5.0 2008 RESULTS FOR INDIVIDUAL WATERSHEDS

This is the main results section of the RAMP 2008 Technical report. Section 5.1 presents 2008 results for the Athabasca River and the Athabasca River Delta; Sections 5.2 to 5.10 present 2008 results for the major tributaries of the Athabasca River in the RAMP Focus Study Area (FSA); Section 5.11 contains the 2008 results for miscellaneous aquatic systems throughout the RAMP FSA that were monitored in 2008.

Table 5-1 Page number guide to watersheds and RAMP component reports.

	Athabasca River and Delta	Muskeg	Steepbank	Tar	MacKay	Calumet	Firebag	Ells	Clearwater-Christina	Hangingstone	Miscellaneous Aquatic Systems
Climate and Hydrology	5-6	5-96	5-157	5-181	5-195	5-217	5-231	5-255	5-270	5-311	5-326
Water Quality	5-7	5-97	5-158	5-182	5-196	5-217	5-232	5-256	5-271	5-312	5-326
Benthic Invertebrate Communities	5-10	5-100	5-159	5-183	5-198	5-219	5-234	5-257	5-273	5-313	5-326
Sediment Quality	5-11	5-105	5-161	5-184	5-199	5-219	5-234	5-257	5-274	5-314	5-326
Fish Populations	5-13	5-107	5-162	5-183	5-199	5-219	5-235	5-257	5-276	5-314	5-326

Definitions for Monitoring Status

The RAMP 2008 Technical 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 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; and
- ***Baseline*** is the term used in this report to describe aquatic resources and physical locations (i.e., stations, reaches, data) that are (in 2008) or were (prior to 2008) 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.

5.1 ATHABASCA RIVER AND ATHABASCA RIVER DELTA

Table 5.1-1 Summary of Results for Athabasca River and Athabasca River Delta.

Athabasca River and Delta	Summary of 2008 Conditions													
	Athabasca River										*Athabasca Delta*			
Climate and Hydrology[1]														
Criteria								**S24** below Eymundson Creek			no stations sampled			
Mean open-water season discharge								Negligible-Low						
Mean winter discharge								Negligible-Low						
Annual maximum daily discharge								Negligible-Low						
Minimum open-water season discharge								Negligible-Low						
Water Quality														
Criteria	**ATR-DC-E** upstream of Donald Creek (east bank)	**ATR-DC-W** upstream of Donald Creek (west bank)	**ATR-SR-E** upstream of Steepbank River (east bank)	**ATR-SR-W** upstream of Steepbank River (west bank)	**ATR-MR-E** upstream of Muskeg River (east bank)	**ATR-MR-W** upstream of Muskeg River (west bank)	no station sampled	**ATR-DD-E** downstream of all development (east bank)	**ATR-DD-W** downstream of all development (west bank)	**ATR-FR** upstream of Firebag River	no stations sampled			
Water Quality	Negligible-Low	Negligible-Low	Moderate	Negligible-Low	Negligible-Low	Negligible-Low		Negligible-Low	Negligible-Low	Negligible-Low				
Benthic Invertebrate Community and Sediment Quality														
Criteria	no reaches sampled										**FLC** Fletcher Channel	**GIC** Goose Island Channel	**BPC** Big Point Channel	**ATR-ER** Athabasca River downstream of Embarras River
Benthic Invertebrate Community											Negligible-Low	Negligible-Low	Negligible-Low	n/a
Sediment Quality											Negligible-Low	Negligible-Low	Negligible-Low	Negligible-Low
Fish Populations														
Criteria	no reach sampled	no reach sampled	**Poplar** upstream and downstream of Poplar Creek	**Steepbank** upstream and downstream of Steepbank River	**Muskeg** upstream and downstream of Muskeg River		**Tar-Ells** upstream and downstream of Tar and Ells rivers	**Fort-Calumet** upstream and downstream of Fort Creek and Calumet River	no reach sampled	no reach sampled	no reaches sampled			
Human Health			**Sp.[2]**	**Size[3]**	**Sub.[4]**	**Gen.[4]**	no fish sampled	no fish sampled						
			LKWH	(all sizes)	Negligible-Low	Negligible-Low								
			WALL	>400mm	High	Moderate								
Fish Palatability			All species: Negligible-Low											
Fish Health			LKWH: Moderate		WALL: Negligible-Low									

Legend: Negligible - Low; Moderate; High; baseline (green shading); test (blue shading)

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper baseline reaches.

[1] For Climate and Hydrology, results are reported for station at the mouth of each watershed

[2] Species (Sp.): WALL=walleye; LKWH=lake whitefish

[3] The classification of risk to human health was Negligible-Low below the size class specified.

[4] Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada (see Section 3.4.7.3)

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

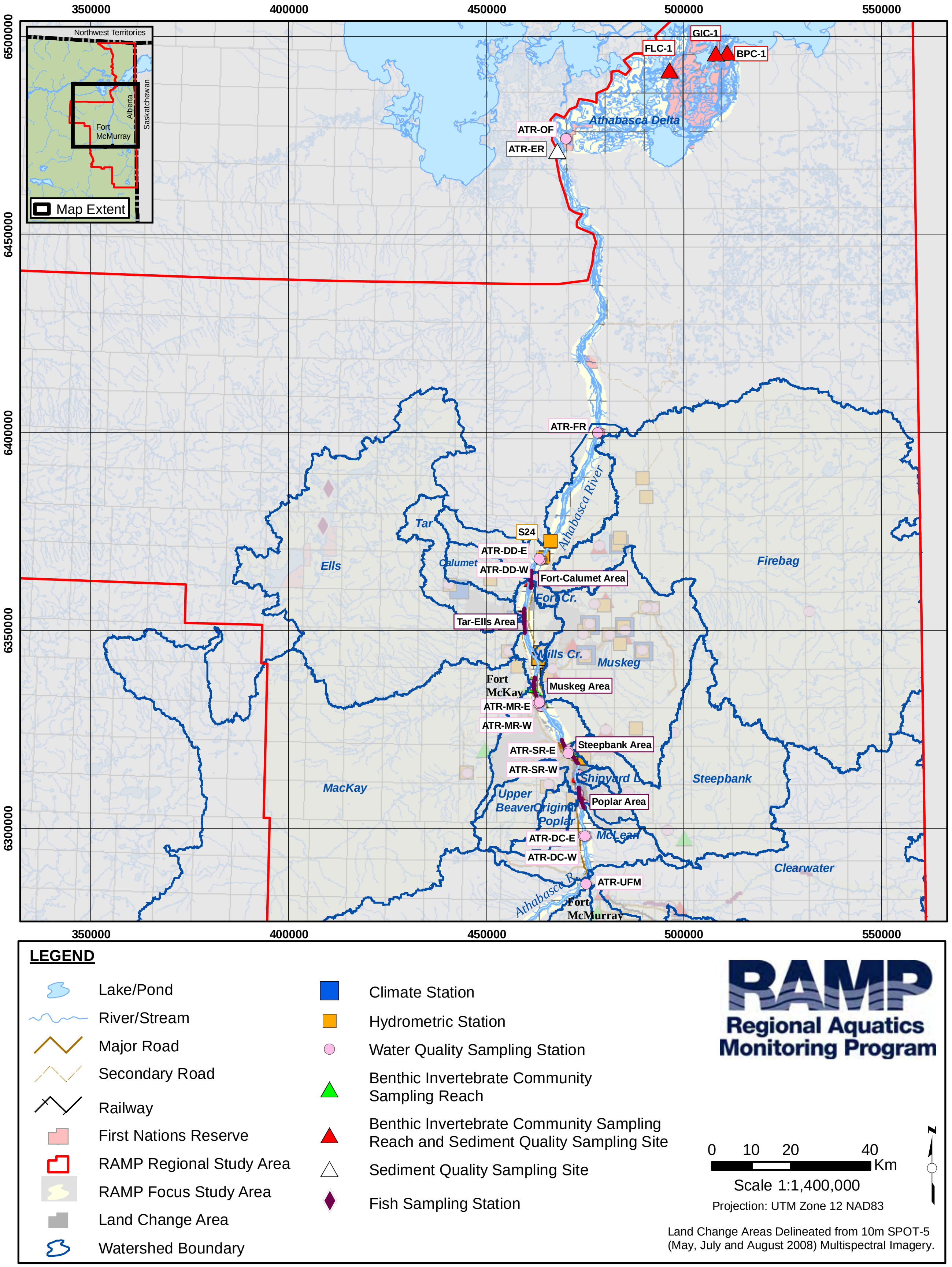
Water Quality: Classification based on adaptation of CCME water quality index, scores classified as follows: 80 to 100: Negligible-Low difference from regional baseline conditions; 60 to 80: Moderate difference from regional baseline conditions; Less than 60: High difference from regional baseline conditions.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Fish Populations: Uses various USEPA and Health Canada criteria for risks to human health, fish health, and tainting from fish tissue concentrations of various substances, see Section 3.4.7.3 for a detailed description of the classification methodology.

Figure 5.1-1 Athabasca River and Athabasca River Delta.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K01_Mainstem_20090420.mxd

Figure 5.1-2 Representative Athabasca River and Athabasca River Delta monitoring stations, fall 2008.

Benthic and Sediment Quality Station BPC-1: Athabasca River Delta – Big Point Channel

Benthic and Sediment Quality Station FLC-1: Athabasca River Delta – Fletcher Channel

Benthic and Sediment Quality Station GIC-1: Athabasca River Delta – Goose Island Channel

Water Quality Stations ATR-SR-W, ATR-SR-E, STR-1 and Benthic Reach STR-E-1: Athabasca River and Mouth of Steepbank River

Water Quality Station ATR-DC-E: Athabasca River at Donald Creek

Water Quality Stations ATR-DD-W, ATR-DD-E: Athabasca River Downstream of all Development

Water Quality Station ATR-MR-W: Athabasca River upstream of the Muskeg River

Water Quality Station ATR-MR-E: Athabasca River upstream of the Muskeg River

5.1.1 Summary of 2008 Conditions

Approximately 76,000 ha of the RAMP FSA have undergone land change as of 2008 from focal projects and other oil sands developments (Table 2.4-2). For 2008, the confluence of McLean Creek with the Athabasca River demarcates the *baseline* (upstream) and *test* (downstream) parts of the Athabasca River.

Table 5.1-1 contains a summary of the 2008 assessment for the Athabasca River and Athabasca River Delta, Figure 5.1-1 is a detailed map of the Athabasca River and Athabasca River Delta, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.1-2 contains a series of pictures from 2008 of a number of the monitoring stations in the Athabasca River and Athabasca River Delta.

Hydrology The observed 2008 discharge for the Athabasca River is estimated to be 1.0% less than the 2008 *baseline* discharge would have been in the absence of focal projects and other oil sands developments in the RAMP FSA. The differences in the Athabasca River between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Negligible-Low** for all calculated hydrologic measurement endpoints.

Water Quality In fall 2008, water quality at most stations in the Athabasca River was assessed as having **Negligible-Low** differences from regional *baseline* conditions irrespective of whether the stations were designated as *test* or *baseline*. Comparisons among stations designated as *test* with those designated as *baseline* showed similar water quality consistent with regional *baseline* conditions and no consistent pattern between *baseline* and *test* stations in trends in concentration of water quality variables. Water quality at one mid-river station, along the east bank upstream of the Steepbank River was assessed as having **Moderate** differences from regional *baseline* conditions, largely through high concentrations of suspended sediments, nitrogen, and some metals.

Benthic Invertebrate Communities and Sediment Quality The differences in benthic invertebrate communities in the ARD as compared to *baseline* depositional sites in the RAMP FSA are classified as **Negligible-Low.** Levels of benthic invertebrate community measurement endpoints in the ARD continue to be within the range of expected values for *baseline* depositional reaches in the RAMP FSA, and there are no time trends in benthic invertebrate community measurement endpoints that indicate a degradation of community composition over time.

The differences in sediment quality conditions in the lower Athabasca River mainstem and the ARD as compared to regional *baseline* sediment quality conditions are classified as **Negligible-Low**. Concentrations of sediment quality from stations in the Athabasca River mainstem and the ARD in 2008 were generally within the range of previously measured concentrations, there were few exceedances of sediment or soil quality guidelines, and little consistent regional differences in the Athabasca River mainstem and ARD between *test* and *baseline* areas.

Fish Populations As of 2008, current and historical fish inventory data from the Athabasca River indicate species-specific variability in relative abundance, length-frequency distribution, and condition factor. Statistically significant differences were observed between years for condition and length-frequency distributions (with the exception of northern pike) of the KIR fish species, and significant increasing trend in relative abundance of walleye and significant decreasing trend in relative abundance of longnose sucker. With the exception of these results, there were no other significant trends that would suggest a consistent negative or positive change in the populations exhibiting changes over time (i.e., likely reflects natural variability).

The average mercury concentration in walleye greater than 400mm from the Athabasca River exceeded the subsistence fisher consumption guideline indicating a **High** risk to human health of subsistence fishers and a Moderate risk to human health of general consumers. The average mercury concentration in lake whitefish from the Athabasca River was below the subsistence fisher guideline indicating a **Negligible-Low** risk to human health. All tainting compounds in walleye and lake whitefish muscle tissue from the Athabasca River were below guideline concentrations indicating a **Negligible-Low** risk to fish palatability. There is a **Moderate** risk to lake whitefish health due to levels of copper exceeding the lethal effects threshold, and selenium levels exceeding the sublethal effects threshold. A **Negligible-Low** risk to walleye was identified given all metals in composite samples were below sublethal effects and no effects criteria. The effects thresholds used for this analyses do not necessarily reflect the toxicity of metals in the Athabasca River, given the sublethal and lethal concentrations were determined from laboratory testing, and will be researched and refined for future studies.

5.1.2 Hydrologic Conditions

2008 Hydrologic Conditions Total flow in the Athabasca River measured at WSC station 07DA001 (Athabasca River below McMurray) was below normal in 2008, with a May 1-October 31 volume of 81% of the long-term average. Relatively high discharges in May and early June were followed by lower quartile discharges from mid-June until early November with the exception of late August (Figure 5.1-3). The maximum daily discharge of 1,730 m^3/s on May 9 was about 30% less than the mean annual flood (the mean of the series of annual maximum daily discharges) of 2,500 m^3/s, and just over half of the 2007 maximum daily discharge. The minimum May to October daily discharge of 286 m^3/s was 34% below the historical average minimum discharge of 431 m^3/s. Discharges measured at RAMP station S24, Athabasca River below Eymundson Creek, downstream of all focal projects and other oil sands developments, were slightly higher than at WSC station 07DA001 (Figure 5.1-3) because of the slight difference in catchment area between the two stations.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrographs Two *baseline* hydrographs were estimated for the Athabasca River for 2008. The focal project case considered only 2008 focal projects; that is, those projects owned by 2008 RAMP funders that were under construction or operational in 2008 in the RAMP FSA. The second case considered all 2008 focal projects plus oil sands projects in the RAMP FSA that were under construction or operational in 2008, but were not owned by 2008 RAMP funders. This latter case can be considered a type of cumulative assessment of hydrologic effects of all significant oil sands activities in the RAMP FSA as of 2008.

A summary of the inputs to the water balance model for the Athabasca River used to create a *baseline* hydrograph for the focal project case is provided below (details are provided in Table 5.1-2):

- Withdrawals from the Athabasca River by focal projects in 2008 are estimated at 118 million m^3;
- Discharges to the Athabasca River by focal projects in 2008 are estimated at 1.02 million m^3;
- A estimated 28.0 million m^3 additional discharge into the Athabasca River in 2008 from major Athabasca River tributaries (Calumet River, Christina River, Ells River, Firebag River, Fort Creek, Hangingstone River, MacKay River, Mills

Creek, Muskeg River, Steepbank River, and Tar River) would have occurred in the absence of focal projects in these watersheds[1]; and

- As of 2008, areas of closed-circuited land change and other land change (not closed-circuited) was 299 km^2 and 106 km^2, respectively, in the watersheds of the minor Athabasca River tributaries entering the Athabasca River between Fort McMurray and RAMP station S24, Athabasca River below Eymundson Creek, (i.e., all Athabasca River tributaries except those listed above) as a result of focal projects in those watersheds (Table 2.4.-1). The effect of these land change areas is estimated to be a decrease of 35.9 million m^3 of discharge to the Athabasca River in 2008 from areas of closed-circuited land change and an increase of 2.53 million m^3 from other land change (not closed-circuited) in the minor Athabasca River tributaries.

The estimated *baseline* hydrograph that would have occurred in 2008 at RAMP station S24, Athabasca River below Eymundson Creek, for the focal project case is presented in Figure 5.1-3. The total discharge for the estimated *baseline* hydrograph is 179 million m^3 greater than for the observed *test* hydrograph at this station, and the total 2008 discharge for the observed *test* hydrograph is estimated to be 1.0% less than the estimated *baseline* hydrograph (Table 5.1-2). The estimated cumulative effect in 2008 is that mean open-water season discharge was reduced by 0.8%, mean winter discharge was reduced by 2.2%, annual maximum daily discharge was decreased by 0.5%, and open-water season minimum daily discharge was decreased by 1.1% (Figure 5.1-3, Table 5.1-3).

A summary of the inputs to the water balance model for the Athabasca River used to create a *baseline* hydrograph for the cumulative assessment case is provided in Table 5.1-2. The only difference in the inputs to the water balance model between the two cases is that an estimated 0.1 million m^3 additional discharge into the Athabasca River in 2008 would have occurred from major Athabasca River tributaries (Calumet, Christina, Ells, Firebag, Fort Creek, Hangingstone, MacKay, Mills, Muskeg, Steepbank, and Tar rivers), and comes from non RAMP-funded oil sands projects in the Hangingstone, Horse, and Christina River watersheds (see Table 2.4.-1). The values of the hydrologic measurement endpoints for the cumulative assessment case are essentially identical to their values in the focal project case (Table 5.1-4).

Summary Based on the available hydrologic information as well as information available regarding focal project activities and other oil sands projects in the RAMP FSA, cumulative, watershed-level changes in hydrologic conditions in the Athabasca River mainstem caused by focal project activities and other oil sands projects in the RAMP FSA as of 2008 have been Negligible-Low (Table 5.1-1).

5.1.3 Water Quality

In 2008, water quality samples were collected by RAMP in the Athabasca River mainstem from:

- upstream of Donald Creek, east and west banks and cross-channel composite, in fall (ATR-DC-E, ATR-DC-CC, ATR-DC-W) (*baseline*, data available most years from 1997 to 2008);

[1] It is assumed that discharges entering the Athabasca River mainstem in 2008 from the upper Beaver drainage via the Poplar Creek spillway would have entered the Athabasca River mainstem in the baseline case via the original Beaver River drainage, and so the incremental effects of the Beaver Creek diversion on Athabasca River mainstem flows are assumed to be zero.

- upstream of the Steepbank River, east and west banks, the fall (ATR-SR-E and ATR-SR-W, *test*, data available from 2000 to 2008);
- upstream of the Muskeg River, east and west banks, in fall (ATR-MR-E and ATR-MR-W, *test*, data available most years from 1998 to 2008);
- "downstream of development" (near Susan Lake), east and west banks, in the winter, spring, summer and fall (ATR-DD-E and ATR-DD-W, *test*, data available from 2002 to 2008); and
- upstream of the Firebag River, cross-channel composite sample, in fall (ATR-FR-CC, *test*, data available from 2002 to 2008).

Concentrations of water quality measurement endpoints measured in fall 2008 in the Athabasca River mainstem are provided in Table 5.1-5. Historical trends in selected measurement endpoints (1997 to 2008), relative to regional *baseline* conditions, are shown in Figure 5.1-4 to Figure 5.1-7. Table 5.1-6 contains all seasonal water quality guideline exceedances observed in 2008 at station ATR-DD-W and station ATR-DD-E, the only stations in the Athabasca River that were sampled in all seasons in 2008. Figure 5.1-8 presents the ionic composition of water sampled in the Athabasca River under RAMP from 1997 to 2008. Figure 5.1-9 and Table 5.1-7 contain the graphical and tabular results, respectively, of the trend analysis conducted on water quality measurement endpoints at AENV water quality monitoring stations in the Athabasca River mainstem. Table 5.1-8 contains the 2008 water quality index values for the Athabasca River mainstem.

Overview of 2008 Results and Comparison with Historical Data Water quality in the Athabasca River mainstem in fall 2008 was generally consistent with observations in fall seasons of previous years, with concentrations of nearly all water quality measurement endpoints within their previously measured range of concentrations (Table 5.1-5). Water quality of samples taken from east and west banks at specific stations were generally similar, although the concentration of major ions, particularly sodium, calcium, magnesium, chloride, and sulphate, often differed between east and west banks at *baseline* station ATR-DC (upstream of Donald Creek). This was likely related to the more saline water from the Clearwater River, which flows into the Athabasca River at Fort McMurray along its east bank and does not mix completely with the Athabasca River until some distance downstream of the confluence.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional *Baseline* Conditions Concentrations of most measured water quality measurement endpoints in the Athabasca River downstream of Fort McMurray in fall 2008 were within regional *baseline* ranges (142 of 150 of measurement endpoint-station combinations, Figure 5.1-4 to Figure 5.1-7). Exceptions where concentrations were greater than their 95th percentile of *baseline* concentrations were: total suspended solids and total nitrogen at *test* stations ATR-SR-E and STR-MR-E; total arsenic at *test* station ATR-SR-E; total dissolved solids at ATR-MR-E; and ultra-trace mercury at *test* stations ATR-SR-E and ATR-MR-W.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Concentrations of all water quality measurement endpoints were below water quality guidelines in fall 2008 with the exception of total aluminum, which exceeded its water quality guideline at every RAMP station in the Athabasca River mainstem, *baseline* or *test* (Table 5.1-5). The concentration of dissolved aluminum, the more bioavailable form of this metal, was below its relevant guideline at all RAMP stations, in the Athabasca River mainstem, *baseline* or *test* (Table 5.1-5).

Other Water Quality Guideline Exceedances Concentrations of a number of other water quality variables exceeded water quality guidelines in the Athabasca River in fall 2008 and in winter, spring, and summer at *test* stations ATR-DD-W and ATR-DD-E (Table 5.1-5), as well as at *baseline* stations ATR-DC-W and ATR-DC-E (Table 5.1-6).

Ion Balance The ionic composition of water sampled in the fall at all stations in the Athabasca River has generally been dominated by calcium and bicarbonate from 1997 to 2008 (Figure 5.1-8). Periodically, including fall 2008, water samples collected near the east bank of the Athabasca River, especially from *baseline* station ATR-DC-E (upstream of Donald Creek), have a greater proportion of sodium and chloride ions (relative to calcium and bicarbonate), which is related to the still-incomplete mixing of the Clearwater River into the Athabasca River mainstem flow where that station is located (Figure 5.1-1).

Trend Analysis Trend analysis conducted on water quality data obtained from Alberta Environment Athabasca River monitoring stations upstream of Fort McMurray (*baseline* station ATR-UFM) and at the head of the Athabasca River Delta at Old Fort (*test* station ATR-OF) found (Figure 5.1-9, Table 5.1-7):

- significant increasing trends in pH at both stations, and in concentration of total aluminum at *test* station ATR-OF ($\alpha = 0.05$); and
- significant decreasing trends in specific conductance at *baseline* station ATR-UFM and in concentration of total molybdenum at both *baseline* station ATR-UFM and *test* station ATR-OF.

Trend analysis conducted on water quality measurement endpoint data obtained from *baseline* station ATR-DC-E and *test* stations ATR-MR-E, ATR-MR-W and ATR-SR-E from 1997 to 2008 ($\alpha = 0.05$) found:

- significant increasing trends in concentration of total nitrogen at *baseline* station ATR-DC-E and *test* station ATR-MR-E; and
- significant decreasing trends in concentration of total strontium at stations *baseline* station ATR-DC-E and *test* station ATR-MR-W, concentration of sodium at *test* station ATR-SR-E, and concentration of sulfate for *baseline* station ATR-DC-E.

No significant trends in water quality measurement endpoints were found at *test* stations ATR-DC-W, ATR-FR or ATR-SR-W over the 1997 to 2008 sampling period ($\alpha = 0.05$, $n = 10$).

Water Quality Index The water quality at all stations sampled by RAMP in the Athabasca River mainstem in fall 2008 was assessed as having Negligible-Low differences from regional *baseline* conditions (Table 5.1-8) with the exception of *test* station ATR-SR-E (upstream of Steepbank River, east bank) which was assessed as having Moderate differences from regional *baseline* conditions. The water quality of nearby stations along the east bank of the Athabasca River (i.e., *baseline* station ATR-DC-E and *test* station ATR-MR-E) had lower WQI values than other upstream and downstream stations (Table 5.1-8). *Test* stations ATR-SR-E and ATR-MR-E both had suspended sediment concentrations in fall 2008 that were more than twice that of any other station sampled on the Athabasca River in fall 2008 (Table 5.1-5), as well as regionally-high values for several other water quality measurement endpoints typically associated with suspended solids, including aluminum, arsenic and mercury. Total nitrogen also was higher at these stations relative to others, and relative to regional baseline conditions. WQI values for *test* station ATR-SR-E from 2000 to 2007 range from 92.2 to 100, and from 83.6 to 100 for *test* station ATR-MR-E.

Given previous studies have shown cross-channel mixing of water generally occurs slowly in this reach of the Athabasca River, it is not surprising that water quality at *test* station ATR-SR-E is similar to that at *test* station ATR-MR-E. Previous studies also have shown that water from the Clearwater River does not completely mix into the Athabasca River from east to west bank until at least the Muskeg River. Both stations were sampled on the same day in fall 2008, while other stations upstream and downstream were sampled on different dates; daily variability in water quality may also help to explain differences observed among stations in fall 2008. However, field crews sampling at ATR-SR-E and ATR-MR-E (on September 4, 2008) recorded visual observations of fibrous suspended material present in water along the east bank at ATR-SR and ATR-MR, which was not visible along the west bank at these locations at the time of sampling. The nature or origin of this suspended material is not known.

Summary In fall 2008, water quality at most stations in the Athabasca River was assessed as having Negligible-Low differences from regional *baseline* conditions irrespective of whether the stations were designated as *test* or *baseline*. Comparisons among stations designated as *test* with those designated as *baseline* showed similar water quality consistent with regional *baseline* conditions and no consistent pattern between *baseline* and *test* stations in the trends in concentration of water quality variables. Water quality at one mid-river station, along the east bank upstream of the Steepbank River was assessed as having Moderate differences from regional *baseline* conditions, largely through high concentrations of suspended sediments, nitrogen and some metals.

5.1.4 Benthic Invertebrate Communities and Sediment Quality

5.1.4.1 Benthic Invertebrate Communities in the Athabasca River Delta

Benthic invertebrate community samples were collected from three depositional stations in the ARD in fall 2008: Fletcher Channel (*test* station FLC), Goose Island Channel (*test* station GIC) and Big Point Channel (*test* station BPC).

2008 Habitat Conditions The three ARD stations at which benthic invertebrate communities were sampled in fall 2008 had similar habitat characteristics (Table 5.1-9), with flow velocity of 0.3 to 0.4 m/s, water depth of 2 to 3 m, slightly alkaline water, and a substrate composition dominated by sand, although *test* station BPC had a higher silt:sand ratio than the other two stations.

Relative Abundance of Benthic Invertebrate Community Taxa in 2008 The benthic invertebrate communities at all three stations were generally similar (Table 5.1-10), all being dominated numerically by tubificid worms, chironomids, fingernail clams (Bivalvia), and nematode worms. A variety of other groups such as Ephemeroptera, Plecoptera, and Trichoptera were present, but in lower numbers. The worms were not identified below the Family level, but the high numbers of tubificids is not uncommon in the shifting-sand environment of the ARD (Barton and Locke, 1979). As in previous years, the dominant chironomids were *Polypedilum* and *Procladius*. *Test* station BPC had the highest diversity of larger insects, with caddisflies that included three genera (*Brachycentrus*, *Hydropsyche* and *Neureclipsis*), also as in previous years. The greater number of larger insects at *test* station BPC suggests that the substrate there was more stable (less shifting) than in the other two stations (Barton 1980a); this is also supported by the greater proportion of silt in the substrate at that station (Table 5.1-9). The mayfly *Ametropus neavei* was present at *test* stations GIC and FLC. This genus is commonly found in sand environments (Clifford and Barton 1979, Barton 1980b).

The temporal trends in the benthic invertebrate community measurement endpoints for the ARD (Table 5.1-10, Figure 5.1-10) have the following characteristics:

- Taxa richness has averaged about 10 to 11 per sample while abundance has fluctuated from 5,000 to over 100,000 individuals per m^2. Values of both these measurement endpoints have, with one exception (total abundance at *test* station BPC in 2004) been within the range of natural variation for *baseline* depositional sites in the RAMP FSA;

- Simpson's diversity and evenness have been more variable over time and have periodically been lower than the range of natural variation for *baseline* depositional sites in the RAMP FSA. Values of both measurement endpoints were within the range of natural variation for *baseline* depositional sites in the RAMP FSA in fall 2008; and

- %EPT (mayflies, stoneflies and caddisflies) has generally been low in the ARD, but that is not atypical for shifting-sand environments (Barton 1980a; Barton and Smith, 1984). %EPT has, with one exception (*test* station BPC in 2008) been within the range of natural variation for *baseline* depositional sites in the RAMP FSA.

The results of the Correspondence Analysis indicate that while benthic invertebrate communities at these three *test* stations have tended to have higher relative abundances of clams (Bivalvia), and snails, (Gastropoda), and no empidids (dance flies), tipulids (crane flies), or enchytraeid worms than at *baseline* depositional sites in the RAMP FSA, the species composition at these three *test* stations has been generally consistent with the species composition of *baseline* depositional sites in the RAMP FSA since RAMP sampling began there in 2002 (Figure 5.1-11).

5.1.4.2 Sediment Quality

Sediment quality was sampled in the lower Athabasca River mainstem and the ARD in fall 2008 from: Athabasca River mainstem upstream of Embarras River (station ATR-ER); Goose Island Channel (station GIC-1); Fletcher Channel (station FLC-1); and Big Point Channel (station BPC-1). All four stations are designated as *test* for 2008. Results from 2008 and earlier for sediment quality measurement endpoints at these stations are presented in Table 5.1-11 to Table 5.1-14 and Figure 5.1-12 to Figure 5.1-20.

2008 Results and Historical Ranges of Concentration Sediment quality at all stations sampled in the Athabasca River mainstem and the ARD in fall 2008 was similar to that observed in previous years, with some exceptions (Table 5.1-11 to Table 5.1-14). Sediments at all four stations were dominated by sand, which was typical of historical sampling at station ATR-ER and station BPC-1, but not at station GIC-1 and station FLC-1, where sediments sampled in recent years had a higher proportion of silt and clay. Total organic carbon in sediments at all stations was relatively low (<2%), but exceeded historical highs at station ATR-ER and station GIC-1.

Concentrations of volatile, low-molecular-weight hydrocarbons (i.e., CCME fraction 1 and BTEX - benzene, toluene, ethylene and xylene) were below detection limits at all stations (Table 5.1-11 to Table 5.1-14). Concentrations of heavier hydrocarbon fractions in fall 2008 were within the range of previously measured fall concentrations at station BPC-1 and station GIC-1, below previously measured minimum concentrations at station FLC-1, and greater than previously measured maximum concentrations at station ATR-ER.

Concentrations of total metals in sediments in fall 2008 were similar to those measured in recent years at all four sampled stations and were similar among all four stations in fall 2008, whether expressed in absolute terms or normalized to percent fine sediments (Figure 5.1-12 to Figure 5.1-15).

Concentrations of PAHs at all four stations in fall 2008 were similar to those measured in recent years when normalized to organic content (Figure 5.1-12 to Figure 5.1-15)[2]. Total PAH concentrations in fall 2008 were greater than the previously measured maximum concentration at station ATR-ER (Figure 5.1-12) and below previously measured minimum concentrations at station GIC-1 and station FLC-1 (Figure 5.1-13, Figure 5.1-14). At all stations in 2008, PAHs were dominated by alkylated species (Table 5.1-11 to Table 5.1-14), indicating these compounds have a petrogenic origin. Potential toxicity of PAHs in sediments at each station[3] were historically-high at all stations except at station ATR-ER (Table 5.1-11 to Table 5.1-14).

Direct tests of sediment toxicity to invertebrates found good survival (i.e., 80% survival or greater of test organisms) of both the midge *Chironomus* and the amphipod (side-swimmer) *Hyalella* at all stations (Table 5.1-11 to Table 5.1-14). Ten-day growth of midges was historically low in sediments from stations ATR-ER, GIC-1 and FLC-1, but growth of amphipods was historically high in sediments from all stations (Table 5.1-11 to Table 5.1-14).

Comparison with Sediment Quality Guidelines No hydrocarbon, PAH or metal concentrations measured at these four stations exceeded relevant sediment or soil quality guidelines in fall 2008 with the exception of CCME fraction-3 hydrocarbons at station ATR-ER, which exceeded the relevant CCME soil-quality guideline (Table 5.1-11).

Regional Context Absolute and carbon-normalized concentrations of total PAHs and total hydrocarbons (i.e., sum of F1-F4), and absolute concentrations of a representative metal, total arsenic, in sediments sampled by RAMP in the Athabasca River mainstem and ARD since 1997 are presented in Figure 5.1-16 to Figure 5.1-20[4]. Historically, the highest concentrations of PAHs and total hydrocarbons in sediments sampled from the Athabasca River mainstem and from the ARD have been measured consistently at *baseline* station ATR-DC (upstream of Donald Creek). Generally, lower concentrations of PAHs and total hydrocarbons have been observed at other Athabasca River mainstem stations, although some individual very high concentrations have been measured at *test* stations ATR-FC and ATR-DD. PAHs and hydrocarbons at all stations in the ARD have been generally stable over time, although the data suggest an upward trend in carbon-normalized PAH concentration at station ATR-ER and a downward trend in carbon-normalized PAH concentrations at station FLC-1 (Figure 5.1-17).

Concentrations of total arsenic in sediments of the Athabasca River mainstem and ARD have generally been similar among all stations and across years (Figure 5.1-20), with concentrations generally below the CCME interim sediment-quality guideline of 5.9 mg/kg (Figure 5.1-20).

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[2] As hydrophobic compounds, PAHs may preferentially adsorb to organic particles. Therefore, both absolute and carbon-normalized concentrations of PAHs and other hydrophobic compounds are important to consider in monitoring. Carbon-normalized data may provide a better measure of change over time, as these data exclude the potentially confounding influence of sediment carbon content on PAH concentration.

[3] calculated using the solubility and aquatic toxicity of each PAH species, and total hydrocarbons in each sample

[4] RAMP sampling of sediments from the Athabasca River between Fort McMurray and the ARD was discontinued in 2004, given the generally non-depositional nature of mainstem sediments, and the confounding effects of variable river wetted widths and eroding bitumen-bearing soils along the river bank at some stations.

Sediment Quality Index SQI values for all stations (i.e., station ATR-ER: 100; station BPC-1: 98.9; station FLC-1: 100; station GIC-1: 89.9) indicate close to complete consistency with regional *baseline* conditions (Table 5.1-15). The somewhat lower value at station GIC-1 was primarily the result of several metals exceeding the 95th percentile of regional *baseline* concentrations, including cobalt, copper, lead, nickel, thallium, and vanadium. However, no metals at any of these stations exhibited concentrations that exceeded sediment quality guidelines.

5.1.4.3 Summary

The differences in benthic invertebrate communities in the ARD as compared to *baseline* depositional sites in the RAMP FSA are classified as Negligible-Low on the basis that:

- levels of benthic invertebrate community measurement endpoints have been within the range of expected values for *baseline* depositional reaches in the RAMP FSA; and
- there are no time trends in benthic invertebrate community measurement endpoints that indicate a degradation of community composition over time.

The differences in sediment quality conditions in the lower Athabasca River mainstem and the ARD as compared to regional *baseline* sediment quality conditions are classified as Negligible-Low. Concentrations of sediment quality from stations in the Athabasca River mainstem and the ARD in 2008 were generally within the range of previously measured concentrations, there were few exceedances of sediment or soil quality guidelines, and little consistent regional differences in the Athabasca River mainstem and ARD between *test* and *baseline* areas.

5.1.5 Fish Populations

Fish population monitoring in 2008 on the Athabasca River included a spring, summer and fall fish inventory, a fall fish tissue program, and a tag return assessment. The summer fish inventory had not been conducted since 2000; seasonal comparisons will be highlighted to assess the change in species composition and population structure of the KIR species between spring, summer and fall.

5.1.5.1 Fish Inventory

Species Composition

A total of 4,938 fish were captured within the ten standardized reaches (Figure 3.4-1) during the spring, summer and fall fish inventories on the Athabasca River, of which:

- 1,505 fish comprised of 17 species were captured during the spring sampling (Table 5.1-16);
- 1,700 fish comprised of 19 species were captured during the summer sampling (Table 5.1-16); and
- 1,733 fish comprised of 15 species were recorded during the fall sampling (Table 5.1-16).

A total of 21 fish species were captured and observed during the 2008 Athabasca fish inventory (Table 5.1-16); this is an increase in the number of fish species captured during the 2007 Athabasca fish inventory and is almost the maximum number of fish species (22 in 1997) captured during a fish inventory (Golder 2003b). White sucker followed by walleye were the most abundant large-bodied species captured in spring 2008 (Table 5.1-16); goldeye followed by walleye were the most abundant large-bodied species captured in summer; while lake whitefish followed by goldeye were the most abundant large-bodied species captured in the fall survey (Table 5.1-16). Trout-perch was the dominant small-bodied species captured in spring and fall; and flathead chub followed by lake chub were the dominant small-bodied species in summer.

Comparisons of spring 2008 species composition to historical spring species composition are summarized as follows (detailed historical information is provided in Figure 5.1-21):

- The percentage of the 2008 spring catch represented by walleye was slightly higher than 2007, but lower than almost all historical records with the exception of 2001, 2003 and 2007;
- The percentage of the 2008 spring catch represented by goldeye was lower than 2007 and average for the period since 2001 (all of the years since 2001 have been lower than 1997 to 1999);
- The percentage of the 2008 spring catch represented by longnose sucker was lower than all years in the data record;
- The percentage of total spring catch in 2008 represented by white sucker was higher than all previous years in the data record; and
- The percentage of total spring catch in 2008 represented by northern pike was only slightly higher than 2006, which was the lowest recorded catch in all years in the data record.

Comparisons of summer 2008 species composition to historical summer species composition (1997-2002) are summarized as follows (detailed historical information is provided in Figure 5.1-23):

- The percentage of the 2008 summer catch represented by walleye was lower than all historical records (1997, 1998, 2000, and 2005);
- The percentage of the 2008 summer catch represented by goldeye was higher than all previous sampling years and has shown an increasing trend across years. The goldeye catch in the summer is primarily juvenile individuals;
- The percentage of the 2008 summer catch represented by longnose sucker was higher than in 2005 when no longnose sucker were captured, but lower than two of the three other years in the data record (1997 and 2000);
- The percentage of the 2008 summer catch represented by white sucker was higher than 2005 when no white suckers were captured, but lower than the three other years in the data record (1997 and 2000); and
- The percentage of the 2008 summer catch represented by northern pike was lower than all previous years in the data record.

Comparisons of fall 2008 species composition to historical fall species composition are summarized as follows (detailed historical information is provided in Figure 5.1-23):

- The percentage of the 2008 fall catch represented by walleye was lower than of any year in the data record and has exhibited a decreasing trend since 2005;

- The percentage of the 2008 fall catch represented by goldeye was much higher than the two previous years;
- The percentage of the 2008 fall catch represented by longnose sucker was lower than all previous year in the data record with the exception of 2004;
- The percentage of the 2008 fall catch represented by white sucker was greater than 2007, but was still within the mid-range of the data record; and
- The percentage of the 2008 fall catch represented by northern pike was the lowest in the data record.

Spatial comparisons of spring 2008 species composition are summarized for KIR species as follows (detailed information is provided in Figure 5.1-24):

- White sucker was the dominant species in the Steepbank, Muskeg, Tar-Ells areas of the Athabasca River;
- Walleye was the dominant species in the Poplar and Fort-Calumet areas;
- There were low numbers of walleye in areas where white sucker were dominant and there were low numbers of white sucker in areas where walleye were dominant;
- The percentage of the total catch represented by northern pike and longnose sucker was low across all areas; and
- There were no clear longitudinal trends in species composition across areas for any large-bodied species.

Spatial comparisons of summer 2008 species composition are summarized for KIR species as follows (detailed information is provided in Figure 5.1-24):

- Goldeye was the dominant species in all areas of the Athabasca River;
- The percentage of the total catch represented by walleye was similar across areas;
- The percentage of the total catch represented by white sucker was low across all areas, but increased in the Fort-Calumet area;
- The percentage of the total catch represented by northern pike, lake whitefish and longnose sucker was low across all areas; and
- There were no clear longitudinal trends in species composition across areas for any large-bodied species.

Spatial comparisons of fall 2008 species composition are summarized for KIR species as follows (detailed information is provided in Figure 5.1-26; lake whitefish was included given that it formed a large proportion of the total catch in fall 2008):

- Similarly to 2007, lake whitefish was the dominant species in all areas except the Tar-Ells area;
- Goldeye was the dominant species in the Tar-Ells area;
- The total catch represented by walleye and white sucker were fairly consistent across areas;

- The total catch represented by northern pike and longnose sucker was low across all areas; and
- There were no clear longitudinal trends in species composition across areas for any large-bodied species.

Generally, there was high variability in the proportion of large-bodied fish species in each area. In spring, when movement is related to spawning activities in smaller tributaries for most species, the highest proportion of white sucker were in the middle three areas (i.e., Steepbank, Muskeg and Tar-Ells), whereas the highest proportion of walleye were in the upper and lower areas (i.e., Poplar and Fort-Calumet) indicating there may be different preferential spawning grounds for these two species. The highest proportions of goldeye and longnose sucker were found in the Steepbank area, whereas northern pike was highest in the Tar-Ells and Fort-Calumet areas. In summer, when migration is minimal and the population is made up of resident species, the highest proportion of each species, with the exception of white sucker were found in the most upstream areas (i.e., Poplar, Steepbank and Muskeg). In fall, when most species are not spawning, the proportion of each species is relatively consistent across areas with the exception of the increase in catch of goldeye in the Tar-Ells area. Lake whitefish spawns in the fall with the highest proportion of catch found in the upper three areas.

Fish that were observed during the Athabasca inventory program, but not captured, are summarized in Table 5.1-17.

Catch per Unit Effort

General The total catch per unit effort (CPUE) for the 2008 spring inventory was the highest in the data record, while the total CPUE for the summer inventory was the second highest on record and the fall inventory was the highest in the data record (Figure 5.1-27).

Spatial Differences and Temporal Trends Statistical trend analyses were performed on KIR species CPUE for spring and fall, where there was sufficient data ($\alpha = 0.10$). Spatial differences and temporal trends in CPUE for KIR species are summarized as follows (detailed information is provided in Figure 5.1-28 to Figure 5.1-32:

- Catch per unit effort of walleye was highest in the Poplar area in spring and summer and highest in the Fort-Calumet area in fall; CPUE in the Poplar area in spring has increased in the past three years and CPUE in the Muskeg area in fall has decreased over the past three years. Statistical trend analysis indicated a significant increasing trend in fall walleye CPUE over time;
- Catch per unit effort of goldeye was variable with no clear trends in any area over time in both spring and fall; in summer, CPUE was highest in the Poplar area and decreasing from upstream to downstream; in spring CPUE was highest in the Steepbank area; in fall CPUE was highest in the Tar-Ells area. There were no significant trends over time in goldeye CPUE;
- Catch per unit effort of longnose sucker also exhibited high variability with no clear trends in any area over time in spring, summer and fall. In spring, there was a shift in dominant areas from the Poplar area to the Steepbank area; in summer CPUE was highest in the Poplar area; in fall, CPUE of longnose sucker was consistently low and similar among areas over time. Trend analysis indicated a significant decrease in spring CPUE of longnose sucker across years;

- Catch per unit effort of white sucker has shown increased in all areas in the last two years; the highest spring CPUE was in the Muskeg which has been consistent since 2004. In fall, there was no area which showed higher CPUE across years; there has been an increase in CPUE in the Poplar, Steepbank and Tar-Ells areas relative to all previous sampling years. There were no significant trends in white sucker CPUE over time; and

- Catch per unit effort of northern pike exhibited very little variability over time in spring but has been consistently higher in the Tar-Ells and Fort-Calumet areas in recent years; in fall there was no area exhibiting consistently higher CPUE across years. There were no significant trends in northern pike over time.

Catch per unit effort of all large bodied species showed high variability in the Athabasca River across areas and years. Generally, the Poplar area CPUE has been consistently the highest CPUE for most species over time, particularly in spring, suggesting tributary streams in this area or in close proximity to this area may be important for spawning. However, there have been increasing trends in KIR species CPUE in the Muskeg and Tar-Ells areas in recent years in spring. In fall, spatial CPUE was more variable with no clear dominance in any area over time.

Age-Frequency Analysis

Age-frequency histograms (1989-2008) for walleye and northern pike are presented in Figure 5.1-34. The dominant age for walleye across years was variable but was less than 9 years for all sampling events. The dominant age for northern pike across years was between 4 and 6 years of age. Male northern pike reach age-at-maturity between 3 and 5 years of age; females reach age-at-maturity between 4 and 6 years of age indicating that the population in the Athabasca River is dominated by mature, adult northern pike.

Length-Frequency Analysis

Length-frequency histograms (1997-2008) for the five KIR species based on standardized capture data are presented in Figure 5.1-35 to Figure 5.1-39. The Kolmogorov-Smirnoff (K-S) pairwise comparison test (two-sided, $\alpha = 0.05$) was used to compare length-frequency distributions over time for each species. With the exception of northern pike, there were numerous significant differences in length-frequency distributions between years; however, there were no consistent trends overtime. Key features of the length-frequency distributions and results from the K-S test for each KIR species are as follows:

- Walleye – the co-dominant length classes of fish captured in 2008 were 351-400 mm and 401-450 mm, whereas the 401-450 mm size class was dominant in 2007. Although the relative frequency of walleye in the dominant classes has been variable ($p < 0.05$, although no difference between 2007 and 2008), the shape of the length frequency distribution has consistently shown two peaks, the first at the 101-150 mm size class and the second at the 401-450 mm size class;

- Goldeye – the dominant length class of fish captured in 2008 was 151-175 mm, which was much smaller than the previous two years (301-325 mm). However, high catches were also recorded in all upper range length classes (326-425 mm). From 1997 to 2005 there was a significant increase in dominant length class from 251-275 mm to 376-400 mm; however, from 2006 to 2008, there has been a significant decrease in dominant length class from 301-325 mm to 151-175 mm ($p < 0.05$);

- Longnose sucker – similar to 2007, the dominant length class of sucker captured in 2008 was 400-450 mm. The dominant length class has varied from year to year with no clear trends in length-frequency distribution ($p < 0.05$). However there has been a shift in the past two years away from smaller size class dominance, which has eliminated the characteristic bimodal distribution (modes at 101-250 mm and 350-501 mm length classes) observed in past years;

- White sucker – the dominant length class of fish captured in 2008 was 400-450 mm, which is similar to 2007 and 2006. Although the dominant size class remained within the 350-400 mm and 400-450 mm length classes each year, the relative number of sucker captured in this size range differed over time ($p < 0.05$). A second smaller peak in the 101-150 mm size class was also evident in all years, but disappeared in 2008; and

- Northern pike – as in 2007, the co-dominant length classes of pike captured in 2008 were 351-400 and 551-600. The dominant length class has varied considerably from year to year with several peaks in the length-frequency distribution between 300 mm and 600 mm. There were no significant differences between years for northern pike length-frequency distributions, which is possibly due to the lack of any clear dominant size class across years (i.e., several smaller peaks over all size classes, $p > 0.05$).

Length frequency distributions of each KIR species were compared between seasons in 2008 (Figure 5.1-40 to Figure 5.1-44). Generally, in spring, the length frequency distribution had one peak in the larger size classes for all species. In summer, there was a shift in dominance to smaller size classes for longnose sucker and goldeye. A bimodal peak was observed in summer for white sucker with two peaks, one in the smaller size classes and a more dominant peak in the larger size classes, consistent with the spring distribution. In fall, there were generally two peaks in the length frequency distribution for each species, one in the smaller size classes and one in the larger size classes. The exception to the general trends observed seasonally was northern pike which showed no clear trends in length frequency distribution between seasons or between length classes. Seasonally, the inventory programs captures larger individuals in spring, when the KIR species are spawning, smaller or juvenile individuals in summer when fish are not spawning or migrating and in fall, a more wide range of size classes of each species.

Recruitment to the Sport Fishery

The ratio of undersize (i.e., less than 400 mm) to legal-size (i.e., greater than 400 mm) walleye, an index of the rate of recruitment to the sport fishery, was 1.3 in 2008, consistent with 2007, but representing a two-fold decrease from 2006 (Figure 5.1-45). The 2008 index was within the historical range of 0.7 to 3.3 (Figure 5.1-45), but lower than the mean rate of recruitment across sampling years (1.6). This suggests that the rate of recruitment to the sport fishery in 2008, as measured using this index, for the second year, was low relative to the long-term average recruitment.

The ratio of under-size to legal-size northern pike was 1.6 in 2008, a decrease in value from 2007 and the lowest index value across all sampling years (1.7 - 4.5) (Figure 5.1-46). This ratio has been much higher in previous years, and a decrease from 2007 could indicate a poor recruitment year to the fishery with lower numbers of northern pike not reaching the legal size class range. However, it should be noted that pike are more abundant in the Clearwater River relative to the Athabasca River, likely reflecting more optimum habitat for spawning and rearing. As such, it is difficult to reflect on recruitment of pike based on data from the Athabasca Rive alone.

Condition Factor

Values of mean condition factor from fish captured from 1997 to 2008 in spring, summer and fall are presented in Figure 5.1-47 and Figure 5.1-49, respectively. Two statistical analyses were performed on the condition data for each species: 1) an analysis of covariance (ANCOVA) was conducted to evaluate possible differences in condition between years; and 2) if differences were observed, analyses were conducted identify potential trends in condition over time ($\alpha < 0.1$). Generally, there were significant year-to-year differences in condition for both spring and fall. However, there were no significant trends, either increasing or decreasing, in condition factor over time for any of the KIR species. Species-specific results have been summarized below (the first *p*-value refers to the comparison of slopes, while the second *p*-value refers to the comparison of intercepts):

- There were significant differences in fall condition factor of walleye among years ($p > 0.01/p < 0.05$); however, there was no clear trend in condition over time. An ANCOVA could not be performed on the spring walleye condition data because the slopes of the weight-length regressions were not equal ($p < 0.01$). Mean spring walleye condition factor has ranged from 0.95 (2003) to 1.08 (2001);

- There were significant differences in fall condition factor of goldeye among years ($p = 0.04/p < 0.05$). Mean fall condition factor has ranged from 1.02 (2001) to 1.31 (2006). Statistical differences in spring condition could not be tested due to the inequality of slopes ($p < 0.01$). Mean spring goldeye condition factor has ranged from 1.06 (2001) to 1.20 (2007);

- There were significant fluctuations in spring and fall condition factor of longnose sucker among years ($p > 0.01/p < 0.05$) with no significant trends over time. Mean spring and fall condition factor for longnose sucker has ranged from 1.16 (1998) to 1.37 (2007) and from 1.18 (1999) to 1.37 (2003), respectively;

- There were significant differences in fall condition of white sucker among years ($p = 0.2/p < 0.05$) with no significant trend over time. Statistical differences in spring condition could not be tested because of differences in the slopes of the weight-length regressions ($p < 0.01$). Mean spring and fall condition for white sucker ranged from 1.47 (2002) to 1.68 (2007) and from 1.20 (2002) to 1.75 (2006), respectively; and

- There were significant differences in the spring and fall condition factor of northern pike among years ($p > 0.01/p > 0.05$) with no significant trends over time for either season. Mean condition factor in spring ranged from 0.65 (2002) to 0.79 (2004) and from 0.65 (1999) to 0.84 (2006) in fall.

Currently only condition can be applied as a measurement endpoint for the large-bodied species in the Athabasca River fish inventory. Environment Canada (2005) has defined a critical effect size for fish condition as ± 10% relative to *baseline* fish. From this perspective, a >10% change in condition is considered important suggesting a need for further evaluation (e.g., confirmation over time, follow-up studies, etc.). For the Athabasca River inventory; however, there are no reaches classified as *baseline* because all reaches are downstream of development.

External Health Assessment

Observed anomalies were primarily associated with minor skin aberrations or wounds and scars and fin erosion; in 2008, 382 out of 1,505 fish (25.3%) in the spring; 62 out of

1,700 fish (3.6%) in the summer and 96 out of 1,734 fish (5.5%) in the fall were found to have some type of external health anomaly. These incidences of external anomalies are approximately half the number of incidences of external anomalies recorded in 2007 (19% in spring and 9% in fall, RAMP [2008]). The mean health assessment index (HAI) for all KIR species (Table 5.1-18) was within the historical range; however, with the exception of goldeye, the HAI was higher in 2008 than at least the previous 2 years of sampling (2006 and 2007).

For fish pathology, only 73 (65 [4.3%] in the spring, 8 [0.5%] in the fall) out of 3,339 fish (2.2%) exhibited some form of pathology such as parasites, growths, lesions or body deformities. A summary of the percentage of fish by year and species with some form of pathology is presented in Table 5.1-19; the percentage of fish with evidence of external pathology in 2008 was within the historical range for all species and was generally lower than the initial years or sampling (i.e., 1997 and 1998).

Summary Assessment for Fish Inventory

As outlined in RAMP (2009), the Athabasca River fish inventory is generally considered to be a community-driven activity, primarily suited for assessing general trends in abundance and population variables for large-bodied species, rather than detailed fish community structure. As of 2008, current and historical fish inventory data from the Athabasca River indicate species-specific variability in relative abundance, length-frequency distribution, and condition factor. Statistically significant differences were observed between years for condition and length-frequency distributions (with the exception of northern pike) of the KIR fish species, and significant increasing trend in relative abundance of walleye and significant decreasing trend in relative abundance of longnose sucker. With the exception of these results, there were no other significant trends that would suggest a consistent negative or positive change in the populations exhibiting changes over time (i.e., likely reflects natural variability).

5.1.5.2 Fish Tag Return Assessment

A total of ten RAMP Floy tags (indicating capture of ten fish tagged by RAMP) were submitted to the Alberta Sustainable Resources Development (ASRD), Fort McMurray office by anglers in 2008. Information provided with each tag return included tag number, species, approximate capture location and date of capture.

Figure 5.1-50 shows the location of first capture and tagging by RAMP and the location of re-capture by the angler, as well as the most direct travel route, for six of the ten fish for which tags were returned in 2008 (four records were incomplete). The 2008 tag returns were for five walleye and one northern pike (Table 5.1-20). A cumulative summary of RAMP tags returned to date is presented in Table 5.1-21 for comparison by species. As in previous years, recaptured walleye in 2008 exhibited the longest overall distance travelled between captures (244 km). In 2008, all recaptured tagged fish were caught in the Clearwater or the Athabasca rivers, with the exception of one walleye that was recaptured in a tributary of Fletcher Channel in the Athabasca River delta. All recaptured fish were initially captured in the Athabasca or Clearwater rivers. Results to date indicate that, although walleye and northern pike have exhibited an ability to travel long distances (Table 5.1-21), the majority of recaptured individuals have remained and/or returned to the area of the Athabasca River downstream of Fort McMurray, or to the Clearwater River.

In addition to the angler returns, 13 fish (8 walleye and 5 northern pike) previously tagged by RAMP were recaptured in the 2008 spring and fall Athabasca and Clearwater River fish inventories.

5.1.5.3 Fish Tissue Analysis Results

Whole-Organism Metrics

A total of 27 walleye (5 males, 4 females and 18 unsexed) and 20 lake whitefish (5 males, 5 females and 10 unsexed) from the Athabasca River were sampled for fish tissue analysis in conjunction with the 2008 fall inventory. The size of sampled walleye ranged from a 237 mm immature fish to a 608 mm adult female. The mean length of sampled walleye was 418 mm, with females (average length=513 mm) slightly larger than males (average length=496 mm). The size of sampled lake whitefish ranged from a 287 mm immature fish to a 482 mm fish of unknown sex. The mean length of sampled lake whitefish was 397 mm, with males (average length=426 mm) larger than females (average length=415 mm).

External and internal fish health assessments were conducted on the nine walleye and ten lake whitefish that were sacrificed for metal and organics tissue analyses. One female walleye had a moderate amount of internal parasites; two female lake whitefish had granular kidneys; one male lake whitefish and one female walleye had mottled kidneys; one male lake whitefish had a fatty liver; and one male lake whitefish had increased mesenteric fat (< 50%). No other internal anomalies were observed, excluding gall bladder colour, which relates to food availability and storage. For fish from which tissue was sampled non-lethally, the most common external anomaly was the presence of minor skin aberrations consisting of scars or fin erosion; one walleye (unknown sex) had a small growth on the jaw.

Mercury

Total mercury concentrations in muscle of non-lethally sampled lake whitefish and walleye collected from the Athabasca River in 2008 are presented in Table 5.1-22. Concentrations of mercury in lake whitefish ranged from 0.02 mg/kg in a 419 mm male individual (age=8) to 0.09 mg/kg in a 482 mm adult (unknown sex and age), with an average concentration of 0.045 mg/kg. Concentrations of mercury in walleye ranged from 0.062 mg/kg in a 232 mm fish (unknown sex and age) to 0.68 mg/kg in a 475 mm male individual (age=13), with an average concentration of 0.28 mg/kg. Temporal trends of average mercury concentrations in both species are presented in Figure 5.1-51 and Figure 5.1-52; for lake whitefish, mercury concentrations in 2008 were lower than previous sampling years. 2008 average mercury concentrations in lake whitefish and walleye for each size class are presented in Figure 5.1-53. Mercury concentrations in lake whitefish remained fairly consistent over size classes; walleye mercury concentrations increased with size class.

A regression of mercury concentrations in muscle of individual lake whitefish against fork length was not significant, with weak, negative correlations between the variables ($p > 0.01$; length adjusted $R^2 = 0.01$, Table 5.1-23, Figure 5.1-54). The regression between mercury concentrations in walleye muscle against fork length was significant, with moderately strong, positive correlations ($p < 0.01$; length adjusted $R^2 = 0.55$, Table 5.1-23, Figure 5.1-54). Correlations between mercury concentrations and age were significant and positive for lake whitefish when all individuals combined, and weak and positive for walleye when all individuals were combined.

Concentrations of mercury in fish standardized to fish weight (i.e., concentration of mercury in 1 kg of fish) from the Athabasca River were compared to mercury concentrations in lake whitefish and walleye historically sampled from waterbodies in the region (DFO 1984, Grey *et al.* 1995, Golder 2004, RAMP 2003, RAMP 2004, RAMP 2008). Mercury levels in the Athabasca River lake whitefish in 2008 were in the mid-range of waterbodies sampled (Figure 5.11-27); mercury levels in Athabasca River walleye in 2008 were within the upper range of waterbodies historically sampled (Figure 5.11-29). A regional assessment of fish tissue mercury concentrations is further discussed in Section 5.11 and 6.4.

Other Chemicals

Two composite samples were analyzed for concentrations of other chemicals in tissue samples of lake whitefish and walleye from the Athabasca River: target-sized females (400 to 450 mm for lake whitefish and 500-550 mm for walleye) and target-sized males (400 to 450 mm for lake whitefish and 450 to 500 mm for walleye). Eleven of the twenty-seven metals analyzed were below the analytical detection limit. All selected tainting compounds were below analytical detection limits for all composite tissue samples with the exception of toluene (Table 5.1-24).

Potential Risks to Human Health

Mercury 2008 lake whitefish and walleye tissue mercury concentration data were screened against National United States Environmental Protection Agency (USEPA) and Health Canada human health criteria for fish consumption (Table 5.1-22). The overall mean mercury concentration (0.045 mg/kg) in lake whitefish did not exceed any guidelines for human health consumption; eight of the twenty lake whitefish captured exceeded the USEPA subsistence fisher guideline (0.049 mg/kg). The overall mean mercury concentration (0.163 mg/kg) in walleye in the Athabasca River exceeded the Health Canada criteria for subsistence fishers (0.2 mg/kg). Sixteen of the twenty-six walleye exceeded the Health Canada criteria for subsistence fishers (0.2 mg/kg), of those sixteen; three walleye exceeded the Health Canada guideline for general consumers (0.5 mg/kg).

Other Chemicals Arsenic concentrations exceeded guidelines for USEPA recreational fishers (0.026 mg/kg) in males and females in both lake whitefish and walleye (Table 5.1-24). No other metals exceeded Health Canada or National USEPA.

Potential Risks to Fish and Fish Health

The following are the results of screening for potential risks of concentrations of chemicals to fish and fish health, comparing the concentrations of chemicals in fish tissue in Table 5.1-24 with the criteria for evaluating potential risk to fish health provided in Table 3.4-9):

- Mercury concentrations did not exceed any of the effects (or no effects) thresholds for fish and fish health;
- Copper concentrations in lake whitefish exceeded the lethal effects threshold for females and the sublethal effects threshold for males. Copper concentrations in male and female lake whitefish in the Athabasca River have shown an increasing trend over sampling years;

- Selenium concentrations in lake whitefish exceeded the lethal no-effects threshold for males and females. Selenium concentrations in lake whitefish has remained generally consistent across sampling years; and
- Vanadium concentrations in male and female lake whitefish and male walleye exceeded the sublethal no-effects threshold.

The criteria for evaluating potential risk to fish health is subject to further investigation given that sublethal and lethal thresholds are determined from controlled laboratory testing and may therefore not reflect the conditions of the water quality in the Athabasca River in relation to toxicity of metals to fish. This is evident with respect to the exceedance of lethal copper concentrations in lake whitefish that were captured alive during the fall inventory program suggesting the copper lethal effects threshold may be lower than needed.

Potential Influence on Fish Palatability

All tainting compounds in Athabasca River lake whitefish and walleye tissue were present at concentrations well below the 1 mg/kg threshold for effects on palatability as outlined in Jardine and Hrudey (1988).

5.1.5.4 Summary Assessment for Fish Tissue

Measurement endpoints used in the assessment of the results of the Athabasca River fish tissue program are the range of metals and tainting compounds included in the tissue analysis for both individual and composite samples. The potential risk to human health was predicted from the individual and composite fish tissue analyses. Results for lake whitefish analysed in the Athabasca River indicate no risk to subsistence fishers or general consumers, characterized by Negligible-Low mercury concentrations. Average mercury concentrations in walleye greater than 400 mm in the Athabasca River exceeded the subsistence fisher consumption guidelina indicating a High risk to human health for subsistence fishers and a Moderate risk to general consumers for consumption of walleye of that size or greater (Table 5.1-1). Risk to human health was classified as Negligible-Low for consumption of walleye less than 400 mm.

To provide a regional context to the mercury results in fish from the Athabasca River, concentrations of mercury standardized to fish weight (i.e., concentration of mercury in 1 kg of fish) from the Athabasca River were compared to mercury concentrations in lake whitefish and walleye historically sampled from waterbodies in the region. Mercury levels in the Athabasca River lake whitefish in 2008 were in the mid-range of waterbodies sampled while mercury levels in Athabasca River walleye were within the upper range of sampled waterbodies.

Fish tissue results for 2008 suggest that there is a Moderate risk to lake whitefish due to levels of copper exceeding the lethal effects threshold, and selenium levels exceeding the sublethal effects threshold. A Negligible-Low risk to walleye was identified given all metals in composite samples were below sublethal effects and no-effects criteria (Table 5.1-1). The effects thresholds used for this analyses do not necessarily reflect the toxicity of metals in the Athabasca River and will be researched and refined if possible for future studies.

All tainting compounds in walleye and lake whitefish muscle tissue from the Athabasca River were below guideline concentrations indicating a Negligible-Low influence on fish palatability (Table 5.1-1).

Figure 5.1-3 Athabasca River: 2008 hydrograph and historical context.

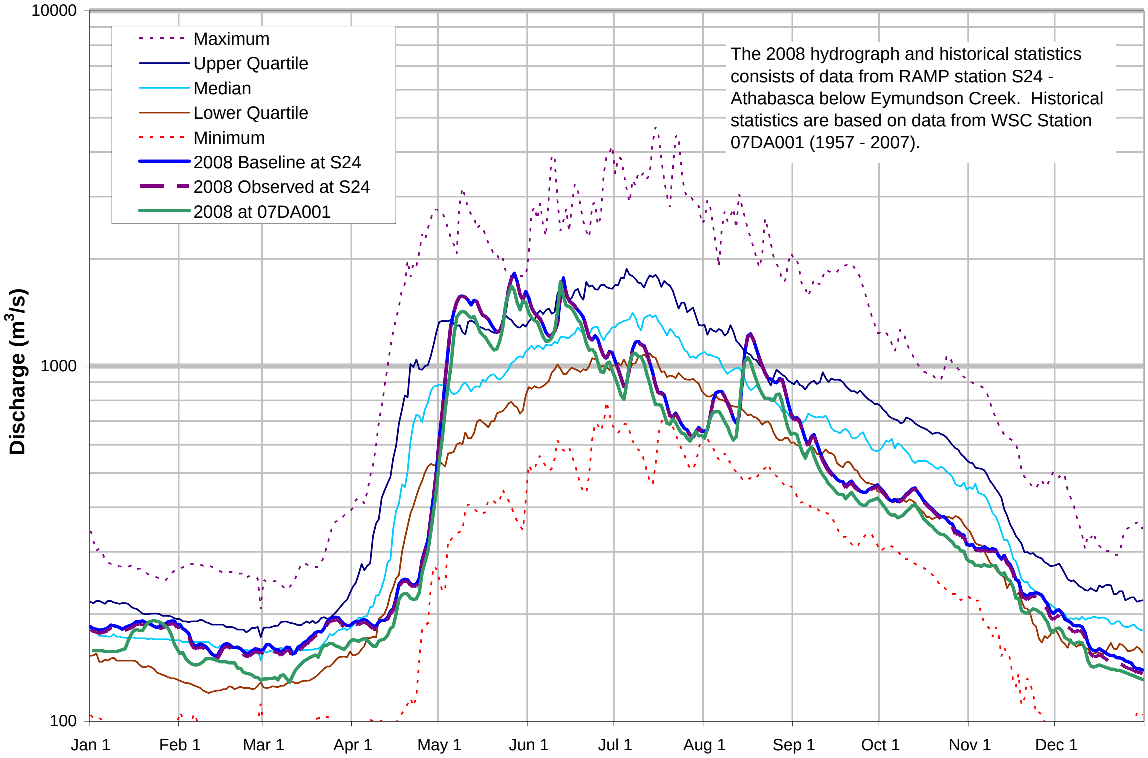


Table 5.1-2 Inputs for calculation of baseline hydrograph at RAMP Station S24, Athabasca River below Eymundson Creek.

Component of Water Balance	Volume (million m^3)		Basis and Source of Data
	Focal Projects	Focal Projects Plus All Other Active Oil Sands Projects in RAMP FSA	
Observed *test* hydrograph (total annual discharge)	**17,400**	**17,400**	**Sum of observed daily discharges obtained from RAMP Station S24, Athabasca River below Eymundson Creek.**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+35.9	+36.0	300 km^2 (299 km^2 focal projects only) within catchments of minor Athabasca River tributaries from Fort McMurray to RAMP station S24 estimated to have been closed-circuited as of 2008 (Table 2.4-1). This includes the McLean Creek and upper Beaver River[1] catchments.
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-2.53	-2.61	109 km^2 (106 km^2 focal projects only) within catchments of minor Athabasca River tributaries from Fort McMurray to RAMP station S24 estimated to have undergone land change as of 2008, but are not closed-circuited (Table 2.4-1). This includes the McLean Creek and upper Beaver River catchments.
Discharge that would have occurred in the absence of water withdrawals from the Athabasca River by focal projects	+45.9	+45.9	Withdrawals by Suncor (annual total[1], Section 2.2).
	+41.2	+41.2	Withdrawals by Syncrude (monthly values[1], Section 2.2).
	+13.5	+13.5	Withdrawals by Albian (daily values, Section 2.2).
	+17.6	+17.6	Withdrawals by CNRL (annual values, Section 2.2).
Amount by which discharge would be lower in the absence of releases to the Athabasca River by focal projects	-0.233	-0.233	Releases by Syncrude (monthly values[1], Section 2.2).
	-0.374	-0.374	Releases by Suncor (annual value[1], Section 2.2).
	-0.413	-0.413	Releases by CNRL (annual value[1], Section 2.2).
The difference between *test* and *baseline* hydrographs on tributary streams	+28.0	+28.1	Net sum of results of hydrologic analyses from major Athabasca River tributaries (Christina, Ells, Firebag, Fort, Hangingstone, MacKay, Mills, Muskeg, Steepbank, and Tar).
***Baseline* hydrograph (total annual discharge)**	**17,500**	**17,500**	**Estimated *baseline* discharge at RAMP Station S24, Athabasca River below Eymundson Creek.**
Incremental flow (change in total annual discharge)	-179	-179	Total annual discharge from observed *test* hydrograph less total annual discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total annual discharge)	-1.0%	-1.0%	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

[1] Annual or monthly totals were prorated to daily estimates using daily data provided in previous years. Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Data are for the period of the 2008 data record for RAMP Station S24, Athabasca River below Eymundson Creek.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.1-3 Estimated changes in hydrologic measurement endpoints for the Athabasca River, focal project case.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	906	899	-0.8%
Mean winter discharge	190	186	-2.2%
Annual maximum daily discharge	1,830	1,820	-0.5%
Open-water season minimum daily discharge	315	311	-1.1%

Note: As measured at RAMP Station S24, Athabasca River below Eymundson Creek.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.1-4 Estimated changes in hydrologic measurement endpoints for the Athabasca River, cumulative assessment case.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	906	899	-0.8%
Mean winter discharge	190	186	-2.2%
Annual maximum daily discharge	1,830	1,820	-0.5%
Open-water season minimum daily discharge	315	311	-1.1%

Note: As measured at RAMP Station S24, Athabasca River below Eymundson Creek.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.1-5 Concentrations of water quality measurement endpoints, Athabasca River mainstem, fall 2008.

Measurement Endpoint	Units	Guideline	Upstream of Fort McMurray (ATR-UFM) Fall AENV data, 1997-2007				Upstream of Donald Creek (ATR-DC-E, ATR-DC-W)		Upstream of Steepbank River (ATR-SR-E, ATR-SR-W)		Upstream of Muskeg River (ATR-MR-E, ATR-MR-W)		Downstream of Development (ATR-DD-E, ATR-DD-W)		Upstream of Firebag River (ATR-FR-CC)
			n	min	median	max	East[1]	West	East	West	East	West	East	West	Cross-channel
Physical variables															
pH	pH units	6.5-9.0	52	7.3	8.1	8.4	8.2	8.3	8.2	8.3	8.2	8.2	8.2	8.2	8.2
Total suspended solids	mg/L	-	45	1	14.4	344	20	23	97	39	102	44	46	27	23
Conductivity	µS/cm	-	49	150	280	446	232	268	238	270	243	241	267	260	251
Nutrients															
Total dissolved phosphorus	mg/L	0.05[2]	35	0.003	0.006	0.025	0.028	0.01	0.023	0.011	0.018	0.016	0.018	0.019	0.018
Total nitrogen*	mg/L	1.0	44	0.133	0.393	**1.903**	0.7	0.7	1	0.5	0.8	0.5	0.7	0.6	0.5
Nitrate+nitrite	mg/L	1.0	53	0.001	0.003	0.843	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	48	2.5	7.7	25	16	9	16	12	13	13	12	13	12
Ions															
Sodium	mg/L	-	50	4	9.95	20	18	11	11	12	11	10	12	12	12
Calcium	mg/L	-	53	19.4	35.5	50.5	20	33.2	24.1	23.4	25.7	26.8	28.5	28.6	26.7
Magnesium	mg/L	-	51	5.4	9.3	14.2	6.2	9.1	7.5	6.8	7.2	7.5	8.2	8.5	7.9
Chloride	mg/L	230, 860[3]	53	1	2.6	7.2	23	3	11	4	10	7	10	7	9
Sulphate	mg/L	100[4]	52	13	29.6	53.1	7.3	25.7	14.7	13.1	15.5	18.3	18.4	20.4	18.6
Total dissolved solids	mg/L	-	41	109	170	263	166	177	190	190	240	210	160	150	140
Total alkalinity	mg/L		53	64.3	118	176	76	109	88	101	92	94	97	99	95
Organic compounds															
Naphthenic acids	mg/L	-	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Selected metals															
Total aluminum	mg/L	0.1	10	0.07	**0.1765**	**1.29**	**0.742**	**1.17**	**2.97**	**1.55**	**1.35**	**1.05**	**1.46**	**0.964**	**1**
Total arsenic	mg/L	0.005	10	0.000287	0.000505	0.0013	0.000997	0.00084	0.00172	0.00102	0.001	0.001	0.00103	0.000885	0.001
Dissolved aluminum	mg/L	0.1[2]	7	0.004	0.00873	0.02	0.0126	0.0403	0.0273	0.0336	0.0293	0.0322	0.0203	0.0231	0.0236
Total boron	mg/L	1.2[5]	9	0.01	0.0274	0.04	0.0336	0.0265	0.0289	0.0286	0.0259	0.024	0.0238	0.0267	0.0262
Total molybdenum	mg/L	0.073	18	0.00066	0.001	0.018	0.000292	0.000602	0.000429	0.000636	0.000442	0.000541	0.000502	0.000524	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[6]	4	0.6	0.6	2.4	2.0	<1.2	3.3	1.6	2.0	3.1	1.5	<1.2	<1.2
Total strontium	mg/L	-	3	0.22	0.235	0.291	0.107	0.196	0.142	0.188	0.158	0.168	0.163	0.168	0.172
Other variables that exceeded CCME/AENV guidelines in 2008															
Total phenols	mg/L	0.004	32	0.001	0.0015	**0.011**	**0.005**	-	**0.005**	-	-	-	**0.02**	**0.015**	-
Sulphide	mg/L	0.002[7]	12	<0.005	<0.001	**0.04**	**0.004**	**0.003**	**0.009**	**0.007**	**0.009**	**0.007**	-	**0.004**	-
Total phosphorus	mg/L	0.05	51	0.006	0.023	**0.35**	**0.07**	**0.054**	**0.106**	**0.056**	**0.12**	**0.074**	**0.072**	-	-
Total cadmium	mg/L	[8]	9	<0.0002	<0.001	0.0004	-	-	**0.0000595**	**0.0000356**	**0.0000504**	**0.0000362**	-	-	-
Total copper	mg/L	[8]	13	<0.001	0.001	0.004	-	-	**0.00367**	-	**0.00249**	-	-	-	-
Total iron	mg/L	0.3	7	0.216	**0.352**	**3.29**	**1.41**	**1.06**	**3.43**	**1.54**	**2.51**	**1.66**	**1.58**	**1.09**	**1.13**
Dissolved iron	mg/L	0.3[2]	21	<0.01	0.07	0.19	**0.425**	-	**0.362**	-	-	-	-	-	-

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

* Total nitrogen calculated as the sum of nitrate+nitrite and total Kjeldahl nitrogen (TKN).

[1] Denotes sampling location. East=east bank; West=west bank; Cross-channel = cross-channel composite.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA guideline for continuous and maximum concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[8] Guidelines are hardness-dependent.

Table 5.1-6 List of water quality guideline exceedances in the Athabasca River mainstem, downstream of development (ATR-DD), 2008.

Variable	Units	Guideline*	ATR-DD-E	ATR-DD-W
Winter				
Sulphide	mg/L	0.002[2]	**0.003**	**-**
Total aluminum	mg/L	0.1	**0.152**	**0.141**
Total iron	mg/L	0.3	**0.451**	**0.421**
Spring				
Dissolved iron	mg/L	0.3[4]	**0.306**	**-**
Sulphide	mg/L	0.002[2]	**0.004**	**0.005**
Total phenolics	mg/L	0.004	**0.007**	**0.007**
Phosphorus, Total	mg/L	0.05	**0.127**	**0.283**
Total Kjeldahl Nitrogen	mg/L	1.0	**-**	**1.2**
Total nitrogen	mg/L	1.0	**1.1**	**1.3**
Total aluminum	mg/L	0.1	**4.24**	**5.09**
Total cadmium	mg/L	-[3]	**-**	**0.00006**
Total copper	mg/L	-[3]	**0.0035**	**0.0042**
Total iron	mg/L	0.3	**3.65**	**4.31**
Ultra-trace Mercury	ng/L	5, 13[1]	**8.3**	**8.3**
Summer				
Sulphide	mg/L	0.002 [2]	**-**	**0.003**
Total phenolics	mg/L	0.004	**-**	**0.007**
Total Aluminum	mg/L	0.1	**2.72**	**2.46**
Total copper	mg/L	-[3]	**0.0023**	**0.0021**
Total iron	mg/L	0.3	**2.23**	**2.3**
Total lead	mg/L	-[3]	**0.00128**	**0.00117**
Total cadmium	mg/L	-[3]	**0.00003**	**0.00003**
Total phosphorus	mg/L	0.05	**0.074**	**0.081**
Fall				
Total phenols	mg/L	0.004	**0.02**	**0.015**
Sulphide	mg/L	0.002 [2]	-	**0.004**
Total Aluminum	mg/L	0.1	**1.46**	**0.964**
Total phosphorus	mg/L	0.05	**0.072**	-
Total iron	mg/L	0.3	**1.58**	**1.09**

ns = not sampled

* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

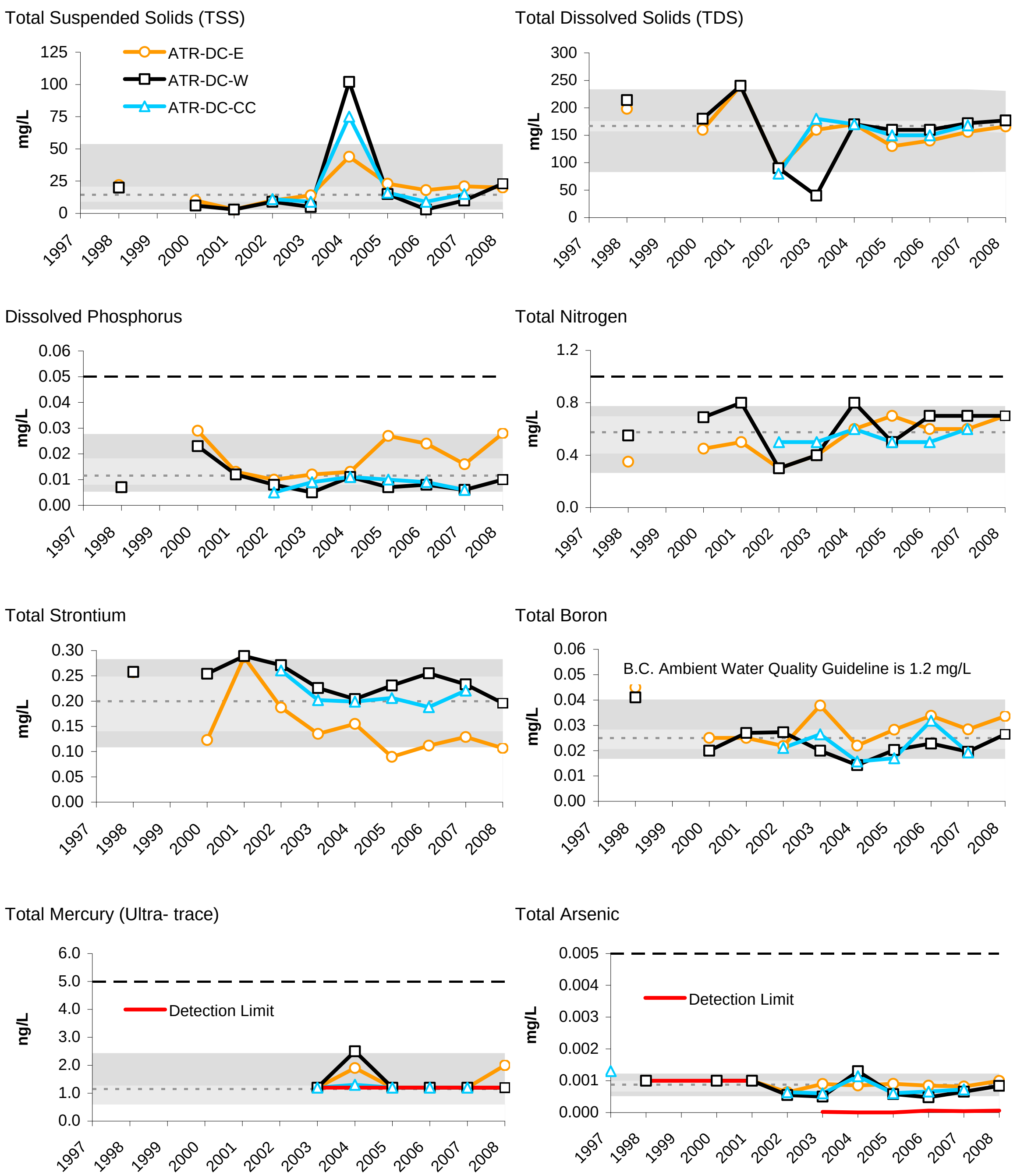
[1] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[2] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[3] Guidelines are hardness-dependent.

[4] Guideline is for total analyte (no guideline for dissolved species).

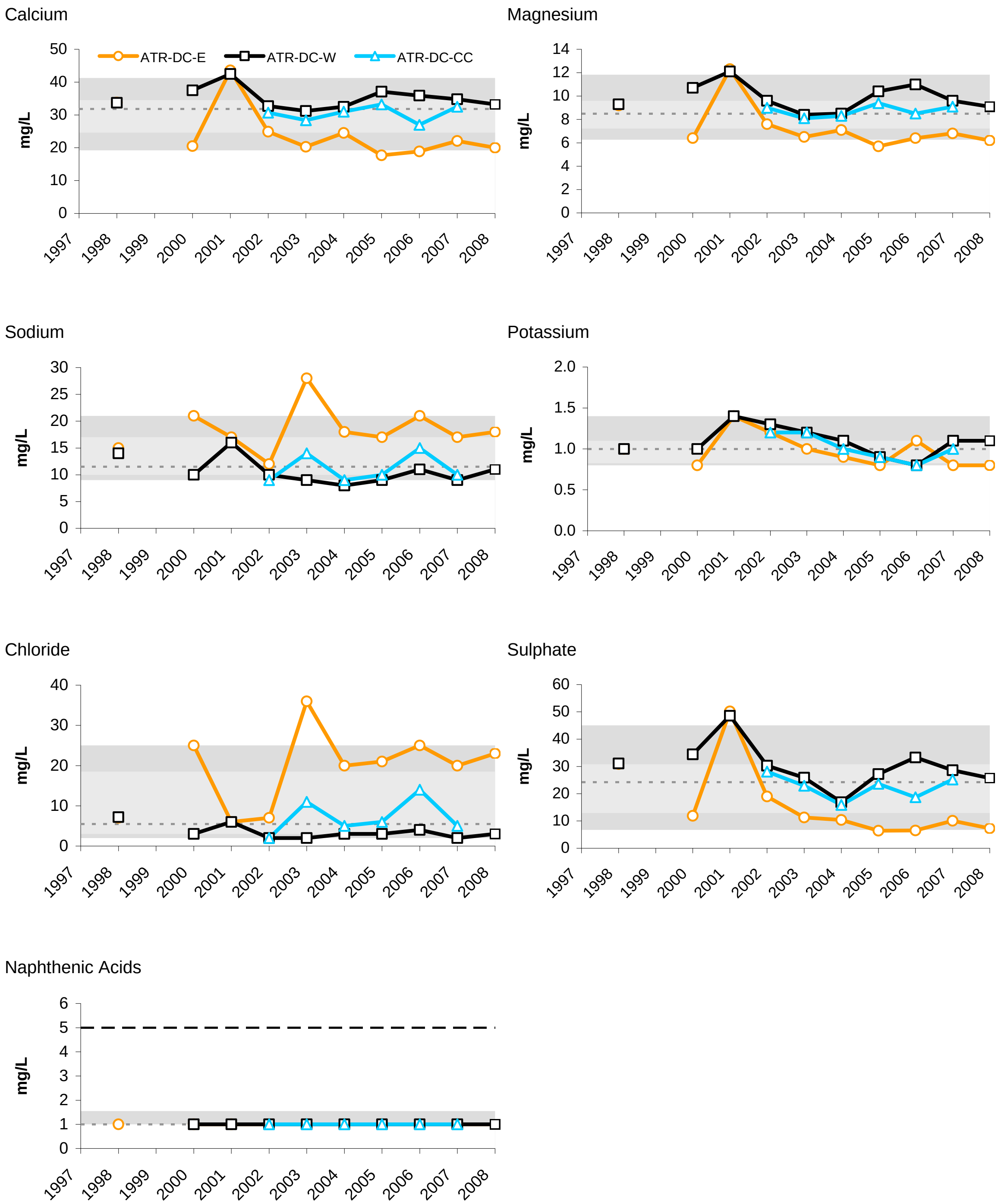
Figure 5.1-4 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of Donald Creek (ATR-DC).



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

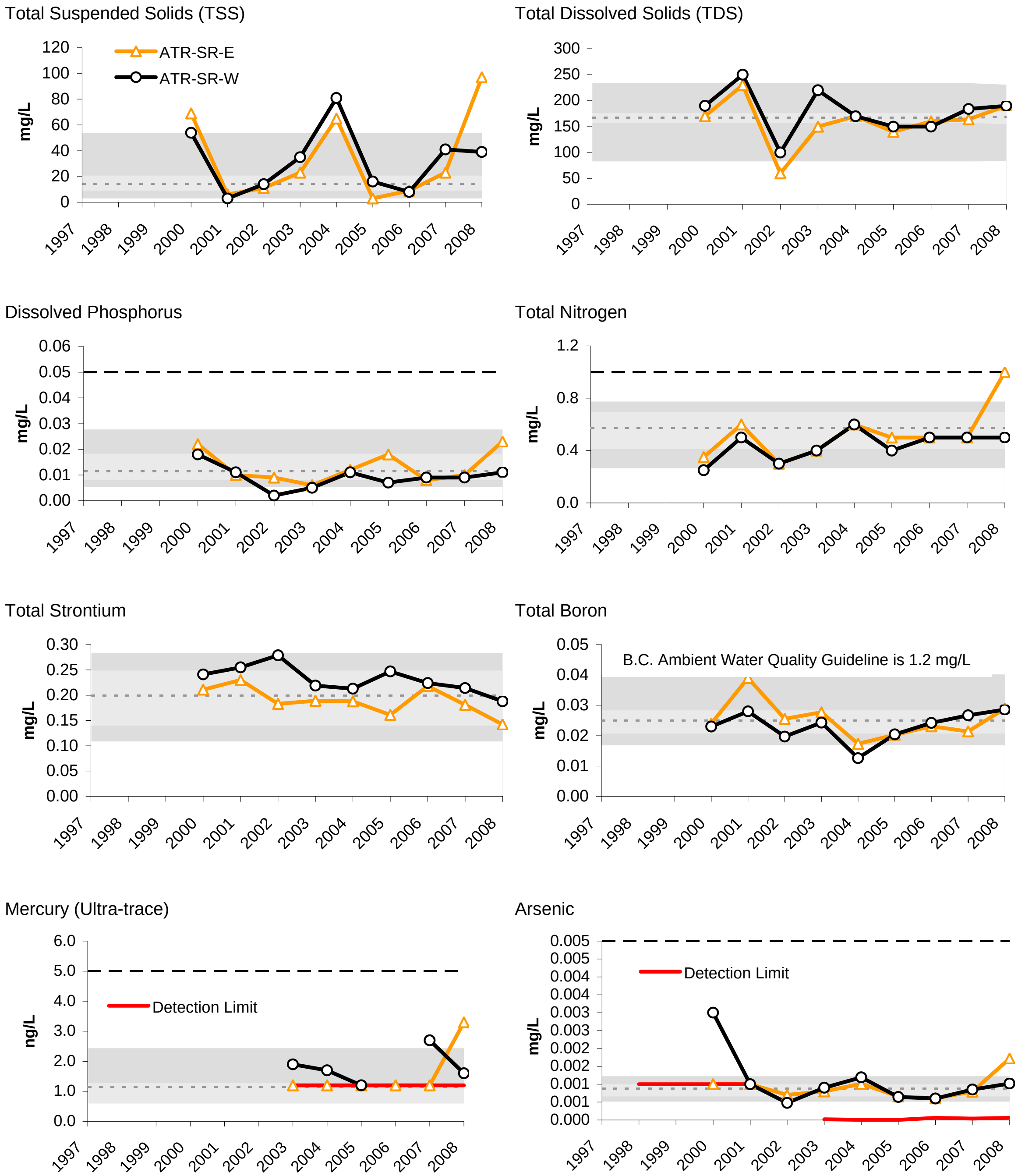
Figure 5.1-4 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

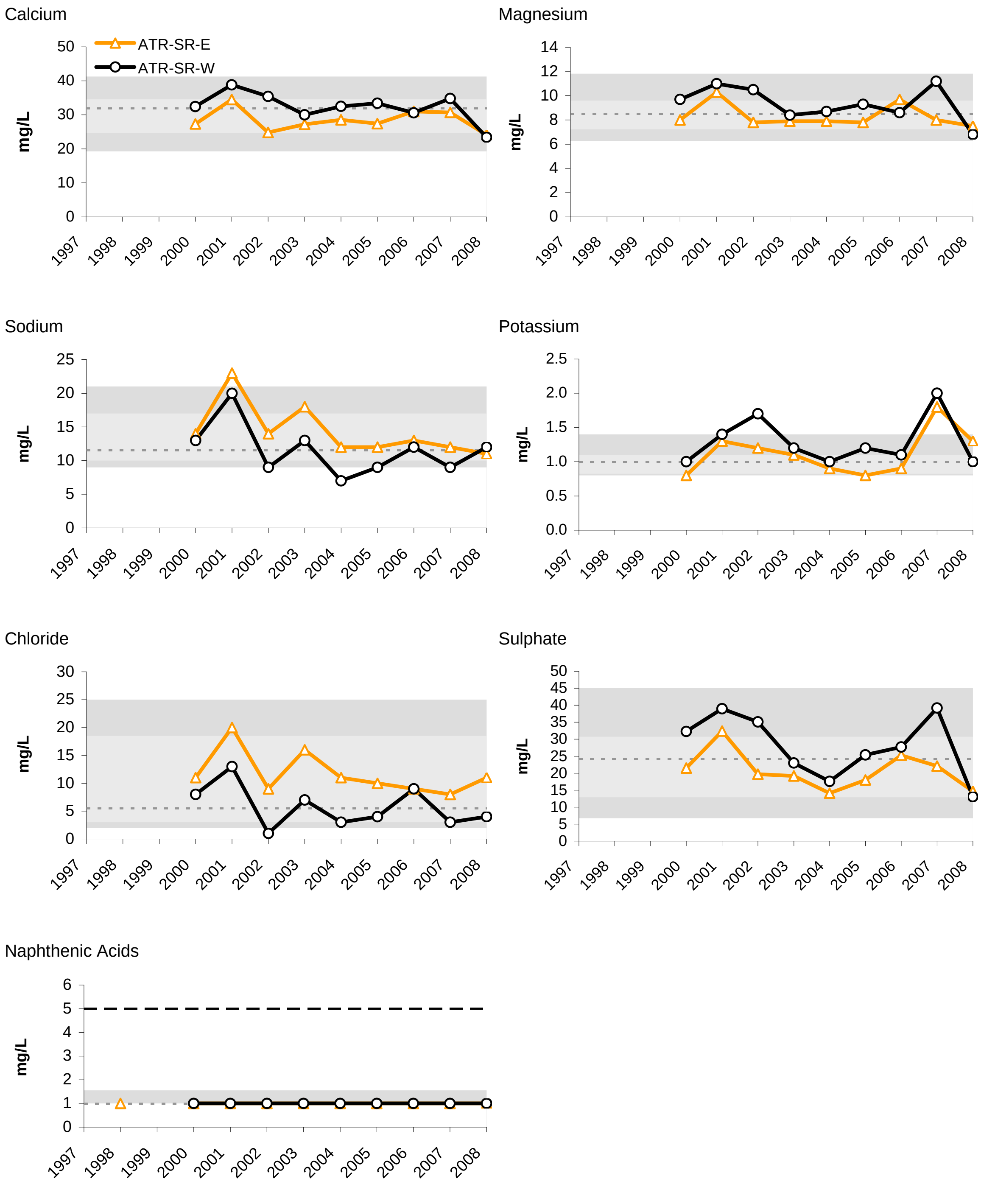
Figure 5.1-5 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of the Steepbank River (ATR-SR).



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

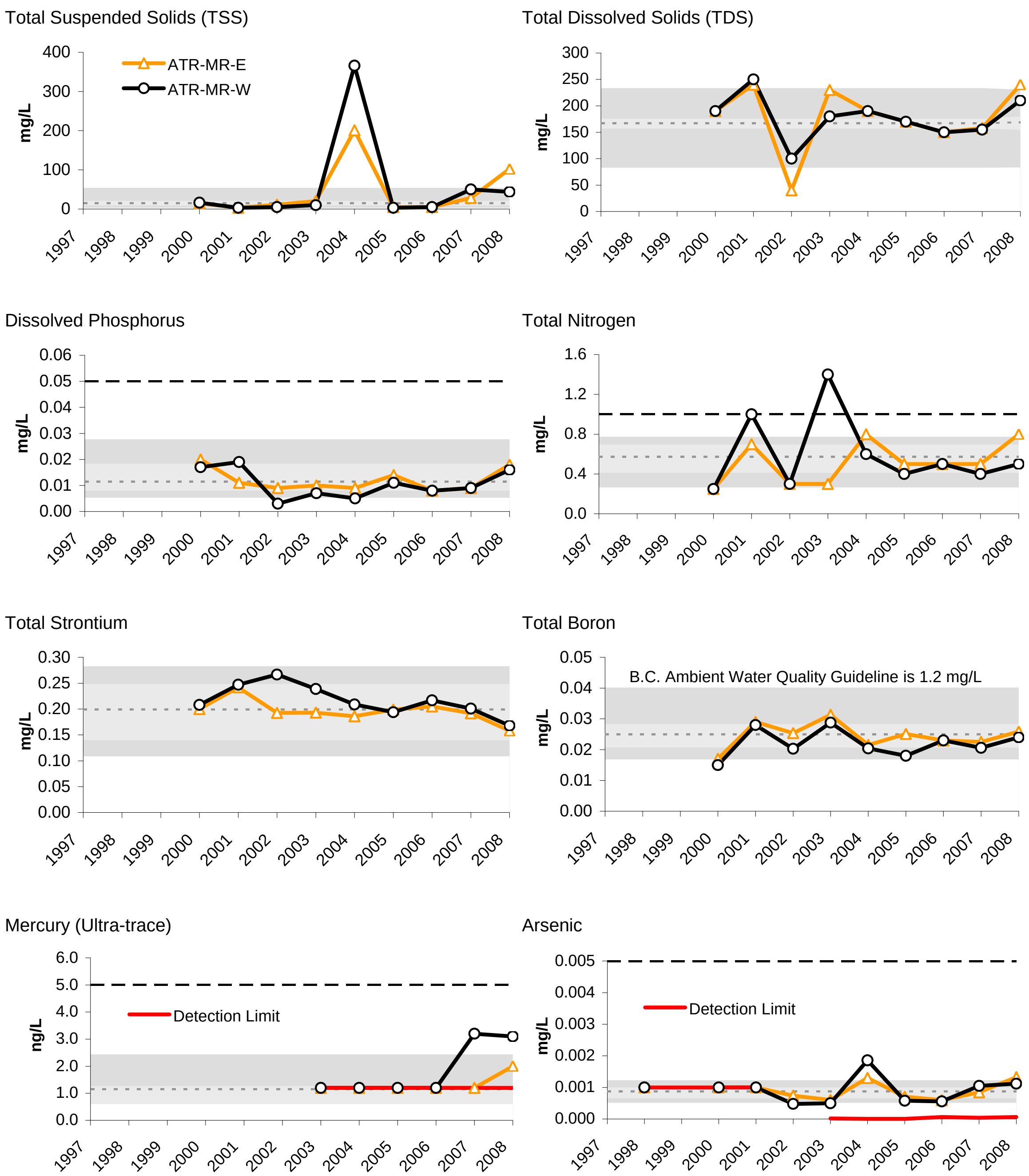
Figure 5.1-5 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

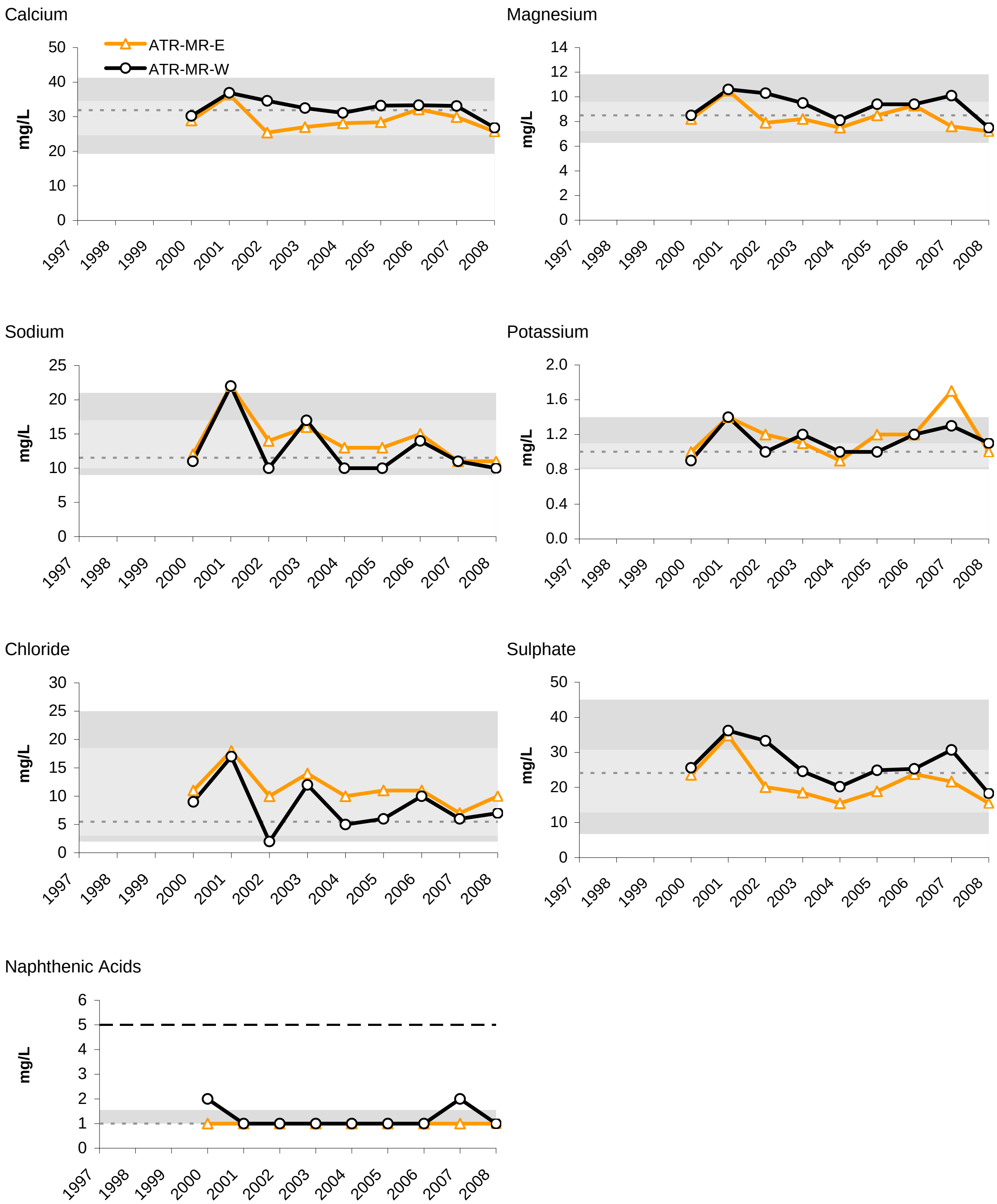
Figure 5.1-6 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of the Muskeg River (ATR-MR).



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

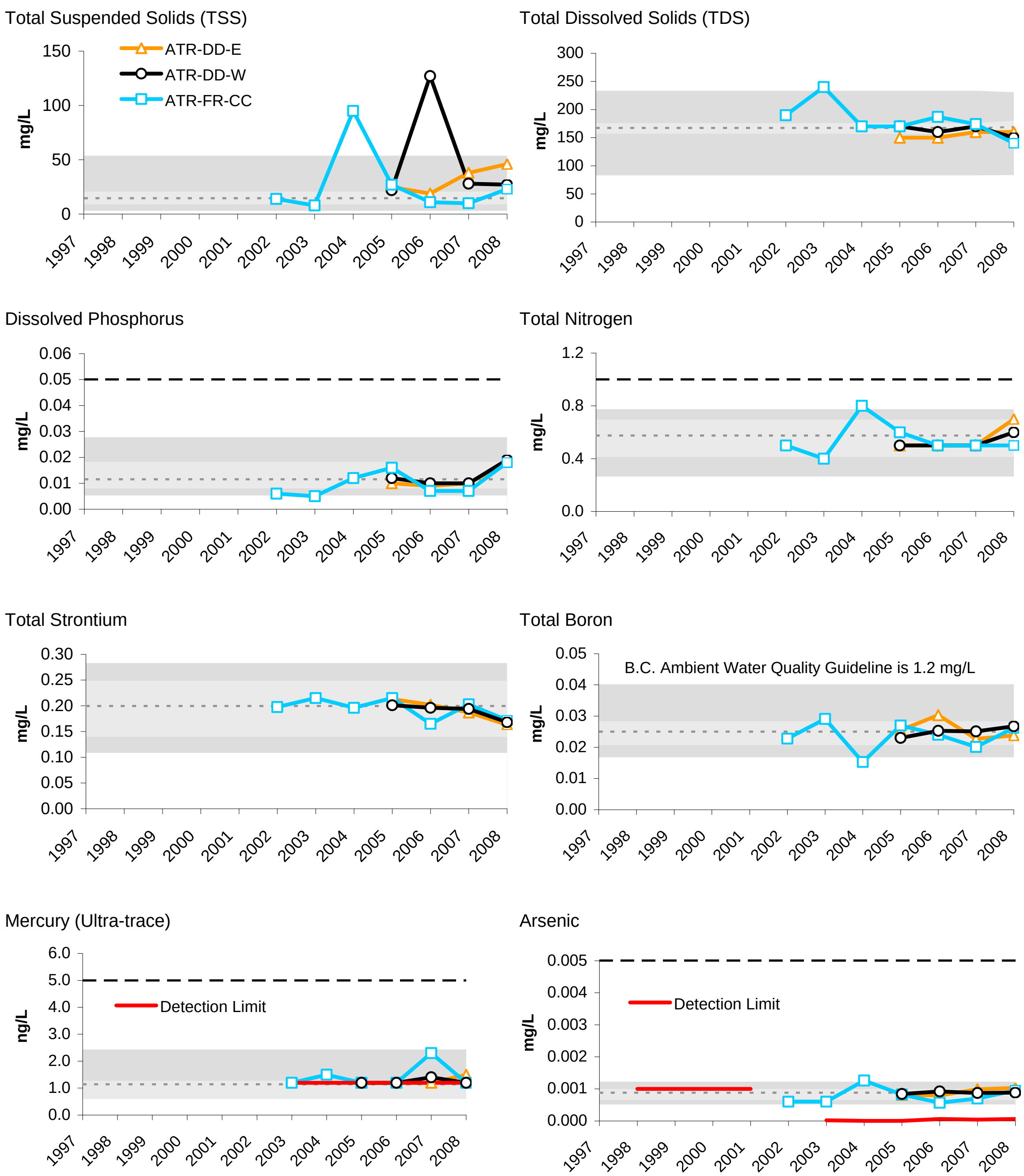
Figure 5.1-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

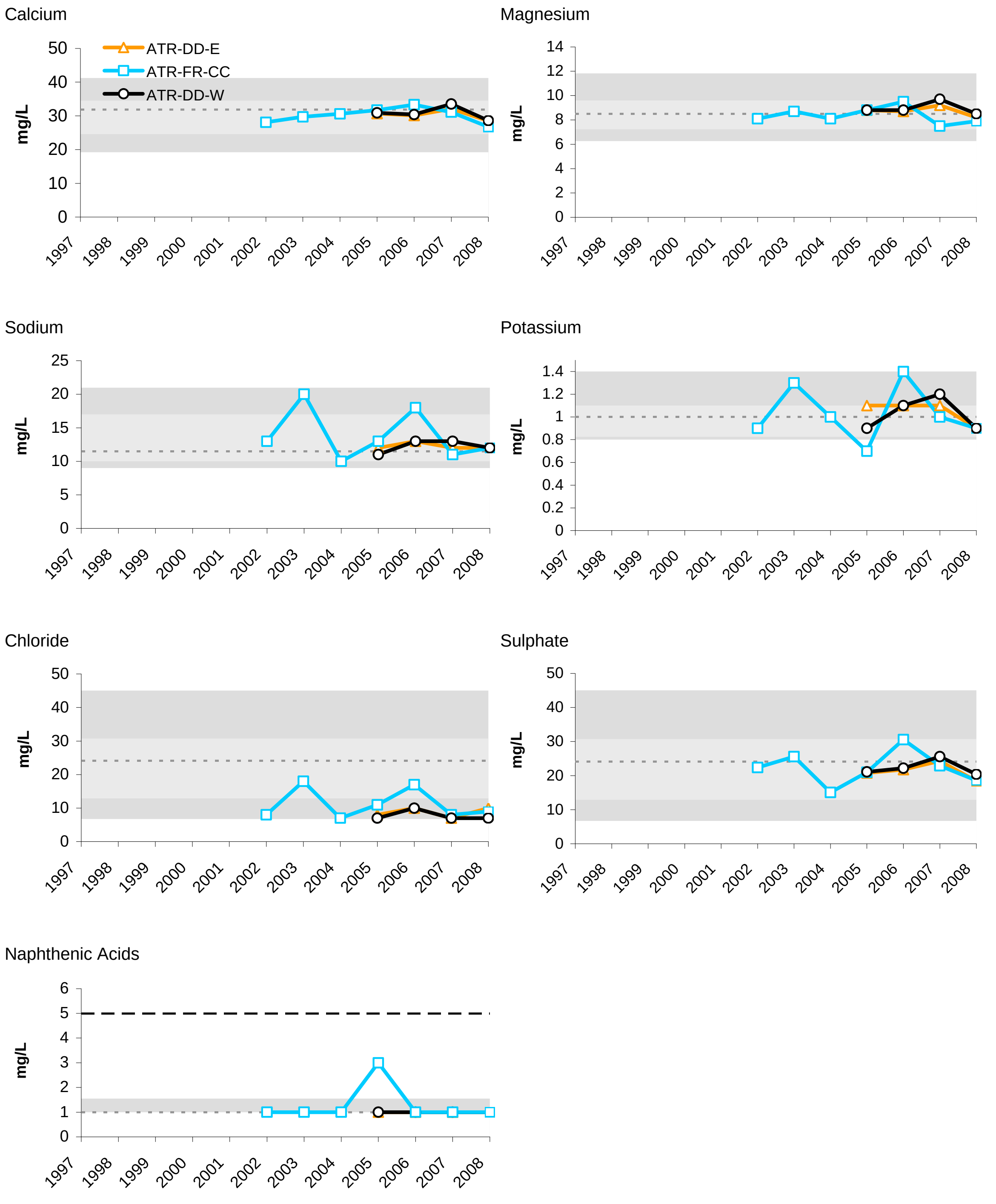
Figure 5.1-7 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, downstream of development (ATR-DD) and upstream of the Firebag River (ATR-FR).



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.1-7 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.1-8 Piper diagram of ion concentrations in Athabasca River mainstem, fall 1997 to 2008.

