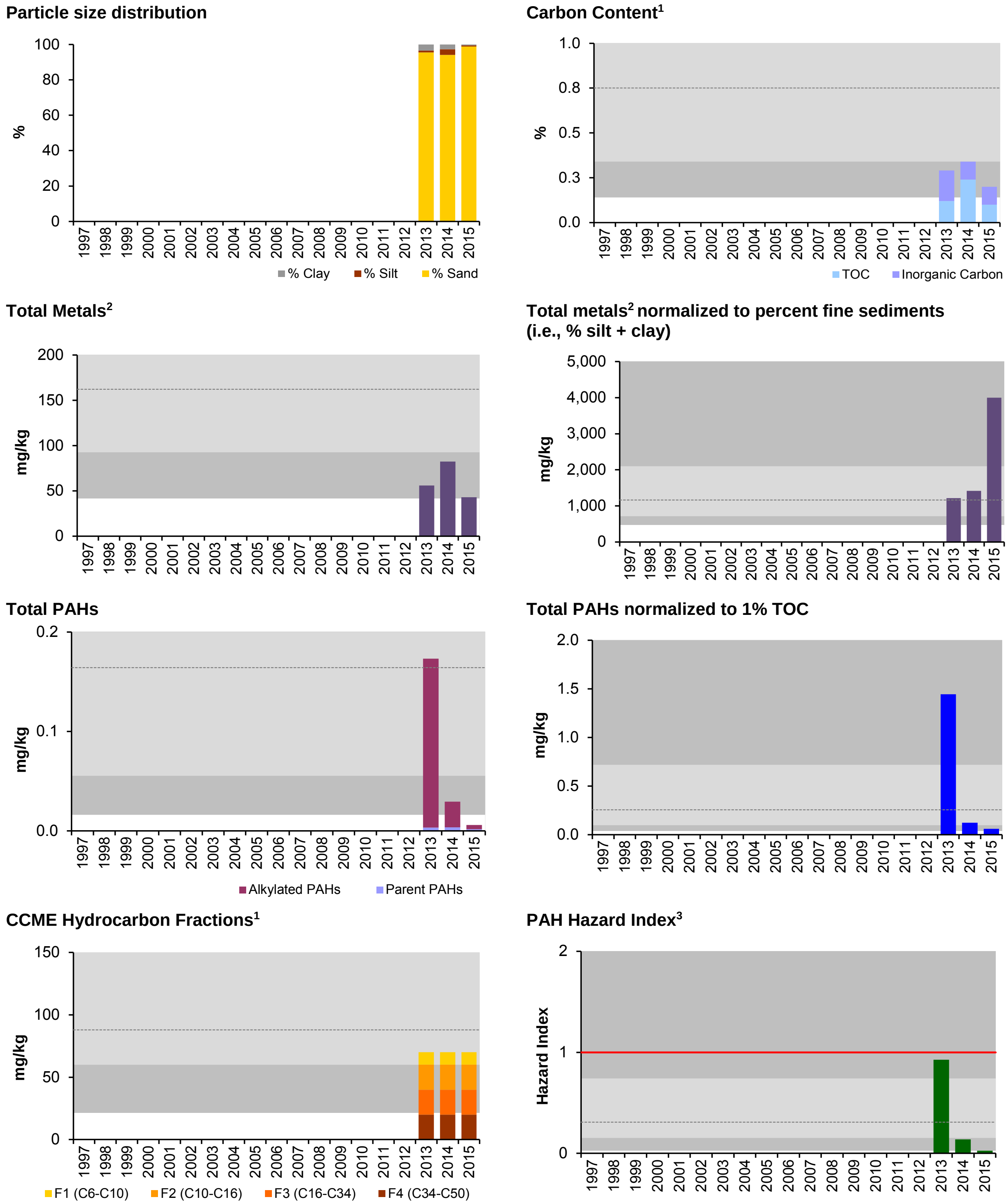
Values <u>underlined</u> indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of Kow (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-43 Variation in sediment quality measurement endpoints in the Sunday Creek, *baseline* station SUC-D2, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-71 Concentrations of selected sediment measurement endpoints, unnamed creek east of Christina Lake (*test* station UNC-D2), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2013-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4.7	2	3.9	4.6	5.2
Silt	%	-	10.7	2	3.1	17.8	32.6
Sand	%	-	84.6	2	62.2	77.6	93.0
Total organic carbon	%	-	1.94	2	0.47	3.44	6.40
Total hydrocarbons							
BTEX	mg/kg	-	<30	2	<10	<35	<60
Fraction 1 (C6-C10)	mg/kg	30[1]	<30	2	<10	**<35**	**<60**
Fraction 2 (C10-C16)	mg/kg	150[1]	<u><40</u>	2	<20	30	39
Fraction 3 (C16-C34)	mg/kg	300[1]	114	2	42	208	**374**
Fraction 4 (C34-C50)	mg/kg	2800[1]	57	2	33	111	188
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0004</u>	2	0.0005	0.0022	0.0039
Retene	mg/kg	-	0.0414	2	0.0342	0.3356	0.6370
Total dibenzothiophenes	mg/kg	-	<u>0.0035</u>	2	0.0086	0.0132	0.0178
Total PAHs	mg/kg	-	<u>0.0910</u>	2	0.1128	0.5380	0.9633
Total Parent PAHs	mg/kg	-	0.0081	2	0.0068	0.0262	0.0455
Total Alkylated PAHs	mg/kg	-	<u>0.0829</u>	2	0.1060	0.5119	0.9178
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.1287</u>	2	0.3470	0.4245	0.5021
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	<u>98</u>	2	62	75	88
Chironomus growth - 10d	mg/organism	-	1.83	2	1.64	1.75	1.85
Hyalella survival - 14d	% surviving	-	96	2	84	90	96
Hyalella growth - 14d	mg/organism	-	<u>0.15</u>	2	0.22	0.24	0.25

Values in **bold** indicate concentrations exceeding guidelines.

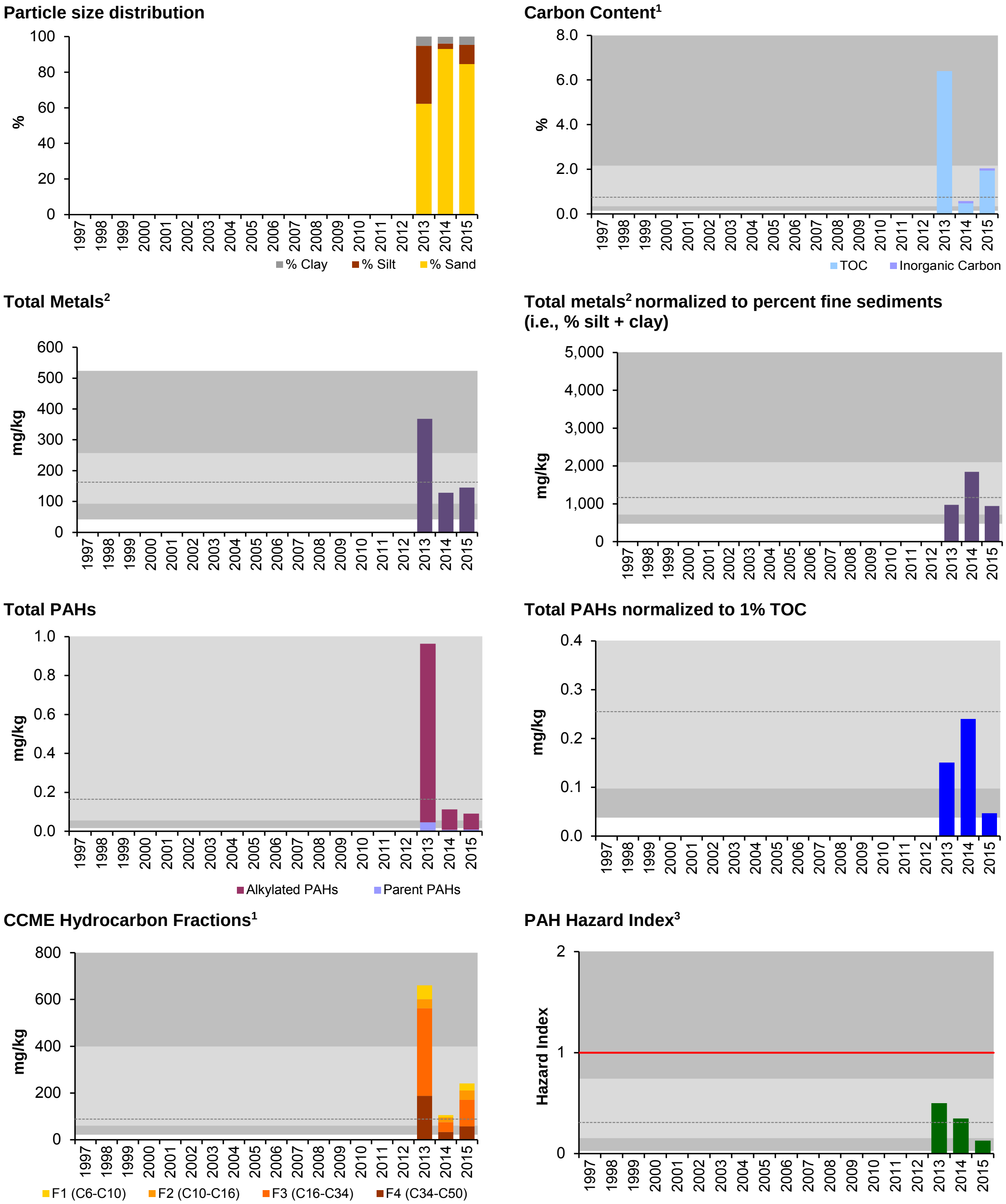
Values <u>underlined</u> indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of Kow (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-44 Variation in sediment quality measurement endpoints in the unnamed creek east of Christina Lake, *test* station UNC-D2, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-72 Concentrations of selected sediment measurement endpoints, unnamed creek south of Christina Lake (*test* station UNC-D3), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2013-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>0.6</u>	2	1.0	1.1	1.1
Silt	%	-	1.4	2	0.7	1.4	2.0
Sand	%	-	98.0	2	97.0	97.6	98.1
Total organic carbon	%	-	<u>0.12</u>	2	0.20	0.25	0.29
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	2	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	2	<20	<20	<20
Fraction 4 (C34-C50)	mg/kg	2800[1]	<20	2	<20	<20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0004	2	0.0003	0.0003	0.0004
Retene	mg/kg	-	0.0020	2	0.0016	0.0025	0.0035
Total dibenzothiophenes	mg/kg	-	<u>0.0006</u>	2	0.0019	0.0019	0.0020
Total PAHs	mg/kg	-	<u>0.0081</u>	2	0.0168	0.0186	0.0203
Total Parent PAHs	mg/kg	-	<u>0.0018</u>	2	0.0021	0.0022	0.0023
Total Alkylated PAHs	mg/kg	-	<u>0.0063</u>	2	0.0145	0.0164	0.0182
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.0373</u>	2	0.0760	0.0851	0.0943
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	78	2	62	73	84
Chironomus growth - 10d	mg/organism	-	<u>2.06</u>	2	2.14	2.86	3.58
Hyalella survival - 14d	# surviving	-	98	2	90	94	98
Hyalella growth - 14d	mg/organism	-	<u>0.19</u>	2	0.37	0.42	0.47

Values in **bold** indicate concentrations exceeding guidelines.

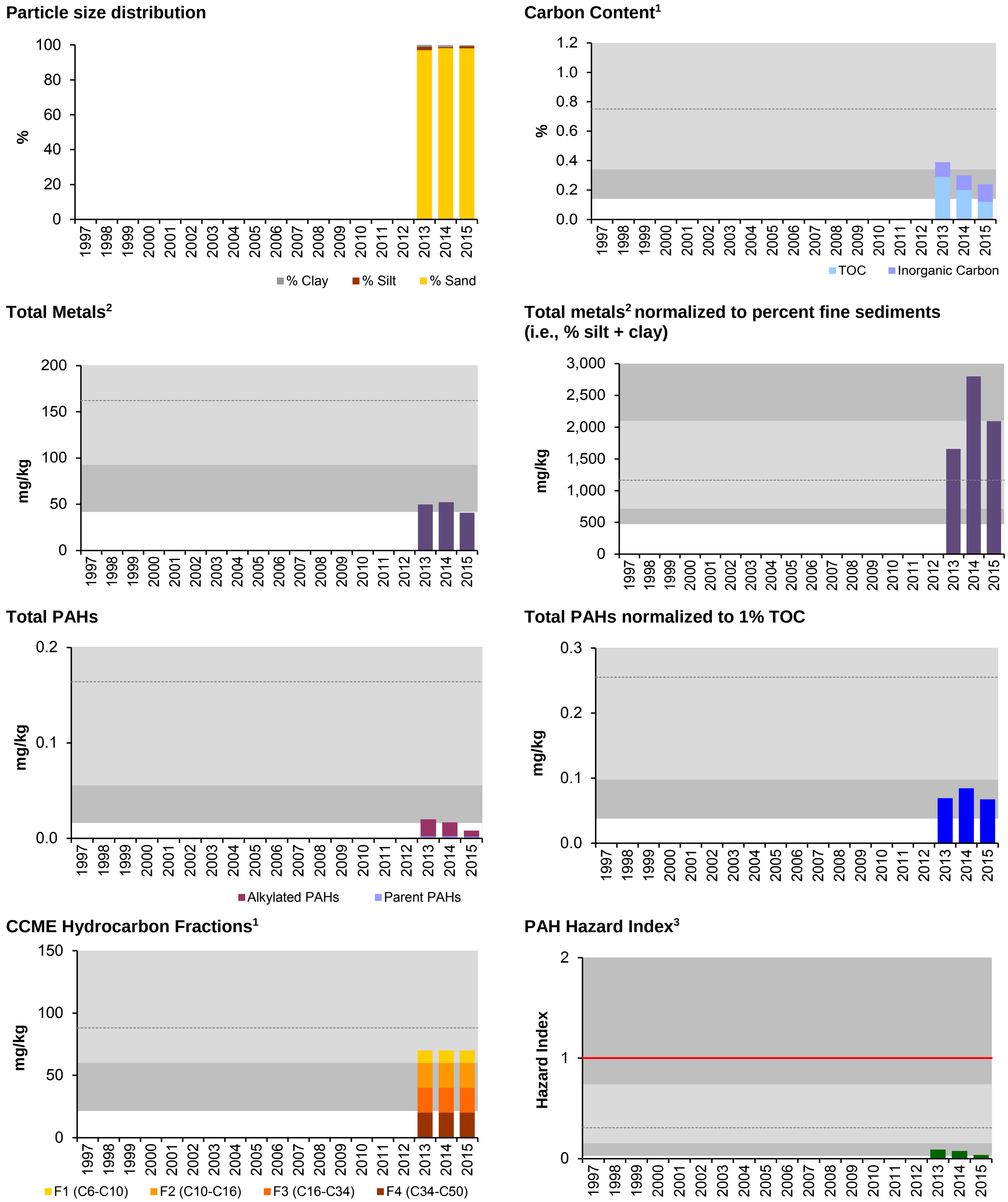
Values <u>underlined</u> indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of Kow (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-45 Variation in sediment quality measurement endpoints in the unnamed creek south of Christina Lake, *test* station UNC-D3, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-73 Concentrations of selected sediment measurement endpoints, Christina Lake (*test* station CHL-1), fall 2015, compared to historical fall concentrations.

Variable	Units	Guideline	September 2015	2012-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3.5	3	0.9	1.0	8.2
Silt	%	-	<u>16.5</u>	3	0.9	2.5	14.2
Sand	%	-	79.9	3	77.6	97.0	98.2
Total organic carbon	%	-	1.80	3	0.22	0.22	17.90
Total hydrocarbons							
BTEX	mg/kg	-	<20	3	<10	<20	<70
Fraction 1 (C6-C10)	mg/kg	30[1]	<20	3	<10	<20	**<70**
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	3	<20	<20	40
Fraction 3 (C16-C34)	mg/kg	300[1]	38	3	<20	<20	**787**
Fraction 4 (C34-C50)	mg/kg	2,800[1]	<20	3	<20	<20	296
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0014	3	0.0003	0.0007	0.0040
Retene	mg/kg	-	0.1410	3	0.0033	0.0047	2.7300
Total dibenzothiophenes	mg/kg	-	0.0038	3	0.0016	0.0027	0.0229
Total PAHs	mg/kg	-	0.2095	3	0.0288	0.0393	3.1873
Total Parent PAHs	mg/kg	-	0.0146	3	0.0024	0.0060	0.0710
Total Alkylated PAHs	mg/kg	-	0.1949	3	0.0264	0.0333	3.1163
Predicted PAH toxicity[3]	H.I.	1.0	0.8376	3	0.1347	0.1786	0.9295
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	<u>94</u>	3	74	80	84
Chironomus growth - 10d	mg/organism	-	<u>1.86</u>	3	2.11	2.77	5.63
Hyalella survival - 14d	# surviving	-	92	3	68	98	100
Hyalella growth - 14d	mg/organism	-	<u>0.15</u>	3	0.31	0.33	0.94

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations (n>3 years).

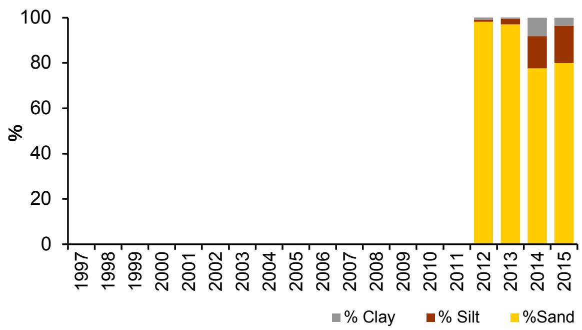
1 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

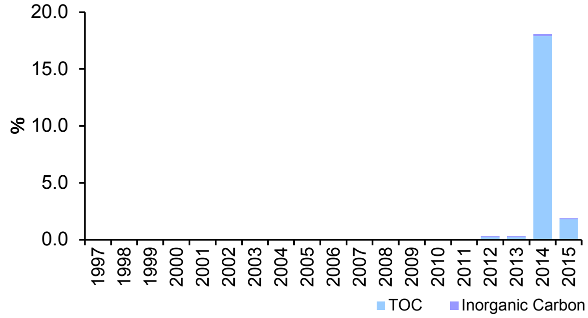
3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-46 Variation in sediment quality measurement endpoints in Christina Lake, *test* station CHL-1, relative to historical concentrations.

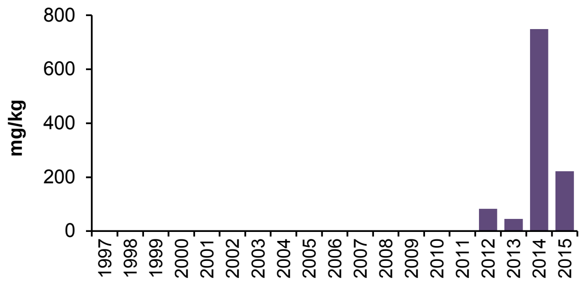
Particle size distribution



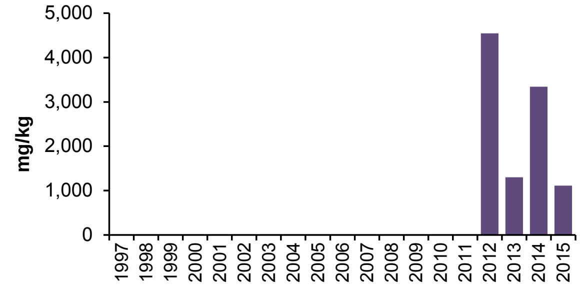
Carbon Content



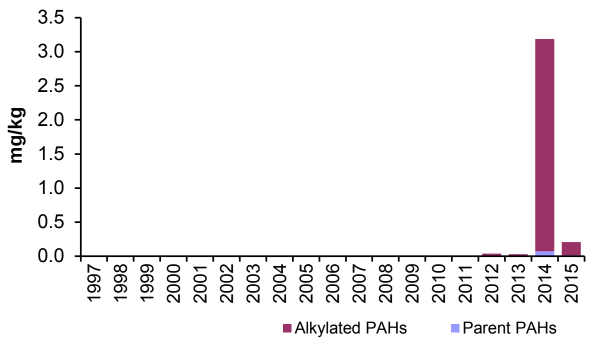
Total Metals[1]



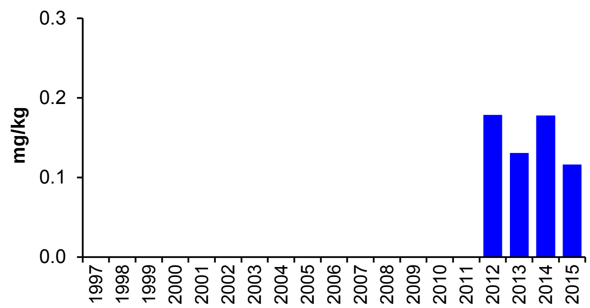
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



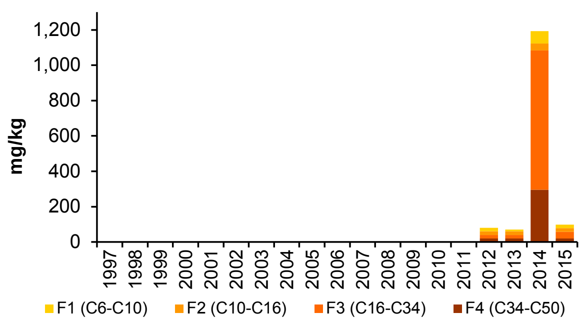
Total PAHs



Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]

[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-74 Concentrations of selected sediment measurement endpoints, Gregoire Lake (*test* station GRL-1), fall 2015 compared to fall 2014 concentrations.

Variable	Units	Guideline	September 2015	September 2014
			Value	Value
Physical variables				
Clay	%	-	2.0	3.4
Silt	%	-	2.2	7.8
Sand	%	-	95.9	88.8
Total organic carbon	%	-	2.01	0.14
Total hydrocarbons				
BTEX	mg/kg	-	<60	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	**<60**	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	21	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	114	<20
Fraction 4 (C34-C50)	mg/kg	2,800[1]	42	<20
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0004	0.0003
Retene	mg/kg	-	0.0020	0.0007
Total dibenzothiophenes	mg/kg	-	0.0017	0.0041
Total PAHs	mg/kg	-	0.0163	0.0233
Total Parent PAHs	mg/kg	-	0.0028	0.0029
Total Alkylated PAHs	mg/kg	-	0.0135	0.0204
Predicted PAH toxicity[3]	H.I.	1.0	0.0254	0.1096
Metals that exceeded CCME guidelines in 2015				
None	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015				
None	-	-	-	-
Chronic toxicity				
Chironomus survival - 10d	# surviving	-	34	86
Chironomus growth - 10d	mg/organism	-	2.93	2.56
Hyalella survival - 14d	# surviving	-	40	90
Hyalella growth - 14d	mg/organism	-	0.08	0.32

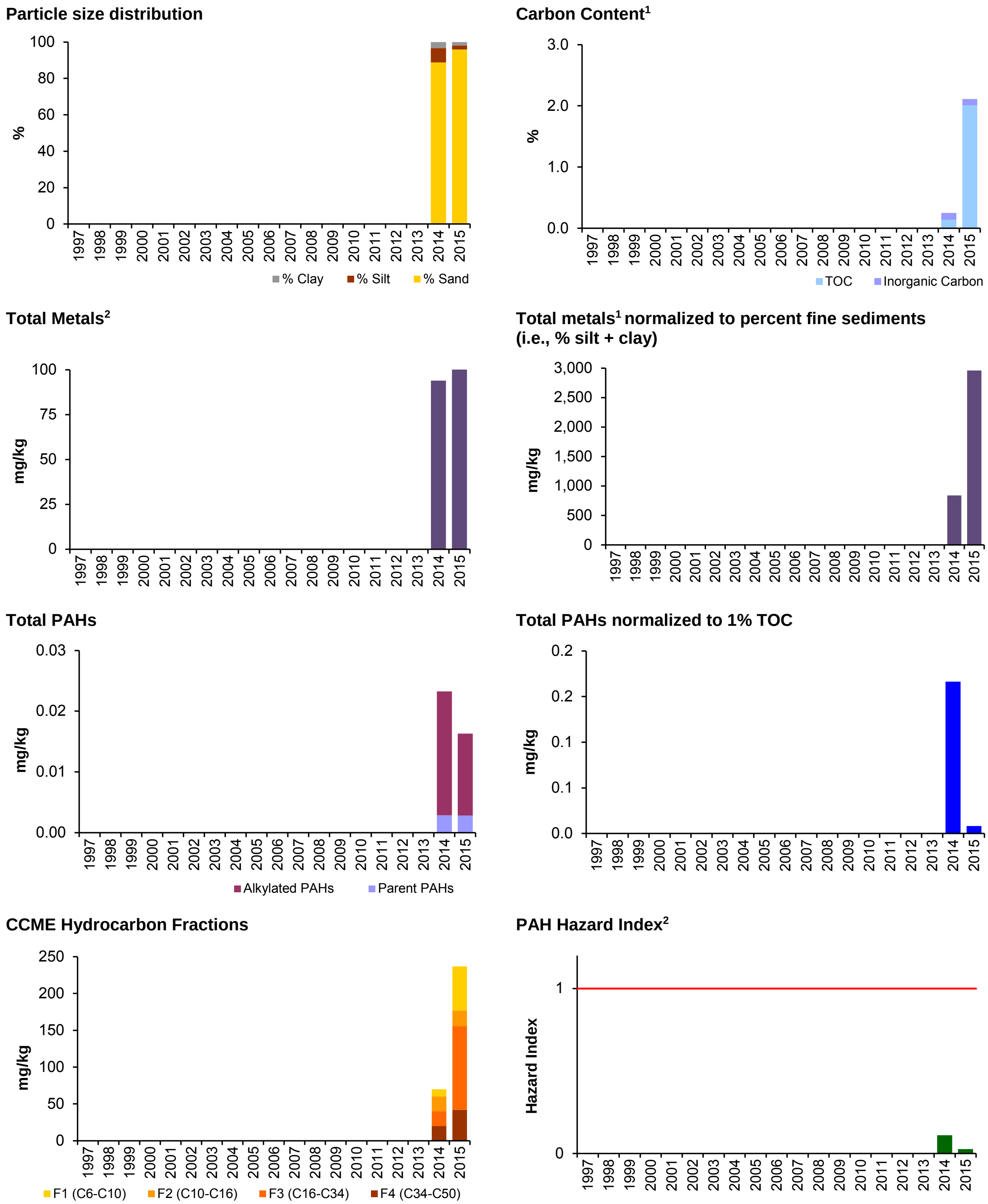
Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.10-47 Variation in sediment quality measurement endpoints in Gregoire Lake, *test* station GRL-1, relative to historical concentrations.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.10-75 Average habitat characteristics of fish community monitoring *test* reach CHR-F2 of the Christina River, fall 2015.

Variable	Units	CHR-F2 *Test* Reach
Sample date	-	September 21, 2015
Habitat type	-	riffle
Maximum depth	m	0.52
Mean depth	m	0.34
Bankfull channel width	m	43.0
Wetted channel width	m	42.0
Substrate		
Dominant	-	coarse gravel
Subdominant	-	fine gravel
Instream cover		
Dominant	-	small and large woody debris, live trees, undercut banks, boulders, filamentous algae, overhanging vegetation
Subdominant	-	-
Field water quality		
Dissolved oxygen (DO)	mg/L	10.1
Conductivity	µS/cm	235
pH	pH units	8.58
Water temperature	^{0}C	9.4
Water velocity		
Left bank velocity	m/s	0.88
Left bank water depth	m	0.30
Centre of channel velocity	m/s	0.33
Centre of channel water depth	m	0.22
Right bank velocity	m/s	0.72
Right bank water depth	m	0.30
Riparian cover – understory (<5 m)		
Dominant	-	woody shrubs and saplings, overhanging vegetation
Subdominant	-	-

Table 5.10-76 Total number and percent composition of fish species captured at reaches of the Christina River, 2012 to 2015.

Common Name	Code	Total Species Catch									Percent of Total Catch								
		CHR-F1		CHR-F2			CHR-F3		CHR-F4		CHR-F1		CHR-F2			CHR-F3		CHR-F4	
		2012	2014	2012	2014	2015	2013	2014	2013	2014	2012	2014	2012	2014	2015	2013	2014	2013	2014
Arctic grayling	ARGR	-	-	2	-	-	-	-	-	-	0	0	3.7	0	0	0	0	0	0
brook stickleback	BRST	-	-	-	-	-	-	-	-	2	0	0	0	0	0	0	0	0	5.6
burbot	BURB	-	16	-	5	-	13	3	-	-	0	27.6	0	45.5	0	33.3	20.0	0	0
flathead chub	FLCH	1	-	-	-	-	-	-	-	-	3.8	0	0	0	0	0	0	0	0
goldeye	GOLD	7	-	-	-	-	-	-	-	-	26.9	0	0	0	0	0	0	0	0
lake chub	LKCH	5	20	3	-	5	-	-	1	-	19.2	34.5	5.6	0	7	0	0	1.9	0
longnose dace	LNDC	-	15	-	-	3	3	-	-	-	0	25.9	0	0	4	7.7	0	0	0
longnose sucker	LNSC	1	-	1	-	34	1	2	3	6	3.8	0	1.9	0	51	2.6	13.3	5.6	16.7
northern pike	NRPK	2	-	-	4	-	2	-	-	-	7.7	0	0	36.4	0	5.1	0	0	0
northern redbelly dace	NRDC	-	-	1	-	-	-	-	-	-	0	0	1.9	0	0	0	0	0	0
pearl dace	PRDC	-	-	1	1	-	1	1	35	15	0	0	1.9	9.1	0	2.6	6.7	64.8	41.7
slimy sculpin	SLSC	3	1	-	-	-	17	6	-	-	11.5	1.7	0	0	0	43.6	40.0	0	0
spoonhead sculpin	SPSC	-	1	-	-	-	-	-	-	-	0	1.7	0	0	0	0	0	0	0
trout-perch	TRPR	4	1	45	1	-	-	-	-	-	15.4	1.7	83.3	9.1	0	0	0	0	0
walleye	WALL	3	1	-	-	-	-	-	-	-	11.5	1.7	0	0	0	0	0	0	0
white sucker	WHSC	-	3	1	-	25	1	-	1	13	0	5.2	1.9	0	37	2.6	0	1.9	36.1
yellow perch	YLPR	-	-	-	-	-	-	3	-	-	0	0	0	0	0	0	20.0	0	0
sucker sp. *	-	-	-	-	-	-	1	-	14	-	0	0	0	0	0	2.6	0	25.9	0
Total		**26**	**58**	**54**	**11**	**67**	**39**	**15**	**54**	**36**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**8**	**8**	**7**	**4**	**4**	**7**	**5**	**4**	**4**	**8**	**8**	**7**	**4**	**4**	**7**	**5**	**4**	**4**
Electrofishing effort (secs)		**1,448**	**2,830**	**2,010**	**2,123**	**2,473**	**2,541**	**2,565**	**2,327**	**1,799**	-	-	-	-	-	-	-	-	-

* Unknown sucker species not included in species richness count.

Underline denotes *baseline* reach.

Note: *Test* reaches CHR-F1 and CHR-F2 were not sampled in 2013; *Test* reaches CHR-F1 and CHR-F3 and *baseline* reach CHR-F4 were not sampled in 2015.

Table 5.10-77 Summary of fish community measurement endpoints (± 1SD) for reaches of the Christina River watershed, 2012 to 2015.

Reach	Designation	Year	Abundance		Richness*			Diversity*		ATI*		CPUE*	
			Mean	SD	Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Christina River mainstem													
CHR-F2	*Test* reach	2012	0.02	0.01	7	2.8	0.84	0.33	0.19	7.43	1.22	2.58	1.45
		2014	0.02	0.01	4	1.6	1.14	0.33	0.30	5.07	2.49	0.53	0.43
		2015	0.11	0.03	4	2.8	1.10	0.42	0.23	5.97	0.92	2.72	0.78
Christina River tributary													
JAR-F1	*Test* reach	2012	0.08	0.03	6	2.8	0.84	0.55	0.09	3.69	1.28	1.38	0.54
		2013	0.11	0.03	5	3.6	0.89	0.50	0.14	2.88	0.44	3.41	0.99
		2014	0.19	0.20	7	4.6	1.67	0.65	0.07	3.57	0.65	6.51	6.90
		2015	0.16	0.09	5	3.6	0.55	0.63	0.08	3.77	0.72	2.76	1.61
Christina Lake tributaries													
SAC-F1	*Test* reach	2012	0.01	0.01	1	0.2	0.00	0.00	-	7.80	0.00	0.06	0.14
		2013	0.00	0.00	0	0.0	-	0.00	-	-	-	0.00	-
		2014	0.00	0.00	0	0.00	-	0.00	-	-	-	0.00	-
		2015	0.00	0.00	0	0.0	-	0.00	-	-	-	0.00	-
SUC-F1	Lower *test* reach	2012	0.18	0.14	7	2.4	0.55	0.25	0.15	3.33	0.39	2.40	1.95
		2013	0.12	0.06	3	2.4	0.55	0.46	0.04	4.39	0.14	2.68	1.45
		2014	0.42	0.50	7	2.2	0.84	0.36	0.24	4.22	1.60	6.15	7.30
		2015	0.37	0.14	5	3.8	0.45	0.49	0.13	4.50	0.87	5.07	1.88
SUC-F2	Upper *baseline* reach	2013	0.12	0.05	5	2.6	0.89	0.49	0.05	5.58	1.74	2.88	1.19
		2014	0.09	0.04	2	1.4	0.55	0.16	0.23	6.99	1.00	2.04	0.86
		2015	0.29	0.07	4	2.8	0.45	0.44	0.17	7.07	0.84	7.31	3.42
UNC-F2	*Test* reach	2013	0.00	0.01	1	0.2	0.45	0.00	0.00	7.60	-	0.08	0.19
		2014	0.01	0.01	1	0.4	0.55	0.00	0.00	7.80	0.00	0.16	0.22
		2015	0.00	0.01	1	0.2	0.45	0.80	0.45	1.56	3.49	0.33	0.75
UNC-F3	*Test* reach	2013	0.02	0.02	3	1.0	1.00	0.20	0.27	7.23	0.90	0.37	0.37
		2014	0.03	0.02	2	1.0	0.71	0.09	0.20	7.69	0.10	0.63	0.45
		2015	0.02	0.03	2	0.8	0.84	0.49	0.50	4.67	4.26	0.38	0.41
BRC-F1	*Baseline* reach	2013	0.03	0.04	1	0.6	0.55	0.00	0.00	7.60	-	0.50	0.56
		2014	0.003	0.01	1	0.2	0.45	0.00	0.00	3.00	-	0.08	0.18
		2015	0.007	0.02	1	0.2	0.45	0.80	0.45	0.60	1.34	0.17	0.38

* Unknown species not included in analysis.
SD = standard deviation across sub-reaches within a reach. Underline denotes *baseline* reaches.

Table 5.10-78 Results of analysis of variance (ANOVA) testing for temporal differences in fish community measurement endpoints for *test* reach CHR-F2 in the Christina River.

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
	Time Trend	Time Trend	
Abundance	**0.008**	56%	Increasing over time.
Richness	1.00	0%	No change.
Diversity	0.60	0%	No change.
ATI	0.21	6%	No change.
CPUE (No./100 sec)	0.79*	0%	No change.

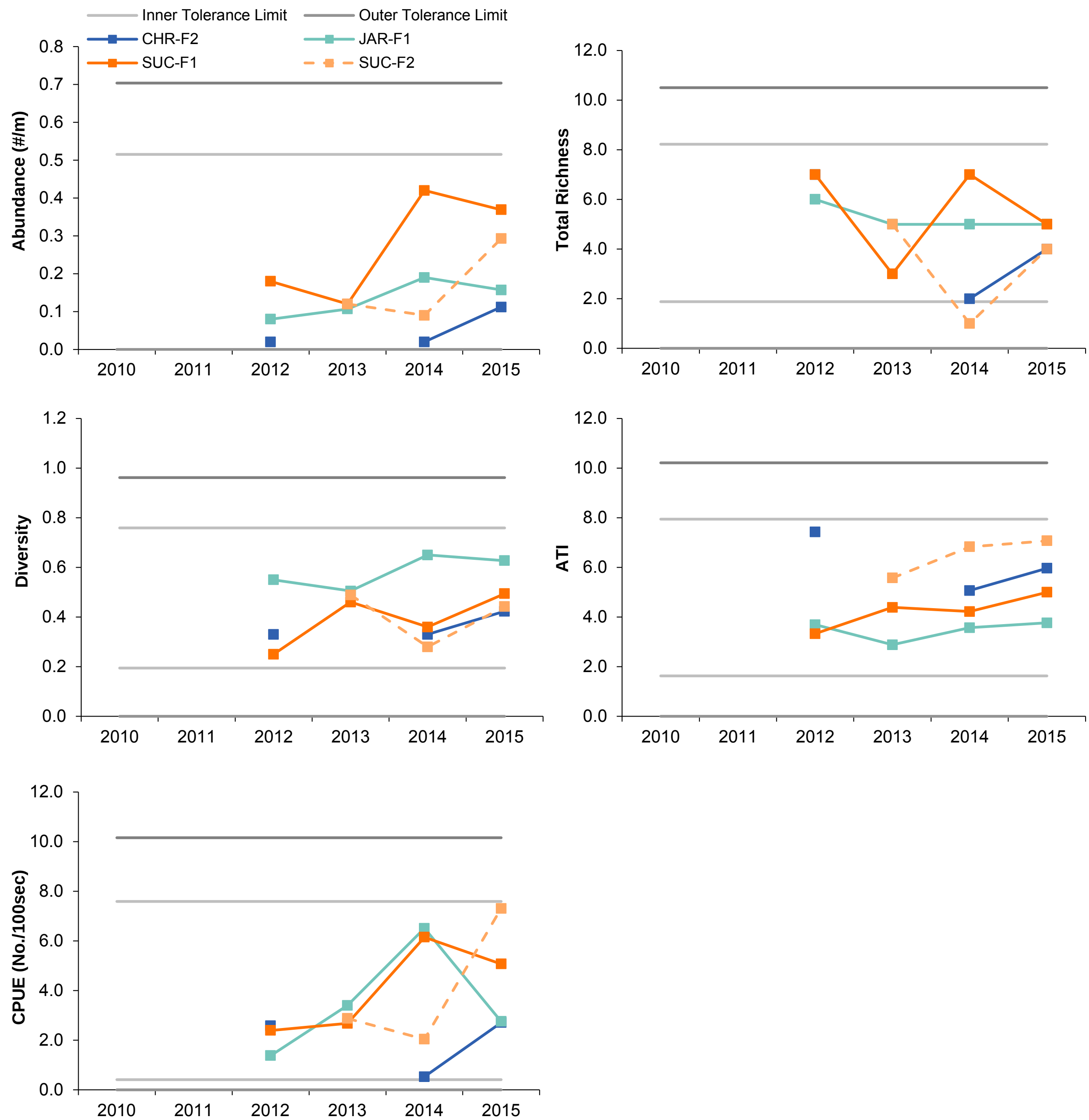
Bold values indicate significant difference (p≤0.05).

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

*indicates data were log-transformed to meet assumptions of ANOVA.

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Figure 5.10-48 Variation in fish community measurement endpoints for *test* reach CHR-F2 in the Christina River, *test* reach JAR-F1 in the Jackfish River, and *test* reach SUC-F1 and *baseline* reach SUC-F2 in Sunday Creek from 2012 to 2015, relative to regional *baseline* conditions.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from cluster 3 (Table 3.2-10).

A dotted line denotes a *baseline* reach; a solid line denotes a *test* reach.

Table 5.10-79 Average habitat characteristics of fish community monitoring *test* reach JAR-F1 of the Jackfish River, fall 2015.

Variable	Units	JAR-F1 *Test* Reach
Sample date	-	September 20, 2015
Habitat type	-	riffle/run
Maximum depth	m	0.70
Mean depth	m	0.39
Bankfull channel width	m	36.5
Wetted channel width	m	33.8
Substrate		
Dominant	-	coarse gravel
Subdominant	-	fine gravel, sand
Instream cover		
Dominant	-	macrophytes
Subdominant	-	filamentous algae, boulders
Field water quality		
Dissolved oxygen (DO)	mg/L	8.6
Conductivity	µS/cm	178
pH	pH units	8.05
Water temperature	^{0}C	11.6
Water velocity		
Left bank velocity	m/s	0.39
Left bank water depth	m	0.46
Centre of channel velocity	m/s	0.21
Centre of channel water depth	m	0.44
Right bank velocity	m/s	0.29
Right bank water depth	m	0.33
Riparian cover – understory (<5 m)		
Dominant	-	woody shrubs and saplings, overhanging vegetation
Subdominant	-	-

Table 5.10-80 Total number and percent composition of fish species captured in tributaries of the Christina River, 2012 to 2015.

Common Name	Code	Total Species				Percent of Total Catch			
		JAR-F1				JAR-F1			
		2012	2013	2014	2015	2012	2013	2014	2015
Arctic grayling	ARGR	-	-	1	-	0	0	0.6	0
brook stickleback	BRST	-	-	-	-	0	0	0	0
burbot	BURB	12	47	83	31	48.0	61.0	46.4	44.928
flathead chub	FLCH	-	-	-	-	0	0	0	0
fathead minnow	FTMN	-	-	-	-	0	0	0	0
finescale dace	FNDC	-	-	-	-	0	0	0	0
goldeye	GOLD	-	-	-	-	0	0	0	0
Iowa darter	IWDR	-	-	-	-	0	0	0	0
lake chub	LKCH	-	-	-	-	0	0	0	0
lake whitefish	LKWH	-	-	-	-	0	0	0	0
longnose dace	LNDC	2	8	21	6	8.0	10.4	11.7	8.6957
longnose sucker	LNSC	1	4	8	9	4.0	5.2	4.5	13.043
northern pike	NRPK	1	-	4	8	4.0	0	2.2	11.594
northern redbelly dace	NRDC	-	-	-	-	0	0	0	0
pearl dace	PRDC	-	-	-	-	0	0	0	0
slimy sculpin	SLSC	6	17	52	15	24.0	22.1	29.1	21.739
spoonhead sculpin	SPSC	-	-	-	-	0	0	0	0
spottail shiner	SPSH	-	-	-	-	0	0	0	0
trout-perch	TRPR	-	1	-	-	0	1.3	0	0
walleye	WALL	-	-	4	-	0	0	2.2	0
white sucker	WHSC	3	-	6	-	12.0	0	3.4	0
Total		**25**	**77**	**179**	**69**	**100**	**100**	**179**	**100**
Total Species Richness		**6**	**5**	**8**	**5**	**6**	**5**	**8**	**5**
Electrofishing effort (secs)		**1,803**	**2,265**	**2,587**	**1,242**	-	-	-	-

Table 5.10-81 Results of analysis of variance (ANOVA) testing for temporal differences in fish community measurement endpoints for *test* reach JAR-F1 in the Jackfish River.

Measurement Endpoint	P-value	Variance Explained (%)	Nature of Change(s)
	Time Trend	Time Trend	
Abundance	0.22	4%	No change.
Richness	0.10	10%	No change.
Diversity	0.10	10%	No change.
ATI	0.47*	0%	No change.
CPUE (No./100 sec)	0.19	4%	No change.

Bold values indicate significant difference (p≤0.05).

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

* indicates data were log-transformed to meet assumptions of ANOVA.

Shading denotes significant differences with >20% variance, which is considered a strong signal in the comparison of time trends to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Table 5.10-82 Average habitat characteristics of fish community monitoring reaches in tributaries of Christina Lake, fall 2015.

Variable	Units	SUC-F1 Lower *Test* Reach of Sunday Creek	SUC-F2 Upper *Baseline* Reach of Sunday Creek	BRC-F1 *Baseline* Reach of Birch Creek	SAC-F1 *Test* Reach of Sawbones Creek	UNC-F2 *Test* Reach of Unnamed Creek east of Christina Lake	UNC-F3 *Test* Reach of Unnamed Creek south of Christina Lake
Sample date	-	Sept 24, 2015	Sept 20, 2015	Sept 20, 2015	Sept 21, 2015	Sept 21, 2015	Sept 24, 2015
Habitat type	-	glide	glide, impoundment pool	glide	glide	glide	Glide
Maximum depth	m	0.58	1.20	0.46	2.20	1.20	0.88
Mean depth	m	0.41	0.59	0.34	1.46	0.96	0.43
Bankfull channel width	m	10.0	8.55	9.0	6.7	6.75	4.8
Wetted channel width	m	9.7	7.55	6.53	6.7	7.95	4.1
Substrate							
Dominant	-	cobble	fines	sand	fines	fines	fines
Subdominant	-	sand	sand	fines	sand	sand	sand
Instream cover							
Dominant	-	filamentous algae, macrophytes, small woody debris, live trees/roots, overhanging vegetation, boulders	macrophytes, large/small woody debris	overhanging vegetation	macrophytes, undercut banks	macrophytes	macrophytes
Subdominant	-	-	overhanging vegetation, undercut banks	macrophytes, undercut banks, large woody debris	overhanging vegetation, small woody debris	small woody debris, undercut banks, overhanging vegetation	filamentous algae, overhanging vegetation
Field water quality							
Dissolved oxygen (DO)	mg/L	10.0	9.2	8.4	7.8	8.4	9.7
Conductivity	µS/cm	232	198	335	-	177	187
pH	pH units	7.54	7.29	8.04	7.68	7.41	7.62
Water temperature	^{0}C	9.4	9.9	11.4	9.4	8.2	10.5
Water velocity							
Left bank velocity	m/s	0.03	0.09	0.00	0.07	-	0.01
Left bank water depth	m	0.18	0.66	0.44	0.92	-	0.19
Centre of channel velocity	m/s	0.21	0.56	0.00	0.07	0.05	0.05
Centre of channel water depth	m	0.32	0.61	0.64	1.60	0.90	0.46
Right bank velocity	m/s	0.17	0.01	0.00	0.08	0.03	0.03
Right bank water depth	m	0.58	0.68	0.77	1.75	0.90	0.48
Riparian cover – understory (<5 m)							
Dominant	-	overhanging vegetation	woody shrubs and saplings	woody shrubs and saplings	woody shrubs and saplings	overhanging vegetation	overhanging vegetation
Subdominant	-	woody shrubs and saplings	overhanging vegetation	overhanging vegetation	-	-	-

Table 5.10-83 Total number and percent composition of fish species captured in tributaries of the Christina River, 2012 to 2015.

Common Name	Code	Total Species																					
		SUC-F1				SUC-F2			SAC-F1				UNC-F2			UNC-F3			BRC-F1		
		2012	2013	2014	2015	2013	2014	2015	2012	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Arctic grayling	ARGR	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
brook stickleback	BRST	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
burbot	BURB	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iowa darter	IWDR	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
lake chub	LKCH	2	-	2	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
longnose sucker	LNSC	1	-	2	4	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
northern pike	NRPK	2	-	1	-	1	-	-	1	-	-	-	-	2	1	3	5	6	-	-	-
pearl dace	PRDC	1	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
slimy sculpin	SLSC	36	39	58	44	18	2	10	-	-	-	-	-	-	-	-	-	-	-	1	2
spottail shiner	SPSH	-	-	27	-	-	-	49	-	-	-	-	-	-	-	-	-	-	-	-	-
white sucker	WHSC	-	8	2	13	14	24	28	-	-	-	-	1	-	-	1	3	1	6	-	-
sucker sp. *	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Total		**44**	**60**	**94**	**72**	**36**	**26**	**88**	**1**	**0**	**0**	**0**	**1**	**2**	**1**	**5**	**8**	**7**	**8**	**1**	**2**
Total Species Richness		**6**	**3**	**7**	**5**	**5**	**2**	**4**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**3**	**2**	**2**	**1**	**1**	**1**
Electrofishing effort (secs)		**1,784**	**1,252**	**2,049**	**1,420**	**2,246**	**1,272**	**1,341**	**1,635**	**1,328**	**1,268**	**1,223**	**1,334**	**1,326**	**1,284**	**1,224**	**1,272**	**1,891**	**2,006**	**1,252**	**1,241**

* not included in total species richness count

Table 5.10-84 Total percent composition of fish species captured in tributaries of the Christina River, 2012 to 2015.

Common Name	Code	Percent of Total Catch																					
		SUC-F1				SUC-F2			SAC-F1				UNC-F2			UNC-F3			BRC-F1		
		2012	2013	2014	2015	2013	2014	2015	2012	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Arctic grayling	ARGR	2.3	0	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
brook stickleback	BRST	0	0	0	0	5.6	0	1.1364	0	0	0	0	0	0	0	0	0	0	0	0	0
burbot	BURB	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iowa darter	IWDR	0	0	0	0	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lake chub	LKCH	4.5	0	2.1	13.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
longnose sucker	LNSC	2.3	0	2.1	5.6	0	0	0	0	0	0	0	0	0	0	20.0	0	0	0	0	0
northern pike	NRPK	4.5	0	1.1	0.0	2.8	0	0	100.0	0	0	0	0	100	100	60.0	62.5	85.7	0	0	0
pearl dace	PRDC	2.3	20.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
slimy sculpin	SLSC	81.8	65.0	61.7	61.1	50.0	7.7	11.4	0	0	0	0	0	0	0	0	0	0	0	100	100
spottail shiner	SPSH	0	0	28.7	0.0	0	0	55.7	0	0	0	0	0	0	0	0	0	0	0	0	0
white sucker	WHSC	0	13.3	2.1	18.1	38.9	92.3	31.8	0	0	0	0	100	0	0	20.0	37.5	14.3	75	0	0
sucker sp. *	-	2.3	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0		25	0	0
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**0**	**0**	**0**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Total Species Richness		**6**	**3**	**7**	**5**	**5**	**2**	**4**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**3**	**2**	**2**	**1**	**1**	1
Electrofishing effort (secs)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* not included in total species richness count

Table 5.10-85 Results of analysis of variance (ANOVA) testing for differences in fish community measurement endpoints for *test* reach SUC-F1 and *baseline* reach SUC-F2 in Sunday Creek.

Measurement Endpoint	P-value			Variance Explained (%)			Nature of Change(s)
	Time Trend (*Test* Reach)	Time Trend (*Baseline* Reach)	*Test* Reach vs. *Baseline* Reach	Time Trend (*Test* Reach)	Time Trend (*Baseline* Reach)	*Test* Reach vs. *Baseline* Reach	
Abundance	**0.001***	**0.004**	0.58*	46%	43%	0%	Increasing over time.
Richness	**0.02**	0.74	0.16	24%	0%	4%	Increasing over time.
Diversity	0.07	0.75	0.68*	12%	0%	0%	No change.
ATI	0.08*	0.08	0.40*	11%	16%	0%	No change.
CPUE (No./100 sec)	**0.04**	**0.03***	0.67*	17%	28%	0%	Increasing over time.

Bold values indicate significant difference (p≤0.05).

ATI = assemblage tolerance index, CPUE = catch-per-unit-effort

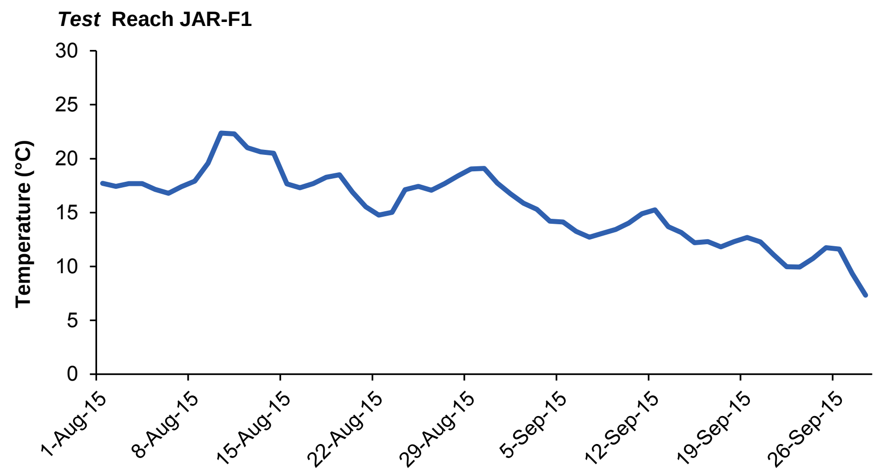
* Denotes data were log transformed to meet assumptions of ANOVA.

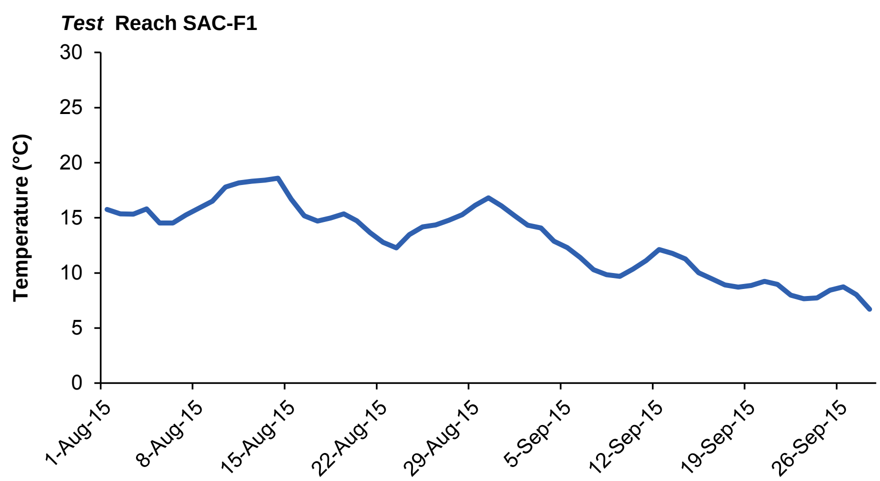
Shading denotes significant differences with >20% variance, which is considered a strong signal in spatial and temporal comparisons to classify results as Negligible-Low; Moderate; or High (Table 3.2-12).

Table 5.10-86 Average habitat characteristics of wild fish health monitoring reaches in the Christina watershed, fall 2015.

Watercourse	Units	JAR-F1 *Test* Reach	SAC-F1 *Test* Reach	SUC-F1 *Test* Reach
Sample date	-	Sept. 28, 2015	Sept. 28, 2015	Sept. 30, 2015
Mean water depth	m	0.5	1.5	0.11
Mean velocity	m/s	0.2	0.02	0.49
Field water quality				
Water temperature	°C	5.4	5.5	9.4
Conductivity	µS/cm	223	148	232
Dissolved oxygen (DO)	mg/L	9.6	7.6	10.0
pH	pH units	8.36	7.33	7.54
Substrate	-	cobble/boulder	sand	cobble/sand/fines

Figure 5.10-49 Daily mean temperatures for wild fish health *test* reaches JAR-F1, SAC-F1, and SUC-F1 in the Christina River watershed, August to September 2015.





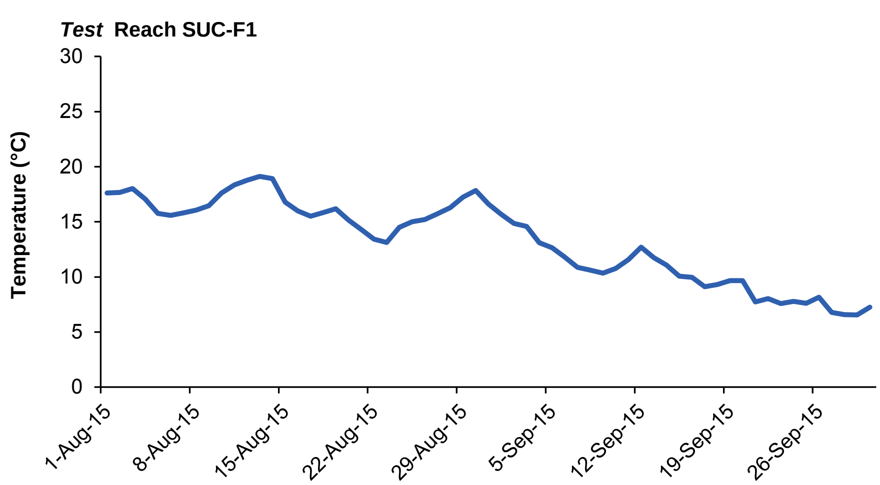
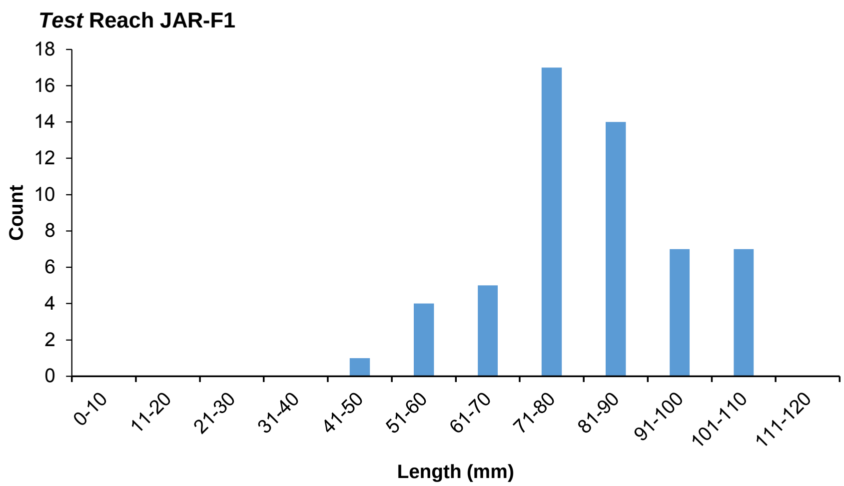


Table 5.10-87 Summary of slimy sculpin caught and mean length, weight and relative abundance of juveniles in reaches of the Christina River watershed, fall 2015.

Reach	Designation	Sample Size		Relative Abundance (%)		Juvenile Measurements		Percentage of External Abnormalities
		Juvenile	Adult	Juvenile	Adult	Mean Length (mm)	Mean Weight (g)	
JAR-F1	*test* reach	0	55	0	100	-	-	3.6
SUC-F1	*test* reach	80	59	57.6	42.4	42.3	0.83	0

Figure 5.10-50 Length-frequency distributions of slimy sculpin in wild fish health *test* reaches JAR-F1 and SUC-F1 in the Christina River watershed, fall 2015.



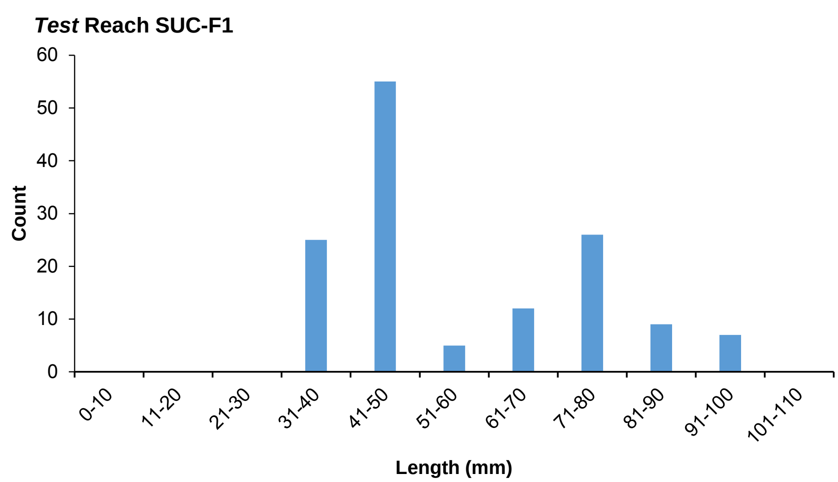


Table 5.10-88 Summary of morphometric data (mean ± 1SE) for slimy sculpin in *test* reaches JAR-F1 and SUC-F1 in the Christina River watershed, fall 2015.

Reach	Units	JAR-F1 *Test* Reach		SUC-F1 Lower *Test* Reach	
n	-	19	20	20	20
Sex	-	Male	Female	Male	Female
Age	years	1.5 ± 0.3	1.7 ± 0.3	1.6 ± 0.2	2.2 ± 0.3
Length	mm	87.47 ± 2.06	79.95 ± 2.89	78.95 ± 1.96	75.65 ± 2.84
Weight	g	7.51 ± 0.65	5.77 ± 0.67	5.33 ± 0.47	4.42 ± 0.47
K	-	1.08 ± 0.02	1.05 ± 0.01	1.04 ± 0.02	0.95 ± 0.02
GSI	-	1.50 ± 0.15	0.89 ± 0.02	1.63 ± 0.09	1.51 ± 0.13
LSI	-	0.83 ± 0.05	1.14 ± 0.07	0.90 ± 0.08	1.07 ± 0.12

K = condition, GSI = gonadosomatic index, LSI = liversomatic index

Figure 5.10-51 Relative age-frequency distributions for slimy sculpin at *test* reaches JAR-F1 and SUC-F1 within the Christina River Watershed, fall 2015.

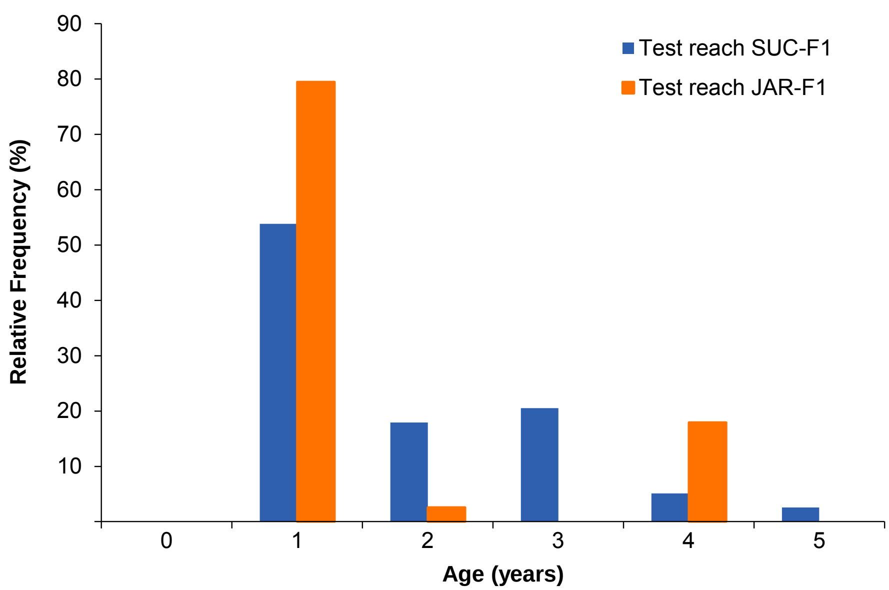


Figure 5.10-52 Relationship between age (years) and body weight (g) of female and male slimy sculpin captured at *test* reach JAR-F1, fall 2015.

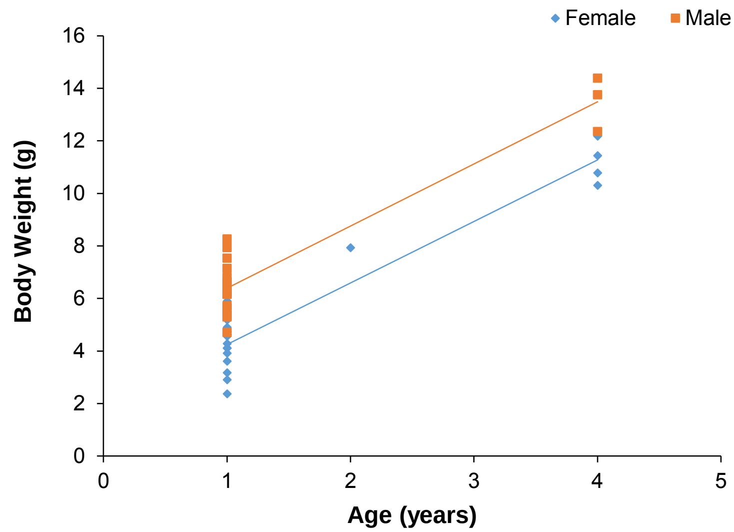


Figure 5.10-53 Mean EROD activity (± 1SE) of female and male slimy sculpin at *test* reach SUC-F1 and *test* reach JAR-F1 in the Christina River Watershed, fall 2015.

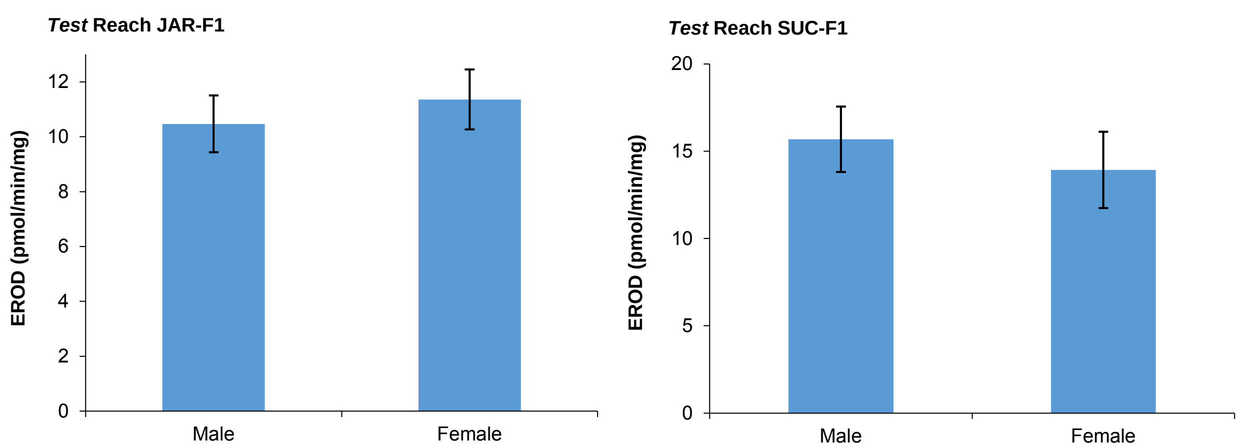
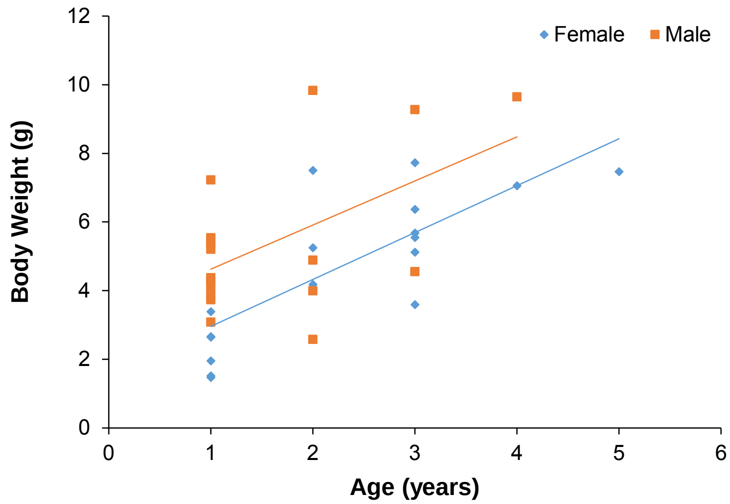


Figure 5.10-54 Relationship between age (years) and body weight (g) of female and male slimy sculpin captured at *test* reach SUC-F1, fall 2015.



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5.11 HANGINGSTONE RIVER WATERSHED

Table 5.11-1 Summary of results for the Hangingstone River watershed.

Hangingstone River Watershed	Summary of 2015 Conditions		
Climate and Hydrology			
Criteria	**07CD004**	no station	**S31**
Mean open-water season discharge	🟡	-	not measured
Mean winter discharge	🟡	-	not measured
Annual maximum daily discharge	🟡	-	not measured
Minimum open-water season discharge	🟡	-	not measured
Water Quality			
Criteria	**HA1**	**HAR-1**	no station
Water Quality Index	🟠	🟡	-
Benthic Invertebrate Communities and Sediment Quality			
Criteria	no reach	**HAR-E1**	no reach
Benthic Invertebrate Communities	-	🟡	-
Sediment Quality Index	No Sediment Quality monitoring was conducted in the 2015 WY.		
Fish Populations			
Criteria	no reach	**HAR-F1**	no reach
Fish Communities	No Fish Communities monitoring was conducted in the 2015 WY.		
Wild Fish Health	-	n/a	-

Legend and Notes

- 🟡 Negligible - Low
- 🟠 Moderate
- 🟤 High

baseline

test

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

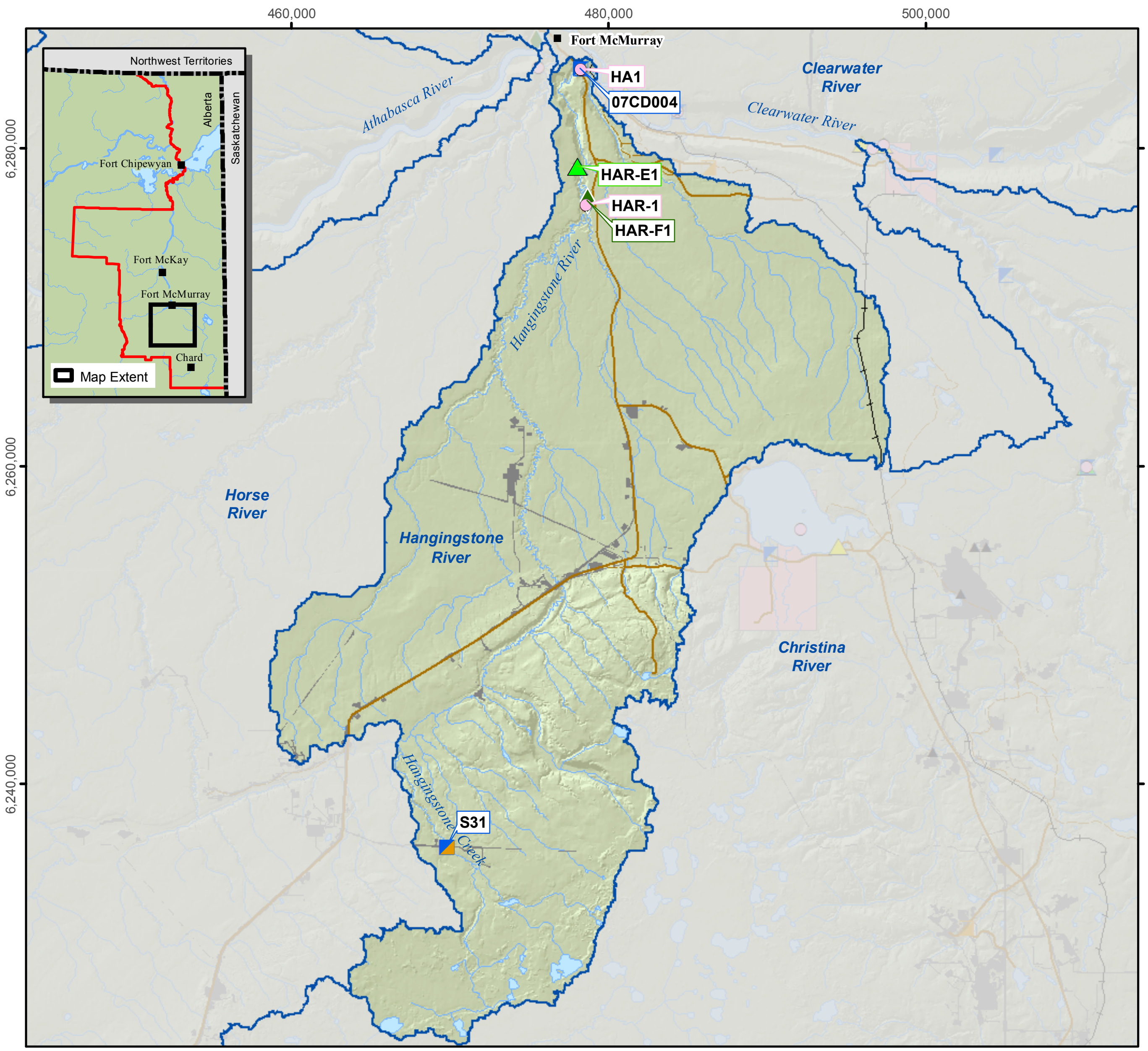
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Fish Populations (Wild Fish Health): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.2 for a detailed description of the classification methodology.

Figure 5.11-1 Hangingstone River watershed.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]
- Water Withdrawal Location
- Water Release Location
- Water Quality Station
- Data Sonde Station
- Hydrometric Station
- Climate Station
- Benthic Invertebrate Communities Reach
- Benthic Invertebrate Communities Reach and Sediment Quality Station
- Fish Community Reach
- Wild Fish Health Reach
- Wild Fish Health Reach with Water and Sediment Quality Stations

0 2.5 5 10 km

N

Scale: 1:400,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

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Figure 5.11-2 Representative monitoring stations of the Hangingstone River watershed, fall 2015.

Hydrology Station S31: Hangingstone Creek at North Star Road, facing upstream

Water Quality Station HA1: Hangingstone River near the mouth, facing downstream

Benthic Invertebrate Communities Station HAR-F1: Hangingstone River, facing downstream

Fish Health Reach HAR-F1: Hangingstone River, facing downstream

5.11.1 Summary of 2015 WY Conditions

Approximately 1% (1,533 ha) of the Hangingstone River watershed had undergone land change from oil sands development as of 2015 (Table 2.3-1). Land change has occurred in the upper portion of the watershed related to the JACOS Hangingstone project; therefore, the majority of the watershed is designated as *test*.

Monitoring activities were conducted in the Hangingstone River watershed in the 2015 WY for the Climate and Hydrology, Water Quality, Benthic Invertebrate Communities, and Fish Population components. Table 5.11-1 is a summary of the 2015 assessment of the Hangingstone River watershed, while Figure 5.11-1 provides the location of the monitoring stations for each component and the locations of the areas with land change as of 2015. Figure 5.11-2 contains fall 2015 photos of representative monitoring stations in the watershed.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Hydrology For the 2015 WY, the differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrograph for the Hangingstone River were all 0.30%. These differences were classified as **Negligible-Low**.

Water Quality Monthly variation in water quality showed similar trends at both *test* stations HAR-1 and HA1, with concentrations of TSS and several associated nutrients and metals highest during freshet and lowest in September/October at open-water low flows, and TDS and most dissolved ions and metals showing an inverse relationship with flow. Generally, concentrations of most water quality measurement endpoints were higher at lower *test* station HA1 than at upper *test* station HAR-1. Monthly water quality measurement endpoints at both stations were within the historical monthly ranges. Concentrations of all water quality measurement endpoints in fall 2015 were lower or within the previously-measured ranges except chloride at both stations (higher than previous observations), and naphthenic acids, oilsands extractable acids, and total alkylated PAHs at *test* station HAR-1 (lower than previous observations). Similarly, concentrations of all water quality measurement endpoints were within the regional *baseline* concentrations with few exceptions. Significant increases in fall concentrations of sodium and chloride from 2003 to 2015 were observed at *test* station HAR-1. Ionic composition of water at both stations was similar to previous years. Based on WQI values, differences in water quality in fall 2015 between *test* stations and the regional *baseline* fall conditions were classified as **Moderate** for *test* station HA1 and **Negligible-Low** for *test* station HAR-1. Variables that exceeded water quality guidelines included dissolved iron, total phenols, and sulphide at both stations, consistent with historical observations by the RAMP and JOSMP at these locations

Benthic Invertebrate Communities Variations in the values of measurement endpoints for benthic invertebrate communities of the Hangingstone River at *test* reach HAR-E1 for fall 2015 were classified as **Negligible-Low** because values of all six benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of *baseline* values for erosional habitats. In addition, the benthic invertebrate community in fall 2015 contained numerous taxa associated with good environmental conditions including a diverse and rich fauna.

Fish Populations (Wild Fish Health) Longnose dace was identified as the target species at *test* reach HAR-F1 on the Hangingstone River. Because an upstream *baseline* reach on the Hangingstone River was not sampled in 2015, quantitative comparisons for assessing potential effects could not be conducted. To provide context to the results for *test* reach HAR-F1, qualitative comparisons of measurement endpoints were made with *baseline* reach MR-U on the MacKay River. These comparisons indicated that longnose dace at *test* reach HAR-F1 were relatively younger with smaller relative gonad and liver sizes than longnose dace from *baseline* reach MR-U. Temporal comparisons were not possible because 2015 was the first year of fish health monitoring at *test* reach HAR-F1.

5.11.2 Hydrologic Conditions

Hydrometric monitoring for the Hangingstone River watershed in the 2015 WY was conducted at the following locations:

- WSC Station 07CD004, Hangingstone River at Fort McMurray; and
- JOSMP Station S31, Hangingstone Creek at North Star Road.

Discharge data from WSC Station 07CD004 were used for the water balance analysis and are presented below; data from Station S31 are provided in Appendix C.

Seasonal data from March to October have been collected at WSC Station 07CD004 every year since 1970 and sporadically between 1965 and 1969. Winter data (November to February) were also collected from 1970 to 1986.

The historical flow record for WSC Station 07CD004 is summarized in Figure 5.11-3 and includes the median, interquartile, and range of flows recorded daily through the water year. Flows of the Hangingstone River have a seasonal runoff pattern characteristic of a northern environment, with flows typically lower in winter than during the open-water season, and generally decreasing from November until early March. Spring thaw and the resulting rapid increase in flows typically begins in late March and continues through April. Monthly flows are highest during May at the peak of freshet and remain elevated in June and July when total monthly rainfall are highest. Flows then generally recede from August until the end of October in response to declining rainfall inputs and eventually river freeze-up.

While the pattern of flow of the Hangingstone River in the 2015 WY was similar to the historical seasonal pattern described above (Figure 5.11-3), flows from late November to the beginning of freshet in mid-March were generally lower than the median historical flow and discharge from late November to mid-January was lower than the historical minimum flow. An increase in flow due to spring thaw occurred in mid-March and the timing of the initiation of freshet was earlier than normal. The annual peak flow of 4.51 m^3/s, recorded on May 4, was 90% lower than the historical mean annual maximum daily flow of 44.0 m^3/s. Flows generally decreased through summer and early fall, and were generally below historical lower quartile flows for this period. Several runoff responses to rainfall occurred in summer, which temporarily increased flows above historical lower quartile flows. The minimum open-water daily flow of 0.46 m^3/s was recorded on August 28, which was 51% lower than the historical mean minimum daily flow of 0.93 m^3/s, calculated for the open-water period.

The 2015 water year runoff volume recorded at WSC Station 07CD004 was 35.9 million m^3, which is 70% lower than the historical mean water year runoff volume of 119.4 million m^3.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance at WSC Station 07CD004 is summarized in Table 5.11-2. Key changes in flows in the 2015 WY included:

1. The closed-circuited land area as of 2015 in the Hangingstone River watershed was estimated to be 0.16 km^2 (Table 2.3-1). The loss of flow to the Hangingstone River that would have otherwise occurred from this land area was estimated at 0.006 million m^3.

2. As of 2015, the area of land change in the Hangingstone watershed that was not closed-circuited was estimated to be 15.2 km^2 (Table 2.3-1). The increase in flow to the Hangingstone River that would not have otherwise occurred was estimated at 0.113 million m^3.

No oil sands-related water releases or withdrawals were reported within the Hangingstone River watershed in the 2015 WY, and all other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2015 WY was an increase in flow of 0.107 million m^3 to the Hangingstone River. For the 2015 WY, the differences in mean open-water discharge, mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge between the observed *test* and estimated *baseline* hydrograph for the Hangingstone River were all +0.30%. These differences were classified as **Negligible-Low** (Table 5.11-3). A spatial analysis to identify the longitudinal hydrological effects along the Hangingstone River was not conducted because the differences in the value of all measurement endpoints between *test* and *baseline* conditions were classified as **Negligible-Low**.

5.11.3 Water Quality

Water quality samples were taken in the 2015 WY from:

- the Hangingstone River near its mouth (lower *test* station HA1, previously called HAR-1A), sampled in the fall season since 2013. This station was sampled monthly from May to October in 2015; and
- the Hangingstone River above Fort McMurray (upper *test* station HAR-1), sampled seasonally from 2004 to 2007 and in the fall season in 2008, 2013, and 2014. This station was sampled monthly from May to October in 2015.

Monthly variations in water quality are summarized in Table 5.11-4, Table 5.11-5 and Figure 5.11-4. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations are provided in Table 5.11-6 and Table 5.11-7. The ionic composition of water in the Hangingstone River is presented in Figure 5.11-5. Water quality guideline exceedances for water quality measurement endpoints are presented in Table 5.11-8 and Figure 5.11-6 presents a comparison of selected water quality measurement endpoints in the Hangingstone River relative to historical regional *baseline* concentrations.

Monthly Variations in Water Quality Monthly data collected from May to October indicate clear and similar temporal trends for most water quality measurement endpoints at lower *test* station HA1 and upper *test* station HAR-1 (Table 5.11-4, Table 5.11-5, Figure 5.11-4). Concentrations of TSS and associated nutrients and some particulate-associated metals (i.e., total mercury and arsenic) were typically highest during freshet (May and June) at both stations while concentrations of TDS and most dissolved ions and metals (including boron and strontium) were highest in September and October during low open-water flows. Concentrations of PAHs were also highest during freshet. Generally, concentrations of most water quality measurement endpoints were higher at lower *test* station HA1 than at upper *test* station HAR-1. Monthly concentrations of water quality measurement endpoints at lower *test* station HA1 in the 2015 WY were similar to historical seasonal concentrations at this station (Figure 5.11-4).

2015 Fall Results Relative to Historical Concentrations Concentrations of all water quality measurement endpoints in fall 2015 were within previously-measured concentrations (Table 5.11-6, Table 5.11-7) with the exception of:

- chloride, with a concentration that exceeded the previously-measured maximum concentration at lower *test* station HA1 (historical data are limited to 2013 and 2014 for this station);

- TSS, TDS, pH, calcium, potassium, total and dissolved aluminum, total arsenic, naphthenic acids, retene, total dibenzothiophenes, total parent PAHs, and total alkylated PAHs, with concentrations that were lower than previously-measured minimum concentrations at lower *test* station HA1 (waterborne naphthenic acids and PAHs have only been measured at current, ultra-trace detection limits since 2011, and that historical comparisons of 2015 data for these measurement endpoints are limited to 2013 and 2014 data);

- chloride, naphthenic acids, oilsands extractable acids, and total alkylated PAHs, with concentrations that exceeded previously-measured maximum concentrations at upper *test* station HAR-1 (historical data are limited to 2013 and 2014 for this station); and

- total dissolved phosphorus and total aluminum, with concentrations that were lower than previously-measured minimum concentrations at upper *test* station HAR-1.

Temporal Trends Significant ($p<0.05$) increases in fall concentrations of sodium and chloride were detected at *test* station HAR-1 from 2004 to 2015; no other significant trends were detected. Trend analysis was not conducted for lower *test* station HA1 because the length of the times series of available water quality data was insufficient for the statistical tests to be conducted.

Ion Balance The ionic composition of water was similar at lower *test* station HA1 and upper *test* station HAR-1 and consistent with previous years. The ionic composition at both stations was equally contributed by calcium and magnesium as cations and bicarbonate as the dominant anion (Figure 5.11-5).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Water quality guideline exceedances measured in the Hangingstone River in the 2015 WY (Table 5.11-8) were:

- dissolved iron at lower *test* station HA1 (May) and upper *test* station HAR-1 (May and August);

- total phenols at lower *test* station HA1 (June to October) and *test* station HAR-1 (May to October); and

- sulphide at upper *test* station HA1 (May to October) and upper *test* station HAR-1 (May to September).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of water quality measurement endpoints at lower *test* station HA1 and upper *test* station HAR-1 in fall 2015 were within regional *baseline* concentrations, with the following exceptions (Figure 5.11-6):

- total boron, total strontium, and calcium at lower *test* station HA1, and sodium, chloride, and sulphate at both lower *test* station HA1 and upper *test* station HAR-1 with concentrations that exceeded the 95th percentile of regional *baseline* concentrations; and

- total dissolved phosphorus, with a concentration below the 5th percentile of regional *baseline* concentrations at lower *test* station HA1.

Water Quality Index The WQI values for lower *test* station HA1 (76.1) and upper *test* station HAR-1 (85.2) indicate **Moderate** and **Negligible-Low** differences, respectively, from regional *baseline* water quality conditions. The water quality index at upper *test* station HAR-1 has improved since 2014 when this station was classified as **Moderate**.

Classification of Fall Results Differences in water quality in fall 2015 between *test* stations and the regional *baseline* fall conditions were classified as **Moderate** for lower *test* station HA1 and **Negligible-Low** for upper *test* station HAR-1.

5.11.4 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 in the Hangingstone River at the erosional *test* reach HAR-E1, which was classified as *baseline* from 2004 to 2008 (Neil-Hess cylinder in riffles), and *test* since 2015 (Kicknet in riffles). Values of benthic invertebrate community measurement endpoints for 2015 were "adjusted" as per the equations in Appendix D to make them comparable to data collected with a Neil-Hess cylinder.

2015 Habitat Conditions Water at *test* reach HAR-E1 in fall of 2015 was shallow (0.2 m), alkaline (pH 8.7), with high conductivity (387 µS/cm) and high concentration of dissolved oxygen (10.0 mg/L) (Table 5.11-9). The substrate was dominated by small cobbles. Full CABIN-supporting data are provided in Appendix D.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach HAR-E1 in fall 2015 was primarily comprised of chironomids (24%), mayflies (23%), and naidid worms (21%), with caddisflies (14%) as subdominant taxa (Table 5.11-10). Chironomids were dominated by *Tvetenia* with *Thienemannimyia gr.*, *Rheotanytarsus*, and *Orthocladius*. Ephemeroptera consisted primarily of the mayfly *Ephemerella*, with *Baetis* the subdominant genus, and Trichoptera consisted primarily of the caddisflies *Hydropsyche* and *Hydroptila,* with *Psychomyia*. Other larvae of flying insects included stoneflies (Chloroperlidae, Perlidae, *Acroneuria*, Perlodidae*, Pteronarcys*, *Taeniopteryx*) and dragonflies (*Ophiogomphus*). Permanent aquatic forms were represented at *test* reach HAR-E1 by the gastropod *Ferrissia*.

Temporal Comparisons *Test* reach HAR-E1 was designated as *baseline* from 2004 to 2008 and sampled with a Neil-Hess cylinder during that time. In 2015, HAR-E1 became a *test* reach and was sampled in fall 2015 using a Kicknet. Given that both the condition of the reach and the gear used to sample the reach HAR-E1 of the Hangingstone River changed in 2015 and because the sampling method was confounded with the change in designation, analysis of changes between *baseline* and *test* periods was not conducted.

Comparison to Published Guidelines The benthic invertebrate community of *test* reach HAR-E1 contained benthic fauna that generally reflected good environmental conditions. The mixture of EPT taxa, flying insects (Odonata), and permanent aquatic forms (Gastropoda) are indicative of favourable long-term water quality (Resh and Unzicker 1975; Niemi et al. 1990). The dominant chironomids, such as *Rheotanytarsus*, are known to represent fair to good water quality, being only moderately-tolerant of poor water (Mandeville 2002).

2015 Results Relative to Regional *Baseline* Conditions Values of benthic invertebrate community measurement endpoints were graphed to illustrate variations over time and, for 2015, were converted to "Neil-Hess cylinder" values using correction factors developed in Appendix D. Values of all six benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of *baseline* values for erosional habitats (Figure 5.11-7; Figure 5.11-8).

Classification of Results Variations in the values of measurement endpoints for benthic invertebrate communities of the Hangingstone River at *test* reach HAR-E1 for fall 2015 were classified as **Negligible-Low** because values of all six benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limits of the normal range of *baseline* values for erosional habitats. In addition, the benthic invertebrate community in fall 2015 contained numerous taxa associated with good environmental conditions including a diverse and rich fauna.

5.11.5 Fish Populations

5.11.5.1 Wild Fish Health

Wild fish health monitoring was conducted at *test* reach HAR-F1 in fall 2015 using longnose dace as the target species.

No upstream *baseline* reach was sampled in the Hangingstone River in 2015. In effort to provide some context to data collected at *test* reach HAR-F1, a *qualitative* comparison was made to data collected from the upstream *baseline* reach MR-U in the MacKay River, which is a *baseline* reach where longnose dace were also sampled in fall 2015 for wild fish health monitoring. Although both reaches are dominated by erosional habitat, it was recognized that the comparison is potentially confounded by differences in watersheds related to physical and chemical habitat conditions and biotic factors, and detailed quantitative comparisons were therefore not considered appropriate. As such, the results from the qualitative assessment should also be interpreted with caution.

Temporal comparisons were not possible with the data collected at *test* reach HAR-F1 in fall 2015 because 2015 was the first year of wild fish health monitoring at this reach

2015 Habitat Conditions In situ water quality at *test* reach HAR-F1 provided conditions suitable for longnose dace, with a concentration of dissolved oxygen of 9.6 mg/L; conductivity of 412 µS/cm; pH of 7.89, and a mean water depth of 0.35 m (Table 5.11-11). The substrate at *test* reach HAR-F1 consisted of fines and cobbles and daily mean water temperature decreased from a high of 26°C on August 30 to a low of 4°C on September 28 (Figure 5.11-9) and was 8.6°C when the field program was conducted.

Collection and Structure of Sentinel Species Populations

Summary of Capture Success of Adults and Juveniles The target number of adult longnose dace (20 of each sex) was achieved for males at *test* reach HAR-F1 but not for females as only six females were caught. The required number of 100 juvenile longnose dace was obtained. A summary of morphometric data for the lake chub caught in the Hangingstone River is provided in Table 5.11-12.

Size Distribution Figure 5.11-10 presents the length-frequency distribution of all longnose dace captured in fall 2015 at *test* reach HAR-F1. A length of 50 mm was used to designate longnose dace juveniles in the Hangingstone River as 50 mm marks the end of the first peak in the bimodal distribution of length (Figure 5.11-10). Length-frequency distributions were compared between *test* reach HAR-F1 and *baseline* reach MR-U (Figure 5.11-10).

The relative abundance of longnose dace juveniles in the total catch of longnose dace in fall 2015 at *test* reach HAR-F1 was larger than for the *baseline* reach MR-U (Table 5.11-12).

Incidence of abnormalities Parasites were the only abnormality observed in 2015, affecting 6% of the longnose dace that were captured (Table 5.11-12).

Spatial Comparison of Fish Responses

Figure 5.11-11 and the following information provides general comparisons of measurement endpoints for longnose dace between *test* reach HAR-F1 and *baseline* reach MR-U. Relative gonad size, relative liver size and condition were estimated by gonadosomatic index (GSI), liversomatic index (LSI), and condition factor (K), respectively.

Age – Mean Age and Age Distribution (Survival) The mean age of adult female longnose dace caught at *test* reach HAR-F1 was two years while the mean age of adult males was less than one year (Figure 5.11-11). The dominant age class was one year (Figure 5.11-12).

The mean age of adult longnose dace captured at *test* reach HAR-F1 was less than the mean age of adults captured for both males and females at *baseline* reach MR-U (Figure 5.11-11).

Growth – Size-at-Age (Energy Use) Female longnose dace at *test* reach HAR-F1 were consistently larger than males of the same age (Figure 5.11-13). The mean weight of the dominant age class of males (one year) was 2.26 g and the mean weight of the dominant age class of females (two years) was 6.80 g. While longnose dace at *test* reach HAR-F1 were heavier at age than *baseline* reach MR-U for both females and males (Figure 5.11-14), the fish captured at *baseline* reach MR-U were older than at *test* reach HAR-F1.

Relative Gonad Weight (Energy Use) The mean GSI of adult female and male longnose dace captured in fall 2015 at *test* reach HAR-F1 was 5.38 and 0.48, respectively, and the mean GSI of female and male longnose dace captured in fall 2015 at *test* reach HAR-F1 were less than the GSI of female and male longnose dace captured at the *baseline* reach MR-U in fall 2015 (Figure 5.11-11).

Relative Liver Weight (Energy Storage) The mean LSI of adult female and male longnose dace captured in fall 2015 at *test* reach HAR-F1 was 1.11 and 0.95, respectively, and the mean LSI of female and male longnose dace captured in fall 2015 at *test* reach HAR-F1 were less than the LSI of female and male longnose dace captured at the *baseline* reach MR-U in fall 2015 (Figure 5.11-11).

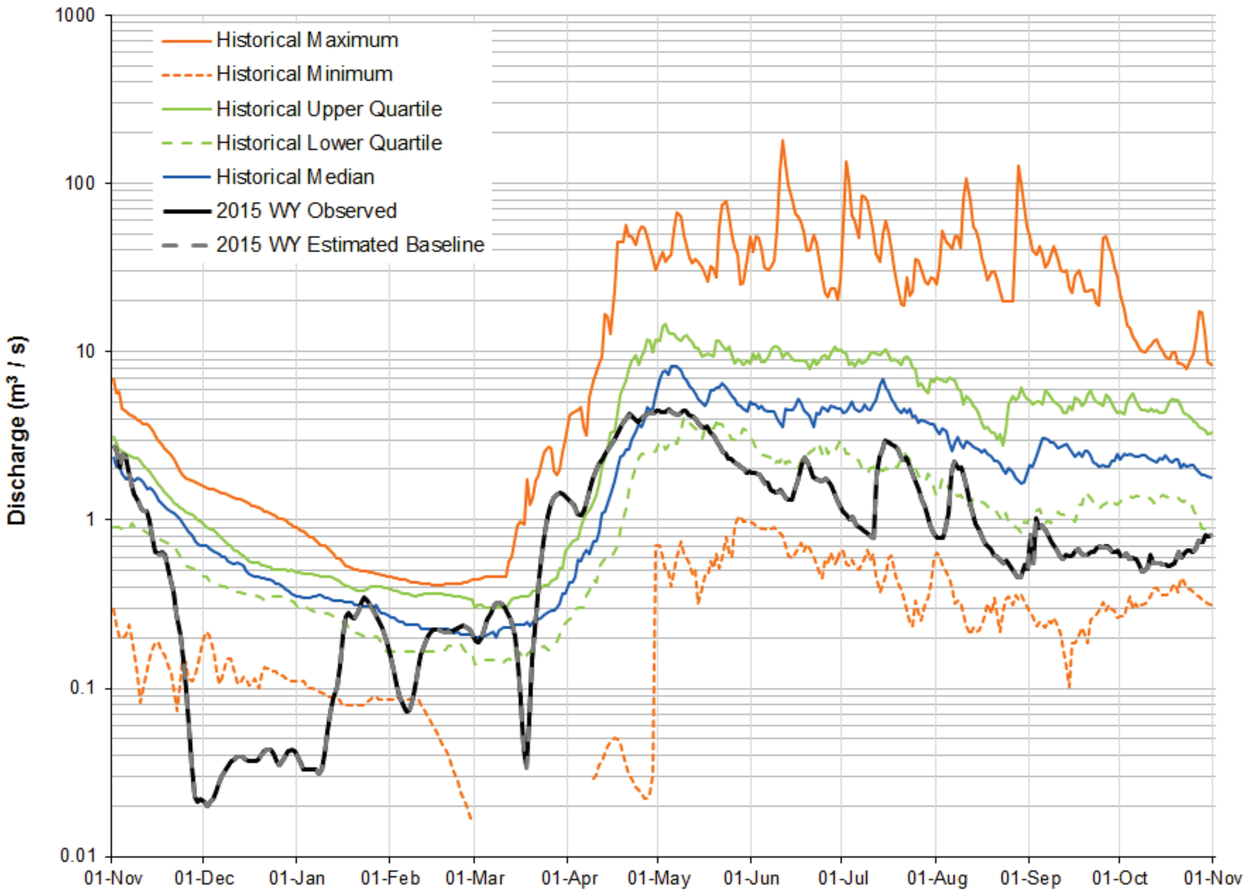
Condition (Energy Storage) The mean condition factor, of adult female and male longnose dace captured in fall 2015 at *test* reach HAR-F1 was 0.95 and 0.98, respectively, and the condition factor of female and male longnose dace captured in fall 2015 at *test* reach HAR-F1 was relatively similar than the condition factor of female and male longnose dace captured at the *baseline* reach MR-U in fall 2015 (Figure 5.11-11).

Exposure – Mixed Function Oxygenase (MFO) Activity The mean EROD activity of adult female and male longnose dace captured in fall 2015 at *test* reach HAR-F1 was 12.18 pmol/min/mm and 16.63 pmol/min/mm, respectively, and adult female and male longnose dace captured in fall 2015 at *test* reach HAR-F1 had a higher mean EROD activity than female and male longnose dace captured at *baseline* reach MR-U in fall 2015 (Figure 5.11-15).

Interpretation of 2015 Responses In general, longnose dace captured in fall 2015 at *test* reach HAR-F1 were younger with smaller relative gonad and liver sizes relative to longnose dace captured in fall 2015 at *baseline* reach MR-U. Differences in habitat do exist between HAR-F1 and *baseline* reach MR-U. Conductivity at *test* reach HAR-F1 was higher than at *baseline* reach MR-U and temperature and concentration of dissolved oxygen were lower at the time of field sampling (Table 5.11-11). In addition, substrate at *test* reach HAR-F1 was dominated by fines, while substrate at *baseline* reach MR-U was dominated by cobble. Longnose dace prefer rocky and gravel substrate, which may explain the lower catch of adults at *test* reach HAR-F1. Establishment of a *baseline* fish health monitoring reach on the Hangingstone River should be considered in future studies so that an effects assessment can be conducted for *test* reach HAR-F1.

Classification of Results Classification of results for fish health at *test* reach HAR-F1 was not possible because an upstream *baseline* reach was not sampled on the Hangingstone River in 2015 and quantitative comparisons of fish health on the Hangingstone River between *test* and *baseline* conditions could therefore not be made.

Figure 5.11-3 The observed (*test*) hydrograph and estimated *baseline* hydrograph for the Hangingstone River in the 2015 WY, compared to historical values.



Notes:

Observed 2015 WY hydrograph was based on data from the 2015 WY from Hangingstone River at Fort McMurray, WSC Station 07CD004. The upstream drainage area of WSC Station 07CD004 is 962 km^2, which is 10% smaller than the size of the entire Hangingstone River watershed (1,066 km^2). Historical values from March 1 to October 31 were calculated for the period from 1965 to 2014, and historical values for other months were calculated for the period from 1970 to 1987.

Historical minimum daily flows were zero from March 1 to April 8, and were not plotted due to the logarithmic axis used in the graph.

Table 5.11-2 Estimated water balance at WSC Station 07CD004, Hangingstone River at Fort McMurray, 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**35.910**	**Observed discharge, obtained from Hangingstone River at Fort McMurray, WSC Station 07CD004**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.006	Estimated 0.16 km^2 of Hangingstone River watershed closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.113	Estimated 15.2 km^2 of Hangingstone River watershed with land change as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Hangingstone River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Hangingstone River watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	0	None reported
The difference between observed and estimated hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**35.803**	**Estimated discharge at Hangingstone River at Fort McMurray, WSC Station 07CD004**
Incremental flow (change in total discharge), relative to the estimated *baseline* hydrograph	0.107	Total discharge from observed *test* hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	0.299	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

Based on data from the 2015 WY for Hangingstone River at Fort McMurray (WSC Station 07CD004).

All non-zero values in this table presented to three decimal places.

Table 5.11-3 Estimated change in hydrologic measurement endpoints for the Hangingstone River watershed, 2015 WY.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water period discharge	1.491	1.495	+0.299%
Mean winter discharge	0.365	0.366	+0.299%
Annual maximum daily discharge	4.497	4.510	+0.299%
Open-water period minimum daily discharge	0.455	0.456	+0.299%

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

Observed discharge was calculated from data from the 2015 WY for Hangingstone River at Fort McMurray (WSC Station 07CD004).

The relative change for each measurement endpoint was calculated using observed and baseline flow values, which were estimated to several decimal places. Flows and percentage change values are presented to three decimal places for the sake of clarity.

The open-water season refers to the period from May 1 to October 31 and the winter season refers to the period from November 1 to March 31.

Table 5.11-4 Monthly concentrations of water quality measurement endpoints, Hangingstone River near the mouth (*test* station HA1 [HAR-1A]), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.30	8.06	May	8.43	Aug
Total suspended solids	mg/L	-	6	10.0	2.0	Sep	33.0	Jun
Conductivity	µS/cm	-	6	435	250	May	520	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.014	0.007	Sep, Oct	0.022	May
Total nitrogen	mg/L	-	6	0.85	0.41	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	<0.005	-
Dissolved organic carbon	mg/L	-	6	18.0	14.0	Oct	27.0	Jul
Ions								
Sodium	mg/L	-	6	44.5	22.0	May	47.0	Sep
Calcium	mg/L	-	6	39.5	23.0	May	46.0	Sep
Magnesium	mg/L	-	6	11.50	7.30	May	14.00	Sep, Oct
Potassium	mg/L	-	6	1.95	1.30	Jul	2.30	Jun
Chloride	mg/L	120-640	6	34.5	19.0	May	46.0	Jul
Sulphate	mg/L	309[b]	6	30.0	17.0	Jul	36.0	Sep
Total dissolved solids	mg/L	-	6	290	130	May	320	Oct
Total alkalinity	mg/L	20 (min)	6	150	79	May	190	Sep, Oct
Selected metals								
Total aluminium	mg/L	-	6	0.3920	0.0714	Aug	2.3000	May
Dissolved aluminium	mg/L	0.05	6	0.01288	0.00492	Sep	0.03450	May
Total arsenic	mg/L	0.005	6	0.00115	0.00093	Sep	0.00123	Aug
Total boron	mg/L	1.5-29	6	0.1145	0.0570	May	0.1750	Oct
Total molybdenum	mg/L	0.073	6	0.00190	0.00088	May	0.00219	Sep
Total mercury (ultra-trace)	ng/L	5-13	6	2.21	0.92	Sep	2.75	Jul
Total methyl mercury	ng/L	1-2	6	0.107	0.070	Oct	0.268	Jul
Total strontium	mg/L	-	6	0.248	0.121	May	0.288	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.55	<0.08	Oct	1.05	Aug
Oilsands extractable acids	mg/L	-	6	2.1	0.10	Oct	5.6	Jun
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	2.33	<0.59	Sep	14.10	Jun
Total dibenzothiophenes[c]	ng/L	-	6	92.6	19.5	Sep	336.7	Jun
Total PAHs[c]	ng/L	-	6	347	152	Sep	1,413	Jun
Total Parent PAHs[c]	ng/L	-	6	29.8	24.0	Sep	165.0	Jun
Total Alkylated PAHs[c]	ng/L	-	6	315	128	Sep	1,248	Jun
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0073**	0.0030	May	**0.0140**	Aug
Sulphide	mg/L	0.0019	6	**0.0054**	**0.0046**	Aug, Sep	**0.0120**	May
Dissolved iron	mg/L	0.3	1	0.2400	0.1520	Oct	**0.5600**	May

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.11-5 Monthly concentrations of water quality measurement endpoints, Hangingstone River above Fort McMurray (*test* station HAR-1), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.29	8.00	May	8.46	Sep
Total suspended solids	mg/L	-	6	4.0	1.3	Oct	13.0	May
Conductivity	µS/cm	-	6	395	220	May	480	Oct
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.018	0.013	Oct	0.024	Jul
Total nitrogen	mg/L	-	6	0.82	0.40	Oct	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	<0.005	-
Dissolved organic carbon	mg/L	-	6	20.0	14.0	Oct	27.0	Jul
Ions								
Sodium	mg/L	-	6	38.5	18.0	May	43.0	Jul
Calcium	mg/L	-	6	35.5	19.0	May	44.0	Oct
Magnesium	mg/L	-	6	10.30	5.90	May	12.00	Sep, Oct
Potassium	mg/L	-	6	1.80	1.40	Jul	2.00	Oct
Chloride	mg/L	120-640	6	27.5	15.0	May	41.0	Jul
Sulphate	mg/L	309[b]	6	24.0	15.0	Jul	30.0	Oct
Total dissolved solids	mg/L	-	6	270	100	May	300	Sep, Oct
Total alkalinity	mg/L	20 (min)	6	140	73	May	190	Oct
Selected metals								
Total aluminium	mg/L	-	6	0.1610	0.0567	Jun	1.5500	May
Dissolved aluminium	mg/L	0.05	6	0.00830	0.00418	Oct	0.03350	May
Total arsenic	mg/L	0.005	6	0.00118	0.00104	Oct	0.00153	Aug
Total boron	mg/L	1.5-29	6	0.1110	0.0525	May	0.1710	Oct
Total molybdenum	mg/L	0.073	6	0.00203	0.00092	May	0.00226	Oct
Total mercury (ultra-trace)	ng/L	5-13	6	1.62	0.76	Oct	2.51	May
Total methyl mercury	ng/L	1-2	6	0.122	0.063	Oct	0.257	Aug
Total strontium	mg/L	-	6	0.2125	0.1080	May	0.2660	Oct
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.49	0.19	Oct	0.74	Jun
Oilsands extractable acids	mg/L	-	6	2.1	1.0	Jul	2.6	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	0.73	<0.59	-	1.38	May
Total dibenzothiophenes[c]	ng/L	-	6	8.17	8.17	-	25.31	May
Total PAHs[c]	ng/L	-	6	126	126	Sep	187	May
Total Parent PAHs[c]	ng/L	-	6	22.7	22.2	Jun	23.8	May
Total Alkylated PAHs[c]	ng/L	-	6	104	103	Sep, Oct	163	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	6	**0.0073**	0.0035	May	**0.0120**	Aug
Sulphide	mg/L	0.0019	5	**0.0056**	<0.0019	Oct	**0.0070**	Jul
Dissolved iron	mg/L	0.3	2	0.2885	0.1750	Oct	**0.4520**	May

Values in **bold** are above guideline.