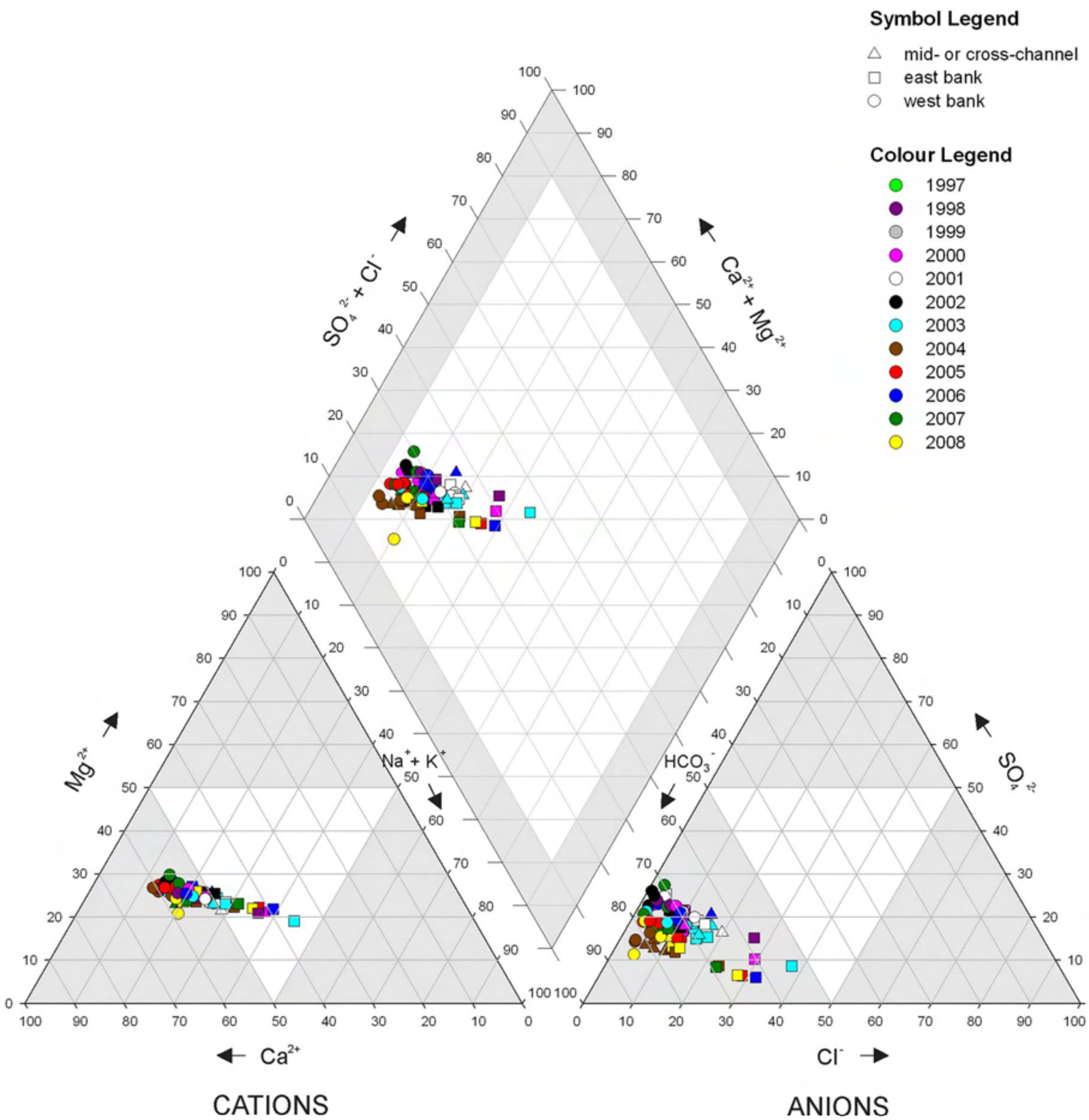


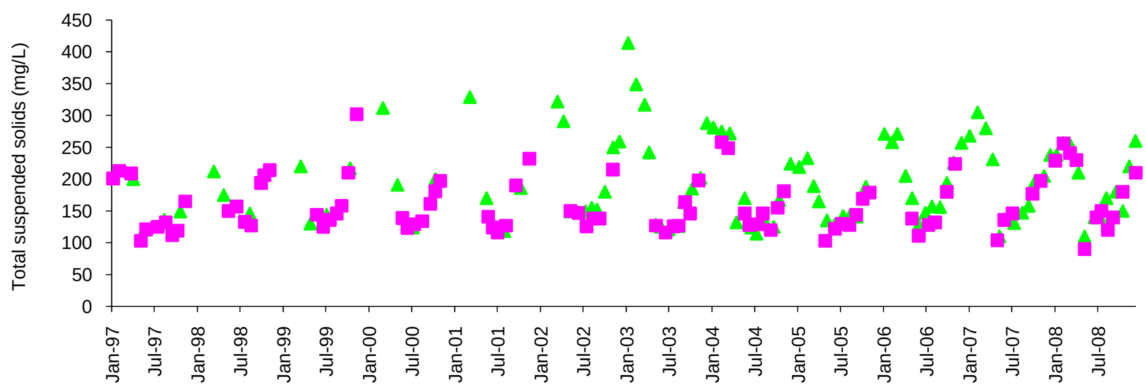
Figure 5.1-9 Water quality measurement endpoints, 1997 to 2008 AENV data for the Athabasca River mainstem.

pH

Trend at ATR-UFM: up Trend at ATR-OF: up

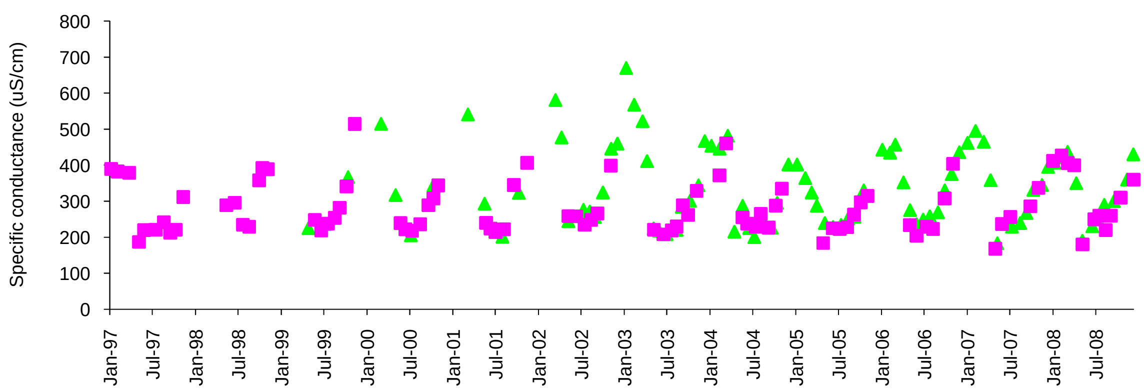
Total dissolved solids

Trend at ATR-UFM: none Trend at ATR-OF: none



Specific conductance

Trend at ATR-UFM: down Trend at ATR-OF: none

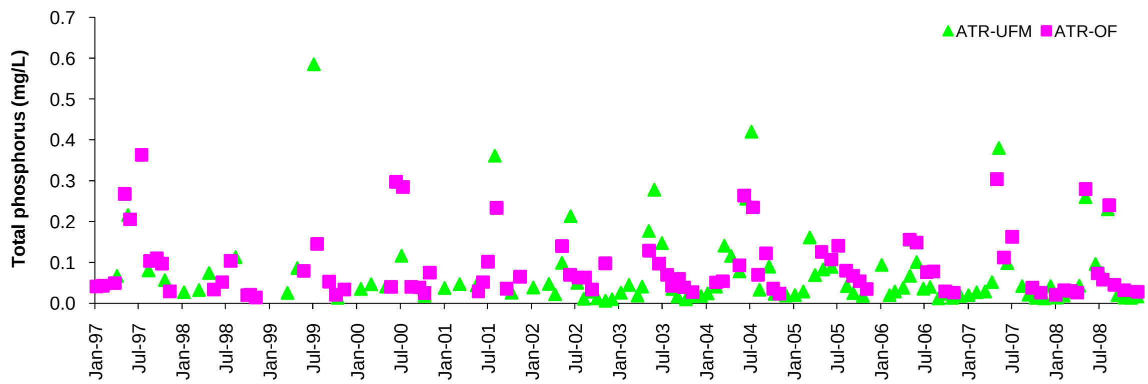


Non-detectable results are shown at the detection limit.

Figure 5.1-9 (Cont'd.)

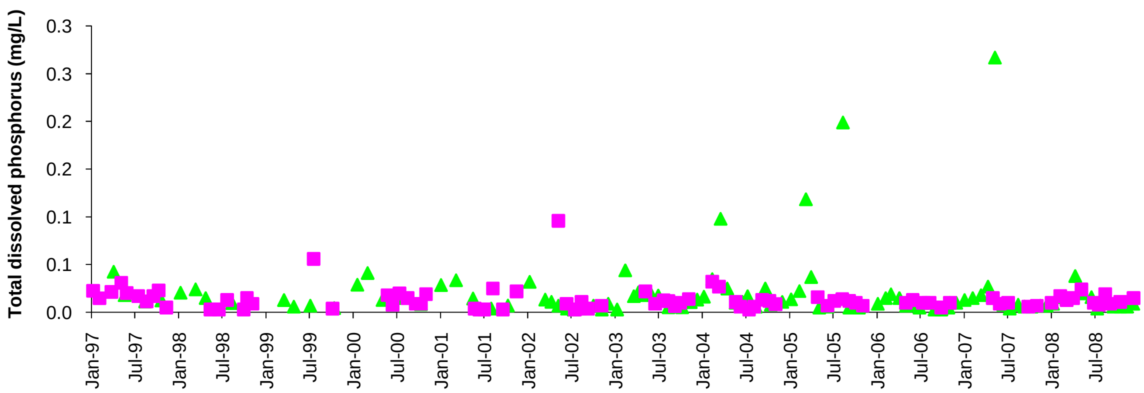
Total phosphorus

Trend at ATR-UFM: none   Trend at ATR-OF: none



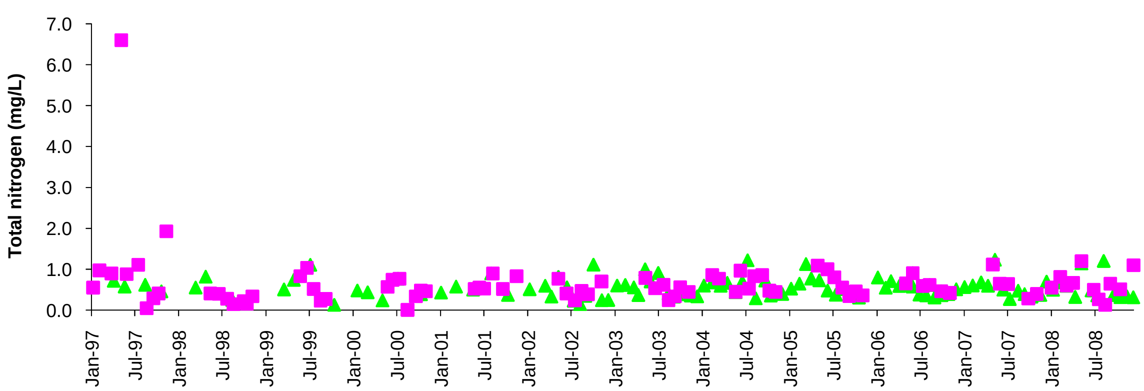
Total dissolved phosphorus

Trend at ATR-UFM: none   Trend at ATR-OF: none



Total nitrogen

Trend at ATR-UFM: none   Trend at ATR-OF: none

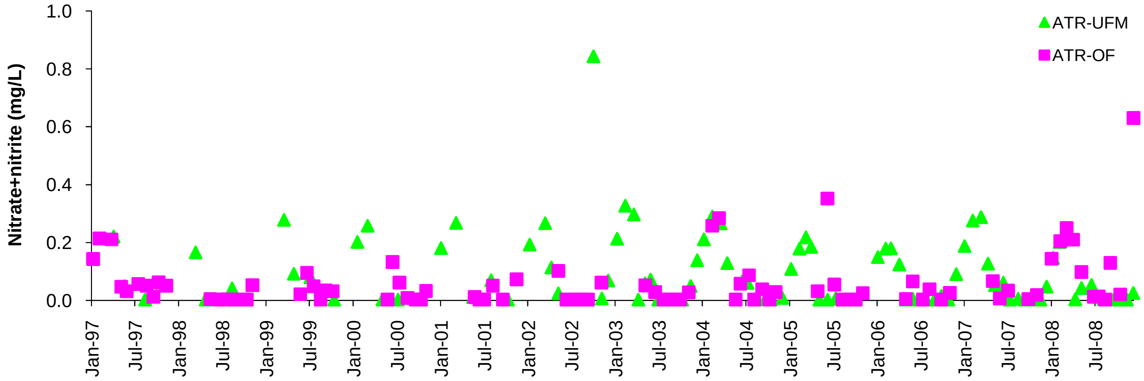


Non-detectable values are shown at the detection limit.

Figure 5.1-9 (Cont'd.)

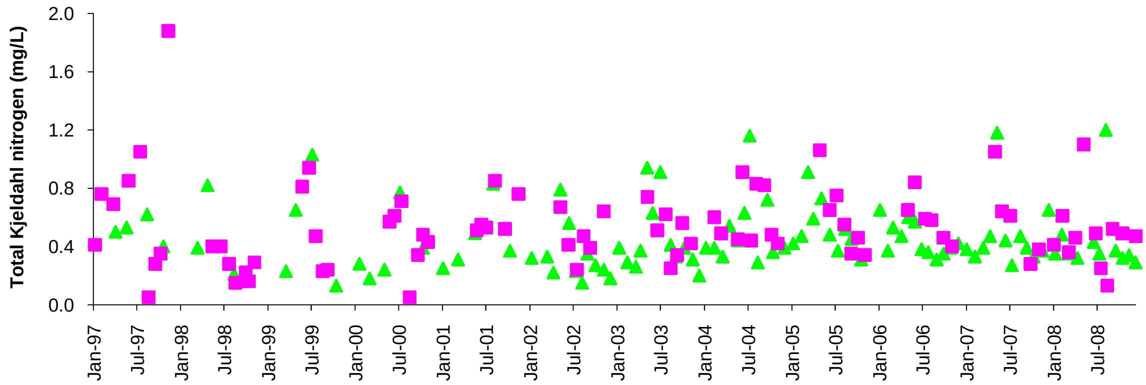
Nitrate + Nitrite

Trend at ATR-UFM: none   Trend at ATR-OF: none



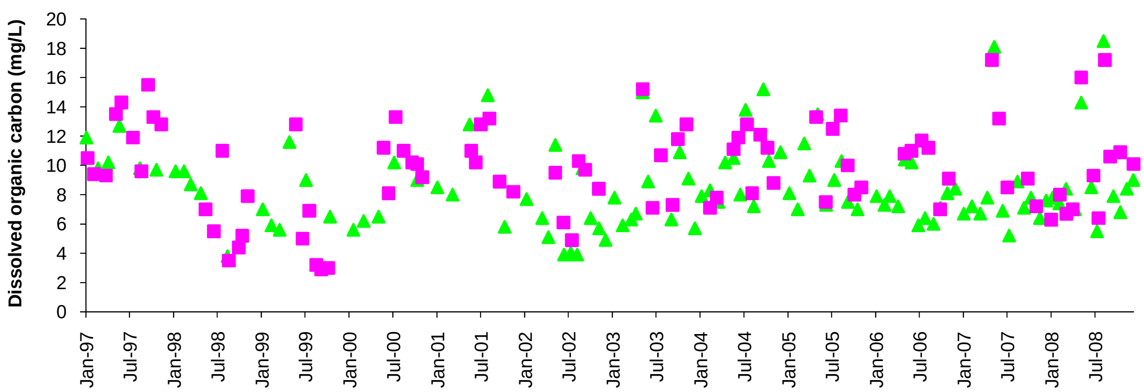
Total Kjeldahl nitrogen

Trend at ATR-UFM: none   Trend at ATR-OF: none



Dissolved organic carbon

Trend at ATR-UFM: none   Trend at ATR-OF: none

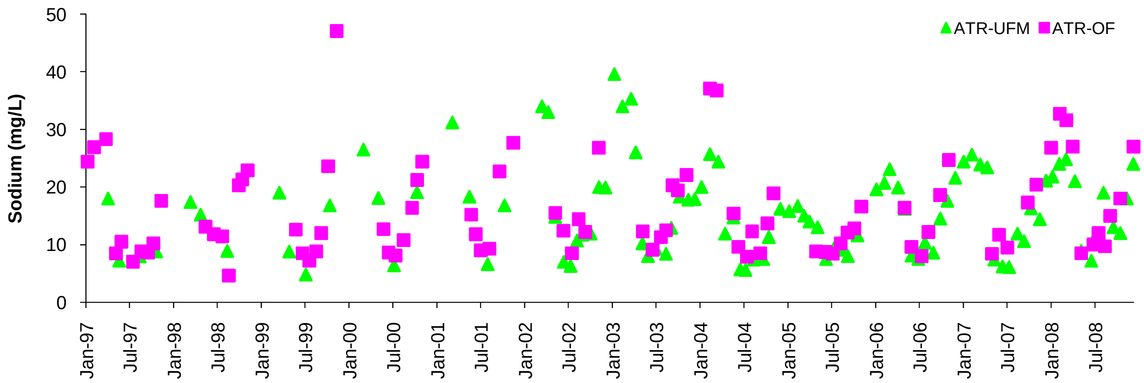


Non-detectable values are shown at the detection limit.

Figure 5.1-9 (Cont'd.)

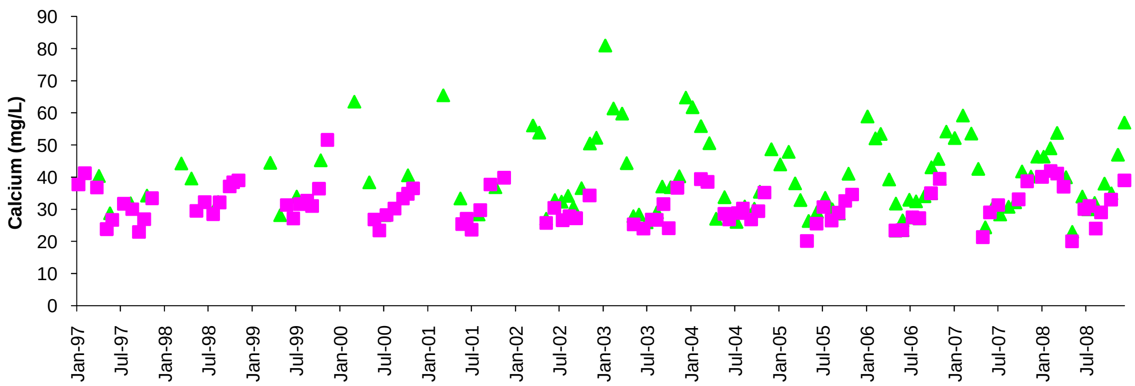
Sodium

Trend at ATR-UFM: none   Trend at ATR-OF: none



Calcium

Trend at ATR-UFM: none   Trend at ATR-OF: none



Magnesium

Trend at ATR-UFM: none   Trend at ATR-OF: none

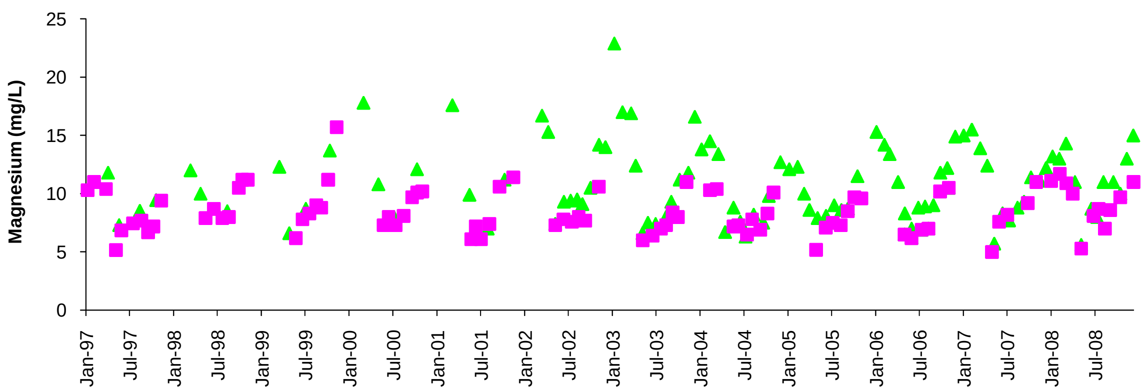
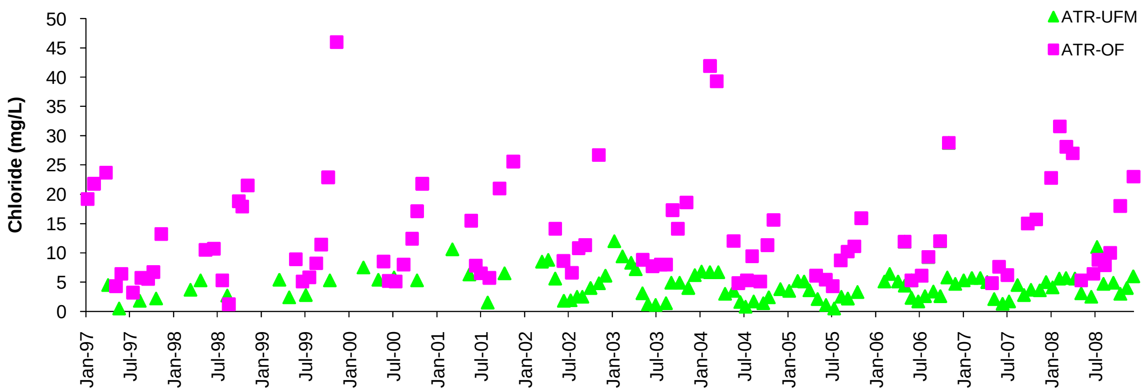


Figure 5.1-9 (Cont'd.)

Chloride

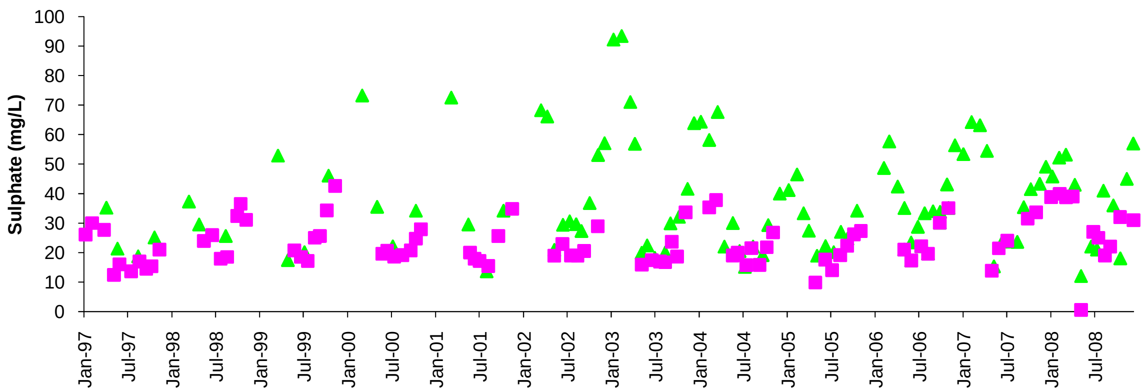
Trend at ATR-UFM: down Trend at ATR-OF: none



Non-detectable values are shown at the detection limit.

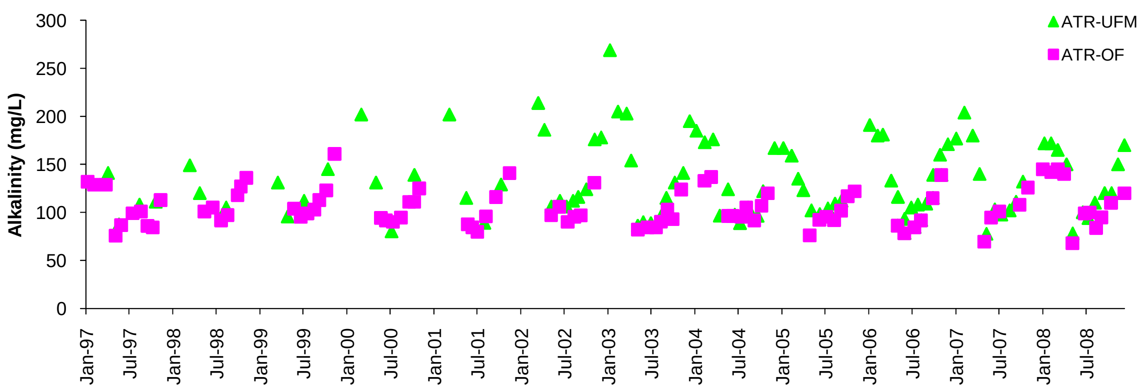
Sulphate

Trend at ATR-UFM: none Trend at ATR-OF: none



Alkalinity (as $CaCO_3$)

Trend at ATR-UFM: none Trend at ATR-OF: none

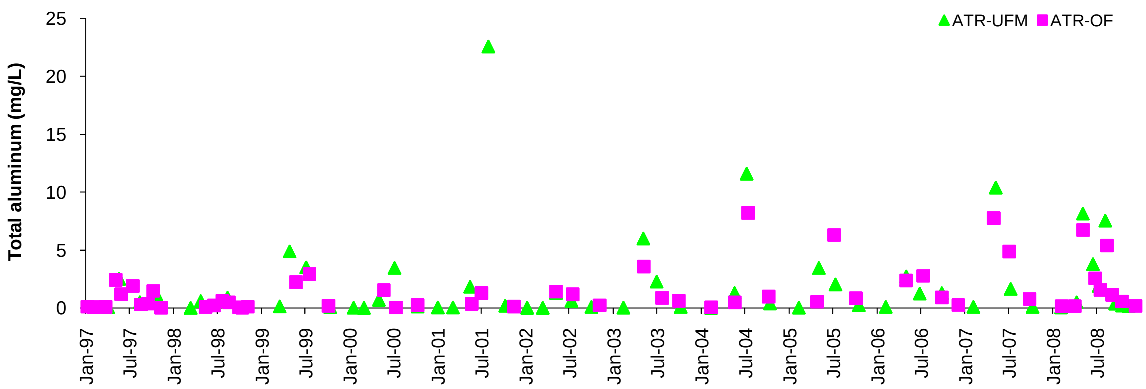


Non-detectable values are shown at the detection limit.

Figure 5.1-9 (Cont'd.)

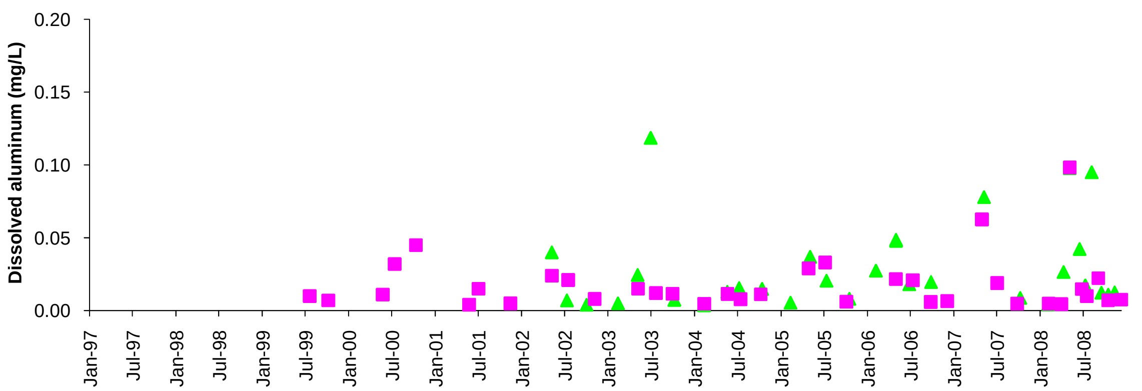
Total aluminum

Trend at ATR-UFM: none Trend at ATR-OF: up



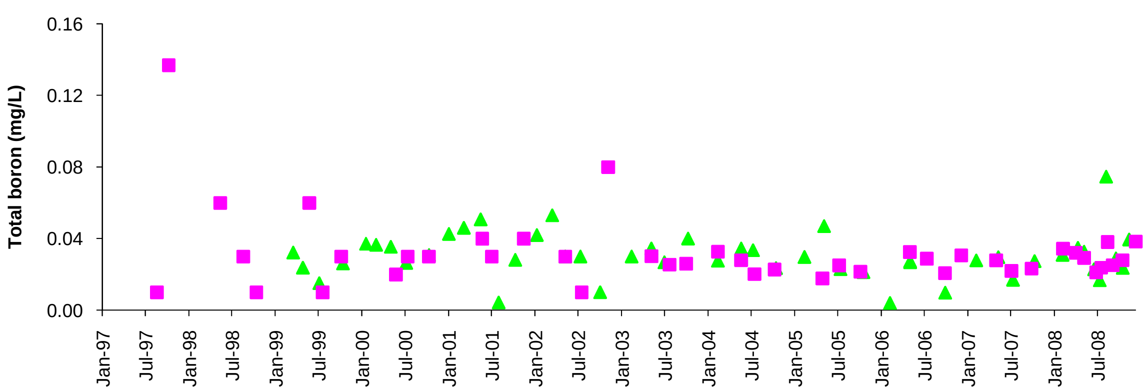
Dissolved aluminum

Trend at ATR-UFM: none Trend at ATR-OF: none



Total boron

Trend at ATR-UFM: none Trend at ATR-OF: none

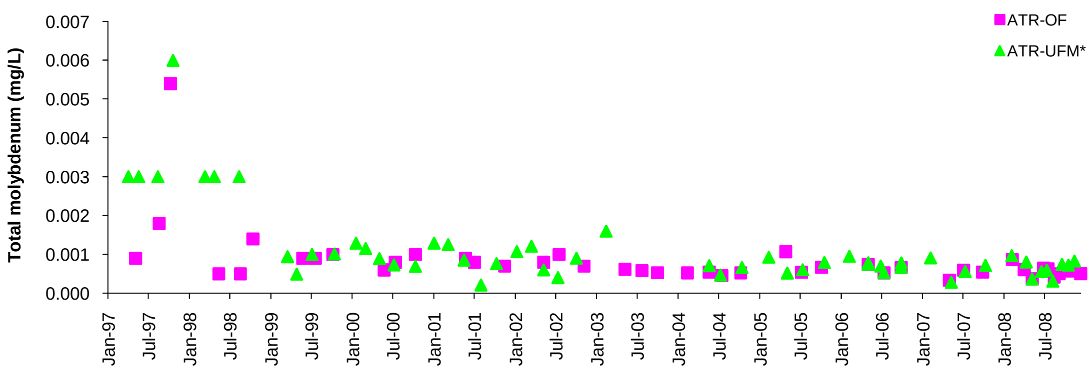


Non-detectable values are shown at the detection limit.

Figure 5.1-9 (Cont'd.)

Total molybdenum

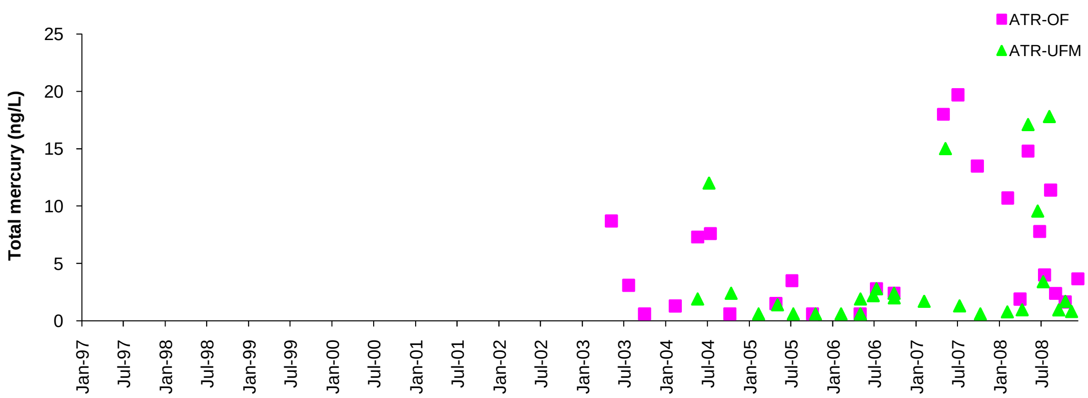
Trend at ATR-UFM: down Trend at ATR-OF: down



* ATR-UFM data analyzed from 1999-2008 due to a higher detection limit in 1997 and 1998.

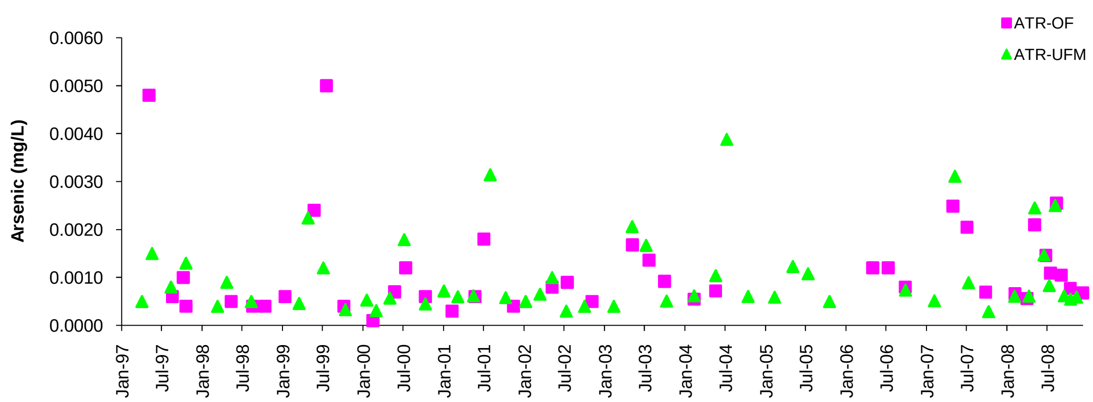
Total mercury (ultra-trace)

Trend at ATR-UFM: none Trend at ATR-OF: none



Total Arsenic

Trend at ATR-UFM: none Trend at ATR-OF: none



Non-detectable values are shown at the detection limit.

Table 5.1-7 Trend analysis of water quality measurement endpoints for Athabasca River mainstem stations.

AENV Water Quality Variable	Upstream of Fort McMurray 1997 - 2008 (station ATR-UFM)			At Old Fort 1997 - 2008 (station ATR-OF)		
	n	Trend Direction	Slope Estimate[1] (units per year)	n	Trend Direction	Slope Estimate[1] (units per year)
Physical variables						
pH	98	up	0.0229	93	up	0.0410
Specific conductance	90	down	-4.636	93	-	-
Nutrients						
Total phosphorus	100	-	-	90	-	-
Total dissolved phosphorus	101	-	-	87	-	-
Total nitrogen	101	-	-	91	-	-
Nitrate+nitrite	101	-	-	92	-	-
Total Kjeldahl nitrogen	101	-	-	90	-	-
Dissolved organic carbon	106	-	-	91	-	-
Ions						
Sodium	98	-	-	93	-	-
Calcium	98	-	-	93	-	-
Magnesium	98	-	-	93	-	-
Chloride	97	-	-	93	-	-
Sulphate	97	-	-	93	-	-
Total dissolved solids (calculated)	98	-	-	93	-	-
Alkalinity (as $CaCO_3$)	98	-	-	93	-	-
Selected metals						
Total aluminum	55	-	-	56	up	0.0971
Dissolved aluminum	29	-	-	37[2]	-	-
Total boron	49	-	-	44[2]	-	-
Total molybdenum	44*	down	-0.000029	45	down	0.000037
Total mercury (ultra-trace)	24[2]	-	-	26[2]	-	-
Total Arsenic	52	-	-	42	-	-

Critical value at 95% confidence level = 1.960.

* Trend analyzed from 1999 to 2007 due to high detection limits in 1997 and 1998.

[1] Reported slope is the median of slopes estimated for individual season (Seasonal Kendall test) or individual time periods (Sen's slope estimate).

[2] Insufficient data in each season for Seasonal Kendall analysis. Trends were assessed using the Mann-Kendall test for trend and Sen's slope estimator.

Table 5.1-8 Water quality index (fall 2008) for Athabasca River mainstem stations.

Station Identifier	Location	2008 Designation	Water Quality Index	Classification
ATR-DC-E	Upstream of Donald Creek, East Bank	*baseline*	88.3	Negligible-Low
ATR-DC-W	Upstream of Donald Creek, West Bank	*baseline*	100.0	Negligible-Low
ATR-DD-E	Downstream of all Development, East Bank	*test*	100.0	Negligible-Low
ATR-DD-W	Downstream of all Development, West Bank	*test*	100.0	Negligible-Low
ATR-FR-CC	Upstream of the Firebag River, Cross-Channel	*test*	100.0	Negligible-Low
ATR-MR-E	Upstream of the Muskeg River, East Bank	*test*	80.5	Negligible-Low
ATR-MR-W	Upstream of the Muskeg River, West Bank	*test*	95.8	Negligible-Low
ATR-SR-E	Upstream of the Steepbank River, East Bank	*test*	75.9	Moderate
ATR-SR-W	Upstream of the Steepbank River, West Bank	*test*	100.0	Negligible-Low

Note: see Figure 5.1-1 for the locations of these water quality stations.

Note: see Section 3.2.7.4 for a description of the Water Quality Index.

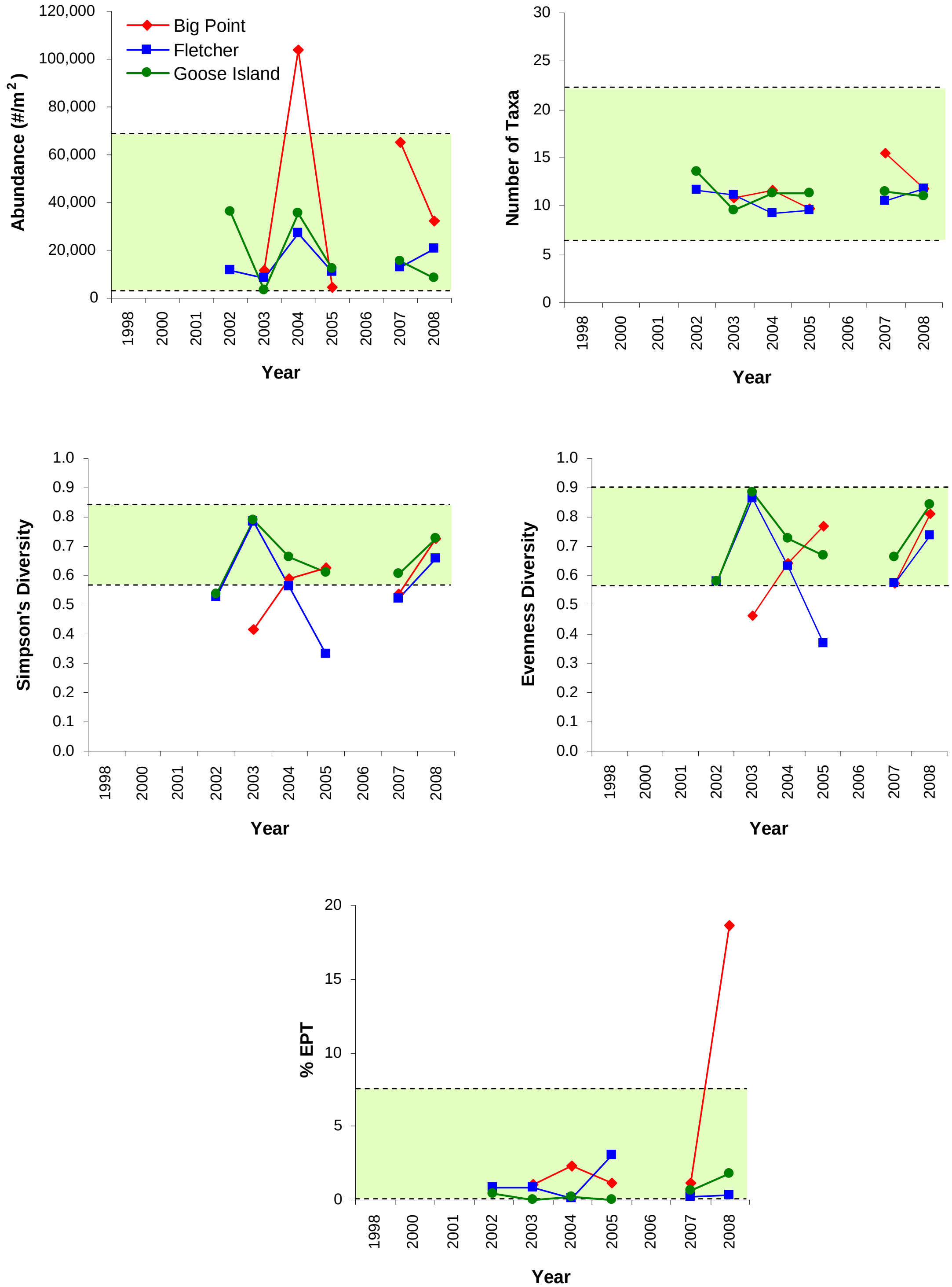
Table 5.1-9 Average habitat characteristics of benthic invertebrate community sampling sites among stations in the Athabasca River Delta.

Variable	Units	Big Point Channel	Fletcher Channel	Goose Island Channel
Sample date	-	Sept. 7, 2008	Sept. 6, 2008	Sept. 6, 2008
Habitat	-	Depositional	Depositional	Depositional
Water depth	m	3	2.5	2
Current velocity	m/s	0.4	0.3	0.4
Field Water Quality				
Dissolved oxygen	mg/L	9.2	8.8	8.8
Conductivity	µS/cm	228	230	229
pH	pH units	8.6	8.6	8.19
Water temperature	°C	12.8	13.3	13.4
Sediment Composition				
Sand	%	49	69	65
Silt	%	39	21	26
Clay	%	12	10	9
Total Organic Carbon	%	1.1	0.9	1.2

Table 5.1-10 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of the Athabasca River Delta.

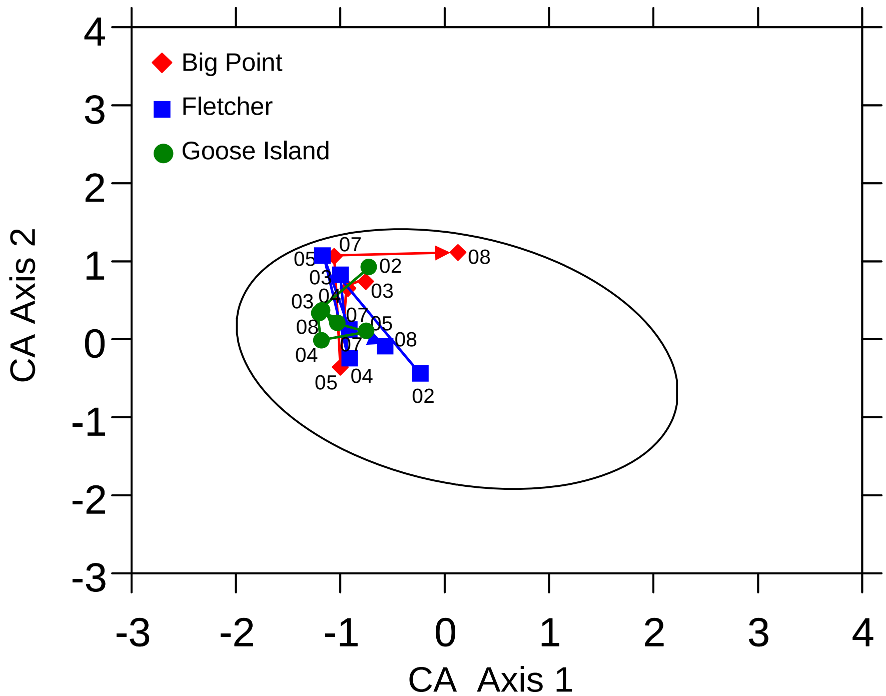
Taxon	Percent Major Taxa Enumerated in Each Year																
	Big Point Channel					Fletcher Channel						Goose Island Channel					
	2003	2004	2005	2007	2008	2002	2003	2004	2005	2007	2008	2002	2003	2004	2005	2007	2008
Amphipoda		<1	2														
Anisoptera	<1	<1	<1	<1	<1		<1	<1	<1	<1		<1	<1	<1		<1	<1
Bivalvia	10	1	8	37	12	1	13	3	3	2	1	13	4	2	3	2	4
Ceratopogonidae	1	<1	7	1	1	2	10	5	2	8	6	1	17	3	2	2	3
Chironomidae	6	40	31	3	11	86	13	27	4	18	52	74	28	64	13	24	27
Copepoda				<1								<1			1		<1
Empididae					<1	<1											
Ephemeroptera	<1	<1	1	<1		<1	1	<1	<1	<1	<1			<1	<1		1
Erpobdellidae		<1															
Gastropoda	4	<1	1	2	12	1	14	<1	2	1	1	5	11	<1	<1	1	24
Heteroptera	<1	<1					<1	<1					<1				
Hydracarina	<1				<1				<1			<1	<1		<1		
Lumbriculidae													<1	<1			
Macrothricidae						<1			<1			<1	2		2		
Megaloptera		<1															
Naididae	1	<1	2	1	<1	<1	15	3		2	1			<1	7	2	<1
Nematoda	<1	<1	1	1	7	5	5	<1	<1	1	22	5		<1	2	2	1
Ostracoda	<1	2	2	<1	<1	3	2	4	4	1	7	1	9	3	8	9	2
Plecoptera				<1	<1				<1								
Tabanidae							<1										
Tipulidae	<1																
Trichoptera	1	2	1	1	4		<1	<1	2	1		<1				1	2
Tubificidae	75	52	46	54	52	2	26	58	81	66	10	<1	27	27	62	57	36
Benthic Invertebrate Community Measurement Endpoints																	
Total Abundance (No./m^2)	11,552	103,983	4,757	64,933	32,419	11,897	8,328	27,207	10,843	13,055	20,696	36,000	2,914	35,776	12,243	15,348	8,270
Richness	11	12	10	15	12	12	11	9	10	11	12	14	10	11	11	12	11
Simpson's Diversity	0.42	0.59	0.63	0.54	0.73	0.53	0.78	0.56	0.33	0.52	0.66	0.54	0.79	0.66	0.61	0.61	0.73
Evenness	0.46	0.64	0.77	0.57	0.81	0.58	0.86	0.63	0.37	0.57	0.74	0.58	0.89	0.73	0.67	0.67	0.84
% EPT	1	2	1	1	19	1	1	<1	3	<1	<1	<1	0	<1	<1	1	2

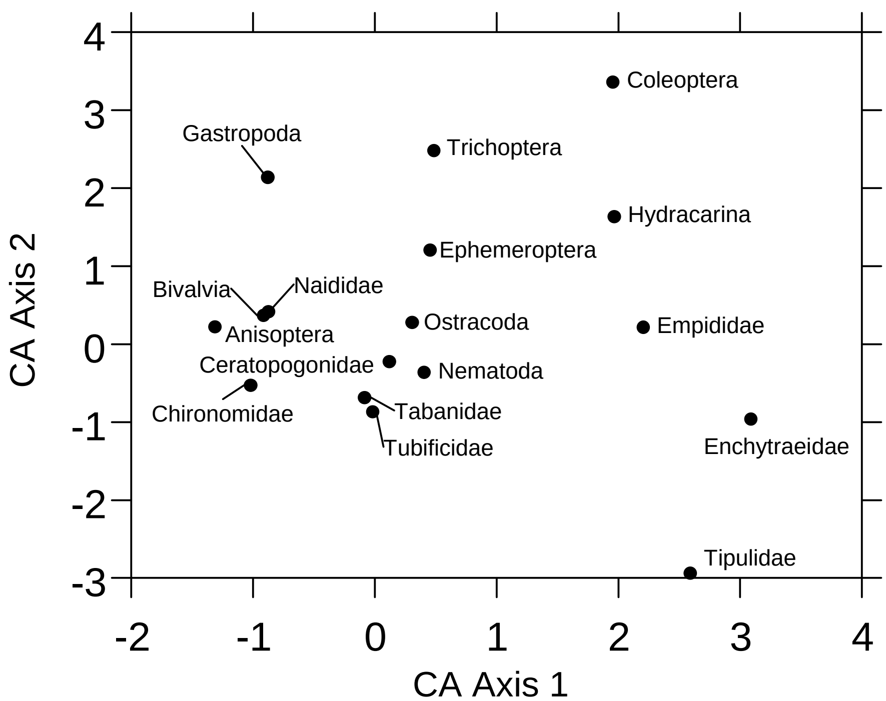
Figure 5.1-10 Variation in benthic invertebrate community measurement endpoints in the Athabasca River Delta between 2002 and 2008.



Note: Dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* depositional reaches in the RAMP FSA.

Figure 5.1-11 Ordination (Correspondence Analysis) of depositional benthic invertebrate communities in the Athabasca River Delta.





Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* depositional sites in the RAMP FSA.

Note: the numbers in the upper panel refer to the sampling year for each data point.

Table 5.1-11 Concentrations of sediment quality measurement endpoints, Athabasca River mainstem upstream of Embarras River (ATR-ER).

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	13	7	10	14	22
Silt	%	-	36	7	29	32	42
Sand	%	-	51	7	36	56	61
Total organic carbon	%	-	1.7	7	0.8	1.1	1.6
Total hydrocarbons							
BTEX	mg/kg	-	<5	3	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	3	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	39	3	11	24	28
Fraction 3 (C16-C34)	mg/kg	300[2]	**570**	3	220	260	**330**
Fraction 4 (C34-C50)	mg/kg	2800[2]	340	3	180	190	240
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.008	7	0.005	0.008	0.037
Retene	mg/kg	-	0.078	7	0.031	0.040	0.081
Total dibenzothiophenes	mg/kg	-	0.749	7	0.092	0.225	0.347
Total PAHs	mg/kg	-	2.482	7	0.816	1.107	1.689
Total Parent PAHs	mg/kg	-	0.127	7	0.084	0.110	0.156
Total Alkylated PAHs	mg/kg	-	2.355	7	0.660	1.017	1.579
Predicted PAH toxicity[1]	H.I.	-	0.773	7	0.408	1.064	1.544
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	3	7	7.4	8
Chironomus growth - 10d	mg/organism	-	1.2	3	2.1	2.2	3.5
Hyalella survival - 14d	# surviving	-	9	1	-	-	10
Hyalella growth - 14d	mg/organism	-	0.3	1	-	-	0.09

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

ns= not sampled

Table 5.1-12 Concentrations of sediment quality measurement endpoints, Goose Island Channel (GIC-1).

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only GIC-1)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	10.6	5	14.6	20	28
Silt	%	-	31.4	5	46	51.4	58
Sand	%	-	57.8	5	17	29	34
Total organic carbon	%	-	1.46	5	1.1	1.7	2.1
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	8	2	<5	11	17
Fraction 3 (C16-C34)	mg/kg	300[2]	280	2	180	270	**360**
Fraction 4 (C34-C50)	mg/kg	2800[2]	88	2	110	155	200
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.009	5	0.005	0.009	0.015
Retene	mg/kg	-	0.056	5	0.027	0.044	0.078
Total dibenzothiophenes	mg/kg	-	0.405	5	0.202	0.223	0.412
Total PAHs	mg/kg	-	1.680	5	1.016	1.239	2.161
Total Parent PAHs	mg/kg	-	0.126	5	0.082	0.121	0.177
Total Alkylated PAHs	mg/kg	-	1.554	5	0.935	1.126	1.984
Predicted PAH toxicity[1]	H.I.	-	1.316	5	0.959	1.136	1.182
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	3	4	7	8
Chironomus growth - 10d	mg/organism	-	1.3	3	2.6	2.7	4.2
Hyalella survival - 14d	# surviving	-	9	1	-	-	9
Hyalella growth - 14d	mg/organism	-	0.3	1	-	-	0.11

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 5 replicates.

ns= not sampled

Table 5.1-13 Concentrations of sediment quality measurement endpoints, Fletcher Channel (FLC-1).

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	10	5	12	14.8	18
Silt	%	-	21.8	5	18	38	52.8
Sand	%	-	68.2	5	32.4	44	70
Total organic carbon	%	-	0.86	5	0.6	1.3	1.6
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	17.5	30
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	17.5	30
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	2	18	20.5	23
Fraction 3 (C16-C34)	mg/kg	300[2]	110	2	290	**360**	**430**
Fraction 4 (C34-C50)	mg/kg	2800[2]	53	2	170	225	280
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.003	5	0.005	0.009	0.011
Retene	mg/kg	-	0.0197	5	0.021	0.044	0.048
Total dibenzothiophenes	mg/kg	-	0.132	5	0.147	0.185	0.260
Total PAHs	mg/kg	-	0.594	5	0.837	1.213	1.357
Total Parent PAHs	mg/kg	-	0.048	5	0.087	0.100	0.109
Total Alkylated PAHs	mg/kg	-	0.546	5	0.747	1.113	1.247
Predicted PAH toxicity[1]	H.I.	-	1.034	5	0.494	0.777	0.910
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	3	6	6	7
Chironomus growth - 10d	mg/organism	-	2.0	3	2.6	2.8	3.6
Hyalella survival - 14d	# surviving	-	10	1	9.6	9.6	9.6
Hyalella growth - 14d	mg/organism	-	0.3	1	0.11	0.11	0.11

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 5 replicates.

ns = not sampled

Table 5.1-14 Concentrations of sediment quality measurement endpoints, Big Point Channel (BPC-1).

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	12.2	7	10	19.2	32
Silt	%	-	41.6	7	26	45	64
Sand	%	-	46.2	7	10	37.2	64
Total organic carbon	%	-	1.1	7	<0.1	1.2	1.76
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	2	<5	14	23
Fraction 3 (C16-C34)	mg/kg	300[2]	110	2	190	200	210
Fraction 4 (C34-C50)	mg/kg	2800[2]	33	2	100	110	120
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.007	7	0.005	0.012	0.024
Retene	mg/kg	-	0.044	6	0.041	0.052	0.096
Total dibenzothiophenes	mg/kg	-	0.311	7	0.15001	0.221	0.27
Total PAHs	mg/kg	-	1.374	7	1.045	1.322	1.54
Total Parent PAHs	mg/kg	-	0.106	7	0.096	0.107	0.21
Total Alkylated PAHs	mg/kg	-	1.268	7	0.945	1.219	1.33
Predicted PAH toxicity[1]	H.I.	-	2.69	7	0.912	1.192	1.46
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	5	3.2	7	9
Chironomus growth - 10d	mg/organism	-	1.8	5	0.89	2	3.6
Hyalella survival - 14d	# surviving	-	8	1	-	-	9
Hyalella growth - 14d	mg/organism	-	0.2	1	-	-	0.12

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

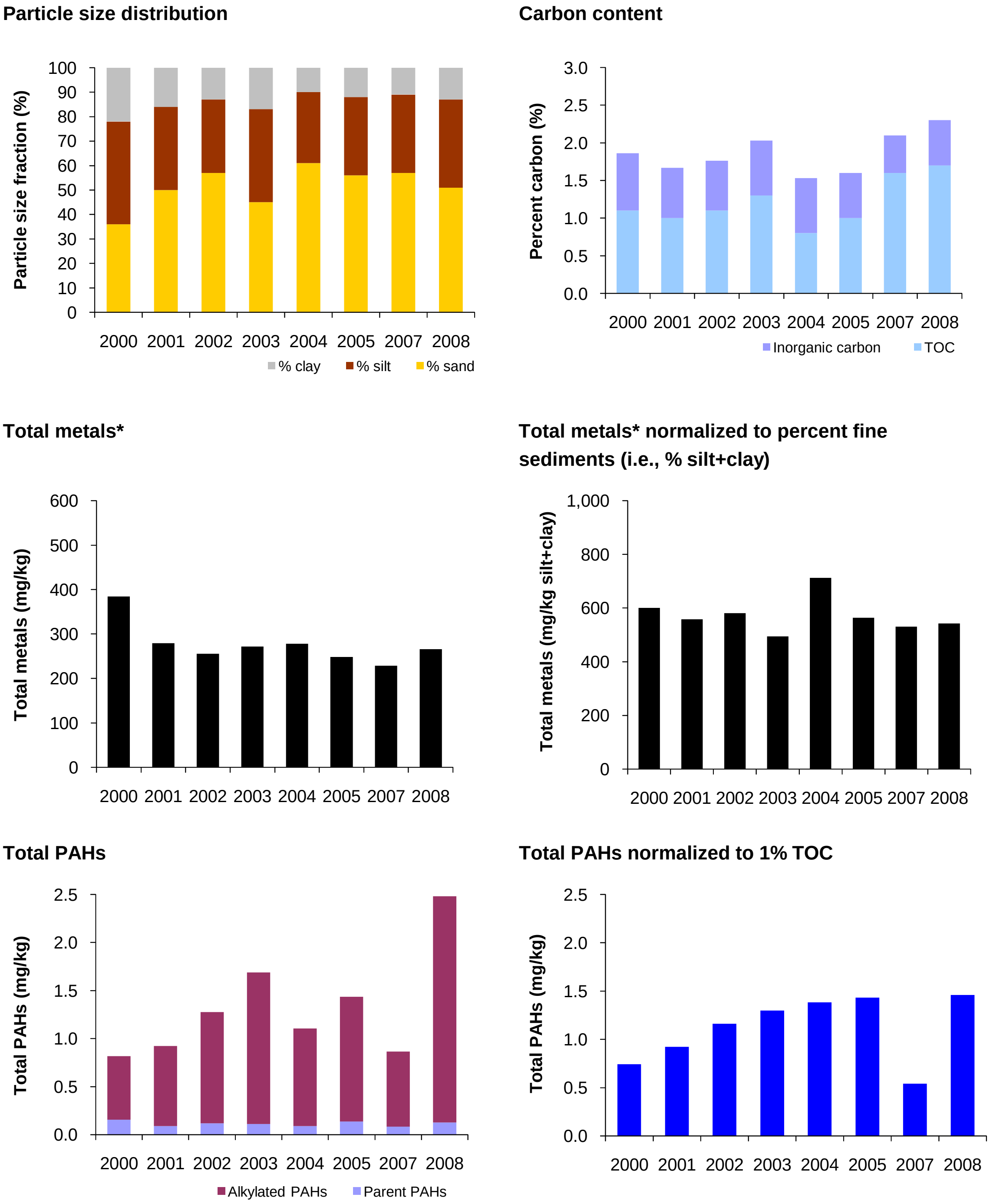
[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 5 replicates.

ns= not sampled

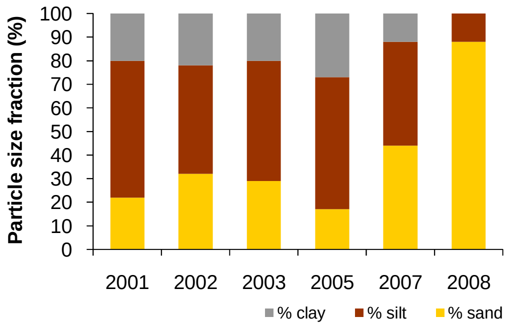
Figure 5.1-12 Characteristics of sediment collected in the Athabasca River upstream of Embarras River, 2000-2008 (fall data only).



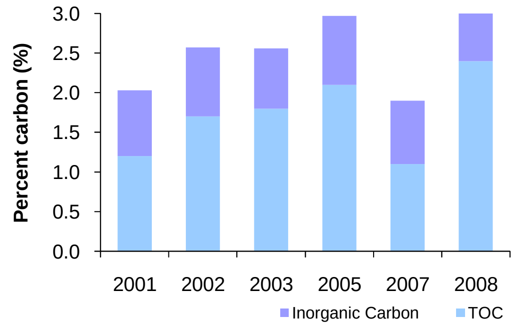
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Tl, U, V, Zn (measured in all years).

Figure 5.1-13 Characteristics of sediment collected in Goose Island Channel (GIC-1), 2001-2008 (fall data only).

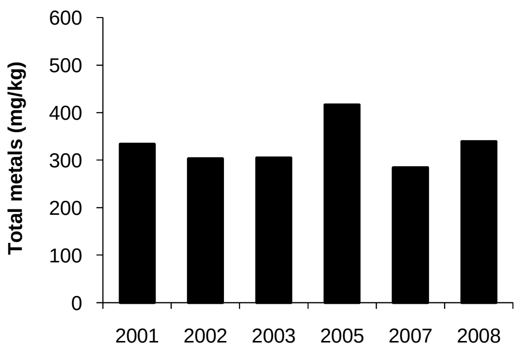
Particle size distribution



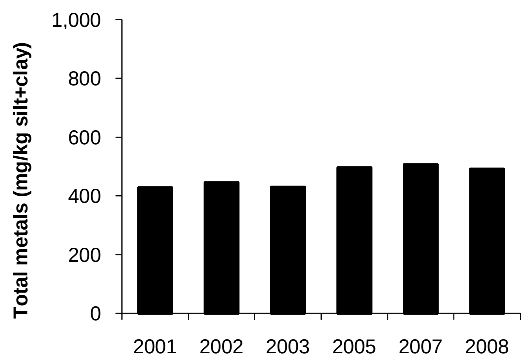
Carbon content



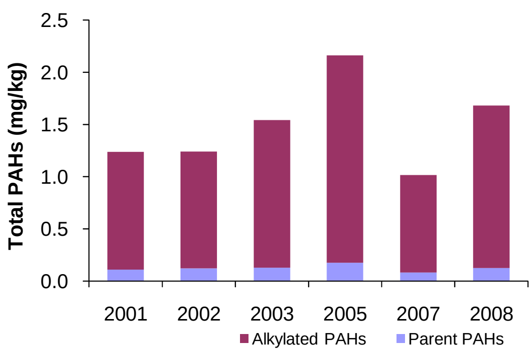
Total metals*



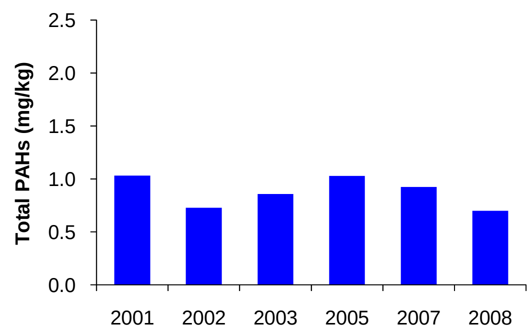
Total metals* normalized to percent fine sediments (i.e., % silt+clay)



Total PAHs

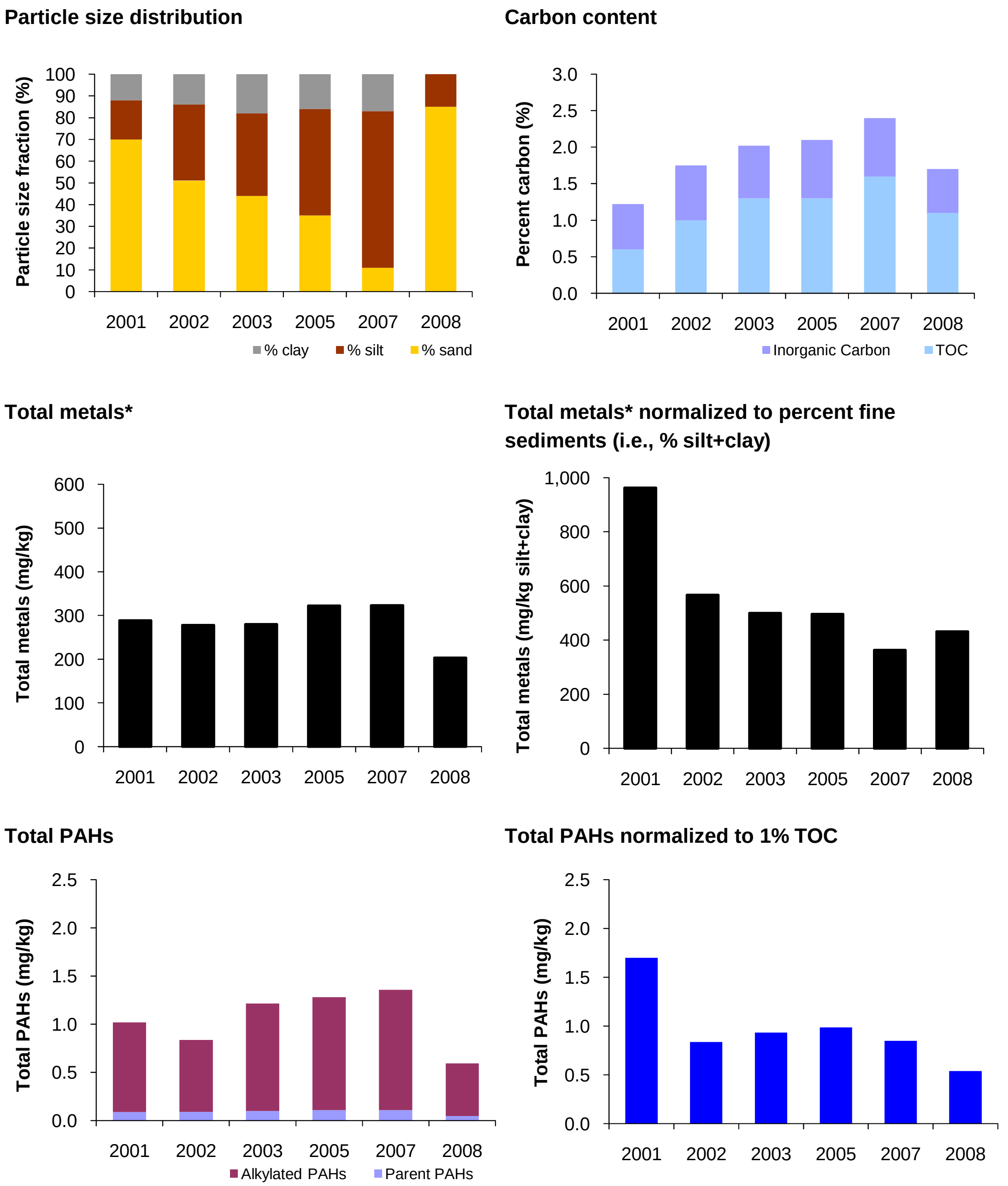


Total PAHs normalized to 1% TOC



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

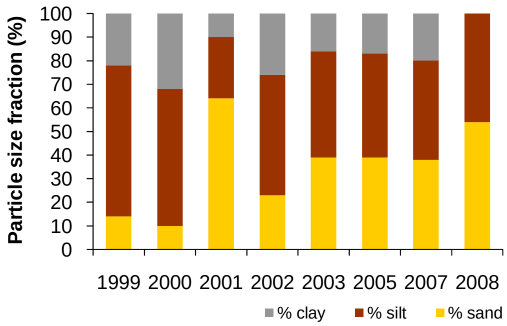
Figure 5.1-14 Characteristics of sediment collected in Fletcher Channel (FLC-1), 2001-2008 (fall data only).



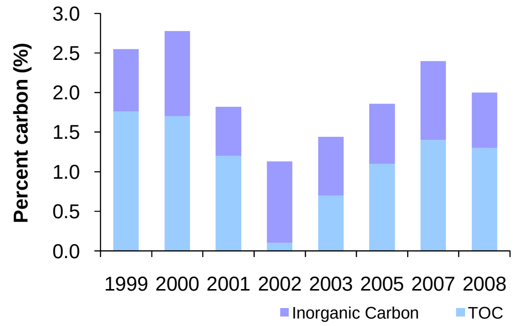
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Tl, U, V, Zn (measured in all years).

Figure 5.1-15 Characteristics of sediment collected in Big Point Channel (BPC-1), 1999-2008 (fall data only).

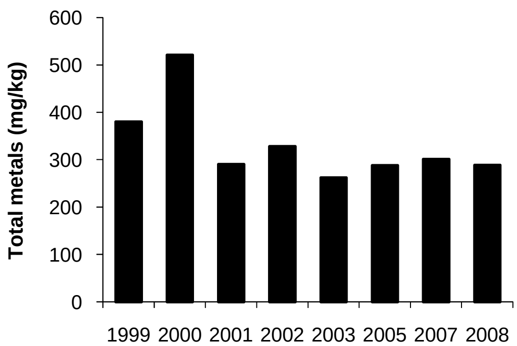
Particle size distribution



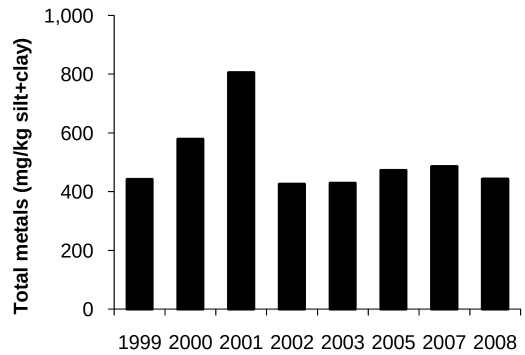
Carbon content



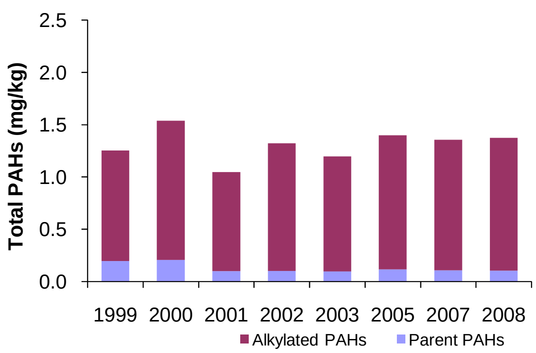
Total metals*



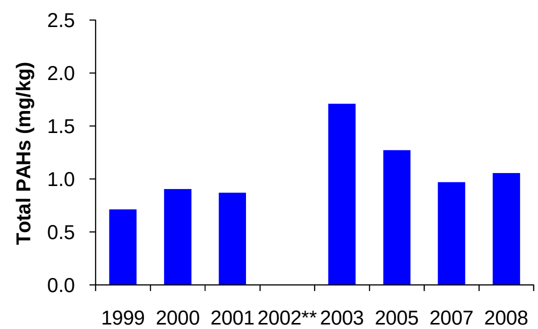
Total metals* normalized to percent fine sediments (i.e., % silt+clay)



Total PAHs



Total PAHs normalized to 1% TOC



* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, U, V, Zn (measured in all years).
** Non-detectable level of total organic carbon in 2002 (<0.1%).

Figure 5.1-16 Concentrations of total PAHs in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2008.

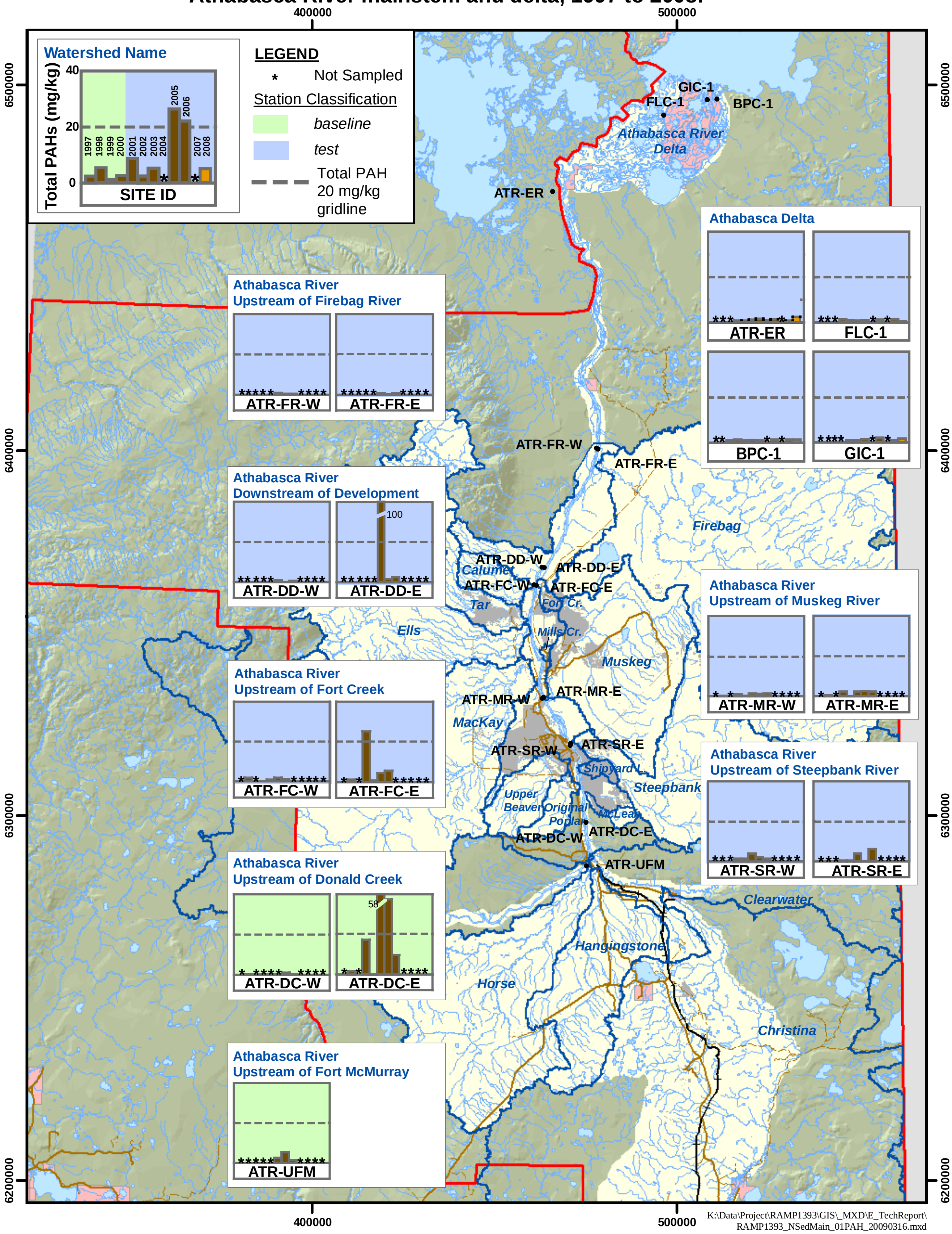


Figure 5.1-17 Carbon-normalized concentrations of total PAHs in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2008.

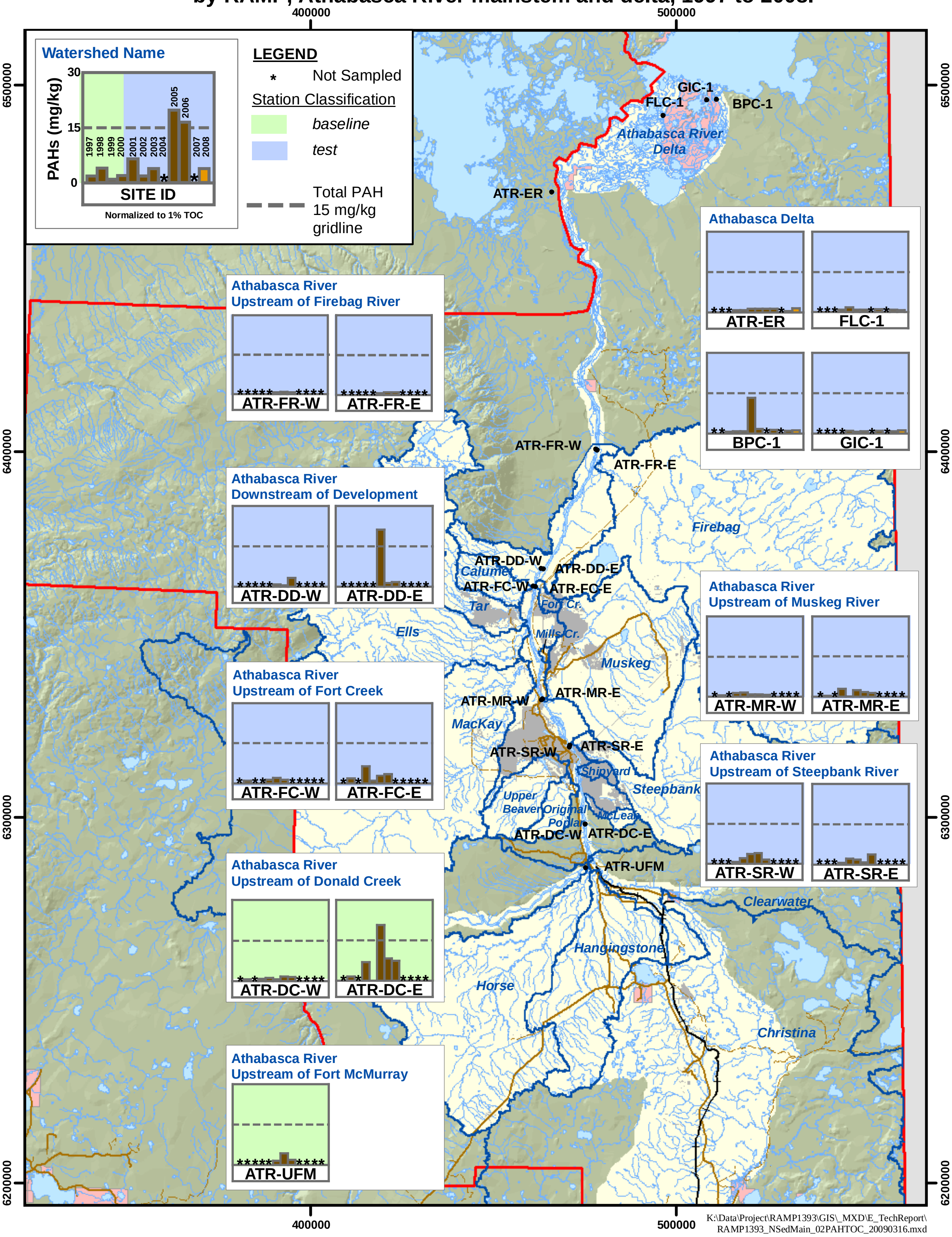


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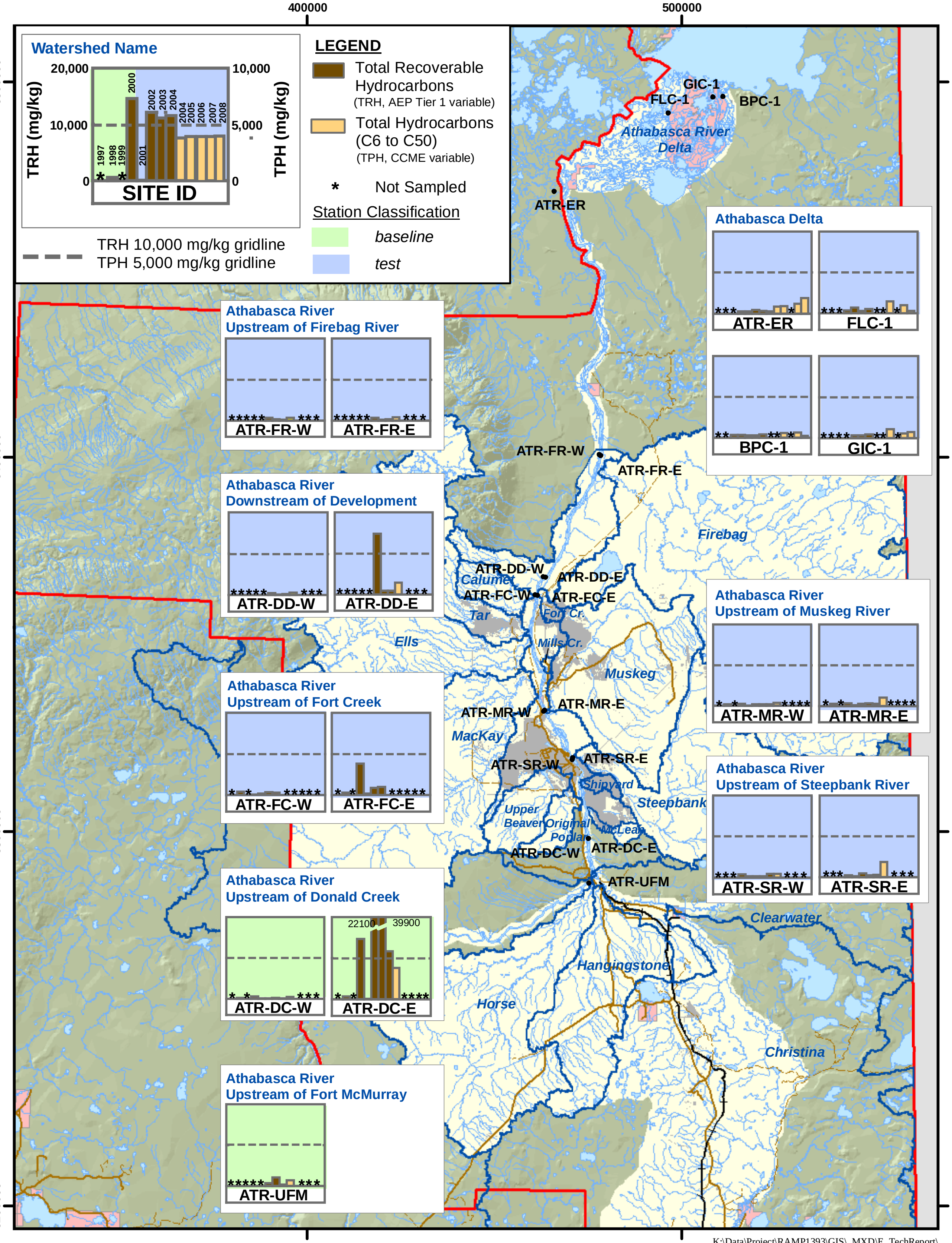
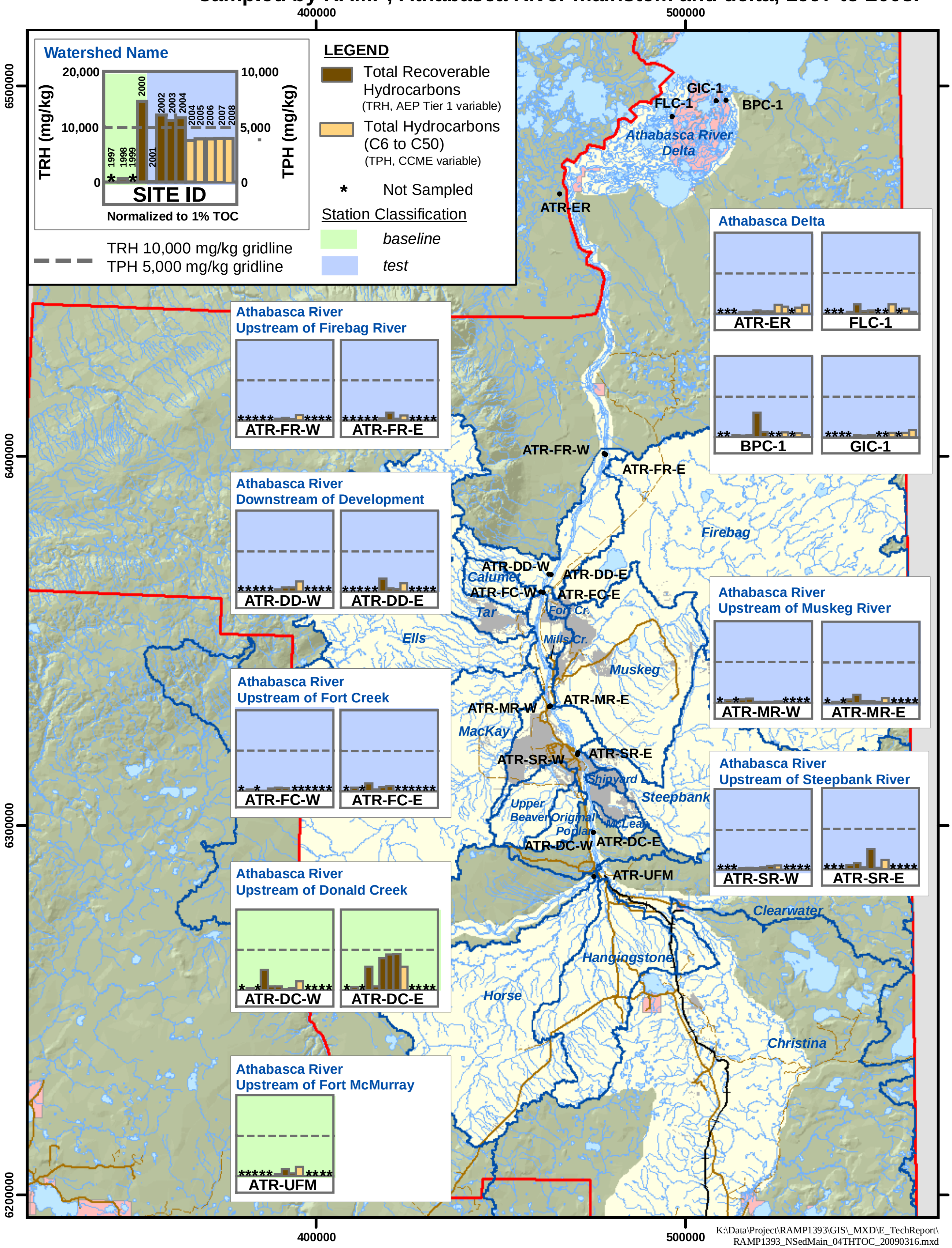
Figure 5.1-18 Concentrations of total hydrocarbons in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2008.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_NSedMain_03TH_20090316.mxd

Figure 5.1-19 Carbon-normalized concentrations of total hydrocarbons in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2008.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_NSedMain_04THTOC_20090316.mxd

Figure 5.1-20 Concentrations of total arsenic in sediments sampled by RAMP, Athabasca River mainstem and delta, 1997 to 2008.

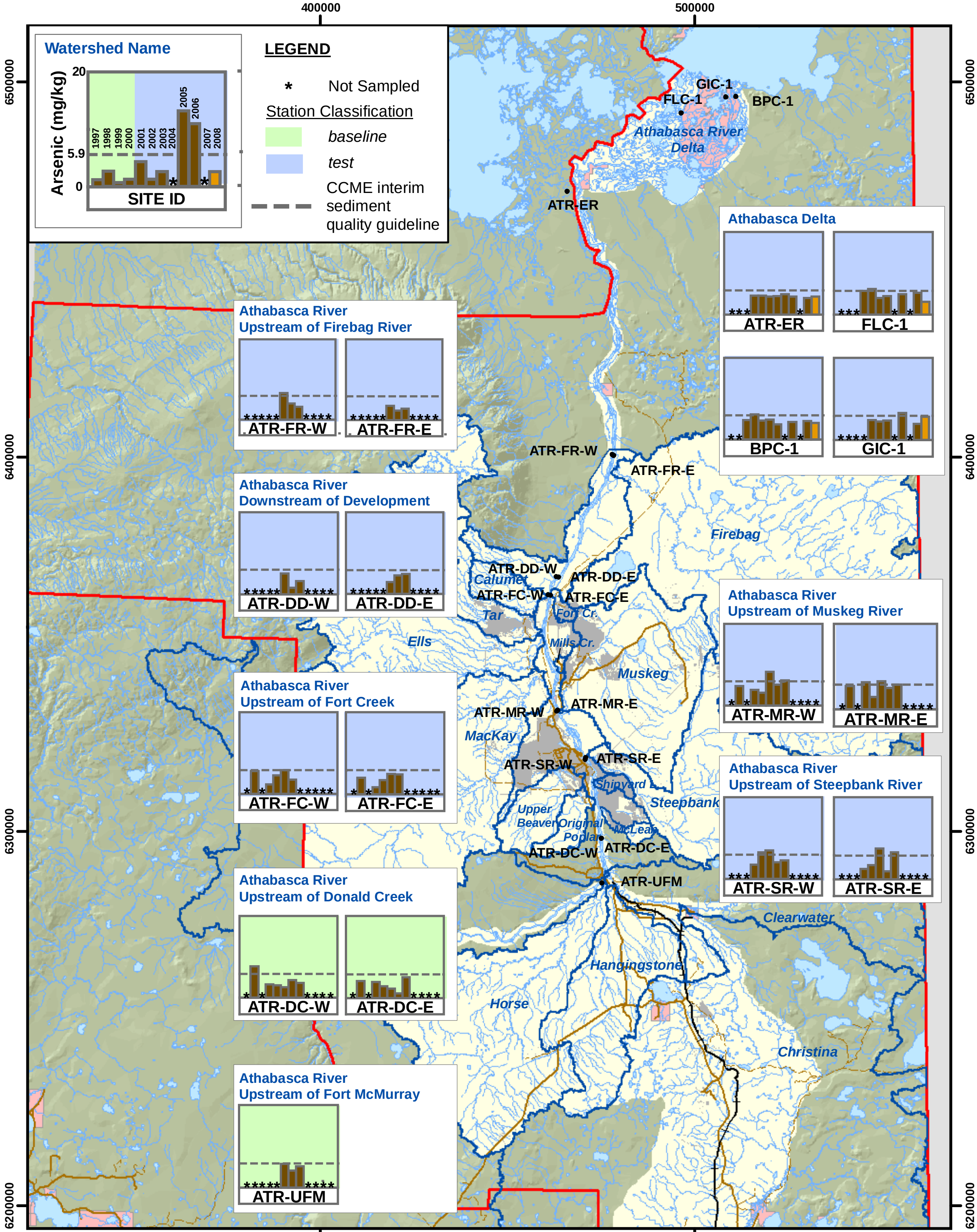


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Table 5.1-15 Sediment quality index (fall 2008) for Athabasca Delta stations.

Station Identifier	Location	2008 Designation	Sediment Quality Index	Classification
GIC-1	Athabasca Delta, Goose Island Channel	*test*	89.9	Negligible-Low
BPC-1	Athabasca Delta, Big Point Channel	*test*	98.9	Negligible-Low
FLC-1	Athabasca Delta, Fletcher Channel	*test*	100.0	Negligible-Low
ATR-ER	Athabasca River at mouth of Embarass River	*test*	100.0	Negligible-Low

Table 5.1-16 Athabasca River fish inventory results, spring, summer, fall 2008.

Species	Spring		Summer		Fall	
	No. Captured	% Total Catch	No. Captured	% Total Catch	No. Captured	% Total Catch
Brook stickleback	1	0.07	0	0.00	0	0.00
Burbot	5	0.33	3	0.18	1	0.06
Emerald shiner	41	2.72	43	2.53	24	1.38
Flathead chub	50	3.32	285	16.76	52	3.00
Finescale dace	5	0.33	0	0.00	0	0.00
Fathead minnow	1	0.07	0	0.00	0	0.00
Goldeye	128	8.50	760	44.71	261	15.06
Lake chub	7	0.47	169	9.94	16	0.92
Lake whitefish	11	0.73	22	1.29	545	31.45
Longnose dace	0	0.00	2	0.12	0	0.00
Longnose sucker	49	3.26	60	3.53	31	1.79
Mountain whitefish	3	0.20	1	0.06	2	0.12
Northern pike	22	1.46	17	1.00	19	1.10
Pearl dace	0	0.00	18	1.06	0	0.00
Sculpin sp.	0	0.00	2	0.12	0	0.00
Slimy sculpin	0	0.00	1	0.06	0	0.00
Spoonhead sculpin	1	0.07	1	0.06	1	0.06
Spottail shiner	0	0.00	14	0.82	8	0.46
Trout-perch	334	22.19	163	9.59	526	30.35
Walleye	306	20.33	107	6.29	140	8.08
White sucker	539	35.81	25	1.47	106	6.12
Yellow perch	1	0.07	7	0.41	1	0.06
Sucker sp.	1	0.07	0	0.00	0	0.00
Total	**1505**	**100**	**1700**	**100**	**1733**	**100**

Figure 5.1-21 Percent composition of large-bodied species, Athabasca River spring inventory, 1997-2008.

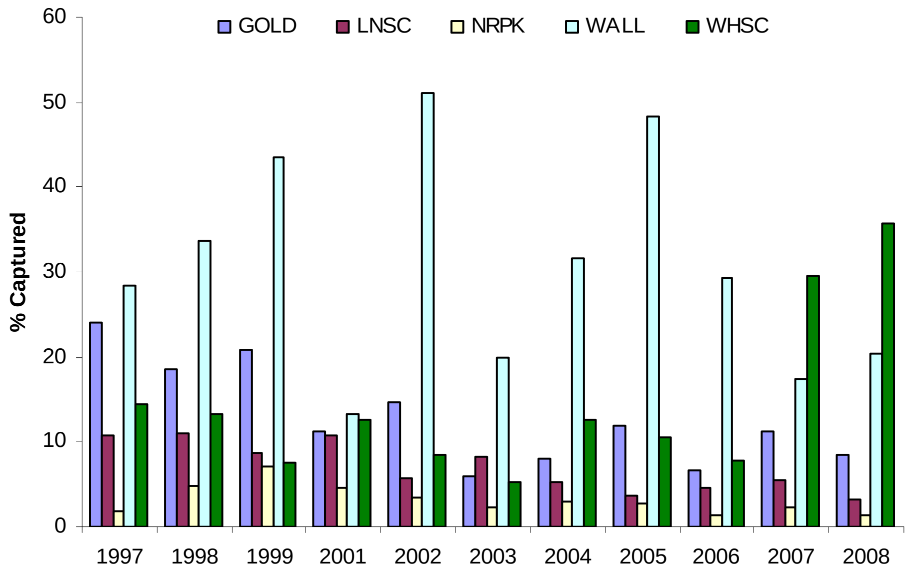


Figure 5.1-22 Percent composition of large-bodied species, Athabasca River summer inventory, 1997-2008.

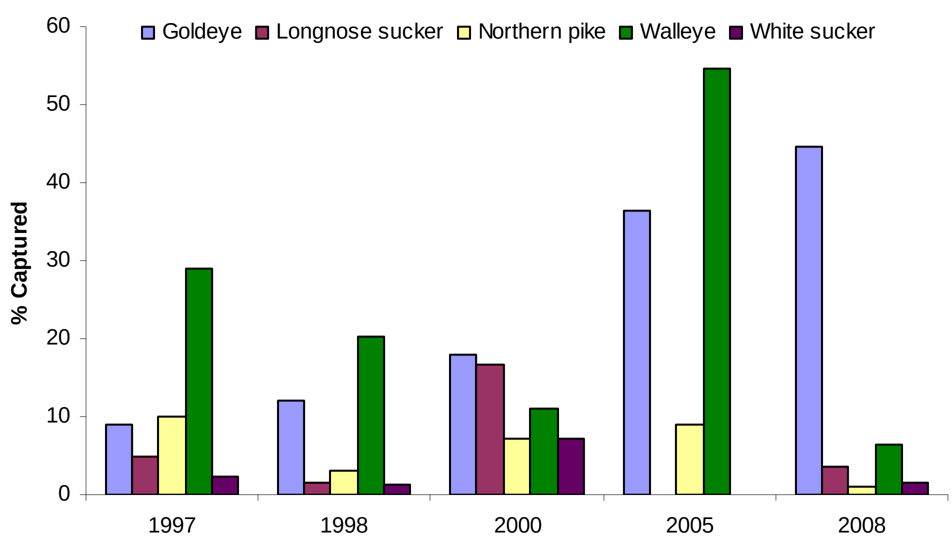


Figure 5.1-23 Percent composition of large-bodied species, Athabasca River, fall inventory, 1997-2008.

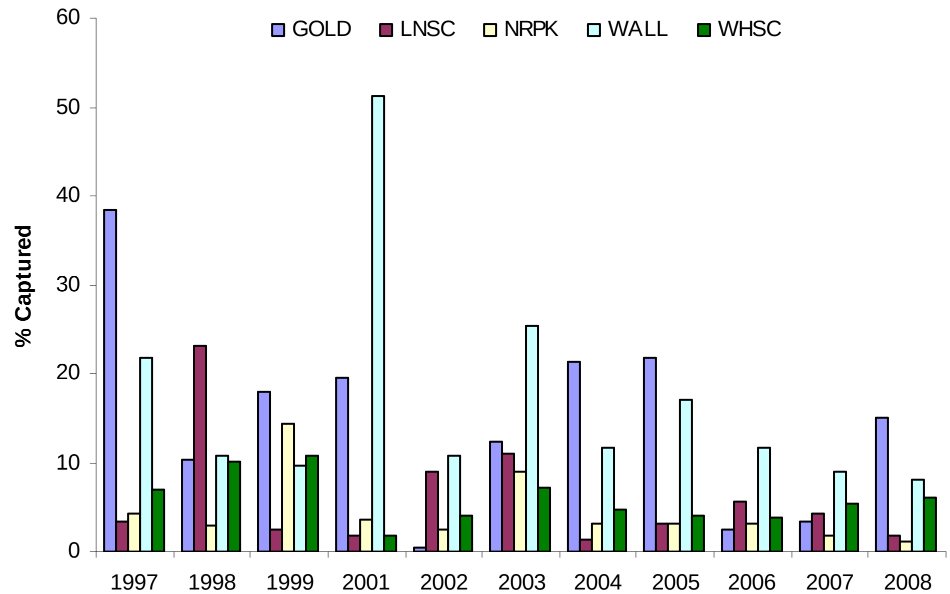


Figure 5.1-24 Percent composition of large-bodied species in each sampled area on the Athabasca River, spring inventory, 2008.

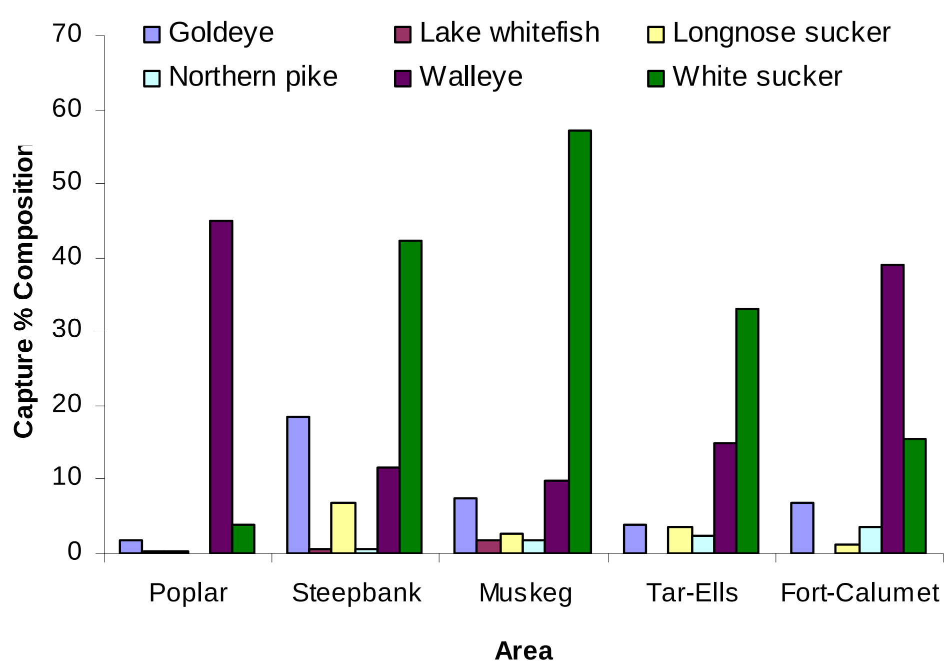


Figure 5.1-25 Percent composition of large-bodied species in each sampled area on the Athabasca River, summer inventory, 2008.

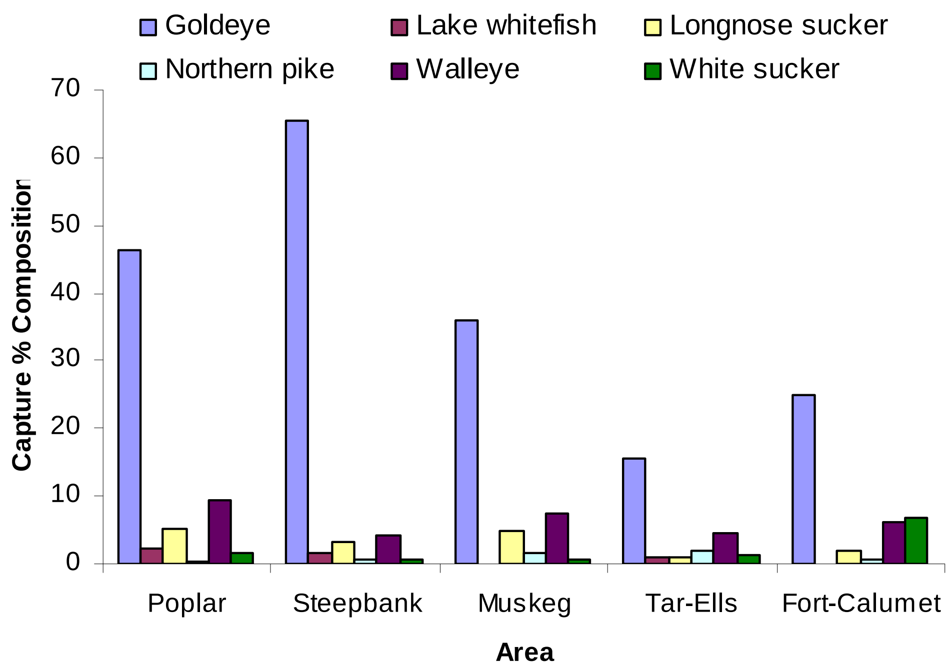


Figure 5.1-26 Percent composition of large-bodied species in each sampled area on the Athabasca River, fall inventory, 2008.

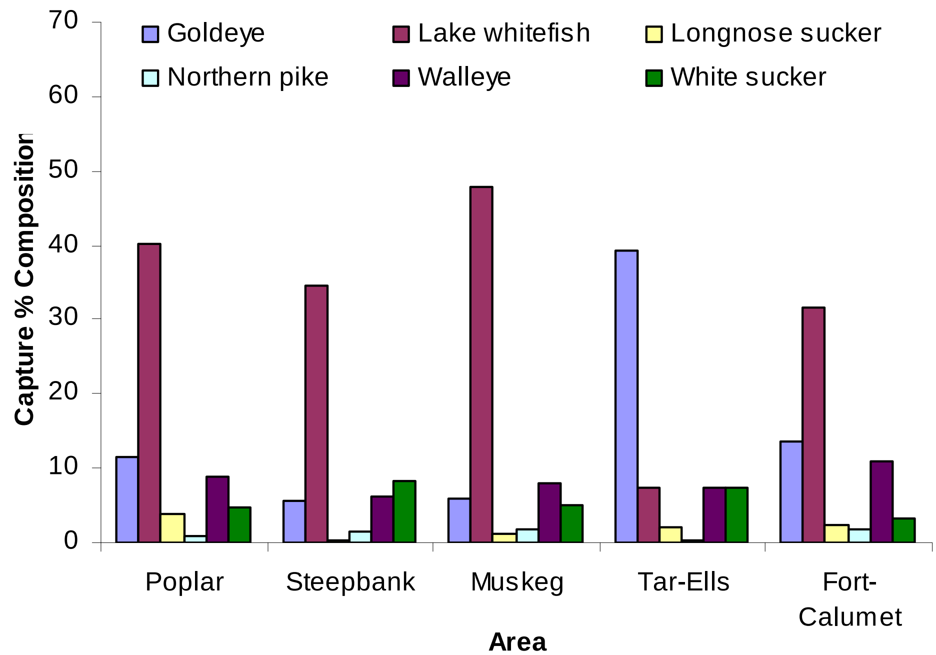


Table 5.1-17 Athabasca River observed but not captured fish inventory results, spring and fall 2008.

Species	Spring	Summer	Fall
Burbot	8	8	1
Emerald shiner	5	4	0
Flathead chub	7	226	4
Goldeye	50	479	83
Lake chub	0	19	0
Lake whitefish	15	1	1,019
Longnose sucker	25	6	6
Mountain whitefish	0	0	0
Northern pike	16	15	7
Spottail shiner	0	0	0
Trout-perch	277	148	322
White sucker	713	15	31
Walleye	114	33	17
Yellow perch	0	0	5
Total	**1,230**	**954**	**1,495**

Figure 5.1-27 Seasonal CPUE (mean ± SE) for captured fish by area, all KIR species combined, Athabasca River spring, summer and fall inventory.

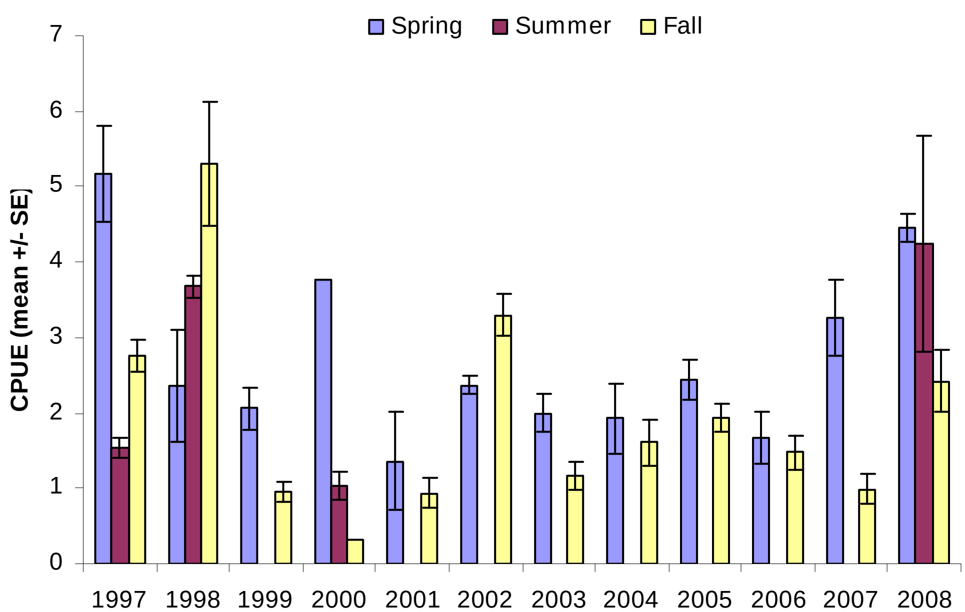
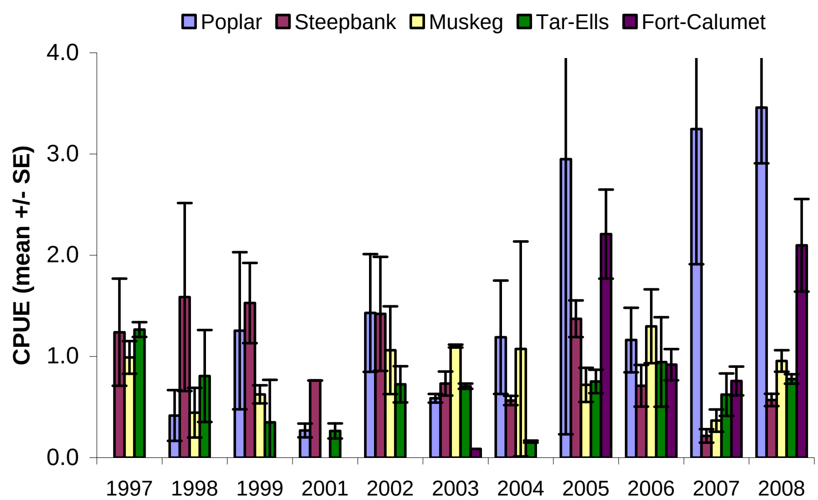
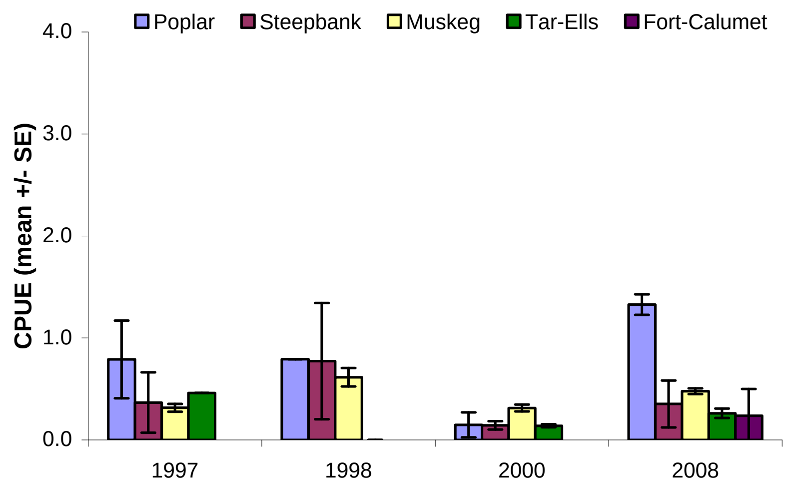


Figure 5.1-28 Seasonal CPUE (mean ± SE) for walleye in each sampled reach on the Athabasca River, spring, summer and fall inventories.

Spring



Summer



Fall

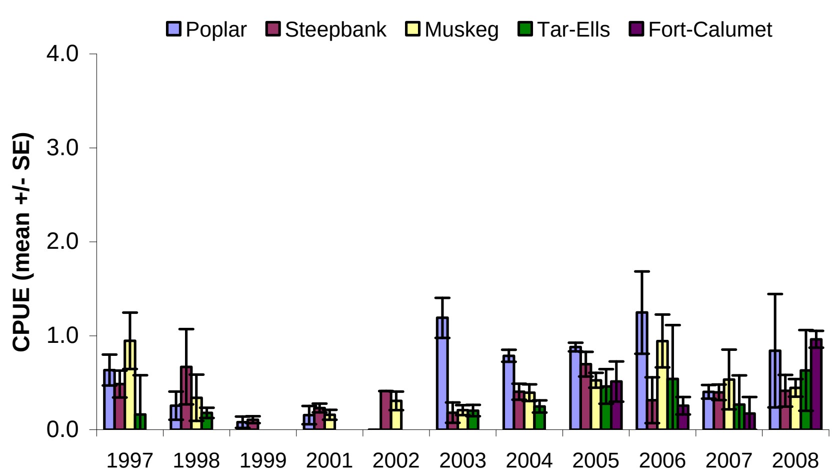
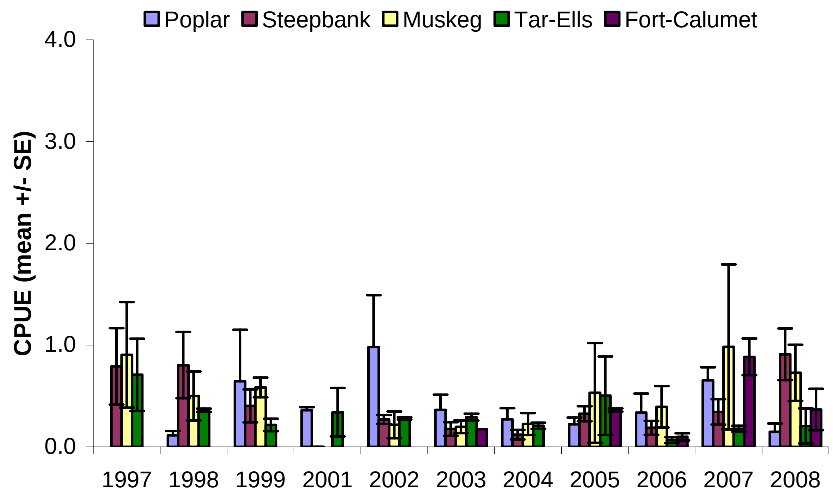
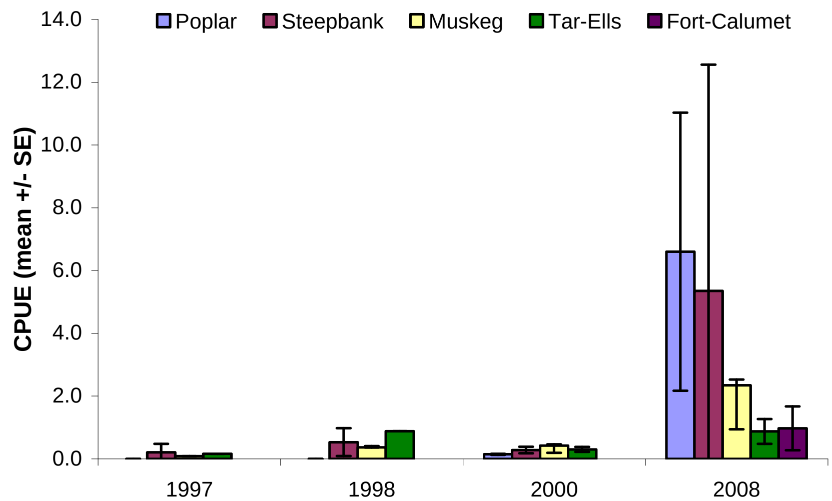


Figure 5.1-29 Seasonal CPUE (mean ± SE) for goldeye in each sampled reach on the Athabasca River, spring, summer and fall inventories.

Spring



Summer



Fall

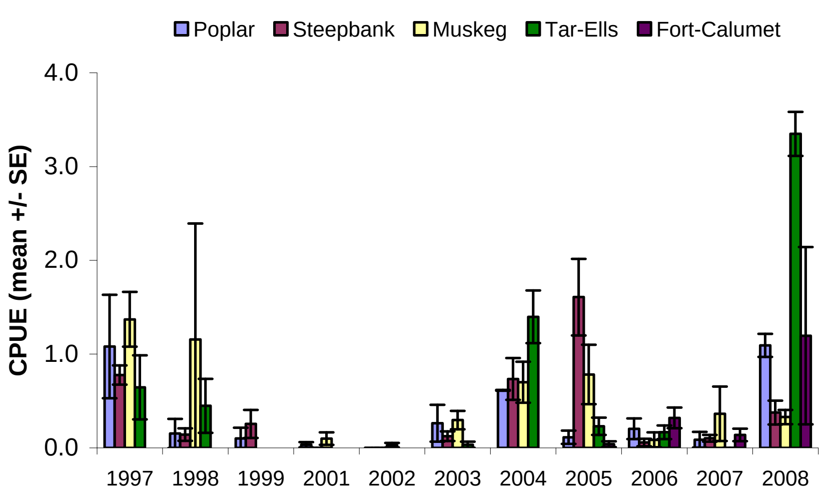
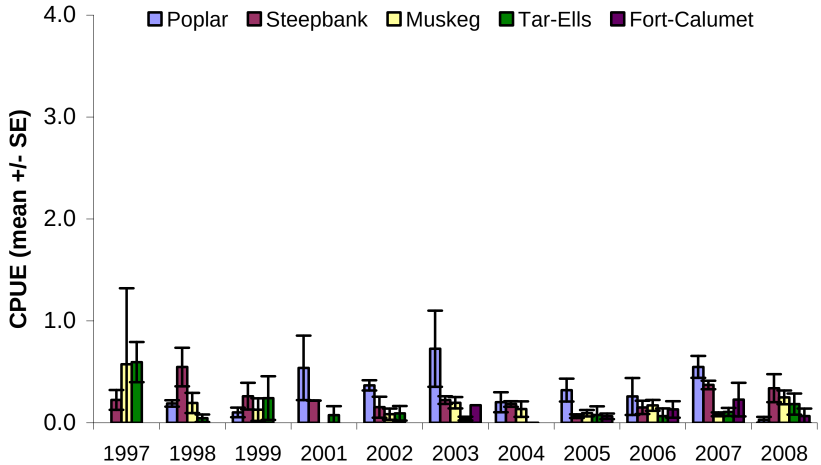
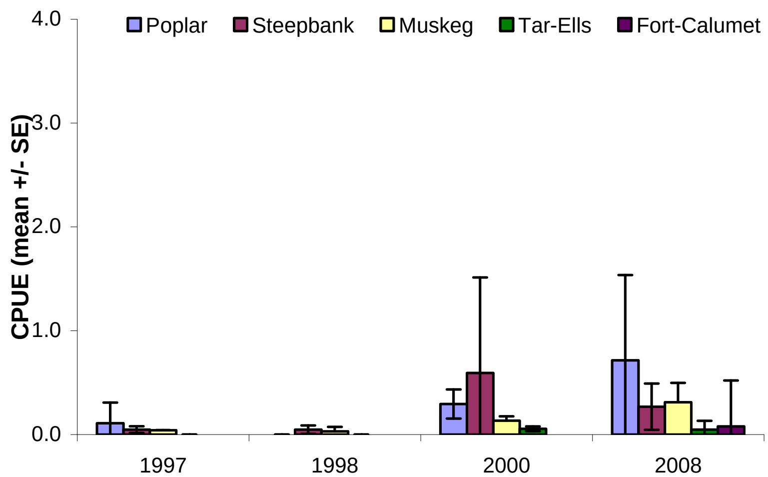


Figure 5.1-30 Seasonal CPUE (mean ± SE) for longnose sucker in each sampled reach on the Athabasca River, spring, summer and fall inventories.

Spring



Summer



Fall

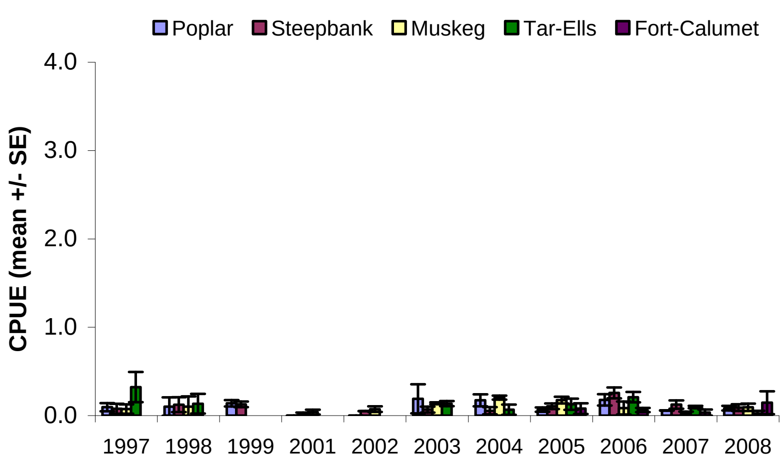
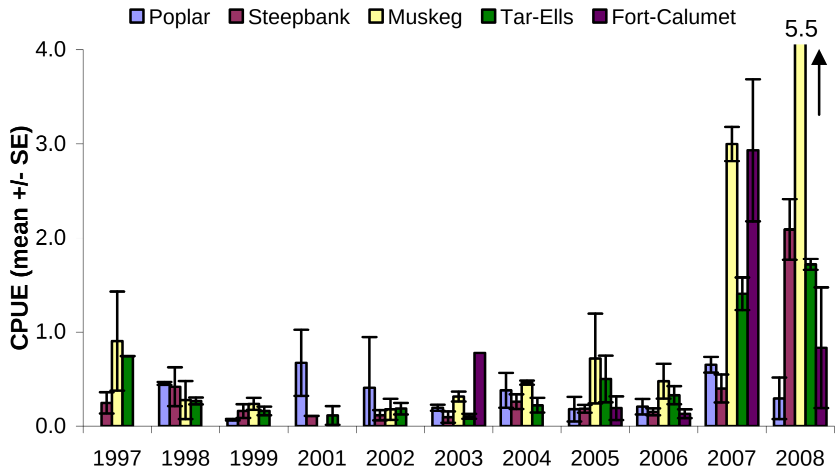
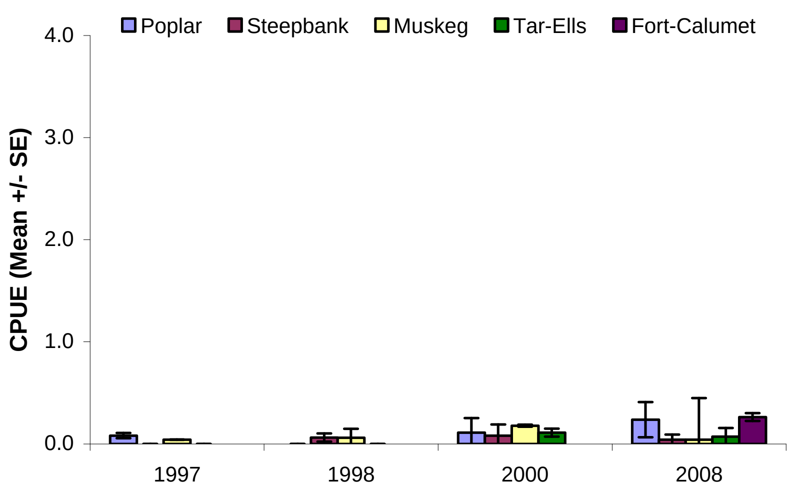


Figure 5.1-31 Seasonal CPUE (mean ± SE) for white sucker in each sampled reach on the Athabasca River, spring, summer and fall inventories.

Spring



Summer



Fall

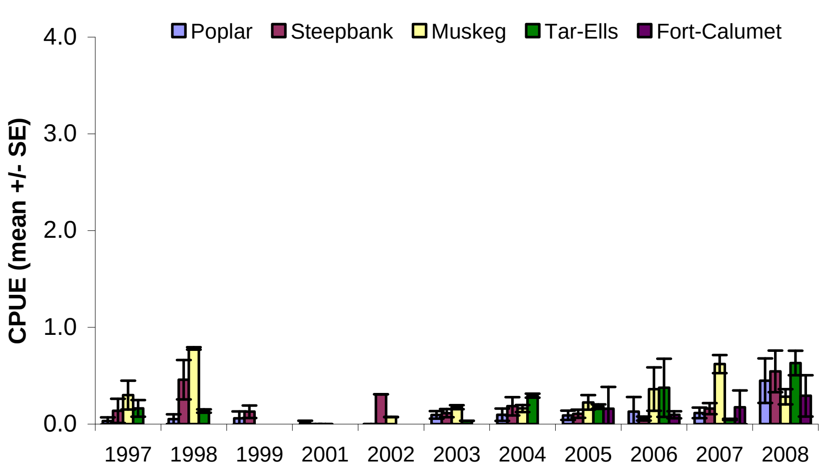
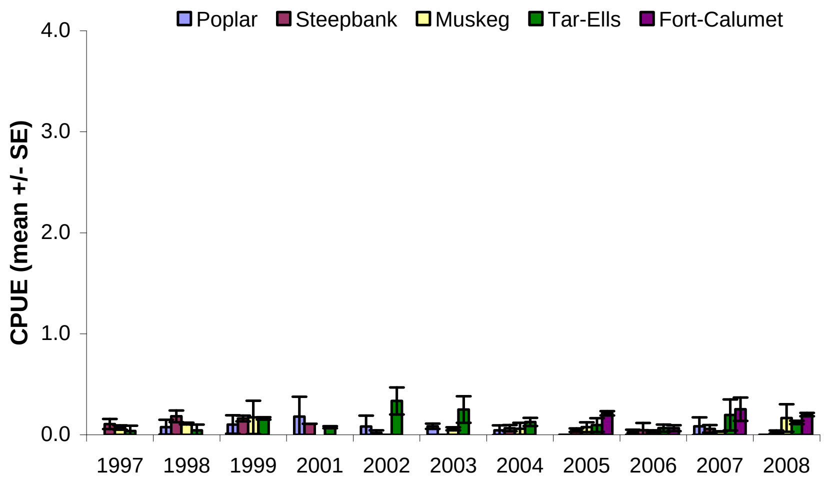
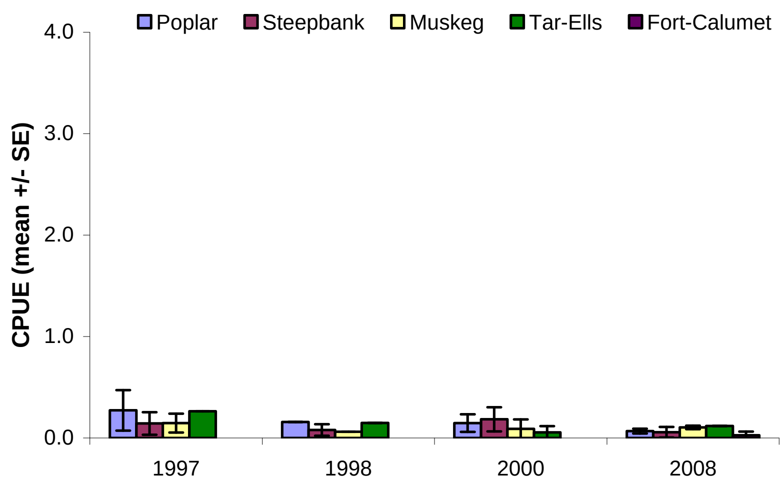


Figure 5.1-32 Seasonal CPUE (mean ± SE) for northern pike in each sampled reach on the Athabasca River, spring, summer and fall inventories.

Spring



Summer



Fall

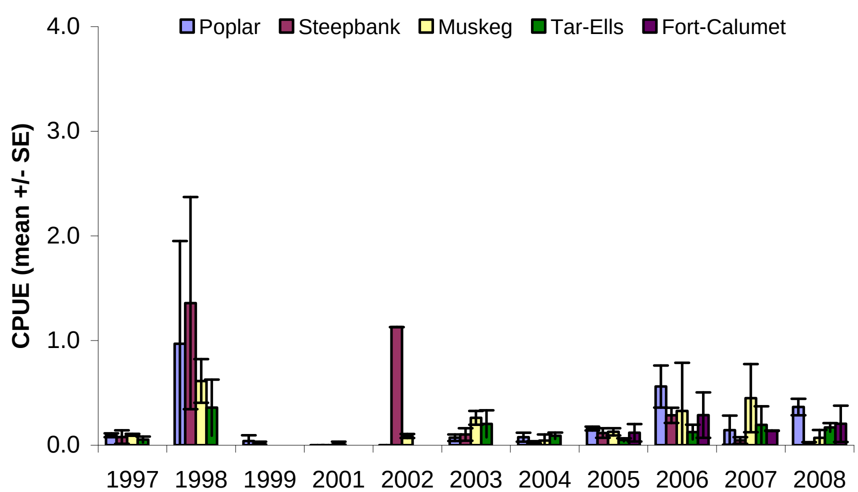


Figure 5.1-33 Relative age-frequency distributions for walleye captured in the Athabasca River, spring and fall 1989-2008.

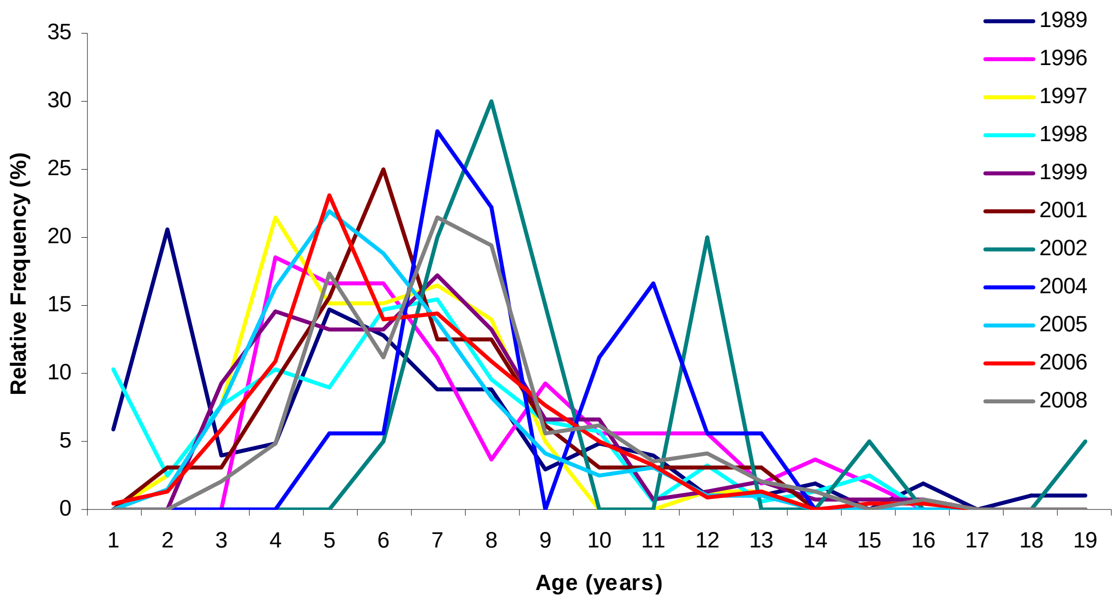


Figure 5.1-34 Relative age-frequency distributions for northern pike captured in the Athabasca River, spring and fall 1996-2008.

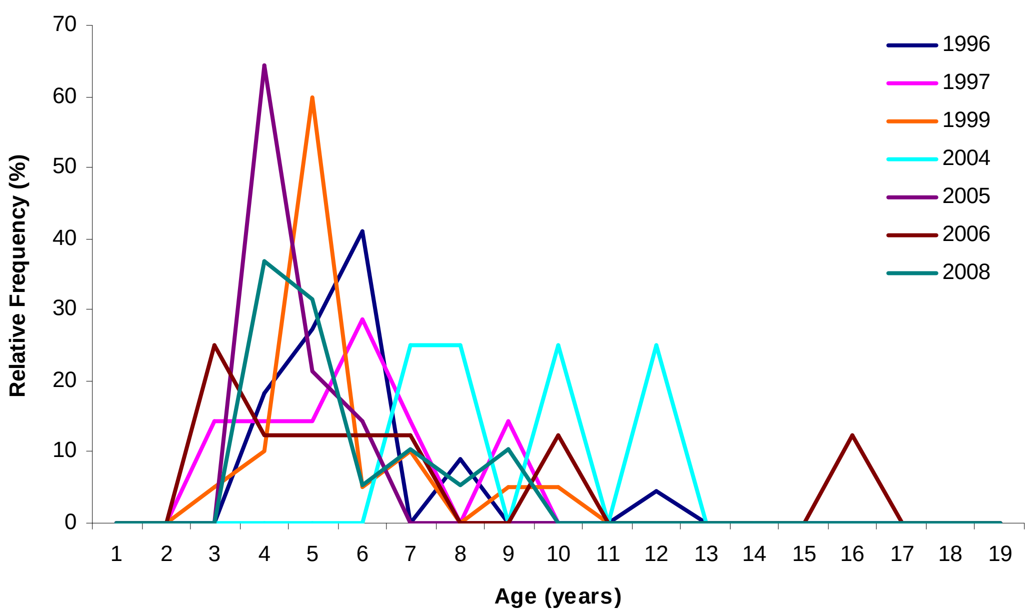


Figure 5.1-35 Relative length-frequency distributions for walleye captured in the Athabasca River, spring and fall, 1997-2008.

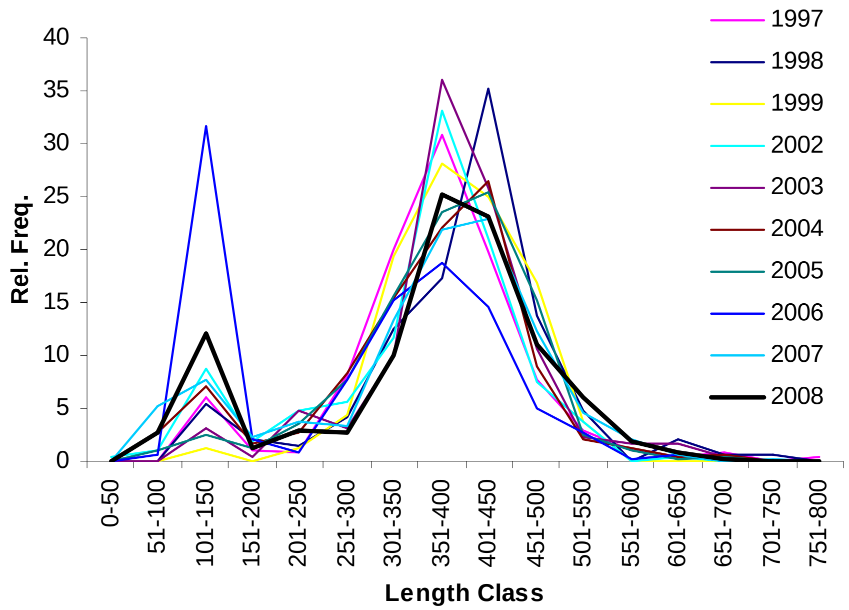


Figure 5.1-36 Relative length-frequency distributions for goldeye captured in the Athabasca River, spring and fall, 1997-2008.

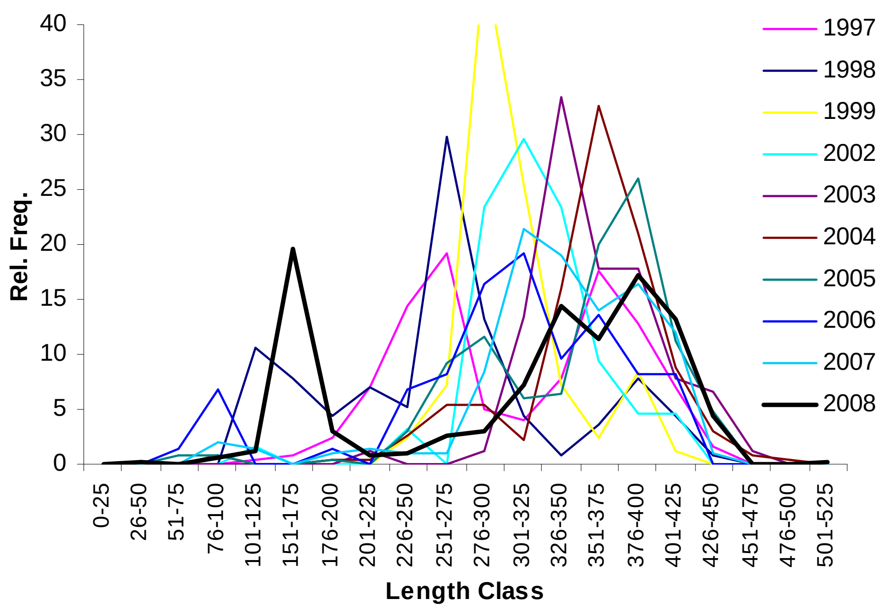


Figure 5.1-37 Relative length-frequency distributions for longnose sucker captured in the Athabasca River, spring and fall, 1997-2008.

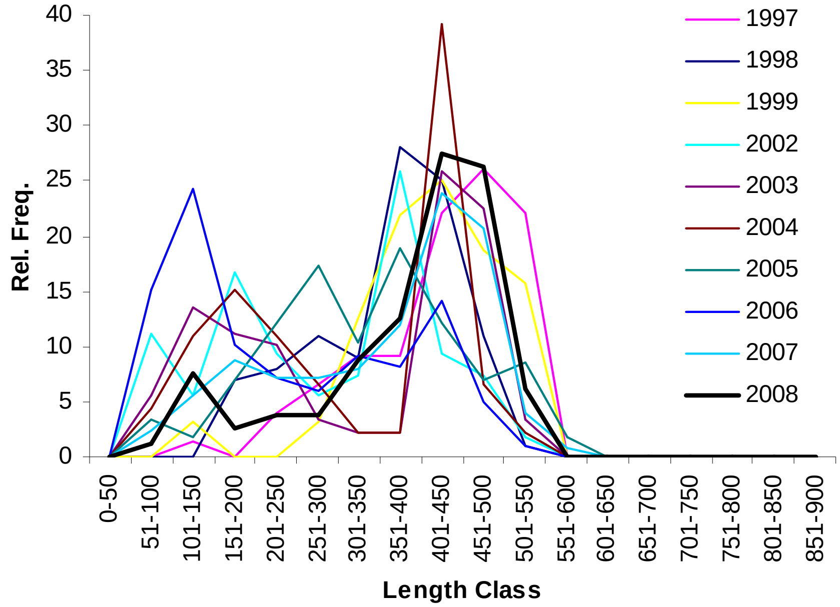


Figure 5.1-38 Relative length-frequency distributions for white sucker captured in the Athabasca River, spring and fall, 1997-2008.

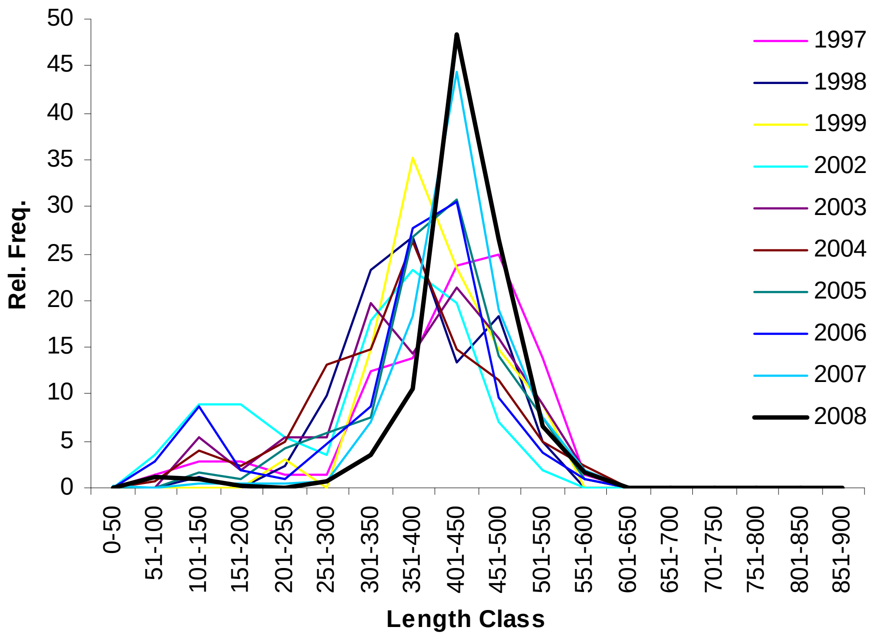


Figure 5.1-39 Relative length-frequency distributions for northern pike captured in the Athabasca River, spring and fall, 1997-2008.

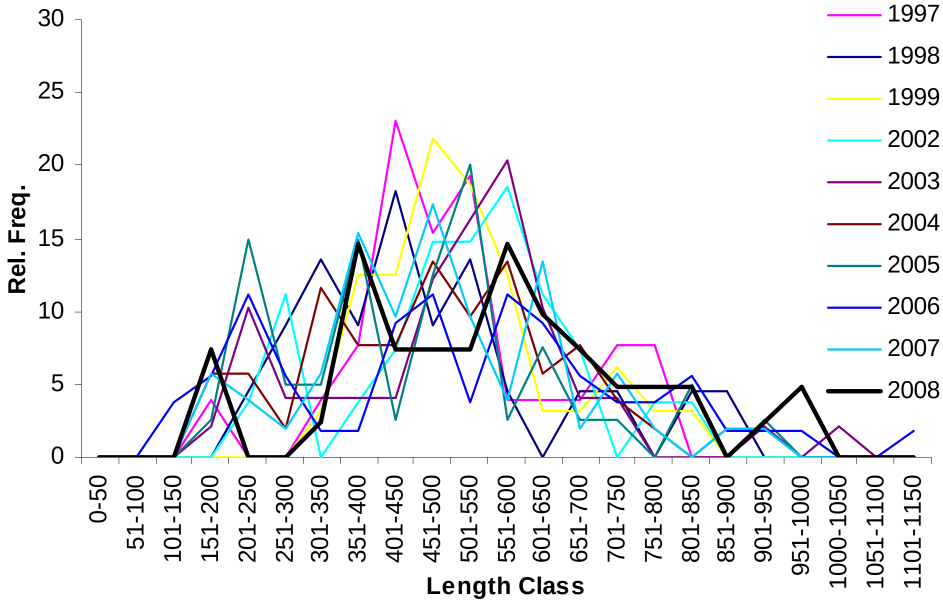


Figure 5.1-40 Seasonal relative length-frequency distributions for walleye in the Athabasca River, spring, summer and fall, 2008.

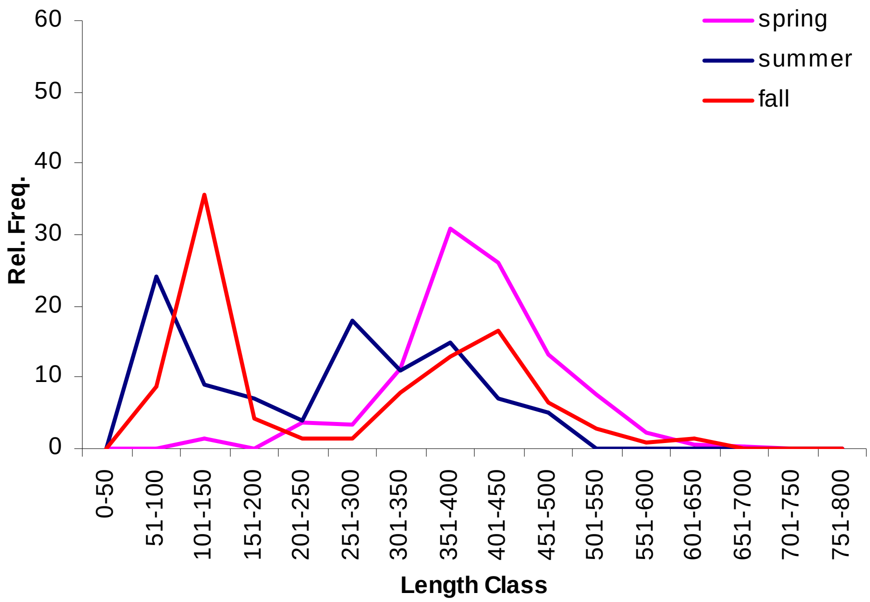


Figure 5.1-41 Seasonal relative length-frequency distributions for goldeye in the Athabasca River, spring, summer and fall, 2008.

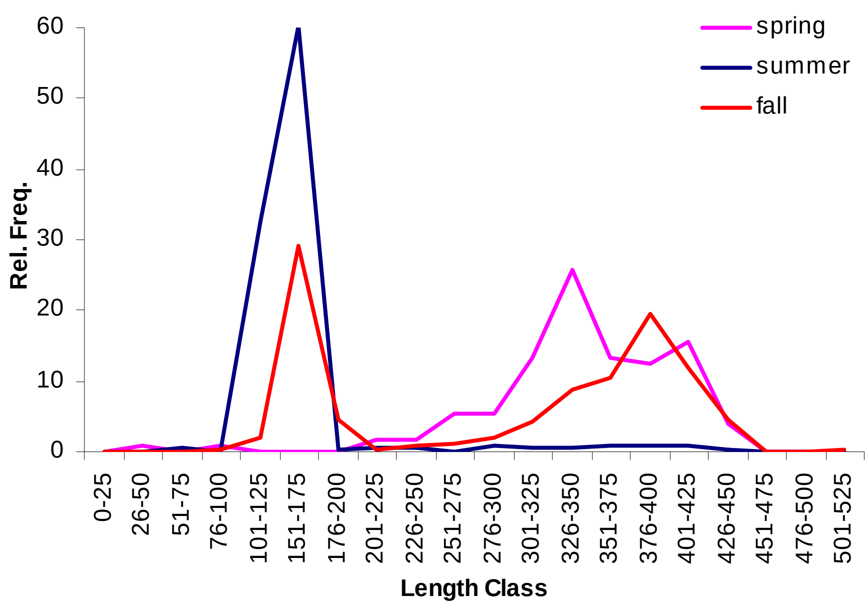


Figure 5.1-42 Seasonal relative length-frequency distributions for longnose sucker in the Athabasca River, spring, summer and fall, 2008.

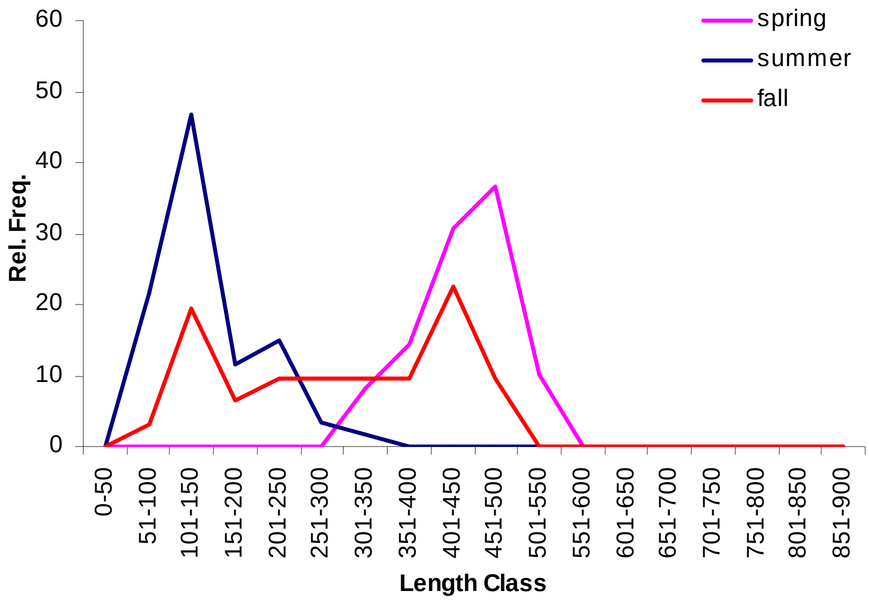


Figure 5.1-43 Seasonal relative length-frequency distributions for white sucker in the Athabasca River, spring, summer and fall, 2008.

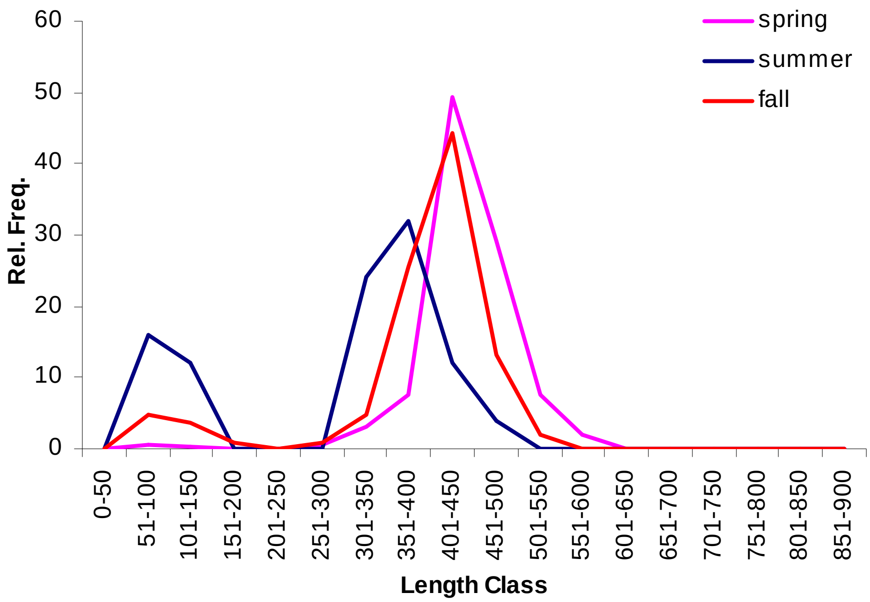


Figure 5.1-44 Seasonal relative length-frequency distributions for northern pike in the Athabasca River, spring, summer and fall, 2008.

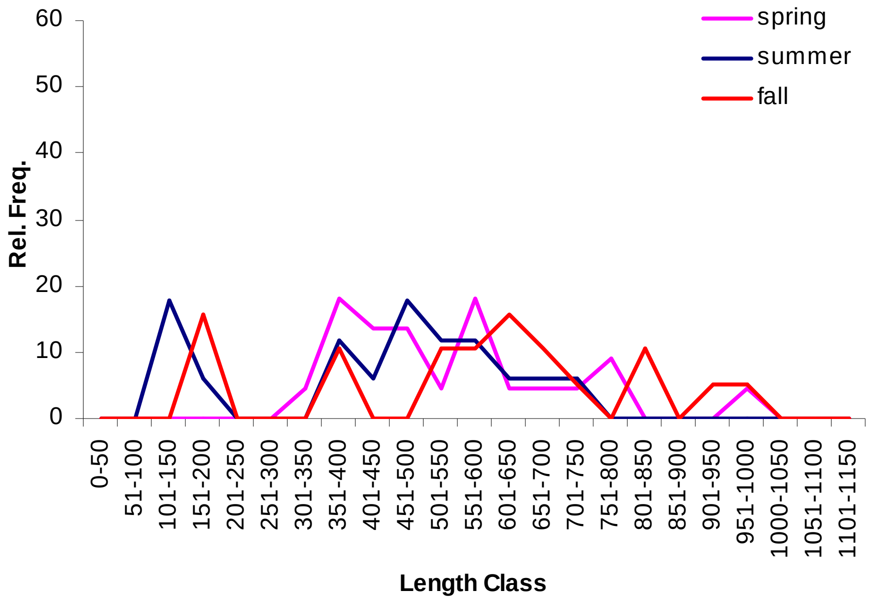


Figure 5.1-45 Ratio of undersize to legal size walleye captured in the Athabasca River, spring and fall 2008.

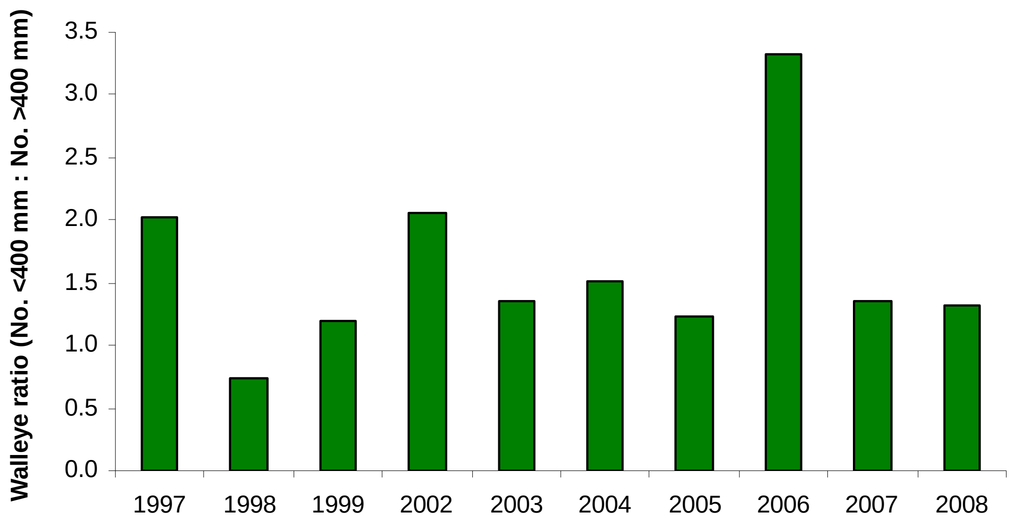


Figure 5.1-46 Ratio of undersize to legal size northern pike captured in the Athabasca River, spring and fall 2008.

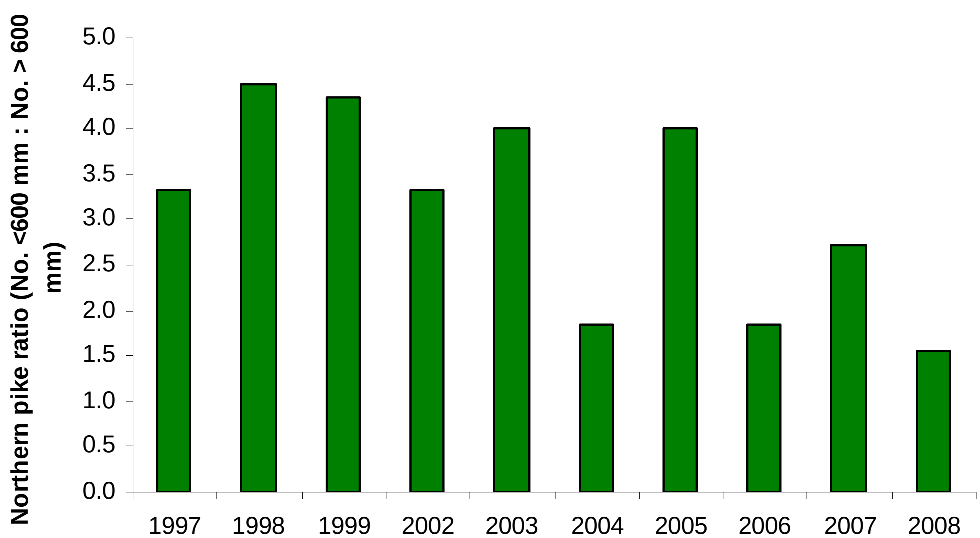


Figure 5.1-47 Mean condition factor for five key indicator fish species, Athabasca River, spring season, 1997-2008.

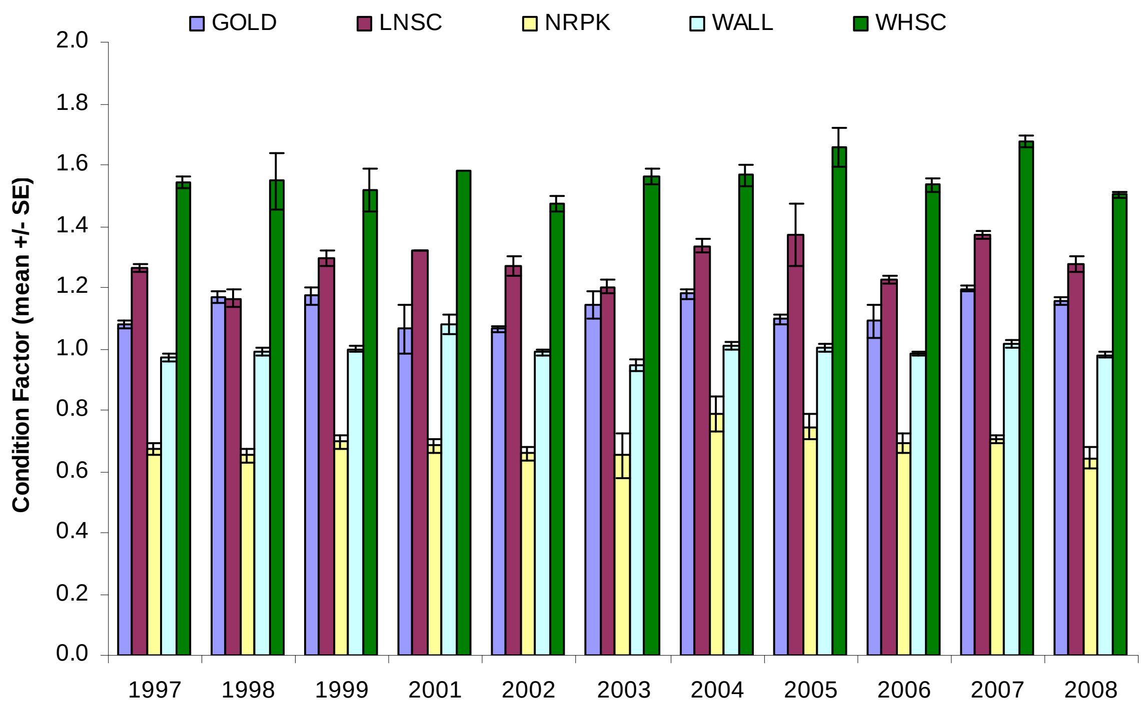


Figure 5.1-48 Mean condition factor for five key indicatory fish species, Athabasca River, summer season, 1997-2008.

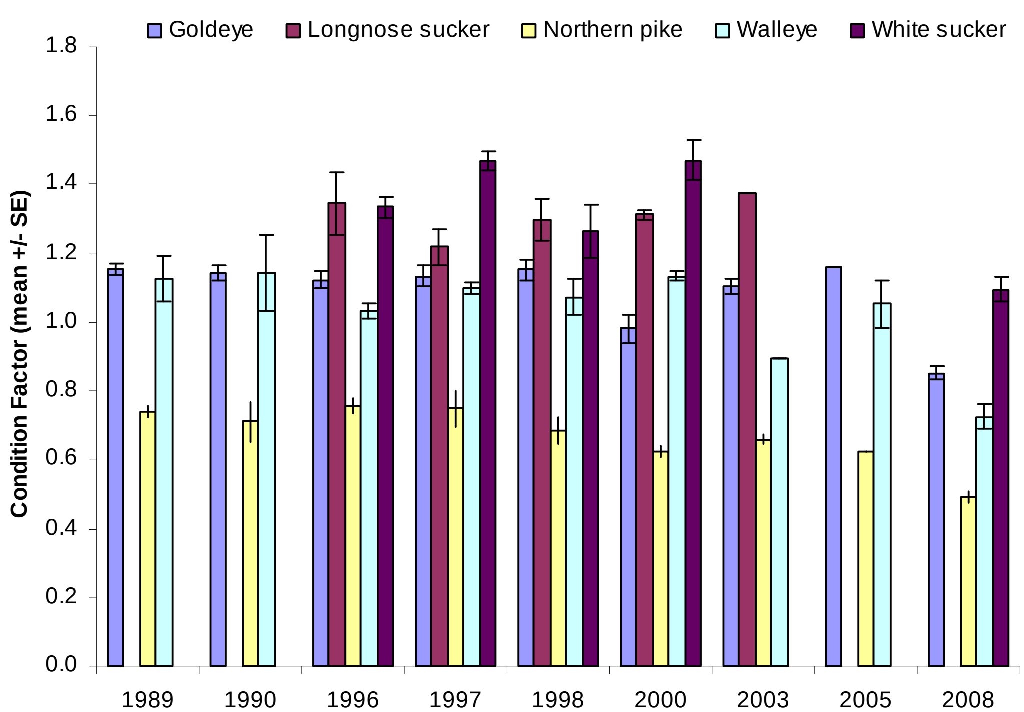


Figure 5.1-49 Mean condition factor for five key indicator fish species, Athabasca River, fall season, 1997-2008.

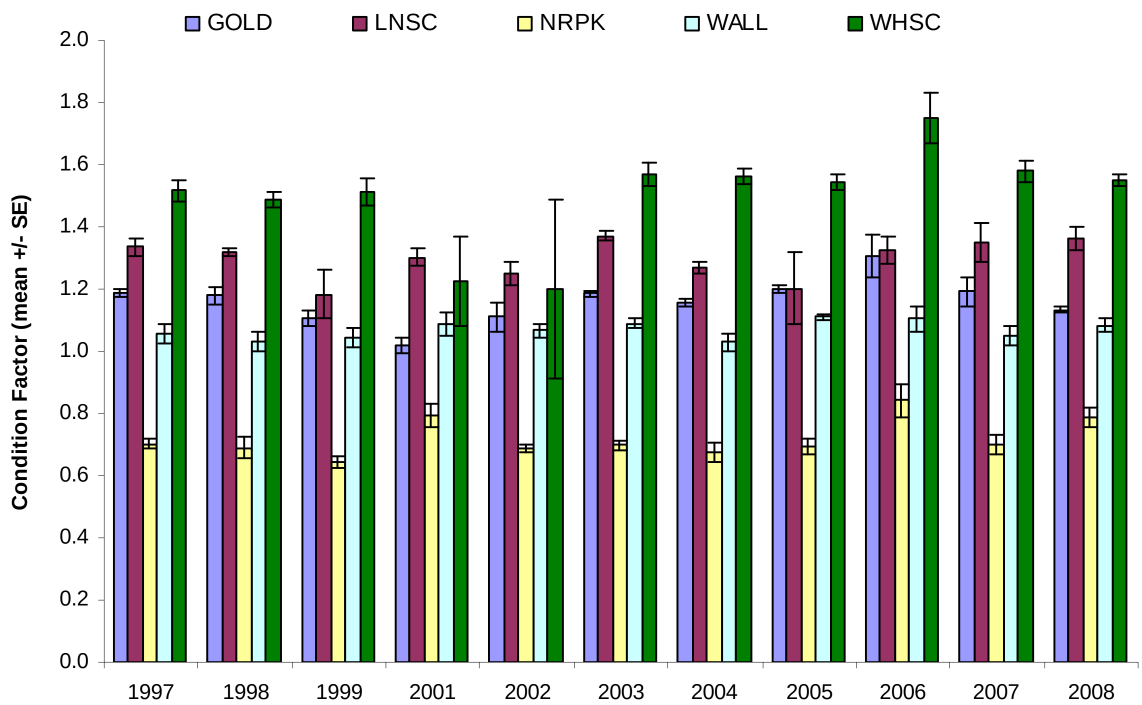


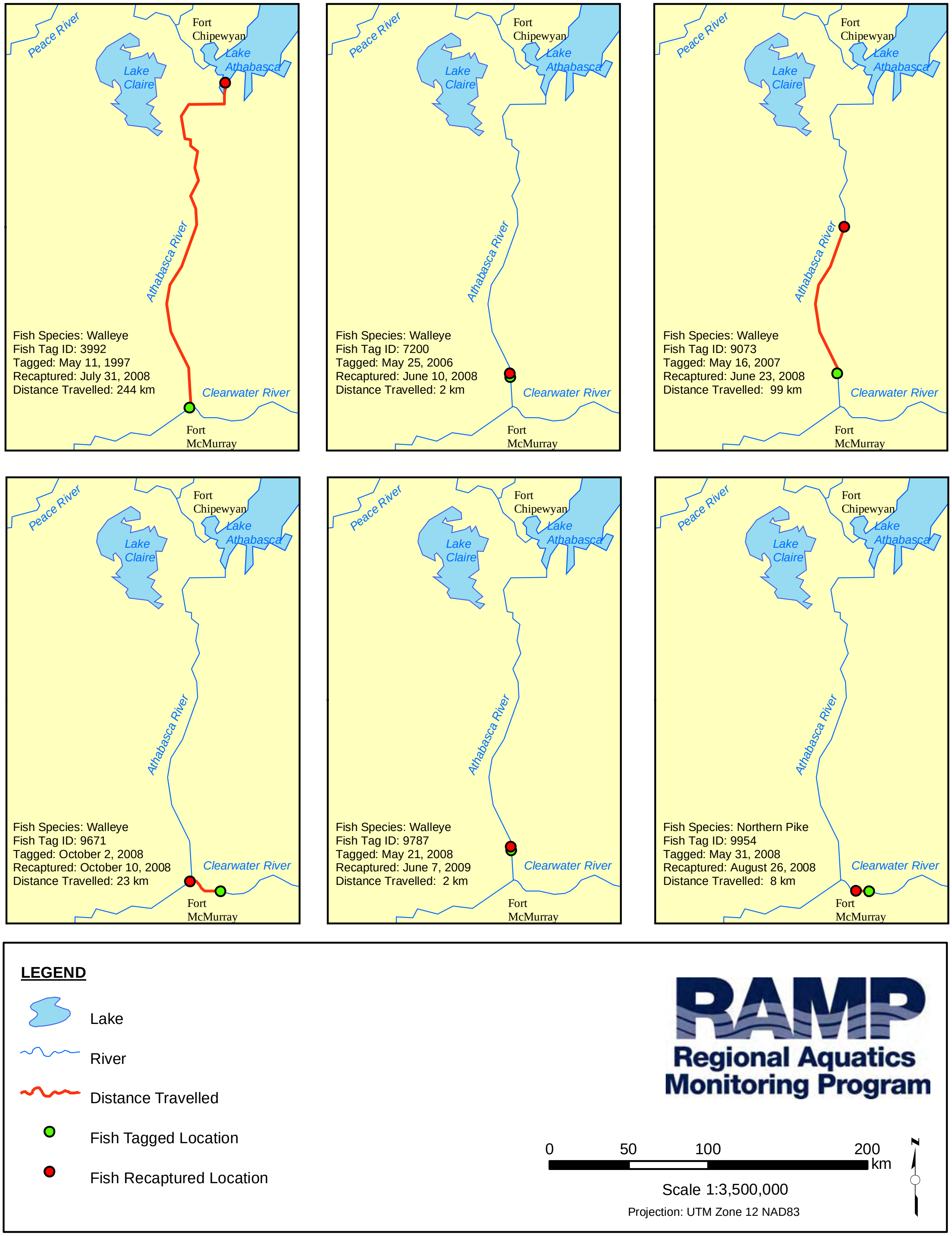
Table 5.1-18 Summary of mean health assessment index (HAI) values for five key indicator fish species, Athabasca River, 1997 to 2008.

Species	Mean Health Assessement Index											
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Goldeye	4.3	0.5	4.3	4.6	0.9	0.4	1.9	0.4	0.7	0.8	1.8	0.9
Longnose sucker	5.8	3.5	6.3	0	1.2	0.9	0.5	1.4	1.1	0.7	2.2	4.1
Northern pike	8.3	3	6	3.9	4	1.1	2.8	2.3	2.2	0.8	1.7	2.4
Walleye	1.5	2.1	2.6	0.2	0.8	1.4	1.1	0.3	1.5	1.2	1.2	2.3
White sucker	3.2	9.6	2.3	2.1	4	0.6	7.1	0.4	2.5	1.6	4.6	5.3

Table 5.1-19 Percent of KIR species fish captured with some form of external pathology, Athabasca River, 1997-2008.

Species	Percent fish captured with severe pathology											
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Goldeye	4.9	1.8	2.4	0.0	0.0	0.0	0.0	0.0	0.7	1.2	0.5	0.8
Longnose sucker	6.4	5.0	9.4	0.0	0.0	1.9	0.0	2.2	1.6	0.0	1.6	6.3
Northern pike	3.8	4.2	14.3	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	2.4
Walleye	3.0	3.4	1.9	0.0	0.0	0.8	1.2	0.7	1.5	1.9	2.3	2.5
White sucker	5.5	4.8	5.7	0.0	10.0	1.8	3.1	2.5	2.3	0.9	2.8	8.2

Figure 5.1-50 Fish tag recovery locations, 2008.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_J_FishTag_200900202.mxd

Table 5.1-20 Results of RAMP fish tag return analysis[1], 2008.

Variable	Fish Species	
	Walleye	Northern Pike
No. of Fish Recaptured	17	6
Minimum Distance Travelled (km)[2]	0	0
Maximum Distance Travelled (km)	244	8

[1] Tag returns include fish captured by anglers in the region and by RAMP personnel during the 2008 fish inventory programs.

[2] Minimum distance travelled is zero because fish were initially captured and recaptured in the same RAMP inventory reach.

Table 5.1-21 Results of RAMP fish tag return analysis, 1999 to 2008.

Variable	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
No. of Fish Recaptured	1	2	20	74	3
Minimum Distance Traveled (km)	271	5.3	0	0	1
Maximum Distance Traveled (km)	271	236	57	715	241

Table 5.1-22 Metrics and mercury concentrations in lake whitefish and walleye collected from the Athabasca River, fall 2008, and screening of concentrations against criteria for fish consumption for the protection of human health.

Species	Sample ID	Sex	Length	Weight	Age	Hg (mg/kg)
LKWH	LKWH-4B-01	U	287	358	-	0.051
LKWH	LKWH-5A-01	U	332	491	-	0.045
LKWH	LKWH-6A-01	U	348	630	-	0.036
LKWH	LKWH-10B-01	U	482	1604	-	0.090
LKWH	LKWH-10B-02	F	428	1258	6	0.027
LKWH	LKWH-10B-03	M	419	1100	8	0.020
LKWH	LKWH-10B-04	M	419	1045	8	0.041
LKWH	LKWH-10B-05	F	421	1150	6	0.026
LKWH	LKWH-10B-06	U	374	817	-	0.066
LKWH	LKWH-10B-07	M	398	965	-	0.047
LKWH	LKWH-10B-08	U	377	974	-	0.028
LKWH	LKWH-10B-09	F	416	1063	9	0.050
LKWH	LKWH-10B-10	U	360	650	-	0.051
LKWH	LKWH-10B-11	U	386	800	-	0.058
LKWH	LKWH-10B-12	U	384	775	-	0.051
LKWH	LKWH-10B-13	M	437	1070	-	0.045
LKWH	LKWH-10B-14	M	414	944	8	0.048
LKWH	LKWH-10B-15	F	404	1065	8	0.054
LKWH	LKWH-10B-16	F	406	1101	7	0.045
LKWH	LKWH-10B-17	M	440	1429	7	0.030
WALL	WALL-00B-01	U	343	568	-	0.089
WALL	WALL-00B-02	U	343	568	-	0.092
WALL	WALL-01A-01	M	457	1021	8	**0.464**
WALL	WALL-01A-02	F	470	1312	10	**0.390**
WALL	WALL-01A-03	F	459	1025	8	**0.235**
WALL	WALL-01A-04	F	608	2527	12	**0.509**
WALL	WALL-01A-05	M	584	2310	16	**0.387**
WALL	WALL-01A-06	U	375	508	7	**0.326**
WALL	WALL-01A-07	U	237	116	-	0.062
WALL	WALL-01A-08	U	388	589	7	**0.158**
WALL	WALL-01A-09	U	332	365	4	**0.149**
WALL	WALL-5B-01	M	475	1130	13	**0.679**
WALL	WALL-5B-03	F	513	1589	12	**0.371**
WALL	WALL-5B-04	U	329	350	4	0.128
WALL	WALL-6A-01	M	494	1484	14	0.133
WALL	WALL-6A-02	M	472	1200	12	**0.523**
WALL	WALL-6A-07	U	326	302	6	0.128
WALL	WALL-6A-08	U	396	661	9	**0.373**
WALL	WALL-10B-01	U	440	930	-	**0.223**
WALL	WALL-10B-02	U	415	773	7	0.107
WALL	WALL-11A-01	U	404	651	11	**0.276**
WALL	WALL-11A-02	U	437	1005	8	**0.261**
WALL	WALL-11A-03	U	424	818	7	**0.344**
WALL	WALL-11A-04	U	325	314	5	**0.161**
WALL	WALL-11A-05	U	434	823	5	**0.259**
WALL	WALL-11A-06	U	344	345	6	**0.220**

M-Male; F-Female; U-Undetermined

exceeds National USEPA Criteria for subsistence fishers (0.049 mg/kg)

exceeds Region III USEPA Risk-Based Criterion (0.14 mg/kg)

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds National USEPA Criteria for recreational fishers (0.40 mg/kg)

exceeds Health Canada Criterion for general consumers (0.50 mg/kg)

Figure 5.1-51 Temporal comparison of mercury concentration in lake whitefish from the Athabasca River, 2002, 2003, 2005, and 2008.

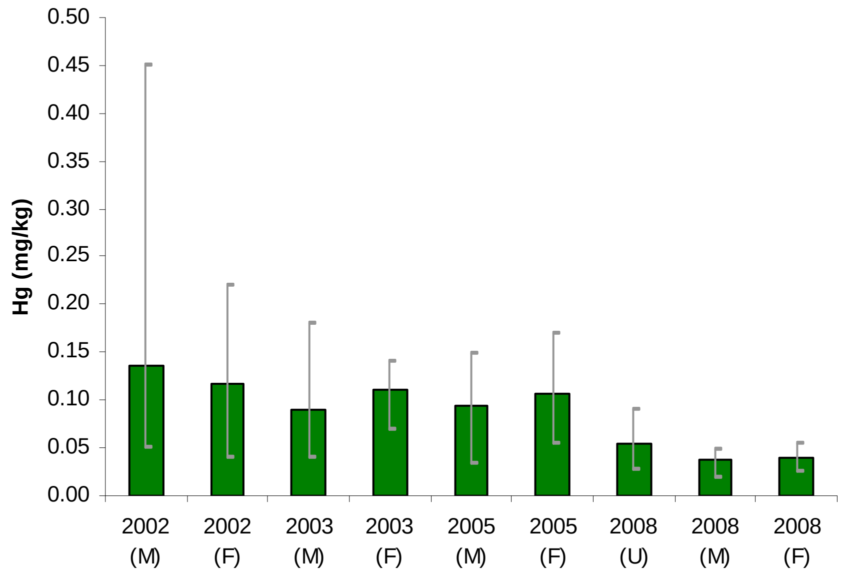


Figure 5.1-52 Temporal comparison of mercury concentration in walleye from the Athabasca River, 2002, 2003, 2005, and 2008.

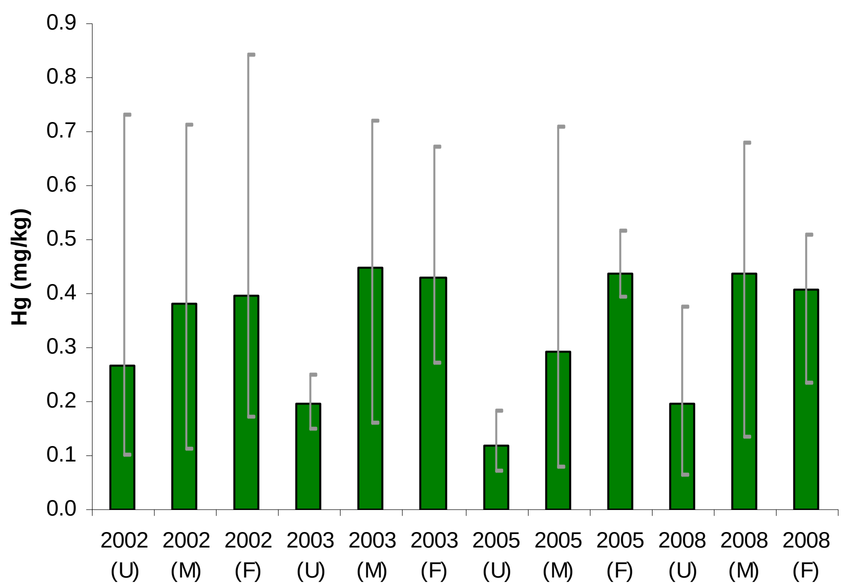
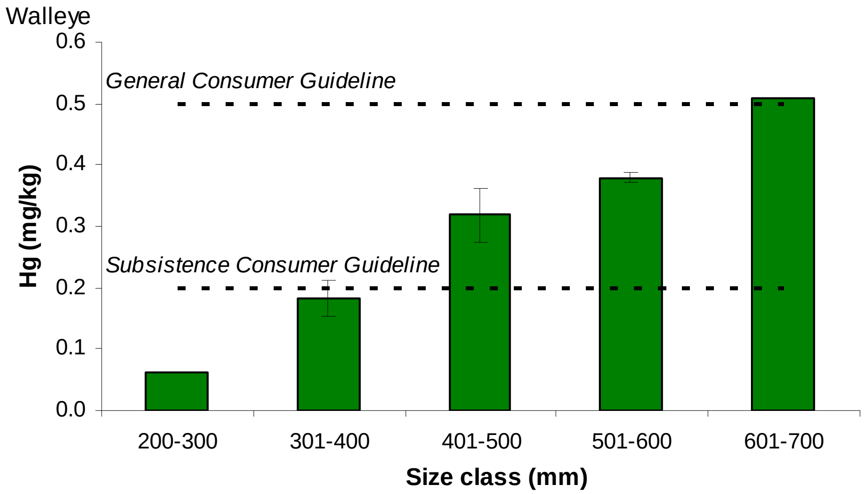


Figure 5.1-53 Mercury concentrations by length class for walleye and lake whitefish from the Athabasca River, fall 2008.



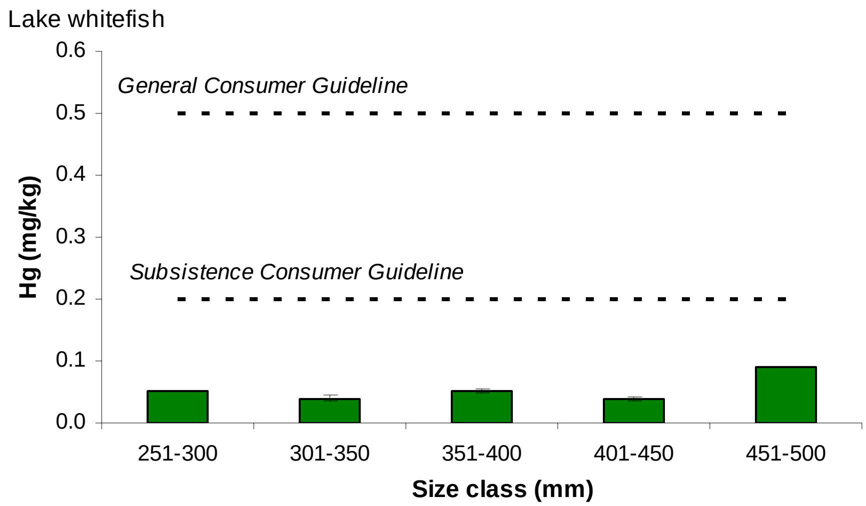


Figure 5.1-54 Regression analysis of mercury concentration in fish muscle versus length and age for lake whitefish and walleye from the Athabasca River, fall 2008.

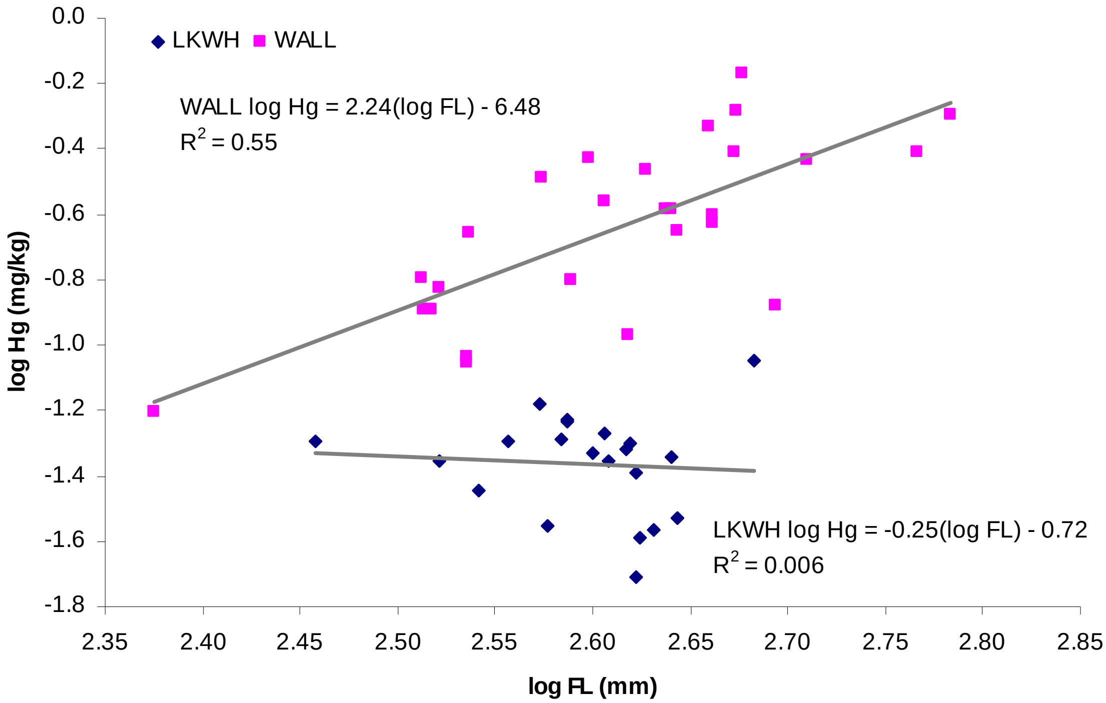


Table 5.1-23 Correlations between mercury concentration and fork length and age in walleye and lake whitefish muscle tissue collected from the Athabasca River, September 2008.

Metric	Lake whitefish			Walleye		
	Male n=6	Female n=5	Combined n=21	Male n=5	Female n=5	Combined n=27
Fork length	-0.609	**-0.800**	-0.266	-0.500	**0.872**	**0.713**
Age	0.264	**0.896**	0.588	-0.283	**0.834**	0.043

value = moderate correlation (0.5 < |r| < 0.75)

value = strong correlation (|r| > 0.75)

value = significant correlation (|r| > critical value)

critical values at α=0.1: n=27, |r|=0.324; n=5, |r|=0.900; n=21, |r|=0.370; and n=6, |r|=0.829

Table 5.1-24 Screening of metals and tainting compounds in lake whitefish and walleye composite samples collected in 2008 from the Athabasca River against criteria for fish consumption and the protection of human health.

	Units	DL	Composite LKWH[1]		Composite WALL[2]		Health Canada Criteria		National USEPA[5]		Region III USEPA[6]
			Male	Female	Male	Female	Subsistence[3]	General[4]	Subsistence	Recreational	Risk-based Criteria
Total Metals											
Aluminum (Al)	mg/kg	2	<2	<2	<2	<2	nc	nc	nc	nc	nc
Antimony (Sb)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc	0.54
Arsenic (As)	mg/kg	0.01	**0.03**	**0.04**	**0.03**	**0.03**	nc	nc	0.00327	0.026	0.0021
Barium (Ba)	mg/kg	0.1	0.1	0.2	<0.1	<0.1	nc	nc	nc	nc	270
Beryllium (Be)	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2	nc	nc	nc	nc	2.7
Cadmium (Cd)	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	1.4
Calcium (Ca)	mg/kg	20	70	550	80	80	nc	nc	nc	nc	nc
Chromium (Cr)	mg/kg	0.1	0.3	0.2	0.1	0.1	nc	nc	nc	nc	4.1
Cobalt (Co)	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	nc	nc	nc	nc	nc
Copper (Cu)	mg/kg	0.05	0.45	0.57	0.24	0.19	nc	nc	nc	nc	54
Iron (Fe)	mg/kg	5	10	8	<5	<5	nc	nc	nc	nc	410
Lead (Pb)	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02	nc	nc	nc	nc	nc
Magnesium (Mg)	mg/kg	5	242	292	262	269	nc	nc	nc	nc	nc
Manganese (Mn)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	nc	nc	nc	nc	190
Molybdenum (Mo)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc	6.8
Nickel (Ni)	mg/kg	0.02	0.06	0.03	<0.02	<0.02	nc	nc	nc	nc	27
Phosphorus (P)	mg/kg	20	1640	2520	2100	2080	nc	nc	nc	nc	nc
Potassium (K)	mg/kg	20	2870	4360	4060	4050	nc	nc	nc	nc	nc
Selenium (Se)	mg/kg	0.002	0.373	0.416	0.271	0.227	nc	nc	2.457	20	6.8
Silver (Ag)	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02	nc	nc	nc	nc	6.8
Sodium (Na)	mg/kg	20	260	430	270	280	nc	nc	nc	nc	nc
Strontium (Sr)	mg/kg	0.05	0.14	1.28	0.08	0.08	nc	nc	nc	nc	810
Thallium (Tl)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc	0.095
Tin (Sn)	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	nc	nc	nc	nc	810
Titanium (Ti)	mg/kg	0.2	<0.2	<0.2	0.2	0.3	nc	nc	nc	nc	nc
Vanadium (V)	mg/kg	0.03	0.03	0.04	0.08	<0.03	nc	nc	nc	nc	1.4
Zinc (Zn)	mg/kg	0.5	5.8	5.2	3.7	3.2	nc	nc	nc	nc	410
Tainting Compounds											
Thiophene	mg/kg	0.0004	<0.0004	<0.0004	<0.0004	<0.0004	nc	nc	nc	nc	nc
Toluene	mg/kg	0.004	0.11	0.3	0.39	1.7	nc	nc	nc	nc	110
m+p-Xylenes	mg/kg	0.008	<0.008	<0.008	<0.008	<0.008	nc	nc	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.004	<0.004	<0.004	<0.004	<0.004	nc	nc	nc	nc	nc
Naphthalene[7]	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc	nc

value = exceeds Region III USEPA Risk-based Criteria;

value = exceeds National USEPA Subsistence fishers;

shaded value = exceeds National USEPA Recreational fisher guideline; nc = no criterion.

[1] Composite sample taken from lake whitefish target size class (400-450 mm for males and females).

[2] Composite sampled taken from walleye target size class (450-500 mm for males; 500-550 mm for females).

[3] Last updated July 2007: http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html

[4] Last updated June 2006: http://www.ainc-inac.gc.ca/ncp/pub/hig/hig15_e.html

[5] Last updated November 2000: http://www.epa.gov/waterscience/fishadvice/volume1/index.html (Chapter 5)

[6] Last updated October 2007: http://www.epa.gov/reg3hwmd/risk/human/index.html

[7] Naphthalene was tested for three target analytes: 1-Methylnaphthalene; 2,6-Dimethylnaphthalene; and 2,3,5-Trimethylnaphthalene all with a detection limit of 0.05 mg/kg.

Table 5.1-25 Screening of metals and tainting compounds in lake whitefish and walleye composite samples collected in 2008 from the Athabasca River against criteria for the protection of fish health.

	Units	DL	Composite LKWH[1]		Composite WALL[2]		Thresholds for the Protection of Fish[3] – Lowest no-effects thresholds		Thresholds for the Protection of Fish[3] – Lowest effects Thresholds	
			Male	Female	Male	Female	Lethal	Sublethal	Lethal	Sublethal
Total Metals										
Aluminum (Al)	mg/kg	2	<2	<2	<2	<2	1	nc	20	nc
Antimony (Sb)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	5	nc	9	nc
Arsenic (As)	mg/kg	0.01	0.03	0.04	0.03	0.03	2.6	0.9	11.2	3.1
Barium (Ba)	mg/kg	0.1	0.1	0.2	<0.1	<0.1	nc	nc	nc	nc
Beryllium (Be)	mg/kg	0.2	<0.2	<0.2	<0.2	<0.2	nc	nc	nc	nc
Cadmium (Cd)	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.09	0.14	0.12
Calcium (Ca)	mg/kg	20	70	550	80	80	nc	nc	nc	nc
Chromium (Cr)	mg/kg	0.1	0.3	0.2	0.1	0.1	nc	nc	nc	nc
Cobalt (Co)	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	nc	nc	nc	nc
Copper (Cu)	mg/kg	0.05	**0.45**	**0.57**	0.24	0.19	0.5	3.4	0.5	0.3
Iron (Fe)	mg/kg	5	10	8	<5	<5	nc	nc	nc	nc
Lead (Pb)	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02	4	nc	nc	nc
Magnesium (Mg)	mg/kg	5	242	292	262	269	nc	nc	nc	nc
Manganese (Mn)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	nc	nc	nc	nc
Mercury (Hg)[4,5]	mg/kg	0.002	0.038	0.04	0.478	0.376	1.91	2.28	3.7	8.6
Molybdenum (Mo)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc
Nickel (Ni)	mg/kg	0.02	0.06	0.03	<0.02	<0.02	0.82	nc	118.1	nc
Phosphorus (P)	mg/kg	20	1640	2520	2100	2080	nc	nc	nc	nc
Potassium (K)	mg/kg	20	2870	4360	4060	4050	nc	nc	nc	nc
Selenium (Se)	mg/kg	0.002	**0.373**	**0.416**	0.271	0.227	0.28	0.08	0.92	0.32
Silver (Ag)[6]	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02	0.003	0.003	nc	nc
Sodium (Na)	mg/kg	20	260	430	270	280	nc	nc	nc	nc
Strontium (Sr)	mg/kg	0.05	0.14	1.28	0.08	0.08	nc	nc	nc	nc
Thallium (Tl)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc
Tin (Sn)	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	nc	nc	nc	nc
Titanium (Ti)	mg/kg	0.2	<0.2	<0.2	0.2	0.3	nc	nc	nc	nc
Vanadium (V)[6]	mg/kg	0.03	0.03	0.04	0.08	<0.03	5.33	0.02	nc	0.41
Zinc (Zn)	mg/kg	0.5	5.8	5.2	3.7	3.2	60	60	nc	nc
Tainting Compounds										
Thiophene	mg/kg	0.0004	<0.0004	<0.0004	<0.0004	<0.0004	nc	nc	nc	nc
Toluene	mg/kg	0.004	0.11	0.3	0.39	1.7	nc	nc	nc	nc
m+p-Xylenes	mg/kg	0.008	<0.008	<0.008	<0.008	<0.008	nc	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.004	<0.004	<0.004	<0.004	<0.004	nc	nc	nc	nc
Naphthalene[7]	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	nc	nc	nc	nc

[1] Composite sample taken from lake whitefish target size class (400-450 mm for males and females).
[2] Composite sampled taken from walleye target size class (450-500 mm for males; 500-550 mm for females).
[3] Threshold values were derived from effects data for fish muscle tissue presented in Jarvinen and Ankley (1999).
[4] Threshold values were derived from methylated forms of mercury (Jarvinen and Ankley 1999).
[5] Mercury results are average values from individual samples.
[6] Threshold values are presented for carcass and not muscle tissue (Jarvinen and Ankley 1999).
value = exceeds sublethal lowest no-effects threshold
value = exceeds sublethal lowest effects threshold
value = exceeds lethal lowest no-effects threshold
shaded value = exceeds lethal lowest effects threshold
nc = no criteria
Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

5.2 MUSKEG RIVER WATERSHED

Table 5.2-1 Summary of results for Muskeg River watershed.

Muskeg River Watershed	Summary of 2008 Conditions													
	Muskeg River					*Jackpine Creek*			*Other*					
Criteria	**S7** near Fort McKay (test)												**L2** Kearl Lake (baseline)	**S9** Kearl Lake Outlet (baseline)
Mean open-water season discharge	Negligible - Low												not measured	not measured
Mean winter discharge	Negligible - Low												not measured	not measured
Annual maximum daily discharge	Moderate												not measured	not measured
Minimum open-water season discharge	Negligible - Low												not measured	not measured
Water Quality														
Criteria	**MUR-1** at the mouth (test)	no station sampled	no station sampled	**MUR-6** upstream of Wapasu Creek (test)	no station sampled	**JAC-1** at the mouth (test)	no station sampled	**JAC-2** upper station (baseline)	**MUC-1** Muskeg Creek at the mouth (test)	**STC-1** Stanley Creek at the mouth (test)	**IYC-1** Iyinimin Creek at the mouth (baseline)	**WAC-1** Wapasu Creek at Canterra (baseline)	**KEL-1** Kearl Lake (baseline)	no station sampled
Water Quality	Negligible - Low			Negligible - Low		Negligible - Low		Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	Negligible - Low	
Benthic Invertebrate Community and Sediment Quality														
Criteria	**MUR-E1** lower reach (test)	no reach sampled	**MUR-D2** middle reach (test)	**MUR-D3** upper reach (test)	no reach sampled	**JAC-D1** lower reach (test)	no reach sampled	**JAC-D2** upper reach (baseline)	no reach sampled	no reach sampled	no reach sampled	no reach sampled	**KEL-1** Kearl Lake (baseline)	no reach sampled
Benthic Invertebrate Community	Negligible - Low		Negligible - Low	Negligible - Low		Negligible - Low		n/a					n/a	
Sediment Quality	n/a		Negligible - Low	Negligible - Low		Negligible - Low		Negligible - Low					Negligible - Low	
Fish Populations														
No fish programs were conducted in 2008.														

Legend:
- ○ (yellow) Negligible - Low
- ○ (orange) Moderate
- ○ (brown) High
- baseline (green shading)
- test (blue shading)

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper baseline reaches.

[1] For Climate and Hydrology, results are reported for station at the mouth of each watershed

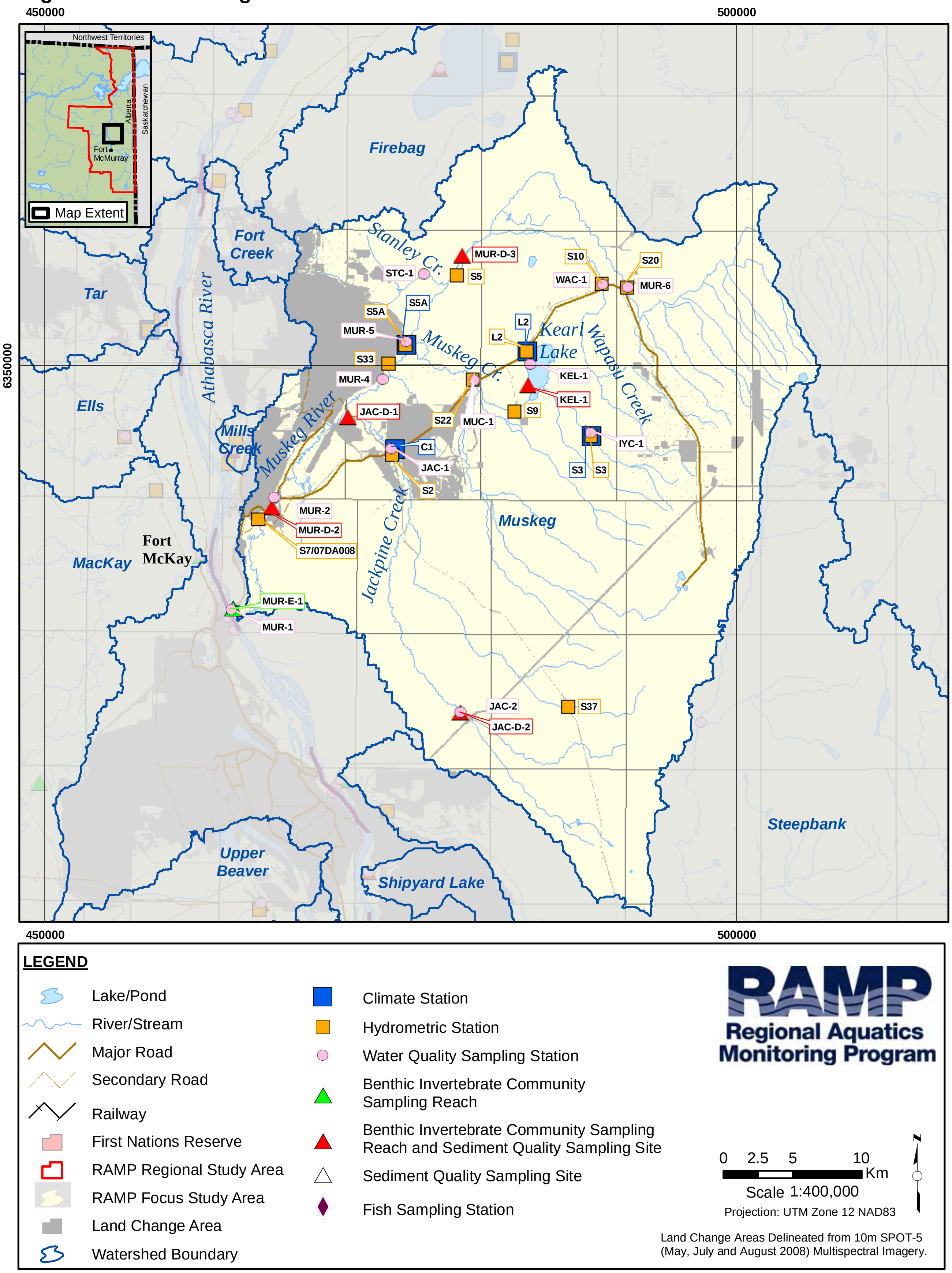
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.2-1 Muskeg River watershed.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K02_Muskeg_20090420.mxd

Figure 5.2-2 Representative Muskeg River watershed monitoring stations, fall 2008.

Water Quality Station MUR-1 (Muskeg River): left downstream bank, facing downstream

Water Quality Station MUR-6 (Muskeg River): right downstream bank, facing upstream

Water Quality Station MUC-1 (Muskeg Creek): centre of channel, facing downstream

Water Quality Station JAC-2 (Jackpine Creek): centre of channel, facing downstream

Water Quality Station STC-1 (Stanley Creek): left downstream bank, facing upstream

Water Quality Station IYC-1 (Iyinimin Creek): centre of channel, facing downstream

Water Quality Station WAC-1 (Wapasu Creek): right downstream bank, facing downstream

Water Quality Station KEL-1: Kearl Lake

5.2.1 Summary of Conditions

As of 2008, approximately 10% of the Muskeg River watershed had undergone land change as a result of focal developments in the watershed (Table 2.4-2). The designations of specific areas of the watershed are therefore as follows:

- The Muskeg River from upstream of Wapasu Creek to the mouth, as well as the lower part of Stanley Creek, Muskeg Creek, Jackpine Creek and Wapasu Creek drainages in the Husky Sunrise, Albian Muskeg River Mine and Shell Jackpine Mine leases are designated as *test*; and
- The remainder of the watershed, including Kearl Lake, Iyinimin Creek, and the upper portion of Jackpine Creek, is designated as *baseline*.

Table 5.2-1 contains a summary of the 2008 assessment for the Muskeg River watershed, Figure 5.2-1 is a detailed map of the Muskeg River watershed, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.2-2 contains a series of pictures from 2008 of a number of the monitoring stations in the watershed.

Hydrology The observed 2008 discharge for the Muskeg River watershed is estimated to be approximately 4% less than the 2008 *baseline* discharge would have been in the absence of focal projects and other oil sands developments in the Muskeg River watershed. The differences in the Muskeg River watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Moderate** for annual maximum daily discharge and **Negligible-Low** for all other calculated hydrologic measurement endpoints.

Water Quality Differences in water quality in fall 2008 in the Muskeg River watershed as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Most exceedances of water quality guidelines in 2008 occurred at multiple stations (both *test* and *baseline*) in the watershed, and water quality in the upper reach of the Muskeg River mainstem was similar to that observed at the mouth of the river.

Benthic Invertebrate Communities and Sediment Quality The differences in benthic invertebrate communities between *test* reaches in the lower and middle Muskeg River watershed as compared to *baseline* data from the upper reach in the watershed are classified as **Negligible-Low**. While there were significant differences in values of benthic invertebrate community measurement endpoints between the lower and upper Muskeg River, these differences are most likely due to the differences in habitat (erosional in the lower Muskeg River versus depositional in the upper Muskeg River). In addition, there were no significant differences in values of benthic invertebrate community measurement endpoints between the middle and the upper Muskeg River. Values of all benthic invertebrate community measurement endpoints in the lower and middle *test* reaches of the Muskeg River, as well as the upper reach in 2008, now a *test* reach, were within the normal range of variation for *baseline* reaches in the RAMP FSA. In addition, %EPT in all three sampled reaches in the Muskeg River watershed was high in fall 2008.

The differences in benthic invertebrate community measurement endpoints measured between a *test* reach in the lower Jackpine Creek watershed and a *baseline* reach from the Jackpine Creek watershed are assessed as **Negligible-Low** because there were no significant differences in values of measurement endpoints between the two reaches and values of benthic invertebrate community measurement endpoints in the lower *test* reach was within the normal range of variation for *baseline* depositional reaches in the RAMP FSA.

Differences in sediment quality in fall 2008 in the Muskeg River watershed as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Sediment quality at all Muskeg River watershed stations sampled by RAMP in 2008 was generally consistent with that of previous years, and largely within historical and regional *baseline* ranges. Sediment quality in the upper reaches of the Muskeg River mainstem and Jackpine Creek was similar to that observed in lower reaches.

5.2.2 Hydrologic Conditions

2008 Hydrologic Conditions: Muskeg River Total runoff in the Muskeg River basin in 2008, as measured at RAMP Station S7, Muskeg River near Fort McKay (07DA008), was slightly above normal at approximately 108% of the long-term average of 87 mm (Figure 5.2-3). Almost half (45% or 42.1 mm) of the total flow occurred in May. The lowest open-water season discharge occurred in July, but large rain events in August increased flow noticeably and 12% of the annual discharge occurred during this month. The annual maximum daily discharge of 35.7 m^3/s was 39% more than the mean annual flood of 25.7 m^3/s, and the minimum open-water season discharge of 1.21 m^3/s was 11% greater than the historical average. Daily flow in 2008 was below the historical median value for the majority of April, the second half of June, and all of July. The mean open-water season discharge was 7.64 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph: Muskeg River A summary of the inputs to the water balance model for the Muskeg River used to create a *baseline* hydrograph for examining possible changes in the hydrologic measurement endpoints are as follows (details are provided in Table 5.2-2):

- Discharges to the Muskeg River by focal projects in 2008 are estimated at 2.53 million m^3. This discharge was via Syncrude's Aurora Clean Water Diversion (CWD). It was assumed for this analysis that none of the water released from the CWD would have reached the Muskeg River naturally. In fact, given that some of the CWD flows are diverted surface water, some proportion of the CWD flow likely would have contributed to the Muskeg River naturally. The assumption that none of the water released from the CWD would have reached the Muskeg River naturally is; therefore, a worst-case assumption; and
- As of 2008, areas of closed-circuited land change and other land change (not closed-circuited) were 99.0 km^2 and 43.6 km^2, respectively, in the Muskeg River drainage as a result of cumulative development of focal projects in the watershed (Table 2.4-1), the estimated effects of which were decreased annual inflows to the Muskeg River by 6.34 million m^3.

The *baseline* hydrograph that would have occurred at the Muskeg River near Fort McKay hydrometric station (WSC station 07DA008, RAMP station S7) in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the station's observed hydrograph recorded in 2008. These estimated influences are predicted to have decreased mean open-water season discharge by 4.9%, increased mean winter discharge by 0.1%, decreased annual maximum daily discharge by 6.0%, and increased open-water minimum daily discharge by 0.7% (Table 5.2-3, Figure 5.2-3). Changes in mean open-water season discharge and open-water season minimum daily discharge are assessed as Negligible-Low, changes in annual maximum daily discharge is assessed as Moderate, and the changes in mean winter discharge are assessed as Negligible-Low (Table 5.2-1).

Water discharge via the CWD and runoff that was estimated to have been captured from land change areas that are closed-circuited were the two most significant contributors to the differences between the *baseline* and observed (i.e., *test*) hydrographs at WSC station 07DA008/RAMP station S7 in 2008 (Table 5.2-2). The increased runoff from land change areas that were not closed-circuited was a minor contributor in 2008 to differences between the observed and calculated *baseline* hydrographs (Figure 5.2-3).

2008 Hydrologic Conditions: Kearl Lake Kearl Lake water levels were below historical median values for most of the year (Figure 5.2-4) except for May, November, and December. In mid-May, the lake reached its highest level for the year, but then fell steadily until early July. An equipment failure prevented reliable data collection from this time until mid-October. Outflows from the lake were above historical median values in May, but decreased to near zero in August before increasing again with increasing lake levels in fall (Figure 5.2-5).

Summary The observed *test* 2008 discharge for RAMP Station S7, Muskeg River near Fort McKay (07DA008), is estimated to be approximately 4% less than 2008 *baseline* discharge would have been in the absence of focal projects and other oil sands developments in the Muskeg River watershed. The differences in the Muskeg River watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at RAMP Station S7, Muskeg River near Fort McKay (07DA008), are assessed as Moderate for annual maximum daily discharge and Negligible-Low for all other measured hydrologic measurement endpoints (Table 5.2-1).

5.2.3 Water Quality

In fall 2008, water quality samples were collected from the following stations:

- Station MUR-1, near the mouth of the Muskeg River (*test*, sampled from 1997 to 2008);
- Station JAC-1, near the mouth of Jackpine Creek (designated as *test* in 2006, sampled from 1998 to 2008);
- Station JAC-2, upper Jackpine Creek (*baseline*, sampled for the first time in 2008);
- Station STC-1, near mouth of Stanley Creek (designated as a *test* station in 2003, sampled from 1998 to 2008);
- Station MUR-6, upstream of Wapasu Creek (designated as *test* in 2008, sampled from 1998 to 2008);
- Station MUC-1, near mouth of Muskeg Creek at Canterra Road (designated as *test* in 2008, sampled from 1998 to 2008);
- Station WAC-1, near mouth of Wapasu Creek (designated as *test* in 2008, sampled intermittently from 1998 to 2008);
- Station IYC-1, near mouth of Iyinimin Creek (*baseline*, sampled in 2007 and 2008); and
- Station KEL-1, Kearl Lake (*baseline*, sampled from 1998-2008).

2008 Results and Historical Ranges of Concentration In the Muskeg River mainstem, concentrations of all water quality measurement endpoints were within historical ranges in fall 2008 with the exception of dissolved organic carbon (historical high) and total aluminum (historical low) at the lower station MUR-1, and dissolved organic carbon and sulphate (both historical lows) at the upper station MUR-6 (Table 5.2-4 and Table 5.2-5). Concentrations of all water quality measurement endpoints have been relatively consistent in the Muskeg River mainstem over the past several years, and have shown clear concordance between upper and lower stations (Figure 5.2-6).

In lower Jackpine Creek (JAC-1), all water quality measurement endpoints were within historical ranges in fall 2008 (Table 5.2-6). Comparisons with historical data could not be made for upper Jackpine Creek (JAC-2) (Table 5.2-7), given 2008 was its first year of sampling.

In other Muskeg River tributaries, all water quality measurement endpoints were within historical ranges in fall 2008, with the exception of the following:

- Stanley Creek (STC-1): historically low sulphate (Table 5.2-8);
- Muskeg Creek (MUC-1): historically high total nitrogen, and historically low total dissolved phosphorus, dissolved organic carbon and total aluminum (Table 5.2-9);
- Wapasu Creek (WAC-1): historically high total nitrogen, historically low dissolved organic carbon and sulphate (Table 5.2-10); and
- Iyinimin Creek (IYC-1): all values in 2008 represented historical highs or lows for this station, given 2008 was only its second year of sampling (Table 5.2-11).

In Kearl Lake (KEL-1), concentrations all water quality measurement endpoints were within the historical range of concentrations, except total boron and pH, which both exceeded previously measured maximum concentrations (Table 5.2-12).

Comparison of Water Quality Measurement Endpoints to Natural Variation in *Baseline* Conditions In fall 2008, concentrations of all water quality measurement endpoints at Muskeg River watershed stations were within their respective range of regional *baseline* concentrations, with the exception of total dissolved solids at MUR-1, which was slightly above the 95th percentile of regional *baseline* concentrations, and total nitrogen and total arsenic in Stanley Creek, which were below the 5th percentile of regional *baseline* concentrations (Figure 5.2-6, Figure 5.2-7 and Figure 5.2-8).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines In fall 2008, all values for all water quality measurement endpoints at Muskeg watershed stations MUR-1, MUR-6, JAC-1, STC-1, and WAC-1 were below relevant water quality guidelines. At other stations, total nitrogen slightly exceeded the relevant guideline in both Muskeg and Wapasu creeks and Kearl Lake, and total aluminum exceeded its relevant guideline in Iynimin Creek and upper Jackpine Creek (Table 5.2-7, Table 5.2-9, Table 5.2-10, Table 5.2-11, and Table 5.2-12).

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded guidelines in the Muskeg River watershed in 2008 (Table 5.2-13):

- Station MUR-1: sulphide, total phenols and total and dissolved iron in fall 2008;
- Station JAC-1: sulphide, total phenols and total and dissolved iron in fall 2008;

- Station JAC-2: sulphide, total aluminum, total phenols and total and dissolved iron in fall 2008;
- Station STC-1: sulphide in fall 2008;
- Station MUR-6: sulphide and total phenols in fall 2008;
- Station MUC-1: sulphide, total Kjeldahl nitrogen, total nitrogen and total phenols in winter, spring, summer and fall 2008; total and dissolved iron in winter and summer 2008 and total aluminum in spring 2008;
- Station WAC-1: sulphide, total phenols and total iron in fall 2008;
- Station IYC-1: sulphide, total aluminum, total phenols and total and dissolved iron in fall 2008; and
- Station KEL-1: sulphide, total Kjeldahl nitrogen, total nitrogen and total phenols.

Ion Balance In fall 2008, the ionic composition throughout the Muskeg River watershed was similar to that observed in previous years (Figure 5.2-9). The ionic composition at Stanley Creek (STC-1) has shown the greatest variability across years of sampling, likely related to site-drainage flows from Syncrude's Aurora North Mine site that occurred earlier this decade. However, the ion balance at this station in 2008 was within the range of historical observations. The ionic character of Kearl Lake in fall 2008 was consistent with that of previous years of sampling, with anions dominated by calcium bicarbonate and low concentrations of sodium and potassium chloride.

Trend Analysis Significant trends in the following water quality measurement endpoints were observed at the Muskeg River watershed over the RAMP sampling period ($\alpha = 0.05$):

- Downward trends in sulphate at stations MUR-6, JAC-1, and MUC-1;
- Downward trends in arsenic at stations STC-1, MUR-6 and MUC-1, likely related only to improved (lower) detection limits after 2002; and
- Upward trend in chloride at station KEL-1.

There have been no significant trends in water quality measurement endpoints at station MUR-1. Trend analyses could not be completed for stations JAC-1, IYC-1, and WAC-1 due to insufficient data.

Water Quality Index WQI values for all stations in the Muskeg River watershed in fall 2008 indicated Negligible-Low difference from regional *baseline* conditions, including the Muskeg River mainstem (MUR-1: 92.2; MUR-6: 96.1), or in any tributaries or lakes (all other stations: 96.1) (Table 5.2-14).

Summary As of 2008, no *baseline* or *test* stations in the Muskeg River watershed had water quality that differed substantially from regional *baseline* conditions. Most exceedances of water quality guidelines in 2008 occurred at multiple stations (both *test* and *baseline*) in the watershed. Water quality in the upper reach of the Muskeg River mainstem was similar to that observed at the mouth of the river. Differences in water quality in fall 2008 at all nine stations monitored in the Muskeg River watershed as compared to regional *baseline* conditions are assessed as Negligible-Low (Table 5.2-1).

5.2.4 Benthic Invertebrate Communities and Sediment Quality

5.2.4.1 Benthic Invertebrate Communities

Muskeg River Reaches

Benthic invertebrate community samples were collected from three reaches on the Muskeg River in 2008:

- A lower erosional reach near the mouth of the Muskeg River (reach MUR-E-1, designated as *test* for its entire data record beginning in 2000);
- A middle depositional reach near the Canterra Road crossing (reach MUR-D-2 designated as *test* for its entire data record beginning in 2000); and
- An upper depositional reach located upstream of the Muskeg River and Aurora North oil sands developments (reach MUR-D-3 designated as *test* for the first time in 2008, sampled since 2002).

2008 Habitat Conditions The lower reach was shallow (0.4 m), and had high current velocity (0.7 m/s) and generally low macrophyte cover at the time of sampling (~6% coverage). Benthic algal biomass (measured as chlorophyll *a*) was low (~40 mg/m^2), and not unusual considering long-term trends in the reach (Figure 5.2-10). Substrate was comprised of a mixture of course materials including boulder, cobble and gravel (Table 5.2-15). By comparison, the middle and upper reaches had deeper water with slower current velocities, and higher macrophyte cover (though not recorded in the Upper Reach). Middle-reach sediments were dominated by sand, while the upper-reach sediments were a mixture of sand, silt and clay. Total organic carbon content in the middle reach was ~1%, and was considerably higher in the upper reach (22%; Table 5.2-15).

Relative Abundance of Benthic Invertebrate Community Taxa The lower reach was dominated in 2008 by naidid worms (30%), mayflies (Ephemeroptera, 25%) and chironomids (15%; Table 5.2-16). Stoneflies and caddisflies were also prevalent, while a number of additional worms (tubificids, nematodes), bivalves (Sphaeriidae fingernail clams), and beetles (Coleoptera) were present in lower abundances.

Benthic invertebrates have been sampled regularly in the lower reach since 1998 and community composition (based on values of measurement endpoints and multivariate descriptors) has consistently reflected the expected community composition based on regional *baseline* data for erosional habitats (Figure 5.2-11):

- Total numbers of benthic organisms was highest in 1998 (~70,000 per m^2) during the initial year of RAMP, but has been ~10,000 to 20,000 organisms per m^2 since, including 2008;
- The number of taxa (richness) has been well within the expected range of values for *baseline* conditions, and has increased marginally over the past two years from a long-term average of 30 taxa, to a present value of close to 40 taxa per sample;
- Diversity (both Simpson's and Evenness) have been close to the upper limit of the expected range for *baseline* conditions, indicating a highly diverse and healthy benthic community; and

- The percentage of fauna represented by mayflies, stoneflies and caddisflies (i.e., % EPT) has also been well within the range expected for *baseline* conditions (Figure 5.2-11). The percent of the fauna as EPT has also been increasing since 2002 when that index was at the low end of natural *baseline* values (~5%). Four of the more sensitive taxa found in the lower reach included the mayfly *Leptophlebia*, and the stoneflies, *Isoperla, Skwala* and *Taeniopteryx*. Other important taxa (numerically) were the mayflies *Ameletus*, *Acentrella*, *Acerpenna* and *Baetis*, the caddisfly *Hydropsyche* and the chironomids *Polypedilum, Rheotanytarsus, Stempellina, Stempellinella* and *Lopesocladius*.

The results of the Correspondence Analysis demonstrated that the faunal assemblage in the lower reach is similar to what is typically found for erosional reaches in a *baseline* condition (Figure 5.2-12).

The benthic community of the middle reach in 2008 was diverse (Table 5.2-17). The numerically dominant taxa were midges (chironomids) and biting midges (ceratopogonids). Other sub-dominant taxa included enchytraeid worms, gastropods, and mites. There were a variety of worms including tubificids, naidids and nematodes in typical numbers for sand-based watercourses. Mayflies (Ephemeroptera including *Acentrella* and *Leptophlebia*), Plecoptera (e.g., *Skwala*) and Trichoptera (*Neureclipsis*) were present, but generally in low numbers. Of the chironomids, *Polypedilum*, *Corynoneura*, and a variety of Tanytarsini were prevalent.

The temporal trends in the benthic invertebrate community measurement endpoints for the middle Muskeg River reach have the following characteristics (Table 5.2-17):

- Total abundance in the middle reach was lower in 2008 (~5,000 individuals/m^2) compared to previous years (up to 60,000 individuals/m^2 in previous years), and near the low end of the expected range for a *baseline* condition;
- The number of taxa, Simpson's Diversity, and Evenness were; however, quite high relative to the normal range of variation for *baseline* conditions; and
- The percent of the fauna as EPT taxa has been variable over the data record, and typically < 5%, but within the range of values for a *baseline* condition.

The results of the Correspondence Analysis demonstrated that the faunal assemblage in the middle reach is similar to what is typically found for depositional reaches in a *baseline* condition (Figure 5.2-14).

The upper reach in 2008 was dominated by chironomids (48%; Table 5.2-17), water mites (Hydracarina, 15%), fingernail clams (Bivalvia, 7%) and tubificid worms (9%). Stoneflies (Plecoptera) were absent, but mayflies (Ephemeroptera: Leptophlebiidae and Baetidae) and caddisflies (Trichoptera) were present though in low abundance.

The temporal trends in the benthic invertebrate community measurement endpoints for the upper Muskeg River reach have the following characteristics (Table 5.2-17):

- Total abundances have been generally in the low range (compared to other depositional reaches in *baseline* condition), with between ~5,000 and 15,000 organisms per m^2. Numbers in 2008 were ~ 15,000 per m^2;

- There were ~ 15 taxa per sample in 2008, which was slightly above the long-term average for the reach, but well within the normal range of *baseline* conditions; and
- The percent of the fauna as EPT taxa was high in 2008 (~10%), and slightly above the expected range of values for a *baseline* depositional reach.

The results of the Correspondence Analysis (Figure 5.2-14) indicate that the benthic community assemblage in the upper reach of the Muskeg River is similar to what has been observed in other *baseline* depositional reaches.

Linear contrasts were used to test for differences in composition for the lower *test* reach in comparison to the upper *baseline* reach; and the middle *test* reach also in comparison with the upper *baseline* reach:

- A difference in average conditions between the lower/middle and upper reach (i.e., *baseline* versus *test* contrast, or BT); and
- A difference in time trends (T) between the lower/middle *test* and upper *baseline* reaches (BT x T), across sampling years (2002 to 2008).

As in previous years, and as expected, measurement endpoints differed between the lower and upper reaches, with the lower reach generally having higher richness, diversity, evenness and a higher percentage of EPT taxa, Figure 5.2-11). The analysis of variance suggested that there was a substantial amount of "noise" in the data (see the "remainder" term in the ANOVA tables, Table 5.2-18) putting into some question the significance of the BT x T contrast.

A caveat in this assessment of the condition of the lower erosional reach is that the assessment has partially relied on data from the upper depositional reach. Comparing time trends in an erosional reach to time trends in a depositional reach assumes that time trends in both habitat types would be similar, an assumption that might not be true. A further caveat to this analysis was that the upper reach in 2008 was classified as *test*. For the lower reach of the Muskeg River, however, there are no relevant *baseline* reaches upstream that have the same erosional characteristics. However, comparisons were allowed between the lower erosional reach and erosional reaches from other regionally situated drainage basins, by an approach adopted in Canada's CABIN program (Reynoldson *et al*. 1999) and elsewhere (Bailey *et al*. 2004) including the United Kingdom (Furse *et al.* 1984, Wright *et al.* 1984) and Australia (Parsons *et al*. 2004).

Averaged across years, the middle reach has had slightly higher total abundance and number of taxa than the upper reach. Differences in time trends were marginally significant (p = 0.034) for abundance due to greater year-to-year variation in the middle reach (Table 5.2-19). The multivariate ordination clearly demonstrated differences in composition between the middle and upper reaches (Figure 5.2-14), reflecting that the upper reach was generally more highly dominated by fingernail clams (Bivalvia) and mayflies (Ephemeroptera), while the middle reach often contained empidid flies, stoneflies (Plecoptera) and tipulid flies. Differences in the multivariate metric CA Axis 1 across years were thus significant (as illustrated in Figure 5.2-14), while there were also differences in time trends in the Axis 1 scores, though those time trends were not overly apparent from inspection of the biplot. The observed differences between the middle and upper reach likely reflect subtle but important differences in habitat character. Although both reaches are depositional in nature, substrates in the upper reach contained more fine materials (silt and clay comprised about 50% of the sediment) and had significant organic content (28% TOC in 2008; Table 5.2-15). Sediments in the middle reach, in contrast, were largely (~95%) sand with traces of silt and clay, and had very low organic content (1%; Table 5.2-15).

Development activities commenced in the upper reach of the Muskeg River in 2008, resulting in this reach being classified as *test* for this year. A linear contrast was constructed to test for differences in measurement endpoints prior to (2002 to 2007) and after (2008) development in the upper catchment (Table 5.2-20). There were no differences between *baseline* and *test* conditions at this reach for conventional measurement endpoints (abundance, richness, Simpson's, Evenness, % EPT). There were, however, statistically significant differences in both CA axes 1 and 2 in 2008 relative to the *baseline* years 2002 to 2007 (Figure 5.2-14). The principal differences in measurement endpoints in 2008 were a higher percentage of mayflies (Ephemeroptera) and water mites (Hydracarina), and a lower percentage of chironomids relative to previous sampling years (Table 5.2-17). There were no changes in the taxonomic composition that was consistent with a substantive change in habitat quality.

Jackpine Creek

Benthic invertebrate community samples were collected from two reaches on Jackpine Creek:

- A lower depositional reach near the mouth of Jackpine Creek (reach JAC-D-1 designated as *test* in 2006, sampled since 2002); and
- An upper depositional reach (reach JAC-D-2, designated as *baseline* for its entire data record).

2008 Habitat Conditions Both the lower and upper reaches are typical of slower depositional habitats in the RAMP FSA with relatively low flow velocities (0.3 m/s). Macrophytes were sporadic in the lower reach JAC-D-1 (3% cover) and absent in the upper reach JAC-D-2. Both reaches were dominated by sand with very low amounts of silt and clay. Total organic carbon content was low in both reaches; 0.6% and 1.5% in the lower and upper reach, respectively (Table 5.2-15).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate communities of both reaches were heavily dominated by chironomids (~60% each; Table 5.2-22). Ephemeroptera (mayflies) were subdominant in both reaches, as were sand flies (Ceratopogonidae) nematode worms, tubificid worms, and naidid worms.

The temporal trends in the benthic invertebrate community measurement endpoints for the Jackpine River (Figure 5.2-15) have the following characteristics:

- Numbers of individuals in the upper reach was "low" (~ 3,000 per m^2), and near the lower limit for reaches in a *baseline* condition. Numbers in the lower reach were not much higher (~9,000 per m^2), but more within the normal range of expected values;
- Both the upper and lower reaches were diverse with approximately 20 taxa per sample in the lower reach and 14 taxa per sample in the upper reach (Figure 5.2-15), and with high Simpson's Diversity and Evenness; and
- The mayflies *Caenis* and *Leptophlebia*, dominated the mayfly fauna in Jackpine Creek, and were present in both reaches. The upper reach contained the

caddisflies *Oxyethira*, and *Lepidostoma*, but in low numbers. The chironomid genus *Cryptochironomus* was numerically important in both the upper and lower reaches in 2008, while *Parakieferiella* was important in the lower reach, and *Nanocladius* was important in the upper each.

Linear contrasts were used to test for differences in composition between the lower *test* and upper *baseline* reach (Table 5.2-23). Having *baseline* data for both the upper and lower reaches provided a comprehensive and complete assessment of this reach. Differences in measurement endpoint values between upper and lower reaches were assessed using the BT contrast. Differences between before and after development in the catchment of the lower reach were tested using the "before-to-after (T)" contrast. Differences in changes from before to after development, between upper and lower reaches was tested using the interaction of the BT and T contrasts (i.e., BT x T). It was this interaction term that is the most relevant in terms for testing for an oil-sands related effect (Green, 1979). None of the BTxT interactions were significant (Table 5.2-23) indicating that the two reaches have varied similarly from before to after development of the catchment of the lower reach. The multivariate ordination (Figure 5.2-16) similarly showed that the faunal assemblage of benthos from the lower reach was well within the expected assemblage for a *baseline* depositional reach. The Correspondence Analysis also showed that the benthic community at the upper reach was somewhat unusual relative to other *baseline* depositional reaches in 2006 and 2007, but has become more similar to the average depositional reach in 2008. This observation reflects the natural variation that is inherent, and the expectation that a fraction (in fact 5%) of observations fall outside the normal range of variation (which is defined as the region enclosing 95% of likely observations).

Kearl Lake

2008 Habitat Conditions Samples were taken at a depth of 2 m (Table 5.2-24). The lake was dominated by sand and silt substrate comprised of comprised of dead and decaying vegetative material, principally the predominant yellow pond lily (*Nuphar lutea*) with high total organic carbon content (37%). Macrophytes covered the majority of the area that was sampled in the lake (90%).

Relative Abundance of Benthic Invertebrate Community Taxa As in previous years, the benthos of Kearl Lake was dominated by chironomids (28%), copepods (38%), and fingernail clams (Bivalvia, 11%; Table 5.2-22). Other less dominant groups included water mites (Hydracarina, 7%), naidid worms (5%), nematode worms (5%), amphipods (Hyalella azteca, 2%), and caddisflies (Trichoptera, 1%). The dominant chironomids were *Chironomus*, *Dicrotendipes, Endochironomus*, *Tanytarsus* and *Procladius*. The genus *Pisidium* represented the clams (bivalves).

The temporal trends in the benthic invertebrate community measurement endpoints for Kearl Lake (Figure 5.2-17) have the following characteristics:

- Total abundance was lower in 2008 (~ 3,200 individuals/m^2) compared to 2006 and 2007 (up to 17,000 individuals/m^2 in previous years), and near the low end of the expected range for a *baseline* condition;
- The number of taxa, Simpson's Diversity, and Evenness were, low relative to previous sampling years and the lowest on record for Diversity and Evenness; and
- The percent of the fauna as EPT taxa has been low over the data record, and 0% in 2008, lower than all previous years.

Results for the Correspondence Analysis show that all years of sampling in Kearl Lake fall within the 95% natural range of variation (Figure 5.2-18).

5.2.4.2 Sediment Quality

Sediment quality was sampled in fall 2008 in depositional reaches in the Muskeg River watershed where benthic invertebrate communities were sampled:

- A middle depositional reach on the Muskeg River near the Canterra Road crossing (reach MUR-D-2 designated as *test* for its entire data record beginning in 2000);
- An upper depositional reach on the Muskeg River located upstream of the Muskeg River Mine and Aurora North oil sands developments but below Husky Sunrise operations (reach MUR-D-3 designated as *test* for the first time in 2008, sampled since 2002);
- A lower depositional reach on Jackpine Creek near the mouth (reach JAC-D-1 designated as *test* in 2006, sampled since 2002);
- An upper depositional reach on Jackpine Creek (reach JAC-D-2, designated as *baseline* for its entire data record); and
- Depositional areas of Kearl Lake (KEL-1, designated as *baseline* for its entire data record).

2008 Results and Historical Ranges of Concentration Sediment quality data sampled in 2008 from all reaches in the Muskeg River watershed may be compared directly with data for these reaches sampled in 2006 and 2007. Prior to integration of the sediment-quality and benthic invertebrate-community components of RAMP in 2006, current benthic reaches MUR-D-2 and MUR-D-3 correspond to pre-2006 sediment-quality stations MUR-2 and MUR-D2, respectively; the current reach JAC-D-1 corresponds with pre-2006 sediment quality station JAC-1. The current reach JAC-D-2 was established in 2006.

At depositional reaches MUR-D-2, MUR-D-3 and JAC-D-1, designated as *test* reaches in fall 2008, most sediment-quality measurement endpoints fell within historical ranges. All of these comparisons are characterized by small sample sizes (n= 2 to 6 years). Concentrations of sediment quality measurement endpoints in fall 2008 that were outside historical ranges included:

- At reach MUR-D-2: silt, sand, total organic carbon, CCME F3 and F4 hydrocarbons, naphthalene, total dibenzothiophenes, and total PAHs were all below historical minima (Table 5.2-26);
- At reach MUR-D-3: CCME F3 and F4 hydrocarbons and *Chironomus* survival (historical highs); retene, total dibenzothiophenes, total PAHs and predicted PAH toxicity (historical lows) (Table 5.2-27); and
- At reach JAC-D-1: CCME F3 and F4 hydrocarbons, retene and *Hyalella* survival (historical highs) (Table 5.2-28).

Only two years of data exist at the *baseline* reach JAC-D-2, and only one year of PAH and sublethal-toxicity data are available; therefore, all 2008 PAH and chronic toxicity data represent either a historical minima or maxima. In fall 2008, sediments from JAC-D-2 exhibited historical low concentrations of clay and silt, total organic carbon and CCME F3 and F4 hydrocarbons (Table 5.2-29).

In fall 2008, sediments in Kearl Lake (KEL-1) exhibited historical high concentrations of hydrocarbons (F2-F4) and *Chironomus* and *Hyalella* growth exceeded historical maxima in Kearl Lake (Table 5.2-30).

Comparison to Sediment Quality Guidelines CCME F3 hydrocarbons exceeded the relevant CCME soil-quality guideline at reaches MUR-D-3 and JAC-D-1 and in Kearl Lake in fall 2008; the CCME F2 hydrocarbons also exceeded the relevant guideline in Kearl Lake (Table 5.2-27, Table 5.2-28, and Table 5.2-30). No other sediment-quality measurement endpoints exceeded relevant guidelines in the Muskeg River watershed in fall 2008.

Qualitative Among-Reach Comparisons The following comparisons in 2008 concentrations of sediment-quality measurement variables among reaches are noted (Table 5.2-26 to Table 5.2-29):

- Silt and total organic carbon concentrations were higher at upstream reach MUR-D-3 (27.1% and 21.3%, respectively) than at mid-river reach MUR-D-2 (2.3% and 0.97%, respectively);
- Hydrocarbons concentrations were highest at upstream station MUR-D-3, followed by JAC-D-1, the lower reach on Jackpine Creek. The Muskeg River middle reach, MUR-D-2, and the upper reach on Jackpine Creek, JAC-D-2 had hydrocarbon concentrations that were much lower than the other two sites;
- PAH concentrations were higher at reach JAC-D-1 than at other reaches;
- Survival of *Chironomus* was highest in MUR-D-3 and JAC-D-2 reaches, while *Chironomus* growth was highest in JAC-D-1; survival and growth of *Hyalella* were similar among all reaches; and
- CCME F1 hydrocarbons (C6-C10) and BTEX (benzene, toluene, ethylene and xylene) were not detectable in sediments from any reach.

Sediment Quality Index SQI values for all stations in the Muskeg River watershed in fall 2008 indicated Negligible-Low difference from regional *baseline* conditions (Table 5.2-31). Reaches in the Muskeg River mainstem (MUR-D-2, MUR-D-3) and lower Jackpine Creek (JAC-D-1) exhibited SQI values of 100, indicating complete consistency with regional *baseline* conditions. Values were slightly lower for upper Jackpine Creek (JAC-D-2, 98.4) and Kearl Lake (KEL-1, 94.1), but still indicated close correspondence with regional *baseline* conditions.