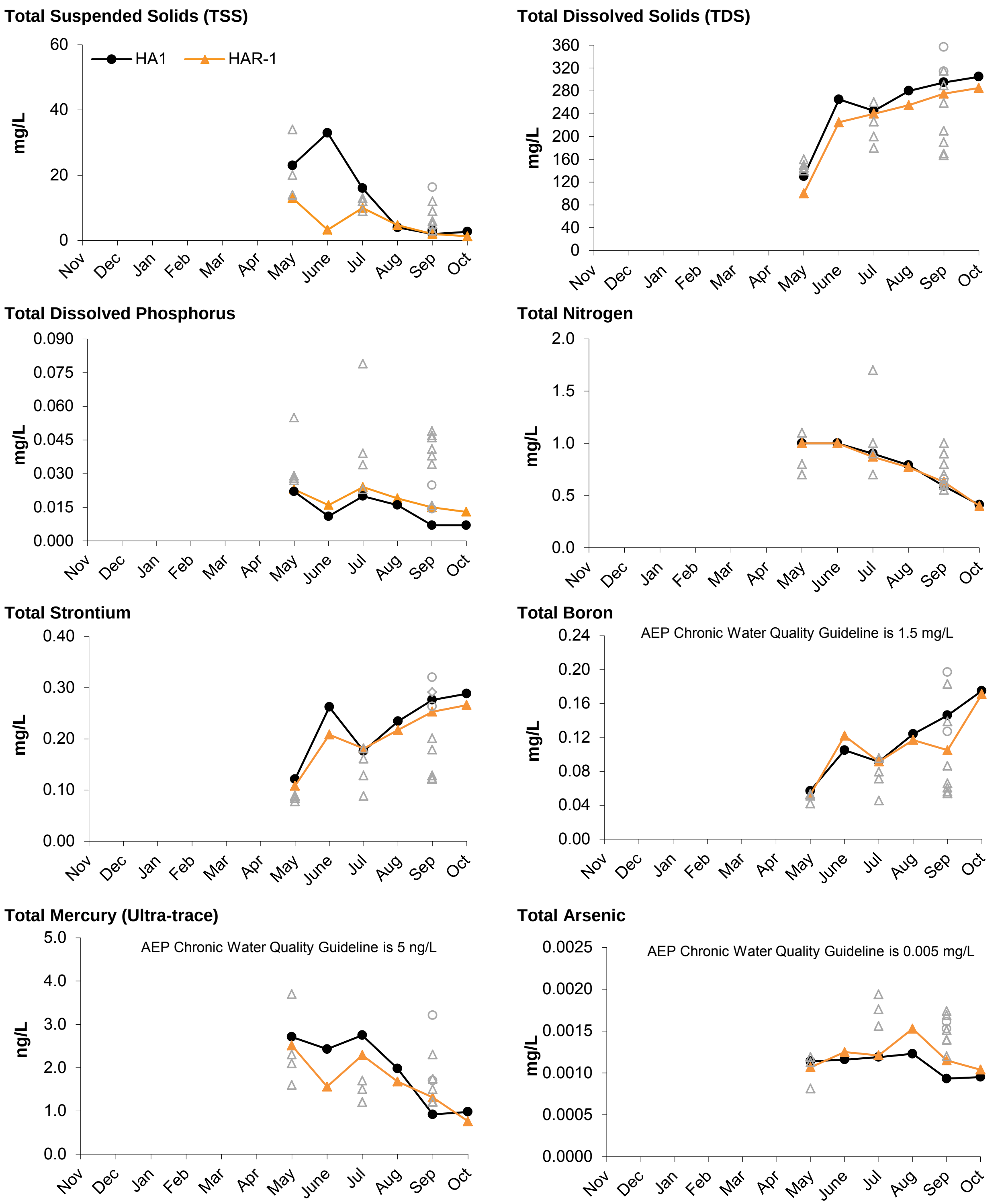
[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Figure 5.11-4 Selected water quality measurement endpoints in the Hangingstone River (monthly data) in the 2015 WY.

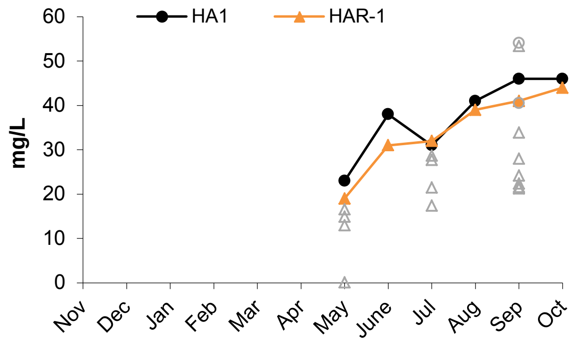


Non-detectable values are shown at the detection limit.

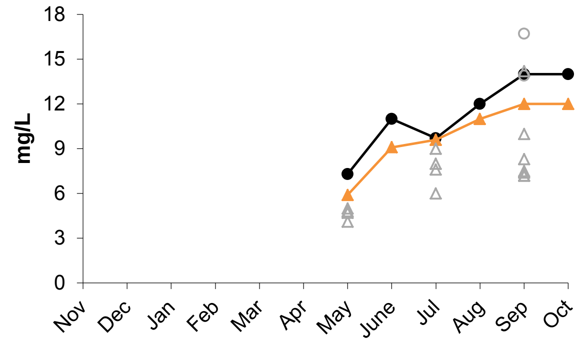
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.11-4 (Cont'd.)

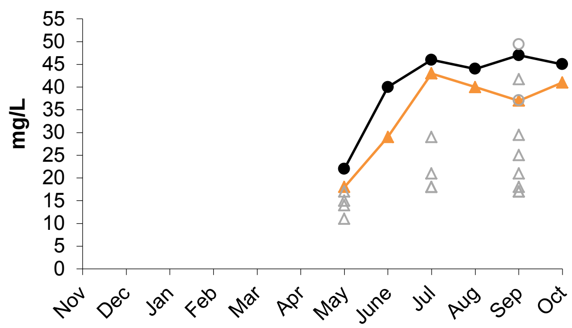
Calcium



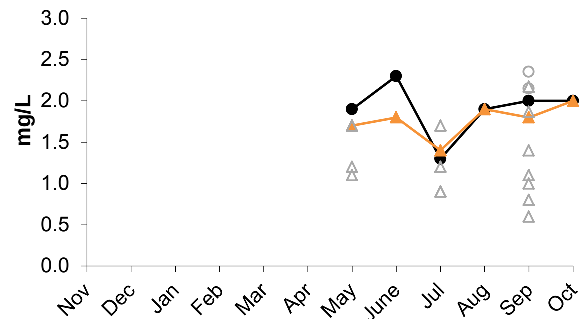
Magnesium



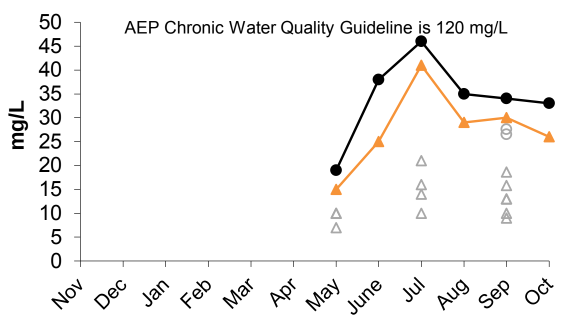
Sodium



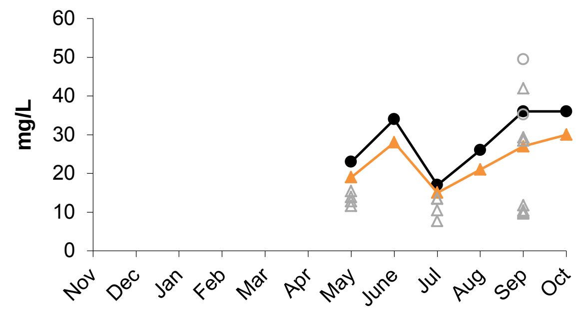
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.11-6 Concentrations of water quality measurement endpoints, Hangingstone River near the mouth (*test* station HA1 [HAR-1A]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2013-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	<u>8.39</u>	2	8.48	8.44	8.52
Total suspended solids	mg/L	-	<u>2.0</u>	2	9.65	3	16.3
Conductivity	µS/cm	-	500	2	523.5	494	553
Nutrients							
Total dissolved phosphorus	mg/L	-	0.0070	2	0.01955	0.0143	0.0248
Total nitrogen	mg/L	-	0.59	2	0.6275	0.601	0.654
Nitrate+nitrite	mg/L	3-124	<0.005	2	0.0625	0.054	0.071
Dissolved organic carbon	mg/L	-	18	2	12.6	3.1	22.1
Ions							
Sodium	mg/L	-	47	2	43.25	37.1	49.4
Calcium	mg/L	-	<u>46</u>	2	50.45	46.6	54.3
Magnesium	mg/L	-	14	2	15.3	13.9	16.7
Potassium	mg/L	-	<u>2.0</u>	2	2.3	2.2	2.4
Chloride	mg/L	120-640	<u>34</u>	2	27.05	26.5	27.6
Sulphate	mg/L	309[b]	36	2	42.35	35.2	49.5
Total dissolved solids	mg/L	-	<u>300</u>	2	335.5	314	357
Total alkalinity	mg/L	20 (min)	190	2	189	176	202
Selected metals							
Total aluminum	mg/L	-	<u>0.114</u>	2	0.5815	0.317	0.846
Dissolved aluminum	mg/L	0.05	<u>0.0049</u>	2	0.00751	0.00708	0.00794
Total arsenic	mg/L	0.005	<u>0.0009</u>	2	0.00157	0.00153	0.00161
Total boron	mg/L	1.5-29	0.146	2	0.162	0.127	0.197
Total molybdenum	mg/L	0.073	0.0022	2	0.002425	0.00221	0.00264
Total mercury (ultra-trace)	ng/L	5-13	0.92	2	2.455	1.7	3.21
Total methyl mercury	ng/L	1-2	0.093	-	-	-	-
Total strontium	mg/L	-	0.276	2	0.2915	0.263	0.32
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.28</u>	2	0.625	0.5	0.75
Oilsands extractable acids	mg/L	-	0.7	2	0.73	0.56	0.9
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.186	<7.21	<15.16
Retene	ng/L	-	<u><0.59</u>	2	4.4	1.6	7.2
Total dibenzothiophenes[c]	ng/L	-	<u>19.5</u>	2	121.5	71.7	171.2
Total PAHs[c]	ng/L	-	<u>152.4</u>	2	486.9	328.6	645.2
Total Parent PAHs[c]	ng/L	-	<u>24.0</u>	2	44.3	33.7	54.8
Total Alkylated PAHs[c]	ng/L	-	<u>128.4</u>	2	442.6	294.9	590.3
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0046**	2	**0.0025**	**0.002**	**0.0029**
Total phenols	mg/L	0.004	**0.0074**	2	**0.0068**	**0.0066**	**0.0070**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.11-7 Concentrations of water quality measurement endpoints, Hangingstone River above Fort McMurray (*test* station HAR-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2004-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.46	7	8.20	8.00	8.48
Total suspended solids	mg/L	-	2.0	7	6.0	<3.0	12.0
Conductivity	µS/cm	-	460	7	233	231	487
Nutrients							
Total dissolved phosphorus	mg/L	-	0.015	7	0.041	0.016	0.049
Total nitrogen	mg/L	-	0.63	7	0.800	0.554	1.00
Nitrate+nitrite	mg/L	3-124	<0.005	7	<0.100	<0.054	<0.100
Dissolved organic carbon	mg/L	-	20	7	21.0	16.1	34.0
Ions							
Sodium	mg/L	-	37	7	21.0	17.0	41.7
Calcium	mg/L	-	41	7	25.8	22.3	50.2
Magnesium	mg/L	-	12	7	7.50	7.20	14.2
Potassium	mg/L	-	1.8	7	1.1	0.6	2.2
Chloride	mg/L	120-640	30	7	13.0	9.0	18.6
Sulphate	mg/L	309[b]	27	7	11.8	9.60	42.0
Total dissolved solids	mg/L	-	300	7	210	167	315
Total alkalinity	mg/L	20 (min)	170	7	99.0	88.0	190
Selected metals							
Total aluminum	mg/L	-	0.103	7	0.180	0.137	0.499
Dissolved aluminum	mg/L	0.05	0.008	7	0.014	0.008	0.037
Total arsenic	mg/L	0.005	0.0012	7	0.0015	0.0012	0.0017
Total boron	mg/L	1.5-29	0.105	7	0.066	0.054	0.183
Total molybdenum	mg/L	0.073	0.0022	7	0.0010	0.0007	0.0029
Total mercury (ultra-trace)	ng/L	5-13	1.31	7	<1.22	<1.20	2.30
Total methyl mercury	ng/L	1-2	0.126	-	-	-	-
Total strontium	mg/L	-	0.253	7	0.128	0.121	0.291
Total hydrocarbons							
BTEX	mg/L	-	<0.01	2	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	2	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	2	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	2	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.50	2	0.24	<0.1	<0.3
Oilsands extractable acids	mg/L	-	2.1	2	0.76	<0.4	<1.1
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	2	<11.2	<7.2	<15.2
Retene	ng/L	-	<0.59	2	0.648	<0.6	<0.7
Total dibenzothiophenes[c]	ng/L	-	8.2	2	7.619	<6.8	<8.4
Total PAHs[c]	ng/L	-	125.9	2	99.8	<86.1	<113.5
Total Parent PAHs[c]	ng/L	-	22.7	2	18.72	<14.5	<23.0
Total Alkylated PAHs[c]	ng/L	-	103.2	2	81.07	<71.6	<90.6
Other variables that exceeded AEP guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0062**	7	**0.004**	**0.003**	**0.018**
Total phenols		0.004	**0.0083**	7	**0.010**	0.003	**0.012**

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Figure 5.11-5 Piper diagram of fall ion concentrations in the Hangingstone River watershed.

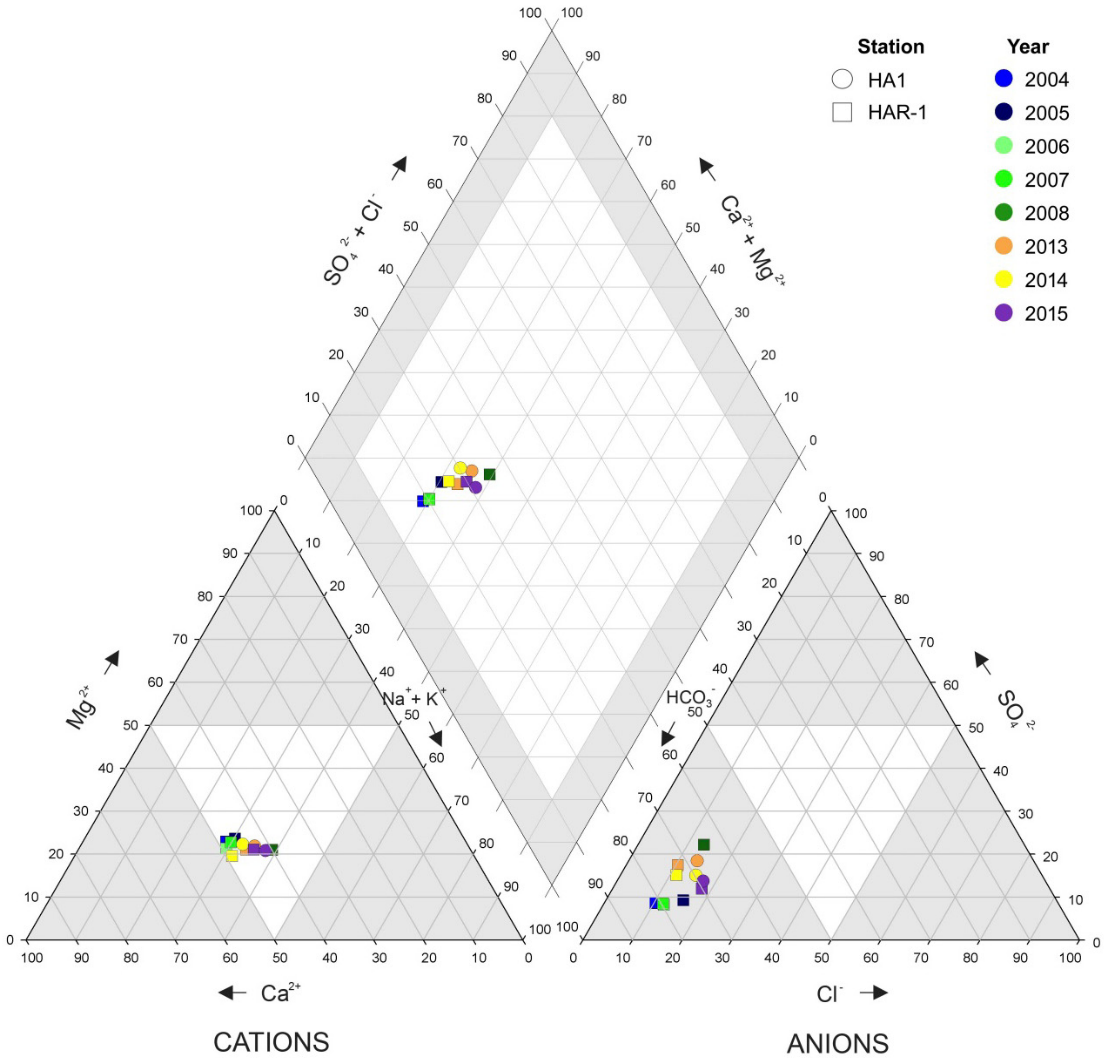


Table 5.11-8 Water quality guideline exceedances in the Hangingstone River watershed, 2015 WY.

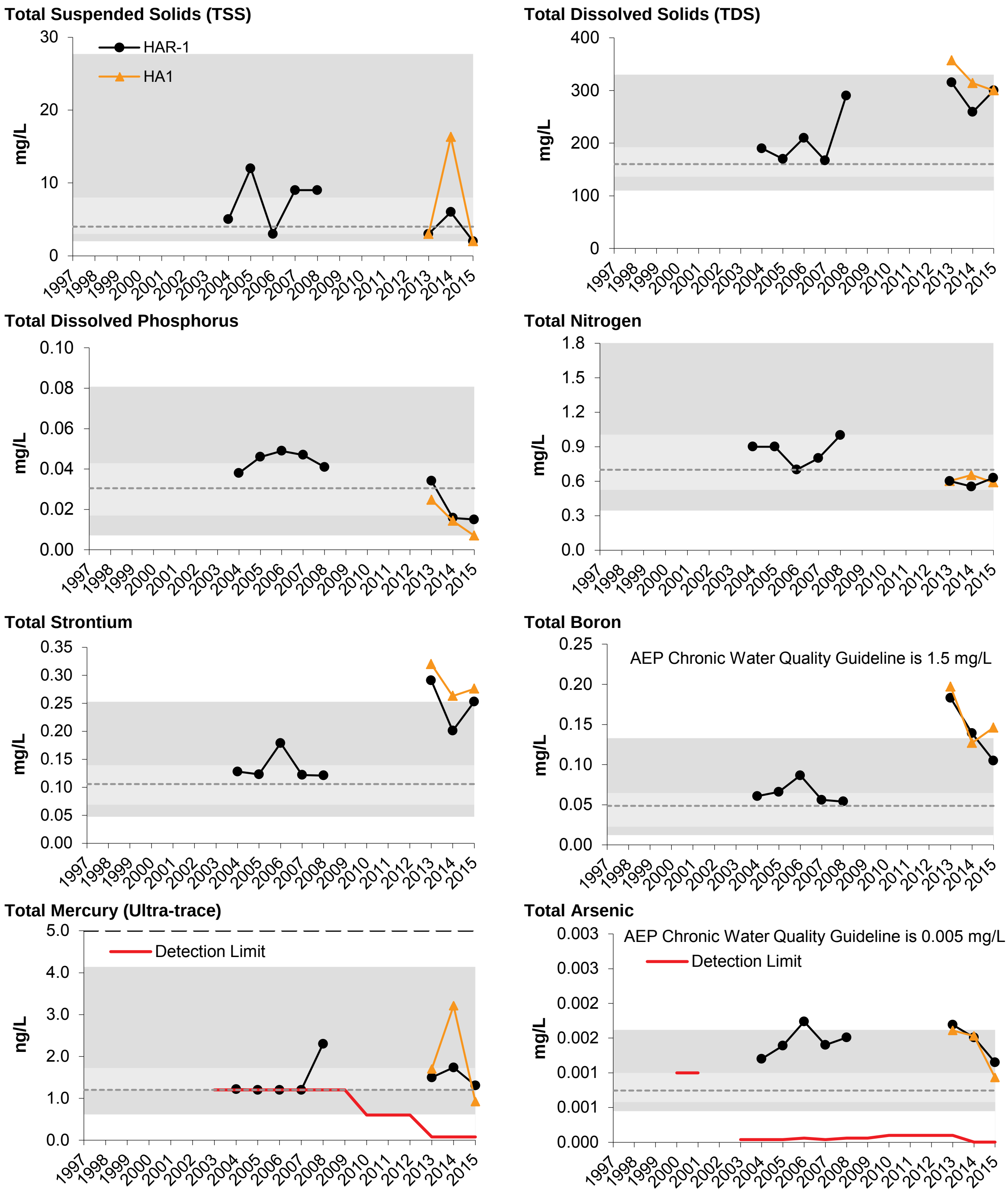
Variable	Units	Guideline[a]	May	June	July	August	September	October
Hangingstone River mouth (HA1)								
Total phenols	mg/L	0.004	0.003	**0.0042**	**0.011**	**0.014**	**0.0074**	**0.0071**
Sulphide	mg/L	0.0019	**0.012**	**0.0049**	**0.0085**	**0.0046**	**0.0046**	**0.0059**
Dissolved Iron	mg/L	0.3	**0.56**	0.219	0.27	0.261	0.163	0.152
Hangingstone River above Fort McMurray (HAR-1)								
Total phenols	mg/L	0.004	**0.0035**	**0.0037**	**0.0078**	**0.012**	**0.0083**	**0.0068**
Sulphide	mg/L	0.0019	**0.0049**	**0.0032**	**0.007**	**0.0062**	**0.0062**	<0.0019
Dissolved iron	mg/L	0.3	**0.452**	0.229	0.296	**0.313**	0.281	0.175

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.11-6 Selected water quality measurement endpoints in the Hangingstone River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



Non-detectable values are shown at the detection limit.

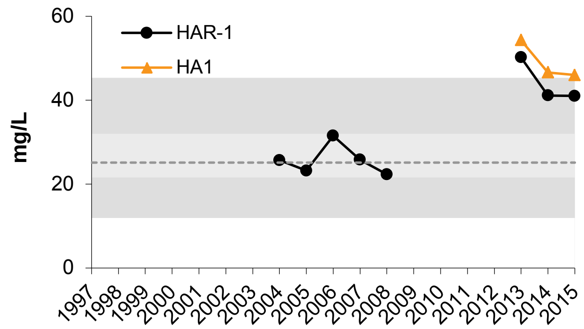
– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

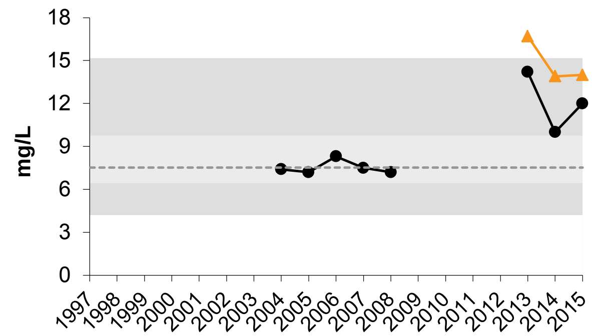
Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.11-6 (Cont'd.)

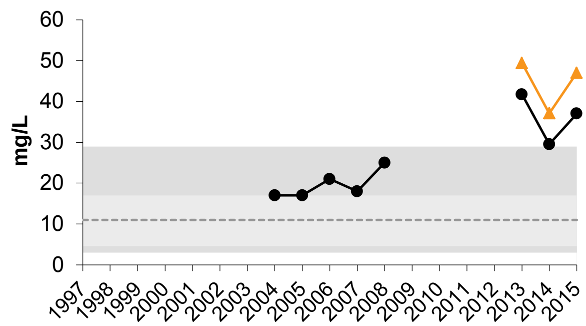
Calcium



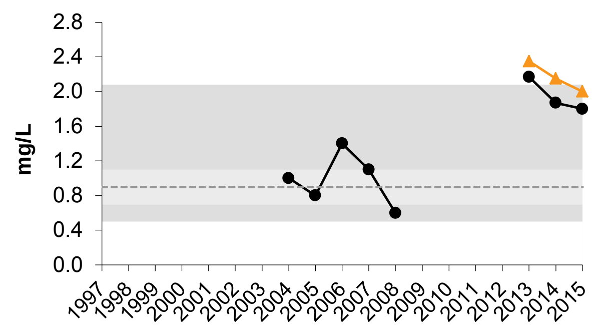
Magnesium



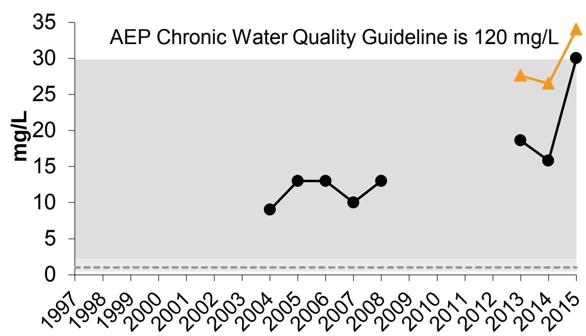
Sodium



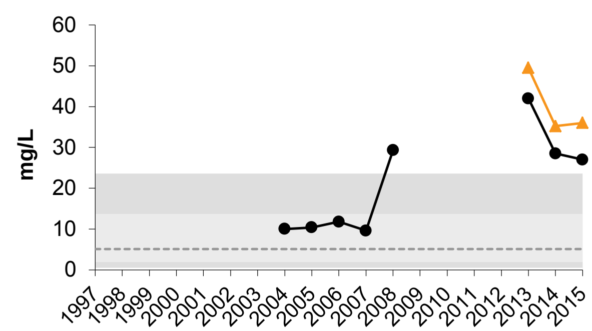
Potassium



Chloride



Sulphate



Non-detectable values are shown at the detection limit.

– – – – –   Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.11-9 Average habitat characteristics of the benthic invertebrate sampling location in the Hangingstone River (*test* reach HAR-E1), fall 2015.

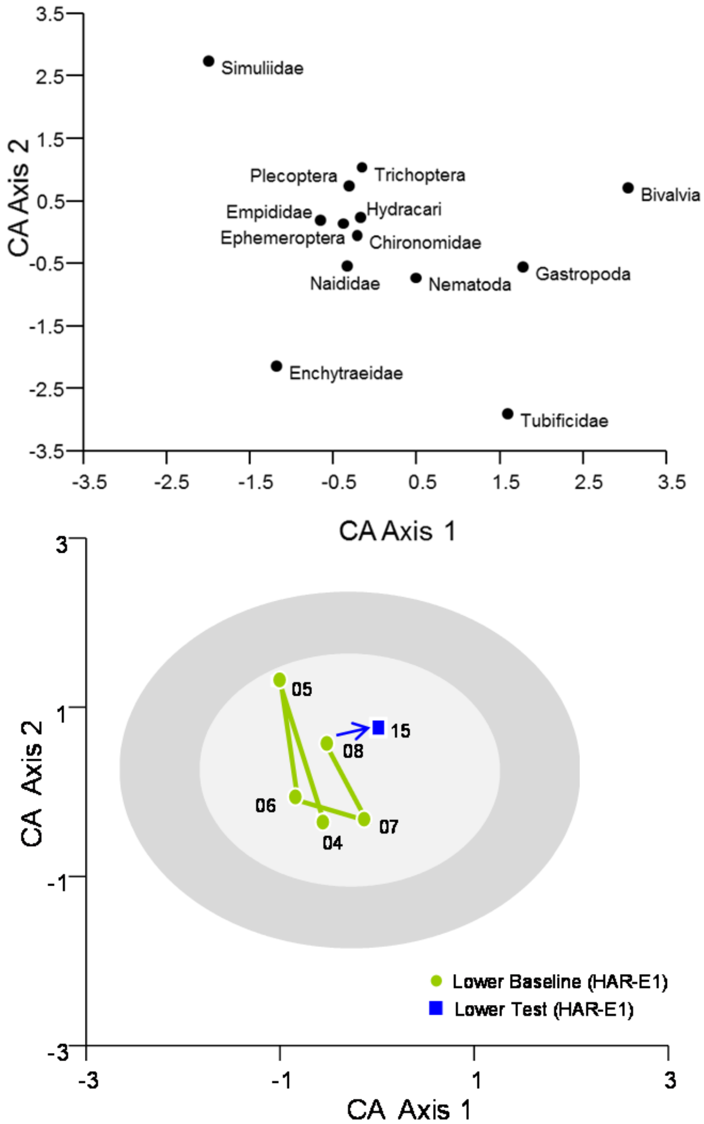
Variable	Units	HAR-E1 Lower *Test* Reach
Sample date	-	September 9, 2015
Habitat	-	Erosional
Water depth	m	0.2
Current velocity	m/s	0.3
Field water quality		
Dissolved oxygen (DO)	mg/L	10.0
Conductivity	µS/cm	387
pH	pH units	8.7
Water temperature	°C	14.9

Table 5.11-10 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community in the Hangingstone River (*test* reach HAR-E1).

Taxon	Percent Major Taxa Enumerated in Each Year	
	Test Reach HAR-E1	
	2004 to 2008	2015
Hydra	0 to 1	-
Nematoda	1 to 6	1
Naididae	3 to 25	21
Tubificidae	<1 to 1	-
Enchytraeidae	<1 to 2	-
Ostracoda	0 to 15	-
Hydracarina	5 to 27	3
Gastropoda	0 to 3	2
Bivalvia	0 to <1	-
Ceratopogonidae	<1 to 2	1
Chironomidae	14 to 40	24
Diptera (misc.)	1 to 4	3
Coleoptera	0 to <1	1
Odonata	1 to 2	1
Ephemeroptera	7 to 34	23
Plecoptera	1 to 10	6
Trichoptera	4 to 17	14
Benthic Invertebrate Community Measurement Endpoints		
Total abundance per sample	70 to 708	2,931
Richness	15 to 39	29
Equitability	0.25 to 0.48	0.25
% EPT	22 to 52	20

Note: All 2015 benthic invertebrate community measurement endpoints, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D). All percent abundances of taxa are based on original counts. % EPT as an index in 2015 does not equal the observed percentages in the kick sample, because the index value was adjusted down to be equivalent to what would have been expected with a Neil-Hess cylinder.

Figure 5.11-7 Ordination (Correspondence Analysis) of erosional reaches, showing the lower reach of the Hangingstone River (*test* reach HAR-E1).

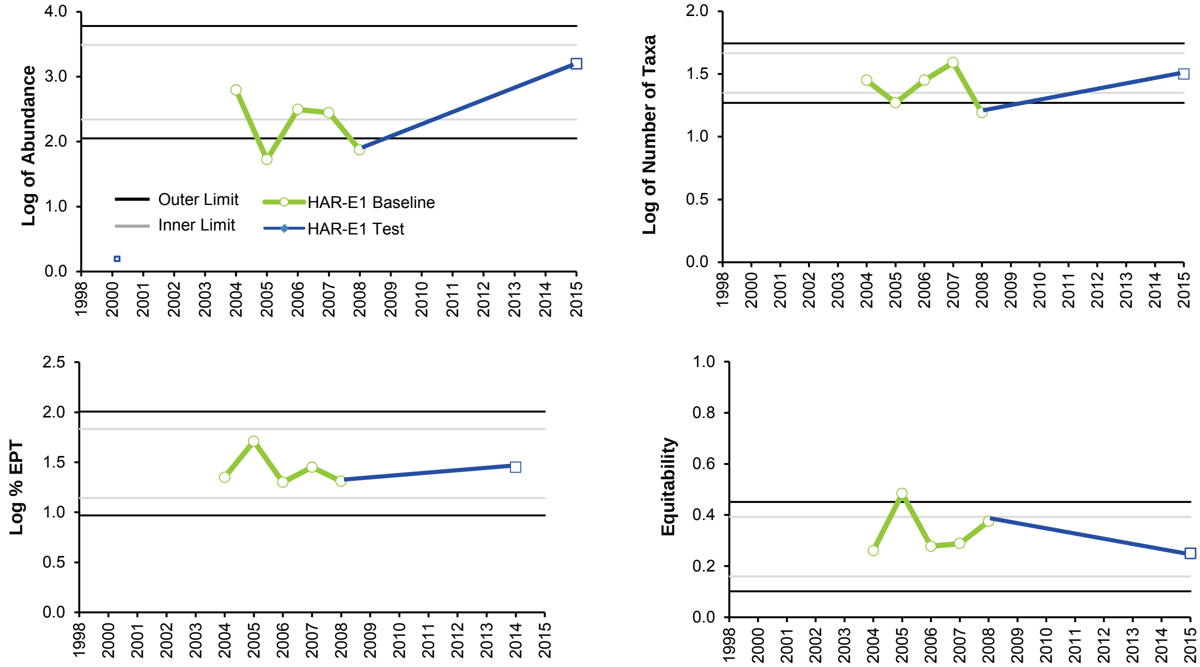


Notes:

The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses are the inner and outer tolerance limits on the 95th percentile for regional *baseline* erosional reaches.

2015 CA scores were projected using the taxa scores and eigenvalues calculated from taxa abundances for erosional reaches from previous years (1998 to 2014; Appendix D).

Figure 5.11-8 Variation in benthic invertebrate community measurement endpoints at *test* reach HAR-E1 in the Hangingstone River relative to regional *baseline* ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from all *baseline* erosional reaches for years up to and including 2014.

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Measurement endpoints for *test* reach HAR-E1 in 2015 were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (Appendix D).

Table 5.11-11 Average habitat characteristics of wild fish health monitoring *test* reach HAR-F1 and *baseline* reach MR-U, fall 2015.

Watercourse	Units	HAR-F1 *Test* Reach	MR-U *Baseline* Reach
Sample date	-		
Mean water depth	m	0.35	0.43
Mean velocity	m/s	ns	0.4
Field water quality			
Water temperature	°C	8.6	6.7
Conductivity	µS/cm	412	208
Dissolved oxygen (DO)	mg/L	9.6	11.6
pH	pH units	7.89	7.87
Substrate	-	fines/cobble	cobble/boulder

ns = not sampled

Figure 5.11-9 Daily mean temperatures for wild fish health *test* reach HAR-F1, August to September 2015.

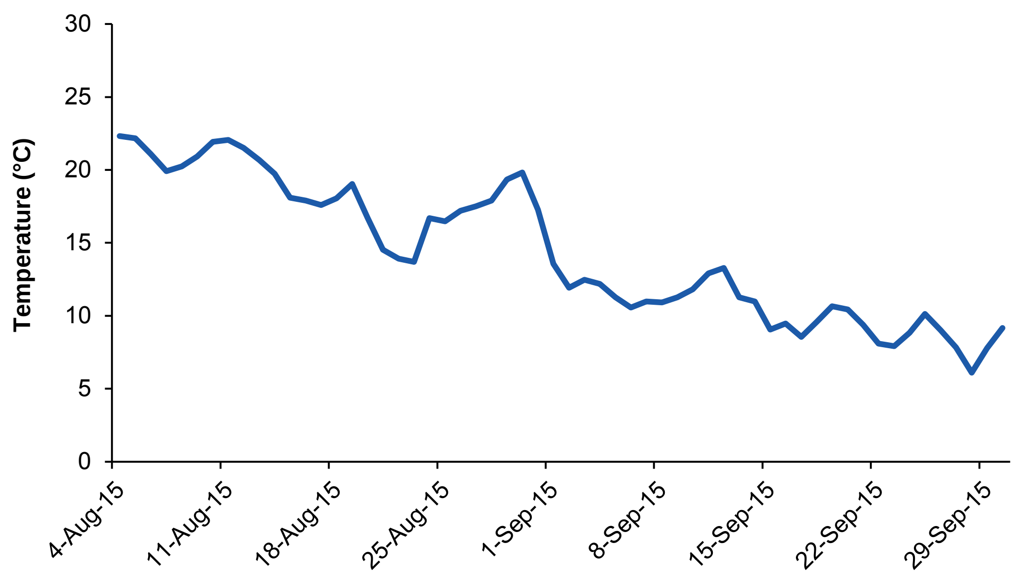


Table 5.11-12 Summary of longnose dace caught and mean length, weight and relative abundance of juveniles at *test* reach HAR-F1 and *baseline* reach MR-U, fall 2015.

Reach	Sample Size		Relative Abundance (%)		Juvenile Measurements		Percentage of External Abnormalities
	Juvenile	Adult	Juvenile	Adult	Mean Length (mm)	Mean Weight (g)	
Test reach HAR-F1	113	45	71.5	28.5	38.9	0.65	6.00
Baseline reach MR-U	40	76	34	66	38.8	0.70	1.72

Figure 5.11-10 Length-frequency distribution of longnose dace at wild fish health *test* reach HAR-F1 and *baseline* reach MR-U, fall 2015.

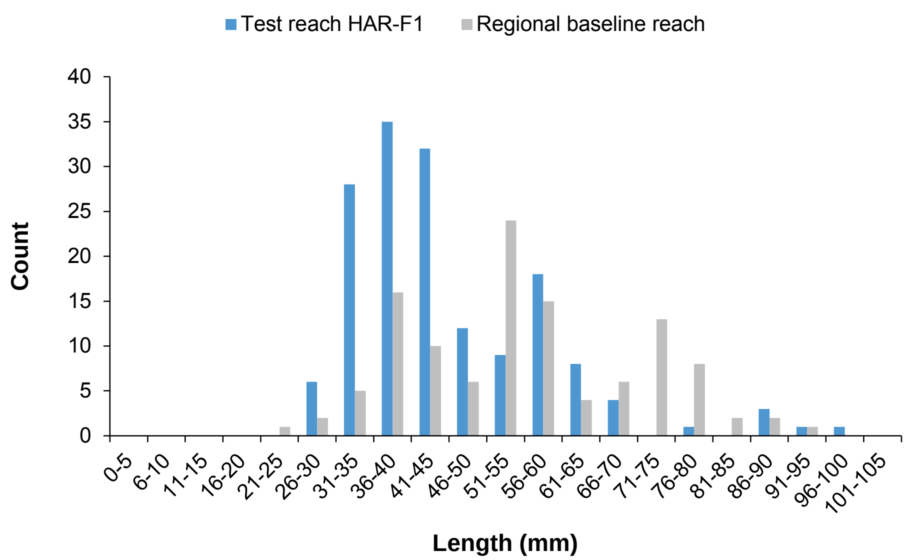


Figure 5.11-11 Measurement endpoints for longnose dace at wild fish health *test* reach HAR-F1 and *baseline* reach MR-U, fall 2015.

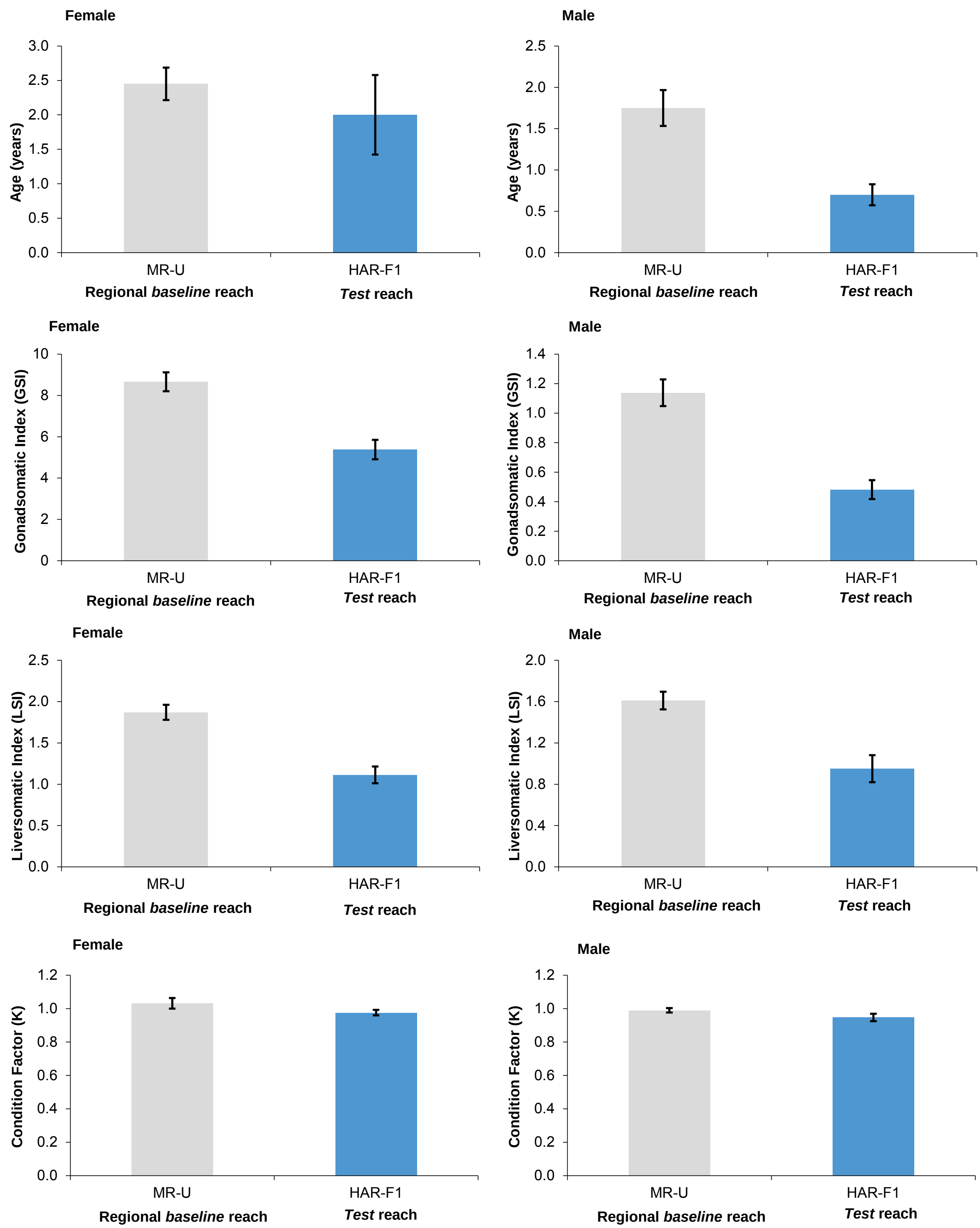


Figure 5.11-12 Relative age-frequency distribution of longnose dace at wild fish health *test* reach HAR-F1, fall 2015.

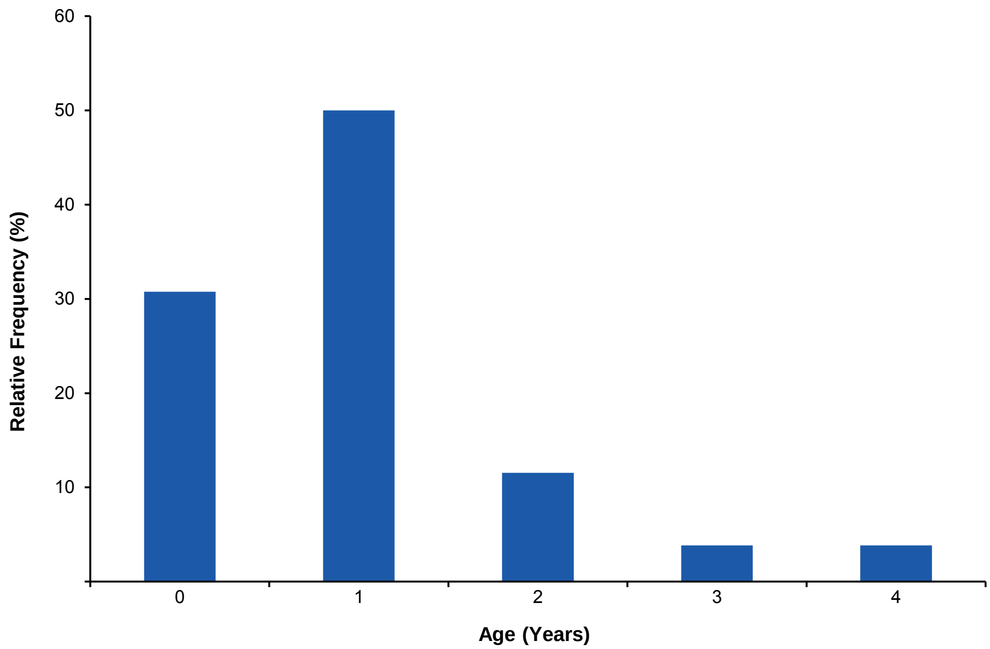


Figure 5.11-13 Relationship between age (years) and body weight (g) of female and male longnose dace at wild fish health *test* reach HAR-F1 in the Hangingstone River, fall 2015.

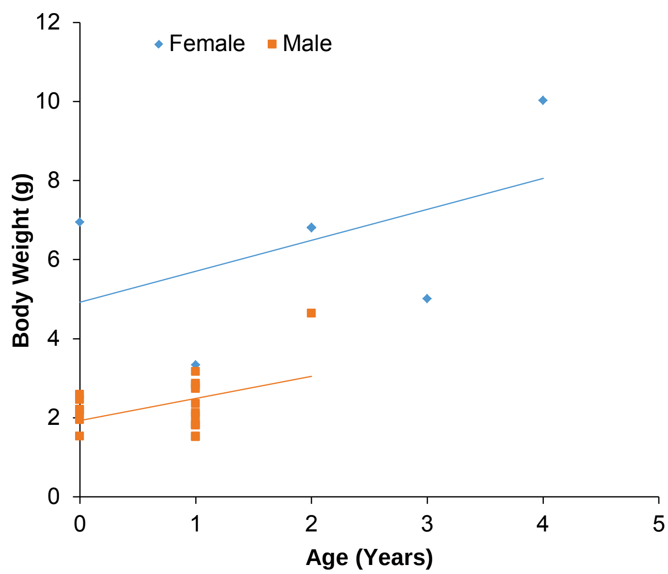


Figure 5.11-14 Growth of longnose dace at wild fish health *test* reach HAR-F1 and *baseline* reach MR-U, fall 2015.

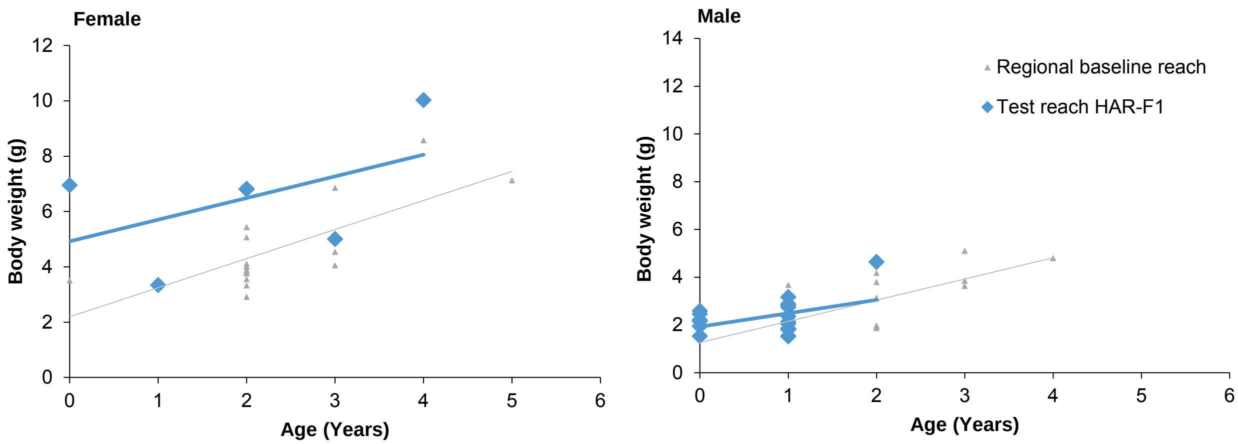
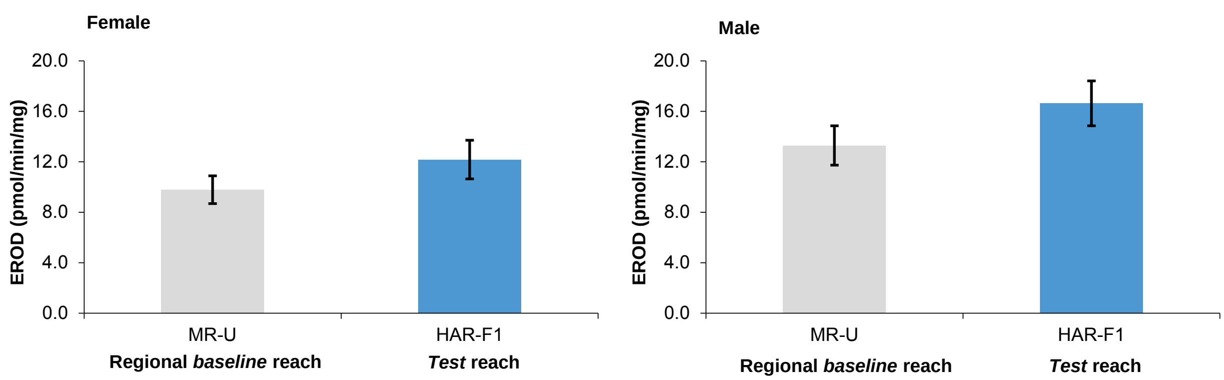


Figure 5.11-15 Mean EROD activity (± 1SE) of female and male longnose at *test* reach HAR-F1 and *baseline* reach MR-U, fall 2015.



5.12 PIERRE RIVER AREA

Table 5.12-1 Summary of results for watersheds in the Pierre River area.

Pierre River Area	Summary of 2015 Conditions				
	Pierre River	Eymundson Creek		Big Creek	Redclay Creek
Climate and Hydrology					
Criteria	**S44**	**S49**	**C4**	**S48**	**S50A**
Mean open-water season discharge	not measured				
Mean winter discharge	not measured				
Annual maximum daily discharge	not measured				
Minimum open-water season discharge	not measured				
Water Quality					
Criteria	**PIR-1**	**EYC-1**	no station	**UN1**	**RCC-1**
Water Quality Index	🟡	🟠	-	🟡	🟡
Benthic Invertebrate Communities and Sediment Quality					
Criteria	**PIR-D1**	**EYC-D1**	no reach	**BIC-D1**	**RCC-E1**
Benthic Invertebrate Communities	n/a	n/a	-	n/a	n/a
Sediment Quality Index	🟡	🟡	-	🟡	no station
Fish Populations					
No Fish Populations monitoring was conducted in 2015.					

Legend and Notes

🟡 Negligible-Low

🟠 Moderate

🟤 High

baseline

test

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Figure 5.12-1 Pierre River area watersheds.

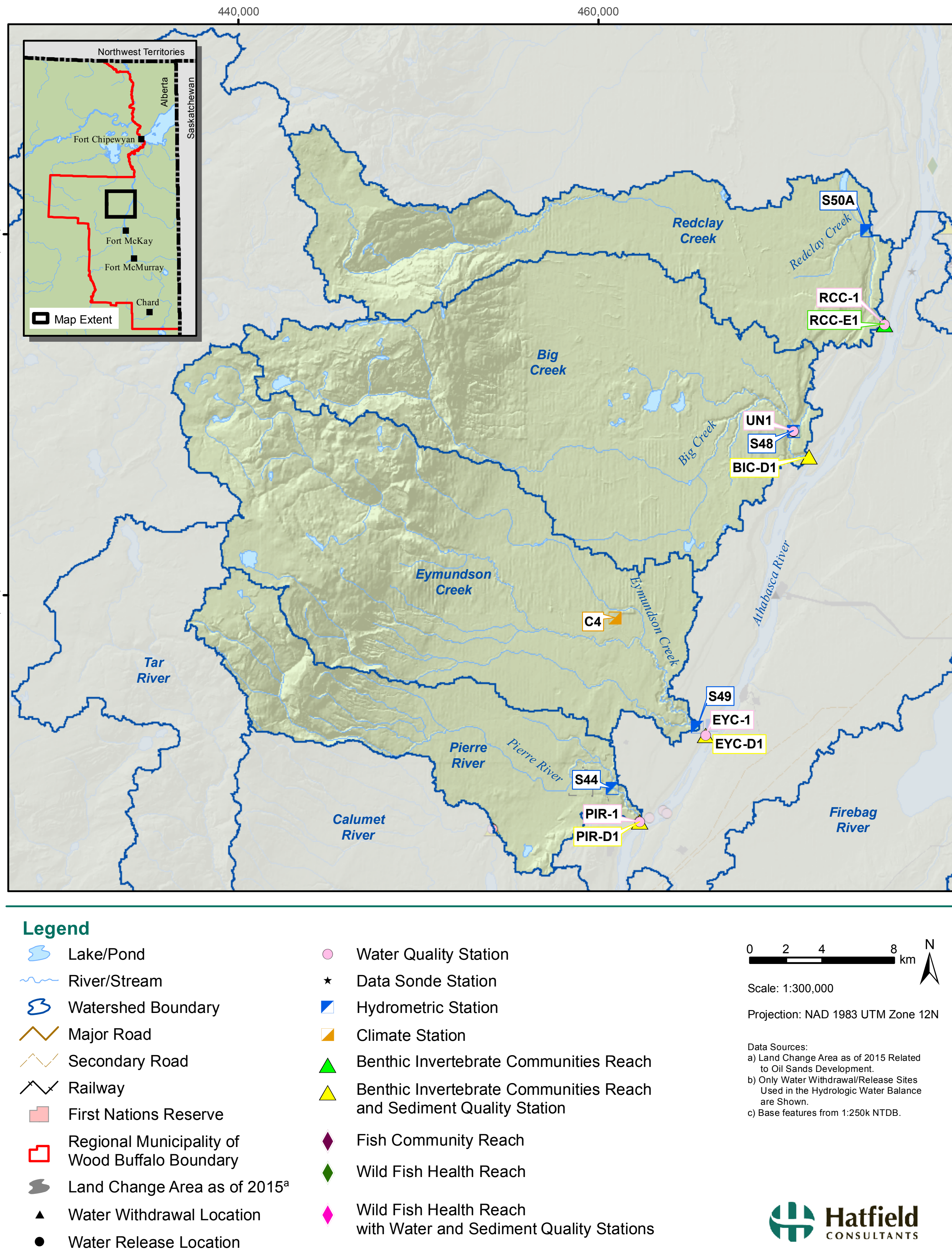


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Figure 5.12-2 Representative monitoring stations of the watersheds in the Pierre River area, fall 2015.

Hydrology Station S44: Pierre River, facing upstream

Water Quality Station and Benthic Invertebrate Communities Reach PIR-1/PIR-D1: Pierre River near the mouth, facing downstream

Water Quality, Benthic Invertebrate Communities and Sediment Quality Station/Reach EYC-1/ EYC-D1: Eymundson Creek near the mouth facing upstream

Hydrology and Water Quality Station S48/UN1: Big Creek, facing upstream

Hydrology Station S50A: mid Redclay Creek, facing upstream

Water Quality Station and Benthic Invertebrate Communities Reach RCC-1/RCC-E1: Redclay Creek near the mouth, facing upstream

5.12.1 Summary of 2015 WY Conditions

This section provides 2015 results for the Pierre River, as well as three other adjacent tributaries to the Athabasca River: Eymundson Creek; Big Creek; and Redclay Creek, all of which are designated as *baseline* watercourses. Less than 1% (18 ha) of the Pierre River watershed had undergone land change from oil sands developments as of 2015 (Table 2.3-1).

Monitoring activities in the Pierre River area were conducted in 2015 WY for the Climate and Hydrology, Water Quality, and Benthic Invertebrate Communities and Sediment Quality components. Monitoring in these watersheds was in advance of development activities for the Shell Pierre River Mine project and the Teck Frontier project. Hydrometric data have been collected to develop hydrographs for each watershed but water balances were not completed given that there was no development. Details for each hydrology station are provided in Appendix C.

Table 5.12-1 is a summary of the 2015 assessment of the watersheds in the Pierre River area, while Figure 5.12-1 provides the locations of the monitoring stations for each component. Figure 5.12-2 provides fall 2015 photos of representative monitoring stations located in watersheds in the Pierre River area.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Water Quality Monthly water quality samples collected between May and September at *baseline* station UN1 exhibited higher concentrations of TSS, associated metals, and PAHs in May and June during high flows, and higher concentrations of dissolved constituents, TDS and associated major ions in fall during low flows. Concentrations and levels of water quality measurement endpoints at all four *baseline* stations in fall 2015 were generally within the range of available previously-measured concentrations and regional *baseline* conditions. Ion balance was similar to historical observations at all stations except *baseline* station UN1, because a historically low concentration of sulphate was measured at fall 2015 at that station. Water quality guideline exceedances included dissolved iron, total mercury, total phenols, and sulphide. These exceedances were consistent with historical monitoring by the RAMP and JOSMP. Differences in water quality in fall 2015 between *baseline* stations BIC-1, PIR-1, and RCC-1 and regional *baseline* fall conditions were classified as **Negligible-Low**, while differences in water quality in fall 2015 between *baseline* station EYC-1 and regional *baseline* fall conditions was classified as **Moderate**.

Benthic Invertebrate Communities and Sediment Quality The benthic invertebrate communities at *baseline* reaches BIC-D1, EYC-D1 and PIR-D1 were typical of sandy-bottomed rivers with a high abundance of chironomids and worms, which are indicative of poor water quality conditions. EPT taxa were present, as were permanent aquatic forms. Overall, a decrease in the abundance of worms and an increasing proportion of EPT taxa indicated stable conditions. The benthic invertebrate communities at *baseline* reach RCC-E1 had a lower proportion of tolerant worms and chironomids in 2015, indicating good habitat quality.

Sediment quality measurement endpoints were within the range of regional *baseline* conditions at all sediment quality stations in the Pierre River area, with the exception of total metals, carbon-normalized total PAHs, and normalized total metals at *baseline* station EYC-D1, normalized total metals at *baseline* station PIR-D1, and carbon-normalized total PAHs at *baseline* station BIC-D1. Differences between sediment quality in fall 2015 at all sediment quality stations in the Pierre River area and regional *baseline* conditions were classified as **Negligible-Low**.

5.12.2 Water Quality

Water quality samples were taken in the 2015 WY from:

- Pierre River (*baseline* station PIR-1), sampled in fall from 2011 to 2015;
- Eymundson Creek (*baseline* station EYC-1), sampled in fall from 2011 to 2015;
- Big Creek/Unnamed Creek (*baseline* station UN1, previously called BIC-1), sampled in fall from 2011 to 2013 and in winter and fall in 2014. This station was sampled on monthly basis from May to September in the 2015 WY; and
- Redclay Creek (*baseline* station RCC-1), sampled in fall from 2011 to 2013 and in winter and fall in 2014. This station was sampled in fall in the 2015 WY.

Monthly variations in water quality at *baseline* station UN1 are summarized in Table 5.12-2 and Figure 5.12-3. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations at the four *baseline* stations are provided in Table 5.12-3 to Table 5.12-6. The ionic composition of water in the Pierre River area is presented in Figure 5.12-4. Guideline exceedances in the 2015 WY for water quality measurement endpoints are presented in Table 5.12-7 and Figure 5.12-5 compares selected water quality measurement endpoints to historical regional *baseline* concentrations.

Monthly Variations in Water Quality Concentrations of TSS and associated metals, and of total and alkylated PAHs were generally highest in May and June at *baseline* station UN1 in 2015, coincident with high stream flows, and lowest in August and September, while concentrations of TDS and associated major ions were highest in months of low flow (Table 5.12-2, Figure 5.12-3). Monthly concentrations and levels of water quality measurement endpoints at *baseline* station UN1 in the 2015 WY were within historical monthly ranges of concentration (Figure 5.12-3).

2015 Fall Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints in fall 2015 were within historical ranges of measured concentrations with the following exceptions (Table 5.12-3 to Table 5.12-6):

- concentrations of total nitrogen, total alkalinity, calcium, chloride, oilsands extractable acids, total phenols, and sulphide at *baseline* station UN1 were higher than previously-measured maximum concentrations;
- concentrations of sodium, potassium, sulphate, pH, total aluminum, total boron, and total molybdenum at *baseline* station UN1 were lower than previously-measured minimum concentrations;
- concentrations of dissolved phosphorus and oilsands extractable acids at *baseline* station EYC-1 were higher than previously-measured maximum concentrations;
- concentrations of TSS, dissolved organic carbon, total arsenic, total boron, total dibenzothiophenes, total PAHs, and total alkylated PAHs at *baseline* station EYC-1 were lower than previously-measured minimum concentrations;
- concentrations of oilsands extractable acids and total phenols at *baseline* station PIR-1 were higher than previously-measured maximum concentrations;

- concentrations of TSS, TDS, dissolved organic carbon, dissolved aluminum, total arsenic, total boron, total molybdenum, total mercury, total dibenzothiophenes, total PAHs, and total alkylated PAHs at *baseline* station PIR-1 were lower than previously-measured minimum concentrations;
- concentrations of chloride, total mercury, oilsands extractable acids, total phenols, and sulphide, at *baseline* station RCC-1 were higher than previously-measured maximum concentrations; and
- specific conductivity, total alkalinity, pH, and concentrations of sodium, potassium, and total boron at *baseline* station RCC-1 were lower than previously-measured minimum levels and concentrations.

Temporal Trends Statistical trend analyses were not conducted on water quality data for stations in the Pierre River area due to insufficient length of the time series in the water quality datasets.

Ion Balance There were differences in ionic composition among the four *baseline* stations in fall 2015 (Figure 5.12-4). Although cation concentration generally was similar among stations, anions were comprised of greater proportions of sulphate at *baseline* station EYC-1 and chloride at *baseline* station PIR-1. The ion balance for *baseline* station UN1 differed in fall 2015 from previous years because sulphate concentrations were historically low (0.7 mg/L).

Comparison of Water Quality Measurement Endpoints to Published Guidelines The following water quality guideline exceedances were measured in the Pierre River area in the 2015 WY (Table 5.12-7):

- dissolved iron at *baseline* stations UN1, EYC-1, and PIR-1, all in September;
- total mercury at *baseline* station EYC-1 in September;
- total phenols at *baseline* station UN1 from July to August, and at all stations in September; and
- sulphide at *baseline* station UN1 from May to July, and at all stations in September.

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations of all water quality measurement endpoints at *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1 were within regional *baseline* concentrations in fall 2015 with the following exceptions (Figure 5.12-5):

- total mercury (ultra-trace) and sulphate at *baseline* station EYC-1 with concentrations that exceeded the 95th percentile of regional *baseline* concentrations;
- total boron, sodium, and sulphate at *baseline* station UN1 with concentrations that were below the 5th percentile of regional *baseline* concentrations; and
- TSS, total nitrogen, and total arsenic at *baseline* station RCC-1 with concentrations that were below the 5th percentile of regional *baseline* concentrations.

Water Quality Index The WQI values for *baseline* stations UN1 (97.4), PIR-1 (98.7), and RCC-1 (100) indicated **Negligible-Low** differences in water quality conditions at these stations in fall 2015 compared to regional *baseline* water quality conditions. The WQI at *baseline* station EYC-1 (75.8) indicated **Moderate** differences in water quality conditions at this station in fall 2015 compared to regional *baseline* water quality conditions because concentrations of total mercury (ultra-trace) and sulphate exceeded the 95th percentile of regional *baseline* concentrations.

Classification of Results Differences in water quality in fall 2015 between *baseline* stations BIC-1, PIR-1, and RCC-1 and regional *baseline* fall conditions were classified as **Negligible-Low,** while differences in water quality in fall 2015 between *baseline* station EYC-1 and regional *baseline* fall conditions was classified as **Moderate**.

5.12.3 Benthic Invertebrate Communities and Sediment Quality

5.12.3.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 at:

- depositional *baseline* reach BIC-D1 of Big Creek sampled since 2013;
- depositional *baseline* reach EYC-D1 of Eymundson Creek sampled since 2013;
- depositional *baseline* reach PIR-D1 of Pierre River sampled since 2013; and
- erosional *baseline* reach RCC-E1 of Redclay Creek sampled since 2013.

2015 Habitat Conditions Water at *baseline* reach BIC-D1 (Big Creek) in fall 2015 was 0.62 m deep, with a pH of 7.0, low velocity (0.15 m/s), a high concentration of dissolved oxygen (10.1 mg/L), and moderate conductivity (382 µS/cm) (Table 5.12-8). Substrate consisted primarily of sand (87%) with small amounts of silt (9%) and clay (4%). The organic content of sediments at *baseline* reach BIC-D1 was low (<2%).

Water at *baseline* reach EYC-D1 (Eymundsen Creek) in fall 2015 was shallow (0.23 m), slightly alkaline (pH 7.9), with a moderate velocity (0.46 m/s), high dissolved oxygen concentration (9.3 mg/L), and moderate conductivity (356 µS/cm) (Table 5.12-8). Substrate consisted primarily of sand (88%) with small amounts of silt (9%) and (3%). The organic content of sediments at *baseline* reach EYC-D1 was low (<1%).

Water at *baseline* reach PIR-D1 (Pierre River) in fall 2015 was shallow (0.18 m), slightly alkaline (pH 8.4), with a moderate velocity (0.43 m/s), high dissolved oxygen concentration (10 mg/L), and moderate conductivity (334 µS/cm) (Table 5.12-8). Substrate consisted primarily of sand (92%) with small amounts of silt (4%) and clay (3%). The total organic carbon content was low (~1%).

Water at *baseline* reach RCC-E1 (Redclay Creek) in fall 2015 was shallow (0.1 m), slightly alkaline (pH 8.0), with a moderate velocity (0.56 m/s), high dissolved oxygen concentration (11.5 mg/L), and moderate conductivity (440 µS/cm) (Table 5.12-8). The substrate was dominated by coarse sand (0.1-0.2 cm). Pebbles at the reach had an average diameter of 8.0 cm with moderate embeddedness (41%). The dominant land use surrounding the reach was forest with streamside vegetation consisting of ferns and grasses, shrubs, deciduous trees, and coniferous trees. Full CABIN-supporting data are provided in Appendix D.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *baseline* reach BIC-D1 (Big Creek) was primarily comprised of chironomids (76%) with the subdominant taxa being tubificid worms (5%) and Ceratopogonidae (4%) (Table 5.12-9). Larvae of large flying insects were present in low relative abundance and included a few individual Ephemeroptera (Baetidae, *Leptophlebia*, and *Siphloplecton*), stoneflies (*Cultus/Dura*), caddisflies (*Hesperophylax*), and *Brychius* beetles. Permanent aquatic forms included the gastropod *Physa* and bivalve *Pisidium*. Dominant chironomids included *Micropsectra*/*Tanytarsus,* *Paralauterborniella*, *Chironomus*, and *Hydrosmittia*/*Pseudosmittia*.

The benthic invertebrate community at *baseline* reach EYC-D1 (Eymundsen Creek) was primarily comprised of chironomids (84%) with subdominant taxa including miscellaneous Diptera (5%) and naidid worms (3%) (Table 5.12-10). Dominant chironomids included *Saetheria*, *Micropsectra/ Tanytarsus*, and *Rheosmittia*/ *Lopesocladius*. EPT taxa were sparse with only a single Trichoptera and a single Lepidoptera. Permanent aquatic forms included Hydracarina and Gastropoda, each present in a single replicate sample.

The benthic community at *baseline* reach PIR-D1 (Pierre River) was dominated by chironomids (70%) (Table 5.12-11). Subdominant taxa included miscellaneous Diptera (10%), Sphaeriidae (6%), Trichoptera (3%) and tubificid worms (3%). Ephemeroptera were primarily *Caenis* and were more abundant at replicate station 6 than any other station in the reach. Other larvae of large flying insects included the mayfly *Baetis*, Capniidae stoneflies as well as unidentifiable caddisflies. Permanent aquatic forms were present in low relative abundances and included the bivalve *Pisidium*, the gastropod *Gyraulus*, and the water mite Hydracarina. Dominant chironomids included *Micropsectra/Tanytarsus, Polypedilum*, *Stempellinella*, and *Paratanytarsus.*

The benthic invertebrate community at *baseline* reach RCC-E1 (Redclay Creek) was diverse and dominated by Trichoptera (29%) and chironomids (19%) (Table 5.12-12). Subdominant taxa included Ephemeroptera (13%), miscellaneous Diptera (7%), and amphipods (5%). Caddisflies included primarily *Hydroptila*, *Hydropsyche*, and *Cheumatopsyche*. Dominant chironomids at the *baseline* reach were *Micropsectra*, *Polypedilum*, *Thienemannimyia gr.*, *Tvetenia*, and *Orthocladius*. Other larvae of flying insects present included mayflies (*Baetis, Leptophlebia*, *Acentrella*, and *Ephemerella*), the stonefly (Perlodidae), and the dragonfly Gomphidae. Permanent aquatic forms such as amphipods (*Gammarus* and *Hyalella*), bivalve clams (*Pisidium*), and gastropods (*Gyraulus* and *Lymnaea*) were also found in the reach.

Comparison to Published Literature The benthic invertebrate community of *baseline* reach BIC-D1 (Big Creek) was typical of a sandy-bottomed river environment, with Chironomids in relatively high abundance. Worm abundance, specifically tubificids, was lower than in 2013, indicating a potential positive change (Pennak 1989). The dominant chironomids present (e.g., *Micropsectra/Tanytarsus*) are tolerant of various conditions (Mandeville 2002).

The benthic invertebrate community of *baseline* reach EYC-D1 (Eymundsen Creek), which was also primarily sand substrate, had a fauna typical of the shifting habitat of a sandy-bottomed river. Chironomids were dominant and included forms that are widely distributed and tolerant of various conditions (e.g., *Micropsectra/Tanytarsus*), forms that are indicative of low levels of organic nutrients (e.g., Lopesocladius) and forms that are tolerant of pollution (e.g., *Saetheria*) (Beck 1977, Mandeville 2001). Flying insects (Trichoptera and Lepidoptera) were present at low relative abundances and richness was low; both observations are common for sandy-bottomed rivers.

Benthic community composition at *baseline* reach PIR-D1 (Pierre River) has showed some improvement since 2013. In 2015, chironomids were still numerically dominant; however, worm and nematode abundance decreased in 2015 compared to 2013 values. Mayflies, caddisflies and stoneflies (not present in 2013 or 2014) were present in 2015, indicating high water and substrate quality (Mandeville 2001). Permanent aquatic forms, also not present in 2013, were present in the *baseline* reach PIR-D1 in fall 2015.

The benthic invertebrate community of *baseline* reach RCC-E1 (Redclay Creek) had benthic fauna representative of good overall water quality. Caddisflies were numerically dominant and several other forms of larval flying insects (mayflies, stoneflies and dragonflies) were found at the *baseline* reach RCC-E1. The reach contained genera such as the mayfly *Ephemerella* and the chironomid *Tvetenia* that require colder and cleaner water (Mandeville 2001). The relative abundance of worms was low (~5%) and permanent aquatic forms were present at the reach in fall 2015.

2015 Results Relative to Regional *Baseline* Conditions Given that all benthic invertebrate sampling reaches in the Pierre River area were *baseline*, the data collected contributed to the regional *baseline* condition for comparisons to *test* reaches in the Athabasca oil sands region. Therefore, comparisons between these reaches and regional *baseline* conditions were not conducted.

Classification of Results The benthic invertebrate communities at *baseline* reaches BIC-D1, EYC-D1 and PIR-D1 were typical of sand-bottomed rivers with a high abundance of chironomids and worms, which are indicative of poor water quality conditions. EPT taxa were present, as were permanent aquatic forms. Overall, a decrease in the abundance of worms and an increasing proportion of EPT taxa indicated stable conditions. The benthic invertebrate communities at *baseline* reach RCC-E1 had a lower proportion of tolerant worms and chironomids in 2015, indicating good habitat quality. Redclay Creek was sampled using a CABIN kick net, and the index values provided in Table 5.12-12 were adjusted for comparison to historical data (see Appendix D). The benthic invertebrate community reaches in the Pierre River area were used as regional *baseline* reaches for comparison to *test* reaches of the Athabasca oil sands region.

5.12.3.2 Sediment Quality

Sediment quality was sampled in the Pierre River area in fall 2015 at:

- *baseline* station BIC-D1 in Big Creek, sampled from 2013 to 2015;
- *baseline* station EYC-D1 in Eymundson Creek, sampled from 2013 to 2015; and
- *baseline* station PIR-D1 in Pierre River, sampled from 2013 to 2015.

Temporal Trends Statistical trend analyses were not conducted on sediment quality data for stations in the Pierre River area due to insufficient length of the time series in the sediment quality datasets.

2015 Results Relative to Historical Concentrations Levels and concentrations of measurement endpoints for sediment quality were within historical ranges in fall 2015 at the stations in the Pierre River area (Table 5.12-13 to Table 5.12-15, Figure 5.12-7 to Figure 5.12-8) with the following exceptions[1]:

- % clay and % silt at *baseline* station BIC-D1 were higher than the previously-measured maximum values, while % sand was lower than the previously-measured minimum value and % total organic carbon was higher than the previously-measured maximum value;
- % clay and % silt at *baseline* station PIR-D1 were lower than the previously-measured minimum values, while % sand was higher than the previously-measured minimum value and % total organic carbon was lower than the previously-measured minimum value;

[1] Sampling at all stations within the Pierre River area was initiated in 2013 and therefore these historical comparisons were made against two years of data (2013 and 2014).

- concentrations of Fraction 3 and 4 hydrocarbons at *baseline* stations BIC-D1, EYC-D1, and PIR-D1 were higher than previously-measured maximum concentrations;
- the concentration of Fraction 2 hydrocarbons at *baseline* station EYC-D1 were higher than the previously-measured maximum concentration;
- the concentration of all PAHs at *baseline* station BIC-D1, with the exception of naphthalene and total parent PAHs, were lower than previously-measured minimum concentrations, while the concentration of total parent PAHs were higher than the previously-measured maximum concentration;
- concentrations of total dibenzothiophenes, total alkylated PAHs, total PAHs, and total arsenic at *baseline* station EYC-D1 were higher than previously-measured maximum concentrations;
- concentrations of all PAHs at *baseline* station PIR-D1 were lower than previously-measured minimum concentrations;
- *Chironomus* 10-day survival at *baseline* stations BIC-D1, EYC-D1, and PIR-D1 was higher than previously-measured maximum values;
- *Hyalella* 14-day growth at *baseline* stations BIC-D1, EYC-D1, and PIR-D1 was lower than previously-measured minimum values; and
- *Chironomus* 10-day growth at *baseline* station EYC-D1 was lower than the previously-measured minimum value.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of measurement endpoints for sediment quality at stations in the Pierre River area were below sediment quality guideline concentrations in fall 2015 (Table 5.12-13 to Table 5.12-15) with the exception of Fraction 3 hydrocarbons at *baseline* station EYC-D1 and *baseline* station PIR-D1, predicted PAH toxicity at *baseline* station EYC-D1, and total arsenic at *baseline* station EYC-D1.

2015 Results Relative to Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints in fall 2015 were within the ranges of regional *baseline* concentrations (Figure 5.12-6 to Figure 5.12-8) with the exception of:

- total metals and total PAHs (when carbon-normalized) at *baseline* station EYC-D1, which were above the 95th percentiles of regional *baseline* concentrations;
- total metals (when normalized to percent fine sediments) at *baseline* station EYC-D1 and *baseline* station PIR-D1, which were above the 95th percentile of regional *baseline* concentrations; and
- total PAHs (when carbon-normalized) at *baseline* station BIC-D1, which was below the 5th percentile of regional *baseline* concentrations.

Sediment Quality Index In fall 2015, SQI values for *baseline* stations BIC-D1, EYC-D1, and PIR-D1 were calculated to be 98.9, 86.0, and 95.8, respectively.

Classification of Results For *baseline* stations BIC-D1, EYC-D1, and PIR-D1, differences in sediment quality in fall 2015 and regional *baseline* conditions were classified as **Negligible-Low**.

Table 5.12-2 Monthly concentrations of water quality measurement endpoints, Big Creek (*baseline* station UN1 [BIC-1]), May to September 2015.

Measurement Endpoint	Units	Guideline[a]	n	Median	Minimum		Maximum	
			Monthly Water Quality Summary and Month of Occurrence					
Physical variables								
pH	pH units	6.5-9.0	5	8.02	7.70	Sep	8.08	Jul
Total suspended solids	mg/L	-	5	11.0	6.7	Aug	37.0	May
Conductivity	µS/cm	-	5	410	340	May	430	Jul, Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.022	0.014	Jun	0.081	Sep
Total nitrogen	mg/L	-	5	0.98	0.42	Aug	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	5	0.022	0.007	-	0.029	-
Dissolved organic carbon	mg/L	-	5	11.0	9.2	Jul	18.0	Sep
Ions								
Sodium	mg/L	-	5	10.0	2.6	Sep	13.0	Jun
Calcium	mg/L	-	5	62.0	41.0	May	69.0	Sep
Magnesium	mg/L	-	5	15.00	11.00	May	16.00	Aug
Potassium	mg/L	-	5	2.10	1.20	Sep	3.20	May
Chloride	mg/L	120-640	5	<1.0	<1.0	May to Jul	1.2	Aug
Sulphate	mg/L	309-429[b]	5	28.0	0.7	Sep	66.0	May
Total dissolved solids	mg/L	-	5	260	140	May	300	Sep
Total alkalinity	mg/L	20 (min)	5	200	110	May	230	Sep
Selected metals								
Total aluminum	mg/L	-	5	0.3390	0.1130	Sep	1.8500	May
Dissolved aluminum	mg/L	0.05	5	0.00197	0.00094	Sep	0.00881	May
Total arsenic	mg/L	0.005	5	0.00074	0.00065	Jun	0.00090	May
Total boron	mg/L	1.5-29	5	0.0672	0.0029	Sep	0.0690	May
Total molybdenum	mg/L	0.073	5	0.00047	0.00011	Sep	0.00053	Aug
Total mercury (ultra-trace)	ng/L	5-13	5	1.34	1.13	Jul	1.89	May
Total methyl mercury	ng/L	1-2	5	0.076	0.071	May	0.782	Sep
Total strontium	mg/L	-	5	0.161	0.138	May	0.192	Jun
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	5	0.84	0.37	Sep	1.18	Aug
Oilsands extractable acids	mg/L	-	5	2.3	2.1	Jun	2.8	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	2.77	0.96	Jun	14.40	May
Total dibenzothiophenes[c]	ng/L	-	5	8.17	8.17	Jun	13.70	May
Total PAHs[c]	ng/L	-	5	128	125	Aug	161	May
Total Parent PAHs[c]	ng/L	-	5	22.8	22.6	Jul	23.4	Sep
Total Alkylated PAHs[c]	ng/L	-	5	106	103	Aug	138	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.0093**	0.0022	May	**0.0120**	Sep
Sulphide	mg/L	0.0019	4	**0.0073**	<0.0019	Aug	**0.0100**	Sep
Dissolved iron	mg/L	0.3	1	0.168	0.029	Aug	**0.331**	Oct

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

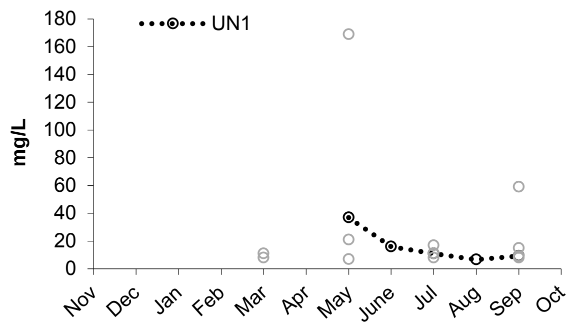
[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

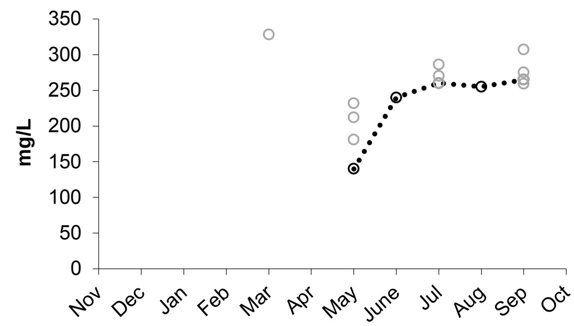
[d] n value refers to number of exceedances in 2015.

Figure 5.12-3 Selected water quality measurement endpoints in Big Creek (monthly data) in the 2015 WY.

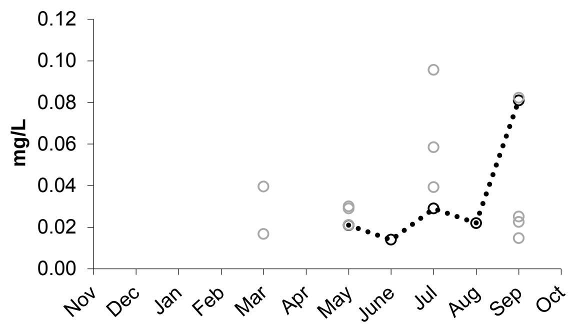
Total Suspended Solids (TSS)



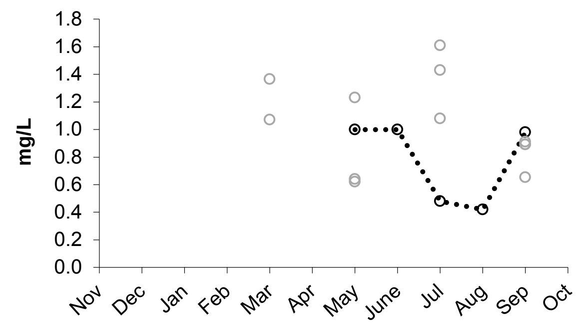
Total Dissolved Solids (TDS)



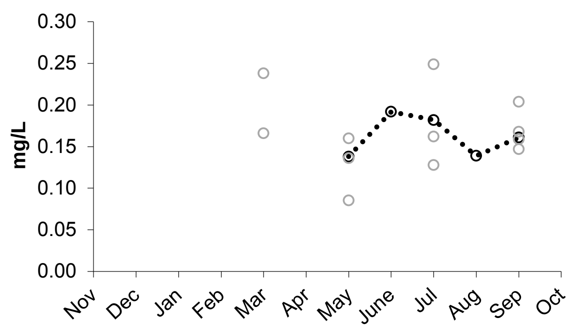
Total Dissolved Phosphorus



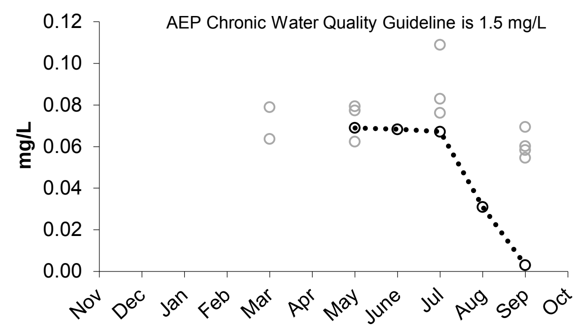
Total Nitrogen



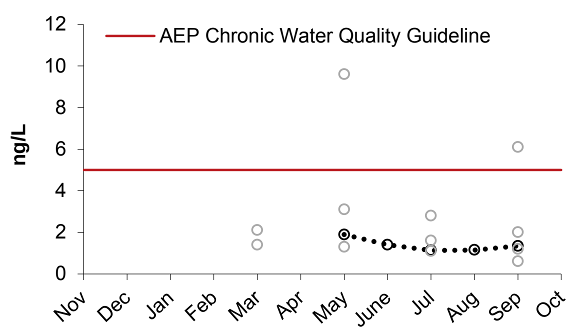
Total Strontium



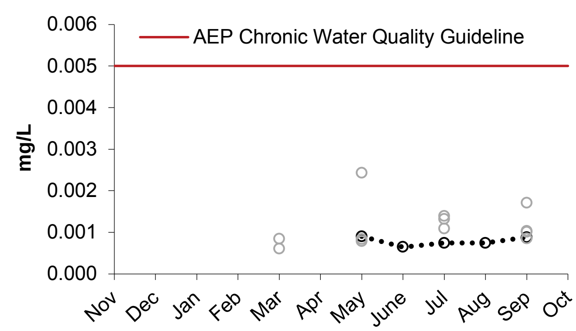
Total Boron



Total Mercury (Ultra-trace)

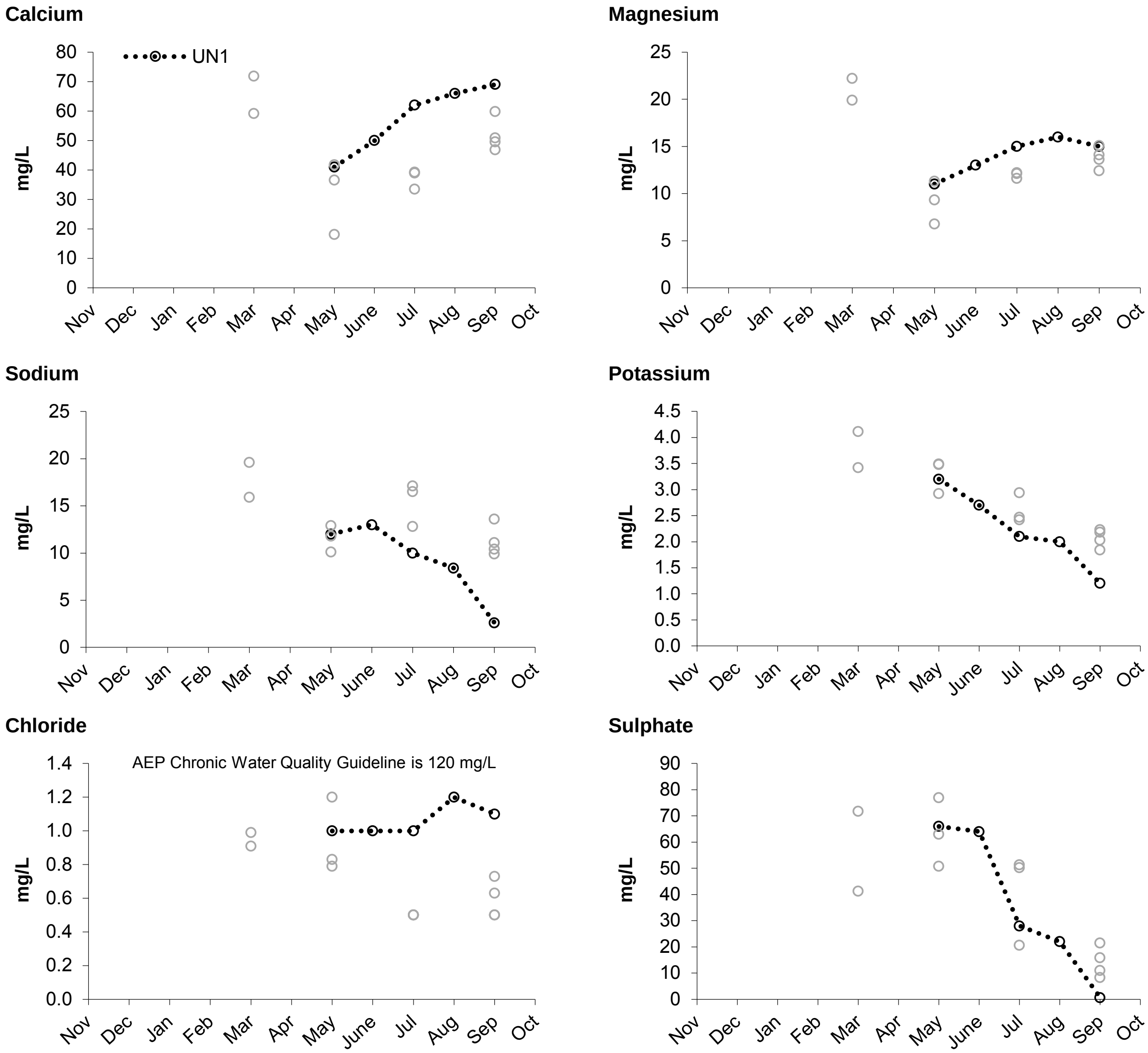


Total Arsenic



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.12-3 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.12-3 Concentrations of water quality measurement endpoints, Big Creek (*baseline* station UN1 [BIC-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2011-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.70	4	8.3	8.1	8.4
Total suspended solids	mg/L	-	9.3	4	12.0	8.0	59.0
Conductivity	µS/cm	-	410	4	394	387	446
Nutrients							
Total dissolved phosphorus	mg/L	-	0.081	4	0.024	0.015	0.082
Total nitrogen	mg/L	-	0.98	4	0.891	0.654	0.911
Nitrate+nitrite	mg/L	3-124	0.024	4	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	18	4	21.6	17.1	27.3
Ions							
Sodium	mg/L	-	2.6	4	10.8	9.9	13.6
Calcium	mg/L	-	69	4	54.4	52.5	57.4
Magnesium	mg/L	-	15	4	13.9	12.4	15.1
Potassium	mg/L	-	1.2	4	1.8	2.1	2.2
Chloride	mg/L	120-640	1.1	4	0.57	<0.50	0.73
Sulphate	mg/L	309[b]	0.7	4	13.5	8.3	21.5
Total dissolved solids	mg/L	-	300	4	270	259	307
Total alkalinity	mg/L	20 (min)	230	4	201	195	223
Selected metals							
Total aluminum	mg/L	-	0.113	4	0.332	0.179	1.740
Dissolved aluminum	mg/L	0.05	0.00094	4	0.0036	0.0020	0.0088
Total arsenic	mg/L	0.005	0.00088	4	0.00102	0.00085	0.00171
Total boron	mg/L	1.5-29	0.003	4	0.059	0.055	0.069
Total molybdenum	mg/L	0.073	0.00011	4	0.00035	0.00031	0.00042
Total mercury (ultra-trace)	ng/L	5-13	1.34	4	1.60	0.60	**6.10**
Total methyl mercury	ng/L	1-2	0.782	-	-	-	-
Total strontium	mg/L	-	0.161	4	0.164	0.147	0.204
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.37	4	0.52	0.05	1.10
Oilsands extractable acids	mg/L	-	2.7	4	1.11	0.31	1.81
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	2.77	4	2.26	0.57	4.16
Total dibenzothiophenes[c]	ng/L	-	8.17	4	9.72	4.13	35.30
Total PAHs[c]	ng/L	-	127.2	4	147.0	75.4	206.5
Total Parent PAHs[c]	ng/L	-	23.4	4	18.26	13.48	23.65
Total Alkylated PAHs[c]	ng/L	-	103.7	4	125.1	61.9	190.0
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.331**	4	**0.33**	0.04	**0.86**
Total phenols	mg/L	0.004	**0.012**	4	**0.0056**	**0.0043**	**0.0073**
Sulphide	mg/L	0.0019	**0.010**	4	**0.006**	<0.002	**0.008**

Values in **bold** are above guideline; underlined values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.12-4 Concentrations of water quality measurement endpoints, Pierre River (*baseline* station PIR-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2011-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.14	4	8.24	8.08	8.40
Total suspended solids	mg/L	-	<u>4.0</u>	4	32.7	21.0	74.0
Conductivity	µS/cm	-	420	4	451	387	554
Nutrients							
Total dissolved phosphorus	mg/L	-	0.049	4	0.049	0.029	0.064
Total nitrogen	mg/L	-	1.0	4	1.01	0.81	1.42
Nitrate+nitrite	mg/L	3-124	<0.005	4	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	<u>27</u>	4	30	28	41
Ions							
Sodium	mg/L	-	22	4	22.5	20.2	28.6
Calcium	mg/L	-	50	4	51.4	41.8	70.5
Magnesium	mg/L	-	15	4	14.9	12.1	20.1
Potassium	mg/L	-	2.7	4	2.5	3.0	3.5
Chloride	mg/L	120-640	5.1	4	6.47	4.05	8.70
Sulphate	mg/L	429[b]	25	4	31.7	23.0	36.4
Total dissolved solids	mg/L	-	<u>300</u>	4	345	303	396
Total alkalinity	mg/L	20 (min)	200	4	193	173	265
Selected metals							
Total aluminum	mg/L	-	0.196	4	0.97	0.48	1.50
Dissolved aluminum	mg/L	0.05	<u>0.0064</u>	4	0.010	0.0078	0.022
Total arsenic	mg/L	0.005	<u>0.0013</u>	4	0.0024	0.0019	0.0026
Total boron	mg/L	1.5-29	<u>0.0683</u>	4	0.106	0.095	0.122
Total molybdenum	mg/L	0.073	<u>0.0008</u>	4	0.00109	0.00094	0.00145
Total mercury (ultra-trace)	ng/L	5-13	<u>1.24</u>	4	4.20	3.16	4.90
Total methyl mercury	ng/L	1-2	0.24	-	-	-	-
Total strontium	mg/L	-	0.206	4	0.214	0.164	0.258
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.84	4	0.76	0.06	1.50
Oilsands extractable acids	mg/L	-	<u>3.8</u>	4	1.49	0.46	2.90
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	3.43	1.71	5.91
Total dibenzothiophenes[c]	ng/L	-	<u>16.2</u>	4	59.23	43.35	238.24
Total PAHs[c]	ng/L	-	<u>139.5</u>	4	284.9	242.1	764.2
Total Parent PAHs[c]	ng/L	-	23.0	4	21.19	16.06	32.76
Total Alkylated PAHs[c]	ng/L	-	<u>116.4</u>	4	263.7	226.0	731.4
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.51**	4	**0.73**	0.28	**1.74**
Sulphide	mg/L	0.002	**0.016**	4	**0.018**	**0.006**	**0.019**
Total phenols	mg/L	0.004	**<u>0.013</u>**	4	**0.0065**	**0.0054**	**0.0099**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.12-5 Concentrations of water quality measurement endpoints, Eymundson Creek (*baseline* station EYC-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2011-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.94	4	8.1	7.95	8.3
Total suspended solids	mg/L	-	<u>37</u>	4	128	54	180
Conductivity	µS/cm	-	410	4	488	318	596
Nutrients							
Total dissolved phosphorus	mg/L	-	<u>0.037</u>	4	0.022	0.009	0.028
Total nitrogen	mg/L	-	0.80	4	0.98	0.79	1.10
Nitrate+nitrite	mg/L	3-124	<0.005	4	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	<u>19</u>	4	24.7	23.0	31.2
Ions							
Sodium	mg/L	-	17	4	20.2	11.6	26.5
Calcium	mg/L	-	50	4	55.0	35.5	76.5
Magnesium	mg/L	-	15	4	16.1	9.9	22.3
Potassium	mg/L	-	2.1	4	1.7	2.5	3.0
Chloride	mg/L	120-640	3.3	4	2.84	1.52	3.62
Sulphate	mg/L	309[b]	86	4	113	59	137
Total dissolved solids	mg/L	-	340	4	366	258	425
Total alkalinity	mg/L	20 (min)	120	4	131	98.7	177
Selected metals							
Total aluminum	mg/L	-	2.52	4	3.80	1.78	5.13
Dissolved aluminum	mg/L	0.05	0.033	4	0.029	0.013	**0.082**
Total arsenic	mg/L	0.005	<u>0.0022</u>	4	0.0030	0.0023	0.0038
Total boron	mg/L	1.5-29	<u>0.061</u>	4	0.099	0.074	0.113
Total molybdenum	mg/L	0.073	0.0016	4	0.0017	0.0013	0.0025
Total mercury (ultra-trace)	ng/L	5-13	**7.08**	4	**12.9**	**9.2**	**21.0**
Total methyl mercury	ng/L	1-2	0.280	-	-	-	-
Total strontium	mg/L	-	0.194	4	0.198	0.114	0.226
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.38	4	0.53	0.10	1.20
Oilsands extractable acids	mg/L	-	<u>1.7</u>	4	1.38	0.51	1.50
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	1.56	4	6.88	4.02	13.6
Total dibenzothiophenes[c]	ng/L	-	<u>34.0</u>	4	71.85	37.08	226.49
Total PAHs[c]	ng/L	-	<u>198.7</u>	4	348.8	250.1	729.8
Total Parent PAHs[c]	ng/L	-	31.8	4	24.14	17.84	36.53
Total Alkylated PAHs[c]	ng/L	-	<u>166.9</u>	4	324.6	232.3	693.2
Other variables that exceeded Alberta guidelines in fall 2015							
Dissolved iron	mg/L	0.3	**0.874**	4	**0.843**	**0.187**	**1.850**
Total phenols	mg/L	0.004	**0.0092**	4	**0.0079**	**0.0052**	**0.0098**
Sulphide	mg/L	0.0019	**0.015**	4	**0.015**	**0.002**	**0.028**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.12-6 Concentrations of water quality measurement endpoints, Redclay Creek (*baseline* station RCC-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2011-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.02	4	8.33	8.07	8.38
Total suspended solids	mg/L	-	<1	4	3.0	<3.0	7.0
Conductivity	µS/cm	-	470	4	509	480	522
Nutrients							
Total dissolved phosphorus	mg/L	-	0.012	4	0.013	0.008	0.018
Total nitrogen	mg/L	-	0.38	4	0.511	0.404	0.551
Nitrate+nitrite	mg/L	3-124	<0.005	4	<0.071	<0.054	<0.071
Dissolved organic carbon	mg/L	-	10	4	13.4	9.8	15.7
Ions							
Sodium	mg/L	-	9.1	4	12.4	10.6	15.7
Calcium	mg/L	-	68	4	70.2	63.4	72.0
Magnesium	mg/L	-	19	4	19.2	16.5	21.3
Potassium	mg/L	-	2.0	4	2.3	2.7	3.1
Chloride	mg/L	120-640	1.9	4	1.54	1.26	1.64
Sulphate	mg/L	309[b]	47	4	45.0	35.9	54.6
Total dissolved solids	mg/L	-	320	4	327	306	337
Total alkalinity	mg/L	20 (min)	210	4	230	220	269
Selected metals							
Total aluminum	mg/L	-	0.0155	4	0.045	0.011	0.303
Dissolved aluminum	mg/L	0.05	0.00051	4	0.0014	0.00048	0.0030
Total arsenic	mg/L	0.005	0.000145	4	0.00017	0.000142	0.00026
Total boron	mg/L	1.5-29	0.0672	4	0.084	0.073	0.115
Total molybdenum	mg/L	0.073	0.000114	4	0.00011	0.00009	0.00014
Total mercury (ultra-trace)	ng/L	5-13	1.34	4	0.81	0.49	1.20
Total methyl mercury	ng/L	1-2	0.112	-	-	-	-
Total strontium	mg/L	-	0.219	4	0.237	0.192	0.268
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.25**	**<0.25**	**<0.25**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.76	4	0.35	0.09	0.95
Oilsands extractable acids	mg/L	-	2.0	4	1.22	0.48	1.91
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	<0.592	0.407	<2.071
Total dibenzothiophenes[c]	ng/L	-	8.17	4	6.45	4.13	35.30
Total PAHs[c]	ng/L	-	125.9	4	127.4	74.1	220.8
Total Parent PAHs[c]	ng/L	-	22.7	4	17.83	13.26	22.86
Total Alkylated PAHs[c]	ng/L	-	103.2	4	106.4	60.8	204.4
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.0019	**0.0046**	4	<0.002	<0.002	<0.002
Total phenols	mg/L	0.004	**0.0097**	4	0.0026	0.0035	**0.0044**

Values in **bold** are above guideline; underlined values are outside of historical range.
[a] Sources for all guidelines are outlined in Table 3.2-1.
[b] based on actual hardness level
[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.12-4 Piper diagram of fall ion concentrations in the Pierre River area.

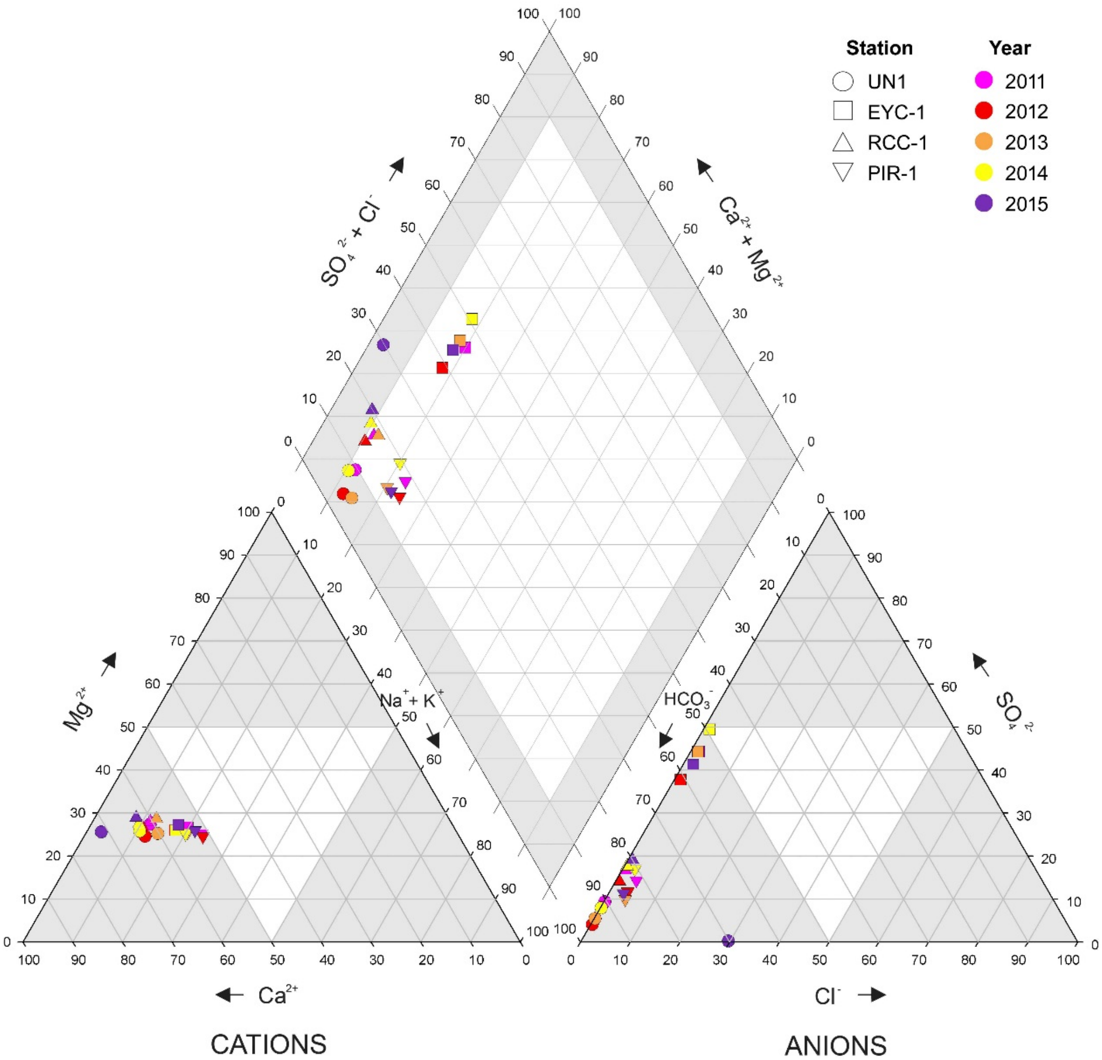


Table 5.12-7 Water quality guideline exceedances in the Pierre River area, 2015 WY.

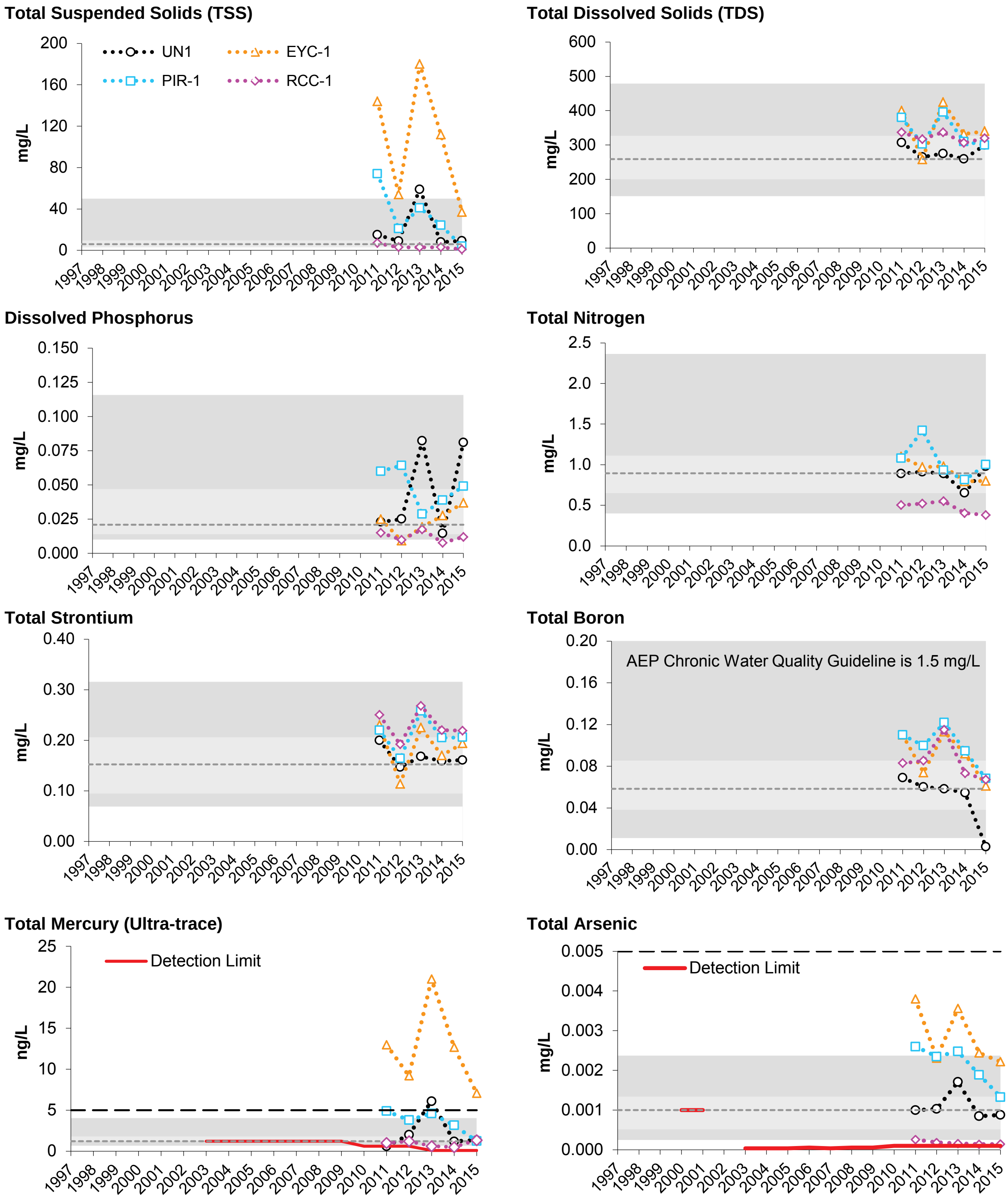
Variable	Units	Guideline[a]	May	June	July	August	September
Big Creek (UN1)							
Total phenols	mg/L	0.004	0.0022	0.0029	**0.01**	**0.0093**	**0.012**
Sulphide	mg/L	0.0019	**0.0073**	**0.0073**	**0.0024**	<0.0019	**0.01**
Dissolved iron	mg/L	0.3	0.237	0.168	0.0653	0.029	**0.331**
Eymundson Creek (EYC-1)							
Dissolved iron	mg/L	0.3	-	-	-	-	**0.874**
Total mercury (ultra-trace)	ng/L	5-13	-	-	-	-	**7.08**
Total phenols	mg/L	0.004	-	-	-	-	**0.0092**
Sulphide	mg/L	0.0019	-	-	-	-	**0.015**
Pierre River (PIR-1)							
Dissolved iron	mg/L	0.3	-	-	-	-	**0.505**
Sulphide	mg/L	0.0019	-	-	-	-	**0.016**
Total phenols	mg/L	0.004	-	-	-	-	**0.013**
Redclay Creek (RCC-1)							
Sulphide	mg/L	0.0019	-	-	-	-	**0.0046**
Total phenols	mg/L	0.004	-	-	-	-	**0.0097**

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Figure 5.12-5 Selected water quality measurement endpoints at *baseline* stations BIC-1, EYC-1, PIR-1, and RCC-1 (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



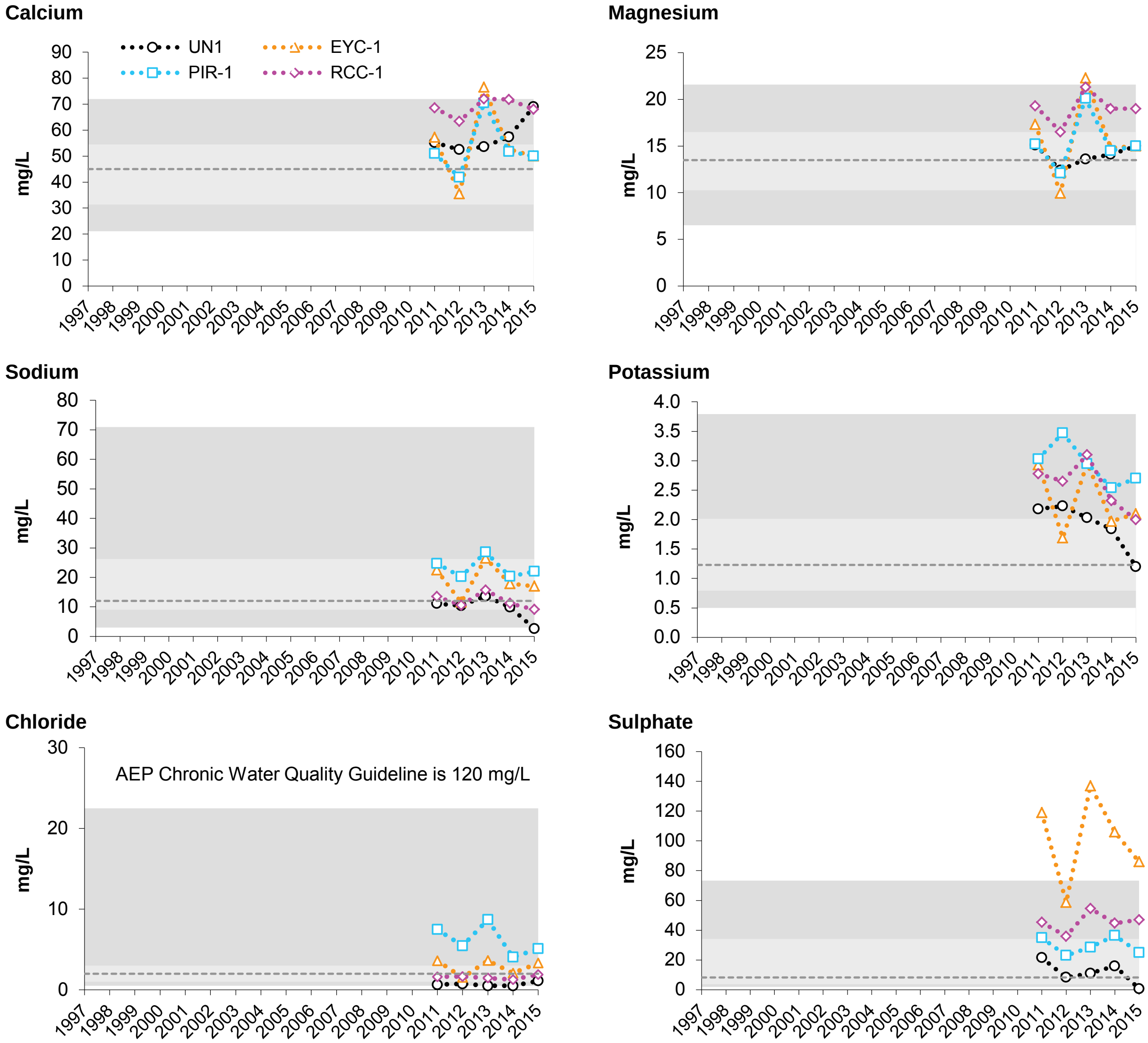
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.12-5 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.12-8 Average habitat characteristics of benthic invertebrate community sampling locations in the Pierre River area (*baseline* reaches BIC-D1, EYC-D1, PIR-D1, and RCC-E1), fall 2015.

Variable	Units	BIC-D1 Lower *Baseline* Reach of Big Creek	EYC-D1 Lower *Baseline* Reach of Eymundson Creek	PIR-D1 Lower *Baseline* Reach of Pierre Creek	RCC-E1 Lower *Baseline* Reach of Redclay Creek
Sample date	-	Sept. 10, 2015	Sept. 12, 2015	Sept. 9, 2014	Sept. 10, 2015
Habitat	-	Depositional	Depositional	Depositional	Erosional
Water depth	m	0.6	0.2	0.2	0.1
Current velocity	m/s	0.15	0.46	0.43	0.56
Field water quality					
Dissolved oxygen (DO)	mg/L	10.1	9.3	10	11.5
Conductivity	µS/cm	382	356	334	440
pH	pH units	7.0	7.9	8.4	8.0
Water temperature	°C	9.8	12.2	10.1	10.4
Sediment composition					
Sand	%	87.2	87.9	92.4	-
Silt	%	8.5	8.9	4.4	-
Clay	%	4.3	3.2	3.2	-
Total organic carbon (TOC)	%	1.5	0.68	1.1	-

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.12-9 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in Big Creek (*baseline* reach BIC-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach BIC-D1		
	2013	2014	2015
Nematoda	5	1	1
Naididae	2	-	4
Tubificidae	11	<1	5
Enchytraeidae	2	<1	-
Lumbriculidae	<1	-	-
Hydracarina	-	<1	-
Gastropoda	10	-	1
Bivalvia	1	-	2
Ceratopogonidae	<1	<1	4
Chironomidae	68	78	76
Diptera (misc)	2	7	1
Coleoptera	-	<1	<1
Ephemeroptera	<1	<1	<1
Trichoptera	-	-	<1
Plecoptera	-	<1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	14	173	469
Richness	4	7	17
Equitability	0.75	0.57	0.31
% EPT	0.05	0.05	0.13

Table 5.12-10 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in Eymundson Creek (*baseline* reach EYC-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach EYC-D1		
	2013	2014	2015
Nematoda	2	6	1
Naididae	6	<1	3
Tubificidae	14	11	2
Enchytraeidae	<1	3	-
Hydracarina	-	7	-
Gastropoda	-	-	<1
Ceratopogonidae	1	5	1
Chironomidae	65	63	84
Diptera (misc)	12	3	5
Lepidoptera	-	-	2
Ephemeroptera	<1	1	-
Trichoptera	-	-	2
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	15	12	75
Richness	4	5	8
Equitability	0.72	0.79	0.58
% EPT	<1	1	2

Table 5.12-11 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in Pierre River (*baseline* reach PIR-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Baseline Reach PIR-D1		
	2013	2014	2015
Nematoda	17	2	1
Naididae	<1	2	2
Tubificidae	22	4	3
Enchytraeidae	<1	8	-
Hirudinea	<1	-	<1
Hydracarina	<1	<1	-
Amphipoda	-	<1	-
Gastropoda	-	<1	1
Bivalvia	<1	2	6
Ceratopogonidae	1	2	1
Chironomidae	57	48	70
Diptera (misc)	<1	3	10
Ephemeroptera	2	8	1
Trichoptera	-	<1	3
Plecoptera	-	-	<1
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	326	205	376
Richness	11	13	18
Equitability	0.46	0.23	0.31
% EPT	2	8	5

Table 5.12-12 Summary of major taxa abundances and measurement endpoints of benthic invertebrate communities in Redclay Creek (*baseline* reach RCC-E1).

Taxon	Percent Major Taxa Enumerated in Each Year *Baseline* Reach RCC-E1 2013	2014	2015
Hydra	<1	-	-
Nematoda	1	1	-
Oligochaeta	<1	-	-
Naididae	3	11	1
Tubificidae	3	<1	4
Enchytraeidae	<1	<1	-
Hydracarina	3	4	15
Amphipoda	<1	<1	5
Gastropoda	<1	<1	2
Bivalvia	<1	<1	4
Ceratopogonidae	<1	-	<1
Chironomidae	73	28	19
Diptera (misc)	5	11	7
Coleoptera	<1	<1	-
Ephemeroptera	2	3	13
Odonata	<1	<1	<1
Megaloptera	-	-	<1
Neuroptera	<1	-	-
Plecoptera	<1	5	2
Trichoptera	8	36	29
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	3,514	3,381	1,431
Richness	31	36	30
Equitability	0.27	0.21	0.39
% EPT	11	45	20

Note: All 2015 benthic invertebrate community measurement endpoints, with the exception of equitability, were calculated using a correction factor, converting Kicknet measures to Neil-Hess measures (see Appendix D). All percent abundances of taxa are based on original counts. % EPT as an index in 2015 does not equal the observed percentages in the kick sample, because the index value was adjusted down to be equivalent to what would have been expected with a Neil-Hess cylinder.

Table 5.12-13 Concentrations of selected sediment quality measurement endpoints in Big Creek (*baseline* station BIC-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2013-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	7.7	2	2.0	2.4	2.7
Silt	%	-	16.9	2	2.6	4.6	6.6
Sand	%	-	75.4	2	91.4	93.1	94.7
Total organic carbon	%	-	6.69	2	0.40	0.58	0.75
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	2	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	126	2	62	63	63
Fraction 4 (C34-C50)	mg/kg	2800[1]	118	2	78	82	86
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0006	2	0.0005	0.0006	0.0006
Retene	mg/kg	-	0.0040	2	0.0042	0.0055	0.0068
Total dibenzothiophenes	mg/kg	-	0.0272	2	0.0277	0.0280	0.0282
Total PAHs	mg/kg	-	0.1613	2	0.1642	0.1715	0.1787
Total Parent PAHs	mg/kg	-	0.0156	2	0.0103	0.0105	0.0108
Total Alkylated PAHs	mg/kg	-	0.1457	2	0.1539	0.1609	0.1680
Predicted PAH toxicity[3]	H.I.	1.0	0.1592	2	0.2793	0.2844	0.2894
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	100	2	52	58	64
Chironomus growth - 10d	mg/organism	-	1.90	2	1.49	2.05	2.60
Hyalella survival - 14d	% surviving	-	90	2	92	93	94
Hyalella growth - 14d	mg/organism	-	0.15	2	0.30	0.30	0.30

Values in **bold** indicate concentrations exceeding guidelines.

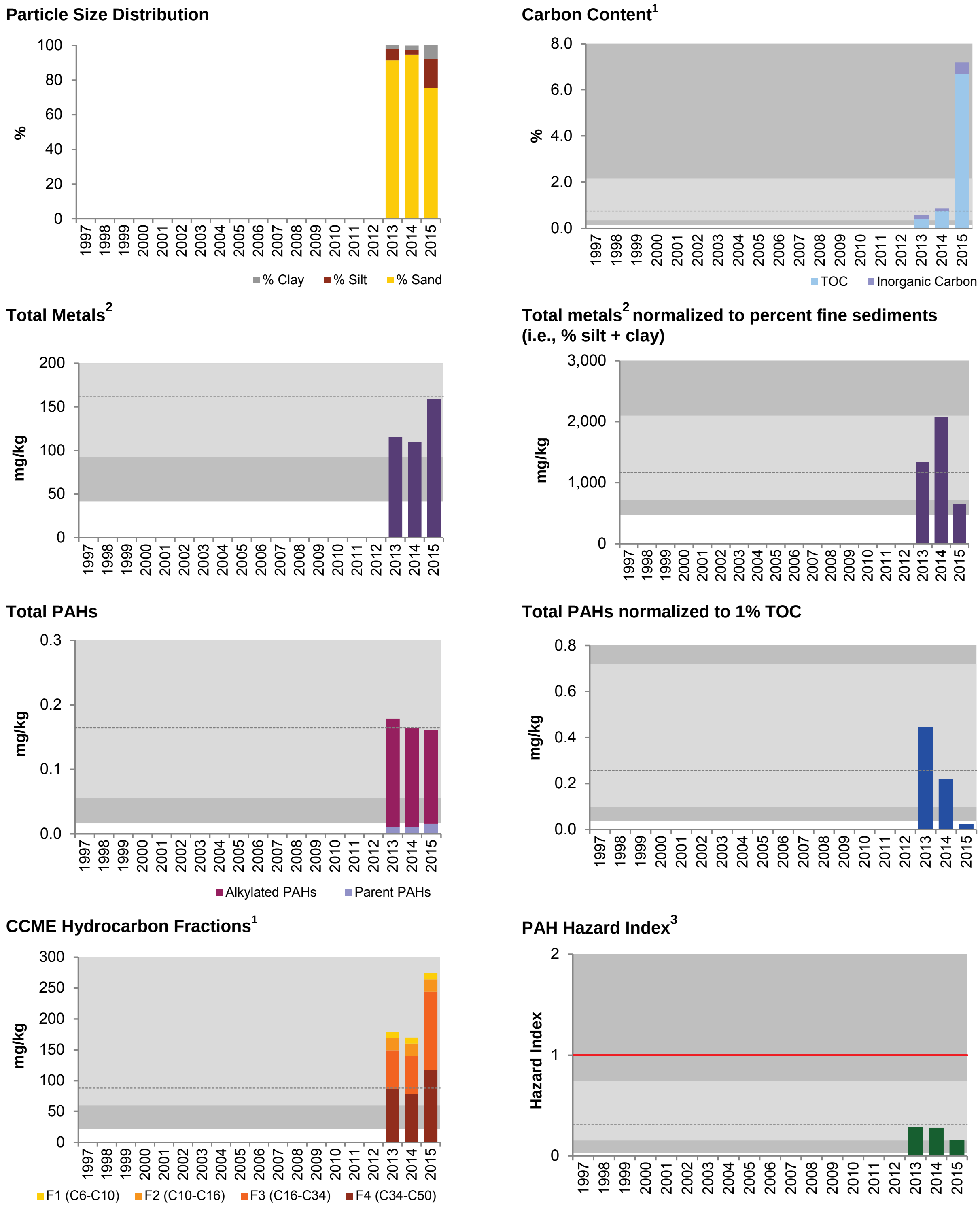
Values underlined indicate concentrations outside the range of historical observations.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.12-6 Variation in sediment quality measurement endpoints in Big Creek, *baseline* station BIC-D1, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.12-14 Concentrations of selected sediment quality measurement endpoints in Pierre River (*baseline* station PIR-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2013-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2.6	2	7.7	11.9	16.1
Silt	%	-	3.0	2	12.3	25.4	38.5
Sand	%	-	94.4	2	45.4	62.7	80.0
Total organic carbon	%	-	0.90	2	3.88	4.46	5.04
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<80	2	72	83.5	95
Fraction 3 (C16-C34)	mg/kg	300[1]	**765**	2	**868**	**999**	**1130**
Fraction 4 (C34-C50)	mg/kg	2800[1]	732	2	735	854	972
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0009	2	0.0020	0.0023	0.0026
Retene	mg/kg	-	0.0253	2	0.0993	0.1967	0.2940
Total dibenzothiophenes	mg/kg	-	1.4103	2	1.9764	3.0299	4.0834
Total PAHs	mg/kg	-	4.5119	2	5.8332	8.8917	11.9503
Total Parent PAHs	mg/kg	-	0.1298	2	0.1585	0.2018	0.2450
Total Alkylated PAHs	mg/kg	-	4.3821	2	5.6747	8.6900	11.7053
Predicted PAH toxicity[3]	H.I.	1.0	0.8146	2	**1.0072**	**1.2840**	**1.5608**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	80	2	56	57	58
Chironomus growth - 10d	mg/organism	-	2.46	2	1.42	2.21	2.99
Hyalella survival - 14d	% surviving	-	96	2	84	91	98
Hyalella growth - 14d	mg/organism	-	0.14	2	0.24	0.25	0.25

Values in **bold** indicate concentrations exceeding guidelines.

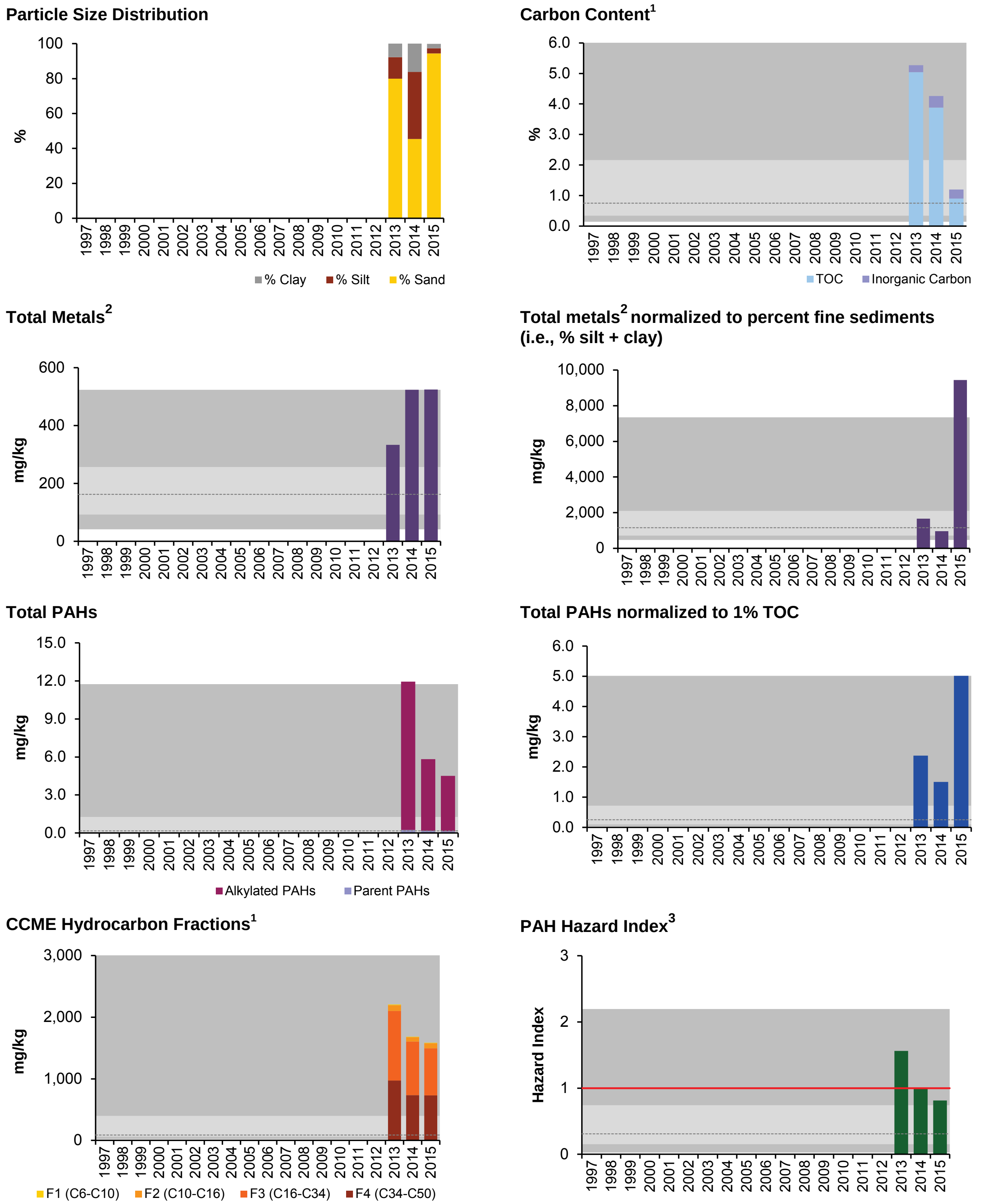
Values underlined indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.12-7 Variation in sediment quality measurement endpoints in Pierre River, *baseline* station PIR-D1, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Table 5.12-15 Concentrations of selected sediment quality measurement endpoints in Eymundson Creek (*baseline* station EYC-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2013-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3.1	2	2.2	10.8	19.3
Silt	%	-	3.5	2	2.3	16.9	31.4
Sand	%	-	93.5	2	49.3	72.4	95.5
Total organic carbon	%	-	0.56	2	0.49	1.08	1.67
Total hydrocarbons							
BTEX	mg/kg	-	<10	2	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	2	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<u>71</u>	2	25	28	31
Fraction 3 (C16-C34)	mg/kg	300[1]	**<u>589</u>**	2	161	191	221
Fraction 4 (C34-C50)	mg/kg	2800[1]	<u>342</u>	2	97	138	179
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0011	2	0.0006	0.0010	0.0014
Retene	mg/kg	-	0.0228	2	0.0109	0.0340	0.0570
Total dibenzothiophenes	mg/kg	-	<u>1.3123</u>	2	0.4586	0.6737	0.8889
Total PAHs	mg/kg	-	<u>3.5083</u>	2	1.3459	2.1622	2.9785
Total Parent PAHs	mg/kg	-	0.0750	2	0.0356	0.0690	0.1024
Total Alkylated PAHs	mg/kg	-	<u>3.4333</u>	2	1.3102	2.0932	2.8762
Predicted PAH toxicity[3]	H.I.	1.0	**1.0298**	2	0.9108	**1.9751**	**3.0393**
Metals that exceeded CCME guidelines in 2015							
Total arsenic	mg/kg	5.9	**<u>41.7</u>**	2	**14.6**	**16.0**	**17.4**
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	<u>98</u>	2	46	67	88
Chironomus growth - 10d	mg/organism	-	<u>1.75</u>	2	2.89	3.40	3.91
Hyalella survival - 14d	% surviving	-	<u>100</u>	2	82	90	98
Hyalella growth - 14d	mg/organism	-	<u>0.13</u>	2	0.23	0.26	0.28

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

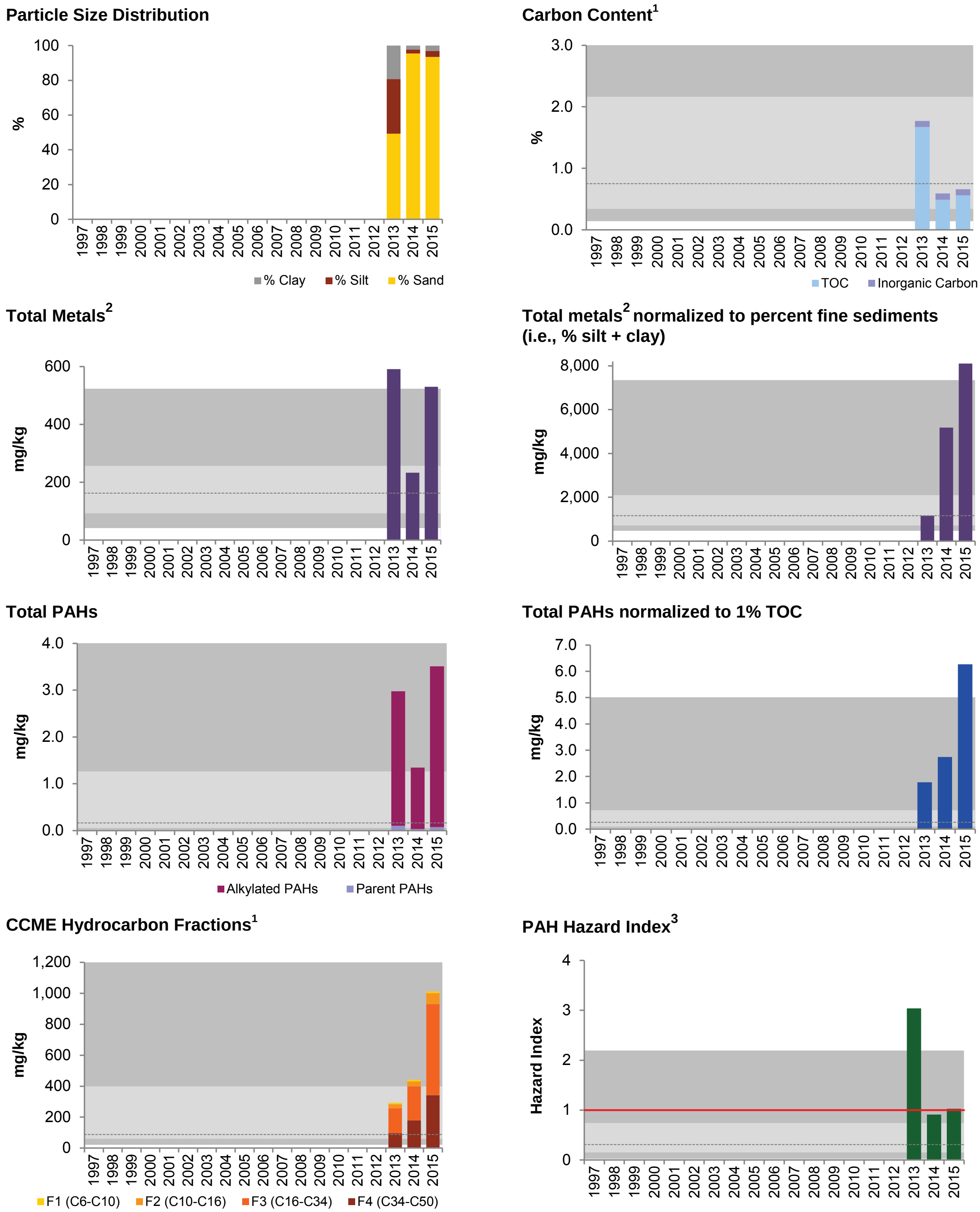
ns = not sampled in 1999, 2000, 2001, 2008, or 2009

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species

Figure 5.12-8 Variation in sediment quality measurement endpoints in Eymundson Creek, *baseline* station EYC-D1, relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

5.13 MISCELLANEOUS AQUATIC SYSTEMS

Table 5.13-1 Summary of results for the miscellaneous aquatic systems of the 2015 JOSMP study area.

Miscellaneous Aquatic Systems	Summary of 2015 Conditions											
	Rivers and Creeks										Lakes	
Climate and Hydrology												
Criteria	no station	**S6**	**3064528**	**S11**	no station	no station	no station	**07DA018**	no station	no station	**L3**	no station
Mean open-water season discharge	-	not measured	climate station - n/a	🟤	-	-	-	not measured	-	-	not measured	-
Mean winter discharge	-	not measured	climate station - n/a	🟡	-	-	-	not measured	-	-	not measured	-
Annual maximum daily discharge	-	not measured	climate station - n/a	🟡	-	-	-	not measured	-	-	not measured	-
Minimum open-water season discharge	-	not measured	climate station - n/a	🟡	-	-	-	not measured	-	-	not measured	-
Water Quality												
Criteria	**FOC-1**	no station	no station	**PO1**	**MCC-1**	**HO2**	**BER-1**	**BER-2**	**AC-DS**	**AC-US**	**ISL-1**	**SHL-1**
Water Quality Index	🟡	-	-	🟡	🟡	🟡	🟡	🟡	🟡	🟡	n/a	n/a
Benthic Invertebrate Communities and Sediment Quality												
Criteria	**FOC-D1**	no reach	no reach	**POC-D1**	no reach	no reach	no reach	**BER-D2**	**AC-DS**	**AC-US**	**ISL-1**	**SHL-1**
Benthic Invertebrate Communities	🟤	-	-	🟠	-	-	-	n/a	no reach	no reach	🟡	🟡
Sediment Quality Index	🟡	-	-	🟡	-	-	-	🟡	🟡	🟡	n/a	n/a
Fish Populations												
Criteria	no reach	no reach	no reach	no reach	no reach	no reach	no reach	no reach	**AC-DS**	**AC-US**	no reach	no reach
Fish Communities	No Fish Communities monitoring was conducted in the 2015 WY.											
Wild Fish Health	-	-	-	-	-	-	-	-	n/a	n/a	-	-

Legend and Notes

- 🟡 Negligible - Low
- 🟠 Moderate
- 🟤 High
- *baseline*
- *test*

n/a – not applicable, summary indicators for *test* reaches/stations were designated based on comparisons with *baseline* reaches/station or regional *baseline* conditions.

"-" – not sampled

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High. The open-water season refers to the time period between May 1 and October 31, 2015, and the winter season refers to the time period between November 1, 2014 and March 31, 2015.

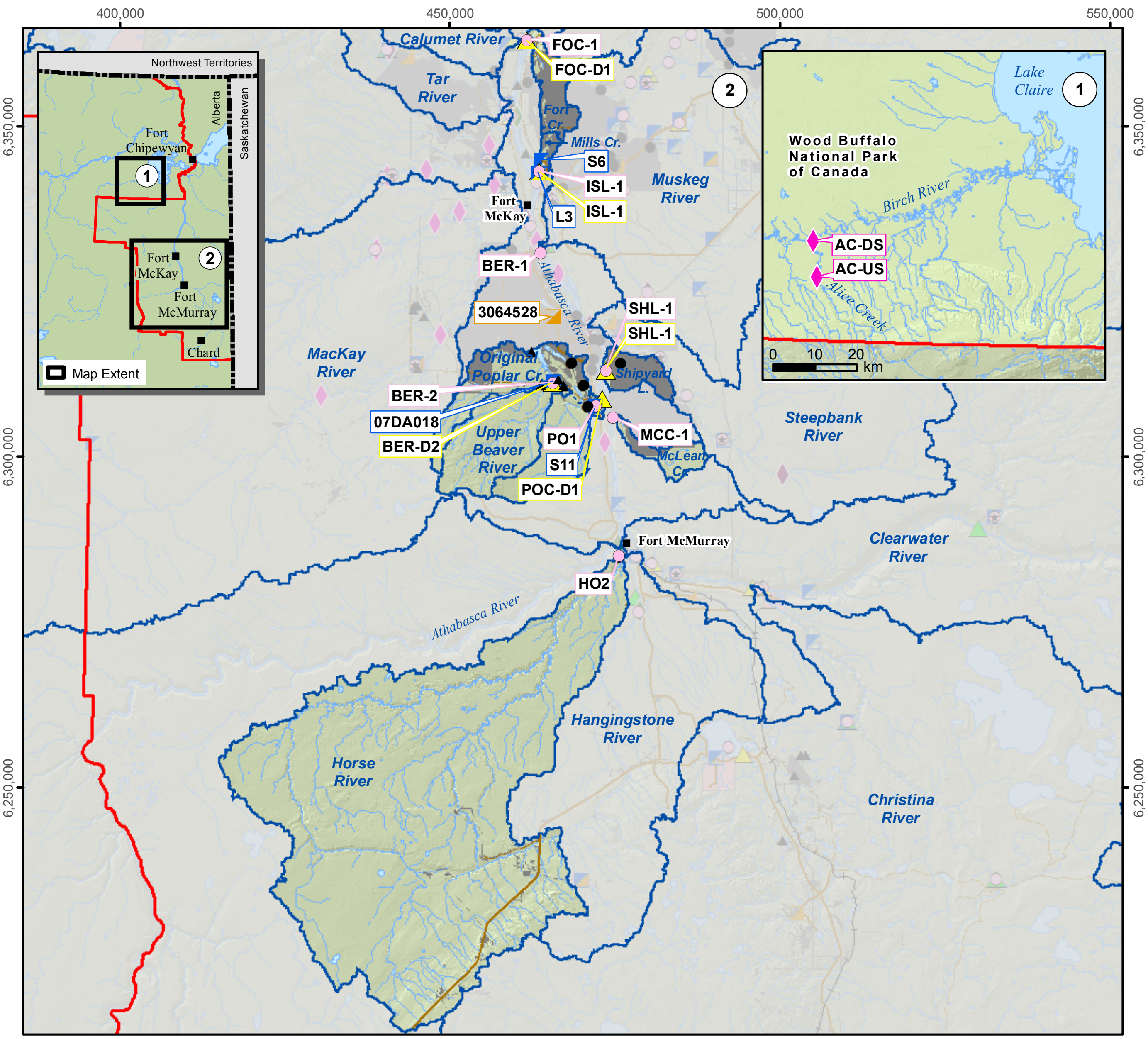
Water Quality: Classification based on adaptation of CCME water quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.2.3 for a detailed description of the classification methodology.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology.

Sediment Quality: Classification based on adaptation of CCME sediment quality index; scores classified as follows: 80 to 100: Negligible-Low difference from regional *baseline* conditions; 60 to 80: Moderate difference from regional *baseline* conditions; Less than 60: High difference from regional *baseline* conditions; see Section 3.2.3.2 for a detailed description of the classification methodology.

Fish Populations (Wild Fish Health): Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches; see Section 3.2.4.2 for a detailed description of the classification methodology.

Figure 5.13-1 Miscellaneous aquatic systems.



Legend

Lake/Pond
River/Stream
Watershed Boundary
Major Road
Secondary Road
Railway
First Nations Reserve
Regional Municipality of Wood Buffalo Boundary
Land Change Area as of 2015[a]
Water Withdrawal Location
Water Release Location
Water Quality Station
Data Sonde Station
Hydrometric Station
Climate Station
Benthic Invertebrate Communities Reach
Benthic Invertebrate Communities Reach and Sediment Quality Station
Fish Community Reach
Wild Fish Health Reach
Wild Fish Health Reach with Water and Sediment Quality Stations

0 5 10 20 km

N

Scale: 1:950,000

Projection: NAD 1983 UTM Zone 12N

Data Sources:
a) Land Change Area as of 2015 Related to Oil Sands Development.
b) Only Water Withdrawal/Release Sites Used in the Hydrologic Water Balance are Shown.
c) Base features from 1:250k NTDB.

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Figure 5.13-2 Representative monitoring stations of miscellaneous aquatic systems, fall 2015.

Water Quality and Benthic Invertebrate Communities Station/Reach FOC-1/ FOC-D1: Fort Creek near the mouth, facing upstream

Hydrology and Water Quality Station S11/PO1: Poplar Creek at Highway 63, facing upstream

Water Quality Station HO2: Horse River near the mouth, facing upstream

Water Quality Station BER-1: Beaver River near the mouth, facing upstream

Water Quality Station and Benthic Invertebrate Communities Reach BER-2/ BER-D2: upper Beaver River, facing upstream

Fish Health Reach AC-DS: Alice Creek downstream, facing downstream

Water Quality and Benthic Invertebrate Communities Station/Reach ISL-1: Isadore's Lake, facing south

Water Quality and Benthic Invertebrate Communities Station/Reach SHL-1: Shipyard Lake, facing west

5.13.1 Summary of 2015 WY Conditions

This section includes 2015 results for the following aquatic systems:

- Fort Creek, Poplar Creek (original watercourse), Horse River, Mills Creek, McLean Creek, Isadore's Lake, and Shipyard Lake are designated as *test*.
- The Beaver River watershed, designated as *test* downstream of the Syncrude Mine.
- Alice Creek is designated as *baseline* within the Lower Peace River sub-catchment.

Land change as of 2015 comprised approximately 19% (5,518 ha) of the original Poplar Creek watershed, 84% (5,593 ha) of the Fort Creek watershed, 33% (1,546 ha) of the McLean Creek watershed, 65% (929 ha) of the Mills Creek watershed, 92% (4,707 ha) of the original watershed draining into Shipyard Lake, and less than 1% (123 ha) of the Upper Beaver River watershed (Table 2.3-1).

Table 5.13-1 is a summary of the 2015 assessment of the miscellaneous aquatic systems in the Athabasca oil sands region, while Figure 5.13-1 provides the locations of the monitoring stations for each component, reported water withdrawal and discharge locations, and the area of land change as of 2015. Figure 5.13-2 contains fall 2015 photos of various monitoring stations located in the miscellaneous aquatic systems of the Athabasca oil sands region.

Please see Section 3.2 for a description of the analytical approach for each monitoring component.

Fort Creek, McLean Creek, and Horse River

Water Quality Differences in water quality in fall 2015 between Fort Creek and regional *baseline* fall conditions were classified as **Negligible-Low** as most concentrations of water quality variables in fall 2015 were within regional *baseline* concentrations. Concentrations of a number of water quality measurement endpoints have increased over time, particularly dissolved ions. Guideline exceedances occurred most frequently between July and September and included total phenols and sulphides, which have commonly exceeded guidelines in previous sampling years.

Differences in water quality in fall 2015 between McLean Creek and regional *baseline* fall conditions were classified as **Negligible-Low**. Concentrations and levels of all water quality measurement endpoints at *test* station MCC-1 in fall 2015 were within the ranges of regional *baseline* concentrations, with the exception of total dissolved solids and several associated ions, including calcium, sodium, chloride, and sulphate, all of which were higher than their respective 95th percentile of regional *baseline* concentrations.

Differences in water quality in fall 2015 between the Horse River and regional *baseline* fall conditions were classified as **Negligible-Low**. Although there were seasonal fluctuations, concentrations of water quality measurement endpoints in fall 2015 were within the ranges of regional *baseline* concentrations.

Benthic Invertebrate Communities and Sediment Quality Variations in measurement endpoints for benthic invertebrate communities at *test* reach FOC-D1 were classified as **High** because, while the presence of clams, snails, and particularly of stoneflies in fall 2015 suggests that the quality of benthic habitat at *test* reach FOC-D1 is good, there were significant differences in values of three of the benthic invertebrate community measurement endpoints (abundance, richness, and equitability) between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means and which suggested degrading conditions for benthic invertebrate communities.

Differences in sediment quality conditions in fall 2015 between *test* station FOC-D1 in Fort Creek and regional *baseline* conditions were classified as **Negligible-Low**. Values of measurement endpoints of sediment quality were below guideline concentrations in fall 2015, with the exception of Fraction 3 hydrocarbons and chrysene, and concentrations of all sediment quality measurement endpoints in fall 2015. Fall 2015 concentrations of measurement endpoints were within the ranges of regional *baseline* concentrations with the exception of total hydrocarbons, with a concentration that was above the 95th percentile of regional *baseline* concentrations.

Poplar Creek and Beaver River

Climate and Hydrology The 2015 WY mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were all -0.25% less in the observed *test* hydrograph than in the estimated *baseline* hydrograph. The mean open-water discharge was 43.95% higher in the *test* hydrograph than in the estimated *baseline* hydrograph and this difference was classified as **High**. The results of a longitudinal assessment suggested that the effects on mean open water flow that were classified as **High** occurred in the lowest 3.5 km of Poplar Creek. (i.e., the portion downstream of the Poplar Creek spillway).

Water Quality WQI values for all stations within the Poplar Creek and Beaver River watersheds indicated **Negligible-Low** differences between water quality conditions at *test* station PO1, *test* station BER-1, and *baseline* station BER-2 in fall 2015 compared to regional *baseline* conditions, with most water quality measurement endpoints within the ranges of regional *baseline* concentrations. In general, the highest concentrations of metals and ions occurred in December 2014 and August 2015 at *test* station PO1 while particulates and total metals at *test* station BER-1 were highest in June 2015. Guideline exceedances occurred most frequently in September at *test* station PO1, while guideline exceedances occurred equally frequently in June, August, and September at *test* station BER-1. Concentrations of total phenols, sulphides, and dissolved iron exceeded guideline concentrations at all stations, while concentrations of total silver in January and total zinc in November exceeded the guidelines at *test* station PO1.

Benthic Invertebrate Communities and Sediment Quality Variations in values of measurement endpoints of benthic invertebrate communities at *test* reach POC-D1 in Poplar Creek were classified as **Moderate**. While the benthic invertebrate community at *test* reach POC-D1 in fall 2015 was in generally good health, as evidenced by trends and levels of %EPT and had a range of fauna typical for a sandy-bottomed river, significant differences in values of equitability between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.

Differences in fall 2015 sediment quality conditions between *test* station POC-D1 and *baseline* station BER-D2 and regional *baseline* conditions were classified as **Negligible-Low**. Sediment quality measurement endpoints were within the ranges of regional *baseline* conditions for *test* station POC-D1 and *baseline* station BER-D2, with the exception of total PAHs at *baseline* station BER-D2. Concentrations of all sediment quality measurement endpoints were below guideline concentrations at *baseline* station BER-D2 in fall 2015. Concentrations of Fraction 3 hydrocarbons and chrysene exceeded CCME guidelines at *test* station POC-D1.

Alice Creek

Water Quality Differences in water quality in fall 2015 between *baseline* stations in Alice Creek and regional *baseline* fall conditions were classified as **Negligible-Low**, with most water quality measurement endpoints within regional *baseline* concentrations.

Sediment Quality Differences in fall 2015 sediment quality conditions between *baseline* station AC-DS and *baseline* station AC-US and regional *baseline* conditions were classified as **Negligible-Low**. All sediment quality measurement endpoints were within regional *baseline* concentrations at both *baseline* stations in Alice Creek, concentrations of all sediment quality measurement endpoints were below published guidelines at *baseline* station AC-DS, and predicted PAH toxicity and total arsenic concentrations exceeded guideline values at *baseline* station AC-US.

Fish Populations (Wild Fish Health) Reaches of Alice Creek consisted solely of *baseline* reaches in fall 2015; therefore, no classification of results could be assessed under the Environment Canada effects criteria guideline. Female and male lake chub at lower *baseline* reach AC-DS exhibited various differences in measurement endpoints relative to fish at upper *baseline* reach AC-US. Results from the lower *baseline* reach indicated that lake chub exhibited lower relative gonad size in females and a lower mean age and relative liver size in both males and females compared to upper *baseline* reach AC-US.

Isadore's Lake

Water Quality Concentrations of most water quality measurement endpoints in fall 2015 at *test* station ISL-1 were within the range of previously-measured concentrations and concentrations and levels of water quality measurement endpoints were below water quality guidelines in fall 2015 with the exception of sulphide. Shifts in ion balance and significant increasing trends in concentrations of many dissolved ions suggest a gradual and ongoing change in water quality in Isadore's Lake over time.

Benthic Invertebrate Communities and Sediment Quality Variations in measurement endpoint of the benthic invertebrate community in Isadore's Lake at *test* station ISL-1 were classified as **Negligible-Low**. While there were a number of significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means, none of these implied degrading conditions for benthic invertebrate communities.

Sediment Quality The following significant temporal trends in fall concentrations of sediment quality measurement endpoints were measured at *test* station ISL-1: (i) increasing concentrations of Fraction 2, 3, and 4 hydrocarbons total alkylated PAHs and total PAHs; and (ii) decreasing concentrations of total metals. Concentrations of all sediment quality measurement endpoints at *test* station ISL-1 in fall 2015 were within the ranges of regional *baseline* concentrations with the exception of Fraction 3 hydrocarbons and total arsenic. In addition, the concentration of Fraction 1 hydrocarbons was not detectable but had a detection limit that exceeded the CCME guideline.

Shipyard Lake

Water Quality Concentrations of most water quality measurement endpoints in fall 2015 at *test* station SHL-1 were within previously-measured concentrations with the exception of sulphide. The ionic composition of water at *test* station SHL-1 has occasionally shifted toward influences of sodium and chloride, particularly in 2010, and also from 2013 to 2015. This observation is consistent with significant temporal trends at *test* station SHL-1 of increasing concentrations of sodium, potassium, and chloride and a decreasing trend in calcium concentration.

Benthic Invertebrate Communities and Sediment Quality Variations in measurement endpoints of benthic invertebrate communities for the *test* station SHL-1 in fall 2015 were classified as **Negligible-Low**. While there were a number of significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means, none of these implied degrading conditions for benthic invertebrate communities.

Significant temporal trends in concentrations of total hydrocarbons (Fractions 1, 2, 3, and 4) and total alkylated PAHs were measured in sediments in fall 2015 at *test* station SHL-1. Concentrations of sediment quality measurement endpoints were below guideline concentrations at *test* station SHL-1 in fall 2015, with the exception of Fraction 3 hydrocarbons; total arsenic, benz[a]anthracene, benzo[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene. In addition, the concentration of Fraction 1 hydrocarbons at *test* station SHL-1 was not detectable but had a detection limit that exceeded the CCME guideline.

5.13.2 Fort Creek, McLean Creek, and Horse River

Monitoring activities were conducted in Fort Creek in the 2015 WY for the Water Quality and Benthic Invertebrate Communities and Sediment Quality components. Monitoring activities in McLean Creek and the Horse River were conducted for the Water Quality component.

5.13.2.1 Water Quality

Water quality samples were taken in the 2015 WY from:

- Fort Creek (*test* station FOC-1), sampled intermittently from 2000 to 2015 and designated as a *baseline* station until 2003. This station was sampled monthly from May 2015 to September 2015;
- McLean Creek near the mouth (*test* station MCC-1), sampled annually in fall since 1999, and monthly during the open water season (May to September) in the 2015 WY;
- Horse River (*test* station HO2), a new station established in 2015 and sampled monthly from May to October 2015.

Monthly variations in water quality in Fort Creek, McLean Creek, and Horse River are summarized in Table 5.13-2 to Table 5.13-4 and Figure 5.13-3. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations are provided in Table 5.13-5 to Table 5.13-7. The ionic composition of water in Fort Creek, McLean Creek, and Horse River is presented in Figure 5.13-4. Guideline exceedances for water quality measurement endpoints are presented in Table 5.13-8, and Figure 5.13-5 and Figure 5.13-6 present a comparison of selected water quality measurement endpoints in Fort Creek, McLean Creek, and Horse River relative to historical concentrations and regional *baseline* concentrations.

Monthly and Seasonal Variations in Water Quality Concentrations and values of water quality measurement endpoints at *test* station FOC-1 were generally consistent throughout the 2015 WY with concentrations and values of some water quality measurement endpoints highest in June or July, consistent with seasonal high flows during freshet (Table 5.13-2, Figure 5.13-3).

Concentrations and values of a number of water quality measurement endpoints (i.e., TSS, TDS, total metals, and all major ions) at *test* station MCC-1 were higher in June than in other months sampled (Table 5.13-3, Figure 5.13-3). High concentrations of total strontium and total boron in June may suggest an influence of groundwater.

Concentrations and values of a number of water quality measurement endpoints (i.e., TDS, total strontium, total boron, and all major ions) at *test* station HO2 were highest in July, decreased in August, and then increased until October (Table 5.13-4, Figure 5.13-3), while concentrations of total suspended solids, total arsenic, and chloride remained relatively constant during the sampling season.

2015 Fall Results Relative to Historical Concentrations Concentrations and levels of water quality measurement endpoints in fall 2015 were within the range of previously-measured concentrations in Fort Creek and McLean Creek with the following exceptions (Table 5.13-5, Table 5.13-6):

- dissolved organic carbon, total aluminum, and total mercury at *test* station FOC-1, with concentrations below previously-measured minimum concentrations;
- chloride, total molybdenum, oilsands extractable acids, and sulphide at *test* station FOC-1, with concentrations that exceeded previously-measured maximum concentrations;
- naphthenic acids at *test* station MCC-1, with a concentration below the previously-measured minimum concentration; and
- total parent PAHs at *test* station MCC-1, with a concentration that exceeded the previously-measured maximum concentration.

No historical comparisons of water quality in fall 2015 at *test* station HO2 were possible because water quality was measured for the first time at *test* station HO2 in 2015.

Temporal Trends The following significant temporal trends ($p<0.05$) in concentrations of water quality measurement endpoints were detected at *test* station FOC-1: (i) decreasing concentrations of dissolved phosphorus and total nitrogen; and (ii) increasing concentrations of total strontium, total boron, sulphate, potassium, magnesium, calcium, and total dissolved solids. There were no significant trends in fall concentrations of water quality measurement endpoints measured at *test* station MCC-1.

Trend analysis could not be conducted for water quality at *test* station HO2 because water quality was measured for the first time at *test* station HO2 in 2015.

Ion Balance The ion balance at *test* station FOC-1 has shifted since 2005 to a greater proportion of magnesium, potassium and sulphate; the relative proportion of sulphate decreased in fall 2015 compared to previous recent years (Figure 5.13-4). The ionic composition of water at *test* station MCC-1 has been variable since sampling began in 1999. Ion balance at *test* station MCC-1 in fall 2015 was generally similar to previous years and was dominated by calcium and bicarbonate. *Test* station HO2 was heavily dominated by calcium and bicarbonate in fall 2015.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Water quality guideline exceedances in Fort Creek, McLean Creek, and the Horse River in the 2015 WY (Table 5.13-8) were:

- total phenols at *test* station FOC-1 (July to September), *test* station MCC-1 (May to September), and *test* station HO2 (June to October);
- sulphide at *test* station FOC-1 (June to September), *test* station MCC-1 (May, and July to September), and *test* station HO2 (August to October);
- total selenium at *test* station MCC-1 (June);
- dissolved aluminum at *test* station HO2 (August); and
- dissolved iron at *test* station HO2 (May to June and August to October).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations and levels of all water quality measurement endpoints at *test* station FOC-1 in fall 2015 were within the ranges of regional *baseline* concentrations (Figure 5.13-5), with the exception of calcium and sulphate, with concentrations that were higher than their respective 95th percentile of regional *baseline* concentrations and dissolved phosphorus, total nitrogen, total mercury, and total arsenic, with concentrations that were lower than their respective 5th percentile of regional *baseline* concentrations.

Concentrations and levels of all water quality measurement endpoints at *test* station MCC-1 in fall 2015 were within the ranges of regional *baseline* concentrations, with the exception of total dissolved solids and several associated ions, including calcium, sodium, chloride, and sulphate, all of which were higher than their respective 95th percentile of regional *baseline* concentrations (Figure 5.13-6).

Concentrations and levels of all water quality measurement endpoints at *test* station HO2 in fall 2015 were within the ranges of regional *baseline* concentrations.

Water Quality Index The WQI calculated for *test* stations FOC-1 (91.3) and MCC-1 (88.5) for fall 2015 are higher than 2014, particularly at *test* station MCC-1, which had a fall 2014 WQI of 66.0. The WQI at *test* station MCC-1 has been variable since fall 2008, with values ranging over this period from 61.7 to 100 over this period. The improvement in the WQI for fall 2015 may be related to decreases in the concentrations of dissolved ions (e.g., calcium, magnesium, potassium and chloride; Figure 5.13-6) to within regional *baseline* ranges.

The WQI value for *test* station HO2 in fall 2015 was 94.9.

Classification of Fall Results The WQI values for *test* stations FOC-1, MCC-1, and HO2 indicated **Negligible-Low** differences between water quality conditions at these stations in fall 2015 compared to regional *baseline* conditions.

5.13.2.2 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 from Fort Creek at depositional *test* reach FOC-D1, which was designated as *baseline* reach from 2001 to 2003 and as *test* reach from 2004 to 2015.

2015 Habitat Conditions Water at *test* reach FOC-D1 in fall 2015 was shallow (0.26 m) with moderate velocity (0.4 m/s), a pH of 7.7, high concentration of dissolved oxygen (9.7mg/L), and moderate to high conductivity (591 µS/cm). The substrate consisted of sand (98%) with low organic carbon content (<1%) (Table 5.13-9).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach FOC-D1 in fall 2015 was dominated by chironomids (66%), with tubificid worms (17%) and miscellaneous Diptera (8%) as the subdominant taxa (Table 5.13-10). Larvae of large flying insects consisted only of two *Zapada* stoneflies. Ephemeroptera and Trichoptera, present in 2013, were not present at *test* reach FOC-D1 in 2014 and 2015. Chironomids were mainly *Paracladopelma* and *Rheosmittia/ Lopesocladius*. Permanent aquatic forms (Gastropoda: *Physa* and Bivalvia: *Pisidium*) were also present in Fort Creek in 2015.

Temporal Comparisons The following temporal comparisons of benthic invertebrate community measurement endpoints at *test* reach FOC-D1 were conducted:

- differences in mean values from before (2001 to 2003) to after (2005 to present) the reach was designated as *test* (Hypothesis 1, Section 3.2.3.1);
- trends over time during the *test* period (i.e., since 2005, Hypothesis 2, Section 3.2.3.1);
- differences between 2015 values and the mean of all *baseline* years (2001 to 2003); and
- differences between 2015 values and the mean of all previous years of sampling.

The comparisons for *test* reach FOC-Dl that were statistically significant were (Table 5.13-11, Figure 5.13-7):

1. Abundance and richness were lower in the *test* period compared to the *baseline* period, explaining 40% and 26% of the variance in annual means, respectively.
2. Equitability was higher in the *test* period compared to the *baseline* period, explaining 22% of the variance in annual means.

Comparison to Published Literature The benthic invertebrate community of *test* reach FOC-D1 was typical of a sandy-bottomed lotic system with high relative abundance of chironomids (66%) and worms (17%) (Hynes 1960; Griffiths 1998). The dominant forms of Chironomidae (e.g., *Paracladopelma*) are known to be moderately-tolerant of poor water quality conditions (Mandeville 2002). Larvae of large flying insects were sparse, typical of sandy-bottomed rivers.

2015 Results Relative to Historical and Regional *Baseline* Conditions Values of all measurement endpoints for *test* reach FOC-D1 were within the inner tolerance limits of the normal range of variation of previous years of sampling, with the exception of %EPT, which was below the 5th percentile of regional *baseline* concentrations (Figure 5.13-7, Figure 5.13-8).

Classification of Results Variations in measurement endpoints for benthic invertebrate communities at *test* reach FOC-D1 were classified as **High** because, while the presence of clams, snails, and particularly of stoneflies in fall 2015 suggests that the quality of benthic habitat at *test* reach FOC-D1 is good, there were significant differences in values of three of the benthic invertebrate community measurement endpoints (abundance, richness, and equitability) between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means and which suggested degrading conditions for benthic invertebrate communities.

Sediment Quality

Fort Creek

Sediment quality was sampled in fall 2015 at *test* station FOC-D1, designated as *baseline* in 2000 and 2002 and as *test* from 2006 to 2008 and 2010 to 2015.

Temporal Trends The following significant ($p<0.05$) temporal trends in concentrations of sediment quality measurement endpoints were determined from 2000 to 2015 at *test* station FOC-1: (i) increasing concentrations of Fraction 4 hydrocarbons; and (ii) decreasing concentrations of total metals.

2015 Results Relative to Historical Conditions Concentrations and values of sediment quality measurement endpoints at *test* station FOC-D1 in fall 2015 were within ranges of previously-measured concentrations and values (Table 5.13-12, Figure 5.13-9) with the exception of:

- %clay, %total organic carbon, and predicted PAH toxicity, which were lower than previously-measured minimum values; and
- *Hyalella* survival, which was higher than the previously-measured maximum value.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Values of measurement endpoints of sediment quality at *test* station FOC-D1 were below guideline concentrations at *test* station FOC-D1 in fall 2015, with the exception of Fraction 3 hydrocarbons and chrysene (Table 5.13-12).

2015 Results Relative to Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints at *test* station FOC-D1 in fall 2015 were within the ranges of regional *baseline* concentrations with the exception of total hydrocarbons, with a concentration that was above the 95th percentile of regional *baseline* concentrations (Figure 5.13-9).

Sediment Quality Index The SQI value for *test* station FOC-D1 for fall 2015 was 87.9, similar to SQI scores calculated for this location for previous years of monitoring.

Classification of Results Based on the calculated SQI score, differences in sediment quality conditions in fall 2015 between *test* station FOC-D1 in Fort Creek and regional *baseline* conditions were classified as **Negligible-Low**.

5.13.3 Poplar Creek and Beaver River

Monitoring activities were conducted in the Poplar Creek and Beaver River watersheds in the 2015 WY for the Climate and Hydrology, Water Quality, and Benthic Invertebrate Communities and Sediment Quality components.

5.13.3.1 Hydrologic Conditions

Hydrometric monitoring for the Poplar Creek watershed in the 2015 WY was conducted at JOSMP Station S11 (WSC Station 07DA007) Poplar Creek at Highway 63 and WSC Station 07DA018 (formerly JOSMP Station S39) Beaver River above Syncrude. Data from JOSMP Station S11 were used for the water balance analysis and are presented below; the data from these stations are provided in Appendix C.

Annual data for JOSMP Station S11 (WSC Station 07DA007) were available from 1973 to 1986 and 2013 to 2015, and open-water data were available from 1996 to 2012.

The historical flow record for JOSMP Station S11 is summarized in Figure 5.13-10 and includes the median, interquartile, and range of flows recorded daily through the WY. Poplar Creek has a typical seasonal runoff pattern characteristic of a northern environment. Flows in winter are lower than during the open-water season. Discharge generally decreases from November until March, and flow often ceases completely in late winter. Spring thaw and the resulting increase in flows occur in late March and April. Monthly flows are highest during May at the peak of freshet and often remain elevated in June and July when total monthly rainfall accumulations are highest. Flows then recede from late July until the end of October, in response to declining rainfall inputs and eventually to river freeze-up.

Flows of Poplar Creek in the 2015 WY were generally similar to the pattern described above, but with several key differences. Winter flows varied from lower than historical median flows before early January to above historical median flows after early January. The annual minimum flow of 0.001 m^3/s occurred in early December. Flows generally increased from December to April and the peak flow of 2.41 m^3/s occurred on April 21, which was 81% lower than the historic average peak flow of 12.9 m^3/s. Flows declined after freshet and were mostly between historical minimum flows and historical lower quartile flows. Several brief periods of increased flow were recorded in summer, likely in response to rainfall events. Flows increased to 1.5 m^3/s on October 19, reaching levels close to the 2015 freshet; this increase in flow corresponded with the timing of a release from the Poplar Creek Reservoir. The peak flow during the event did not exceed the historical maximum flow.

Overall, the annual runoff volume at JOSMP Station S11 in the 2015 WY was 8.71 million m^3, which was 75% lower than the mean historical annual runoff volume based on the available period of record.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Poplar Creek at Highway 63 (JOSMP Station S11) is summarized in Table 5.13-13. Key changes in flows included:

1. The closed-circuited land change area as of 2015 was estimated to be 0.55 km^2 (Table 2.3-1). The loss of flow to Poplar Creek that would have otherwise occurred from this land area was estimated at 0.027 million m^3.
2. As of 2015, the area of land change in the Poplar Creek watershed that was not closed-circuited was estimated to be 0.89 km^2 (Table 2.3-1). The increase in flow to Poplar Creek that would not have otherwise occurred from this land area was estimated at 0.010 million m^3.
3. In the 2015 WY, Syncrude reported a total diversion of 3.662 million m^3 of water into Poplar Creek via the Poplar Creek spillway. The final value applied within the water balance analysis (1.419 million m^3) was reduced to account for the releases that were not observed at the Poplar Creek S11 station.

All other potential changes in surface water flows were assumed to be insignificant.

The estimated cumulative effect of oil sands development in the 2015 WY was an increase in flow of 1.40 million m³ at JOSMP Station S11 (WSC 07DA007). The observed *test* and estimated *baseline* hydrographs for Station S11 (WSC 07DA007), Poplar Creek at Highway 63, are presented in Figure 5.13-10. The 2015 WY mean winter discharge, annual maximum daily discharge, and open-water minimum daily discharge were all 0.25% less in the observed *test* hydrograph than in the estimated *baseline* hydrograph and is classified as **Negligible-Low** (Table 5.13-14). The mean open water change in discharge was assessed as 43.95% greater than the *baseline* hydrograph and was classified as **High** (Table 5.13-14).

The **High** classification of water balance result for the mean open water change in discharge required an additional longitudinal classification of change for the length of Poplar Creek, using the methods outlined in Section 3.2.1.5. The results of this analysis are presented in Figure 5.13-11, which shows the classified hydrologic changes along the length of Poplar Creek. Assessed changes to the hydrology of Poplar Creek, were classified as **High** from the mouth of the creek until the confluence with the Poplar Creek spillway (approximately 1.5 km upstream of JOSMP Station S11), and **Negligible-Low** upstream of the Poplar Creek spillway confluence for approximately 4 km to where a closed-circuited area influences the creek (Figure 5.13-11). Poplar Creek is considered *baseline* upstream of this closed-circuited area as there is no further oil sands development. The results from this longitudinal assessment suggested that the effects on mean open water flow that were classified as **High** occurred in the lowest 3.5 km of Poplar Creek.

5.13.3.2 Water Quality

Water quality samples in the 2015 WY were taken from the Poplar Creek and Beaver River watersheds at:

- Poplar Creek near the mouth (*test* station PO1, previously called POC-1), which was sampled monthly from November 2014 to January 2015, and in March, and May to October 2015 (*test* station PO1 was not sampled in February 2015 because the river was frozen to depth and an acceptable sample could not be collected). This station has been sampled as a *test* station since 2000;

- the lower Beaver River, near the mouth (*test* station BER-1), which was sampled monthly in the open water season from May 2015 to September 2015. *Test* station BER-1 has been sampled as a *test* station since 2003; and

- the upper Beaver River; upstream of oil sands development (*baseline* station BER-2), which was sampled in September 2015 to support the benthic invertebrate communities monitoring component. *Baseline* station BER-2 has been sampled as a *baseline* station since 2008.

The upper Beaver River flows via the Poplar Creek Reservoir into Poplar Creek (i.e., it is hydrologically connected to *test* station POC-1) rather than to the lower Beaver River, where *test* station BER-1 is located. The lower Beaver River was isolated from the upper Beaver River watershed in the early 1970s through the development of Syncrude's Mildred Lake project. The lower Beaver River is downstream of a seepage-collection pond located downstream of the dam of the Mildred Lake tailings facility (seepage collected in this pond is pumped back into the tailings facility).

Monthly variations in water quality are summarized in Table 5.13-15 to Table 5.13-16 and Figure 5.13-3. Water quality results from the fall season for the 2015 WY relative to historical fall concentrations are provided in Table 5.13-17 to Table 5.13-19. The ionic composition of water in Polar Creek and Beaver River is presented in Figure 5.13-12. Guideline exceedances for water quality measurement endpoints are presented in Table 5.13-8 and Figure 5.13-13 presents a comparison of selected water quality measurement endpoints in Polar Creek and Beaver River relative to historical concentrations and regional *baseline* concentrations.

Monthly Variations in Water Quality Concentrations of many water quality constituents (including TDS and all major ions) at *test* station PO1 were higher in December 2014 and August 2015, whereas concentrations of particulates (TSS) stayed relatively constant throughout the 2015 WY (Table 5.13-15, Table 5.13-16, Figure 5.13-3). In contrast, at *test* station BER-1, concentrations of particulates (TSS) and many total metals were higher in June while concentrations of total dissolved solids (TDS) were relatively constant throughout the 2015 WY.

2015 Fall Results Relative to Historical Concentrations Concentrations and levels of water quality measurement endpoints in fall 2015 in Poplar Creek and the Beaver River were within the range of previously-measured concentrations with the following exceptions (Table 5.13-17 to Table 5.13-19):

- total aluminum, ultra-trace total mercury, naphthenic acid, retene, total dibenzothiophene, total PAH, total parent PAH, and total alkylated PAH at *test* station PO1, with concentrations above previously-measured maximum concentrations;
- total nitrogen, chloride, and ultra-trace total mercury at *test* station BER-1, with concentrations below previously-measured minimum concentrations;
- magnesium, chloride, oilsands extractable acids, and total parent PAH at *baseline* station BER-2, with concentrations above previously-measured maxima; and
- sulphate and retene at *baseline* station BER-2, with concentrations below previously-measured minimum concentrations.

Temporal Trends There were no significant trends ($p<0.05$) in fall concentrations of water quality measurement endpoints at *test* station PO1. Significant temporal trends detected for *test* station BER-1 and *baseline* station BER-2 consisted of increasing calcium concentrations at *test* station BER-1 and increasing potassium and magnesium concentrations at *baseline* station BER-2.

Ion Balance The ionic composition of water at *test* station PO1 and *test* station BER-1 has varied considerably over the monitoring period (Figure 5.13-12), possibly due to influences of seepage from the Mildred Lake settling pond on *test* station BER-1 and possibly from salts from Highway 63 on *test* station PO1. There was a lower influence of sodium and chloride at *test* station PO1 in fall 2015 than in fall 2014 and a greater influence of calcium and bicarbonate at *test* station BER-1 in fall 2015 than in fall 2014. The ionic composition of water at *baseline* station BER-2 has exhibited less variability than at *test* station PO1 and *test* station BER-1, particularly with respect to anions, as it has been consistently dominated by bicarbonate ions over the monitoring period.

Comparison of Water Quality Measurement Endpoints to Published Guidelines Water quality guideline exceedances in Fort Creek and Beaver River in the 2015 WY (Table 5.13-8) were:

- total phenols at *test* stations PO1 (July to October) and BER-1 (May to September) and at *baseline* station BER-2 (September);
- sulphide at *test* stations PO1 (January, March to July, and September to October) and BER-1 (May, August to September) and at *baseline* station BER-2 (September);
- dissolved iron at *test* station PO1 (June to September) and at *baseline* station BER-2 (September); and
- total silver in January and total zinc in November at *test* station PO1.

While Fraction 2 hydrocarbons at *test* station PO1 were not detectable in November or December 2014 (<0.25 mg/L), the sample analysis used a detection limit that exceeded the guideline of 0.11 mg/L.

2015 Results Relative to Regional *Baseline* Concentrations Concentrations and levels of all water quality measurement endpoints in fall 2015 at stations in the Beaver and Poplar watersheds were within the ranges of regional *baseline* concentrations (Figure 5.13-13), with the exception of:

- total dissolved solids, total strontium, magnesium, and chloride at *test* stations PO1 and BER-1, with concentrations above the 95th percentiles of regional *baseline* concentrations;
- total boron at *baseline* station BER-2, with a concentration above the 95th percentile of regional *baseline* concentrations;
- calcium and sulphate at *test* station BER-1, with concentrations above the 95th percentiles of regional *baseline* concentrations;
- sodium at *test* station PO1 and *baseline* station BER-2, with concentrations above the 95th percentile;
- dissolved phosphorus at *test* station PO1 and *test* station BER-1, with concentrations below the 5th percentile of regional *baseline* concentrations; and
- ultra-trace total mercury at *test* station BER-1, with a concentration below the 5th percentile of regional *baseline* concentrations.

Water Quality Index The WQI for fall 2015 calculated for *test* station PO1, *test* station BER-1, and *baseline* station BER-2 in fall 2015 were 80.8, 82.4, and 96.0, respectively. The WQI value for *baseline* station BER-2 has remained relatively constant since 2011, while the WQI value for *test* station PO1 has fluctuated between 74.6 and 98.0 since 2013 and the WQI for *test* station BER-1 has improved since fall 2013 when the WQI was 69.4.

Classification of Fall Results The WQI values for all stations within the Poplar Creek and Beaver River watersheds indicated **Negligible-Low** differences between water quality conditions at *test* station PO1, *test* station BER-1, and *baseline* station BER-2 in fall 2015 compared to regional *baseline* conditions.

5.13.3.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 at:

- depositional *test* reach POC-D1 of Poplar Creek, sampled since 2008; and
- depositional *baseline* reach BER-D2 of the Beaver River, sampled since 2008 and used as a *baseline* for comparison with *test* reach POC-D1.

2015 Habitat Conditions Water at *test* reach POC-D1 in fall 2015 was moderately deep (0.4 m), weakly alkaline (pH 7.4), and had high conductivity (883 µS/cm). The substrate consisted of sand (86%) with some silt (8%) and clay (6%), with moderate organic carbon content (1.6%) (Table 5.13-20).

Water at *baseline* reach BER-D2 in fall 2015 was moderately deep (0.6 m), weakly alkaline (pH 7.7) and had high conductivity (532 µS/cm). The substrate consisted of sand (96%) with some silt (3%) and clay (1%), with low organic carbon content (0.3%) (Table 5.13-20).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* reach POC-D1 was dominated by chironomids (42%) and tubificid worms (22%) (Table 5.13-21). Subdominant taxa included mayflies (12%) and Ceratopogonidae (7%). Dominant chironomid genera consisted primarily of *Polypedilum, Cladotanytarsus, Cryptochironomus* and *Micropsectra/Tanytarsus*, all of which are common in north-temperate waters (Wiederholm 1983). Ephemeroptera were represented by the genera *Caenis, Callibaetis, Hexagenia limbata*, and *Leptophlebia*. Other larvae of flying insects included caddisflies (Trichoptera: *Oecetis, Ptilostomis*). Amphipods (*Hyalella azteca*), Bivalves (*Pisidium, Sphaerium*) and Gastropods (*Physa*) were also present.

The benthic invertebrate community at *baseline* reach BER-D2 was dominated by chironomids (89%) (Table 5.13-21). Dominant chironomid genera consisted of *Paralauterborniella, Polypedilum*, and *Micropsectra/Tanytarsus*, which are common in north-temperate waters (Wiederholm 1983). Larvae of large flying insects were present in low relative abundances and were represented by Ephemeroptera (*Caenis* and *Hexagenia limbata*) and Trichoptera (*Oecetis*). Permanent aquatic forms were also present at *baseline* reach BER-D2 in fall 2015, including fingernail clams (*Pisidium*) and Gastropods (*Gyraulus*).

Temporal and Spatial Comparisons The spatial and temporal comparisons of benthic invertebrate community measurement endpoints that were possible given the data available for Poplar Creek (*test* station POC-D1) and Beaver River (*baseline* reach BER-D2) were:

- differences between reaches across years (Hypothesis 2, Section 3.2.3.1);
- difference in time trends between reaches;
- difference between 2015 in *test* reach POC-D1 and the mean of all years in *baseline* reach BER-D2; and
- difference between 2015 in *test* reach POC-D1 and all prior years in *test* reach POC-D1.

The temporal and spatial comparisons that were statistically significant were (Table 5.13-11, Figure 5.13-14):

1. Equitability was significantly higher in *test* reach POC-D1 than in the *baseline* reach BER-D2 in fall 2015, significantly lower in fall 2015 at *test* reach POC-D1 than the mean of prior years in *baseline* reach BER-D2, and significantly higher in fall 2015 at *test* reach POC-D1 than the mean of prior years, accounting for 21%, 47% and 25% of the variation in annual reach means, respectively.

2. There was a significant increase over time in %EPT at *test* reach POC-D1, and a significantly higher percentage of EPT in 2015 at *test* reach POC-D1 than the mean of previous years, accounting for 22% and 28% of the variation in annual means, respectively.

3. CA Axis 1 scores were significantly lower in *test* reach POC-D1 than in *baseline* reach BER-D2, accounting for 47% of the variance in annual means. This was likely due to a greater proportion of mayflies (Ephemeroptera) observed at *test* reach POC-D1 compared to previous years (Table 5.13-21, Figure 5.13-14) and therefore is not considered to be indicative of a negative change or degrading conditions for benthic invertebrate communities.

Comparison to Published Literature The benthic invertebrate community at *test* reach POC-D1 in fall 2015 included high proportions of worms (~22%) and chironomids (42%), which is typical for a sandy-bottomed river (Hynes 1960, Griffiths 1998). The benthic invertebrate community in *test* reach POC-D1 also included permanent aquatic forms, such as fingernail clams and flying insects (mayflies and caddisflies) in equal or relative higher abundances to what has been found in previous years.

2015 Results Relative to Regional Baseline Conditions Values of measurement endpoints for benthic invertebrate communities at *test* reach POC-Dl and *baseline* reach BER-D2 in fall 2015 were within the inner tolerance limits of the normal range of variation for regional *baseline* depositional reaches (Figure 5.13-15) with the exception of %EPT at *test* reach POC-D1, which was higher than the upper inner tolerance limit. This result is not considered to be indicative of a negative change or degrading conditions for benthic invertebrate communities.

Classification of Results Variations in values of measurement endpoints of benthic invertebrate communities at *test* reach POC-D1 in Poplar Creek were classified as **Moderate**. While the benthic invertebrate community at *test* reach POC-D1 in fall 2015 was in generally good health as evidenced by trends and levels of %EPT and had a range of fauna typical for a sandy-bottomed river, significant differences in values of equitability between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means implied degrading conditions for benthic invertebrate communities.

Sediment Quality

Sediment quality was collected in fall 2015 from:

- *test* station POC-D1 on Poplar Creek, sampled in 1997, 2002, 2004, and from 2008 to 2015; and
- *baseline* station BER-D2 on Beaver River, sampled from 2008 to 2015.

Temporal Trends The following significant (p<0.05) temporal trends in concentrations of sediment quality measurement endpoints were observed in fall 2015: (i) increasing concentrations of Fraction 3 and 4 hydrocarbons at *test* station POC-D1; and (ii) decreasing potential PAH toxicity at *baseline* station BER-D2.

2015 Results Relative to Historical Conditions Concentrations and values of sediment quality measurement endpoints at *test* station POC-D1 and *baseline* station BER-D2 in fall 2015 were within ranges of previously-measured concentrations and values (Table 5.13-23 to Table 5.13-24, Figure 5.13-16 to Figure 5.13-17) with the exception of:

- *test* station POC-D1: %clay, %silt, and *Hyalella* survival which were lower than previously-measured minimum values, and %sand which was higher than the previously-measured maximum value; and
- *baseline* station BER-D2: %clay and predicated PAH toxicity which were lower than previously-measured minimum values, and %sand which was higher than the previously-measured maximum value.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Measurement endpoints of sediment quality for stations in Poplar Creek and Beaver River were below guideline concentrations in fall 2015, with the exception of Fraction 3 hydrocarbons and chrysene at *test* station POC-D1.

2015 Results Relative to Regional *Baseline* Concentrations Concentrations of all sediment quality measurement endpoints at *test* station POC-D1 and *baseline* station BER-D2 in fall 2015 were within the ranges of regional *baseline* concentrations with the exception of total PAHs at *baseline* station BER-D2, which had a concentration in fall 2015 that was lower than the 5th percentile of regional *baseline* concentrations.

Sediment Quality Index The SQI values for *test* station POC-D1 and *baseline* station BER-D2 for fall 2015 were 90.3 and 98.9, respectively; these values were similar to those calculated for fall 2014 conditions.

Classification of Results Based on the calculated SQI values, differences in fall 2015 sediment quality conditions between *test* station POC-D1 and *baseline* station BER-D2 and regional *baseline* conditions were classified as **Negligible-Low**.

5.13.4 Alice Creek

Monitoring activities were conducted in Alice Creek in the lower Peace River catchment for the first time in 2015. Monitoring activities were focused on assessing Fish Populations, with Water Quality and Sediment Quality samples collected to support the interpretation of the wild fish health results.

5.13.4.1 Water Quality

Water quality monitoring was initiated in reaches of Alice Creek in fall 2015 at *baseline* stations AC-DS (downstream) and AC-US (upstream). Because 2015 was the first year of monitoring water quality in Alice Creek, and only fall sampling was conducted in 2015, monthly and seasonal variations in concentrations and levels of water quality measurement endpoints, comparisons to historical conditions and assessing temporal trends could not be presented.

Ion Balance The ionic composition of water at *baseline* station AC-US and *baseline* station AC-DS had no clear dominance of specific cations or anions (Figure 5.13-18).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations and levels of water quality measurement endpoints were below water quality guidelines at *baseline* station AC-US and *baseline* station AC-DS with the exception of dissolved aluminum, dissolved iron, and sulphides at both stations as well as total phenols at *baseline* station AC-DS (Table 5.13-25).

2015 Fall Results Relative to Regional *Baseline* Concentrations Concentrations and levels of all water quality measurement endpoints at *baseline* station AC-US and *baseline* station AC-DS in fall 2015 were within the ranges of regional *baseline* concentrations with the exception of total strontium, calcium, and magnesium at both stations, which were below the 5^{th} percentile of regional *baseline* concentrations (Figure 5.13-5).

Water Quality Index The WQI for *baseline* stations AC-US and AC-DS in fall 2015 was 93.8 and 93.0, respectively.

Classification of Fall Results The WQI values calculated for *baseline* stations AC-US and AC-DS in fall 2015 indicated **Negligible-Low** differences in water quality conditions at these stations from regional *baseline* conditions.

5.13.4.2 Sediment Quality

Sediment quality sampling was initiated in fall 2015 at *baseline* station AC-DS (downstream) and *baseline* station AC-US (upstream) to support wild fish health monitoring activities on Alice Creek.

Temporal Trends Trend analyses were not conducted for *baseline* station AC-DS or *baseline* station AC-US because fall 2015 was the first year of monitoring of sediment quality at these stations.

2015 Results Relative to Historical Conditions No historical comparisons could be conducted for *baseline* station AC-DS or *baseline* station AC-US because fall 2015 was the first year of monitoring of sediment quality at these stations; Table 5.13-26 presents the values of the sediment quality measurement endpoints for *baseline* station AC-DS and *baseline* station AC-US in fall 2015.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations and levels of all measurement endpoints of sediment quality were below guideline concentrations at both *baseline* station AC-DS and *baseline* station AC-US in fall 2015 with the exception of predicted PAH toxicity and total arsenic at *baseline* station AC-US (Table 5.13-26).

2015 Results Relative to Regional *Baseline* Concentrations All sediment quality measurement endpoints at *baseline* station AC-DS and *baseline* station AC-US in fall 2015 were within regional *baseline* concentrations (Figure 5.13-19, Figure 5.13-20).

Sediment Quality Index SQI values for *baseline* station AC-DS and *baseline* station AC-US in fall 2015 were both 100.

Classification of Results Based on the calculated SQI values, differences in fall 2015 sediment quality conditions between *baseline* station AC-DS and *baseline* station AC-US and regional *baseline* conditions were classified as **Negligible-Low**.

5.13.4.3 Fish Populations

Wild Fish Health

Wild fish health monitoring was conducted at two reaches in Alice Creek in fall 2015, using lake chub as the target species: *baseline* reach AC-US in the upper reaches of Alice Creek; and *baseline* reach AC-DS in the lower reaches of Alice Creek (AC-DS).

2015 is the first year of wild fish health monitoring at these reaches; therefore, no temporal comparisons could be made. In addition, because both monitored reaches are designated as *baseline*, spatial comparisons were only made between the reaches to assess natural variability and to develop *baseline* data for future reach-specific comparisons.

Habitat Conditions In situ water quality at both reaches indicated suitable conditions for lake chub (Table 5.13-27), with concentration of dissolved oxygen ranging from 9.0 to 9.9 mg/L; conductivity ranging from 133 to 163 µS/cm; and pH ranging from 6.91 to 7.65. Mean depth ranged from 0.45 m to 0.60 m, flow velocities ranged from 0.05 m/s to 0.25 m/s. The dominant substrate at upper *baseline* reach AC-US was cobble, while the substrate at lower *baseline* reach AC-DS was a mixture of silt and gravel. Water temperatures measured during monitoring field visits ranged from 8.45°C to 11.6°C and daily mean water temperatures decreased from a high of 22°C at the beginning of August to a low 5°C at the end of September (Figure 5.13-21).

Collection and Structure of Target Populations

Summary of Capture Success of Adults and Juveniles The target number of lake chub (20 adult fish of each sex) was collected at both reaches. Although fishing effort was maximized to capture the required number of 100 juvenile lake chub per reach, these numbers were not obtainedat either of the reaches. A summary of the capture success of lake chub in Alice Creek is provided in Table 5.13-28.

Size Distribution Figure 5.13-22 presents the length-frequency distribution of all lake chub captured in fall 2015 at each of the two reaches monitored in Alice Creek. A bimodal distribution of lake chub was suggested in the fall 2015 data from Alice Creek (Figure 5.13-22) with perhaps a third peak occurring at length >70 mm; a length of 50 mm was used to designate juvenile lake chub in Alice Creek based on field observations and distributions of lake chub in other watersheds.

Length-frequency distributions of juvenile fish were compared among reaches of Alice Creek (Figure 5.13-22). Upper *baseline* reach AC-US generally had a larger frequency of smaller fish; it was difficult to make comparisons with lower *baseline* reach AC-DS given the smaller sample size of juveniles (Table 5.13-28).

The relative abundance of lake chub juveniles in the total catch of lake chub in fall 2015 was lower at lower *baseline* reach AC-DS than at upper *baseline* reach AC-US (Table 5.13-28).

Incidence of Abnormalities No abnormalities were observed on fish caught at upper *baseline* reach AC-US; a small percentage of lake chub (1.1%) were observed with fin erosion at the lower *baseline* reach AC-DS in fall 2015 (Table 5.13-28).

Spatial Comparison of Measurement Endpoints and Wild Fish Health

A summary of morphometric data for the adult lake chub caught in Alice Creek is provided in Table 5.13-29. The following information provides statistical analyses of the responses of lake chub populations collected at each reach on Alice Creek. This information was used to test for spatial differences in values of measurement endpoints for wild fish health between upper *baseline* reach AC-US and lower *baseline* reach AC-DS.

Age – Mean Age and Age Distribution (Survival) The relative age-frequency distributions of lake chub captured showed a slightly younger age class of fish at lower *baseline* reach AC-DS compared to upper *baseline* reach AC-US (Figure 5.13-23). Both female and male lake chub were significantly older at upper *baseline* reach AC-US compared to lower *baseline* reach AC-DS (Table 5.13-30) and an exceedance of the effects criterion (±25% difference in ages of fish between reaches) was measured for both males and females.

Growth – Size-at-Age (Energy Use) Growth did not differ significantly between reaches for either male or female lake chub (Table 5.13-30).

Relative Gonad Size Weight (Energy Use) Relative gonad size in female lake chub was significantly greater at upper *baseline* reach AC-US than lower *baseline* reach AC-DS (Table 5.13-30) but there was no exceedance of the effects criterion (±25% difference in relative gonad weight of fish between reaches).

Relative Liver Weight (Energy Storage) Relative liver weight for both male and female lake chub was significantly higher at upper *baseline* reach AC-US compared to lower *baseline* reach AC-DS (Table 5.13-30); an exceedance of the effects criterion (±25% difference in relative liver weight of fish between reaches) was measured in male lake chub, but not in female lake chub.

Condition (Energy Storage) There were no significant differences in condition for either female or male lake chub (Table 5.13-30).

Power Analysis to Investigate Influence of Sample Size Power analyses were conducted for comparisons that were not statistically significant for each measurement endpoint using the effects size of ±25% for age, weight-at-age, GSI, and LSI and ±10% for condition (Table 5.13-30). Power was relatively low for some comparisons, ranging from 0.11 to 0.99. Two comparisons did not achieve the desired level of Power (>0.90) (Environment Canada 2010): growth and condition, indicating that the sample size was too low to detect a significant difference for an effect size of ±25% or ±10%, respectively. For condition, lengths and weights of the additional fish sexed while searching for the target number of males to dissect were used in an effort to increase power.

Exposure – Mixed Function Oxygenase (MFO) Activity While in fall 2015, EROD activity in adult lake chub was higher at lower *baseline* reach AC-DS than upper *baseline* reach AC-US for both females and males (Figure 5.13-24), there were no significant differences in EROD activity in either female (p=0.08) or male (p=0.75) between reaches.

Interpretation of 2015 Responses The 2015 monitoring results assessed the variability in wild fish health of lake chub in Alice Creek under *baseline* conditions given the absence of oil sands development in this watershed. Female and male lake chub at lower *baseline* reach AC-DS exhibited a number differences in values of wild fish health measurement endpoints relative to fish at upper *baseline* reach AC-US. These included lower relative gonad size in females and a lower mean age and relative liver size in both males and females at lower *baseline* reach AC-DS compared to upper *baseline* reach AC-US.

Classification of Results The selected criteria for determining change in a measurement endpoint for sentinel species monitoring was established for effects monitoring where exposed *test* reaches are compared to *baseline* reaches (Environment Canada 2010). Reaches of Alice Creek consisted solely of *baseline* reaches in fall 2015 and no classification of results could therefore be assessed under the Environment Canada effects criteria guidelines.

5.13.5 Mills Creek, Isadore's Lake

Monitoring activities were conducted in the 2015 WY in Mills Creek for the Climate and Hydrology component and at Isadore's Lake for the Water Quality and Benthic Invertebrate Communities and Sediment Quality components.

5.13.5.1 Hydrologic Conditions

Hydrometric monitoring in the Mills Creek watershed was conducted at Mills Creek at Highway 63 (JOSMP Station S6) and Isadore's Lake (JOSMP Station L3) from November 1, 2014 to March 31, 2015. Because the stations in this watershed were discontinued part way through the 2015 WY no water balance analysis was conducted. Data for JOSMP Station S6 and JOSMP Station L3 in the 2015 WY are provided in Appendix C.

5.13.5.2 Water Quality

Water quality samples were taken in fall 2015 from Isadore's Lake at *test* station ISL-1. *Test* station ISL-1 was previously sampled in 2000, 2001, and annually since 2004.

Monthly and Seasonal Variations in Water Quality Monthly variations in water quality could not be assessed for *test* station ISL-1 because water quality monitoring was conducted at the station in fall 2015 only.

2015 Fall Results Relative to Historical Concentrations Concentrations and levels of water quality measurement endpoints in fall 2015 were within the range of previously-measured concentrations at *test* station ISL-1 with the following exceptions (Table 5.13-31):

- total alkalinity, total and dissolved aluminum, and total mercury, with concentrations and levels that were below previously-measured minimum values; and
- sodium, magnesium, potassium, naphthenic acids, and oilsands extractable acids, with concentrations that were higher than previously-measured maximum concentrations.

Temporal Trends Significant temporal trends (p<0.05) detected for *test* station ISL-1 consisted of increasing fall concentrations of chloride, sodium, sulphate, potassium, magnesium, total boron, total dissolved solids, and total strontium.

Ion Balance In the first two years of sampling (2000 and 2001), the ionic composition of water at *test* station ISL-1 was dominated by calcium and bicarbonate. However, since that time, ion balance has shifted considerably and consistently away from calcium and bicarbonate toward greater proportions of sodium, magnesium, chloride, and sulphate, as was the case for fall 2015 (Figure 5.13-18).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations and levels of water quality measurement endpoints were below water quality guidelines at *test* station ISL-1 in fall 2015 with the exception of sulphide.

2015 Fall Results Relative to Regional *Baseline* Concentrations No comparisons were made between fall 2015 water quality concentrations at *test* station ISL-1 and regional *baseline* concentrations because lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers and the relative lack of *baseline* data for lakes in the region.

Water Quality Index A WQI was not calculated for *test* station ISL-1 because lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers and the relative lack of *baseline* data for lakes in the region.

5.13.5.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 at depositional *test* station ISL-1 in Isadore's Lake. This station has been sampled since 2006.

2015 Habitat Conditions Water in Isadore's Lake in fall 2015 was slightly alkaline (pH 7.7), with high conductivity (591 µS/cm), and a high concentration of dissolved oxygen (9.7 mg/L). The substrate was dominated by silt (95%) and had a relatively high total organic carbon content (4%) (Table 5.13-32).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of *test* station ISL-1 in fall 2015 was dominated by oligochaete worms Naididae (47%) and chironomids (33%), with nematodes as the subdominant taxa (14%) (Table 5.13-33). Chironomids were principally of the genera *Tanytarsus* and *Dicrotendipes.* Larvae of flying insects were sparse but were represented by Ephemeroptera (*Caenis*) in four sample replicates and the dragonfly *Enallagma* in one sample replicate.

Temporal Comparisons The temporal comparisons of values of benthic invertebrate community measurement endpoints that were possible given the data available for Isadore's Lake for *test* station ISL-1 were:

- changes over time (Hypothesis 5, Section 3.2.3.1); and
- changes between 2015 values and the mean values from all previous years of sampling.

The following statistically-significant differences were measured at *test* station ISL-1 (Table 5.13-34, Figure 5.13-26):

1. There were significant increases over time in richness and %EPT and values of both measurement endpoints were higher in 2015 than the means of all prior years of sampling, accounting for from 21% to 61% of the variance in annual means. None of these significant differences implied degrading conditions for benthic invertebrate communities.

2. There was a significant decrease over time in equitability, and equitability was lower in fall 2015 than the mean of prior years, accounting for 20% and 34% of the variance in annual means, respectively. Neither of these significant differences implied degrading conditions for benthic invertebrate communities.

3. There was a significant decrease over time in CA Axis 1 scores, and the CA Axis 1 score was lower in fall 2015 than the mean of prior years, accounting 30% and 31% of the variance in annual means, respectively.

4. The CA Axis 2 score was higher in 2015 than the mean of prior years in the lake, accounting for 38% of the variance in annual means. Changes in CA Axis 1 and CA Axis 2 scores are likely due to the increase in relative abundance of naidid worms over time in the lake (Figure 5.13-26) and do not imply degrading conditions for benthic invertebrate communities.

Comparison to Published Literature Isadore's Lake has historically had low diversity and high abundances of nematodes, making it unique in comparison to the other lakes in the Program. The benthic invertebrate community in fall 2015 at Isadore's Lake was different from the community observed in fall 2014. The abundance of nematodes and naidid worms increased since 2014, possibly indicating a change in water quality (Pennak 1989). New taxa were also present in 2015 (i.e., *Hydra*, Odonata). Chironomids were still abundant in 2015 and larvae of flying insects were also found, including *Caenis* mayflies and Corduliidae dragonflies, suggesting that conditions are at least moderately favourable. Chironomids were principally of the genera *Tanytarsus* and *Dicrotendipes,* which are commonly distributed in north-temperate lakes (Wiederholm 1983).

2015 Results Relative to Historical Conditions Abundance, richness, and %EPT in fall 2015 were higher than the inner tolerance limit of the 95^{th} percentile of the normal range of all previous years of sampling at *test* station ISL-1, while equitability in fall 2015 was lower than the inner tolerance limit of the 5^{th} percentile of the normal range of all previous years of sampling at *test* station ISL-1 (Figure 5.13-27). None of these results were indicative of degrading conditions for benthic invertebrate communities at *test* station ISL-1.

Classification of Results Variations in measurement endpoint of the benthic invertebrate community in Isadore's Lake at *test* station ISL-1 were classified as **Negligible-Low**. While there were a number of significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means, none of these implied degrading conditions for benthic invertebrate communities.

Sediment Quality

Sediment quality in fall 2015 was sampled at *test* station ISL-1 in Isadore's Lake. Sediment quality sampling was initiated at this station in 2001 and was sampled continuously from 2006 to 2015.

Temporal Trends The following significant ($p<0.05$) temporal trends in concentrations of sediment quality measurement endpoints were measured from 2001 to 2015 at *test* station ISL-1: (i) increasing concentrations of Fraction 2, 3, and 4 hydrocarbons, total alkylated PAHs, and total PAHs; and (ii) decreasing concentrations of total metals.

2015 Results Relative to Historical Conditions

Concentrations and values of sediment quality measurement endpoints at *test* station ISL-1 in fall 2015 were within ranges of previously-measured concentrations and values (Table 5.13-35, Figure 5.13-28) with the exception of:

- %clay, %sand, naphthalene, retene, and *Hyalella* growth, which were lower than previously-measured minimum concentrations and values; and
- %silt, total arsenic, and *Chironomus* growth, which were higher than previously-measured maximum concentrations and values.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of all sediment quality measurement endpoints at *test* station ISL-1 in fall 2015 were within the ranges of regional *baseline* concentrations with the exception of Fraction 3 hydrocarbons and total arsenic. In addition, the concentration of Fraction 1 hydrocarbons at *test* station ISL-1 was not detectable but had a detection limit that exceeded the CCME guideline.

2015 Results Relative to Regional *Baseline* Concentrations No comparisons were made between fall 2015 sediment quality concentrations at *test* station ISL-1 and regional *baseline* concentrations because lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers and the relative lack of *baseline* data for lakes in the region.

Sediment Quality Index An SQI was not calculated for *test* station ISL-1 for fall 2015 because lakes were not included in the regional *baseline* conditions due to ecological variability between lakes and rivers and the relative lack of *baseline* data for lakes in the region.

5.13.6 Shipyard Lake

Monitoring activities were conducted in Shipyard Lake in the 2015 WY for the Water Quality and Benthic Invertebrate Communities and Sediment Quality components.

5.13.6.1 Water Quality

Water quality was sampled in fall 2015 at Shipyard Lake at *test* station SHL-1. This station has been sampled annually since 1998.

Monthly and Seasonal Variations in Water Quality Monthly variations in water quality could not be assessed for *test* station SHL-1 because water quality monitoring was conducted at the station in fall 2015 only.

2015 Fall Results Relative to Historical Concentrations Concentrations of water quality measurement endpoints in fall 2015 at *test* station SHL-1 were within ranges of previously-measured concentrations at *test* station SHL-1, with the exception of total boron, naphthenic acids, and oilsands extractable acids, with concentrations in fall 2015 that were higher than previously-measured maximum concentrations (Table 5.13-36).

Temporal Trends The following significant ($p<0.05$) temporal trends in fall concentrations of water quality measurement endpoints were measured for *test* station SHL-1: (i) increasing concentrations of total boron, sodium, potassium, and chloride; and (ii) decreasing concentrations of calcium and total arsenic.

Ion Balance The ionic composition of water at *test* station SHL-1 has occasionally shifted toward influences of sodium and chloride, particularly in 2010, and also from 2013 to 2015 (Figure 5.13-18). This observation is consistent with significant temporal trends at *test* station SHL-1 of increasing concentrations of sodium, potassium, and chloride and a decreasing trend in calcium concentration. This shift from calcium-bicarbonate to sodium-chloride ion balance may be a result of reduced surface-water inflow and increases in groundwater influence due to changes in the lake's catchment area (previously discussed further in RAMP 2010; 2011).

Comparison of Water Quality Measurement Endpoints to Published Guidelines Concentrations and levels of water quality measurement endpoints at *test* station SHL-1 in fall 2015 were below water quality guidelines with the exception of sulphide (Table 5.13-36).

2015 Fall Results Relative to Regional *Baseline* Concentrations No comparisons were made between fall 2015 water quality concentrations at *test* station SHL-1 and regional *baseline* concentrations because lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers and the relative lack of *baseline* data for lakes in the region.

Water Quality Index A WQI was not calculated for *test* station SHL-1 because lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers and the relative lack of *baseline* data for lakes in the region.

5.13.6.2 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2015 at depositional *test* station SHL-1 in Shipyard Lake, which has been sampled since 2000.

2015 Habitat Conditions Water in Shipyard Lake in fall 2015 had a pH of 7.5, moderate conductivity (392 µS/cm) and relatively low concentration of dissolved oxygen (6.4 mg/L) (Table 5.13-37). The substrate consisted of silt (62%), with moderate amounts of clay (38%) and relatively high total organic carbon (15%).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community at *test* station SHL-1 in fall 2015 was dominated by Naididae (44%) and Chironomidae (27%) (Table 5.13-38). Dominant chironomids included *Tanytarsus*, *Cricotopus/Orthocladius*, *Polypedilum*, and *Procladius*, all of which are commonly distributed in north temperate regions (Wiederholm 1983). EPT taxa were present in all ten replicates at *test* station SHL-1 (Ephemeroptera: *Caenis* and Trichoptera: *Oecetis*, *Triaenodes*, *Phryganea* and *Polycentropus*). Several groups of flying insect larvae were present including dragonflies Anisoptera (*Cordulia shurtleffi*, Libellulidae, *Leucorrhinia*, *Libellula*) and damselflies Zygoptera (Coenagrionidae, *Enallagma*). Bivalves (*Pisidium*) and gastropods, primarily from the genus *Gyraulus*, were present in low relative abundances. Other permanent aquatic forms (Amphipoda: *Hyalella azteca*, *Gammarus lacustris*) were also present.

Temporal Comparisons The temporal comparisons of values of benthic invertebrate community measurement endpoints that were possible given the data available for Shipyard Lake for *test* station SHL-1 were:

- changes over time (Hypothesis 5, Section 3.2.3.1); and
- changes between 2015 values and the mean values from all previous years of sampling.

The following statistically-significant differences were measured at *test* station SHL-1: (Table 5.13-39, Figure 5.13-29):

1. There were significant increases in abundance and richness over time, accounting for 27% and 28% of the variance in annual means, respectively.
2. There was a significant decrease in equitability over time, accounting for 35% of the variance in annual means.

None of these significant differences implied degrading conditions for benthic invertebrate communities at *test* station SHL-1.

Comparison to Published Guidelines The benthic invertebrate community at *test* station SHL-1 of Shipyard Lake contained fauna in fall 2015 that would be expected for a lake benthic community in the Athabasca oil sands region (Parsons et al. 2010). The community contained several permanent aquatic forms, such as fingernail clams (*Pisidium*), snails (Gastropoda), and amphipods (*Hyalella azteca*, *Gammarus lacustris*), and larvae of larger flying insects (Ephemeroptera, Odonata and Trichoptera) were present in Shipyard Lake in 2015.

2015 Results Relative to Historical Conditions Values of all benthic invertebrate community measurement endpoints at *test* station SHL-1 were within the tolerance limits for the normal range of variation for previous years of sampling (Figure 5.13-30) with the exception of abundance, which was above the inner tolerance limit of the 95th percentile of the normal range of all previous years of sampling at *test* station SHL-1. This excursion in fall 2015 of abundance outside the inner tolerance limits is not indicative of degrading conditions for benthic invertebrate communities at *test* station SHL-1.

Classification of Results Variations in measurement endpoints of benthic invertebrate communities for the *test* station SHL-1 in fall 2015 were classified as **Negligible-Low**. While there were a number of significant differences in values of measurement endpoints between *test* and *baseline* conditions that accounted for more than 20% of the variance in annual means, none of these implied degrading conditions for benthic invertebrate communities.

Sediment Quality

Sediment quality in fall 2015 was sampled in Shipyard Lake at *test* station SHL-1, which has been sampled from 2001 to 2004 and 2006 to 2015.

Temporal Trends The following significant ($p<0.05$) temporal trends in concentrations of sediment quality measurement endpoints were observed in fall 2015 at *test* station SHL-1: (i) increasing concentrations of total hydrocarbons (Fractions 1, 2, 3, and 4); and (ii) increasing concentrations of total alkylated PAHs.

2015 Results Relative to Historical Conditions Concentrations and values of sediment quality measurement endpoints at *test* station SHL-1 in fall 2015 were within ranges of previously-measured concentrations and values (Table 5.13-40, Figure 5.13-31) with the exception of:

- %sand and retene, which were lower than previously-measured minimum concentrations and values; and
- *Hyalella* survival, which was higher than the previously-measured maximum value.

Comparison of Sediment Quality Measurement Endpoints to Published Guidelines Concentrations of measurement endpoints of sediment quality were below guideline concentrations at *test* station SHL-1 in fall 2015, with the exception of Fraction 3 hydrocarbons; total arsenic, benz[a]anthracene, benzo[a]pyrene, chrysene, dibenz(a,h)anthracene, and phenanthrene (Table 5.13-40). In addition, the concentration of Fraction 1 hydrocarbons at *test* station SHL-1 was not detectable but had a detection limit that exceeded the CCME guideline (Table 5.13-40).

2015 Results Relative to Regional *Baseline* Concentrations No comparisons were between fall 2015 sediment quality concentrations at *test* station SHL-1 and regional *baseline* concentrations because lakes were not included in the regional *baseline* concentration calculations due to ecological variability between lakes and rivers and the relative lack of *baseline* data for lakes in the region.