5.2.4.3 Summary

The differences in benthic invertebrate community measurement endpoints observed between *test* reaches in the lower and middle Muskeg River watershed as compared to *baseline* data from the upper reach (prior to 2008) in the Muskeg River watershed are classified as Negligible-Low on the basis of the following:

- While there were significant differences in values of benthic invertebrate community measurement endpoints between the lower *test* reach and upper *baseline* reach these differences are most likely due to the differences in habitat (erosional in the lower *test* reach versus depositional in the upper *baseline* reach.

- There were no significant differences in values of benthic invertebrate community measurement endpoints between the middle *test* reach and the upper *baseline* reach.
- Values of all benthic invertebrate community measurement endpoints in the lower and middle *test* reaches and in the upper reach in 2008, now a *test* reach, were within the normal range of variation for *baseline* erosional and depositional reaches in the RAMP FSA.

In addition, %EPT in all three sampled reaches in the Muskeg River was high in fall 2008.

The differences in benthic invertebrate community measurement endpoints observed between a *test* reach in the lower Jackpine Creek watershed and a *baseline* reach from the Jackpine Creek watershed are assessed as Negligible-Low because there were no significant differences in values of measurement endpoints between the two reaches and values of benthic invertebrate community measurement endpoints in the lower *test* reach was within the normal range of variation for *baseline* depositional reaches in the RAMP FSA.

Sediment quality at all Muskeg River watershed stations sampled by RAMP in 2008 was generally consistent with that of previous years, and largely within historical and regional *baseline* ranges. Sediment quality in the upper reaches of the Muskeg River mainstem and Jackpine Creek was similar to that observed in lower reaches. Differences in sediment quality in fall 2008 at all five stations monitored in the Muskeg River watershed as compared to regional *baseline* conditions are assessed as Negligible-Low (Table 5.2-1).

5.2.5 Fish Populations

The Muskeg River fish fence program was planned for spring 2008, but not implemented due to prohibitively high water levels. The RAMP 2008 Fish Population component therefore did not include any activities in the Muskeg River watershed.

Figure 5.2-3 Muskeg River: 2008 hydrograph and historical context.

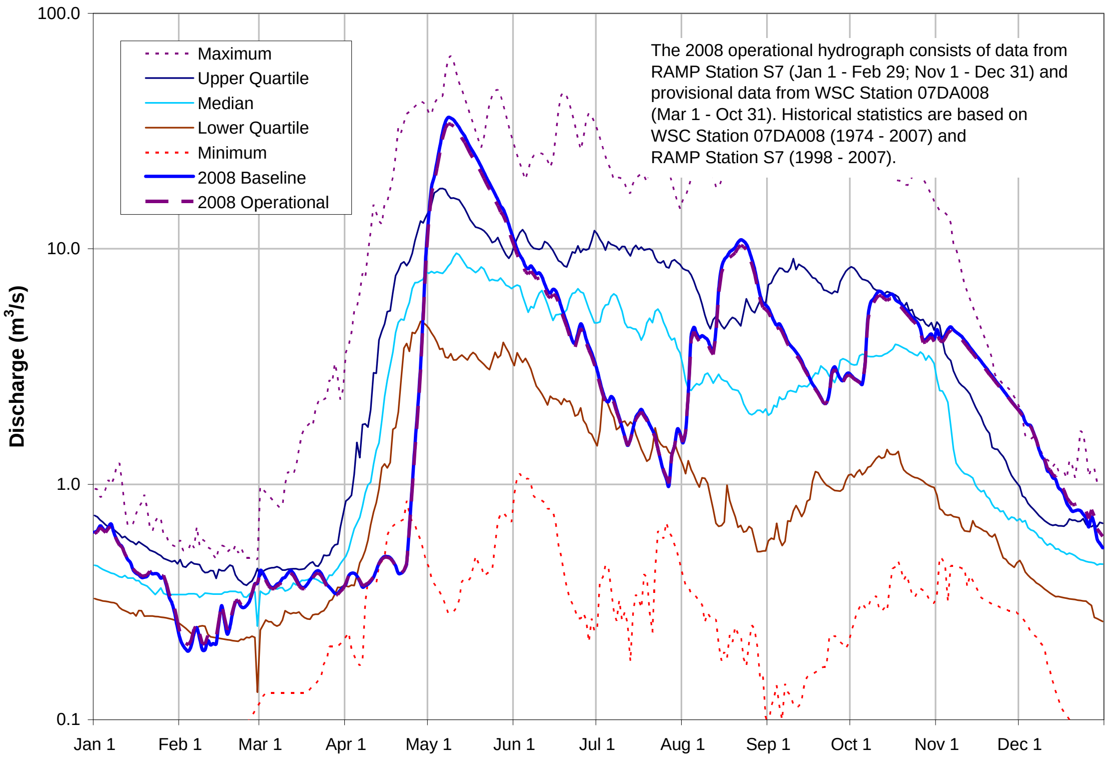


Table 5.2-2 Estimated water balance at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008), in 2008.

Component	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total annual discharge)	**137.1**	**Observed annual discharge obtained from RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008)**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+9.72	99.0 km^2 within Muskeg River catchment estimated to have been closed-circuited by focal projects as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.856	43.6 km^2 within Muskeg River catchment estimated to have undergone land change by focal projects as of 2008, but are not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from the Muskeg River by focal projects	0	Unknown, assumed to be negligible
Amount by which discharge would be lower without releases to the Muskeg River watershed by focal projects	-2.53	Aurora Clean Water Diversion discharges to Stanley Creek – annual total (Section 2.2), data provided by Syncrude
Diversions into or out of the watershed	0	None
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of Muskeg River not accounted for in figures contained in this table
***Baseline* hydrograph (total annual discharge)**	**143.5**	**Estimated *baseline* annual discharge at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008)**
Incremental flow (change in total annual discharge)	-6.34	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total annual discharge)	-4.4%	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.2-3 Calculated changes in hydrologic measurement endpoints for the Muskeg River watershed.

Measurement Endpoint[1]	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	8.03	7.64	-4.8%
Mean winter discharge	0.94	0.94	0.1%
Annual maximum daily discharge	38.0	35.7	-6.0%
Open-water season minimum daily discharge	1.20	1.21	0.7%

[1] As measured at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008).

Note: *Baseline* values shown in the table are likely underestimated, because they are based on the simplifying assumption that none of the releases from the Aurora Clean Water Diversion would have reached the Muskeg River naturally.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Figure 5.2-4 Kearl Lake: 2008 hydrograph and historical context.

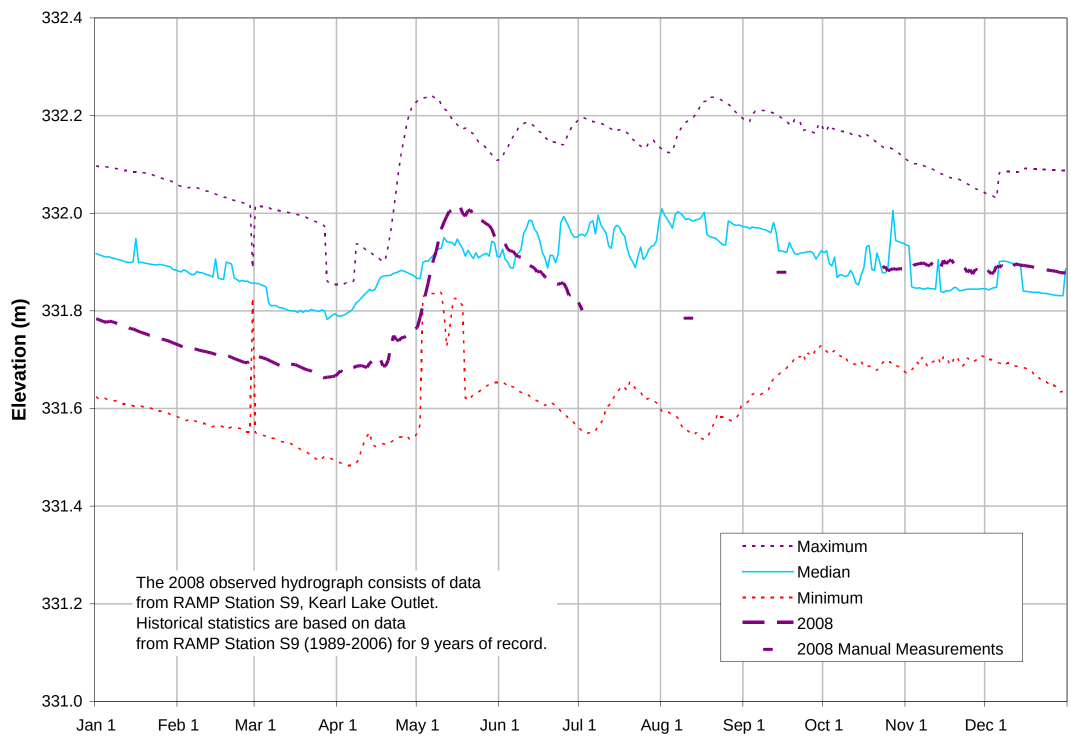


Figure 5.2-5 Kearl Lake outlet: 2008 hydrograph and historical context.

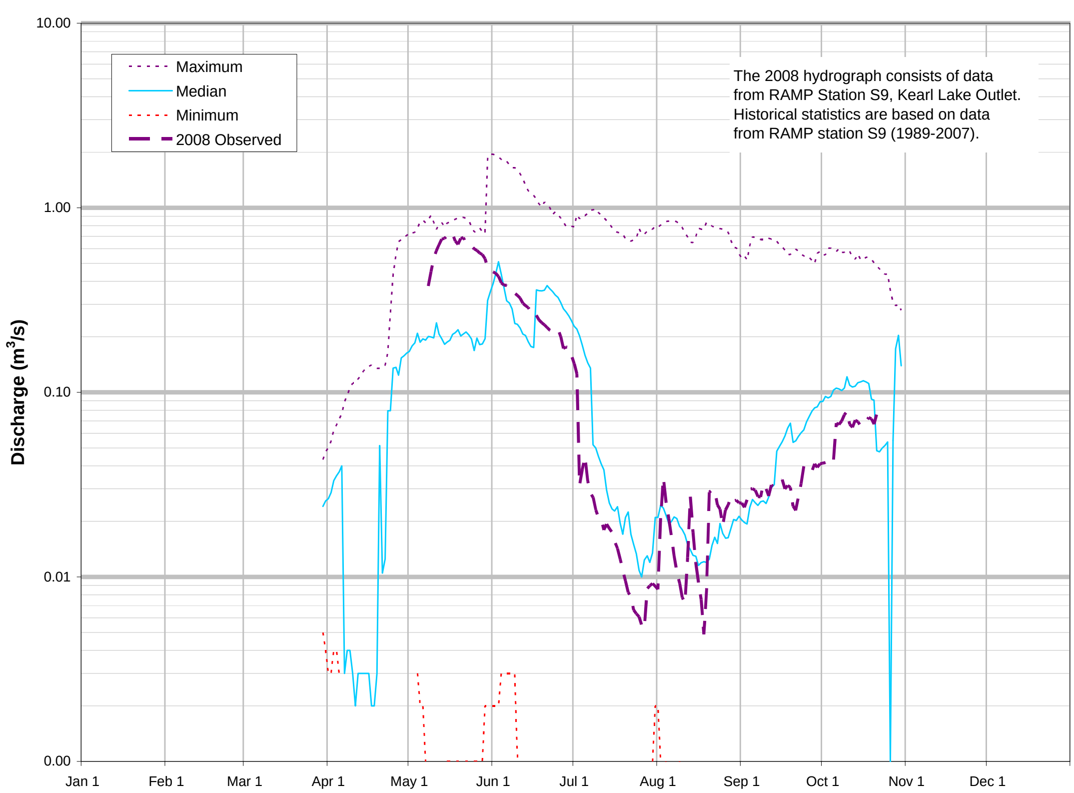


Table 5.2-4 Concentrations of selected water quality measurement endpoints, Muskeg River mouth (station MUR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	11	7.4	8.2	8.4
Total suspended solids	mg/L	-[1]	3	11	<3	3	70
Conductivity	µS/cm	-	314	11	220	338	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.017	11	0.004	0.013	0.03
Total nitrogen*	mg/L	1.0	0.9	11	0.4	0.9	**1.2**
Nitrate+nitrite	mg/L	1.0	<0.1	11	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	29	11	15	21	25
Ions							
Sodium	mg/L	-	12	11	8	13	64
Calcium	mg/L	-	42	11	28.8	50.6	108
Magnesium	mg/L	-	11.5	11	7.1	12.0	18.9
Chloride	mg/L	230, 860[3]	3	11	1	3	36
Sulphate	mg/L	100[4]	4.1	11	0.6	5.4	91
Total dissolved solids	mg/L	-	330	11	170	280	405
Total alkalinity	mg/L		165	11	105	177	313
Organic compounds							
Naphthenic acids	mg/L	-	<1	11	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0263	11	0.027	0.078	**1.2**
Dissolved aluminum	mg/L	0.1[2]	0.0041	11	<0.01	0.0034	0.030
Total arsenic	mg/L	0.005	0.0005	11	<0.001	0.0004	0.001
Total boron	mg/L	1.2[5]	0.0395	11	0.032	0.044	0.15
Total molybdenum	mg/L	0.073	0.0001	11	<0.0001	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.123	11	0.086	0.127	0.296
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.01**	11	**<0.003**	**0.004**	**0.022**
Dissolved iron	mg/L	0.3[2]	**0.522**	11	0.14	**0.34**	**1.02**
Total iron	mg/L	0.3	**0.809**	11	0.287	**0.625**	**1.81**
Total phenols	mg/L	0.004	**0.007**	11	<0.001	0.002	**0.011**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.2-5 Concentrations of selected water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (station MUR-6), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	10	7.2	8.1	8.4
Total suspended solids	mg/L	-[1]	3	10	<3	3	25
Conductivity	µS/cm	-	320	10	233	307.5	441
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.013	10	0.011	0.014	0.029
Total nitrogen*	mg/L	1.0	0.9	10	0.3	0.80	**1.65**
Nitrate+nitrite	mg/L	1.0	<0.1	10	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13	10	14	18.5	24
Ions							
Sodium	mg/L	-	3	10	3	3.5	7
Calcium	mg/L	-	43.5	10	31.3	46.9	67.4
Magnesium	mg/L	-	15.9	10	11.6	16.1	21.4
Chloride	mg/L	230, 860[3]	1	10	<1	1	3
Sulphate	mg/L	100[4]	1.5	10	1.6	4.5	6.3
Total dissolved solids	mg/L	-	210	10	180	250	320
Total alkalinity	mg/L		166	10	120	186	235
Organic compounds							
Naphthenic acids	mg/L	-	<1	10	<1	<1	12
Selected metals							
Total aluminum	mg/L	0.1	0.0103	10	<0.02	0.021	**0.11**
Dissolved aluminum	mg/L	0.1[2]	0.0034	10	<0.01	0.0027	0.01
Total arsenic	mg/L	0.005	0.0003	10	<0.001	0.0003	0.0004
Total boron	mg/L	1.2[5]	0.0106	10	0.006	0.0113	0.01573
Total molybdenum	mg/L	0.073	0.0001	10	<0.0001	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0837	10	0.058	0.085	0.164
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.011**	**10**	**<0.003**	**0.007**	**0.014**
Total phenols	mg/L	0.004	**0.007**	**10**	<0.001	0.004	**0.01**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.2-6 Concentrations of selected water quality measurement endpoints Jackpine Creek (station JAC-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	9	7.8	8.00	8.3
Total suspended solids	mg/L	-[1]	3	9	<3	<3	8
Conductivity	µS/cm	-	242	9	183	237	413
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.016	9	0.006	0.014	0.026
Total nitrogen*	mg/L	1.0	0.9	9	0.7	0.900	**1.5**
Nitrate+nitrite	mg/L	1.0	<0.1	9	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	30	9	18.6	22	28
Ions							
Sodium	mg/L	-	12	9	10	12	18
Calcium	mg/L	-	29.2	9	22.2	28.9	56.6
Magnesium	mg/L	-	8.7	9	6.6	7.3	14.2
Chloride	mg/L	230, 860[3]	2	9	1	2	6
Sulphate	mg/L	100[4]	1.7	9	<3	2.7	4.3
Total dissolved solids	mg/L	-	180	9	110	210	234
Total alkalinity	mg/L		122	9	93	118	227
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0233	9	0.0179	0.074	0.12
Dissolved aluminum	mg/L	0.1[2]	0.0060	9	<0.01	0.0087	0.17
Total arsenic	mg/L	0.005	0.0005	9	<0.001	0.0003	0.0006
Total boron	mg/L	1.2[5]	0.0386	9	0.033	0.0422	0.066
Total molybdenum	mg/L	0.073	0.0001	9	0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.112	9	0.085	0.102	0.171
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.01**	9	**0.006**	**0.009**	**0.103**
Dissolved iron	mg/L	0.3[2]	**0.377**	9	0.19	0.28	**0.699**
Total iron	mg/L	0.3	**0.547**	9	**0.38**	**0.591**	**1.57**
Total phenols	mg/L	0.004	**0.007**	9	<0.001	**0.006**	**0.019**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.2-7 Concentrations of selected water quality measurement endpoints Jackpine Creek (station JAC-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008 Value
Physical variables			
pH	pH units	6.5-9.0	8
Total suspended solids	mg/L	-[1]	6
Conductivity	µS/cm	-	213
Nutrients			
Total dissolved phosphorus	mg/L	0.05[2]	0.017
Total nitrogen*	mg/L	1.0	0.9
Nitrate+nitrite	mg/L	1.0	<0.1
Dissolved organic carbon	mg/L	-	25
Ions			
Sodium	mg/L	-	10
Calcium	mg/L	-	26.9
Magnesium	mg/L	-	8.6
Chloride	mg/L	230, 860[3]	1
Sulphate	mg/L	100[4]	2
Total dissolved solids	mg/L	-	150
Total alkalinity	mg/L		110
Organic compounds			
Naphthenic acids	mg/L	-	<1
Selected metals			
Total aluminum	mg/L	0.1	**0.202**
Dissolved aluminum	mg/L	0.1[2]	0.0104
Total arsenic	mg/L	0.005	0.0007
Total boron	mg/L	1.2[5]	0.0571
Total molybdenum	mg/L	0.073	0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2
Total strontium	mg/L	-	0.104
Other variables that exceeded CCME/AENV guidelines in fall 2008			
Sulphide	mg/L	0.002[7]	**0.007**
Dissolved iron	mg/L	0.3[2]	**0.411**
Total iron	mg/L	0.3	**0.698**
Total phenols	mg/L	0.004	**0.012**

JAC-2 only sampled in 2008.

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.2-8 Concentrations of selected water quality measurement endpoints, Stanley Creek (station STC-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	7	7.6	8.0	8.2
Total suspended solids	mg/L	-[1]	<3	7	<3	<3	6
Conductivity	µS/cm	-	381	7	271	435	760
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.021	8	0.01	0.01	0.03
Total nitrogen*	mg/L	1.0	0.4	8	0.3	0.4	**2.1**
Nitrate+nitrite	mg/L	1.0	<0.1	8	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	9	7	6	8	10
Ions							
Sodium	mg/L	-	3	7	2	5	26
Calcium	mg/L	-	61.1	7	45.4	68.1	112
Magnesium	mg/L	-	12.9	7	11.1	15.2	20.5
Chloride	mg/L	230, 860[3]	<1	7	<1	2	14
Sulphate	mg/L	100[4]	1.1	7	2.4	30.9	**126**
Total dissolved solids	mg/L	-	244	7	200	264	480
Total alkalinity	mg/L		205	7	157	206	260
Organic compounds							
Naphthenic acids	mg/L	-	1	8	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0057	8	<0.02	0.007	0.02
Dissolved aluminum	mg/L	0.1[2]	<0.001	8	<0.01	0.0004	0.02
Total arsenic	mg/L	0.005	0.0001	8	<0.001	0.0001	0.0005
Total boron	mg/L	1.2[5]	0.0281	8	0.018	0.023	0.087
Total molybdenum	mg/L	0.073	<0.000008	8	<0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.139	8	0.075	0.128	0.248
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.004**	8	**<0.003**	**0.0045**	**0.013**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.2-9 Concentrations of selected water quality measurement endpoints, Muskeg Creek (station MUC-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	10	7.4	7.8	8.2
Total suspended solids	mg/L	-[1]	6	10	<3	3.5	9
Conductivity	µS/cm	-	231	10	184	274	671
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.012	10	0.013	0.016	0.034
Total nitrogen*	mg/L	1.0	**1.2**	10	0.4	1.0	**1.15**
Nitrate+nitrite	mg/L	1.0	<0.1	10	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	12	10	20	23.5	29
Ions							
Sodium	mg/L	-	18	10	7	17	64
Calcium	mg/L	-	26.9	10	20.8	32.1	71.1
Magnesium	mg/L	-	9.7	10	6.5	9.7	17.3
Chloride	mg/L	230, 860[3]	1	10	<1	3	36
Sulphate	mg/L	100[4]	2.1	10	2	3.9	8
Total dissolved solids	mg/L	-	170	10	140	215	378
Total alkalinity	mg/L	-	121	10	93	138	313
Organic compounds							
Naphthenic acids	mg/L	-	<1	10	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.0215	10	0.031	0.050	**0.142**
Dissolved aluminum	mg/L	0.1[2]	0.006	10	<0.01	0.0059	0.03
Total arsenic	mg/L	0.005	0.0005	10	<0.001	0.0003	0.0007
Total boron	mg/L	1.2[5]	0.042	10	0.024	0.0551	0.15
Total molybdenum	mg/L	0.073	0.00004	10	<0.0001	0.00006	0.0064
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	1.8
Total strontium	mg/L	-	0.0914	10	0.069	0.096	0.296
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.019**	10	<0.002	**0.01**	**0.068**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.1**	10	0.3	0.9	**1.1**
Total phenols	mg/L	0.004	**0.008**	10	<0.001	**0.005**	**0.017**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[8] Guideline is for total nitrogen.

Table 5.2-10 Concentrations of selected water quality measurement endpoints, Wapasu Creek (station WAC-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	5	7.7	7.9	8.2
Total suspended solids	mg/L	-[1]	<3	5	<3	<3	3
Conductivity	µS/cm	-	247	5	209	284	339
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.011	5	0.009	0.014	0.022
Total nitrogen*	mg/L	1.0	1.1	5	0.8	1.0	1.0
Nitrate+nitrite	mg/L	1.0	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	11	5	17	18	26
Ions							
Sodium	mg/L	-	7	5	6	6	9
Calcium	mg/L	-	33.1	5	29.1	44.0	53.8
Magnesium	mg/L	-	11.1	5	8.6	14.8	17.2
Chloride	mg/L	230, 860[3]	2	5	2	2	3
Sulphate	mg/L	100[4]	1.6	5	1.9	3.1	5.2
Total dissolved solids	mg/L	-	190	5	160	230	250
Total alkalinity	mg/L		124	5	103	168	197
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.015	5	0.014	0.015	0.02
Dissolved aluminum	mg/L	0.1[2]	0.0060	5	<0.01	0.0041	0.0064
Total arsenic	mg/L	0.005	0.0003	5	<0.001	0.0003	0.0003
Total boron	mg/L	1.2[5]	0.019	5	0.014	0.021	0.0316
Total molybdenum	mg/L	0.073	0.00004	5	<0.0001	0.00004	0.00005
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	3.3
Total strontium	mg/L	-	0.082	5	0.067	0.096	0.103
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.018**	5	**<0.003**	**0.006**	**0.019**
Total iron	mg/L	0.3	**0.306**	5	0.177	**0.39**	**0.6**
Total phenols	mg/L	0.004	**0.009**	5	0.002	**0.008**	**0.016**
Total nitrogen	mg/L	1.0	**1.1**	5	0.8	1	1

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);

Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.2-11 Concentrations of selected water quality measurement endpoints, Iyinimin Creek (station IYC-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	1	-	-	8
Total suspended solids	mg/L	-[1]	<3	1	-	-	17
Conductivity	µS/cm	-	202	1	-	-	143
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.031	1	-	-	0.018
Total nitrogen*	mg/L	1.0	0.9	1	-	-	0.9
Nitrate+nitrite	mg/L	1.0	<0.1	1	-	-	<0.1
Dissolved organic carbon	mg/L	-	27	1	-	-	33
Ions							
Sodium	mg/L	-	9	1	-	-	7
Calcium	mg/L	-	24	1	-	-	18.8
Magnesium	mg/L	-	8.3	1	-	-	6.5
Chloride	mg/L	230, 860[3]	1	1	-	-	2
Sulphate	mg/L	100[4]	2.7	1	-	-	3.9
Total dissolved solids	mg/L	-	172	1	-	-	134
Total alkalinity	mg/L		104	1	-	-	72
Organic compounds					-	-	
Naphthenic acids	mg/L	-	<1	1	-	-	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.115**	1	-	-	0.889
Dissolved aluminum	mg/L	0.1[2]	0.0215	1	-	-	0.0439
Total arsenic	mg/L	0.005	0.0008	1	-	-	0.0007
Total boron	mg/L	1.2[5]	0.0487	1	-	-	0.0254
Total molybdenum	mg/L	0.073	0.0002	1	-	-	0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	1	-	-	2.4
Total strontium	mg/L	-	0.0732	1	-	-	0.050
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.007**	1	-	-	**0.013**
Dissolved iron	mg/L	0.3[2]	**0.714**	1	-	-	**0.301**
Total iron	mg/L	0.3	**0.964**	1	-	-	**1.15**
Total phenols	mg/L	0.004	**0.016**	1	-	-	**0.009**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.2-12 Concentrations of selected water quality measurement endpoints, Kearl Lake (station KEL-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	9	7.6	8.0	8.1
Total suspended solids	mg/L	-[1]	4	9	<3	7	19
Conductivity	µS/cm	-	176	9	133	174	183
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.008	9	0.002	0.008	0.013
Total nitrogen*	mg/L	1.0	**1.2**	9	0.45	**1.4**	**1.8**
Nitrate+nitrite	mg/L	1.0	<0.1	9	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	24	9	15	21	24
Ions							
Sodium	mg/L	-	10	9	8	10	11
Calcium	mg/L	-	19.2	9	16.5	19.6	20.6
Magnesium	mg/L	-	6.8	9	5.7	6.9	7.6
Chloride	mg/L	230, 860[3]	<1	9	<1	<0.5	3
Sulphate	mg/L	100[4]	4.2	9	2.7	4.8	5.7
Total dissolved solids	mg/L	-	220	9	94	154	220
Total alkalinity	mg/L		89	9	72	87	93
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0153	9	0.011	0.030	**0.13**
Dissolved aluminum	mg/L	0.1[2]	0.0010	9	<0.01	0.0014	0.030
Total arsenic	mg/L	0.005	0.0004	9	<0.001	0.0003	0.0004
Total boron	mg/L	1.2[5]	0.0523	9	0.012	0.047	0.0493
Total molybdenum	mg/L	0.073	0.0001	9	<0.0001	0.00011	0.0009
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0683	9	0.056	0.0638	0.215
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.005**	9	**<0.003**	**0.006**	**0.01**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.1**	9	0.4	**1.3**	**1.7**
Total phenols	mg/L	0.004	**0.009**	9	<0.001	<0.001	**0.012**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

8 Guideline is for total nitrogen.

Table 5.2-13 Water quality guideline exceedances, Muskeg River watershed, fall 2008.

Variable	Units	Guideline*	JAC-1	JAC-2	MUR-1	STC-1	MUC-1	MUR-6	WAC-1	IYC-1	KEL-1
Winter											
Sulphide	mg/L	0.002[1]	ns	ns	ns	ns	**0.021**	ns	ns	ns	ns
Dissolved iron	mg/L	0.3[3]	ns	ns	ns	ns	**0.551**	ns	ns	ns	ns
Total iron	mg/L	0.3	ns	ns	ns	ns	**0.677**	ns	ns	ns	ns
Total Kjeldahl nitrogen	mg/L	1.0[2]	ns	ns	ns	ns	**1.7**	ns	ns	ns	ns
Total nitrogen	mg/L	1.0	ns	ns	ns	ns	**1.9**	ns	ns	ns	ns
Total phenols	mg/L	0.004	ns	ns	ns	ns	**0.008**	ns	ns	ns	ns
Spring											
Sulphide	mg/L	0.002[1]	ns	ns	ns	ns	**0.009**	ns	ns	ns	ns
Total aluminum	mg/L	0.10	ns	ns	ns	ns	**0.138**	ns	ns	ns	ns
Total Kjeldahl nitrogen	mg/L	1.0[2]	ns	ns	ns	ns	**1.7**	ns	ns	ns	ns
Total nitrogen	mg/L	1.0	ns	ns	ns	ns	**1.8**	ns	ns	ns	ns
Total phenols	mg/L	0.004	ns	ns	ns	ns	**0.009**	ns	ns	ns	ns
Summer											
Sulphide	mg/L	0.002[1]	ns	ns	ns	ns	**0.02**	ns	ns	ns	ns
Dissolved iron	mg/L	0.3[3]	ns	ns	ns	ns	**0.393**	ns	ns	ns	ns
Total iron	mg/L	0.3	ns	ns	ns	ns	**0.523**	ns	ns	ns	ns
Total Kjeldahl nitrogen	mg/L	1.0[2]	ns	ns	ns	ns	**1.1**	ns	ns	ns	ns
Total nitrogen	mg/L	1.0	ns	ns	ns	ns	**1.2**	ns	ns	ns	ns
Total phenols	mg/L	0.004	ns	ns	ns	ns	**0.006**	ns	ns	ns	ns
Fall											
Sulphide	mg/L	0.002[1]	**0.01**	**0.007**	**0.01**	**0.004**	**0.019**	**0.011**	**0.018**	**0.007**	**0.005**
Total aluminum	mg/L	0.10	**-**	**0.202**	**-**	-	-	-	-	**0.115**	-
Dissolved iron	mg/L	0.3[3]	**0.377**	**0.411**	**0.522**	-	-	-	-	**0.714**	-
Total iron	mg/L	0.3	**0.547**	**0.698**	**0.809**	-	**-**	-	**0.306**	**0.964**	
Total phenols	mg/L	0.004	**0.007**	**0.012**	**0.007**	-	**0.008**	**0.007**	**0.009**	**0.016**	**0.009**
Total Kjeldahl nitrogen	mg/L	1.0[2]	**-**	**-**	**-**	-	**1.1**	**-**	**-**	**-**	**1.1**
Total nitrogen	mg/L	1.0	**-**	**-**	**-**	-	**1.2**	**-**	**1.1**	**-**	**1.2**

All sites were sampled only in fall 2008 except for MUC-1 which was sampled in winter, spring, summer and fall 2008.

ns = not sampled

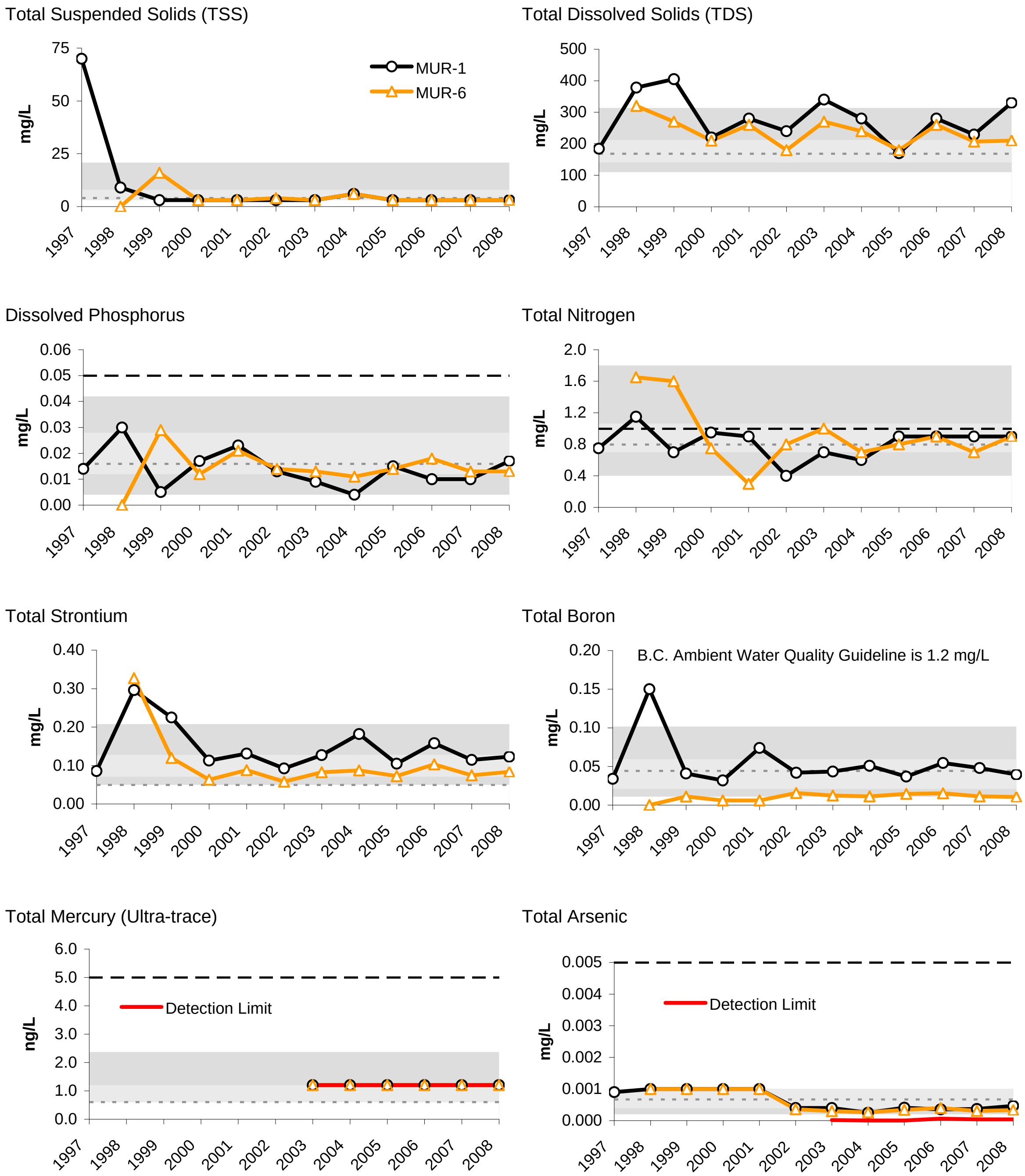
* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[2] Guideline is for total nitrogen (no guideline for TKN).

[3] Guideline is for total metal (no guideline for dissolved analyte).

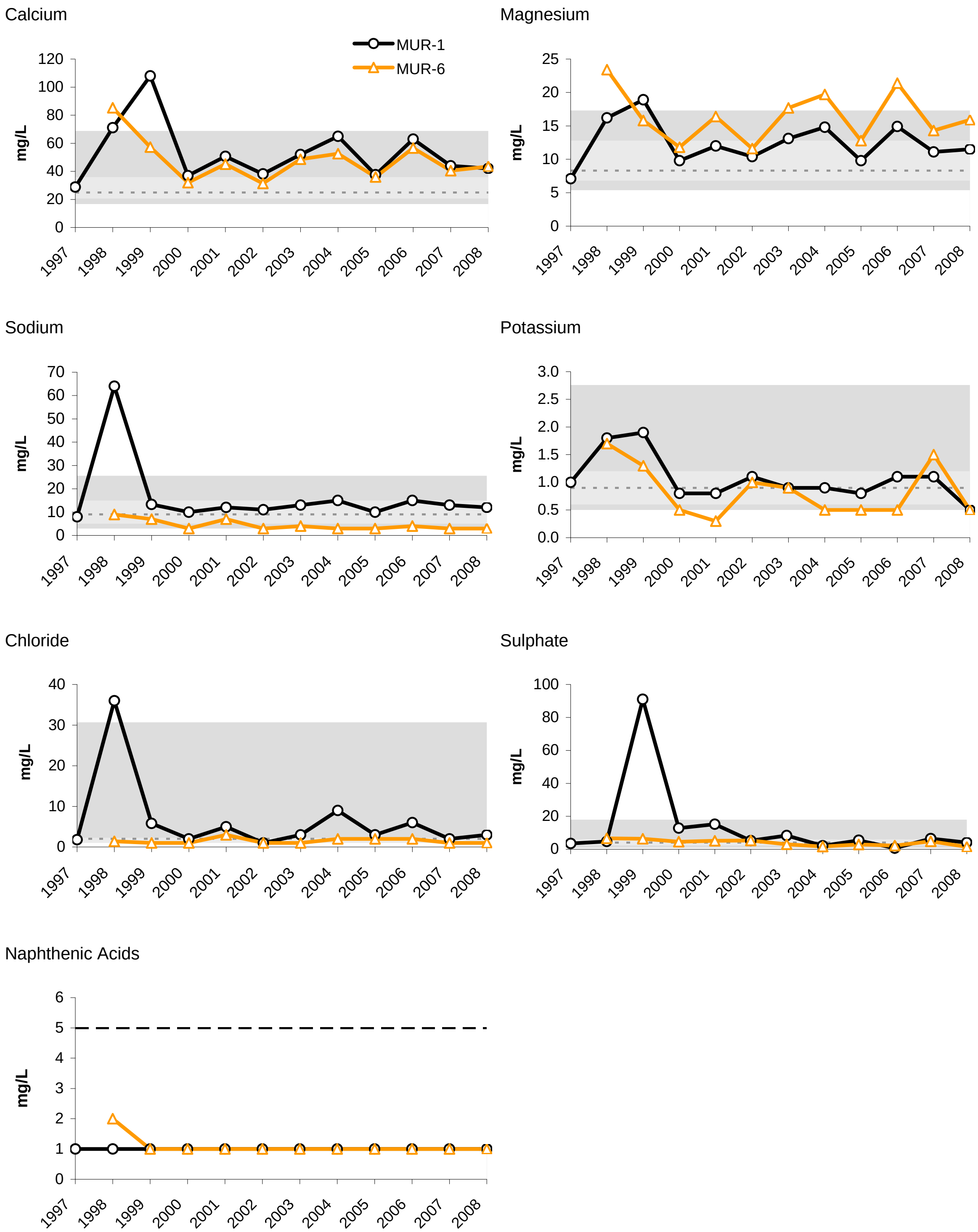
Figure 5.2-6 Selected water quality measurement endpoints in the Muskeg River at the mouth (station MUR-1) and upstream of Wapasu Creek (station MUR-6), fall data, relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

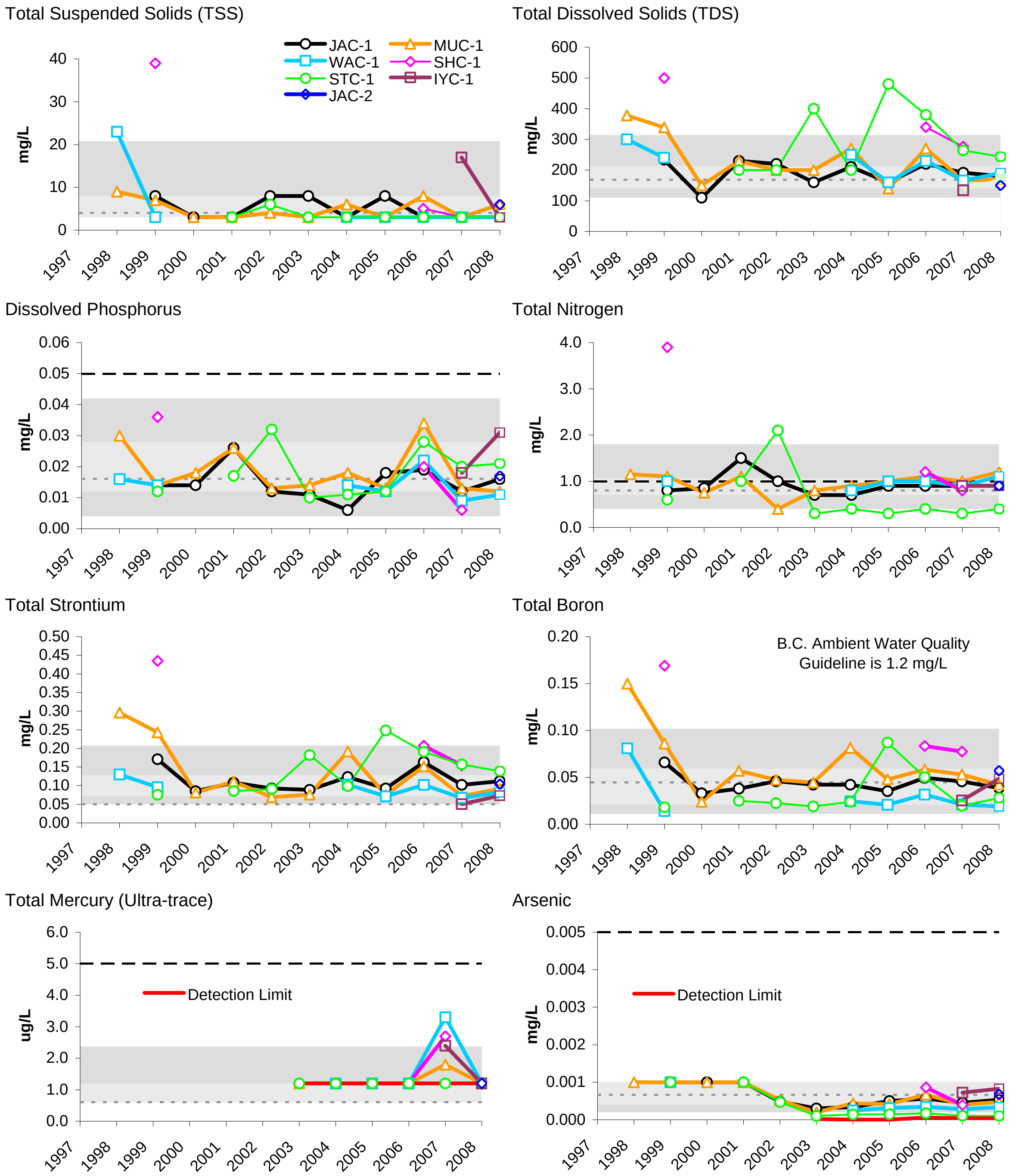
Figure 5.2-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

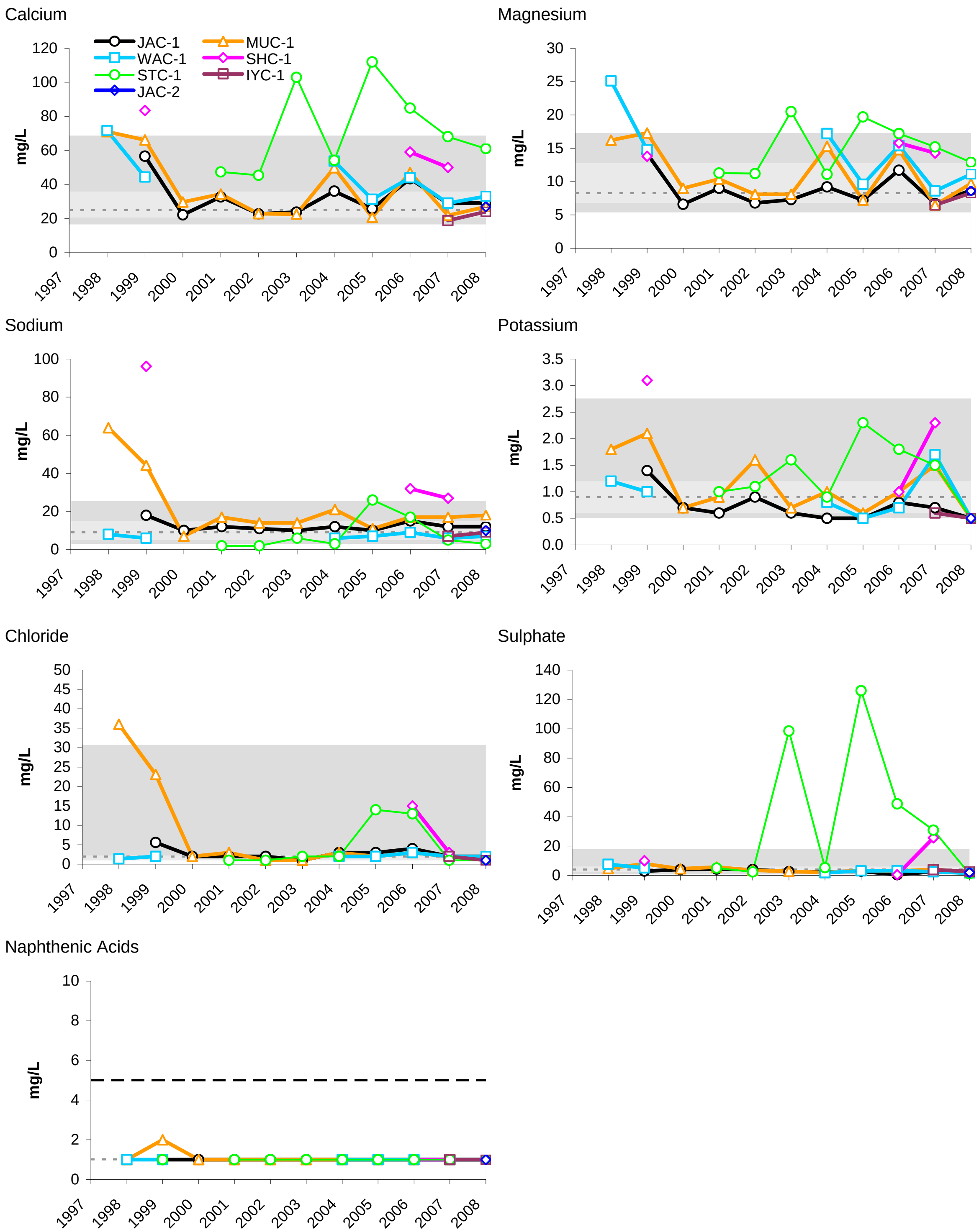
Figure 5.2-7 Selected water quality measurement endpoints in Muskeg River tributaries, fall data, relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

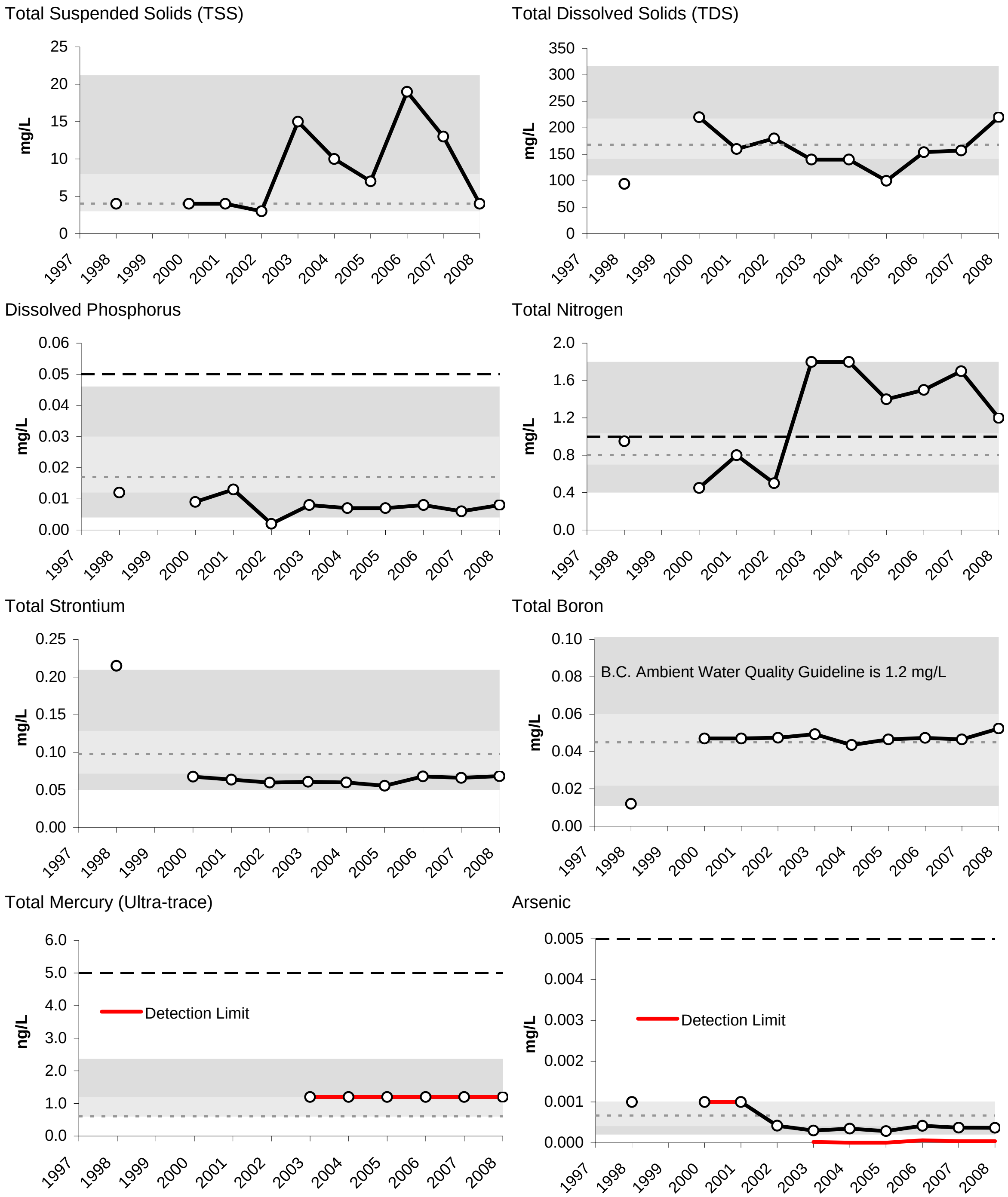
Figure 5.2-7 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Section 3.2.7 for a discussion of this approach, and Appendix D for these regional baseline ranges.

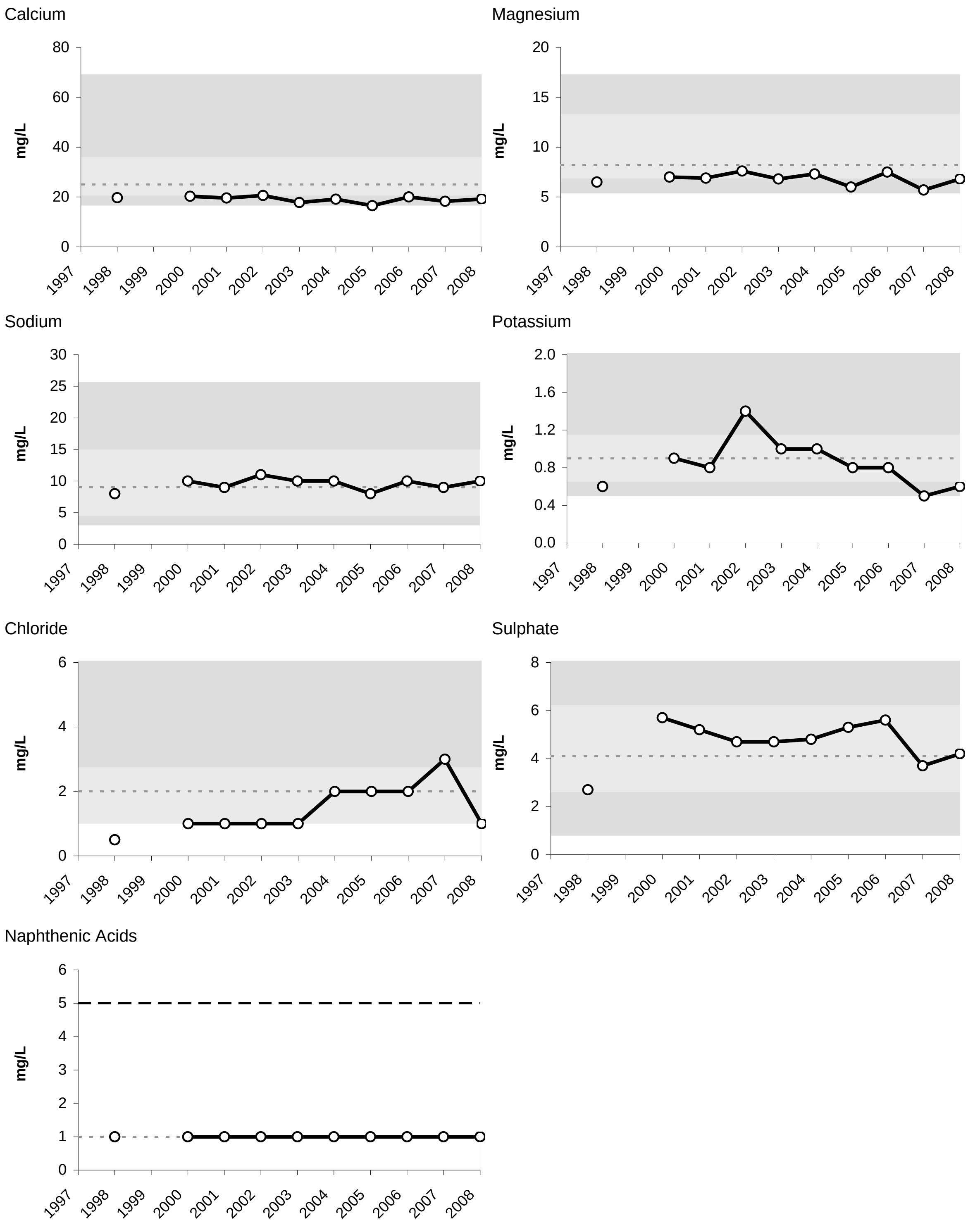
Figure 5.2-8 Selected water quality measurement endpoints in Kearl Lake, fall data, relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.2-8 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.2-9 Piper diagram of fall ion concentrations in the Muskeg River, its tributaries and Kearl Lake, 1997 to 2008.

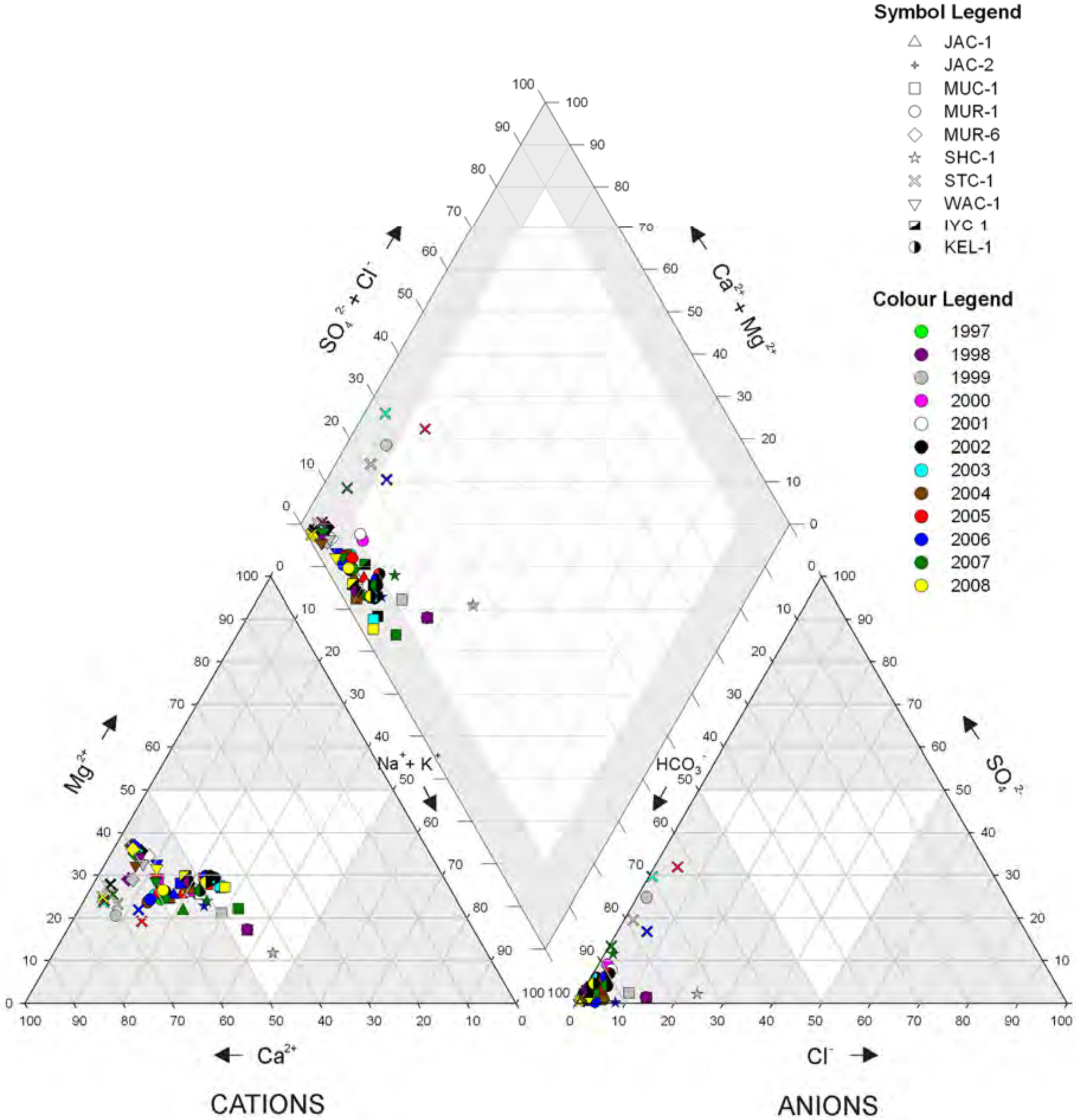


Table 5.2-14 Water quality index (fall 2008) for Muskeg River watershed stations.

Station Identifier	Location	2008 Designation	Water Quality Index	Classification
MUR-1	Lower Muskeg River	*test*	92.2	Negligible-Low
MUR-6	Upstream of Wapasu Creek	*test*	96.1	Negligible-Low
MUC-1	Near mouth of Muskeg Creek	*test*	96.1	Negligible-Low
JAC-1	Near mouth of Jackpine Creek	*test*	96.1	Negligible-Low
JAC-2	Upper Jackpine Creek	*baseline*	96.1	Negligible-Low
STC-1	Near mouth of Stanley Creek	*test*	96.1	Negligible-Low
IYC-1	Near mouth of Iyinimin Creek	*baseline*	96.1	Negligible-Low
WAC-1	Near mouth of Wapasu Creek	*test*	96.1	Negligible-Low
KEL-1	Kearl Lake	*baseline*	96.1	Negligible-Low

Note: see Figure 5.2-1 for the locations of these water quality stations.
Note: see Section 3.2.7.4 for a description of the Water Quality Index.

Table 5.2-15 Habitat characteristics of benthic invertebrate community sampling reaches in the Muskeg River, fall 2008.

Variable	Units	MUR-E-1 Lower Reach of the Muskeg River	MUR-D-2 Middle Reach of the Muskeg River	MUR-D-3 Upper Reach of the Muskeg River
Sample date	-	Sept. 8, 2008	Sept. 11, 2008	Sept. 4, 2008
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.4	1.5	0.6
Current velocity	m/s	0.7	0.2	n/a
Macrophyte cover	%	6	16.5	n/a
Field Water Quality				
Dissolved oxygen	mg/L	12.8	9.6	7.1
Conductivity	µS/cm	351	318	n/a
pH	pH units	8.2	8.3	n/a
Water temperature	°C	9.6	9.5	n/a
Sediment Composition				
Sand	%		94	39
Silt	%		3	27
Clay	%		3	34
Total Organic Carbon	%		1	22
Sand/Silt/Clay	%	3		
Small gravel	%	27		
Large gravel	%	45		
Small cobble	%	19		
Large cobble	%	5		
Boulder	%	1		
Bedrock	%	0		

n/a – not available

Figure 5.2-10 Variation in periphyton chlorophyll *a* in the lower Muskeg River (reach MUR-E-1).

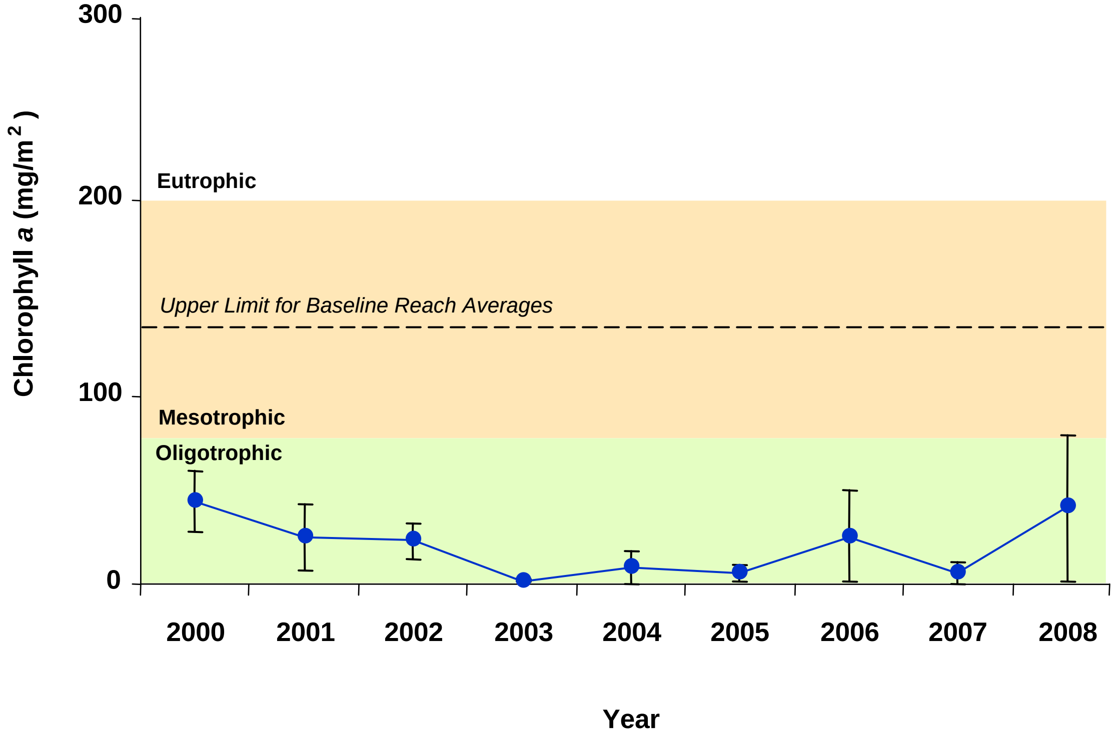


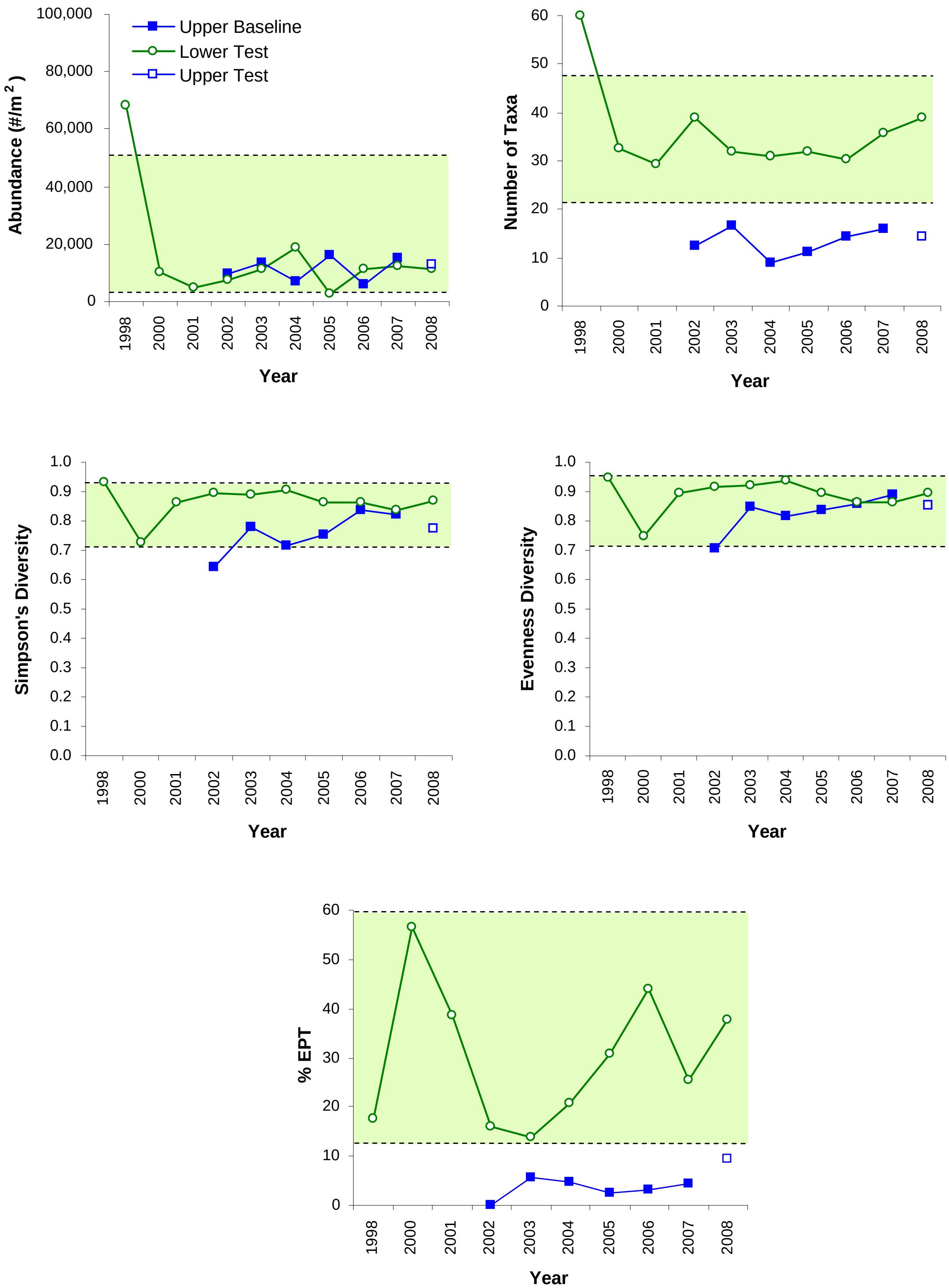
Table 5.2-16 Major taxon percent abundances and benthic invertebrate community composition in the lower Muskeg River.

Taxon	Percent Major Taxa Enumerated in Each Year									
	Reach MUR-E-1									
	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008
Amphipoda		<1		<1	<1					
Anisoptera	<1	<1	2	1	1	2	<1	<1	1	2
Bivalvia	6	1	3	5	1	3	2		5	4
Ceratopogonidae	1	<1	<1	1		<1	<1	1	2	<1
Chironomidae	32	31	23	37	58	37	20	31	25	15
Coleoptera	5	1	2	1	3	10	5	3	2	1
Copepoda	<1	<1	<1	2	<1	<1	1		<1	<1
Empididae	4	<1	2	2	3	6	22	1	<1	<1
Enchytraeidae	<1	<1	1	<1	<1	1	1	<1		1
Ephemeroptera	12	50	28	5	5	9	21	24	20	25
Erpobdellidae				<1						
Gastropoda	3	<1	<1	<1	<1				7	2
Glossiphoniidae				<1						
Hydra		<1	<1	<1						
Hydracarina	14	6	15	13	13		10	11	17	8
Lumbriculidae				<1	<1	<1				<1
Naididae	5	1	6	14	3	3	1	4	3	30
Nematoda	2	<1	4	2	3	5	2	1	1	<1
Ostracoda	3	1	<1	3	<1			<1	2	1
Plecoptera	4	6	5	5	3	8	8	5	3	2
Simuliidae	<1							<1	<1	
Tabanidae	0	<1	<1			<1				
Tipulidae	<1	<1	<1	<1	<1	<1		<1	<1	<1
Trichoptera	2	1	8	5	4	4	2	16	3	2
Tubificidae	5	<1	<1	1	1	13	5		7	7
Benthic Invertebrate Community Measurement Endpoints										
Total Abundance (No./m^2)	68,374	9,983	4,953	7,754	11,343	18,757	2,849	11,131	12,296	11,223
Richness	60	32	29	39	32	31	32	30	36	39
Simpson's Diversity	0.93	0.72	0.86	0.89	0.89	0.91	0.87	0.86	0.84	0.87
Evenness	0.95	0.75	0.89	0.92	0.92	0.94	0.89	0.86	0.86	0.89
% EPT	18	57	39	16	14	21	31	44	25	30

Table 5.2-17 Major taxon percent abundances and benthic invertebrate community measurement endpoints in the middle and upper Muskeg River.

Taxon	Percent Major Taxa Enumerated in Each Year															
	Reach MUR-D-2									Reach MUR-D-3						
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2002	2003	2004	2005	2006	2007	2008
Amphipoda		<1	<1	1	<1	<1	<1	2		<1	1	5	<1	1	<1	<1
Anisoptera	<1	<1	<1	<1		<1		<1	<1		<1	<1				<1
Bivalvia	4	1	3	1	1	<1		2	4	28	17	18	8		5	7
Ceratopogonidae	1	1	2	3	7	4	2	28	11	<1	2	2	1	1	1	1
Chironomidae	75	84	69	81	74	44	55	32	56	66	65	27	79	54	60	48
Coleoptera	<1	<1	<1		<1	1	<1	<1			<1	<1			1	1
Copepoda	<1	1	<1	<1	1	<1	<1	2	<1		1	3	1		<1	2
Empididae	<1	<1	<1	<1	1	1	1		4							
Enchytraeidae	<1	1	2	2	3	3	<1	6	1		<1	1	<1		<1	<1
Ephemeroptera	<1	1	2	1	<1	6	1	2	1		5	5	2	3	3	7
Erpobdellidae	<1	<1	<1	<1		<1		<1		<1	<1	<1	<1	<1	<1	
Gastropoda	<1	3	1	<1		<1	1	2	4	<1	1	2	<1	<1	<1	<1
Glossiphoniidae	<1	<1	<1	<1			<1	<1	<1	<1	1	1	<1	3	<1	<1
Hydra	<1	<1				<1	<1	1	<1				<1	1	<1	
Hydracarina	1	1	2	1	<1	<1	2	<1	3	<1	1	<1	<1		<1	15
Lumbriculidae	1	<1	<1	1		<1	<1	<1			<1	1		1	<1	
Naididae	2	1	<1	2	1	11	1	4	4	<1	1	1	2	2	7	2
Nematoda	2	1	6	3	3	6	1	6	5	1	2	6	3	4	5	2
Ostracoda	1	2	5		<1	10	<1	3	<1	4	1	7	1		2	3
Plecoptera	<1	<1	<1	<1		<1	<1		<1						1	
Simuliidae						1							<1			
Tabanidae	<1	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1	1	<1
Tipulidae	1	<1			<1		<1	<1	1							
Trichoptera	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	1		<1	<1
Tubificidae	10	<1	3	2	8	10	31	5	3	<1	2	15	2	15	16	9
Benthic Invertebrate Community Measurement Endpoints																
Total Abundance (No./m^2)	59,328	64,032	34,672	12,635	10,440	11,948	27,123	14,796	6,322	9,905	13,566	7,190	15,887	6,087	15,001	12,779
Richness	26	30	21	14	10	17	24	20	23	12	17	9	11	15	16	14
Simpson's Diversity	0.75	0.84	0.86	0.7	0.68	0.78	0.69	0.85	0.87	0.64	0.78	0.71	0.75	0.84	0.82	0.77
Evenness	0.78	0.87	0.91	0.77	0.77	0.83	0.69	0.90	0.95	0.71	0.85	0.81	0.83	0.86	0.89	0.85
% EPT	<1	1	2	2	<1	5	1	2	1	<1	6	5	2	3	4	9

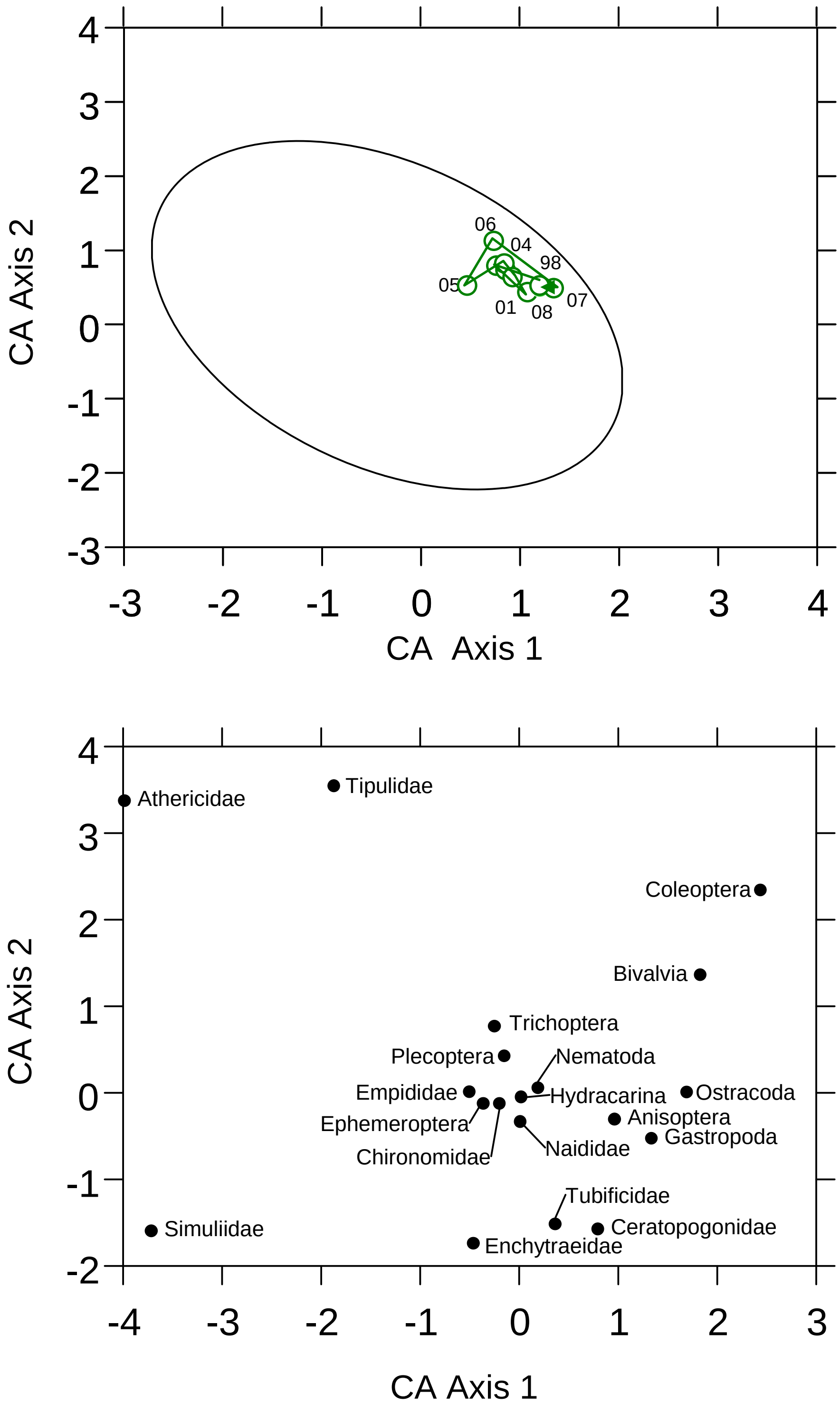
Figure 5.2-11 Variation in benthic invertebrate community measurement endpoints in the lower (MUR-E-1) and upper (MUR-D-3) reaches of the Muskeg River.



Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* erosional sites in the RAMP FSA.

Note: Upper *Baseline* and Upper *Test* – MUR-D-3; Lower *Test* – MUR-E-1

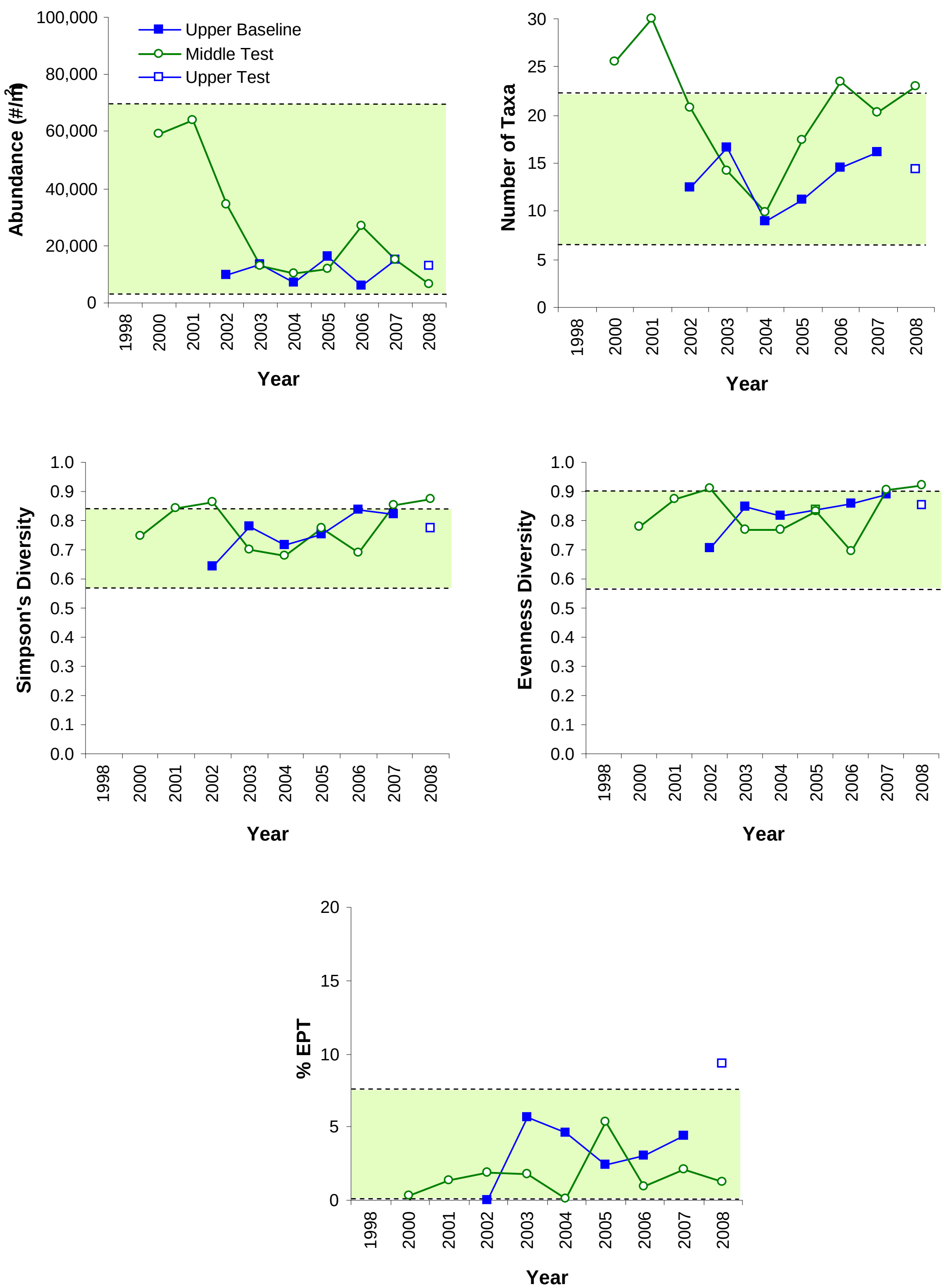
Figure 5.2-12 Ordination (Correspondence Analysis) of benthic invertebrate communities in the lower reach of the Muskeg River (reach MUR-E-1).



Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data for erosional river habitats in the RAMP FSA.

Note: the numbers in the upper panel refer to the sampling year for each data point.

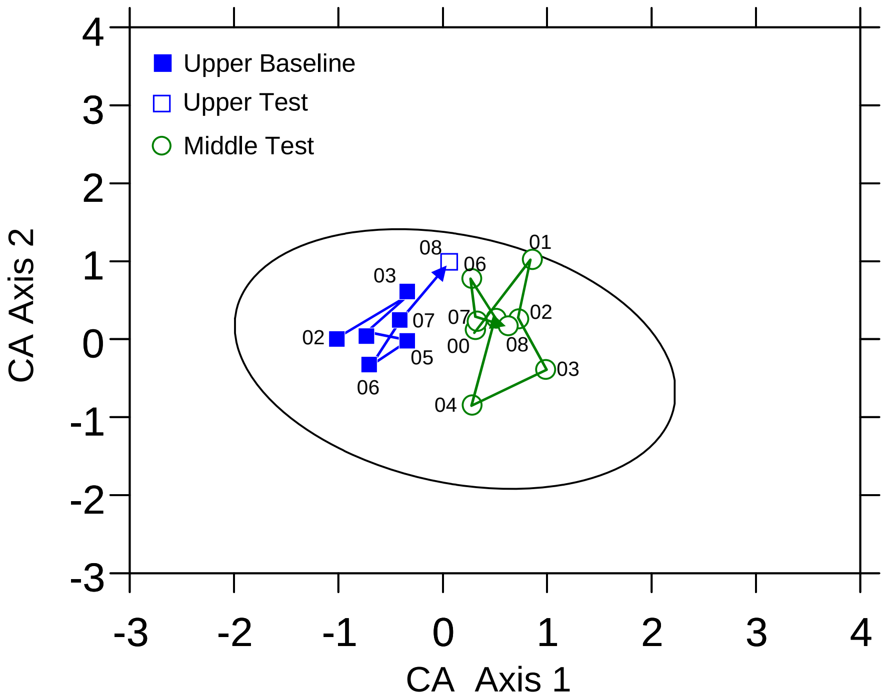
Figure 5.2-13 Variations in benthic invertebrate community measurement endpoints in the middle (MUR-D-2) and upper (MUR-D-3) reaches of the Muskeg River.

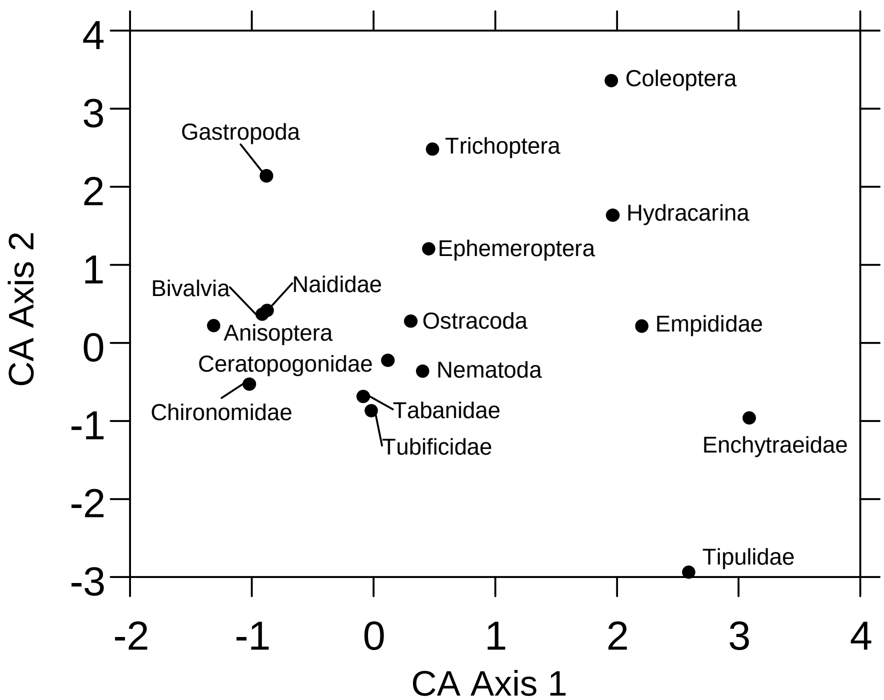


Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* depositional sites in the RAMP FSA

Note: Upper *Baseline* and Upper *Test* – MUR-D-3; Lower *Test* – MUR-D-2

Figure 5.2-14 Ordination (Correspondence Analysis) of depositional reach benthos showing the middle reach (MUR-D-2) of the Muskeg River.





Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data for erosional river habitats in the RAMP FSA.

Note: the numbers in the upper panel refer to the sampling year for each data point.

Table 5.2-18 Results of analysis of variance (ANOVA) between the lower (MUR-E-1) and upper (MUR-D-3) reaches of the Muskeg River.

Variable	Source	SS	df	MS	F-ratio	P
Log Abundance	Reach - Year	8.326	16	0.520	4.78	0.000
	Baseline vs Test (BT)	0.001	1	0.001	0.01	0.910
	Linear Time Trend (T)	0.007	1	0.007	0.07	0.796
	BT x T	0.082	1	0.082	0.75	0.386
	Remainder (noise)	8.235	13	0.633	5.82	0.017
	Error	19.360	178	0.109		
Log Richness	Reach - Year	9.468	16	0.592	30.91	0.000
	Baseline vs Test (BT)	5.417	1	5.417	282.92	0.000
	Linear Time Trend (T)	0.024	1	0.024	1.26	0.263
	BT x T	0.003	1	0.003	0.15	0.698
	Remainder (noise)	4.024	13	0.310	16.21	0.000
	Error	3.408	178	0.019		
Diversity	Reach - Year	1.232	16	0.077	7.85	0.000
	Baseline vs Test (BT)	0.399	1	0.399	40.71	0.000
	Linear Time Trend (T)	0.033	1	0.033	3.36	0.069
	BT x T	0.141	1	0.141	14.39	0.000
	Remainder (noise)	0.658	13	0.051	5.17	0.024
	Error	1.746	178	0.010		
Evenness	Reach - Year	0.866	16	0.054	5.47	0.000
	Baseline vs Test (BT)	0.118	1	0.118	11.89	0.001
	Linear Time Trend (T)	0.028	1	0.028	2.84	0.094
	BT x T	0.161	1	0.161	16.28	0.000
	Remainder (noise)	0.560	13	0.043	4.35	0.038
	Error	1.760	178	0.010		
Log %EPT	Reach - Year	58.70	16	3.67	17.88	0.000
	Baseline vs Test (BT)	19.50	1	19.50	95.02	0.000
	Linear Time Trend (T)	3.05	1	3.05	14.88	0.000
	BT x T	0.46	1	0.46	2.26	0.135
	Remainder (noise)	35.69	13	2.75	13.38	0.000
	Error	36.53	178	0.21		

Table 5.2-19 Results of analysis of variance (ANOVA) between middle (MUR-D-2) and upper (MUR-D-3) reaches of the Muskeg River.

Variable	Source	SS	df	MS	F-ratio	P
Log Abundance	Reach - Year	19.473	15	1.298	9.38	0.000
	Baseline vs Test (BT)	0.896	1	0.896	6.47	0.012
	Linear Time Trend (T)	0.353	1	0.353	2.55	0.112
	BT x T	0.632	1	0.632	4.57	0.034
	Remainder (noise)	17.592	12	1.466	10.59	0.001
	Error	25.470	184	0.138		
Log Richness	Reach - Year	4.471	15	0.298	10.93	0.000
	Baseline vs Test (BT)	0.703	1	0.703	25.77	0.000
	Linear Time Trend (T)	0.227	1	0.227	8.32	0.004
	BT x T	0.071	1	0.071	2.62	0.108
	Remainder (noise)	3.470	12	0.289	10.59	0.001
	Error	5.017	184	0.027		
Diversity	Reach - Year	1.016	15	0.068	4.87	0.000
	Baseline vs Test (BT)	0.011	1	0.011	0.77	0.382
	Linear Time Trend (T)	0.193	1	0.193	13.88	0.000
	BT x T	0.014	1	0.014	1.00	0.319
	Remainder (noise)	0.798	12	0.067	4.78	0.030
	Error	2.560	184	0.014		
Evenness	Reach - Year	1.016	15	0.068	4.87	0.000
	Baseline vs Test (BT)	0.01	1	0.01	0.77	0.382
	Linear Time Trend (T)	0.19	1	0.19	13.88	0.000
	BT x T	0.014	1	0.014	1.00	0.319
	Remainder (noise)	0.798	12	0.067	4.78	0.030
	Error	2.560	184	0.014	0	
Log %EPT	Reach - Year	0.87	15	0.06	4.13	0.000
	Baseline vs Test (BT)	0.00	1	0.00	0.04	0.842
	Linear Time Trend (T)	0.16	1	0.16	11.06	0.001
	BT x T	0.03	1	0.03	2.17	0.142
	Remainder (noise)	0.68	12	0.06	4.06	0.045
	Error	2.58	184	0.01		
CA Axis 1	Reach - Year	74.06	15	4.94	9.86	0.000
	Baseline vs Test (BT)	41.89	1	41.89	83.64	0.000
	Linear Time Trend (T)	0.53	1	0.53	1.05	0.306
	BT x T	4.95	1	4.95	9.89	0.002
	Remainder (noise)	26.7	12	2.224	4.44	0.036
	Error	92.16	184	0.50		
CA Axis 2	Lake - Year	47.91	15	3.19	5.05	0.000
	Baseline vs Test (BT)	0.88	1	0.88	1.40	0.239
	Linear Time Trend (T)	4.40	1	4.40	6.96	0.009
	BT x T	0.10	1	0.10	0.15	0.698
	Remainder (noise)	42.52	12	3.54	5.61	0.019
	Error	116.33	184	0.63		

Table 5.2-20 Analysis of variance (ANOVA) testing variations from before to after development in the upper Muskeg River catchment.

Variable	Source	SS	df	MS	F-ratio	P
Log Abundance	Reach - Year	1.828	6	0.305	2.25	0.047
	Before to After (T)	0.104	1	0.104	0.77	0.383
	Remainder (noise)	1.724	5	0.345	2.55	0.114
	Error	10.552	78	0.135		
Log Richness	Reach - Year	0.561	6	0.094	2.71	0.019
	Before to After (T)	0.000	1	0.000	0.01	0.930
	Remainder (noise)	0.561	5	0.112	3.26	0.075
	Error	2.687	78	0.034		
Diversity	Reach - Year	0.340	6	0.057	3.61	0.003
	BT x T	0.002	1	0.002	0.13	0.719
	Remainder (noise)	0.338	5	0.068	4.30	0.041
	Error	1.223	78	0.016		
Evenness	Reach - Year	0.344	6	0.057	3.68	0.003
	Before to After (T)	0.00	1	0.00	0.20	0.654
	Remainder (noise)	0.341	5	0.068	4.37	0.040
	Error	1.216	78	0.016		
Log %EPT	Reach - Year	15.60	6	2.60	6.13	0.000
	Before to After (T)	0.01	1	0.01	0.02	0.892
	Remainder (noise)	15.59	5	3.12	7.35	0.008
	Error	33.09	78	0.42		
CA Axis 1	Reach - Year	9.25	6	1.54	3.43	0.005
	Before to After (T)	4.15	1	4.15	9.22	0.003
	Remainder (noise)	5.1	5	1.021	2.27	0.136
	Error	35.06	78	0.45		
CA Axis 2	Reach - Year	12.70	6	2.12	3.47	0.004
	Baseline vs Test (BT)	7.85	1	7.85	12.86	0.001
	Remainder (noise)	4.84	5	0.97	1.59	0.212
	Error	47.63	78	0.61		

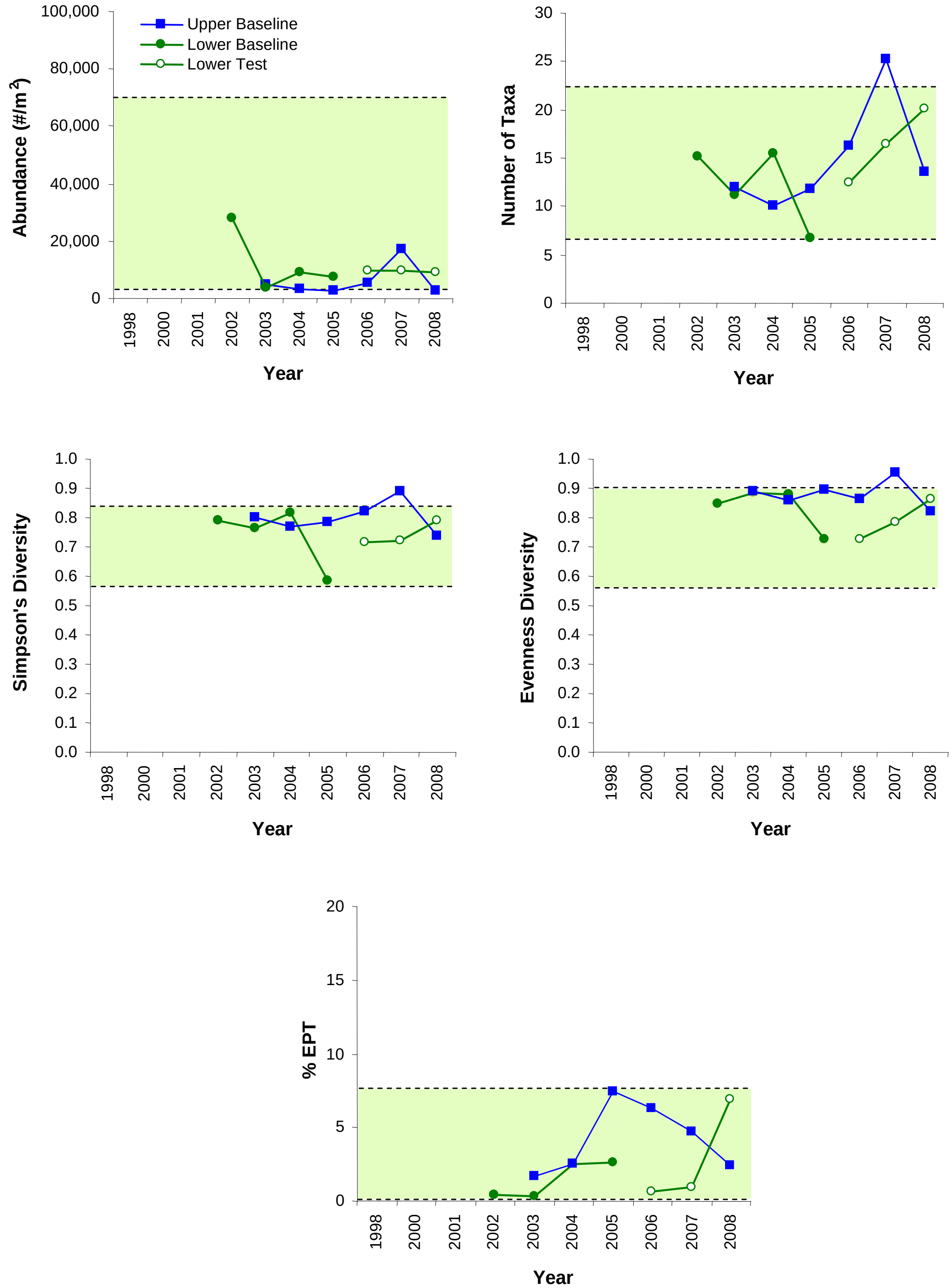
Table 5.2-21 Habitat characteristics of benthic invertebrate community sampling reaches in Jackpine Creek.

Variable	Units	JAC-D-1 Lower Reach of Jackpine Creek	JAC-D-2 Upper Reach of Jackpine Creek
Sample date	-	Sept 9 2008	Sept 10 2008
Habitat	-	Depositional	Depositional
Water depth	m	0.6	0.6
Current velocity	m/s	0.3	0.3
Macrophyte cover	%	3	0
Field Water Quality			
Dissolved oxygen	mg/L	9.1	9.6
Conductivity	µS/cm	224	194
pH	pH units	8.3	8.0
Water temperature	°C	9.8	8.3
Sediment Composition			
Sand	%	87	89
Silt	%	8	6
Clay	%	5	5
Total Organic Carbon	%	0.6	1.5

Table 5.2-22 Major taxon percent abundances and benthic invertebrate community measurement endpoints composition in Jackpine Creek.

Taxon	Percent Major Taxa Enumerated in Each Year												
	Reach JAC-D-1							Reach JAC-D-2					
	2002	2003	2004	2005	2006	2007	2008	2003	2004	2005	2006	2007	2008
Amphipoda		<1	<1										
Anisoptera	<1	<1	<1		1	<1	<1			<1			
Bivalvia	1	3	<1	<1		<1	1	<1	<1	<1		<1	2
Ceratopogonidae	2	2	4		5	2	9	1	31	4	2	5	19
Chironomidae	88	66	69	69	86	66	57	67	3	44	63	66	60
Cladocera			8		<1	2	<1		<1			<1	
Coleoptera		<1	<1				<1	6	3	6	1	2	3
Copepoda	<1	1	6	1		1			2	3		<1	<1
Empididae	<1	2	2	4	2	1	1	1	<1	3	3	1	
Enchytraeidae	<1	4	<1			<1	1	1	1	1	2	<1	<1
Ephemeroptera	<1		2	1	1	1	7	<1	2	1	6	4	3
Gastropoda	<1		<1			2	1			<1	<1	<1	<1
Glossiphoniidae		<1											<1
Hydra			<1									<1	
Hydracarina	1	1	1	8	1	5	4	<1	<1	18	1	2	<1
Naididae	<1	2	2		1	<1	1	3	1	1	2	8	2
Nematoda	5	6	1	4	2	2	6	6	4	2	4	5	3
Ostracoda	<1		2	4		1	<1	<1	1	3	1	<1	<1
Plecoptera					1		<1	<1					<1
Tabanidae	<1	<1	<1	<1	<1	<1	1	1	2	<1	<1	<1	<1
Tipulidae	<1	2	1	1	1	<1	<1	1	13	4	2	<1	<1
Trichoptera	<1	<1	<1	3	<1	<1	2	<1	1	7	1	2	1
Tubificidae	<1	<1	1	5	<1	17	8	2	5	1	2	5	2
Benthic Invertebrate Community Measurement Endpoints													
Total Abundance (No./m^2)	28,172	4,017	9,230	7,417	9,561	9,644	8,913	4,787	3,448	2,957	5,174	16,966	2,752
Richness	15	11	15	7	12	16	20	12	10	12	16	25	14
Simpson's Diversity	0.79	0.76	0.81	0.58	0.72	0.72	0.79	0.8	0.77	0.78	0.82	0.89	0.74
Evenness	0.85	0.88	0.88	0.73	0.73	0.78	0.82	0.89	0.86	0.9	0.86	0.95	0.87
% EPT	<1	<1	2	3	<1	1	2	2	2	7	6	5	6

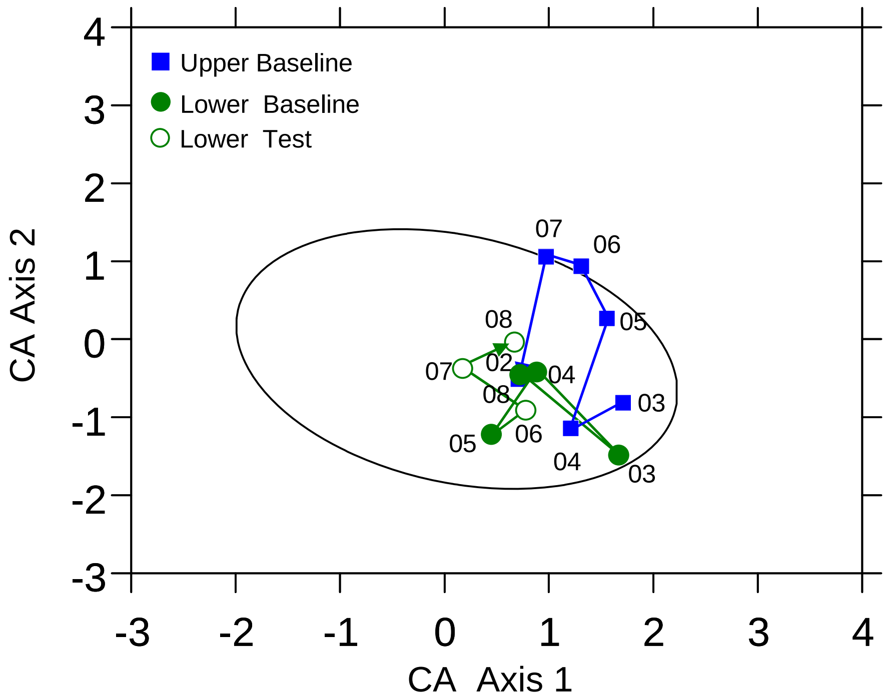
Figure 5.2-15 Variations in benthic invertebrate community measurement endpoints in lower (JAC-D-1) and upper (JAC-D-2) reaches of Jackpine Creek.

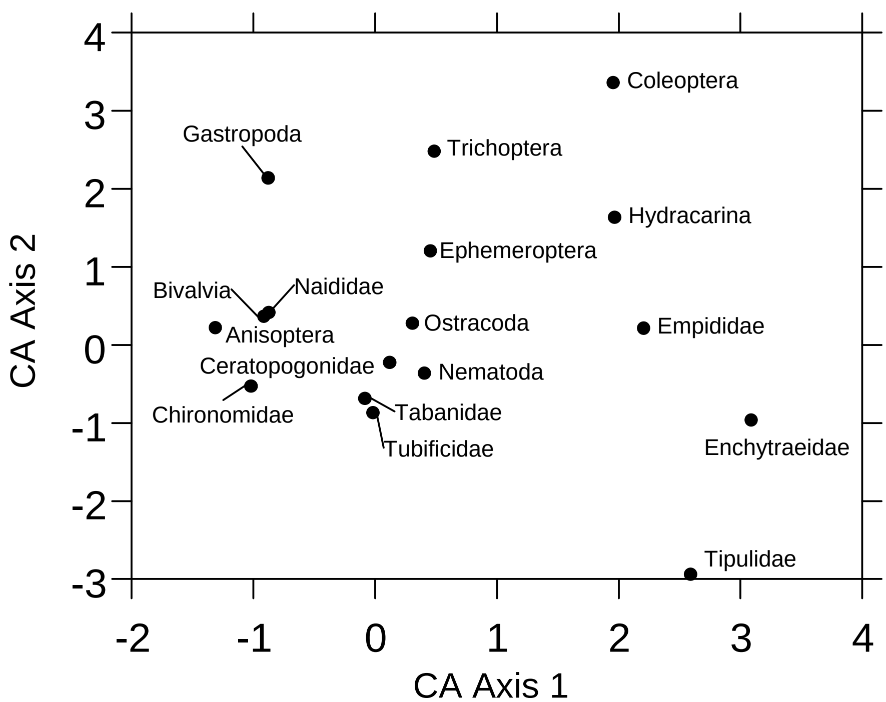


Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* depositional sites in the RAMP FSA

Note: Lower *Baseline* and Lower *Test* – JAC-D-1; Lower *Test* – JAC-D-2

Figure 5.2-16 Ordination (Correspondence Analysis) of depositional reach benthos showing the lower reach (JAC-D-1) of Jackpine Creek.





Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data for erosional river habitats in the RAMP FSA.

Note: the numbers in the upper panel refer to the sampling year for each data point.

Table 5.2-23 Analysis of variance (ANOVA) between lower (JAC-D-1) and upper (JAC-D-2) reaches of Jackpine Creek.

Variable	Source	SS	df	MS	F-ratio	P
Log Abundance	Reach - Year	18.293	12	1.524	5.79	0.000
	Baseline vs Test (BT)	0.957	1	0.957	3.64	0.059
	Before to After (T)	2.549	1	2.549	9.69	0.002
	BT x T	0.170	1	0.170	0.64	0.424
	Remainder (noise)	14.618	9	1.624	6.17	0.014
	Error	37.098	141	0.263		
Log Richness	Reach - Year	2.036	12	0.170	3.60	0.000
	Baseline vs Test (BT)	0.064	1	0.064	1.37	0.244
	Before to After (T)	0.698	1	0.698	14.82	0.000
	BT x T	0.001	1	0.001	0.02	0.884
	Remainder (noise)	1.272	9	0.141	3.00	0.085
	Error	6.639	141	0.047		
Diversity	Reach - Year	0.639	12	0.053	2.41	0.007
	Baseline vs Test (BT)	0.156	1	0.156	7.05	0.009
	Before to After (T)	0.025	1	0.025	1.13	0.289
	BT x T	0.001	1	0.001	0.03	0.862
	Remainder (noise)	0.457	9	0.051	2.30	0.132
	Error	3.120	141	0.022		
Evenness	Reach - Year	0.426	12	0.036	1.76	0.060
	Baseline vs Test (BT)	0.14	1	0.14	6.72	0.011
	Before to After (T)	0.00	1	0.00	0.02	0.895
	BT x T	0.004	1	0.004	0.20	0.655
	Remainder (noise)	0.286	9	0.032	1.58	0.211
	Error	2.839	141	0.020		
Log %EPT	Reach - Year	36.43	12	3.04	9.99	0.000
	Baseline vs Test (BT)	3.10	1	3.10	10.18	0.002
	Before to After (T)	5.68	1	5.68	18.69	0.000
	BT x T	0.63	1	0.63	2.06	0.154
	Remainder (noise)	27.02	9	3.00	9.88	0.002
	Error	42.86	141	0.30		
CA Axis 1	Reach - Year	33.21	12	2.77	2.99	0.001
	Baseline vs Test (BT)	7.87	1	7.87	8.51	0.004
	Before to After (T)	7.69	1	7.69	8.31	0.005
	BT x T	0.01	1	0.01	0.02	0.902
	Remainder (noise)	17.6	9	1.960	2.12	0.148
	Error	130.43	141	0.93		
CA Axis 2	Lake - Year	82.31	12	6.86	4.06	0.000
	Baseline vs Test (BT)	16.67	1	16.67	9.88	0.002
	Before to After (T)	23.18	1	23.18	13.73	0.000
	BT x T	1.79	1	1.79	1.06	0.304
	Remainder (noise)	40.66	9	4.52	2.68	0.104
	Error	237.99	141	1.69		

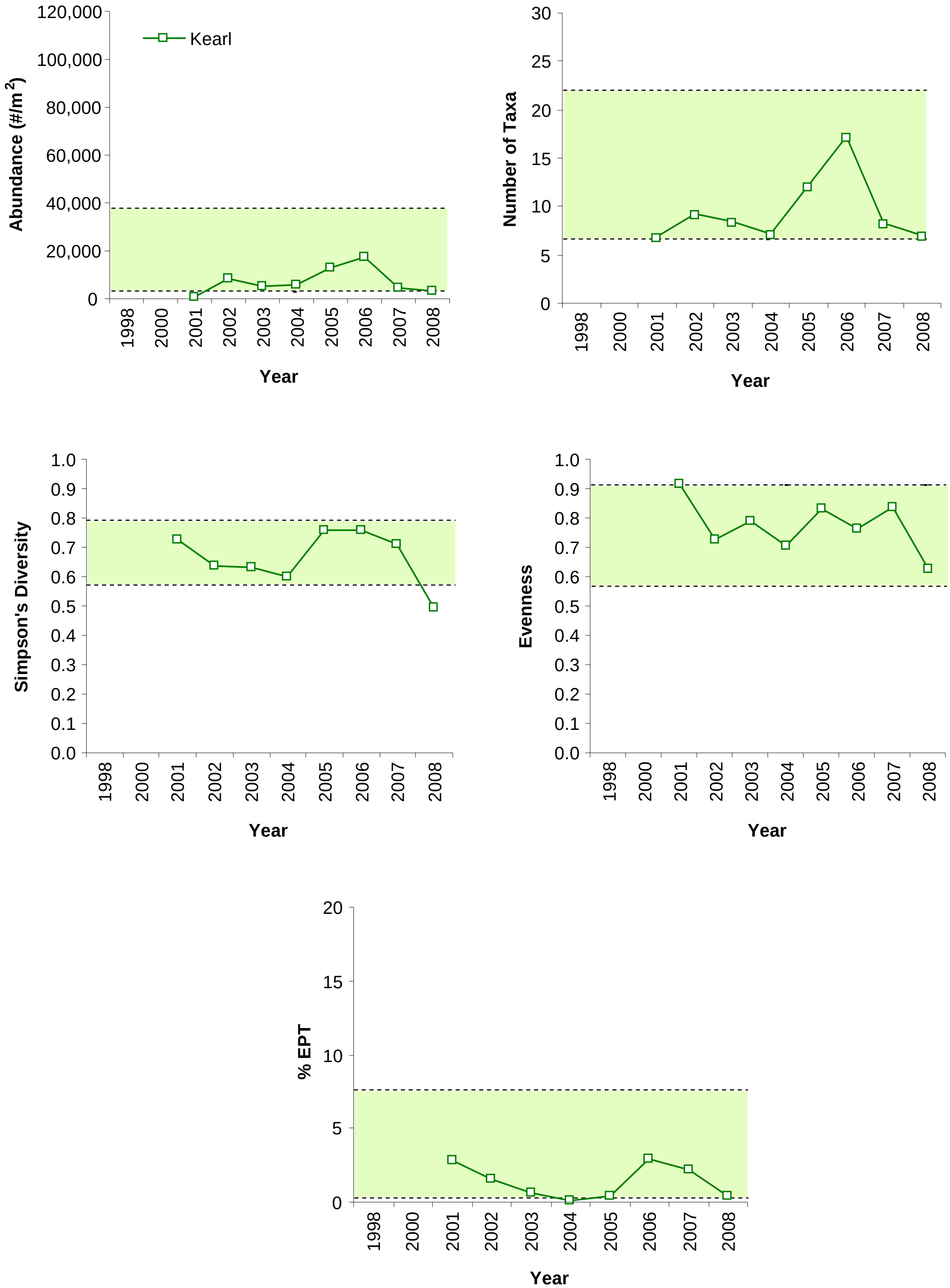
Table 5.2-24 Habitat characteristics of benthic invertebrate community sampling reaches in Kearl Lake.

Variable	Units	Kearl Lake
Sample date	-	Sept 9, 2008
Habitat	-	Depositional
Water depth	m	2
Macrophyte cover	%	90
Field Water Quality		
Dissolved oxygen	mg/L	10
Conductivity	µS/cm	171
pH	pH units	8.3
Water temperature	°C	12
Sediment Composition		
Sand	%	37
Silt	%	36
Clay	%	27
Total Organic Carbon	%	37

Table 5.2-25 Percent abundances of major taxa in Kearl Lake.