Sediment Quality Index An SQI was not calculated for *test* station SHL-1 for fall 2015 because lakes were not included in the regional *baseline* conditions due to ecological variability between lakes and rivers and the relative lack of *baseline* data for lakes in the region.

Table 5.13-2 Monthly concentrations of water quality measurement endpoints, Fort Creek (*test* station FOC-1), May to September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.25	8.14	Jun	8.29	Jul
Total suspended solids	mg/L	-	5	4.7	3.3	Sep	11.0	Jul
Conductivity	µS/cm	-	5	670	650	May, Jun	700	Aug
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.012	0.007	Sep	0.014	Jull
Total nitrogen	mg/L	-	5	0.51	0.38	Sep	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	5	0.008	<0.005	Jun	0.038	Sep
Dissolved organic carbon	mg/L	-	5	8.7	7.8	May, Jun	11.0	Aug
Ions								
Sodium	mg/L	-	5	11.0	9.3	May	12.0	Aug, Sep
Calcium	mg/L	-	5	100.0	86.0	Sep	110.0	Jul, Aug
Magnesium	mg/L	-	5	23.00	20.00	Sep	25.00	Jul, Aug
Potassium	mg/L	-	5	2.00	1.80	Jun	2.00	May, Aug, Sep
Chloride	mg/L	120-640	5	3.7	2.8	Jul	9.2	Sep
Sulphate	mg/L	309[b]	5	110.0	110.0	Jun, Jul	130.0	May
Total dissolved solids	mg/L	-	5	450	420	Jun	480	Jul, Aug
Total alkalinity	mg/L	20 (min)	5	250	230	May	280	Aug
Selected metals								
Total aluminum	mg/L	-	5	0.0522	0.0295	Sep	0.1120	Jul
Dissolved aluminum	mg/L	0.05	5	0.00062	0.00051	Jun	0.00076	Sep
Total arsenic	mg/L	0.005	5	0.00021	0.00018	May	0.00027	Jul
Total boron	mg/L	1.5-29	5	0.0641	0.0611	Sep	0.0758	Jul
Total molybdenum	mg/L	0.073	5	0.00019	0.00013	Aug	0.00035	May
Total mercury (ultra-trace)	ng/L	5-13	5	0.53	0.36	May	0.92	Jun
Total methyl mercury	ng/L	1-2	5	0.035	0.025	Sep	0.060	Jul
Total strontium	mg/L	-	5	0.2660	0.2280	Sep	0.2740	Jun
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	5	1.50	0.65	Sep	2.43	May
Oilsands extractable acids	mg/L	-	5	4.30	2.40	Sep	6.40	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	2.27	1.87	Aug	7.63	Jul
Total dibenzothiophenes[c]	ng/L	-	5	117.62	81.12	Sep	300.62	Jul
Total PAHs[c]	ng/L	-	5	372	311	Sep	821	Jul
Total Parent PAHs[c]	ng/L	-	5	26.3	25.5	Jun	31.9	Jul
Total Alkylated PAHs[c]	ng/L	-	5	347	285	Sep	789	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	3	**0.0078**	0.0029	May	**0.0110**	Jul
Sulphide	mg/L	0.0019	4	**0.0057**	<0.0019	May	**0.0180**	Jul

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.13-3 Monthly concentrations of water quality measurement endpoints, McLean Creek (*test* station MCC-1), May to September 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly water quality summary and month of occurrence						
			n	Median	Minimum		Maximum		
Physical variables								
pH	pH units	6.5-9.0	5	8.27	8.10	Jul	8.35	Sep
Total suspended solids	mg/L	-	5	8.7	4.7	May	130.0	Jun
Conductivity	µS/cm	-	5	530	490	Jul	2100	Jun
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.010	0.006	Jun	0.015	Jul
Total nitrogen	mg/L	-	5	<1.00	0.84	Sep	1.00	Aug
Nitrate+nitrite	mg/L	3-124	5	0.015	<0.005	Jul	0.13	Jun
Dissolved organic carbon	mg/L	-	5	22.0	16.0	May	25.0	Aug
Ions								
Sodium	mg/L	-	5	57.0	48.0	Sep	350.0	Jun
Calcium	mg/L	-	5	45.0	34.0	Jul	68.0	Jun
Magnesium	mg/L	-	5	14.00	13.00	May	25.00	Jun
Potassium	mg/L	-	5	2.40	1.80	Sep	4.30	Jun
Chloride	mg/L	120-640	5	38.0	30.0	Sep	400.0	Jun
Sulphate	mg/L	309[b]	5	55.0	43.0	Aug	120.0	Jun
Total dissolved solids	mg/L	-	5	340	320	Jul	1200	Jun
Total alkalinity	mg/L	20 (min)	5	180	140	Jul	340	Jun
Selected metals								
Total aluminum	mg/L	-	5	0.3400	0.2530	Aug	0.5190	May
Dissolved aluminum	mg/L	0.05	5	0.01080	0.00325	Jun	0.01900	May
Total arsenic	mg/L	0.005	5	0.00112	0.00081	Sep	0.00139	Jun
Total boron	mg/L	1.5-29	5	0.1290	0.0961	Sep	0.3390	Jun
Total molybdenum	mg/L	0.073	5	0.00066	0.00045	Sep	0.00107	May
Total mercury (ultra-trace)	ng/L	5-13	5	1.54	1.02	Sep	2.41	Jun
Total methyl mercury	ng/L	1-2	5	0.165	0.114	May	0.249	Aug
Total strontium	mg/L	-	5	0.1870	0.1670	Jul	0.6190	Jun
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	5	3.58	0.62	Sep	9.73	Jun
Oilsands extractable acids	mg/L	-	5	6.90	2.30	Sep	27.60	Jun
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	0.79	<0.59	Jun, Sep	1.03	Jul
Total dibenzothiophenes[c]	ng/L	-	5	23.77	8.17	Sep	27.13	May
Total PAHs[c]	ng/L	-	5	180	147	Sep	209	May
Total Parent PAHs[c]	ng/L	-	5	25.0	22.7	Sep	26.4	Jul
Total Alkylated PAHs[c]	ng/L	-	5	156	124	Sep	184	May
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0110**	**0.0049**	May	**0.0140**	Jul
Sulphide	mg/L	0.0019	4	**0.0054**	<0.0019	Jun	**0.0077**	Sep
Total selenium	mg/L	0.001	1	0.00026	0.00024	Oct	**0.00151**	Jun

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.13-4 Monthly concentrations of water quality measurement endpoints, Horse River (*test* station HO2), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	6	8.08	7.66	Aug	8.64	Jul
Total suspended solids	mg/L	-	6	9.2	2.0	Oct	25.0	May
Conductivity	µS/cm	-	6	240	140	Aug	370	Jul
Nutrients								
Total dissolved phosphorus	mg/L	-	6	0.036	0.010	Jul	0.053	Aug
Total nitrogen	mg/L	-	6	<1.00	0.68	Oct	1.30	Aug
Nitrate+nitrite	mg/L	3-124	6	<0.005	<0.003	May	0.091	Sep
Dissolved organic carbon	mg/L	-	6	24.5	19.0	Jul	41.0	Aug
Ions								
Sodium	mg/L	-	6	17.5	12.0	Aug	28.0	Jul
Calcium	mg/L	-	6	25.5	16.0	Aug	41.0	Jul
Magnesium	mg/L	-	6	7.50	4.80	Aug	13.00	Jul
Potassium	mg/L	-	6	1.50	0.73	Aug	2.10	Jul
Chloride	mg/L	120-640	6	4.7	3.2	May	8.5	Jul
Sulphate	mg/L	309[b]	6	13.0	5.6	Aug	26.0	Jul
Total dissolved solids	mg/L	-	6	185	92	May	270	Jul
Total alkalinity	mg/L	20 (min)	6	104	59	Aug	170	Jul
Selected metals								
Total aluminum	mg/L	-	6	0.3830	0.0539	Jun	1.5600	May
Dissolved aluminum	mg/L	0.05	6	0.03200	0.01170	Jun	**0.07770**	Aug
Total arsenic	mg/L	0.005	6	0.00111	0.00096	Sep	0.00142	Aug
Total boron	mg/L	1.5-29	6	0.0763	0.0410	Aug	0.1350	Jul
Total molybdenum	mg/L	0.073	6	0.00067	0.00041	Aug	0.00157	Jul
Total mercury (ultra-trace)	ng/L	5-13	6	2.99	1.68	Oct	3.48	Sep
Total methyl mercury	ng/L	1-2	6	0.168	0.119	Jul	0.603	Aug
Total strontium	mg/L	-	6	0.1340	0.0766	Aug	0.2290	Jul
Total hydrocarbons								
BTEX	mg/L	-	6	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	6	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	6	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	6	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	6	0.54	<0.08	Oct	1.30	Jun
Oilsands extractable acids	mg/L	-	6	1.35	<0.10	Oct	3.00	Jul
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	6	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	6	2.50	0.77	Oct	6.03	Aug
Total dibenzothiophenes[c]	ng/L	-	6	63.91	18.33	Oct	106.35	May
Total PAHs[c]	ng/L	-	6	263	149	Oct	395	Jul
Total Parent PAHs[c]	ng/L	-	6	24.8	23.0	Jun	26.7	Jul
Total Alkylated PAHs[c]	ng/L	-	6	239	126	Oct	368	Jul
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0084**	0.0031	May	**0.0140**	Aug
Sulphide	mg/L	0.0019	4	**0.0053**	<0.0019	May, Jul	**0.0150**	Aug
Dissolved iron	mg/L	0.3	5	**0.8405**	0.1310	Jul	**0.9350**	May

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

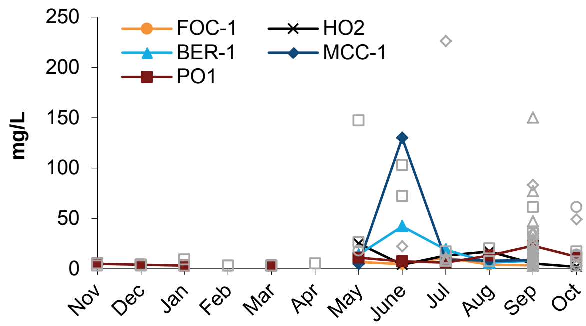
[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

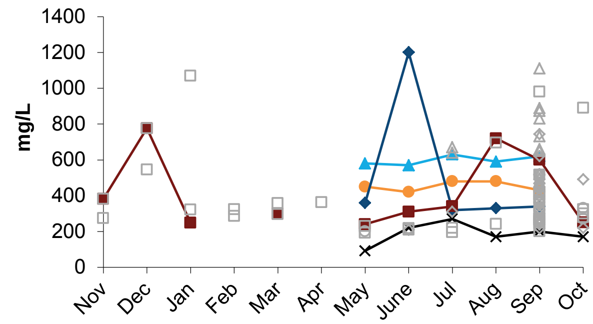
[d] n value refers to number of exceedances in 2015.

Figure 5.13-3 Selected water quality measurement endpoints in Fort Creek, McLean Creek, Horse River, Poplar River, and Beaver River (monthly data) in the 2015 WY.

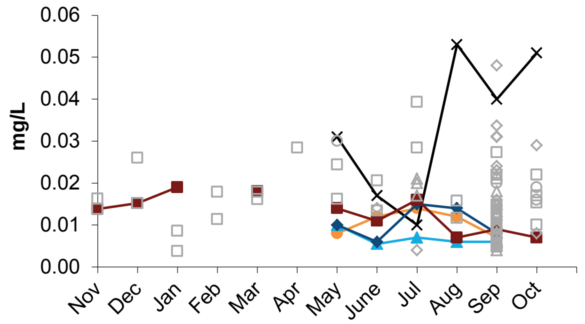
Total Suspended Solids (TSS)



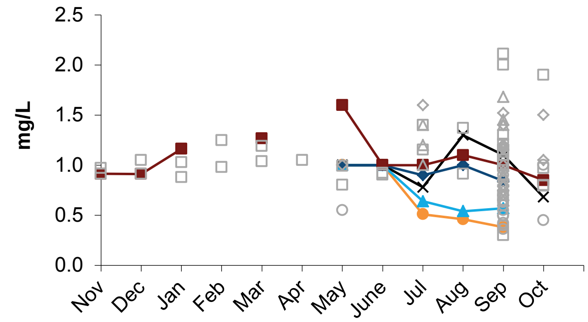
Total Dissolved Solids (TDS)



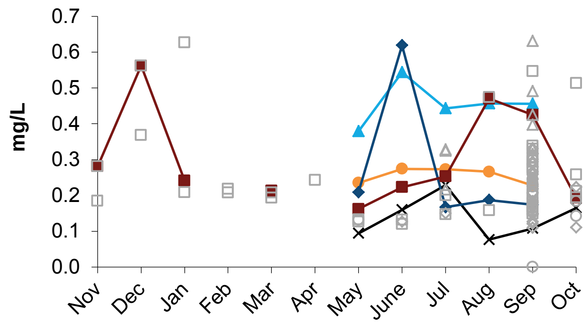
Total Dissolved Phosphorus



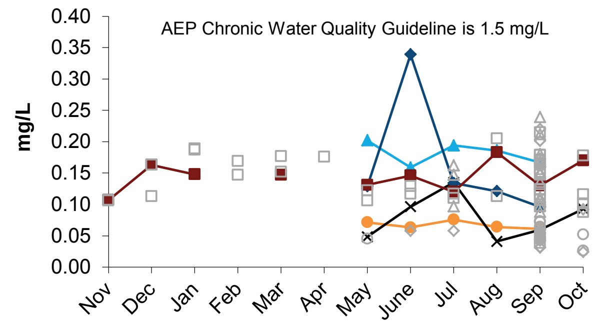
Total Nitrogen



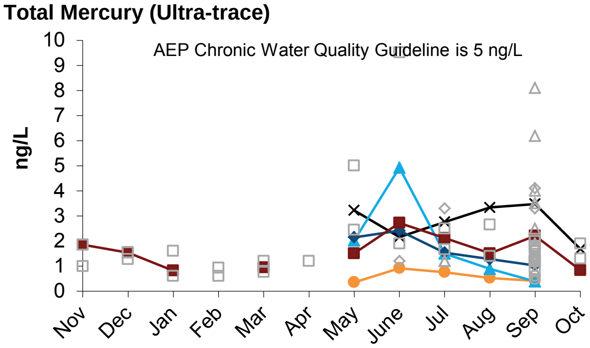
Total Strontium



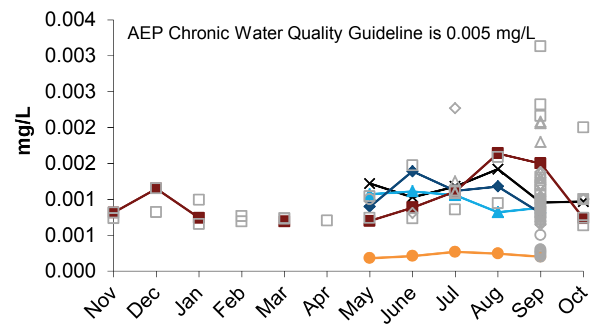
Total Boron



Total Mercury (Ultra-trace)

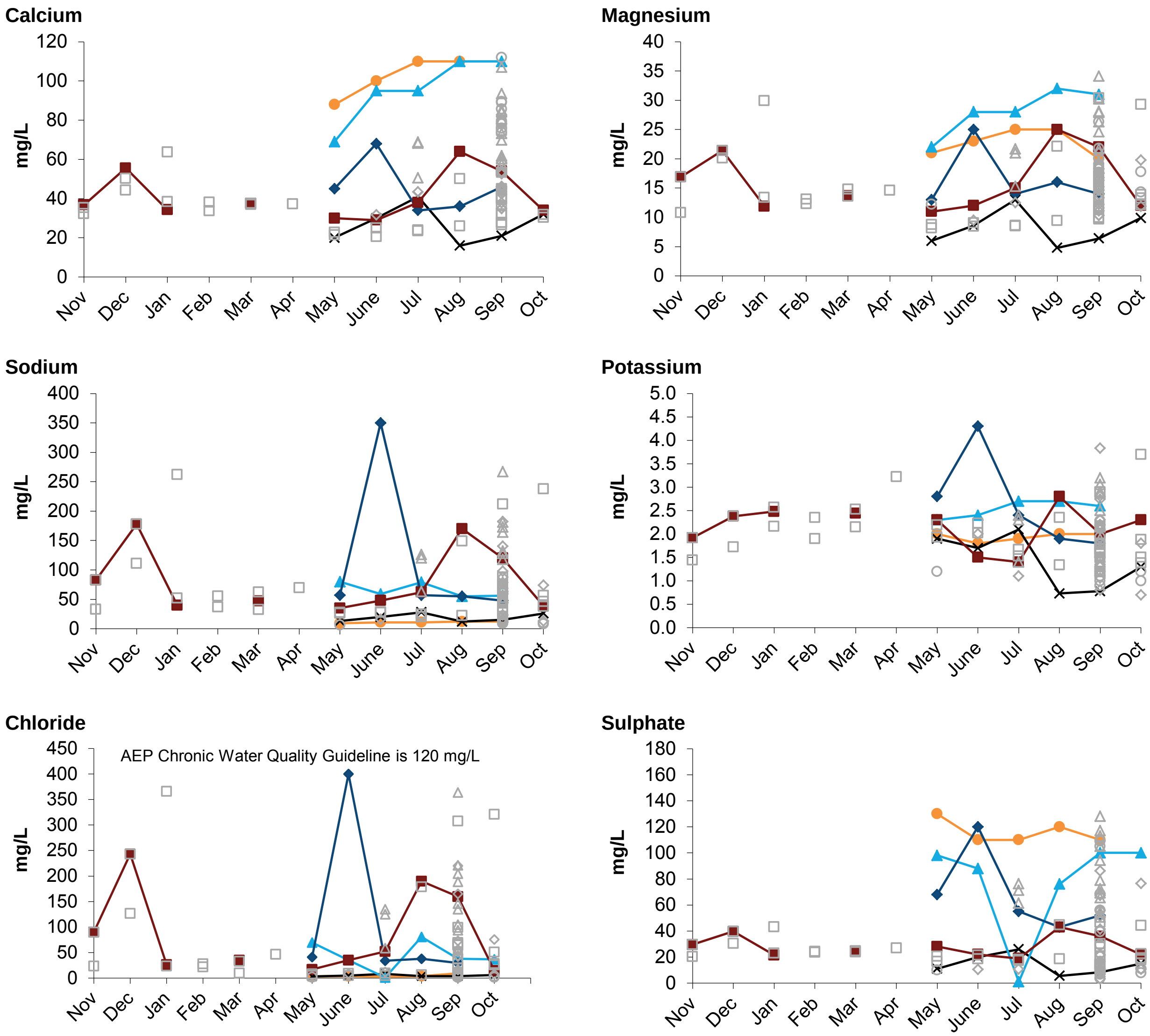


Total Arsenic



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Figure 5.13-3 (Cont'd.)



Non-detectable values are shown at the detection limit.
Colour markers indicate data from the 2015 WY and corresponding grey markers indicate historical data.

Table 5.13-5 Concentrations of water quality measurement endpoints, Fort Creek (*test* station FOC-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2000-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.19	13	8.31	8.10	8.42
Total suspended solids	mg/L	-	3.3	13	9.0	<3.0	35.5
Conductivity	µS/cm	-	670	13	570	432	743
Nutrients							
Total dissolved phosphorus	mg/L	-	0.007	13	0.010	0.005	0.019
Total nitrogen	mg/L	-	0.380	13	0.550	0.361	1.000
Nitrate+nitrite	mg/L	3-124	0.008	13	<0.071	<0.050	<0.100
Dissolved organic carbon	mg/L	-	<u>8.5</u>	13	13.0	9.1	14.0
Ions							
Sodium	mg/L	-	12.0	13	11.0	9.0	18.0
Calcium	mg/L	-	86.0	13	85.1	69.4	117.0
Magnesium	mg/L	-	20.0	13	18.6	14.6	26.3
Potassium	mg/L	-	2.0	13	0.9	1.5	2.4
Chloride	mg/L	120-640	<u>9.2</u>	13	3.0	2.0	7.0
Sulphate	mg/L	309[b]	110.0	13	29.3	3.7	167.0
Total dissolved solids	mg/L	-	430	13	360	260	509
Total alkalinity	mg/L	20 (min)	240	13	277	225	309
Selected metals							
Total aluminum	mg/L	-	<u>0.030</u>	13	0.084	0.031	**0.850**
Dissolved aluminum	mg/L	0.05	0.0008	13	0.0015	<0.0010	0.0500
Total arsenic	mg/L	0.005	0.00020	13	0.00027	0.00020	<0.0010
Total boron	mg/L	1.5-29	0.0611	13	0.0547	0.0380	0.0731
Total molybdenum	mg/L	0.073	<u>0.00019</u>	12	0.00010	<0.00001	0.00015
Total mercury (ultra-trace)	ng/L	5-13	<u>0.42</u>	10	<1.20	0.48	1.40
Total methyl mercury	ng/L	1-2	0.025	-	-	-	-
Total strontium	mg/L	-	0.22800	13	0.20600	<0.00001	0.26000
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.250**	**<0.250**	**<0.250**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.65	4	0.65	0.25	1.00
Oilsands extractable acids	mg/L	-	<u>2.40</u>	4	1.72	0.58	1.92
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.210	<15.16
Retene	ng/L	-	1.97	4	4.95	0.96	8.79
Total dibenzothiophenes[c]	ng/L	-	81.1	4	195.7	42.5	445.2
Total PAHs[c]	ng/L	-	292	4	623	234	1,529
Total Parent PAHs[c]	ng/L	-	26.0	4	24.3	22.6	36.3
Total Alkylated PAHs[c]	ng/L	-	266	4	600	209	1,492
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.002	<u>**0.0062**</u>	13	**0.0022**	0.0005	**0.0060**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.13-6 Concentrations of water quality measurement endpoints, McLean Creek (*test* station MCC-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1999-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.35	16	8.33	8.00	8.60
Total suspended solids	mg/L	-	8.7	16	9	<3.0	83
Conductivity	µS/cm	-	520	16	457	289	1,220
Nutrients							
Total dissolved phosphorus	mg/L	-	0.008	16	0.015	0.005	0.048
Total nitrogen	mg/L	-	0.84	16	1.11	0.70	1.52
Nitrate+nitrite	mg/L	3-124	<u>0.015</u>	16	<0.100	<0.050	<1.00
Dissolved organic carbon	mg/L	-	22.0	16	25.5	4.90	35.0
Ions							
Sodium	mg/L	-	48.0	16	44.0	10.3	182.0
Calcium	mg/L	-	46.0	16	49.3	37.9	81.7
Magnesium	mg/L	-	14.0	16	13.7	10.3	21.0
Potassium	mg/L	-	1.8	16	0.7	1.5	3.8
Chloride	mg/L	120-640	30.0	16	43.1	4.8	220.0
Sulphate	mg/L	309[b]	52.0	16	19.0	3.2	86.2
Total dissolved solids	mg/L	-	340	16	333	218	743
Total alkalinity	mg/L	20 (min)	180	16	182	141	319
Selected metals							
Total aluminum	mg/L	-	0.340	16	0.349	0.070	2.581
Dissolved aluminum	mg/L	0.05	0.0075	16	0.0083	0.0025	0.0204
Total arsenic	mg/L	0.005	0.00081	16	0.00096	0.00065	0.00138
Total boron	mg/L	1.5-29	0.0961	16	0.0597	0.0240	0.2200
Total molybdenum	mg/L	0.073	0.00045	16	0.00021	0.00012	0.00107
Total mercury (ultra-trace)	ng/L	5-13	1.02	12	1.33	<1.20	4.10
Total methyl mercury	ng/L	1-2	0.173	-	-	-	-
Total strontium	mg/L	-	0.174	16	0.182	0.110	0.331
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.250**	**<0.250**	**<0.250**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.6</u>	4	2.62	0.700	7.94
Oilsands extractable acids	mg/L	-	2.3	4	3.11	1.19	11.9
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.210	<15.16
Retene	ng/L	-	1.54	4	1.61	0.68	5.10
Total dibenzothiophenes[c]	ng/L	-	58.2	4	27.9	16.7	140.5
Total PAHs	ng/L	-	260	4	233	123	629
Total Parent PAHs[c]	ng/L	-	<u>29.3</u>	4	25.1	15.3	26.7
Total Alkylated PAHs[c]	ng/L	-	231	4	208	107	602
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.002	**0.0077**	16	**0.0071**	**0.0024**	**0.0250**
Total phenols	mg/L	0.004	**0.0081**	16	**0.0068**	<0.0010	**0.0120**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.13-7 Concentrations of water quality measurement endpoints, Horse River (*test* station HO2), fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015 Value
Physical variables			
pH	pH units	6.5-9.0	7.87
Total suspended solids	mg/L	-	5.3
Conductivity	µS/cm	-	190
Nutrients			
Total dissolved phosphorus	mg/L	-	0.04
Total nitrogen	mg/L	-	1.1
Nitrate+nitrite	mg/L	3-124	0.091
Dissolved organic carbon	mg/L	-	35.00
Ions			
Sodium	mg/L	-	15
Calcium	mg/L	-	21
Magnesium	mg/L	-	6.4
Potassium	mg/L	-	0.8
Chloride	mg/L	120-640	4.2
Sulphate	mg/L	309[b]	8.3
Total dissolved solids	mg/L	-	200
Total alkalinity	mg/L	20 (min)	87
Selected metals			
Total aluminum	mg/L	-	0.295
Dissolved aluminum	mg/L	0.05	0.043
Total arsenic	mg/L	0.005	0.001
Total boron	mg/L	1.5-29	0.060
Total molybdenum	mg/L	0.073	0.001
Total mercury (ultra-trace)	ng/L	5-13	3.48
Total methyl mercury	ng/L	1-2	0.326
Total strontium	mg/L	-	0.108
Total hydrocarbons			
BTEX	mg/L	-	<0.01
Fraction 1 (C6-C10)	mg/L	0.15	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02
Naphthenic Acids	mg/L	-	0.18
Oilsands extractable acids	mg/L	-	1.4
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	ng/L	1,000	<13.55
Retene	ng/L	-	1.07
Total dibenzothiophenes[c]	ng/L	-	18.89
Total PAHs[c]	ng/L	-	147.80
Total Parent PAHs[c]	ng/L	-	23.80
Total Alkylated PAHs[c]	ng/L	-	124.00
Other variables that exceeded Alberta guidelines in fall 2015			
Total phenols	mg/L	0.004	0.01
Sulphide	mg/L	0.002	0.0085
Dissolved iron	mg/L	0.3	0.762

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.13-4 Piper diagram of fall ion balance in Fort Creek, McLean Creek, and Horse River.

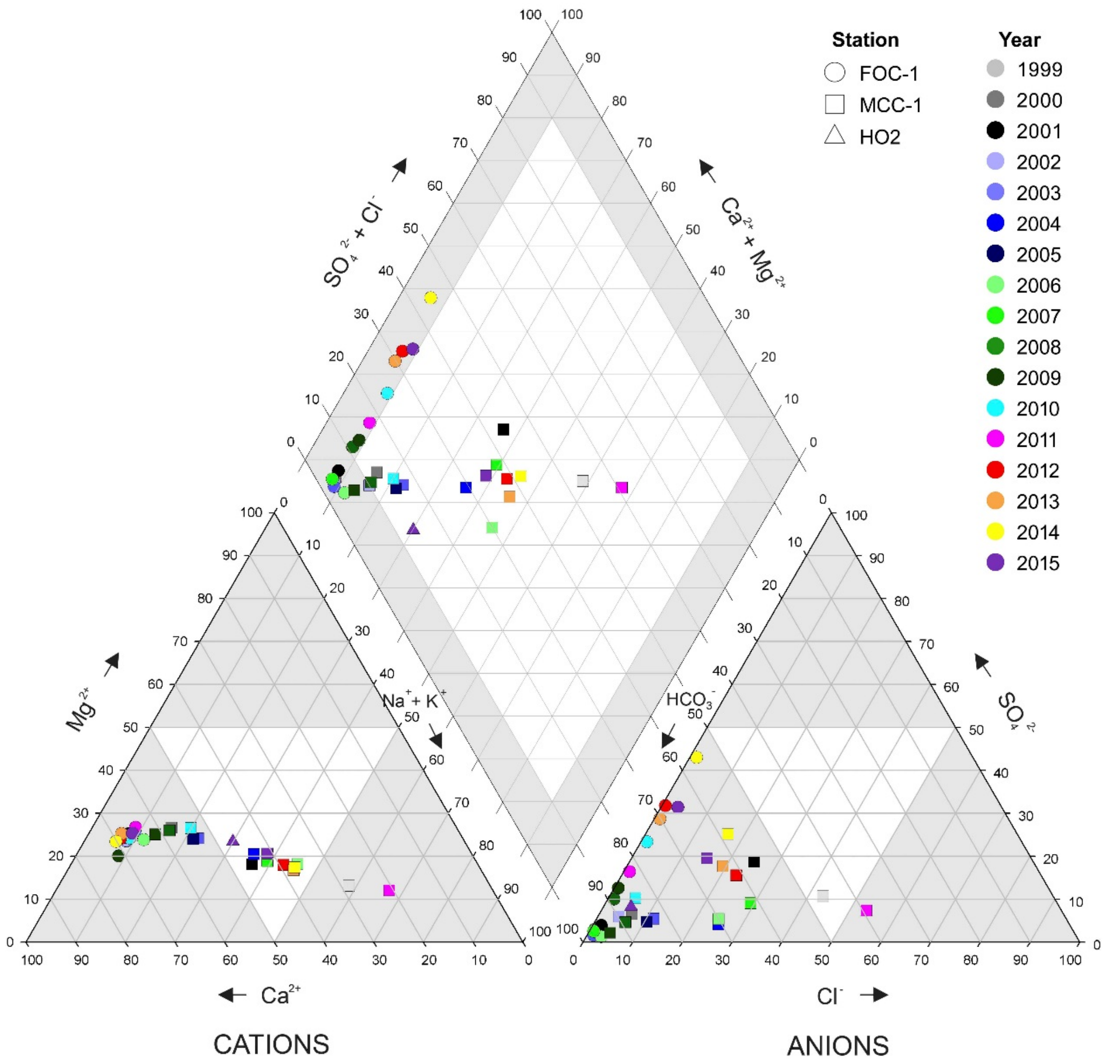


Table 5.13-8 Water quality guideline exceedances at *test* station FOC-1, *test* station PO1, *test* station BER-1, *baseline* station BER-2, *test* station HO2, *test* station MCC-1, *baseline* stations AC-DS and AC-US, *test* station ISL-1, and *test* station SHL-1, 2015 WY.

Variable	Units	Guideline[a]	January	March	May	June	July	August	September	October
Fort Creek (FOC-1)										
Total phenols	mg/L	0.004	-	-	0.0029	0.0031	**0.0110**	**0.0092**	**0.0078**	**-**
Sulphide	mg/L	0.0019	-	-	<0.0019	**0.0057**	**0.0180**	**0.0039**	**0.0062**	**-**
Poplar Creek (PO1)										
Total phenols	mg/L	0.004	<0.001	<0.001	0.0039	0.0022	**0.016**	**0.015**	**0.011**	**0.0063**
Sulphide	mg/L	0.0019	**0.005**	**0.0082**	**0.0041**	**0.0041**	**0.0031**	<0.0019	**0.0054**	**0.0059**
Dissolved iron	mg/L	0.3	0.198	0.172	0.224	**0.704**	**0.663**	**0.718**	**0.594**	0.018
Beaver River lower (BER-1)										
Total phenols	mg/L	0.004	-	-	**0.0054**	**0.0064**	**0.016**	**0.011**	**0.0079**	-
Sulphide	mg/L	0.0019	-	-	**0.0097**	<0.0019	<0.0019	**0.0077**	**0.0062**	-
Beaver River upper (BER-2)										
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0100**	-
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.0046**	-
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	**0.792**	-
Horse River (HO2)										
Total phenols	mg/L	0.004	-	-	0.0031	**0.0049**	**0.013**	**0.014**	**0.01**	**0.0067**
Sulphide	mg/L	0.0019	-	-	<0.0019	**0.0032**	<0.0019	**0.015**	**0.0085**	**0.0073**
Dissolved iron	mg/L	0.3	-	-	**0.935**	**0.587**	0.131	**0.919**	**0.762**	**0.922**
McLean Creek (MCC-1)										
Total phenols	mg/L	0.004	-	-	**0.0049**	**0.011**	**0.014**	**0.012**	**0.0081**	-
Sulphide	mg/L	0.0019	-	-	**0.0049**	0.0019	**0.007**	**0.0054**	**0.0077**	-
Total selenium	mg/L	0.001	-	-	0.00025	**0.00151**	0.00038	0.00026	0.00024	-

Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

"-" = not sampled.

Table 5.13-8 (Cont'd)

Variable	Units	Guideline[a]	January	March	May	June	July	August	September	October
Alice Creek downstream (AC-DS)										
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.0062**	-
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	**1.58**	-
Alice Creek upstream (AC-US)										
Total phenols	mg/L	0.004	-	-	-	-	-	-	**0.0044**	-
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.0054**	-
Dissolved iron	mg/L	0.3	-	-	-	-	-	-	**1.65**	-
Isadore's Lake (ISL-1)										
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.0062**	-
Shipyard Lake (SHL-1)										
Sulphide	mg/L	0.0019	-	-	-	-	-	-	**0.007**	-

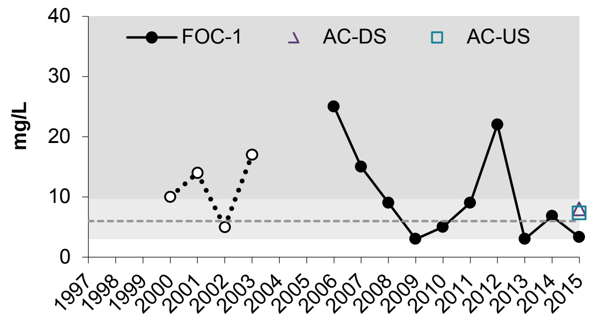
Values in **bold** are above the guideline

[a] Sources for all guidelines are outlined in Table 3.2-1.

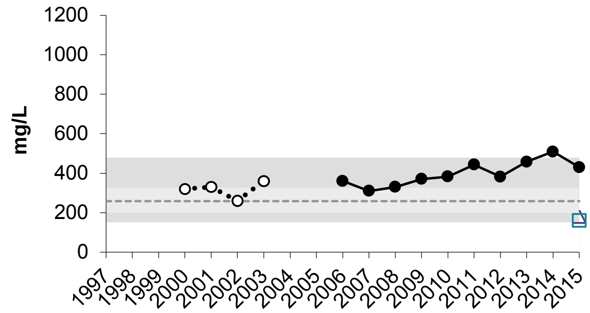
"-" = not sampled.

Figure 5.13-5 Selected fall water quality measurement endpoints, Fort Creek and Alice Creek (fall data), relative to historical concentrations and regional *baseline* fall concentrations.

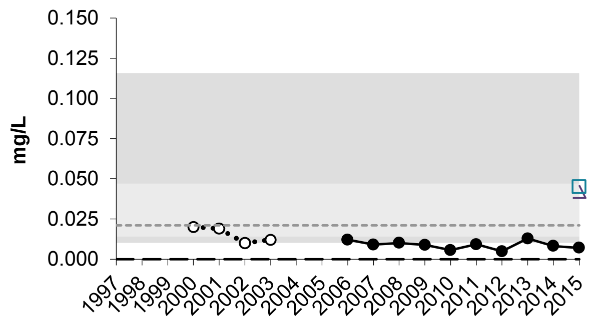
Total Suspended Solids (TSS)



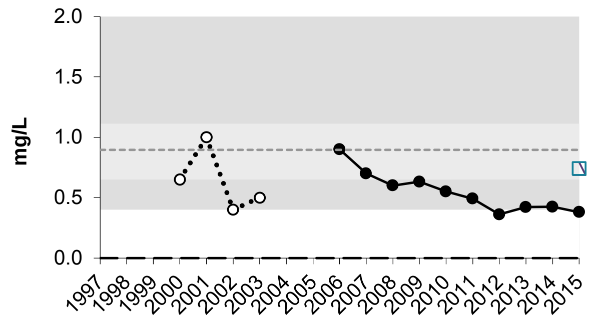
Total Dissolved Solids (TDS)



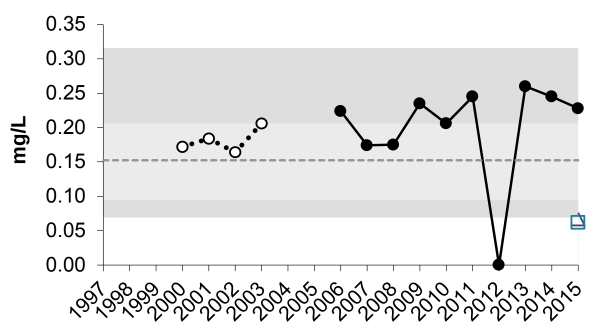
Dissolved Phosphorus



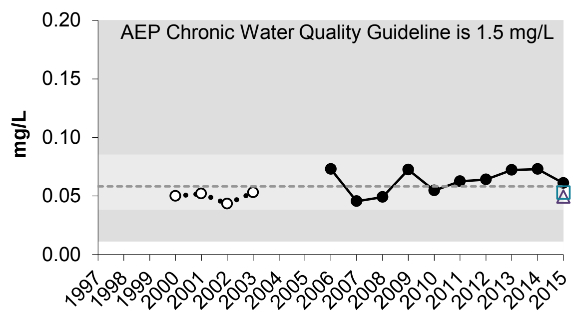
Total Nitrogen



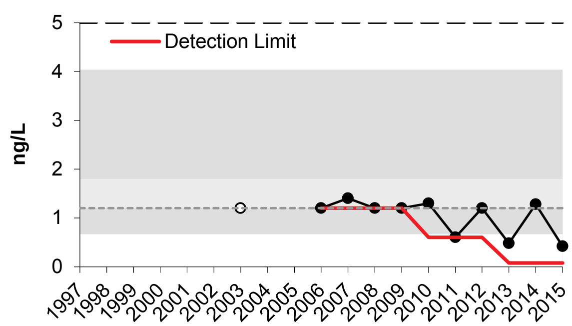
Total Strontium



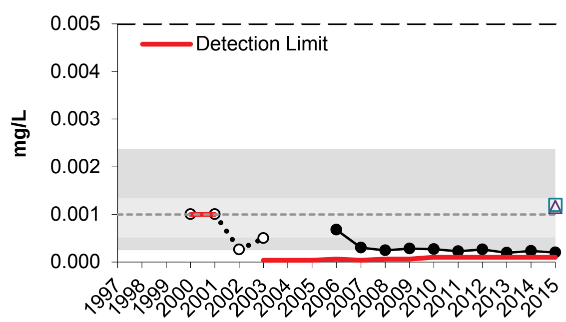
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



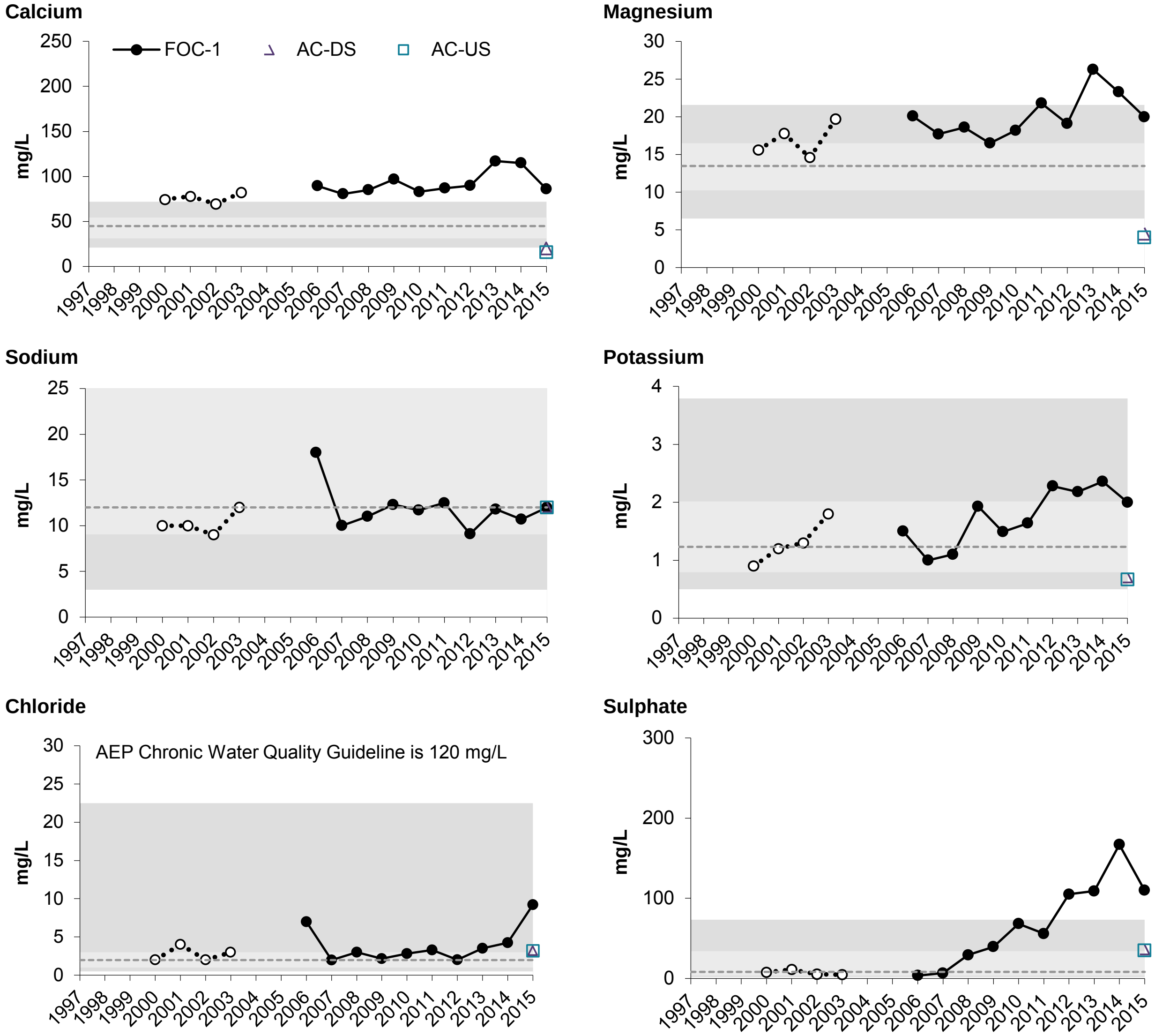
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all WQ guidelines.

○······○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-5 (Cont'd.)



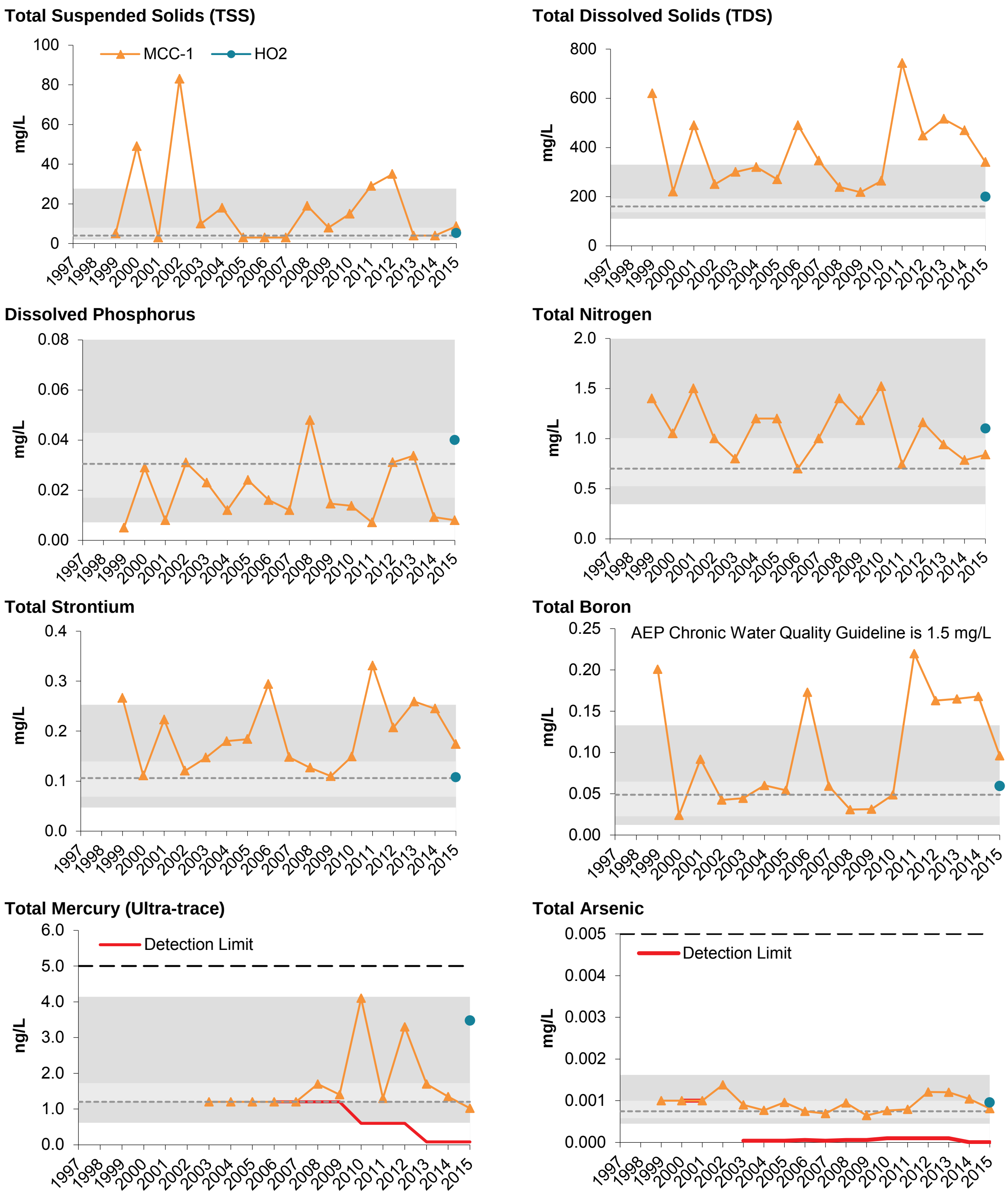
Non-detectable values are shown at the detection limit.

- - - - - Water quality guideline. See Table 3.2-1 for all WQ guidelines.

○·····○ Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-6 Selected fall water quality measurement endpoints, McLean Creek and Horse River, relative to historical concentrations and regional *baseline* fall concentrations.



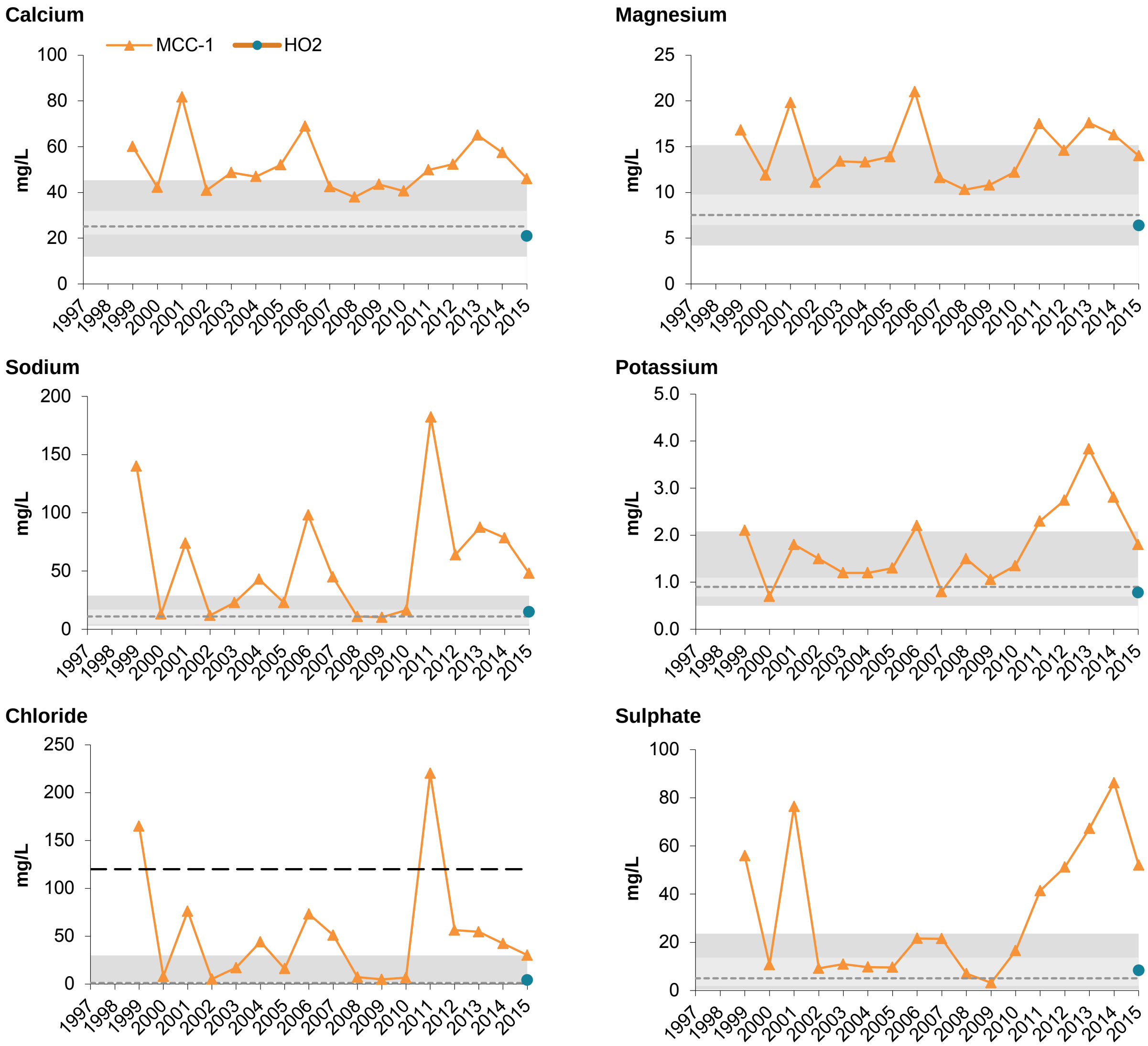
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all WQ guidelines.

O······O Sampled as a *baseline* station ●——● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all WQ guidelines.

○⋯⋯○ Sampled as a *baseline* station ●━━● Sampled as a *test* station

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.13-9 Average habitat characteristics of benthic invertebrate sampling location in Fort Creek (*test* reach FOC-D1), fall 2015.

Variable	Units	FOC-D-1 Lower *Test* Reach
Sample date	-	September 18, 2015
Habitat	-	Depositional
Water depth	m	0.26
Current velocity	m/s	0.4
Field water quality		
Dissolved oxygen (DO)	mg/L	9.7
Conductivity	µS/cm	591
pH	pH units	7.7
Water temperature	°C	8.1
Sediment composition		
Sand	%	98.1
Silt	%	1.65
Clay	%	0.30
Total organic carbon (TOC)	%	0.95

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.13-10 Summary of major taxon abundances and measurement endpoints for the benthic invertebrate community at lower Fort Creek (*test* reach FOC-D1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Test Reach FOC-D1		
	2001	2002 - 2014	2015
Nematoda	2	1 to 24	<1
Oligochaeta (indet.)	-	0 to 15	-
Naididae	1	0 to 3	-
Tubificidae	-	<1 to 66	17
Enchytraeidae	1	0 to 3	-
Lumbricidae	-	7	-
Erpobdellidae	-	0 to <1	-
Glossiphoniidae	-	0 to <1	-
Hydracarina	<1	0 to 2	-
Gastropoda	<1	0 to 9	1
Bivalvia	5	0 to 8	3
Ceratopogonidae	<1	0 to 8	<1
Chironomidae	80	18 to 95	66
Diptera (misc.)	9	0 to 14	8
Ephemeroptera	<1	0 to 1	-
Plecoptera	-	0 to 7	1
Trichoptera	-	0 to <1	-
Heteroptera	-	0 to <1	-
Benthic Invertebrate Community Measurement Endpoints			
Total abundance per sample	91	13 to 1,603	65
Richness	15	4 to 14	10
Equitability	0.50	0.30 to 0.80	0.5
% EPT	<1	0 to 9	0.6

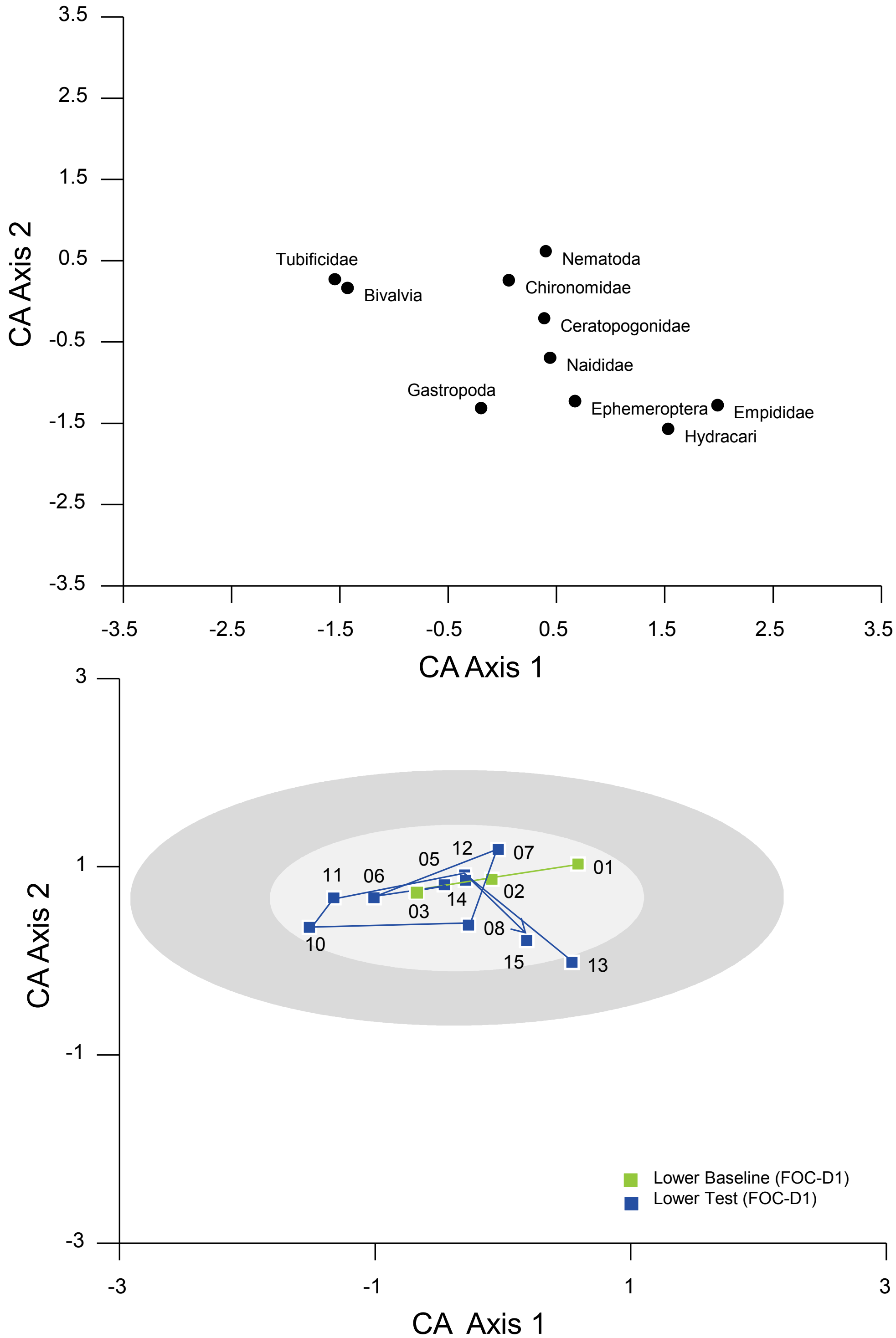
Table 5.13-11 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in lower Fort Creek (*test* reach FOC-D1).

Measurement Endpoint	P-value				Variance Explained (%)				Nature of Change(s)
	Before vs. After	Time Trend in *Test* Period	2015 vs. *Baseline*	2015 vs. Previous Years	Before vs. After	Time Trend in *Test* Period	2015 vs. *Baseline*	2015 vs. Previous Years	
Log of Abundance	**<0.001**	0.620	0.137	0.415	40	1	6	2	Abundance was higher during the *baseline* period.
Log of Richness	**0.003**	0.095	0.783	0.069	26	8	0	9	Richness was higher during the *baseline* period.
Equitability	**0.009**	0.681	0.451	0.327	22	1	2	3	Equitability was higher during the *test* period.
Log of EPT	0.474	0.605	0.895	0.734	5	3	0	1	No change.
CA Axis 1	0.272	0.196	0.692	0.214	7	10	1	9	No change.
CA Axis 2	0.313	0.307	0.198	0.388	11	12	19	8	No change.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results per Table 3.2-6.

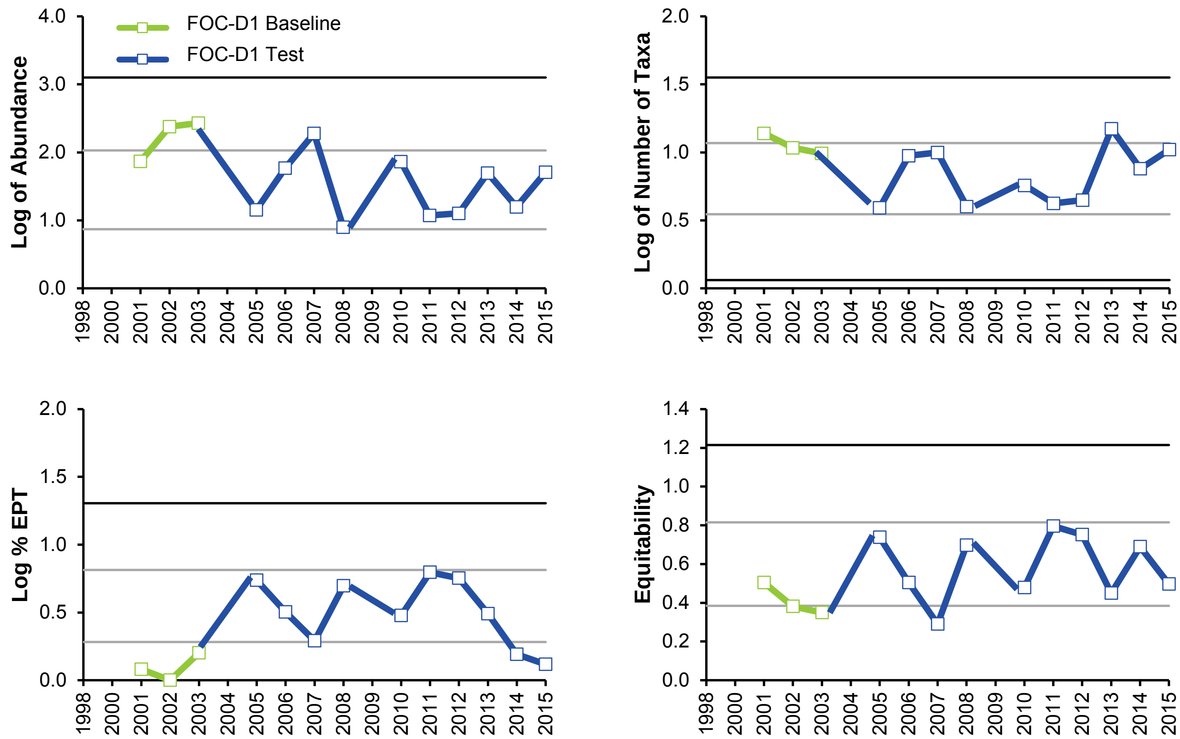
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-7 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of Fort Creek (*test* reach FOC-D1).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner 5th and outer 95th percentiles for previous years at *test* reach FOC-D1.

Figure 5.13-8 Variation in benthic invertebrate community measurement endpoints at *test* reach FOC-D1 of Fort Creek relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from previous years (2001 to 2014).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed before the average was calculated.

Table 5.13-12 Concentrations of sediment quality measurement endpoints, Fort Creek (*test* station FOC-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2000-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>0.9</u>	8	1.0	3.9	15.0
Silt	%	-	3.9	8	1.0	5.9	29.0
Sand	%	-	95.2	8	56.0	89.7	97.9
Total organic carbon	%	-	<u>1.15</u>	10	1.48	3.06	7.10
Total hydrocarbons							
BTEX	mg/kg	-	<10	7	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	7	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	101	7	16	100	**311**
Fraction 3 (C16-C34)	mg/kg	300[1]	**2370**	7	**440**	**2020**	**2930**
Fraction 4 (C34-C50)	mg/kg	2800[1]	1720	7	450	1500	2330
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0013	10	0.0006	0.0028	0.0170
Retene	mg/kg	-	0.0320	10	0.0320	0.0749	0.6790
Total dibenzothiophenes	mg/kg	-	0.9587	10	0.1613	1.8439	3.2203
Total PAHs	mg/kg	-	4.4855	10	1.8536	8.7678	14.2560
Total Parent PAHs	mg/kg	-	0.1792	10	0.1592	0.2756	0.8740
Total Alkylated PAHs	mg/kg	-	4.3063	10	1.6890	8.5285	13.3820
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.2952</u>	9	0.4246	0.5698	**1.5013**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
Chrysene	mg/kg	0.0571	**0.0575**	10	0.0181	**0.0929**	**0.2300**
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	98	9	32	90	100
Chironomus growth - 10d	mg/organism	-	1.42	9	1.24	2.26	3.30
Hyalella survival - 14d	% surviving	-	<u>98</u>	9	60	88	96
Hyalella growth - 14d	mg/organism	-	0.13	9	0.10	0.20	0.28

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

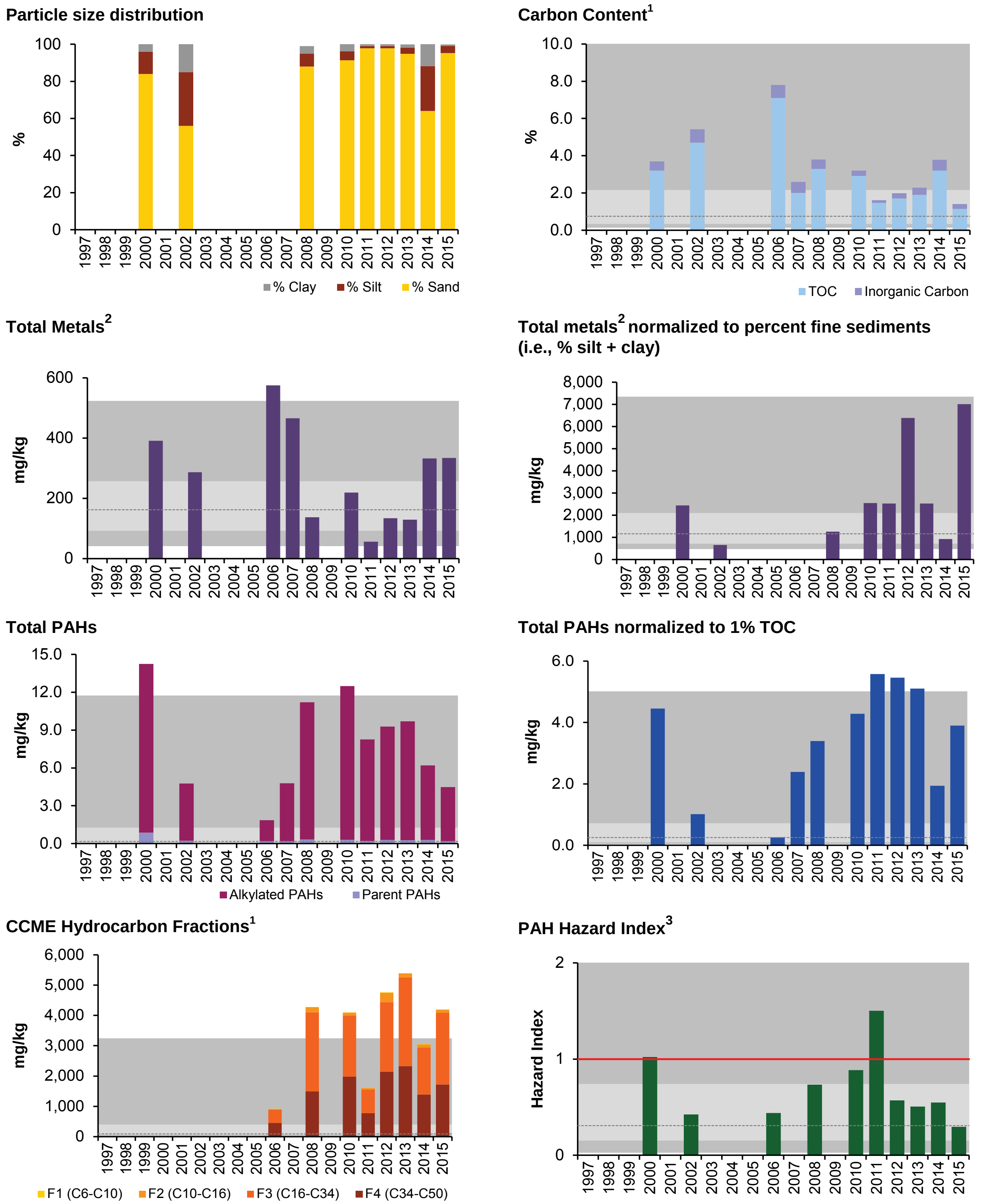
ns = not sampled in 2001, 2003-2005, or 2009.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-9 Variation in sediment quality measurement endpoints in Fort Creek, *test* station FOC-D1 (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



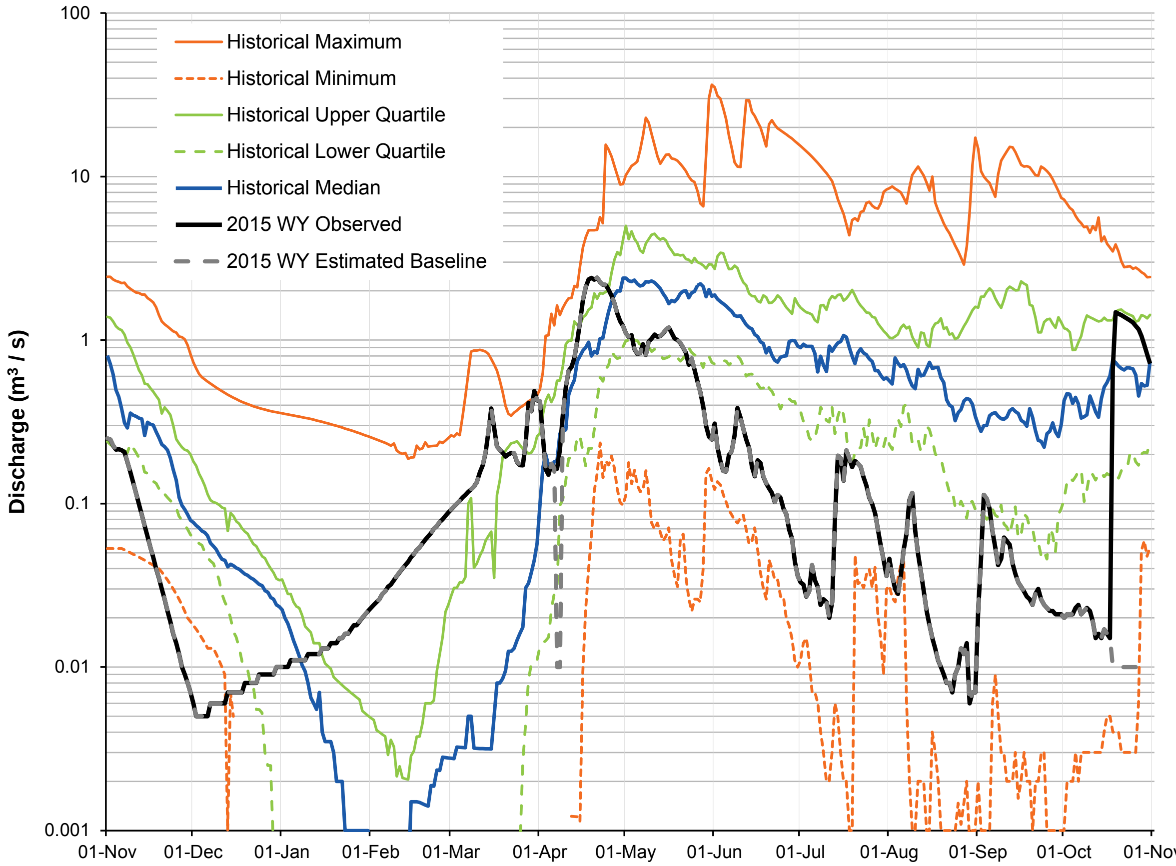
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.13-10 The observed (*test*) hydrograph and estimated *baseline* hydrograph for Poplar Creek in 2015, compared to historical values.



Note: The observed 2015 WY hydrograph is based on data for the 2015 WY for Poplar Creek at Highway 63, WSC Station 07DA007. The upstream drainage area is 151 km^2. Historical values from May 1 to October 31 were calculated from data collected from 1973 to 1986 and 1996 to 2014, and from 1973 to 1986 for other months.

Table 5.13-13 Estimated water balance at WSC Station 07DA007 (JOSMP Station S11), Poplar Creek at Highway 63, 2015 WY.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**8.707**	**Observed daily discharges, obtained from Poplar Creek at Highway 63, WSC Station 07DA007 (JOSMP Station S11)**
Closed-circuited area water loss, relative to the estimated *baseline* hydrograph	-0.027	Estimated 0.6 km^2 of the Poplar Creek watershed is closed-circuited as of 2015 (Table 2.3-1)
Incremental runoff from land clearing (not closed-circuited area), relative to the estimated *baseline* hydrograph	0.009	Estimated 0.9 km^2 of the Poplar Creek watershed with land change from oil sands developments as of 2015 that is not closed-circuited (Table 2.3-1)
Water withdrawals from the Poplar Creek watershed, relative to the estimated *baseline* hydrograph	0	None reported
Water releases into the Poplar Creek watershed, relative to the estimated *baseline* hydrograph	0	None reported
Diversions into or out of the watershed, relative to the estimated *baseline* hydrograph	1.419	Diversion from original upper Beaver River catchment area into Poplar Creek via the spillway.
The difference between *test* and *baseline* hydrographs on tributary streams, relative to the estimated *baseline* hydrograph	0	Not applicable
Estimated *baseline* hydrograph (total discharge)	**7.288**	**Estimated *baseline* discharge at Poplar Creek at Highway 63, WSC Station 07DA007 (JOSMP Station S11)**
Incremental flow (change in total annual discharge), relative to the estimated *baseline* hydrograph	1.401	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of total discharge), relative to the estimated *baseline* hydrograph	19.475	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

Notes:

Definitions and assumptions are discussed in Section 3.2.1.

Based on data for the 2015 WY for Poplar Creek at Highway 63, WSC Station 07DA007.

All non-zero values in this table are presented to three decimal places.

Table 5.13-14 Calculated change in hydrologic measurement endpoints for the Poplar Creek watershed, 2015 WY.

Measurement Endpoint	Value from *Test* Hydrograph (m^3/s)	Value from *Baseline* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.301	0.294	+43.946%
Mean winter discharge	0.075	0.075	-0.246%
Annual maximum daily discharge	2.406	2.412	-0.246%
Open-water season minimum daily discharge	0.006	0.006	-0.246%

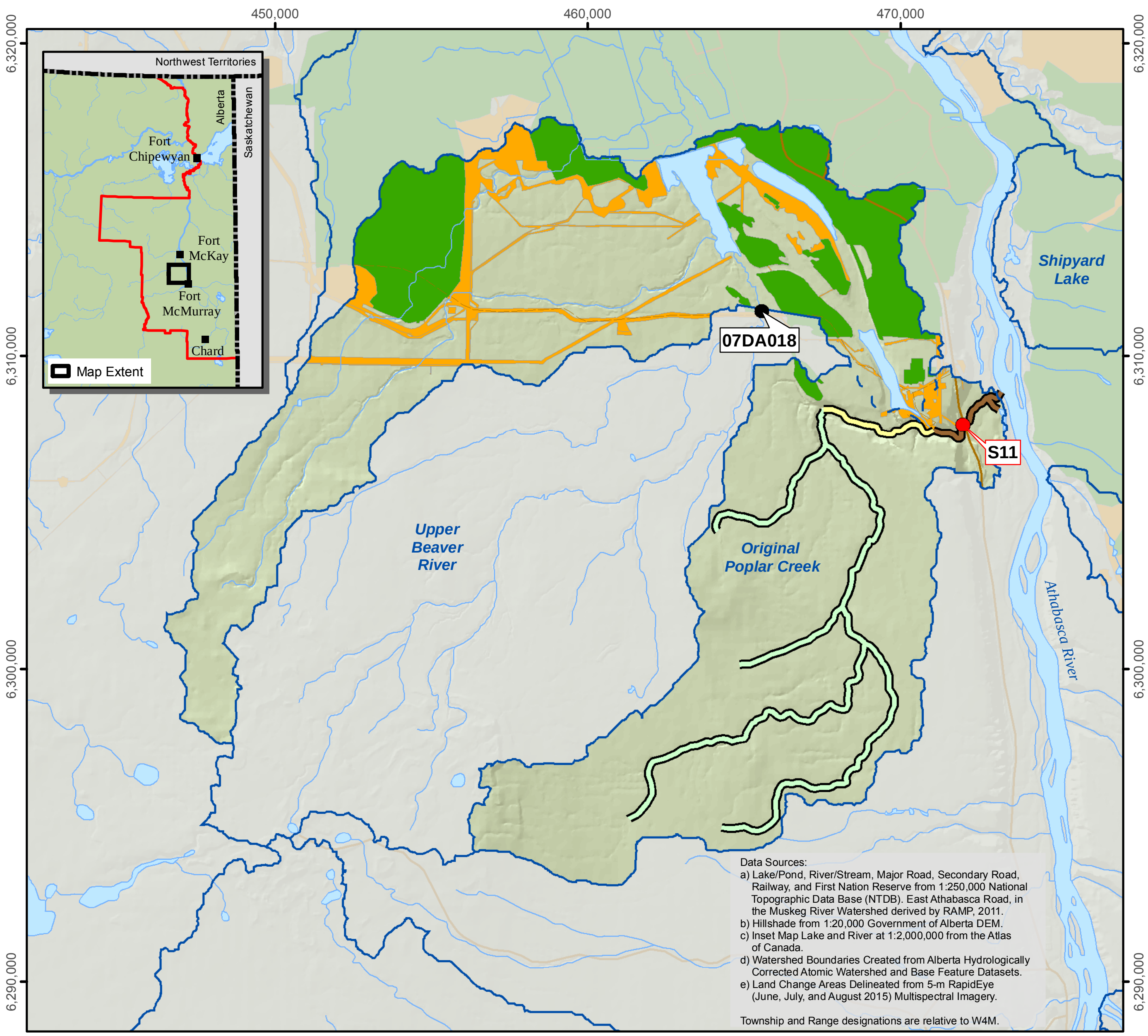
Notes:

Definitions and assumptions are discussed in Section 3.2.1.

The relative change for each measurement endpoint was calculated using observed and *baseline* flow values, which were estimated to several decimal places. Flow values are presented to three decimal places for the sake of clarity.

The open-water season refers to the period from May 1 and October 31 and the winter season refers to the period from November 1 and March 31.

Figure 5.13-11 Hydrologic change classification of the Original Poplar Creek, 2015 WY.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Sub-Watershed Boundary
- Major Road
- Secondary Road

Land Change Area as of 2015[e]

- Not Hydrologically Closed-Circuited
- Hydrologically Closed-Circuited

Hydrometric Monitoring Station

- Year-Round, managed by Hatfield
- Water Survey of Canada (Year-Round)

Hydrologic Change Classification

- Baseline
- Negligible-Low
- High

0 2.5 5 km

N

Scale: 1:200,000

Projection: NAD 1983 UTM Zone 12N

Hatfield CONSULTANTS

K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_N3_Poplar_20160331_SB.mxd

Table 5.13-15 Monthly concentrations of water quality measurement endpoints, Poplar Creek (*test* station PO1 [POC-1]), November 2014 to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	10	8.15	7.96	Mar	8.40	Jul
Total suspended solids	mg/L	-	10	6.7	<3.0	Mar	23.0	Sep
Conductivity	µS/cm	-	10	506	370	May	1330	Dec
Nutrients								
Total dissolved phosphorus	mg/L	-	10	0.0139	0.0070	Aug	0.0190	Jan
Total nitrogen	mg/L	-	10	1.00	0.85	Oct	1.60	May
Nitrate+nitrite	mg/L	3-124	10	0.026	<0.003	May	0.378	Mar
Dissolved organic carbon	mg/L	-	10	25.8	19.0	Oct	31.7	Nov
Ions								
Sodium	mg/L	-	10	55.0	35.0	May	178.0	Dec
Calcium	mg/L	-	10	37.2	29.0	Jun	64.0	Aug
Magnesium	mg/L	-	10	14.35	11.00	May	25.00	Aug
Potassium	mg/L	-	10	2.30	1.40	Jul	2.80	Aug
Chloride	mg/L	120-640	10	43.6	15.0	Oct	243.0	Dec
Sulphate	mg/L	309[b]	10	26.3	19.0	Jul	43.0	Aug
Total dissolved solids	mg/L	-	10	325	240	May	776	Dec
Total alkalinity	mg/L	20 (min)	10	175	140	May	270	Aug
Selected metals								
Total aluminum	mg/L	-	10	0.395	0.020	Mar	1.510	Sep
Dissolved aluminum	mg/L	0.05	10	0.00954	0.00128	Mar	0.01620	Sep
Total arsenic	mg/L	0.005	10	0.00085	0.00069	Mar	0.00164	Aug
Total boron	mg/L	1.5-29	10	0.1465	0.1070	Nov	0.1830	Aug
Total molybdenum	mg/L	0.073	10	0.000355	0.000246	Dec	0.000460	Aug
Total mercury (ultra-trace)	ng/L	5-13	10	1.53	0.82	Jan	2.72	Jun
Total methyl mercury	ng/L	1-2	6	0.24	0.06	Oct	0.34	Jul
Total strontium	mg/L	-	10	0.247	0.162	May	0.562	Dec
Total hydrocarbons								
BTEX	mg/L	-	10	<0.01	<0.01	-	<0.10	-
Fraction 1 (C6-C10)	mg/L	0.15	10	<0.01	<0.01	-	<0.10	-
Fraction 2 (C10-C16)	mg/L	0.11	10	<0.005	<0.005	-	**<0.250**	-
Fraction 3 (C16-C34)	mg/L	-	10	<0.02	<0.02	-	<0.25	-
Fraction 4 (C34-C50)	mg/L	-	10	<0.02	<0.02	-	<0.25	-
Naphthenic acids	mg/L	-	10	1.06	0.38	Oct	2.80	Aug
Oilsands extractable acids	mg/L	-	10	3.05	1.80	Oct	7.90	Aug
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	10	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	10	1.11	<0.59	Jan	3.32	Sep
Total dibenzothiophenes[c]	ng/L	-	10	30.6	8.2	Mar	88.8	Sep
Total PAHs[c]	ng/L	-	10	193	111	Mar	388	Sep
Total Parent PAHs[c]	ng/L	-	10	24.6	8.6	Mar	38.0	Sep
Total Alkylated PAHs[c]	ng/L	-	10	169	103	Mar	350	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	4	0.0031	<0.0010	Nov, Dec, Jan, Mar	**0.0160**	Jul
Sulphide	mg/L	0.0019	7	**0.0048**	<0.0019	Aug	**0.0115**	Nov
Dissolved iron	mg/L	0.3	4	**0.6285**	0.0180	Oct	**1.8700**	Dec
Total silver	mg/L	0.0001	1	0.0000055	**<0.000002**	Mar	**0.000124**	Jan
Total zinc	mg/L	0.03	1	0.00165	0.0009	Mar	**0.0474**	Nov

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.13-16 Monthly concentrations of water quality measurement endpoints, Beaver River near the mouth (*test* station BER-1), May to October 2015.

Measurement Endpoint	Units	Guideline[a]	Monthly Water Quality Summary and Month of Occurrence					
			n	Median	Minimum		Maximum	
Physical variables								
pH	pH units	6.5-9.0	5	8.19	8.00	Sep	8.22	Jul, Aug
Total suspended solids	mg/L	-	5	14.0	6.0	Aug	83.0	Jun
Conductivity	µS/cm	-	5	910	900	May, Jun	980	Jul
Nutrients								
Total dissolved phosphorus	mg/L	-	5	0.007	0.006	Aug, Sep	0.010	May
Total nitrogen	mg/L	-	5	0.64	0.54	Aug	<1.00	May, Jun
Nitrate+nitrite	mg/L	3-124	5	<0.005	<0.003	May	0.008	Jun
Dissolved organic carbon	mg/L	-	5	22.0	21.0	Jul	26.0	May
Ions								
Sodium	mg/L	-	5	59.0	55.0	Aug	80.0	May
Calcium	mg/L	-	5	95.0	69.0	May	110.0	Aug, Sep
Magnesium	mg/L	-	5	28.00	22.00	May	32.00	Aug
Potassium	mg/L	-	5	2.60	2.30	May	2.70	Jul, Aug
Chloride	mg/L	120-640	5	38.0	35.0	Jun	81.0	Jul
Sulphate	mg/L	309[b]	5	98.0	76.0	Jul	100.0	Aug, Sep
Total dissolved solids	mg/L	-	5	590	570	Jun	630	Jul
Total alkalinity	mg/L	20 (min)	5	360	280	May	370	Jun
Selected metals								
Total aluminum	mg/L	-	5	0.5560	0.0313	Aug	2.2400	Jun
Dissolved aluminum	mg/L	0.05	5	0.00123	0.00102	Jul	0.01010	May
Total arsenic	mg/L	0.005	5	0.00106	0.00082	Aug	0.00111	Jun
Total boron	mg/L	1.5-29	5	0.1860	0.1590	Jun	0.2020	May
Total molybdenum	mg/L	0.073	5	0.00047	0.00040	Sep	0.00076	May
Total mercury (ultra-trace)	ng/L	5-13	5	1.50	0.39	Sep	4.92	Jun
Total methyl mercury	ng/L	1-2	5	0.074	0.056	Sep	0.110	Jun
Total strontium	mg/L	-	5	0.4560	0.3790	May	0.5440	Jun
Total hydrocarbons								
BTEX	mg/L	-	5	<0.01	<0.01	-	<0.01	-
Fraction 1 (C6-C10)	mg/L	0.15	5	<0.01	<0.01	-	<0.01	-
Fraction 2 (C10-C16)	mg/L	0.11	5	<0.005	<0.005	-	<0.005	-
Fraction 3 (C16-C34)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Fraction 4 (C34-C50)	mg/L	-	5	<0.02	<0.02	-	<0.02	-
Naphthenic acids	mg/L	-	5	2.24	1.32	Sep	4.28	May
Oilsands extractable acids	mg/L	-	5	4.80	3.50	Jun	13.30	May
Polycyclic Aromatic Hydrocarbons (PAHs)								
Naphthalene	ng/L	1,000	5	<13.55	<13.55	-	<13.55	-
Retene	ng/L	-	5	0.99	<0.59	Aug, Sep	6.55	Jun
Total dibenzothiophenes[c]	ng/L	-	5	23.41	9.22	Aug	548.54	Sep
Total PAHs[c]	ng/L	-	5	166	128	Aug	8823	Sep
Total Parent PAHs[c]	ng/L	-	5	23.2	22.8	Aug	1087.2	Sep
Total Alkylated PAHs[c]	ng/L	-	5	142	106	Aug	7736	Sep
Other variables that exceeded Alberta guidelines in 2015[d]								
Total phenols	mg/L	0.004	5	**0.0079**	**0.0054**	May	**0.0160**	Jul
Sulphide	mg/L	0.0019	3	**0.0062**	<0.0019	Jun, Jul	**0.0097**	May

Values in **bold** are above guideline.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

[d] n value refers to number of exceedances in 2015.

Table 5.13-17 Concentrations of water quality measurement endpoints, Poplar Creek (*test* station PO1 [POC-1]), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2000-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.10	15	8.29	7.95	8.40
Total suspended solids	mg/L	-	23.0	15	10.0	4.0	61.0
Conductivity	µS/cm	-	1,000	15	482	308	1,710
Nutrients							
Total dissolved phosphorus	mg/L	-	0.009	15	0.013	0.005	0.027
Total nitrogen	mg/L	-	1.00	15	1.10	0.30	2.11
Nitrate+nitrite	mg/L	3-124	0.014	15	<0.100	<0.050	<0.100
Dissolved organic carbon	mg/L	-	25.0	15	26.0	4.70	32.0
Ions							
Sodium	mg/L	-	120.0	15	49.0	10.0	238.0
Calcium	mg/L	-	54.0	15	41.3	28.2	93.3
Magnesium	mg/L	-	22.0	15	15.3	9.7	30.4
Potassium	mg/L	-	2.0	15	1.2	1.7	3.7
Chloride	mg/L	120-640	160.0	15	38.0	2.0	321.0
Sulphate	mg/L	429[b]	36.0	15	14.7	7.8	46.7
Total dissolved solids	mg/L	-	600	15	320	200	981
Total alkalinity	mg/L	20 (min)	250	15	198	135	356
Selected metals							
Total aluminum	mg/L	-	<u>1.510</u>	15	0.289	0.050	1.440
Dissolved aluminum	mg/L	0.05	0.0162	15	0.0071	0.0016	**<0.0900**
Total arsenic	mg/L	0.005	0.00150	15	0.00112	0.00075	0.00313
Total boron	mg/L	1.5-29	0.1300	15	0.1470	0.0385	0.2150
Total molybdenum	mg/L	0.073	0.00036	15	0.00028	0.00010	0.00096
Total mercury (ultra-trace)	ng/L	5-13	<u>2.21</u>	12	1.20	0.80	2.00
Total methyl mercury	ng/L	1-2	0.257	-	-	-	-
Total strontium	mg/L	-	0.425	15	0.276	0.149	0.547
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.250**	**<0.250**	**<0.250**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	0.46
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic Acids	mg/L	-	<u>1.91</u>	4	0.70	0.19	1.60
Oilsands extractable acids	mg/L	-	5.10	4	1.90	0.51	5.30
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<u>3.32</u>	4	1.65	1.10	2.17
Total dibenzothiophenes[c]	ng/L	-	<u>88.8</u>	4	33.7	17.0	51.7
Total PAHs[c]	ng/L	-	<u>369</u>	4	194	149	282
Total Parent PAHs[c]	ng/L	-	<u>37.0</u>	4	19.3	16.1	24.5
Total Alkylated PAHs[c]	ng/L	-	<u>332</u>	4	176	125	264
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.002	**0.0054**	15	**0.0062**	**<0.003**	**0.0102**
Dissolved iron	mg/L	0.3	**0.594**	15	0.249	0.050	2.320

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.13-18 Concentrations of water quality measurement endpoints, Beaver River near the mouth (*test* station BER-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2003-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.00	12	8.16	7.95	8.60
Total suspended solids	mg/L	-	8.0	12	12.0	<3.0	150.0
Conductivity	µS/cm	-	940	12	1095	566	1,930
Nutrients							
Total dissolved phosphorus	mg/L	-	0.006	12	0.007	0.004	0.022
Total nitrogen	mg/L	-	<u>0.57</u>	12	0.91	0.64	1.68
Nitrate+nitrite	mg/L	3-124	<0.005	12	<0.086	<0.054	<0.100
Dissolved organic carbon	mg/L	-	22.0	12	24.8	3.10	52.0
Ions							
Sodium	mg/L	-	56.0	12	123.0	53.0	267.0
Calcium	mg/L	-	110.0	12	76.3	49.1	120.0
Magnesium	mg/L	-	31.0	12	23.2	15.5	34.1
Potassium	mg/L	-	2.6	12	1.2	2.4	3.2
Chloride	mg/L	120-640	<u>37.0</u>	12	120.0	55.0	364.0
Sulphate	mg/L	429[b]	100.0	12	75.6	50.7	128.0
Total dissolved solids	mg/L	-	620	12	657	450	1110
Total alkalinity	mg/L	20 (min)	360	12	267	158	371
Selected metals							
Total aluminum	mg/L	-	0.200	12	0.292	0.031	5.320
Dissolved aluminum	mg/L	0.05	0.0012	12	0.0045	0.0008	0.0445
Total arsenic	mg/L	0.005	0.0009	12	0.0010	0.0007	0.0021
Total boron	mg/L	1.5-29	0.1670	12	0.1505	0.0883	0.2390
Total molybdenum	mg/L	0.073	0.00040	12	0.00033	0.00019	0.00066
Total mercury (ultra-trace)	ng/L	5-13	<u>0.39</u>	12	1.60	0.80	8.10
Total methyl mercury	ng/L	1-2	0.056	-	-	-	-
Total strontium	mg/L	-	0.456	12	0.323	0.233	0.631
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.250**	**<0.250**	**<0.250**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	1.32	4	4.85	1.26	7.26
Oilsands extractable acids	mg/L	-	4.50	4	4.74	0.96	9.34
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.96	<7.21	15.70
Retene	ng/L	-	<0.59	4	6.65	0.48	57.10
Total dibenzothiophenes	ng/L	-	10.50	4	40.99	9.48	49.63
Total PAHs[c]	ng/L	-	131	4	349	88	372
Total Parent PAHs[c]	ng/L	-	22.8	4	27.7	13.9	33.5
Total Alkylated PAHs[c]	ng/L	-	108	4	320	74	342
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.004	**0.0079**	12	**0.0077**	0.0020	**0.0147**
Sulphide	mg/L	0.0019	**0.0062**	12	**0.016**	0.0015	**0.038**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.13-19 Concentrations of water quality measurement endpoints, upper Beaver River (*baseline* station BER-2), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2008-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	8.30	7	8.15	7.83	8.35
Total suspended solids	mg/L	-	7.3	7	9.0	5.4	93
Conductivity	µS/cm	-	540	7	445	255	558
Nutrients							
Total dissolved phosphorus	mg/L	-	0.081	7	0.064	0.037	0.105
Total nitrogen	mg/L	-	0.820	7	1.021	0.734	2.441
Nitrate+nitrite	mg/L	3-124	<0.005	7	<0.071	<0.054	<0.100
Dissolved organic carbon	mg/L	-	20.0	7	24.6	17.6	34.0
Ions							
Sodium	mg/L	-	74.0	7	53.5	20.9	75.3
Calcium	mg/L	-	34.0	7	34.1	22.5	36.3
Magnesium	mg/L	-	<u>13.0</u>	7	11.3	7.52	12.5
Potassium	mg/L	-	1.7	7	0.90	1.6	1.97
Chloride	mg/L	120-640	<u>2.40</u>	7	1.59	0.68	2.00
Sulphate	mg/L	309[b]	<u>11.0</u>	7	14.8	12.5	17.7
Total dissolved solids	mg/L	-	360	7	332	210	382
Total alkalinity	mg/L	20 (min)	<u>290</u>	7	225	118	285
Selected metals							
Total aluminum	mg/L	-	0.334	7	0.486	0.266	2.170
Dissolved aluminum	mg/L	0.05	0.0129	7	0.0228	0.0114	0.0344
Total arsenic	mg/L	0.005	0.00155	7	0.00161	0.00137	0.00190
Total boron	mg/L	1.5-29	0.3990	7	0.2660	0.0893	0.4240
Total molybdenum	mg/L	0.073	0.000626	7	0.000515	0.000195	0.000748
Total mercury (ultra-trace)	ng/L	5-13	2.27	7	2.40	0.90	10.6
Total methyl mercury	ng/L	1-2	0.252	-	-	-	-
Total strontium	mg/L	-	0.231	7	0.212	0.146	0.267
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.1	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.1	<0.1	<0.1
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.250**	**<0.250**	**<0.250**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	0.41	4	0.37	0.32	0.44
Oilsands extractable acids	mg/L	-	<u>1.60</u>	4	0.88	0.27	0.90
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.86	<7.21	<15.16
Retene	ng/L	-	<u>0.82</u>	4	1.58	1.26	2.86
Total dibenzothiophenes[c]	ng/L	-	8.17	4	6.27	4.13	35.31
Total PAHs[c]	ng/L	-	107	4	128	74	205
Total Parent PAHs[c]	ng/L	-	<u>22.9</u>	4	18.4	13.3	22.4
Total Alkylated PAHs[c]	ng/L	-	84	4	107	61	187
Other variables that exceeded Alberta guidelines in fall 2015							
Total phenols	mg/L	0.0019	<u>**0.0100**</u>	6	**0.0075**	**0.0047**	**0.0097**
Sulphide	mg/L	0.002	<u>**0.0046**</u>	7	**0.0112**	**0.0054**	**0.0170**
Dissolved iron	mg/L	0.3	**0.792**	7	**0.857**	**0.387**	**1.700**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.13-12 Piper diagram of fall ion concentrations in Poplar Creek and Beaver Creek.

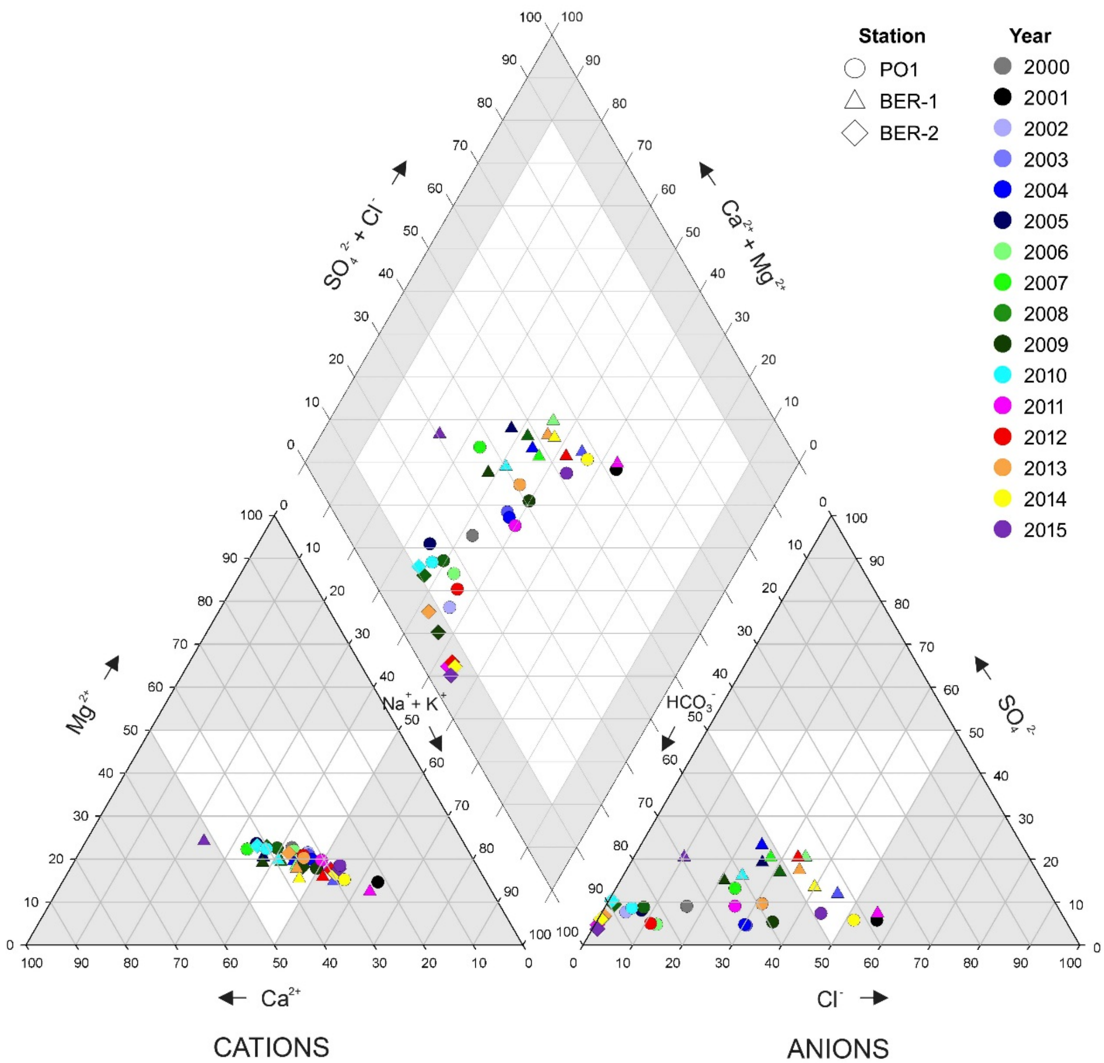
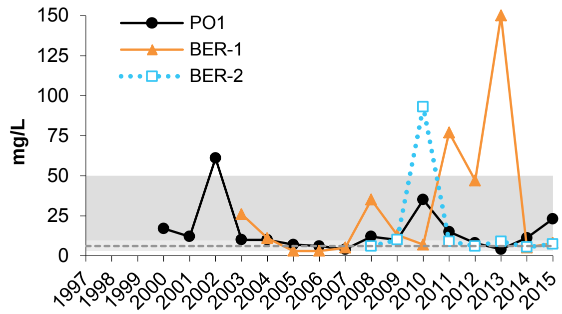
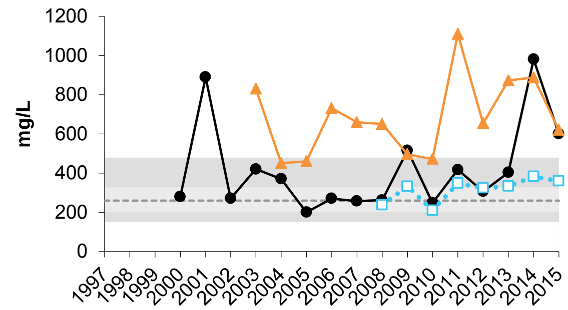


Figure 5.13-13 Selected water quality measurement endpoints in Poplar Creek and Beaver River (fall data) relative to historical concentrations and regional *baseline* fall concentrations.

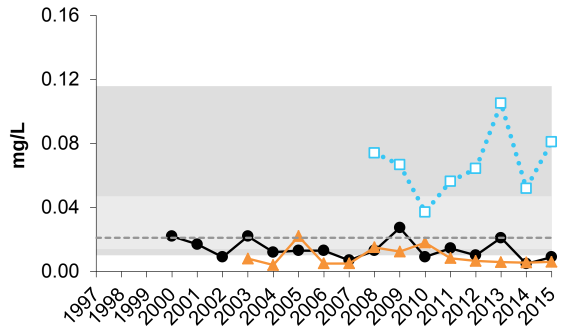
Total Suspended Solids (TSS)



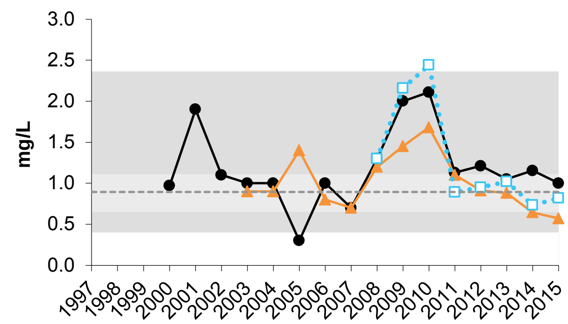
Total Dissolved Solids (TDS)



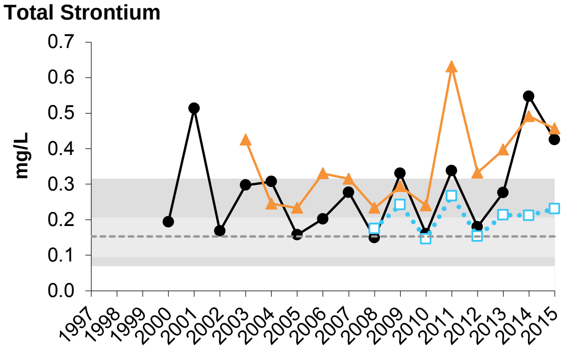
Total Dissolved Phosphorus



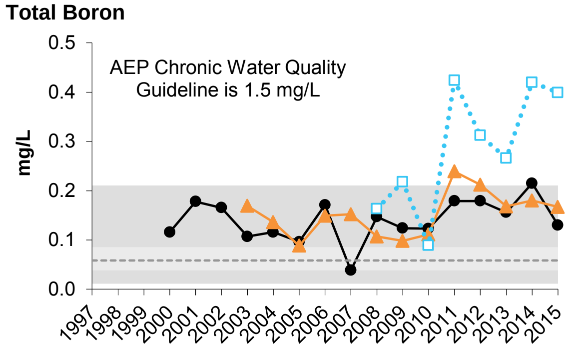
Total Nitrogen



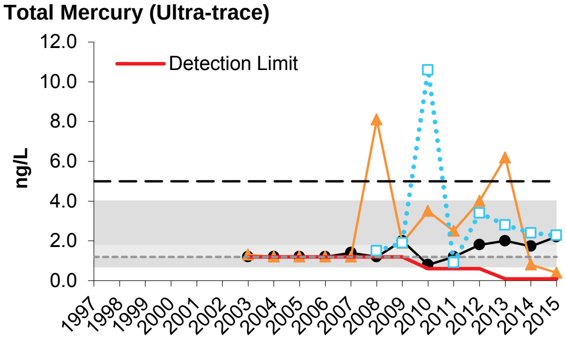
Total Strontium



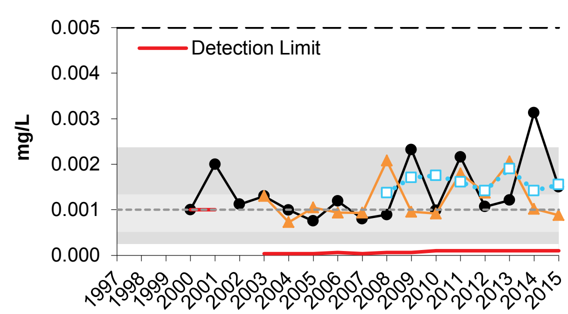
Total Boron



Total Mercury (Ultra-trace)



Total Arsenic



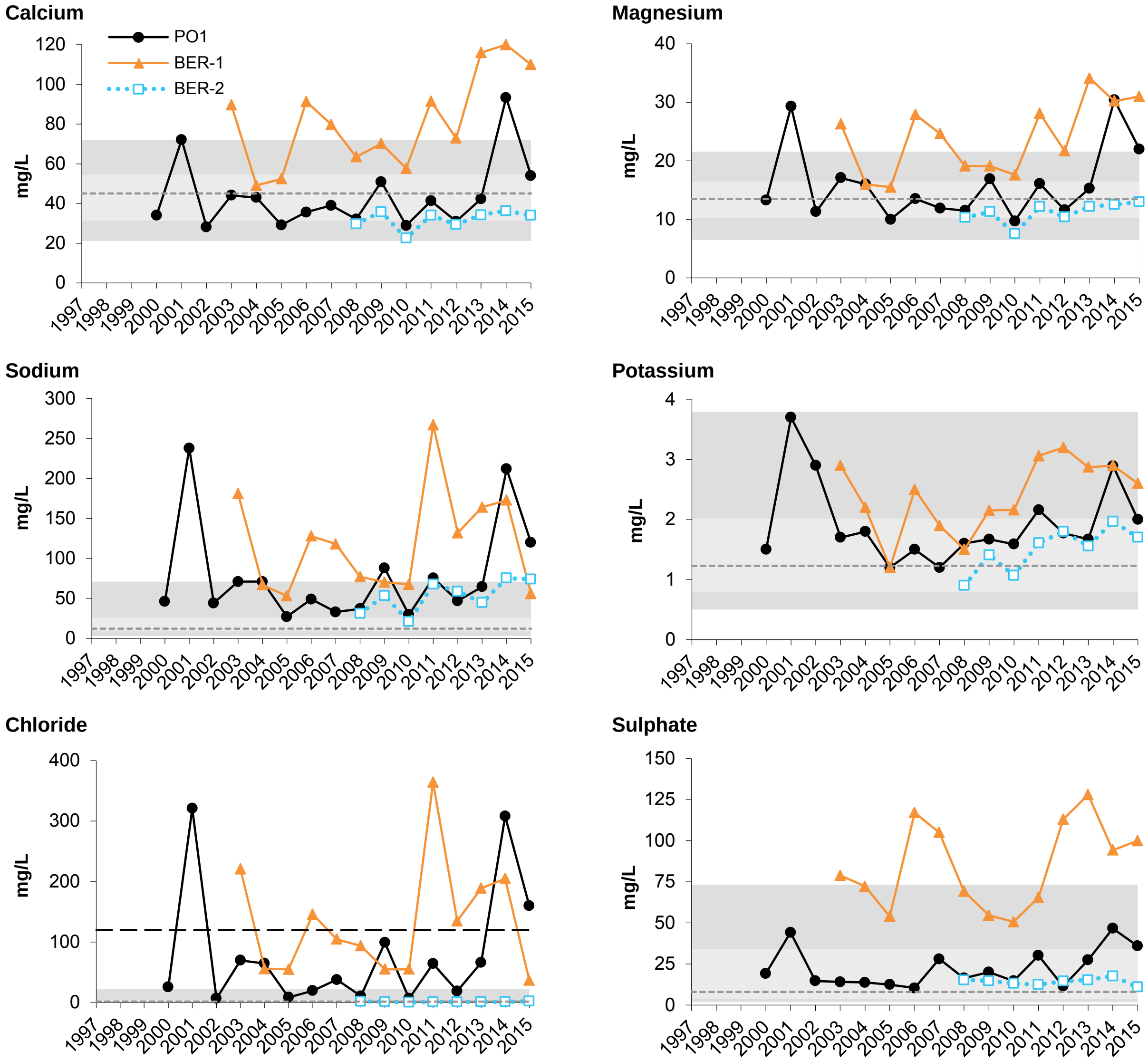
Non-detectable values are shown at the detection limit.

– – – – –   Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-13 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.13-20 Average habitat characteristics of benthic invertebrate sampling locations in the Beaver River (*baseline* reach BER-D2) and Poplar Creek (*test* reach POC-D1), fall 2015.

Variable	Units	BER-D2 Upper *Baseline* Reach	POC-D1 Lower *Test* Reach
Sample date	-	Sept. 8, 2015	Sept. 10, 2015
Habitat	-	Depositional	Depositional
Water depth	m	0.6	0.4
Current velocity	m/s	0.09	0.22
Field water quality			
Dissolved oxygen (DO)	mg/L	8.8	8.9
Conductivity	µS/cm	532	883
pH	pH units	7.5	7.4
Water temperature	°C	10.7	10.8
Sediment composition			
Sand	%	96.0	86.3
Silt	%	3.3	8.2
Clay	%	0.7	5.5
Total organic carbon (TOC)	%	0.3	1.6

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.13-21 Summary of major taxon abundances and measurement endpoints of the benthic invertebrate communities at the upper Beaver River (*baseline* reach BER-D2) and lower Poplar Creek (*test* reach POC-D1).

Taxon	Percent Major Taxa Enumerated in Each Year					
	Baseline Reach BER-D2			*Test* Reach POC-D1		
	2008	2009 to 2014	2015	2008	2009 to 2014	2015
Hydra	-	0 to <1	<1	-	0 to 1	1
Nematoda	1	<1 to 4	1	2	1 to 5	2
Lumbriculidae	-	<1	-	-	-	-
Naididae	<1	3 to 8	1	<1	<1 to 2	6
Tubificidae	1	2 to 36	3	72	13 to 24	22
Enchytraeidae	<1	0 to 3	-	-	0 to 17	-
Erpobdellidae	-	<1	-	-	-	-
Hirudinea	<1	0 to <1	-	-	0 to <1	-
Hydracarina	1	<1 to 8	-	-	0 to <1	-
Amphipoda	-	<1	-	-	0 to <1	1
Gastropoda	<1	<1 to 3	<1	-	<1	1
Bivalvia	1	<1	<1	1	4 to 13	3
Ceratopogonidae	6	3 to 11	1	2	0 to 11	7
Chironomidae	84	32 to 71	89	21	20 to 64	42
Dixidae	-	<1	-	-	-	-
Dolichopodidae	-	<1	-	-	-	-
Diptera (misc.)	1	0 to 4	1	<1	0 to 2	1
Coleoptera	-	2 to 10	1	<1	<1 to 2	1
Ephemeroptera	4	2 to 12	1	<1	<1 to 5	12
Hemiptera	-	-	-	-	-	<1
Odonata	-	<1	-	-	0 to <1	-
Plecoptera	-	0 to <1	-	-	-	-
Neuroptera	-	<1	-	-	-	-
Trichoptera	<1	0 to <1	<1	<1	<1	<1
Lepidoptera	-	0 to <1	-	-	-	-
Benthic Invertebrate Community Measurement Endpoints						
Total abundance per sample	174	101 to 672	725	185	263 to 1054	202
Richness	13	8 to 26	18	8	17 to 25	17
Equitability	0.38	0.26 to 0.63	0.3	0.4	0.05 to 0.77	0.4
% EPT	3	<1 to 13	0.8	<1	<1 to 6	12

Table 5.13-22 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at lower Poplar Creek (*test* reach POC-D1) and upper Beaver River (*baseline* reach BER-D2).

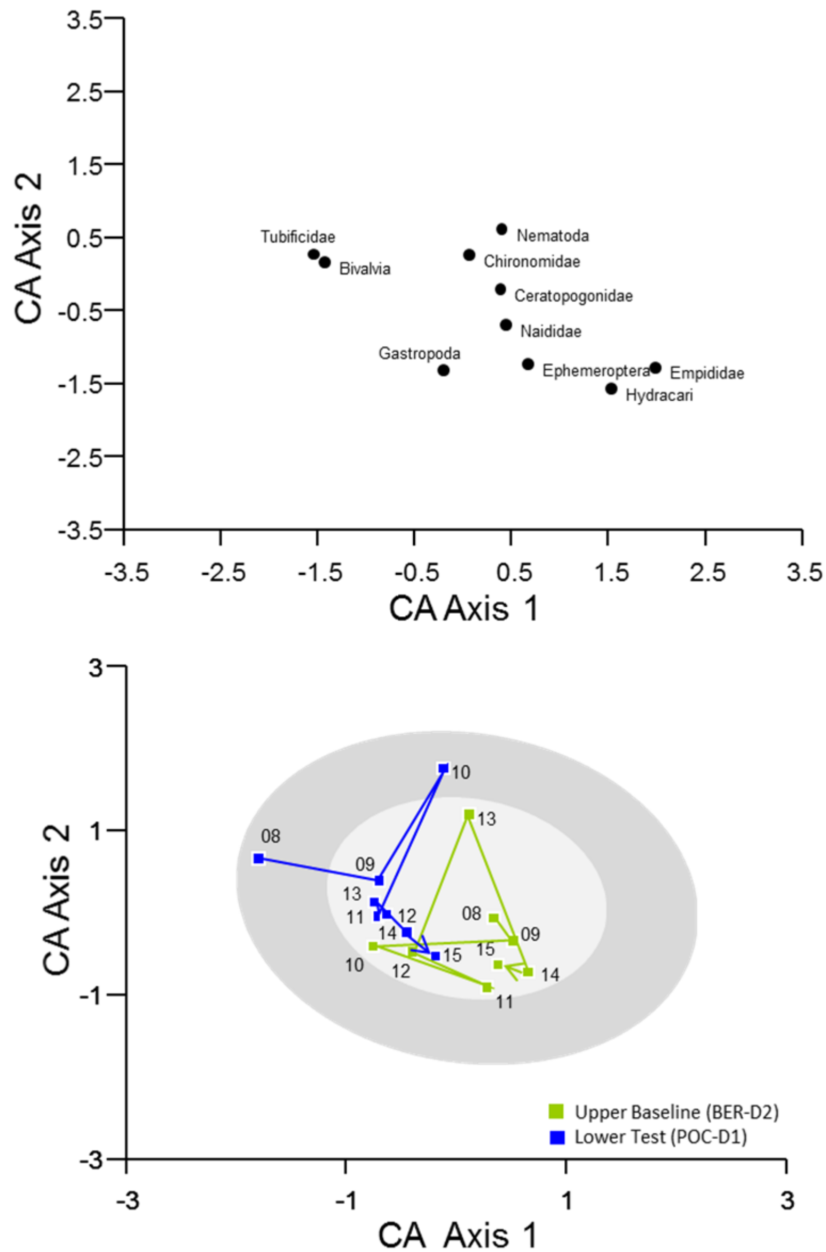
Measurement Endpoint	P-value					Variance Explained (%)					Nature of Change(s)
	Baseline vs. *Test*	Time Trend in *Test* Period	Difference in Time Trend (*test*)	2015 vs. *Baseline*	2105 vs. Previous Years	*Baseline* vs. *Test*	Time Trend in *Test* Period	Difference in Time Trend (*test*)	2015 vs. *Baseline*	2105 vs. Previous Years	
Log of Abundance	**<0.001**	0.409	**0.019**	0.521	**0.008**	13	1	6	0	7	Abundance was higher in the upper *baseline* reach in 2015, increasing over time in the *baseline* reach but decreasing over time in the *test* reach. Abundance was lower in 2015 in the *test* reach than the mean of prior years in the reach.
Log of Richness	0.230	**<0.001**	0.981	0.149	0.360	2	18	0	3	1	Richness increased over time in the *test* reach.
Equitability	**<0.001**	**<0.001**	0.878	**<0.001**	**<0.001**	21	19	0	47	25	Equitability was higher in the lower *test* reach in 2015, lower in 2015 than the mean of the *baseline* reach but higher in 2015 than the mean of prior years in the lower *test* reach.
Log of EPT	**0.007**	**<0.001**	**0.002**	**0.043**	**<0.001**	11	22	14	6	28	EPT was higher in the lower *test* reach in 2015 and increased over time in the lower *test* reach. EPT was higher in 2015 in the lower *test* reach than the mean of baseline years and the mean of prior years in the reach.
CA Axis 1	**<0.001**	**0.004**	0.137	**0.021**	0.543	47	9	2	6	0	CA Axis 1 scores were higher in the upper *baseline* reach in 2015. CA Axis 1 scores increased over time in the *test* reach, scores were higher in 2015 in the *test* reach than the mean of all years in the *baseline* reach and the mean of prior years in the reach.
CA Axis 2	**<0.001**	**<0.001**	**<0.001**	0.825	**0.021**	16	9	11	0	4	CA Axis 2 scores were higher in the *test* reach in 2015, although decreasing over time in the lower *test* reach while increasing over time in the upper reach. CA Axis 2 scores were higher in 2015 in the *test* reach than the mean of all years in the reach.

Bold values indicate significant variation as per the specified contrast (p<0.05). Significance contributes to the classification of results per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

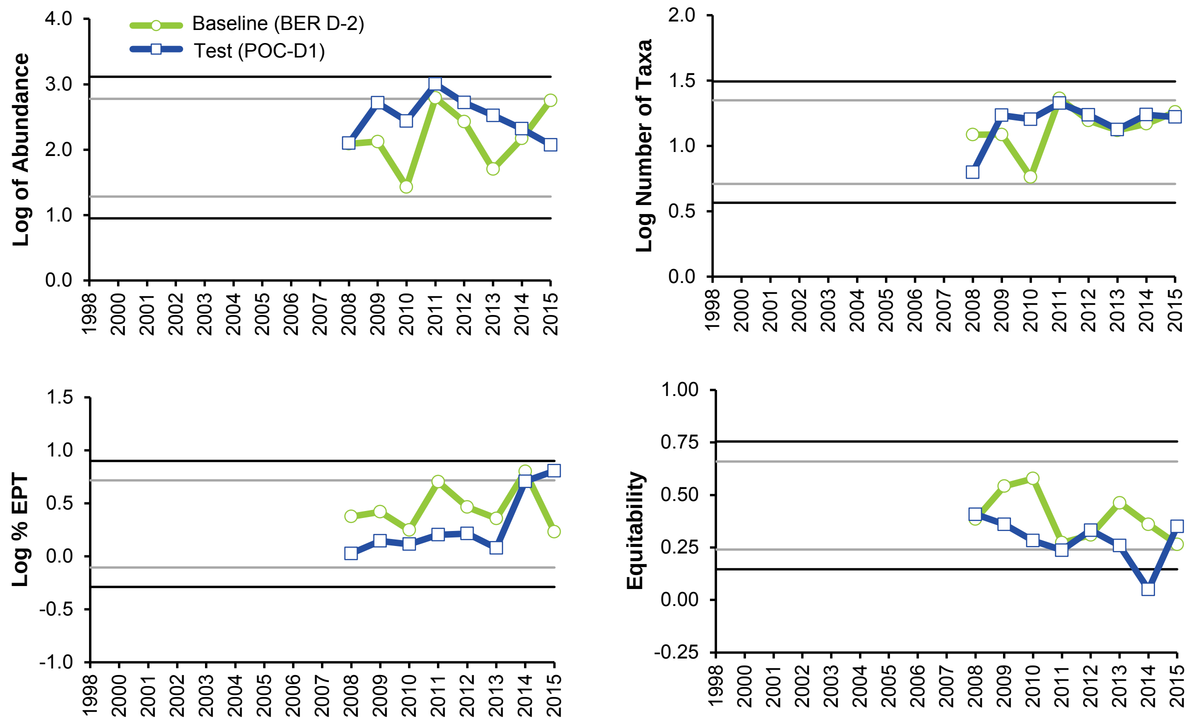
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-14 Ordination (Correspondence Analysis) of benthic invertebrate communities of depositional reaches, showing the lower reach of Poplar Creek (*test* reach POC-D1) and the upper reach of Beaver River (*baseline* reach BER-D2).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for regional *baseline* depositional reaches in the Athabasca oil sands region.

Figure 5.13-15 Variation in benthic invertebrate community measurement endpoints at the lower Beaver River (*baseline* reach BER-D2) and upper Poplar Creek (*test* reach POC-D1) relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from regional *baseline* depositional reaches.

Abundance, richness, and %EPT data were log10(x+1) transformed before the average was calculated.

Table 5.13-23 Concentrations of sediment quality measurement endpoints, Poplar Creek (*test* station POC-D1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2001-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>7.6</u>	10	8.3	17.8	35.0
Silt	%	-	<u>9.1</u>	10	13.3	29.0	68.3
Sand	%	-	<u>83.3</u>	10	0.9	57.7	73.0
Total organic carbon	%	-	1.77	10	1.07	2.15	2.53
Total hydrocarbons							
BTEX	mg/kg	-	<10	8	<5	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	8	<5	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	89	8	<5	61	**3640**
Fraction 3 (C16-C34)	mg/kg	300[1]	**1470**	8	170	**916**	**2830**
Fraction 4 (C34-C50)	mg/kg	2800[1]	1270	8	54	848	**2820**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0021	10	0.0017	0.0068	0.0205
Retene	mg/kg	-	0.0595	9	0.0482	0.1080	0.1670
Total dibenzothiophenes	mg/kg	-	2.9430	10	0.2487	1.1323	3.9838
Total PAHs	mg/kg	-	7.3635	10	1.7530	4.1144	13.2610
Total Parent PAHs	mg/kg	-	0.1787	10	0.1216	0.1947	0.4398
Total Alkylated PAHs	mg/kg	-	7.1848	10	1.6050	3.9155	12.8211
Predicted PAH toxicity[3]	H.I.	1.0	0.7414	10	0.1585	0.9537	**4.1542**
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Other analytes that exceeded CCME guidelines in 2015							
Chrysene	mg/kg	0.0571	**0.0587**	9	0.0181	0.0501	**0.1310**
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	<u>96</u>	8	42	74	92
Chironomus growth - 10d	mg/organism	-	1.79	8	1.55	1.72	3.85
Hyalella survival - 14d	% surviving	-	<u>78</u>	9	80	90	96
Hyalella growth - 14d	mg/organism	-	0.13	9	0.10	0.20	0.66

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historical observations.

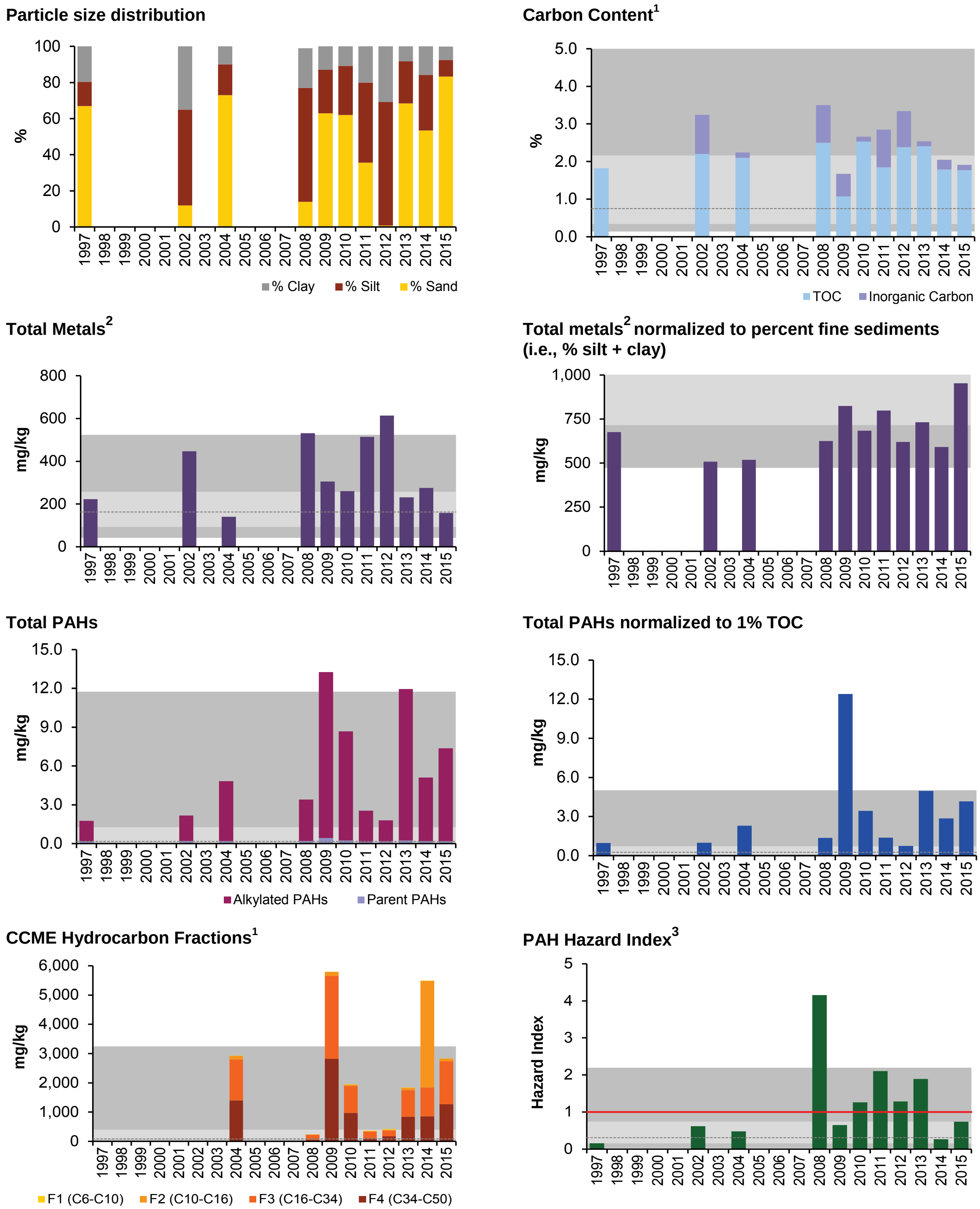
ns = not sampled in 1998-2001, 2003, or 2005-2007

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-16 Variation in sediment quality measurement endpoints at *test* station POC-D1, relative to historical concentrations and to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.13-24 Concentrations of sediment quality measurement endpoints, upper Beaver River (*baseline* station BER-D2), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2008-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>0.3</u>	7	2.2	5.0	9.0
Silt	%	-	1.5	7	1.0	2.3	21.0
Sand	%	-	<u>98.2</u>	7	70.0	94.0	96.1
Total organic carbon	%	-	0.18	7	0.10	0.30	1.97
Total hydrocarbons							
BTEX	mg/kg	-	<10	6	<10	<10	<20
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	6	<10	<10	<20
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	6	<20	<20	40
Fraction 3 (C16-C34)	mg/kg	300[1]	<20	6	<20	<20	119
Fraction 4 (C34-C50)	mg/kg	2800[1]	<20	6	<20	<20	94
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0012	7	0.0003	0.0010	0.0030
Retene	mg/kg	-	0.0015	7	0.0002	0.0055	0.5200
Total dibenzothiophenes	mg/kg	-	0.0025	7	0.0006	0.0027	0.0145
Total PAHs	mg/kg	-	0.0148	7	0.0061	0.0325	0.7036
Total Parent PAHs	mg/kg	-	0.0033	7	0.0020	0.0045	0.0173
Total Alkylated PAHs	mg/kg	-	0.0116	7	0.0042	0.0280	0.6864
Predicted PAH toxicity[3]	H.I.	1.0	<u>0.0665</u>	6	0.0897	0.2583	0.8812
Metals that exceeded CCME guidelines in 2015							
None	-	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	<u>98</u>	7	68	80	88
Chironomus growth - 10d	mg/organism	-	1.83	7	1.60	2.14	3.93
Hyalella survival - 14d	% surviving	-	92	7	66	90	96
Hyalella growth - 14d	mg/organism	-	<u>0.13</u>	7	0.17	0.31	0.45

Values in **bold** indicate concentrations exceeding guidelines.

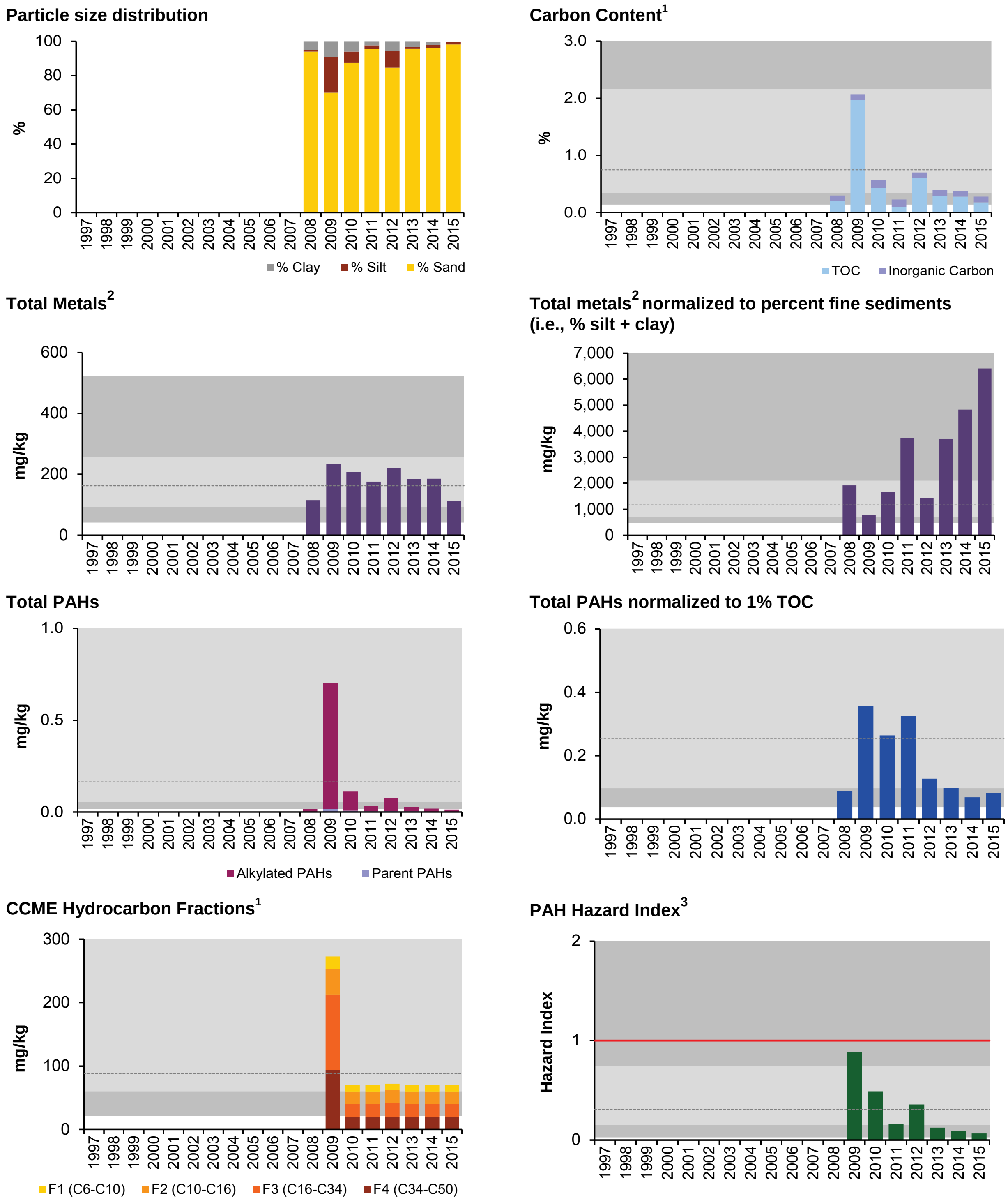
Values <u>underlined</u> indicate concentrations outside the range of historical observations.

[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-17 Variation in sediment quality measurement endpoints at *baseline* station BER-D2, relative to historical concentrations and to regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997-2014).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.13-18 Piper diagram of fall ion concentrations in in Alice Creek, Isadore's Lake, and Shipyard Lake.

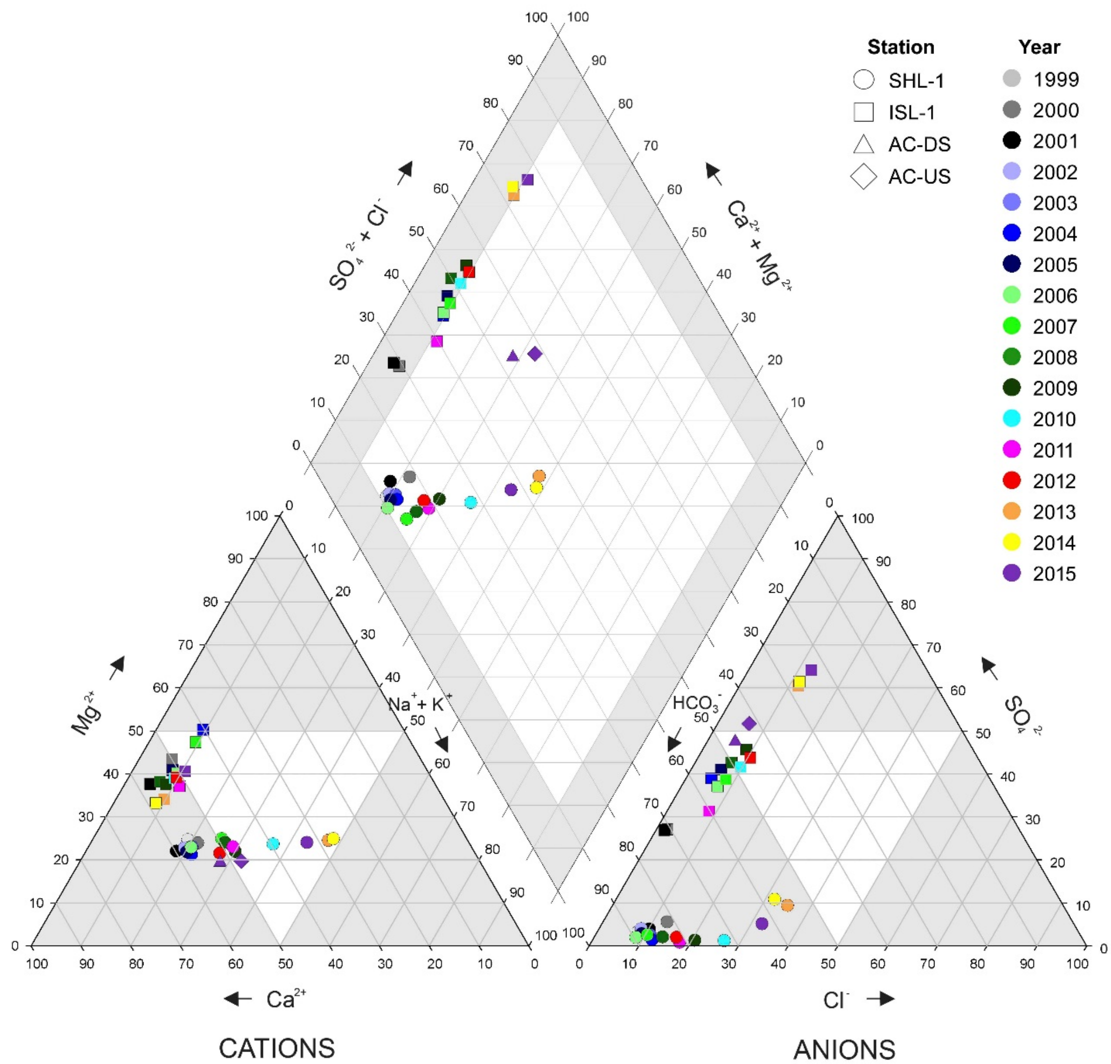


Table 5.13-25 Concentrations of water quality measurement endpoints, Alice Creek at wild fish health reaches (*baseline* stations AC-DS and AC-US), fall 2015.

Measurement Endpoint	Units	Guideline[a]	September 2015	
			AC-DS	AC-US
Physical variables				
pH	pH units	6.5-9.0	7.47	7.32
Total suspended solids	mg/L	-	8.0	7.3
Conductivity	µS/cm	-	170	150
Nutrients				
Total dissolved phosphorus	mg/L	-	0.042	0.045
Total nitrogen	mg/L	-	0.74	0.74
Nitrate+nitrite	mg/L	3-124	<0.005	<0.005
Dissolved organic carbon	mg/L	-	30	30
Ions				
Sodium	mg/L	-	12	12
Calcium	mg/L	-	20	16
Magnesium	mg/L	-	4.5	4
Potassium	mg/L	-	0.7	0.67
Chloride	mg/L	120-640	3.2	3.2
Sulphate	mg/L	309[b]	36	35
Total dissolved solids	mg/L	-	180	160
Total alkalinity	mg/L	20 (min)	37	29
Selected metals				
Total aluminum	mg/L	-	0.765	0.7
Dissolved aluminum	mg/L	0.05	**0.153**	**0.186**
Total arsenic	mg/L	0.005	0.0012	0.0012
Total boron	mg/L	1.5-29	0.050	0.053
Total molybdenum	mg/L	0.073	0.0005	0.0005
Total mercury (ultra-trace)	ng/L	5-13	-	-
Total methyl mercury	ng/L	-	-	-
Total strontium	mg/L	-	0.0669	0.0618
Total hydrocarbons				
BTEX	mg/L	-	<0.1	<0.1
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	<0.01
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	<0.005
Fraction 3 (C16-C34)	mg/L	-	<0.02	<0.02
Fraction 4 (C34-C50)	mg/L	-	<0.02	<0.02
Naphthenic acids	mg/L	-	0.41	0.43
Oilsands extractable acids	mg/L	-	1.5	1.7
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	ng/L	1,000	13.55	13.55
Retene	ng/L	-	1.23	0.87
Total dibenzothiophenes[c]	ng/L	-	8.17	8.17
Total PAHs[c]	ng/L	-	120.91	120.45
Total Parent PAHs[c]	ng/L	-	24.35	24.01
Total Alkylated PAHs[c]	ng/L	-	96.56	96.44
Other variables that exceeded Alberta guidelines in fall 2015				
Phenols	mg/L	0.004	0.0029	**0.0044**
Dissolved iron	mg/L	0.3	**1.58**	**1.65**
Sulphide	mg/L	0.0019	**0.0062**	**0.0054**

Values in **bold** are above guideline; sampling began in 2015 and therefore no historical comparisons are possible.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.13-26 Concentrations of selected sediment quality measurement endpoints, Alice Creek at wild fish health reaches (*baseline* stations AC-DS and AC-US), fall 2015.

Variables	Units	Guideline	September 2015	
			AC-DS	AC-US
Physical variables				
Clay[4]	%	-	1.3	6.8
Silt[4]	%	-	1.8	15.3
Sand[4]	%	-	96.9	77.9
Total organic carbon	%	-	0.24	0.69
Total hydrocarbons				
BTEX	mg/kg	-	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	20	33
Fraction 4 (C34-C50)	mg/kg	2,800[1]	20	<20
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	mg/kg	0.0346[2]	0.0003	0.0006
Retene	mg/kg	-	0.0028	0.0242
Total dibenzothiophenes	mg/kg	-	0.0107	0.0805
Total PAHs	mg/kg	-	0.0645	0.5735
Total Parent PAHs	mg/kg	-	0.0056	0.0397
Total Alkylated PAHs	mg/kg	-	0.0589	0.5337
Predicted PAH toxicity[3]	H.I.	1.0	0.3014	**2.1948**
Metals that exceeded CCME guidelines in 2015				
Total Arsenic	mg/kg	5.9	-	**8.3**
Chronic toxicity				
Chironomus survival - 10d	% surviving	-	94	85
Chironomus growth - 10d	mg/organism	-	1.96	2.18
Hyalella survival - 14d	% surviving	-	98	90
Hyalella growth - 14d	mg/organism	-	0.15	0.12

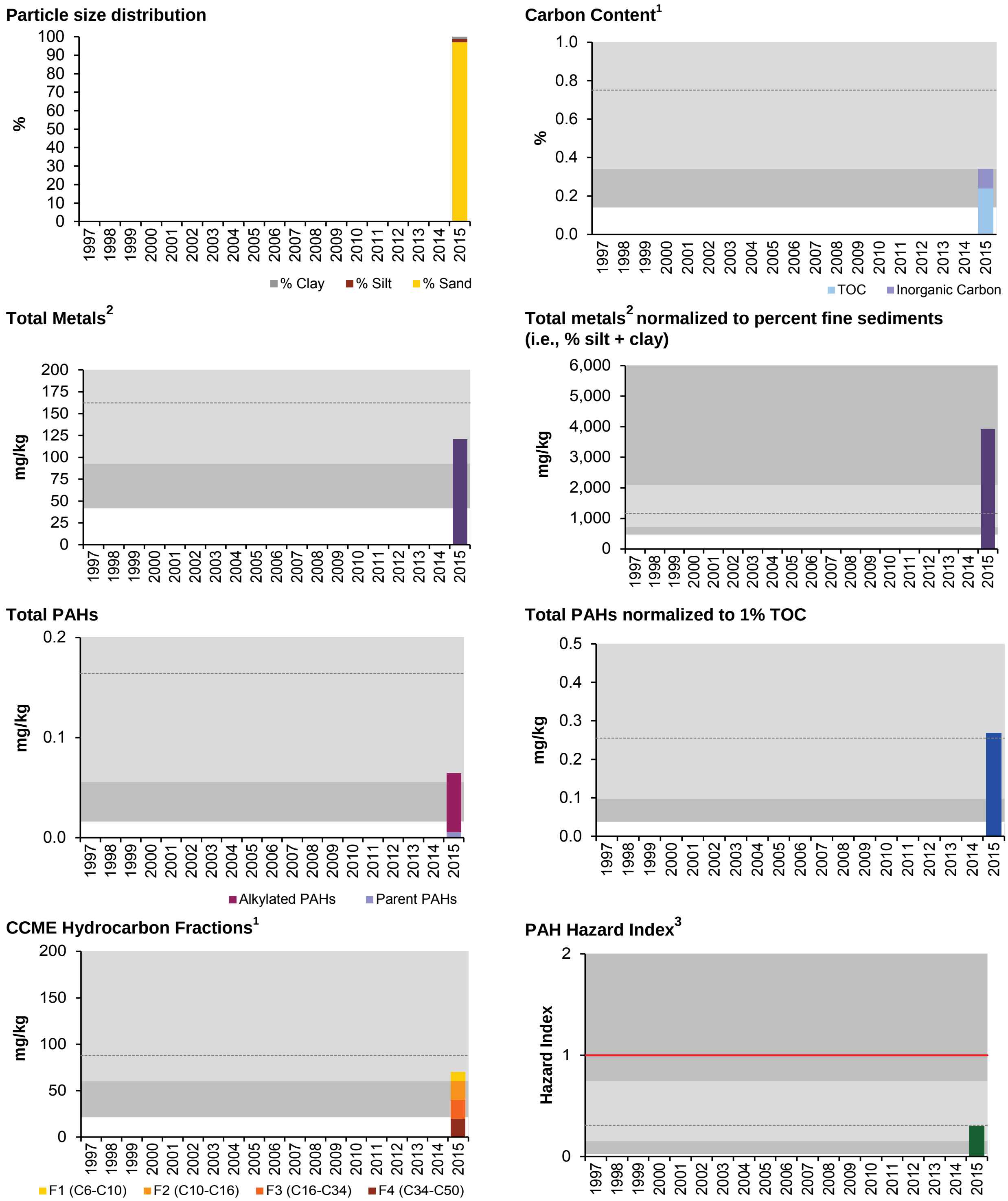
Values in **bold** indicate concentrations exceeding guidelines.

1 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

2 Interim sediment quality guideline (ISQG) (CCME 2002).

3 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-19 Variation in sediment quality measurement endpoints, Alice Creek at the downstream wild fish health reach (*baseline* station AC-DS), relative to historical concentrations and regional *baseline* fall concentrations.



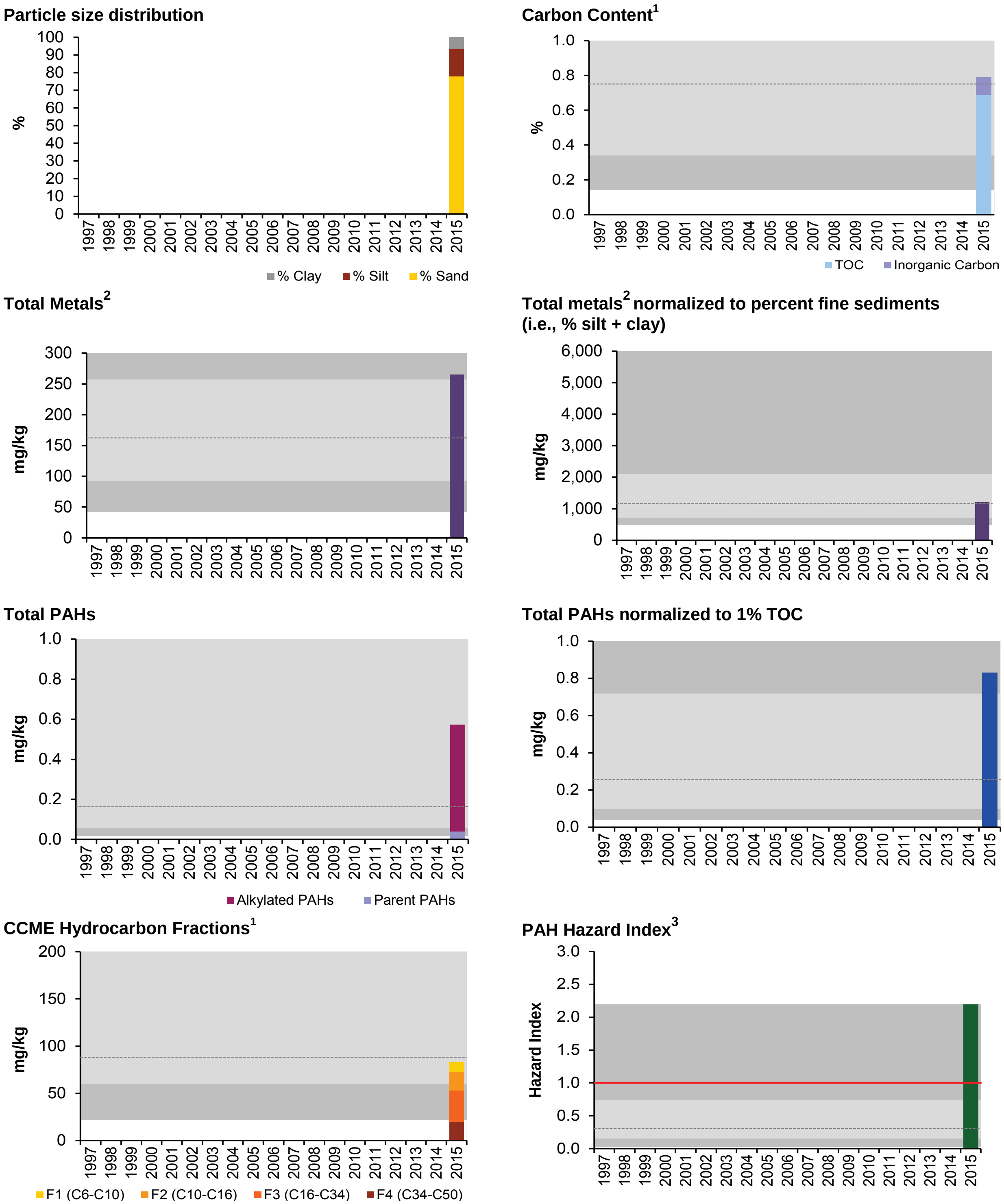
Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

[1] Regional *baseline* values represent "total" values for multi-variable data.

[2] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[3] Red line indicates potential chronic effects level (HI = 1.0).

Figure 5.13-20 Variation in sediment quality measurement endpoints, Alice Creek at the upstream wild fish health reach (*baseline* station AC-US), relative to historical concentrations and regional *baseline* fall concentrations.



Regional *baseline* values reflect pooled results for all *baseline* stations excluding the Athabasca Delta, from all years of sampling (1997 to 2015).

1 Regional *baseline* values represent "total" values for multi-variable data.

2 Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

3 Red line indicates potential chronic effects level (HI = 1.0).

Table 5.13-27 Average habitat characteristics of wild fish health monitoring reaches in Alice Creek (*baseline* stations AC-DS and AC-US), fall 2015.

Variable	Units	AC-US Upper *baseline* reach	AC-DS Lower *baseline* reach
Sample date	-	October 10, 2015	October 10, 2015
Mean water depth	m	0.45	0.6
Mean velocity	m/s	0.05	0.25
Field water quality			
Water temperature	°C	8.45	11.6
Conductivity	µS/cm	133	163
Dissolved oxygen (DO)	mg/L	9.9	9
pH	pH units	6.91	7.65
Substrate	-	cobble	silt/gravel

Figure 5.13-21 Daily mean water temperatures for wild fish health reaches in Alice Creek, August to September 2015.

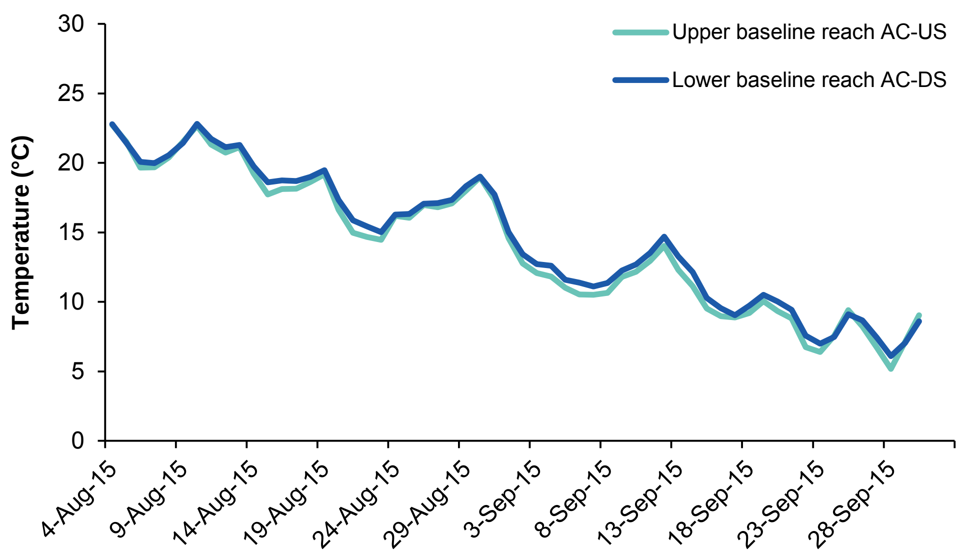
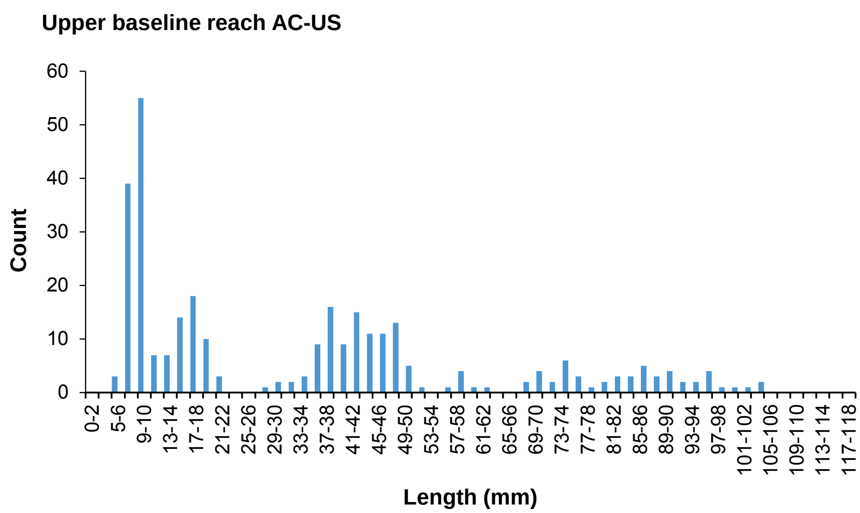


Table 5.13-28 Summary of lake chub caught and mean length, weight, and relative abundance of juveniles at sampling reaches of Alice Creek, fall 2015.

Reach	Designation	Sample Size		Relative Abundance (%)		Juvenile Measurements		Percentage of External Abnormalities
		Juvenile	Adult	Juvenile	Adult	Mean Length (mm)	Mean Weight (g)	
AC-US	upper *baseline* reach	97	59	62.2	37.8	41.2	0.76	0
AC-DS	lower *baseline* reach	18	70	20.5	79.5	44.4	1.11	1.1

Figure 5.13-22 Length-frequency distribution of lake chub in wild fish health reaches of Alice Creek, fall 2015.



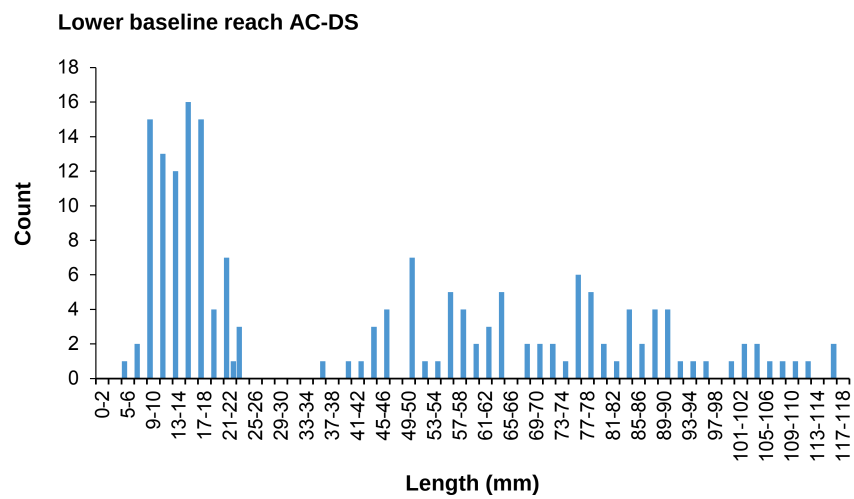


Table 5.13-29 Summary of morphometric data (mean ± 1SE) for lake chub in reaches of Alice Creek, fall 2015.

Reach	Units	AC-US upper *baseline* reach		AC-DS lower *baseline* reach	
n	-	20	20	20	20
Sex	-	Male	Female	Male	Female
Age	years	2.6 ± 0.3	2.6 ± 0.2	1.4 ± 0.2	1.60± 0.2
Length	mm	81.15 ± 1.68	87.70 ± 2.36	86.00 ± 3.08	88.00 ± 3.30
Weight	g	5.48 ± 0.38	7.33 ± 0.54	7.22 ± 0.81	7.32 ± 0.83
K	-	1.00 ± 0.03	1.05 ± 0.02	1.05 ± 0.05	0.99 ± 0.03
GSI	-	1.04 ± 0.13	6.58 ± 0.56	0.94 ± 0.08	5.59 ± 0.90
LSI	-	1.91 ± 0.08	2.15 ± 0.14	1.40 ± 0.08	1.83 ± 0.11

K = condition, GSI = gonadosomatic index, LSI = liversomatic index

Figure 5.13-23 Relative age-frequency distributions for lake chub at *baseline* reaches of Alice Creek, fall 2015.

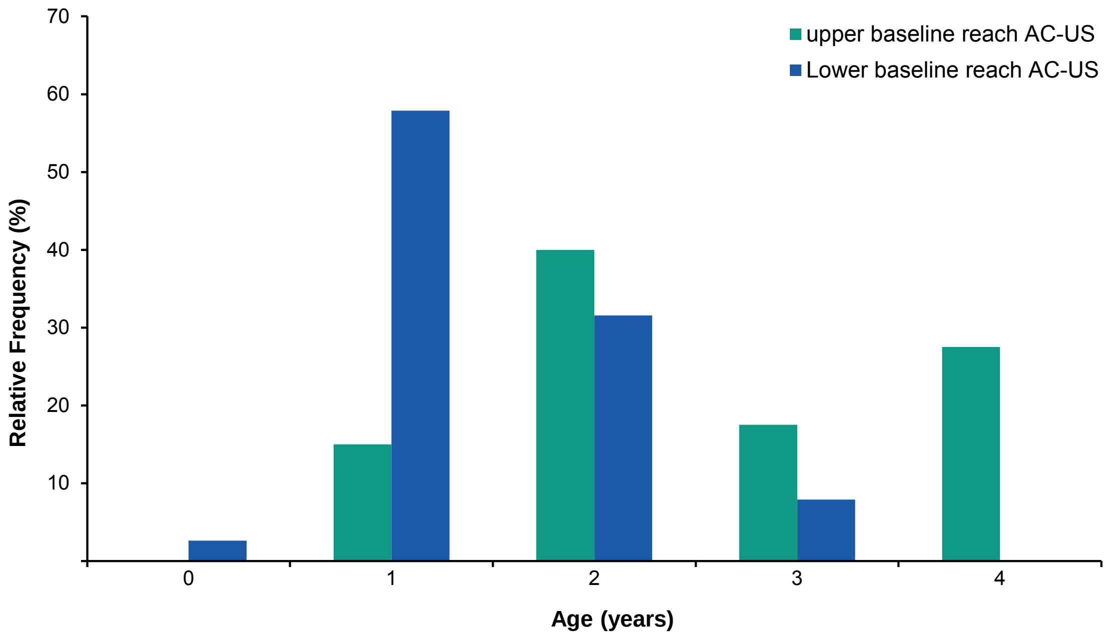


Table 5.13-30 Results of analysis of variance (ANOVA) and analysis of covariance (ANCOVA) for differences in measurement endpoints of lake chub in Alice Creek (*baseline* reaches AC-US and AC-DS), fall 2015.

Analysis	Sex	Comparison	Actual Sample Size	p value	Effect	Effects Criteria	% Difference[2]	Post Hoc
ANOVA								
Age (Survival)								
	Female	AC-US vs. AC-DS	18,20	**0.001**	AC-US > AC-DS	±25%	<u>-40%</u>	-
	Male	AC-US vs. AC-DS	20,20	**<0.001**	AC-US > AC-DS	±25%	<u>-47%</u>	-
ANCOVA								
Growth – Size-at-age (Energy Use)								
	Female	AC-US vs. AC-DS	18,20	0.17	None	±25%	23%	*0.41*
	Male*	AC-US vs. AC-DS	20,20	0.11	None	±25%	31%	*0.11*
Relative Gonad Weight (Energy Use)								
	Female	AC-US vs. AC-DS	20,19	**0.01**	AC-US > AC-DS	±25%	-21%	-
	Male	AC-US vs. AC-DS	19,20	0.31	None	±25%	-14%	>0.99
Relative Liver Weight (Energy Storage)								
	Female*	AC-US vs. AC-DS	19,20	**0.01**	AC-US > AC-DS	±25%	-18%	-
	Male*	AC-US vs. AC-DS	19,15	**<0.001**	AC-US > AC-DS	±25%	<u>-27%</u>	-
Condition (Energy Storage)								
	Female*	AC-US vs. AC-DS	29,20	0.28	None	±10%	-4%	*0.21*
	Male	AC-US vs. AC-DS	20,26	0.17	None	±10%	5%	*0.77*

Bold values indicate significant difference (p≤0.05).

* Data were log-transformed.

[1] Percent difference was calculated using ANOVA-adjusted least squared means with upstream reaches as the reference. <u>Underlined</u> values signify instances when significant differences were observed and the effect size exceeded EC's criterion for 25% for age, weight-at-age, GSI, and LSI, and 10% for condition.

[2] Power was calculated for the three-way ANOVA when no significant differences were found among reaches. Values in *italics* denote comparisons where power was inadequate and sample size was too low.

[3] The results of ANCOVA tests are presented only if slopes of the regression of the variables used in the ANCOVA were not significantly different (p<0.01).

Figure 5.13-24 Mean EROD activity (± 1SE) of female and male lake chub at *baseline* (AC-US and AC-DS) reaches on Alice Creek, fall 2015.

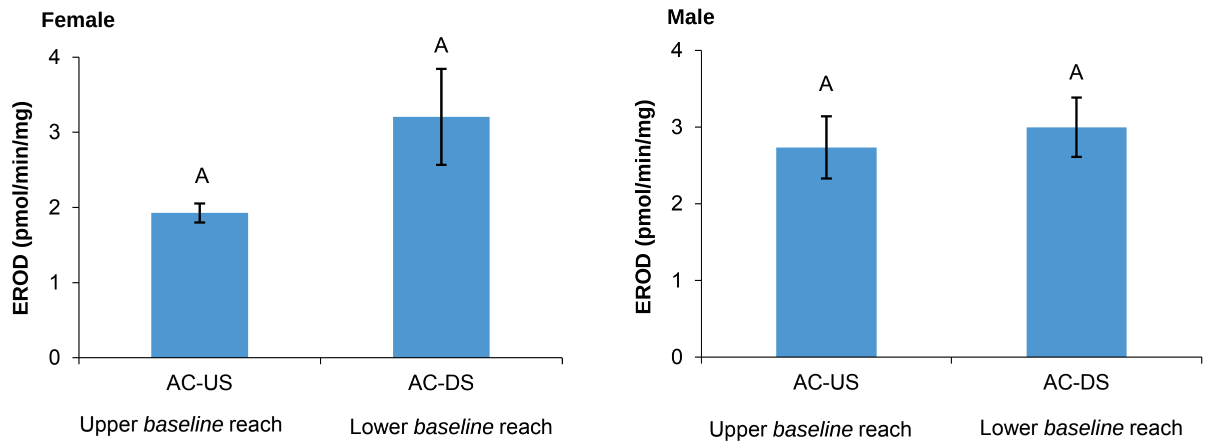


Table 5.13-31 Concentrations of water quality measurement endpoints, Isadore's Lake (*test* station ISL-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	2000-2014 (fall data only)			
			Value	n	Median	Min	Max
Physical variables							
pH	pH units	6.5-9.0	7.86	13	8.15	7.70	8.30
Total suspended solids	mg/L	-	2.0	13	6.0	<3.0	10.0
Conductivity	µS/cm	-	760	13	584	353	891
Nutrients							
Total dissolved phosphorus	mg/L	-	0.011	13	0.007	0.003	0.067
Total nitrogen	mg/L	-	1.00	13	0.91	0.30	1.25
Nitrate+nitrite	mg/L	3-124	<0.005	13	<0.071	<0.050	0.300
Dissolved organic carbon	mg/L	-	11.0	13	10.2	8.0	12.9
Ions							
Sodium	mg/L	-	<u>18.0</u>	13	11.4	6.0	16.4
Calcium	mg/L	-	79.0	13	66.8	37.0	107.0
Magnesium	mg/L	-	<u>40.0</u>	13	30.6	25.0	37.0
Potassium	mg/L	-	<u>2.9</u>	13	1.3	2.2	2.7
Chloride	mg/L	120-640	35.0	13	17.5	4.0	38.8
Sulphate	mg/L	309[b]	240.0	13	109.0	63.9	277.0
Total dissolved solids	mg/L	-	550.0	13	377.0	250.0	591.0
Total alkalinity	mg/L	20 (min)	<u>89.0</u>	13	147.0	116.0	227.0
Selected metals							
Total aluminum	mg/L	-	<u>0.004</u>	13	0.020	0.006	0.182
Dissolved aluminum	mg/L	0.05	<u>0.00038</u>	13	<0.00100	0.00041	0.02000
Total arsenic	mg/L	0.005	0.00051	13	0.00067	0.00046	0.00116
Total boron	mg/L	1.5-29	0.0612	13	0.0439	0.0350	0.0613
Total molybdenum	mg/L	0.073	<0.000008	13	<0.000100	<0.000008	0.000125
Total mercury (ultra-trace)	ng/L	5-13	<u>0.50</u>	11	<1.20	0.53	1.60
Total methyl mercury	ng/L	1-2	0.081	-	-	-	-
Total strontium	mg/L	-	0.295	13	0.237	0.162	0.319
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.250**	**<0.250**	**<0.250**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>0.87</u>	4	0.22	0.07	0.45
Oilsands extractable acids	mg/L	-	<u>2.50</u>	4	0.98	0.38	1.70
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<11.44	<7.21	<15.16
Retene	ng/L	-	<0.59	4	<0.61	0.43	<2.07
Total dibenzothiophenes[c]	ng/L	-	8.17	4	7.67	6.02	35.45
Total PAHs[c]	ng/L	-	108	4	142	81	308
Total Parent PAHs[c]	ng/L	-	22.6	4	19.9	13.4	23.4
Total Alkylated PAHs[c]	ng/L	-	86	4	119	68	290
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.004	**0.0062**	13	**0.0080**	<0.0020	**0.0878**

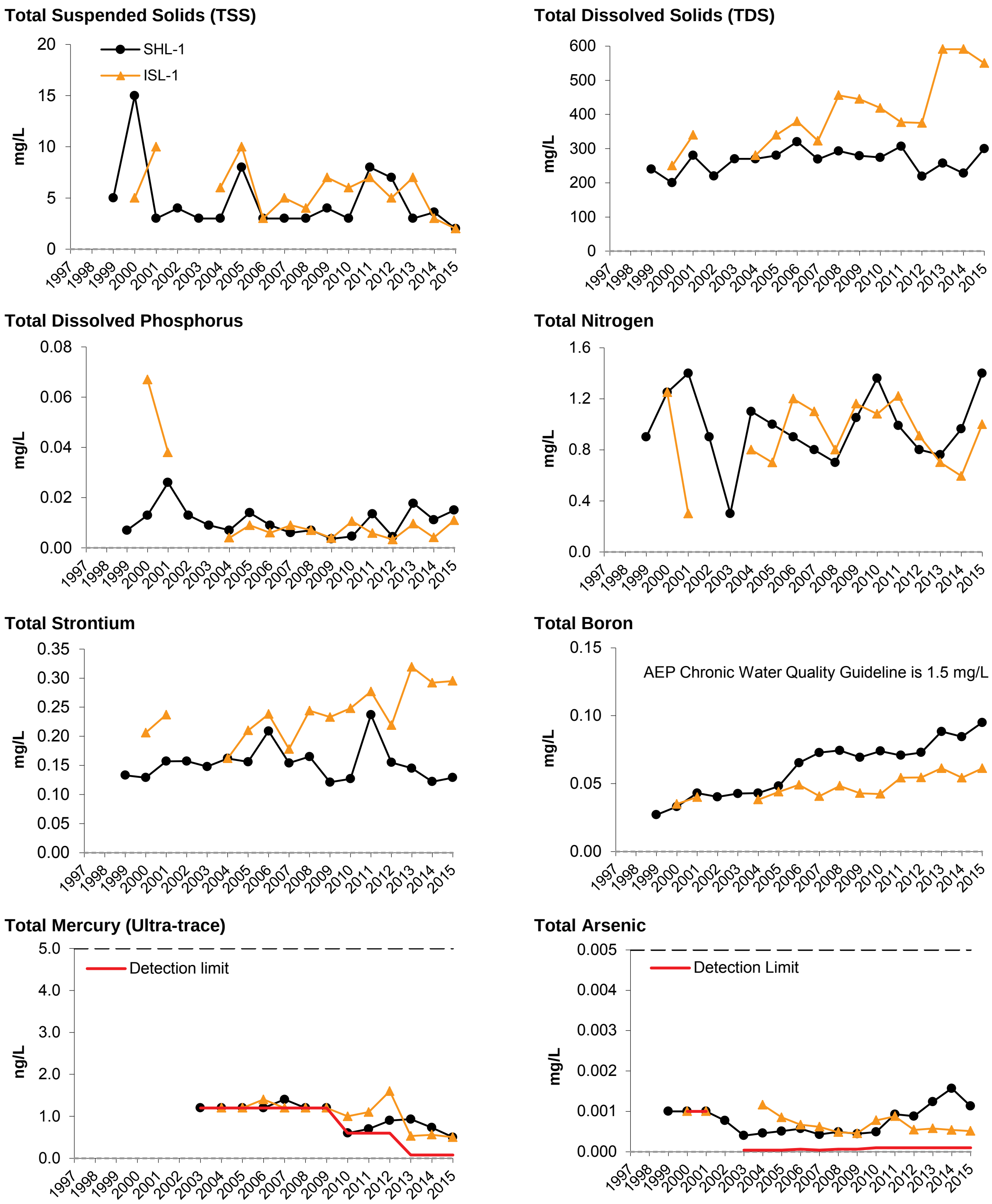
Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] based on actual hardness level

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Figure 5.13-25 Selected water quality measurement endpoints in Isadore's Lake and Shipyard Lake (fall data) relative to historical concentrations and regional *baseline* fall concentrations.



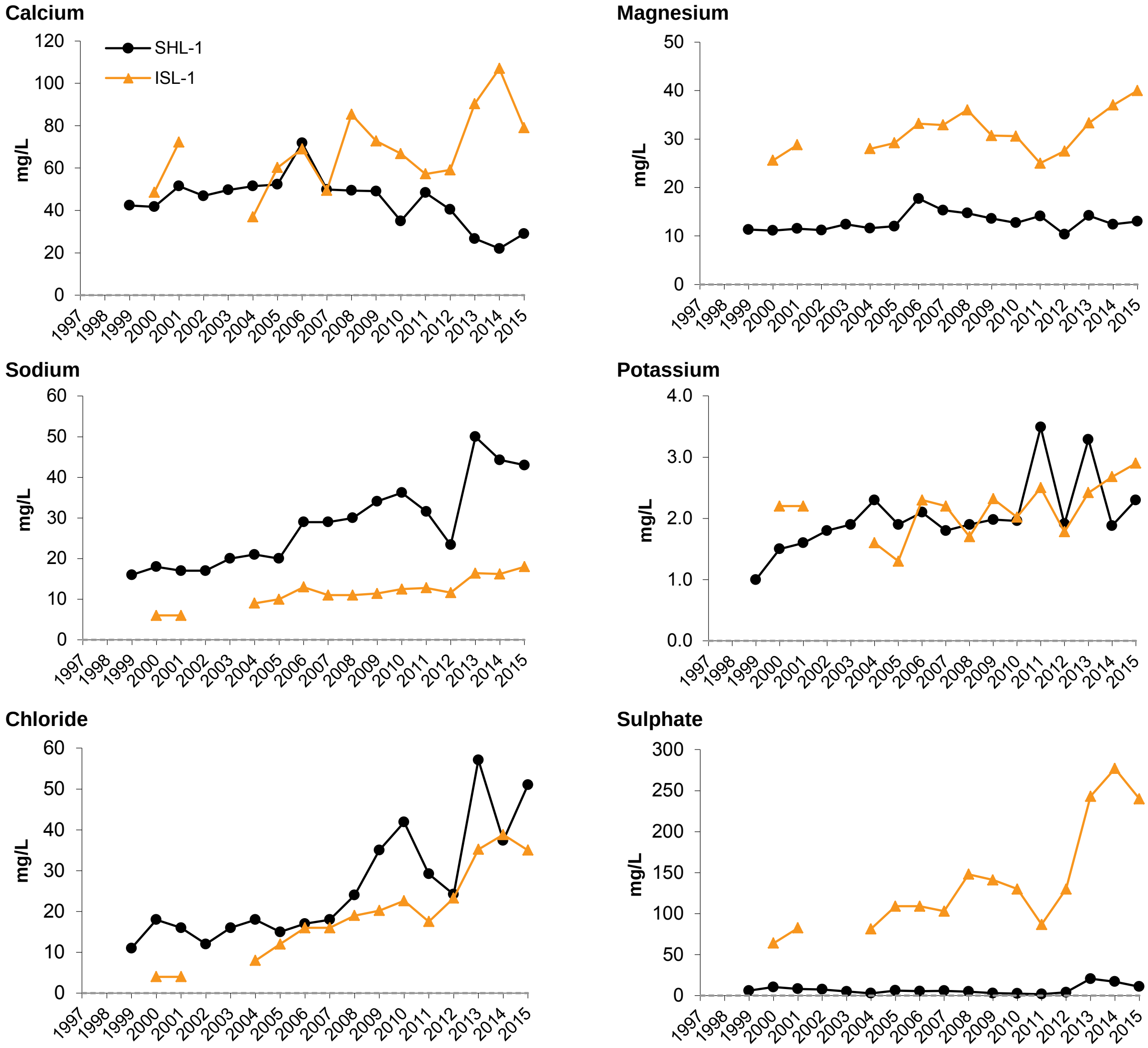
Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-1 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Figure 5.13-25 (Cont'd.)



Non-detectable values are shown at the detection limit.

– – – – – Water quality guideline. See Table 3.2-5 for all water quality guidelines.

Dashed lines denote *baseline* sampling periods. Solid lines denote *test* sampling periods.

Regional *baseline* values reflect pooled results for all *baseline* stations in a similar region, from all years of sampling. See Section 3.2.2.2 for a discussion of this approach.

Table 5.13-32 Average habitat characteristics of the benthic invertebrate sampling location in Isadore's Lake (*test* station ISL-1), fall 2015.

Variable	Units	Isadore's Lake *Test* Station ISL-1
Sample date	-	September 3, 2015
Habitat	-	Depositional
Water depth	m	0.26
Field water quality		
Dissolved oxygen (DO)	mg/L	9.7
Conductivity	µS/cm	591
pH	pH units	7.73
Water temperature	°C	8.1
Sediment composition		
Sand	%	0
Silt	%	94.9
Clay	%	5.1
Total organic carbon (TOC)	%	4.3

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.13-33 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Isadore's Lake (*test* station ISL-1).

Taxon	Percent Major Taxa Enumerated in Each Year Isadore's Lake (*test* station ISL-1)		
	2006	2007 - 2014	2015
Hydra	-	-	2
Nematoda	72	3 to 69	14
Naididae	4	0 to 37	47
Tubificidae	-	0 to 2	-
Hirudinea	-	0 to <1	-
Hydracarina	-	0 to 8	-
Gastropoda	-	0 to 4	<1
Ceratopogonidae	<1	0 to 4	<1
Chironomidae	2	7 to 60	33
Diptera (misc)	<1	0 to 2	-
Ephemeroptera	-	0 to 3	1
Odonata	-	-	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	282	211 to 288	231
Richness	10	5 to 13	7
Equitability	0.23	0.27 to 0.57	0.41
% EPT	0	0 to 3	1

Table 5.13-34 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at Isadore's Lake (*test* station ISL-1).

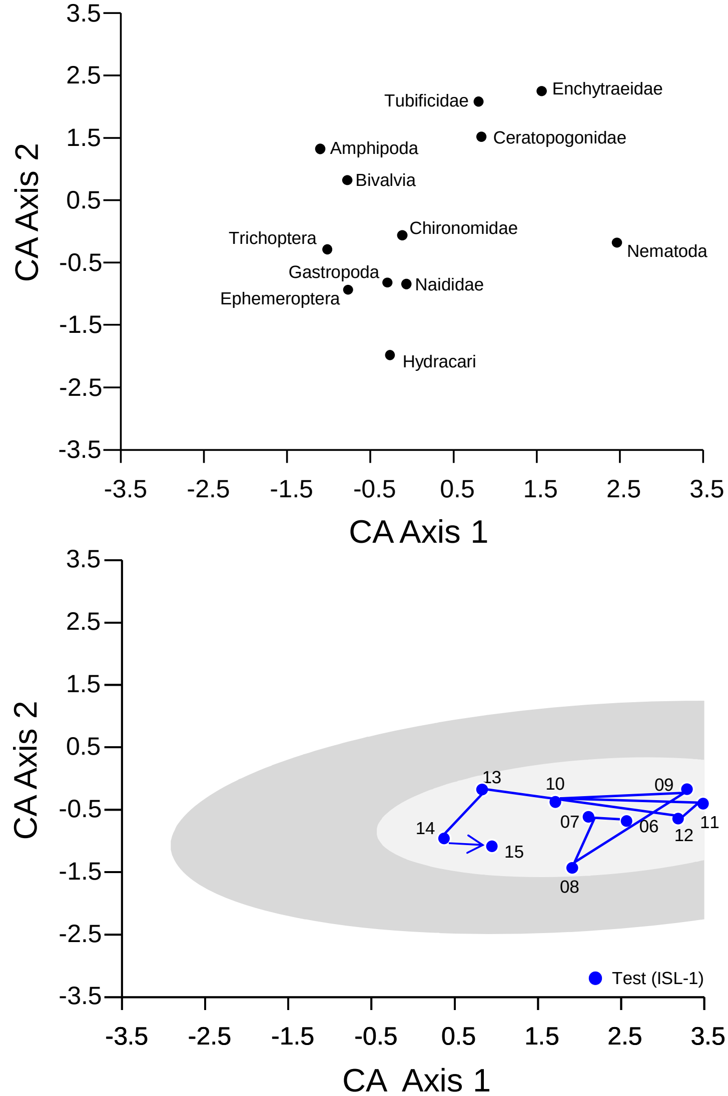
Measurement Endpoint	P-value		Variance Explained (%)		Nature of Change(s)
	Linear	2015 vs. Previous Years	Linear	2015 vs. Previous Years	
Log of Abundance	**0.014**	**0.018**	13	12	Abundance increased over time and was higher in 2015 than the mean of prior years in the lake.
Log of Richness	**<0.001**	**<0.001**	26	28	Richness increased over time and was higher in 2015 than the mean of prior years.
Equitability	**0.005**	**<0.001**	20	34	Equitability decreased over time and was lower in 2015 than the mean of all prior years.
Log of EPT	**<0.001**	**0.001**	61	21	EPT increased over time and was higher in 2015 than the mean of previous years.
CA Axis 1	**<0.001**	**<0.001**	30	31	CA Axis 1 scores decreased over time and were lower in 2015 than the mean of all prior years.
CA Axis 2	0.589	**<0.001**	0	38	CA Axis 2 scores increased over time and were higher in 2015 than the means of all prior years.

Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

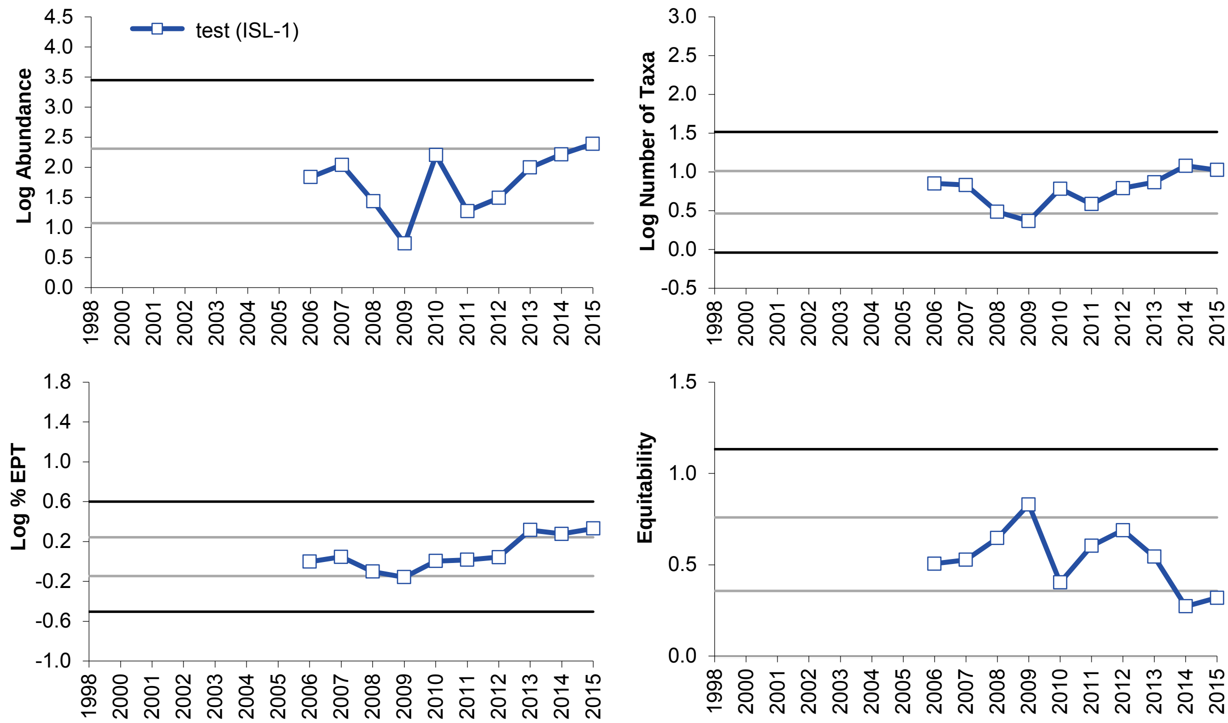
Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Figure 5.13-26 Ordination (Correspondence Analysis) of benthic invertebrate communities in regional lakes, showing Isadore's Lake (*test* station ISL-1).



Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.13-27 Variation in benthic invertebrate community measurement endpoints in Isadore's Lake (*test* station ISL-1) relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from 2000 to 2014.

Measurement endpoints were adjusted to a common depth of 2 m (see Appendix D).

Abundance, richness, and %EPT data were $log_{10}(x+1)$ transformed.

Table 5.13-35 Concentrations of sediment quality measurement endpoints, Isadore's Lake (*test* station ISL-1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2001-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<u>3.5</u>	10	11.3	26.0	57.0
Silt	%	-	<u>96.4</u>	10	0.7	57.9	85.5
Sand	%	-	<u><0.1</u>	10	1.6	12.1	77.8
Total organic carbon	%	-	3.13	10	1.30	5.16	18.80
Total hydrocarbons							
BTEX	mg/kg	-	<50	9	<5	<20	<130
Fraction 1 (C6-C10)	mg/kg	30[1]	**<50**	9	<5	<20	**<130**
Fraction 2 (C10-C16)	mg/kg	150[1]	<50	9	<5	<72	**1670**
Fraction 3 (C16-C34)	mg/kg	300[1]	**415**	9	150	**539**	**4600**
Fraction 4 (C34-C50)	mg/kg	2800[1]	234	9	89	319	**3500**
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	<u>0.0132</u>	10	0.0049	0.0066	0.0119
Retene	mg/kg	-	<u>0.0028</u>	10	0.0367	0.0608	0.6250
Total dibenzothiophenes	mg/kg	-	0.2652	10	0.1146	0.1837	0.6888
Total PAHs	mg/kg	-	1.5823	10	0.7792	1.5532	3.5335
Total Parent PAHs	mg/kg	-	0.1144	10	0.0683	0.1450	0.2555
Total Alkylated PAHs	mg/kg	-	1.4679	10	0.7109	1.4200	3.2780
Predicted PAH toxicity[3]	H.I.	1.0	0.6053	10	0.0723	0.5774	**1.2875**
Metals that exceeded CCME guidelines in 2015							
Total Arsenic	mg/kg	5.9	<u>**8.6**</u>	10	3.6	**6.5**	**7.5**
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	82	7	64	74	90
Chironomus growth - 10d	mg/organism	-	<u>3.15</u>	7	1.06	2.43	2.99
Hyalella survival - 14d	% surviving	-	96	7	64	80	98
Hyalella growth - 14d	mg/organism	-	<u>0.17</u>	7	0.20	0.34	0.46

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historic observations.

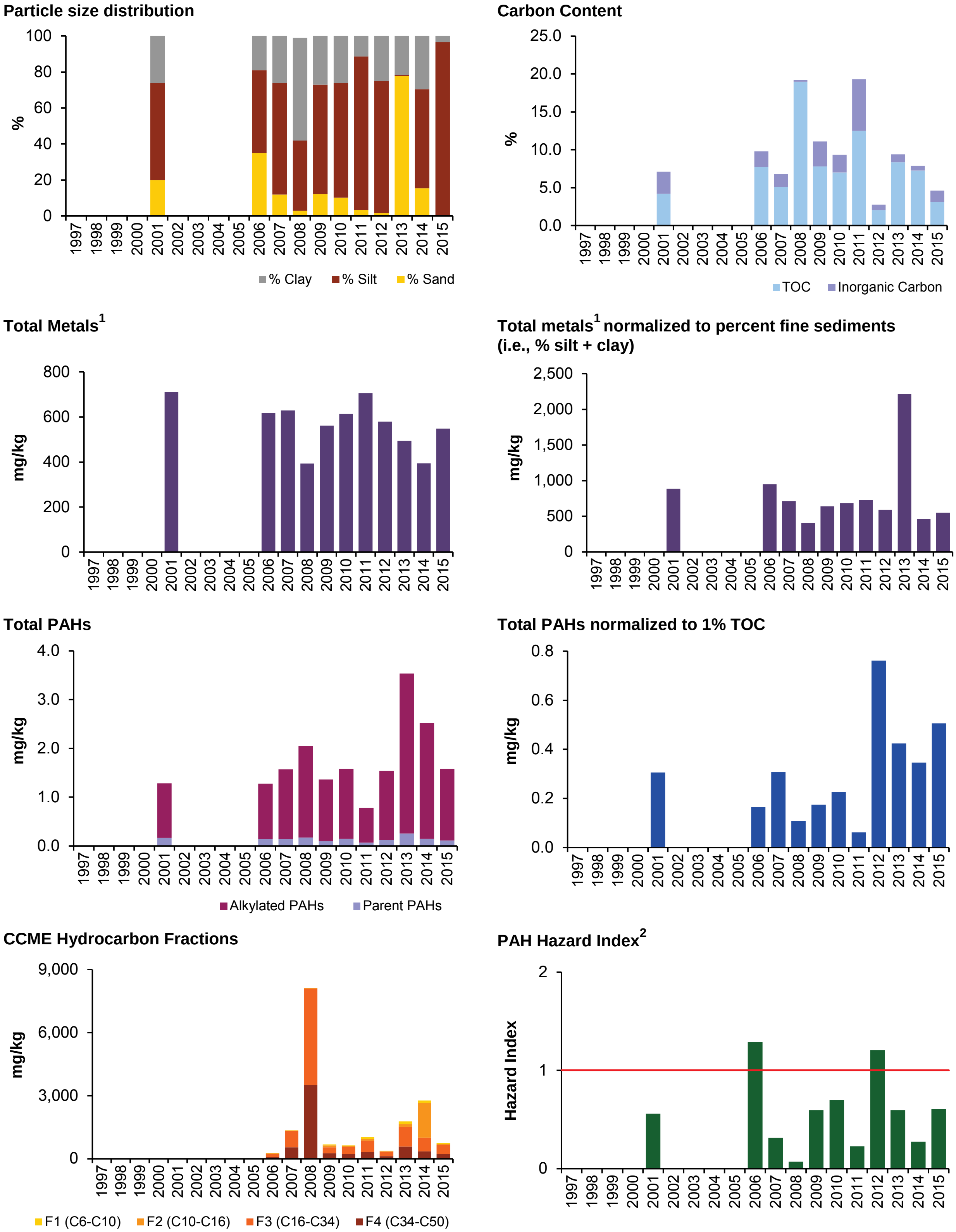
ns = not sampled in 2002-2005

[1] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-28 Variation in sediment quality measurement endpoints in Isadore's Lake, *test* station ISL-1, relative to historical concentrations.



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

Table 5.13-36 Concentrations of water quality measurement endpoints, Shipyard Lake (*test* station SHL-1), fall 2015, compared to historical fall concentrations.

Measurement Endpoint	Units	Guideline[a]	September 2015	1999-2014 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.94	16	7.70	8.10	9.16
Total suspended solids	mg/L	-	2.0	16	<3.0	3.3	15
Conductivity	µS/cm	-	440	16	358	411	509
Nutrients							
Total dissolved phosphorus	mg/L	-	0.015	16	0.004	0.009	0.026
Total nitrogen	mg/L	-	1.40	16	0.30	0.93	1.40
Nitrate+nitrite	mg/L	3-124	<0.005	16	<0.050	<0.100	<0.100
Dissolved organic carbon	mg/L	-	17.0	16	16.7	19.4	24.0
Ions							
Sodium	mg/L	-	43.0	16	16.0	26.2	50.0
Calcium	mg/L	-	29.0	16	22.0	48.8	71.8
Magnesium	mg/L	-	13.0	16	10.3	12.4	17.7
Potassium	mg/L	-	2.3	16	1.0	1.9	3.5
Chloride	mg/L	120-640	51.0	16	11.0	18.0	57.1
Sulphate	mg/L	309[b]	11.0	16	1.87	5.60	20.6
Total dissolved solids	mg/L	-	300	16	200	270	320
Total alkalinity	mg/L	20 (min)	140	16	124	179	251
Selected metals							
Total aluminum	mg/L	-	0.039	16	<0.002	0.019	0.190
Dissolved aluminum	mg/L	0.05	0.0007	16	<0.0010	0.0020	<0.0100
Total arsenic	mg/L	0.005	0.00113	16	0.00040	0.00067	0.00157
Total boron	mg/L	1.5-29	<u>0.0950</u>	16	0.0270	0.0673	0.0883
Total molybdenum	mg/L	0.073	0.00016	16	0.00002	<0.00010	0.00020
Total mercury (ultra-trace)	ng/L	5-13	0.50	12	<0.60	<1.20	1.40
Total methyl mercury	ng/L	1-2	0.179	-	-	-	-
Total strontium	mg/L	-	0.129	16	0.121	0.155	0.237
Total hydrocarbons							
BTEX	mg/L	-	<0.01	4	<0.10	<0.10	<0.10
Fraction 1 (C6-C10)	mg/L	0.15	<0.01	4	<0.10	<0.10	<0.10
Fraction 2 (C10-C16)	mg/L	0.11	<0.005	4	**<0.250**	**<0.250**	**<0.250**
Fraction 3 (C16-C34)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Fraction 4 (C34-C50)	mg/L	-	<0.02	4	<0.25	<0.25	<0.25
Naphthenic acids	mg/L	-	<u>1.76</u>	4	0.17	0.72	1.23
Oilsands extractable acids	mg/L	-	<u>5.40</u>	4	0.59	1.61	2.80
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	ng/L	1,000	<13.55	4	<7.21	<11.44	<15.16
Retene	ng/L	-	<0.59	4	<0.41	<0.61	<2.07
Total dibenzothiophenes[c]	ng/L	-	13.17	4	8.43	10.50	36.50
Total PAHs[c]	ng/L	-	118	4	91	137	225
Total Parent PAHs[c]	ng/L	-	23.0	4	14.5	19.6	23.4
Total Alkylated PAHs[c]	ng/L	-	95	4	77	114	207
Other variables that exceeded Alberta guidelines in fall 2015							
Sulphide	mg/L	0.002	**0.007**	16	**<0.003**	**0.0072**	**0.0140**

Values in **bold** are above guideline; <u>underlined</u> values are outside of historical range.

[a] Sources for all guidelines are outlined in Table 3.2-1.

[b] Based on actual hardness level.

[c] Non-detectable values treated as 1 x blank-corrected Method Detection Limit in summary calculations.

Table 5.13-37 Average habitat characteristics of benthic invertebrate sampling locations in Shipyard Lake, fall 2015.

Variable	Units	Shipyard Lake *Test* station SHL-1
Sample date	-	September 3, 2015
Habitat	-	Depositional
Water depth	m	0.95
Field water quality		
Dissolved oxygen (DO)	mg/L	6.4
Conductivity	µS/cm	392
pH	pH units	7.5
Water temperature	°C	13
Sediment composition		
Sand	%	0.7
Silt	%	61.5
Clay	%	37.8
Total organic carbon (TOC)	%	15.4

Note: Sediment composition values may not total 100% as these values represent means of the separate replicates.

Table 5.13-38 Summary of major taxon abundances and benthic invertebrate measurement endpoints, Shipyard Lake (*test* station SHL-1).

Taxon	Percent Major Taxa Enumerated in Each Year		
	Shipyard Lake (*test* station SHL-1)		
	2000	2001 - 2014	2015
Hydra	-	0 to <1	<1
Planariidae	-	-	1
Nematoda	-	0 to 21	7
Naididae	8	0 to 33	44
Tubificidae	1	0 to 7	4
Enchytraeidae	-	0 to 7	-
Lumbriculidae	-	0 to <1	-
Hirudinea	-	0 to 1	<1
Hydracarina	-	0 to 5	-
Amphipoda	7	0 to 18	5
Gastropoda	18	<1 to 28	5
Bivalvia	7	<1 to 8	1
Ceratopogonidae	-	0 to 6	1
Chironomidae	25	3 to 48	27
Diptera (misc)	3	0 to 53	-
Coleoptera	-	-	<1
Ephemeroptera	16	0 to 6	4
Odonata	3	0 to 1	<1
Trichoptera	2	0 to 1	<1
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance per sample	95	28 to 1,254	1,005
Richness	13	4 to 27	19
Equitability	0.56	0.08 to 0.75	0.27
% EPT	19	<1 to 5	4

Table 5.13-39 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints at Shipyard Lake (*test* station SHL-1).

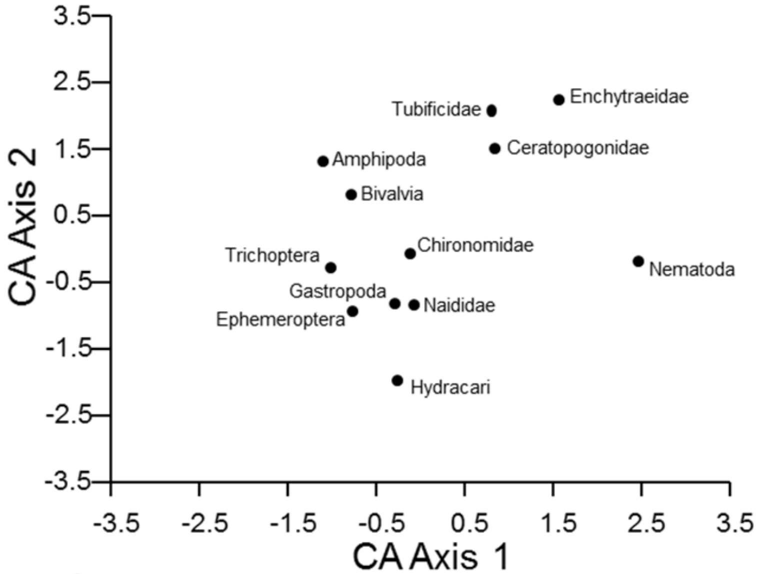
Variable	P-value		Variance Explained (%)		Nature of Change(s)
	Linear	2015 vs. Prior	Linear	2015 vs. Prior	
Log of Abundance	**<0.001**	**<0.001**	27	15	Abundance increased over time and was higher in 2015 than the mean of all prior years.
Log of Richness	**<0.001**	**0.003**	28	7	Richness increased over time in the reach and was higher in 2015 than the mean of prior years.
Equitability	**<0.001**	**0.005**	35	6	Equitability decreased over time and was lower in 2015 than the mean of all prior years.
Log of EPT	**0.036**	**0.028**	3	3	Percent of the fauna as EPT taxa has been increasing over time (since 2011) and was higher in 2015 than the mean of all prior years.
CA Axis 1	**0.011**	0.899	11	0	CA Axis 1 scores increased over time and was higher in 2015 than the mean of all prior years.
CA Axis 2	0.219	0.078	3	5	No change.

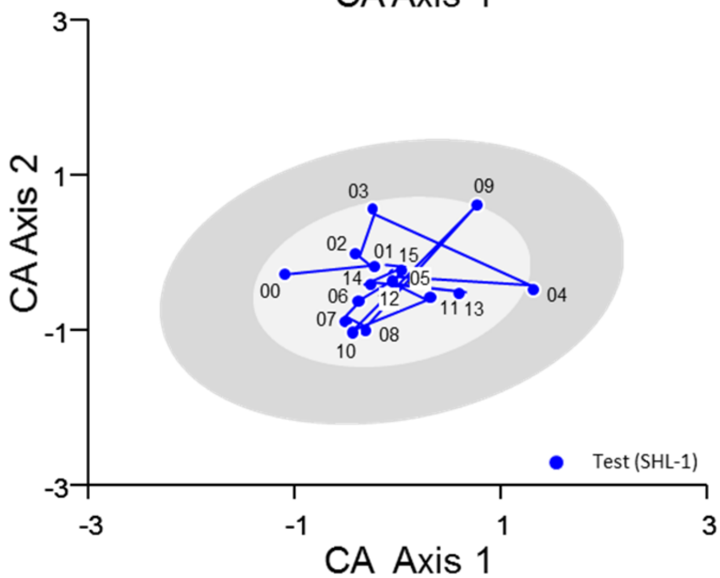
Bold values indicate significant variation as per the specified contrast ($p<0.05$). Significance contributes to the classification of results as per Table 3.2-6.

Shaded cells indicate that the specified contrast accounts for > 20% of the variation in annual means and contributes to the classification of results as per Table 3.2-6.

Note: Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed

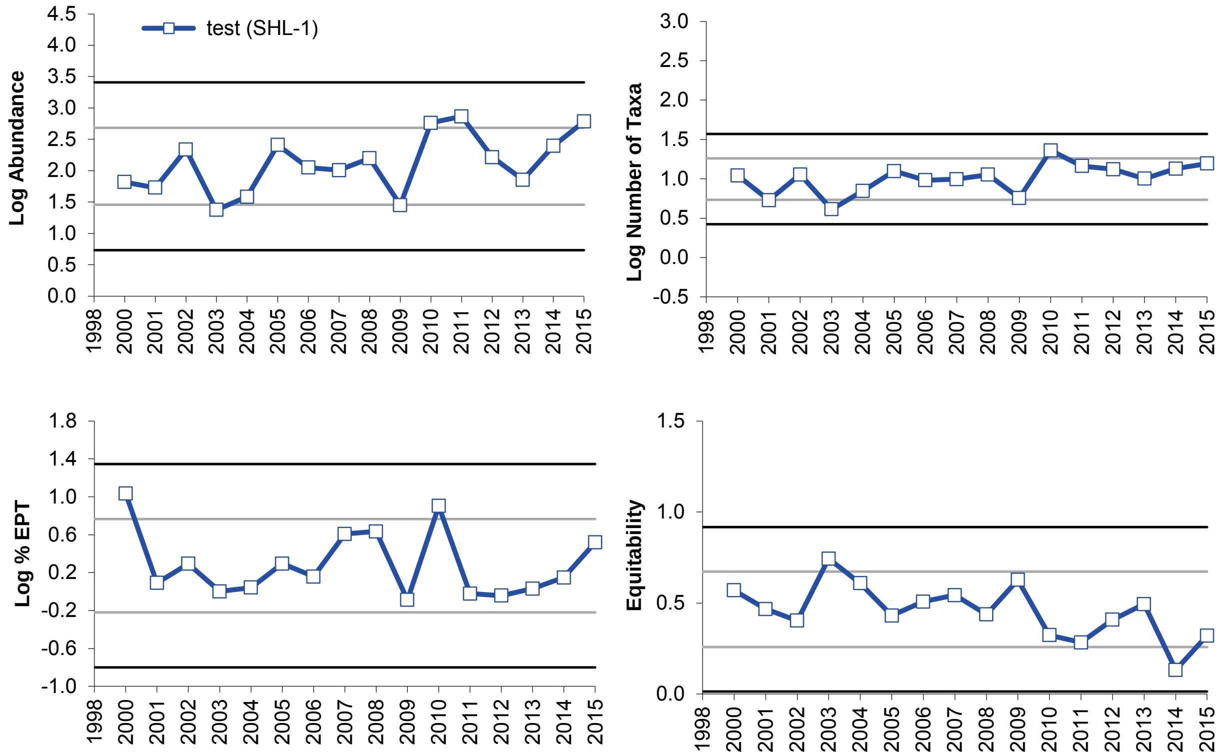
Figure 5.13-29 Ordination (Correspondence Analysis) of benthic invertebrate communities in regional lakes, showing Shipyard Lake (*test* station SHL-1).





Note: The upper panel is the scatterplot of taxa scores while the lower panel is the scatterplot of sample scores. The ellipses in the lower panel are the inner and outer tolerance limits on the 95th percentile for all previous years.

Figure 5.13-30 Variation in benthic invertebrate community measurement endpoints in Shipyard Lake (*test* station SHL-1) relative to the historical ranges of variability.



Notes:

Tolerance limits for the 5th and 95th percentiles were calculated using data from 2000 to 2014.

Measurement endpoints were adjusted to a common depth of 2 m (see Appendix D).

Abundance, richness, and %EPT data were $\log_{10}(x+1)$ transformed.

Table 5.13-40 Concentrations of sediment quality measurement endpoints, Shipyard Lake (*test* station SHL-1), fall 2015, compared to historical fall concentrations.

Variables	Units	Guideline	September 2015	2001-2014 (fall data only)[ns]			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	19.4	12	9.6	33.2	60.0
Silt	%	-	79.9	12	16.4	41.4	86.2
Sand	%	-	<u>0.6</u>	12	1.0	10.5	74.0
Total organic carbon	%	-	18.00	13	5.50	13.40	25.90
Total hydrocarbons							
BTEX	mg/kg	-	<160	10	<5	<80	<300
Fraction 1 (C6-C10)	mg/kg	30[1]	**<160**	10	<5	**<80**	**<300**
Fraction 2 (C10-C16)	mg/kg	150[1]	<140	10	<5	<130	**6750**
Fraction 3 (C16-C34)	mg/kg	300[1]	**1630**	10	290	**1190**	**3030**
Fraction 4 (C34-C50)	mg/kg	2800[1]	876	10	<5	473	1400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[2]	0.0216	11	0.0108	0.0186	0.0306
Retene	mg/kg	-	<u>0.0404</u>	13	0.0460	0.0821	0.1990
Total dibenzothiophenes	mg/kg	-	1.5192	13	0.2645	0.9910	2.6221
Total PAHs	mg/kg	-	5.9933	13	2.2756	6.3120	10.7175
Total Parent PAHs	mg/kg	-	0.5191	13	0.2305	0.3283	0.6725
Total Alkylated PAHs	mg/kg	-	5.4741	13	2.0200	5.8324	10.1060
Predicted PAH toxicity[3]	H.I.	1.0	0.6202	13	0.0969	0.6954	3.7862
Metals that exceeded CCME guidelines in 2015							
Total Arsenic	mg/kg	5.9	**6.7**	13	5.5	**6.7**	**8.0**
Other analytes that exceeded CCME guidelines in 2015							
Benz[a]anthracene	mg/kg	0.0317	**0.0506**	13	0.0100	0.0221	**0.0639**
Benzo[a]pyrene	mg/kg	0.0319	**0.0628**	13	0.0130	0.0280	**0.0785**
Chrysene	mg/kg	0.0571	**0.1190**	13	0.0334	**0.0658**	**0.1630**
Dibenz(a,h)anthracene	mg/kg	0.0062	**0.0232**	13	0.0041	**0.0110**	**0.0273**
Phenanthrene	mg/kg	0.0419	**0.0536**	13	0.0258	**0.0446**	**0.0678**
Chronic toxicity							
Chironomus survival - 10d	% surviving	-	72	9	56	76	88
Chironomus growth - 10d	mg/organism	-	2.25	9	1.25	2.18	4.04
Hyalella survival - 14d	% surviving	-	<u>88</u>	9	40	77	84
Hyalella growth - 14d	mg/organism	-	0.15	9	0.10	0.28	0.45

Values in **bold** indicate concentrations exceeding guidelines.

Values <u>underlined</u> indicate concentrations outside the range of historic observations.

ns = not sampled in 2005

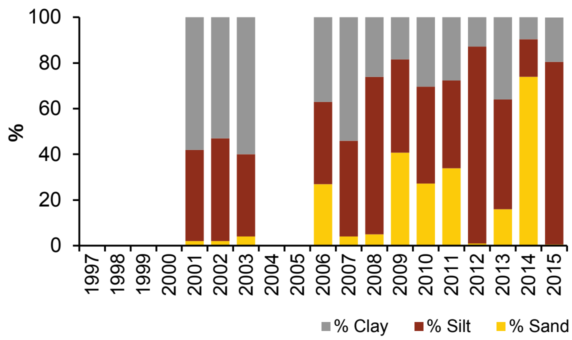
[1] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[2] Interim sediment quality guideline (ISQG) (CCME 2002).

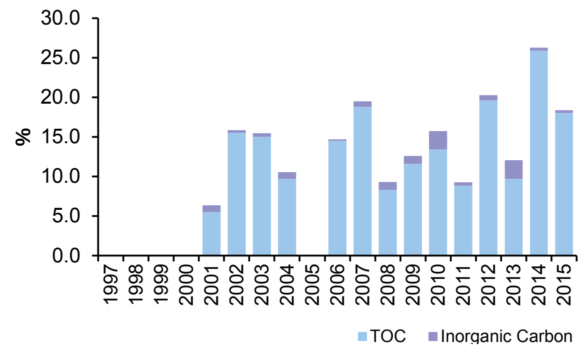
[3] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

Figure 5.13-31 Variation in sediment quality measurement endpoints in Shipyard Lake, *test* station SHL-1, relative to historical concentrations.

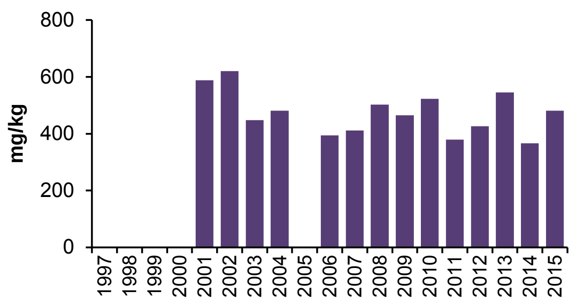
Particle size distribution



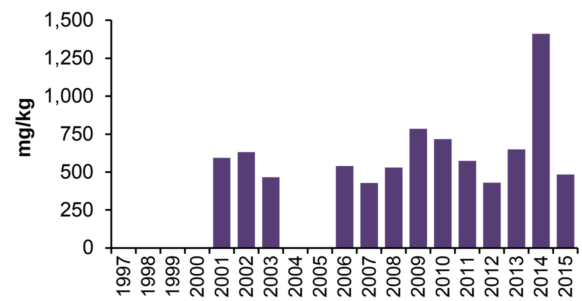
Carbon Content



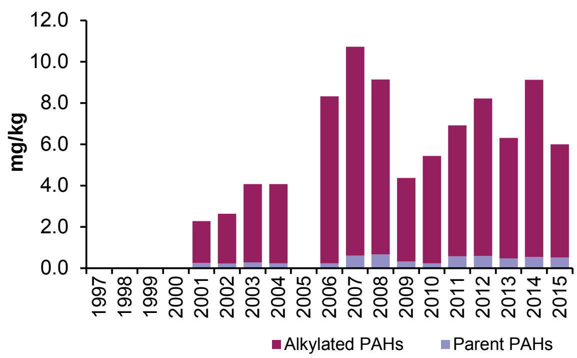
Total Metals[1]



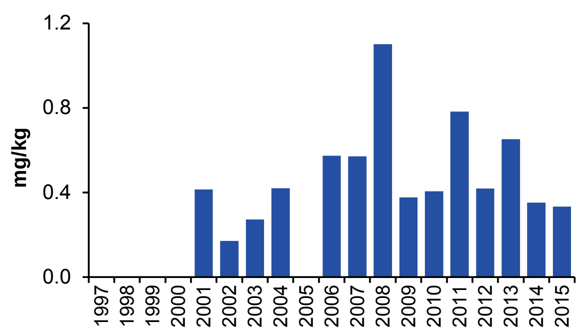
Total metals[1] normalized to percent fine sediments (i.e., % silt + clay)



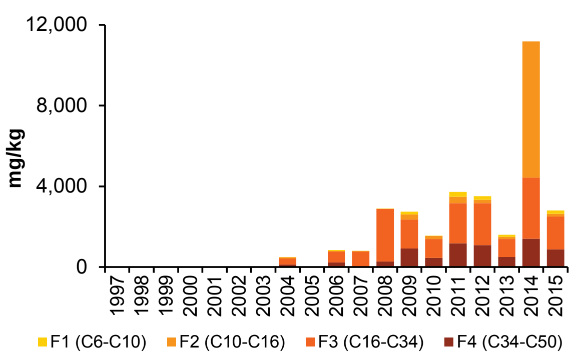
Total PAHs



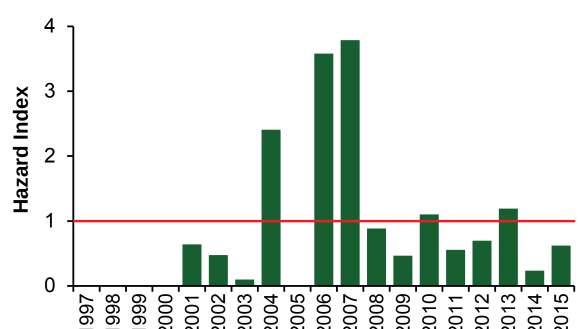
Total PAHs normalized to 1% TOC



CCME Hydrocarbon Fractions



PAH Hazard Index[2]



[1] Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Sr, Tl, Ti, Sn, Ag, U, V, Zn (measured in all years).

[2] Red line indicates potential chronic effects level (HI = 1.0).

5.14 ACID-SENSITIVE LAKES

This section presents the results of the Acid-Sensitive Lakes (ASL) component of the JOSMP for the 2015 WY. Chemical changes in the 50 ASL study lakes over the 16 years of monitoring were identified and a series of analyses were conducted to determine whether these changes provided evidence of acidification of these lakes. The analyses and subsequent data interpretation attempted to distinguish between acidification-related changes and natural variability in the water quality of these lakes.

5.14.1 General Characteristics of the ASL Component Lakes in the 2015 WY

The lakes monitored for the ASL component (the acid-sensitive lakes) are typically small and shallow with a median area of 1.32 km^2 and a median maximum depth of 1.83 m (Table 5.14-1). Given the shallow depth of these lakes, a large proportion of the water volume in many of the lakes freezes to depth each winter. Freezing to depth results in large changes in lake chemistry (e.g., anoxia, decreases in pH, and increases in alkalinity) that reverse when melting occurs in spring (See Appendix H in RAMP 2008).

The water chemistry variables measured in the 50 acid-sensitive lakes from 1999 to 2015 are summarized in Table 5.14-2[1]. The five lakes sampled in the Caribou Mountains were removed from the program in 2014 but restored in 2015 and data from these five lakes are included in the summary statistics in Table 5.14-2. The lakes in the in the Caribou Mountains and Canadian Shield regions are classified as *baseline* lakes remote from oil sands emissions[2].