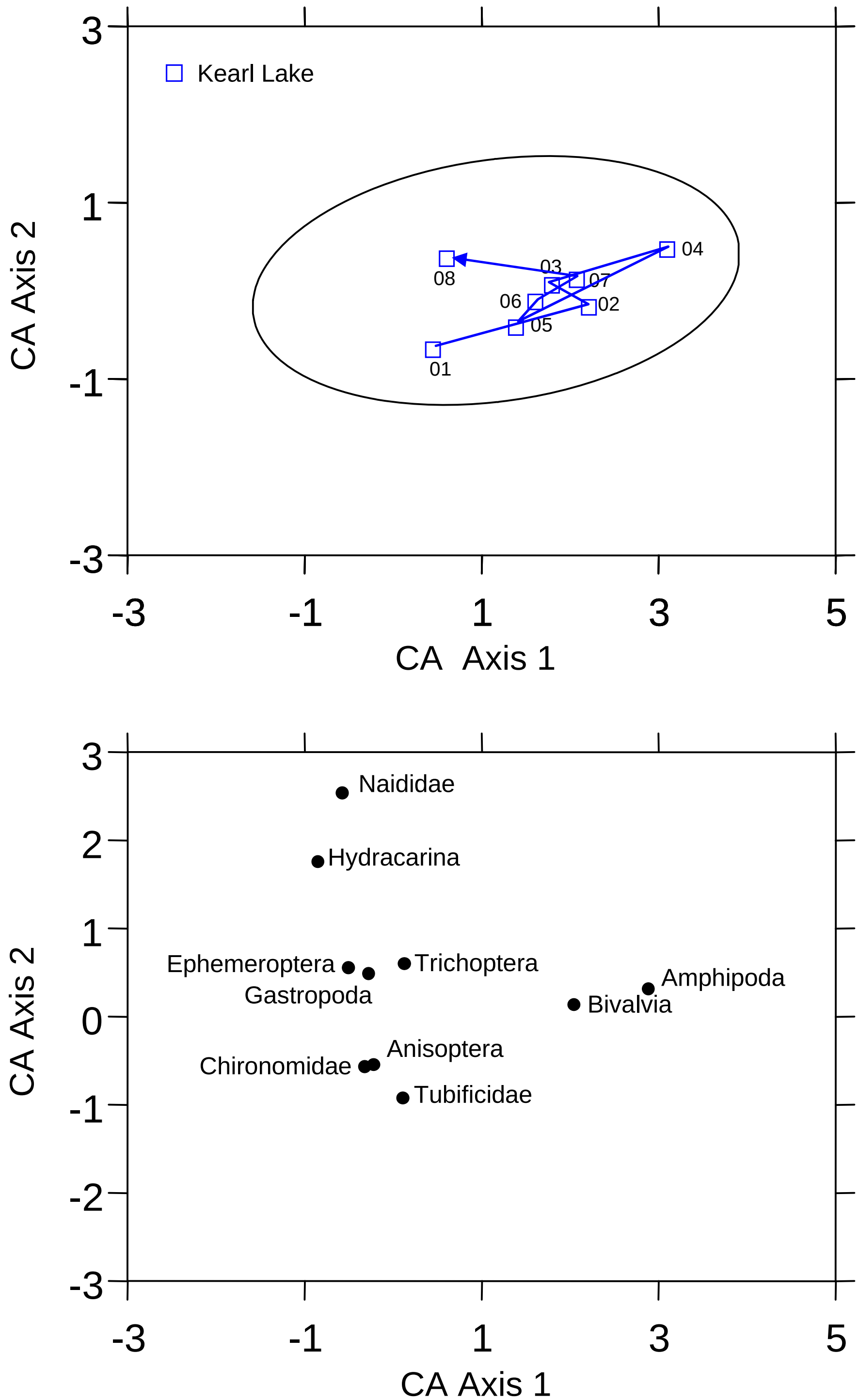
Taxon	Percent Major Taxa Enumerated in Each Year							
	Kearl							
	2001	2002	2003	2004	2005	2006	2007	2008
Amphipoda	13	46	36	58	25	23	27	2
Anisoptera						<1		
Bivalvia	4	4	6	9	4	23	7	11
Ceratopogonidae		1	1			<1		<1
Chaoboridae	1						<1	<1
Chironomidae	6	42	46	20	45	42	24	28
Cladocera	1		<1	1	7	<1		1
Copepoda	<1	<1		2	15	<1	31	38
Ephemeroptera	<1	1				2	1	
Erpobdellidae					<1	<1		<1
Gastropoda	1	<1				<1		1
Glossiphoniidae	<1	1	1	<1				<1
Hydracarina	<1		<1				2	7
Lumbriculidae						<1		
Naididae		<1	6	5	1	3	2	5
Nematoda					1	1	3	5
Ostracoda	7	7	4	4	1	<1	1	
Trichoptera	2	1	1	<1	<1	1	2	1
Tubificidae					1	2	1	<1
Zygoptera								
Benthic Invertebrate Community Measurement Endpoints								
Total Abundance (No./m^2)	891	8,706	5,366	5,690	12,691	17,405	4,217	3,209
Richness	7	9	8	7	12	17	8	7
Simpson's Diversity	0.73	0.64	0.63	0.6	0.76	0.76	0.71	0.49
Evenness	0.92	0.72	0.79	0.71	0.83	0.76	0.84	0.62
% EPT	3	2	1	<1	<1	2	2	0

Figure 5.2-17 Variations in benthic invertebrate community measurement endpoints in Kearl Lake.



Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in regional *baselines* for lakes.

Figure 5.2-18 Ordination (Correspondence Analysis) of benthic invertebrate communities in Kearl Lake (KEL-1).



Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data for lakes in the RAMP FSA.

Note: the numbers in the upper panel refer to the sampling year for each data point.

Table 5.2-26 Concentrations of selected sediment quality measurement endpoints in middle reach of the Muskeg River, near the Canterra Road crossing (reach MUR-D-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only, station MUR-2)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	3.3	5	0.4	6.1	12
Silt	%	-	2.3	5	13	16	22
Sand	%	-	93.9	5	72	79	85.9
Total organic carbon	%	-	0.97	6	2.1	2.75	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<5	4	<5	<5	<10
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	4	<5	<5	<10
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	4	<5	135	**180**
Fraction 3 (C16-C34)	mg/kg	300[2]	110	4	**1200**	**2350**	**2900**
Fraction 4 (C34-C50)	mg/kg	2800[2]	62	4	1100	1500	2100
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0013	6	0.0016	0.0042	0.0200
Retene	mg/kg	-	0.0116	6	<0.21	0.1645	0.314
Total dibenzothiophenes	mg/kg	-	0.29	6	2.81	5.69	11.04
Total PAHs	mg/kg	-	0.90	6	7.84	18.11	30.44
Total Parent PAHs	mg/kg	-	0.03	6	0.25	0.41	1.30
Total Alkylated PAHs	mg/kg	-	0.87	6	7.59	17.75	29.76
Predicted PAH toxicity[1]	H.I.	-	1.52	6	0.95	1.46	1.75
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	5	3	7	9
Chironomus growth - 10d	mg/organism	-	2.2	5	0.68	2.1	2.5
Hyalella survival - 14d	# surviving	-	9	5	8	8	9
Hyalella growth - 14d	mg/organism	-	0.3	5	0.11	0.2	0.35

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 10 replicates.

Table 5.2-27 Concentrations of selected sediment quality measurement endpoints in upper reach of the Muskeg River (reach MUR-D-3), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only, reach MUR-D-3, station MUR-D2)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	34.3	5	5	7	40
Silt	%	-	27.1	5	10	15	29
Sand	%	-	38.5	5	31	79	85
Total organic carbon	%	-	21.3	5	1.7	24.7	29.6
Total hydrocarbons							
BTEX	mg/kg	-	<5	4	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	4	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	47	4	<5	6	130
Fraction 3 (C16-C34)	mg/kg	300[2]	**2600**	4	52	**640**	**1900**
Fraction 4 (C34-C50)	mg/kg	2800[2]	1800	4	71	420	1400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.008	5	0.002	0.004	0.015
Retene	mg/kg	-	0.131	5	0.146	0.398	0.522
Total dibenzothiophenes	mg/kg	-	0.05	5	0.10	0.13	2.81
Total PAHs	mg/kg	-	0.38	5	0.67	1.26	1.39
Total Parent PAHs	mg/kg	-	0.03	5	0.03	0.08	0.34
Total Alkylated PAHs	mg/kg	-	0.35	5	0.64	1.08	1.19
Predicted PAH toxicity[1]	H.I.	-	0.04	5	0.15	0.56	0.72
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	5	3	6	8
Chironomus growth - 10d	mg/organism	-	1.4	5	1.4	1.8	2.2
Hyalella survival - 14d	# surviving	-	9	5	7	8	9
Hyalella growth - 14d	mg/organism	-	0.3	5	0.11	0.2	0.34

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 10 replicates.

Table 5.2-28 Concentrations of selected sediment quality measurement endpoints in lower reach of the Jackpine River (reach JAC-D-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	5.0	4	<1	3.2	18.7
Silt	%	-	7.6	4	0.3	6.1	11
Sand	%	-	87.3	4	81	90.0	98.3
Total organic carbon	%	-	1.5	4	0.55	1	2
Total hydrocarbons							
BTEX	mg/kg	-	<5	3	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	3	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	25	3	13	17	71
Fraction 3 (C16-C34)	mg/kg	300[2]	**790**	3	150	**450**	**510**
Fraction 4 (C34-C50)	mg/kg	2800[2]	820	3	210	530	750
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.00086	4	<0.003	0.002	0.002
Retene	mg/kg	-	0.951	3	0.007	0.042	0.061
Total dibenzothiophenes	mg/kg	-	1.223	4	0.105	0.579	1.639
Total PAHs	mg/kg	-	4.283	4	0.413	1.629	4.492
Total Parent PAHs	mg/kg	-	0.101	4	0.022	0.113	0.136
Total Alkylated PAHs	mg/kg	-	4.183	4	0.391	1.506	4.375
Predicted PAH toxicity[1]	H.I.	-	0.977	4	0.214	0.300	1.128
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	2	7	8	9
Chironomus growth - 10d	mg/organism	-	3.1	2	2.4	2.8	3.2
Hyalella survival - 14d	# surviving	-	10	2	7	8	9
Hyalella growth - 14d	mg/organism	-	0.3	2	0.14	0.22	0.3

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 10 replicates.

ns= not sampled

Table 5.2-29 Concentrations of selected sediment quality measurement endpoints in the upper reach of Jackpine Creek (reach JAC-D-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	5.1	2	9.5	10.3	11.1
Silt	%	-	5.1	2	12.5	17.6	22.8
Sand	%	-	89.2	2	66.1	71.9	77.7
Total organic carbon	%	-	0.6	2	1.4	1.6	1.7
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	<7.5	<10
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	<7.5	<10
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	2	<5	6.5	8
Fraction 3 (C16-C34)	mg/kg	300[2]	10	2	160	175	190
Fraction 4 (C34-C50)	mg/kg	2800[2]	<5	2	89	124.5	160
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.001	1	-	-	0.002
Retene	mg/kg	-	0.001	1	-	-	0.033
Total dibenzothiophenes	mg/kg	-	0.0019	1	-	-	0.01
Total PAHs	mg/kg	-	0.014	1	-	-	0.12
Total Parent PAHs	mg/kg	-	0.004	1	-	-	0.02
Total Alkylated PAHs	mg/kg	-	0.01	1	-	-	0.10
Predicted PAH toxicity[1]	H.I.	-	0.21	1	-	-	0.18
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	1	-	-	10
Chironomus growth - 10d	mg/organism	-	2.4	1	-	-	2.3
Hyalella survival - 14d	# surviving	-	10	1	-	-	8
Hyalella growth - 14d	mg/organism	-	0.3	1	-	-	0.3

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 10 replicates.

ns= not sampled

Table 5.2-30 Concentrations of selected sediment quality measurement endpoints in Kearl Lake (KEL-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only, station KEL-1)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	27.5	3	<1	3.6	58
Silt	%	-	35.8	3	9.2	11.4	33
Sand	%	-	36.7	3	9	85	91.9
Total organic carbon	%	-	36.6	4	33.5	34.5	36.2
Total hydrocarbons							
BTEX	mg/kg	-	<5	3	<5	8	<80
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	3	<5	8	<80
Fraction 2 (C10-C16)	mg/kg	150[2]	**530**	3	<5	<5	13
Fraction 3 (C16-C34)	mg/kg	300[2]	**3600**	3	230	**320**	**3000**
Fraction 4 (C34-C50)	mg/kg	2800[2]	2500	3	81	130	2000
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0198	2	0.012	0.02	0.04
Retene	mg/kg	-	0.03	4	0.037	0.06	0.11
Total dibenzothiophenes	mg/kg	-	0.028	4	0.03	0.05	0.08
Total PAHs	mg/kg	-	0.79	4	0.86	1.07	1.43
Total Parent PAHs	mg/kg	-	0.12	4	0.13	0.14	0.34
Total Alkylated PAHs	mg/kg	-	0.67	4	0.71	0.84	1.29
Predicted PAH toxicity[1]	H.I.	-	0.03	4	0.08	0.52	0.97
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	2	9	9	9
Chironomus growth - 10d	mg/organism	-	1.5	2	1.2	1.25	1.3
Hyalella survival - 14d	# surviving	-	9	2	8	8.5	9
Hyalella growth - 14d	mg/organism	-	0.3	2	0.1	0.15	0.2

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 10 replicates.

ns= not sampled

Table 5.2-31 Sediment quality index (fall 2008) for Muskeg River watershed stations.

Station Identifier	Location	2008 Designation	Sediment Quality Index	Classification
KEL-1	Kearl Lake	*baseline*	94.1	Negligible-Low
JAC-D1	Mouth of Jackpine Creek	*test*	98.4	Negligible-Low
JAC-D2	Upper Jackpine Creek	*baseline*	100.0	Negligible-Low
MUR-D2	Muskeg River at Canterra Road	*test*	100.0	Negligible-Low
MUR-D3	Upp Muskeg River	*test*	100.0	Negligible-Low

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5.3 STEEPBANK RIVER WATERSHED

Table 5.3-1 Summary of results for Steepbank River watershed.

Steepbank River Watershed	Summary of 2008 Conditions			
	Steepbank River			*North Steepbank River*
Climate and Hydrology[1]				
Criteria	**S38** near Fort McMurray			
Mean open-water season discharge	○			
Mean winter discharge	not measured			
Annual maximum daily discharge	○			
Minimum open-water season discharge	○			
Water Quality				
Criteria	**STR-1** at the mouth	**STR-2** upstream of Project Millenium	**STR-3** upstream of North Steepbank River	**NSR-1** North Steepbank River
Water Quality	○	○	○	○
Benthic Invertebrate Community and Sediment Quality				
Criteria	**STR-E-1** lower reach	no reach sampled	**STR-E-2** upper reach	no reach sampled
Benthic Invertebrate Community	◐		n/a	
Fish Populations				
No fish programs were conducted in 2008.				

○ Negligible - Low
◐ Moderate
● High
baseline (green)
test (blue)

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches.

[1] For Climate and Hydrology, results are reported for station at the mouth of the watershed

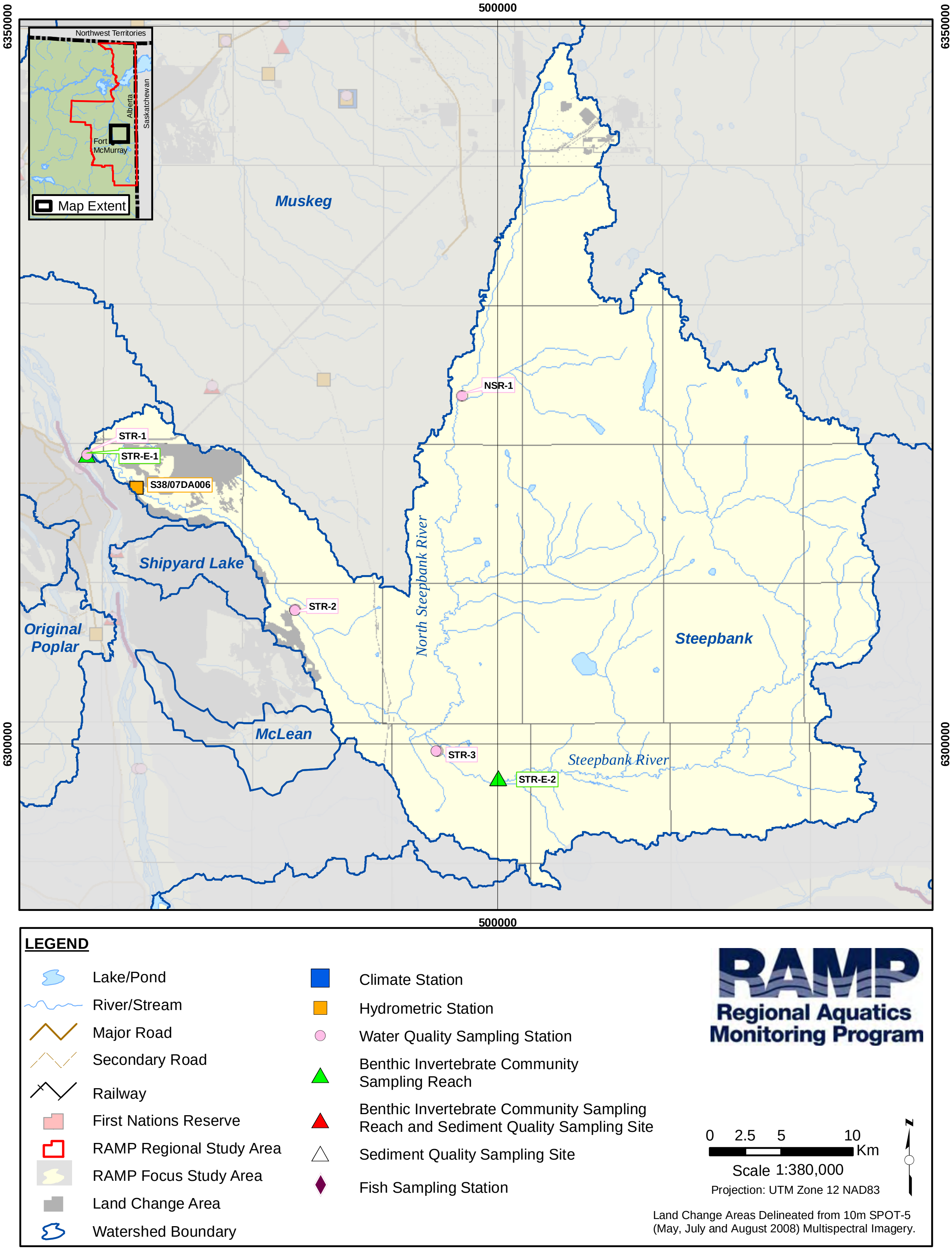
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.3-1 Steepbank River watershed.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K03_Steepbank_20090420.mxd

Figure 5.3-2 Representative Steepbank River monitoring stations, fall 2008.

Water Quality Station STR-1: right downstream bank, facing downstream

Water Quality Station STR-1: right downstream bank, facing upstream

Water Quality Station STR-2: from channel centre, facing downstream

Water Quality Station STR-2: right downstream bank, facing upstream

5.3.1 Summary of Conditions

Approximately 2.6% of the Steepbank River watershed has undergone land change as of 2008 from focal project activities (Table 2.4-2), and much of this land change is concentrated in the lower portion of the watershed. The designations of specific areas of the watershed for 2008 are as follows:

- The Steepbank River watershed downstream of the Suncor oil sands developments (Figure 5.3-1) is designated as *test*.
- The remainder of the watershed is designated as *baseline*.

Hydrology The observed 2008 discharge for the Steepbank River watershed is estimated to be 0.35% less than the 2008 *baseline* discharge would have been in the absence of focal projects. The differences in the Steepbank River watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Negligible-Low** for all calculated hydrologic measurement endpoints.

Water Quality Differences in water quality in fall 2008 in the Steepbank River watershed as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Concentrations of all water quality measurement endpoints were within the range of natural variability as they have consistently been since the beginning of RAMP water quality monitoring in the Steepbank River watershed. In addition, ionic composition at all water quality monitoring stations in the watershed was consistent with previous years and continues to show little year-to-year variation.

Benthic Invertebrate Communities The differences in the benthic invertebrate community in the lower Steepbank River compared to the upper Steepbank River are assessed as **Moderate**. While the lower Steepbank River has significantly lower total abundance, number of taxa, and %EPT, values of all measurement endpoints in the lower Steepbank River in fall 2008 except %EPT are within the normal range of variation for *baseline* erosional reaches in the RAMP FSA. There has been a general decline in %EPT in the lower Steepbank River since RAMP sampling began there in 1998.

5.3.2 Hydrologic Conditions

2008 Hydrologic Conditions The Steepbank River basin produced 133 mm of runoff in March to October 2008, about 17% more than the historical mean runoff of 114 mm (Figure 5.3-3). The spring runoff was well above normal, peaking in early May, but discharge dropped below median values from mid-June to August. Flows exceeded upper quartile values in August following a significant period of rainfall. The maximum recorded daily discharge of 33.8 m^3/s, was slightly below the historical range of 35.0 m^3/s, while the minimum open-water discharge of 2.61 m^3/s was higher than the historical average minimum discharge of 1.67 m^3/s. The mean open-water season discharge was 10.7 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Steepbank River for the March to October 2008 period is provided in Table 5.3-2. As of 2008, the area of hydrographically closed-circuited and not closed-circuited land change was 9.61 km^2 and 25.2 km^2, respectively, in the Steepbank River watershed (Table 2.4-1), the estimated net effects of which were decreased inflows to the Steepbank River by 0.608 million m^3 from March to October 2008.

The *baseline* hydrograph that would have occurred from March to October 2008 at RAMP Station S38, Steepbank River near Fort McMurray, (07DA006) was estimated by removing the 0.608 million m^3 of flow from the station's observed hydrograph recorded from March to October 2008; the resulting estimated *baseline* hydrograph is presented in Figure 5.3-3. The effect on the hydrologic measurement endpoints of the difference between the observed and estimated *baseline* hydrograph for RAMP Station S38, Steepbank River near Fort McMurray, (07DA006) is a 0.3% decrease in mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge (Table 5.3-3). All hydrologic measurement endpoints for the Steepbank River watershed are estimated to be similar to what they would have been under *baseline* conditions (Figure 5.3-3, Table 5.3-3).

Summary The observed *test* 2008 discharge for RAMP Station S38, Steepbank River near Fort McMurray, (07DA006) is estimated to be approximately 0.35% less than 2008 *baseline* discharge would have been in the absence of focal projects in the Steepbank River watershed. The differences in the Steepbank River watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at RAMP Station S38, Steepbank River near Fort McMurray (07DA006), are assessed as Negligible-Low for all hydrologic measurement endpoints (Table 5.3-1).

5.3.3 Water Quality

Water quality samples were collected from four stations in the Steepbank River watershed in fall 2008:

- Station STR-1, near the mouth of the Steepbank River (*test*, sampled from 1997 to 2008);
- Station STR-2, upstream of Suncor's oil sands developments (designated as *test* in 2008 for the first time, sampled from 2002 to 2008);
- Station STR-3, upper Steepbank River, above the confluence with the North Steepbank River (*baseline*, sampled from 2004 to 2008); and
- Station NSR-1, North Steepbank River (*baseline*, sampled from 2002 to 2008).

All stations were sampled in fall 2008. Winter sampling was conducted at station STR-1 in 2008.

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations of three water quality measurement endpoints at station STR-1 were outside of the range of historical measurements (Table 5.3-4): dissolved organic carbon and ultra-trace mercury concentrations were both greater than their historically-measured maximum concentration; and the chloride concentration was below the historically-measured minimum concentration. Dissolved organic carbon concentration was above the historically-measured maximum concentration at *baseline* stations STR-3 (Table 5.3-6) and NSR-1 (Table 5.3-7) as well as at *test* station STR-1 (Table 5.3-4) in fall 2008. At station STR-3, the concentrations of dissolved phosphorus and sulphate were greater and lower than their historically-measured minimum and maximum concentration, respectively (Table 5.3-6). The concentration of ultra-trace mercury and dissolved phosphorus exceeded historically-measured maximum concentrations at *test* station STR-1 (i.e., 1.6 ng/L of total mercury compared to below a detection limit of 1.2 ng/L in all previous years) (Table 5.3-4). Concentrations of both of these water quality measurement endpoints were below their relevant water quality guideline values in fall 2008 at station STR-1 (Table 5.3-4). Concentrations of all water quality measurement endpoints were within the range of historically-measured concentrations for *test* station STR-2 in fall 2008 (Table 5.3-5).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions Concentrations of all water quality measurement endpoints at all four water quality monitoring stations on the Steepbank River in fall 2008 were within the range of regional *baseline* concentrations (Figure 5.3-4). In addition, concentrations of water quality measurement endpoints at all four water quality monitoring stations have been within the range of regional *baseline* concentrations since RAMP water quality monitoring began in the Steepbank River watershed in 1997 (Figure 5.3-4).

Concentrations of several water quality measurement endpoints that were present mostly or entirely as dissolved species (e.g., total dissolved solids, dissolved phosphorus, total boron, total strontium, calcium, magnesium, sodium, sulphate) were greater in the upper Steepbank River above the confluence of the North Steepbank River (station STR-3) than in the North Steepbank River (station NSR-1) (Figure 5.3-4). This could indicate a greater relative contribution of groundwater to the surface flows at station STR-3 in fall 2008. Concentrations of these water quality measurement endpoints in the Steepbank River at the stations below the confluence of the North Steepbank River (i.e., stations STR-2 and

STR-1) were intermediate to the respective concentrations at stations NSR-1 and STR-3 with the exception of sulphate (Figure 5.3-4).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines There were two cases in which concentrations of water quality measurement endpoints exceeded water quality guideline concentrations at the four water quality monitoring stations in the Steepbank River watershed in fall 2008: total aluminum at station STR-1 (Table 5.3-4); and total nitrogen at station STR-2 (Table 5.3-5). The concentration of total aluminum at station STR-1 in fall 2008 was within the range of historically-measured concentrations and lower than the historically-measured maximum concentration. In addition, the concentration of dissolved aluminum at station STR-1, more bioavailable than total aluminum, was below its water quality guideline in fall 2008 (Table 5.3-4). The concentration of total nitrogen at STR-2 only slightly exceeded its water quality guideline and was below its historically-measured maximum concentration at station STR-2 (Table 5.3-5).

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded relevant water quality guidelines in 2008 in the Steepbank River watershed (Table 5.3-8):

- Total iron at station STR-1 in winter;
- Dissolved iron, total iron, total phenols, and sulphide at all four water quality stations in fall 2008; and
- Total phosphorus at station STR-3 in fall 2008.

Ion Balance In fall 2008, the ionic composition of all stations in the Steepbank River watershed was dominated by calcium and bicarbonate ions (Figure 5.3-5). The ionic characteristics of surface water in the Steepbank River watershed have changed little since initial sampling by RAMP in 1997.

Trend Analysis As of 2008, sufficient data existed to allow statistical trend analysis of fall water quality data for Steepbank River stations STR-1 (n=11), STR-2 (n=7), and NSR-1 (n=7) but not for STR-3 (n=5). The only statistically-significant trend detected was a decrease in sulphate concentration at station STR-1 (α=0.05).

Water Quality Index WQI values for all stations in the Steepbank River watershed (i.e., all stations: 96.1) indicated Negligible-Low difference from regional *baseline* conditions (Table 5.3-9).

Summary Concentrations of all water quality measurement endpoints in fall 2008 were within the range of natural variability as they have consistently been since the beginning of the RAMP water quality data record for the Steepbank River watershed. In addition, ionic composition at all water quality monitoring stations in the watershed was consistent with previous years and continues to show little year-to-year variation. Differences in water quality in fall 2008 at all nine stations monitored in the Steepbank River watershed as compared to regional *baseline* conditions are assessed as Negligible-Low (Table 5.3-1).

5.3.4 Benthic Invertebrate Communities and Sediment Quality

5.3.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in 2008 in the Steepbank River watershed at:

- a lower erosional reach near the mouth of the Steepbank River (reach STR-E-1, designated as *test* for its entire data record); and
- an upper erosional reach (reach STR-E-2, designated as *baseline* for its entire data record).

2008 Habitat Conditions Both the lower and upper reaches are typical of erosional habitats in the RAMP FSA with relatively high flow velocities (0.7 to 1 m/s) and coarse substrate consisting of gravel and cobble (Table 5.3-10). Macrophytes were absent in the lower reach (reach STR-E-1) and encountered periodically in reach STR-E-2 (8% cover). The concentration of periphyton chlorophyll *a* on cobble in the upper reach (reach STR-E-2) is indicative of mesotrophic conditions, and in the lower reach (reach STR-E-1) is indicative of oligotrophic conditions (Figure 5.3-6). Measured chlorophyll *a* levels in the lower reach were greater than the upper limit of chlorophyll *a* concentrations for *baseline* reaches in the RAMP FSA (Figure 5.3-6).

Relative Abundance of Benthic Invertebrate Community Taxa Both the upper and lower reaches sampled in the Steepbank River watershed had diverse benthic communities (Table 5.3-11). Both reaches were dominated numerically by chironomids, mayflies (Ephemeroptera), and water mites (Hydracarina). Caddisflies (Trichoptera) were dominant (10%) in the upper reach (reach STR-E-2), and present also in the lower reach (reach STR-E-1) although in lower relative abundance (1%).

The temporal trends in the benthic invertebrate community measurement endpoints for the Steepbank River watershed (Figure 5.3-7) have the following characteristics:

- Total abundance in *test* reach STR-E-1 in 2008 was near the lower limit for *baseline* erosional reaches in the RAMP FSA and similar to total abundance measured at this reach since RAMP sampling began there in 1998;
- The number of taxa in *test* reach STR-E-1 was also near the lower limit for *baseline* erosional reaches in the RAMP FSA and also similar to the number of taxa measured at this reach since RAMP sampling began there in 1998, including the period between 2002 and 2005 in which the number of taxa at this reach was lower than the natural range observed in *baseline* reaches;
- Both diversity measurement endpoints at *test* reach STR-E-1 were within the natural range observed in *baseline* erosional reaches in the RAMP FSA in 2008. Both diversity measurement endpoints at *test* reach STR-E-1 have generally been within the normal range observed in *baseline* erosional reaches and at similar levels to the diversity measurement endpoint values observed for the upper *baseline* reach (reach STR-E-2) for the entire RAMP benthic invertebrate community data record for the Steepbank River watershed; and
- The percent of the fauna as EPT taxa in 2008 for *test* reach STR-E-1 was below the natural range observed in *baseline* erosional reaches in the RAMP FSA. %EPT at *test* reach STR-E-1 has generally been declining since RAMP sampling began there in 1998, and the difference in %EPT between *test* reach STR-E-1 and *baseline* reach STR-E-2 has been increasing since sampling at reach STR-E-2 began in 2004.

The results of the Correspondence Analysis indicate a difference in species composition between the upper *baseline* and lower *test* reaches over the period of the data record (Figure 5.3-8). Although sensitive taxa have been present in both reaches, there has been a higher diversity of sensitive species in the upper *baseline* reach than in the lower *test* reach. The lower reach (reach STR-E-1) has had a relatively high abundance of the mayflies (Ephemeroptera) *Drunella*, *Ephemerella* and *Baetis*. The upper reach, in contrast had high relative abundances of the stonefly (Plecoptera) *Zapada*, the mayflies *Stenonema*, *Drunella*, *Ephemerella* and *Baetis*, and the caddisflies (Trichoptera) *Lepidostoma*, *Hydroptila*, *Hydropsyche*, *Micrasema* and *Brachycentrus*. The chironomid (midge) assemblages have also been different between the two reaches. The chironomid community in the lower *test* reach was dominated by *Polypedilum* and *Demicryptochironomus*, while the chironomid community in the upper *baseline* reach has been more diverse with high relative abundances of cold/cool-water taxa including *Synorthocladius*, *Potthastia longimana*, *Cricotopus*/*Orthocladius*, and *Rheotanytarsus*.

Linear contrasts were used to test for:

- a difference in the average value of the benthic invertebrate community measurement endpoints between the upper *baseline* reach (reach STR-E-2) and the lower *test* reach (reach STR-E-1), designated as "BT" in Table 5.3-12; and
- differences in time trends (designated as "T" in Table 5.3-12) between the upper *baseline* and lower *test* reach which would occur if the benthic invertebrate community in the lower *test* reach was continuing to degrade (designated as "BT x T" in Table 5.3-12).

The average values of all benthic invertebrate community endpoints were significantly different in the lower *test* reach than in the upper *baseline* reach, with lower abundance, number of taxa, and %EPT, and higher Simpson's diversity and evenness in the lower *test* reach (Figure 5.3-7, Table 5.3-12). Differences in time trends were generally significant (Table 5.3-12), but difficult to interpret from the time series of benthic invertebrate community measurement endpoints (Figure 5.3-7). While the BT and BT x T comparisons were statistically significant, the remainder (noise) was stronger (Table 5.3-12). The reduction in %EPT at *test* reach STR-E-1 was a function of the proportion of EPT taxa being diluted by higher relative abundances of tubificid worms and water mites (Hydracarina). The absolute and relative abundances of both of those groups have generally increased over the past three years, and this has contributed to a decrease in relative abundance of Ephemeroptera (Table 5.3-11).

5.3.4.2 Sediment Quality

As sediment quality in 2008 was only sampled in the depositional reaches in which benthic invertebrate communities were sampled, and as both reaches of the Steepbank River watershed in which benthic invertebrate communities were sampled are erosional, no sediment quality sampling was conducted in the Steepbank River in 2008.

5.3.4.3 Summary

The differences in the benthic invertebrate community in the lower Steepbank River, designated as *test* in 2008, as compared to the benthic invertebrate community in the upper Steepbank River, designated as *baseline* in 2008 are assessed as Moderate on the basis of the following (Table 5.3-1):

- Differences in values of benthic invertebrate community measurement endpoints between lower *test* reach STR-E-1 and upper *baseline* reach STR-E-2 were statistically significant and evident, including lower total abundance, and lower number of taxa, and lower %EPT in lower *test* reach STR-E-1.
- Values of all benthic invertebrate community measurement endpoints with the exception of %EPT in lower *test* reach STR-E-1 were within the normal range of variation for *baseline* erosional reaches in the RAMP FSA (Figure 5.3-7).

In addition, there has been a general decline in %EPT in lower *test* reach STR-E-1 since RAMP sampling began there in 1998.

5.3.5 Fish Populations

The 2008 RAMP Fish Population component did not include any activities in the Steepbank River watershed.

Figure 5.3-3 Steepbank River: 2008 hydrograph and historical context.

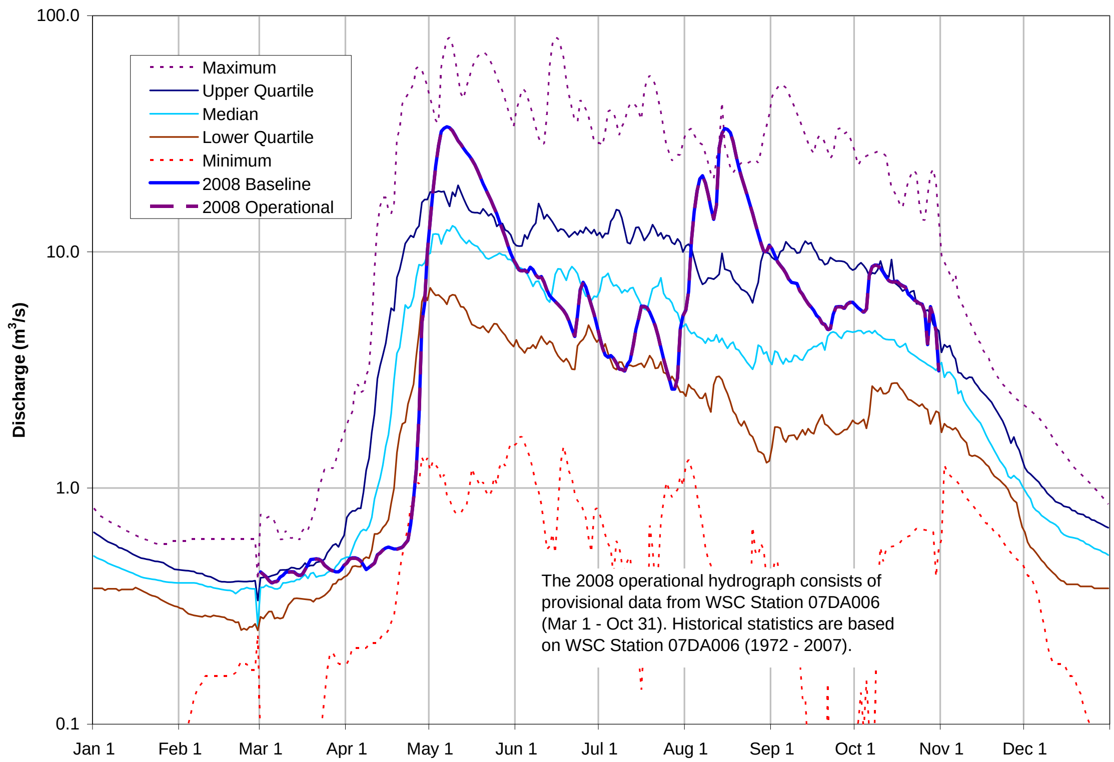


Table 5.3-2 Estimated water balance at WSC Station 07DA006, Steepbank River near Fort McMurray for 2008.

Component of Calculation	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total discharge)	**175**	**Observed discharge, obtained from WSC Station 07DA006, Steepbank River near Fort McMurray**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+1.278	9.61 km^2 within Steepbank River drainage estimated to have been closed-circuited by focal projects as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.670	25.2 km^2 within Steepbank River drainage estimated to have undergone land change by focal projects as of 2008, but are not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from the Steepbank River by focal projects	0	Unknown, none reported, assumed to be negligible
Amount by which discharge would be lower without releases to the Steepbank River watershed by focal projects	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Steepbank River not accounted for in figures contained in this table
***Baseline* hydrograph (total discharge)**	**176**	**Estimated *baseline* discharge at WSC Station 07DA006, Steepbank River near Fort McMurray (i.e., without focal projects)**
Incremental flow (change in total discharge)	-0.608	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total discharge)	-0.35%	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Data are for the period of the 2008 data record for WSC Station 07DA006, Steepbank River near Fort McMurray.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.3-3 Calculated change in hydrologic measurement endpoints for the Steepbank River watershed for 2008.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	10.8	10.7	-0.3%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	33.9	33.8	-0.3%
Open-water season minimum daily discharge	2.62	2.61	-0.3%

Note: As measured at WSC Station 07DA006, Steepbank River near Fort McMurray.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.3-4 Concentrations of water quality measurement endpoints in the Steepbank River (station STR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	10	7.7	8.25	8.5
Total Suspended Solids	mg/L	-[1]	8	10	<3	5	60
Conductivity	µS/cm	-	210	10	141	240.5	516
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.029	10	0.006	0.020	0.032
Total nitrogen*	mg/L	1.0	0.9	10	0.25	0.7	**2.40**
Nitrate+Nitrite	mg/L	1.0	<0.1	10	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	30	10	10	17.5	26
Ions							
Sodium	mg/L	-	9	10	6	12	38
Calcium	mg/L	-	27.5	10	17.2	30.6	50.3
Magnesium	mg/L	-	8.6	10	5.4	8.9	16.2
Chloride	mg/L	230, 860[3]	<1	10	1.0	2.5	8.4
Sulphate	mg/L	100[4]	4.3	10	2.8	4.8	12.3
Total Dissolved Solids	mg/L	-	179	10	120	186	320
Total Alkalinity	mg/L		105	10	63	120.5	263
Organic compounds							
Naphthenic acids	mg/L	-	<1	10	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.188**	10	0.040	**0.114**	**2.73**
Dissolved aluminum	mg/L	0.1[2]	0.0135	10	<0.01	0.012	0.099
Total arsenic	mg/L	0.005	0.0008	10	<0.001	0.0007	0.0008
Total boron	mg/L	1.2[5]	0.0466	10	0.025	0.067	0.200
Total molybdenum	mg/L	0.073	0.0002	10	0.0002	0.0002	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.6	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.102	10	0.064	0.117	0.252
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.006**	10	**<0.003**	**0.006**	**0.041**
Dissolved iron	mg/L	0.3[2]	**0.599**	10	0.187	**0.373**	**0.551**
Total iron	mg/L	0.3	**1.02**	10	**0.47**	**0.79**	**2.28**
Total phenols	mg/L	0.004	**0.007**	10	<0.001	0.002	**0.013**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.3-5 Concentrations of water quality measurement endpoints in the Steepbank River (station STR-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	6	7.8	8.2	8.3
Total Suspended Solids	mg/L	-[1]	<3	6	<3	6	28
Conductivity	µS/cm	-	200	6	121	198.5	274
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.027	6	0.014	0.021	0.038
Total nitrogen*	mg/L	1.0	**1.1**	6	0.6	0.8	**1.5**
Nitrate+Nitrite	mg/L	1.0	<0.1	6	<0.1	<0.1	0.1
Dissolved organic carbon	mg/L	-	28	6	14	22.5	29
Ions							
Sodium	mg/L	-	9	6	5	8.5	16
Calcium	mg/L	-	26.4	6	16.8	26	35.9
Magnesium	mg/L	-	8.1	6	5.3	7.8	10.8
Chloride	mg/L	230, 860[3]	2	6	1	2	3
Sulphate	mg/L	100[4]	2.6	6	<0.5	3.35	5.5
Total Dissolved Solids	mg/L	-	171	6	140	160	200
Total Alkalinity	mg/L		104	6	61	102.5	155
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0388	6	0.018	**0.165**	**0.536**
Dissolved aluminum	mg/L	0.1[2]	0.0127	6	0.0023	0.0101	0.0294
Total arsenic	mg/L	0.005	0.0007	6	0.0005	0.0006	0.0007
Total boron	mg/L	1.2[5]	0.0542	6	0.0227	0.0658	0.0969
Total molybdenum	mg/L	0.073	0.0001	6	0.0001	0.0002	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.5	5	<1.2	<1.2	2.3
Total strontium	mg/L	-	0.0994	6	0.053	0.109	0.167
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.012**	6	**<0.003**	**0.0065**	**0.01**
Dissolved iron	mg/L	0.3[2]	**0.597**	6	**0.347**	**0.4335**	**0.538**
Total iron	mg/L	0.3	**0.845**	6	**0.749**	**0.8245**	**1.07**
Total phenols	mg/L	0.004	**0.011**	6	<0.001	**0.0065**	**0.009**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.3-6 Concentrations of water quality measurement endpoints in the Steepbank River (station STR-3), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	4	8.0	8.25	8.3
Total Suspended Solids	mg/L	-[1]	<3	4	<3	3	4
Conductivity	µS/cm	-	229	4	196	289.5	317
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.042	4	0.027	0.036	0.041
Total nitrogen*	mg/L	1.0	0.8	4	0.6	0.65	0.8
Nitrate+Nitrite	mg/L	1.0	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	28	4	14	18.5	25
Ions							
Sodium	mg/L	-	11	4	9	15	17
Calcium	mg/L	-	30	4	25.5	38.6	40.7
Magnesium	mg/L	-	9.1	4	7.7	11.55	12.4
Chloride	mg/L	230, 860[3]	1	4	1	2	2
Sulphate	mg/L	100[4]	2.1	4	3	3.15	3.4
Total Dissolved Solids	mg/L	-	186	4	140	204.5	220
Total Alkalinity	mg/L		121	4	100	167.5	170
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0327	4	0.021	0.040	0.089
Dissolved aluminum	mg/L	0.1[2]	0.0137	4	0.0040	0.0057	0.0175
Total arsenic	mg/L	0.005	0.0007	4	0.0005	0.0006	0.0007
Total boron	mg/L	1.2[5]	0.0715	4	0.049	0.07635	0.114
Total molybdenum	mg/L	0.073	0.0002	4	0.0002	0.0002	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	1.3
Total strontium	mg/L	-	0.109	4	0.0945	0.1275	0.150
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.011**	4	**0.004**	**0.005**	**0.009**
Total phosphorus	mg/L	0.05	**0.056**	4	**0.051**	**0.052**	**0.06**
Total phenols	mg/L	0.004	**0.019**	4	<0.001	0.004	**0.005**
Dissolved iron	mg/L	0.3[2]	**0.751**	4	**0.405**	**0.6205**	**0.717**
Total iron	mg/L	0.3	**1.04**	4	**0.698**	**0.9275**	**0.995**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.3-7 Concentrations of water quality measurement endpoints in the North Steepbank River (station NSR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	6	7.5	8	8.1
Total Suspended Solids	mg/L	-[1]	4	6	<3	3.5	8
Conductivity	µS/cm	-	164	6	110	142.5	191
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.024	6	0.015	0.020	0.042
Total nitrogen*	mg/L	1.0	0.8	6	0.4	0.7	0.80
Nitrate+Nitrite	mg/L	1.0	<0.1	6	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	23	6	13	17	21
Ions							
Sodium	mg/L	-	3	6	2	3	4
Calcium	mg/L	-	23.1	6	16.5	22.1	31
Magnesium	mg/L	-	6.7	6	4.9	6.3	8.8
Chloride	mg/L	230, 860[3]	1	6	<1	1	2
Sulphate	mg/L	100[4]	0.9	6	<0.5	1.8	5.2
Total Dissolved Solids	mg/L	-	139	6	109	140	160
Total Alkalinity	mg/L		86	6	55	72.5	106
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.0327	6	0.028	0.052	**0.13**
Dissolved aluminum	mg/L	0.1[2]	0.01	6	0.005	0.011	0.015
Total arsenic	mg/L	0.005	0.0009	6	0.0005	0.0007	0.0013
Total boron	mg/L	1.2[5]	0.015	6	0.010	0.013	0.020
Total molybdenum	mg/L	0.073	0.0002	6	0.0001	0.0002	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.087	6	0.049	0.069	0.111
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.006**	6	**0.004**	**0.0055**	**0.008**
Dissolved iron	mg/L	0.3[2]	**0.611**	6	0.275	**0.4605**	**0.77**
Total iron	mg/L	0.3	**0.938**	6	**0.507**	**0.687**	**1.17**
Total phenols	mg/L	0.004	**0.008**	6	<0.001	**0.0065**	**0.01**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);

Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.3-8 Water quality guideline exceedances, Steepbank River watershed, 2008.

Variable	Units	Guideline*	STR-1	STR-2	STR-3	NSR-1
Winter						
Total iron	mg/L	0.3	**0.419**	ns	ns	ns
Fall						
Sulphide	mg/L	0.002[1]	**0.006**	**0.012**	**0.011**	**0.006**
Total phosphorus	mg/L	0.05	**-**	**-**	**0.056**	**-**
Dissolved iron	mg/L	0.3[2]	**0.599**	**0.597**	**0.751**	**0.611**
Total iron	mg/L	0.3	**1.02**	**0.845**	**1.04**	**0.938**
Total phenols	mg/L	0.004	**0.007**	**0.011**	**0.019**	**0.008**
Total nitrogen	mg/L	1	**-**	**1.1**	**-**	**-**
Total aluminum	mg/L	0.1	**0.188**	**-**	**-**	**-**

STR-2, STR-3 and NSR-1 were sampled only in fall 2008. STR-1 was sampled in winter and fall 2008.

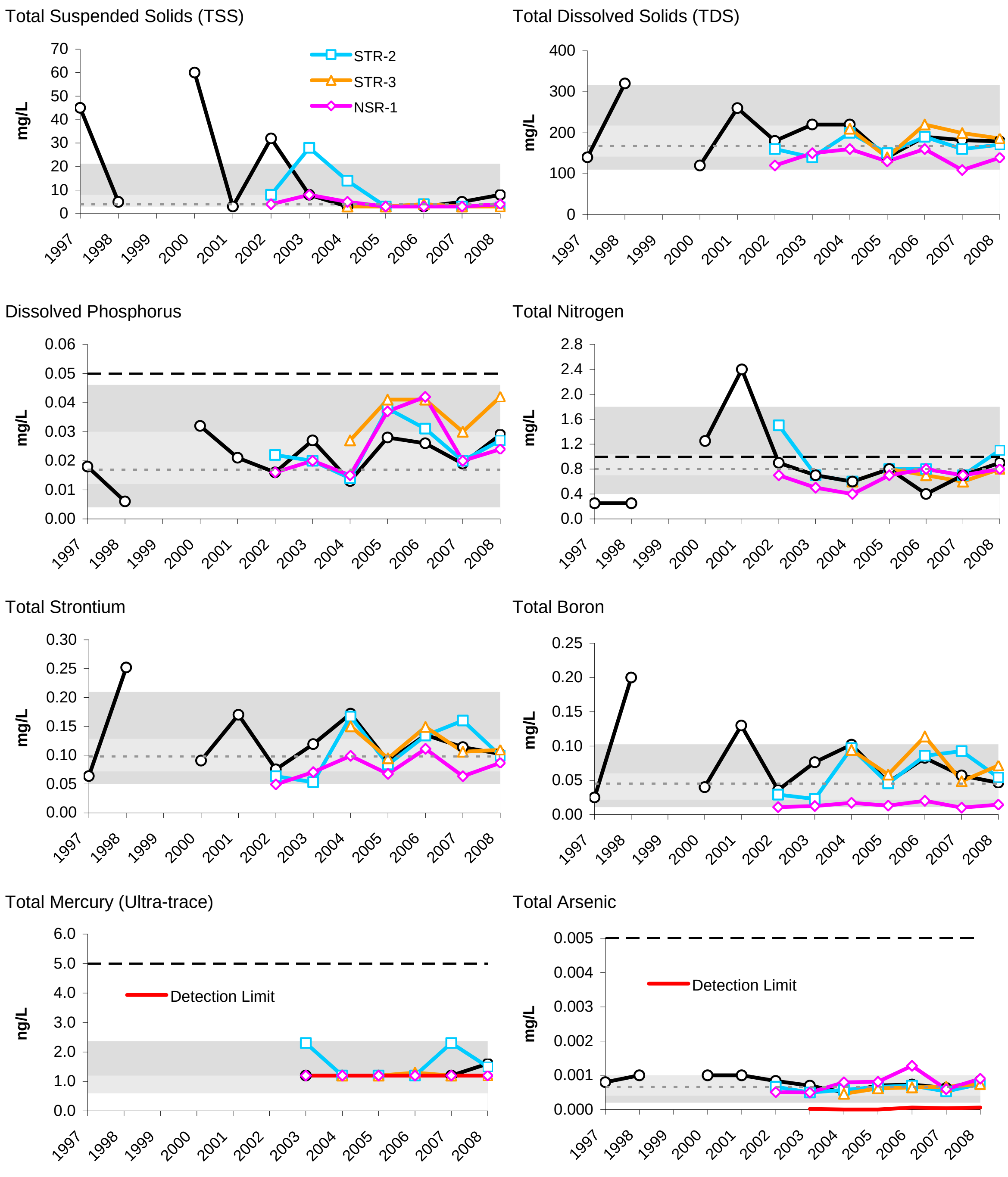
ns = not sampled

* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[2] Guideline is for total metal (no guideline for dissolved species).

Figure 5.3-4 Concentrations of selected water quality measurement endpoints in the Steepbank River (fall data) relative to regional baseline fall concentrations.

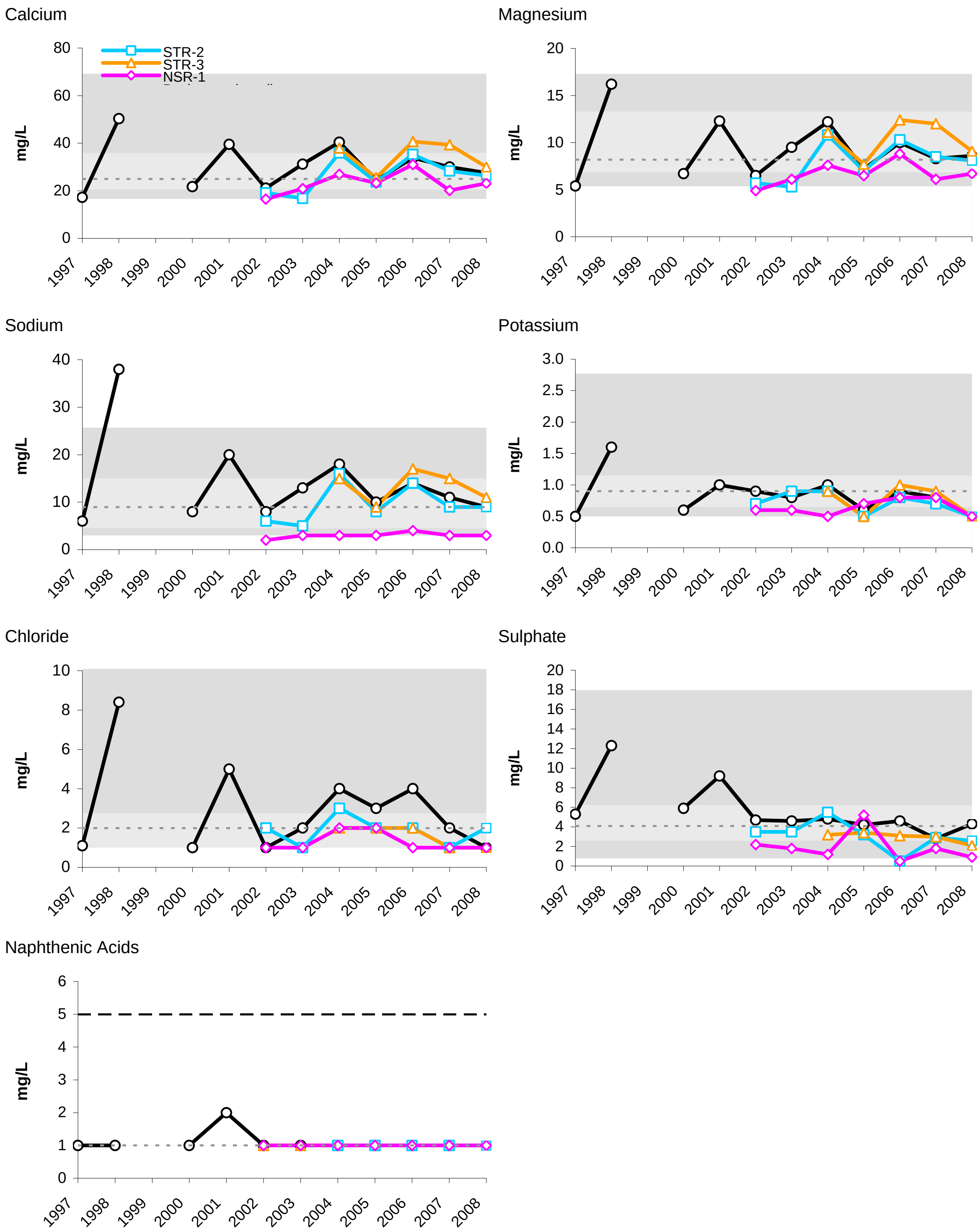


Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.

See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.3-4 (Cont'd.)



Non-detectable values are shown at the detection limit.
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.
See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.3-5 Piper diagram of fall ion concentrations in the Steepbank River, fall 2008.

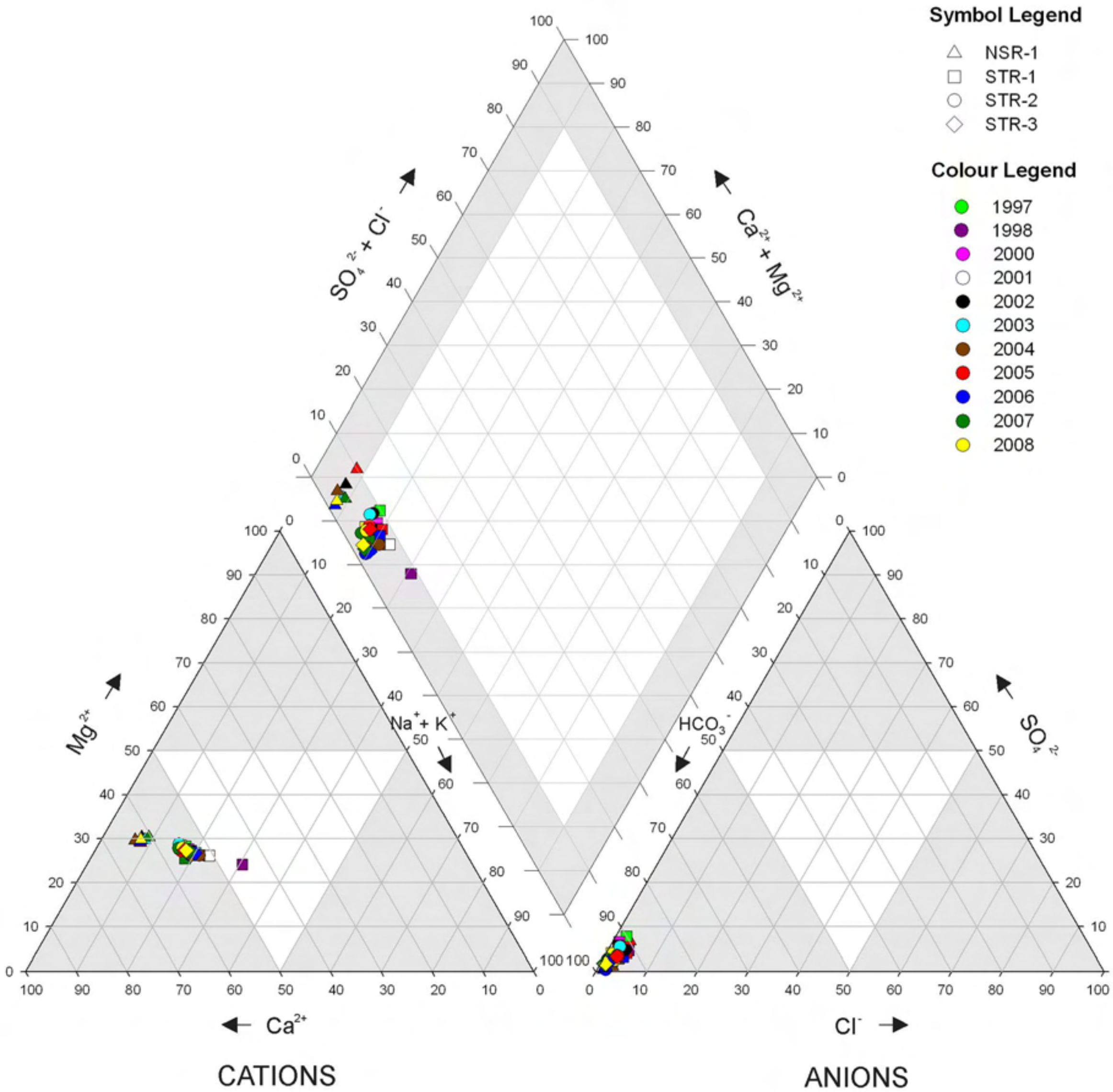


Table 5.3-9 Water quality index (fall 2008) for Steepbank River watershed stations.

Station Identifier	Location	2008 Designation	Water Quality Index	Classification
STR-1	Lower Steepbank River	*test*	96.1	Negligible-Low
STR-2	Upstream of Project Millenium	*test*	96.1	Negligible-Low
STR-3	Upstream of North Steepbank River	*baseline*	96.1	Negligible-Low
NSR-1	North Steepbank River	*baseline*	96.1	Negligible-Low

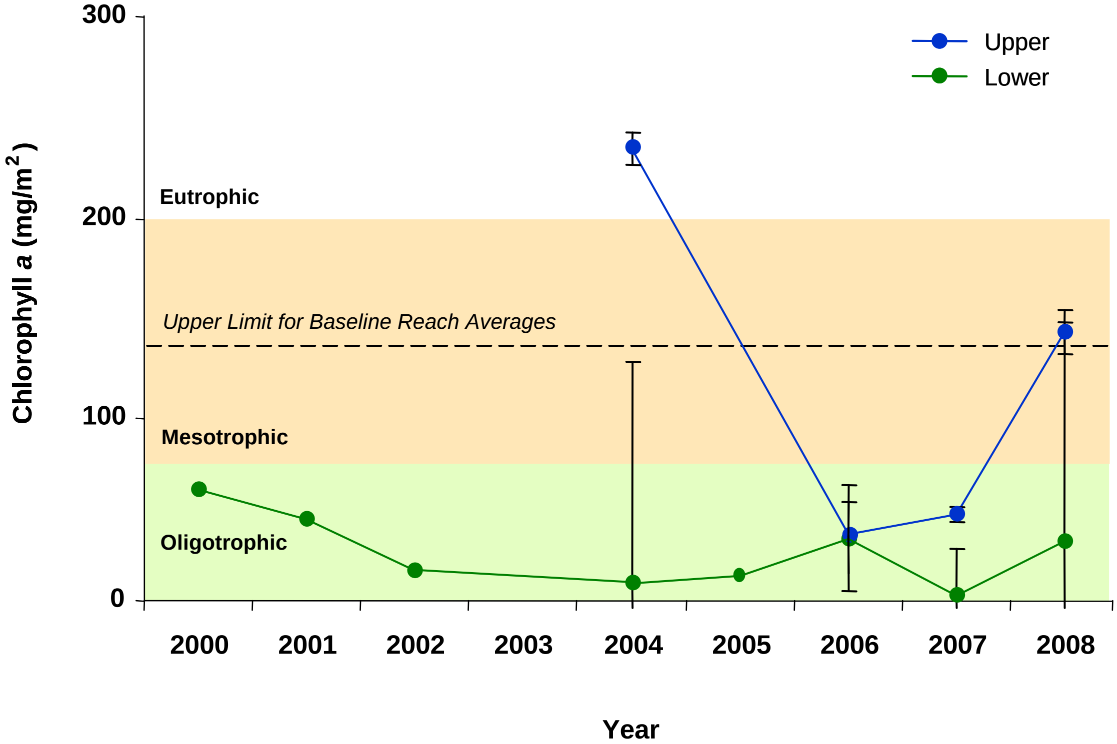
Note: see Figure 5.3-1 for the locations of these water quality stations.

Note: see Section 3.2.7.4 for a description of the Water Quality Index.

Table 5.3-10 Habitat characteristics of benthic invertebrate community reaches in the Steepbank River.

Variable	Units	Lower Reach of the Steepbank River (STR-E-1)	Upper Reach of the Steepbank River (STR-E-2)
Sample Date	-	Sept 7, 2008	Sept 8, 2008
Habitat	-	Erosional	Erosional
Water Depth	m	0.3	0.3
Current Velocity	m/s	1.1	0.7
Macrophyte Cover	%	0	8
Field Water Quality			
Dissolved Oxygen	mg/L	11.3	11.0
Conductivity	µS/cm	201	193
pH		8.6	8.2
Water Temperature	°C	9.1	8.3
Sediment Composition			
Sand/Silt/Clay	%	0	13
Small Gravel	%	8	8
Large Gravel	%	41	9
Small Cobble	%	33	30
Large Cobble	%	12	36
Boulder	%	5	4
Bedrock	%	1	0

Figure 5.3-6 Variations in benthic chlorophyll *a* in lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.

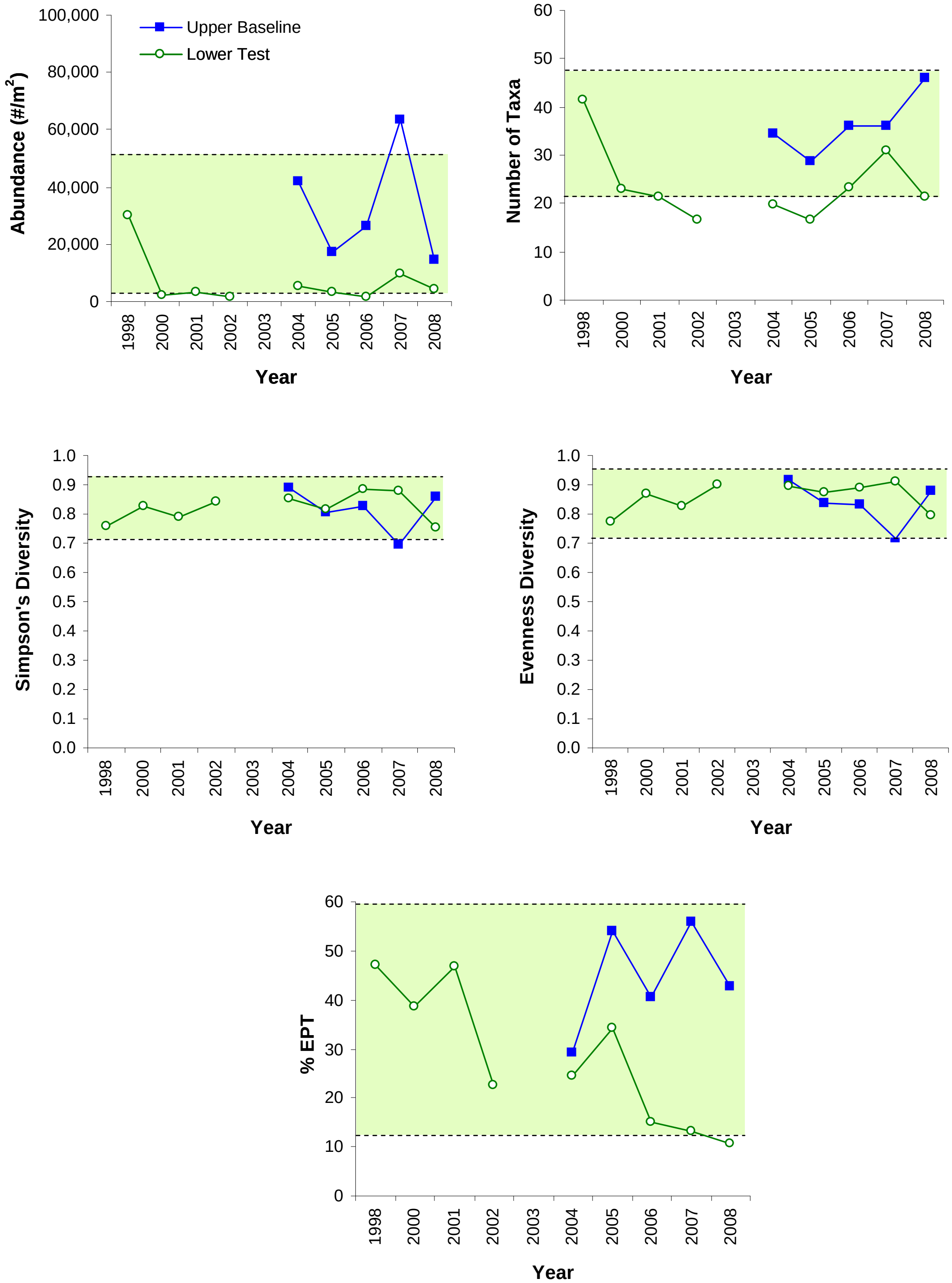


Concentrations defining oligotrophic, mesotrophic and eutrophic conditions are provided in Section 3.3.1.9.

Table 5.3-11 Major taxon percent abundances and benthic invertebrate community measurement endpoints in the Steepbank River.

Taxon	Percent Major Taxa Enumerated in Each Year													
	Reach STR-E-1									Reach STR-E-2				
	1998	2000	2001	2002	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
Anisoptera	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	0.3	<1	<1
Athericidae		<1	<1	<1	<1	<1	<1	1	1	<1	3	1	1	2
Bivalvia				<1				<1	>1		<1		1	4
Ceratopogonidae	<1		<1	<1	<1		<1	3	1				7	<1
Chironomidae	31	15	25	43	38	25	29	36	17	46	32	24	52	24
Cladocera	1	<1								4		<1	1	
Collembola	<1	<1						1	<1	<1				<1
Copepoda	<1	<1	<1	<1		<1		1	<1	4	<1	1		<1
Empididae	2	1	2	6	4	9	7	<1	1	2	6	2	<1	3
Enchytraeidae	1	11	1	9	6	9	15	6	9	<1	1			1
Ephemeroptera	51	42	51	19	23	38	15	1	11	18	23	17	6	35
Gastropoda	<1	<1	<1	<1	<1		1	6	2			<1	<1	<1
Heteroptera		<1	<1	<1										
Hydracarina	6	3	6	4	4	9	15	14	20	7	3	5	8	12
Lepidoptera		<1		<1										
Lumbriculidae		<1			<1									
Naididae	2	21	2	2	21	5	13	4	17	2	2	24	16	2
Nematoda	1	2	2	2	1	<1	1	1	1	3	1	1	1	3
Ostracoda	1	<1	<1	<1			<1	5		1			18	<1
Plecoptera	<1	1	<1	1	1	<1	<1	1	<1	2	4	2	1	2
Psychodidae		<1												<1
Simuliidae	3	<1	<1	1	<1	3	1	<1	<1	<1	1	1	<1	
Tabanidae	<1	<1			<1			<1		<1	<1	0	<1	<1
Tipulidae	<1	<1						<1		1	1	1	<1	1
Trichoptera	1	<1	<1	1	1	1	<1	2	1	9	24	22	6	10
Tubificidae	2	1	<1	1	<1	1	1	10	19	<1		1	1	<1
Benthic Invertebrate Community Measurement Endpoints														
Total Abundance (No./m^2)	29,87	2,321	3,156	1,725	5,259	3,105	1,691	9,497	4,418	41,844	17,317	26,123	63,294	14,725
Richness	41	23	21	17	20	17	23	31	21	34	29	36	36	46
Simpson's Diversity	0.76	0.83	0.79	0.84	0.85	0.81	0.88	0.88	0.75	0.89	0.81	0.83	0.70	0.86
Evenness	0.78	0.87	0.83	0.9	0.9	0.87	0.89	0.91	0.8	0.92	0.83	0.83	0.72	0.88
% EPT	47	39	47	23	24	34	15	13	10	29	54	40	56	31

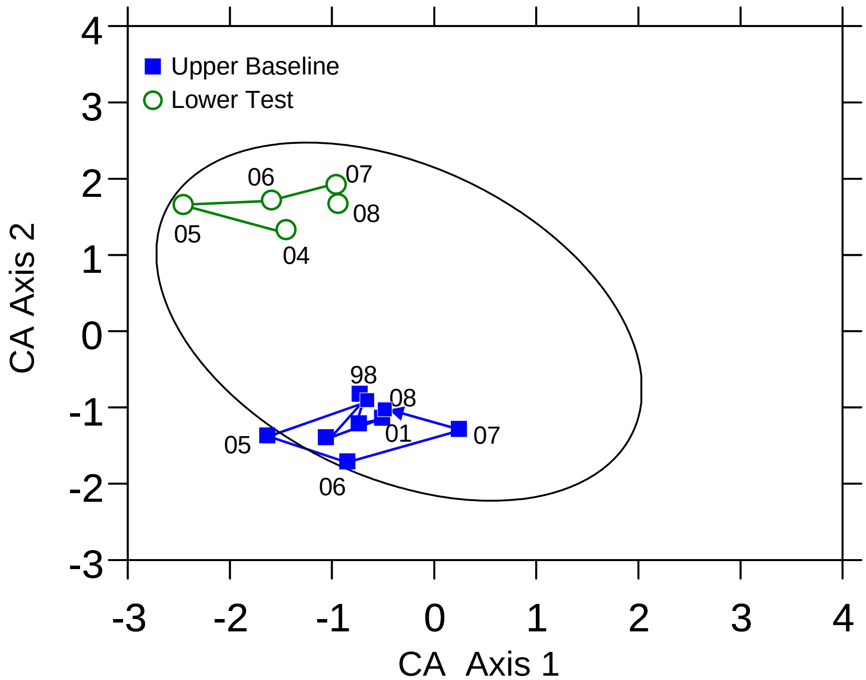
Figure 5.3-7 Variation in benthic invertebrate community measurement endpoints in the lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.

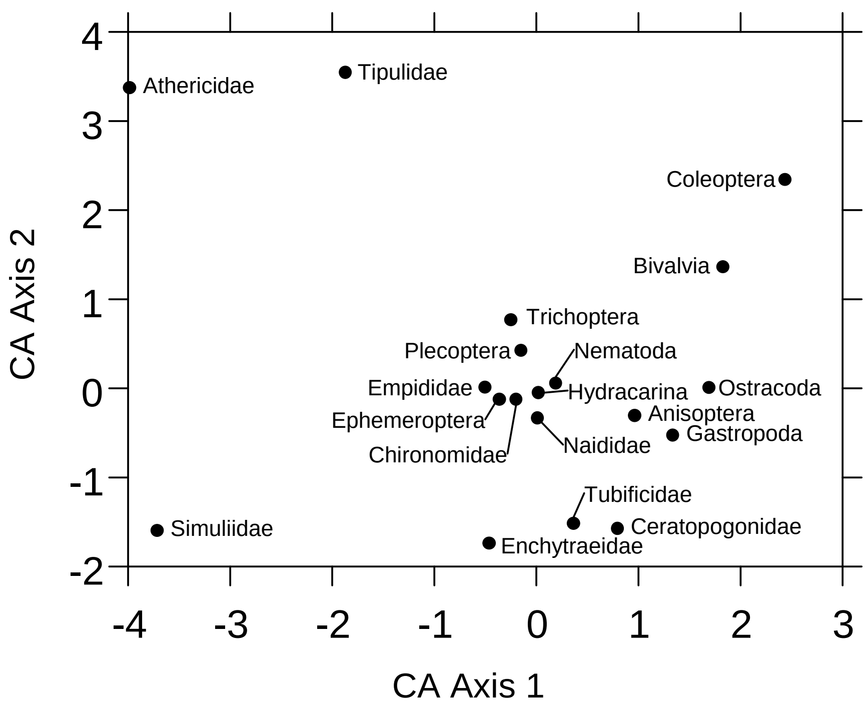


Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* erosional sites in the RAMP FSA.

Note: Upper *Baseline* – STR-E-2; Lower *Test* – STR-E-1

Figure 5.3-8 Ordination (Correspondence Analysis) of erosional river benthic communities showing the lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.





Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data for erosional river habitats in the RAMP FSA.

Note: the numbers in the upper panel refer to the sampling year for each data point.

Table 5.3-12 Results of analysis of variance (ANOVA) between lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.

Variable	Source	SS	df	MS	F-ratio	*p*
Log Abundance	Reach - Year	44.74	13	3.44	48.81	0.000
	Baseline vs Test (BT)	9.25	2	4.62	65.58	0.000
	Linear Time Trend (T)	3.78	2	1.89	26.78	0.000
	BT x T	11.09	2	5.54	78.63	0.000
	Remainder (noise)	20.62	7	2.95	41.79	0.000
	Error	10.15	144	0.07		
Log Richness	Reach - Year	2.837	13	0.218	20.25	0.000
	Baseline vs Test (BT)	0.759	2	0.379	35.21	0.000
	Linear Time Trend (T)	0.363	2	0.182	16.85	0.000
	BT x T	0.369	2	0.184	17.11	0.000
	Remainder (noise)	1.346	7	0.192	17.80	0.000
	Error	1.552	144	0.011		
Diversity	Reach - Year	0.406	13	0.031	4.71	0.000
	Baseline vs Test (BT)	0.062	2	0.031	4.64	0.011
	Linear Time Trend (T)	0.020	2	0.010	1.48	0.232
	BT x T	0.015	2	0.007	1.12	0.329
	Remainder (noise)	0.310	7	0.044	6.71	0.011
	Error	0.955	144	0.007		
Evenness	Reach - Year	0.435	13	0.034	4.78	0.000
	Baseline vs Test (BT)	0.10	2	0.05	7.40	0.001
	Linear Time Trend (T)	0.03	2	0.01	1.82	0.166
	BT x T	0.026	2	0.013	1.87	0.158
	Remainder (noise)	0.280	7	0.040	5.71	0.018
	Error	1.008	144	0.007		
Log %EPT	Reach - Year	13.27	13	1.02	18.37	0.000
	Baseline vs Test (BT)	1.23	2	0.61	11.04	0.000
	Linear Time Trend (T)	1.42	2	0.71	12.79	0.000
	BT x T	0.57	2	0.29	5.17	0.007
	Remainder (noise)	10.05	7	1.44	25.82	0.000
	Error	8.00	144	0.06		
CA Axis 1	Reach - Year	55.66	13	4.28	11.79	0.000
	Baseline vs Test (BT)	9.33	2	4.66	12.84	0.000
	Linear Time Trend (T)	12.64	2	6.32	17.40	0.000
	BT x T	6.13	2	3.07	8.44	0.000
	Remainder (noise)	27.6	7	3.937	10.84	0.001
	Error	52.29	144	0.36		
CA Axis 2	Reach - Year	301.62	13	23.20	74.10	0.000
	Baseline vs Test (BT)	140.59	2	70.29	224.51	0.000
	Linear Time Trend (T)	5.85	2	2.92	9.34	0.000
	BT x T	67.26	2	33.63	107.41	0.000
	Remainder (noise)	87.93	7	12.56	40.12	0.000
	Error	45.09	144	0.31		

Notes: Log is $\log_{10}$; CA Axes refer to ordination (correspondence analysis of benthic invertebrate community data (Figure 5.3-8)

5.4 TAR RIVER WATERSHED

Table 5.4-1 Summary of results for Tar River watershed.

Tar River Watershed	Summary of 2008 Conditions	
Climate and Hydrology[1]		
Criteria	**S15A** near the mouth	no station sampled
Mean open-water season discharge	🟤	
Mean winter discharge	not measured	
Annual maximum daily discharge	🟤	
Minimum open-water season discharge	🟤	
Water Quality		
Criteria	**TAR-1** at the mouth	**TAR-2** upstream of Canadian Natural Horizon
Water Quality	🟤	🟡
Benthic Invertebrate Community and Sediment Quality		
No benthic invertebrate community and sediment programs were conducted in 2008.		
Fish Populations		
No fish programs were conducted in 2008.		

🟡 Negligible - Low
🟠 Moderate
🟤 High
baseline (green)
test (blue)

[1] For Climate and Hydrology, results are reported for station at the mouth of the watershed

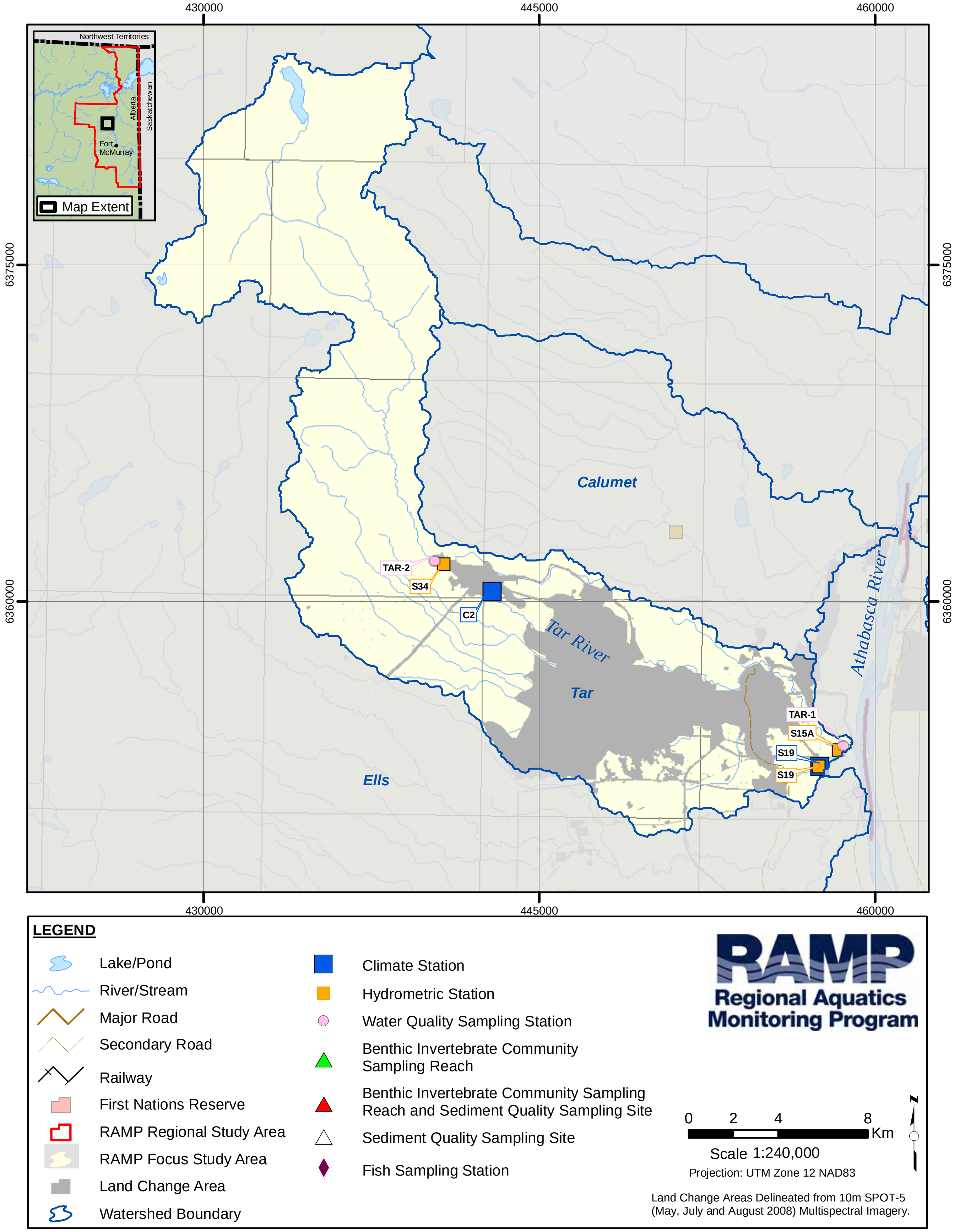
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.4-1 Tar River watershed.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K04_Tar_20090420.mxd

Figure 5.4-2 Representative Tar River monitoring stations, fall 2008.

Water Quality Station TAR-1:
centre of channel, facing downstream

Water Quality Station TAR-1:
right downstream bank, facing upstream

Water Quality Station TAR-2:
left downstream bank, facing downstream

Water Quality Station TAR-2:
right downstream bank, facing upstream

5.4.1 Summary of Conditions

As of 2008, approximately 22% of the Tar River watershed had undergone land change as a result of focal projects (Table 2.4-2). In addition, in spring 2008, a 76.7 ha compensation lake was filled and, once the lake was filled, water was diverted to a tailings pond[1].

The designations of specific areas of the watershed are therefore as follows:

- The Tar River watershed downstream of the CNRL Horizon Project operations is designated as *test*.
- The remainder of the watershed is designated as *baseline* (Figure 5.4-1).

[1] In 2004, Canadian Natural was granted DFO authorization to divert the lower reaches of the Tar River in response to the development of the Horizon Oil Sands. To compensate for the loss of fisheries habitat from the Tar River, a No Net Loss Plan was developed and approved by DFO. The plan involved the construction of a 76.7 ha compensation lake and the eventual diversion of flows from the Tar River to the Calumet River watershed, planned for 2018. Construction of the Tar River dam was initiated in 2006.

Table 5.4-1 contains a summary of the 2008 assessment for the Tar River watershed, Figure 5.4-1 is a detailed map of the Tar River watershed, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.4-2 contains a series of pictures from 2008 of a number of the monitoring stations in the watershed.

Hydrology The observed 2008 discharge for the Tar River watershed is estimated to be 74% less than the 2008 *baseline* discharge would have been in the absence of focal projects. The differences in the Tar River watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **High** for all calculated hydrologic measurement endpoints.

Water Quality Differences in water quality in fall 2008 in the lower Tar River as compared to regional *baseline* conditions are assessed as **High**:

- Concentrations of a number of nutrients and ions have increased to concentrations outside the range of both historical measurements and natural *baseline* concentrations.
- All water quality guideline exceedances of nutrients and ions that occurred in the lower Tar River were not observed in the upper Tar River.
- Ionic composition of water in the lower Tar River has changed since 2005 toward a greater proportion of sulphate and chloride and a reduced proportion of bicarbonate, in contrast to the ion balance of water in the upper Tar River which remains dominated by calcium and bicarbonate.

5.4.2 Hydrologic Conditions

2008 Hydrologic Conditions The observed May 11 to October 15 runoff volume in the Tar River watershed, as measured at RAMP Station S15A, Tar River near the Mouth, was 15.3 mm (Figure 5.4-3). This was approximately 35% of what was measured in 2007 for the same time period. The maximum observed daily discharge of 2.85 m^3/s was approximately 38% of the mean annual flood of 7.45 m^3/s; however, it is likely that higher flows occurred prior to station installation. The minimum open-water discharge was 0.076 m^3/s, which is well below the average minimum open-water discharge of 0.255 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph A summary of the inputs to the water balance model for the Tar River used to create a *baseline* hydrograph is as follows (details are provided in Table 5.4-2 and Table 5.4-3):

- As of 2008, the area of closed-circuited and not closed-circuited land change was 64.0 km^2 and 8.26 km^2, respectively, as a result of cumulative development of focal projects in the Tar River watershed (Table 2.4-1), the estimated net effects of which were decreased inflows to the Tar River by 3.64 million m^3; and
- Withdrawals from the Tar River by focal projects in 2008 are estimated at 10.4 million m^3 during the May to October 2008 period when RAMP station S15A was operational. These withdrawals are attributed to the rerouting of Canadian Natural Compensation Lake outflow from diversion ditch DD4 to a tailings pond.

The estimated net effect of these focal project activities was to decrease flow in the Tar River by an estimated 14.0 million m^3 in the May to October period in 2008. The estimated cumulative effect in 2008 is that the mean open-water season discharge was decreased by 74%, and the open-water season minimum daily discharge was decreased by 75% (Figure 5.4-3, Table 5.4-3).

Summary The observed *test* 2008 discharge for RAMP Station S15A, Tar River near the Mouth, is estimated to be approximately 74% less than 2008 *baseline* discharge would have been in the absence of focal projects in the Tar River watershed. Most of this difference is attributable to the filling of Canadian Natural's compensation lake in May and the redirection of the flow into a tailings pond for the remainder of the year. The differences in the Tar River watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at RAMP Station S15A, Tar River near the Mouth, are assessed as High for all measured hydrologic measurement endpoints (Table 5.4-1).

5.4.3 Water Quality

In fall 2008, RAMP collected the following water quality samples from the Tar River:

- The mouth of the Tar River (station TAR-1, designated as *test* in summer 2004, sampled from 1998 to 2008); and
- Tar River upstream in the fall season (station TAR-2, designated as *baseline* since station establishment in 2004).

2008 Results and Historical Ranges of Concentration At station TAR-1 in fall 2008, most water quality measurement endpoints exhibited concentrations that fell outside the range of historical observations at this station (Table 5.4-4), including the following:

- Several nutrients (i.e., total nitrogen, nitrate + nitrite, and total dissolved phosphorus) and several ions or indicators of dissolved ions (sodium, calcium, magnesium, chloride, sulphate, total dissolved solids, and conductivity), and total strontium, all exceeded previously observed maxima; and
- Total suspended solids fell below its previously measured minimum in fall 2008 (Table 5.4-4), although earlier in 2008 suspended sediments in the lower Tar River had been high due to sedimentation problems at Canadian Natural's diversion pond (R. Kavanagh, Canadian Natural, *pers. comm.*, 2009).

At upstream station TAR-2, all key water quality measurement endpoints were within historical ranges in fall 2008 except: total arsenic, pH, total boron, and total molybdenum (historical highs); and total suspended solids and total aluminum (historical lows) (Table 5.4-5).

Concentrations of many ions in the lower Tar River (station TAR-1) were greater in fall 2008 than in fall 2007 (Figure 5.4-4), consistent with increasing trends in recent years (see Trend Analysis below).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions Concentrations of nine water quality measurement endpoints were greater than the 95th percentile of regional *baseline* concentrations at station TAR-1 in fall 2008, including total nitrogen, sulphate, total dissolved solids, total strontium, calcium, magnesium, potassium, and chloride. At the upstream station, TAR-2, no water quality measurement endpoints exceeded above the 95th percentile of regional *baseline* concentrations, but total suspended solids and chloride concentrations fell below the 5th percentile of regional *baseline* concentrations (Figure 5.4-4).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Concentrations of total nitrogen, sulphate, total aluminum, and total dissolved phosphorus exceeded water quality guidelines at TAR-1 in fall 2008 (Table 5.4-4). No water quality measurement endpoints exceeded guidelines at station TAR-2 (Table 5.4-5).

Other Water Quality Guideline Exceedances The following are other water quality guideline exceedances that were observed in the Tar River during fall 2008 (Table 5.4-6):

- Station TAR-1 in fall 2008 - sulphide, sulphate, total aluminum, dissolved selenium, total selenium, total dissolved phosphorus, total phosphorus, total iron, total phenols, nitrate +nitrite and total nitrogen; and
- Station TAR-2 in fall 2008 - sulphide, total phosphorus and total iron.

Ion Balance Ion balance at station TAR-1 has showed steady changes since 2005, toward a greater proportion of sulphate and chloride and a reduced proportion to bicarbonate. In contrast, ion balance at station TAR-2 has remained more consistent than TAR-1 since 2004 (Figure 5.4-5).

Trend Analysis Significant upward trends in total nitrogen, sulphate, and chloride were observed in water quality data from 1997 to 2008 for station TAR-1 (α=0.05).

Water Quality Index The WQI value of 59.1 for the lower Tar River (*test* station TAR-1) in fall 2008 indicates water quality at this station is dissimilar from regional *baseline* conditions; the calculated value for 2008 was a large decline from previous years up to and including 2007, for which WQI values of over 85 were calculated. Water quality in the upper Tar River (*baseline* station TAR-2) was consistent with regional *baseline* data (WQI=96.1).

Summary Differences in water quality in fall 2008 in the lower Tar River as compared to regional *baseline* conditions are assessed as High (Table 5.4-1), with measurable changes in water quality in the lower Tar River watershed that include the following:

- Concentrations of some nutrients (especially nitrogen) and several ions have increased to concentrations outside the range of both historical measurements and natural *baseline* concentrations.
- All water quality guideline exceedances of nutrients and ions that occurred at the lower *test* station were not observed at the upper *baseline* station.

Ionic composition at *test* station TAR-1 in the lower Tar River has changed since 2005 toward a greater proportion of sulphate and chloride and a reduced proportion of bicarbonate, in contrast to the ion balance at *baseline* station TAR-2 in the upper Tar River which remains dominated by calcium and bicarbonate (Table 5.4-1).

5.4.4 Benthic Invertebrate Communities and Sediment Quality

5.4.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were not sampled by RAMP in the Tar River watershed in 2008. Benthic invertebrate sampling was completed by Canadian Natural as part of the Horizon Fisheries and Aquatic Monitoring.

5.4.4.2 Sediment Quality

Sediment quality was not sampled in the Tar River watershed in 2008.

5.4.5 Fish Populations

The 2008 RAMP Fish Population component did not include any activities in the Tar River watershed. Fish populations were sampled by Canadian Natural as part of the Horizon Fisheries and Aquatics Monitoring.

Figure 5.4-3 Tar River: 2008 hydrograph and historical context.

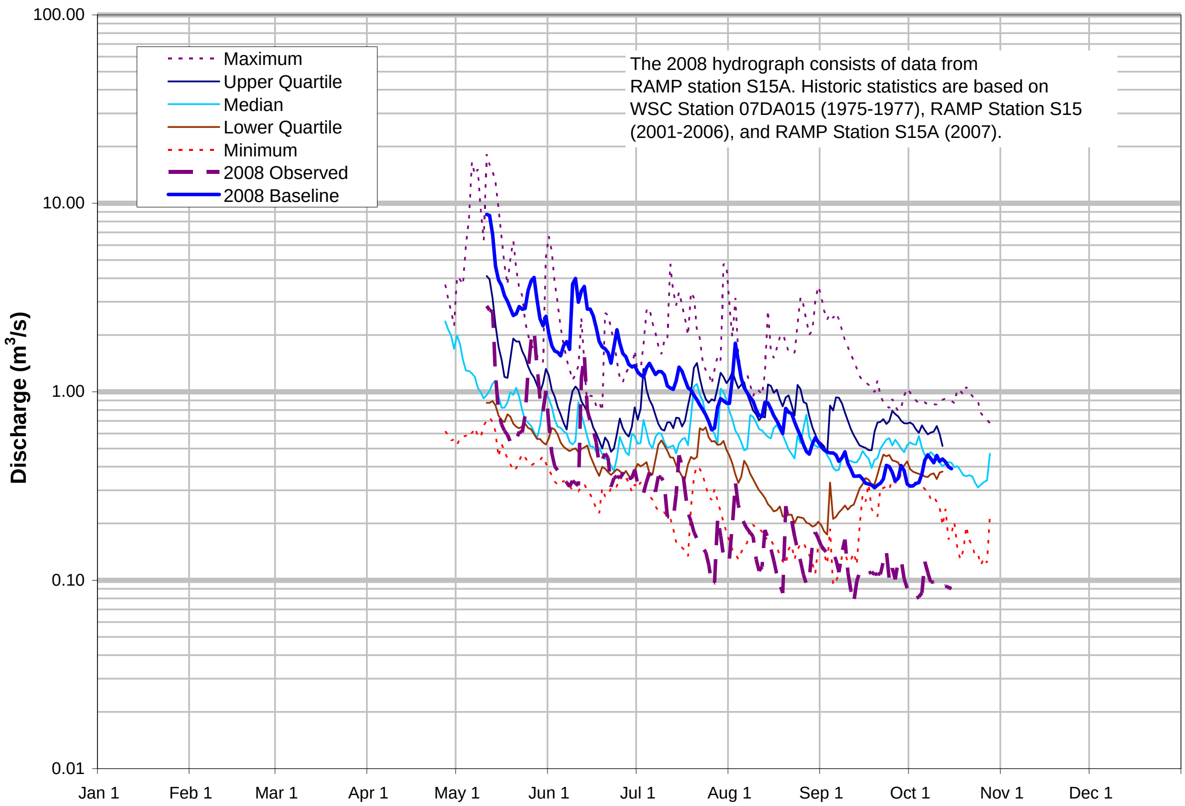


Table 5.4-2 Estimated water balance at RAMP Station S15A, Tar River near the Mouth in 2008.

Component	Volume (million m^3)	Basis and Data Source
Observed *test* hydrograph (total discharge)	**4.94**	**Observed discharge at RAMP Station S15A, Tar River near the Mouth**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+3.74	64 km^2 within the Tar River watershed closed-circuited by focal projects as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.097	8.26 km^2 within Tar River watershed estimated to have undergone land change by focal projects of 2008, but are not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from the Tar River by focal projects	+10.4	Water directed to CNRL tailings pond from Compensation Lake
Amount by which discharge would be lower without releases to the Tar River watershed by focal projects	0	Assumed to be zero
Diversions into or out of the watershed	0	None
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Tar River not accounted for in figures contained in this table
***Baseline* hydrograph (total discharge)**	**18.9**	**Estimated *baseline* discharge at RAMP Station S15A, Tar River near the Mouth**
Incremental flow (change in total discharge)	-14.0	Total discharge from observed hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of total discharge)	-74%	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Data are for the period of the 2008 data record for RAMP Station S15A, Tar River near the Mouth.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.4-3 Calculated change in hydrologic measurement endpoints for the Tar River watershed.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	1.39	0.362	-74%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	8.73*	2.85*	-67%
Open-water season minimum daily discharge	0.309	0.076	-75%

Note: As measured at and calculated for RAMP/WSC Station S15A, Tar River near the Mouth

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

* Value may be underestimated as maximum daily discharge likely occurred prior to station installation.

Table 5.4-4 Concentrations of water quality measurement endpoints, lower Tar River (station TAR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	7	8.1	8.2	8.5
Total Suspended Solids	mg/L	-[1]	7	7	11	36	214
Conductivity	µS/cm	-	875	7	302	427	602
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.125**	7	0.013	0.017	**0.067**
Total nitrogen*	mg/L	1.0	**4.3**	7	0.5	1	**3.60**
Nitrate+Nitrite	mg/L	1.0	**3.5**	7	<0.1	0.1	**1.5**
Dissolved organic carbon	mg/L	-	17	7	12	16	21
Ions							
Sodium	mg/L	-	50	7	15	27	38
Calcium	mg/L	-	88.5	7	38	49.2	65.8
Magnesium	mg/L	-	24.3	7	11.3	15.4	19.8
Chloride	mg/L	230, 860[3]	50	7	1.7	4	24
Sulphate	mg/L	100[4]	**173**	7	20.4	38.1	95.1
Total Dissolved Solids	mg/L	-	590	7	170	300	393
Total Alkalinity	mg/L		171	7	121	179	210
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.384**	7	**0.36**	**0.53**	**3.95**
Dissolved aluminum	mg/L	0.1[2]	0.0056	7	0.005	0.010	0.026
Total arsenic	mg/L	0.005	0.0012	7	0.0011	0.0017	0.0022
Total boron	mg/L	1.2[5]	0.126	7	0.054	0.099	0.145
Total molybdenum	mg/L	0.073	0.0007	7	0.0004	0.0012	0.0020
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	**5.6**
Total strontium	mg/L	-	0.442	7	0.143	0.202	0.29
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.011**	7	**<0.003**	**0.007**	**0.023**
Dissolved selenium	mg/L	0.001[2]	**0.00102**	7	<0.0005	0.0002	0.0007
Total selenium	mg/L	0.001	**0.0012**	7	<0.0008	0.0002	0.0008
Total phosphorus	mg/L	0.05	**0.205**	7	**0.057**	**0.085**	**0.232**
Total iron	mg/L	0.3	**1.4**	7	**1.46**	**2.22**	**7.03**
Total phenols	mg/L	0.004	**0.006**	7	<0.001	**0.005**	**0.008**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.4-5 Concentrations of water quality measurement endpoints, upper Tar River (station TAR-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	4	8.0	8.25	8.3
Total Suspended Solids	mg/L	-[1]	<3	4	5	5.5	7
Conductivity	µS/cm	-	371	4	233	314	383
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.028	4	0.024	**0.053**	**0.058**
Total nitrogen*	mg/L	1.0	0.5	4	0.4	0.5	0.60
Nitrate+Nitrite	mg/L	1.0	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13	4	8	10.5	14
Ions							
Sodium	mg/L	-	12	4	6	12.5	16
Calcium	mg/L	-	46.4	4	31.4	44.8	49
Magnesium	mg/L	-	13.5	4	8.8	13.45	14.3
Chloride	mg/L	230, 860[3]	1.0	4	1.0	2.0	2.0
Sulphate	mg/L	100[4]	37.2	4	20	33.75	38
Total Dissolved Solids	mg/L	-	248	4	160	222	280
Total Alkalinity	mg/L		159	4	100	145	162
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0732	4	0.087	**0.207**	**0.708**
Dissolved aluminum	mg/L	0.1[2]	0.0248	4	0.008	0.0163	0.026
Total arsenic	mg/L	0.005	0.0014	4	0.0008	0.0011	0.0012
Total boron	mg/L	1.2[5]	0.0674	4	0.035	0.0526	0.066
Total molybdenum	mg/L	0.073	0.0015	4	0.0008	0.0013	0.0014
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	0.05	1.4
Total strontium	mg/L	-	0.161	4	0.101	0.1425	0.185
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.005**	4	**<0.003**	**0.0045**	**0.008**
Total phosphorus	mg/L	0.05	**0.065**	4	**0.053**	**0.0775**	**0.1**
Total iron	mg/L	0.3	**1.23**	4	**0.856**	**1.031**	**1.59**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

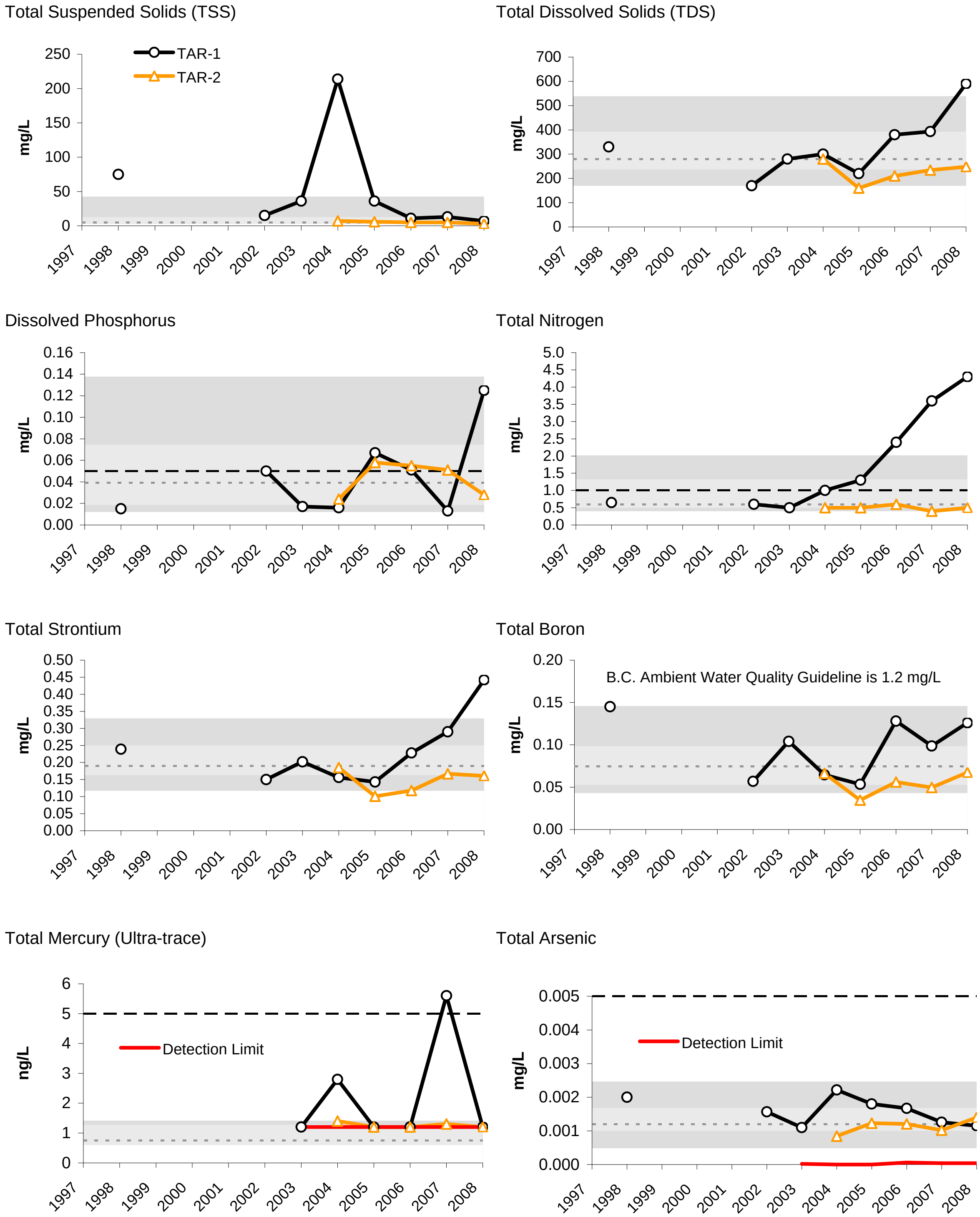
[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

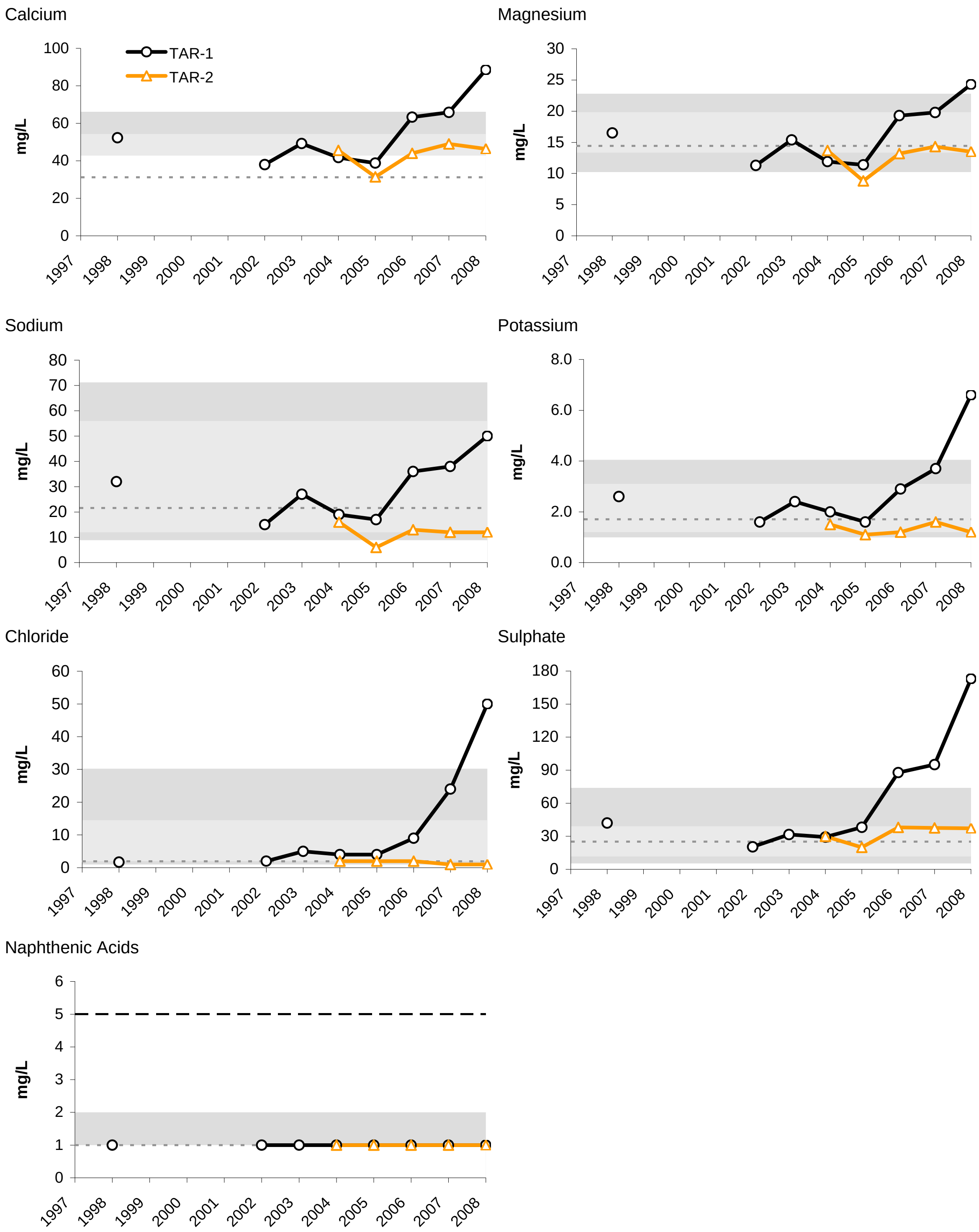
Figure 5.4-4 Concentrations of selected water quality measurement endpoints in the Tar River (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.4-4 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Table 5.4-6 Water quality guideline exceedances, Tar River, fall 2008.

Variable	Units	Guideline*	TAR-1	TAR-2
Fall				
Sulphide	mg/L	0.002[1]	**0.011**	**0.005**
Sulphate	mg/L	100[3]	**173**	**-**
Total aluminum	mg/L	0.1	**0.384**	**-**
Dissolved selenium	mg/L	0.001[2]	**0.00102**	-
Total selenium	mg/L	0.001	**0.00121**	**-**
Total dissolved phosphorus	mg/L	0.05[2]	**0.125**	**-**
Total phosphorus	mg/L	0.05	**0.205**	**0.065**
Total iron	mg/L	0.3	**1.4**	**1.23**
Total phenols	mg/L	0.004	**0.006**	-
Nitrate+Nitrite	mg/L	1.0	**3.5**	-
Total nitrogen	mg/L	1.0	**4.3**	-

TAR-1 and TAR-2 were sampled only in fall 2008.

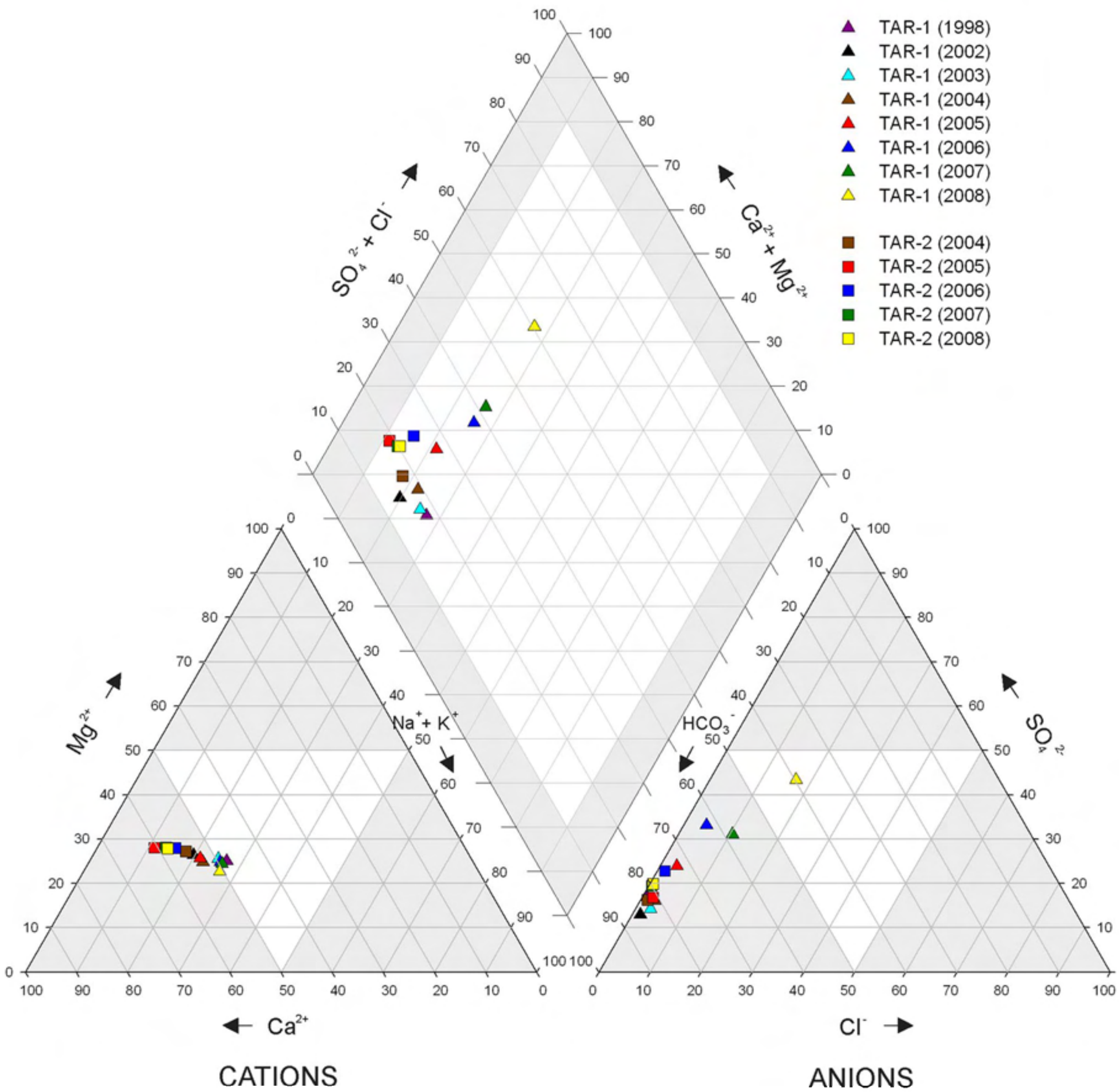
* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

Figure 5.4-5 Piper diagram of fall ion concentrations, Tar River.



5.5 MACKAY RIVER WATERSHED

Table 5.5-1 Summary of results for MacKay River watershed.

MacKay River Watershed	Summary of 2008 Conditions	
	Climate and Hydrology[1]	
Criteria	**S26** near Fort McKay	
Mean open-water season discharge	○	
Mean winter discharge	○	
Annual maximum daily discharge	○	
Minimum open-water season discharge	○	
	Water Quality	
Criteria	**MAR-1** at the mouth	**MAR-2** upstream of Petro-Canada MacKay
Water Quality	○	○
	Benthic Invertebrate Community and Sediment Quality	
Criteria	**MAR-E-1** at the mouth	**MAR-E-2** upstream of Petro-Canada MacKay
Benthic Invertebrate Community	○	n/a
	Fish Populations	
	No fish programs were conducted in 2008.	

○ Negligible - Low
● Moderate
● High
baseline
test

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches.