The acid-sensitive lakes cover a wide range of water hardness and pH. Historically, the pH of the lakes has ranged from 3.97 to 9.87, with a median of 6.86. The median pH of the acid-sensitive lakes in 2015 was 7.14, slightly higher than the historical median. Two lakes in the Smoky Mountains (SM9/169) and SM8/287) and one lake in the Birch Mountains (BM3/464) had measured values of pH in 2015 that exceeded three standard deviations from their historic mean pH value.

Gran alkalinity in the acid-sensitive lakes has historically ranged from negative values to 2,023 µeq/L (median: 212 µeq/L). The median Gran alkalinity in 2015 was 236 µeq/L, similar to that recorded in 2014 (247 µeq/L). The highest values of Gran alkalinity have been consistently measured in Kearl Lake (NE11). The Gran alkalinity in Kearl Lake in 2015 (1,802 µeq/L) was greater than the historical mean for this lake (1,690 µeq/L). In 2015, the Gran alkalinity in lake BM11 in the Birch Mountains (1,827 µeq/L) exceeded that of Kearl Lake and was identified as a statistical outlier falling greater than three standard deviations (SD) from the historic mean Gran alkalinity for this lake.

Conductivity in the acid-sensitive lakes has historically ranged from 8.4 µS/cm to 200 µS/cm (median: 37.5 µS/cm). As with Gran alkalinity, the highest values of conductivity have consistently been recorded in Kearl Lake. The conductivity in Kearl Lake in 2015 was 177 µS/cm. The conductivity in lake BM11 in the Birch Mountains in 2015 (200 µS/cm) exceeded that in Kearl Lake and was identified as a statistical outlier falling greater than 3 SD from the historic mean for this lake.

[1] Concentrations of metals in the acid-sensitive lakes are discussed in greater detail in Appendix F.

[2] Depositional modelling has indicated that the catchments of these *baseline* lakes may receive higher levels of acidic deposition than many of the lakes closer to the oil sands developments because they receive lower levels of base cations from mining activities (Davies 2015; See Section 5.14.4)

Total dissolved solids (TDS) in the acid-sensitive lakes has historically ranged from non-detectable to 219 mg/L (median: 61.5 mg/L). In 2015, the median TDS was 63.0 mg/L, which was near the historic median value. None of the acid-sensitive lakes in 2015 had concentrations of TDS that were greater than three times the historic mean concentration.

The concentration of sulphate in the acid-sensitive lakes has ranged from non-detectable to 19.0 mg/L, with a median concentration of 1.11 mg/L. The median sulphate concentration in 2015 (1.07 mg/L) was near the historical median. None of the acid-sensitive lakes in 2015 had concentrations of sulphate that were greater than three times the historic mean concentration.

By conventional standards (Kortelainen et al. 1989, Forsius et al. 1992, Driscoll et al. 1991), most of the acid-sensitive lakes are considered humic, with an historic median concentration of 21.6 mg/L for dissolved organic carbon (DOC) across all monitoring years. In 2015, the median DOC concentration (20.3 mg/L) was near the historical median concentration. None of the acid-sensitive lakes in 2015 had concentrations of DOC that were greater than three times the historic mean concentration.

Concentrations of nitrates in the acid-sensitive lakes are highly variable and range over two to three orders of magnitude, from non-detectable to 733 µg/L (median: 3.0 µg/L). In 2015, nitrates were considerably lower than in previous years, ranging from non-detectable to 276 µg/L. The median concentration in 2015 was non-detectable. None of the acid-sensitive lakes in 2015 had concentrations of nitrates that were greater than three times the historic mean concentration.

The concentration of chlorophyll *a* has historically ranged from non-detectable to 371 µg/L (median: 10.0 µg/L). Chlorophyll concentrations in 2015 ranged from 0.5 µg/L to 227 µg/L (median: 10.1 µg/L). None of the acid-sensitive lakes in 2015 had concentrations of chlorophyll *a* that were greater than three times the historic mean concentration.

The concentration of total phosphorus in the acid-sensitive lakes has historically ranged from 3 µg/L to 451 µg/L (median: 38.9 µg/L) and; therefore, cover the range of trophic conditions from oligotrophic to hypereutrophic (Wetzel 2001). The median concentration of total phosphorus in 2015 was 36.5 µg/L, similar to the historical median concentration. Dissolved phosphorus in the acid-sensitive lakes has historically ranged from non-detectable values to 197 µg/L (median: 11 µg/L). In 2015, the median dissolved phosphorous concentration (9 µg/L) was lower than the historical median. The difference between the dissolved and total phosphorus concentrations indicates that a large fraction of the total phosphorus is bound to suspended particulates. None of the acid-sensitive lakes in 2015 had concentrations of either total or dissolved phosphorus that were greater than three times the historic mean concentrations.

Lakes having “unusual” water chemistry, defined as those lakes with values and concentrations of at least one of three measurement endpoints – pH, Gran alkalinity, and DOC – that were below or above the 5th and 95th percentile in value or concentration, respectively, measured across all the acid-sensitive lakes in 2015 (Table 5.14-3) were generally the same lakes as in previous years:

1. Measured pH in three lakes (SM6/170, SM4/290 and Clayton Lake/BM7) was below the 5th percentile of measured pH across all acid-sensitive lakes in 2015.
2. Concentration of Gran alkalinity in three lakes (SM9/169, SM6/170 and Clayton Lake/BM7) was below the 5th percentile of Gran alkalinity concentrations across all acid-sensitive lakes in 2015.

These three lakes represent the most poorly-buffered of the acid-sensitive lakes in 2015 and are found in organic soils within the Stony and Birch Mountains subregions.

3. Concentration of DOC in three lakes in the Birch Mountains subregion (Namur Lake/BM2, Legend Lake/BM1 and BM11/199) was below the 5th percentile of DOC concentrations across all acid-sensitive lakes in 2015.

4. Measured pH in three lakes (NE6/182, Kearl Lake/NE11 and BM3/464) was greater than the 95th percentile of measured pH across all acid-sensitive lakes in 2015.

5. Concentration of Gran alkalinity in three lakes (NE10/271, Kearl Lake/NE11 and BM11/199) was greater than the 95th percentile of Gran alkalinity concentrations across all acid-sensitive lakes in 2015. These represent the least acid-sensitive acid-sensitive lakes.

6. Concentration of DOC in two lakes (WF1/165 and WF4/223) both in the West of Fort McMurray, subregion, was greater than the 95th percentile of DOC concentrations across all acid-sensitive lakes in 2015.

5.14.2 Temporal Trends

5.14.2.1 Among-Year Comparisons of Measurement Endpoints using ANOVA

Results of the one-way ANOVA are summarized in Table 5.14-4. The pH and nitrates were the only measurement endpoints showing significant changes over the monitoring years. Based on Tukey's multi-comparison test, the mean pH for the 50 acid-sensitive lakes has increased over the years and was significantly greater in the years following 2008 than in years before 2008 (Figure 5.14-1). A regression fitted to the yearly data in Figure 5.14-1 was statistically significant ($p<0.05$) and accounted for 54% of the variability in the pH between 2002 and 2015. An increase in pH such as this is the opposite effect expected under an acidification scenario.

Concentration of nitrates are decreasing over time in the acid-sensitive lakes (Figure 5.14-1), a trend that is also inconsistent with an acidification scenario. The regression for this trend was also statistically significant ($p<0.05$), although accounting for only 30% of the variability in concentration of nitrates between 2002 and 2015. Concentrations of nitrates are highly variable in the acid-sensitive lakes, both among lakes and among years within each lake. Nitrates are also nutrients that are essential to algal growth and are taken up by actively-growing algae and their high variability and eutrophying characteristics make it difficult to attribute changes in concentration of nitrates in the acid-sensitive lakes to acidification from emission sources. As indicated in Section 5.14.1, concentrations of nitrates were unusually low in the acid-sensitive lakes both in 2014 and 2015.

5.14.2.2 Among-Year Comparisons of Measurement Endpoints and Associated Water Quality Variables using the General Linear Model

The general linear model (GLM) (described in Section 3.2.5.1) was applied to three separate cases:

- Case 1 – all 50 acid-sensitive lakes;
- Case 2 – the ten *baseline* lakes from the Canadian Shield and Caribou Mountains located outside of the area receiving acidifying deposition from oil sands development; and
- Case 3 – the 40 *test* lakes potentially exposed to acidifying emissions.

Table 5.14-4 presents the variables showing statistically-significant changes over time, the direction of the change (slope as positive or negative), and the significance (or non-significance) of the interaction term (lake x year) for each water quality variable. The percentage of the variability accounted for by each significant interaction term is presented in parentheses. Significant differences in an interaction term accounting for more than 5% of the variability occurred for:

- Case 1 (all 50 lakes) – nitrates and chlorophyll *a*;
- Case 2 (*baseline* lakes) – Gran alkalinity, conductivity, calcium, bicarbonate, total phosphorus and chlorophyll *a*; and
- Case 3 (*test* lakes) – nitrates and chlorophyll *a*.

The significant/non-significant designation for a time-related trend was therefore less reliable for the variables listed above.

There was a significant increase in pH in all three cases from 2002 to 2015, which is opposite to the trend expected under an acidification scenario. The fact that a significant increase in pH was observed in both the *baseline* lakes and the *test* lakes suggested that region-wide factors (e.g., changes to the regional hydrology) may be responsible for the increasing pH in these lakes. An increase in pH was also noted in the one-way ANOVA (Section 5.14.2.1).

There was a significant increase in Gran alkalinity in Case 1 and Case 2. The effect was not significant for Case 3 (*test* lakes), although the direction of change for Case 3 (*test* lakes) was still positive. Similar results were observed in 2014. As with pH, an increase in Gran alkalinity is inconsistent with an acidification scenario; the fact that the *baseline* lakes showed significant increases in Gran alkalinity over time suggests that regional factors were responsible.

There were no statistically-significant changes in sulphate in the acid-sensitive lakes from 2002 to 2015 in all three Cases. The direction of change in the *test* lakes (Case 1) was negative while positive in the *baseline* lakes (Case 2). Sulphate is the principal acidifying agent found in oil sands emissions.

Consistent with the results of the one-way ANOVA, there were significant decreases in concentrations of nitrates in Case 1 (all lakes) and Case 3 (*test* lakes) although the variability attributable to the interaction term (lake x year) rendered the results of these tests less reliable. There was also a decrease in concentrations of nitrates in the *baseline* lakes (Case 2) but this decrease was not statistically-significant. A decrease in concentration of nitrates is also inconsistent with an acidification scenario. The variability of nitrates in these lakes and the problems in utilizing nitrates as a measurement endpoint for acidification are discussed in Section 5.14.2.1.

There were no significant changes in DOC across sampling years. The concentration of DOC was increasing (positive slope) in the *test* lakes, although this increase was not statistically significant. Under acidification, decreases in DOC are anticipated.

There was a significant increase in the sum of base cations (SBC) in Case 1 (all lakes) and in the *baseline* lakes (Case 2) but not in the *test* lakes (Case 3). Theoretically, base cations will increase under an acidification scenario as cations in soil are displaced by hydrogen ions. As the *baseline* lakes are remote from the main sources of oil sands emissions and the increase in SBC was not accompanied by decreases in Gran alkalinity or pH, factors other than acidifying emissions were likely causing the increase in SBC in these lakes.

There was no significant change in the concentration of dissolved aluminum across years in any of the three cases. An increase in aluminum was anticipated under an acidification scenario.

There were several significant changes in the ionic characteristics of the acid-sensitive lakes, including:

- an increase in potassium (Cases 1, 2, and 3);
- an increase in bicarbonate (Cases 1, 2, and 3); and
- a decrease in chloride (Cases 1 and 3).

Changes in these ions may be attributed to long-term changes in the hydrologic conditions of the acid-sensitive lakes. These may include changes in the proportion of groundwater input (vs. surface runoff) to each lake.

Chlorophyll *a* increased significantly in Case 1 and Case 3 but the variability attributed to the interaction term (lake x year) rendered these observations unreliable.

Although significant trends in values and concentrations of measurement endpoints in the 50 acid-sensitive lakes were observed, they did not occur in directions indicative of acidification. In the cases of pH, Gran alkalinity and nitrates, significant trends occurred in a direction opposite to that expected under an acidification scenario. Increases in SBC were observed, consistent with acidification, but these increases were also found in the *baseline* lakes and may be a regional phenomenon unrelated to acidification. Changes in SBC in the acid-sensitive lakes are discussed in greater detail in Section 5.14.5. Significant changes in major cations and anions were also observed that may reflect changing hydrological conditions over the monitoring period.

5.14.3 Critical Loads of Acidity and Exceedances of Critical Load

The critical loads of acidity (CL) were calculated for each ASL lake for 2002 to 2015 using the Henriksen steady state water chemistry model modified to include the contribution of organic anions as both strong acids and weak organic buffers (Section 3.2.5.2; WRS 2006; RAMP 2005). The CL is an inherent property of each lake that defines the greatest load of acidifying substances that will not cause ecological damage to the lake. Therefore, the CL represents a measure of the acid-sensitivity of a lake, with a lower critical load representing greater sensitivity to acidification.

Calculations of the CL included the calculation of the original base cation concentrations from the current base cation concentrations using the methodology of Brakke et al. (1990) (Section 3.2.5.3). The values of the runoff for each lake were provided by John Gibson (pers. comm.) and are presented in Appendix F. As noted in Gibson et al. (2010) and RAMP (2012), water yields vary considerably between years with the highest values of yield logically occurring in years with high precipitation. Significant changes in the runoff to a lake result in changes to the critical load and; therefore, the acid sensitivity of a lake may vary depending on the hydrologic regime. Recent studies also suggest that permafrost melt may be contributing to the runoff in 14 northern lakes (notably in the Birch Mountains, Caribou Mountains and NE of Fort McMurray) (Gibson et al. 2015a, 2015b).

Table 5.14-5 provides estimates of the CL of each lake from 2002 to 2015; summary statistics are provided in Table 5.14-6. In 2015, the values of CL ranged from -0.828 keq H^+/ha/yr to 3.952 keq H^+/ha/yr, with a median CL of 0.546 keq H^+/ha/y. The yearly variability in the critical load is evident in Table 5.14-6 in which the median CL for the 50 acid-sensitive lakes appears to be increasing over time. This increase in CL in the ASL was significant ($p<0.05$) in a Mann-Kendall trend analysis and is likely the result of increases in lake buffering capacity (Gran alkalinity) noted in Section 5.14.2.2.

Mean values of CL in 2015 in the five subregions are presented in Table 5.14-7. Similar to previous years, the lowest critical loads were found in lakes in the Stony Mountains subregion, followed by lakes in the West of Fort McMurray and the Canadian Shield subregions. Negative critical loads were calculated for many of the lakes, especially in the Stony Mountains subregion. Negative critical loads occur when the export of alkalinity to the lakes is less than the biological threshold assumed in the model to maintain the ecological integrity of the lake (Section 3.5.5.3). The Stony Mountain lakes with the lowest values of CL, were the most acid-sensitive of the acid-sensitive lakes in 2015 (Table 5.14-7).

5.14.4 Comparison of Critical Loads of Acidity to Modeled Net Potential Acid Input

The critical loads of acidity for each lake were compared to modeled rates of acid deposition for each lake calculated for Teck Energy's Frontier Project (M. Davies, personal communication. February, 2015; Davies et al. 2015). Acid deposition was expressed as the Net Potential Acid Input (PAI), which corrects for nitrogen uptake by plants in the lake catchments (AENV 2007, CEMA 2004b). Nitrogen uptake by plants represents a eutrophying rather than acidifying effect of nitrogen on lake catchments and water chemistry. Results of a study by Watmough et al. (2014) indicate that most of the nitrogen in deposition is currently retained in the catchment. The 2015 PAI predictions provided new estimates of base cation deposition determined from mixed-bed ion exchange resin collectors deployed from 2009 to 2010 at CEMA TEEM study sites in the Athabasca oil sands region (Fenn et al. 2015). The new base cation deposition rates reflect fugitive dust inputs to the lake catchments from oil sands operations. Bulk base cation deposition rates from open study sites were used in the estimate of PAI rather than rates of base cation deposition measured in "flow-through" sites representing deposition to the forest canopy. The open study sites typically displayed lower rates of base cation deposition than "flow-through" sites and therefore result in higher (more conservative) estimates of PAI. The PAI modeling for Teck Energy's Frontier Project also included the deposition of reduced forms of nitrogen (ammonia and ammonium). An "existing conditions" emissions scenario was assumed in the modeling (Davies et al. 2015). As the *baseline* lakes from the Shield and Caribou Mountains were not included in the Teck modeling domain, the isopleths of N and S and base cation deposition furthest from the industrial centre were used to calculate the PAI for these lakes.

The 2015 PAI values for the 50 acid-sensitive lakes ranged from -1.569 keqH+/Ha/y to 0.049 keqH+/Ha/y, with a median of -0.192 keqH+/Ha/y (Table 5.14-5). As indicated by the negative PAI values in Table 5.14-5, the majority of lake catchments (31 of the 50 acid-sensitive lakes) were exposed to basic rather than acidic deposition, the result of high rates of base cation deposition from fugitive dust emissions. Most of the lakes exposed to acidifying deposition were found in the Birch Mountains, the Canadian Shield and the Caribou Mountains, which are regions with relatively low base cation deposition. Ironically, those lakes most remote from sources of oil sands emissions receive the highest levels of acidic deposition. In the case of the Canadian Shield and the Caribou Mountains, the acidic deposition is assumed to result from natural rather than anthropogenic sources. Similar results were found in a soil modeling study conducted by Watmough et al. (2014) in the Athabasca oil sands region in which the potential risk of soil acidification was mitigated by high levels of base cation deposition despite the very low base cation weathering rates in these sandy soils.

Only one of the acid-sensitive lakes exposed to acidifying deposition (BM7/Clayton Lake in the Birch Mountains subregion) had modeled PAI values greater than its CL (Table 5.14-5). In previous years (when the PAI did not include the updated estimates of base cation deposition), 11 to 18 lakes had a CL exceeded by the PAI. BM7/Clayton Lake in 2015 was high in DOC (26 mg/L), very low in pH (4.58 units) and had a very low buffering capacity (Gran alkalinity: -23.2 µeq/L) (Table 5.14-8). BM7/Clayton Lake was noted in Section 5.14.1 and Table 5.14-3 as being the lake with the lowest buffering capacity of the 50 acid-sensitive lakes.

The percentage of acid-sensitive lakes with a PAI in 2015 that exceeded CL (2%, one lake) was lower than the 8% reported in an earlier study on 399 regional lakes conducted for CEMA's NO_xSO_x Management Working Group (WRS 2006). The higher proportion of lakes having CL exceedances in the CEMA study reflected the lower base cation deposition rates incorporated in that study's PAI predictions. For comparison, Henriksen et al. (2002) reported that 11% to 26% of lakes in four sensitive regions of Ontario had levels of PAI exceeding the critical load.

A modeled PAI greater than the critical load of a lake does not mean that acidification is imminent but that there is a potential risk of acidification. Other factors, such as the influence of highly-buffered groundwater seepage to each lake must also be considered in assessing the risks of acidification.

In summary, the results from 2015 indicate that most (31 of 50) of the acid-sensitive lakes were subjected to basic rather than acid deposition and are at low risk of acidification. Only one lake (BM7/Clayton Lake) had a predicted PAI that exceeded its CL. It is also apparent that the depositional rates of base cations from fugitive dust emissions from oil sands operations determine the risk of acidification to an individual lake. Lakes that are remote from the centre of the oil sands developments (>20 km) are exposed to greater rates of acidic deposition than those close to these developments (Watmough et al. 2014). As a result of their exposure to lower rates of base cation deposition, the Birch Mountain lakes were at greater risk to acidification than the Stony Mountain lakes, despite the higher acid sensitivity of the Stony Mountain lakes compared to the Birch Mountain lakes (Section 5.14.3).

5.14.5 Trend Analysis on Measurement Endpoints

Table 5.14-9 presents results of the Mann-Kendall statistical test for each measurement endpoint for each ASL lake. A significant trend over time is indicated by the shading, with red denoting a direction indicative of acidification and green denoting the opposite direction. Directions of change that are consistent with an acidification scenario are: (i) decrease in pH, Gran alkalinity, and concentration of DOC; and (ii) increase in concentration of nitrates, sum of base cations, and concentrations of aluminum and sulphate.

It is important to note that the Mann-Kendall test is a non-parametric test and small consistent increases or decreases in the values of a measurement endpoint that may not be ecologically significant or that fall within the range of analytical error can result in a false conclusion that a significant acidifying trend is occurring. The results of these analyses must therefore be interpreted carefully. In order to help interpret the results of the trend analyses, Shewhart control charts of the measurement endpoints have been prepared for those lakes where significant changes have occurred in a direction indicative of acidification (Figure 5.14-2). The control charts graphically display the variable in the particular lake over time and help to avoid false conclusions that may arise from the Mann-Kendall analysis. The control charts were interpreted using the rules outlined in Section 3.2.5.2.

The trends, both indicative and counter-indicative, of acidification from Table 5.14-9 were:

1. There were significant increases in pH in 27 of the 50 acid-sensitive lakes over all subregions. An increase in pH is the opposite effect expected from an acidification scenario. Most of the lakes showing an increase in pH in 2015 also showed this trend in previous years. Significant increases in pH over time in the acid-sensitive lakes were also detected in both the one-way and the GLM analyses of variance (Section 5.14.2). An increase in pH appears to be a regional phenomenon, perhaps the result of changing hydrologic conditions in the acid-sensitive lakes or high rates of base cation deposition (Section 5.14.4).

2. Gran alkalinity increased significantly in 18 acid-sensitive lakes located in all of the subregions, including the Stony Mountains (Table 5.14-9). Lakes from the Stony Mountains are the most acid-sensitive of the acid-sensitive lakes and would be expected to show the earliest indications of acidification (Section 5.14.3). A significant increase in Gran alkalinity over time was also detected in the GLM analyses of variance for Case 1 (all lakes) and Case 2 (*baseline* lakes) (Section 5.14.2.2). As with pH, changing hydrologic conditions may be responsible for the observed increases in Gran alkalinity in the acid-sensitive lakes. A significant decreasing trend in Gran alkalinity was detected in only one ASL lake, NE9. This lake is highly-buffered (mean Gran alkalinity: 1301 μeq/L) and is located in the NE of Fort McMurray subregion. The decrease in Gran alkalinity in this lake was not accompanied by a significant increase in the concentration of sulphate, which is the principal acidifying agent. In addition, the control chart for this lake did not indicate that a significant trend of decreasing Gran alkalinity was occurring (Figure 5.14-2). Acidification therefore does not appear to be the reason for the decline in Gran alkalinity in this lake.

3. There was a significant decrease in sulphate concentrations in ten acid-sensitive lakes. These decreases in sulphate occurred in lakes located in most of the subregions and are inconsistent with an acidification scenario as sulphate is the principal acidifying agent. There was a significant increase in sulphate concentrations in three acid-sensitive lakes (WF4 in the West of Fort McMurray subregion, BM2 in the Birch Mountains and CM1 in the Caribou Mountains). All three lakes are highly-buffered with mean Gran alkalinities of 730 μeq/L, 421 μeq/L and 474 μeq/L, respectively. The actual range of sulphate concentrations in these lake over the 14 to 16 years of monitoring was quite small but sufficiently consistent in direction to be significant in the trend analysis. In none of these three lakes was the increase in sulphate associated with significant decreases in pH or Gran alkalinity that would be expected under an acidification scenario. In lakes BM2 and CM1, the increases in sulphate were in fact associated with significant increases in pH and Gran alkalinity. The control charts for these three lakes suggest that a statistically-significant trend of increasing sulphate has not yet occurred in lakes WF4 and BM2 but is

occurring in lake CM1 (Figure 5.14-2). It is unlikely that acidification is occurring in CM1 as the sulphate increases in this lake were associated with increases in pH and Gran alkalinity. Acidification does not appear to be the reason for the increase in sulphate concentration in these three acid-sensitive lakes.

4. There were no significant increases in the concentration of nitrates over time in any of the acid-sensitive lakes (Table 5.14-9). These observations are consistent with the results of the ANOVA in Section 5.14.2. The modeling study of Watmough et al. (2014) found that practically all of the N deposition in the Athabasca oil sands region is eutrophying and is retained in soil and vegetation in the lake catchments.

5. There were significant decreases in concentrations of DOC in five acid-sensitive lakes: SM1 and SM4 and SM8 in the Stony Mountains subregion; NE9 in the NE of Fort McMurray subregion; and BM2 in the Birch Mountains. The decreasing trends in DOC concentration in these lakes were largely inconsistent with trends in other variables expected under an acidification scenario:

    - The decrease in DOC concentration in lake SM8 was associated with a significant increase in Gran alkalinity;
    - The decrease in DOC concentration in lake SM1 was associated with a significant increase in pH and decrease in sulphate;
    - The decrease in DOC concentration in lake SM4 was not associated with significant changes in pH, Gran alkalinity or sulphate but was associated with a significant decrease in SBC;
    - The decrease in DOC concentration in lake BM2 was associated with significant increases in both pH and Gran alkalinity;
    - The decrease in DOC concentration in lake NE9 was associated with a significant decrease in Gran alkalinity but was not associated with the expected decrease in pH or increase in sulphate.

    The control charts for these five lakes indicate that a significant decreasing trend in concentration of DOC is not occurring in any of these lakes (Figure 5.14-2).The control chart for lake NE9 shows that DOC in this lake has actually changed little in the last ten years and the significant trend is the result of small changes in concentration that are within the analytical error for this analysis. The changes in DOC concentrations in these lakes were likely attributable to factors other than acidification.

6. In most regions, exposure to acidic emissions initially results in an increase in SBC in a lake as these ions are displaced by hydrogen ions from soils in the lake catchment. The trend analysis identified significant increases in SBC over time in lakes WF2 and WF7, located in the West of Fort McMurray subregion; lakes NE8 and NE11 (Kearl Lake), located NE of Fort McMurray; Namur Lake (BM2) and Lake BM1 located in the Birch Mountains subregion; lake S3 in the Shield subregion; and lakes CM1 and CM2 located in the Caribou Mountains. In all cases except for Kearl Lake (NE11), the increases in SBC were associated with a significant increase in pH and/or

Gran alkalinity and often a decrease in sulphate, both trends inconsistent with acidification. Kearl Lake has historically been the lake with the highest buffering capacity in the acid-sensitive lakes (Gran alkalinity: 1802 µeq/L in 2015). The control charts indicate that no significant increasing trend in SBC was occurring in any of these lakes except for Lake CM1, a *baseline* lake in the Caribou Mountains remote from oil sands emissions (Figure 5.14-2). The increases in SBC in these nine lakes can therefore be attributed to increased alkalinity loading to these lakes consisting of calcium and magnesium bicarbonates rather than calcium and magnesium sulphates that would be expected during catchment acidification. It is interesting to note that significant increases in bicarbonate were indeed noted in the ANOVA in both *baseline* and *test* lakes (Section 5.14.2.2). Loading of calcium and magnesium sulphates would tend to lower both Gran alkalinity and pH and increase sulphate concentrations.

The use of SBC as a measurement endpoint in the Athabasca oil sands region is more complicated than elsewhere because of high rates of base cation deposition from fugitive dust sources resulting from mining activities (Fenn et al. 2015, Watmough et al. 2014). Modelling and lysimeter measurements have indicated that the high rates of base cation deposition in the Athabasca oil sands region have resulted in high concentrations of base cations in catchment soil solutions, despite very low natural base cation weathering rates (Watmough et al. 2014). Given the importance of groundwater sources to these lakes and their high hydrological connectivity to their wetlands-dominated basins (e.g., Schmidt et al. 2010, Gibson et al. 2002), increasing base cation concentrations would be expected in many of the acid-sensitive lakes even without soil acidification.

7. There was a significant increase in concentrations of dissolved aluminum in Lake NE9 located in the NE of Fort McMurray subregion. Similar to nitrates, concentrations of dissolved aluminum in the acid-sensitive lakes are highly variable both among lakes and among years within a given lake. The increase in concentrations of dissolved aluminum in this lake was associated with a significant decrease in Gran alkalinity and DOC concentration, consistent with an acidification scenario. However, the control chart for this lake (Figure 5.14-2) indicates that there is no significant increasing trend in concentration of dissolved aluminum in this lake and that concentrations of dissolved aluminum in this lake are low and ranged from non-detectable to only 4.29 µg/L (mean: 1.28 µg/L). The small year-to-year changes detected in the trend analysis likely reflect natural variability in this measurement endpoint.

The results of the Mann-Kendall trend analyses revealed a number of significant chemical trends in individual acid-sensitive lakes. There were significant increases in pH (27 lakes) and Gran alkalinity (18 lakes) and decreases in sulphate (10 lakes) all inconsistent with an acidification scenario. In a small number of lakes, trends in the values of the measurement endpoints occurred in a direction indicative of acidification but these were either not supported by concomitant decreases in pH or Gran alkalinity or the changes were very small and within analytical error. The natural variability in concentration was high for some measurement endpoints (e.g., nitrates) and outliers were common. Trends in some of these variables may reflect hydrological changes to these lakes and their catchments or the effects of high base cation deposition. In general, the significant trends identified by the Mann-Kendall analysis were not supported statistically by the control plots.

5.14.6 Control Charting of ASL Measurement Endpoints in Lakes at Greatest Risk to Acidification

Of the 19 lakes exposed to acid deposition (nine lakes in the Birch Mountains subregion, five lakes in the Canadian Shield subregion and five in the Caribou Mountains, Table 5.14-5), the five lakes most at risk to acidification were selected for control charting. An acidification risk factor was calculated from the ratio of PAI to the critical load (Table 5.14-10). The greater the ratio in a lake, the greater the risk of acidification. Four of the lakes are located in the Birch Mountains while the fifth lake is located in the Canadian Shield. Acidification, if it were occurring, would be evident first in these lakes.

Control charts for pH, SBC, sulphate, DOC, nitrates, Gran alkalinity, and dissolved aluminum are presented in Figure 5.14-3 to Figure 5.14-9. Potential trends identified in the control charts were examined using the control chart rules presented in Section 3.2.5.2. Similar to previous years, the control charts for all measurement endpoints showed isolated exceedances of ±2SD during the monitoring period and some of these exceedances were in a direction consistent with acidification, while others were not. Two consecutive exceedances of the ±2SD limit in a direction consistent with acidification are required to indicate a significant trend.

The following measurement endpoints/lakes showed exceedances of the ±2SD limit in a direction consistent with acidification at some point during the period of data record:

- pH – lake BM9 (1999) and BM7/Clayton Lake (1999);
- SBC – lake BM6 (2015) and BM7/Clayton Lake. (2011);
- Sulphate – lakes BM5 (1999), BM6 (1999), BM9/442 (1999), and BM7/Clayton Lake. (2007);
- DOC – lakes BM5/457 and BM6 (2010);
- Nitrates –lakes BM3 (2001, 2011), BM6 (2001), BM9 (2001) and BM7/Clayton Lake. (2011); and
- Gran alkalinity – lake BM6 (2005).

In all cases (except lake BM6 in 2015), the concentrations of the measurement endpoints returned to values within the ±2SD limits in the following year. The SBC in lake BM6 in 2015 and nitrates in lake BM9 in 2001 and Clayton Lake (BM7) in 2011 actually exceeded the 3SD limit for these variables and then (in the latter two cases) returned to normal values in the following year (Figure 5.14-7). Based on the appearance of the control charts, these three values appear to be outliers and anomalies rather than evidence of trends in these lakes indicative of acidification. With these three exceptions, the results of the control chart analyses do not indicate that acidification was occurring in any of these five lakes that were most at risk to acidification.

5.14.7 Classification of Results

Results of the analysis of the acid-sensitive lakes in 2015 compared to the historical data suggested that there have been no significant changes in the water chemistry of the 50 lakes across the years of monitoring that could be attributed directly to acidification. These results were consistent with the revised estimates of potential acid input (PAI) suggesting that only 19 of the 50 acid-sensitive lakes (all remote from the industrial developments) were actually exposed to acidifying deposition.

A summary of the acid-sensitive lakes in 2015 with respect to the potential for acidification was prepared for each physiographic subregion by examining deviations from the mean concentrations of the measurement endpoints (in a direction indicative of acidification) for each lake within a subregion. A two standard deviation criterion was used in each case. In 2015, there were eight exceedances of the ±2SD criterion over four measurement endpoints. The Stony Mountains, Birch Mountains and Caribou Mountains were rated as having a **Moderate** indication of incipient acidification. The higher ratings in 2015 (compared with previous years) were largely attributed to five exceedances of the ±2SD criterion for SBC in the acid-sensitive lakes. As discussed in Section 5.14.5, the increases in base cation concentrations in these lakes may be due to hydrological changes affecting base cation loading rates rather than increased weathering processes resulting from acidification. The other three subregions (NE of Fort McMurray, W of Fort McMurray and the Canadian Shield), were rated as having a **Negligible-Low** indication of incipient acidification.

Table 5.14-1 Morphometric statistics for the 50 acid-sensitive lakes.

Variable	Lake Area (km^2)	Catchment Area (km^2)	Maximum Depth (m)
Minimum	0.03	0.57	0.91
Maximum	44.0	166	27.4
Median	1.32	13.2	1.83

Table 5.14-2 Summary of chemical characteristics of the acid-sensitive lakes, 1999 to 2015.

Variable	Mean		Median		Minimum		Maximum		5th percentile 2015	95th percentile 2015	Coef. Variation 1999 to 2015
	1999 to 2015	2015	1999 to 2015	2015	1999 to 2015	2015	1999 to 2015	2015			
Lab pH	6.70	7.12	6.86	7.14	3.97	4.58	9.87	9.19	5.43	8.52	14.3
Total alkalinity (µeq/L)	342	421	230	271	0.000	25.0	2032	1852	25.0	1247	19.2
Gran alkalinity (µeq/L)	327	395	212	236	-57.2	-23.20	2023	1827	10.53	1264	5.53
Specific conductivity (µS/cm)	45.6	53.4	33.8	37.5	8.40	9.99	200	200	12.7	135	79.1
Total dissolved solids (mg/L)	69.0	68.7	61.5	63.0	0.02	10.00	219	152	14.2	128	53.3
Turbidity (NTU)	4.71	8.49	2.31	3.30	0.010	0.280	54.4	54.4	0.784	31.5	141
Total suspended solids (mg/L)	7.76	14.5	2.67	5.00	0.000	0.025	175	158	0.025	42.7	233
Colour (TCU)	150	86.9	120	70.10	0.500	0.500	948	296	6.28	234	78.2
Sodium (mg/L)	2.05	2.45	1.37	1.70	0.020	0.21	12.4	10.8	0.47	7.32	98.9
Potassium (mg/L)	0.543	0.581	0.440	0.400	0.000	0.050	2.450	1.75	0.099	1.36	75.5
Calcium (mg/L)	5.91	6.78	4.80	5.27	0.002	0.280	32.2	24.1	1.06	18.7	81.6
Magnesium (mg/L)	1.92	2.10	1.49	1.52	0.005	0.005	13.6	10.1	0.264	5.70	85.3
Bicarbonate (mg/L)	20.8	25.4	14.00	16.0	0.000	1.25	124	113	1.25	78.5	101
Chloride (mg/L)	0.324	0.295	0.157	0.110	0.015	0.040	2.64	2.37	0.050	1.10	143
Sulphate (mg/L)	2.35	2.70	1.11	1.070	0.020	0.020	19.0	18.2	0.02	13.1	141
Total dissolved nitrogen (µg/L)	828	776	699	629	105	270	3010	2750	360	1841	55.8
Ammonia (µg/L)	35.0	19.5	14.0	8.00	0.35	1.5	1509	568	1.5	18.2	282
Nitrate + Nitrite (µg/L)	17.5	8.2	3.0	1.0	0.020	1.0	733	276	1.0	12.2	315
Total phosphorus (µg/L)	56.1	65.8	38.9	36.5	3.0	3.0	451	332	11.5	219	96.9
Dissolved phosphorous (µg/L)	20.9	17.2	11.00	9.00	1.00	1.00	197	93.0	2.45	55.2	119
Dissolved inorganic carbon (mg/L)	3.46	4.37	2.10	2.45	0.027	0.30	22.3	22.3	0.30	14.8	114
Dissolved organic carbon (mg/L)	23.1	20.4	21.6	20.3	6.60	6.60	92.2	43.2	8.03	39.4	45
Chlorophyll *a* (µg/L)	22.5	28.8	10.0	10.1	0.10	0.497	371	227	1.13	130	173
Iron (mg/L)	0.413	0.313	0.185	0.138	0.001	0.002	5.44	2.17	0.009	1.25	142
Total nitrogen (µg/L)	1200	1303	966	1050	274	361	7100	7100	470	3256	76.0
Total Kjeldahl nitrogen (µg/L)	1181	1296	941	1050	273	361	7094	7094	464	3250	76.9
Sum base cations (µeq/L)	555	632	443	476	32.2	40.5	2411	2181	143	1562	76.8
Dissolved aluminum (µg/L)	72.7	65.8	21.3	18.7	0.100	0.66	850	828	0.725	222	164

Notes:

Grey shading denotes measurement endpoints for the ASL component.

Yellow shading denotes values that are less than the detection limit with values set to one half the detection limit.

Table 5.14-3 Acid-sensitive lakes with chemical characteristics either below the 5th or above the 95th percentile in 2015.

Lake	Subregion	pH	Gran Alkalinity (µeq/L)	DOC (mg/L)
5th percentile (2015)		5.43	10.5	8.03
95th percentile (2015)		8.52	1264	39.4
SM9/169	Smoky Mountains	6.20	2.00	15.7
SM6/170	Smoky Mountains	4.99	3.60	17.3
SM4/290	Smoky Mountains	5.43	21.40	12.5
WF1/165	West of Fort McMurray	6.95	343.20	40.1
WF4/223	West of Fort McMurray	7.70	773.60	42.2
NE6/182	Northeast of Fort McMurray	8.76	1,157.00	16.6
NE10/271	Northeast of Fort McMurray	8.32	1,345.40	18.0
NE11/418 (Kearl L.)	Northeast of Fort McMurray	8.69	1,802.40	22.2
BM2/436 (Namur L.)	Birch Mountains	7.65	460.80	7.0
BM1/444 (Legend L.)	Birch Mountains	7.34	217.40	7.8
BM7/448 (Clayton)	Birch Mountains	4.58	-23.2	26.0
BM3/464	Birch Mountains	9.19	287.60	18.0
BM11/199	Birch Mountains	7.96	1,827.40	6.6

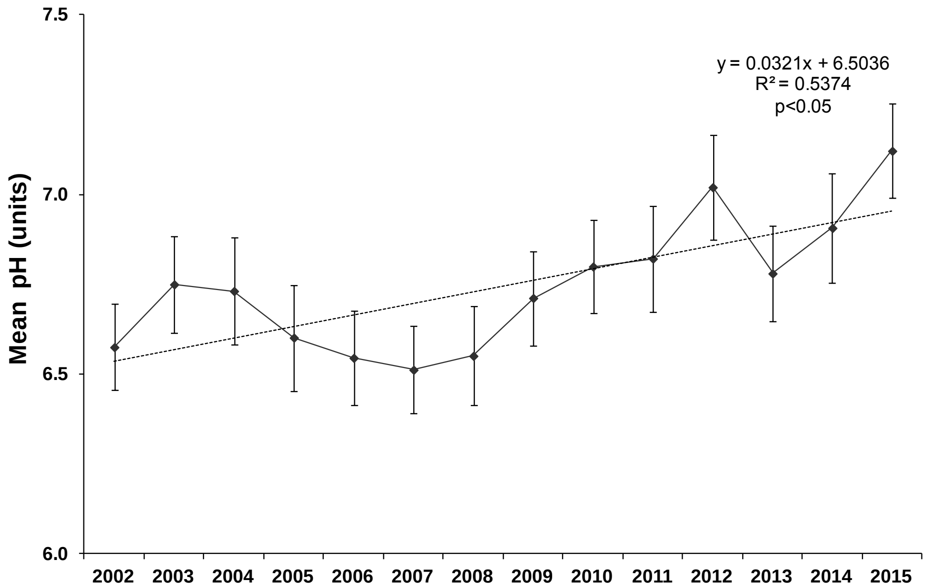
Notes:

Yellow shading denotes values below the 5th percentile in 2015.

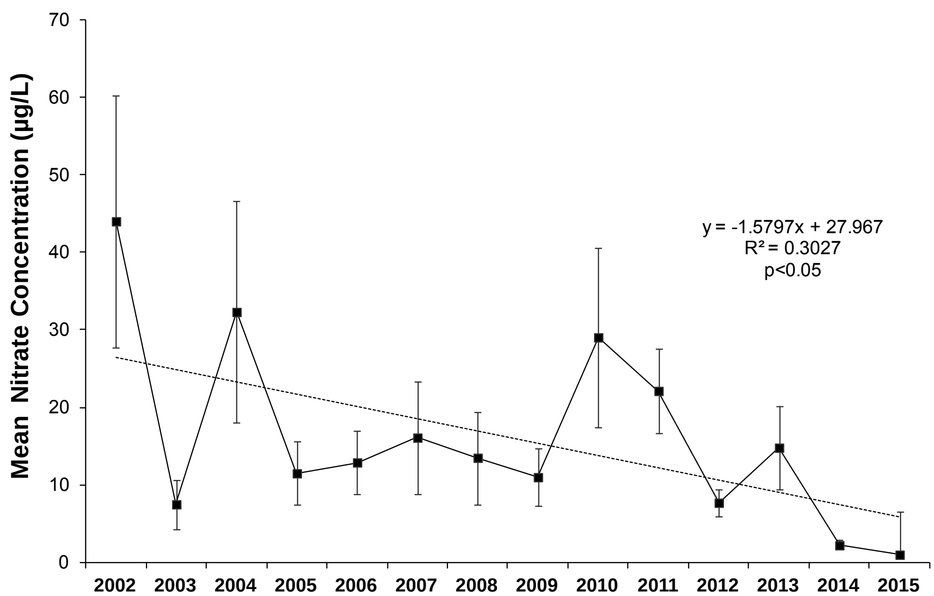
Green shading denotes values above the 95th percentile in 2015.

Figure 5.14-1 a) pH and b) concentration of nitrates in all 50 acid-sensitive lakes combined, 2002 to 2015.

(a)



(b)



Note: Error bars represent one standard error of the mean.

Table 5.14-4 Among-year comparisons of ASL measurement endpoints using the one-way analysis of variance (ANOVA) and the general linear model (GLM), 2002 to 2015.

Measurement Endpoint	One-Way ANOVA/K-W All Lakes	GLM Case 1 – All Lakes			GLM Case 2 – *Baseline* Lakes			GLM Case 3 – *Test* Lakes		
	Significance	Significance	Direction (slope)	Interactive Term	Significance	Direction (slope)	Interactive Term	Significance	Direction (slope)	Interactive Term
pH	S	S	Positive	S (1.37)	S	Positive	NS	S	Positive	NS
Gran alkalinity	NS	S	Positive	S (2.1)	S	Positive	S (6.59)	NS	Positive	S(1.14)
Sum base cations	NS	S	Positive	S (2.36)	S	Positive	NS	NS	Positive	S (1.37)
Conductivity	NS	NS	Positive	S (2.51)	S	Positive	S (9.20)	NS	Negative	S (1.18)
TDS	NS	NS	Positive	NS	S	Positive	NS	NS	Positive	NS
Sodium	NS	NS	Positive	NS	NS	Positive	NS	NS	Negative	NS
Potassium	S	S	Positive	S (4.1)	S	Positive	NS	S	Positive	NS
Calcium	NS	NS	Positive	S (2.59)	S	Positive	S (8.13)	NS	Negative	NS
Magnesium	NS	NS	Positive	S	NS	Positive	NS	NS	Positive	S (1.53)
Bicarbonate	NS	S	Positive	S (2.1)	S	Positive	S (6.83)	S	Positive	S (1.08)
Chloride	NS	S	Negative	S (2.82)	NS	Negative	S (1.4)	S	Negative	S
Sulphates	NS	NS	Positive	S (2.59)	NS	Positive	S	NS	Negative	S (1.82)
Nitrates	S	S	Negative	S (29.7)	NS	Negative	NS	S	Negative	S (30.47)
Total phosphorus	NS	S	Positive	S (3.8)	NS	Negative	S (7.83)	NS	Positive	NS
DOC	NS	NS	Negative	NS	NS	Negative	NS	NS	Positive	S (4.55)
Chlorophyll *a*	NS	S	Positive	S (10.8)	NS	Positive	S (20.1)	S	Positive	S (10.8)
Aluminum	NS	NS	Positive	NS	NS	Positive	NS	NS	Positive	NS

Note: S = statistically significant (p<0.05), NS = not statistically significant. Percentage of the variation attributed to the interaction between lake number and year is indicated in brackets when the term was significant. Shading denotes measurement endpoints for the ASL component. Kruskal Wallis (K-W) non-parametric test was used in the one-way ANOVA when the variances were significantly different.

Table 5.14-5 Critical loads of acidity in the acid-sensitive lakes, 2002 to 2015.

NO_xSO_x GIS No.	Original AESRD Designation	Current AEP Name	Gross Catchment Area (km^2)	Critical Loads (keqH+/Ha/y)[1]														
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Net PAI (keqH+/Ha/y)
Stony Mountains Subregion																		
168	A21	SM10	18.2	-0.071	-0.082	-0.099	-0.131	-0.101	-0.052	-0.117	-0.101	-0.140	-0.121	-0.121	-0.145	-0.130	-0.036	-0.220
169	A24	SM9	8.3	-0.184	-0.141	-0.394	-0.519	-0.257	-0.078	-0.234	-0.206	-0.258	-0.422	-0.326	-0.383	-0.311	0.029	-0.269
170	A26	SM6	13.1	-0.016	-0.019	-0.029	-0.052	-0.042	-0.009	0.002	-0.026	-0.049	-0.035	-0.046	-0.060	-0.046	-0.038	-0.309
167	A29	SM5	3.7	-0.078	-0.055	-0.014	0.004	0.090	-0.010	-0.257	0.042	-0.283	-0.096	-0.122	-0.281	-0.140	0.397	-0.245
166	A86	SM7	6.9	0.064	0.141	0.182	0.249	0.193	0.144	0.472	0.511	0.316	0.041	0.280	0.277	0.125	0.319	-0.454
287	25	SM8	9.6	-0.092	-0.135	-0.198	-0.284	-0.201	-0.026	-0.166	-0.215	-0.266	-0.199	-0.212	-0.265	-0.208	0.013	-0.310
289	27	SM3	7.4	0.034	0.071	0.079	0.126	0.076	0.088	0.092	0.115	0.001	0.057	0.115	0.066	0.151	0.207	-0.252
290	28	SM4	11.7	0.001	0.019	-0.004	-0.005	0.006	-0.007	0.001	0.000	-0.033	-0.007	-0.015	-0.022	-0.016	-0.029	-0.344
342	82	SM2	15.4	0.064	0.059	0.117	0.155	0.118	0.012	0.115	0.139	0.140	0.095	0.107	0.096	0.080	0.109	-0.434
354	94	SM1	9.6	0.707	0.676	0.803	1.033	0.426	0.152	1.394	1.413	1.022	0.727	0.823	0.772	0.809	0.802	-0.750
West of Fort McMurray Subregion																		
165	A42	WF1	10.4	0.382	0.883	1.378	2.112	0.964	0.727	2.110	2.252	1.858	1.352	1.167	1.380	0.798	1.109	-0.217
171	A47	WF2	4.3	0.104	0.170	0.126	0.468	0.150	-	0.792	0.390	0.169	0.239	0.318	0.291	0.361	0.321	-0.222
172	A59	WF3	51.6	0.006	0.000	-0.001	-0.019	-0.027	-0.018	0.035	0.021	0.010	0.011	-0.013	-0.027	0.004	0.030	-0.297
223	P94	WF4	1.8	0.112	0.090	0.117	1.199	0.194	0.087	0.330	0.318	0.155	0.262	0.306	0.296	0.329	0.331	-0.270
225	P96	WF5	5.0	0.123	0.264	0.229	1.469	0.383	0.202	0.413	0.451	0.553	0.868	0.703	0.443	0.533	0.457	-0.167
226	P97	WF6	4.2	0.088	0.340	0.202	2.655	0.192	0.166	0.287	0.391	0.464	0.374	0.358	0.470	0.463	0.368	-0.008
227	P98	WF7	1.6	0.288	1.131	0.576	0.835	0.947	0.460	1.058	1.451	1.645	1.245	1.365	1.324	1.169	1.392	-0.051
267	1	WF8	23.1	0.197	0.400	0.349	0.934	0.415	0.147	-	0.758	0.348	0.517	0.522	0.410	0.429	0.457	-1.141
Northeast of Fort McMurray Subregion																		
452	L4	NE1	16.8	0.092	0.092	0.069	0.262	0.087	0.064	0.243	0.125	0.078	0.202	0.243	0.165	0.162	0.077	-1.091
470	L7	NE2	15.1	0.171	0.141	0.074	0.312	0.745	0.156	0.228	0.201	0.208	0.285	0.356	0.232	0.195	0.297	-0.966
471	L8	NE3	24.0	0.341	0.601	0.431	1.107	0.604	0.226	0.445	0.486	0.424	0.572	0.802	0.598	0.660	0.656	-0.793
400	L39	NE4	3.2	1.069	0.913	0.715	0.654	1.473	0.723	1.344	1.347	0.796	1.239	1.143	0.913	0.782	1.329	-0.004
268	E15	NE5	7.3	1.349	2.186	1.478	2.291	0.257	0.409	1.976	2.842	2.286	2.031	2.357	0.329	1.521	1.928	-0.919
182	P23	NE6	8.3	0.352	1.251	1.443	4.085	0.347	2.000	0.065	2.360	3.172	2.817	2.570	1.426	3.060	2.356	-0.997
185	P27	NE7	5.9	0.037	0.015	-0.072	0.279	-0.029	0.031	0.047	0.016	0.046	0.088	-0.146	-0.004	0.118	0.170	-1.107
209	P7	NE8	0.8	0.852	0.781	0.348	0.600	0.416	0.413	2.472	0.836	1.267	0.945	0.705	1.611	1.211	1.418	-0.935

Note: Shaded values denote modeled Potential Acid Input that exceed critical loads. PAI obtained from the Frontier Project EIA (Teck 2015, provisional) representing emissions from industrial sources that include all the existing sources and approved sources from 2008. The PAI is the net PAI after correction for nitrogen uptake by plants in the catchment (eutrophication). Runoff in all CL measurements estimated using the IMB method from data provided by Gibson et al. (pers. comm.).

[1] Please see Section 3.2.5.2 for a description of how critical loads were calculated.

Table 5.14-5 (Cont'd.)

NO_xSO_x GIS No.	Original AESRD Designation	Current AEP Name	Gross Catchment Area (km^2)	Critical Loads (keqH+/Ha/y)[1]														Net PAI (keqH+/Ha/y)
				2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Northeast of Fort McMurray (Cont'd)																		
270	4	NE9	11.2	3.371	4.488	4.986	8.031	4.567	1.331	3.932	6.714	5.356	4.528	4.236	3.414	3.619	3.721	-0.672
271	6	NE10	17.1	2.446	2.659	6.395	7.347	3.557	2.317	3.067	4.905	3.638	3.994	3.901	3.486	3.273	3.641	-0.626
418	Kearl L.	NE11	77.2		2.759	2.316	5.097	1.715	0.801	2.588	2.739	2.046	2.984	3.169	2.624	2.593	2.943	-1.569
Birch Mountains Subregion																		
436	L18	BM2	165.5	1.382	2.067	1.715	2.194	1.726	1.077	2.356	2.283	2.185	2.056	2.093	2.104	2.029	1.992	0.031
442	L23	BM9	33.3	0.260	0.353	0.267	0.362	0.308	0.295	0.427	0.437	0.233	0.113	0.394	0.427	0.378	0.328	0.040
444	L25	BM1	58.7	0.491	0.819	0.772	0.854	0.901	0.560	1.092	1.301	0.847	0.933	1.177	1.231	1.221	1.057	0.044
447	L28	BM6	13.7	-0.123	-0.179	-0.012	-0.340	-0.242	-0.017	0.001	-0.184	0.115	-0.084	-0.080	-0.204	-0.177	0.290	0.028
448	L29	BM7	4.7	-0.685	-0.505	-0.490	-0.717	-0.419	-0.082	-0.390	-0.697	-0.485	-0.312	-1.015	-0.761	-0.762	-0.828	0.041
454	L46	BM8	32.5	0.433	0.590	0.351	0.855	0.409	0.328	0.514	0.618	0.348	0.517	0.607	0.492	0.674	0.726	0.032
455	L47	BM4	37.3	0.572	0.735	1.640	1.436	0.807	0.406	0.854	1.321	0.871	1.086	1.003	1.117	0.886	0.929	0.026
457	L49	BM5	30.6	0.457	0.664	0.417	0.883	0.501	0.227	0.565	0.714	0.438	0.414	0.638	0.533	0.578	0.704	0.049
464	L60	BM3	29.8	0.336	0.634	0.490	0.736	0.375	0.237	0.549	0.579	0.436	0.570	0.789	0.579	0.616	0.904	0.035
175	P13	BM10	5.2	0.393	0.345	0.662	1.455	0.618	0.298	0.813	2.806	0.520	0.932	0.972	0.655	0.715	0.761	-0.015
199	P49	BM11	0.6	0.110	0.150	0.168	0.196	0.209	0.079	0.139	0.143	0.103	0.152	1.830	0.124	0.139	2.056	-0.005
Canadian Shield Subregion																		
473	A301	S4	114.6	0.105	0.130	0.102	0.327	0.165	-	0.213	0.196	0.147	0.196	0.218	0.191	0.175	0.196	0.017
118	L107	S1	13.4	2.042	2.265	1.785	2.679	1.998	1.431	2.706	2.156	2.228	2.290	2.383	2.335	2.350	2.407	0.017
84	L109	S2	112.6	0.181	0.208	0.147	0.333	0.156	-	0.244	0.318	0.165	0.278	0.308	0.265	0.258	0.283	0.017
88	O-10	S5	4.5	0.273	0.312	0.204		0.282	-	0.400	0.544	0.209	0.328	0.375	0.374	0.281	0.415	0.017
90	R1	S3	37.9	0.346	0.479	0.351	0.550	0.444	0.547	0.608	0.587	0.460	0.544	0.590	0.581	0.558	0.613	0.017
Caribou Mountains Subregion																		
146	E52	CM1	24.	1.049	1.332	0.994	2.344	1.801	2.065	3.763	3.048	3.497	2.898	3.399	3.613		3.952	0.017
152	E59	CM2	46.8	0.486	0.593	0.439	0.956	0.604	0.578	0.791	1.005	0.999	0.909	1.075	1.162		0.597	0.017
89	E68	CM3	28.0	0.468	0.458	0.269	1.275	0.729	0.538	0.432	0.664	0.706	0.638	0.901	0.678		0.656	0.017
97	O-2 E67	CM4	38.1	0.532	0.563	0.345	0.187	0.310	0.387	0.457	0.447	0.904	0.697	0.854	0.779		0.777	0.017
91	O-1/E55	CM5	2.8	0.093	0.138	0.084	8.728	0.858	0.291	0.394	0.669	0.260	1.051	0.531	0.480		0.496	0.017

Note: Shaded values denote modeled Potential Acid Input that exceed critical loads. PAI obtained from the Frontier Project EIA (Teck 2015) representing emissions from industrial sources that include all the existing sources and approved sources from 2008. The PAI is the net PAI after correction for nitrogen uptake by plants in the catchment (eutrophication). Runoff in all CL measurements estimated using the IMB method from data provided by Gibson et al. (pers. comm.).

[1] Please see Section 3.2.5.2 for a description of how critical loads were calculated.

Table 5.14-6 Summary of critical loads of acidity in the acid-sensitive lakes, 2002 to 2015.

Item	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
No. of lakes	49	50	50	49	50	46	49	50	50	50	50	50	45	50
Minimum CL	-0.685	-0.505	-0.490	-0.717	-0.419	-0.082	-0.390	-0.697	-0.485	-0.422	-1.015	-0.761	-0.762	-0.828
Maximum CL	3.371	4.488	6.395	8.728	4.567	2.317	3.932	6.714	5.356	4.528	4.236	3.613	3.619	3.952
Average CL	0.429	0.637	0.645	1.339	0.597	0.428	0.809	0.984	0.803	0.816	0.872	0.724	0.700	0.882
Median CL	0.260	0.349	0.262	0.736	0.361	0.232	0.432	0.527	0.386	0.517	0.598	0.457	0.429	0.546
No. of lakes in which the PAI is greater than the CL	2	2	2	2	2	2	2	2	1	2	2	2	2	1

Table 5.14-7 Mean critical loads of acidity for acid-sensitive lakes within each subregion in 2015.

Subregion	Critical Load keq H^+/ha/y
Stony Mountains	0.177
West of Fort McMurray	0.558
Northeast of Fort McMurray	1.685
Birch Mountains	0.811
Canadian Shield	0.783
Caribou Mountains	1.295

Table 5.14-8 Chemical characteristics of acid-sensitive lakes with the modeled potential acid input in 2015 greater than the calculated critical load.

AEP Name	NO_xSO_x No.	Subregion	pH	Gran Alkalinity (µeq/L)	Conductivity (µS/cm)	DOC (mg/L)	Lake Area (km^2)
BM7(Clayton L.)	448	Birch Mts.	4.58	-23.2	13.6	26.0	0.65

Table 5.14-9 Results of Mann-Kendall trend analyses on measurement endpoints for the acid-sensitive lakes, 1999 to 2015.

AEP ID	NO_XSO_X ID	pH	Gran Alkalinity (µeq/L)	Sulphate mg/L	Nitrates (µg/L)	Diss. Organic Carbon (mg/L)	SBC (µeq/L)	Aluminum (µg/L)	Potential Acid Input keq/H+/ha/y
SM10	168	1.57	0.86	-3.42	-0.66	-1.61	-2.35	-1.03	-0.220
SM9	169	1.61	0.50	-2.60	-0.70	0.45	-1.11	-0.48	-0.269
SM6	170	-0.37	1.85	-2.60	-1.11	0.74	-1.77	1.17	-0.309
SM5	167	2.68	2.84	-1.94	0.79	-1.07	-0.29	0.07	-0.245
SM7	166	2.61	2.18	-1.22	0.00	-0.77	1.13	-0.75	-0.454
SM8	287	0.77	1.97	-1.20	0.88	-1.97	-1.31	-1.40	-0.310
SM3	289	2.52	2.63	-0.44	0.94	-0.16	0.66	-0.34	-0.252
SM4	290	0.16	-0.22	-1.37	-1.78	-1.97	-2.74	-0.14	-0.344
SM2	342	0.60	-1.48	-3.15	-0.90	-1.64	-3.07	-1.58	-0.434
SM1	354	2.14	-1.20	-1.98	-0.39	-2.58	-2.30	-0.55	-0.750
WF1	165	2.56	0.14	-1.44	1.09	-1.77	0.21	-0.62	-0.217
WF2	171	2.84	2.39	-1.11	-1.61	0.29	2.68	-1.24	-0.222
WF3	172	0.00	-0.32	-1.61	-0.45	-0.58	0.04	-2.13	-0.297
WF4	223	0.16	-1.37	2.96	-1.01	-0.16	1.09	0.93	-0.270
WF5	225	1.37	-0.11	0.88	0.11	0.77	0.11	-0.08	-0.167
WF6	226	**1.37**	-0.11	0.88	0.11	0.77	0.11	-0.08	-0.008
WF7	227	3.18	1.20	-2.30	-0.67	-0.33	2.74	-0.08	-0.051
WF8	267	1.22	-0.55	-1.78	0.62	0.67	-0.55	-0.08	-1.141
NE1	452	2.68	2.39	-0.70	0.12	0.95	0.78	1.71	-1.091
NE2	470	2.47	1.40	-0.62	-0.04	-0.45	0.45	-0.93	-0.966
NE3	471	2.21	-0.74	-0.77	-1.27	0.99	-0.41	0.00	-0.793
NE4	400	2.15	1.49	-0.37	0.25	1.07	-0.70	0.00	-0.004
NE5	268	1.44	-0.41	-0.95	-0.72	0.14	-0.95	-0.75	-0.919
NE6	182	1.75	1.31	-1.86	0.66	0.71	1.42	0.31	-0.997
NE7	185	1.98	1.97	0.77	-0.66	0.11	0.88	-0.72	-1.107
NE8	209	2.64	2.52	-0.05	1.76	0.22	2.30	-0.16	-0.935
NE9	270	-1.65	-2.63	-1.20	0.00	-2.58	-2.30	2.26	-0.672
NE10	271	-0.05	-0.71	-1.54	-0.17	-1.70	-0.88	-1.56	-0.626
NE11	418	1.71	1.59	-2.14	0.19	0.06	2.14	1.95	-1.569
BM2	436	3.46	3.92	1.98	-1.01	-2.10	2.27	1.03	0.031
BM9	442	3.01	0.99	-1.28	1.33	-0.45	-1.03	1.17	0.040
BM1	444	3.46	3.02	-1.40	-0.32	-0.21	2.76	-0.34	0.044
BM6	447	2.10	2.48	-0.54	-0.54	0.91	0.78	0.07	0.028
BM7	448	2.79	-0.15	-3.48	0.05	2.66	-1.40	-1.64	0.041
BM8	454	0.62	0.68	-1.03	-0.29	1.11	-0.21	0.00	0.032
BM4	455	2.23	1.13	0.08	-0.45	0.62	0.87	0.41	0.026
BM5	457	0.00	-1.04	-0.58	-1.65	1.07	-1.69	0.34	0.049
BM3	464	1.69	1.94	-1.44	-0.04	1.90	1.36	0.21	0.035
BM10	175	0.22	-1.64	-2.41	-0.73	-0.99	-1.20	0.00	-0.015
BM11	199	1.09	1.42	0.22	0.61	-0.11	0.44	0.55	-0.005
S4	473	2.91	2.41	-0.22	0.00	-1.53	1.53	-0.54	0.017
S1	118	3.56	3.34	0.27	-0.18	-0.18	1.85	-0.16	0.017
S2	84	3.30	1.76	-1.57	-1.15	0.70	1.85	0.00	0.017
S5	88	2.77	0.99	-1.34	0.10	0.99	-0.20	-0.36	0.017
S3	90	3.67	2.48	-0.49	0.33	-1.36	2.35	0.23	0.017
CM1	146	3.02	4.06	3.11	-0.68	-1.04	3.74	-1.97	0.017
CM2	152	2.75	2.77	-3.20	-0.86	0.50	2.57	0.00	0.017
CM3	89	1.04	-0.49	-1.48	-0.15	0.00	-0.79	0.72	0.017
CM4	97	2.07	2.03	1.85	-0.23	0.00	0.32	0.00	0.017
CM5	91	3.06	2.67	1.49	-2.12	1.22	-2.30	0.36	0.017

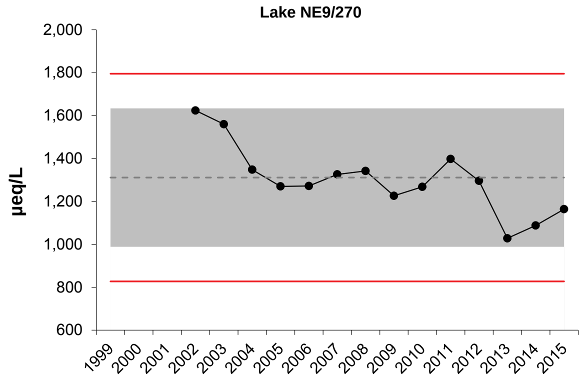
Notes:

Numbers represent the Z statistic used in the analysis. Negative values represent overall decreases in a variable and positive values represent increases.

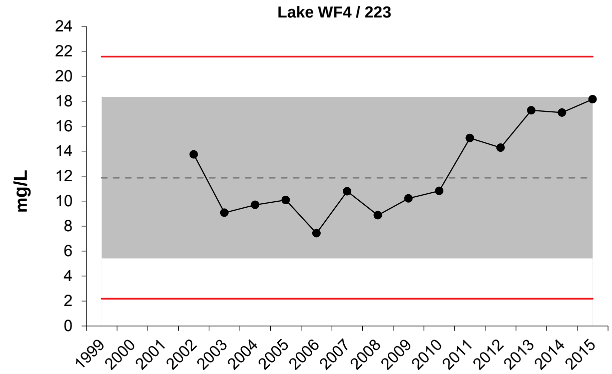
Shaded values are statistically significant – yellow in a direction consistent with an acidification scenario, and green in a direction inconsistent with acidification.

Figure 5.14-2 Control charts for acid-sensitive lakes showing significant trends in measurement endpoints identified in the Mann-Kendall trend analysis, 1999 to 2015.

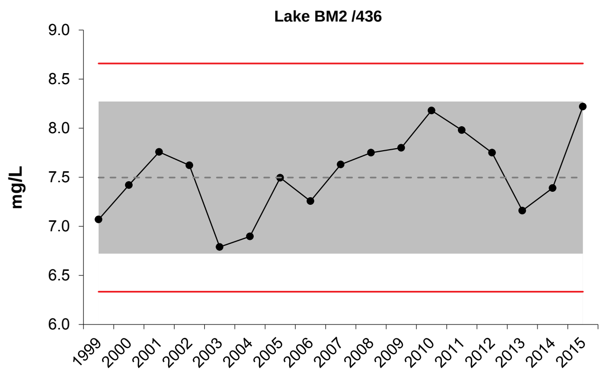
Gran Alkalinity



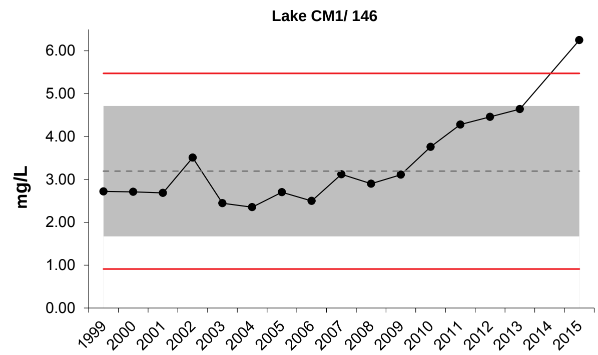
Sulphate



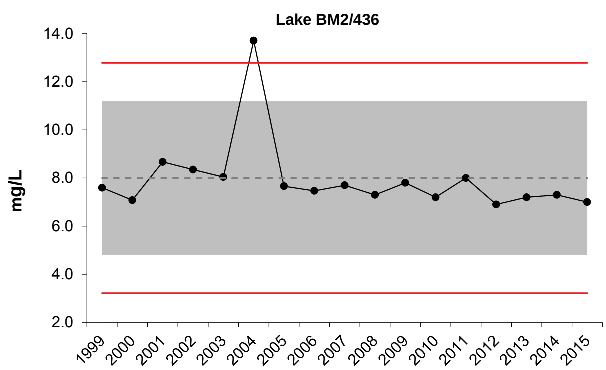
Sulphate



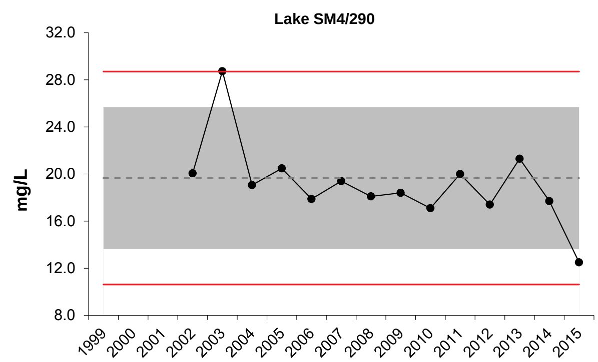
Sulphate



Dissolved Organic Carbon



Dissolved Organic Carbon



Notes:

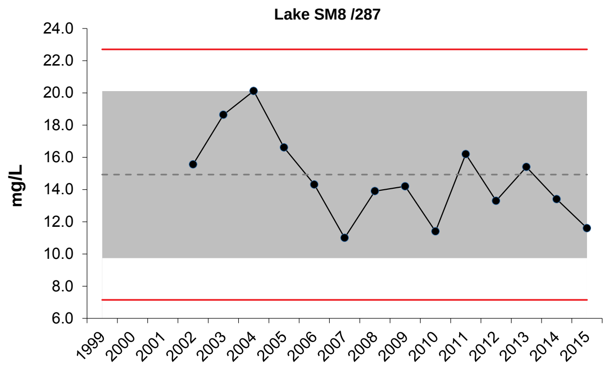
Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

Only significant trends in a direction indicative of acidification are presented.

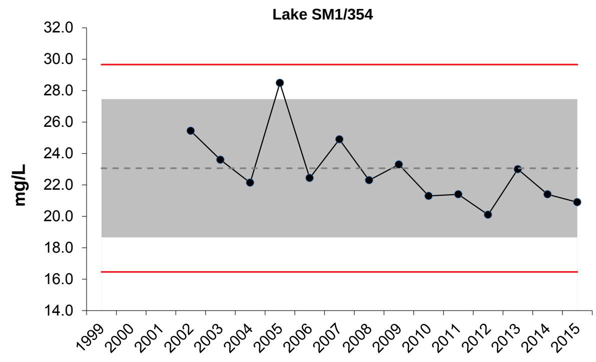
See Section 3.2.5.1 for a description of the interpretation of control charts.

Figure 5.14-2 (Cont'd.)

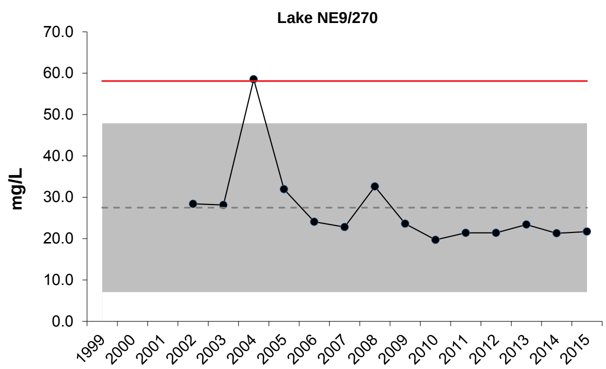
Dissolved Organic Carbon



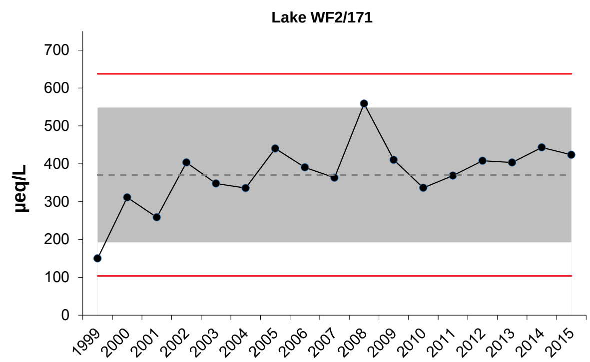
Dissolved Organic Carbon



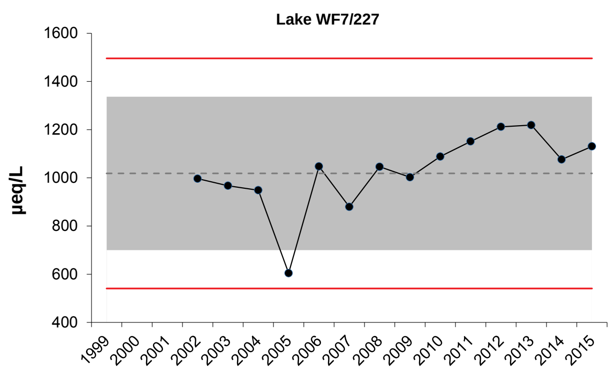
Dissolved Organic Carbon



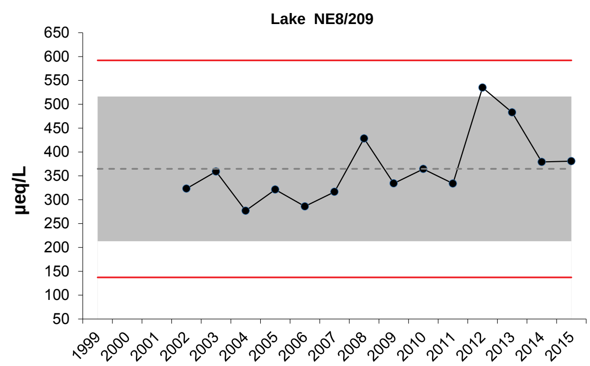
Sum of Base Cations



Sum of Base Cations



Sum of Base Cations



Notes:

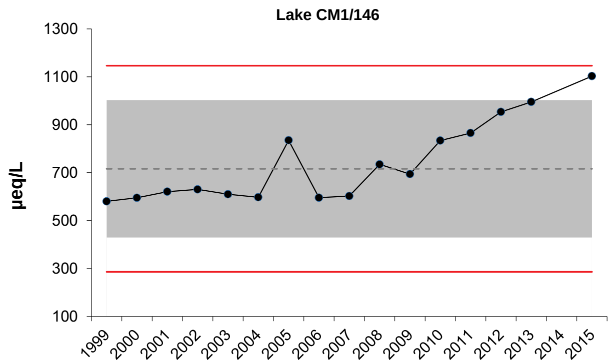
Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

Only significant trends in a direction indicative of acidification are presented.

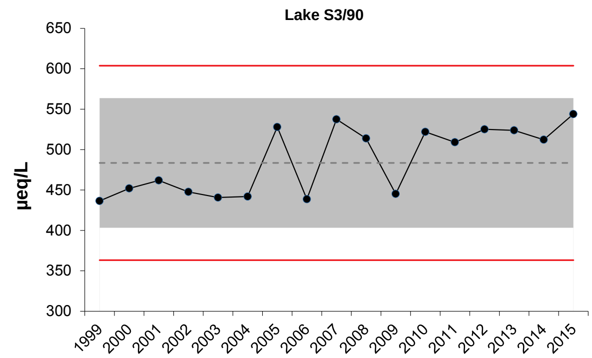
See Section 3.2.5.1 for a description of the interpretation of control charts.

Figure 5.14-2 (Cont'd.)

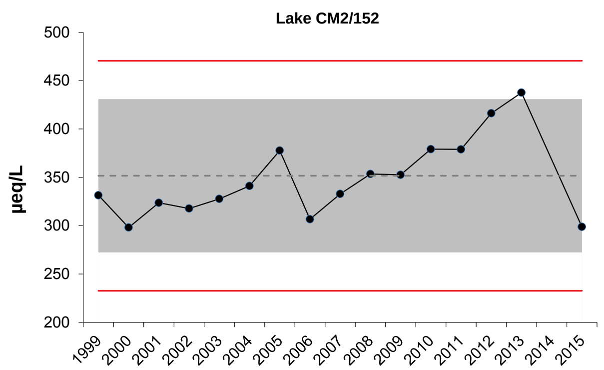
Sum of Base Cations



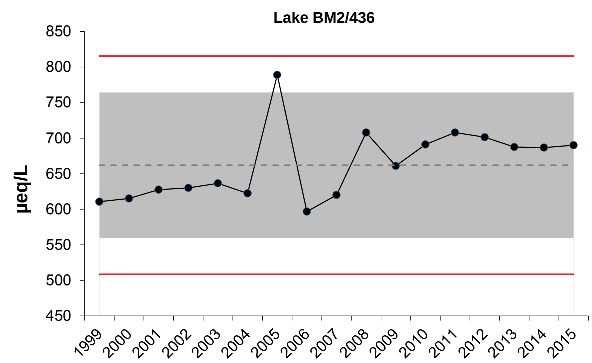
Sum of Base Cations



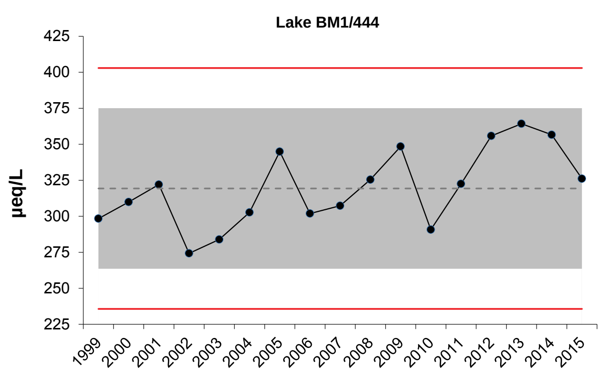
Sum of Base Cations



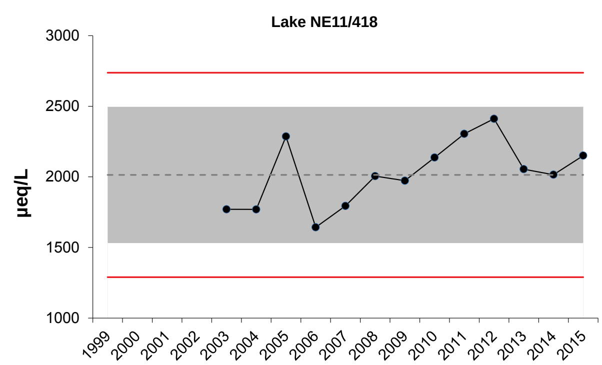
Sum of Base Cations



Sum of Base Cations



Sum of Base Cations



Notes:

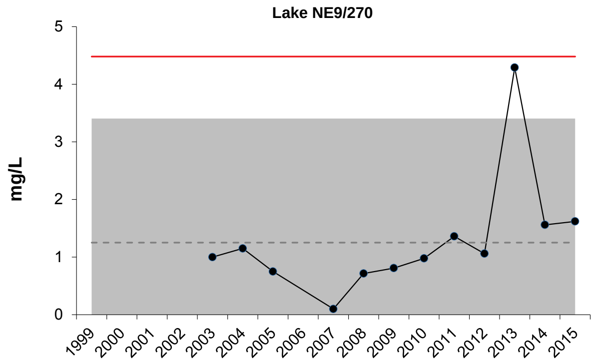
Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

Only significant trends in a direction indicative of acidification are presented.

See Section 3.2.5.1 for a description of the interpretation of control charts.

Figure 5.14-2 (Cont'd.)

Dissolved Aluminum



Notes:

Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

Only significant trends in a direction indicative of acidification are presented.

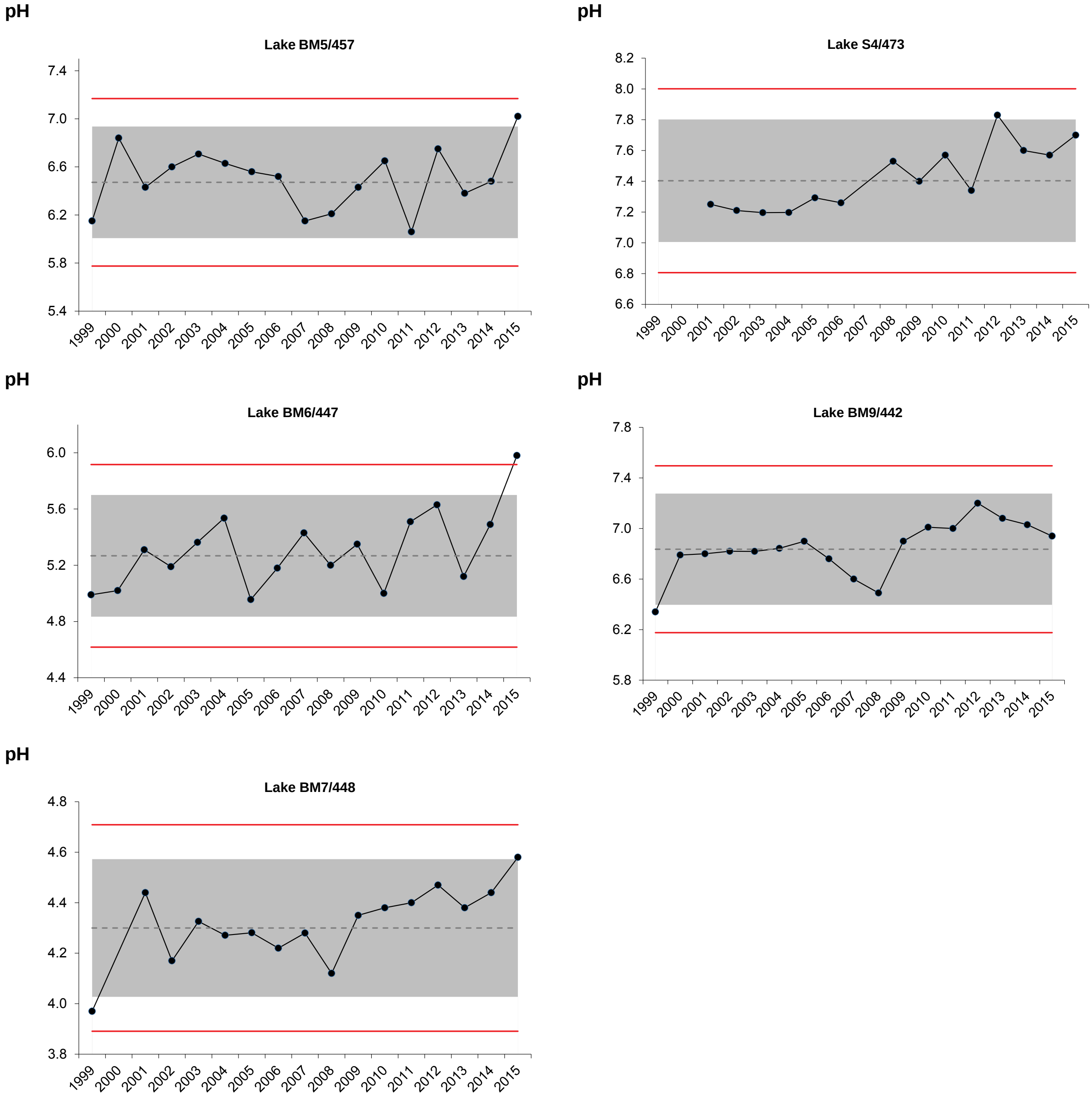
See Section 3.2.5.1 for a description of the interpretation of control charts.

Table 5.14-10 Acidification risk factor for individual acid-sensitive lakes exposed to acidifying emissions, 2015.

AEP Designation	NO_XSO_X No.	Subregion	Critical Load (keq/Ha/y) IMB	PAI	Acidification Risk Factor PAI/CL
CM1	146	Caribou Mountains	3.952	0.017	0.004
S1/Weekes	118	Canadian Shield	2.407	0.017	0.007
BM 2/Namur	436	Birch Mountains	1.992	0.031	0.016
CM4	97	Caribou Mountains	0.777	0.017	0.022
CM3/Whitesand	89	Caribou Mountains	0.656	0.017	0.026
S3	90	Canadian Shield	0.613	0.017	0.028
BM 4	455	Birch Mountains	0.929	0.026	0.028
CM2/Rocky I.	152	Caribou Mountains	0.597	0.017	0.028
CM5	91	Caribou Mountains	0.496	0.017	0.034
BM3	464	Birch Mountains	0.904	0.035	0.039
S5	88	Canadian Shield	0.415	0.017	0.041
BM1/Legend	444	Birch Mountains	1.057	0.044	0.042
BM8/Bayard	454	Birch Mountains	0.726	0.032	0.044
S2/Fletcher	84	Canadian Shield	0.283	0.017	0.060
BM5	457	Birch Mountains	0.704	0.049	0.070
S4	473	Canadian Shield	0.196	0.017	0.087
BM6	447	Birch Mountains	0.290	0.028	0.097
BM9/Otasan	442	Birch Mountains	0.328	0.040	0.122
BM7/Clayton	448	Birch Mountains	-0.828	0.041	41

Note: Shading denotes those lakes most at risk to acidification.

Figure 5.14-3 Control charts of pH in the five acid-sensitive lakes most at risk to acidification, 1999 to 2015.



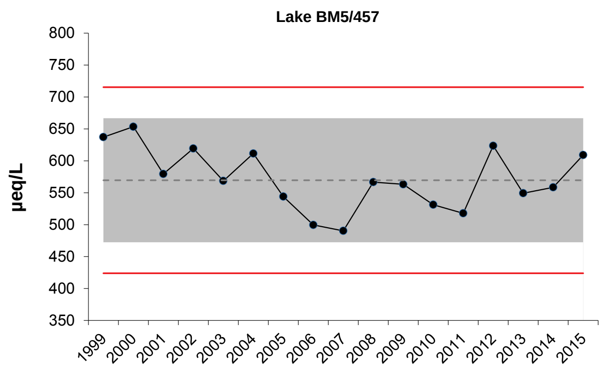
Notes:

Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

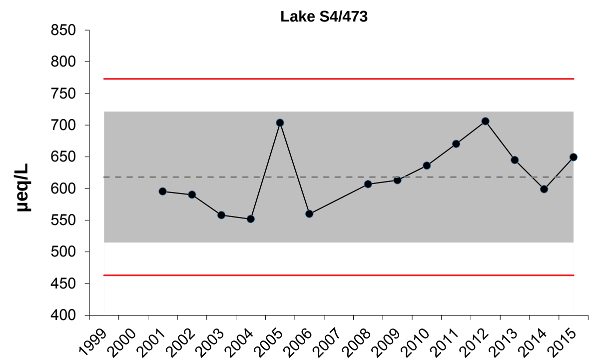
See Section 3.2.5.1 for a description of the interpretation of control charts.

Figure 5.14-4 Control charts of the sum of base cations in the five acid-sensitive lakes most at risk to acidification, 1999 to 2015.

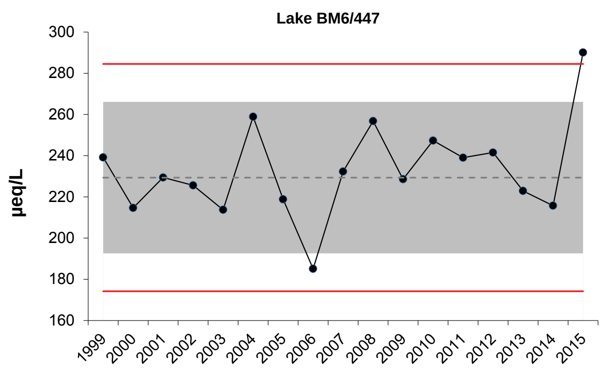
Sum of Base Cations



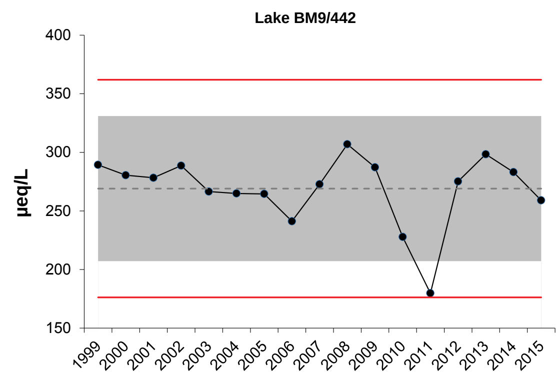
Sum of Base Cations



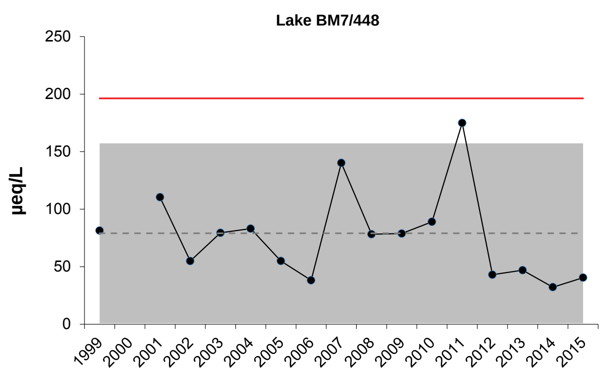
Sum of Base Cations



Sum of Base Cations



Sum of Base Cations

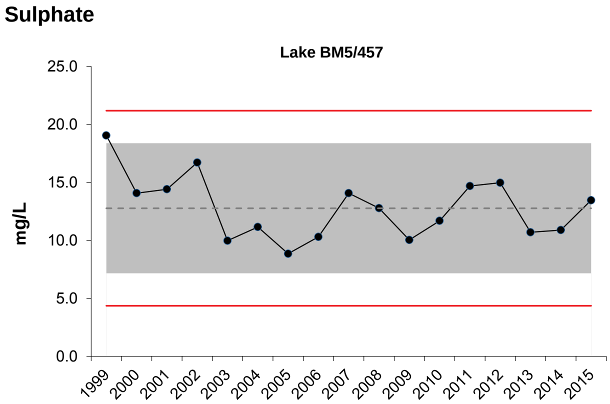


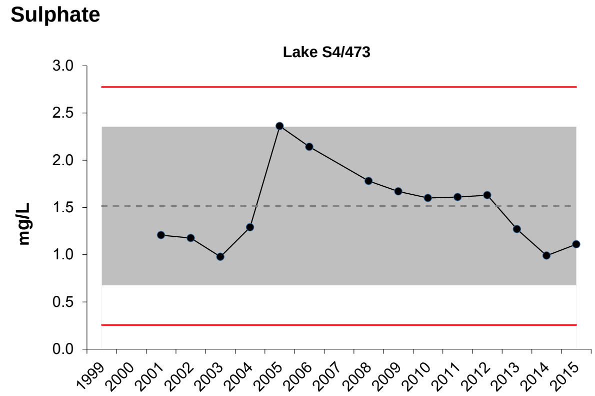
Notes:

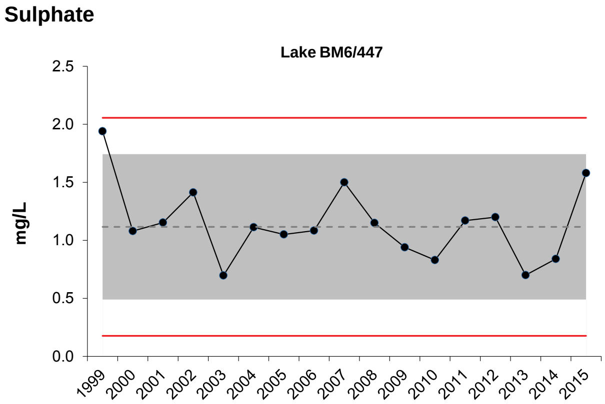
Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

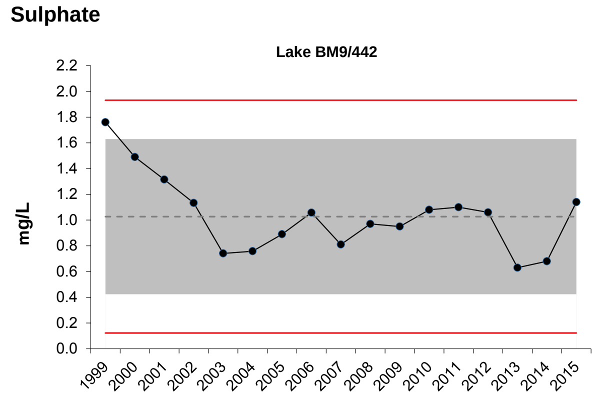
See Section 3.2.5.1 for a description of the interpretation of control charts.

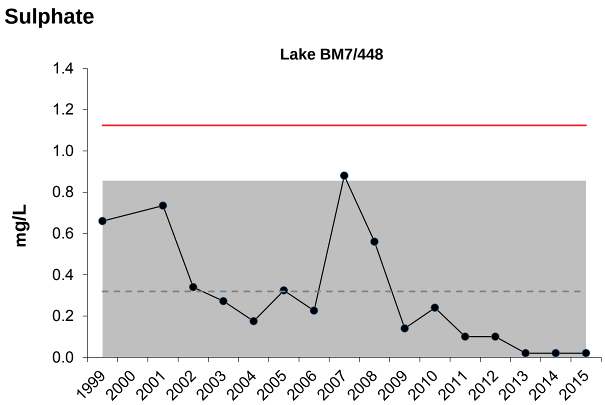
Figure 5.14-5 Control charts of concentration of sulphate in the five acid-sensitive lakes most at risk to acidification, 1999 to 2015.











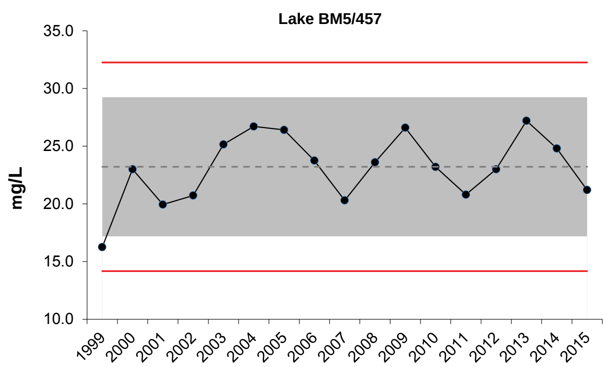
Notes:

Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

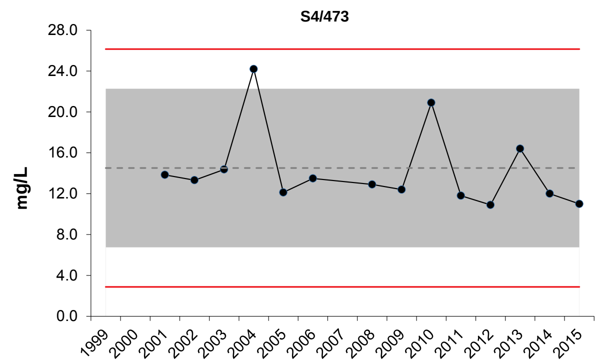
See Section 3.2.5.1 for a description of the interpretation of control charts.

Figure 5.14-6 Control charts of concentration of dissolved organic carbon in the five acid-sensitive lakes most at risk to acidification, 1999 to 2015.

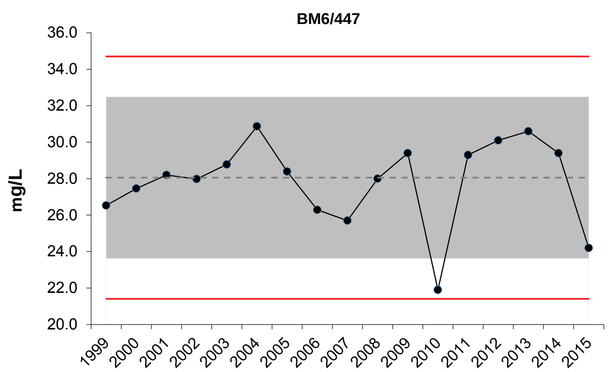
Dissolved Organic Carbon



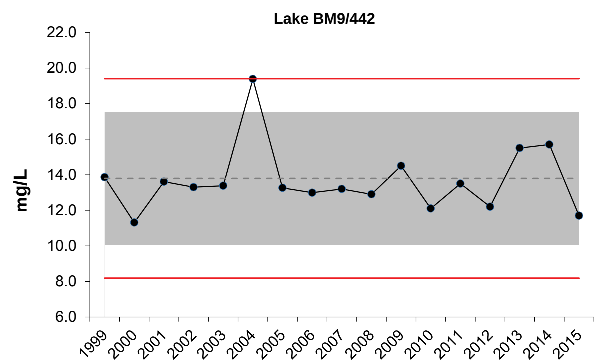
Dissolved Organic Carbon



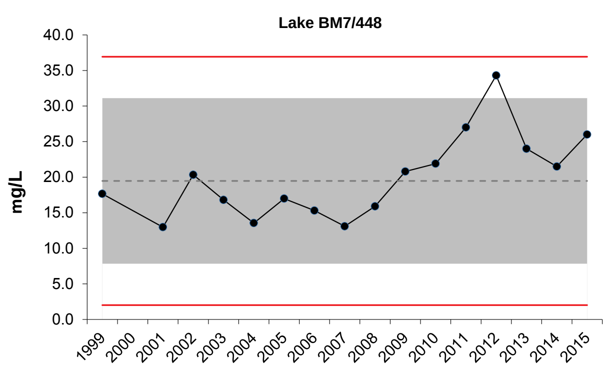
Dissolved Organic Carbon



Dissolved Organic Carbon



Dissolved Organic Carbon



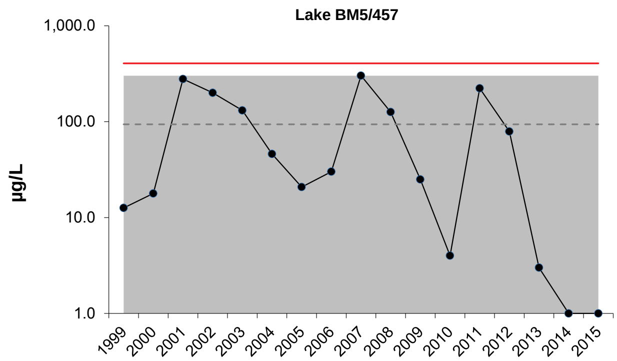
Notes:

Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

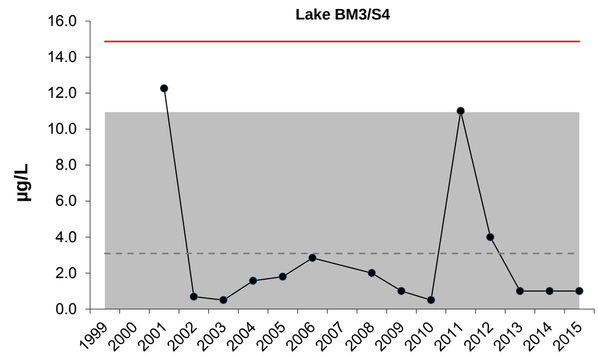
See Section 3.2.5.1 for a description of the interpretation of control charts.

Figure 5.14-7 Control charts of concentration of nitrates in the five acid-sensitive lakes most at risk to acidification, 1999 to 2015.

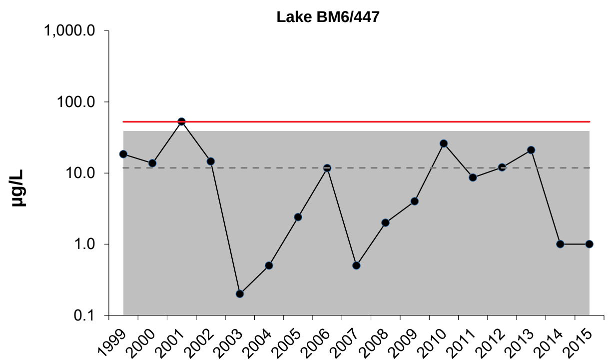
Log$_{10}$ Nitrates



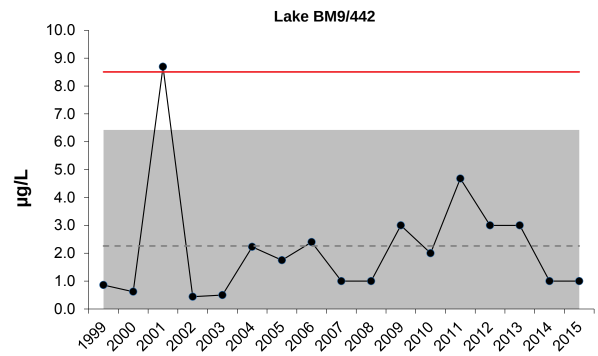
Nitrates



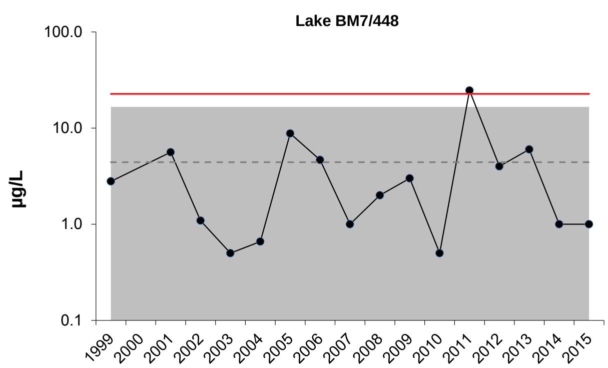
Log$_{10}$ Nitrates



Nitrates



Log$_{10}$ Nitrates



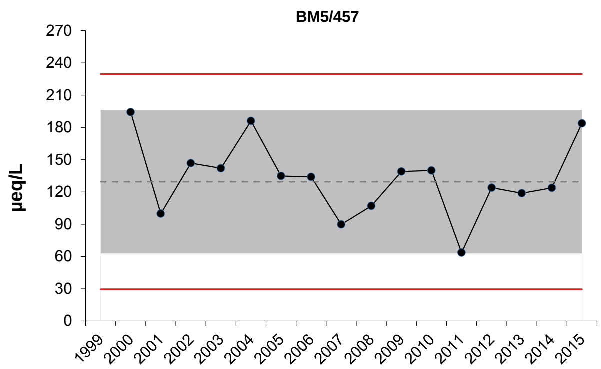
Notes:

Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

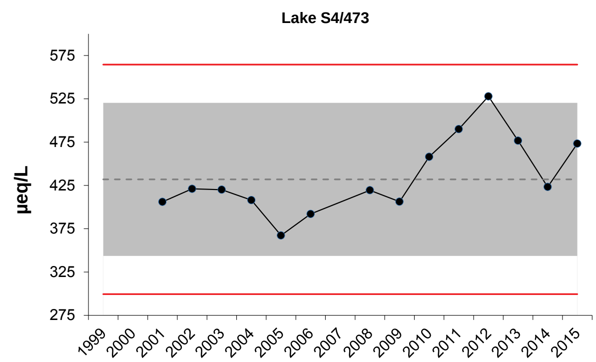
See Section 3.2.5.1 for a description of the interpretation of control charts.

Figure 5.14-8 Control charts of Gran alkalinity in five lakes in the five acid-sensitive lakes most at risk to acidification, 1999 to 2015.

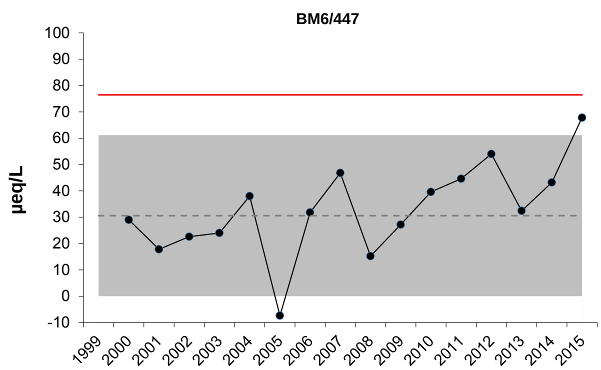
Gran Alkalinity



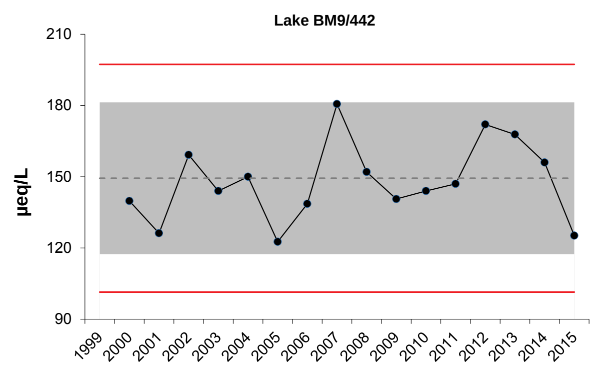
Gran Alkalinity



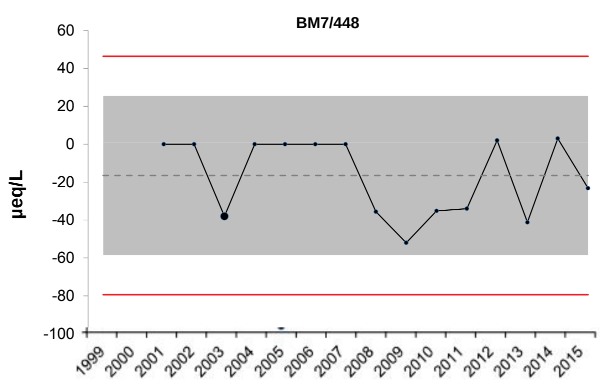
Gran Alkalinity



Gran Alkalinity



Gran Alkalinity



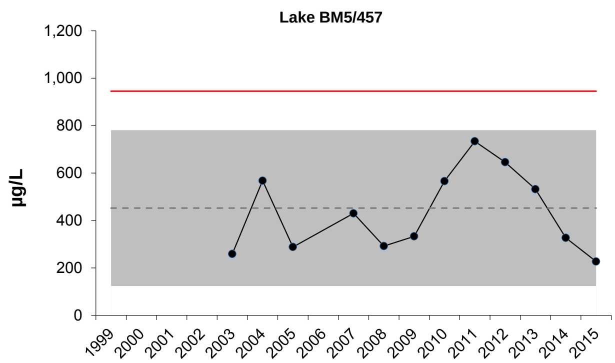
Notes:

Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

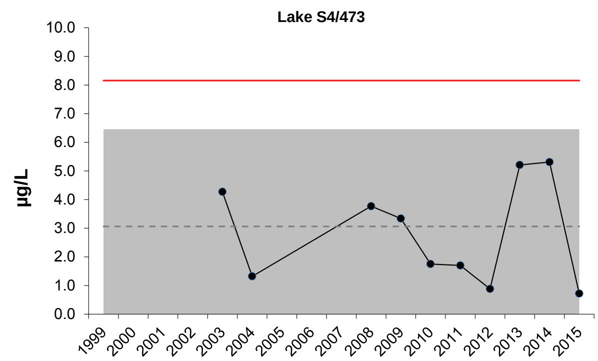
See Section 3.2.5.1 for a description of the interpretation of control charts.