[1] For Climate and Hydrology, results are reported for station at the mouth of the watershed

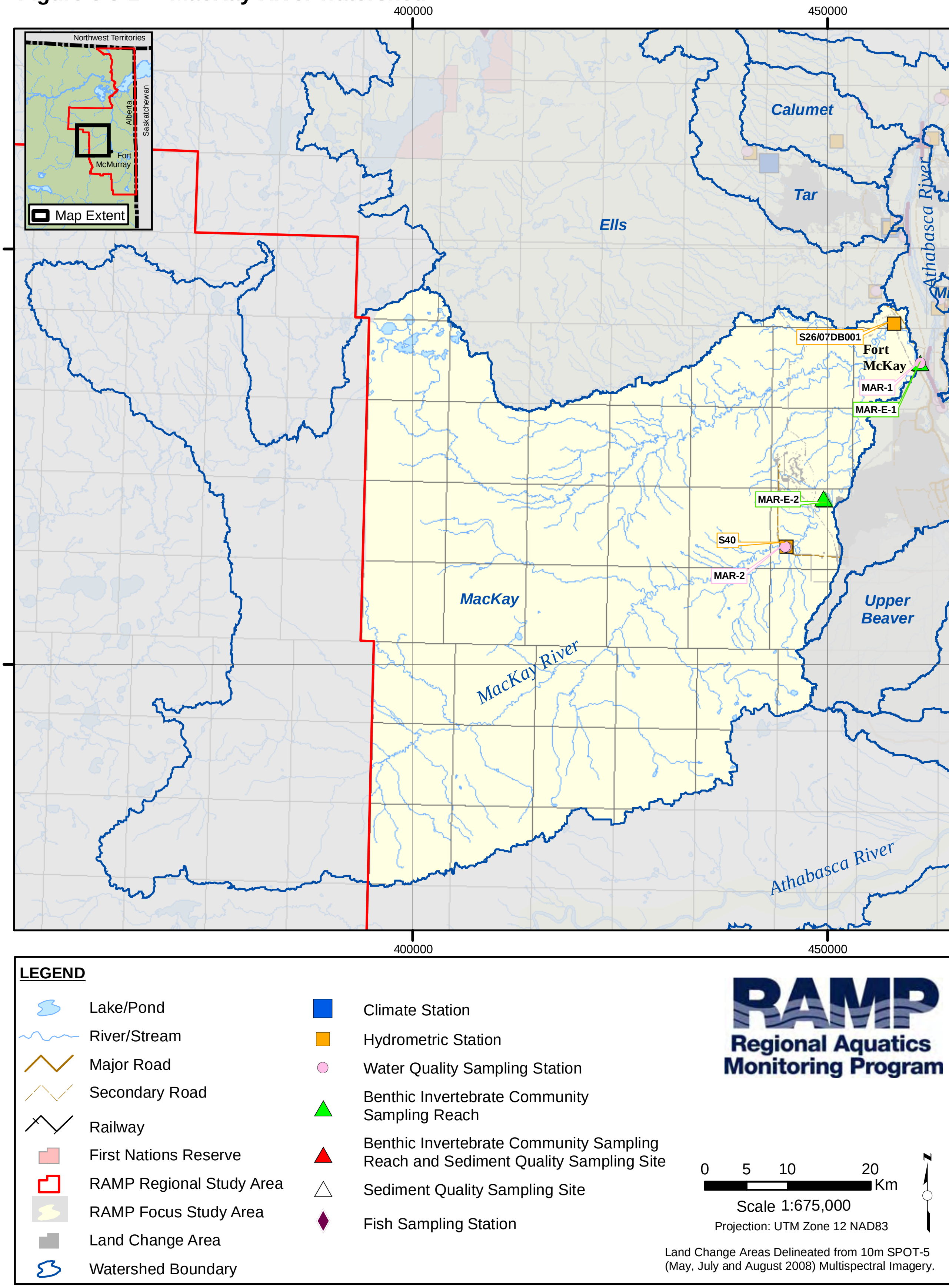
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.5-1 MacKay River watershed.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K05_MacKay_20090420.mxd

Figure 5.5-2 Representative MacKay River monitoring stations, fall 2008.

Water Quality Station MAR-1:
right downstream bank, facing downstream

Water Quality Station MAR-1:
right downstream bank, facing upstream

Water Quality Station MAR-2:
left downstream bank, facing downstream

Water Quality Station MAR-2:
left downstream bank, facing upstream

5.5.1 Summary of Conditions

As of 2008, less than 1% of the MacKay River watershed had undergone land change as a result of focal developments in the watershed (Table 2.4-2). The designations of specific areas of the watershed are therefore as follows:

- The MacKay River watershed downstream of the Petro-Canada 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*; and
- The remainder of the watershed is designated as *baseline*.

Table 5.5-1 contains a summary of the 2008 assessment for the MacKay River watershed, Figure 5.5-1 is a detailed map of the MacKay River watershed, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.5-2 contains a series of pictures from 2008 of a number of the monitoring stations in the watershed.

Hydrology The observed 2008 discharge for the MacKay River watershed is estimated to be 0.01% less than the 2008 *baseline* discharge would have been in the absence of focal projects. The differences in the MacKay River watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Negligible-Low** for all calculated hydrologic measurement endpoints.

Water Quality Differences in water quality in fall 2008 in the MacKay River watershed as compared to regional *baseline* conditions are assessed as **Negligible-Low**:

- Most exceedances of water quality guidelines in 2008 occurred at multiple stations (both *test* and *baseline*) throughout the watershed.
- Almost all concentrations of all water quality measurement endpoints in fall 2008, were within the range of natural variability as they have consistently been since the beginning of RAMP water quality monitoring in the MacKay River watershed.
- Ionic composition at all water quality monitoring stations in the watershed in 2008 was consistent with previous years and continues to show little year-to-year variation.

Benthic Invertebrate Communities The differences in the benthic invertebrate community in the lower MacKay River as compared to the upper MacKay River are assessed as **Negligible-Low**. Differences in benthic invertebrate community measurement endpoints between the lower and upper Mackay River were statistically weak and values of all benthic invertebrate community measurement endpoints in the lower MacKay River in fall 2008 were within the normal range of variation for *baseline* erosional reaches in the RAMP FSA.

5.5.2 Hydrologic Conditions

2008 Hydrologic Conditions Streamflow in the MacKay River basin, as measured at RAMP Station S26 and WSC Station 07DB001, was close to normal in 2008 (Figure 5.5-3). The basin produced 100 mm of runoff in 2008, 22% more than 2007. Almost one-third of the annual flow occurred in May and approximately one-fifth occurred in August. The maximum daily discharge of 106 m^3/s that occurred in May was 87% of the mean annual flood of 122 m^3/s. The average daily discharge during the open water period and winter period was 32.7 m^3/s and 2.83 m^3/s, respectively. Daily flow in 2008 was above historical median values for all but the second half of April and the end of July.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the MacKay River is provided in Table 5.5-2. As of 2008, the areas of closed-circuited and not closed-circuited land change were 2.78 km^2 and 11.0 km^2, respectively, in the MacKay River catchment as a result of cumulative development of focal projects in the watershed (Table 2.4-1), the estimated net effects of which were decreased annual inflows to the MacKay River by 0.058 million m^3.

The estimated effect of these reduced flows was a reduction of 0.01% in mean open-water season discharge, annual maximum daily discharge, mean winter discharge, and open-water season minimum daily discharge (Table 5.5-3). The cumulative effect is that all hydrologic measurement endpoints for the MacKay River watershed are estimated to be similar to what they would have been under *baseline* conditions (Figure 5.5-3, Table 5.5-3).

Summary The observed *test* 2008 discharge for RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001), is estimated to be 0.01% less than 2008 *baseline* discharge would have been in the absence of focal projects in the MacKay River watershed. The differences in the MacKay River watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at RAMP RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001), are assessed as Negligible-Low for all measured hydrologic measurement endpoints (Table 5.5-1).

5.5.3 Water Quality

In fall 2008, water quality samples were collected from:

- The mouth of the MacKay River (station MAR-1, *test*, first sampled in 1998, fall sampling every year from 2000 to 2008); and
- Upstream of the Petro-Canada MacKay River Devon *in situ* developments (station MAR-2, *baseline*, sampled from 2002 to 2008).

The upper and lower MacKay River stations were sampled in all seasons during 2008.

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations of four water quality measurement endpoints fell outside of the range of historical observations at both the downstream *test* station MAR-1 and the upstream *baseline* station, MAR-2 (Table 5.5-4 and Table 5.5-5): dissolved organic carbon was above its previously measured maximum, while sulphate, total boron, and total molybdenum fell below observed historical minima. Additional water quality measurement endpoints fell outside their range of historical data at station MAR-2 in fall 2008, including total dissolved phosphorus, which exceeded its previously measured maximum, and conductivity which fell below its range of historical observations (Table 5.5-6). The concentration of dissolved phosphorus has shown an increasing trend in both MAR-1 and MAR-2 in recent years, with MAR-2 exceeding its historical maximum, but remaining below the relevant water quality guideline. Generally, water quality at MAR-1 was very similar to that at MAR-2 in fall 2008 (Figure 5.5-4).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions In fall 2008, concentrations of all water quality measurement endpoints at both the mouth of the Mackay River, MAR-1, and upstream Mackay River, MAR-2, were within the range of regional *baseline* concentrations with the exception of dissolved phosphorus at MAR-1, which was slightly above the 95^{th} percentile regional *baseline* concentration (Figure 5.5-4). Dissolved phosphorus has shown non-significant, U-shaped trends over time at both MAR-1 and MAR-2 in recent years, with MAR-1 exceeding the 95^{th} percentile regional *baseline* concentration, but remaining below the relevant water quality guideline.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Concentrations of total aluminum and total nitrogen exceeded their relevant water quality guidelines at both MAR-1 and MAR-2 in fall 2008 (Table 5.5-4, Table 5.5-5). The guideline exceedances of total nitrogen and total aluminum in fall 2008 at both the *baseline* and the *test* station make it unlikely that focal projects are a possible cause of the guideline exceedances observed at station MAR-1 (*test*).

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded relevant water quality guidelines in 2008 in the Mackay River watershed (Table 5.5-6):

- Sulphide, total aluminum, total phosphorus, total nitrogen, total iron, dissolved iron, and total phenols at both MAR-1, and MAR-2 in winter 2008;
- Sulphide, total aluminum, total phenols, total phosphorus, total nitrogen, total iron, and dissolved iron at both MAR-1 and MAR-2 in spring 2008;
- Dissolved aluminum, total cadmium, total copper, and ultra-trace mercury at MAR-1 in spring 2008;
- Sulphide, total dissolved phosphorus, total phosphorus, total nitrogen, total aluminum, total iron, dissolved iron, and total phenols at both MAR-1 and MAR-2 in summer 2008;
- Total Kjeldahl nitrogen at MAR-1 in summer 2008; and
- Sulphide, total phosphorus, total iron, dissolved iron, total phenols at both MAR-1 and MAR-2 in fall 2008.

Ion Balance In fall 2008, the ionic composition of MAR-1 and MAR-2 was quite similar and was dominated by bicarbonate ions. These ionic characteristics remained consistent with data observed in previous years (Figure 5.5-5).

Trend Analysis As of 2008, sufficient data existed to allow statistical trend analysis of fall water quality data for both MacKay River stations MAR-1 (n=10), and MAR-2 (n=7). A significant downward trend was observed in sulphate at both MAR-1 and MAR-2 (α=0.05), although 2008 concentrations of sulphate were lower than all previous years at these stations, concentrations were still within the regional *baseline* range. A significant downward trend was also observed in total boron at station MAR-1. Given total boron is a signature of groundwater, the decreasing trend could indicate a decrease in groundwater seepage to the MacKay River.

Water Quality Index WQI values for both stations in the Mackay River watershed (i.e., MAR-1: 88.3; MAR-2: 92.2) indicated Negligible-Low differences from regional *baseline* conditions.

Summary Differences in water quality in fall 2008 in the lower MacKay River designated as *test*, as compared to regional *baseline* conditions are assessed as Negligible-Low (Table 5.5-1), with measurable changes in water quality in the lower MacKay River watershed that include the following:

- Most exceedances of water quality guidelines in 2008 occurred at multiple stations (both *test* and *baseline*) throughout the watershed;
- Almost all concentrations of all water quality measurement endpoints in fall 2008, were within the range of natural variability as they have consistently been since the beginning of the RAMP water quality data record for the MacKay River watershed; and
- Ionic composition at all water quality monitoring stations in the watershed in 2008 was consistent with previous years and continues to show little year-to-year variation.

5.5.4 Benthic Invertebrate Communities and Sediment Quality

5.5.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in 2008 in the MacKay River watershed at:

- a lower erosional reach near the mouth of the MacKay River (reach MAR-E-1, designated as *test* as of 2002); and
- an upper erosional reach (reach MAR-E-2, designated as *baseline* for its entire data record).

2008 Habitat Conditions Both the lower reach and the upper reach are typical erosional habitats in the RAMP FSA, with moderate current velocities (< 1 m/s) and shallow mid-channel water depths (0.3 m) (Table 5.5-7). Periphyton chlorophyll *a* biomass was low in both reaches, with densities classifying the two reaches as oligotrophic (Figure 5.5-6). Substrate was similar in the two reaches, consisting of a broad mixture of sand through boulder, with somewhat finer materials (more sand and small gravel) in the lower reach (Table 5.5-7).

Relative Abundance of Benthic Invertebrate Community Taxa Benthic communities of the upper and lower reaches of the MacKay River were generally very similar (Table 5.5-8). Both the upper and lower reach communities were dominated by chironomids (> 30%), water mites (Hydracarina), naidid worms, and mayflies (Ephemeroptera, principally Baetidae, Ephemerellidae and Heptageniidae). The upper reach was somewhat more dominated by caddisflies (Trichoptera) than was the lower reach. Stoneflies (Plecoptera) were present in both reaches, but did not comprise a large fraction of the total benthos. *Isoperla* and *Taeniopteryx* were the two stonefly genera dominant in the lower reach, while *Skwala* and *Claasenia sabulosa* were more dominant in the upper reach.

Time trends in the benthic invertebrate community measurement endpoints for the MacKay River watershed (Figure 5.5-7) have the following characteristics:

- All measurement endpoints were within the normal range of variation for *baseline* erosional reaches (Figure 5.5-7);
- Total numbers of organisms in both the upper and lower reach were about 6,000 individuals per m^2, while the number of taxa per sample averaged 25 in the lower reach and 35 in the upper reach;
- Diversity measures have been high in both the upper and lower reaches, near the upper limits of expected values for a *baseline* condition; and
- The percent of the fauna as mayflies, stoneflies and caddisflies (%EPT) is about average for a *baseline* condition, with about 26% in both the upper and the lower reaches in 2008 (Figure 5.5-7).

The biplot of the multivariate CA axis scores (Figure 5.5-8) indicated the lack of variation in community composition from year to year compared to the expected range of variation for *baseline* erosional reaches.

Linear contrasts were used to test for:

- a difference between the upper *baseline* and lower *test* reaches across all common years (designated as "BT" in Table 5.5-9); and
- a difference in time trends between *baseline* and *test* (designated as "BT x T" in Table 5.5-9). A significant BT x T interaction indicates a difference in time trends of measurement endpoints between *baseline* and *test* reaches, and is the most important contrast in terms of determining if there are differences of interest between *baseline* and *test* reaches.

The BT x T interaction was significant for total abundance and taxa richness (Table 5.5-9). Differences in time trends in total abundance appear to have occurred early in the data record, i.e., 2002 through 2004, but since then total abundance appears to have varied similarly in the two reaches. The number of taxa in the lower *test* reach has also generally tracked number of taxa in the upper *baseline* reach, with the potential exception of 2006 when the lower *test* reach had a higher taxa richness than the upper *baseline* reach.

The BT x T interaction was not significant for Simpson's Diversity, evenness or %EPT, likely because the error variation was higher than the within-reach-year variation for those measurement endpoints. The "remainder" variation was also high, statistically significant, and accounted for more variation for each benthic community measurement endpoint than did any of the BT x T contrasts. Over the long term, the time trends indicate benthic communities with high diversity and presence of numerous sensitive organisms in both the lower *test* reach and the upper *baseline* reach of the MacKay River. The relatively high percent of the fauna as EPT taxa, especially in the lower *test* reach, indicates the high quality of habitat and water quality of this river.

5.5.4.2 Sediment Quality

As sediment quality in 2008 was only sampled in the depositional reaches in which benthic invertebrate communities were sampled, and as both reaches of the MacKay River watershed in which benthic invertebrate communities were sampled are erosional, no sediment quality sampling was conducted in the MacKay River in 2008.

5.5.4.3 Summary

The differences in the benthic invertebrate community in the lower MacKay River, designated as *test* in 2008, as compared to the benthic invertebrate community in the upper MacKay River, designated as *baseline* in 2008 are assessed as Negligible-Low (Table 5.5-1) on the basis of the following:

- Differences in benthic invertebrate community measurement endpoints between the lower *test* reach MAR-E-1 and upper *baseline* reach MAR-E-2 were statistically weak; and
- Values of all benthic invertebrate community measurement endpoints in lower *test* reach MAR-E-1 were within the normal range of variation for *baseline* erosional reaches in the RAMP FSA.

5.5.5 Fish Populations

The RAMP 2008 Fish Population component did not include any activities in the MacKay River watershed.

Figure 5.5-3 MacKay River: 2008 hydrograph and historical context.

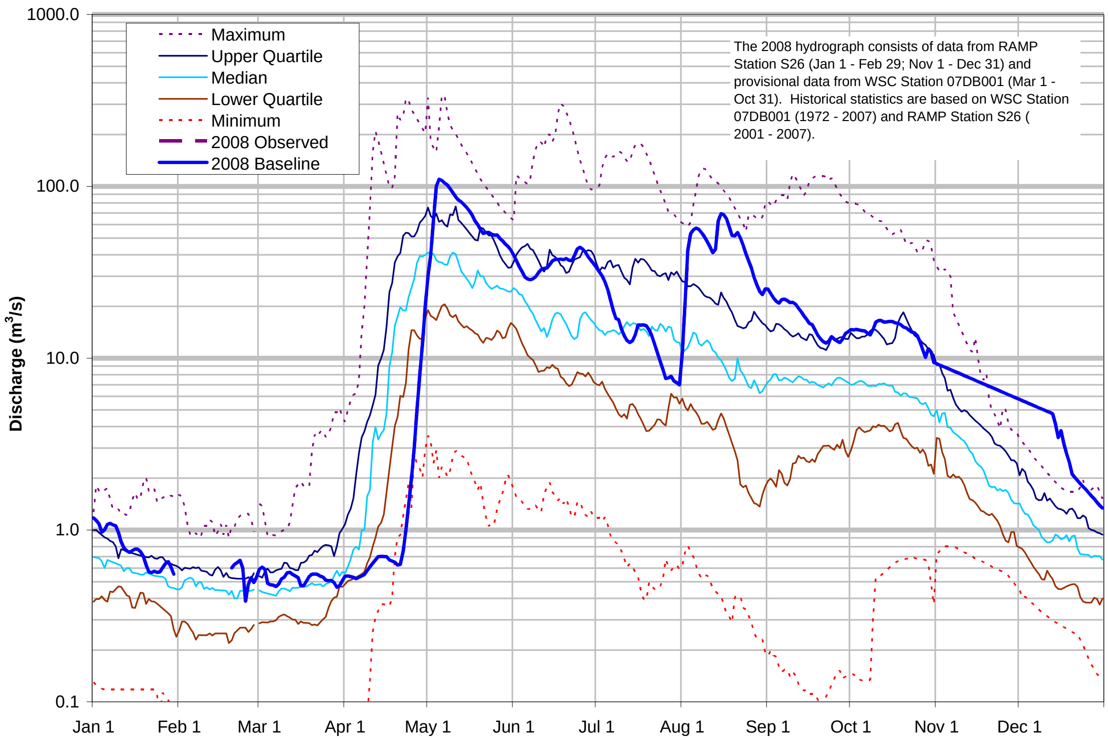


Table 5.5-2 Estimated water balance at RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001) for 2008.

Component	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total annual discharge)	**557**	**Observed annual discharge obtained from RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001)**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+0.278	2.78 km^2 within MacKay River watershed estimated to have been closed-circuited by focal projects as of 2008 (Table 2.6-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.220	11.0 km^2 within MacKay River watershed estimated to have undergone land change by focal projects as of 2008, but area is not closed-circuited (Table 2.6-1)
Discharge that would have occurred in the absence of water withdrawals from the MacKay River by focal projects	0	Water withdrawals are from groundwater
Amount by which discharge would be lower without releases to the MacKay River watershed by focal projects	0	Unknown and assumed to be negligible
Diversions into or out of the watershed	0	None
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects on tributaries of Muskeg River not accounted for in figures contained in this table
***Baseline* hydrograph (total annual discharge)**	**557**	**Estimated *baseline* annual discharge at RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001)**
Incremental flow (change in total annual discharge)	-0.058	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total annual discharge)	-0.01%	Incremental flow as a percentage of total annual discharge of estimated *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.5-3 Calculated change in hydrologic measurement endpoints for the MacKay River watershed.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	32.7	32.7	-0.01%
Mean winter discharge	2.83	2.83	-0.01%
Annual maximum daily discharge	106	106	-0.01%
Open-water season minimum daily discharge	6.99	6.99	-0.01%

Note: As measured at and calculated for RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001).

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.5-4 Concentrations of water quality measurement endpoints, mouth of MacKay River (station MAR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	9	7.6	8.2	8.6
Total Suspended Solids	mg/L	-[1]	6	9	<3	7	26
Conductivity	µS/cm	-	220	9	196	268	576
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.047	9	0.004	0.022	0.047
Total nitrogen*	mg/L	1.0	**1.4**	9	0.4	**1.1**	**3.2**
Nitrate+Nitrite	mg/L	1.0	<0.1	9	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	40	9	20	24	34
Ions							
Sodium	mg/L	-	18	9	15	20	60
Calcium	mg/L	-	25.2	9	24.7	28.5	44.7
Magnesium	mg/L	-	9	9	8.1	9.3	15.9
Chloride	mg/L	230, 860[3]	3	9	3.0	6.0	41.2
Sulphate	mg/L	100[4]	9.3	9	12.1	18.0	35.5
Total Dissolved Solids	mg/L	-	207	9	170	238	342
Total Alkalinity	mg/L		116	9	96	124	202
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.168**	9	0.050	**0.238**	**0.501**
Dissolved aluminum	mg/L	0.1[2]	0.0275	9	0.010	0.020	0.030
Total arsenic	mg/L	0.005	0.001	9	<0.001	0.0008	0.001
Total boron	mg/L	1.2[5]	0.0566	9	0.063	0.084	0.140
Total molybdenum	mg/L	0.073	0.0001	9	0.0002	0.0004	0.0006
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.14	9	0.133	0.158	0.287
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.026**	9	**0.003**	**0.009**	**0.032**
Total phosphorus	mg/L	0.05	**0.059**	9	0.011	0.038	**0.054**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.3**	9	0.3	1.0	**3.1**
Total iron	mg/L	0.3	**1.18**	9	**0.31**	**0.883**	**23.3**
Dissolved iron	mg/L	0.3[2]	**0.787**	9	0.23	**0.469**	**0.694**
Total phenols	mg/L	0.004	**0.011**	9	<0.001	0.002	**0.011**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

8 Guideline is for total nitrogen.

Table 5.5-5 Concentrations of water quality measurement endpoints, upstream MacKay River (station MAR-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	6	7.8	8.2	8.3
Total Suspended Solids	mg/L	-[1]	4	6	<3	<3	10
Conductivity	µS/cm	-	180	6	182	228	249
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.043	6	0.008	0.033	0.039
Total nitrogen*	mg/L	1.0	**1.2**	6	0.8	**1.25**	**3.1**
Nitrate+Nitrite	mg/L	1.0	<0.1	6	<0.1	<0.1	0.1
Dissolved organic carbon	mg/L	-	41	6	22	31.5	38
Ions							
Sodium	mg/L	-	12	6	11	16.5	19
Calcium	mg/L	-	22.3	6	21.3	25.2	31.5
Magnesium	mg/L	-	7.5	6	6.9	8.5	10.1
Chloride	mg/L	230, 860[3]	2	6	1	2	3
Sulphate	mg/L	100[4]	7	6	8.1	13.2	23.7
Total Dissolved Solids	mg/L	-	183	6	160	195	240
Total Alkalinity	mg/L	-	88	6	81	106	128
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.14**	6	0.020	**0.167**	**0.468**
Dissolved aluminum	mg/L	0.1[2]	0.0253	6	<0.0002	0.0241	0.0268
Total arsenic	mg/L	0.005	0.0009	6	0.0006	0.0008	0.001
Total boron	mg/L	1.2[5]	0.043	6	0.051	0.062	0.105
Total molybdenum	mg/L	0.073	0.0001	6	0.0002	0.0003	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	1.8
Total strontium	mg/L	-	0.117	6	0.114	0.134	0.197
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.028**	6	**0.008**	**0.02**	**0.03**
Total phosphorus	mg/L	0.05	**0.056**	6	0.014	0.0465	**0.074**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.1**	6	0.7	**1.15**	**3**
Total iron	mg/L	0.3	**1.07**	6	**0.386**	**0.866**	**1.277**
Dissolved iron	mg/L	0.3[2]	**0.68**	6	0.289	**0.537**	**0.76**
Total phenols	mg/L	0.004	**0.011**	6	<0.001	**0.0085**	**0.02**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);

Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

8 Guideline is for total nitrogen.

Table 5.5-6 Water quality guideline exceedances, MacKay River watershed, 2008.

Variable	Units	Guideline*	MAR-1	MAR-2
Winter				
Sulphide	mg/L	0.002[1]	**0.008**	**0.01**
Total aluminum	mg/L	0.1	**0.143**	**0.957**
Total phosphorus	mg/L	0.05	**0.064**	**0.109**
Total nitrogen	mg/L	1.0	**1.5**	**1.7**
Total iron	mg/L	0.3	**1.33**	**2.39**
Dissolved iron	mg/L	0.3[2]	**0.407**	**0.768**
Total phenols	mg/L	0.004	**0.008**	**0.006**
Spring				
Sulphide	mg/L	0.002[1]	**0.011**	**0.012**
Dissolved aluminum	mg/L	0.1[2]	**0.111**	**-**
Total aluminum	mg/L	0.1	**4.39**	**2.59**
Total cadmium	mg/L	-[3]	**0.0000798**	**-**
Total phenols	mg/L	0.004	**0.013**	**0.012**
Total phosphorus	mg/L	0.05	**0.144**	**0.113**
Total Kjeldahl nitrogen	mg/L	1.0	**1.9**	**1.9**
Total nitrogen	mg/L	1.0	**2**	**2**
Total copper	mg/L	-[3]	**0.00298**	**-**
Dissolved iron	mg/L	0.3[2]	**0.484**	**0.443**
Total iron	mg/L	0.3	**3.74**	**2.7**
Mercury (ultra-trace)	ng/L	13	**6.4**	**-**
Summer				
Sulphide	mg/L	0.002[1]	**0.019**	**0.032**
Total dissolved phosphorus	mg/L	0.05	**0.054**	**0.059**
Total phosphorus	mg/L	0.05	**0.081**	**0.093**
Total Kjeldahl nitrogen	mg/L	1.0	**1.1**	**-**
Total nitrogen	mg/L	1.0	**1.2**	**1.1**
Total aluminum	mg/L	0.1	**0.304**	**0.225**
Total iron	mg/L	0.3	**1.62**	**1.62**
Dissolved iron	mg/L	0.3[2]	**1.1**	**1.24**
Total phenols	mg/L	0.004	**0.009**	**0.009**
Fall				
Sulphide	mg/L	0.002[1]	**0.026**	**0.028**
Total aluminum	mg/L	0.1	**0.168**	**0.14**
Total phosphorus	mg/L	0.05	**0.059**	**0.056**
Total Kjeldahl nitrogen	mg/L	1.0	**1.3**	**1.1**
Total nitrogen	mg/L	1.0	**1.4**	**1.2**
Total iron	mg/L	0.3	**1.18**	**1.07**
Dissolved iron	mg/L	0.3[2]	**0.787**	**0.68**
Total phenols	mg/L	0.004	**0.011**	**0.011**

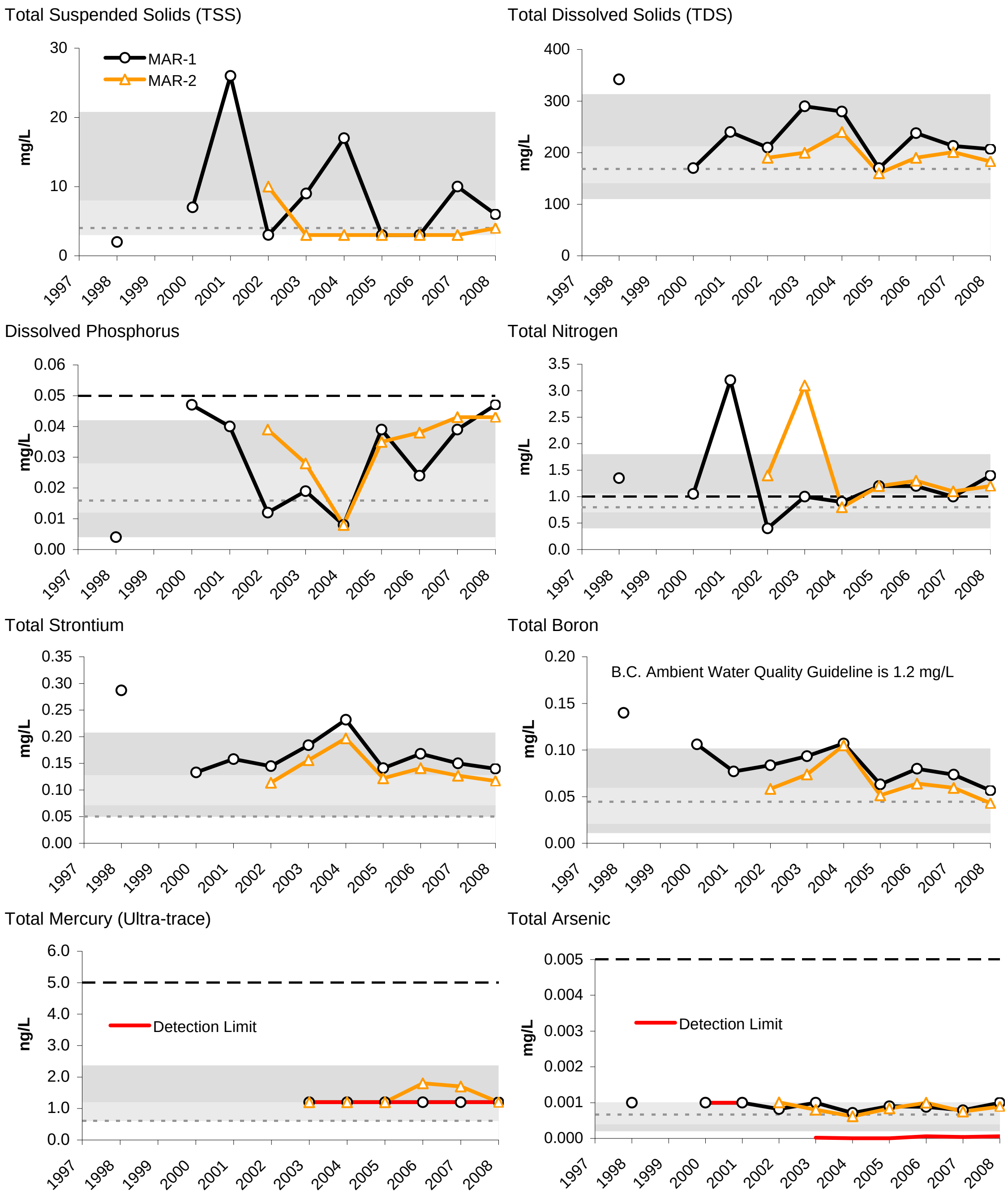
* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (2006).

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] Guideline is hardness-dependent.

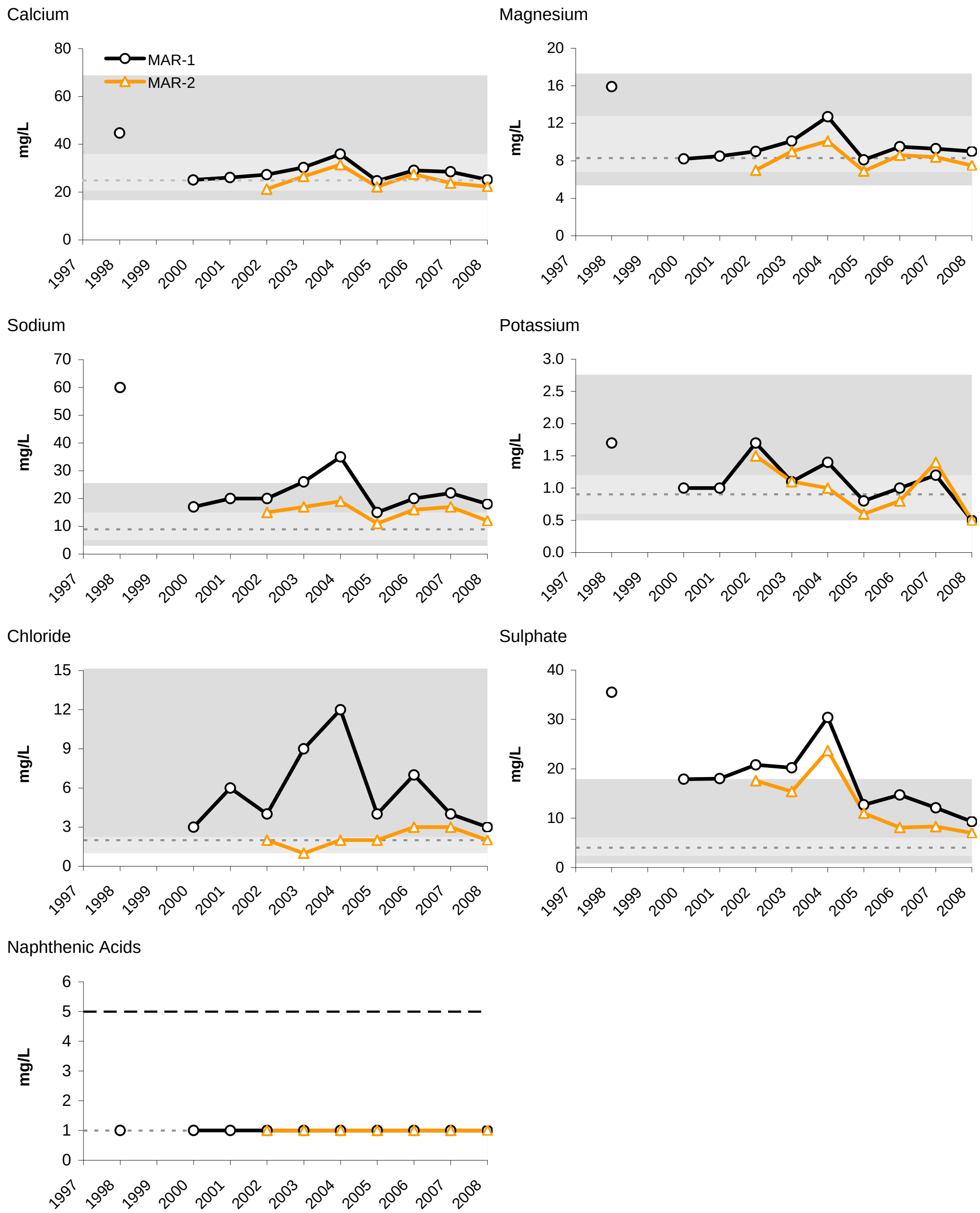
Figure 5.5-4 Concentrations of selected water quality measurement endpoints in the MacKay River (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.5-4 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.5-5 Piper diagram of fall ion concentrations in the MacKay River watershed.

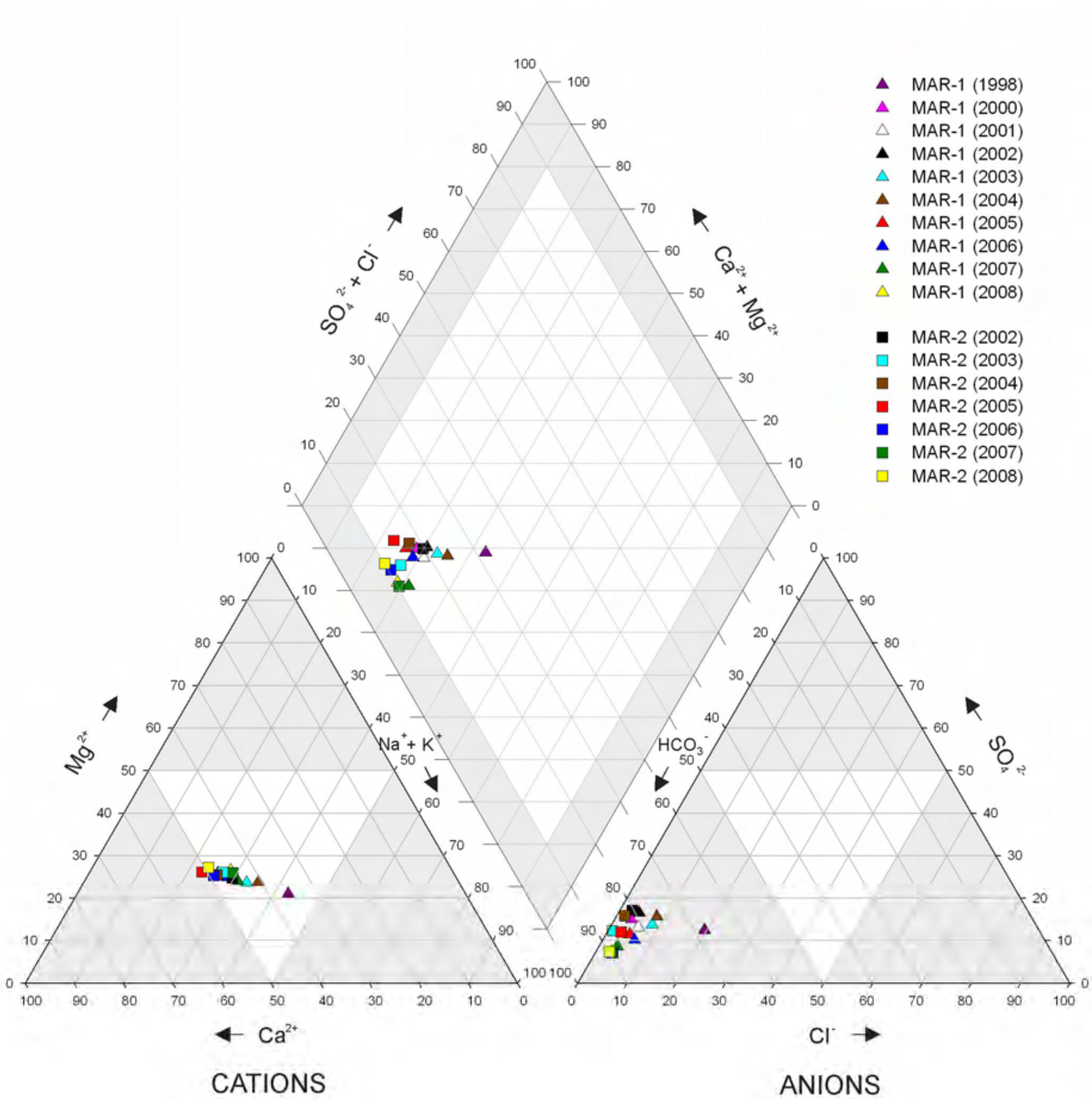


Table 5.5-7 Habitat characteristics of benthic invertebrate community sampling reaches in the MacKay River.

Variable	Units	MAR-E-1 Lower Reach of the MacKay River	MAR-E-2 Upper Reach of the MacKay River
Sample date	-	Sept 5, 2008	Sept 6, 2008
Habitat	-	Erosional	Erosional
Water depth	m	0.3	0.3
Current velocity	m/s	0.5	0.9
Field Water Quality			
Dissolved oxygen	mg/L	9.6	11.0
Conductivity	µS/cm	201	179
pH	pH units	8.3	8.5
Water temperature	°C	11.3	10.4
Sediment Composition			
Sand/Silt/Clay	%	29	4
Small gravel	%	25	0
Large gravel	%	18	6
Small cobble	%	23	32
Large cobble	%	4	34
Boulder	%	0	24
Bedrock	%	1	0

Figure 5.5-6 Variation in periphyton chlorophyll *a* in the lower (MAR-E-1) and upper (MAR-E-2) reaches of the MacKay River.

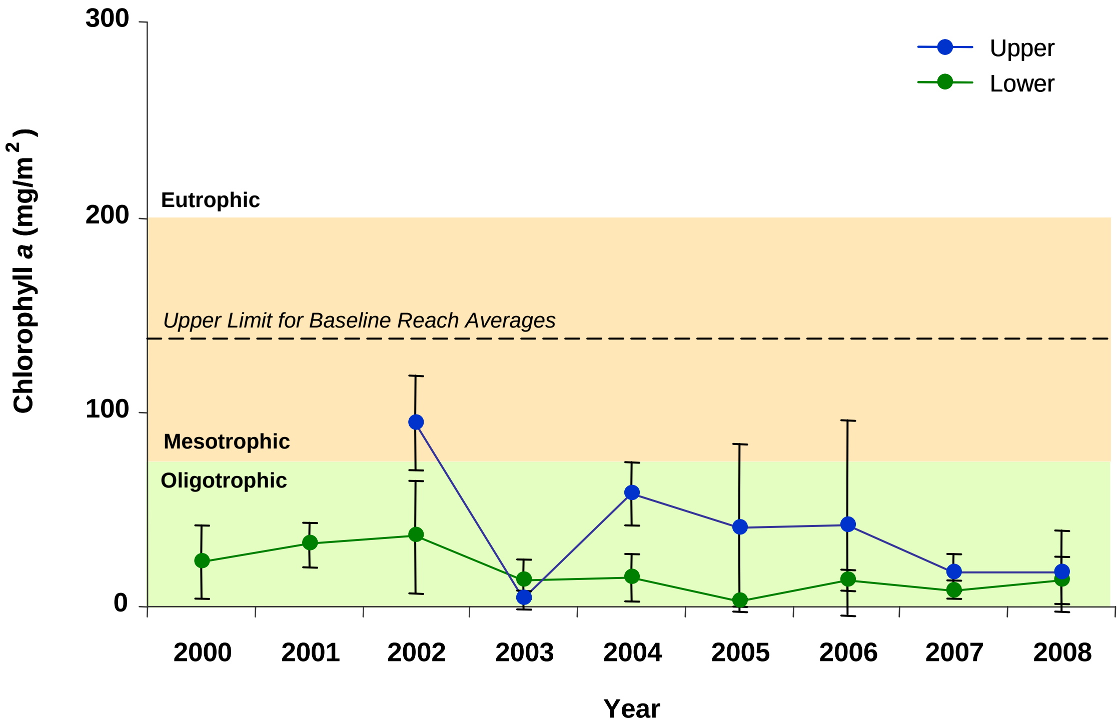
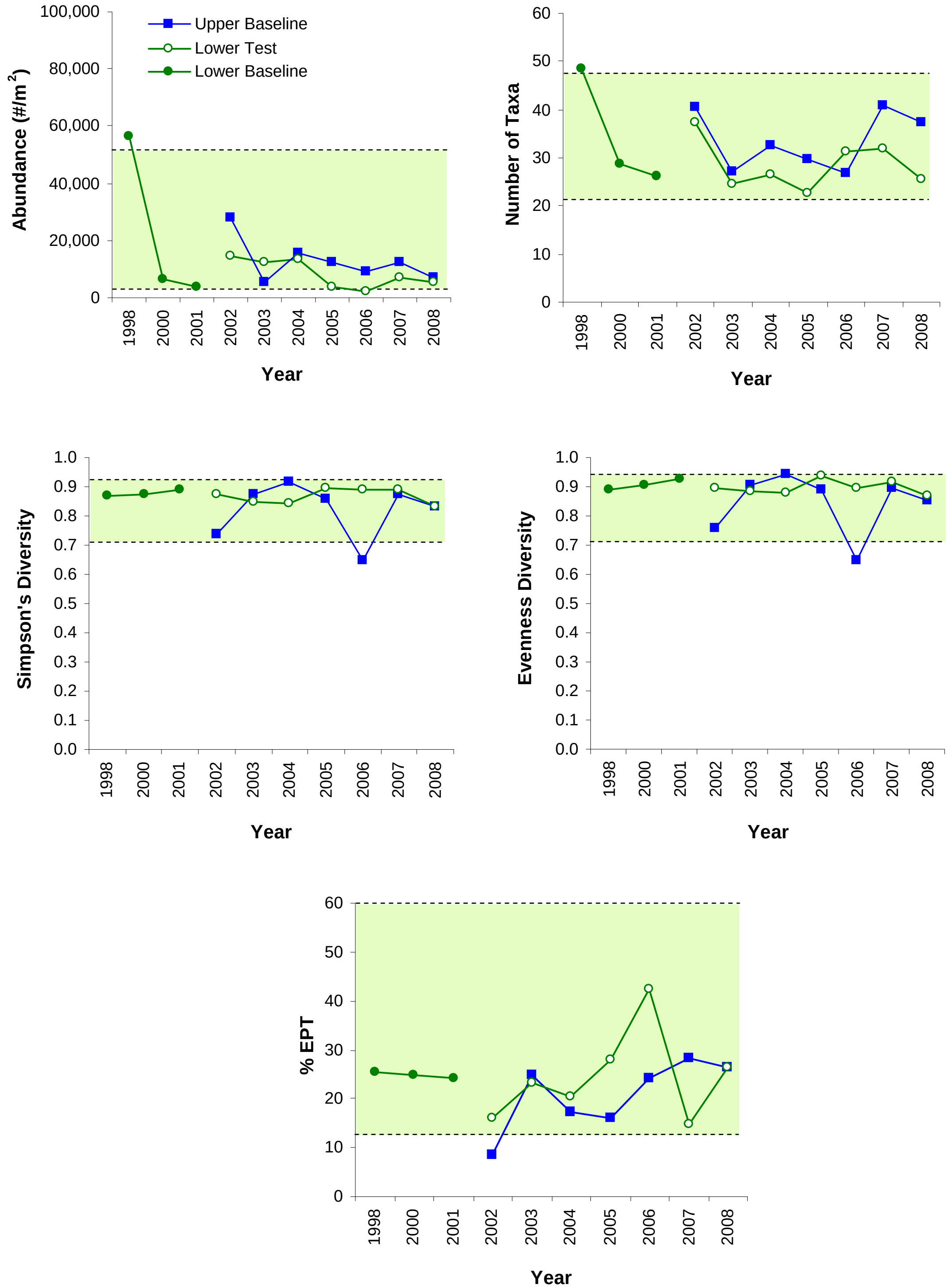


Table 5.5-8 Major taxon percent abundances and benthic invertebrate community measurement endpoints in reaches of the MacKay River.

Taxon	Percent Major Taxa Enumerated in Each Year																
	Reach MAR-E-1										Reach MAR-E-2						
	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2002	2003	2004	2005	2006	2007	2008
Anisoptera	1	1	2	1	1	3	2	2	1	5	<1	1	<1	<1	<1	<1	<1
Bivalvia		<1	<1	1	2	2	1		<1	1	<1	4	1	<1		<1	1
Ceratopogonidae	1	1	<1	1	<1	1	5	3	1	1	<1	<1	1	1	1	1	2
Chironomidae	57	34	4	31	4	57	2	3	40	34	31	3	59	49	63	39	43
Coleoptera	<1	<1			<1	<1		<1		<1		<1	<1	<1		<1	<1
Copepoda	<1	<1	<1	<1				<1	1	<1	<1		<1				<1
Empididae	1	1	4	3	2	2	12	6	1	1	1	2	1	5	<1	<1	<1
Enchytraeidae	4	12	1	5	5	1	1	1	1	3	1	4	3	3	1	1	2
Ephemeroptera	26	21	18	12	19	13	25	29	13	21	2	14	11	1	12	16	8
Erpobdellidae						<1						<1					
Gastropoda	<1	<1	1	2	<1	1		1	1	3	<1	<1	<1	<1		1	1
Heteroptera	<1		<1														
Hydra	<1			1	<1					<1	<1						
Hydracarina	1	4	6	3	18	6	1	2	15	14	7	21	4	9	5	17	10
Lumbriculidae					<1							<1		<1		1	
Macrothricidae		<1		1													
Naididae	2	17	2	24	8	3	11	8	9	6	48	15	4	15	2	9	11
Nematoda	2	2	8	6	1	3	1	1	3	2	3	1	3	1	3	3	3
Ostracoda	<1	1	1	6		<1		<1	1	1	<1	<1	<1			1	<1
Plecoptera	2	5	5	<1	1	3	3	8	2	3	<1	3	3	1	2	3	2
Simuliidae	1	<1	<1	<1	<1		2	<1	1	<1		<1		<1	<1	1	
Tabanidae					<1		1		1			<1					
Tipulidae	<1	<1			<1				1		<1	<1	<1		1	<1	<1
Trichoptera	<1	<1	3	3	2	5	<1	5	1	<1	6	4	3	5	1	10	12
Tubificidae	2	<1	1	2	<1	1	6	2	1	3	<1	<1	8	1	1	2	4
Benthic Invertebrate Community Measurement Endpoints																	
Total Abundance (No./m^2)	56,434	6680	3745	14425	12347	13290	3592	2,055	6,916	6,970	28,222	5,568	15,733	12,332	9,409	12,130	5,257
Richness	49	29	26	37	24	27	23	30	32	38	40	27	32	30	27	41	39
Simpson's Diversity	0.87	0.87	0.89	0.87	0.85	0.84	0.9	0.89	0.89	0.83	0.74	0.87	0.91	0.86	0.65	0.87	0.83
Evenness	0.89	0.91	0.93	0.90	0.89	0.88	0.94	0.89	0.92	0.85	0.76	0.91	0.94	0.89	0.65	0.89	0.87
% EPT	26	25	24	16	23	20	28	42	15	26	8	25	17	16	24	28	26

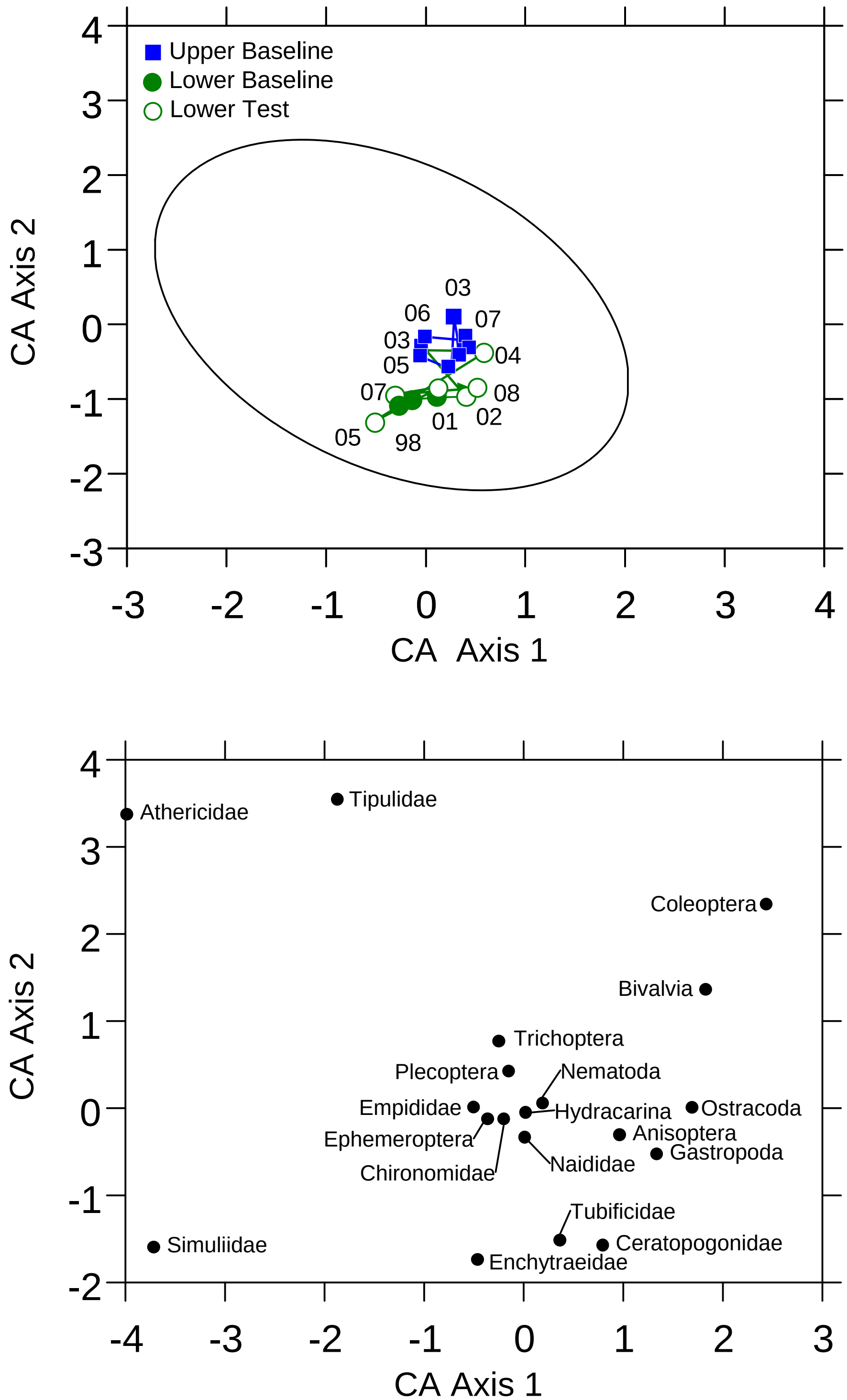
Figure 5.5-7 Variations in benthic invertebrate community measurement endpoints in the MacKay River, reaches MAR-E-1 and MAR-E-2.



Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* erosional sites in the RAMP FSA.

Note: Lower *Baseline* and Lower *Test* – MAR-E-1; Upper *Baseline* – MAR-E-2

Figure 5.5-8 Ordination (Correspondence Analysis) of erosional river benthic communities showing the lower reach (MAR-E-1) and upper reach (MAR-E-2) of the MacKay River.



Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data for erosional river habitats in the RAMP FSA.

Note: the numbers in the upper panel refer to the sampling year for each data point.

Note: Lower *Baseline* and Lower *Test* – MAR-E-1; Upper *Baseline* – MAR-E-2

Table 5.5-9 Results of analysis of variance (ANOVA) on MacKay River, reaches MAR-E-1 and MAR-E-2, with planned comparisons.

Variable	Source	SS	df	MS	F-ratio	P
Log Abundance	Reach - Year	18.961	16	1.185	20.19	0.000
	Baseline vs Test (BT)	1.919	1	1.919	32.71	0.000
	Linear Time Trend (T)	3.597	1	3.597	61.29	0.000
	BT x T	0.455	1	0.455	7.76	0.006
	Remainder (noise)	12.990	13	0.999	17.02	0.000
	Error	10.857	185	0.059		
Log Richness	Reach - Year	1.215	16	0.076	14.51	0.000
	Baseline vs Test (BT)	0.187	1	0.187	35.64	0.000
	Linear Time Trend (T)	0.000	1	0.000	0.00	0.966
	BT x T	0.026	1	0.026	4.91	0.028
	Remainder (noise)	1.003	13	0.077	14.83	0.000
	Error	0.968	185	0.005		
Diversity	Reach - Year	0.779	16	0.049	6.75	0.000
	Baseline vs Test (BT)	0.097	1	0.097	13.49	0.000
	Linear Time Trend (T)	0.000	1	0.000	0.01	0.916
	BT x T	0.000	1	0.000	0.00	0.999
	Remainder (noise)	0.682	13	0.052	7.28	0.008
	Error	1.335	185	0.007		
Evenness	Reach - Year	0.951	16	0.059	7.95	0.000
	Baseline vs Test (BT)	0.13	1	0.13	16.81	0.000
	Linear Time Trend (T)	0.00	1	0.00	0.04	0.838
	BT x T	0.000	1	0.000	0.02	0.882
	Remainder (noise)	0.825	13	0.063	8.46	0.004
	Error	1.382	185	0.008		
Log %EPT	Reach - Year	5.48	16	0.34	6.02	0.000
	Baseline vs Test (BT)	0.66	1	0.66	11.68	0.001
	Linear Time Trend (T)	0.02	1	0.02	0.43	0.514
	BT x T	0.00	1	0.00	0.03	0.867
	Remainder (noise)	4.79	13	0.37	6.48	0.012
	Error	10.52	185	0.06		
CA Axis 1	Reach - Year	16.70	16	1.04	4.49	0.000
	Baseline vs Test (BT)	0.45	1	0.45	1.95	0.164
	Linear Time Trend (T)	0.21	1	0.21	0.92	0.340
	BT x T	0.03	1	0.03	0.11	0.740
	Remainder (noise)	16.0	13	1.232	5.30	0.022
	Error	43.01	185	0.23		
CA Axis 2	Lake - Year	28.38	16	1.77	9.51	0.000
	Baseline vs Test (BT)	10.58	1	10.58	56.72	0.000
	Linear Time Trend (T)	0.61	1	0.61	3.25	0.073
	BT x T	0.21	1	0.21	1.13	0.289
	Remainder (noise)	16.99	13	1.31	7.01	0.009
	Error	34.50	185	0.19		

5.6 CALUMET RIVER WATERSHED

Table 5.6-1 Summary of results for Calumet River watershed.

Calumet River Watershed	Summary of 2008 Conditions	
Climate and Hydrology[1]		
Criteria	**CNRL Station CR-1** at the mouth	
Mean open-water season discharge	○	
Mean winter discharge	not measured	
Annual maximum daily discharge	○	
Minimum open-water season discharge	○	
Water Quality		
Criteria	**CAR-1** at the mouth	**CAR-2** upstream of Canadian Natural Horizon
Water Quality	○	○
Benthic Invertebrate Community and Sediment Quality		
No benthic invertebrate community and sediment programs were conducted in 2008.		
Fish Populations		
No fish programs were conducted in 2008.		

○ Negligible - Low
● Moderate
● High
baseline
test

[1] For Climate and Hydrology, results are reported for station at the mouth of the watershed

Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.6-1 Calumet River watershed.

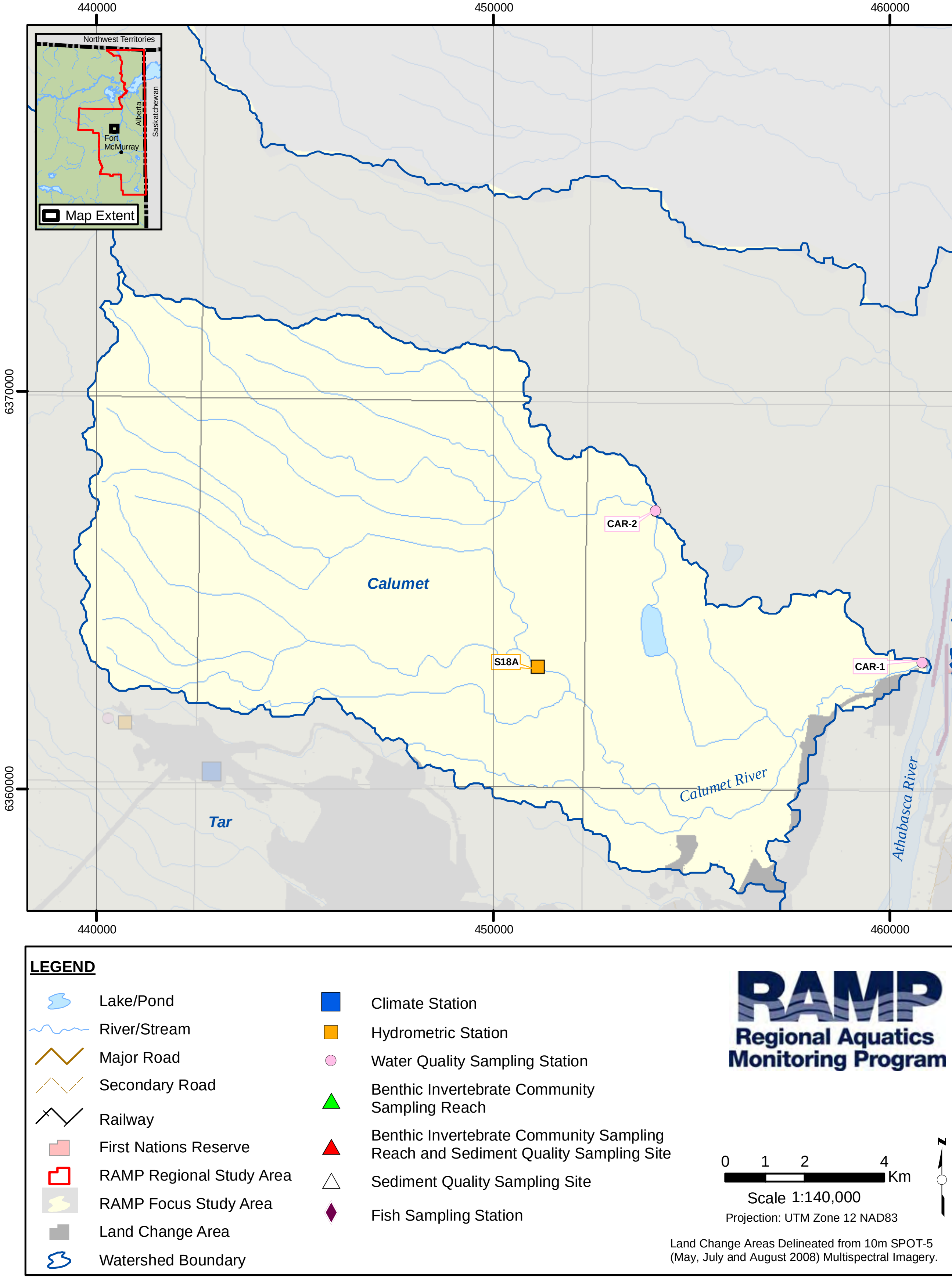


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Figure 5.6-2 Representative Calumet River monitoring stations, fall 2008.

Water Quality Station CAR-1:
centre of channel, at the mouth

Water Quality Station CAR-1:
centre of channel, facing upstream

Water Quality Station CAR-2:
left downstream bank, facing downstream

Water Quality Station CAR-2:
left downstream bank, facing upstream

5.6.1 Summary of Conditions

As of 2008, 1.2% of the Calumet River watershed had undergone land change as a result of focal developments in the watershed (Table 2.4-2). The designations of specific areas of the watershed are therefore as follows:

- The Calumet River watershed downstream of the CNRL Horizon Project operations is designated as *test*; and
- The remainder of the watershed is designated as *baseline* (Figure 5.6-1).

Table 5.6-1 contains a summary of the 2008 assessment for the Calumet River watershed, Figure 5.6-1 is a detailed map of the Calumet River watershed, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.6-2 contains a series of pictures from 2008 of a number of the monitoring stations in the watershed.

Hydrology The observed 2008 discharge for the Calumet River watershed is estimated to be approximately 1% less than the 2008 *baseline* discharge would have been in the absence of focal projects. The differences in the Calumet River watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Negligible-Low** for all calculated hydrologic measurement endpoints.

Water Quality Differences in water quality in fall 2008 in the Calumet River watershed as compared to regional *baseline* conditions are assessed as **Negligible-Low** (Table 5.6-1).

5.6.2 Hydrologic Conditions

2008 Hydrologic Conditions The 2008 hydrograph for the Calumet River as provided by CNRL for their station CR-1 is presented in Figure 5.6-3. The flow peaked early in May, and then dropped below 0.1 m^3/s by early June, data loss occurred from the beginning of July to mid-August. The river recovered after this low flow event and remained above maximum values for the majority of the monitored season.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph A summary of the inputs to the water balance model for the Calumet River to examine possible changes in the hydrologic measurement endpoints is provided in Table 5.6-2 (for the period where data is missing, observed flow is not included in the water balance calculations). As of 2008, areas of close-circuited land change and other land change (not closed-circuited) were 1.75 km^2 and 0.4 km^2, respectively, in the Calumet River catchment. As a result of cumulative development of focal projects in the watershed (Table 2.4-1), the estimated net effects was a decrease in flows to the Calumet River over the period of the 2008 data record for CNRL Station CR-1, Calumet River near the mouth by 0.038 million m^3.

The *baseline* hydrograph that would have occurred at CNRL Station CR-1, Calumet River near the mouth, in the absence of focal project activities was estimated by removing the estimated influences of these projects as listed above from the station's operational hydrograph recorded in 2008. These estimated influences are predicted to have decreased mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge by 1.0%. The cumulative effect is that all hydrologic measurement endpoints for the Calumet River watershed are estimated to be slightly less than what they would have been in the absence of focal project activities (Figure 5.6-3, Table 5.6-3).

Summary The observed *test* 2008 discharge for CNRL Station CR-1, Calumet River near the Mouth, is estimated to be approximately 1% less than 2008 *baseline* discharge would have been in the absence of focal projects in the Calumet River watershed. The differences in the Calumet River watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at CNRL Station CR-1, Calumet River near the Mouth, are assessed as Negligible-Low for all measured hydrologic measurement endpoints (Table 5.6-1).

5.6.3 Water Quality

In fall 2008, water quality samples were collected from:

- the mouth of the Calumet River (station CAR-1, established in 2002, designated as *test* since 2005); and
- the upper Calumet River (station CAR-2, designated as *baseline,* sampled from 2005 to 2008).

2008 Results and Historical Ranges of Concentration At *test* station CAR-1, concentrations of total nitrogen and dissolved organic carbon were above their previously observed maxima (Table 5.6-4). At *baseline* station CAR-2, total dissolved solids, pH, total boron and total mercury were above previously measured maximum concentrations, while concentrations of total dissolved phosphorus and total aluminum were below the historical minimum concentrations (Table 5.6-5).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions Concentrations of selected water quality measurement endpoints were generally within the 5th to 95th percentile range of regional *baseline* concentrations at both Calumet stations in fall 2008; with the exception of total dissolved solids at station CAR-1 which was greater than the 95th percentile of regional *baseline* concentrations (Figure 5.6-4).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Concentrations of three water quality measurement endpoints exceeded water quality guidelines at station CAR-1 in fall 2008: total nitrogen, total dissolved phosphorus, and total aluminum (Table 5.6-4). Concentrations of two water quality measurement endpoints exceeded water quality guidelines at station CAR-2 in fall 2008: total nitrogen and total dissolved phosphorus (Table 5.6-5).

Other Water Quality Guidelines Exceedances Concentrations of a number of other water quality variables exceeded relevant water quality guidelines in the Calumet River watershed in 2008 (Table 5.6-6):

- Station CAR-1 in fall 2008 - sulphide, total phosphorus, total nitrogen, total Kjeldahl nitrogen, dissolved iron, total aluminum, total iron, total phenols and total dissolved phosphorus; and
- Station CAR-2 in fall 2008 - sulphide, total phosphorus, total nitrogen, total Kjeldahl nitrogen, total iron, total phenols and total dissolved phosphorus.

For most variables that exceeded guidelines, concentrations were higher at *baseline* station CAR-2 than at *test* station CAR-1.

Ion Balance Ion balance at station CAR-1 has remained consistent since 2002, except in 2007 when the ion balance shifted towards a more calcium dominated cation composition compared to previous years. The balance of major ions at CAR-2 has been relatively consistent over the sampling period and fairly consistent with station CAR-1, but with a slightly lower bicarbonate composition than the lower *test* station (Figure 5.6-5).

Trend Analysis There have been no significant trends in water quality measurement endpoints at stations CAR-1 and CAR-2 over the RAMP sampling period ($\alpha = 0.05$).

Water Quality Index Water-quality index values calculated for CAR-1 and CAR-2 for fall 2008 (100 and 96.1, respectively) indicate that water quality at both stations was consistent with regional *baseline* conditions.

Summary Differences in water quality in fall 2008 in the Calumet River watershed as compared to regional *baseline* conditions are assessed as Negligible-Low (Table 5.6-1).

5.6.4 Benthic Invertebrate Communities and Sediment Quality

5.6.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were not sampled in the Calumet River watershed in 2008.

5.6.4.2 Sediment Quality

Sediment quality was not sampled in the Calumet River watershed in 2008.

5.6.5 Fish Populations

The 2008 RAMP Fish Population component did not include any activities in the Calumet River watershed.

Figure 5.6-3 Calumet River: 2008 hydrograph and historical context.

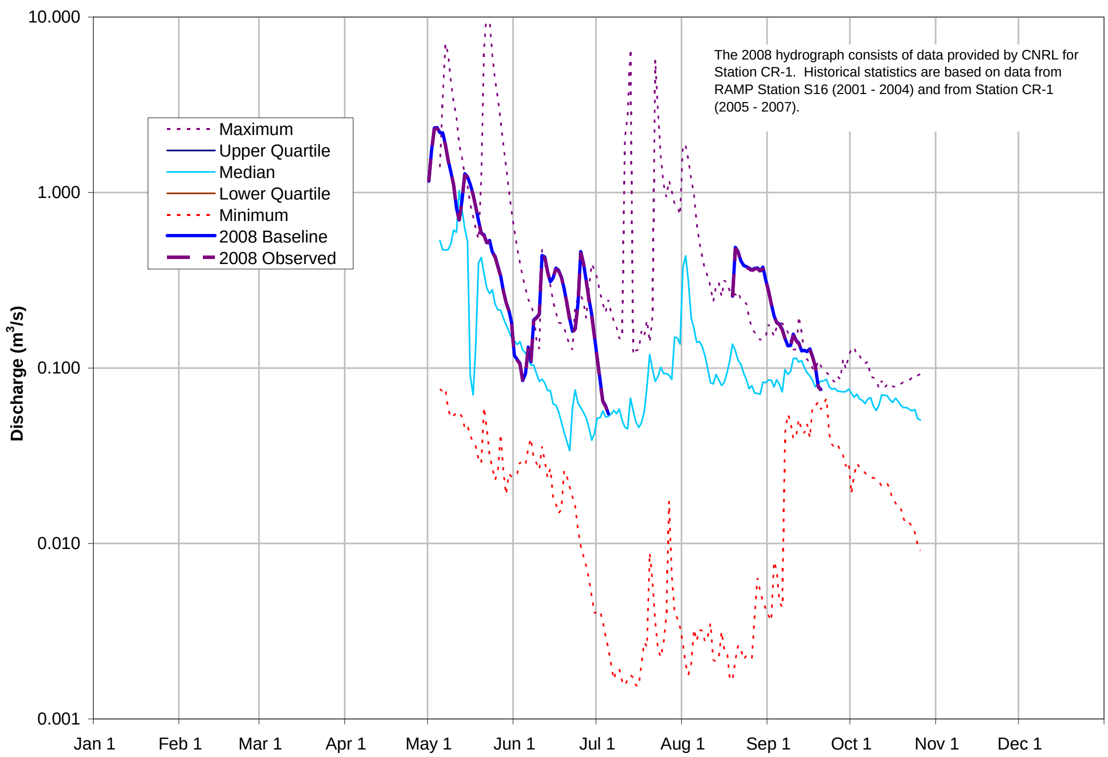


Table 5.6-2 Estimated water balance at CNRL Station CR-1, Calumet River near the mouth, in 2008.

Component	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total discharge)	**3.98**	**Observed discharge obtained from CNRL Station CR-1, Calumet River near the mouth**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+0.04	1.75 km^2 within Calumet River watershed closed-circuited by focal projects as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.002	0.40 km^2 within Calumet River watershed estimated to have undergone land change by focal projects of 2008, but are not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from the Calumet River by focal projects	0	Unknown, none reported, assumed to be negligible
Amount by which discharge would be lower without releases to the Calumet River watershed by focal projects	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Calumet River not accounted for in figures contained in this table
***Baseline* hydrograph (total discharge)**	**4.02**	**Estimated *baseline* discharge at CNRL Station CR-1, Calumet River near the mouth**
Incremental flow (change in total discharge)	-0.038	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total discharge)	-1.0%	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Data are for the period of the 2008 data record for CNRL Station CR-1, Calumet River near the mouth.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.6-3 Calculated change in hydrologic measurement endpoints for the Calumet River watershed.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.470	0.466	-1.0%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	2.34	2.32	-1.0%
Open-water season minimum daily discharge	0.055	0.054	-1.0%

Note: As measured at and calculated for CNRL Station CR-1, Calumet River near the Mouth.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.6-4 Concentrations of water quality measurement endpoints, mouth of Calumet River (station CAR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	6	8.1	8.2	8.4
Total suspended solids	mg/L	-[1]	12	6	<3	10.5	41
Conductivity	µS/cm	-	611	6	188	559	702
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.055**	6	0.025	0.037	**0.076**
Total nitrogen*	mg/L	1.0	**1.5**	6	0.8	**1.2**	**1.4**
Nitrate+nitrite	mg/L	1.0	<0.1	6	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	38	6	22	30	34
Ions							
Sodium	mg/L	-	55	6	7	56	71
Calcium	mg/L	-	55.7	6	25.3	57.6	67.3
Magnesium	mg/L	-	19.4	6	7.8	18.3	22.5
Chloride	mg/L	230, 860[3]	18	6	2	19	34
Sulphate	mg/L	100[4]	10.1	6	3.6	12.1	14.5
Total dissolved solids	mg/L	-	400	6	151	390	480
Total alkalinity	mg/L	-	295	6	96	278	337
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.179**	6	0.040	**0.152**	**0.337**
Dissolved aluminum	mg/L	0.1[2]	0.0032	6	0.0013	0.0039	0.0058
Total arsenic	mg/L	0.005	0.0011	6	0.0009	0.001	0.0012
Total boron	mg/L	1.2[5]	0.0795	6	0.074	0.096	0.122
Total molybdenum	mg/L	0.073	0.0001	6	0.0001	0.0002	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.228	6	0.195	0.269	0.297
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.028**	6	**0.007**	**0.0125**	**0.02**
Total phosphorus	mg/L	0.05	**0.094**	6	**0.066**	**0.085**	**0.099**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.4**	6	0.7	**1.1**	**1.3**
Total iron	mg/L	0.3	**1.46**	6	**0.6**	**1.765**	**3.14**
Dissolved iron	mg/L	0.3[2]	**0.622**	6	**0.339**	**0.49**	**0.911**
Total phenols	mg/L	0.004	**0.013**	5	<0.001	**0.005**	**0.01**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

8 Guideline is for total nitrogen.

Table 5.6-5 Concentrations of water quality measurement endpoints, upper Calumet River (station CAR-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	3	7.8	7.9	8.1
Total suspended solids	mg/L	-[1]	<3	3	<3	3	5
Conductivity	µS/cm	-	740	3	526	577	772
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.086**	3	**0.119**	**0.129**	**0.305**
Total nitrogen*	mg/L	1.0	**1.8**	3	**1.8**	**2**	**2.4**
Nitrate+nitrite	mg/L	1.0	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	48	3	40	47	48
Ions							
Sodium	mg/L	-	69	3	53	65	76
Calcium	mg/L	-	60.3	3	44	48.5	68.2
Magnesium	mg/L	-	22.6	3	18	20.6	26.6
Chloride	mg/L	230, 860[3]	16	3	14	16	17
Sulphate	mg/L	100[4]	73.7	3	45.3	50.6	78.4
Total dissolved solids	mg/L	-	547	3	370	460	538
Total alkalinity	mg/L	-	297	3	213	234	315
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.0203	3	0.0245	0.0495	0.0621
Dissolved aluminum	mg/L	0.1[2]	0.0046	3	0.0036	0.0132	0.0172
Total arsenic	mg/L	0.005	0.0022	3	0.0021	0.0025	0.0028
Total boron	mg/L	1.2[5]	0.128	3	0.0817	0.0876	0.0965
Total molybdenum	mg/L	0.073	0.0007	3	0.0001	0.0002	0.0008
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.3	3	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.328	3	0.242	0.273	0.356
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.027**	3	**0.024**	**0.025**	**0.095**
Total phosphorus	mg/L	0.05	**0.101**	3	**0.19**	**0.311**	**0.349**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.7**	3	**1.7**	**1.9**	**2.3**
Total iron	mg/L	0.3	**0.564**	3	**0.551**	**0.721**	**1.45**
Total phenols	mg/L	0.004	**0.008**	3	**0.012**	**0.012**	**0.041**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);

Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

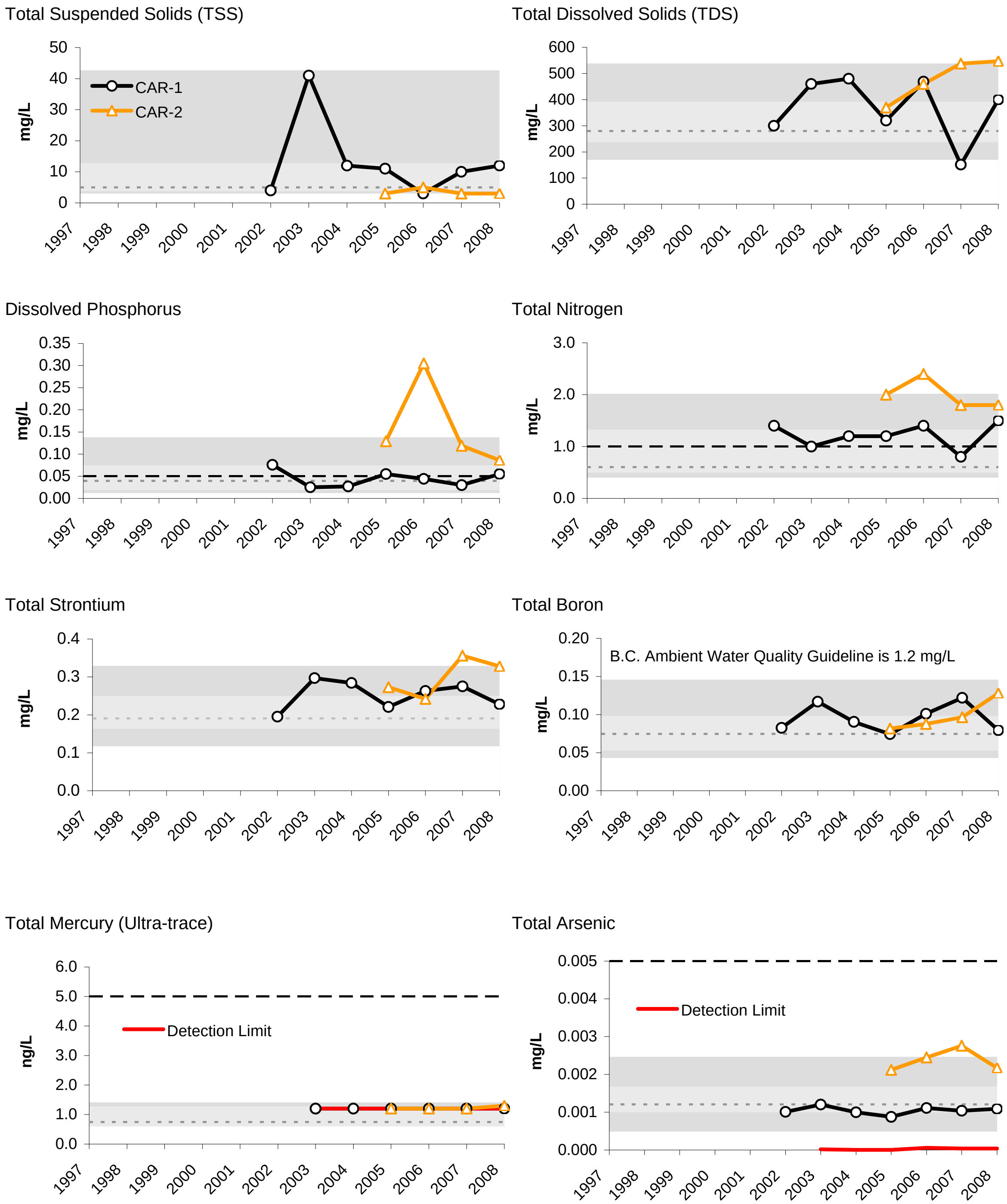
5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

8 Guideline is for total nitrogen.

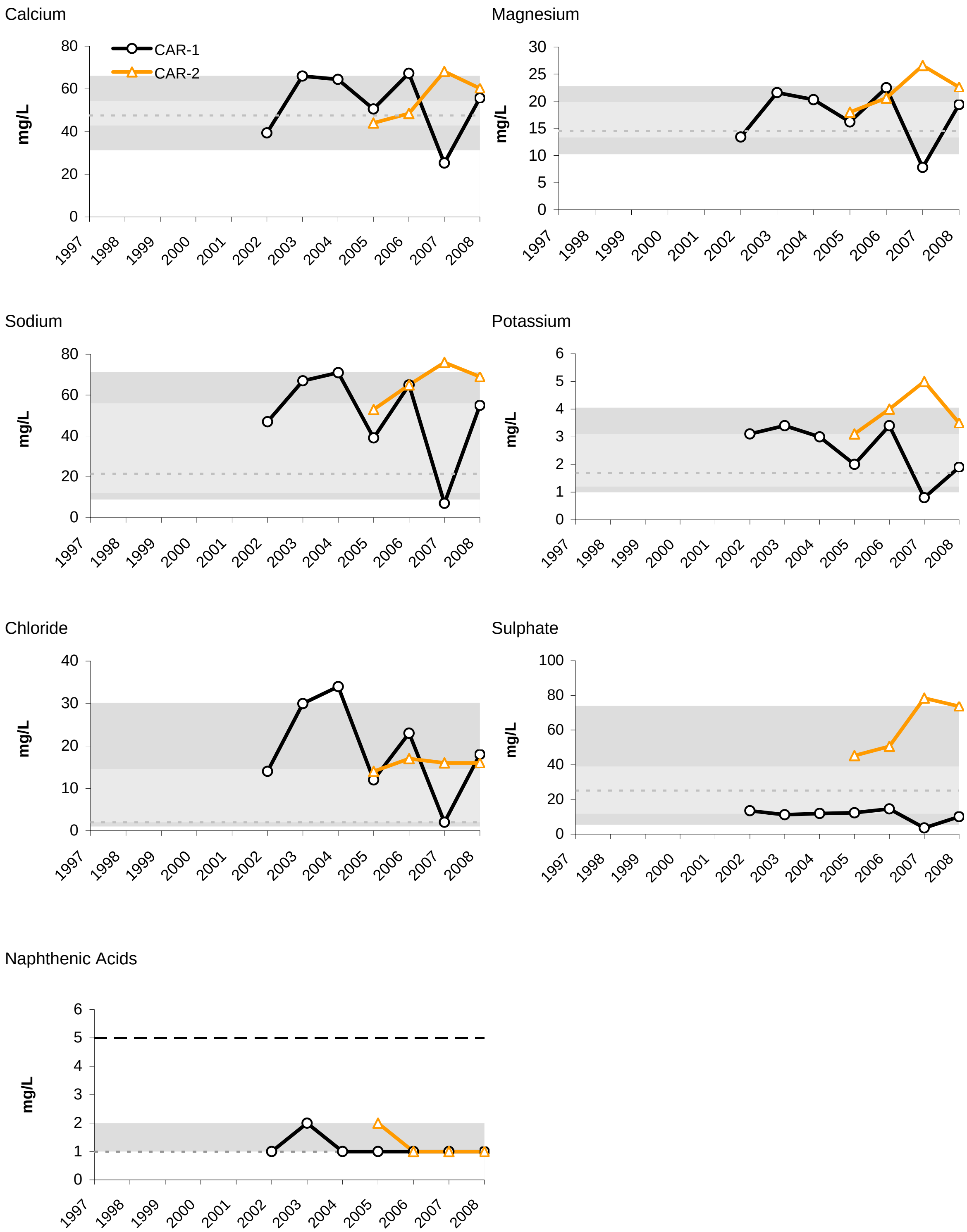
Figure 5.6-4 Concentrations of selected water quality measurement endpoints in the Calumet River (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.6-4 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Table 5.6-6 Water quality guideline exceedances, Calumet River watershed, 2008.

Variable	Units	Guideline*	CAR-1	CAR-2
Fall				
Sulphide	mg/L	0.002[1]	**0.028**	**0.027**
Total phosphorus	mg/L	0.05	**0.094**	**0.101**
Total nitrogen	mg/L	1.0	**1.5**	**1.8**
Total Kjeldahl nitrogen	mg/L	1.0	**1.4**	**1.7**
Dissolved iron	mg/L	0.3[2]	**0.622**	-
Total aluminum	mg/L	0.1	**0.179**	-
Total iron	mg/L	0.3	**1.46**	**0.564**
Total phenols	mg/L	0.004	**0.013**	**0.008**
Total dissolved phosphorus	mg/L	0.05[2]	**0.055**	**0.086**

CAR-1 and CAR-2 were sampled only in fall 2008.

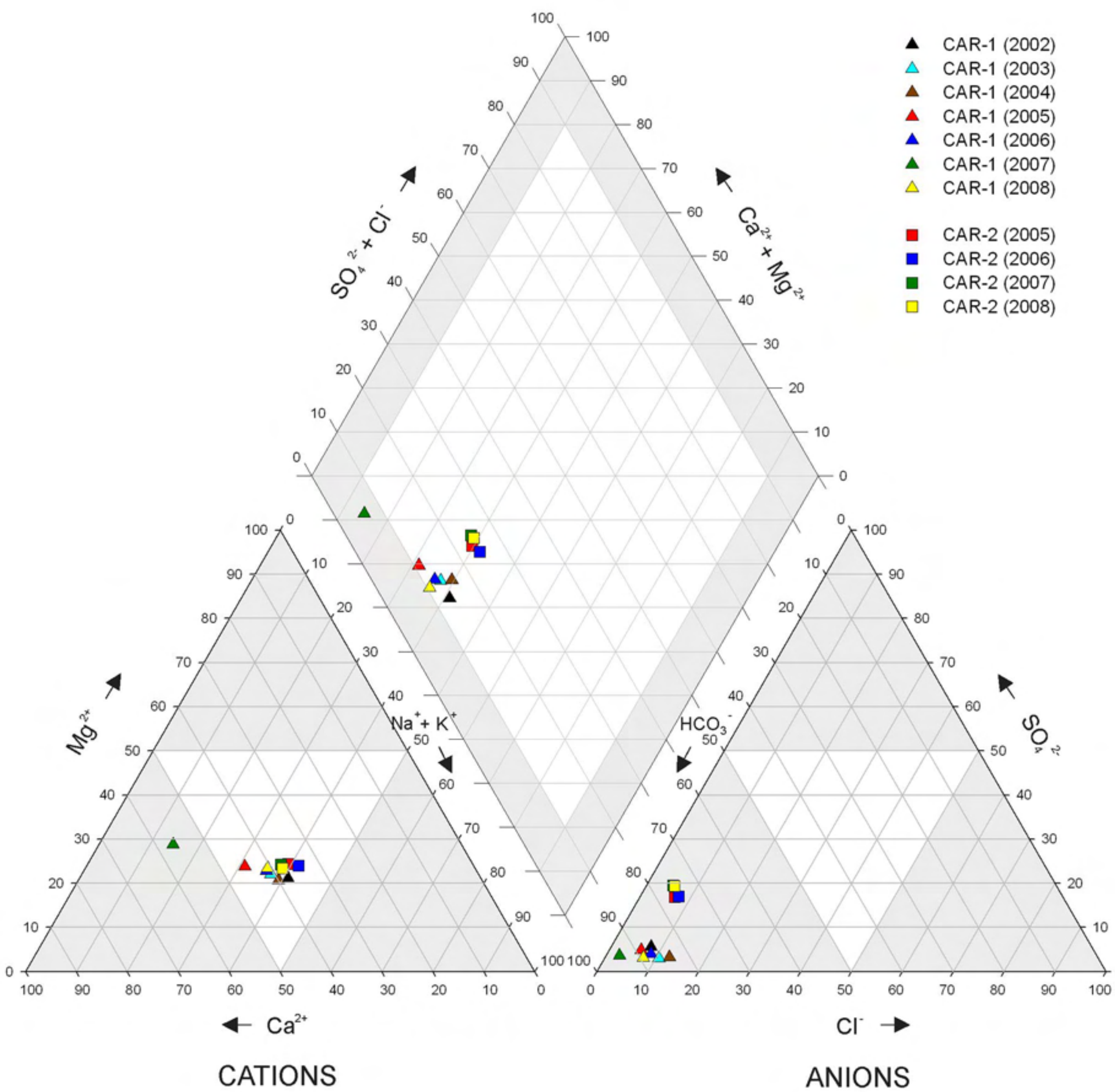
* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

Figure 5.6-5 Piper diagram of fall ion concentrations in Calumet River watershed.



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5.7 FIREBAG RIVER WATERSHED

Table 5.7-1 Summary of results for Firebag River watershed.

Firebag River Watershed	**Summary of 2008 Conditions**		
	Firebag River		***Other***
Climate and Hydrology[1]			
Criteria	**S27** at the mouth		
Mean open-water season discharge	○		
Mean winter discharge	○		
Annual maximum daily discharge	○		
Minimum open-water season discharge	○		
Water Quality			
Criteria	**FIR-1** at the mouth	**FIR-2** upstream of Suncor Firebag	**MCL-1** McClelland Lake
Water Quality	○	○	○
Benthic Invertebrate Community and Sediment Quality			
Criteria	no reach sampled	no reach sampled	**MCL-1** McClelland Lake
Benthic Invertebrate Community			n/a
Fish Populations			
No fish programs were conducted in 2008.			

○ Negligible - Low (yellow)
● Moderate (orange)
● High (brown)
baseline (green shading)
test (blue shading)

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches.

[1] For Climate and Hydrology, results are reported for station at the mouth of each watershed

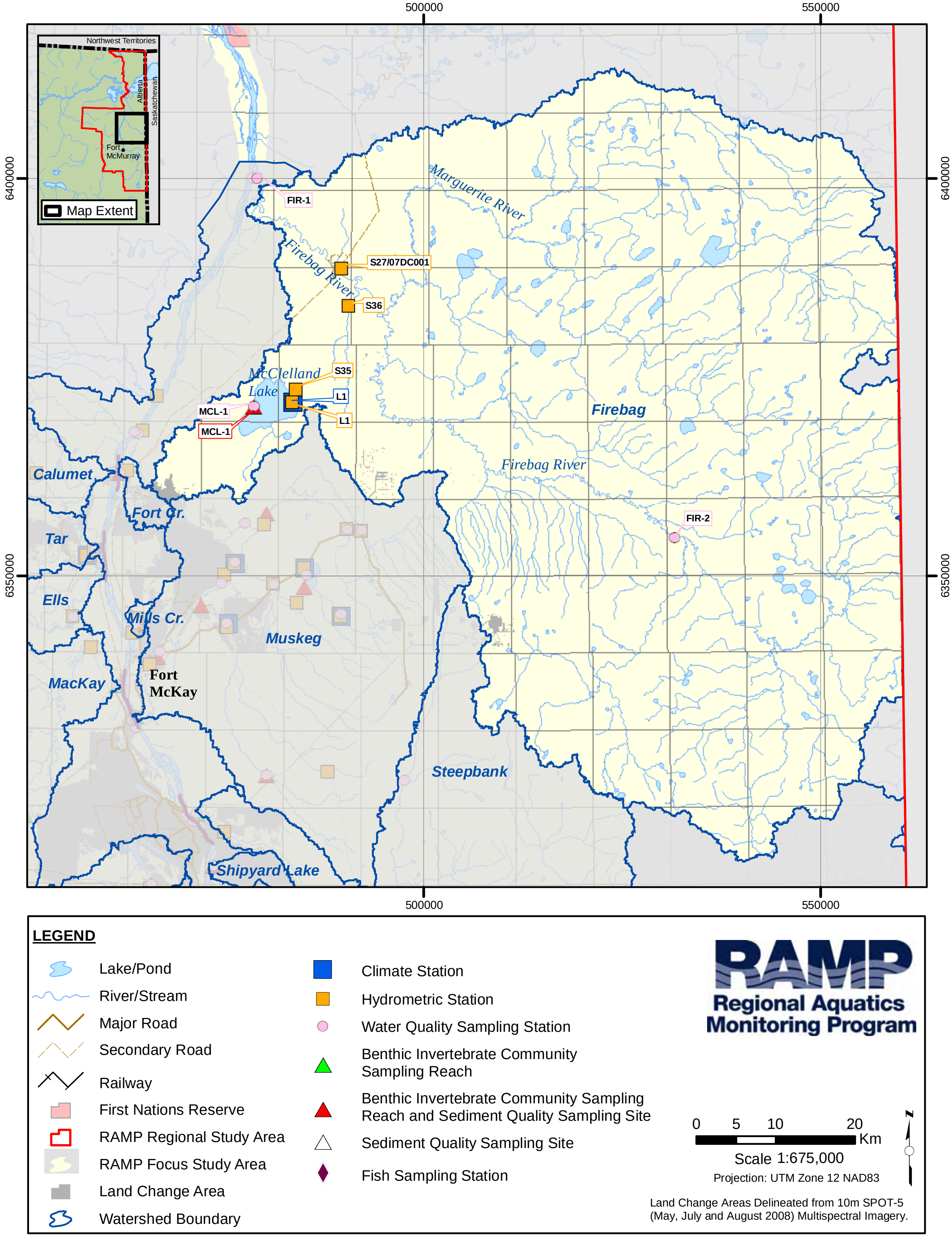
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.7-1 Firebag River watershed.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K07_Firebag_20090420.mxd

Figure 5.7-2 Representative Firebag River watershed monitoring stations, fall 2008.

Water Quality Station FIR-1:
right downstream bank, facing downstream

Water Quality Station FIR-1:
right downstream bank, facing upstream

Water Quality Station FIR-2:
right downstream bank, facing downstream

Water Quality Station FIR-2:
left downstream bank, facing upstream

Water Quality Station MCL-1:
McClelland Lake, aerial view

Water Quality Station MCL-1:
McClelland Lake, aerial view

5.7.1 Summary of 2008 Conditions

Approximately 0.85% of the area of the Firebag River watershed has undergone land change as of 2008 from focal project activities (Table 2.4-2). That part of the watershed downstream of those portions of the Suncor Firebag, Imperial Kearl, Petro-Canada Fort Hills, and Husky Sunrise projects that are in the Firebag River watershed (Figure 5.7-1) is designated as *test*; the remainder of the watershed are designated as *baseline*.

Table 5.7-1 contains a summary of the 2008 assessment for the Firebag River watershed, Figure 5.7-1 is a detailed map of the Firebag River watershed, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.7-2 contains a series of pictures from 2008 of a number of the monitoring stations in the watershed.

Hydrology The observed annual discharge for 2008 for the Firebag River is estimated to be 0.04% less than the 2008 *baseline* discharge would have been in the absence of focal projects. The differences in the Firebag River watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Negligible-Low** for all calculated hydrologic measurement endpoints.

Water Quality Differences in water quality in fall 2008 in the Firebag River watershed, including McClelland Lake, as compared to regional *baseline* conditions are assessed as **Negligible-Low**.

Benthic Invertebrate Communities and Sediment Quality Values of measurement endpoints for the benthic invertebrate community in McClelland Lake were within or above the natural range of variation for *baseline* lakes in the RAMP FSA. Differences in sediment quality in McClelland Lake compared to regional *baseline* conditions are assessed as **Negligible-Low**.

5.7.2 Hydrologic Conditions

2008 Hydrologic Conditions: Firebag River Total annual runoff in the Firebag River watershed, as measured at RAMP/WSC Station S27, Firebag River near the mouth (07DC001), in 2008 was 157 mm, 13% greater than the historical average runoff. The highest flow occurred in spring, with a secondary peak in August as a result of a large rain event in early August (Figure 5.7-2). The maximum daily discharge of 171 m^3/s was measured in early May, a month which contributed to 30% of the annual flow. The mean daily open-water season discharge was 47.3 m^3/s while the minimum open-water discharge was 14.3 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Firebag River for 2008 is provided in Table 5.7-2. As of 2008, the area of closed-circuited and not closed-circuited land change was 4.36 km^2 and 9.67 km^2, respectively, in the Firebag River watershed (Table 2.4-1), the estimated net effects of which were to decrease annual inflows to the Firebag River by 0.380 million m^3 in 2008.

The *baseline* hydrograph that would have occurred at RAMP/WSC Station S27, Firebag River near the mouth (07DC001), was estimated by adding the 0.380 million m^3 of flow to the station's observed hydrograph recorded in 2008; the resulting estimated *baseline* hydrograph is presented in Figure 5.7-3. The difference between the observed and estimated *baseline* hydrograph for RAMP/WSC Station S27, Firebag River near the Mouth

(07DC001) is a 0.04% decrease in mean open-water season discharge, mean winter discharge, annual maximum daily discharge, and open-season minimum daily discharge (Table 5.7-3). All hydrologic measurement endpoints for the Firebag River watershed are estimated to be similar to what they would have been under *baseline* conditions (Figure 5.7-3, Table 5.7-3).

2008 Hydrologic Conditions: McClelland Lake McClelland Lake water levels in 2008 were above the upper quartile values for most of 2008, with the exception being at the end of July (Figure 5.7-4). Water levels fluctuated only slightly within the year, with a total range between the highest and lowest observed levels of 0.18 m.

Summary Based on the available hydrologic information, as well as information available regarding focal project activities in the Firebag River watershed, watershed-level changes in hydrologic conditions in the Firebag River caused by focal project activities in the watershed as of 2008 have been Negligible-Low (Table 5.7-1).

5.7.3 Water Quality

In fall 2008, water quality samples were collected from:

- near the mouth of the Firebag River (station FIR-1, *test*, first sampled in 2002 and designated as *test* since 2002);
- on the Firebag River upstream of all focal project developments (station FIR-2, *baseline*, first sampled in 2003); and
- in McClelland Lake (station MCL-1, *baseline*, sampled from 2000 to 2008).

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations of the most water quality measurement endpoints were within the range of historical measurements with the following exceptions (Table 5.7-4 to Table 5.7-6):

- at *test* station FIR-1 concentrations of magnesium, total alkalinity, total boron, and total strontium were greater than their historically-measured maximum concentrations (Table 5.7-4);
- at *baseline* station FIR-2 the concentration of sulphate and total aluminum were below their historically-measured minimum concentration (Table 5.7-5); and
- at *baseline* station MCL-1 the concentration of dissolved aluminum and total molybdenum were below their historically-measured minimum concentrations, and total mercury (ultra-trace) and total alkalinity exceeded their historically measured maximum (Table 5.7-6).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions In fall 2008, concentrations of all selected water quality measurement endpoints were within the range of regional *baseline* concentrations (Figure 5.7-5 and Figure 5.7-6) with the exception of dissolved phosphorus at *baseline* station FIR-2 and potassium at *baseline* station MCL-1, which were greater than the 95th percentile of *baseline* regional concentrations in fall 2008. In addition, dissolved phosphorus and sulphate at station MCL-1 were lower than the 5th percentile of regional *baseline* concentrations (Figure 5.7-6). When comparing the upper and lower Firebag River stations, with the exception of dissolved phosphorus, concentrations of most selected water quality measurement endpoints were similar at both stations in 2008 and similar to historical levels overall (Figure 5.7-5).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines No water quality measurement endpoints exceeded their relevant water quality guidelines at either *test* station FIR-1 or *baseline* stations FIR-2 and MCL-1 in fall 2008 with the exception of total dissolved phosphorus at *baseline* station FIR-2 (Table 5.7-4 to Table 5.7-6).

Other Water Quality Guideline Exceedances Concentrations of total and dissolved iron, total phosphorus, and sulphide exceeded relevant water quality guidelines in fall 2008 at both *test* station FIR-1 and *baseline* station FIR-2, while the concentration of total phenols exceeded its water quality guideline at both *baseline* stations FIR-2 and MCL-1 in fall 2008 in the Firebag River watershed (Table 5.7-7).

Ion Balance In fall 2008, the ionic composition of both stations FIR-1 and FIR-2 was dominated by calcium and bicarbonate ions, and overall ionic composition in fall 2008 is consistent with the measured ion balance measured at both *test* station FIR-1 and *baseline* station FIR-2 in previous years with the exception of 2007 (Figure 5.7-7). The ionic character of McClelland Lake in fall 2008 was consistent with that of previous years of sampling, with anions dominated by magnesium bicarbonate and low concentrations of sodium and potassium chloride. The ionic composition of the lake had slightly higher magnesium concentrations and lower calcium concentrations relative to the Firebag River stations (Figure 5.7-7).

Trend Analysis As of 2008, sufficient data existed to allow statistical trend analysis of fall water quality data for *test* station FIR-1 and the *baseline* station MCL-1 using the Mann-Kendall statistical procedure (n=7). The Mann-Kendall statistical procedure could not be applied to data gathered at *baseline* station FIR-2 because, as of 2008, only six years of water quality data are available for that station. There were no significant trends in water quality endpoints at *test* station FIR-1 (α=0.05). Significant trends in the following water-quality measurement endpoints were observed at station MCL-1 over the RAMP sampling period (α = 0.05):

- Upward trend in magnesium at station MCL-1; and
- Downward trend in arsenic at station MCL-1, likely an artifact of a lower detection limit after the 2002 sampling year.

Water Quality Index WQI values for all stations in the Firebag watershed (i.e., FIR-1: 96.1; FIR-2: 92.2; MCL-1: 88.3) indicated Negligible-Low difference from regional *baseline* conditions (Table 5.7-8).

Summary All but two excursions of water quality guidelines in 2008 occurred at both upstream and downstream Firebag River mainstem stations. Concentrations of all but one of the selected water quality measurement endpoints in fall 2008 were within the range of regional *baseline* concentrations as they have been, with few exceptions, consistently since the beginning of the RAMP water quality data record for the Firebag River watershed. In addition, ionic composition at both water quality monitoring stations in the watershed was consistent with previous years and continues to show little year-to-year variation, with the exception of 2007, when an atypical ionic composition was measured at *baseline* station FIR-2. In summary, water quality at all stations in the Firebag River watershed show Negligible-Low difference from regional *baseline* conditions (Table 5.7-1).

5.7.4 Benthic Invertebrate Communities and Sediment Quality

5.7.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in 2008 in Firebag River watershed in McClelland Lake (MCL-1), a depositional waterbody designated as *baseline* for its entire data record.

2008 Habitat Conditions Samples were taken at a depth of 2 m in McClelland Lake. The lake was dominated by sand substrate in an area that had a highly organic substrate (36% TOC), comprised of dead and decaying vegetative material, primarily of the plant species, *Chara*.

Relative Abundance of Benthic Invertebrate Community Taxa The benthos of McClelland Lake was dominated by chironomids (33%), naidid worms (17%), cladocerans (14%), and copepods (13%; Table 5.7-10). Water mites (Hydracarina, 6%), mayflies (Ephemeroptera, 5%), amphipods (3%), and cladocerans (3% were subdominant. Snails (gastropods, <1%), fingernail clams (Bivalvia, 1%), and caddisflies (Trichoptera, 1%) were also present. The dominant chironomids included *Cladopelma*, *Dicrotendipes*, *Polypedilum*, *Zavrelia marmorata*, *Cladotanytarus*, *Tanytarsus*, and *Ablabesmyia,* all of which are very common. Mayflies were represented by the common form *Caenis*, while caddisflies were represented by *Oxyethira*, *Mystacides*, *Oecetis* and *Molanna*.

The temporal trends in the benthic invertebrate community measurement endpoints for McClelland Lake (Figure 5.7-8) have the following characteristics:

- Total abundance (~ 36,000) and taxa richness in 2008 were near the historical high values in 2006;
- Both diversity and evenness were the highest in the data record; and
- The percent of the fauna as EPT taxa in 2008 was within mid-range of historical values.

Results for the Correspondence Analysis show that all years of sampling in McClelland Lake fall within the 95% natural range of variation (Figure 5.7-9).

5.7.4.2 Sediment Quality

Sediment quality in fall 2008 was sampled in McClelland Lake (MCL-1, *baseline*) at the same locations at which benthic invertebrate community sampling was undertaken in fall 2008.

2008 Results and Historical Ranges of Concentration As in previous years, sediment composition in McClelland Lake (MCL-1) was dominated by sand with high total organic carbon (>25%). Sediment quality measurements were within historical ranges with the exception of historically high PAH toxicity and *Chironomus* growth (Table 5.7-11).

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines CCME F3 hydrocarbon concentrations were above the sediment or soil quality guidelines in fall 2008 (Table 5.7-11).

Sediment Quality Index A SQI of 98.7 was calculated for McClelland Lake in 2008. Of the 71 variables assessed for the SQI in 2008, only strontium fell above the range of regional *baseline* conditions. Since RAMP began monitoring sediment quality in

McClelland Lake in 2002, SQI values have been over 94, indicating consistent sediment quality over time and Negligible-Low differences from historical regional *baseline* values (Table 5.7-1)

5.7.5 Fish Populations

The 2008 RAMP Fish Population component did not include any activities in the Firebag River watershed.

Figure 5.7-3 Firebag River: 2008 hydrograph and historical context.

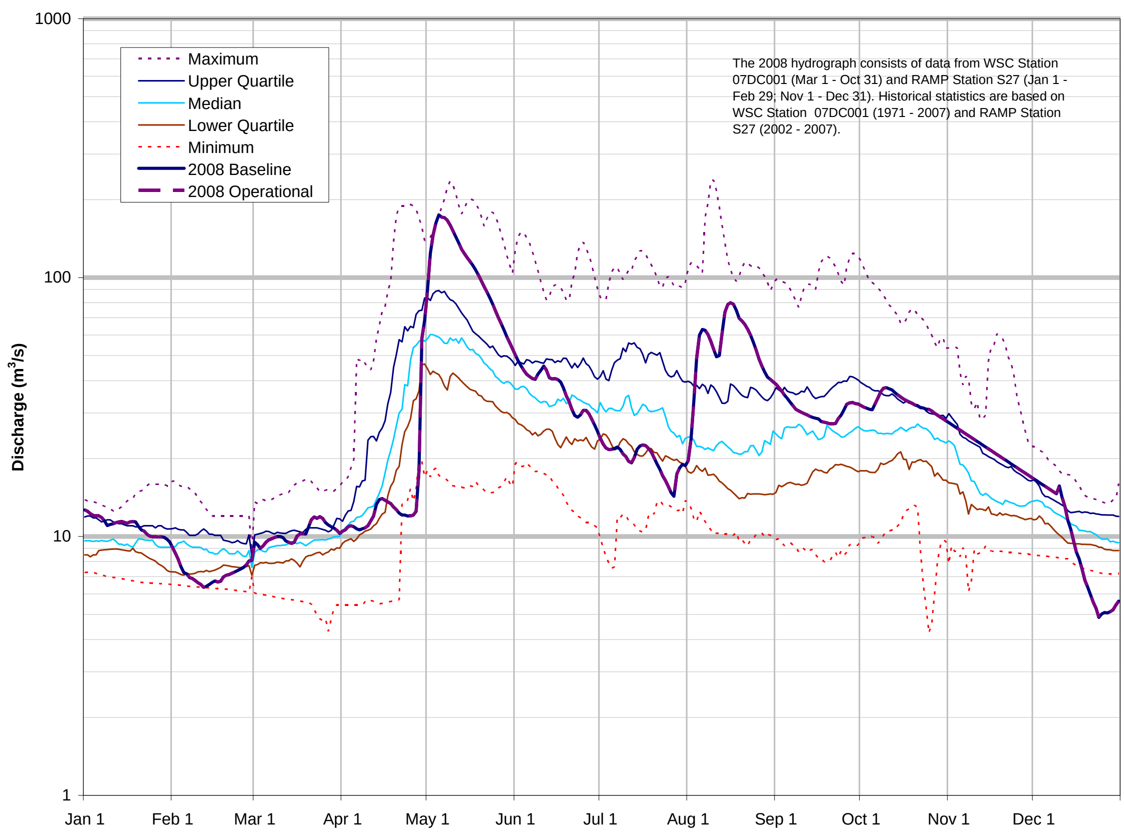


Table 5.7-2 Estimated water balance at RAMP/WSC Station S27, Firebag River near the Mouth (07DC001) for 2008.

Component	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total annual discharge)	**939**	**Observed annual discharge at RAMP/WSCStation S27, Firebag River near the Mouth**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+0.683	4.36 km^2 within Firebag River drainage estimated to have been closed-circuited as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.303	9.67 km^2 within Firebag River drainage estimated to have undergone land change as of 2008, but is not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from the Firebag River by focal projects	0	Unknown, none reported, assumed to be negligible
Amount by which discharge would be lower without releases to the Firebag River watershed by focal projects	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Firebag River not accounted for in figures contained in this table
***Baseline* hydrograph (total annual discharge)**	**939**	**Estimated *baseline* annual discharge at RAMP/WSC Station S27, Firebag River near the Mouth**
Incremental flow (change in total annual discharge)	-0.380	Total annual discharge from observed *test* hydrograph less total annual discharge from estimated *baseline* hydrograph.
Incremental flow (% of total annual discharge)	-0.04%	Incremental flow as a percentage of total discharge of estimated annual *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.7-3 Calculated change in hydrologic measurement endpoints for the Firebag River watershed.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	47.3	47.3	-0.04%
Mean winter discharge	11.6	11.5	-0.04%
Annual maximum daily discharge	171	171	-0.04%
Open-water season minimum daily discharge	14.3	14.3	-0.04%

Note: As measured at and calculated for RAMP/WSC Station S27, Firebag River near the Mouth (07DC001).

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Figure 5.7-4 McClelland Lake: 2008 hydrograph and historical context.

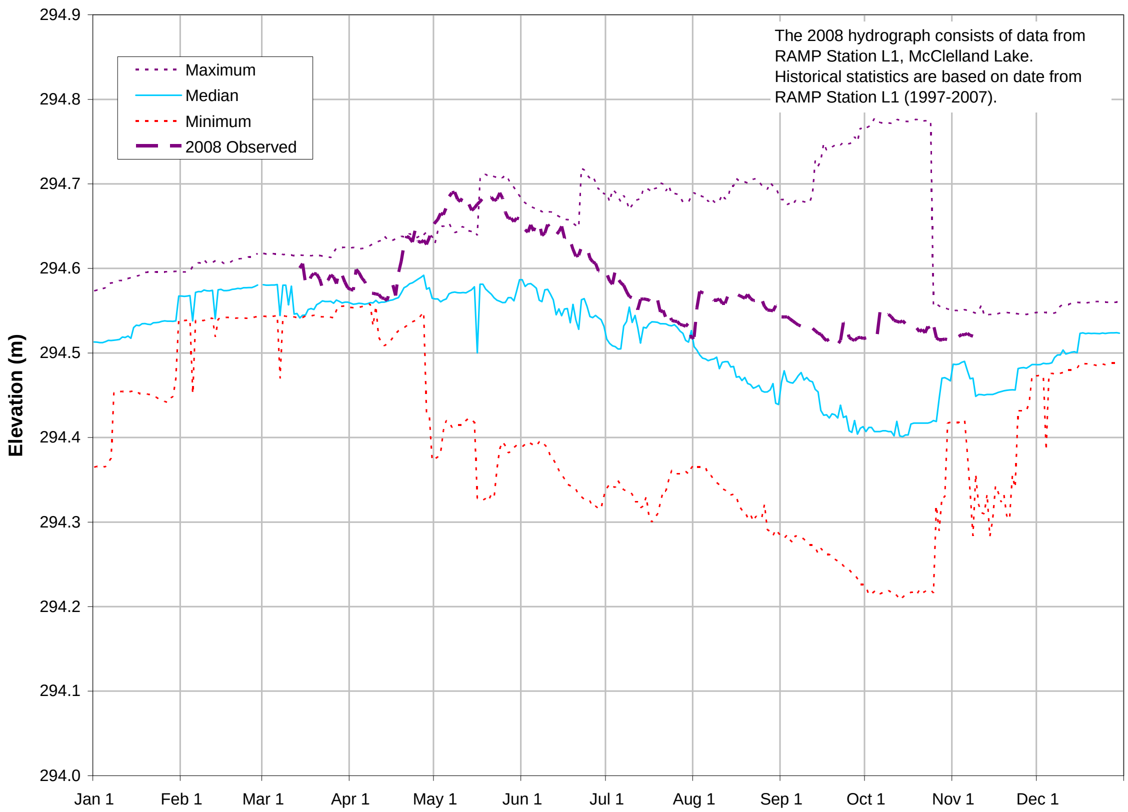


Table 5.7-4 Concentrations of water quality measurement endpoints, mouth of Firebag River (station FIR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	6	7.9	8.2	8.2
Total suspended solids	mg/L	-[1]	4	6	<3	6	17
Conductivity	µS/cm	-	221	6	178	197.5	227
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.032	6	0.016	0.033	**0.057**
Total nitrogen*	mg/L	1.0	0.6	6	0.4	0.6	**1.7**
Nitrate+nitrite	mg/L	1.0	<0.1	6	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	14	6	8	13	16
Ions							
Sodium	mg/L	-	4	6	2	4	4
Calcium	mg/L	-	30.8	6	25.2	28.8	33.2
Magnesium	mg/L	-	9.7	6	6.8	8.9	9.5
Chloride	mg/L	230, 860[3]	2	6	2	2.5	3
Sulphate	mg/L	100[4]	2.1	6	1.7	3.3	10.3
Total dissolved solids	mg/L	-	130	6	60	138.5	170
Total alkalinity	mg/L		114	6	87	104	112
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0457	6	0.033	**0.122**	**0.292**
Dissolved aluminum	mg/L	0.1[2]	0.0049	6	0.0028	0.0045	0.0089
Total arsenic	mg/L	0.005	0.0004	6	0.0003	0.0004	0.0006
Total boron	mg/L	1.2[5]	0.02	6	0.0136	0.0152	0.0190
Total molybdenum	mg/L	0.073	0.0001	5	0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0757	5	0.053	0.065	0.073
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.003**	6	**<0.003**	**0.0035**	**0.006**
Total phosphorus	mg/L	0.05	**0.057**	6	0.027	**0.054**	**0.093**
Dissolved iron	mg/L	0.3[2]	**0.417**	6	0.235	**0.337**	**0.54**
Total iron	mg/L	0.3	**0.792**	6	**0.394**	**0.746**	**1.06**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.7-5 Concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag project (station FIR-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	7.9	8.1	8.3
Total suspended solids	mg/L	-[1]	<3	5	<3	3	8
Conductivity	µS/cm	-	182	5	160	169	261
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.061**	5	0.009	**0.060**	**0.096**
Total nitrogen*	mg/L	1.0	0.7	5	0.5	0.7	0.8
Nitrate+nitrite	mg/L	1.0	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	12	5	8	13	16
Ions							
Sodium	mg/L	-	4	5	3	4	16
Calcium	mg/L	-	25.5	5	22.9	25.7	28.4
Magnesium	mg/L	-	7.3	5	6.4	7.3	8.7
Chloride	mg/L	230, 860[3]	1	5	<1	2	2
Sulphate	mg/L	100[4]	0.9	5	1.9	2.9	22.6
Total dissolved solids	mg/L	-	110	5	110	140	158
Total alkalinity	mg/L		97	5	81	91	114
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.0154	5	0.0232	0.0359	0.0369
Dissolved aluminum	mg/L	0.1[2]	0.0042	5	0.0031	0.0043	0.0066
Total arsenic	mg/L	0.005	0.0006	5	0.0001	0.0006	0.0006
Total boron	mg/L	1.2[5]	0.0134	5	0.0107	0.013	0.0153
Total molybdenum	mg/L	0.073	0.0002	5	0.0002	0.0002	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0551	5	0.046	0.049	0.068
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.004**	5	**0.003**	**0.004**	**0.009**
Total phosphorus	mg/L	0.05	**0.105**	5	**0.068**	**0.119**	**0.134**
Dissolved iron	mg/L	0.3[2]	**0.456**	5	0.281	**0.405**	**0.886**
Total iron	mg/L	0.3	**0.823**	5	0.525	0.679	**1.39**
Total phenols	mg/L	0.004	**0.005**	5	<0.001	0.003	**0.012**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.7-6 Concentrations of water quality measurement endpoints, McClelland Lake (station MCL-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.6	6	8.1	8.4	8.7
Total suspended solids	mg/L	-[1]	<3	6	<3	0	5
Conductivity	µS/cm	-	240	6	224	239	253
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.004	6	0.002	0.004	0.013
Total nitrogen*	mg/L	1.0	0.9	6	0.6	1.0	**2.0**
Nitrate+nitrite	mg/L	1.0	<0.1	6	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	13	6	11	12.5	17
Ions							
Sodium	mg/L	-	4	6	4	4.5	6
Calcium	mg/L	-	22.3	6	19.3	20.85	25.8
Magnesium	mg/L	-	16.8	6	14.6	16.55	17.3
Chloride	mg/L	230, 860[3]	<1	6	<1	<1	1
Sulphate	mg/L	100[4]	0.6	6	<0.5	1.8	4.3
Total dissolved solids	mg/L	-	163	6	80	152.5	167
Total alkalinity	mg/L		145	6	122	126	135
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.017	6	<0.02	0.004	0.026
Dissolved aluminum	mg/L	0.1[2]	<0.001	6	<0.01	0.0001	0.010
Total arsenic	mg/L	0.005	0.0002	6	<0.001	0.0002	0.0003
Total boron	mg/L	1.2[5]	0.0666	6	0.0513	0.0629	0.0670
Total molybdenum	mg/L	0.073	<0.000008	6	<0.0001	<0.000014	0.00003
Total mercury (ultra-trace)	ng/L	5, 13[6]	2.4	3	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.139	6	0.112	0.130	0.145
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Total phenols	mg/L	0.004	**0.005**	6	<0.001	0.001	0.003

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

Table 5.7-7 Water quality guideline exceedances, Firebag River watershed, 2008.

Variable	Units	Guideline*	FIR-1	FIR-2	MCL-1
Fall					
Sulphide	mg/L	0.002[1]	**0.003**	**0.004**	-
Total phosphorus	mg/L	0.05	**0.057**	**0.105**	-
Dissolved iron	mg/L	0.3[2]	**0.417**	**0.456**	-
Total iron	mg/L	0.3	**0.792**	**0.823**	-
Total phenols	mg/L	0.004	-	**0.005**	**0.005**
Total dissolved phosphorus	mg/L	0.05[2]	-	**0.061**	-

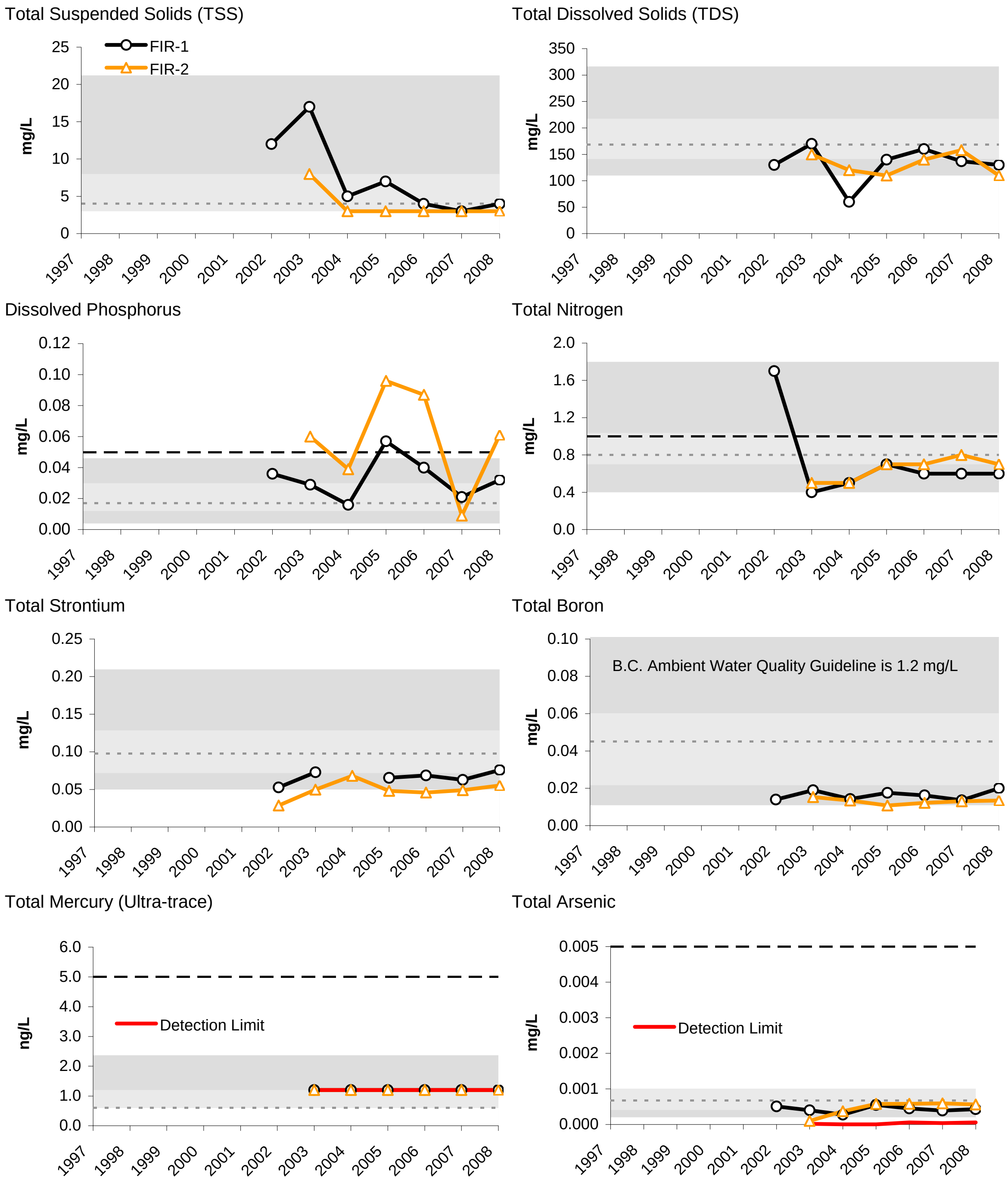
FIR-1, FIR-2 and MCL-1 sampled only in fall 2008.

* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[2] Guideline is for total analyte (no guideline for dissolved analyte).

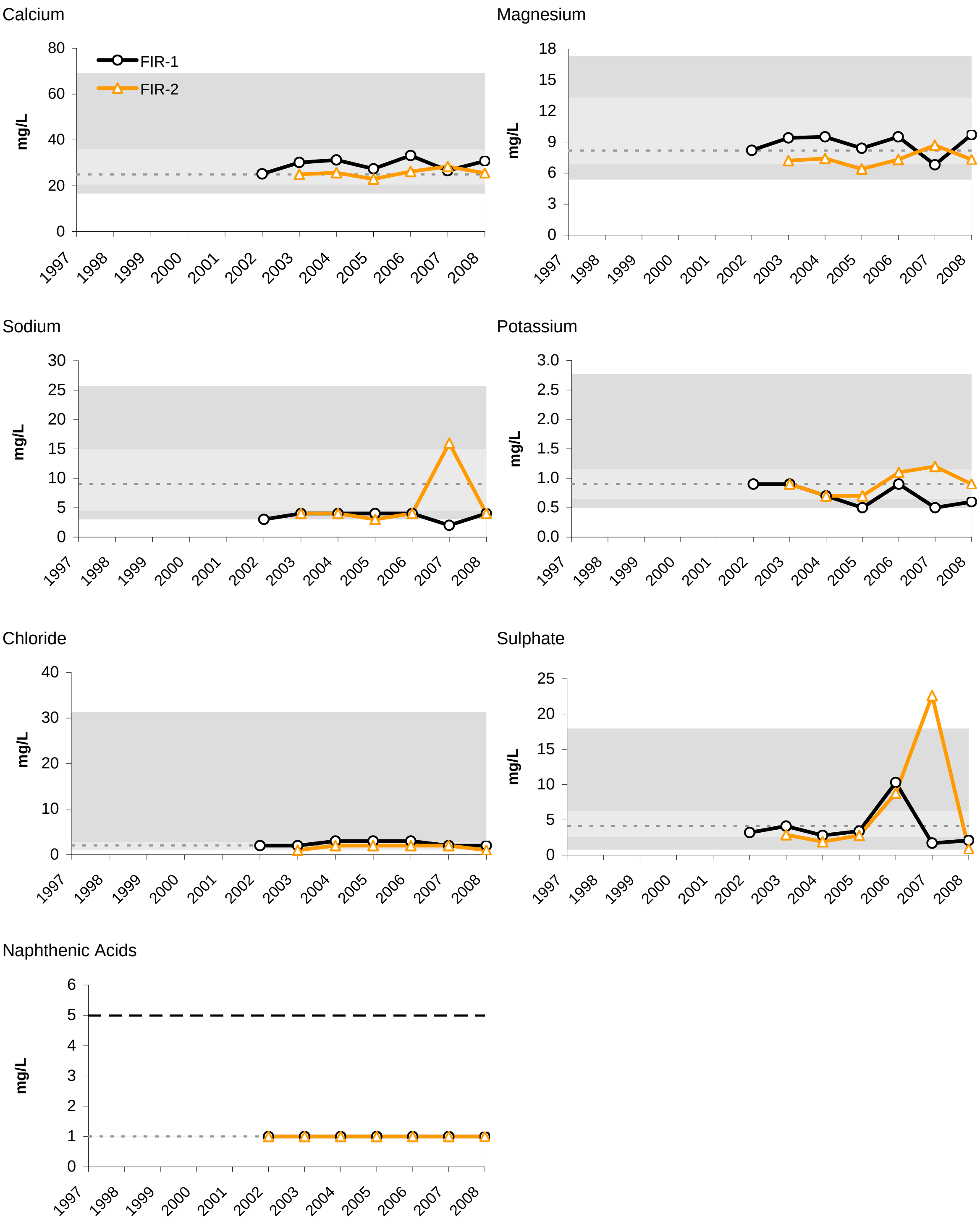
Figure 5.7-5 Concentrations of selected water quality measurement endpoints in the Firebag River watershed (fall 2008) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

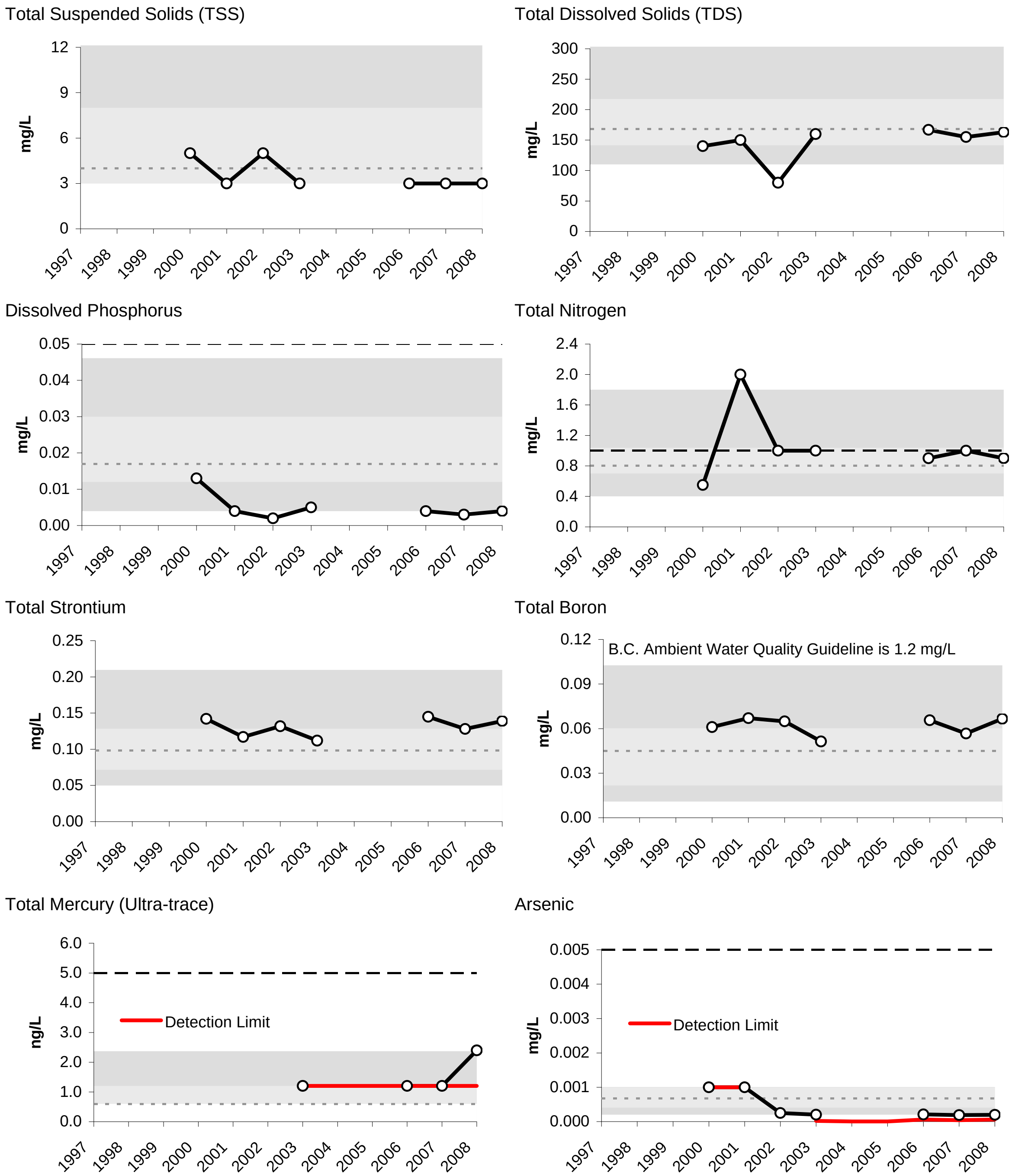
Figure 5.7-3 (Cont'd.)



Non-detectable values are shown at the detection limit.

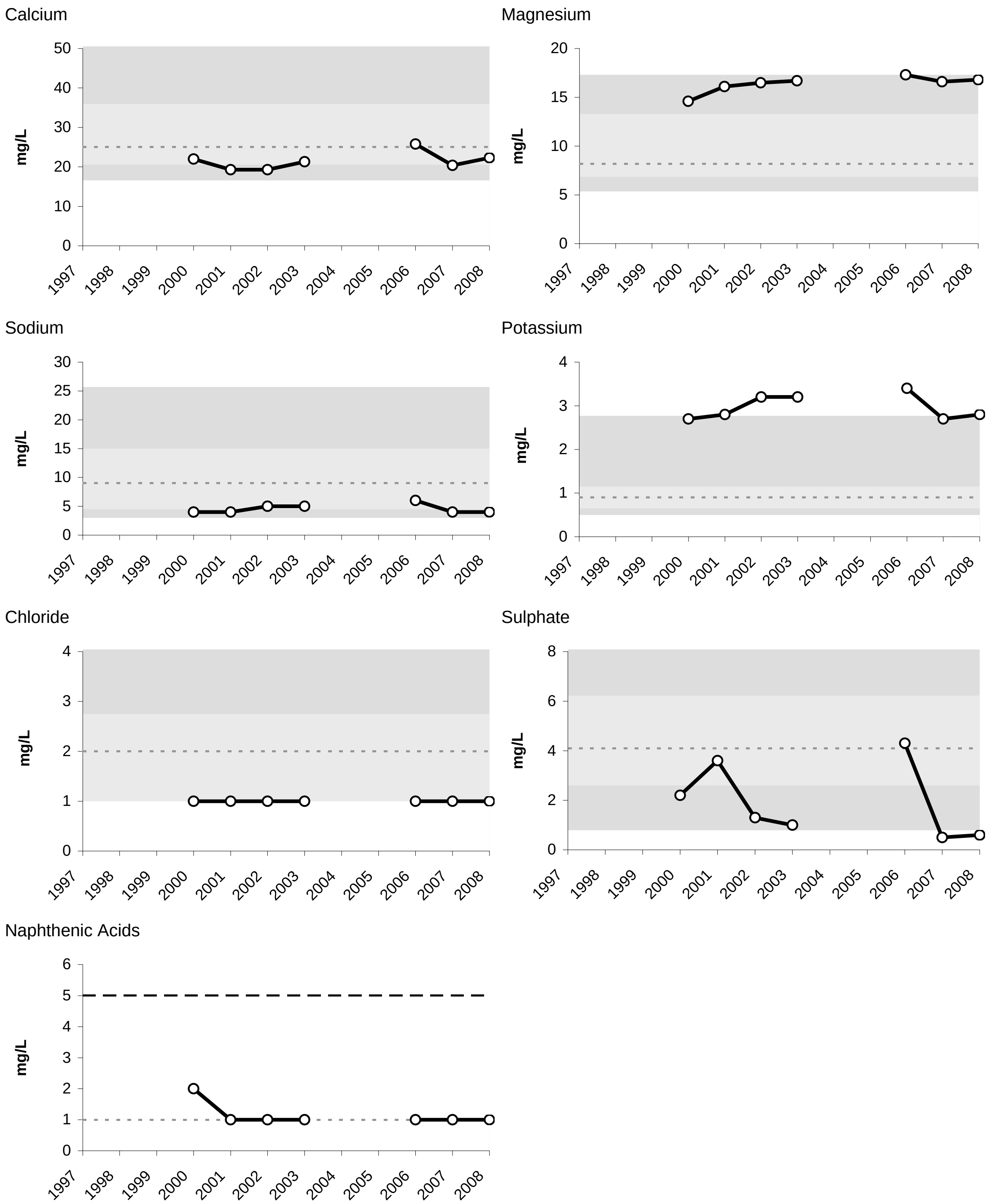
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.7-6 Concentrations of selected water quality measurement endpoints in McClelland Lake (fall 2008) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.
See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.7-6 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.7-7 Piper diagram of fall ion concentrations in the Firebag River watershed, fall 2008.

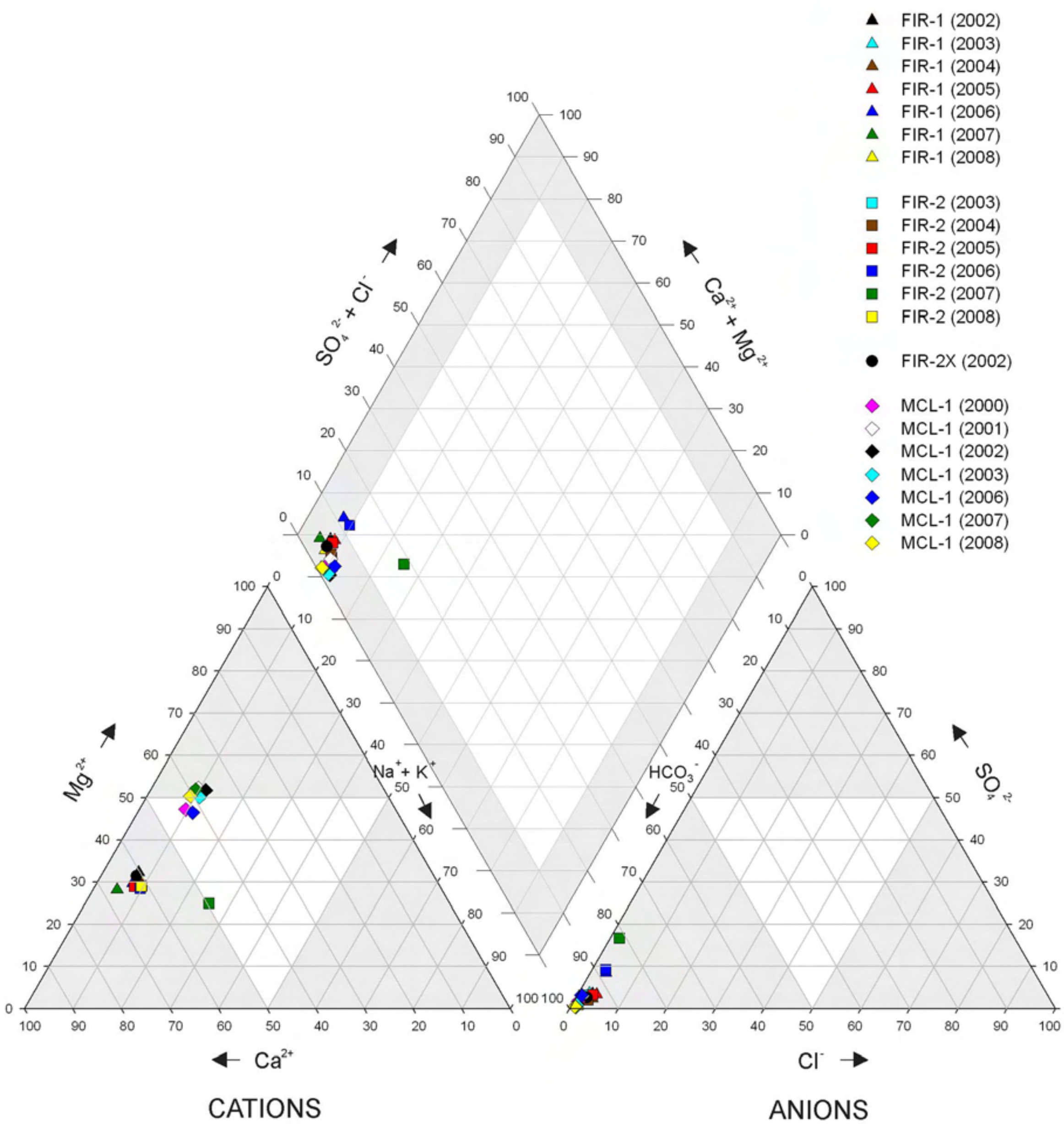


Table 5.7-8 Water quality index (fall 2008) for Firebag River watershed stations.

Station Identifier	Location	2008 Designation	Water Quality Index	Classification
FIR-1	Near mouth of the Firebag River	*test*	96.1	Negligible-Low
FIR-2	Upstream of Suncor Firebag	*baseline*	92.2	Negligible-Low
MCL-1	McClelland Lake	*baseline*	88.3	Negligible-Low

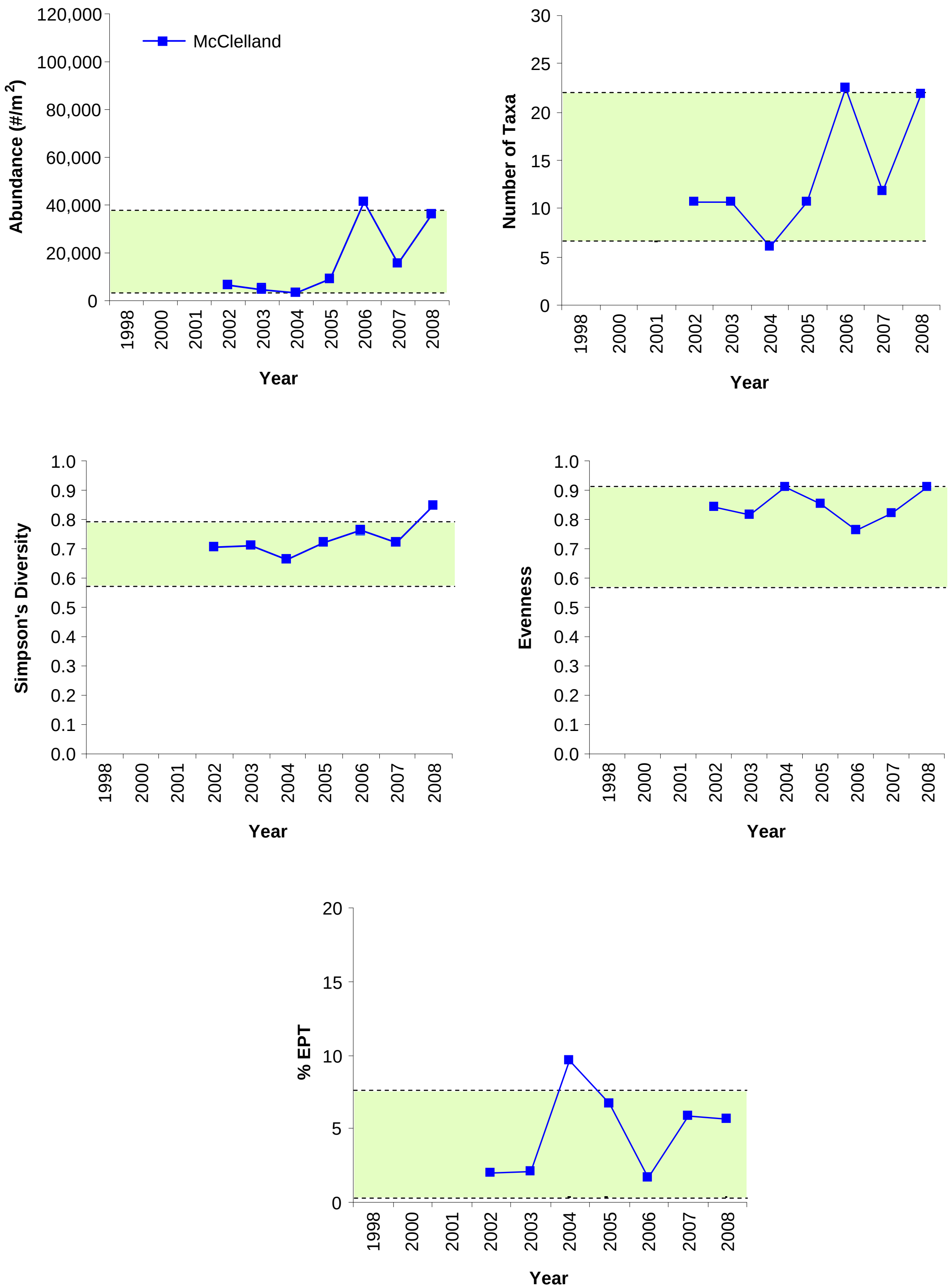
Table 5.7-9 Habitat characteristics of benthic invertebrate sampling locations in McClelland Lake, fall 2008.

Variable	Units	McClelland Lake
Sample date	-	Sept. 8, 2008
Habitat	-	Depositional
Water depth	m	2.2
Macrophyte cover	%	n/a
Field Water Quality		
Dissolved oxygen	mg/L	10.2
Conductivity	µS/cm	231
pH	-	9.0
Water temperature	°C	12.7
Sediment Composition		
Sand	%	71
Silt	%	19
Clay	%	10
Total Organic Carbon	%	36

Table 5.7-10 Percent abundances of major taxa and benthic invertebrate community measurement endpoints in McClelland Lake.

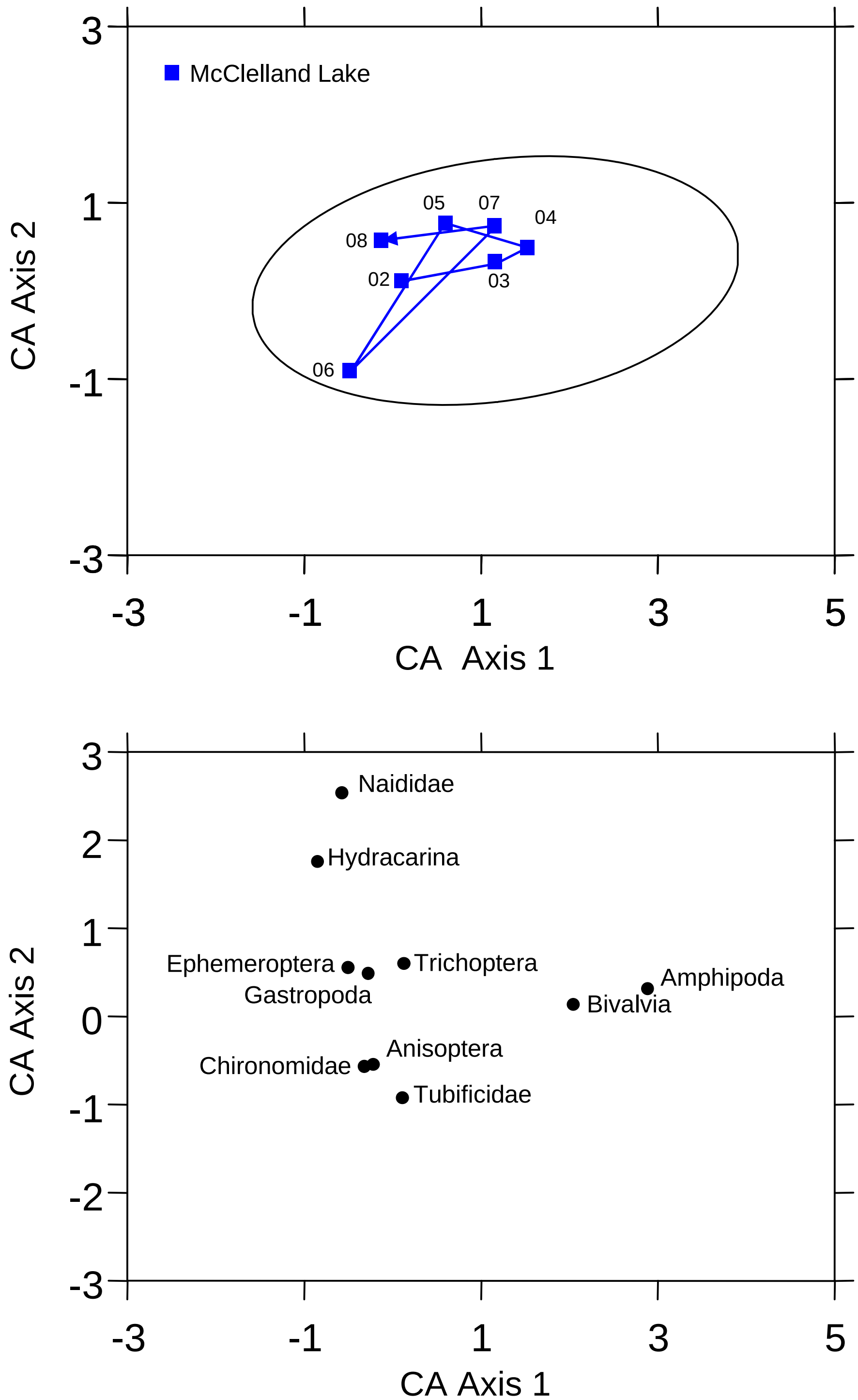
Taxon	Percent Major Taxa Enumerated in Each Year						
	McClelland						
	2002	2003	2004	2005	2006	2007	2008
Amphipoda	11	22	21	7	<1	4	3
Anisoptera			<1	1	<1		<1
Bivalvia	2	8	6	9	<1	1	1
Ceratopogonidae				1	<1		
Chaoboridae							
Chironomidae	58	39	24	27	91	41	33
Cladocera	<1		2	2	1	7	14
Copepoda			2	1	1	10	13
Ephemeroptera	1	2	8	7	1	12	5
Erpobdellidae	1	<1	<1				<1
Gastropoda	<1	1		2	<1		<1
Glossiphoniidae							<1
Hydracarina	1	<1		1			6
Lumbriculidae		<1	<1	<1		8	<1
Naididae	14	13	7	12	2	12	17
Nematoda	1	<1	4	<1	1		1
Ostracoda	10	8	15	29	1	3	3
Trichoptera	1		3	1	<1	2	1
Tubificidae		6	<1		1		<1
Zygoptera		<1			1		
Benthic Invertebrate Community Measurement Endpoints							
Total Abundance (No./m^2)	6,352	4,823	3,504	8,874	40,526	15,591	36,071
Richness	11	11	6	11	23	12	22
Simpson's Diversity	0.71	0.71	0.66	0.72	0.76	0.72	0.85
Evenness	0.84	0.81	0.91	0.85	0.76	0.82	0.91
% EPT	2	2	10	7	2	6	5

Figure 5.7-8 Variation in benthic invertebrate community measurement endpoints in McClelland Lake.



Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in regional *baselines* for lakes.

Figure 5.7-9 Ordination (Correspondence Analysis) of lake benthic invertebrate communities showing trends over time in McClelland Lake.



Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data for lakes in the RAMP FSA.

Note: the numbers in the upper panel refer to the sampling year for each data point.

Table 5.7-11 Concentrations of sediment quality measurement endpoints, McClelland Lake (station MCL-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only, station MCL-1)			
			Value	n	Min	Median	Max
Physical variables[5]							
Clay	%	-	10.0	4	11.8	28.1	49
Silt	%	-	18.7	4	14.7	29.1	37
Sand	%	-	71	4	14	45.6	68
Total organic carbon	%	-	35.7	4	22.2	28.4	30
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	<52.5	<100
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	<52.5	<100
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	2	<5	35	65
Fraction 3 (C16-C34)	mg/kg	300[2]	**360**	2	**1200**	**2050**	**2900**
Fraction 4 (C34-C50)	mg/kg	2800[2]	38	2	580	1490	2400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	[4]	2	0.011	0.018	0.024
Retene	mg/kg	-	0.149	4	0.019	0.103	0.161
Total dibenzothiophenes	mg/kg	-	0.03	4	0.03	0.03	0.08
Total PAHs	mg/kg	-	0.51	4	0.36	0.65	0.75
Total Parent PAHs	mg/kg	-	0.07	4	0.05	0.07	0.11
Total Alkylated PAHs	mg/kg	-	0.45	4	0.31	0.56	0.67
Predicted PAH toxicity[1]	H.I.	-	0.50	4	0.05	0.16	0.20
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	2	8	8.5	9
Chironomus growth - 10d	mg/organism	-	1.9	2	1.4	1.45	1.5
Hyalella survival - 14d	# surviving	-	10	2	7	7.5	8
Hyalella growth - 14d	mg/organism	-	0.3	2	0.2	0.25	0.3

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value was not quantifiable due to extremely low recovery of napthalene surrogate.

[5] Value is calculated from an average of 3 replicates.

5.8 ELLS RIVER WATERSHED

Table 5.8-1 Summary of results for Ells River watershed.

Ells River Watershed	Summary of 2008 Conditions	
Climate and Hydrology[1]		
Criteria		**S14A** at CNRL bridge
Mean open-water season discharge		Negligible - Low
Mean winter discharge		Negligible - Low
Annual maximum daily discharge		Negligible - Low
Minimum open-water season discharge		Negligible - Low
Water Quality		
Criteria	**ELR-1** at the mouth	**ELR-2** upstream of Canadian Natural Lease 7
Water Quality Summary Indicator	Negligible - Low	Negligible - Low
Benthic Invertebrate Community and Sediment Quality		
No benthic invertebrate community and sediment programs were conducted in 2008.		
Fish Populations		
No fish programs were conducted in 2008.		

Negligible - Low

Moderate

High

baseline

test

[1] For Climate and Hydrology, results are reported for station at the mouth of each watershed

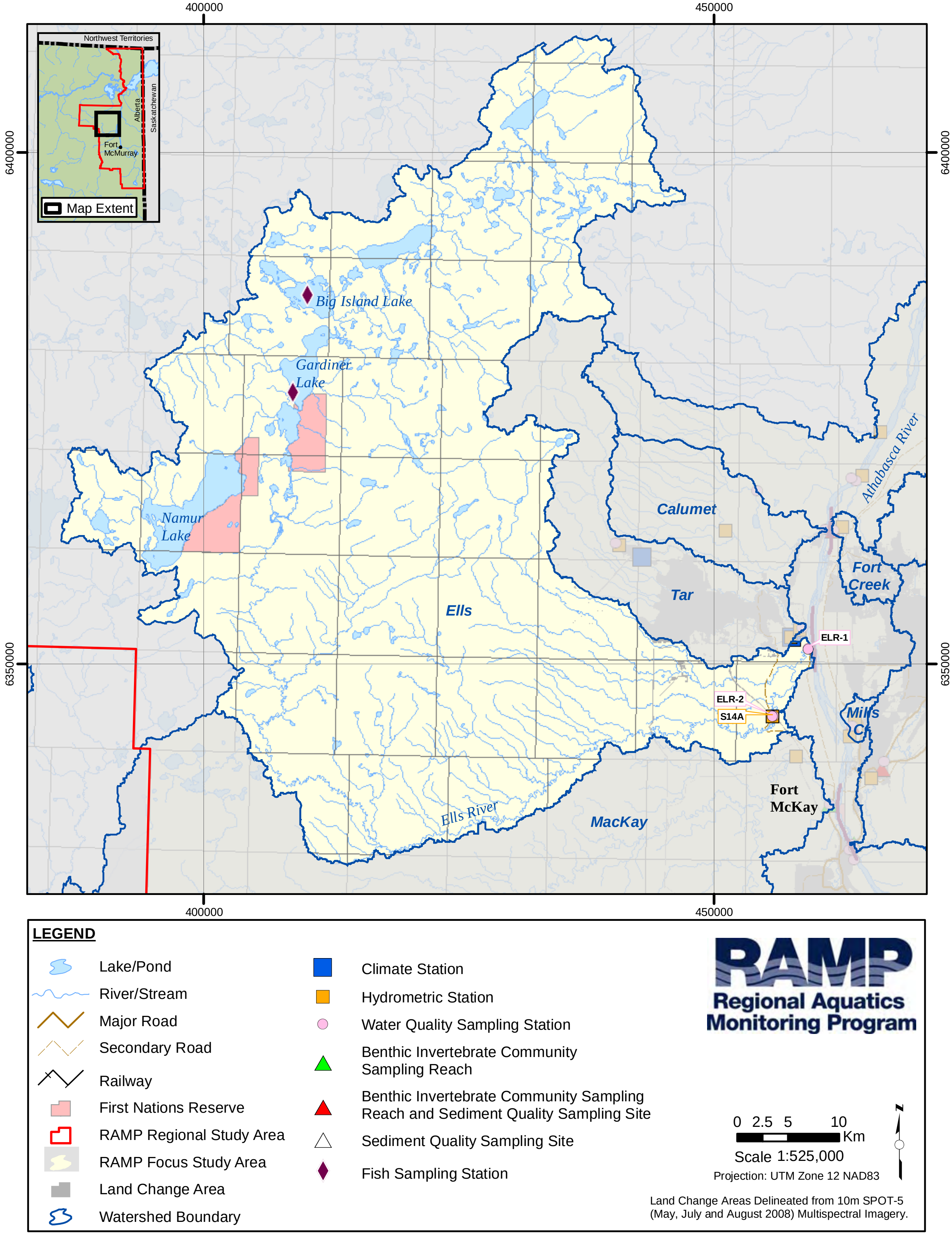
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.8-1 Ells River watershed.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K08_Ells_20090420.mxd

Figure 5.8-2 Representative Ells River monitoring stations, fall 2008.

**Water Quality Station ELR-1:
right downstream bank, facing downstream**

**Water Quality Station ELR-1:
right downstream bank, facing upstream**

**Water Quality Station ELR-2:
left downstream bank, facing downstream**

**Water Quality Station ELR-2:
left downstream bank, facing upstream**

5.8.1 Summary of 2008 Conditions

Approximately 0.19% of the Ells River watershed has undergone land change as of 2008 from focal project activities (Table 2.4-2); much of this land change is located in the Joslyn Creek drainage. The designations of specific areas of the watershed are as follows:

- The Ells River watershed downstream of the confluence of Joslyn Creek with the Ells River (Figure 5.8-1) is designated as *test*; and
- The remainder of the watershed is designated as *baseline*.

Table 5.8-1 contains a summary of the 2008 assessment for the Ells River watershed, Figure 5.8-1 is a detailed map of the Ells River watershed, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.8-2 contains a series of pictures from 2008 of a number of the monitoring stations in the watershed.

Hydrology The observed 2008 discharge for the Ells River watershed is estimated to be approximately 0.04% less than the 2008 *baseline* discharge would have been in the absence of focal projects. The differences in the Ells River watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Negligible-Low** for all calculated hydrologic measurement endpoints.

Water Quality Differences in water quality in fall 2008 in the lower Ells River as compared to regional *baseline* conditions are assessed as **Negligible-Low**:

- As of 2008, there are no measurable, consistent differences in water quality in the lower and upper Ells River.
- All but one exceedance of water quality guidelines in 2008 occurred at both *test* and *baseline* stations in the watershed.
- Concentrations of all water quality measurement endpoints in both the lower and upper Ells River in fall 2008 were within the range of regional *baseline* conditions as they have been, with few exceptions, since the beginning of RAMP water quality monitoring in the Ells River watershed.
- Ionic composition of sampled water at both the lower and upper Ells River in fall 2008 was consistent with previous years and continues to show little year-to-year variation.

5.8.2 Hydrologic Conditions

2008 Hydrologic Conditions Runoff volume in the Ells River basin, as measured at RAMP Station S14A, Ells River above Joslyn Creek, was above average in 2008 (Figure 5.8-3), with a May to October runoff depth of 77 mm compared to the historical mean of 62 mm. Although nine days of data were missing in May 2008 due to a faulty datalogger, more than 25% of the annual flow took place in this month (Figure 5.8-3). The maximum recorded daily discharge of 29.5 m^3/s was likely less than actual because of the missing data, while the minimum open-water discharge of 2.6 m^3/s was slightly lower than the mean open-water minimum discharge of 2.73 m^3/s. The mean open-water season discharge was 11.7 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Ells River for 2008 is provided in Table 5.8-2. As of 2008, the area of closed-circuited and not closed-circuited land change was 1.61 km^2 and 2.95 km^2, respectively, in the Ells River watershed (Table 2.4-1); the estimated net effects of which were to decrease inflows to the Ells River by 0.085 million m^3 in 2008 .

The *baseline* hydrograph that would have occurred at RAMP Station S14, Ells River above Joslyn Creek, was estimated by adding the 0.085 million m^3 of flow to the station's observed hydrograph from the station's observed hydrograph recorded in 2008; the resulting estimated *baseline* hydrograph is presented in Figure 5.8-3. The effect on the hydrologic measurement endpoints of the difference between the observed and estimated *baseline* hydrograph for RAMP Station S14, Ells River above Joslyn Creek over the period recorded in 2008, is a 0.04% decrease in mean open-water season discharge, mean winter discharge, annual maximum daily discharge, and open-season minimum daily discharge (Table 5.8-3). All hydrologic measurement endpoints for the Ells River watershed are estimated to be similar to what they would have been under *baseline* conditions (Figure 5.8-3, Table 5.8-3).

Summary The observed *test* 2008 discharge for RAMP Station S14A, Ells River above Joslyn Creek, is estimated to be approximately 0.04% less than 2008 *baseline* discharge would have been in the absence of focal projects in the Ells River watershed. The differences in the Ells River watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at RAMP Station S14A, Ells River above Joslyn Creek, are assessed as Negligible-Low for all measured hydrologic measurement endpoints (Table 5.8-1).

5.8.3 Water Quality

Water quality samples in the Ells River watershed in fall 2008 were collected from:

- the mouth of the Ells River (station ELR-1, *test*, established in 1998, sampled every year since 2002); and
- upstream Ells River (ELR-2, *baseline*, established in 2000, sampled every year since 2004).

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations of the most water quality measurement endpoints were within the range of historical measurements with the following exceptions (Table 5.8-4):

- At station ELR-1 concentrations of total nitrogen, dissolved organic carbon and total arsenic were greater than their historically-measured maximum concentrations (Table 5.8-4); and
- At station ELR-2 the concentration of total molybdenum was below its historically-measured minimum concentration, while pH and conductivity, as well as concentrations of total suspended solids, total nitrogen, dissolved organic carbon, and calcium and magnesium were greater than their historically-measured maximum levels and concentrations (Table 5.8-5). Concentrations of total dissolved solids and total arsenic were equal to historically-measured maximum concentrations.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions With the exception of total arsenic, concentrations of all selected water quality measurement endpoints were within the 5th-to-95th percentile of regional *baseline* concentrations at both *test* station ELR-1 and *baseline* station ELR-2 in fall 2008 (Figure 5.8-4). The concentration of total arsenic was greater than and equal to the 95th percentile of regional *baseline* concentrations for *test* station ELR-1 and *baseline* station ELR-2, respectively in fall 2008 (Figure 5.8-4).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines There were three water quality guideline exceedances measured in the Ells River watershed in fall 2008: the concentration of total aluminum at both *test* station ELR-1 and *baseline* station ELR-2; and the concentration of total nitrogen at *test* station ELR-1 (Table 5.8-4, Table 5.8-5).

Other Water Quality Guideline Exceedances Concentrations of total and dissolved iron, total phenols, and sulphide exceeded relevant water quality guidelines in fall 2008 at both *test* station ELR-1 and *baseline* station ELR-2, and these were the only other water quality variables with measured concentrations that exceeded water quality guidelines in fall 2008 in the Ells River watershed.

Ion Balance In fall 2008, the ionic composition of the stations in the Ells River watershed was dominated by calcium and bicarbonate ions (Figure 5.8-5). The ionic characteristics of surface water at both *test* station ELR-1 and *baseline* station ELR-2 in the Ells River watershed have changed little since RAMP water quality sampling began there in 1998 with the exception of *baseline* station ELR-2 in 2007 which had higher than historical relative concentrations of calcium and bicarbonate; the relative concentrations of calcium and bicarbonate returned to historical relative concentrations in fall 2008 (Figure 5.8-5).

Trend Analysis There have been no significant trends in water quality measurement endpoints at station ELR-1 over the RAMP sampling period ($\alpha = 0.05$).

Water Quality Index WQI values for both stations in the Ells River watershed (i.e., 92.2 for both *test* station ELR-1 and *baseline* station ELR-2) indicated Negligible-Low difference from regional *baseline* conditions.

Summary Differences in water quality in fall 2008 in the lower Ells River designated as *test*, as compared to regional *baseline* conditions are assessed as Negligible-Low (Table 5.8-1), with measurable changes in water quality in the lower Ells River watershed that include the following:

- As of 2008, there are no measurable, consistent differences in water quality in the Ells River watershed between *baseline* station ELR-2 and *test* station ELR-1.
- All but one exceedance of water quality guidelines in 2008 occurred at both *baseline* station ELR-2 and *test* station ELR-1.
- Concentrations of all water quality measurement endpoints for both *baseline* station ELR-2 and *test* station ELR-1in fall 2008 were within the range of regional *baseline* conditions as they have been, with few exceptions, since the beginning of the RAMP water quality data monitoring in the Ells River watershed in 1998.
- Ionic composition both water quality monitoring stations in the watershed was consistent with previous years and continues to show little year-to-year variation.

5.8.4 Benthic Invertebrate Communities and Sediment Quality

5.8.4.1 Benthic Invertebrate Communities

Benthic invertebrate communities were not sampled in the Ells River watershed in 2008.

5.8.4.2 Sediment Quality

Sediment quality was not sampled in the Ells River watershed in 2008.

5.8.5 Fish Populations

The 2008 RAMP Fish Population component did not include any activities in the Ells River watershed.

Figure 5.8-3 Ells River: 2008 hydrograph and historical context.

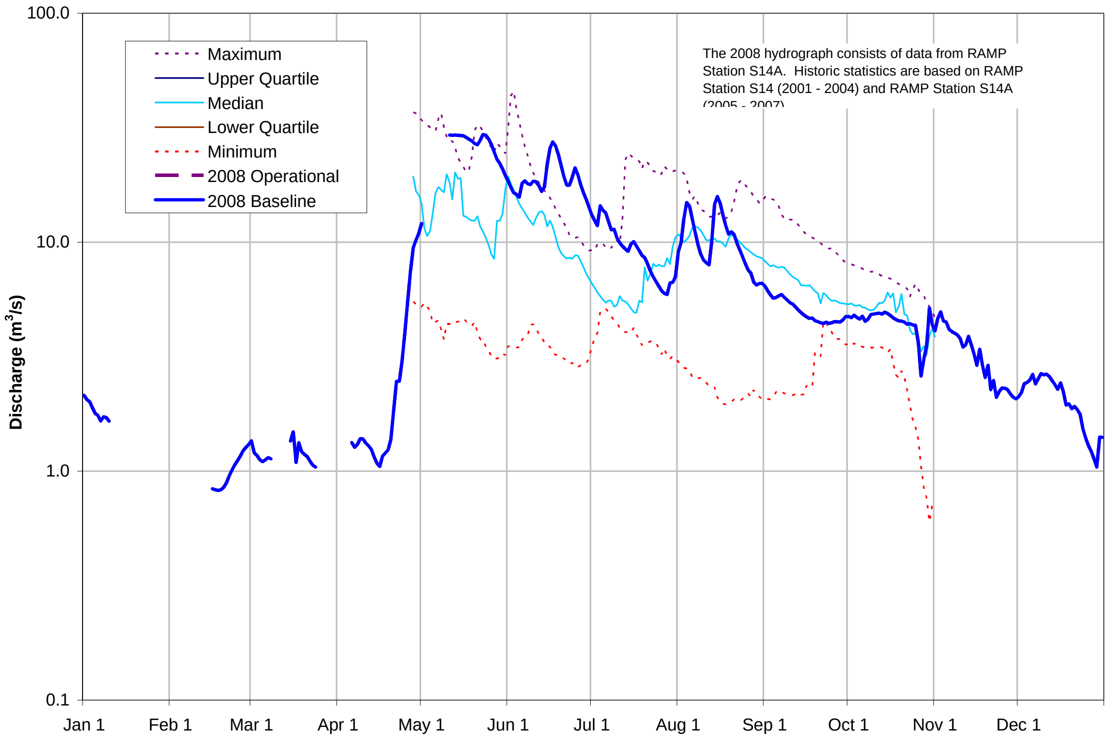


Table 5.8-2 Estimated water balance at RAMP Station S14, Ells River above Joslyn Creek for 2008.

Component	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total discharge)	**203**	**Observed discharge, obtained from RAMP Station S14A, Ells River above Joslyn Creek**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+0.134	1.61 km^2 within Ells River drainage estimated to have been closed-circuited as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.049	2.95 km^2 within Ells River drainage estimated to have undergone land change as of 2008, but is not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from the Ells River by focal projects	0	Unknown, none reported, assumed to be negligible
Amount by which discharge would be lower without releases to the Ells River watershed by focal projects	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Ells River not accounted for in figures contained in this table
***Baseline* hydrograph (total discharge)**	**202**	**Estimated *baseline* discharge at RAMP Station S14A, Ells River above Joslyn Creek**
Incremental flow (change in total discharge)	-0.085	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total discharge)	-0.04%	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Data are for the period of the 2008 data record for RAMP Station S14A, Ells River above Joslyn Creek.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.8-3 Calculated change in hydrologic measurement endpoints for the Ells River watershed.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	11.7	11.7	-0.04%
Mean winter discharge	2.08	2.08	-0.04%
Annual maximum daily discharge	29.5	29.5	-0.04%
Open-water season minimum daily discharge	2.60	2.60	-0.04%

Note: As measured at and calculated for RAMP Station S14A, Ells River above Joslyn Creek.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.8-4 Concentrations of water quality measurement endpoints, mouth of Ells River (station ELR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	7	7.8	8.2	8.4
Total suspended solids	mg/L	-[1]	13	7	3	6	16
Conductivity	µS/cm	-	229	7	175	236	272
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.019	7	0.003	0.008	0.02
Total nitrogen*	mg/L	1.0	**1.1**	7	0.3	0.6	0.9
Nitrate+nitrite	mg/L	1.0	<0.1	7	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	20	7	11	12	15
Ions							
Sodium	mg/L	-	10	7	8	12	18
Calcium	mg/L	-	23.5	7	21.6	25.1	30.4
Magnesium	mg/L	-	7.3	7	6.5	7.8	9.1
Chloride	mg/L	230, 860[3]	2	7	<1	2	4
Sulphate	mg/L	100[4]	13.4	7	10.5	17.7	27.9
Total dissolved solids	mg/L	-	180	7	110	160	220
Total alkalinity	mg/L	-	99	7	76	97	117
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	3
Selected metals							
Total aluminum	mg/L	0.1	**0.389**	7	0.06	**0.264**	**0.673**
Dissolved aluminum	mg/L	0.1[2]	0.0259	7	0.0077	0.0171	0.078
Total arsenic	mg/L	0.005	0.0012	7	<0.001	0.0007	0.0011
Total boron	mg/L	1.2[5]	0.0622	7	0.0410	0.0649	0.0834
Total molybdenum	mg/L	0.073	0.0006	7	0.0006	0.0007	0.0008
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.133	7	0.095	0.124	0.14
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.014**	7	**<0.003**	**0.005**	**0.135**
Total iron	mg/L	0.3	**1.14**	7	**0.45**	**0.512**	**0.945**
Dissolved iron	mg/L	0.3[2]	**0.404**	7	0.162	0.23	0.262
Total phenols	mg/L	0.004	**0.005**	7	<0.001	0.004	**0.011**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.8-5 Concentrations of water quality measurement endpoints, upper Ells River (station ELR-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	4	7.7	7.95	8.1
Total suspended solids	mg/L	-[1]	8	4	<3	4	6
Conductivity	µS/cm	-	219	4	164	179	195
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.023	4	0.004	0.013	0.061
Total nitrogen*	mg/L	1.0	1	4	0.6	0.65	0.8
Nitrate+nitrite	mg/L	1.0	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	20	4	10	13.5	16
Ions							
Sodium	mg/L	-	11	4	3	7	13
Calcium	mg/L	-	24.9	4	20.5	23.4	24.8
Magnesium	mg/L	-	7.8	4	6.2	6.95	7.2
Chloride	mg/L	230, 860[3]	2	4	2	2	3
Sulphate	mg/L	100[4]	15.6	4	2.2	10.8	18.9
Total dissolved solids	mg/L	-	190	4	110	123	190
Total alkalinity	mg/L	-	96	4	73	87.5	110
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.318**	4	0.0515	**0.2655**	**0.735**
Dissolved aluminum	mg/L	0.1[2]	0.0237	4	<0.0002	0.0143	0.0255
Total arsenic	mg/L	0.005	0.0011	4	0.0006	0.0008	0.0011
Total boron	mg/L	1.2[5]	0.0591	4	0.0405	0.0626	0.0836
Total molybdenum	mg/L	0.073	0.0006	4	0.0007	0.0007	0.0008
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.129	4	0.094	0.106	0.137
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.014**	4	**0.003**	**0.005**	**0.008**
Total iron	mg/L	0.3	**0.906**	4	0.26	**0.438**	**0.922**
Dissolved iron	mg/L	0.3[2]	**0.359**	4	0.152	0.171	0.208
Total phenols	mg/L	0.004	**0.006**	4	<0.001	0.0015	**0.007**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

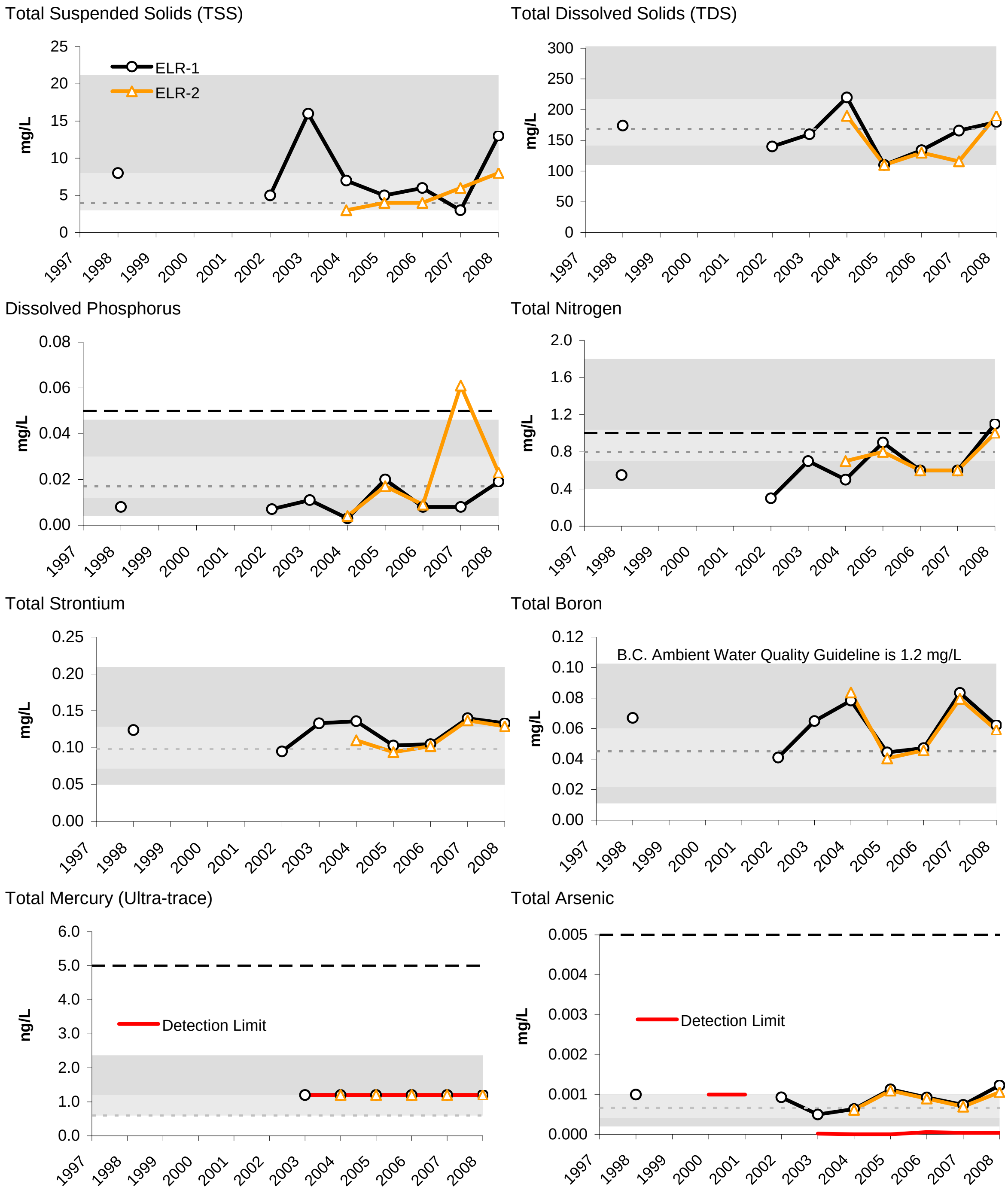
[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Figure 5.8-4 Selected water quality measurement endpoints in the Ells River (fall data) relative to regional baseline fall concentrations.

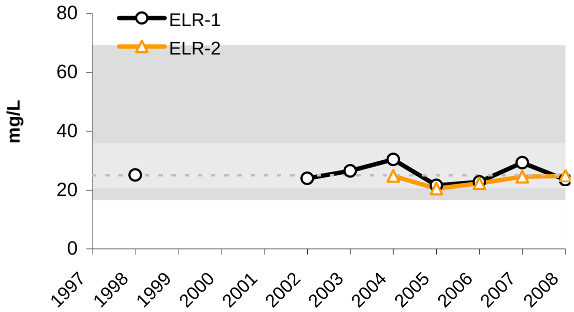


Non-detectable values are shown at the detection limit.

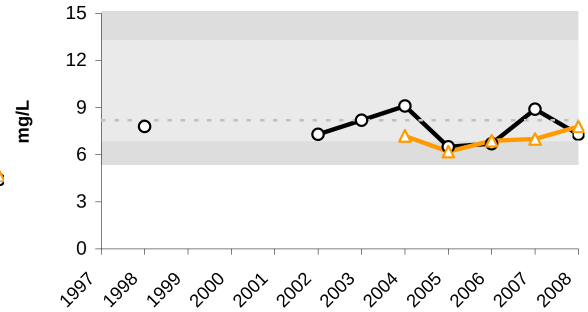
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.8-4 (Cont'd.)

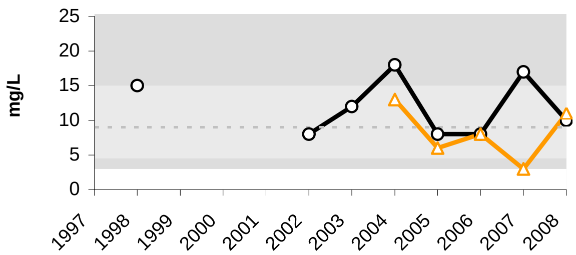
Calcium



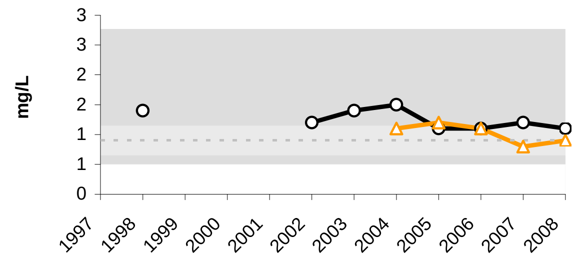
Magnesium



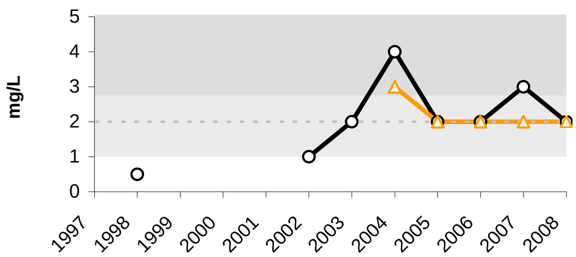
Sodium



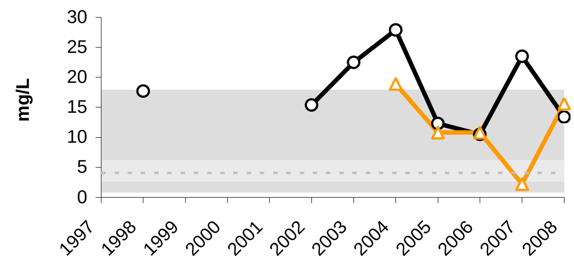
Potassium



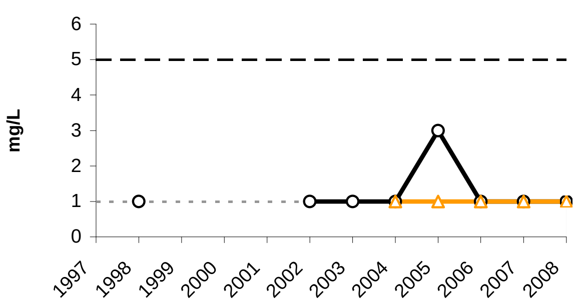
Chloride



Sulphate



Naphthenic Acids



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Table 5.8-6 Water quality guideline exceedances, Ells River watershed, 2008.

Variable	Units	Guideline*	ELR-1	ELR-2
Fall				
Sulphide	mg/L	0.002[1]	**0.014**	**0.014**
Total aluminum	mg/L	0.1	**0.389**	**0.318**
Dissolved iron	mg/L	0.3[2]	**0.404**	**0.359**
Total iron	mg/L	0.3	**1.14**	**0.906**
Total phenols	mg/L	0.004	**0.005**	**0.006**
Total nitrogen	mg/L	1.0	**1.1**	**-**

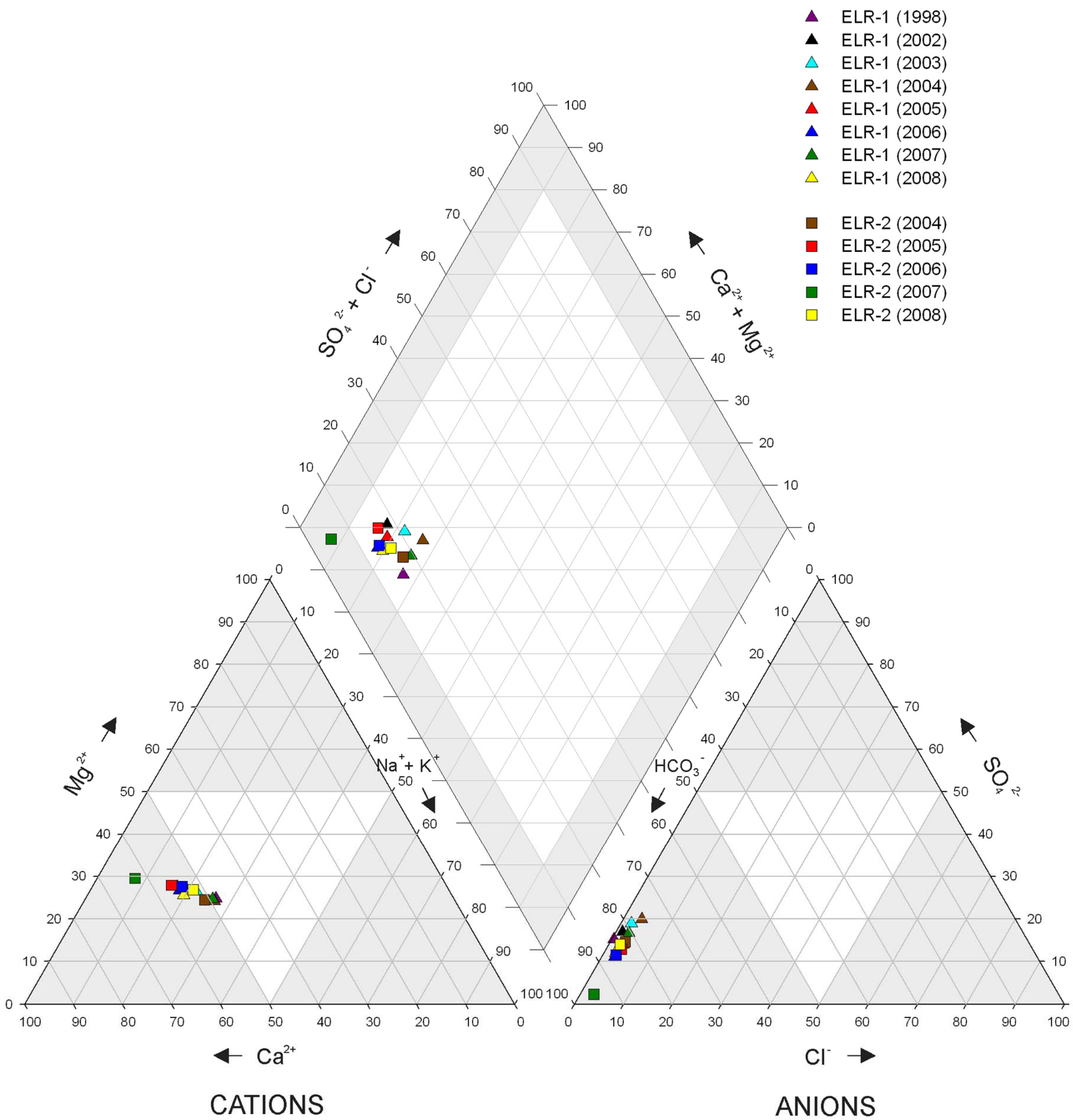
ELR-1 and ELR-2 were sampled only in fall 2008.

* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[2] Guideline is for total analyte (no guideline for dissolved species).

Figure 5.8-5 Piper diagram of fall ion concentrations in the Ells River watershed.



5.9 CLEARWATER-CHRISTINA RIVER WATERSHEDS

Table 5.9-1 Summary of results for Clearwater-Christina River watersheds.

Clearwater-Christina River Watershed	Summary of 2008 Conditions			
	Clearwater River		*Christina River*	
Climate and Hydrology[1]				
Criteria		**07CD001** Clearwater River at Draper		**S29** Christina River near Chard
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	**CLR-1** upstream of Fort McMurray	**CLR-2** upstream of Christina River	**CHR-1** at the mouth	**CHR-2** upstream of Janvier
Water Quality	Negligible - Low	Negligible - Low	Moderate	Negligible - Low
Benthic Invertebrate Community and Sediment Quality				
Criteria	**CLR-D-1** lower reach	**CLR-D-2** upper reach	no reaches sampled	
Benthic Invertebrate Community	Negligible - Low	n/a		
Sediment Quality	Negligible - Low	Negligible - Low		
Fish Populations				
No fish tissue programs were conducted in 2008				

Negligible - Low
Moderate
High
baseline
test

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper *baseline* reaches.

[1] For Climate and Hydrology, results are reported for station at the mouht of each watershed

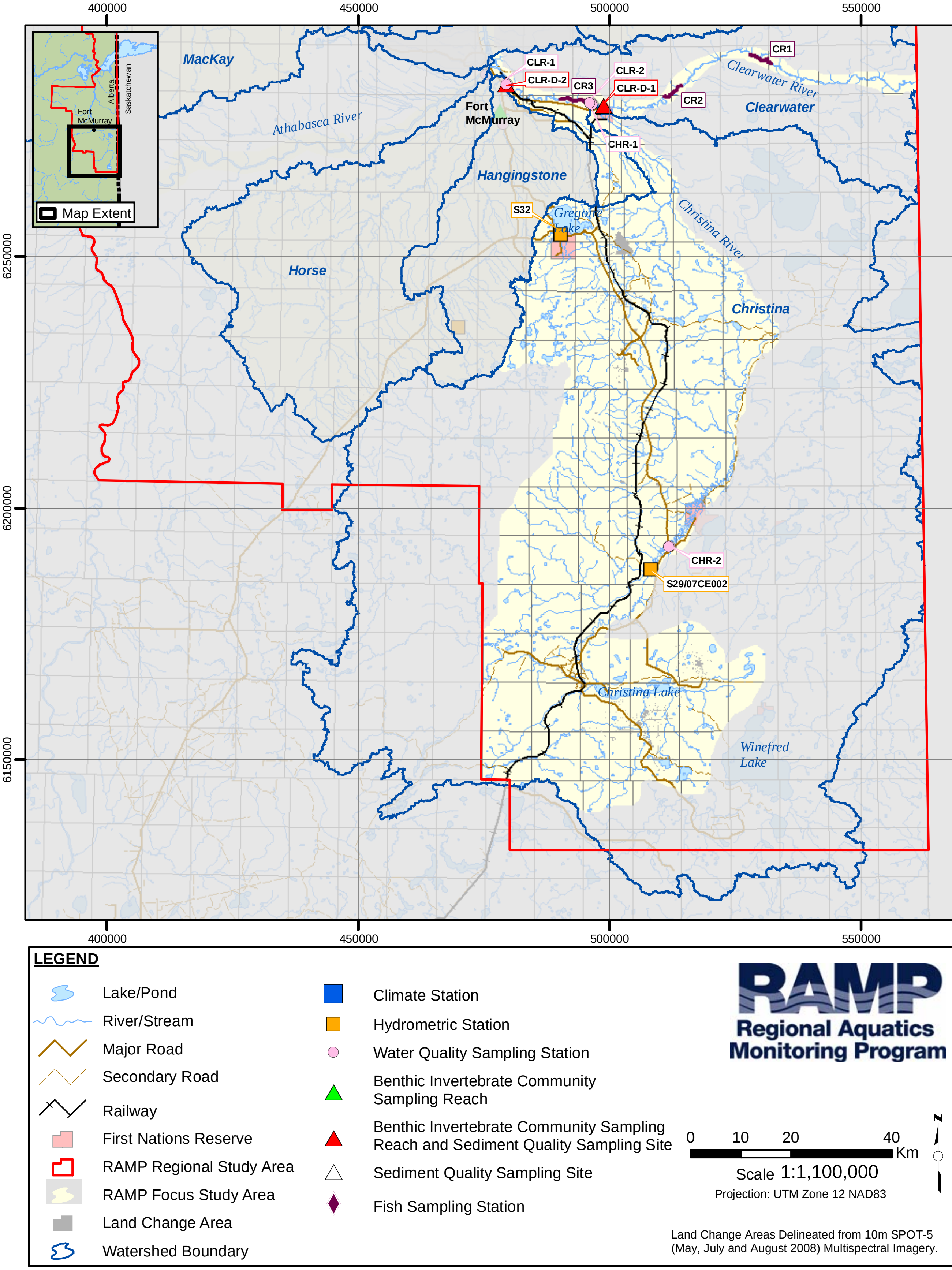
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.9-1 Clearwater-Christina River watersheds.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K09_ChrisClear_20090406.mxd

Figure 5.9-2 Representative monitoring stations in Clearwater-Christina River watersheds, fall 2008.

Water Quality Station CHR-1 (Christina River): from channel centre, facing upstream

Water Quality Station CLR-1 (Clearwater River): from channel centre, facing upstream

Water Quality Station CHR-2 (Christina River): right downstream bank, facing downstream

Water Quality Station CLR-2 (Clearwater River): from channel centre, facing downstream

5.9.1 Summary of 2008 Conditions

As of 2008, approximately 0.3% of the Christina River watershed had undergone land change as a result of focal project activities and other oil sands developments (Table 2.4-2). In addition, none of the part of the Clearwater River basin that is in the RAMP FSA contains any focal projects or other oil sands developments. The designations of specific areas of the Clearwater-Christina River system for 2008 are as follows:

- That part of the Christina River watershed downstream of the OPTI/Nexen Long Lake Project is designated as *test*;
- The remainder of the Christina River watershed is designated as *baseline* for 2008, but monitoring data from this part of the Christina River watershed were not used in the calculation of regional baselines for water quality, benthic invertebrate communities, or sediment quality because of the existence of a number of non-RAMP oil sands development activities in the watershed upstream of the OPTI/Nexen Project (Figure 5.9-1);

- All parts of the Clearwater River upstream of the confluence with the Christina River are designated as *baseline*; and
- All parts of the Clearwater River downstream of the confluence with the Christina River are designated as *test*.

Table 5.9-1 contains a summary of the 2008 assessment for the Clearwater-Christina River system, Figure 5.9-1 is a detailed map of the Clearwater-Christina River system, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.9-2 contains a series of pictures from 2008 of a number of the monitoring stations in the system.

Hydrology While hydrologic measurement endpoints for the Christina River watershed could not be estimated because there is no hydrometric station at the mouth of the Christina River, estimated effects of the focal project activities in 2008 were to remove 0.004 mm of runoff depth from the watershed.

Water Quality Differences in water quality in fall 2008 in the Clearwater River as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Differences in water quality in fall 2008 in the lower Christina River as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Although the water quality index score for lower Christina River *test* station CHR-1 was slightly below the benchmark value of 80 (i.e., 79.8), it was comparable with upstream *baseline* station CHR-2, which had similar score (80.4) and similar variation from regional *baseline* conditions.

Benthic Invertebrate Communities and Sediment Quality Differences in the benthic invertebrate community in the lower Clearwater River as compared to the Clearwater River above its confluence with the Christina River are assessed as **Negligible-Low**. Differences in benthic invertebrate community measurement endpoints between these two reaches of the Clearwater River have remained the same between the period when the lower Clearwater River was designated as *baseline* and when it was designated as *test*. Also, values of all benthic invertebrate community measurement endpoints are currently within the normal range of variation for *baseline* depositional reaches in the RAMP FSA, and both monitored reaches of the Clearwater River in fall 2008 contained a number of benthic invertebrate taxa that are considered sensitive.

Differences in sediment quality in fall 2008 in the lower Clearwater River compared to regional *baseline* conditions, are assessed as **Negligible-Low**. Sediment quality at both the lower Clearwater River and the Clearwater River upstream of its confluence with the Christina River in fall 2008 was generally consistent with that of previous years, with concentrations of sediment quality measurement endpoints largely within previously measured and regional *baseline* ranges; no clear differences in sediment quality in fall 2008 were apparent between these two parts of the river.

Fish Populations The results of the 2008 Clearwater fish inventory indicate:

- few changes or trends in length and age frequency distributions, with the exception of a shift in dominant length class for longnose sucker (increasing) and white sucker (decreasing);
- continued increasing trends in spring and fall total CPUE for all species with the exception of goldeye in the spring;
- increased instances of significant year-to-year variability in condition factor of fish captured in the fall than in the spring;

- longnose sucker and northern pike in *test* reach CR3 had a greater than 10% difference in condition relative to *baseline* reaches CR1 and CR2; and
- health assessment index and percentage of fish captured with evidence of external pathology for all species was within previously measured ranges with the exception of walleye for which both of these measurement endpoints were greater than previously measured maxima.

5.9.2 Hydrologic Conditions

2008 Hydrologic Conditions On the Clearwater River, one-third of the 2008 open water flow measured at WSC Station 07CD001, Clearwater River at Draper, occurred in May, with a maximum daily discharge of 249 m^3/s (Figure 5.9-3). Discharge fell below normal in summer; in August the river rose in response to significant rainfall, and remained near normal for the rest of the year. The minimum open-water discharge on the Clearwater River was 62.7 m^3/s compared to the mean annual minimum discharge of 46.4 m^3/s.

In the Christina River basin, 33% and 25% of the 2008 flow measured at RAMP/WSC Station S29, Christina River near Chard (07CE002), occurred during May and August, respectively (Figure 5.9-4). Total runoff for the year was 131 mm. Daily discharge peaked in May at 94.9 m^3/s, the minimum open-water discharge was 5.55 m^3/s, and the mean open-water daily discharge was 33.5 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph An assessment was made of the hydrologic effects of the existing land change area in the Christina River watershed. As there is no hydrometric station at the mouth of the Christina River it is not possible to estimate changes in hydrologic measurement endpoints at the watershed level. However, it is possible to estimate the overall changes in discharge as a result of land change and water withdrawals and discharges related to focal projects and other oil sands developments; these were used in the calculation of hydrologic effects in the Athabasca River (Section 5.1.2) and are; therefore, reported in detail here.

Changes in discharge in 2008 in the Christina River were estimated for two cases. The first case considered only 2008 focal projects; that is, those projects owned by 2008 RAMP funders which were under construction or operational in 2008 in the Christina River watershed. The second case considered all 2008 focal projects plus active oil sands projects in the Christina River watershed that were not owned by 2008 RAMP funders. This latter case can be considered a type of cumulative hydrologic assessment of all significant oil sands activities in the Christina River watershed as of 2008.

The results of the two cases are presented in Table 5.9-2. In the first case, (i.e., focal projects only) it is estimated that a *baseline* hydrograph for 2008 for the entire Christina River watershed would have had 0.200 million m^3 less flow than a 2008 operational hydrograph; this is equivalent to 0.04 mm of additional runoff depth for the entire Christina River watershed. In the second case (i.e., focal projects plus all other active oil sands projects) it is estimated that a *baseline* hydrograph for 2008 for the entire Christina River watershed would have 0.043 million m^3 less flow than a 2008 operational hydrograph; this is equivalent to a reduction of 0.008 mm of runoff depth for the entire Christina River watershed.

5.9.3 Water Quality

In fall 2008, water quality samples were collected from the:

- Clearwater River upstream of Fort McMurray (station CLR-1, *test*, data available from 2001);
- Clearwater River upstream of the Christina River confluence (station CLR-2, *baseline* data, available from 2001);
- Christina River at the mouth (station CHR-1, *test*, data available from 2002); and
- Christina River upstream of Janvier (station CHR-2, *baseline*, data available from 2002). Data obtained from station CHR-2 have been excluded from the calculation of regional water quality baselines because of upstream non-RAMP oil-sands activities (Figure 5.9-1).

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations of the most water quality measurement endpoints were within the range of historical measurements at the two RAMP water quality stations in the Clearwater-Christina watersheds with the following exceptions (Table 5.9-3, Table 5.9-4):

- At *test* station CLR-1 the concentration of total nitrogen was equal to its previously measured maximum concentration (Table 5.9-3);
- At *baseline* station CLR-2 the concentrations of calcium and magnesium were above their previously measured maximum concentrations, the concentrations of sodium and total and dissolved aluminum were below their previously measured minimum concentration, and levels of total alkalinity, dissolved organic carbon and pH were equal to their previously measured maximum concentrations (Table 5.9-4);
- At *test* station CHR-1 the concentrations of 10 (45%) of 22 water quality measurement endpoints were greater or less than their previously measured maximum or minimum concentrations at this station. The concentrations of total suspended solids, total dissolved phosphorus, dissolved organic carbon, dissolved aluminum and total arsenic were above their previously measured maximum concentrations, while levels and concentrations of sodium, calcium, chloride, total alkalinity and conductivity were below their previously measured minimum concentrations and levels (Table 5.9-5); and
- At *baseline* station CHR-2 the concentrations of 13 (60%) of 22 water quality measurement endpoints were greater or less than their previously measured maximum or minimum concentrations at this station. Concentrations of total suspended solids, total dissolved phosphorus, dissolved organic carbon, dissolved aluminum, total arsenic and total ultra-trace mercury were above their previously measured maximum concentrations, while concentrations and levels of conductivity, sodium, calcium, magnesium, total alkalinity, total boron and total strontium were below their previously measured minimum concentrations and levels (Table 5.9-6).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions In fall 2008, concentrations of all selected water quality measurement endpoints were within regional baseline concentrations (i.e., 5^{th} to 95^{th} percentile of concentrations) with the exception of total suspended solids, dissolved phosphorus and total arsenic concentrations whose concentrations exceeded the 95^{th}

percentile of regional baseline concentrations at both *test* station CHR-1 and *baseline* station CHR-2 (Figure 5.9-5).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Water quality measurement endpoints whose concentrations exceeded water quality guidelines in the Clearwater-Christina River system in fall 2008 were (Table 5.9-3 to Table 5.9-6):

- total aluminum at all stations; and
- total dissolved phosphorus and total nitrogen at *test* station CHR-1 and *baseline* station CHR-2.

Other Water Quality Guideline Exceedances Other water quality variables whose concentrations exceeded water quality guidelines in the Clearwater-Christina River system in fall 2008 were (Table 5.9-7):

- *test* station CLR-1 - sulphide, total phosphorus, dissolved iron and total iron;
- *baseline* station CLR-2 - sulphide and total iron;
- *test* station CHR-1 - sulphide, total phosphorus, dissolved iron, total iron, total Kjeldahl nitrogen, and total phenols; and
- *baseline* station CHR-2 - sulphide, total phosphorus, dissolved iron, total iron, and total phenols.

Ion Balance The ionic composition of water as measured in fall 2008 was similar to previous years for all stations except for *baseline* station CLR-2 (upper Clearwater River) where a shift in relative concentration of cations was measured, with lower relative sodium and potassium concentrations and greater relative calcium and magnesium concentrations (Figure 5.9-6).

Trend Analysis Significant downward trends in the following water-quality measurement end-points were observed in the Christina and Clearwater River system over the RAMP sampling period at each station ($\alpha = 0.05$): sulphate at *test* station CHR-1; and calcium, magnesium and sodium at *baseline* station CHR-2. Total arsenic at *baseline* station CLR-2 also had a statistically significant downward trend, but this is likely an artifact of a decrease in the detection limit for total arsenic from 2003 onwards (Figure 5.9-5).

Water Quality Index WQI values for upstream and downstream stations on the Clearwater River for fall 2008 were identical (i.e., 96.1) and indicated consistency with regional *baseline* conditions (Table 5.9-8). WQI values for both Christina River stations also were similar (i.e., CHR-1: 79.8; CHR-2: 80.4, Table 5.9-8), but indicated a Negligible-Low to Moderate difference from regional baseline conditions, specifically related to relatively high suspended solids, total arsenic, and dissolved phosphorus, which have typically been high in the Christina River over the period of record relative to regional baseline values (Figure 5.9-5).

Summary As of 2008, water quality at stations in the Clearwater River (at *test* station CLR-1 and *baseline* station CLR-2) showed Negligible-Low differences from regional *baseline* conditions. However, water quality at both stations in the Christina River (*baseline* station CHR-2 and *test* station CHR-1) showed deviations from regional *baseline* conditions, including concentrations of suspended solids, dissolved phosphorus and total arsenic that exceeded regional *baseline* conditions in fall 2008. These water quality characteristics have remained relatively consistent over several years at both *test* and *baseline* stations in the Christina River. Although the water quality index score for lower Christina River *test* station CHR-1 was slightly below the benchmark value of 80 (i.e., 79.8), it was comparable with upstream *baseline* station CHR-2, which had similar score (80.4) and identical variation from regional *baseline* conditions. Therefore, Christina River water quality is naturally somewhat different from the regionally defined baseline. Based on *baseline-test* similarities, water quality changes in the Christina River were assessed as Negligible-Low (Table 5.9-1).

5.9.4 Benthic Invertebrate Communities and Sediment Quality

5.9.4.1 Benthic Invertebrate Communities

In fall 2008, benthic invertebrate community samples were collected from:

- a depositional lower reach on the Clearwater River located below the confluence with the Christina River (reach CLR-D-1, designated as *test* since 2002, data available from 2001); and
- a depositional reach on the Clearwater River located above the confluence with the Christina River (reach CLR-D-2, designated as *baseline*, data available from 2001).

2008 Habitat Conditions The physical habitat characteristics two reaches are similar (Table 5.9-9), with depths of 0.5 to 0.6 deep at the time of fall 2008 sampling, and with current velocities of 0.2 to 0.3 m/s. The substrate of both reaches was dominated by sand, with silt and clay less dominant, and, at approximately 1%, total organic carbon content of sediments was low in both reaches (Table 5.9-9). Both reaches had an estimated 0% macrophyte cover.

Relative Abundance of Benthic Invertebrate Community Taxa in 2008 Benthic communities were similar in the lower upper and lower reaches of the Clearwater River, with chironomids comprising over 50% of the fauna in both reaches (Table 5.9-10). Mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) were found in both reaches in low relative abundance. Other dominant groups included fingernail clams (Bivalvia: *Sphaerium*) which accounted for 6% of the fauna in the lower *test* reach and 21% of the fauna in the upper *baseline* reach, and ostracods. A variety of sensitive taxa were present in both reaches in 2008 including the stoneflies *Isoperla* and *Taeniopteryx*, and the mayfly *Ametropus neavei*. The most common chironomids in each reach included *Cryptochironomus*, *Paralauterborniella*, *Polypedilum* and *Stempellinella*.

Values of all benthic invertebrate community measurement endpoints in fall 2008 were within the ranges of normal variation for *baseline* depositional reaches in the RAMP FSA (Figure 5.9-7). Total abundance was highest in 2001 and 2002 at approximately 20,000 individuals per m^2, and is currently lower and at similar levels in both reaches. The number of taxa in fall 2008 was equal to or greater than the previously measured maximum number of taxa at these two reaches. Simpson's Diversity in the lower *test* reach has historically been below the 5^{th} percentile of *baseline* depositional reaches in the RAMP FSA and less than diversity values in the upper *baseline* reach. However, in 2008, diversity at the *test* reach was within the normal range of diversity values for *baseline* depositional reaches in the RAMP FSA and higher than the upper *baseline* reach (Figure 5.9-7). Reach CLR-D-1 had a Simpson's Diversity value that was below the 5^{th} percentile of diversity values for depositional reaches in 2001 when it was still designated as *baseline*; low diversity is not unusual for reach CLR-D-1. %EPT has varied in both reaches from near zero to about 8%, and current values are at about the long-term average for both reaches (Figure 5.9-7).

The results of the Correspondence Analysis indicate (Figure 5.9-8) that the species composition of both reach CLR-D-1, when it was designated as *baseline* and then as *test*, and *baseline* reach CLR-D-2 has up to and including 2008 been within the normal range of variation of *baseline* depositional reaches in the RAMP FSA.

Linear contrasts were used to test for differences in benthic invertebrate community measurement endpoints between reach CLR-D-1 and reach CLR-D-2 (Table 5.9-11). Given that reach CLR-D-1 was designated as *baseline* in 2001 and *test* from 2002 onwards, while reach CLR-D-2 has been designated as *baseline* for the entire period of RAMP sampling, it was possible to test whether differences in benthic measurement endpoints between reaches CLR-D-1 and CLR-D-2 became greater over time in the period that reach CLR-D-1 was designated as *test* (i.e., 2002 and onwards) compared to when it was designated as *baseline* (i.e., 2001). The BT x T contrast presented in Table 5.9-11 makes that comparison. There were no significant differences for any of the benthic invertebrate community measurement endpoints (i.e., BT x T interactions all had p values > 0.05). This result means that the differences in the measurement endpoints between reach CLR-D-1 and reach CLR-D-2 did not become greater over time in the period that reach CLR-D-1 was designated as *test* (i.e., from 2002 onward) as compared to the period it was designated as *baseline* (i.e., 2001).

5.9.4.2 Sediment Quality

Sediment quality was sampled in fall 2008 in the Clearwater River where benthic invertebrate communities were sampled: reach CLR-D-1, upstream of Fort McMurray, designated as *test*, and CLR-D-2, upstream of the Christina River confluence, designated as *baseline*. Fall 2008 sediment quality data from these stations were compared with 2001 to 2003 data.

2008 Results and Historical Ranges of Concentration Sediments at reaches CLR-D-1 and CLR-D-2 were dominated by sand and silt in fall 2008, with a greater proportion of finer particles (i.e., clay and silt) present than in previous years (Table 5.9-12 and Table 5.9-13). Total organic carbon was low for both *test* reach CLR-D-1 (0.64%) and *baseline* reach CLR-D-2 (1.17%). Hydrocarbon concentrations were at or near analytical detection limits for all fractions at *test* reach CLR-D-1, but higher at *baseline* reach CLR-D-2. CLR-D-2 hydrocarbons were dominated by Fraction 3 (C16-C34).

Concentrations of all sediment quality measurement endpoints at *test* reach CLR-D-1 in fall 2008 were within previously measured minimum and maximum concentrations with the exception of several PAH endpoints, which exceeded previously measured (2001-2003) maximum concentrations (Table 5.9-12). Even though the total PAH concentration (1.813 mg/kg) was similar to or lower than sediment samples taken at most sediment quality monitoring stations in the RAMP FSA, the predicted PAH toxicity hazard index for sediments at *test* reach CLR-D-1 was 31.95 (Table 5.9-12); this is extremely high relative to previous RAMP observations anywhere in the RAMP FSA. This high predicted PAH toxicity value is confounded by the nearly non-detectable concentration of total hydrocarbons (C6-C50) in fall 2008 at *test* reach CLR-D-1; the concentration of total hydrocarbons is used in the PAH toxicity prediction to partition soluble PAHs between water and hydrocarbon fractions (Appendix F). Total hydrocarbon and PAH concentrations in sediments are generally correlated in the sediment of the RAMP FSA (RAMP 2007), given PAHs are a component of the total hydrocarbons. The moderate PAH concentrations and the nearly non-detectable total hydrocarbon concentration at *test* reach CLR-D-1 in fall 2008 are therefore difficult to reconcile. Discussions with the consulting analytical laboratories confirmed each result, with appropriate quality-assurance targets met. This inconsistency may possibly be related to heterogeneous distribution of hydrocarbons in the sampled sediments.

At *baseline* reach CLR-D-2, the concentration of total organic carbon and the survival and growth of *Chironomus* were greater than previously measured maxima, while concentrations of retene, total dibenzothiophenes, and total PAHs, as well as predicted PAH toxicity were lower than previously measured minima (Table 5.9-13).

Comparison to Sediment Quality Guidelines The only sediment or soil quality guideline exceedance in sampled sediments in the Clearwater River in fall 2008 was CCME hydrocarbon Fraction 3 for *baseline* reach CLR-D-2, which at 740 mg/kg exceeded the guideline of 300 mg/kg (Table 5.9-13).

Sediment Quality Index SQI values for Clearwater River stations were high for both upstream *baseline* and downstream *test* stations (i.e., 98.4 for both stations), with only one variable out of 73 slightly outside the range of regional *baseline* values at each station (molybdenum at CLR-1, and titanium at CLR-2).

5.9.4.3 Summary

The differences in the benthic invertebrate community in the lower Clearwater River, designated as *test* in 2008, as compared to the benthic invertebrate community in the Clearwater River above the confluence with the Christina River, designated as *baseline* in 2008, are assessed as Negligible-Low (Table 5.9-1) on the basis of the following:

- Differences in benthic invertebrate community measurement endpoints between *test* reach CLR-D-1 and reach CLR-D-2 have been the same between the two periods when *test* reach CLR-D-1 changed from *baseline* to *test* (i.e. 2001 [*baseline*] versus 2002 to 2008 [*test*]).
- All benthic invertebrate community measurement endpoints are currently within the normal range of variation for *baseline* depositional reaches in the RAMP FSA.

In addition, both *test* reach CLR-D-1 and *baseline* reach CLR-D-2 currently contain a number of benthic invertebrate taxa that are considered sensitive.

Differences in sediment quality in fall 2008 in the lower Clearwater River designated as *test*, as compared to regional baseline conditions, are assessed as Negligible-Low (Table 5.9-1):

- Sediment quality at *test* station CLR-D-1 and *baseline* station CLR-D-2 was generally consistent with that of previous years, with concentrations of sediment quality measurement endpoints largely within previously measured and regional *baseline* ranges.
- No clear differences in sediment quality in fall 2008 were apparent between upstream and downstream stations.
- Although a very high predicted PAH toxicity value was calculated for sediment at *test* station CLR-D-1, this was caused by very low total hydrocarbon concentrations measured at this station relative to absolute PAH concentrations, which were similar to historical values and within regional *baseline* ranges.

5.9.5 Fish Populations

Fish population monitoring for 2008 in the Clearwater River/Christina River watersheds consisted of a spring and fall fish inventory on the Clearwater River, as well as fish tissue analysis of northern pike captured during the inventory.

5.9.5.1 Clearwater River Fish Inventory

Species Composition

A total of 1,802 fish were captured during the spring and fall fish inventories in the three reaches of the Clearwater River (Figure 3.4-1), of which:

- 950 fish comprised of 18 species were captured in the spring (Table 5.9-14); and
- 852 fish comprised of 15 species were captured in the fall (Table 5.9-14).

A total of 22 species were captured in the 2008 Clearwater River fish inventory. The species richness in 2008 was the highest-recorded across all sampling years in the RAMP Clearwater River fish inventory data record.

White sucker was the dominant large-bodied fish species captured in both spring and fall, comprising 27% and 30% of the total catch, respectively (Table 5.9-14), followed by walleye in spring, comprising 12% of the total catch and northern pike in the fall, comprising 13% of the total catch. Lake chub was the dominant small-bodied species captured in the spring (16% of the total catch), and trout-perch was the dominant small-bodied species captured in the fall (16% of the total catch) (Table 5.9-14).

As in fall 2007 (the first year that lake whitefish had been captured or observed in the Clearwater River in RAMP fall fish inventories), lake whitefish were captured in low quantities (one individual) in the Clearwater River in the fall season in 2008. It is well documented that lake whitefish migrate in the fall from Lake Athabasca to spawning grounds located upstream of Fort McMurray at Cascade and Mountain rapids in the Athabasca River (Jones *et al*. 1978). The low numbers of lake whitefish captured in the Clearwater River fall fish inventory in fall 2007 and fall 2008 do not represent any deviation from the typical spawning pattern in the Athabasca River.

Sucker species generally undertake a spring migration up the Athabasca River to spawning areas in smaller tributaries in the RAMP FSA and further upstream of Fort McMurray. However, in fall 2008, three longnose suckers exhibiting the red lateral stripe indicative of a ripe male were captured in the Clearwater River. Given the relatively low numbers of male longnose suckers with this secondary spawning characteristic that were captured, it is unlikely to be representative of any deviation from typical spawning patterns.

Fish that were observed but not captured are summarized in Table 5.9-15.

Catch per Unit Effort

The total catch per unit effort (CPUE) for spring and fall 2008 was the highest-recorded CPUE and continues a pattern of increase in total CPUE in both seasons since the beginning of the Clearwater River fish inventory in 2003 (Figure 5.9-9). A summary of CPUE for key indicator species (KIR) species in 2008 and comparisons of 2008 fish inventory results to previous years are as follows (Figure 5.9-10):

- CPUE for walleye in spring 2008 was higher than all previous sampling years, while CPUE in fall 2008 was higher than 2007 (when only one reach was completed) and similar to 2006;

- CPUE for goldeye in spring 2008 was similar to previous years and slightly higher than 2007. As in all years since 2003, there were no goldeye caught in the fall;
- CPUE for white sucker in spring 2008 was lower than in spring 2007 but higher than all other sampling years. CPUE in fall 2008 was the highest-recorded to date;
- CPUE for longnose sucker in spring 2008 was lower than 2007 and second-lowest only to 2005. CPUE in fall 2008 was the highest-recorded to date; and
- CPUE for northern pike in spring and fall 2008 was lower than 2007, but generally higher than all other sampling years.

With the exception of goldeye in the spring, the abundance of KIR species in the Clearwater River, as measured by CPUE, continues to either increase (Figure 5.9-10), particularly for white sucker and walleye, or remain consistent. These trends indicate the use of the Clearwater River for most fish species for spawning activities (spring) and as a feeding area (fall).

Age-Frequency Analysis

Age-frequency distributions (2004, 2005, 2006 and 2008) for fall and spring inventories combined are presented in Figure 5.9-11 and Figure 5.9-12 for walleye and northern pike, respectively. The dominant age classes for walleye were generally within the range of 5 to 7 years across all sampling years (Figure 5.9-11). Male and female walleye reach the age of maturity at 5 and 6 years of age (Joynt and Sullivan 2003), respectively, indicating a dominance of mature adult walleye in the Clearwater River. For northern pike, the dominant age class was between 3 and 5 years (Figure 5.9-12), which is approximately the age at maturity for males and females (Joynt and Sullivan 2003). A second peak was evident between 7 and 8 years of age, but the frequency from 2004 to 2008 in this older age class has decreased, indicating that the northern pike population in the Clearwater River is shifting dominance away from older and towards younger individuals, but is still maintaining a mature adult population necessary for recruitment.

Length-Frequency Analysis

Length-frequency distributions (2003 to 2008) for five KIR for fall and spring inventories combined are presented in Figure 5.9-13 to Figure 5.9-17. Key features of the length-frequency distribution for each species follow.

The dominant length class for walleye in 2008 was 401 to 450 mm (31% of all walleye captured), which was one of the two dominant length classes in 2007 (the 351 to 400 mm length class was also dominant in 2007) (Figure 5.9-13). The 2008 length frequency distribution is similar to historical length-frequency distributions for this species, but exhibits a decrease in abundance of walleye in the smaller length classes that has been observed in previous years possibly indicating a shift in dominance to an older population in the Clearwater River. In the Athabasca River, the abundance in the smaller length classes has shown an increase from all historical years with the exception of 2006 (Figure 5.9-13). The number of walleye captured in 2008 was higher than all previous sampling years and so indicating a representative sample of the population.

Similarly to 2007, the dominant length class for goldeye in 2008 was 401 to 425 mm (Figure 5.9-14), an increase in dominant length class from prior years (351 to 375 mm and 376 to 400 mm) and also greater than the dominant goldeye length class in the 2008

Athabasca River fish inventory, (Figure 5.9-14, 151 to 175 mm). While the goldeye length-frequency distribution in the Clearwater River in 2008 indicates a shift in dominance to larger individuals, there were relatively few goldeye caught in 2008 (n=14) and the length-frequency distribution of these captured individuals is likely not representative of the length-frequency distribution of the entire goldeye population.

The dominant length class for longnose sucker captured in 2008 was 251 to 300 mm, which is higher than the dominant length class in 2007 (101 to 150 mm) and for previous Clearwater fish inventories (Figure 5.9-15). However, as with all previous years of the Clearwater fish inventory (with few exceptions), all captured longnose sucker in 2008 were less than 400 mm. In contrast, the dominant length class of longnose sucker captured in the Athabasca River in 2008 was 401 to 450 mm (Figure 5.9-15). As the number of longnose sucker caught in 2008 (n=92, Table 5.9-14) was the most of the entire RAMP fish inventory for the Clearwater river, the length-frequency distribution of the captured population is likely a good representation of the length-frequency distribution of the entire population of longnose sucker in the Clearwater River.

The dominant length class for white sucker captured in 2008 was 101 to 150 mm, (Figure 5.9-16); this is lower than historical length-frequency distributions for this species in the Clearwater River fish inventory. The white sucker length-frequency distribution in the Clearwater River in 2008 exhibited a shift to shorter lengths as compared to previous years (Figure 5.9-16). In the Athabasca River; however, the dominant length class of 401 to 450 mm remained consistent with that of previous years (Figure 5.9-16). As 515 white sucker were caught in 2008 (Table 5.9-14), the length-frequency distribution of the captured population is likely a good representation of the length-frequency distribution of the entire population of white sucker in the Clearwater River.

The co-dominant length classes for northern pike in the 2008 Clearwater River fish inventory were 551 to 600 mm and 601 to 650 mm (Figure 5.9-17), which is similar to the 2007 length-frequency distribution for this species. The northern pike length-frequency distribution in the Athabasca River fish inventory in 2008 also indicated a dominance in the 551 to 600 mm length class (Figure 5.9-17), as well as dominance in the 351 to 400 mm size class. As 163 northern pike were caught in the 2008 Clearwater River fish inventory (Table 5.9-14), the length-frequency distribution of the captured population is likely a good representation of the length-frequency distribution of the entire population of northern pike in the Clearwater River.

Condition Factor

Mean condition factor for KIR fish species captured during the 2008 Clearwater River inventory are presented in Figure 5.9-18 for spring and fall, 2003 to 2008. Separate analysis of covariance (ANCOVA) was performed on spring- and fall-captured fish. As with the ANCOVA analysis from 2007, there were more instances of significant year-to-year differences in condition factor of fish captured in the fall than in the spring. The species-specific results are as follows (two p-values are given for each ANCOVA, the first is for the comparison of slopes and the second is for the comparison of intercepts):

- There were significant differences among years in the condition of both spring-captured walleye ($p = 0.4/p < 0.05$) and fall-captured walleye ($p = 0.8/p > 0.05$). Condition of spring and fall walleye was variable among years but lower in both seasons in 2008 than in previous years;

- There were no significant differences in the condition of spring-captured goldeye among years ($p = 0.3/p > 0.05$); there were no goldeye captured during the fall inventory;

- While there were no significant differences in the condition of spring-captured longnose sucker among years ($p = 0.9/p > 0.05$), there were significant differences in condition of fall-captured longnose sucker among years ($p = 0.1/p < 0.05$). Condition of longnose sucker was higher in 2008 relative to previous years in spring, but lower relative to previous years in fall;

- As with the ANCOVA results for white sucker in 2007, there were no significant differences among years in condition of white sucker in spring ($p = 0.9/p > 0.05$), but there were significant differences in condition of white sucker in fall ($p = 0.7/p < 0.05$). In 2008, white sucker condition was higher in spring and lower in fall relative to previous years of sampling (condition only showed relatively little variability across years up until 2008); and

- There were significant differences among years in condition of northern pike captured in the spring ($p = 0.05/\mathrm{p} < 0.05$) and fall ($p = 0.1/p < 0.05$). In spring and fall, the condition factor of northern pike was lower than all previous years of the Clearwater River fish inventory.

Currently only condition can be applied as a measurement endpoint for the large-bodied species in the Clearwater River fish inventory. Environment Canada (2005) has defined a critical effect size for fish condition as ± 10% relative to *baseline* fish. From this perspective, a >10% change in condition is considered important suggesting a need for further evaluation (e.g., confirmation over time, follow-up studies, etc.) The two upper reaches (CR1 and CR2) of the Clearwater fish inventory are designated as *baseline* and the lower reach (CR3) is designated as *test*. This criterion was exceeded for northern pike in spring and longnose sucker in fall for which there was a greater than 10% difference in the average condition factor in *test* reach CR3 as compared to *baseline* reaches CR1 and CR2.

External Health Assessment

Observed anomalies were primarily associated with minor skin aberrations or wounds, scars and fin erosion. In 2008, 103 out of 950 fish (10.8%) in the spring and 22 out of 852 fish (2.6%) in the fall were found to have some type of external anomaly. These incidences of external anomalies are approximately half the incidence of external anomalies recorded in 2007 (RAMP 2008) and similar to the incidence of external anomalies recorded in 2006 (RAMP 2007). The mean health assessment index (HAI) for all KIR species (Table 5.9-16) was within the historical range for all species and lower than 2007 for all species with the exception of walleye, which in 2008 had the highest-recorded health assessment index for the RAMP Clearwater fish inventory.

Thirteen (8 in the spring, 5 in the fall) out of 1,802 fish (0.7%) showed more severe anomalies such as parasites, growths, lesions or body deformities. A summary of the percentage of fish by year and species with some form of pathology is presented in Table 5.9-17; the percentage of captured fish with evidence of external pathology in 2008 was within the historical range for all species with the exception of walleye.

Summary Assessment for Fish Inventory

The Clearwater fish inventory is considered to be a community-driven activity which is primarily suited for assessing general trends in abundance and population variables for large-bodied species, rather than assessing detailed fish community structure. A summary of the 2008 Clearwater fish inventory indicates:

- few changes or trends in length and age frequency distributions, with the exception of a shift in dominant length class for longnose sucker (increasing) and white sucker (decreasing);
- continued increasing trends in spring and fall total CPUE for all species with the exception of goldeye in the spring;
- more instances of significant year-to-year differences in condition factor of fish captured in the fall than in the spring;
- longnose sucker and northern pike in *test* reach CR3 had a greater than 10% difference in condition relative to *baseline* reaches CR1 and CR2; and
- health assessment index and %captured fish with external pathology for all species was within previously measured ranges with the exception of walleye for which both of these measurement endpoints were greater than previously measured maxima.

Figure 5.9-3 Clearwater River: 2008 hydrograph and historical context.

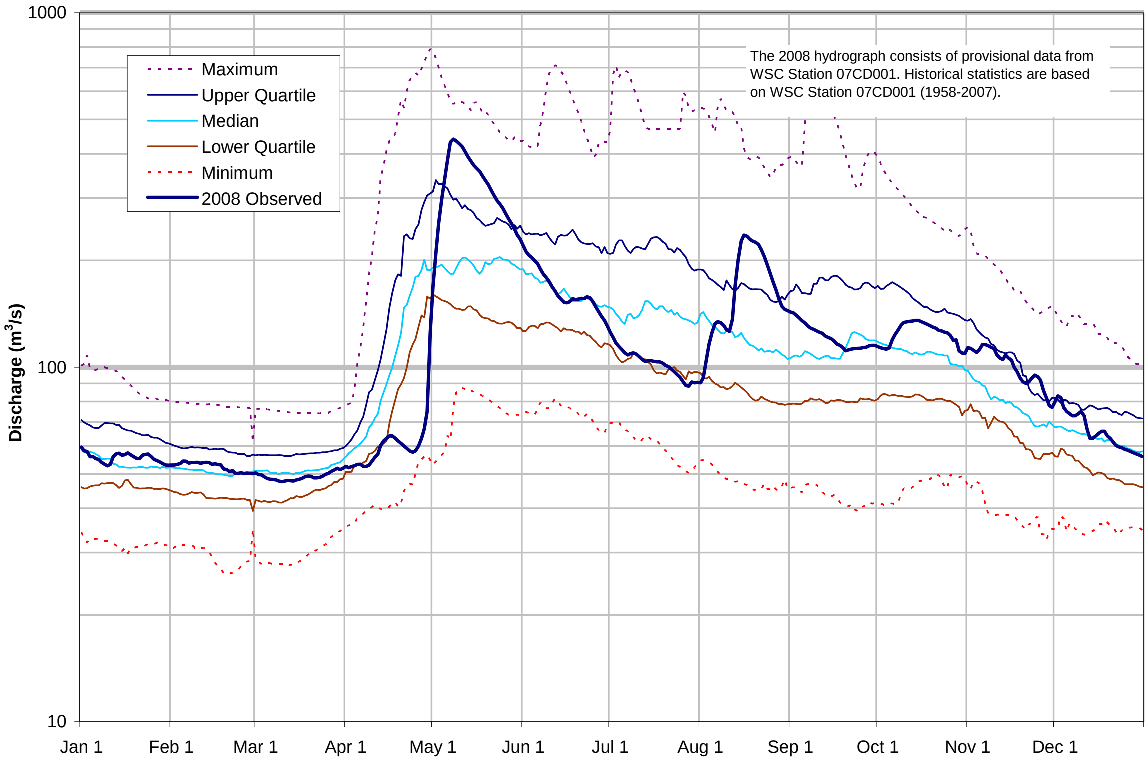


Figure 5.9-4 Christina River: 2008 hydrograph and historical context.