Figure 5.14-9 Control charts of concentration of dissolved aluminum in the five acid-sensitive lakes most at risk to acidification, 1999 to 2015.

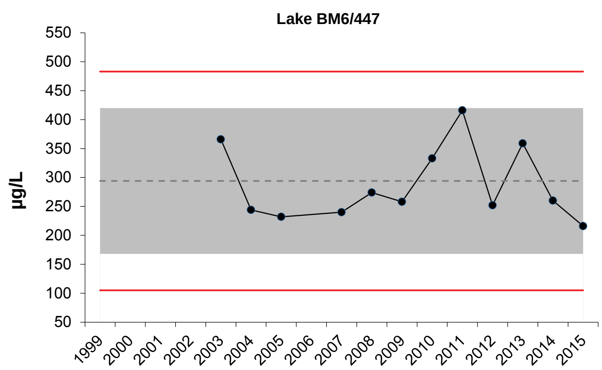
Dissolved Aluminum



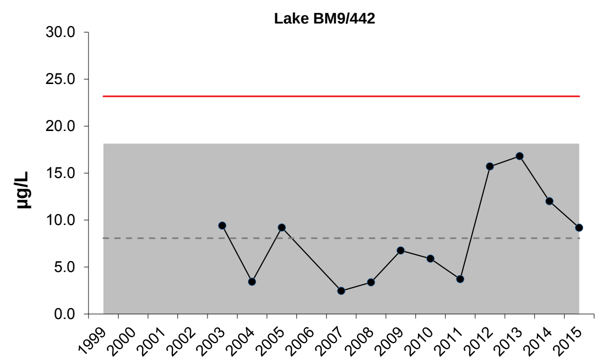
Dissolved Aluminum



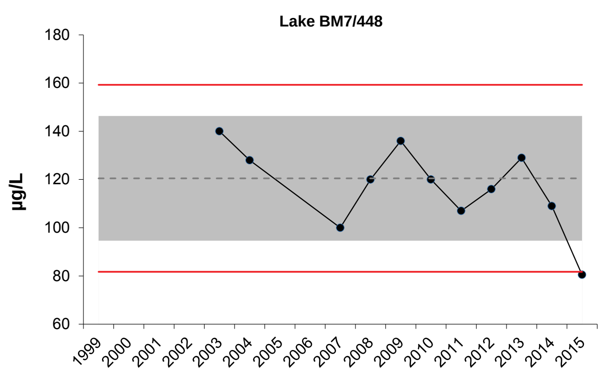
Dissolved Aluminum



Dissolved Aluminum



Dissolved Aluminum



Notes:

Grey shading: ± 2 standard deviations; red lines: ± 3 standard deviations; dotted line: mean.

See Section 3.2.5.1 for a description of the interpretation of control charts.

Table 5.14-11 Rating of acid-sensitive lakes in 2015 for evidence of incipient acidification.

Subregion	Location	No. of Lakes in Subregion	Number of Lakes-Endpoint Excursions of 2 SD of the Mean in 2015							Total	Percent of Lakes X Endpoints	Rating
			pH	Alkalinity	Nitrates	DOC	Sulphate	Aluminum	SBC			
SM	Stony Mountains	10	0	0	1	0	0	1	2	4	5.7	**Moderate**
WFM	West of Fort McMurray	8	0	0	0	0	1	0	0	1	1.8	**Negligible-Low**
NE	Northeast of Fort McMurray	11	0	0	0	0	0	0	0	0	0.0	**Negligible-Low**
BM	Birch Mountains	11	0	0	0	0	0	0	2	2	2.6	**Moderate**
CS	Canadian Shield	5	0	0	0	0	0	0	0	0	0.0	**Negligible-Low**
CM	Caribou Mountains	5	0	0	0	0	0	0	1	1	2.9	**Moderate**

6.0 SPECIAL STUDIES

6.1 RELATIONSHIPS BETWEEN TURBIDITY, TOTAL SUSPENDED SOLIDS, AND DISCHARGE IN TRIBUTARIES TO THE ATHABASCA RIVER

6.1.1 Initial Results from the Calibration of Continuously-Measured Turbidity to Total Suspended Solids in the JOSMP Study Area

6.1.1.1 Introduction

Data sondes were deployed at 16 locations in the study area in the 2015 WY at *test* and *baseline* stations with the objective of characterizing selected water quality variables at a high temporal frequency. These data sondes were equipped with sensors that recorded turbidity every 15 minutes, most in near-real time.

The objective of this study was to calibrate levels of turbidity obtained from the data sondes to concentrations of total suspended solids (TSS), and to present time series of TSS from stations where calibration occurred. Developing calibrations between turbidity and TSS is potentially useful because:

- it is a necessary first step in calculating sediment loads and assessing sediment availability. This is useful when TSS is recorded continuously at a high frequency, near a hydrometric station where river discharge is recorded, sediment fluxes can be calculated;
- it helps disentangle sources of turbidity (e.g., to what extent is turbidity controlled by suspended sediment vs. dissolved organic material?). The timing and magnitude of TSS exceedances (e.g., CCME 2002; AESRD 2014) could provide more specific information to stakeholders, relative to turbidity; and
- turbidity is measured and transmitted in near-real time in the JOSMP study area, allowing for quick assessments of the above two points. Recording at high temporal frequency also allows sediment fluxes and concentrations during short-lived, high-magnitude events to be recorded (e.g., rainfall runoff events).

If a relationship exists between turbidity and TSS, it is typically site-specific (CCME 2011). Site-specificity is controlled by:

- the concentration of total suspended solids and dissolved matter;
- shape, colour, and size (including flocculated particles) of suspended particulate matter;
- concentration of air bubbles;
- wavelength of the light source produced by the turbidity sensor (e.g., white vs. infrared); and
- composition of suspended and dissolved matter. For example, organic matter, clastic[1] material, plankton, organic acids, other organic material, and dyes.

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[1] composed of fragments of existing minerals and rock

Results presented below should be considered preliminary. Little information is currently available regarding whether turbidity-TSS relationships vary through time (e.g., at times when discharge is dominated by snowmelt, precipitation, and baseflow), or through space (e.g., between reaches or across cross-sections). Also, data sondes were not deployed during the 2015 WY freshet; sediment budgets have been developed for the delplo確ment period (late July to late October, 2015).

6.1.1.2 Station Description

The current study focused on four of the 16 stations at which data sondes were deployed in the 2015 WY (Figure 6.1-1, Table 6.1-1); two stations are on the Ells River (EL2 and ELLS RIFF 5), and two are on the MacKay River (MA2 and MA1). ELLS RIFF 5 is about 16 km upstream of EL2 and MA2 is about 35 km upstream of MA1 (not accounting for river sinuosity).

Table 6.1-1 Station information for data sonde stations where turbidity-TSS relationships were explored, with associated hydrology stations.

Data sonde Station ID	Waterbody	UTM Coordinates (NAD83, Zone 12)		AEMERA Nomenclature	Nearby Hydrometric Station	Reach Designation	Upstream Watershed Area (km^2)
		Easting	Northing				
EL2	Ells River	455738	6344943	AB07DA3007	S14A	*Test*	2,420
ELLS RIFF 5	Ells River	440330	6342392	AB07DA2999	S45	*Baseline*	2,231
MA1	MacKay River	458031	6341077	AB07DB0060	07DB001[a]	*Test*	5,569
MA2	MacKay River	444948	6314177	AB07DB0350	S40	*Test*	4,090

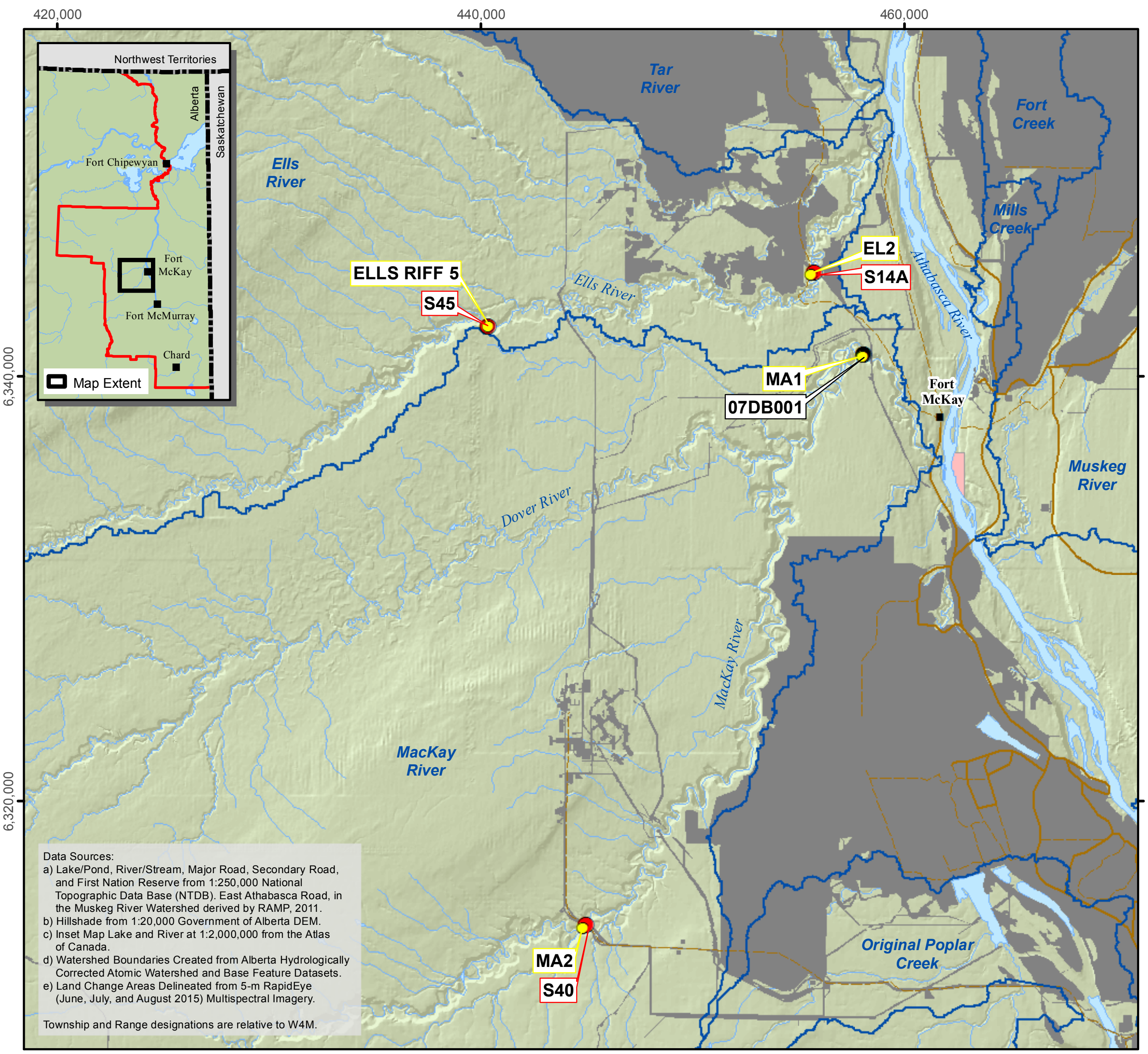
[a] Operated by the Water Survey of Canada. Other hydrometric stations are operated under AEMERA as part of the JOSMP network.

6.1.1.3 Methods

Field Methods

Hydrologic, data sonde, and water quality methods are described in Section 3 and Appendices B and C. Field methods pertinent to this study are summarized below.

Figure 6.1-1 Data sonde and hydrometric monitoring stations on the MacKay and Ells rivers.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- First Nations Reserve
- Regional Municipality of Wood Buffalo Boundary
- Land Change Area as of 2015[a]

- Data Sonde Monitoring Station

Hydrometric Monitoring Station
- Year-Round, manged by Hatfield
- Water Survey of Canada (Year-Round)

0 1.5 3 6 km

N

Scale: 1:300,000

Projection: NAD 1983 UTM Zone 12N

Hatfield CONSULTANTS

K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_P_TurbidityTSS_20160329_ss.mxd

Continuously Recording Data Sondes

Data sonde time series described here were recorded with YSI EXO2, from roughly the third week in July to the end of October, 2015. YSI EXO2 turbidity sensors use near-infrared light, detect scattering at 90º to the incident light beam, are nephelometric near-IR turbidimeters, and are non-ratiometric (SKU: 599101-01; YSI 2014). For the range of turbidity measurements recorded in the field, turbidity sensor accuracy is 0.3 FNU Formazin Nephelometric Units (FNU) or ±2% of the reading, whichever is greater. Resolution is 0.01 FNU. EXO2 are equipped with a wiper that cleans the turbidity sensor prior to each measurement to avoid sensor fouling and maintain accuracy.

Deployed EXO2 sondes were replaced monthly with recalibrated sondes; turbidity sensors were calibrated with zero Nephelometric Turbidity Unit (NTU) and 126 NTU calibration solutions, manufactured by YSI, and recommended for use with EXO2 data sondes. Compensation for calibration drift was conducted in Aquatic Informatics Aquarius Springboard (v. 3.10.71); using guidelines developed from RISC (2006) and Wagner et al. (2006).

Sondes were deployed in housings that consisted of perforated PVC pipes. The pipes were angled at approximately 45 degrees, with sensors facing down and elevated above the stream bottom. EXO2 data sondes recorded every 15 minutes.

Collection of Water Samples

Samples for determination of TSS were obtained by hand dipping 500-mL bottles, as far as possible under the surface of the water. Samples were typically obtained within wadeable distance to a river bank. Water samples were obtained roughly monthly at each of the data sonde stations.

Hydrometric Data

Three of the four hydrometric stations are part of the JOSMP hydrometric network. The fourth, 07DB001, is a Water Survey of Canada (WSC) station (Table 6.1-1). Provisional daily discharge data from 07DB001 were obtained from the WSC, and are subject to change. The methods described below apply to JOSMP hydrometric stations.

Water level was logged every 15 minutes. Field visits were conducted roughly monthly to measure discharge and survey water levels. Rating curves were constructed that relate measured water level to measured discharge, and rating curves were applied to the stage time series to derive discharge.

Laboratory and Desktop Methods

Determination of TSS

TSS samples reported here were analyzed by Maxxam Laboratories (laboratory method FTMCSOP-00005, analytical method SM 2540D) with a detection limit of 1 mg/L. Determination of TSS involves subsampling from a volume of water, then vacuum filtering on pre-weighed 0.45 µm, drying, and weighing the filtered sediment (modified from APHA 2012; Burton pers. comm.). TSS typically includes both biotic and abiotic components (CCME 2011). By contrast, methods of measuring suspended sediment concentration (SSC) involve filtering the entire sample volume. When water samples contain significant amounts of coarse grained sediment, SSC is typically higher than TSS, and the two are not correlated

(Rasmussen et al. 2011). However, TSS and SSC are typically well-correlated and close to the true concentration when particles are up to coarse-silt sized (53 µm; Guo 2006). Particle size analyses of the suspended load of rivers described here have not been conducted; however, visual assessment of water samples showed that suspended sediment was dominantly finer than sand-sized.

Turbidity-TSS Calibrations

Turbidity-TSS calibrations consisted of simple linear regressions. Data were normalized by $\log_{10}$-transformation (CCME 2002, Rasmussen 2011). Summary statistics described here include the root mean square error (RMSE), upper model standard percentage error (MSPE), and lower MSPE, defined as:

$$\text{RMSE}=\sqrt{1/n\sum_{i=1}^{n}(\hat{y}_i-y_i)^2}$$

$$\text{Upper MSPE} = (10^{\text{RMSE}}-1) \times 100$$

$$\text{Lower MSPE} = (1 - 10^{-\text{RMSE}}) \times 100$$

Streamflow is sometimes used with turbidity to construct multivariate linear regression models that predict TSS. However, USGS guidelines for transformation of turbidity to SSC state that a linear regression model is the preferred method if the MSPE is less than 20 % (Rasmussen et al. 2011).

Relating Turbidity to TSS using Laboratory Samples

Turbidimeters were calibrated to TSS in the laboratory following procedures outlined by Alberta Transportation (undated) as follows: sediment and water samples were obtained from the Ells (EL2) and MacKay (MA2) rivers (Table 6.1-1); sondes were placed in a bucket of river water; turbidity was progressively increased by adding suspended river sediment; and water aliquots were obtained after each addition of suspended sediment. Specifics of the procedure are described below.

Sondes were placed in buckets of EL2 water and MA2 water (two sondes, two buckets). Initial turbidity was noted and 500-mL aliquots of water were obtained for TSS analysis. Next, two high concentration water-sediment slurries were made by mixing EL2 and MA2 river sediment and water in small bottles. The slurries were continually agitated to ensure sediment remained in suspension. Capfuls of slurry were added to the buckets, and the buckets were mixed. Turbidity readings were recorded when they stabilized, then aliquots of water were obtained. Ten aliquots were subsampled from each bucket, at turbidities ranging from 2 FNU and 266 FNU, equating to a TSS range from <1 mg/L (undetectable) to 720 mg/L.

Relating Turbidity to TSS using Field Samples

Applicability of the controlled TSS-turbidity calibration conducted in the laboratory was tested using data collected in the field. Turbidity was obtained from deployed sonde time series (Section 6.1.1.3, *Continuously Recording Data Sondes*), and TSS samples were obtained in the field (Section 6.1.1.3, *Collection of Water Samples*). A total of 55 samples were obtained and analyzed from stations where sondes were deployed in the 2015 WY.

6.1.1.4 Results

Do Turbidimeters of the Same Model Report the Same Turbidity?

Field visits during the 2015 WY involved swapping in freshly-calibrated sondes, and removing sondes that had been deployed for approximately a month (Section 6.1.1.3, *Continuously Recording Data Sondes*). Although the identical model of turbidimeter was used at all four stations, different turbidimeters were used throughout the monitoring period.

To test whether different turbidimeters report different values, six turbidimeters were mounted to two sondes during the laboratory turbidity-TSS calibration procedure (Section 6.1.1.3, *Continuously Recroding Data Sondes*). Turbidity values from all six of the turbidimeters were noted as concentration of TSS was increased. Single factor ANOVA tests were performed to determine whether variability in measurements of turbidity among turbidimeters is significant. For both the Ells and Mackay river tests the results were insignificant, with $p>0.05$, indicating that different turbidimeters of the same model do not report significantly-different turbidities.

Calibration of Turbidity to Total Suspended Solids

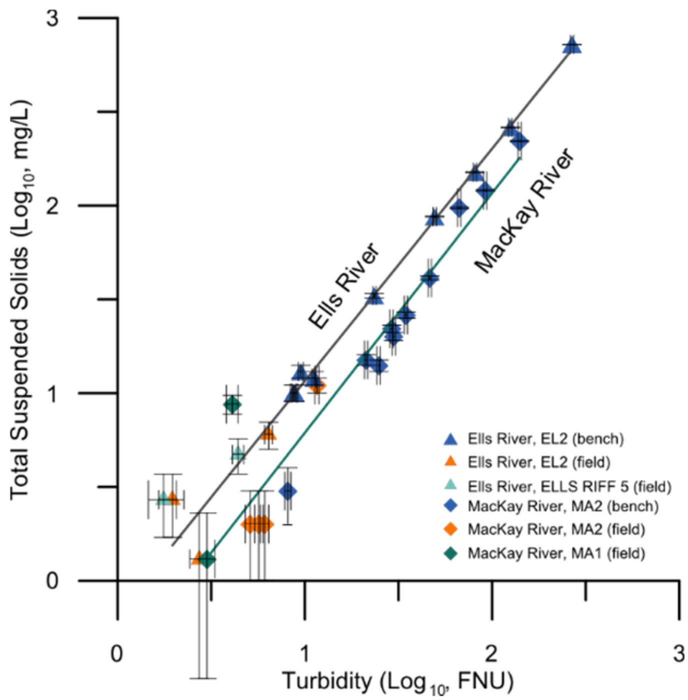
Relationships between turbidity and TSS for the Ells and MacKay rivers are presented in Figure 6.1-2. Horizontal error bars represent the accuracy of the EXO turbidimeter (0.3 FNU or ±2% of reading, whichever is greater), and vertical error bars represent the laboratory detection limit for TSS (1 mg/L).

Turbidity and TSS data from station EL2 and station MA2 form two distinct groups. While the slopes of the regression lines for both groups are similar (Table 6.1-2), the Ells River has a higher y-axis offset, indicating that for a given turbidity, TSS is higher in the Ells River sample. For both regressions, $p<0.05$, indicating that the relationships are statistically-significant.

Turbidity-TSS results from field samples generally concur with the laboratory turbidity-TSS results (Figure 6.1-2). Scatter can largely be explained by the high analytical detection limit and low TSS and turbidity of field samples. Preliminary results indicate that the turbidity-TSS relationship is consistent between the two Ells River stations (station EL2 and station ELLS RIFF 5) and the two Mackay River stations (station MA2 and station MA1). The upper and lower MSPE for the Ells and MacKay regressions are all less than 20% (Table 6.1-2), indicating that the simple linear regression method is the preferred method for calibration and development of a multivariate model is not necessary (Section 6.1.1.3, *Turbidity-TSS Calibrations*).

While field results suggest that the turbidity-TSS relationship was consistent throughout the monitoring period, the sample size of field results is small and the range of recorded TSS-turbidity values is low and the results should therefore be considered preliminary.

Figure 6.1-2 Relationships between levels of turbidity and concentrations of total suspended solids for the Ells and MacKay rivers.



Note: Regression analyses only use data from MA2 and EL2. Error bars represent analytical TSS detection limit (vertical) and turbidimeter accuracy (horizontal).

Table 6.1-2 Statistics for best-fit linear regressions that predict TSS using turbidity, for the Ells and MacKay rivers

Statistic	Ells River	MacKay River
Linear best-fit regression equation*	Y = 1.238*X - 0.173	Y = 1.449*X - 0.767
Number of data points	12	14
Coefficient of determination, r^2	0.98	0.98
RMSE (log units)	0.032	0.062
Upper MSPE (mg/L units)	7.68	15.27
Lower MSPE (mg/L units)	7.14	13.24

* where Y=$\log_{10}$ transformed TSS in mg/L, and X=$\log_{10}$ transformed turbidity in FNU.

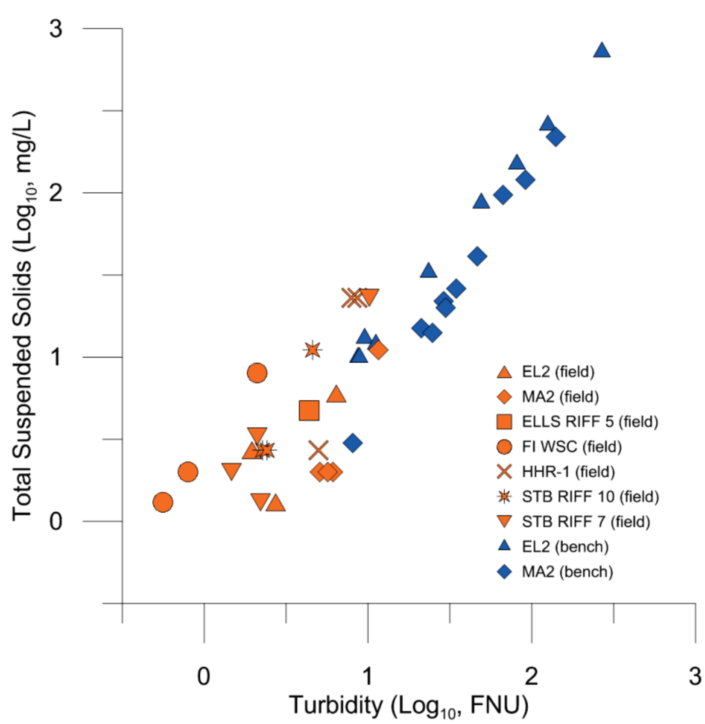
Do Different Rivers in the Study Area Have Different Turbidity-TSS Relationships?

Factors that control turbidity were noted in Section 6.1.1.1. The turbidity-TSS relationship may change if these controlling factors vary by river, by reach, within a river cross-section, or temporally. Results from the Ells and Mackay rivers show that turbidity-TSS relationships are different (Figure 6.1-2); therefore, further analysis is needed to determine relationships in other project area rivers.

To test the effect of the different regression parameters on total suspended solid load (TSSL), the EL2 and MA2 equations were applied to the EL2 turbidity and discharge records. When the MA2 regression equation was applied to EL2 data, predicted TSSL was reduced by two-thirds compared to the EL2 regression. This suggests that site-specific calibrations are required for the Ells and MacKay rivers to calculate accurate sediment loads.

To test whether unique turbidity-TSS relationships exist at other JOSMP data sonde stations, data were included from hand-dipped monthly TSS sampling (Section 6.1.1.3, *Turbidity-TSS Calculations*; Figure 6.1-3). At present, the data set is relatively small, and not all sonde stations have TSS samples, since the data sonde program under the JOSMP began in late July 2015. While data obtained to date suggest a consistent relationship may exist at some stations (e.g., FI WSC), an insufficient number of data points are currently available from these other stations to develop reliable calibration functions. In addition, no consistent relationship is seen between turbidity and TSS at other stations (e.g., STB RIFF 7), suggesting that further testing is required to develop reliable turbidity-TSS relationships for some of the other rivers in the study area.

Figure 6.1-3 Relationships between levels of turbidity and concentrations of total suspended solids for all JOSMP sonde stations (2015 open-water period).



Sediment Loads and Balances in the 2015 Monitoring Period

MacKay River

Discharge generally declined from late July to the first week in August, 2015 in the Mackay River (Figure 6.1-4A). Precipitation events in the first week of September (Figure 6.1-4B[2]) caused an increase in discharge, followed by a consistent decrease in discharge for the remainder of the 2015 WY. No industry water releases were reported in the MacKay catchment in the 2015 WY, and as of 2015, 0.79% of the watershed had been cleared (not-closed circuited), and 0.14% had been hydrologically closed circuited (Section 2.2, Section 2.3, Section 5.5). Discharge was generally higher and increases in discharge occurred later at downstream station MA1 compared to the upstream station MA2 (Figure 6.1-4A). Runoff in the period described here was 7.89 mm at the upstream S40/MA2 station and 7.35 mm at the downstream 07DB001/MA1 station.

Sediment concentrations and loads at station MA2 in the period of record are dominated by a nine-hour event that occurred on July 24, 2015 (Figure 6.1-4C-D). 29.9 t of sediment, 26% of the total monitored amount, were transported at station MA2 on this day. Unfortunately, the data sonde at downstream station MA2 was not yet deployed at this time.

In Figure 6.1-4E, daily sediment loads measured at the upstream station MA2 have been subtracted from daily loads measured at downstream station MA1[3].

For the monitoring period as a whole, more sediment was recorded at upstream station MA2 (56.5 t) than at downstream downstream station MA1 (47.3 t) (Figure 6.1-4B)[4], indicating that the Mackay River between the monitoring stations was depositional for the monitoring period as a whole. Most of the difference of 9.2 t of sediment that was recorded at the upstream station MA2 but not the downstream station MA1 was deposited at the early-August discharge peak, when 5.5 t more sediment was recorded upstream compared to downstream on August 7, 2015.

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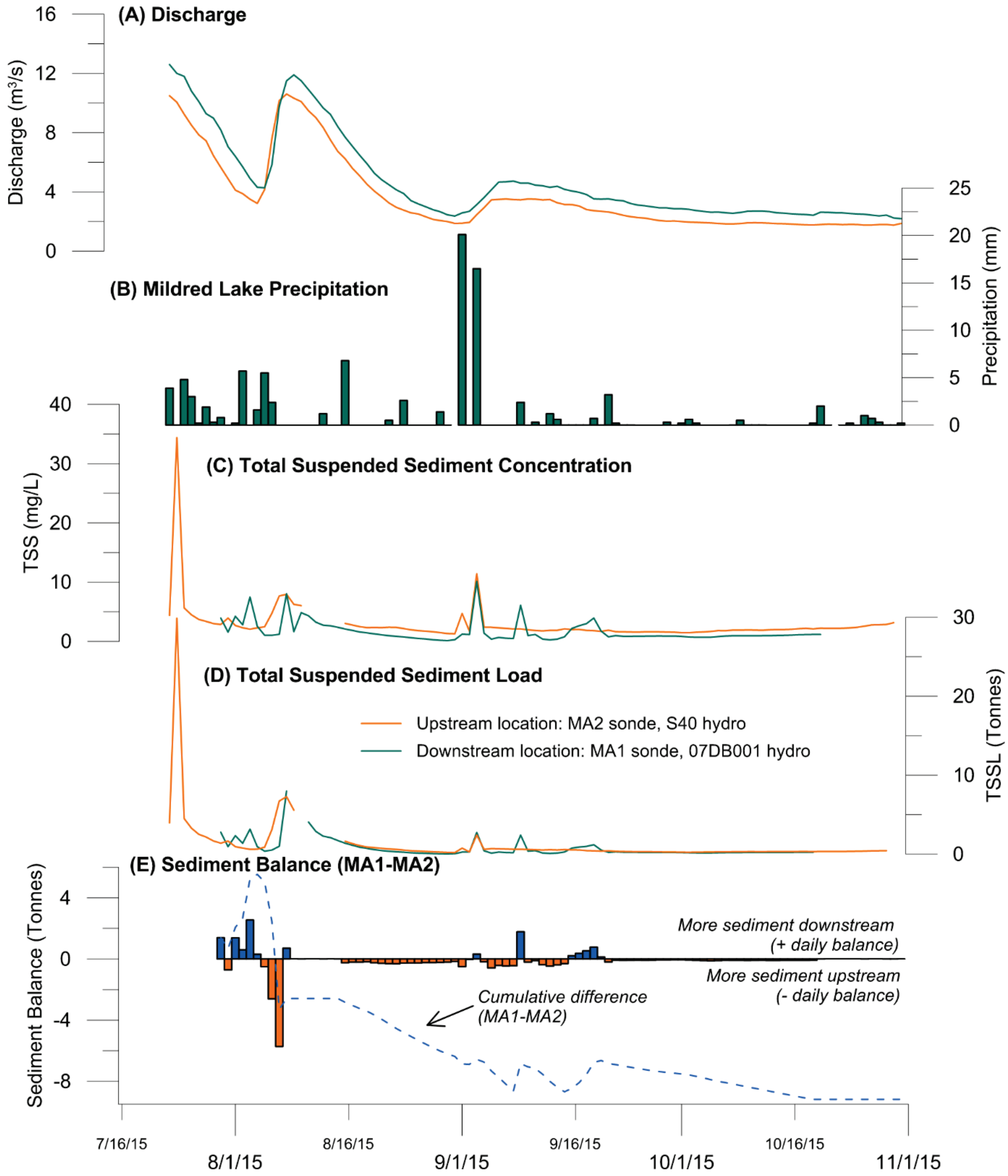
[2] Recorded at Environment Canada Mildred Lake Station, Climate ID 3064528, 310 masl, 466086 m E, 6322101 m N (UTM 12V), located about 24 km east-northeast of station MA2, and about 16 km south-southeast of station MA1.

[3] A positive difference signifies that more sediment was recorded downstream than upstream, indicating net production of suspended sediment along the reach and that the reach is erosional. A negative difference signifies that more sediment was recorded upstream than downstream indicating that sediment was deposited along the reach.

[4] Over the period when TSS data were available from both stations.

Figure 6.1-4 MacKay River sediment loads and balance in the 2015 monitoring period.



Note: Discharge data are from WSC station 07DB001, and are preliminary and subject to change.

Ells River

Discharge at the two Ells River hydrometric stations was generally of similar magnitude and pattern in the monitoring period (Figure 6.1-5A). The watershed areas of each of the stations differ by only 8% (Table 6.1-1) and runoff depths (discharge normalized by watershed area) were similar at both stations: 7.3 mm at station EL2, compared to 7.9 mm at station ELLS RIFF 5.

The two recorded increases in discharge (Figure 6.1-5B) were likely a result of: (i) a sustained period of low-intensity precipitation in late July; and (ii) a period of heavy rain in early September (Figure 6.1-5B)[5]. Precipitation data presented here were recorded at Environment Canada Mildred Lake Station (32 km southeast of ELLS RIFF 5, and 25 km south-southeast of EL2). No industry water releases were reported in the Ells River catchment in the 2015 WY, 0.15% of the watershed has been hydrologically closed-circuited, and 1.50% has been cleared (but not closed-circuited; Section 2.2, Section 2.3, Section 5.8).

Downstream station EL2 generally experienced more short-lived, higher-magnitude TSS events in the 2015 monitoring period than upstream station ELLS RIFF 5 (Figure 6.1-5C). Overall, 2.4 t more sediment was recorded at downstream station EL2 than upstream station ELLS RIFF 5 (37.7 t vrs. 35.3 t, Figure 6.1-5D).

The river between upstream station ELLS RIFF 5 and downstream station EL2 was both erosional and depositional during the monitoring period. The reach was generally depositional during periods of declining discharge (Figure 6.1-5E, orange bars), and generally erosional during periods of increasing discharge (Figure 6.1-5E, blue bars). For example, in the discharge event in the first week in September, 2015, the reach was initially erosional, but gradually shifted to depositional as flows receded over the remainder of the monitoring period.

6.1.1.5 Conclusions

Calibration of turbidity to TSS was successful for data sonde locations on the MacKay and Ells rivers. Data suggest that site-specific relationships exist between turbidity and TSS in the study area and results also show that different EXO2 turbidimeters provide similar and statistically-significant results.

Sondes on the MacKay and Ells Rivers were deployed in upstream/downstream pairs and also deployed alongside hydrometric monitoring stations. This allowed calculations of sediment budgets for both rivers. Records from 2015 are relatively short, but between each of the two pairs of monitoring stations, the MacKay River was depositional overall, and the Ells River was slightly erosional. Generally, spikes in TSS concentration and loads appear to have hydroclimatic sources, and increase in response to precipitation and discharge events.

Results from this preliminary study suggest that further turbidity-TSS calibrations for data sonde stations in the JOSMP network is a useful first step in the characterization of baseline or current conditions, identification of disturbances, and calculation of sediment budgets between monitoring stations.

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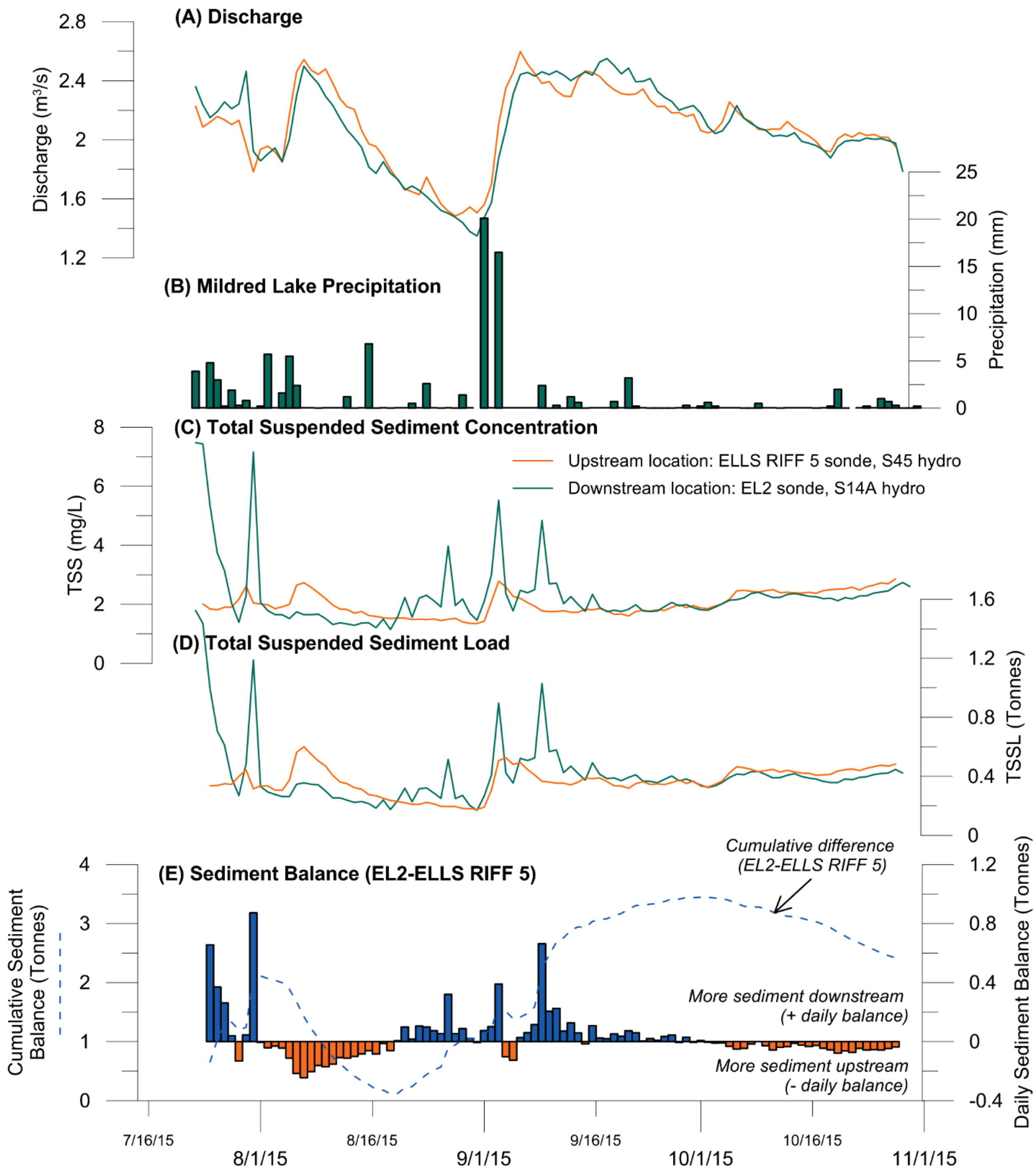
5 Recorded at Environment Canada Mildred Lake Station, Climate ID 3064528, 310 masl, 466086 m E, 6322101 m N (UTM 12V), 32 km southeast of station Ells Riff 5 and 25 km south-southeast of station EL2.

Figure 6.1-5 Ells River sediment loads and balance in the 2015 monitoring period.



6.1.1.6 Potential Future Analyses

Bench tests have proven useful for producing controlled turbidity-TSS calibrations. Additional bench tests could be conducted to develop site-specific turbidity-TSS relationships for the remaining JOSMP sonde locations. Additional bench tests could also be conducted with samples from multiple reaches along rivers, and from multiple time periods to ensure that calibrations are temporally and spatially consistent.

Additional field sampling of TSS from sonde locations could also help verify that field-based calibrations are consistent with bench test results. Care should be taken to obtain undisturbed samples near sonde deployments and to sample across a wide range of TSS concentrations. Low TSS/turbidity data that are close to the analytical detection limit or the accuracy of the turbidimeter will not be useful for generation of calibration curves; extending linear calibration lines down from high turbidity levels and associated TSS concentrations will yield more accurate results (e.g., error bars in Figure 6.1-2).

Given that the rivers described here are relatively small and well-mixed, it is assumed that TSS concentration is consistent across the river cross-sections, and that measurement of turbidity in a fixed-location is representative of turbidity in a cross-section. This is not always a valid assumption (Horowitz et al. 1990, RISC 2006, Rovira et al. 2012), and could also be tested in the JOSMP study area.

Canadian water quality guidelines define TSS exceedances based on deviation from "background levels" (CCME 2002). A longer-term study and/or a study that defines background levels from baseline stations, would better define these levels, which could then be used to more accurately define TSS exceedances. Additional work could also compare turbidity exceedances to TSS exceedances, to determine whether additional information for assessment of ecosystem health is obtained.

6.1.2 An assessment of Uncertainty in Estimating Total Suspended Solids Loading from Computed Discharge Records in the Study Area

6.1.2.1 Introduction

This study assesses the value of collecting total TSS samples specifically along with discharge measurements, which has been conducted historically as part of the Climate and Hydrology component for the RAMP and the JOSMP. This assessment is based on a literature review of the Water Survey of Canada (WSC) sediment program and a discussions of errors associated with sediment load calculations using continuous discharge data.

Historically, discharge (Q) measurements and sampling for TSS were conducted synchronously for the RAMP and JOSMP programs as a means to potentially calculate sediment loads using Q-TSS relationships. Under JOSMP, the water quality sampling frequency was increased to monthly and also includes TSS analysis. This change has resulted in questioning the need to sample TSS independently along with Q measurements to maintain this historic Q-TSS dataset.

6.1.2.2 Assessment of Uncertainty

The WSC conducted monitoring of suspended sediment in the study area from the early 1970s until 1993 (Lindeman et al. 2011a, b). The frequency of suspended sediment sampling conducted by the WSC varied from hourly to weekly; the size of a basin and its runoff characteristics also influenced sampling frequency (Anderson 2001). Sampling methods varied by river, but typically involved depth-integrated sampling to obtain samples with a vertically-representative sediment concentration. Multiple depth-integrated samples were obtained across channels. Despite these protocols, uncertainty[6] estimates for the determination of suspended sediment load "varied with flow conditions, but values of 100% or more can be demonstrated in this historic data" (Lindeman et al. 2011 a,b).

By contrast, in the JOSMP study area, TSS samples are obtained roughly monthly, and are obtained as hand-dipped samples. In the RAMP Technical Design and Rationale document, it was stated that "a reasonable level of accuracy [*for determination of sediment loads and fluxes*] would require continuous, rather than monthly, sediment sampling" (RAMP 2009b).

Uncertainty for a manual discharge measurement are well understood and generally range from 3% to 20% (Sauer and Meyer 1992; Herschy 2009). Continuous Q derived from stage records incorporates additional sources of uncertainty that are derived from the continuous stage records, the stage-discharge relationship, and the hydraulic conditions at the station (Le Coz 2012). This generally results in uncertainty of continuous Q that are greater than that of the manual measurement, but are still within the same order of magnitude as manual measurement uncertainty.

Collecting TSS samples that are not paired with manual Q measurements will increase the uncertainty of the Q-TSS relationship by incorporating the additional uncertainty from the computed Q. However, given that calculated sediment load uncertainty for the WSC sediment monitoring program was greater than 100%, the increased uncertainty of not using manual Q measurements in a Q-TSS relationship is relatively small.

6.1.2.3 Concluding Remarks

This assessment was conducted to investigate the possibility of discontinuing the paired TSS samples that have been collected along with manual discharge measurements for the RAMP and JOSMP program. Uncertainties associated with the derivation of continuous TSS data from a discharge record are greater than the increase in uncertainty using computed Q values with TSS samples collected during routine water quality sampling. Therefore, discontinuing TSS sampling along with manual Q measurements would only marginally increase the uncertainty in any Q-TSS relationship that is developed.

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6 As used here, uncertainty is a quantification of the doubt about measurement results. Error is the difference between the measured value and the "true value" of the thing being measured (Bell 1999).

6.2 EXPANDED FISH COMMUNITY STUDY

6.2.1 Introduction

The fish community monitoring program was established under the RAMP in 2009 (RAMP 2010) in order to assess potential changes in the fish assemblage of a watercourse within and outside of oil sands development, and to develop regional trends in indicators of ecological condition. Fish and habitat data are analyzed on the basis of a number of measurement endpoints: total abundance (fish per meter of watercourse sampled); relative abundance (catch per unit effort); diversity; richness; and the assemblage tolerance index (ATI)[7].

Sampling for the fish community monitoring program has historically involved reporting the catch from electrofishing five sub-reaches within a sampled reach, with the length of each sub-reach being a function of the wetted width and with the sub-reaches being adjacent to each other. The extent to which the values of the measurement endpoints obtained with this five sub-reach approach are characteristic of the fish community had never been assessed, and an “expanded” fish community study was therefore implemented in fall 2015 in conjunction with the original fish community monitoring program in order to test the adequacy of the five sub-reach protocol. First, the extent of differences in measurement endpoints between the two methods was assessed, then adequacy was determined by which method produced more precise estimates.

In the expanded fish community study, the fish community was collected from a total of 10 sub-reaches from each of ten river reaches at which the original fish community monitoring program was being conducted. The approach to assessing whether a five sub-reach sampling design was adequate involved comparison of values of measurement endpoints from the n=5 sub-reaches to values of measurement endpoints computed from the n=10 sub-reaches. The analysis of the data examined bias and precision. With respect to bias, the question was:

> *Do the values of measurement endpoints from the n=5 sub-reaches have a significant positive or negative bias compared to the values of measurement endpoints from the n=10 sub-reaches?*

That is, would the index values obtained with n=5 sub-reaches over- or under-estimate the “condition” of the fish community? Then, to determine the adequacy of each method with respect to precision, the question was:

> *How many sub-reaches would be required to achieve a certain within-reach precision in estimating reach-scale average values of measurement endpoints for fish communities?*

Environment Canada (2012) recommends that within-reach replication for collections of benthic invertebrates be determined on the basis of precision, with the number of sub-samples required being the number that will produce within-reach estimates of indices that are within ± 20% of the true value. This criterion was adopted for this (precision) component of the study.

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[7] The concept of assemblage tolerance index (ATI) was developed by Whittier et al. (2007) for stream and river fish assemblages in the western United States to quantify the tolerance of fish species to an overall human disturbance gradient.

In addition, selective fishing with additional backpack electrofishing and other supplemental gear types were used for a sub-set of the 10 sub-reaches to determine whether the ability to identify all species present could be improved. Selective fishing focuses effort on specific habitat types suitable for fish species and gear type selection is important for fishing certain habitats (i.e., minnow traps in deep pools). Species composition and richness were compared in datasets collected using primary backpack electrofishing across all 10 sub-reaches and data collected from selectively fishing a sub-set of 10 sub-reaches using either additional backpack electrofishing, boat electrofishing, seine netting, or minnow trapping.

6.2.2 Methods

6.2.2.1 Field Methods

Fish Sampling

The expanded fish community study was conducted in conjunction with the current JOSMP fish community monitoring program from September 17 to 23, 2015 at ten existing fish community monitoring reaches located on tributaries to the Athabasca River (Table 6.2-1, Figure 6.2-1).

Under the current monitoring program, fish communities are surveyed using a backpack electrofishing unit within a stream reach that is approximately 20x the wetted width. Each reach is divided into five sub-reaches within which electrofishing is carried out and the fish catch in each sub-reach is documented. The rationale for splitting the reach catch into five sub-reaches is to examine and quantify within-reach variability in fish community composition. A detailed description of the current sampling methodology is described in Section 3.1.1.2. The expanded fish community study involved a doubling of the fishing effort. Fish communities were surveyed by backpack electrofishing along a reach that was approximately 40x the wetted width. The reach was divided into 10 sub-reaches with the sub-reaches being adjacent to each other, and the catch in each sub-reach documented.

Additional sampling, using backpack electrofishing, boat electrofishing, minnow traps, and/or seine nets, was also conducted for a subset of the 10 sub-reaches. Additional electrofishing effort and supplemental gear types targeted specific habitat types and augmented the primary backpack electrofishing efforts that covered the entirety of each sub-reach. The selection of sub-reaches and gear types for the additional sampling was based on mesohabitat type (Table 6.2-2, Table 6.2-3). Additional backpack electrofishing and seining were used in shallow areas (<0.5 m water depth) and in riffle habitat, while boat electrofishing and minnow trapping were carried out in deep-water areas that were not wadeable (>1.0 m).

Fish collected from each sub-reach were kept in a holding bucket of river water until the completion of all fishing. For each sub-reach, fish were measured (fork length ± 1 mm) and weighed (± 0.01 g), and the external physical condition of individual fish was assessed and documented.

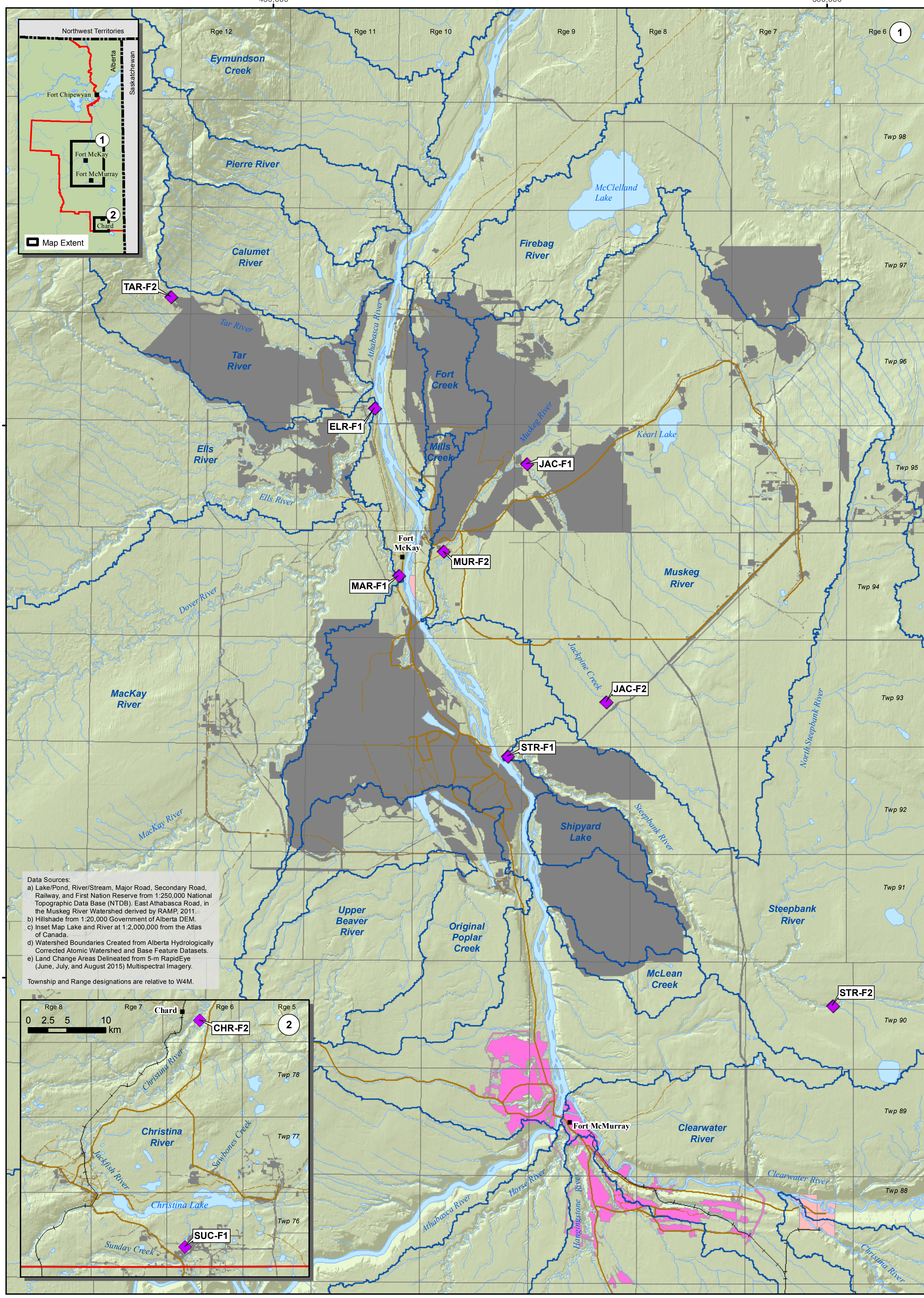
Table 6.2-1 Sampling locations for the expanded fish community program on tributaries of the Athabasca River, fall 2015.

Waterbody	Reach Name	Reach Designation	UTM Coordinates (NAD83, Zone 12)			
			Downstream Boundary		Upstream Boundary	
			Easting	Northing	Easting	Northing
Muskeg River Watershed						
Muskeg River	MUR-F2	*Test*	465560	6338177	465341	6338621
Jackpine Creek (lower)	JAC-F1	*Test*	472819	6346542	472977	6346373
Jackpine Creek (upper)	JAC-F2	*Baseline*	480040	6324996	480130	6324878
MacKay River Watershed						
MacKay River	MAR-F1	*Test*	461288	6336411	460426	6337270
Steepbank River Watershed						
Steepbank River (lower)	STR-F1	*Test*	471138	6320064	471576	6320337
Steepbank River (upper)	STR-F2	*Baseline*	500458	6297490	500732	6297509
Ells River Watershed						
Ells River (lower)	ELR-F1	*Test*	459122	6351612	458636	6351572
Tar River Watershed						
Tar River (upper)	TAR-F2	*Baseline*	440731	6361668	440715	6361688
Christina River Watershed						
Christina River at Hwy 881	CHR-F2	*Test*	508221	6187713	508552	6187106
Sunday Creek (Lower)	SUC-F1	*Test*	506296	6158399	506374	6158221

Table 6.2-2 Description of mesohabitat categories used to select fishing habitat for additional backpack electrofishing and supplemental gear types.

Habitat Type	Gear Selection	Class	Description
Riffle	Backpack Electrofishing	-	High velocity/gradient relative to run habitat; surface broken due to submerged or exposed bed material; shallow relative to other mesohabitat units; coarse substrate; usually limited instream or overhead cover for juvenile or adult fish.
Run	Boat Electrofishing, Seine Netting, or minnow trappeing	1	Highest quality/deepest run habitat; generally deep/slow type; coarse substrate; high instream cover from substrate and/or depth (generally > 1.0 m deep).
	Backpack electrofishing, seine netting, or minnow trappeing	2	Moderate quality/depth; high to moderate instream cover except at low flow; generally deep/fast or moderately deep/slow type (generally 0.75 -1.0 m deep).
		3	Lowest quality/depth; generally shallow/slow or shallow/fast type; low instream cover in all but high flows (generally 0.5 - 0.75 m deep).
Pool	Boat electrofishing, seine netting, or minnow trappeing	1	Highest quality pool habitat based on size and depth; high instream cover due to instream features and depth; suitable holding water for adults and for overwintering (generally > 1.5 m).
		2	Moderate quality shallower than pool #1 with high to moderate instream cover except during low flow conditions; not suitable for overwintering.
		3	Low quality pool habitat; shallow and/or small; low instream cover at all but high flow events.

Figure 6.2-1 Locations of expanded fish community monitoring activities conducted in support of the 2015 JOSMP.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- Regional Municipality of Wood Buffalo Boundary
- First Nations Reserve
- Town of Fort McMurray
- Land Change Area as of 2015[e]
- Expanded Fish Community Monitoring Reach

0 2.5 5 10 km N

Scale: 1:350,000

Projection: NAD 1983 UTM Zone 12N

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Table 6.2-3 Supplemental gear types used within sub-reaches of each expanded fish monitoring reach.

Reach	Sub-reach									
	1	2	3	4	5	6	7	8	9	10
MUR-F2	-	BP	B	-	-	-	-	-	-	-
JAC-F1	M	M	M	M	M	-	-	-	-	-
JAC-F2	M	M	-	M	M	M	M	-	-	-
MAR-F1	BP	S	-	-	-	-	-	-	-	-
STR-F1	-	-	-	-	-	S	S	S	-	-
STR-F2	B	-	BP	BP	-	-	-	-	-	BP
ELR-F1	B	-	-	-	-	-	B	-	-	-
TAR-F2	-	M	-	-		-	-	-	-	-
CHR-F2	-	-	B	B	-	-	-	BP, B	-	-
SUC-F1	M	M, S	M	M	M	-	-	-	-	-

BP = additional backpack electrofishing, B = boat electrofishing, M = minnow trap, S = seine netting.

"-" no additional survey effort.

6.2.2.2 Analytical Approach

Selection of Measurement Endpoints

Measurement endpoints calculated for each sub-reach were:

- Total abundance – total number of fish caught in the reach divided by the lineal length of the reach (No. fish/m);
- Catch-per-unit-effort (CPUE) – total number of fish caught per 100 seconds of electrofishing;
- Richness – total number of fish species collected per reach. Higher richness values are typically used to infer a "healthier" fish community;
- Diversity – this measurement endpoint was computed for each reach following the calculation for Simpson's Diversity (D):

$$D = 1 - \sum (p_i)^2$$

  Where,

  - p_i is the proportion of the total abundance accounted for by species *i.*

  Higher diversity values are typically used to infer a "healthier" fish assemblage; and

- Assemblage Tolerance Index (ATI) (Table 6.2-4) For species captured in the Athabasca oil sands region, but not assessed by Whittier et al. (2007), a number was assigned based on species similarity to those with calculated values. With this index, lower tolerance values imply a species that is more sensitive to disturbance.

Values of measurement endpoints were averaged for the original n=5 sub-reaches and also for the expanded n=10 sub-reaches. Richness and ATI were the only measurement endpoints calculated for the augmented fishing effort given that the focus of the assessment was on determining whether additional fishing efforts increased the number of species caught.

Table 6.2-4 Tolerance values for fish collected during the expanded fish community study of the 2015 JOSMP (adapted from Whittier et al. 2007).

Common Name	Species Code	Tolerance Value
Arctic grayling	ARGR	2.0
brook stickleback*	BRST	9.4
burbot	BURB	2.0[1]
cisco	CISC	2.5[1]
emerald shiner	EMSH	6.9
finescale dace*	FNDC	7.0
fathead minnow*	FTMN	8.3
goldeye	GOLD	9.3
lake chub*	LKCH	5.5
lake whitefish*	LKWH	2.5[1]
longnose dace*	LNDC	6.2
longnose sucker*	LNSC	4.6
northern redbelly dace*	NRDC	7.0[1]
northern pike	NRPK	7.8
pearl dace*	PRDC	6.7
slimy sculpin*	SLSC	3.0[1]
spoonhead sculpin	SPSC	3.0[1]
spottail shiner*	SPSH	7.7
trout-perch*	TRPR	8.4
walleye	WALL	8.7
white sucker*	WHSC	7.6
yellow perch	YLPR	7.4

* Commonly caught fish species of Athabasca River tributaries in the Alberta oil sands region.

1 Judgment-based score from values for similar species.

Comparison of Expanded 10 Sub-Reach Design to Original 5 Sub-Reach Design

Bias

A measurement of the range of potential bias between the results of the expanded 10 sub-reach design compared to the original 5 sub-reach design was calculated for each of the measurement endpoints, following the methodology outlined in Bland and Altman (1986), as:

$$\bar{d} \pm 2*SD$$

Where,

- $\bar{d}$ is the overall average difference, i.e., the average difference in the values of a given measurement endpoint of the original 5 sub-reach design compared to the expanded 10 sub-reach design in the ten reaches that were part of the study (Table 6.2-1); and
- SD is the standard deviation of the differences in the values of a given measurement endpoint of the original 5 sub-reach design compared to the expanded 10 sub-reach design in the ten reaches that were part of the study.

If the original n=5 sampling routine is to be used as the basis for comparison, the range of values defined by d is the approximate 95% likelihood for deviations from the values that would be obtained using the expanded 10 sub-reach design. Assuming that the n=10 provides a better approximation to the actual endpoint values, knowing how incorrect the n=5 endpoint values are should be informative. Deciding if the n=5 values will be potentially too deviant becomes somewhat subjective, still, despite quantifying the variability.

Precision

Precision was calculated for both the expanded 10 sub-reach design and the original 5 sub-reach design as:

$$P=(S)/(\text{sqrt}(n)*\bar{x})$$

where,

- P is the precision, expressed as the ability to estimate a measurement endpoint within P% of the true mean value;
- n is the sample size (i.e., number of sub-reaches, or here either 5 or 10);
- S is the standard deviation of measurement endpoint values across n sub-reaches (computed separately for the n=5 and n=10 sub-reach designs; and
- $\bar{x}$ is the mean measurement endpoint value across n sub-reaches (again computed separately for the n=5 and 10 sub-reach designs).

Supplemental Gear Comparison

Species composition and richness were compared at a sub-reach and reach level to determine whether additional backpack electrofishing and the use of supplemental gear improved the ability to identify all fish species present within a given area. At each reach, additional backpack electrofishing and/or supplemental gear was used selectively across sub-reaches one to ten; therefore, species composition and richness were compared between data obtained using primary backpack electrofishing methods (sub-reaches one to ten) and data obtained using selective electrofishing methods and supplemental gear (see Table 6.2-3). Additional species captured using selective fishing methods were also assessed by the species' tolerance to an overall human disturbance gradient using values summarized in Table 6.2-4. With this index, lower tolerance values imply a species that is more sensitive to disturbance. Comparisons are presented graphically and in tabular format.

6.2.3 Results

6.2.3.1 Measurement Endpoints

Values of the each of the measurements endpoints for each of the reaches for both the original 5 sub-reach design and the expanded 10 sub-reach design are presented in Table 6.2-5.

6.2.3.2 Comparison of Expanded 10 Sub-Reach Design to Original 5 Sub-Reach Design

Bias

There was a negative overall bias in estimates using the original n=5 sub-reach sampling design compared to the n=10 sub-reach design for all measurement endpoints, and a large potential bias relative to the overall mean for all measurement endpoints with the exception of ATI. The overall bias for abundance was -0.001 (# of fish/m), with a potential bias of -0.12 (# of fish/m) to 0.11 (# of fish/m), and an overall mean of 0.23 (# of fish/m). This indicates that on average abundance is 0.001 (# of fish/m) lower using the n=5 sub-reach than the n=10 sub-reach design, but could potentially be as much as 0.12 (# of fish/m) lower or 0.11 (# of fish/m) higher, which is a large difference considering the overall mean is 0.23 (# of fish/m) (Table 6.2-5). Similar results were generated for average richness, diversity, and CPUE. Richness had an overall mean of 3.06 with an overall bias of -0.07. The range of potential bias indicated that average richness using the original survey effort could be 1.25 less or 1.11 higher than that of the expanded method, which was about half or double the overall mean of 3.06. Diversity had an overall mean of 0.44 and an overall bias of -0.002, with a potential bias ranging from 0.18 less than or 0.17 greater than diversity generated using the expanded survey effort. CPUE had an overall mean of 4.13 and an overall bias of -0.12, with a potential bias ranging from 2.44 less than or 2.19 greater than the CPUE generated using the expanded survey effort. ATI was the only measurement endpoint where the bias (overall and potential) indicated that both the original and expanded survey efforts produced similar results. The ATI had an overall mean of 5.47 with an overall bias of -0.15, and a potential bias ranging from 0.70 less than or 0.40 greater than ATI generated using the expanded effort; a relatively small deviation of estimates (less one unit of ATI) given the overall mean was 5.47 (Table 6.2-5).

Precision

While precision was similar between the expanded 10 sub-reach design and the original 5 sub-reach design, the expanded 10 sub-reach design collected enough samples to allow all measurement endpoints to be estimated to less than 20% of the true mean of each measurement endpoint (Table 6.2-6). The average difference in precision between the two designs was 6%, ranging from 1% (ATI) to 10% (diversity). Average precision of the expanded 10 sub-reach design ranged from 6% (ATI) to 19% (abundance and CPUE) indicating that values of measurement endpoints were estimated to within 6% to 19% of the true mean. Under the original 5 sub-reach design too few samples were collected to estimate abundance, diversity, and CPUE within 20% of the true mean.

Table 6.2-5 Measurement endpoints for each expanded fish community monitoring reach using expanded 10 sub-reach design to original 5 sub-reach design, fall 2015.

Reach	Abundance (No. fish/m)			CPUE (No. fish/100 sec)			Richness			Diversity			ATI		
	Original	Expanded	Diff.	Original	Expanded	Diff.	Original	Expanded	Diff.	Original	Expanded	Diff.	Original	Expanded	Diff.
MUR-F2	0.19	0.12	0.07	4.38	2.83	1.55	2.60	2.10	0.50	0.47	0.37	0.10	5.91	6.44	-0.53
JAC-F1	0.26	0.27	-0.01	3.15	3.21	-0.06	3.40	3.40	0.00	0.60	0.60	0.00	4.55	5.01	-0.47
JAC-F2	0.18	0.19	-0.01	2.22	2.36	-0.14	3.00	3.00	0.00	0.62	0.53	0.09	7.21	7.43	-0.23
MAR-F1	0.12	0.12	0.00	4.15	4.19	-0.04	4.20	3.90	0.30	0.44	0.43	0.01	6.69	6.71	-0.02
STR-F1	0.07	0.10	-0.03	1.13	1.60	-0.47	1.80	2.60	-0.80	0.25	0.43	-0.18	4.16	4.49	-0.32
STR-F2	0.21	0.21	0.00	3.25	3.09	0.17	2.60	2.70	-0.10	0.33	0.34	-0.01	5.10	4.90	0.20
ELR-F1	0.24	0.35	-0.11	5.92	8.51	-2.59	4.60	4.80	-0.20	0.62	0.60	0.03	6.72	6.64	0.08
TAR-F2	0.58	0.53	0.05	8.70	8.22	0.48	1.40	1.80	-0.40	0.11	0.18	-0.07	3.11	3.22	-0.11
CHR-F2	0.11	0.16	-0.05	2.72	3.92	-1.20	2.80	3.80	-1.00	0.42	0.50	-0.07	5.97	5.70	0.26
SUC-F1	0.37	0.29	0.08	5.07	4.01	1.07	3.80	2.80	1.00	0.49	0.40	0.10	4.50	4.86	-0.36
Mean Value of Measurement Endpoint in 5 Sub-Reach and 10 Sub-Reach Designs	0.23			4.13			3.06			0.44			5.47		
Mean of Differences (Overall Bias) Among Reaches			-0.001			-0.12			-0.07			-0.002			-0.15
SD of Differences Among Reaches			0.06			1.16			0.59			0.09			0.28
Approximate 95th Percentile of Measured Differences			0.11			2.19			1.11			0.17			0.41
Approximate 5th Percentile of Measured Differences			-0.12			-2.44			-1.25			-0.18			-0.70

Diff. = difference

SD = standard deviation

Table 6.2-6 Precision of estimating measurement endpoints using original (n=5 sub-reaches) and extended (n=10 sub-reaches) survey efforts by reach and overall, fall 2015.

Reach	Estimate of Precision									
	Abundance (No. of fish/m)		CPUE (No. fish/100sec)		Richness		Diversity		ATI	
	Original (%)	Expanded (%)	Original (%)	Expanded (%)	Original (%)	Expanded (%)	Original (%)	Expanded (%)	Original (%)	Expanded (%)
MUR-F2	42	36	41	36	9	11	23	22	4	4
JAC-F1	27	14	28	14	18	10	11	6	5	5
JAC-F2	25	17	24	16	11	12	5	13	4	4
MAR-F1	28	15	29	15	16	9	28	15	7	5
STR-F1	50	22	52	22	27	15	62	23	12	8
STR-F2	20	18	22	17	31	21	42	28	21	12
ELR-F1	19	17	19	17	5	4	9	6	4	3
TAR-F2	12	11	14	12	17	14	61	37	2	3
CHR-F2	8	20	12	21	16	9	23	11	6	3
SUC-F1	17	17	17	16	5	14	12	21	9	8
Average	25	19	26	19	16	12	28	18	7	6

Shaded cells indicate that estimated measurement endpoints are generally >±20% of the true mean value.

6.2.3.3 Supplemental Gear Comparison

Selective backpack and boat electrofishing appeared to be a more effective method for capturing a higher proportion of all species present than expanding effort from five to ten sub-reaches alone, and caught more sensitive species (Figure 6.2-2). With the exception of *baseline* reaches TAR-F2, STR-F2, and *test* reach CHR-F2, the majority of fish species were caught within the first five sub-reaches in the expanded 10 sub-reach design (Figure 6.2-2). However, additional selective electrofishing increased species richness for some reaches (i.e., *test* reach MUR-F2 and *baseline* reach STR-F2), where cumulative richness appeared to asymptote after five sub-reaches. Comparing across all 10 sub-reaches, selective electrofishing increased species richness at all but one of the sub-reaches in which it was applied (Table 6.2-7), and at five of ten reaches overall (Table 6.2-8). Additional species caught overall through selective electrofishing included Arctic grayling, burbot, and slimy sculpin, which are classified as more sensitive than most other species caught during the study (Table 6.2-4).

Seine netting was the least effective gear type, with no additional species caught; however, it was also the least commonly used supplemental method. Minnow trapping was moderately effective, catching one additional species at sub-reaches 3 (white sucker) and 7 (northern dace) of *baseline* reach JAC-F2 that primary backpack electrofishing methods did not catch. The use of minnow trapping did not increase richness overall at this reach as these species were caught at other sub-reaches using the primary backpack electrofishing method.

Table 6.2-7 Comparison of fish species composition and effort by sub-reach sampled using primary backpack electrofishing methods and supplemental gear types.

Reach	Sub-reach	Primary Backpack Electrofishing Method		Supplemental Fishing							
				Additional Species Caught and Effort							
		Species	Effort (sec)	Additional BPEF	Effort (sec)	Boat EF	Effort (sec)	Minnow Trap	Effort (hours)	Seine Net	Effort (# of pulls)
MUR-F2	2	LKCH, LNSC	278	LNDC	1,006	-	-	-	-	-	-
	3	LKCH, TRPR, WHSC	278	-	-	BURB	784	-	-	-	-
JAC-F1	1	LNDC, SLSC	242	-	-	-	-	-	10.00	-	-
	2	LNSC, SLSC	256	-	-	-	-	-	14.25	-	-
	3	LKCH, LNDC, LNSC, SLSC, WHSC	251	-	-	-	-	-	13.50	-	-
	4	LKCH, LNDC, LNSC, SLSC	242	-	-	-	-	-	4.25	-	-
	5	ARGR, LKCH, LNSC, SLSC	251	-	-	-	-	-	4.00	-	-
JAC-F2	1	BRST, FNDC, LKCH	229	-	-	-	-	-	7.00	-	-
	2	BRST, LKCH	238	-	-	-	-	-	3.50	-	-
	4	BRST, LKCH, LNSC	245	-	-	-	-	WHSC	7.00	-	-
	5	BRST, LNSC, NRDC, WHSC	251	-	-	-	-	-	3.50	-	-
	6	FNDC, NRDC	215	-	-	-	-	-	7.50	-	-
	7	BRST	241	-	-	-	-	NRDC	3.50	-	-
MAR-F1	1	LKCH, LNSC, TRPR, WHSC	458	WALL	505	-	-	-	-	-	-
	2	LKCH, LNDC, LNSC, NRPK, TRPR	474	-	-	-	-	-	-	-	3
STR-F1	6	LKCH, LNSC, SLSC	310	-	-	-	-	-	-	-	1
	7	BURB, LNDC, SLSC	322	-	-	-	-	-	-	-	1
	8	FNDC, LNDC, NRPK, SLSC, WHSC	313	-	-	-	-	-	-	-	1

BP = backpack, EF = electrofishing

"-" not sampled

Table 6.2-7 (Cont'd.)

Reach	Sub-reach	Primary Backpack Electrofishing Method		Supplemental Fishing							
				Additional Species Caught and Effort							
		Species	Effort (sec)	Additional BPEF	Effort (sec)	Boat EF	Effort (sec)	Minnow Trap	Effort (hours)	Seine Net	Effort (# of pulls)
STR-F2	1	SLSC	354	-	-	ARGR, LKCH, LNDC, PRDC, TRPR, WHSC	705	-	-	-	-
	3	LKCH, LNSC, PRDC, SLSC, TRPR	349	LNDC	93	-	-	-	-	-	-
	4	LKCH, LNDC, SLSC, TRPR	344	0	187	-	-	-	-	-	-
	10	SLSC, TRPR	343	LNSC	337	-	-	-	-	-	-
ELR-F1	1	LKCH, LNSC, TRPR, WHSC	459	-	-	SPSH	88	-	-	-	-
	7	LKCH, NRPK, TRPR, WHSC	464	-	-	SLSC	95	-	-	-	-
TAR-F2	2	SLSC	183	-	-	-	-	LNSC	30.00	-	-
CHR-F2	3	LNSC, WHSC	497	-	-	LKCH, NRPK, TRPR, WALL	1,740	-	-	-	-
	4	BURB, LNSC, WHSC	500	-	-	LKCH, NRPK, TRPR	1,074	-	-	-	-
	8	BURB, LKCH, LNDC, LNSC, WHSC	505	FNDC, TRPR, WALL	1,121	NRPK	636	-	-	-	-
SUC-F1	1	BURB, LKCH, SLSC, WHSC	286	-	-	-	-	0	2.50	-	-
	2	LKCH, LNSC, SLSC, WHSC	283	-	-	-	-	0	3.25	0	3
	3	LKCH, LNSC, SLSC, WHSC	281	-	-	-	-	0	4.50	-	-
	4	LKCH, SLSC, WHSC	290	-	-	-	-	0	3.00	-	-
	5	LKCH, LNSC, SLSC, WHSC	280	-	-	-	-	0	2.00	-	-

BP = backpack, EF = electrofishing, "-" not sampled

Table 6.2-8 Summary of species composition, richness, and effort by reach using the primary backpack electrofishing methods and supplemental gear types.

Station	Primary Backpack Electrofishing Method		Supplemental Fishing								Station Richness-Primary BPEF	Additional Richness for Supplemental Fishing	Cumulative Richness
			Additional Type of Species										
	Types of Species	Effort (sec)	Additional BP	Effort (sec)	Boat EF	Effort (sec)	Minnow Trap	Effort (hours)	Seine Net	Effort (# of pulls)			
MUR-F2	LKCH, LNSC, TRPR, WHSC	2,800	LNDC	1,006	BURB	784	-	-	-	-	4	2	6
JAC-F1	ARGR, LKCH, LNDC, LNSC, SLSC, WHSC	2,490	-	-	-	-	0	46	-	-	6	0	6
JAC-F2	BRST, FNDC, LKCH, LNSC, NRDC, SLSC, WHSC	2,393	-	-	-	-	0	32	-	-	7	0	7
MAR-F1	LKCH, LNDC, LNSC, NRPK, SLSC, SPSH, SPSH, TRPR, WALL, YLPR	4,719	0	505	-	-	-	-	0	3	10	0	10
STR-F1	BURB, FNDC, LKCH, LNDC, LNSC, NRPK, SLSC, TRPR, WHSC	3,109	-	-	-	-	-	-	0	3	9	0	9
STR-F2	LKCH, LNDC, LNSC, PRDC, SLSC, TRPR, WHSC	3,797	0	617	ARGR, WHSC	705	-	-	-	-	7	2	9
ELR-F1	LKCH, LNDC, LNSC, NRPK, SPSC, SPSH, TRPR, WALL, WHSC	4,552	-	-	SLSC	183	-	-	-	-	9	1	10
TAR-F2	ARGR, LKCH, LNSC, SLSC	1,943	-	-	-	-	LNSC	30	-	-	4	1	5
CHR-F2	BURB, LKCH, LNDC, LNSC, TRPR, WHSC, YLPR	4,965	FNDC	1,121	NRPK, WALL	3,450	-	-	-	-	7	3	9
SUC-F1	BURB, LKCH, LNSC, SLSC, WHSC	2,776	-	-	-	-	0	15.25	0	3	5	0	5

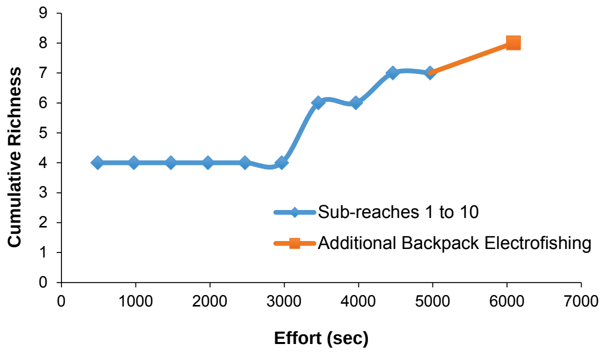
BP = backpack, EF = electrofishing

"-" not sampled

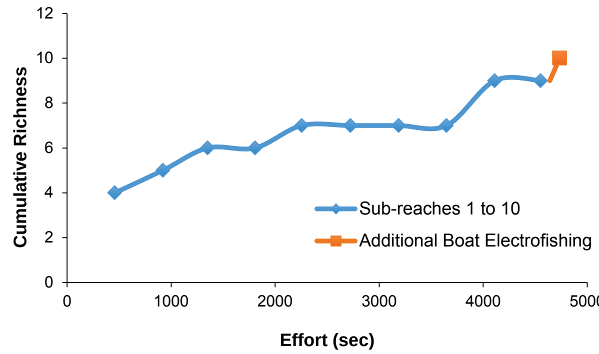
Shaded cells indicate where additional species were captured overall.

Figure 6.2-2 Cumulative number of species caught by electrofishing for each sub-reach 1 to 10 and additional electrofishing effort.

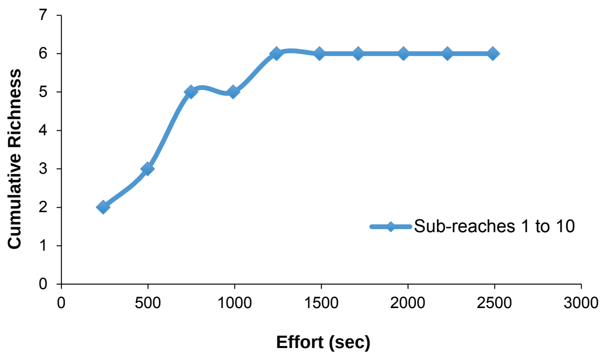
CHR-F2



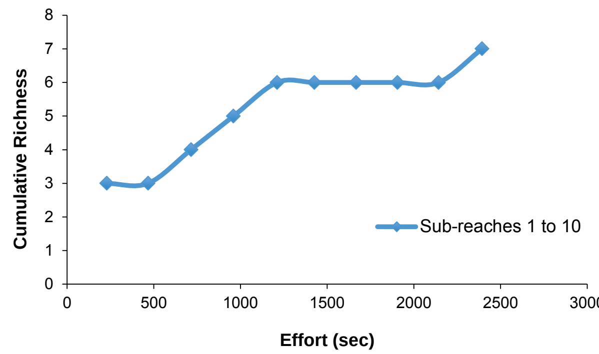
ELR-F1



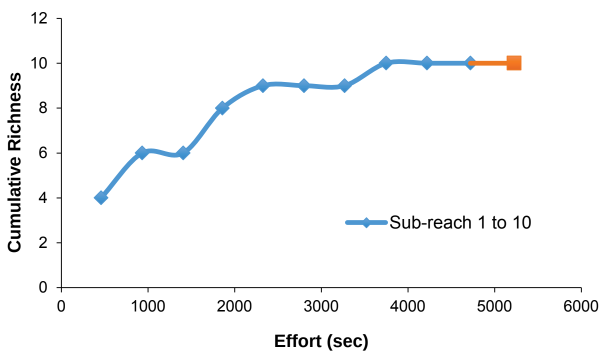
JAC-F1



JAC-F2



MAR-F1



MUR-F2

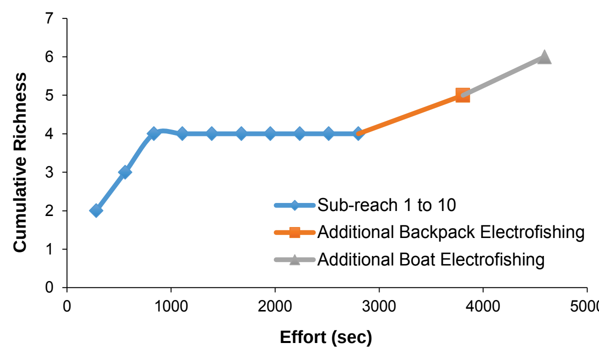
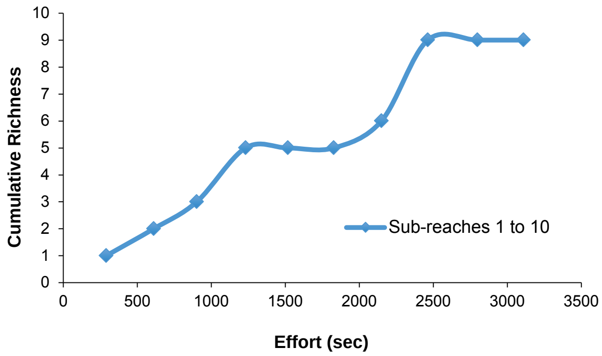
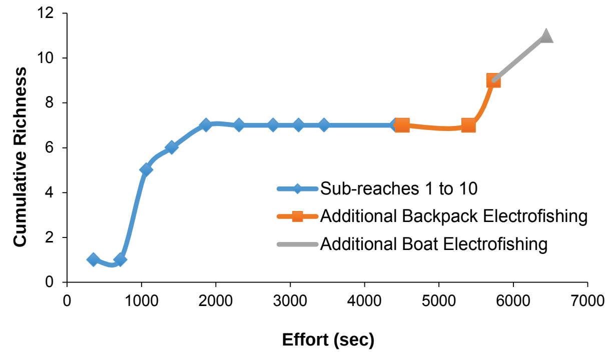


Figure 6.2-2 (Cont'd.)

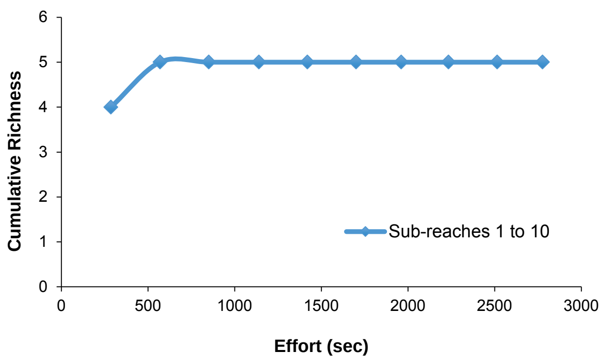
STR-F1



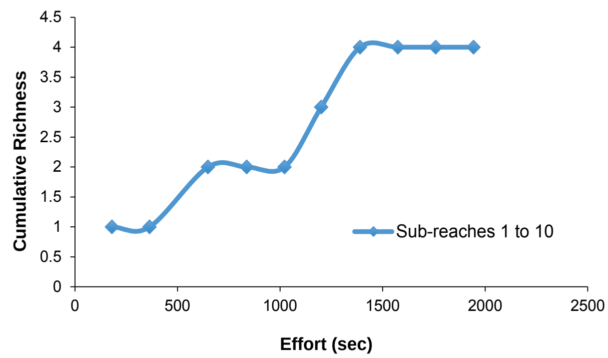
STR-F2



SUC-F1



TAR-F2



6.2.4 Discussion and Recommendations

The results of the study demonstrate that additional information can be gained by expanding the fish sampling effort, and that selective electrofishing can improve the ability to identify fish species present at a monitoring reach. Although changes in the biological interpretation of data arising from discrepancies between method estimates is a question of judgment, the range of potential bias showed that measurement endpoint estimates calculated using the original survey efforts can be half as much or double those estimated using expanded methods. Such discrepancies are likely to change the biological interpretation of a given fish community and the precision analysis indicated that estimates generated using 10 sub-reaches are more precise. On average, the expanded survey effort allowed for more precise estimates of measurement endpoints. Selective electrofishing further increased the number of fish species caught at each monitoring reach, including sensitive species that were not recorded using the primary electrofishing methods.

When evaluating methodology, it is also important to take into consideration the additional cost incurred. The expanded 10 sub-reach design was approximately 200% of the cost per reach of the original 5 sub-reach design. This additional cost is a conservative estimate because fish community assessments on reaches of the Christina River, Jackpine Creek, Steepbank River, and Muskeg River, were done in collaboration with the Fisheries Sustainable Habitat (FiSH) Committee under the Canada's Oil Sands Innovation Alliance (COSIA), which also conducted fish community-type assessments at the same reaches and was also implemented by Hatfield. The total cost of expanded sampling would increase in the future if no other projects were taking place in the area at that time.

Statistically speaking, budget and effort may be better allocated at increasing the number of data points (i.e., reaches) than increasing precision for a given data point (i.e., reducing within-reach variability). Although expanded and increased efforts within a reach may allow for a better estimate of measurement endpoints by reducing within-reach variability, increasing sample size (i.e., reaches) may improve the ability to make inferences about a population. Future studies may consider how increasing reaches may change the interpretation of a fish community in a given area.

6.3 STATUS OF FISH IN THE ATHABASCA RIVER – PILOT STUDY

6.3.1 Introduction

As part of the 2015 JOSMP, a pilot study was initiated to evaluate the feasibility of monitoring fish populations of the lower Athabasca River using the Alberta Fisheries approach (ASRD 2011) for sampling key sportfish species (walleye [*Sander vitreus*], goldeye [*Hiodon alosoides*], lake whitefish [*Coregonus clupeaformis*], and northern pike [*Esox lucius*]), and more generally on the fish community as a whole, during the summer season. The provincial approach assesses changes in the fish community based on species composition and guilds (forage fish, sportfish, and large-bodied fish) and is in contrast to the non-lethal adult fish survey approach taken by the federal Environmental Effects Monitoring program (Environment Canada 2010), which evaluates changes in select sentinel fish populations. An overall objective of the pilot study is to collect data on the size and abundance of fish species of the mainstem Athabasca River such that a comparison can be made between the Alberta monitoring approach and the federal EEM approach with regards to cost-effectiveness, data interpretation and the ability to detect changes in fish populations over time. Although this detailed analysis will be completed in the near future under AEMERA, the scope of the current write-up was to provide a preliminary summary of the data, including the extent of capture success, species composition, size frequency comparisons and recommendations that may assist in refining the program in future years.

Where possible, results of the pilot study were also compared to historical inventory data collected by the Regional Aquatics Monitoring Program (RAMP 1997 to 2013), Joint Oil Sands Monitoring Plan (JOSMP 2014) and to data collected as early as 1989 by Syncrude Canada Ltd (RAMP database, www.ramp-alberta.org).

6.3.2 Methods

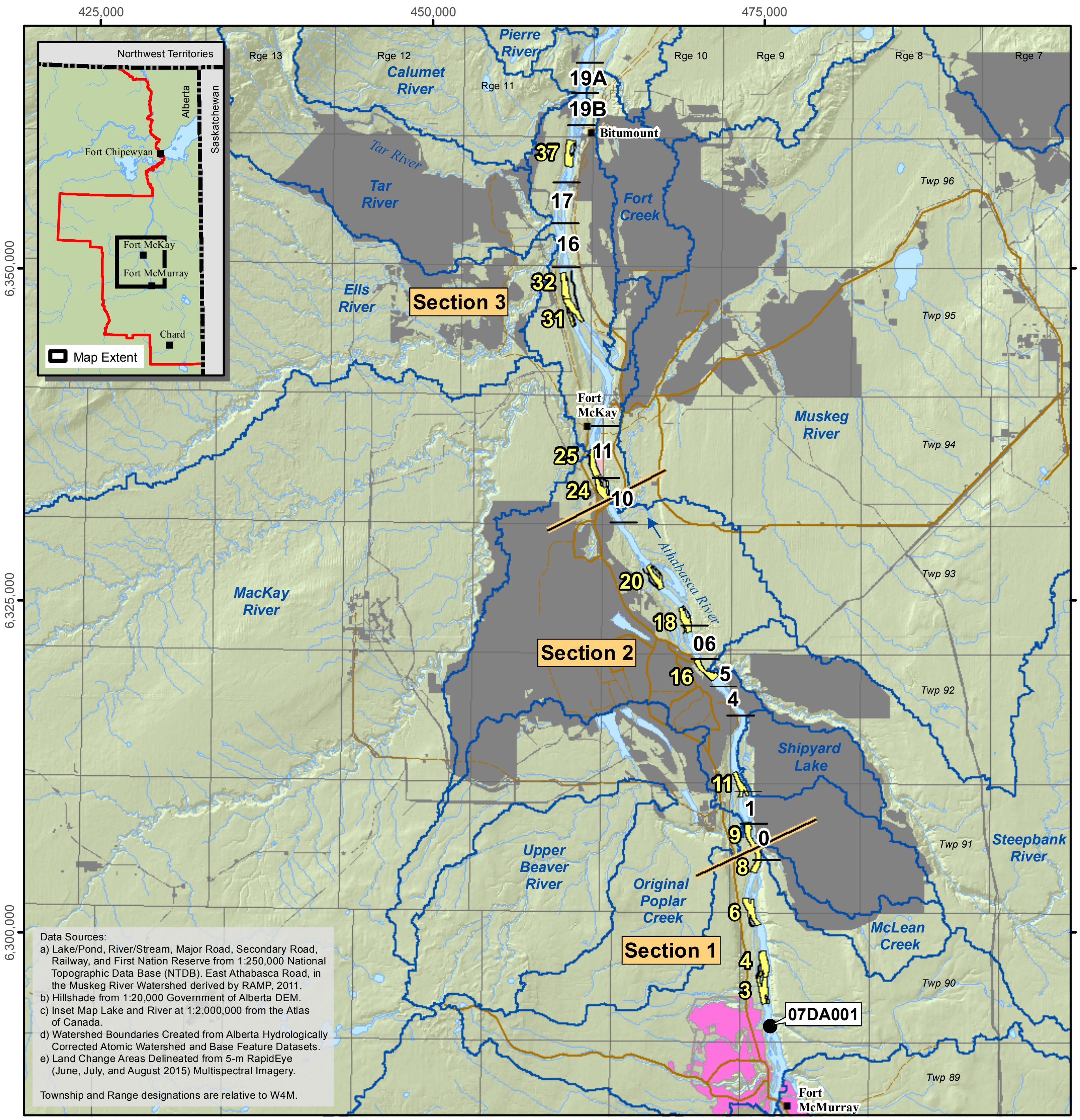
The pilot study was conducted using methods developed by the province of Alberta and described in the document entitled, *Fish Survey Methods for Rivers* (ASRD 2011). The pilot study used a slightly-modified sampling design (described below) to account for the relatively large size of the river system being sampled, and to control for variability of modifying factors such as distance from oil sands developments and major tributaries.

6.3.2.1 Reach Selection and Mapping

Fish sampling was conducted within 14 randomly-selected reaches, each 2 km long, located within an 80 km stretch of the Athabasca River between Fort McMurray and Bitumount, Alberta (Figure 6.3-1). The standard reach selection approach defined by ASRD (2011) was modified to incorporate a stratified random sampling design. Forty 2 km long reaches were created within the 80 km stretch of the Athabasca River between Fort McMurray and Bitumount. These 40 reaches were divided into three sections based on confluences of the river with major tributaries and oil sands developments (Figure 6.3-1):

- Section 1 – section of river largely uninfluenced by oil sands mining development (although downstream from in situ developments in the Christina River watershed), but downstream of town of Fort McMurray, extending from just below the Clearwater River confluence to Poplar Creek);

Figure 6.3-1 Overview of sampling area and sampling reaches for the Athabasca Summer Fish Inventory Pilot Study.



Legend

- Lake/Pond
- River/Stream
- Watershed Boundary
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- Town of Fort McMurray
- Land Change Area as of 2015[e]
- Water Survey of Canada Hydrometric Monitoring Station (Year-Round)
- # RAMP/JOSMP Fish Inventory Reach
- Section # Section Break
- # Fish Inventory Pilot Study Reach

0 2.5 5 10 km

N

Scale: 1:450,000

Projection: NAD 1983 UTM Zone 12N

Hatfield CONSULTANTS

K:\Data\Project\AEM7250\A_MXD\TechRpt\AEM7250_L_Pilot_Overview_20160329_ss.mxd

- Section 2 – section of river adjacent to Suncor and Syncrude oil sands development, extending from McLean Creek to just upstream of the Muskeg River confluence; and

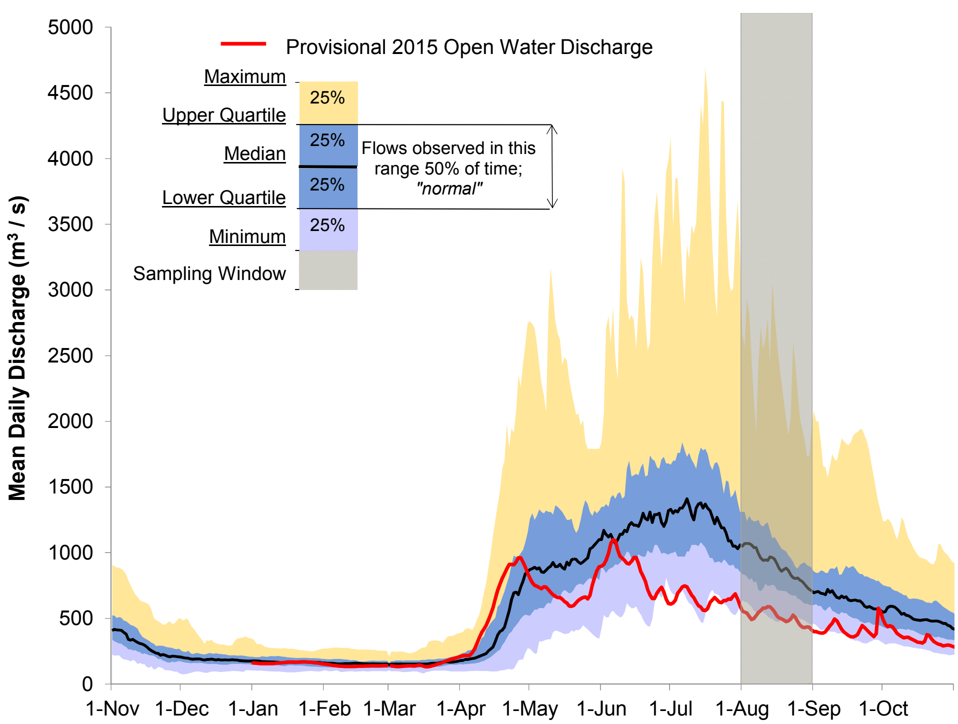
- Section 3 – section of river adjacent to oil sands development in the Muskeg, Ells, Tar rivers and Fort Creek, extending downstream to Bitumount.

Four or five of the 2 km sampling reaches were randomly selected using a random number generator within each of the three river sections. Each 2 km sampling reach was further sub-divided into four 500 m sub-reaches. Maps of each sampling reach were created using 5 m RapidEye satellite imagery, with each sub-reach demarcated to facilitate logistical planning and to verify habitat characteristics. Individual reach maps are provided in Appendix G.

6.3.2.2 Timing of Field Survey

The Alberta monitoring approach stipulates that fish surveys be completed within a 2-week period when the river discharge is within the 1st and 3rd quartiles of the historical range (ASRD 2011). However, discharge was below the lower quartile range during the summer period from July 1 to August 31, 2015 (Figure 6.3-2). Following discussions with AEMERA and AEP, fish sampling was conducted from August 22 to August 27 2015, when the average daily discharge was 481 m^3/s, approximately 27% below the historical 1st quartile flow rate of 658.3 m^3/s at WSC station 07DA001 downstream of Fort McMurray (Figure 6.3-2). Average daily discharge levels were below the historical minimum levels for four days of the field survey (August 22, and August 25 to 27).

Figure 6.3-2 Timing of the summer fish inventory pilot study relative to 2015 and historical (1957-2014) discharge of the Athabasca River.



Note: Provisional discharge data were obtained from WSC Station 07DA001 located downstream of Fort McMurray (Figure 6.3-1).

6.3.2.3 Habitat Assessment

Physical habitat characteristics of each sub-reach were recorded for the river channel and for two of the three riparian habitat zones as defined in the Alberta monitoring protocol (ASRD 2011) (Figure 6.3-3).

Channel widths were measured using a laser rangefinder (±1 m) where possible, and estimated from satellite imagery where measurements were not possible using the rangefinder, for example when the distance between banks exceeded the maximum range of the rangefinder or a habitat feature, such as an instream island, blocked the line of sight between banks. Channel depths (±0.1 m) were measured using a Lowrance HD7 depth-sounder and water velocity was measured at the upstream end of each sub-reach, using a Marsh McBirney flow-meter at a depth of approximately 1 m.

Riparian zone habitat was characterized within 100 m long transects centered at the start and end of each sub-reach, for a total of five transects and two of the three riparian habitats delineated in ASRD (2011) (Figure 6.3-3) were sampled: Riparian Zone 1 consisted of river channel habitat within the bankfull zone; while Riparian Zone 2 consisted of the habitat extending outwards from the edge of the bank to the first riparian vegetation break, or 10 m from the edge of the bankfull zone if no break was present. Table 6.3-1 lists the measurements recorded within each of the two riparian zones that were sampled.

Figure 6.3-3 Riparian habitat zones delineated in the Alberta Fish Survey Methods for Rivers (taken from ASRD 2011).

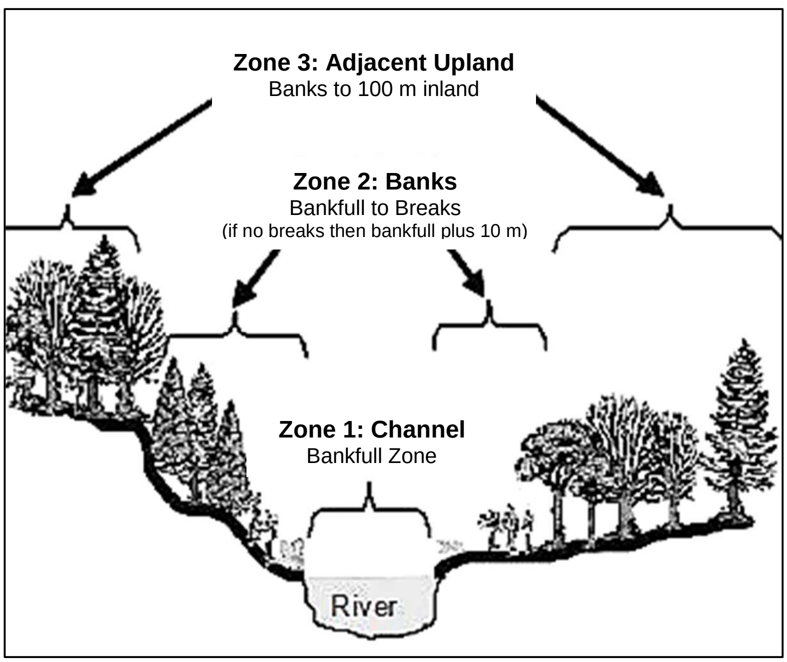


Table 6.3-1 Habitat data collected from each sub-reach in support of the summer fish inventory pilot study.

Habitat Location	Sampling Location	Measurements Collected
Channel characteristics	Cross-sections at the start and end of each sub-reach	▪ bankfull width (m) ▪ wetted width (m) ▪ maximum depth in fished area (m) ▪ water velocity (m/s)
Riparian Zone 1: Channel	100 m section of river channel centered at the start and end of each sub-reach	▪ composition of habitat classes (riffles, runs, pools; %) ▪ presence of barriers to fish passage (beaver dam, cascade or chute, culvert, human created dam, natural falls, rock, or log jam; height and completeness of barrier; %) ▪ bank stability (stable, moderate, low, unstable) ▪ degree of bank undercut (None, <25%, 25-50%, 51-75%, >75%)
Riparian Zone 2: Banks	100 m section of each river bank centered at the start and end of each sub-reach	▪ composition of bank habitat (water, rock, bare soil, vegetation classes; %) ▪ proportion of bank affected by anthropogenic disturbance (trails, residential or industrial facilities, agriculture, linear features, harvesting; %)

Standardized photographs were taken at each sub-reach (upstream, downstream, cross-channel), and the following additional field observations recorded:

- Environmental conditions (weather, air quality);
- Water conditions (e.g., visible turbidity, surface foam, waves);
- Instream obstructions and notable habitat structures present in the sub-reach (e.g., sand bars, beaver lodges); and
- Presence/absence of wildlife.

The protocols of the Alberta monitoring approach (ASRD 2011) include a desktop assessment of habitats in the adjacent upland area (Riparian Zone 3; Figure 6.3-3) using aerial photography or satellite imagery. An assessment of Riparian Zone 3 was not conducted as part of the pilot study due to the lack of resolution in the available satellite imagery. It is important to note that habitat comparisons to historical data were not possible anyway given the RAMP/JOSMP inventories did not include an assessment of riparian zone habitat.

6.3.2.4 Water Quality

In situ water quality was measured at the upstream end of each reach using a YSI 86 multi-probe (dissolved oxygen [DO] ±0.1 mg/L; pH ±0.01 pH units; conductivity ±1 μS/cm; temperature ± 0.1°C).

Single grab samples of water were also collected at the start of each reach and submitted to Maaxam Analytics, Calgary, for analysis of total nitrogen, total phosphorous, and dissolved organic carbon (DOC). One duplicate grab sample was collected for quality assurance and quality control (QA/QC) purposes.

6.3.2.5 Fish Sampling

Fish sampling was conducted using a Smith-Root GPP 5.0 electrofishing unit mounted on an aluminum boat, which employed two netters and one driver. One pass was completed within each sub-reach, moving in a downstream direction within the effective depths for electrofishing (<1.5 m); sampling of each sub-reach was conducted on alternating sides of the channel, where possible. Electrofishing effort was standardized between sub-reaches by setting the target effort level (in seconds) for a sub-reach based on the effort expended during the first sub-reach. While the fish sampling methods were comparable to the protocols of the Alberta monitoring approach (ASRD 2011), fish sampling was not conducted mid-channel due to the wide nature of the channel (regularly exceeding 500 m) and limitations of the electrofishing unit, which can only effectively fish at depths less than 2 m.

All fish caught were identified to species and measured for fork length (±1 mm) and weight (±0.1 g for small-bodied fish and ±10 g for large bodied fish). Aging structures (fin rays) were collected from all key sport-fish species that were captured (walleye, goldeye, northern pike [lake whitefish were not captured]) with a fork-length greater than 200 mm, prior to releasing the fish back into the river. Aging structures were stored and dried in coin envelopes and submitted to North/South Consultants Inc., Manitoba, for aging analysis.

6.3.3 Data Analysis

Fish and fish habitat data were compiled and summarized by reach to examine inter-reach variability and combined over all reaches to compare with the historical inventory data collected within the same area by the RAMP/JOSMP. Fish communities were described using the average catch-per-unit-effort (CPUE) as a proxy for the relative abundance of each species by guild (sportfish, coarse fish, forage fish) (Table 6.3-2). Size and age distributions were also examined for each of the key sportfish species that were caught in sufficient numbers during the pilot survey (goldeye, northern pike and walleye).

Fish assemblages, size distributions, and age data were compared with historical data compiled from fish inventory programs conducted in summer within the same study area (downstream of Fort McMurray to Bitumount, Figure 6.3-1) between 1989 and 2014. The historical inventory data were divided into three periods for comparison to the pilot study data:

- the baseline period from 1989 to 1996, prior to the intensive development of oil sands operations – summer sampling was conducted by Syncrude Canada Ltd. in 1989, 1990, and 1996;
- the pre-standardized RAMP phase from 1997 to 2005 – summer sampling[8] was conducted under the RAMP in 1997, 1998, and 2000; and

[8] Eleven of the 13 reaches sampled under the RAMP/JOSMP were within the Pilot study survey area (Figure 6.3-1); data from these 11 reaches were used for the Pilot study comparison.

- the standardized RAMP/JOSMP phase from 2006 onwards – summer sampling was conducted annually from 2008 to 2013 under the RAMP and in 2014 under the JOSMP[9].

Fishing methods were generally comparable between the RAMP and JOSMP inventories (1997-2014) and the Pilot study, with all programs employing single pass boat electrofishing and targeting shallow habitats on the river margins.

Table 6.3-2 Common name, scientific name and species codes for fish species caught during the pilot study and the RAMP/JOSMP summer inventories.

Common Name	Scientific Name	Species Code
goldeye	*Hiodon alosoides*	GOLD
lake whitefish	*Coregonus clupeaformis*	LKWH
northern pike	*Esox lucius*	NRPK
walleye	*Sander vitreus*	WALL
burbot	*Lota lota*	BURB
mountain whitefish	*Prosopium williamsoni*	MNWH
yellow perch	*Perca flavescens*	YLPR
longnose sucker	*Catostomus catostomus*	LNSC
white sucker	*Catostomus commersonii*	WHSC
brook stickleback	*Culaea inconstans*	BRST
emerald shiner	*Notropis atherinoides*	EMSH
flathead chub	*Platygobio gracilis*	FLCH
finescale dace	*Phoxinus neogaeus*	FNDC
lake chub	*Couesius plumbeus*	LKCH
longnose dace	*Rhinichthys cataractae*	LNDC
northern dace	*Chrosomus eos*	NRDC
pearl dace	*Margariscus margarita*	PRDC
slimy sculpin	*Cottus cognatus*	SLSC
spoonhead sculpin	*Cottus ricei*	SPSC
spottail shiner	*Notropis hudsonius*	SPSH
trout-perch	*Percopsis omiscomaycus*	TRPR

Note: shaded entries are the key Athabasca River sportfish species defined by AEMERA

9 The standardization of the RAMP Athabasca River inventory program in 2006 included establishing a standard level of effort for each sampling reach, and consistent start and endpoints for each sampling reach (RAMP 2007).

6.3.4 Quality Assurance/Quality Control Procedures

Quality assurance and quality control procedures for all components of the Pilot study are described in Appendix B. All data entered from field datasheets were re-checked for transcription errors. Water quality samples were collected in accordance with the SOPs contained in the RAMP Technical Design and Rationale (RAMP 2009), with one duplicate grab sample collected for QA/QC purposes. Aging structures were submitted according to laboratory SOPs.

6.3.5 Results and Discussion

6.3.5.1 Habitat Assessments

Habitat characteristics and water quality were very similar among study reaches, with low water levels creating snyes within shallow side channels that often restricted boat access (Table 6.3-3 to Table 6.3-5). The average wetted width of each reach ranged 316 m to 547 m; bankfull widths ranged from 418 m to 853 m. Water velocity was fairly consistent among reaches, ranging from 0.17 m/s to 0.39 m/s. The dominant habitat in Riparian Zone 1 was run habitat with some small riffles observed in a number of reaches; with the exception of a small beaver dam at reach 11, there were no other habitat features in Riparian Zone 1 in any reach (Table 6.3-4). Habitat in Riparian Zone 2 was dominated by bare soils on exposed river banks, and new shrub and forb growth; there was little human disturbance throughout any of the Riparian Zone 2 that was surveyed (Table 6.3-5).

Water quality was relatively homogeneous throughout the reaches, and concentrations of all water quality variables were within the regulatory guidelines where available (Table 6.3-6).

Complete habitat data for each reach are available from the online database on the RAMP website (www.ramp-alberta.org).

Table 6.3-3 Average characteristics of the river channel at each reach of the pilot study, summer 2015.

Reach	River Channel Characteristics				
	Wetted Width (m)	Bankfull Width (m)	Velocity (m/s)	Average Depth (m)	Maximum Depth in Fished Areas (m)
3	455	493	0.36	0.94	3.26
4	467	609	0.45	1.36	2.25
6	429	583	0.26	1.00	2.79
8	405	427	0.34	0.71	1.40
9	316	429	0.27	0.73	1.60
11	373	418	0.20	0.88	2.27
16	374	485	0.26	1.16	3.67
18	423	511	0.26	1.20	3.21
20	491	748	0.30	1.99	4.96
24	460	677	0.33	1.40	3.27
25	424	473	0.39	1.00	4.69
31	547	853	0.17	1.57	4.67
32	449	826	0.24	1.34	4.92
37	476	651	0.39	1.75	4.26

Table 6.3-4 Average characteristics of Riparian Zone 1 at each reach of the pilot study, summer 2015.

Reach	Riparian Zone 1 Characteristics									
	Runs (%)	Riffles (%)	Pools (%)	Beaver Dam (m)	Human Dam (m)	Log Jam (m)	Cascade / Chute (%)	Culvert (%)	Natural Falls (%)	Undercut Banks (%)
3	97	0	3	0	0	0	0	0	0	0
4	86	14	0	0	0	0	0	0	0	0
6	100	0	0	0	0	0	0	0	0	0
8	100	0	0	0	0	0	0	0	0	0
9	100	0	0	0	0	0	0	0	0	0
11	100	0	0	2.5	0	0	0	0	0	0
16	100	0	0	0	0	0	0	0	0	0
18	100	0	0	0	0	0	0	0	0	0
20	100	0	0	0	0	0	0	0	0	0
24	100	0	0	0	0	0	0	0	0	0
25	100	0	0	0	0	0	0	0	0	0
31	100	0	0	0	0	0	0	0	0	0
32	96	4	0	0	0	0	0	0	0	0
37	100	0	0	0	0	0	0	0	0	0

Table 6.3-5 Average characteristics of Riparian Zone 2 at each reach of the pilot study, summer 2015.

Reach	Riparian Zone 2 Characteristics								
	Water (%)	Rock (%)	Bare Soils – Natural (%)	Lichens, Fungi, Non-Vascular Plants (%)	Forbs (%)	Grasses, Sedges, Rushes (%)	Shrubs and Deciduous Trees (%)	Coniferous Trees (%)	Human Disturbance (%)
3	0	68.0	13.5	0	10.9	6.4	0	0	<1[1]
4	0	3.6	79.8	0	7.8	7.9	0.4	0	0
6	0.8	20.1	61.8	0	2.6	6.4	4.2	0	0
8	0.3	10.6	77.0	0.3	2.1	1.9	5.6	0	0
9	0	3.3	82.5	2.2	3.2	1.6	6.9	0	0
11	0	9.6	77.0	0.1	2.2	2.9	6.4	0	0
16	1.3	0.1	87.9	0.1	0.5	1.7	2.7	0	<1[2]
18	0.3	3.3	86.5	0.1	1.1	2.4	3.4	0	0
20	0	0	88.5	0.4	3.1	2.3	4.0	0	0
24	0	20.3	68.0	0.1	6.1	3.1	1.4	0	<1[3]
25	0	5.3	77.5	0.3	2.6	2.4	10.3	0	0
31	0	6.1	84.5	0	4.9	3.4	0.3	0	<1[4]
32	0.3	6.3	80.5	0	7.0	5.4	0.3	0	0
37	0.3	8.3	72.0	0	3.5	14.1	0.7	0	0

[1] unimproved vehicle path
[2] industrial facility (water intake); rip rap weir
[3] vehicle bridge
[4] industrial facility (water intake)

Table 6.3-6 Summary of water quality within each study reach of the pilot study, summer 2015.

Reach	In situ Water Quality					Analytical Water Quality						
	Conductivity (µs/cm)	Dissolved Oxygen (mg/L)	Temperature (°C)	pH	Turbidity (NTU)	Dissolved Nitrate (mg/L)	Dissolved Nitrite (mg/L)	DOC (mg/L)	Nitrate plus Nitrite (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Kjeldahl Nitrogen (mg/L)
Guideline[1]	-	**6.5-9.5**	-	**6.5-9.0**	-	**3**	**0.020**	-	-	-	-	-
3	288.0	9.58	14.8	7.75	16.2	<0.003	<0.003	8.2	<0.005	0.44	0.047	0.44
4	286.6	9.90	15.3	8.20	10.0	<0.003	<0.003	9.6	<0.005	0.43	0.037	0.43
6	285.8	9.16	17.1	7.83	12.1	<0.003	<0.003	8.0	<0.005	0.47	0.065	0.47
8	265.0	9.07	17.1	8.09	11.6	0.025	<0.003	3.0	0.025	0.22	0.021	0.20
9	285.2	9.30	18	7.99	10.9	0.0076	<0.003	7.8	0.0076	0.42	0.031	0.41
11	262.7	9.29	18.3	8.06	22.4	0.0089	<0.003	3.8	0.0089	0.22	0.032	0.21
16	273.2	9.19	17.4	7.85	7.0	<0.003	<0.003	6.9	<0.005	0.30	0.020	0.30
18	272.2	9.31	18.3	7.79	6.7	<0.003	<0.003	6.6	<0.005	0.31	0.024	0.31
20	272.5	9.38	18.9	8.10	5.5	<0.003	<0.003	6.3	<0.005	0.28	0.017	0.28
24	279.9	9.55	16.6	7.99	7.5	0.6	<0.003	4.1	0.6	0.89	0.019	0.29
25	272.3	9.71	17.5	8.17	7.3	0.025	<0.003	4.1	0.025	0.51	0.086	0.48
31	270.7	9.59	15.8	7.48	7.1	<0.003	<0.003	6.0	<0.005	0.28	0.021	0.28
32	272.0	9.69	16.2	7.64	20.1	<0.003	<0.003	6.1	<0.005	0.27	0.027	0.27
37	281.8	9.54	14.6	8.07	12.2	0.0055	<0.003	6.1	0.0055	0.29	0.040	0.28

[1] from AESRD (2014)

DOC = dissolved organic carbon

6.3.5.2 Relative Abundance of Fish Species

A total of 1,648 fish from 13 different species were caught within the 14 selected reaches (Table 6.3-7). Three of the four key sportfish species were caught and include goldeye, northern pike, and walleye (lake whitefish were not captured). Catches within each reach were dominated by emerald shiner (Figure 6.3-4).

The most abundant species by guild were walleye (sportfish), longnose sucker (coarse fish), and emerald shiner (forage fish). Emerald shiner and walleye were the only species caught in every reach. Species-specific catch-per-unit-effort (CPUE) from each reach are presented in Table 6.3-8.

All goldeye caught during the survey were between two and 11 years old, with the majority being less than six years old (Figure 6.3-5, Figure 6.3-6). Of the 70 walleye caught only 24 were aged as most were below the size threshold for aging (Figure 6.3-5, Figure 6.3-6); those that were aged ranged from one to 20 years old (Figure 6.3-5, Figure 6.3-6). The 46 walleye that were not aged were likely young-of-the-year (YOY). Only five northern pike were caught; both juvenile and adults were present in the five individuals caught (Figure 6.3-5, Figure 6.3-6). External abnormalities observed on fish caught during the pilot study included growths, lesions, deformities, parasites, and wounds. The total prevalence of external abnormalities was less than 2% in all fish and approximately 5% of all sportfish sampled (Table 6.3-9). The higher prevalence of external abnormalities for sportfish was due to the lower numbers of sportfish caught (Table 6.3-10).

Table 6.3-7 Number of fish captured by species and species richness within each sampling reach of the pilot study, summer 2015.

Guild	Species	Reach														Total
		3	4	6	8	9	11	16	18	20	24	25	31	32	37	
Sportfish	GOLD	0	0	4	2	8	4	5	4	3	1	6	1	4	1	43
	NRPK	0	0	0	0	0	2	1	0	0	0	2	0	0	0	5
	WALL	5	1	3	10	10	9	7	3	1	3	9	1	7	1	70
	LKWH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	YLPR	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Coarse fish	BURB	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
	LNSC	8	3	11	34	19	21	2	5	0	4	14	3	8	1	133
	WHSC	5	0	1	2	1	0	0	0	0	0	6	2	1	1	19
Forage fish	EMSH	33	37	41	75	58	96	77	89	11	28	90	49	117	40	841
	FLCH	35	26	20	36	10	8	1	15	0	24	33	17	16	11	252
	LKCH	1	0	7	8	6	2	5	9	1	12	9	6	5	5	76
	SLSC	0	0	0	0	0	0	0	0	0	2	1	0	0	0	3
	SPSH	3	1	8	7	14	7	13	3	0	6	18	8	2	4	94
	TRPR	22	0	7	19	17	11	4	4	0	1	20	4	0	0	109
Total		112	68	102	194	143	161	116	132	16	81	208	91	160	64	1648
Species Richness		8	5	9	10	9	10	10	8	4	9	11	9	8	8	

Note: shaded entries are the key Athabasca River sportfish species defined by AEMERA

Figure 6.3-4 Composition of fish communities in each reach of the pilot study, summer 2015.

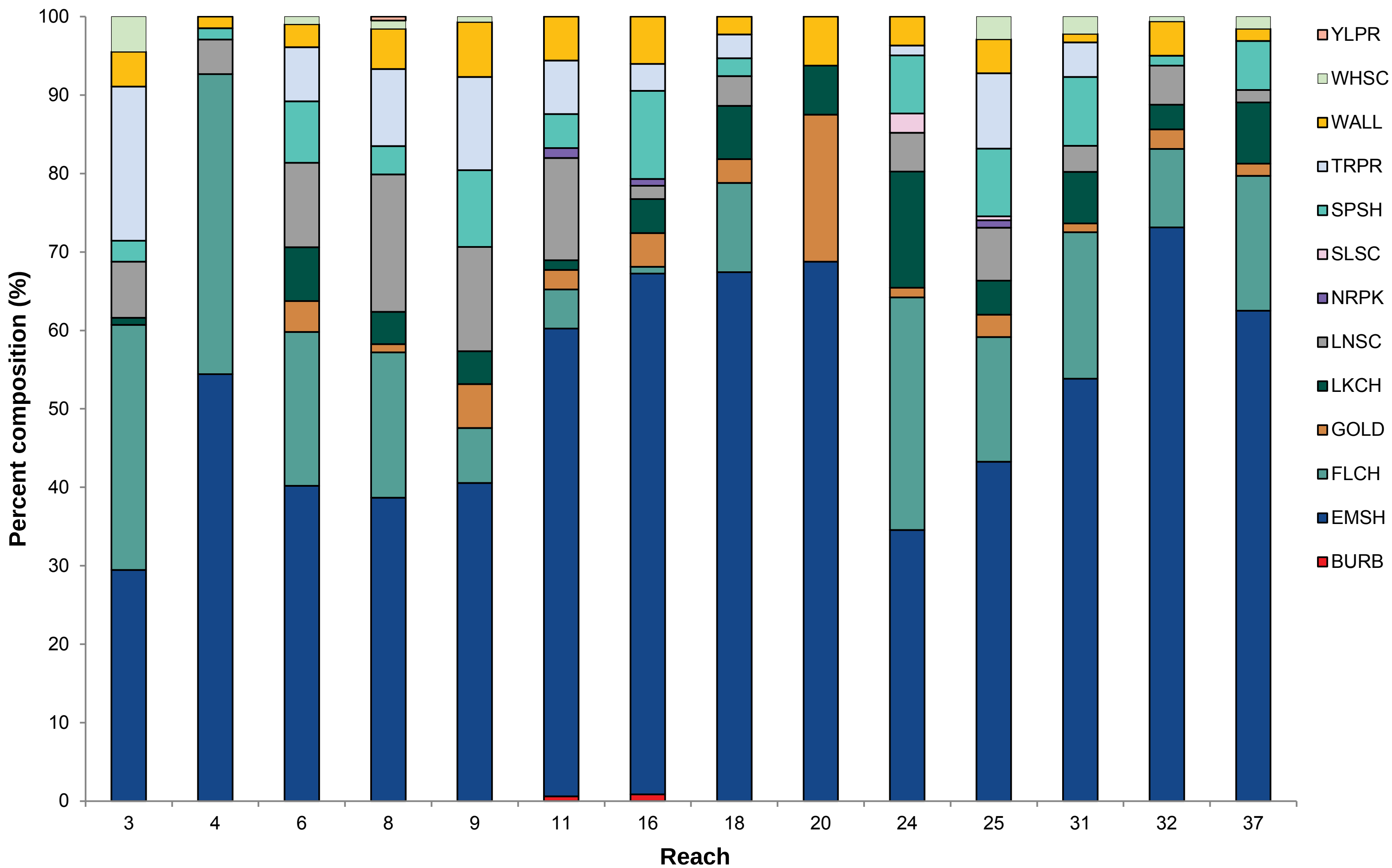


Table 6.3-8 Catch-per-unit-effort by species for each sampling reach of the pilot study, summer 2015.

Guild	Species	Catch per Unit Effort (No. fish/100 s)														
		Reach														Average
		3	4	6	8	9	11	16	18	20	24	25	31	32	37	
Sport fish	GOLD	0	0	0.451	0.196	0.802	0.444	0.372	0.368	0.323	0.090	0.575	0.094	0.393	0.093	**0.297**
	NRPK	0	0	0	0	0	0.222	0.074	0.000	0	0	0.192	0	0	0	**0.035**
	WALL	0.517	0.095	0.339	0.981	1.003	1.000	0.521	0.276	0.108	0.271	0.863	0.094	0.688	0.093	**0.483**
	YLPR	0	0	0	0.098	0	0	0	0	0	0	0	0	0	0	**0.007**
Coarse fish	BURB	0	0	0	0	0	0.111	0.074	0	0	0	0	0	0	0	**0.014**
	LNSC	0.826	0.285	1.242	3.337	1.906	2.333	0.149	0.460	0	0.362	1.342	0.282	0.786	0.093	**0.918**
	WHSC	0.517	0	0.113	0.196	0.100	0	0	0	0	0	0.575	0.188	0.098	0.093	**0.131**
Forage fish	EMSH	3.409	3.520	4.628	7.360	5.817	10.667	5.729	8.188	1.185	2.534	8.629	4.614	11.493	3.711	**5.806**
	FLCH	3.616	2.474	2.257	3.533	1.003	0.889	0.074	1.380	0	2.172	3.164	1.601	1.572	1.020	**1.740**
	LKCH	0.103	0	0.790	0.785	0.602	0.222	0.372	0.828	0.108	1.086	0.863	0.565	0.491	0.464	**0.525**
	SLSC	0	0	0	0	0	0	0	0	0	0.181	0.096	0	0	0	**0.021**
	SPSH	0.310	0.095	0.903	0.687	1.404	0.778	0.967	0.276	0	0.543	1.726	0.753	0.196	0.371	**0.649**
	TRPR	2.273	0	0.790	1.865	1.705	1.222	0.298	0.368	0	0.090	1.918	0.377	0	0	**0.752**
All species		**11.570**	**6.470**	**11.512**	**19.038**	**14.343**	**17.889**	**8.631**	**12.144**	**1.724**	**7.330**	**19.942**	**8.569**	**15.717**	**5.937**	

Note: shaded entries are the key Athabasca River sportfish species defined by AEMERA

Figure 6.3-5 Size distributions of key sportfish species caught during the pilot study, summer 2015.

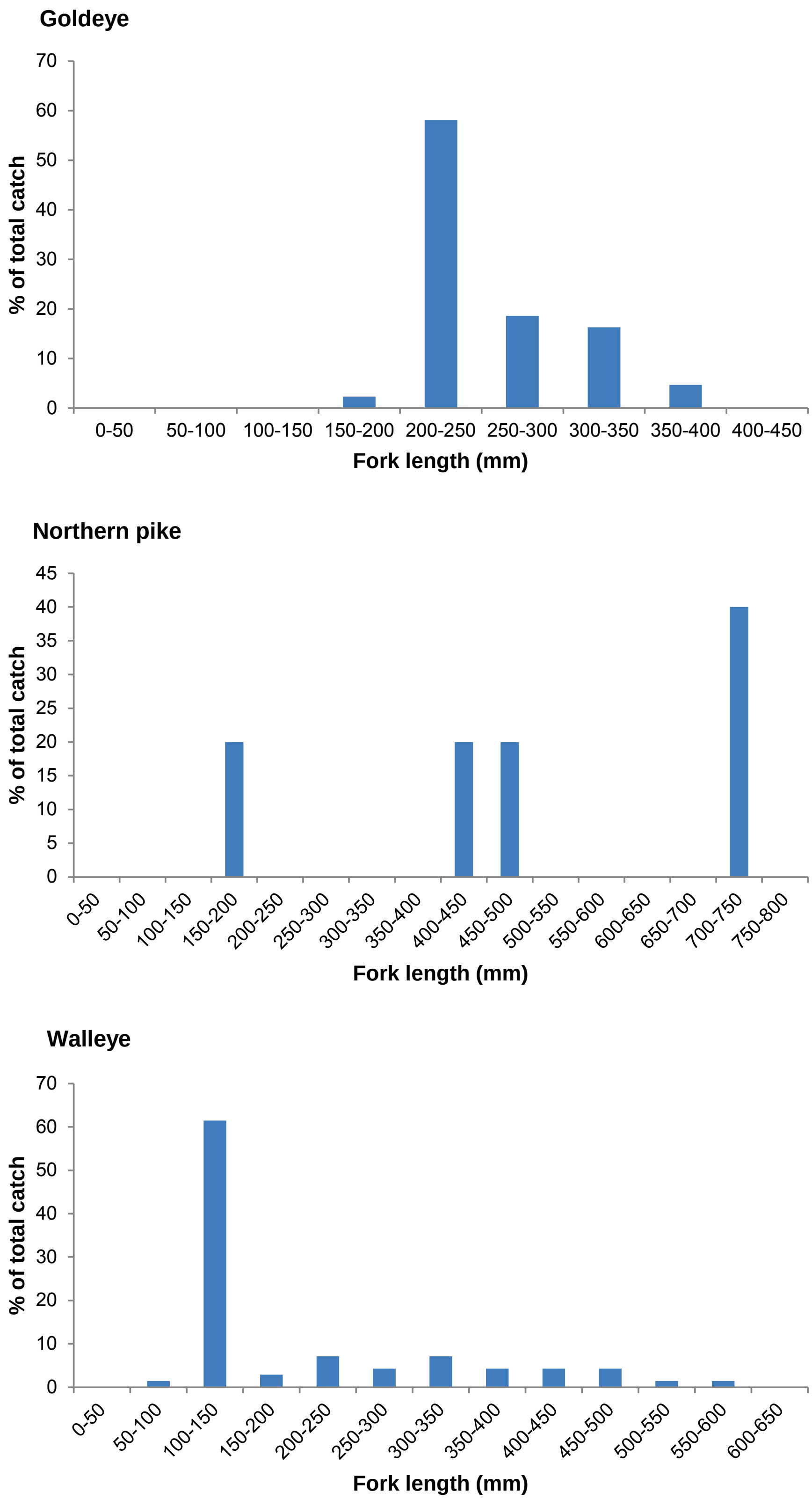
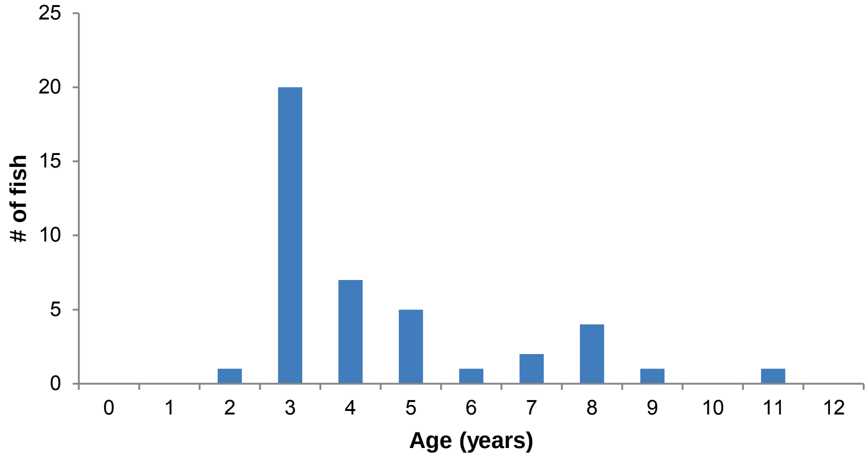
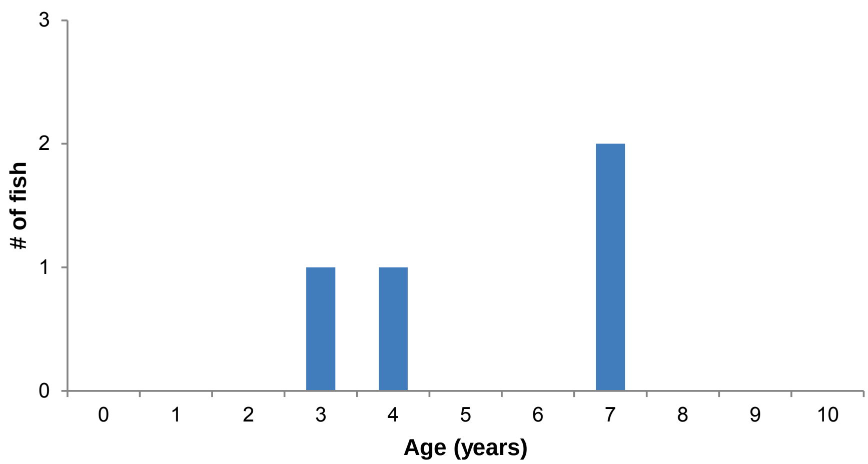


Figure 6.3-6 Age distributions of key sportfish species caught during the pilot study, summer 2015.

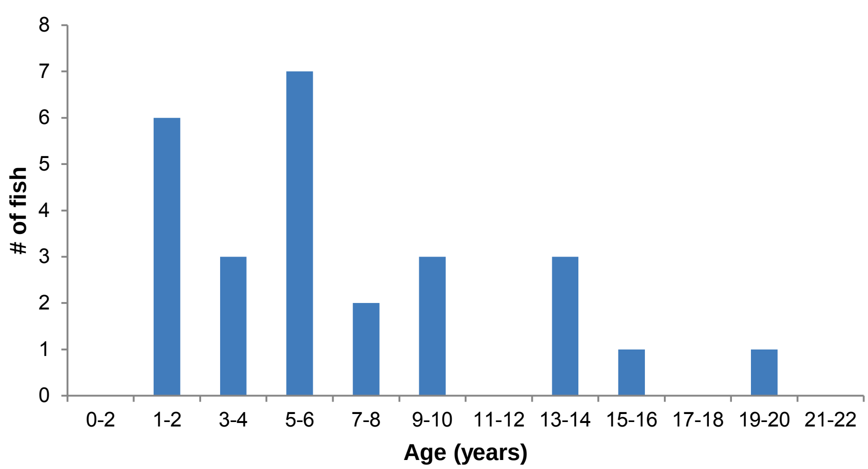
Goldeye



Northern pike



Walleye



Note: Not all fish of these species captured in the Pilot study are presented in this figure as only fish with a fork-length greater than 200 mm were aged.

Table 6.3-9 Incidence of external health abnormalities in fish captured during the pilot study, summer 2015.

Reach	All Fish			Sportfish		
	No. Abnormalities	No. Fish Caught	% With Abnormalities	No. Abnormalities	No. Fish Caught	% With Abnormalities
3	1	112	0.9	0	5	0
4	3	68	4.4	0	1	0
6	1	102	1.0	0	7	0
8	2	194	1.0	0	13	0
9	7	143	4.9	0	18	0
11	0	161	0	0	15	0
16	3	116	2.6	3	13	23.1
18	0	132	0	0	7	0
20	0	16	0	0	4	0
24	1	81	1.2	0	4	0
25	5	208	2.4	2	17	11.8
31	1	91	1.1	1	2	50.0
32	2	160	1.3	0	11	0
37	0	64	0	0	2	0
Total	**26**	**1648**	**1.6**	**6**	**119**	**5.0**

Table 6.3-10 Percent of sportfish captured in the Pilot study with external pathology (growth/lesion, deformity, parasites), summer 2015.

Reach	% Growth/Lesion	% Deformity (body/fins)	% Parasites	% Total	No. Fish Caught
3	0	0	0	0	5
4	0	0	0	0	1
6	0	0	0	0	7
8	0	0	0	0	13
9	0	0	0	0	18
11	0	0	0	0	15
16	15.4	0	0	15.4	13
18	0	0	0	0	7
20	0	0	0	0	4
24	0	0	0	0	4
25	0	0	5.9	5.9	17
31	0	0	0	0	2
32	0	0	0	0	11
37	0	0	0	0	2

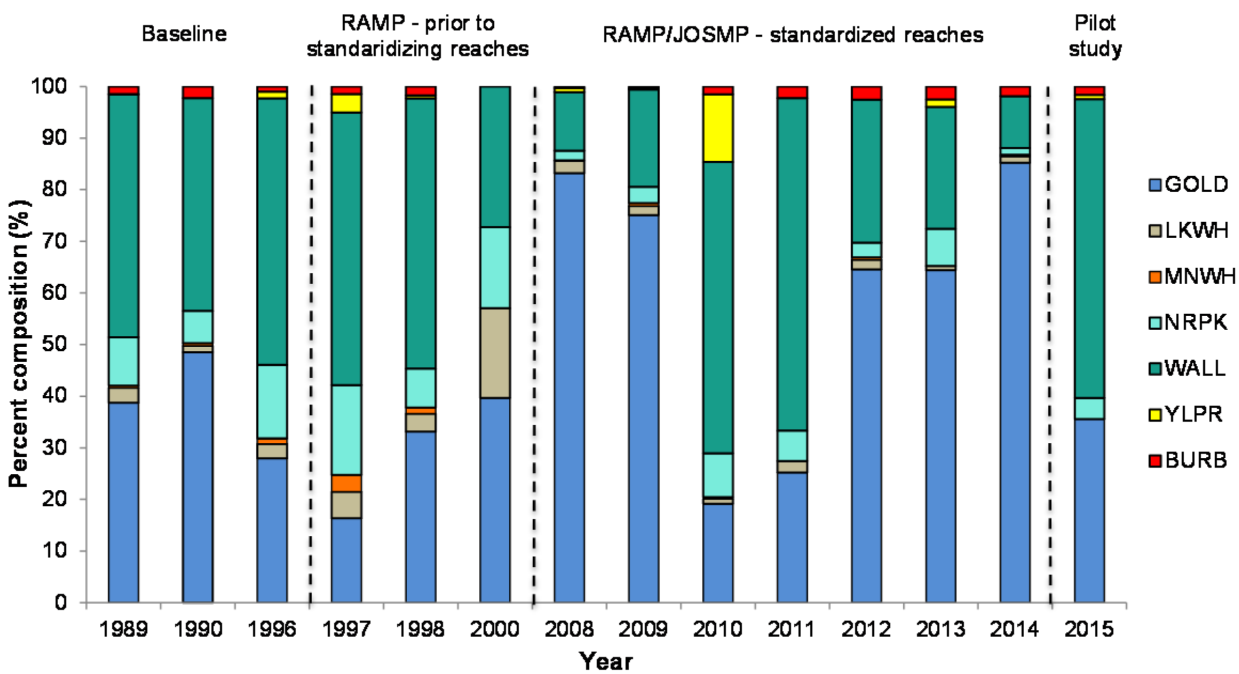
6.3.5.3 Comparison of Pilot Study to Historical Surveys

Composition of Fish Communities

Thirteen different fish species were caught during the pilot study compared to between 7 and 21 species caught during the previous 13 summer inventories under the RAMP/JOSMP, and compared to 13 to 21 species captured during the standardized RAMP inventories (2008 to 2014).

The four key sportfish species (goldeye, lake whitefish, northern pike, and walleye) were caught in all previous RAMP summer inventories (Figure 6.3-7); lake whitefish were not caught in the 2015 pilot study, either in newly-sampled reaches or in reaches where lake whitefish were previously caught during the RAMP/JOSMP inventories, e.g., near the mouths of the Ells and Muskeg River (JOSMP 2014) (Figure 6.3-1). The abundance of lake whitefish in the Athabasca River was low during the previous summer inventories, with the individuals caught possibly representing a small proportion of the population that overwinter in the Athabasca River (Bond 1980, RAMP 2014). Most lake whitefish rear/feed in Lake Athabasca (downstream of the study area) during the summer and a significant number enter the Athabasca River in the fall to spawn upstream of Fort McMurray.

Figure 6.3-7 Catch composition of sportfish during the 2015 pilot study compared to previous summer inventories in the Athabasca River (1989 to 2014).



Catch-Per-Unit-Effort

The catch-per-unit-effort (CPUE) for sportfish species was lower during the pilot study than observed in previous summer inventories, whereas the CPUE for other guilds (i.e., forage fish and coarse fish) was slightly higher than previous inventories (Table 6.3-11). The average CPUE for all sportfish species combined during the standardized RAMP/JOSMP inventories (2008 to 2014) was 2.44 fish/100 s compared to 0.85 fish/100 s during the pilot study. The survey effort expended for fish inventories varied considerably between 1989 and 2014, ranging from 11,418 s to 46,662 s of electrofishing effort per survey (Table 6.3-11). The effort expended during the pilot study was 14,486 s, below the standardized RAMP survey average effort of 18,747 seconds (Table 6.3-11). When standardized by reach length, the effort expended during the pilot study was approximately 10% less than during the previous standardized RAMP/JOSMP summer inventories (approximately 517 s/km for the pilot study compared to an average effort of approximately 568 s/km for the standardized RAMP inventories between 2008 and 2014) (Table 6.3-12).

The difference in the CPUE for sportfish between the different programs is unlikely to be explained by the minor differences in relative effort and sampling methodology (i.e., randomized vs. standardized reaches, and length of reaches). Part of the difference may be attributed to the RAMP inventories targeting the highly-productive areas near the confluences of major tributaries (Figure 6.3-1), although the timing and environmental conditions during the pilot study were likely of greater influence (see Section 6.3.5.3, *Influence of Environmental Factors).*

Table 6.3-11 Catch-per-unit-effort by species for the 2015 pilot study compared to previous summer inventories in the Athabasca River (1989 to 2014).

Guild	Species	1989	1990	1996	1997	1998	2000	2008	2009	2010	2011	2012	2013	2014	Average[1]	2015
Sportfish	GOLD	0.992	1.699	0.859	0.224	0.494	0.306	3.995	2.097	0.295	0.292	1.643	1.565	1.580	1.638	0.297
	LKWH	0.075	0.044	0.086	0.070	0.052	0.134	0.116	0.049	0.014	0.026	0.048	0.020	0.023	0.042	0.000
	NRPK	0.240	0.219	0.437	0.238	0.113	0.121	0.089	0.088	0.131	0.068	0.072	0.174	0.023	0.092	0.035
	WALL	1.204	1.445	1.584	0.720	0.780	0.210	0.546	0.527	0.867	0.746	0.705	0.573	0.187	0.593	0.483
Coarse fish	BURB	0.039	0.079	0.031	0.020	0.026	0.000	0.016	0.011	0.023	0.026	0.066	0.061	0.035	0.034	0.014
	LNSC	0.154	0.000	0.156	0.109	0.061	0.287	0.326	0.093	0.234	0.219	0.287	0.133	0.157	0.207	0.918
	WHSC	0.043	0.000	0.406	0.070	0.052	0.121	0.137	0.044	0.009	0.162	0.173	0.077	0.017	0.088	0.131
Forage fish	BRST	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.001	0.000
	EMSH	0.000	0.000	0.133	0.025	0.546	0.045	0.226	0.445	0.375	0.344	0.777	0.409	0.630	0.458	5.806
	FNDC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.036	0.000	0.006	0.000
	FLCH	0.004	0.026	0.749	0.432	0.511	0.389	1.496	0.862	2.319	0.146	0.591	1.115	0.752	1.040	1.740
	LKCH	0.000	0.000	0.297	0.204	0.035	0.006	0.887	0.165	0.445	0.188	0.006	0.169	0.093	0.279	0.525
	LNDC	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.010	0.000	0.000	0.000	0.003	0.000
	MNWH	0.011	0.018	0.031	0.045	0.017	0.000	0.005	0.016	0.005	0.000	0.012	0.000	0.006	0.006	0.000
	NRDC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.001	0.000
	PRDC	0.000	0.000	0.000	0.000	0.000	0.000	0.095	0.000	0.000	0.000	0.000	0.026	0.000	0.017	0.000
	TRPR	0.000	0.009	0.398	0.184	0.815	0.089	0.856	1.076	2.417	1.628	0.603	0.609	0.111	1.043	0.752
	SLSC	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.014	0.005	0.000	0.010	0.000	0.006	0.021
	SPSC	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.006	0.000	0.000	0.002	0.000
	SPSH	0.000	0.000	0.031	0.084	0.321	0.013	0.079	0.033	0.066	0.021	0.090	0.435	0.128	0.122	0.649
	YLPR	0.002	0.000	0.039	0.050	0.009	0.000	0.037	0.005	0.201	0.000	0.000	0.036	0.000	0.040	0.007
Total Richness		**11**	**7**	**12**	**14**	**14**	**11**	**17**	**15**	**17**	**16**	**14**	**17**	**13**	**21**	**13**

Note: shaded entries are the key Athabasca River sportfish species defined by AEMERA

[1] average of standardized RAMP inventories (2008-2014)

Table 6.3-12 Total relative effort for the 2015 pilot study compared to previous summer inventories in the Athabasca River (1989 to 2014).

Effort	1989	1990	1996	1997	1998	2000	2008	2009	2010	2011	2012	2013	2014	Average[2]	2015
Total effort (sec)	46,662	11,418	12,813	20,132	11,535	15,695	19,047	18,214	21,349	19,169	16,741	19,555	17,155	18,747	14,486
Reaches sampled	30	9	6	11	9	10	11	11	11	11	11	11	11	11	14
Estimated length[1]	90	27	18	33	27	30	33	33	33	33	33	33	33	33	28
Relative effort (sec/km)	518	423	712	610	427	523	577	552	647	581	507	593	520	568	517

[1] Based on an average reach length of 3 km for the RAMP/JOSMP inventories

[2] Average of standardized RAMP inventories (2008-2014)

Size Distributions

The size distributions for the two most commonly-caught sportfish species in the pilot study, walleye and goldeye, were generally similar to the size distributions for these species in previous summer inventories (Figure 6.3-8, Figure 6.3-9), although there was a slightly larger proportion of juvenile walleye (<150 mm; likely YOY) caught during the pilot study than in the previous RAMP/JOSMP inventories and a slightly higher proportion of adult walleye caught during the baseline period (1989 to 1996) (Figure 6.3-8). The size range of goldeye caught during the pilot study was similar to all previous summer inventories; however, the proportion of small goldeye (< 200 mm) caught during the pilot study was much smaller than previous inventories (Figure 6.3-9), which may have been a result of the later timing of the pilot study allowing more time for the smaller fish to grow. The majority of the RAMP/JOSMP summer inventories took place in mid-to-late July, about a month earlier than the Pilot study.

Figure 6.3-8 Size distributions of walleye caught in the Athabasca River during the 2015 pilot study and in previous summer inventories (1989 to 2014).

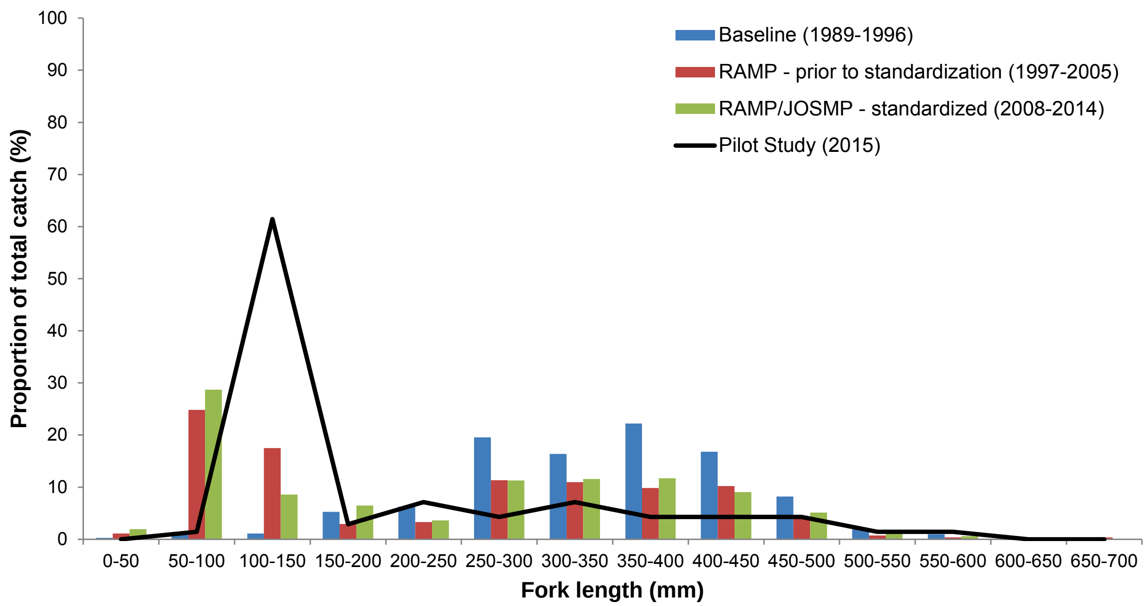
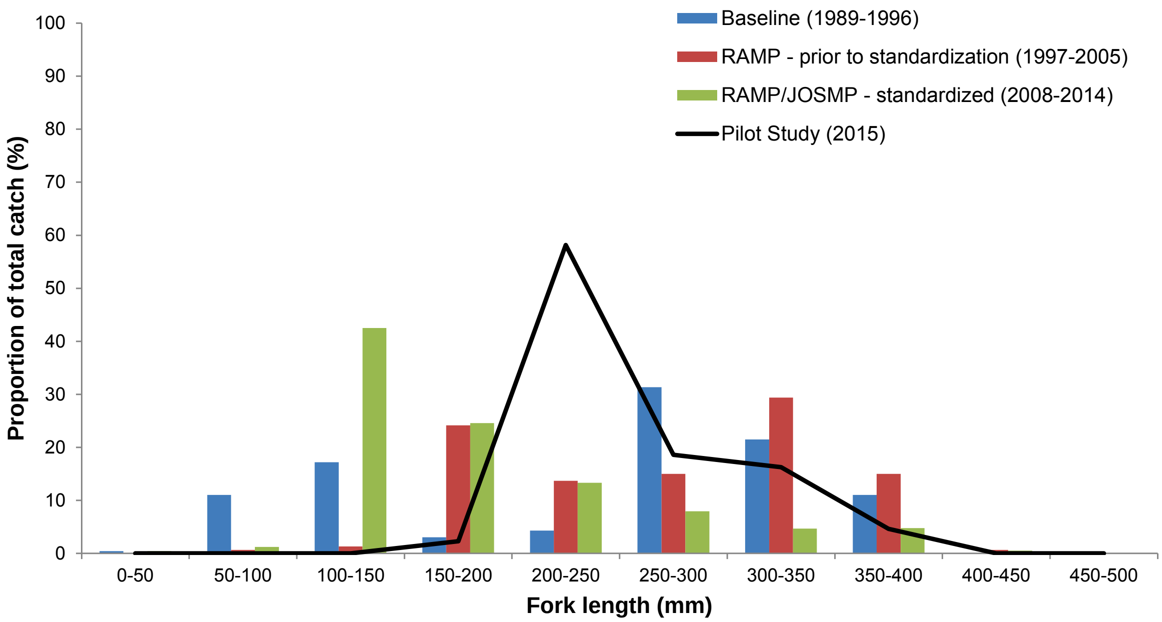


Figure 6.3-9 Size distributions of goldeye caught in the Athabasca River during the 2015 pilot Study and in previous summer inventories (1989 to 2014).



Influence of Environmental Factors

Given the similarities between the fishing methods employed in the pilot study and the RAMP/JOSMP inventories, the low CPUE for sportfish indicate that fishing efficiency and/or abundance were much lower for sportfish in 2015. Several environmental factors may have contributed to the lower catches of sportsfish in the pilot study, particularly the late-summer timing of the 2015 study and the very low water levels that occurred during the sampling period.

Between summer and fall, large-scale redistributions of fish populations start to occur in the Athabasca River. In the fall, goldeye return to overwintering habitat after spending the spring and summer feeding in the river, while lake whitefish start their spawning migration into the Athabasca River (Bond 1980). Due to the late summer timing of the pilot study, some goldeye may have already left the river, while lake whitefish migrating up from the lake may not have yet reached the study area (the spawning run is typically observed moving through the Athabasca River Delta in early September (Bond 1980).

A factor that likely contributed to differences in fish catches between the pilot study and RAMP/JOSMP inventories was the uncharacteristically low flow levels that occurred in 2015 (Figure 6.3-2). In 2015, the average daily discharge was below the historical minimum daily discharge for 31 of the 62 days in July and August (compared to the average daily summer discharge between 1957 and 2014) (Figure 6.3-2). Low water levels may have displaced large-bodied fish away from the river margins where sampling occurred. The greater relative abundance of forage fish in the pilot study compared to the RAMP/JOSMP inventories (Table 6.3-11) may have resulted from a reduction in the quantity and quality of margin habitats as the available cover reduced with the low flow. Higher concentrations of forage fish would likely attract and increase the prevalence of predators such as walleye and northern pike. Thus lower water levels may partly explain the higher CPUEs of forage fish, and relatively high CPUE for walleye (relative to other sportfish) observed during the pilot study. The low CPUE for northern pike was within the range of historical CPUE observed for this species during the RAMP/JOSMP summer inventories (Table 6.3-11) and the difference in CPUE from previous years was less than that observed for some other sportfish (i.e., goldeye and lake whitefish).

6.3.6 Conclusions

Historically low-flow conditions were present in the Athabasca River for most of the 2015 summer period. Accordingly, the timing of the pilot study in mid-late August did not meet the flow requirements stipulated in the Alberta monitoring approach (ASRD 2011); however, it is worth noting that at no time in July or August were the flow conditions appropriate for sampling. Lower catches and CPUE observed for sportfish caught during the pilot study, compared to previous summer inventories conducted by RAMP/JOSMP, were likely a result of the low water levels in the Athabasca River observed during summer 2015.

Of the four key sportfish targeted during the pilot study, lake whitefish was the only species that was not captured. Moderate numbers of goldeye (n=70) and walleye (n=43) were caught in sufficient numbers to create approximate size and age class distributions, although samples sizes >100 individuals is often preferred for distribution analyses. Only five northern pike were captured throughout the study area.

Summer is typically a poor time to sample for sportfish species in the study area as resident populations of targeted species are often low. Fish populations of the Athabasca River downstream of Fort McMurray are strongly influenced by the Athabasca River Delta and Lake Athabasca. Accordingly, the presence of species such as walleye, lake whitefish and goldeye in the oil sands region of the Athabasca River is strongly influenced by spring and fall migration and spawning activities (Bond 1980). Similarly, higher numbers of northern pike are found during the spring spawning period, but even during that time, a greater number of pike have been captured in the Clearwater River than the Athabasca River due to the availability of spawning habitat (JOSMP 2014). Goldeye, particularly juveniles, are typically prevalent and relatively abundant (with respect to the other key sportfish species) throughout this stretch of the river during the summer, but there has been marked annual variability in the summer catch of goldeye during previous RAMP/JOSMP inventories (JOSMP 2014). Inter-reach variability in fish assemblages and CPUE observed in the pilot study was greater than the variability observed in the river margin habitat variables surveyed. Fish assemblages in the Athabasca River mainstem are likely to be more correlated with proximity to major tributaries or specific spawning and/or instream habitat variables, such as in-stream cover or spawning substrates.

7.0 SYNTHESIS OF 2015 WY RESULTS

This section provides a summary of the results presented in Chapter 5 for each monitoring component and a summary of the special studies presented in Chapter 6. Table 7.1-1 is a compilation of the results of the 2015 Program by watershed and by component. Overall conclusions and general comments for each component are presented in the following sections.

7.1 CLIMATE AND HYDROLOGY

Hydrologic changes in the Athabasca oil sands region during the 2015 WY were assessed as **Negligible-Low** in nine of the 12 watersheds that were assessed (Table 7.1-1). The exceptions to this assessment were the Tar River, Muskeg River, and Poplar Creek watersheds, in which at least one of the four hydrology measurement endpoints was classified as **Moderate** or **High** (Table 7.1-2). The oil sands development activities that contributed to hydrologic changes in the 2015 WY, in order of decreasing water volumes influencing flow regimes in the watersheds of the study area, were:

- industrial water withdrawals, releases, and diversions;
- closed-circuited land area resulting in a loss of flow to natural watercourses that would have otherwise occurred in the absence of oil sands developments; and
- land area that is cleared and not closed-circuited thereby contributing to increased flows to natural watercourses that would not have otherwise occurred in the absence of oil sands developments.

The cumulative effect of oil sands development on the surface hydrology was assessed using the Athabasca River mainstem. Relative changes from *baseline* to *test* conditions for values of all four measurement endpoints (i.e., differences between observed *test* and estimated *baseline* values for mean open-water season discharge, mean winter discharge, annual maximum daily discharge, and open-water season minimum daily discharge) were classified as **Negligible-Low** at Station 07DD001, Athabasca River at Embarras Airport, for the 2015 WY (Table 7.1-2). For each of these measurement endpoints, the observed *test* hydrograph value was lower than the estimated *baseline* hydrograph value that would have occurred in the absence of oil sands development.

Temporal changes on the cumulative effect of oil sands development on hydrology was assessed by plotting the values of the hydrology measurement endpoints over time at Station S24, Athabasca River below Eymundson Creek from 2004 to 2011, Station S46, Athabasca River near Embarras Airport from 2012 to 2014, and Station 07DD001, Athabasca River at Embarras Airport in 2015 (Figure 7.1-1). The percent change in the values of all measurement endpoints in the 2015 WY were greater than in the 2014 WY, and regressions of the changes in values of the measurement endpoints over time were statistically significant ($p<0.05$) for both mean open-water season discharge and annual maximum daily discharge over the monitoring record.

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Table 7.1-1 Summary assessment of 2015 WY monitoring results.

Watershed/Region	Differences Between *Test* and *Baseline* Conditions						Acid-Sensitive Lakes[7]
	Hydrology[1]	Water Quality[2]	Benthic Invertebrate Communities[3]	Sediment Quality[4]	Fish Communities[5]	Wild Fish Health[6]	
Athabasca River	🟡	🟡	-	-	-	🟡/🟠/🟤	-
Athabasca River Delta	-	🟡	🟡/🟠	n/a	-	-	-
Muskeg River	🟡/🟠	🟡	🟡	🟡	🟡	n/a	-
Jackpine Creek	nm	🟡	🟡	🟡	🟡	-	-
Stanley Creek	-	🟡	-	-	-	-	-
Wapasu Creek	-	nm	-	-	-	-	-
Kearl Lake	nm	n/a	🟡	n/a	-	-	-
Steepbank River	🟡	🟡	-	-	🟤	-	-
Tar River	🟤	🟡	🟠	🟡	n/a	-	-
MacKay River	🟡	🟡	-	🟡	🟡	🟡/🟠	-
Dover River	nm	🟡	-	🟡	-	n/a	-
Calumet River	🟡	🟡	🟡	🟡/🟠	-	-	-
Firebag River	🟡	🟡	🟠	🟡	-	-	-
Moose Creek	nm	-	-	-	-	-	
McClelland Lake	nm	n/a	🟡	n/a	-	-	-
Johnson Lake	-	n/a	n/a	n/a	-	-	-
Ells River	🟡	🟡	🟡	🟡/🟠/🟤	🟡	🟡/🟠	-
Namur Lake	-	n/a	n/a	n/a	-	-	-
Gardiner Lake	-	n/a	n/a	n/a	-	-	-
Clearwater River	🟡	🟡/🟠	🟡	🟡	-	-	-
High Hills River	nm	🟡	n/a	-	-	-	-
Christina River	🟡	🟡	🟡/🟠	🟡	🟡	-	-
Sawbones Creek	nm	🟡	🟠	🟡	nm	nm	-
Sunday Creek	nm	🟡	🟤	🟡	🟡	nm	-
unnamed creeks (east and south of Christina Lake)	nm	🟡	🟡	🟡	nm	-	-
Birch Creek	nm	🟡	n/a	🟡	nm	-	-
Jackfish River	nm	🟡	🟠	-	🟡	nm	-
Gregoire River	nm	🟡	🟡	-	-	-	-
Christina Lake	nm	n/a	🟤	n/a	-	-	-
Gregoire Lake	nm	n/a	🟡	n/a	-	-	-
Hangingstone River	🟡	🟡/🟠	🟡	-	-	n/a	-
Pierre River	nm	🟡	n/a	🟡	-	-	-
Eymundson Creek	nm	🟠	n/a	🟡	-	-	-
Big Creek (Unnamed Creek)	nm	🟡	n/a	🟡	-	-	-
Redclay Creek	nm	🟡	n/a	-	-	-	-
Fort Creek	nm	🟡	🟤	🟡	-	-	-
Poplar Creek	🟡/🟤	🟡	🟠	🟡	-	-	-
McLean Creek	-	🟡	-	-	-	-	-
Horse River	-	🟡	-	-	-	-	-
Beaver River	-	🟡	n/a	🟡	-	-	-
Alice Creek	-	🟡	-	🟡	-	n/a	-
Mills Creek	nm	-	-	-	-	-	-
Isadore's Lake	nm	n/a	🟡	n/a	-	-	-
Shipyard Lake	-	n/a	🟡	n/a	-	-	-
Stony Mountains	-	-	-	-	-	-	🟠
West of Fort McMurray	-	-	-	-	-	-	🟡
Northeast of Fort McMurray	-	-	-	-	-	-	🟡
Birch Mountains	-	-	-	-	-	-	🟠
Canadian Shield	-	-	-	-	-	-	🟡
Caribou Mountains	-	-	-	-	-	-	🟠

Legend and Notes

🟡 **Negligible-Low** change "-" program was not completed in 2015 WY; nm – not measured in the 2015 WY

🟠 **Moderate** change n/a – classification not completed as there were no *baseline* conditions against which to compare or reach was sampled to add to regional *baseline*

🟤 **High** change

1 **Hydrology:** (i) Measurement endpoints were calculated on differences between observed *test* and estimated *baseline* hydrographs that would have been observed in the absence of oil sands developments in the watershed: 5% - Negligible-Low; ± 15% - Moderate; > 15% - High; (ii) Not all hydrology measurement endpoints were calculated for each watershed because of differing lengths of the hydrographic record for 2015. The hydrology results presented are for those measurement endpoints that were calculated; (iii) Mean Open-Water Season Discharge, Annual Maximum Daily Discharge, and Minimum Open-Water Season Discharge in the Muskeg River assessed as **Negligible-Low**; Mean Winter Discharge assessed as **Moderate**; (iv) Mean Open-Water Season Discharge in Poplar Creek was assessed as **High**, while Mean Winter Discharge, Annual Maximum Daily Discharge, and Mean Open-Water Season Discharge were assessed as **Negligible-Low**.

2 **Water Quality:** (i) Classification based on adaptation of CCME water quality index; see Section 3.2.2.4 for a detailed description of the classification methodology; (ii) Water quality in the Clearwater River was assessed as **Negligible-Low** at the lower station, and **Moderate** at the middle station; (iii) Water quality in the Hangingstone River was assessed as **Moderate** at the lower station and **Negligible-Low** at the middle station.

3 **Benthic Invertebrate Communities:** (i) Classification based on statistical differences in measurement endpoints between *baseline* and *test* reaches as well as comparison to regional *baseline* conditions; see Section 3.2.3.1 for a detailed description of the classification methodology; (ii) Benthic invertebrate communities in the Athabasca River Delta were assessed as **Negligible-Low** at Big Point Channel, the Embarras River, and Fletcher Channel, and **Moderate** at Goose Island Channel; (iii) Benthic invertebrate communities in the Christina River were classified as **Moderate** at the lower reach and **Negligible-Low** at the upper reach.

4 **Sediment Quality:** (i) Classification based on adaptation of CCME sediment quality index (Section 3.2.3.2); (ii) Sediment quality in the Calumet River was assessed as **Moderate** at the lower reach and **Negligible-Low** at the upper reach; (iii) Sediment quality in the Ells River was assessed as **Moderate** near the mouth, High at the lower reach, and **Negligible-Low** at the middle and upper reaches.

5 **Fish Populations (Fish Communities):** Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches (Section 3.2.4.1).

6 **Fish Populations (Wild Fish Health):** (i) Classification based on exceedances of measurement endpoints from the regional variation in *baseline* reaches (Section 3.2.4.2); (ii) Classification for the Athabasca River was based on exceedances of measurement endpoints at each monitoring reach relative to the reach located immediately upstream on the Athabasca River (i.e., considered a "*baseline*" reach for comparison purposes) in an effort to isolate potential effects related to specific influences of interest; see Section 3.2.4.2 for a detailed description of the classification methodology. Wild fish health in the Athabasca River was assessed as **Negligible-Low** above the Muskeg River, **Moderate** in reaches between Poachers Landing and Northlands (below Fort McMurray), below the Muskeg River and near the Athabasca Delta, and **High** in reaches above the Ells River and below the Firebag River; (iii) Wild fish health in the MacKay River was assessed as **Moderate** at the lower reach and **Negligible-Low** at the middle reach; (iv) Wild fish health in the Ells River was assessed as **Moderate** at the lower reach and **Negligible-Low** at the middle reach.

7 **Acid-Sensitive Lakes:** Classification based on the frequency in which values of seven measurement endpoints in 2015 were more than twice the standard deviation from their long-term mean in each lake.

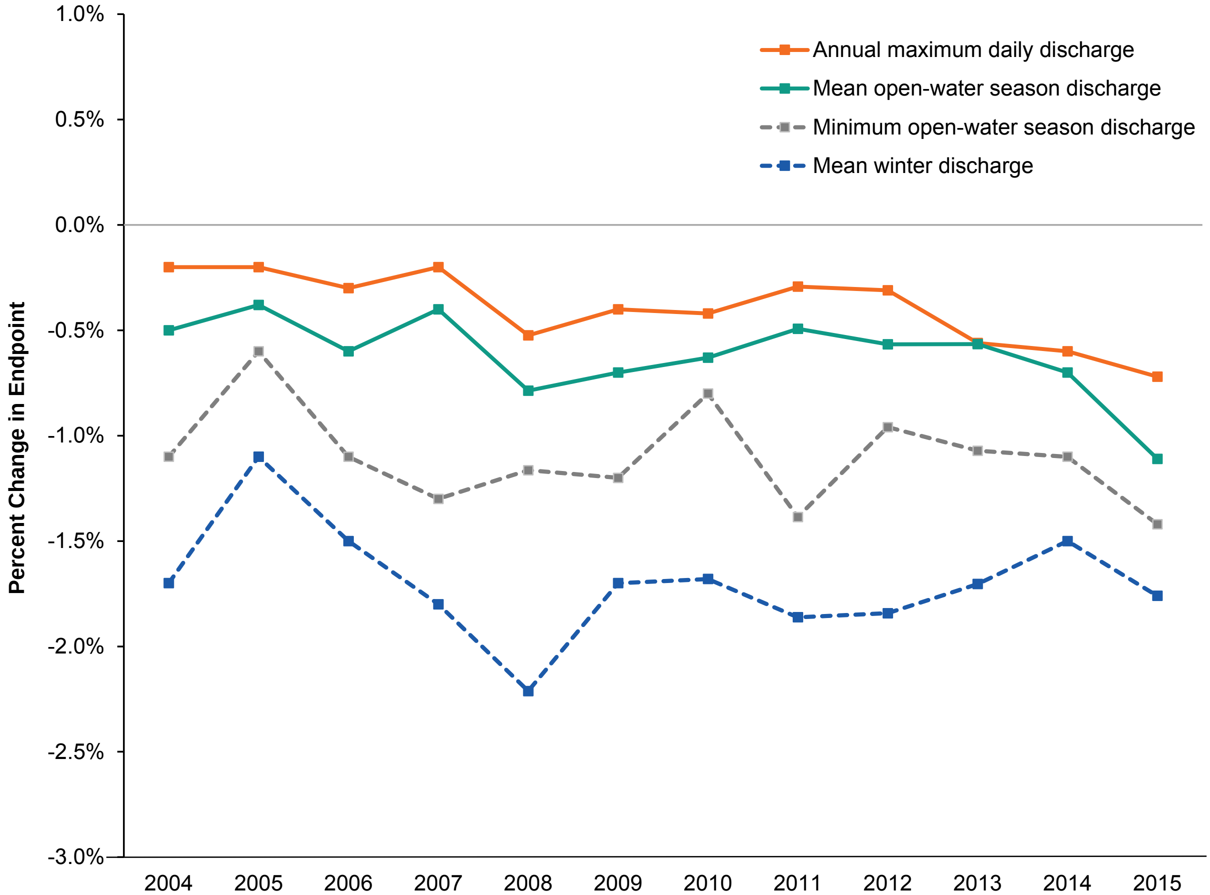
Table 7.1-2 Summary assessment of the 2015 WY hydrologic monitoring results.

Watershed	Hydrologic Measurement Endpoint			
	Mean Open-Water Season Discharge	Mean Winter Discharge	Annual Maximum Daily Discharge	Minimum Open-Water Season Discharge
Athabasca River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Muskeg River	Negligible-Low	Moderate (+)	Negligible-Low	Negligible-Low
Steepbank River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Tar River	High (-)	not measured	High (-)	High (-)
MacKay River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Calumet River	Negligible-Low	not measured	Negligible-Low	Negligible-Low
Firebag River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Ells River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Clearwater River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Christina River	Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Hangingstone River	Negligible-Low	not measured	Negligible-Low	Negligible-Low
Poplar Creek	High (+)	Negligible-Low	Negligible-Low	Negligible-Low

Assessments based on comparisons of calculated incremental change in hydrology measurement endpoints: Negligible-Low: ± 5%; Moderate: ±15%; High: > ± 15%.

Direction indicators (+ or -) indicate a calculated increase or decrease in discharge in observed *test* conditions compared to estimated *baseline* conditions. Direction indicators are shown only for differences of 5% or greater (i.e., Moderate or High).

Figure 7.1-1 Changes in values of hydrologic measurement endpoints in the Athabasca River as a result of oil sands developments.



Note: Measurement endpoints were calculated from estimated *baseline* and observed *test* hydrographs at Station S24, Athabasca River below Eymundson Creek, from 2004 to 2011, Stations S46, Athabasca River near Embarras Airport, from 2012 to 2014, and Station 07DD001, Athabasca River at Embarras Airport in 2015. A comparison of water balances from the S24 and S46 Athabasca River stations, using 2013 WY data, indicated essentially no difference in the value of measurement endpoints (RAMP 2014).

7.2 WATER QUALITY

Water quality measured in the study area in the 2015 Program was generally consistent with historical and regional *baseline* observations obtained in regional monitoring conducted in the study area since 1997. However, water quality at some stations exhibited characteristics outside the range of regional *baseline* observations, or showed significant temporal trends in values of water quality measurement endpoints. These stations included the following:

- **Upper Clearwater River** – Water quality at *baseline* station CLR-2, upstream of the confluence of the Christina River, was classified as exhibiting **Moderate** difference from regional *baseline* conditions, due to concentrations of water quality endpoints including total mercury, chloride, and total suspended solids that exceeded the 95th percentile of regional *baseline* conditions in fall 2015.

- **Lower Hangingstone River** – Differences in water quality in fall 2015 between *test* station HA1 in the lower Hangingstone River and regional *baseline* fall conditions were classified as **Moderate** due to higher concentrations of ions, total boron, and total strontium and a lower concentration of total dissolved phosphorus at *test* station HA1 relative to regional *baseline* concentrations.

- **Eymundson Creek** – Differences in water quality in fall 2015 between *baseline* station EYC-1 in the Pierre River area and regional *baseline* fall conditions were classified as **Moderate** because concentrations of total mercury (ultra-trace) and sulphate exceeded the 95th percentile of regional *baseline* conditions in fall 2015 at *baseline* station EYC-1.

- **Fort Creek** – Although water quality at *test* station FOC-1 in fall 2015 showed **Negligible-Low** differences compared to regional *baseline* water quality conditions in fall 2015, water quality at this station was measured to have significant increasing trends over time in concentrations of dissolved phosphorus, total nitrogen, total strontium, total boron, sulphate, potassium, magnesium, calcium, and total dissolved solids.

- **Shipyard Lake** – The ionic composition of water at *test* station SHL-1 continued to exhibit an increase in concentrations of sodium and chloride relative to historical concentrations, with significant increasing trends over time in sodium, chloride, and potassium.

- **Isadore's Lake** – Shifts in ion balance and significant increasing trends in concentrations of a number of dissolved ions at *test* station ISL-1 suggest an ongoing change in water quality in Isadore's Lake over time.

Continuous monitoring of in situ water quality variables in the Athabasca, Muskeg, Steepbank, MacKay, Firebag, Ells, Clearwater, and High Hills rivers indicated that all waters monitored were generally well-oxygenated, alkaline, and showed gradual seasonal changes, with dissolved oxygen highest in colder water temperatures, and specific conductivity typically higher in low-flow periods. Turbidity levels were variable and were generally low with the occasional large increase in turbidity associated with high-flow events such as storm-related runoff.

Monthly water quality sampling was introduced at many stations in May 2015, with insufficient data available (i.e., typically less than six months) to allow conclusions to be drawn in regards to monthly, intra-year variation in water quality. Key within-year patterns noted at a number of water quality stations throughout the study area were the: (i) during the spring freshet, high levels of TSS and concentrations of water quality variables typically associated with particulates, such as a number of total metals and nutrients; and (ii) in the lower-flow summer period, relatively high concentrations of TDS and concentrations of water quality variables typically associated with TDS, such as ions. Continued collection and analysis of comprehensive monthly water quality data will help to clarify and quantify sources of seasonal variation in ion concentrations.

7.3 BENTHIC INVERTEBRATE COMMUNITIES AND SEDIMENT QUALITY

7.3.1 Benthic Invertebrate Communities

Athabasca River Delta Variations in the values of measurement endpoints for benthic invertebrate communities in fall 2015 at Big Point Channel, Fletcher Channel, and Embarras River were classified as **Negligible-Low**, while variations in the values of measurement endpoints for benthic invertebrate communities in Goose Island Channel were classified as **Moderate** on the basis of high abundances (>120,000 individuals per m^2), low percentage of EPT taxa (Ephemeroptera, Plecoptera, Trichoptera), and the dominance of tubificid worms.

Lakes Variations in the values of measurement endpoints for benthic invertebrate communities at *test* stations in Kearl, McClelland, Isadore's, Shipyard, and Gregoire lakes were classified as **Negligible-Low** because values of benthic invertebrate community measurement endpoints in fall 2015 were not indicative of degrading habitat conditions. Variations in the values of measurement endpoints for benthic invertebrate communities at Christina Lake in fall 2015 were classified as **High** on the basis of reductions in richness and percent EPT taxa, and higher equitability in 2015 implying degrading conditions for benthic invertebrate communities. The 2015 Program monitored benthic invertebrate communities at three *baseline* lakes: Gardiner; Johnson; and Namur and values of benthic invertebrate community measurement endpoints at these lakes in fall 2015 were similar to values from previous years of monitoring at these lakes.

Rivers Variations in the values of measurement endpoints for benthic invertebrate communities of the following *test* reaches were classified as **High** for 2015:

- **Lower Sunday Creek** – Abundance and richness were significantly lower, and equitability was significantly higher at the lower *test* reach in Sunday Creek compared to the upper *baseline* reach, all of which imply degrading conditions for benthic invertebrate communities at the lower *test* reach in Sunday Creek. It is worth noting that the %EPT in the lower *test* reach was similar to the upper *baseline* reach in fall 2015 and values of all benthic invertebrate community measurement endpoints in fall 2015 were within the inner tolerance limit of the 95^{th} percentile of the normal range of values for regional *baseline* variability.

- **Lower Fort Creek** – While the presence of clams, snails, and stoneflies in fall 2015 suggested that the quality of benthic habitat at the lower *test* reach in Fort Creek, there were significant differences in values of three of the benthic invertebrate community measurement endpoints (abundance, richness, and equitability) between *test* and *baseline* conditions in lower *test* reach in Fort Creek, all of which suggested degrading conditions for benthic invertebrate communities.

Variations in the values of measurement endpoints for benthic invertebrate communities of the following *test* reaches were classified as **Moderate** for 2015:

- **Lower Tar River** – Richness was significantly lower during the *test* period compared to the *baseline* period (2002 to 2003) and significantly lower in fall 2015 than the mean of *baseline* years, both of which indicated degrading conditions for benthic invertebrate communities. Mayflies and caddisflies, which were present during the *baseline* period and in most of the previous sampling years have been absent since 2013. It is worth noting that values of all benthic invertebrate community measurement endpoints in fall 2015 were within the normal range of values for regional *baseline* variability.

- **Lower Firebag River** – Richness was significantly lower in fall 2015 at the lower *test* reach in the Firebag River compared to the mean of prior years and was also below the normal range of regional *baseline* conditions; the benthic invertebrate community at the lower *test* reach in the Firebag River in fall 2015 also did not contain EPT taxa or permanent aquatic forms.

- **Lower Christina River** – While the benthic invertebrate community at the lower *test* reach in the Christina River in fall 2015 included several taxa that are typically associated with relatively good environmental conditions, values of all benthic invertebrate community measurement endpoints at the lower *test* reach in the Christina Rive were outside the inner tolerance limits of the normal range of variation from previous years of sampling, including a lower %EPT compared to previous years.

- **Lower Sawbones Creek** – Abundance and the percentage of EPT taxa at the lower *test* reach in Sawbones Creek were significantly higher and significantly lower, respectively, in fall 2015 than the mean of previous years at the *test* reach, both of which suggest degrading conditions for benthic invertebrate communities. However, CA axis 1 scores were lower in fall 2015 than the mean of prior years in the reach due to increases in the relative abundance of chironomids and mayflies, which indicate favourable long-term habitat quality.

- **Lower Jackfish River** – Richness and %EPT were significantly lower in fall 2015 than the mean of prior years at the lower *test* reach in the Jackfish River, both of which indicate degrading conditions for benthic invertebrate communities; however, the relative abundance of worms decreased in fall 2015 at the lower *test* reach in the Jackfish River and the reach in fall 2015 contained several taxa indicative of good water and sediment quality.

- **Poplar Creek** – While the benthic invertebrate community at the lower *test* reach in Poplar Creek in fall 2015 was in generally good health as evidenced by trends and levels of %EPT and had a range of fauna typical for a sandy-bottomed river, there were significant differences in values of equitability between *test* and *baseline* conditions that implied degrading conditions for benthic invertebrate communities.

Variations in the values of measurement endpoints for benthic invertebrate communities of the following *test* reaches were classified as **Negligible-Low** because there were no significant variations in values of benthic invertebrate community measurement endpoints indicative of degraded conditions and no exceedances of historical or regional *baseline* ranges: Muskeg River (lower, middle, and upper); Jackpine Creek; Calumet River; Ells River; Clearwater River; Christina River (lower-middle, middle, upper-middle); unnamed creeks east and south of Christina Lake; Gregoire River; and Hangingstone River.

7.3.2 Sediment Quality

Sediments in rivers and lakes of the study area naturally contain concentrations of hydrocarbons and PAHs that may exceed environmental-quality guidelines. Sediment quality in fall 2015 was generally similar to historical observations at all sampling locations and showed **Negligible-Low** differences in sediment quality from regional *baseline* conditions, with the exception of samples from two rivers in areas known to have surface expression of bitumen:

- **Lower Calumet River** – *Test* station CAR-D1 was classified as **Moderate** because the concentration of total PAHs, carbon-normalized total PAHs, and total hydrocarbons in fall 2015 that were above the 95th percentile of regional *baseline* concentrations; and

- **Lower Ells River** – *Test* stations ELR-D1 and ER-L were classified as **Moderate** and **High**, respectively, due to concentrations of hydrocarbons and PAHs in fall 2015 that were above the 95th percentile of regional *baseline* concentrations.

Significant increasing trends over time in concentrations of various hydrocarbon fractions were observed in sediments at the *baseline* station in upper Jackpine Creek (Fraction 1), at *test* stations in Fletcher Channel and Big Point Channel in the ARD (Fraction 4), the lower reaches of Poplar Creek (Fractions 3 and 4), Fort Creek (Fraction 4), Tar River (Fractions 1, 2, 3, and 4), and Ells River (Fractions 2, 3, and 4), as well as at McClelland Lake (Fraction 3), and Isadore's and Shipyard lakes (Fractions 1, 2, 3, and 4). Significant decreasing trends over time in concentrations of total PAHs were measured in sediments at *test* stations in the lower and upper Christina River, middle Muskeg River, and Kearl Lake, while a significant increasing trend in concentrations of total PAHs was observed at Isadore's Lake.

7.4 FISH POPULATIONS

7.4.1.1 Fish Communities

Differences in values of measurement endpoints for fish communities were classified as **High** in the lower Steepbank River as three of the five measurement endpoints (abundance, richness, and CPUE) were measured to have decreased significantly over time and more than 20% of the variance in mean values of these measurement endpoints was explained by these trends. It is worth noting that mean abundance, richness, and CPUE in the lower Steepbank River were higher in 2015 than 2014.

Differences in measurement endpoints for fish communities were classified as **Negligible-Low** compared to regional *baseline* conditions at *test* reaches in the: Muskeg River; Jackpine Creek; MacKay River; Ells River; Christina River; Sunday Creek; and Jackfish River.

7.4.1.2 Wild Fish Health Monitoring

Athabasca River There was a concentration of changes in values of measurement endpoints for wild fish health that started below the confluence of the Muskeg River, became more prominent just above the confluence with the Ells River, and then dissipated near the Athabasca River Delta; a similar trend was measured in EROD activity of trout perch. When each monitoring reach in the Athabasca River Delta was compared to the reach located immediately upstream (i.e., considered a "*baseline*" reach for comparison purposes in an effort to test for specific influences of interest), the classification of results for wild fish health was **High** at the:

- *test* reach below the Firebag River (M8) because both male and female fish were significantly lighter at a given age and had larger liver size, female fish were significantly older, and male fish had significantly larger gonad size; and

- *test* reach above the Ells River (M7) because male and female fish had smaller gonad and liver sizes and female fish were significantly younger.

The classification of results for wild fish health was **Moderate** at the following reaches when compared to the reach immediately upstream:

- *test* reach near the Athabasca River Delta (M9) because male and female fish had smaller liver sizes, and male fish were significantly older;
- the *test* reach below the Muskeg River (M4-DS) because female fish were significantly older and male and female fish were significantly heavier at a given age;
- *baseline* reach below Fort McMurray at Northlands (M3) because female fish were significantly heavier at a given age;
- *baseline* reach above Fort McMurray (M2) because female fish had significantly smaller gonad size; and
- *baseline* reach at Poachers Landing, downstream of the town of Athabasca and the ALPAC mill, (M0-DS), because female fish were lighter a given age.

The classification of results for wild fish health was **Negligible-Low** at the *test* reach above the Muskeg River (M4-US) as there were no significant differences in values of wild fish health measurement endpoints between this reach and the reach immediately upstream.

MacKay River Wild fish health in the lower MacKay River was assessed as **Moderate** because male fish at the lower *test* reach had significantly smaller liver size than male fish at the middle *test* reach and upper *baseline* reach. The middle *test* reach was assessed as **Negligible-Low** as values of measurement endpoints for wild fish health did not differ significantly with those at the *baseline* reach.

Ells River Wild fish health in the lower Ells River was assessed as **Moderate** because female and male fish at the lower *test* reach were significantly younger than fish at the middle *test* reach and upper *baseline* reach. The middle *test* reach was assessed as **Negligible-Low** as values of measurement endpoints did not differ significantly from the *baseline* reach.

Classification of the results of wild fish health monitoring could not be assessed for reaches in:

- Dover River and Alice Creek because no *test* reaches were monitored in these watercourses in the 2015 Program and because 2015 was the first year of wild fish health monitoring in these watersheds;
- Hangingstone River because no *baseline* reach was monitored in the Hangingstone River in the 2015 Program. Qualitative comparisons were instead made to data collected from the upstream *baseline* reach of the MacKay River;
- Muskeg River because no *baseline* reach was monitored in the Muskeg River in the 2015 Program and because lake chub was the target species in fall 2015 while historical monitoring in the Muskeg River used slimy sculpin as the target species; and

- Sawbones Creek, Sunday Creek, and Jackfish River because no *baseline* reaches were sampled in the Christina River watershed for wild fish health monitoring in fall 2015 and slimy sculpin were not sampled at any regional *baseline* reach in the 2015 Program.

7.5 ACID-SENSITIVE LAKES

With few exceptions, concentrations of chemical variables monitored in the ASL program in the 2015 WY were similar to historical levels. In among-year comparisons, pH and Gran alkalinity increased significantly over time while nitrates decreased over the monitoring years, often in both *baseline* and *test* lakes. These trends were opposite in direction to those expected under an acidification scenario. There were no significant changes in sulphates, the principal acidifying species generated by NO_xSO_x emissions. There were no significant increases in aluminum or decreases in dissolved organic carbon. The sum of base cations increased significantly in the *baseline* lakes and over all the lakes (*baseline* and *test* lakes combined). These increases in base cations were not considered to be indicative of acidification. Changes in conservative ions such as potassium and bicarbonate were most likely due to hydrologic changes over time involving a possible increase in the role of surficial groundwater in determining lake chemistry.

Critical loads of acidity in the 50 lakes ranged from -0.828 keq H^+/ha/yr to 3.952 keq H^+/ha/yr, with a median value of 0.546 keq H^+/ha/y. Critical loads have significantly increased over time, which is consistent with increases in lake buffering capacity (i.e., Gran alkalinity). The lowest critical loads were found in lakes in the Stony Mountains, West of Fort McMurray, and Canadian Shield subregions. Lakes in the Stony Mountains, having the lowest critical loads, were the most acid-sensitive of the ASL lakes.

The critical loads of acidity for each individual lake were compared to modeled rates of acid deposition (Potential Acid Input, PAI) The majority of the lake catchments (31 of 50) were exposed to basic rather than acidic deposition, reflected in negative PAI values. Most of the lakes exposed to acidifying deposition are located in the Birch Mountains, the Canadian Shield and Caribou Mountain subregions, which are all remote from NO_xSO_x emissions but having low rates of base cation deposition. Only one lake (BM7/448 Clayton Lake), in the Birch Mountains, had a modeled PAI estimate exceeding the critical load and was at potential risk of acidification.

While Mann-Kendall trend analysis applied to the seven measurement endpoints in each of the 50 lakes identified 19 significant trends in a direction indicative of acidification, these trends were inconsistent with any reasonable acidification scenario. For example, significant increases in sulphates in CM1 and BM2 were associated with significant increases (rather than decreases) in pH and Gran alkalinity in these lakes. Significant increases in the sum of base cations in nine lakes were attributed to increased alkalinity loading to these lakes consisting of calcium and magnesium bicarbonates rather than calcium and magnesium sulphates expected during catchment acidification. The trends identified in the Mann-Kendall analysis were consistent with the results of the among-year comparisons (ANOVA) in showing significant increases in Gran alkalinity in 18 lakes and significant increases in pH in 27 lakes.

Shewhart control charting was applied to the ASL measurement endpoints in order to detect acidifying trends in the five individual lakes most at risk to acidification. These five lakes were located in the Birch Mountains (four) and Canadian Shield subregions (one). While the control charts showed a number of isolated exceedances of the two standard deviation limits in individual lakes across years, these variables returned to normal in the following year and there was no evidence to suggest from the control charts that acidifying trends were occurring in these five lakes.

Results of the analysis of the acid-sensitive lakes in 2015 compared to the historical data suggested that there have been no significant changes in the water chemistry of the 50 lakes across years that could be attributed to acidification. These results were consistent with the revised estimates of PAI suggesting that only 19 of the 50 lakes were actually exposed to acidifying deposition, all remote from NO_xSO_x emissions.

In 2015 there were no exceedances of the criterion for any of the measurement endpoints in the Canadian Shield, West of Fort McMurray and Northeast of Fort McMurray subregions. These three subregions were classified as having a **Negligible-Low** indication of incipient acidification. The Stony Mountains, the Birch Mountains and the Caribou Mountains were classified as having a **Moderate** indication of incipient acidification largely because of increases in the sum of base cations. As described above, these increases in the sum of base cations were not attributed to catchment acidification but increases in alkalinity loadings to these lakes.

7.6 SPECIAL STUDIES

7.6.1 Relationships between Turbidity, Total Suspended Solids, and Discharge in Tributaries to the Athabasca River

The objectives of studying the relationships between turbidity, TSS and discharge in tributaries to the Athabasca River were to:

- calibrate levels of turbidity obtained from the data sondes to concentrations of total suspended solids (TSS) and present time series of TSS from sites where calibration occurred; and
- assess the value of collecting total TSS samples specifically along with discharge measurements, which has been conducted historically as part of the Climate and Hydrology component for the RAMP/JOSMP; this assessment was based on a literature review of the Water Survey of Canada (WSC) sediment program and a discussions of errors associated with sediment load calculations using continuous discharge data.

Calibration of turbidity to TSS was successful for data sonde locations on the MacKay and Ells rivers. Data suggest that site-specific relationships exist between turbidity and TSS in the study area. Results from this preliminary study suggest that further turbidity-TSS calibrations for data sonde stations in the JOSMP network is a useful first step in the characterization of *baseline* or current conditions, identification of disturbances, and calculation of sediment budgets between monitoring stations.

Uncertainties associated with the derivation of continuous TSS data from a discharge record were deemed to be greater than the increase in uncertainty using computed discharge values with TSS samples collected during routine water quality sampling. Therefore, discontinuing TSS sampling along with manual discharge measurements would only marginally increase the uncertainty in any TSS-discharge relationship that is developed.

7.6.2 Expanded Fish Community Study

The objective of the expanded fish community study conducted in fall 2015 was to test the adequacy of the historical methods used to sample fish communities under the RAMP/JOSMP by comparing the results obtained using the historical five sub-reach sampling approach with the results of an expanded ten sub-reach sampling approach that also used supplemental fishing methods. First, the extent of differences in measurement endpoints between the two methods was assessed, then adequacy was determined by which method produced more precise estimates.

The results of the study demonstrated that additional information can be gained by expanding the fish sampling effort and that selective electrofishing can improve the ability to identify fish species present at a monitoring reach. Although changes in the biological interpretation of data arising from discrepancies between method estimates is a question of professional judgment, the range of potential bias showed that measurement endpoint estimates calculated using the original survey efforts can be half as much or double those estimated using expanded methods. Such discrepancies may influence the biological interpretation of the results of a fish community sampling program. In addition, the precision analysis indicated that estimates generated using an expanded ten sub-reach sampling approach are more precise and, on average, the expanded survey effort allowed for more precise estimates of measurement endpoints. Selective electrofishing further increased the number of fish species caught at each monitoring reach, including sensitive species that were not recorded using the primary electrofishing methods. Although expanded and increased efforts within a reach may allow for a better estimate of measurement endpoints by reducing within-reach variability, increasing sample size (i.e., number of reaches) may also improve the ability to make inferences about a population. Future studies may consider how increasing the number of reaches may change the interpretation of a fish community in a given area.

7.6.3 Status of Fish in the Athabasca River – Pilot Study

A pilot study was initiated in summer 2015 to evaluate the feasibility of monitoring fish populations of the lower Athabasca River using the Alberta Fisheries approach (ASRD 2011) for sampling key sportfish species (walleye, goldeye, lake whitefish, and northern pike), and more generally on the fish community as a whole, during the summer season. The scope was to provide a preliminary summary of the data, including the extent of capture success, species composition, size frequency comparisons, and considerations for future studies.

Catches of sportfish during the pilot study were low compared to previous summer inventories conducted by the RAMP/JOSMP, and were likely a result of the low water levels in the Athabasca River observed during summer 2015. No lake whitefish were captured during the pilot study; the absence of lake whitefish was perhaps related to the timing of the summer survey, as lake whitefish are typically more prevalent in the Athabasca River after their spawning run in fall (Bond 1980). Results of the pilot study confirmed that summer is typically a poor time to sample for most sportfish species in the study area as resident populations of targeted species are often low. The size distributions for the two most commonly-caught sportfish species in the pilot study, walleye and goldeye, were generally similar to the size distributions for these species in previous summer inventories. Based on the results of the pilot study and previous RAMP/JOSMP inventories, future studies need to consider whether the specific target species are commonly abundant in the Athabasca River, and if so, what season are they most abundant so as to maximize the capture of these target species.

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9.0 GLOSSARY AND LIST OF ACRONYMS

9.1 GLOSSARY

Abundance — Number of organisms in a defined sampling unit, usually expressed as aerial coverage (e.g., #/m^2, #/100 sec).

Acute — Acute refers to a stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.

Ageing Structures — Parts of the fish that are taken for ageing analyses. These structures contain bands for each year of growth or maturity that can be counted. Some examples of these structures are scales, fin rays, otoliths, and opercula. Most ageing structures can be taken with minimal effect on the fish and vary according to fish species.

Alkalinity — A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates, and organic substances. It is expressed as an equivalent of calcium carbonate. The composition of alkalinity is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates, and hydroxides. The sum of these three components is called total alkalinity.

ANCOVA — Analysis of covariance. ANCOVA is an extension of ANOVA that provides a way of statistically controlling the effect of variables that one does not want to examine in a study (i.e., a covariate). For example, ANCOVA is used for comparing reach differences in liver size of a target fish species, while controlling the influence of body size.

ANOVA — Analysis of variance. An ANOVA tests for differences among levels of one or more factors. For example, individual sites are levels of the factor site. Two or more factors can be included in an ANOVA (e.g., site and year).

Baseline | *Baseline* is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2015) or were (prior to 2015) upstream of all focal projects; data collected from these locations are to be designated as *baseline* for the purposes of data analysis, assessment, and reporting. The terms *test* and *baseline* depend solely on location of the aquatic resource in relation to the location of the focal projects to allow for long-term comparison of trends between *baseline* and *test* stations.

Benthic Invertebrates | Invertebrate organisms living on the bottom of lakes, ponds, and streams. Examples of benthic invertebrates include the aquatic insects such as caddisfly larvae, which spend at least part of their life on or in bottom sediments. Many benthic invertebrates are major food sources for fish.

Benthos | Organisms that inhabit the bottom substrates (sediments, debris, logs, macrophytes) of aquatic habitats for at least part of their life cycle. The term benthic is used as an adjective, as in benthic invertebrates.

Bioaccumulation | A general term meaning that an organism stores within its body a higher concentration of a substance than is found in the environment. This is not necessarily harmful. For example, freshwater fish must bioaccumulate salt to survive in intertidal waters. Many toxicants, such as arsenic, are not included among the dangerous bioaccumulative substances because they can be handled and excreted by aquatic organisms.

Bioavailability | The amount of chemical that enters the general circulation of the body following administration or exposure.

Bioconcentration | A process where there is a net accumulation of a chemical directly from an exposure medium into an organism.

Biological Indicator (Bioindicator) | Any biological variable used to indicate the response of individuals, populations or ecosystems to environmental stress. For example, growth is a biological indicator.

Biomonitoring | The use of living organisms as indicators of the quality and integrity of aquatic or terrestrial systems in which they reside.

Bitumen | A highly viscous, tarry, black hydrocarbon material having an API (American Petroleum Institute) gravity of about 9º (specific gravity about 1.0). It is a complex mixture of organic compounds. Carbon accounts for 80% to 85% of the elemental composition of bitumen, hydrogen – 10%, sulphur - 5%, and nitrogen, oxygen and trace elements the remainder.

BOD Biochemical oxygen demand. The test measures the oxygen utilized during a specified incubation period for the biochemical degradation of organic material and the oxygen used to oxidize inorganic material such as sulfides and ferrous iron. Usually conducted as a 5-day test (i.e., BOD_5).

Bottom Sediments Substrates that lie at the bottom of a body of water. For example, soft mud, silt, sand, gravel, rock, and organic litter, that make up a river bottom.

Catch Per Unit Effort A measure which relates to the catch of fish, with a particular type of gear, per unit of time (number of fish/100 seconds). Results can be given for a particular species or the entire catch. The results can reflect both the density and/or the vulnerability of the gear utilized, of a species in a particular system.

Chronic Defines a stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of the organism. The measurement of a chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.

CL Confidence limit. A set of possible values within which the true value will lie with a specified level of probability.

Colour True colour of water is the colour of a filtered water sample (and thus with turbidity removed), and results from materials which are dissolved in the water. These materials include natural mineral components such as iron and calcium carbonate, as well as dissolved organic matter such as humic acids, tannin, and lignin. Organic and inorganic compounds from industrial or agricultural uses may also add colour to water. As with turbidity, colour hinders the transmission of light through water, and thus "regulates" biological processes within the body of water.

Community A set of taxa coexisting at a specified spatial or temporal scale.

Concentration Quantifiable amount of a chemical in environmental medium, expressed as mass of a substance per unit volume (e.g., mg/L), or per unit sample mass (e.g., mg/g).

Concentration Units

Concentration Units	Abbreviation	Units
Parts per million	ppm	mg/kg or µg/g or mg/L
Parts per billion	ppb	µg/kg or ng/g or µg/L
Parts per trillion	ppt	ng/kg or pg/g or ng/L
Parts per quadrillion	ppq	pg/kg or fg/g or pg/L

Condition Factor — A measure of how plump or "fat" an aquatic organism is. For oysters and mussels, values are based on the ratio of the soft tissue dry weight to the volume of the shell cavity. For finfish, the condition factor is based on weight-length relationships.

Conductivity — A measure of water's capacity to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water.

Contaminant Body Burdens — The total concentration of a contaminant found in either whole-body or individual tissue samples.

Covariate — An independent variable; a measurement taken on each experimental unit that predicts to some degree the final response of the treatment, but which is unrelated to the treatment (e.g., body size [covariate] included in the analysis to compare gonad weights of fish collected from reference and exposed areas).

CWQG — Canadian Water Quality Guidelines. Numerical concentrations or narrative statements recommended to support and maintain a designated water use in Canada. The guidelines contain recommendations for chemical, physical, radiological and biological parameters necessary to protect and enhance designated uses of water.

Detection Limit — The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level of a given method and representative matrix.

Development Area — Any area altered to an unnatural state. This represents all land and water areas included within activities associated with development of the oil sands leases.

Discharge — In a stream or river, the volume of water that flows past a given point in a unit of time (i.e., m^3/s).

Diversity — The variety, distribution, and abundance of different plant and animal communities and species within an area.

DO Dissolved oxygen, the gaseous oxygen in solution with water. At low concentrations it may become a limiting factor for the maintenance of aquatic life. It is normally measured in milligrams/litre, and is widely used as a criterion of receiving water quality. The level of dissolved oxygen which can exist in water before the saturation point is reached is primarily controlled by temperature, with lower temperatures allowing for more oxygen to exist in solution. Photosynthetic activity may cause the dissolved oxygen to exist at a level which is higher than this saturation point, whereas respiration may cause it to exist at a level which is lower than this saturation point. At high saturation, fish may contract gas bubble disease, which produces lesions in blood vessels and other tissues and subsequent physiological dysfunctions.

Drainage Basin The total area that contributes water to a stream.

EC*p* A point estimate of the concentration of test material that causes a specified percentage effective toxicity (sublethal or lethal). In most instances, the EC*p* is statistically derived by analysis of an observed biological response (e.g., incidence of nonviable embryos or reduced hatching success) for various test concentrations after a fixed period of exposure. EC_{25} is used for the rainbow trout sublethal toxicity test.

Ecological Indicator Any ecological variable used to indicate the response of individuals, populations or ecosystems to environmental stress.

Ecosystem An integrated and stable association of living and non-living resources functioning within a defined physical location.

Environmental Impact Assessment A review of the effects that a proposed development will have on the local and regional environment.

Evenness A measure of the similarity, in terms of abundance, of different species in a community. When there are similar proportions of all species then evenness is one, but when the abundances are very dissimilar (some rare and some common species) then the value increases.

Exposure The contact reaction between a chemical and a biological system, or organism.

Fauna A term referring to an association of animals living in a particular place or at a particular time.

Fecundity The number of eggs or offspring produced by a female.

Fecundity Index	The most common measure of reproductive potential in fishes. It is the number of eggs in the ovary of a female fish. It is most commonly measured in gravid fish. Fecundity increases with the size of the female.
Filter-Feeders	Organisms that feed by straining small organisms or organic particles from the water column.
Forage Fish	Small-bodied fish that provide food for larger fish (e.g., trout-perch, fathead minnow).
Gonad	A male or female organ producing reproductive cells or gametes (i.e., female ovum, male sperm). The male gonad is the testis; the female gonad is the ovary.
Gonad Somatic Index (GSI)	The proportion of reproductive tissue in the body of a fish. It is calculated by expressing gonad weight as a percentage of whole body weight. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth.
GPS	Global Positioning System. This system is based on a constellation of satellites which orbit the earth every 24 hours. GPS provides exact position in standard geographic grid (e.g., UTM).
Habitat	The place where an animal or plant naturally or normally lives and grows, for example, a stream habitat or a forest habitat.
Hardness	Total hardness is defined as the sum of the calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per litre.
IC*p*	A point estimate of the concentration of test material that causes a specified percentage impairment in a quantitative biological test which measures a change in rate, such as reproduction, growth, or respiration.
Inorganics	Pertaining to a compound that contains no carbon.
LC_{50}	Median lethal concentration. The concentration of a substance that is estimated to kill half of a group of organisms. The duration of exposure must be specified (e.g., 96-hour LC_{50}).
Lesions	Pathological change in a body tissue.
Lethal	Causing death by direct action.
Littoral Zone	The zone in a lake that is closest to the shore.

Liver Somatic Index (LSI)	Calculated by expressing liver weight as a percent of whole body weight.
Macro-invertebrates	Those invertebrate (without backbone) animals that are visible to the eye and retained by a sieve with 500 µm mesh openings for freshwater, or 1,000 µm mesh openings for marine surveys (EEM methods).
Mean Annual Flood	The average of the series of annual maximum daily discharges.
Microtox®	A toxicity test that includes an assay of light production by a strain of luminescent bacteria (*Photobacterium phosphoreum*).
Negative Control	Material (e.g., water) that is essentially free of contaminants and of any other characteristics that could adversely affect the test organism. It is used to assess the "background response" of the test organism to determine the acceptability of the test using predefined criteria.
NO_x	A measure of the oxides of nitrogen comprised of nitric oxide (NO) and nitrogen dioxide (NO_2).
Nutrients	Environmental substances (elements or compounds) such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
Oil Sands	A sand deposit containing a heavy hydrocarbon (bitumen) in the intergranular pore space of sands and fine-grained particles. Typical oil sands comprise approximately 10 wt% bitumen, 85% coarse sand (>44 µm), and a fines (>44 µm) fraction, consisting of silts and clays.
Operational	The term used to characterize data and information gathered from stations that are designated as exposed.
Organics	Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., $CaCO_3$).
PAH	Polycyclic Aromatic Hydrocarbon. A series of petroleum-related chemicals composed of at least two fused benzene rings. Toxicity increases with molecular size and degree of alkylation.
PAI	The Potential Acid Input is a composite measure of acidification determined from the relative quantities of deposition from background and industrial emissions of sulphur, nitrogen and base cations.
Pathology	The science which deals with the cause and nature of disease or diseased tissues.

Peat	A material composed almost entirely of organic matter from the partial decomposition of plants growing in wet conditions.
PEL	Probable Effect Level. Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.
pH	A measure of the acid or alkaline nature of water or some other medium. Specifically, pH is the negative logarithm of the hydronium ion (H_30^+) concentration (or more precisely, activity). Practically, pH 7 represents a neutral condition in which the acid hydrogen ions balance the alkaline hydroxide ions. The pH of the water can have an important influence on the toxicity and mobility of chemicals.
Population	A group of organisms belonging to a particular species or taxon, found within a particular region, territory or sampling unit. A collection of organisms that interbreed and share a bounded segment of space.
Quality Assurance (QA)	Refers to the externally imposed technical and management practices which ensure the generation of quality and defensible data commensurate with the intended use of the data; a set of operating principles that, if strictly followed, will produce data of known defensible quality.
Quality Control (QC)	Specific aspect of quality assurance which refers to the internal techniques used to measure and assess data quality and the remedial actions to be taken when data quality objectives are not realized.
Reach	A comparatively short length of river, stream channel, or shore. The length of the reach is defined by the purpose of the study.
Receptor	The person or organism subjected to exposure to chemicals or physical agents.
Reference Toxicant	A chemical of quantified toxicity to test organisms, used to gauge the fitness, health, and sensitivity of a batch of test organisms.
Relative Abundance	The proportional representation of a species in a sample or a community.
Replicate	Duplicate analyses of an individual sample. Replicate analyses are used for measuring precision in quality control.
Riffle Habit	Shallow rapids in a river where the water flows swiftly over completely or partially submerged materials to produce surface agitation.
Run Habitat	Areas of swiftly flowing water in a river, without surface waves, that approximates uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.

Runoff Depth	Streamflow volume divided by catchment area.
Sediments	Solid fragments of inorganic or organic material that fall out of suspension in water, wastewater, or other liquid.
Sentinel Species	A monitoring species selected to be representative of the local receiving environment.
Simpson's Diversity Index	A calculation used to estimate species diversity using both species richness and relative abundance. A basic count of the number of species present in a community represents species richness. The number of individuals of each species occurring in a community is the species relative abundance.
Spawning Habitat	A particular type of area where a fish species chooses to reproduce. Preferred habitat (substrate, water flow, temperature) varies from species to species.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Species Richness	The number of different species occupying a given area.
Sportfish	Large-bodied fish that are caught for food or sport (e.g., northern pike, trout, walleye).
Stressor	An agent, a condition, or another stimulus that causes stress to an organism.
Sublethal	A concentration or level that would not cause death. An effect that is not directly lethal.
Suspended Sediments	Particles of matter suspended in the water. Measured as the oven dry weight of the solids in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have 200 mg/L of suspended sediments.
Test	*Test* is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) downstream of a focal project; data collected from these locations are designated as *test* for the purposes of analysis, assessment, and reporting. The use of this term does not imply or presume that effects are occurring or have occurred, but simply that data collected from these locations are being tested against baseline conditions to assess potential changes.

Thalweg The (imaginary) line connecting the lowest points along a streambed or valley. Within rivers, the deep channel area.

Tolerance The ability of an organism to subsist under a given set of environmental conditions. Organisms with high tolerance to pollution are usually indicators of poor water quality.

Total Dissolved Solids The total concentration of all dissolved compounds solids found in a water sample.

Toxic A substance, dose, or concentration that is harmful to a living organism.

Toxicity The inherent potential or capacity of a material to cause adverse effects in a living organism.

Transect A line drawn perpendicular to the flow in a channel along which measurements are taken.

TSS Total suspended solids (TSS) is a measurement of the oven dry weight of particles of matter suspended in the water which can be filtered through a standard filter paper with pore size of 0.45 micrometres.

Turbidity Turbidity in water is caused by the presence of matter such as clay, silt, organic matter, plankton, and other microscopic organisms that are held in suspension.

VOC Volatile Organic compounds include aldehydes and all of the hydrocarbons except for ethane and methane. VOCs represent the airborne organic compounds likely to undergo or have a role in the chemical transformation of pollutants in the atmosphere.

Watershed The entire surface drainage area that contributes water to a lake or river.

Wetlands Term for a broad group of wet habitats. Wetlands are transitional between terrestrial and aquatic systems, whether the water table is usually at or near the surface or the land is covered by shallow water. Wetlands include features that are permanently wet, or intermittently water-covered such as swamps, marshes, bogs, muskeg, potholes, swales, glades, slashes, and overflow land of river valleys.

9.2 LIST OF ACRONYMS

ADC	Acoustic Digital Current
ADCP	Acoustic Doppler Current Profiler
ADV	Acoustic Doppler Velocimeter
AER	Alberta Energy Regulator
AESRD	Alberta Environment and Sustainable Resource Development
AEMERA	Alberta Environmental Monitoring, Evaluation and Reporting Agency
AEP	Alberta Environment Protection
AEP	Alberta Environment and Parks
AITF	Alberta Innovates Technology Futures
ALS	ALS Laboratory Ltd.
AMF	Adaptive Monitoring Framework
ANC	Acid Neutralizing Capacity
ANC_{org}	ANC attributable to weak organic acids
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
AOSERP	Alberta Oil Sands Environmental Research Program
ARD	Athabasca River Delta
ASL	Acid-Sensitive Lakes
ASRD	Alberta Sustainable Resource Development
ATI	Assemblage Tolerance Index
AXYS	AXYS Analytical Services
BACI	Before-After-Control-Impact
BASL	Biogeochemical Analytical Service Laboratory
BC MOE	BC Ministry of Environment
BPEF	Backpack Electrofisher
BP	Backpack
bpd	barrels per day
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CA	Correspondence Analysis

CABIN	Canadian Aquatic Biomonitoring Network
CALA	Canadian Association for Laboratory Accreditation
CANR	Canterra Road
CCME	Canadian Council of Ministers of the Environment
CEMA	Cumulative Environmental Management Association
CL	Critical Load
CLRTAP	Convention of Long-range Transboundary Air Pollution
CNRL	Canadian Natural Resources Ltd.
COC	Chain of Custody
COSIA	Canada's Oil Sands Innovation Alliance
CPR	Cardiopulmonary resuscitation
CPUE	Catch Per Unit Effort
CWD	Clean Water Diversion
DL	Detection Limit
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EC	Environment Canada
EDA	Exploratory Data Analysis
EEM	Environmental Effects Monitoring
EF	Electrofisher
EIA	Environmental Impact Assessment
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
EPA	Environmental Priority Areas
EPT	Ephemeroptera, Plecoptera, and Trichoptera
EROD	Ethoxyresorufin-O-deethylase
FiSH	Fisheries Sustainable Habitat
FNU	Formazin Nephelometric Unit
FWIs	Field Work Instructions
FWMIS	Fisheries and Wildlife Management Information System

GLM	General Linear Model
GOA	Government of Alberta
GOES	Global Online Enrollment System
GPS	Global Positioning System
GSI	Gonadosomatic Index
HI	Hazard Index
HSD	Honest Significant Difference
ICP/MS	Inductively Coupled Plasma Mass Spectroscopy
IMB method	Isotope Mass Balance method
ISQG	Interim Sediment Quality Guidelines
JACOS	Japan Canada Oil Sands Limited
JOSMP	Joint Oil Sands Monitoring Plan
K	Condition Factor
K_{ow}	Octanol-Water Partition Coefficient
LARP	Lower Athabasca Regional Plan
LRMS	Low-Resolution Mass Spectrometry
LSI	Liversomatic Index
LWD	Large woody debris
MAKESENS	Mann-Kendall test for trend and Sen's slope estimates
masl	metres above sea level
MDL	Method Detection Limit
MEG	McCaffery Energy Group Inc.
MFO	Mixed Function Oxygenases
MSPE	Model Standard Percentage Error
NAD	North American Datum
NE	North-East
ns	not sampled
NSMWG	NO_x and SO_x Management Working Group
NTU	Nephelometric Turbidity Units
NWRI	National Water Research Institute
PAH	Polycyclic Aromatic Hydrocarbon

PAI	Potential Acid Input
PCA	Principal Component Analysis
PDE	Percent Difference in Enumeration
ppb	parts per billion
ppm	parts per million
ppq	parts per quadrillion
PQL	Practical Quantitation Limit
PTD	Percent Taxonomic Disagreement
PVC	Polyvinyl Chloride
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
RAMP	Regional Aquatics Monitoring Program
RL	Reaction Limit
RMCC	Research and Monitoring Coordinating Committee
RMSE	Root Mean Square Error
RMWB	Regional Municipality of Wood Buffalo
SBC	Sum of Base Cations
SD	Standard Deviation
SE	Standard Error
SKU	Stock Keeping Unit
SOP	Standard Operating Procedures
SQI	Sediment Quality Index
SSC	Suspended Sediment Concentration
SSWQO	Site-specific Water Quality Objectives
STP	Sewage Treatment Plant
SWD	Small Woody Debris
SWE	Snow Water Equivalent
TBRG	Tipping Bucket Rain Gauge
TCU	True Colour Units
TDG	Transportation of Dangerous Goods

TDS	Total Dissolved Solids
TEEM	Terrestrial Environmental Effects Monitoring Committee
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TSSL	Total Suspended Solid Load
US	United States
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WBEA	Wood Buffalo Environmental Association
WHMIS	Workplace Hazardous Materials Information System
WQ	Water Quality
WQI	Water Quality Index
WSC	Water Survey of Canada
WY	Water Year
YOY	Young of Year