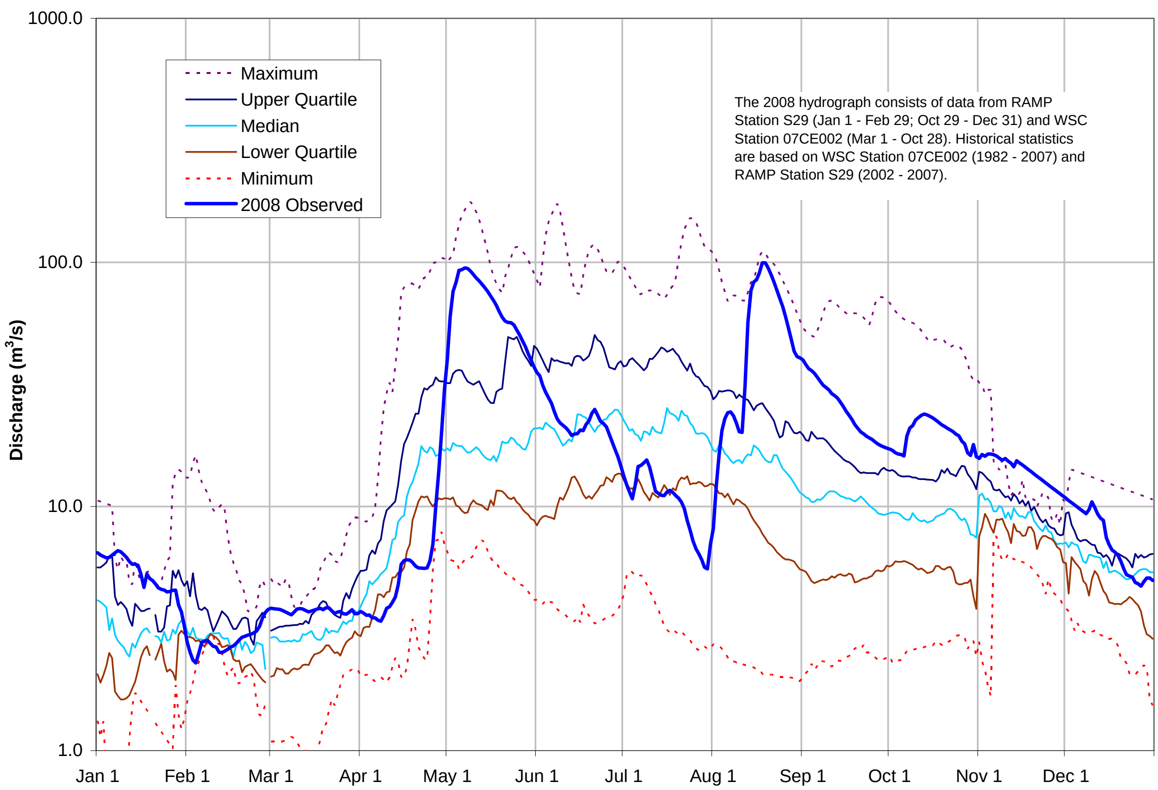


Table 5.9-2 Estimated changes in annual discharge in the Christina River watershed as a result of focal projects and other active oil sands projects in the watershed.

Component of Calculation	Volume (million m^3)		Basis and Source of Data
	Focal Projects	Focal Projects Plus All Other Active Oil Sands Projects in Christina River Watershed	
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+0.146	+0.845	1.12 km^2 and 5.35 km^2 estimated to have been closed-circuited from focal projects and from focal projects plus other active oil sands projects, respectively, within Christina River watershed as of 2008 (Table 2.4-1).
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.347	-0.888	13.28 km^2 and 20.72 km^2 estimated to have undergone land change as of 2008, but are not closed-circuited, from focal projects and from focal projects plus other active oil sands projects, respectively, within Christina River watershed as of 2008 (Table 2.4-1).
Withdrawals from the Christina River by focal projects or oil sands developments	0	0	None reported, assumed to be negligible
Releases to the Christina River by focal projects or oil sands developments	0	0	None reported, assumed to be negligible
Diversions into or out of the watershed	0	0	None reported
The difference between observed and *baseline* hydrographs on tributary streams	0	0	No focal projects or other oil sands projects on tributaries of Christina River not accounted for in figures contained in this table.
Incremental flow (change in total annual discharge)	-0.20	-0.043	Total annual discharge from estimated *baseline* hydrograph less total annual discharge measured from observed hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.9-3 Concentrations of water quality measurement endpoints, mouth of Clearwater River (CLR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	7	7.5	8.1	8.2
Total Suspended Solids	mg/L	-[1]	16	7	<3	12	38
Conductivity	µS/cm	-	230	7	177	233	291
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.026	7	0.012	0.022	0.044
Total nitrogen*	mg/L	1.0	0.7	7	0.3	0.6	0.7
Nitrate+Nitrite	mg/L	1.0	<0.1	7	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	14	7	8	10	16
Ions							
Sodium	mg/L	-	19	7	16	22	31
Calcium	mg/L	-	17.9	7	14.7	17.4	20.1
Magnesium	mg/L	-	5.9	7	5.1	5.7	6.5
Chloride	mg/L	230, 860[3]	26	7	17	25	43
Sulphate	mg/L	100[4]	5.3	7	1.4	6	7.7
Total Dissolved Solids	mg/L	-	163	7	60	150	200
Total Alkalinity	mg/L	-	72	7	59	66	74
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.37**	7	**0.14**	**0.58**	**1.46**
Dissolved aluminum	mg/L	0.1[2]	0.009	7	<0.01	0.009	0.015
Total arsenic	mg/L	0.005	0.0009	7	<0.001	0.0008	0.0014
Total boron	mg/L	1.2[5]	0.0323	7	0.0275	0.0342	0.0548
Total molybdenum	mg/L	0.073	0.0002	7	0.0002	0.0002	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0989	7	0.079	0.101	0.118
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.005**	7	**<0.003**	**0.004**	**0.009**
Dissolved iron	mg/L	0.3[2]	**0.425**	7	0.161	0.277	**0.756**
Total phosphorus	mg/L	0.05	**0.063**	7	0.033	**0.051**	**0.109**
Total iron	mg/L	0.3	**1.27**	7	**0.51**	**1.04**	**2.43**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.9-4 Concentrations of water quality measurement endpoints, upper Clearwater River (CLR-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	7	7.2	7.9	8.0
Total Suspended Solids	mg/L	-[1]	12	7	7	14	36
Conductivity	µS/cm	-	202	7	138	205	249
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.017	7	0.010	0.020	0.026
Total nitrogen*	mg/L	1.0	0.4	7	0.3	0.5	**1.2**
Nitrate+Nitrite	mg/L	1.0	<0.1	7	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	9	7	6	7	9
Ions							
Sodium	mg/L	-	11	7	13	18	29
Calcium	mg/L	-	21.6	7	10.0	11.9	14.7
Magnesium	mg/L	-	7	7	3.7	4.2	4.5
Chloride	mg/L	230, 860[3]	29	7	16	28	43
Sulphate	mg/L	100[4]	5.5	7	<0.5	6.4	7.7
Total Dissolved Solids	mg/L	-	124	7	40	114	160
Total Alkalinity	mg/L	-	51	7	39	44	51
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.102**	7	**0.13**	**0.24**	**0.70**
Dissolved aluminum	mg/L	0.1[2]	0.0048	7	0.0051	0.0072	0.0400
Total arsenic	mg/L	0.005	0.0241	7	0.0142	0.0236	0.03
Total boron	mg/L	1.2[5]	0.0004	7	<0.001	0.001	0.001
Total molybdenum	mg/L	0.073	0.0001	7	0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	1.2
Total strontium	mg/L	-	0.0853	7	0.061	0.084	0.094
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.005**	7	**<0.003**	0.005	**0.013**
Total iron	mg/L	0.3	**0.545**	7	**0.56**	**0.79**	**2.07**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.9-5 Concentrations of water quality measurement endpoints, mouth of Christina River (CHR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	6	8.1	8.3	8.4
Total Suspended Solids	mg/L	-[1]	49	6	<3	20.5	38
Conductivity	µS/cm	-	244	6	269	293	375
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.054**	6	0.021	0.024	0.033
Total nitrogen*	mg/L	1.0	**1.2**	6	0.6	0.95	**1.6**
Nitrate+Nitrite	mg/L	1.0	<0.1	6	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	25	6	14	18	22
Ions							
Sodium	mg/L	-	16	6	19	25.5	34
Calcium	mg/L	-	25.4	6	25.9	27.6	29.7
Magnesium	mg/L	-	7.9	6	7.8	8.45	9.1
Chloride	mg/L	230, 860[3]	17	6	21	26	41
Sulphate	mg/L	100[4]	5	6	2.2	6.9	7.9
Total Dissolved Solids	mg/L	-	185	6	140	189.5	250
Total Alkalinity	mg/L	-	95	6	101	107	118
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.57**	6	**0.24**	**0.60**	**0.77**
Dissolved aluminum	mg/L	0.1[2]	0.0182	6	0.0066	0.0095	0.0144
Total arsenic	mg/L	0.005	0.0017	6	0.0007	0.0010	0.0012
Total boron	mg/L	1.2[5]	0.0391	6	0.027	0.052	0.066
Total molybdenum	mg/L	0.073	0.0004	6	0.0002	0.0004	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	2.4
Total strontium	mg/L	-	0.107	6	0.078	0.127	0.145
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.009**	6	**<0.003**	**0.0045**	**0.011**
Total phosphorus	mg/L	0.05	**0.131**	6	0.049	**0.063**	**0.108**
Total Kjeldahl nitrogen	mg/L	1.0	**1.1**	6	0.5	0.85	**1.5**
Total iron	mg/L	0.3	**2.51**	6	**0.778**	**1.335**	**1.69**
Dissolved iron	mg/L	0.3[2]	**0.957**	6	0.255	**0.434**	**0.711**
Total phenols	mg/L	0.004	**0.008**	6	<0.001	0.0025	**0.014**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[8] Guidelines are for chromium III (0.0089 mg/L) and chromium VI (0.0010 mg/L).

Table 5.9-6 Concentrations of water quality measurement endpoints, upper Christina River (CHR-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	6	8	8.2	8.3
Total Suspended Solids	mg/L	-[1]	22	6	<3	8	13
Conductivity	µS/cm	-	164	6	187	208	266
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	**0.053**	6	0.026	0.036	**0.051**
Total nitrogen*	mg/L	1.0	**1.1**	6	0.6	0.8	**1.4**
Nitrate+Nitrite	mg/L	1.0	<0.1	6	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	26	6	13	16.5	20
Ions							
Sodium	mg/L	-	5	6	6	6.5	10
Calcium	mg/L	-	22.6	6	25.5	28.0	35.1
Magnesium	mg/L	-	7	6	7.6	8.15	10.6
Chloride	mg/L	230, 860[3]	1	6	<1	2	2
Sulphate	mg/L	100[4]	3.2	6	3.2	5.1	9.6
Total Dissolved Solids	mg/L	-	139	6	130	146	240
Total Alkalinity	mg/L	-	82	6	92	104	138
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.293**	5	0.049	**0.186**	**0.304**
Dissolved aluminum	mg/L	0.1[2]	0.0193	5	0.0041	0.0078	0.0129
Total arsenic	mg/L	0.005	0.0016	5	0.0007	0.0009	0.0012
Total boron	mg/L	1.2[5]	0.0253	5	0.0276	0.0316	0.0459
Total molybdenum	mg/L	0.073	0.0004	5	0.0004	0.0004	0.0006
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.8	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.0872	5	0.096	0.099	0.147
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.007**	6	**<0.003**	**0.0065**	**0.04**
Total phosphorus	mg/L	0.05	**0.108**	6	0.048	**0.0635**	**0.095**
Total iron	mg/L	0.3	**2.35**	5	**0.999**	**1.13**	**2.62**
Dissolved iron	mg/L	0.3[2]	**1.08**	5	**0.406**	**0.636**	**1.41**
Total phenols	mg/L	0.004	**0.008**	6	<0.001	**0.01**	**0.019**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.9-7 Water quality guideline accidences, Clearwater-Christina River watersheds, 2008.

Variable	Units	Guideline*	CHR-1	CHR-2	CLR-1	CLR-2
Fall						
Sulphide	mg/L	0.002[2]	**0.009**	**0.007**	**0.005**	**0.005**
Total phosphorus	mg/L	0.05	**0.131**	**0.108**	**0.063**	**-**
Total dissolved phosphorus	mg/L	0.05[1]	**0.054**	**0.053**	**-**	**-**
Total aluminum	mg/L	0.1	**0.57**	**0.293**	**0.37**	**0.102**
Dissolved iron	mg/L	0.3[1]	**0.957**	**1.08**	**0.425**	**-**
Total iron	mg/L	0.3	**2.51**	**2.35**	**1.27**	**0.545**
Total Kjeldahl Nitrogen	mg/L	1.0	**1.1**	**-**	**-**	**-**
Total nitrogen	mg/L	1.0	**1.2**	**1.1**	**-**	**-**
Total phenols	mg/L	0.004	**0.008**	**0.008**	**-**	**-**

CHR-1, CHR-2, CLR-1 and CLR-2 were sampled only in fall 2008.

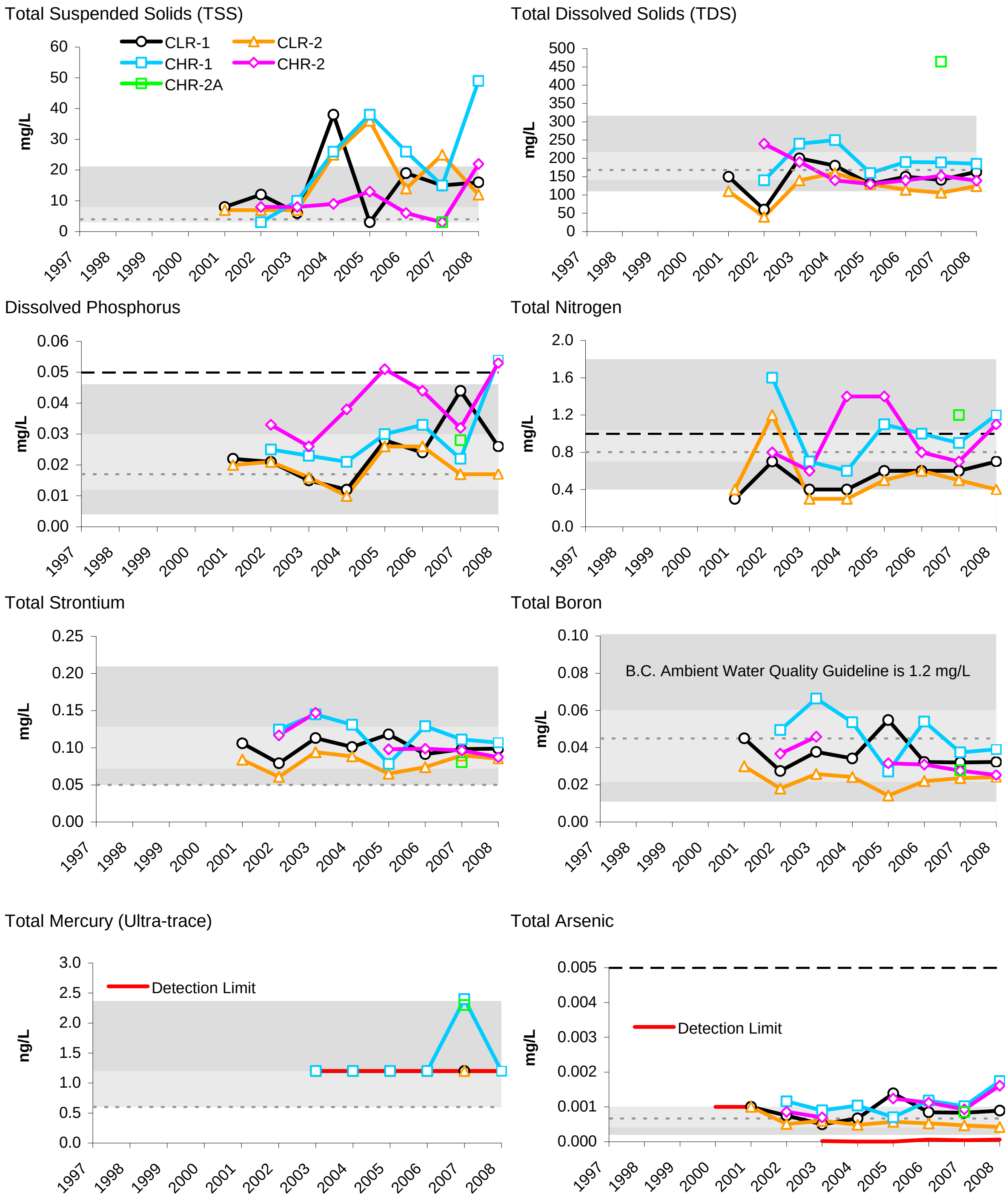
* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] Guideline is for total analyte (no guideline for dissolved species).

[2] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[3] Guidelines are hardness-dependent.

Figure 5.9-5 Concentrations of selected water quality measurement endpoints in the Clearwater and Christina watersheds (fall data) relative to regional baseline fall concentrations.

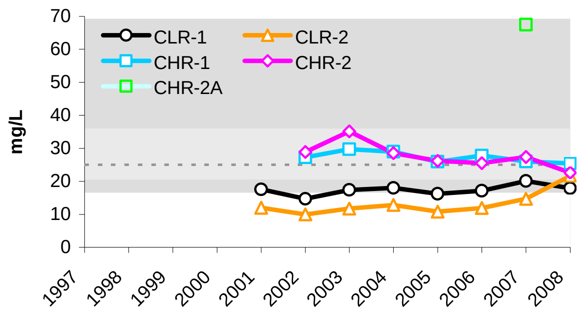


Non-detectable values are shown at the detection limit.

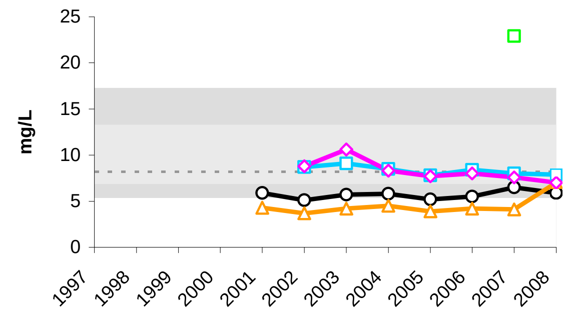
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.9-5 (Cont'd.)

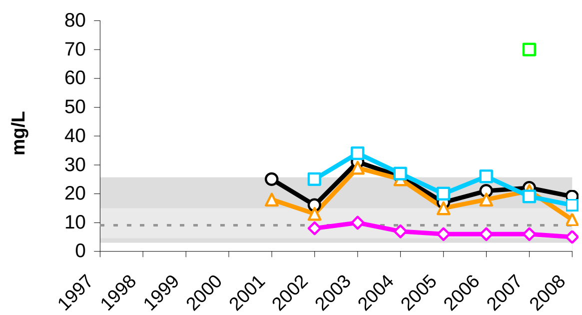
Calcium



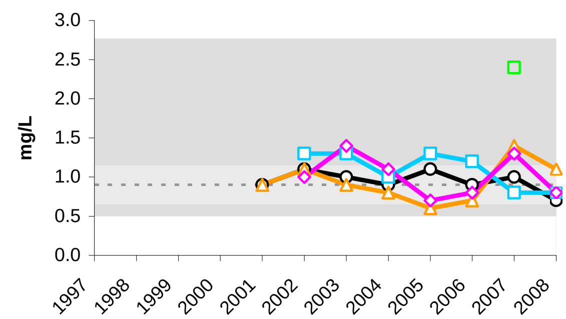
Magnesium



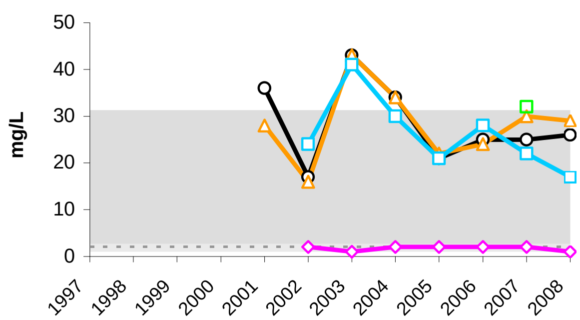
Sodium



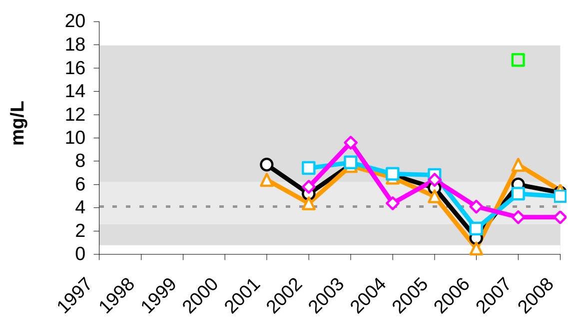
Potassium



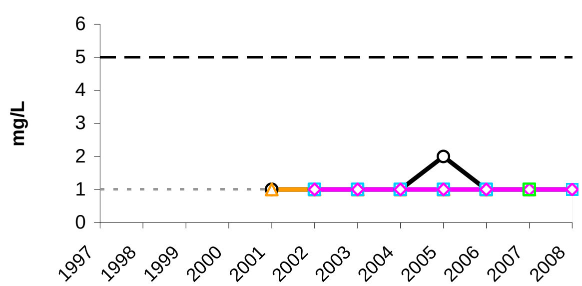
Chloride



Sulphate



Naphthenic Acids



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.9-6 Piper diagram of fall ion concentrations in the Clearwater-Christina River watersheds.

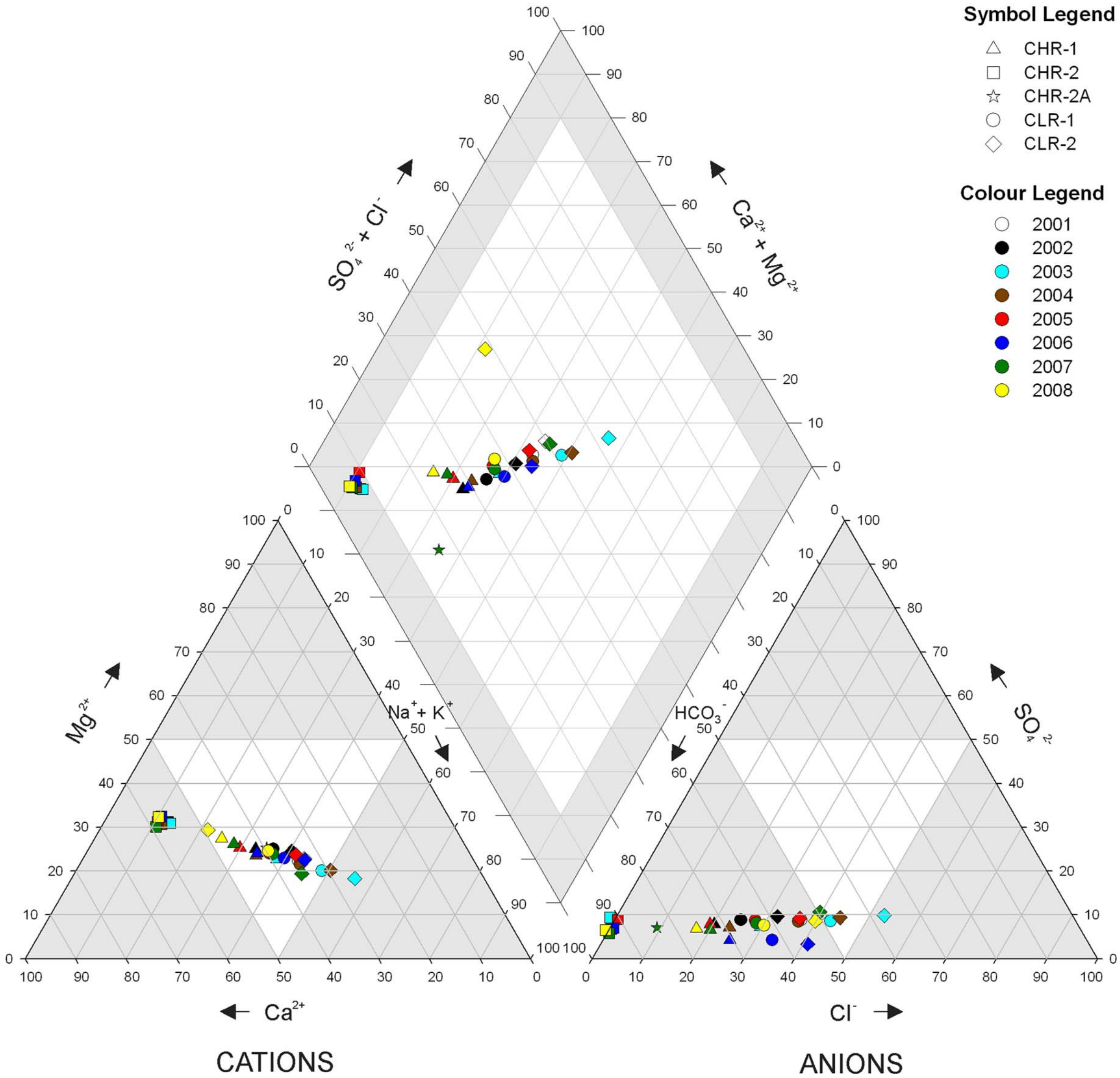


Table 5.9-8 Water quality index (fall 2008) for Clearwater-Christina river watershed stations.

Station Identifier	Location	2008 Designation	Water Quality Index	Classification
CLR-1	Upstream of Fort McMurray	*test*	96.1	Negligible-Low
CLR-2	Upstream of Christina River	*baseline*	96.1	Negligible-Low
CHR-1	Near the mouth of the Christina River	*test*	79.8	Moderate
CHR-2	Upstream of Janvier	*baseline*	80.4	Negligible-Low

Note: see Figure 5.9-1 for the locations of these water quality stations.
Note: see Section 3.2.7.4 for a description of the Water Quality Index.

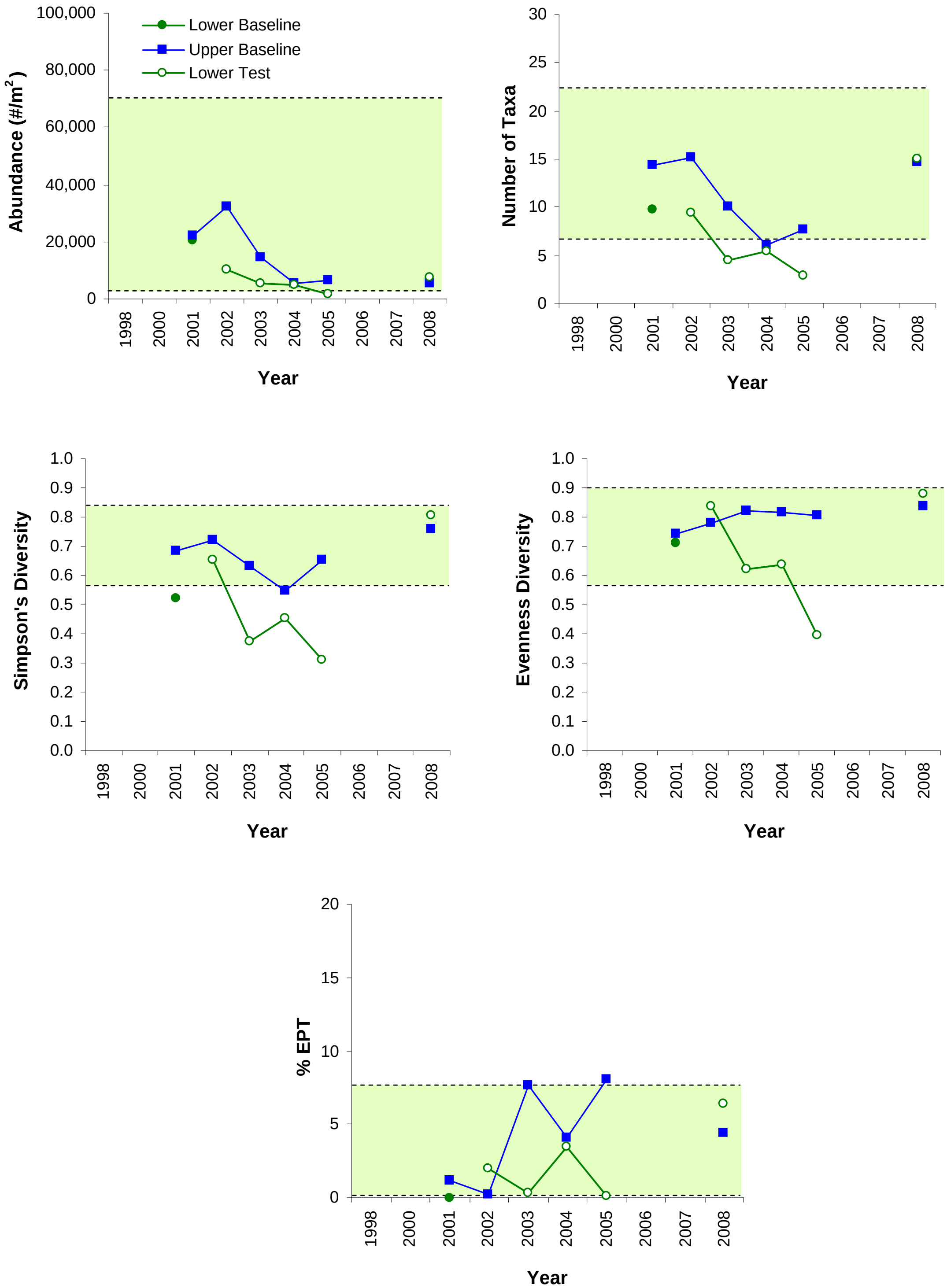
Table 5.9-9 Habitat characteristics of benthic invertebrate community sampling reaches in the Clearwater River.

Variable	Units	Lower Clearwater Reach CLR-D-1	Upper Clearwater Reach CLR-D-2
Sample date	-	Sept. 11, 2008	Sept. 5, 2008
Habitat	-	Depositional	Depositional
Water depth	m	0.5	0.6
Current velocity	m/s	0.3	0.2
Macrophyte cover	%	0	0
Field Water Quality			
Dissolved oxygen	mg/L	8.8	10.6
Conductivity	µS/cm	224	189
pH	pH units	8.2	8.1
Water temperature	°C	12.2	13.4
Sediment Composition			
Sand	%	80	70
Silt	%	13	21
Clay	%	7	9
Total Organic Carbon	%	0.7	1.2

Table 5.9-10 Major taxon percent abundances and benthic invertebrate community measurement endpoints in the Clearwater River.

Taxon	Percent Major Taxa Enumerated in Each Year											
	Reach CLR-D-1						Reach CLR-D-2					
	2001	2002	2003	2004	2005	2008	2001	2002	2003	2004	2005	2008
Amphipoda							<1	<1	<1			
Anisoptera	1	1	<1	<1	<1	1	<1	<1	<1	1	2	<1
Bivalvia	20	6	1	1	<1	6	11	10	33	14	1	21
Ceratopogonidae	1	2	<1	1	6	2	1	1	4	<1	1	1
Chironomidae	38	68	80	87	57	51	34	51	27	32	44	58
Chydoridae	3			<1			1	<1	<1			
Coleoptera		<1		<1			<1	<1	<1			
Copepoda							<1	<1		1		<1
Dolichopodidae									<1	<1		
Empididae		1		<1	1	<1	<1	<1		1	1	1
Enchytraeidae		2		<1		<1	<1		1		1	<1
Ephemeroptera	<1	2	<1	1	<1	1	1	<1	<1	1	1	1
Erpobdellidae									<1	<1		
Gastropoda	<1	<1			<1	<1	1	<1	<1		<1	<1
Glossiphoniidae	<1						<1		<1	<1		
Heteroptera	<1	0						<1	<1			
Hydracarina	<1			<1			<1	<1	<1			
Lepidoptera		<1						<1				
Lumbriculidae			<1					<1	<1	<1		
Macrothricidae								5	<1	<1		
Megaloptera							<1					
Naididae	3	3	2	1	<1	5	21	5	10	1	1	<1
Nematoda	<1	<1	<1	<1	4	1	1	1	1	8	<1	5
Ostracoda	6	2				14	3	7	12	<1		4
Plecoptera		1		<1		1	<1		<1	<1	1	<1
Simuliidae		<1	2			<1	<1	<1				2
Tabanidae	<1	<1					<1	<1		<1	<1	<1
Tipulidae								<1	<1	1		<1
Trichoptera		1				<1	<1	<1	<1		2	1
Tubificidae	27	10	14	6	31	17	26	17	8	40	45	3
Zygoptera	<1	<1					<1	<1		<1		
Benthic Invertebrate Community Measurement Endpoints												
Total Abundance (No./m^2)	21,842	32,491	14,310	5,572	6,443	5,452	20,601	10,141	5,126	4,991	1,522	7,379
Richness	14	15	10	6	8	15	10	9	4	5	3	15
Simpson's Diversity	0.68	0.72	0.63	0.55	0.65	0.76	0.52	0.65	0.37	0.45	0.31	0.81
Evenness	0.74	0.78	0.82	0.81	0.80	0.84	0.71	0.84	0.62	0.64	0.40	0.88
% EPT	1	0	8	2	8	3	0	1	0	3	0	4

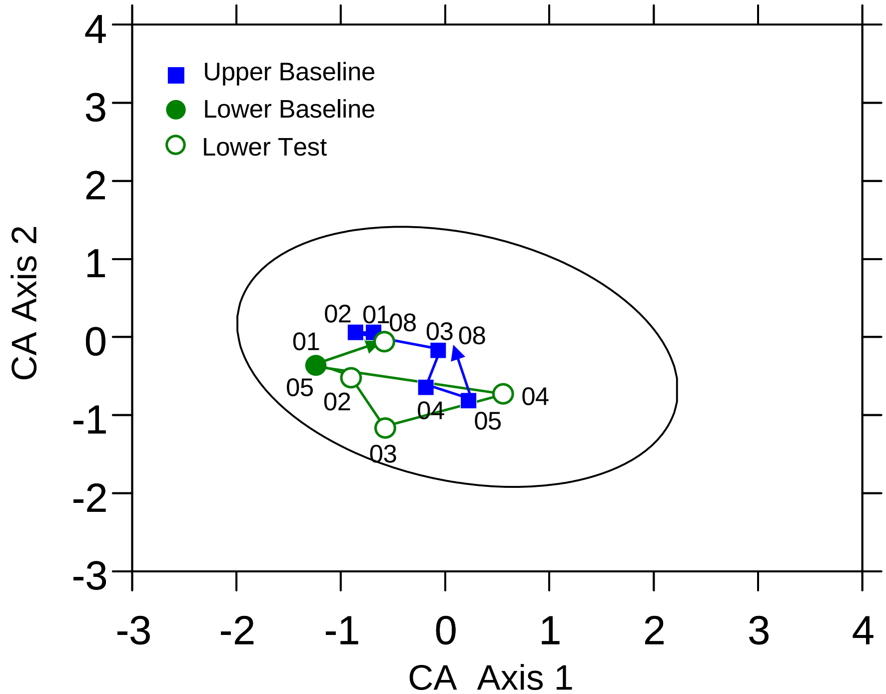
Figure 5.9-7 Variation in benthic invertebrate community measurement endpoints in the Clearwater River, reach CLR-D-1 and reach CLR-D-2.

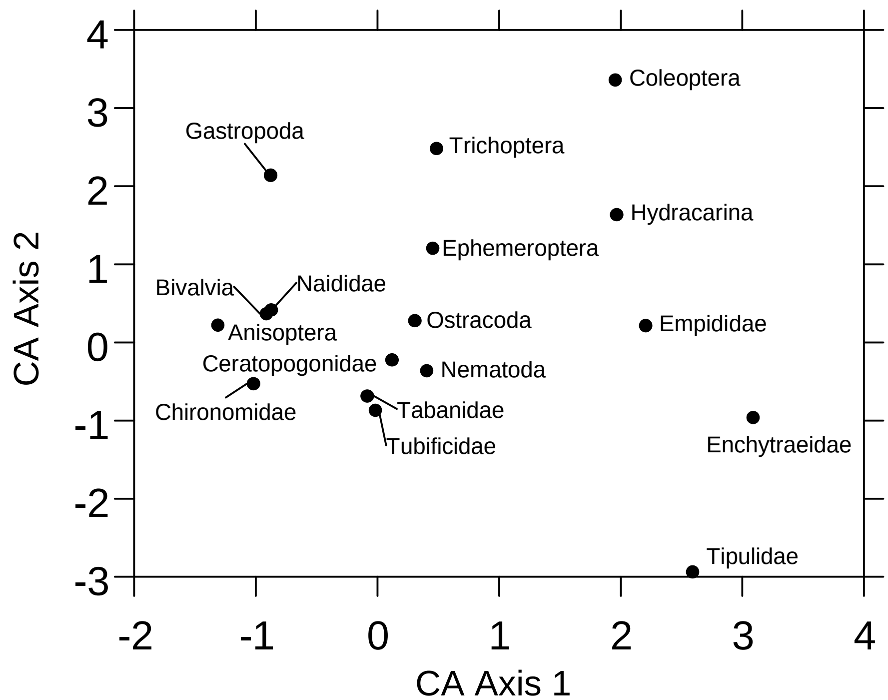


Note: dotted lines indicated the 5th and 95th percentiles for each measurement endpoint based on distribution of annual means in *baseline* erosional reaches in the RAMP FSA.

Note: lower *baseline* - reach CLR-D-1 in 2001; lower *test* - reach CLR-D-1 from 2002 onward; upper *baseline* – reach CLR-D-2

Figure 5.9-8 Ordination (Correspondence Analysis) of depositional river benthic invertebrate communities showing the upper and lower reaches of the Clearwater River.





Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the data for *baseline* depositional reaches in the RAMP FSA.

Note: lower *baseline* - reach CLR-D-1 in 2001; lower *test* - reach CLR-D-1 from 2002 onward; upper *baseline* – reach CLR-D-2; numbers in upper panel refer to the sampling year for each data point.

Table 5.9-11 Results of analysis of variance (ANOVA) between lower (CLR-D-1) and upper (CLR-D-2) reaches of the Clearwater River.

Variable	Source	SS	df	MS	F-ratio	P
Log Abundance	Reach - Year	35.901	11	3.264	5.67	0.000
	Baseline vs Test (BT)	3.961	1	3.961	6.89	0.010
	Linear Time Trend (T)	8.306	1	8.306	14.44	0.000
	BT x T	0.014	1	0.014	0.03	0.875
	Remainder (noise)	23.619	8	2.952	5.13	0.025
	Error	85.147	148	0.575		
Log Richness	Reach - Year	6.487	11	0.590	9.04	0.000
	Baseline vs Test (BT)	1.410	1	1.410	21.62	0.000
	Linear Time Trend (T)	0.671	1	0.671	10.29	0.002
	BT x T	0.000	1	0.000	0.00	0.947
	Remainder (noise)	4.406	8	0.551	8.45	0.004
	Error	9.650	148	0.065		
Diversity	Reach - Year	3.144	11	0.286	5.15	0.000
	Baseline vs Test (BT)	0.842	1	0.842	15.16	0.000
	Linear Time Trend (T)	0.002	1	0.002	0.04	0.842
	BT x T	0.002	1	0.002	0.04	0.843
	Remainder (noise)	2.298	8	0.287	5.18	0.024
	Error	8.221	148	0.056		
Evenness	Reach - Year	2.240	11	0.204	3.95	0.000
	Baseline vs Test (BT)	0.55	1	0.55	10.66	0.001
	Linear Time Trend (T)	0.01	1	0.01	0.16	0.694
	BT x T	0.065	1	0.065	1.25	0.265
	Remainder (noise)	1.617	8	0.202	3.92	0.050
	Error	7.635	148	0.052		
Log %EPT	Reach - Year	2.66	11	0.24	1.53	0.125
	Baseline vs Test (BT)	0.25	1	0.25	1.58	0.211
	Linear Time Trend (T)	0.39	1	0.39	2.45	0.119
	BT x T	0.10	1	0.10	0.67	0.416
	Remainder (noise)	1.92	8	0.24	1.52	0.219
	Error	23.31	148	0.16		
CA Axis 1	Reach - Year	49.77	11	4.52	5.12	0.000
	Baseline vs Test (BT)	6.69	1	6.69	7.58	0.007
	Linear Time Trend (T)	9.02	1	9.02	10.21	0.002
	BT x T	0.09	1	0.09	0.10	0.756
	Remainder (noise)	34.0	8	4.246	4.81	0.030
	Error	129.87	147	0.88		
CA Axis 2	Lake - Year	22.03	11	2.00	2.01	0.032
	Baseline vs Test (BT)	2.84	1	2.84	2.85	0.094
	Linear Time Trend (T)	1.68	1	1.68	1.68	0.196
	BT x T	0.09	1	0.09	0.09	0.767
	Remainder (noise)	17.42	8	2.18	2.18	0.142
	Error	146.82	147	1.00		

Table 5.9-12 Sediment quality measurement endpoints, Clearwater River near Fort McMurray (reach CLR-D-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables [4]							
Clay	%	-	6.4	3	2	4	33
Silt	%	-	13.2	3	12	24	29
Sand	%	-	80.2	3	38	74	84
Total organic carbon	%	-	0.64	3	0.3	0.3	1
Total hydrocarbons							
BTEX	mg/kg	-	<5	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	5	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	300[2]	<5	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	7	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0025	3	0.001	0.001	0.002
Retene	mg/kg	-	0.047	3	0.008	0.010	0.01
Total dibenzothiophenes	mg/kg	-	0.520	3	0.027	0.106	0.11
Total PAHs	mg/kg	-	1.813	3	0.297	0.434	0.64
Total Parent PAHs	mg/kg	-	0.087	3	0.028	0.030	0.04
Total Alkylated PAHs	mg/kg	-	1.726	3	0.269	0.404	0.61
Predicted PAH toxicity[1]	H.I.	-	31.95	3	0.173	0.717	1.37
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	ns	-	-	-	-
Chironomus growth - 10d	mg/organism	-	ns	-	-	-	-
Hyalella survival - 14d	# surviving	-	ns	1	-	-	5
Hyalella growth - 14d	mg/organism	-	ns	1	-	-	1.1

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 10 replicates.

ns= not sampled

Table 5.9-13 Sediment quality measurement endpoints, Clearwater River above confluence with Christina River (reach CLR-D-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	9.2	3	2	4	33
Silt	%	-	20.9	3	12	24	29
Sand	%	-	69.7	3	38	74	84
Total organic carbon	%	-	1.17	3	0.3	0.3	1
Total hydrocarbons							
BTEX	mg/kg	-	<5	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	65	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	300[2]	**740**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	450	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.001	3	0.001	0.001	0.002
Retene	mg/kg	-	0.0018	3	0.003	0.003	0.004
Total dibenzothiophenes	mg/kg	-	0.001	3	0.001	0.002	0.00
Total PAHs	mg/kg	-	0.013	3	0.033	0.035	0.20
Total Parent PAHs	mg/kg	-	0.004	3	0.005	0.009	0.02
Total Alkylated PAHs	mg/kg	-	0.009	3	0.026	0.028	0.18
Predicted PAH toxicity[1]	H.I.	-	0.003	3	0.216	0.223	0.40
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	1	-	-	8
Chironomus growth - 10d	mg/organism	-	2.6	1	-	-	1.1
Hyalella survival - 14d	# surviving	-	9	-	-	-	-
Hyalella growth - 14d	mg/organism	-	0.3	-	-	-	-

Values in **bold** indicate concentrations exceeding guidelines.

1 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.

2 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

3 Interim sediment quality guideline (ISQG) (CCME 2002).

4 Value is calculated from an average of 10 replicates.

ns= not sampled

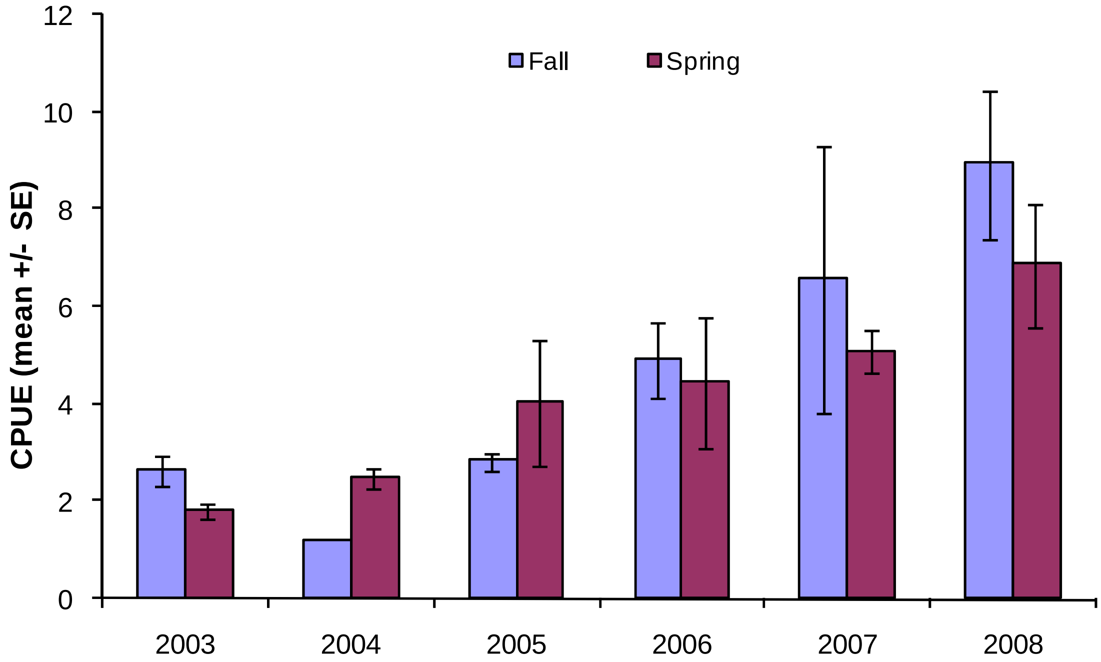
Table 5.9-14 Clearwater River fish inventory species composition, spring and fall 2008.

Species	Spring		Fall	
	No. Individuals	% of Total	No. Individuals	% of Total
Arctic grayling	0	-	3	0.35
Brook stickleback	7	0.74	0	0.00
Burbot	1	0.11	1	0.12
Emerald shiner	1	0.11	0	0.00
Fathead minnow	2	0.21	0	0.00
Finescale dace	4	0.42	0	0.00
Flathead chub	1	0.11	0	0.00
Goldeye	14	1.47	0	0.00
Lake chub	156	16.42	54	6.34
Lake whitefish	0	0.00	1	0.12
Longnose dace	9	0.95	1	0.12
Longnose sucker	13	1.37	79	9.27
Mountain whitefish	16	1.68	15	1.76
Northern pike	56	5.89	107	12.56
Pearl dace	1	0.11	0	0.00
Slimy sculpin	2	0.21	38	4.46
Spoonhead sculpin	0	0.00	1	0.12
Spottail shiner	150	15.79	110	12.91
Sucker sp.	22	2.32	0	0.00
Trout-perch	116	12.21	138	16.20
Walleye	118	12.42	41	4.81
White sucker	261	27.47	254	29.81
Yellow perch	0	0.00	9	1.06
Total	**950**	**100**	**852**	**100**

Table 5.9-15 Species composition of fish observed but not captured, spring and fall 2008 (counts are approximate).

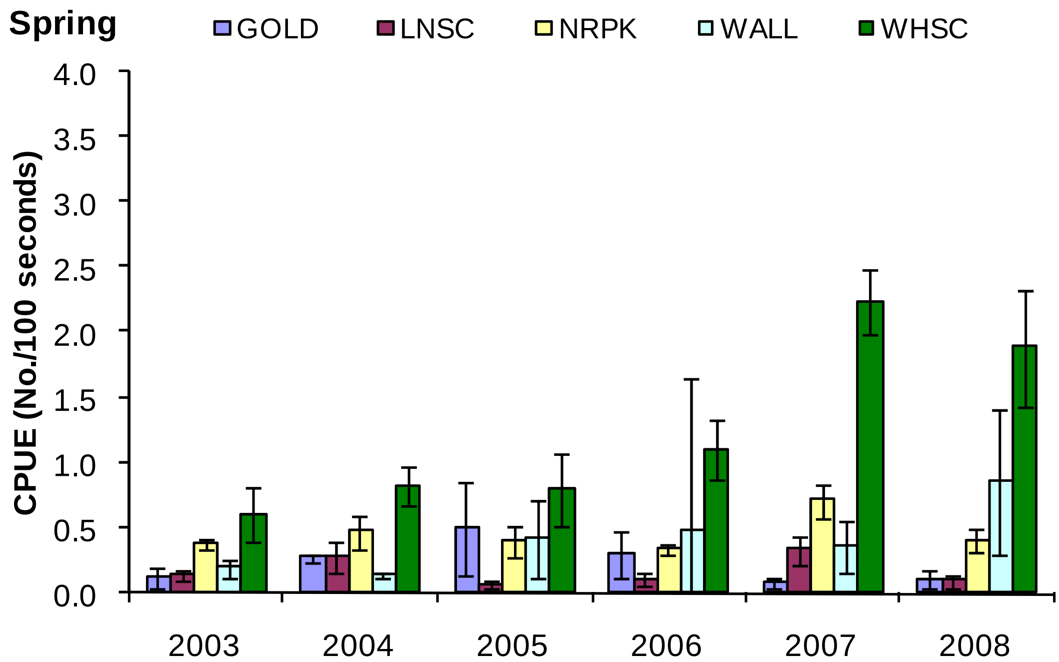
Species	Spring	Fall
Northern pike	86	42
White sucker	380	550
Walleye	81	9
Flathead chub	0	0
Goldeye	17	9
Lake whitefish	0	0
Longnose sucker	0	16
Trout-perch	484	196
Spottail shiner	492	1,210
Lake chub	80	220
Burbot	1	0
Emerald shiner	0	0
Mountain whitefish	0	24
Yellow perch	0	0
Total	**1,621**	**2,276**

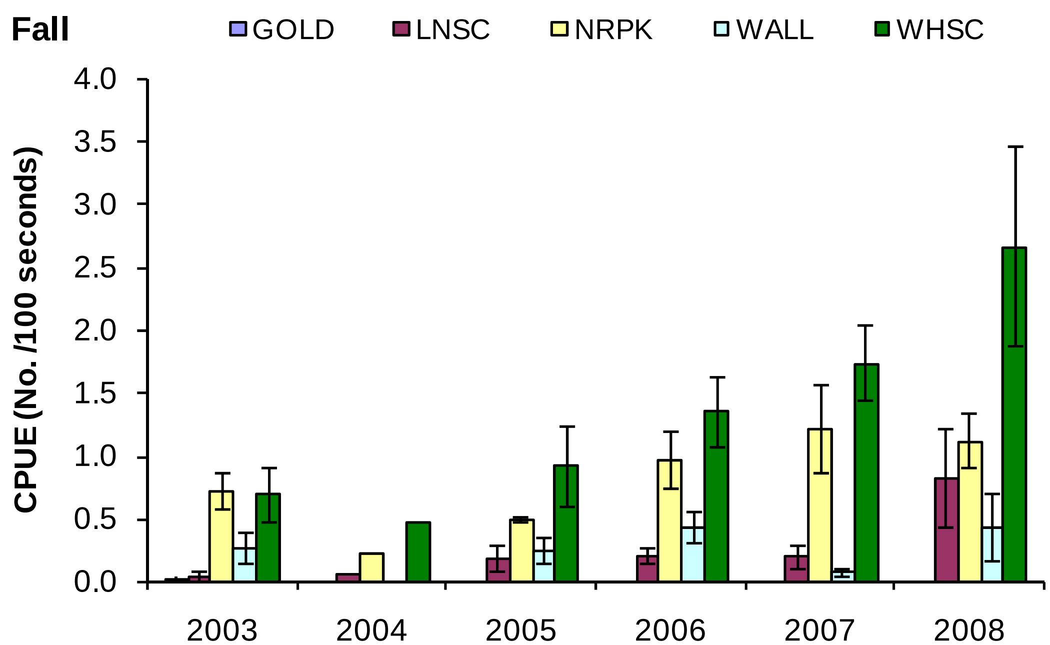
Figure 5.9-9 Seasonal catch per unit effort (mean ± SE) for captured fish of all species combined, Clearwater River, 2003 to 2008.



Note: only one reach (reach CR1) was sampled in fall 2007, and so 2007 fall figures are for reach CR1 only.

Figure 5.9-10 Seasonal CPUE (mean ± SE) for five key indicator fish species, spring and fall 2008.





Note: only one reach (reach CR1) was sampled in fall 2007, and so 2007 fall figures are for reach CR1 only.

Figure 5.9-11 Age-frequency distributions for walleye captured in the Clearwater River, spring and fall 2004, 2005, 2006 and 2008.

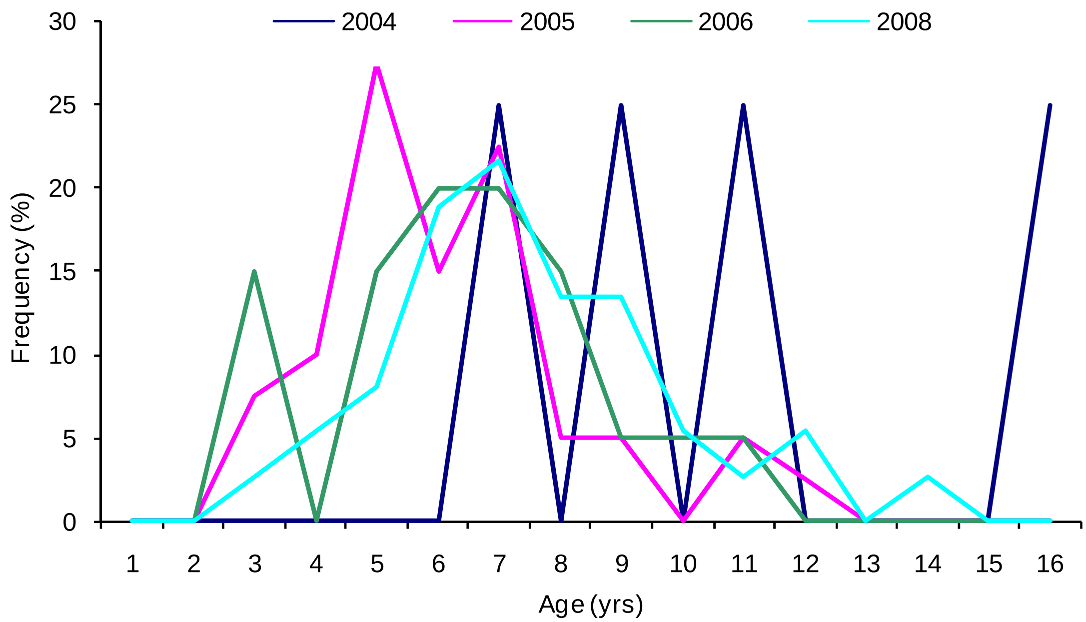


Figure 5.9-12 Age-frequency distributions for northern pike captured in the Clearwater River, spring and fall 2004, 2005, 2006 and 2008.

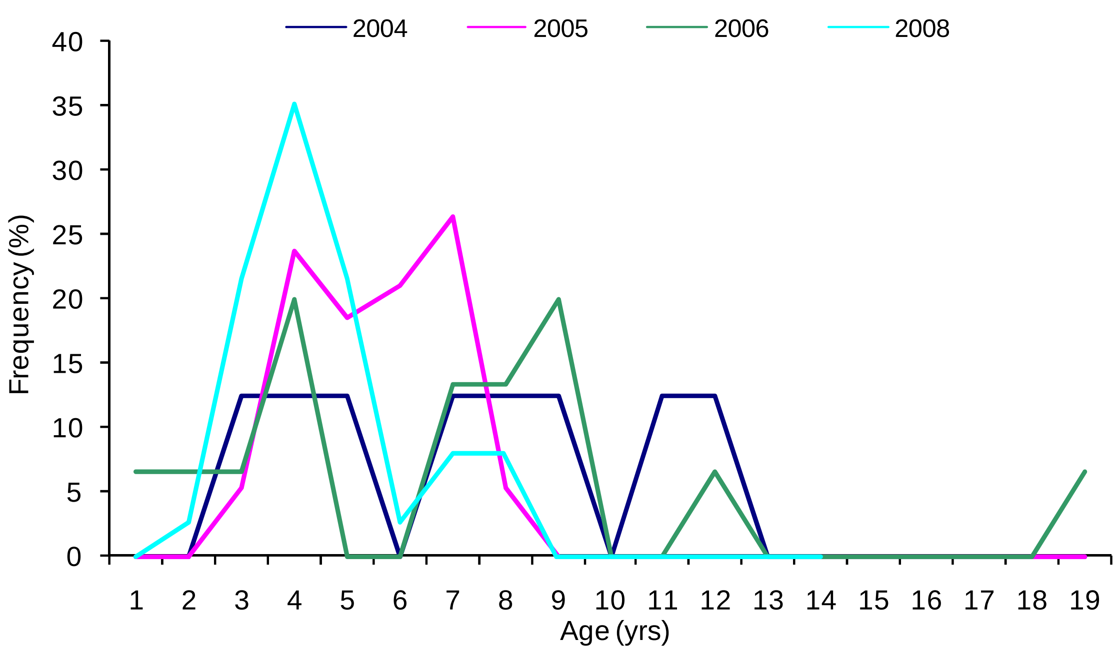
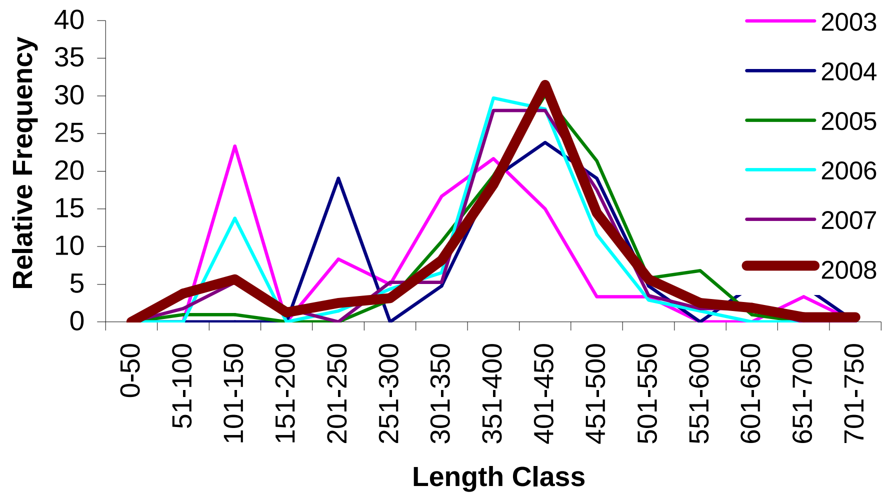


Figure 5.9-13 Relative length-frequency distributions for walleye captured in the Clearwater River, spring and fall, 2003 to 2008.



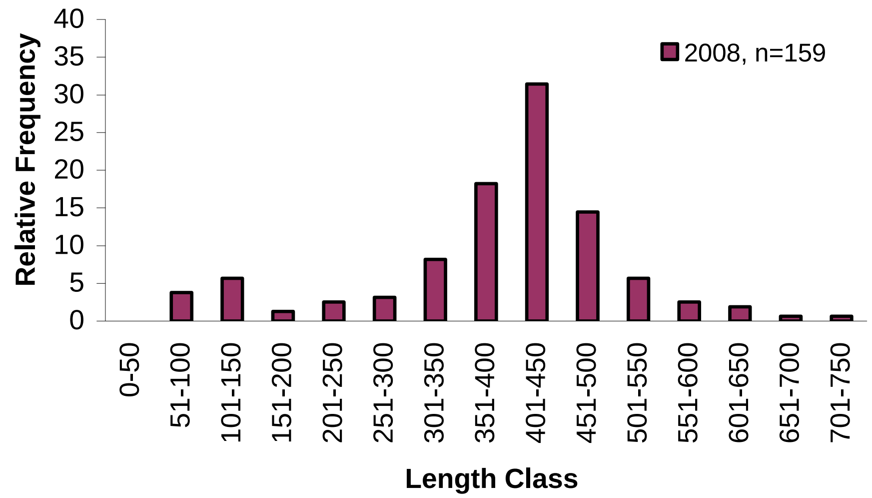
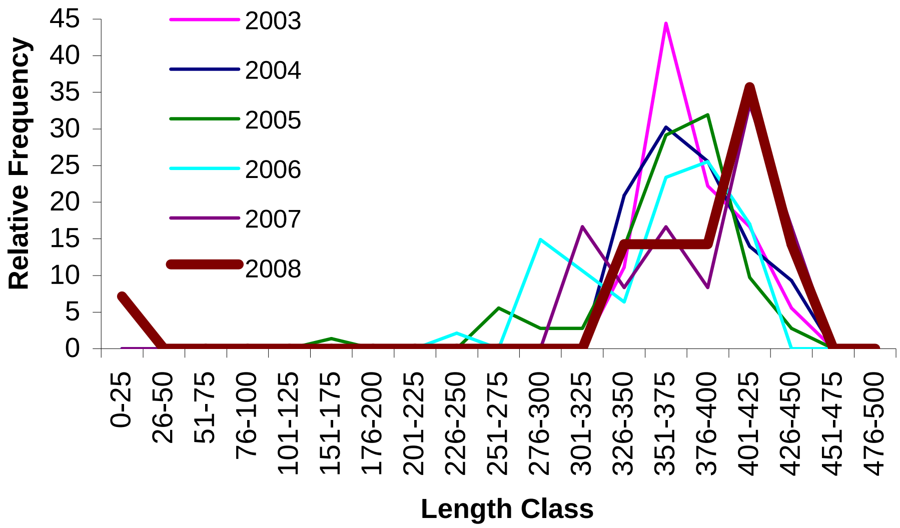


Figure 5.9-14 Relative length-frequency distributions for goldeye captured in the Clearwater River, spring and fall 2003 to 2008.



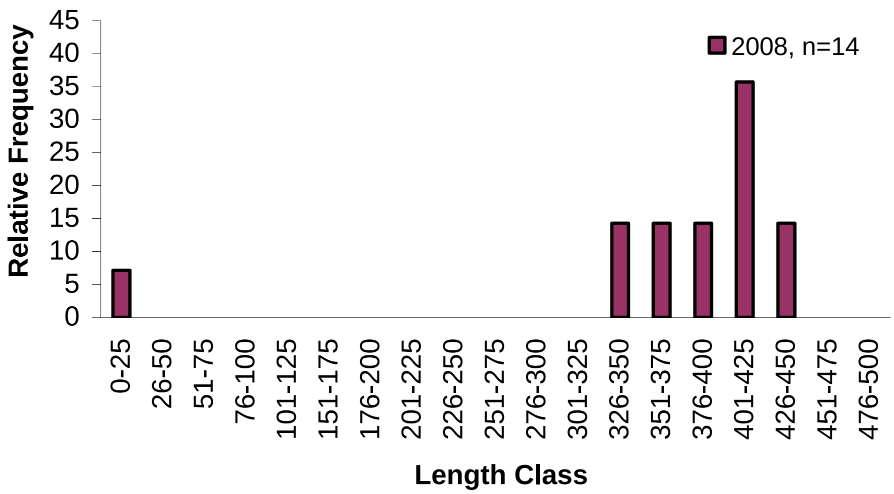
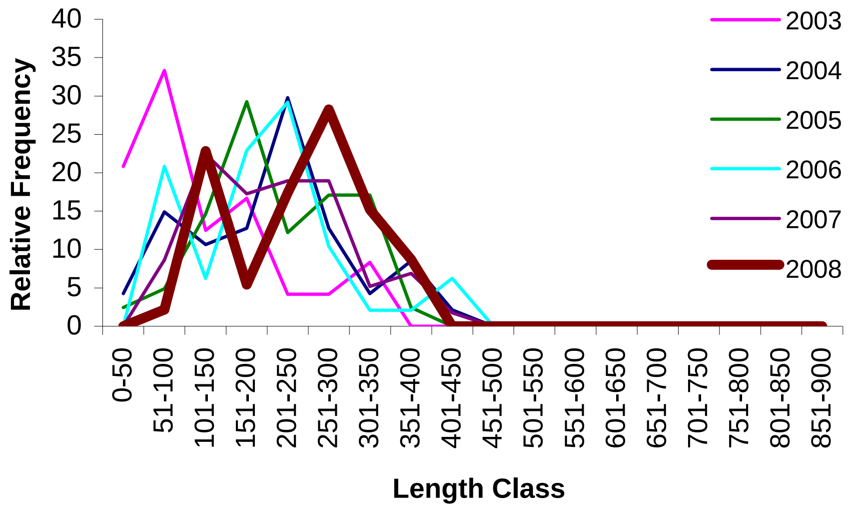


Figure 5.9-15 Relative length-frequency distributions for longnose sucker captured in the Clearwater River, spring and fall 2003 to 2008.



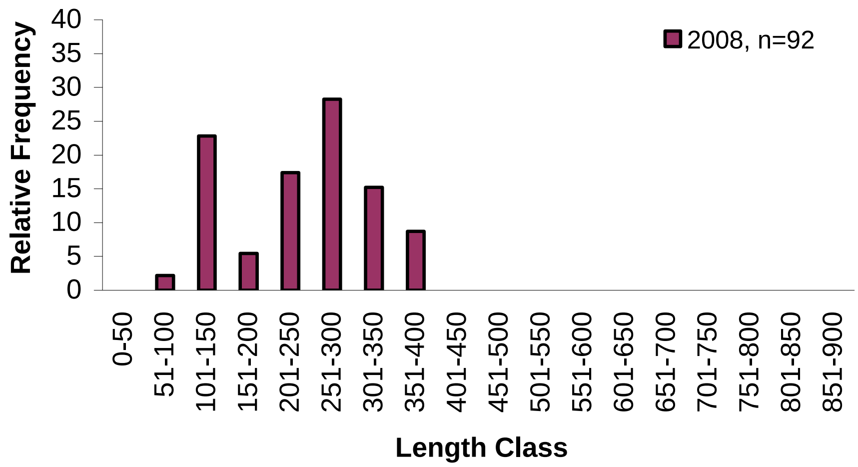


Figure 5.9-16 Relative length-frequency distributions for white sucker captured in the Clearwater River, spring and fall 2003 to 2008.

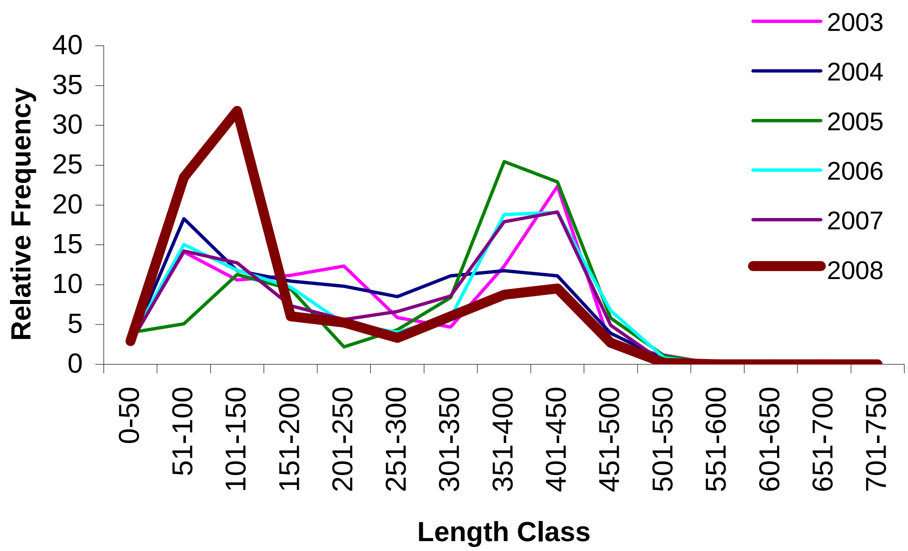
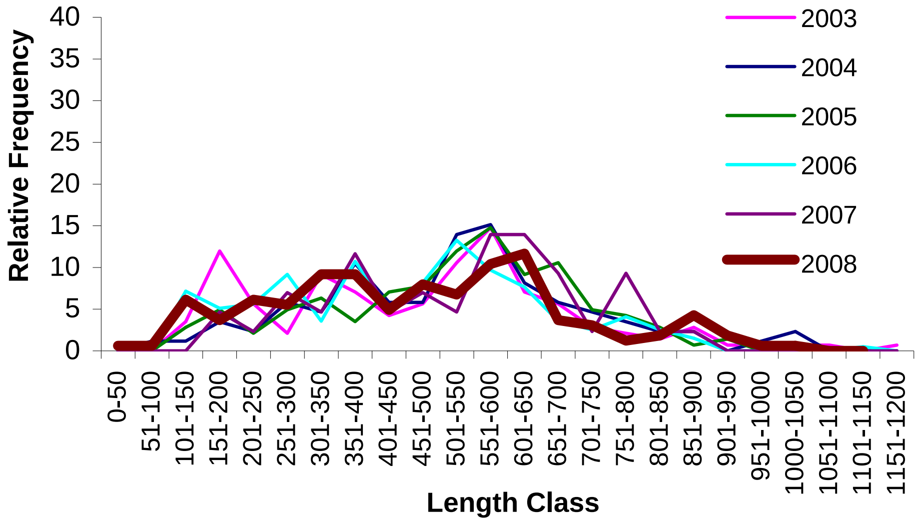


Figure 5.9-17 Relative length-frequency distributions for northern pike captured in the Clearwater River, spring and fall 2003 to 2008.



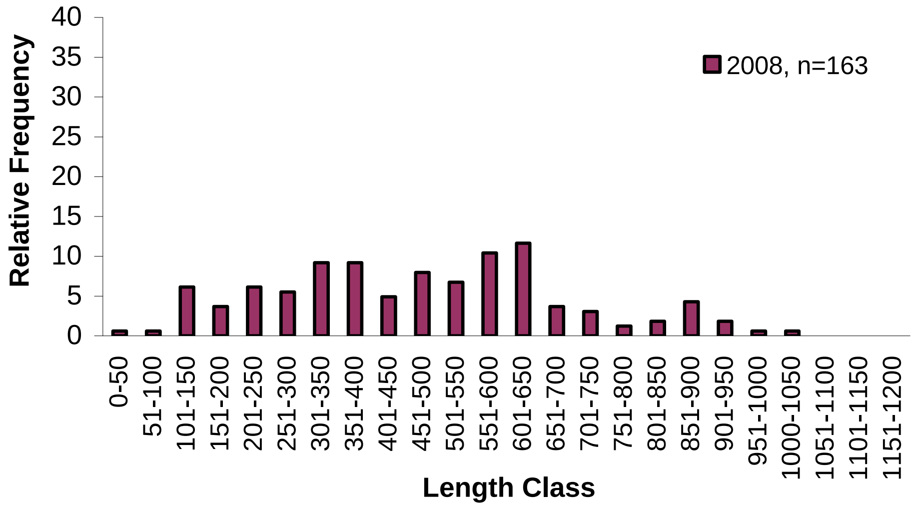
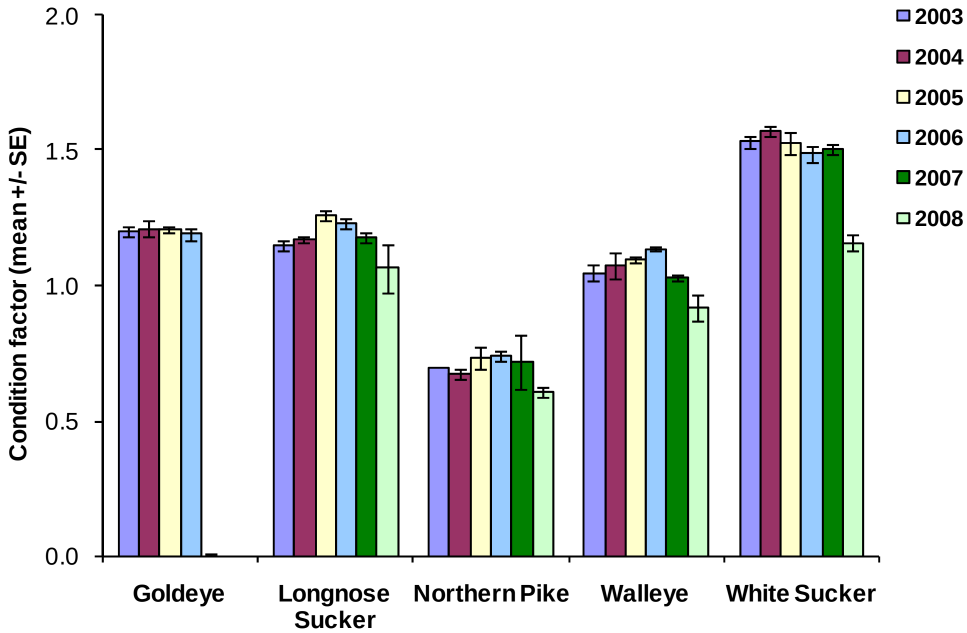


Figure 5.9-18 Condition factor for key indicator fish species, Clearwater River, 2003 to 2008.



Note: Condition factor = (weight / length^3) * 10^5

Table 5.9-16 Summary of mean health assessment index (HAI) values for five key indicator fish species, Clearwater River, 2003 to 2008.

Species	Mean Health Assessment Index (HAI)					
	2003	2004	2005	2006	2007	2008
Walleye	1.0	0.5	0.2	0.7	0.5	2.2
Goldeye	1.7	0.2	0.4	1.9	3.3	2.9
Longnose Sucker	0.4	0.3	1.1	1.0	1.0	0.5
White Sucker	3.0	0.7	0.8	1.4	3.1	1.4
Northern Pike	0.7	2.3	2.5	1.7	3.8	2.7

Table 5.9-17 Percent of KIR species fish captured with some form of external pathology, Clearwater River, 2003 to 2008.

Species	Percent Fish Captured with Pathology					
	2003	2004	2005	2006	2007	2008
Walleye	1.7	0.0	1.0	0.0	0.0	2.5
Goldeye	0.0	0.0	1.4	2.1	8.3	0.0
Longnose sucker	0.0	0.0	2.4	0.0	0.0	2.2
White sucker	0.0	0.0	0.0	0.3	1.0	1.0
Northern pike	2.1	0.0	0.0	1.5	5.1	1.2

5.10 HANGINGSTONE RIVER WATERSHED

Table 5.10-1 Summary of results for Hangingstone River watershed.

Hangingstone River Watershed	Summary of 2008 Conditions
Climate and Hydrology[1]	
Criteria	**S31** near the mouth
Mean open-water season discharge	○ (Negligible - Low)
Mean winter discharge	not measured
Annual maximum daily discharge	○ (Negligible - Low)
Minimum open-water season discharge	○ (Negligible - Low)
Water Quality	
Criteria	**HAR-1** upstream of Fort McMurray
Water Quality	○ (Negligible - Low)
Benthic Invertebrate Community and Sediment Quality	
Criteria	**HAR-E-1** lower reach
Benthic Invertebrate Community	n/a
Fish Populations	
No fish programs were conducted in 2008.	

○ Negligible - Low
○ Moderate
○ High
baseline
test

n/a - not applicable, summary indicators for *test* reaches were designated based on comparisons with upper baseline reaches.

[1] For Climate and Hydrology, results are reported for station at the mouth of each watershed

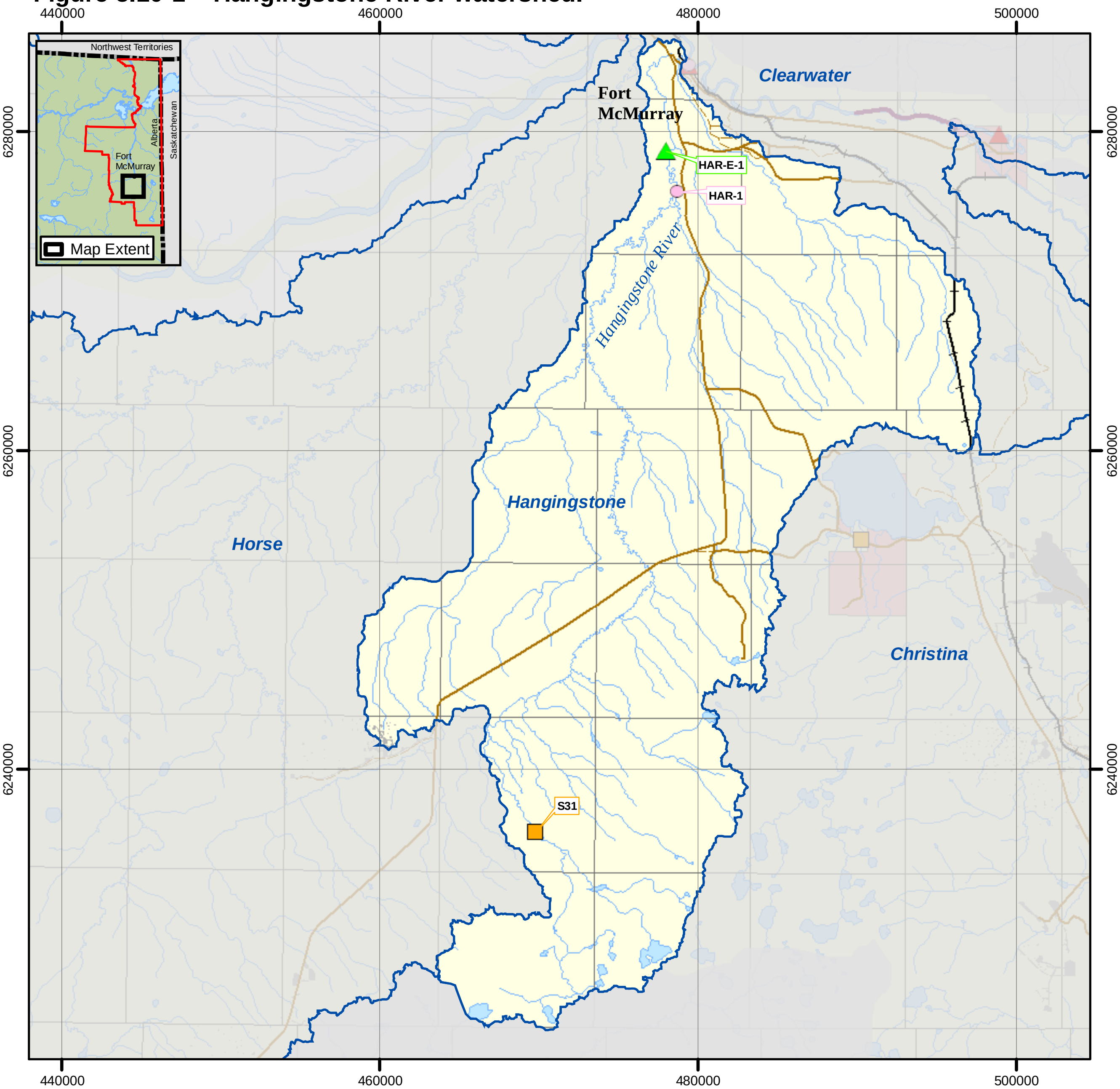
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

Benthic Invertebrate Communities: Classification based on statistical differences in measurement endpoints between baseline and test areas as well as comparison to regional baselines; see Section 3.3.1.10 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.

Figure 5.10-1 Hangingstone River watershed.



LEGEND

- Lake/Pond
- River/Stream
- Major Road
- Secondary Road
- Railway
- First Nations Reserve
- RAMP Regional Study Area
- RAMP Focus Study Area
- Land Change Area
- Watershed Boundary
- Climate Station
- Hydrometric Station
- Water Quality Sampling Station
- Benthic Invertebrate Community Sampling Reach
- Benthic Invertebrate Community Sampling Reach and Sediment Quality Sampling Site
- Sediment Quality Sampling Site
- Fish Sampling Station

RAMP Regional Aquatics Monitoring Program

0 2.5 5 10 Km

Scale 1:400,000

Projection: UTM Zone 12 NAD83

Land Change Areas Delineated from 10m SPOT-5 (May, July and August 2008) Multispectral Imagery.

K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K10_Hangingstone_20090406.mxd

Figure 5.10-2 Representative Hangingstone River monitoring stations, fall 2008.

Water Quality Station HAR-1:
right downstream bank, facing downstream

Water Quality Station HAR-1:
right downstream bank, facing upstream

5.10.1 Summary of 2008 Conditions

Approximately 0.06% of the Hangingstone River watershed has undergone land change as of 2008 from oil sands developments (Table 2.4-2); none of this land change has been due to focal projects, as there have been no focal projects located in the Hangingstone River watershed to date. The entire Hangingstone River watershed is designated as *baseline* for 2008, but monitoring data from the Hangingstone River watershed were not used in the calculation of regional baselines for water quality, benthic invertebrate communities, or sediment quality because of the existence of oil sands development activities (non-RAMP projects) in the watershed upstream of RAMP monitoring stations (Figure 5.10-1).

Table 5.10-1 contains a summary of the 2008 assessment for the Hangingstone River watershed, Figure 5.10-1 is a detailed map of the Hangingstone River watershed, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.10-2 contains a series of pictures from 2008 of a number of the monitoring stations in the watershed.

Hydrology The observed 2008 discharge for the Hangingstone River watershed is estimated to be approximately 0.05% less than the 2008 *baseline* discharge would have been in the absence of focal projects. The differences in the Hangingstone River watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Negligible-Low** for all calculated hydrologic measurement endpoints.

Water Quality Differences in water quality in fall 2008 in the lower Hangingstone River, designated as *baseline*, as compared to regional *baseline* conditions, are assessed as **Negligible-Low**. Water quality in the lower Hangingstone River in fall 2008 was characterized by concentrations of a number of measurement endpoints that fell outside historical ranges. Although several endpoints also fell outside the 5th to 95th percentile of regional *baseline* concentrations, all but one of these was below the 5th percentile of regional values, rather than above the 95th percentile. A shift in ionic composition towards greater relative concentration of sulphate, sodium, and potassium, and lower relative concentration of bicarbonate and calcium also was measured.

Benthic Invertebrate Communities The benthic invertebrate communities of the lower Hangingstone River in fall 2008 appear to have been influenced by the very high flows in the Hangingstone River in the second half of August 2008. Total benthic invertebrate community abundance and number of taxa were below the 5^{th} percentile of regional *baseline* values for erosional reaches in the RAMP FSA, reflecting possible high rates of benthic drift or burrowing deep into the reach substrate to avoid drifting during the high flow period. Benthic invertebrate community diversity and %EPT in the lower Hangingstone River in fall 2008 were within regional baselines for erosional reaches in the RAMP FSA, consistent with previous values for these measurement endpoints in the lower Hangingstone River.

5.10.2 Hydrologic Conditions

2008 Hydrologic Conditions Total runoff volume in the Hangingstone River watershed, as measured at WSC Station 07CD004, Hangingstone River at Fort McMurray, was below normal in 2008 for April, June and July (Figure 5.10-3). The March 1 to October 15 runoff depth was 92 mm. Most of the runoff occurred in August and May, with 38% and 26% in each month, respectively. By early June, streamflow subsided to below median levels and remained low for most of the summer. The August rainfall (Section 4.0) event produced a noticeable runoff response in the Hangingstone River watershed. The highest maximum daily discharge of 53.2 m^3/s, which occurred in August, was above the mean annual flood of 42.2 m^3/s. The minimum open-water season daily discharge was 0.57 m^3/s, 40% less than the historical mean of 0.95 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for the Hangingstone River for 2008 is provided in Table 5.10-2. As of 2008, the area of closed-circuited and not closed-circuited land change was 0.47 km^2 and 0.17 km^2, respectively, in the Hangingstone River watershed (Table 2.4-1), the estimated net effect of which was decreased inflow to the Hangingstone River by 0.04 million m^3 in 2008 (Table 5.10-2).

The *baseline* hydrograph that would have occurred at WSC Station 07CD004, Hangingstone River at Fort McMurray, was estimated by adding the 0.04 million m^3 of flow to the station's observed hydrograph recorded from March to mid-October 2008; the resulting estimated *baseline* hydrograph is presented in Figure 5.10-3. The effect on the hydrologic measurement endpoints of the difference between the observed and estimated *baseline* hydrograph for WSC Station 07CD004, Hangingstone River at Fort McMurray is a 0.05% decrease in mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge (Table 5.10-3). All hydrologic measurement endpoints for the Hangingstone River watershed are estimated to be similar to what they would have been under *baseline* conditions (Figure 5.10-3, Table 5.10-3).

Summary The observed *test* 2008 discharge for WSC Station 07CD004, Hangingstone River at Fort McMurray, is estimated to be approximately 0.05% less than 2008 *baseline* discharge would have been in the absence of focal projects in the Hangingstone River watershed. The differences in the Hangingstone River watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at WSC Station 07CD004, Hangingstone River at Fort McMurray, are assessed as Negligible-Low for all measured hydrologic measurement endpoints (Table 5.10-1).

5.10.3 Water Quality

Water quality samples were collected from station HAR-1, Hangingstone River upstream of Fort McMurray in fall 2008. Water quality has been sampled under RAMP at station HAR-1 since 2004; it is designated as a *baseline* station, and data obtained from that station have been excluded from the calculation of regional water quality baselines because of upstream non-RAMP oil-sands activities (Figure 5.10-1).

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations of the almost half (9 out of 22) water quality measurement endpoints were outside the range of historical measurements at station HAR-1 (Table 5.10-4):

- Concentrations of total nitrogen, dissolved organic carbon, sodium, sulphate, total dissolved solids, dissolved aluminum, and ultra-trace mercury in fall 2008 concentrations were greater than their historically-measured maximum concentrations; and
- Concentrations of calcium and total boron in fall 2008 were lower than their historically-measured minimum concentrations.

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions In fall 2008, concentrations of five of the 15 selected water quality measurement endpoints were outside the regional *baseline* range of natural variability (Figure 5.10-4):

- The concentration of ultra-trace mercury was greater than the 95th percentile of regional *baseline* concentrations in fall 2008. This is the first year this has been observed since RAMP water sampling at station HAR-1; and
- The concentration of total strontium, calcium, magnesium, and potassium were below the 5th percentile of regional *baseline* concentrations in fall 2008. Calcium and magnesium concentrations at station HAR-1 have been below the 5th percentile of regional *baseline* concentrations since RAMP water sampling began there in 2004, while the concentration of total strontium and potassium have been below the 5th percentile of regional *baseline* concentrations a total of four and three years, respectively, since RAMP water sampling began there in 2004.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only water quality measurement endpoint with a concentration that exceeded water quality guidelines at station HAR-1 in fall 2008 (Table 5.10-4). This guideline exceedance may be related to a concentration of total suspended solids that was above its historical median value in fall 2008 (Table 5.10-4). Similar results were observed at station HAR-1 in fall 2007 (RAMP 2008). The concentration of dissolved aluminum, the bioavailable form of aluminum, was below its water quality guideline at station HAR-1 in fall 2008. In addition, although the concentration of ultra-trace mercury exceeded the 95th percentile of regional *baseline* concentrations in fall 2008, its concentration was below its water quality guideline (Table 5.10-4).

Other Water Quality Guideline Exceedances Sulphide, total phosphorus, total iron, dissolved iron, and total phenols had concentrations that exceeded water quality guidelines at station HAR-1 in fall 2008 (Table 5.10-4).

Ion Balance The ionic composition of water in the fall season at station HAR-1 has been generally consistent up to and including 2007, but was characterized in fall 2008 by a greater relative concentration of sulphate and a decreased relative concentration of bicarbonate, as well as greater relative concentrations of sodium and potassium and lower relative concentration of calcium concentrations (Figure 5.10-5).

Water Quality Index The WQI value of 95.8 for HAR-1 in fall 2008 indicated a Negligible-Low difference from regional *baseline* conditions. Although several ions exhibited concentrations below the regional range of natural variability in 2008, the WQI only considered excursions above this range, rather than those below it.

Summary Differences in water quality in fall 2008 in the lower Hangingstone River, designated as *baseline*, as compared to regional *baseline* conditions, are assessed as Negligible-Low. Water quality at station HAR-1 in fall 2008 was characterized by concentrations of numerous measurement endpoints that fell outside historical ranges. Although several endpoints also fell outside the 5th to 95th percentile of regional *baseline* concentrations, all but one of these was below the 5th percentile of regional values, rather than above the 95th percentile. A shift in ionic composition towards greater relative concentration of sulphate, sodium, and potassium, and lower relative concentration of bicarbonate and calcium also was observed (Table 5.10-1).

5.10.4 Benthic Invertebrate Communities and Sediment Quality

5.10.4.1 Benthic Invertebrate Communities

In fall 2008, benthic invertebrate community samples were collected from a lower erosional reach in the Hangingstone River (reach HAR-E-1, *baseline*, first sampled in 2004).

2008 Habitat Conditions Reach HAR-E-1 in the lower Hangingstone River is a classic erosional reach with a substrate containing a mixture of small and large cobble, boulder, and sand in the interstices of the larger materials (Table 5.10-5). Water was basic (pH 8.3), with a relatively high conductivity (224 µS/cm). Samples were collected from water that was approximately 0.3 m in depth and relatively fast-flowing (0.6 m/s). Periphyton biomass in fall 2008 was about 40 mg/m^2, indicating, as in previous year, oligotrophic conditions for the lower Hangingstone River (Figure 5.10-6).

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate community of the lower reach of the Hangingstone River (reach HAR-E-1) was dominated in fall 2008 by chironomids (31%), caddisflies (Trichoptera, 17%), and mayflies (Ephemeroptera, 7%, Table 5.10-6). Stoneflies (Plecoptera) were also present (1%). Chironomids were diverse, and included *Polypedilum*, *Saetheria* and *Lopesocladius*. Some of the more sensitive larger-insect genera included the mayflies *Baetis* and *Ephemerella*, the stoneflies *Isoperla*, and the caddisflies *Brachycentrus*, *Helicopsyche* and *Hydropsyche*.

Total benthic invertebrate community abundance in reach HAR-E-1 was below the 5th percentile of regional *baseline* abundance for erosional reaches in the RAMP FSA in fall 2008, and has been near or below this 5th percentile most years at reach HAR-E-1 since RAMP began sampling there in 2004 (Figure 5.10-7). Low total abundance in reach HAR-E-1 is probably substrate driven. Substrate in this reach is generally quite large, and was comprised of almost 70% cobble and boulder in fall 2008 (Table 5.10-5). Substrate elements are often larger than the diameter of the Neil-Hess cylinder that is used to make the benthic community collection. Dominance of the bed material by large rocks minimizes the diversity of substrate and interstitial spaces that benthic organisms can live in and around. The number of taxa in reach HAR-E-1 was 18 in fall 2008, which is below the regional *baseline* for erosional reaches in the RAMP FSA (Figure 5.10-7). The reduction in number of taxa may have been because of extremely high flows in the Hangingstone River in late August 2008 that were between the upper quartile and the maximum-observed flows in the hydrologic data record for WSC Station 07CD004, Hangingstone River at Fort McMurray (Figure 5.10-3). These very high flows may have caused large numbers of organisms to drift downstream or to burrow into the deeper sediments to avoid drifting. The values for the diversity and %EPT measurement endpoints for benthic invertebrate communities in reach HAR-E-1 in fall 2008 were within regional *baseline*s for erosional reaches in the RAMP FSA (Figure 5.10-7), as they have been every year since RAMP began sampling benthic invertebrate communities at reach HAR-E-1. The results of the Correspondence Analysis Figure 5.10-8) further illustrates the variation in species composition from year to year; these results also demonstrate that, despite the year to year variation in species composition, reach HAR-E-1 has had an assemblage of benthic invertebrate community organisms that is characteristic of a *baseline* erosional reach in the RAMP FSA throughout the RAMP data record for this reach.

5.10.4.2 Sediment Quality

Because the lower reach in the Hangingstone River sampled for benthic invertebrate communities (reach HAR-E-1) is an erosional reach, no sediment quality sampling was conducted in the Hangingstone River watershed in 2008.

5.10.4.3 Summary

The benthic invertebrate communities of the lower Hangingstone River in fall 2008 appear to have been influenced by the very high flows in the Hangingstone River in the second half of August 2008. Total benthic invertebrate community abundance and number of taxa were below the 5th percentile of regional *baseline* values for erosional reaches in the RAMP FSA, reflecting possible high rates of benthic drift or burrowing deep into the reach substrate to avoid drifting during the high flow period. Benthic invertebrate community diversity and %EPT in the lower Hangingstone River in fall 2008 were within regional baselines for erosional reaches in the RAMP FSA, consistent with previous values for these measurement endpoints in the lower Hangingstone River. The lower Hangingstone River continued to have an assemblage of benthic invertebrate community organisms that is characteristic of a *baseline* erosional reach in the RAMP FSA.

5.10.5 Fish Populations

The 2008 RAMP Fish Population component did not include any activities in the Hangingstone River watershed.

Figure 5.10-3 Hangingstone River: 2008 hydrograph and historical context.

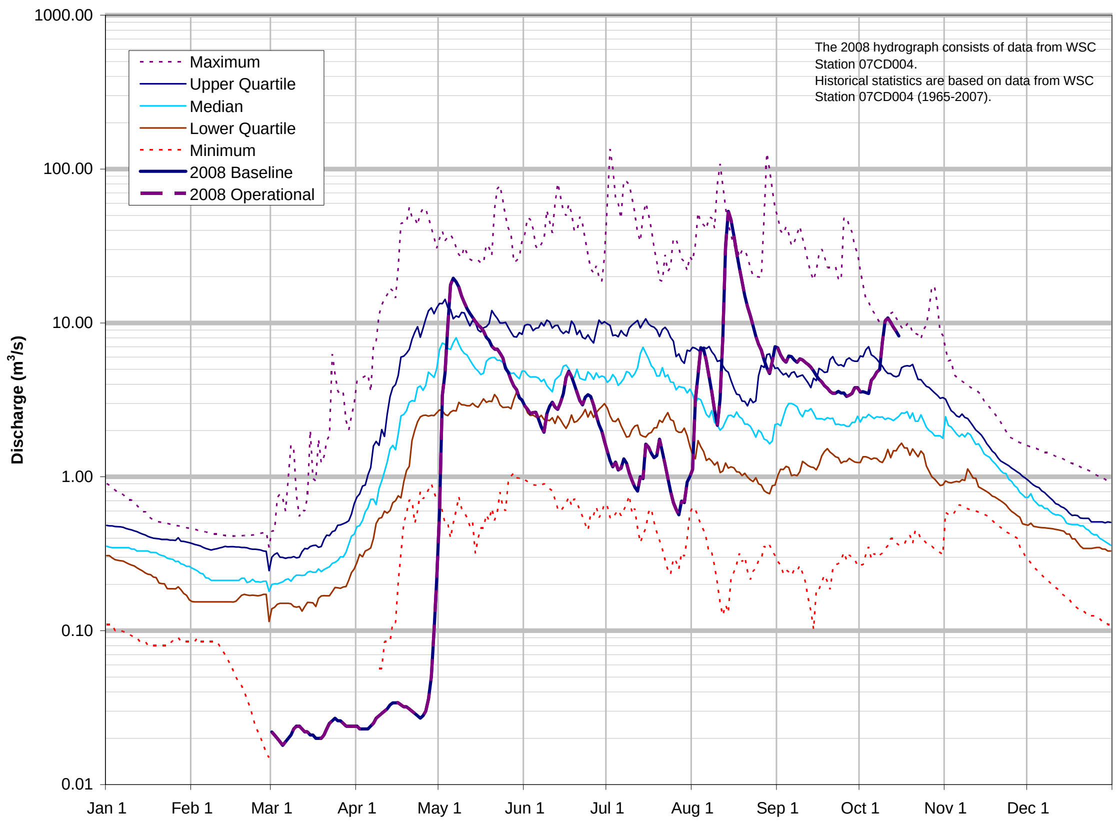


Table 5.10-2 Estimated water balance at WSC Station 07CD004, Hangingstone River at Fort McMurray, 2008.

Component of Calculation	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total discharge)	**88.3**	**Observed discharge, obtained from WSC Station 07CD004, Hangingstone River at Fort McMurray**
Natural runoff that would have occurred from closed-circuited areas as of 2008	+0.043	0.47 km^2 within Hangingstone River drainage estimated to have been closed-circuited by oil sands development projects as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that are not closed-circuited	-0.03	0.17 km^2 within Hangingstone River drainage estimated to have undergone land change by oil sands development projects as of 2008, but are not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from the Hangingstone River by focal projects	0	Unknown, none reported, assumed to be negligible
Amount by which discharge would be lower without releases to the Hangingstone River watershed by focal projects	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Hangingstone River not accounted for in figures contained in this table
***Baseline* hydrograph (total discharge)**	**88.3**	**Estimated baseline discharge at WSC Station 07CD004, Hangingstone River at Fort McMurray (i.e., without oil sands developments)**
Incremental flow (change in total discharge)	-0.04	Total discharge from observed hydrograph less total discharge of estimated *baseline* hydrograph
Incremental flow (% of observed total discharge)	-0.05%	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Data are for the period of the 2008 data record for WSC Station 07CD004, Hangingstone River at Fort McMurray.

Note: None of the oil sands development projects in the Hangingstone River watershed as of 2008 are focal projects.

Note: Rounding of results occurs due to the use of a maximum of three significant digits

Table 5.10-3 Calculated change in hydrologic measurement endpoints for the Hangingstone River watershed for 2008.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from Observed Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	6.07	6.07	-0.04%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	53.2	53.2	-0.04%
Open-water season minimum daily discharge	0.566	0.566	-0.04%

Note: As measured at WSC Station 07CDA00, Hangingstone River at Fort McMurray.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.10-4 Water quality measurement endpoints, mouth of Hangingstone River (station HAR-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	4	8.0	8.2	8.3
Total Suspended Solids	mg/L	-[1]	9	4	<3	7	12
Conductivity	µS/cm	-	231	4	231	232.5	278
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.041	4	0.038	0.0465	0.049
Total nitrogen*	mg/L	1.0	1	4	0.7	0.85	0.9
Nitrate+Nitrite	mg/L	1.0	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	34	4	17	24.5	29
Ions							
Sodium	mg/L	-	25	4	17	17.5	21
Calcium	mg/L	-	22.3	4	23.2	25.75	31.5
Magnesium	mg/L	-	7.2	4	7.2	7.45	8.3
Chloride	mg/L	230, 860[3]	13	4	9	11.5	13
Sulphate	mg/L	100[4]	29.3	4	9.6	10.2	11.8
Total Dissolved Solids	mg/L	-	290	4	167	180	210
Total Alkalinity	mg/L	-	89	4	88	96.5	119
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.464**	4	**0.17**	**0.30**	**0.50**
Dissolved aluminum	mg/L	0.1[2]	0.0373	4	0.0113	0.0155	0.0296
Total arsenic	mg/L	0.005	0.0015	4	0.0012	0.0014	0.0017
Total boron	mg/L	1.2[5]	0.054	4	0.056	0.063	0.0866
Total molybdenum	mg/L	0.073	0.0007	4	0.0007	0.001	0.0016
Total mercury (ultra-trace)	ng/L	5, 13[6]	2.3	4	<1.2	<1.2	1.22
Total strontium	mg/L	-	0.121	4	0.122	0.1255	0.179
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.013**	4	**0.003**	**0.006**	**0.018**
Total phosphorus	mg/L	0.05	**0.065**	4	**0.059**	**0.068**	**0.075**
Dissolved iron	mg/L	0.3[2]	**0.824**	4	**0.646**	**0.7555**	**0.788**
Total iron	mg/L	0.3	**1.57**	4	**1.13**	**1.38**	**1.42**
Total phenols	mg/L	0.004	**0.012**	4	**0.008**	**0.0105**	**0.011**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

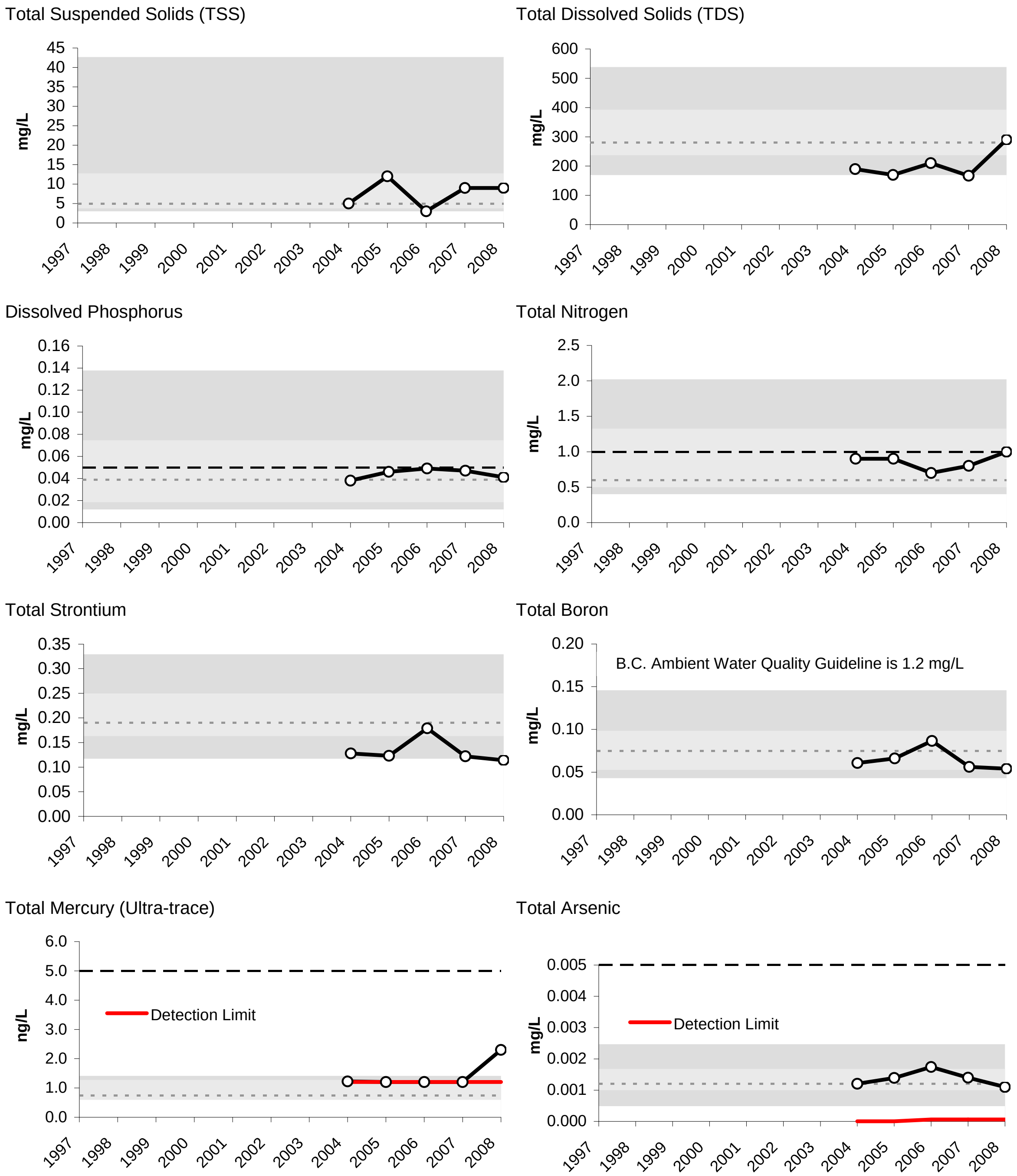
[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006)

Figure 5.10-4 Concentrations of selected water quality measurement endpoints at the mouth of the Hangingstone River (station HAR-1, fall 2008) relative to regional baseline fall concentrations.

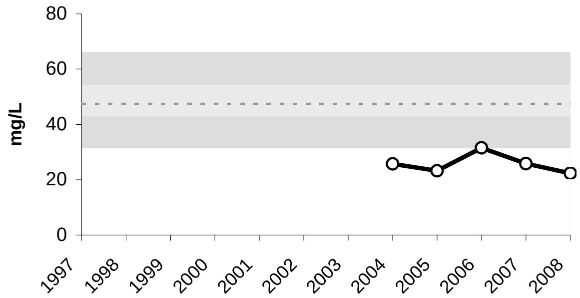


Non-detectable values are shown at the detection limit.

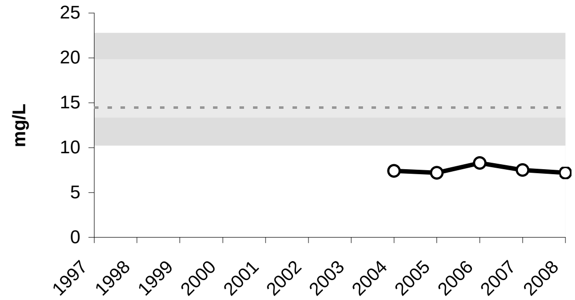
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.10-6 (Cont'd.)

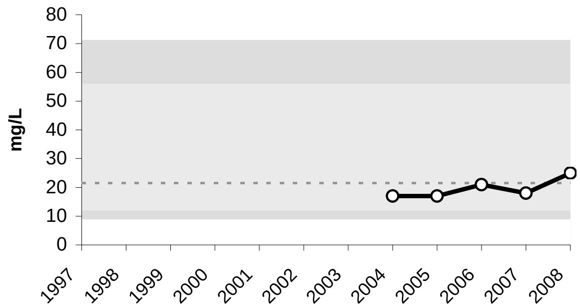
Calcium



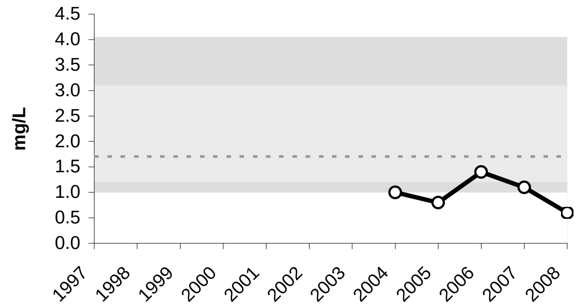
Magnesium



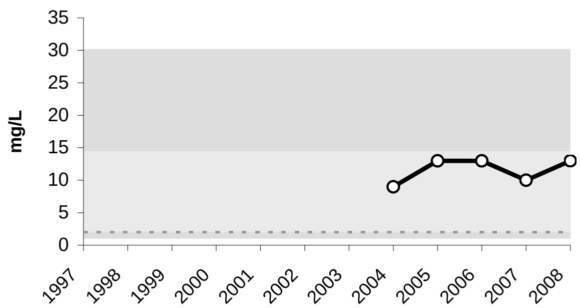
Sodium



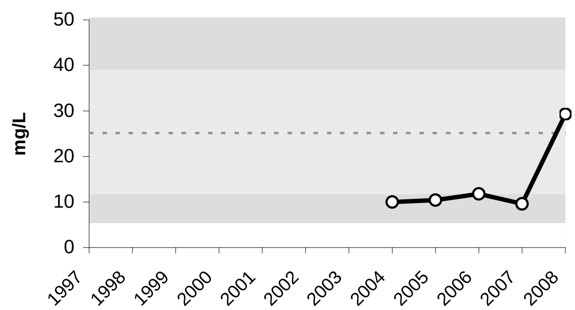
Potassium



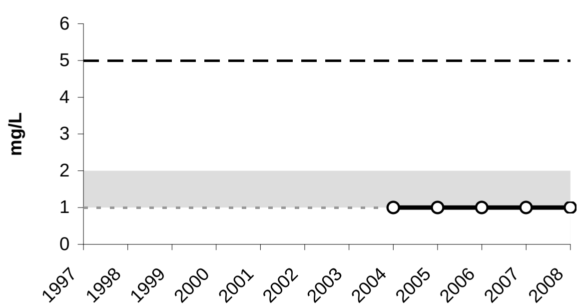
Chloride



Sulphate



Naphthenic Acids



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling. See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.10-5 Piper diagram of fall ion concentrations, mouth of Hangingstone River (station HAR-1), fall 2008.

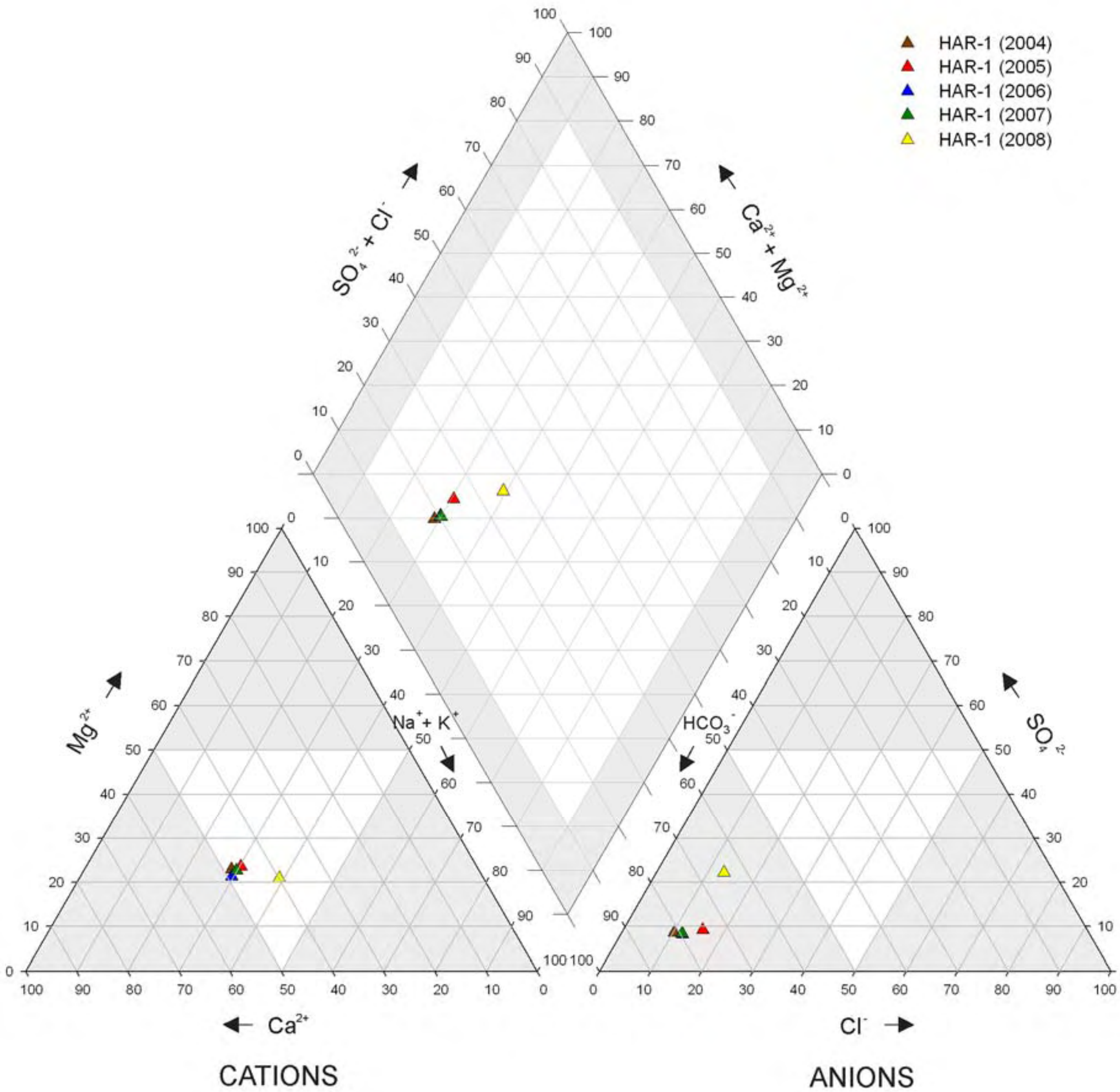


Table 5.10-5 Average habitat characteristics of benthic invertebrate community sampling reaches in the Hangingstone River, fall 2008.

Variable	Units	Lower Reach of Hangingstone River (Reach HAR-E-1)
Sample date	-	Sept 3, 2008
Habitat	-	Erosional
Water depth	m	0.3
Current velocity	m/s	0.6
Macrophyte cover	%	Not measured
Field Water Quality		
Dissolved oxygen	mg/L	8.9
Conductivity	µS/cm	224
pH	pH units	8.3
Water temperature	°C	13.1
Sediment Composition		
Sand/Silt/Clay	%	13
Small gravel	%	8
Large gravel	%	11
Small cobble	%	4
Large cobble	%	53
Boulder	%	11
Bedrock	%	0

Figure 5.10-6 Annual variation in chlorophyll *a* in the lower reach of the Hangingstone River (reach HAR-E-1).

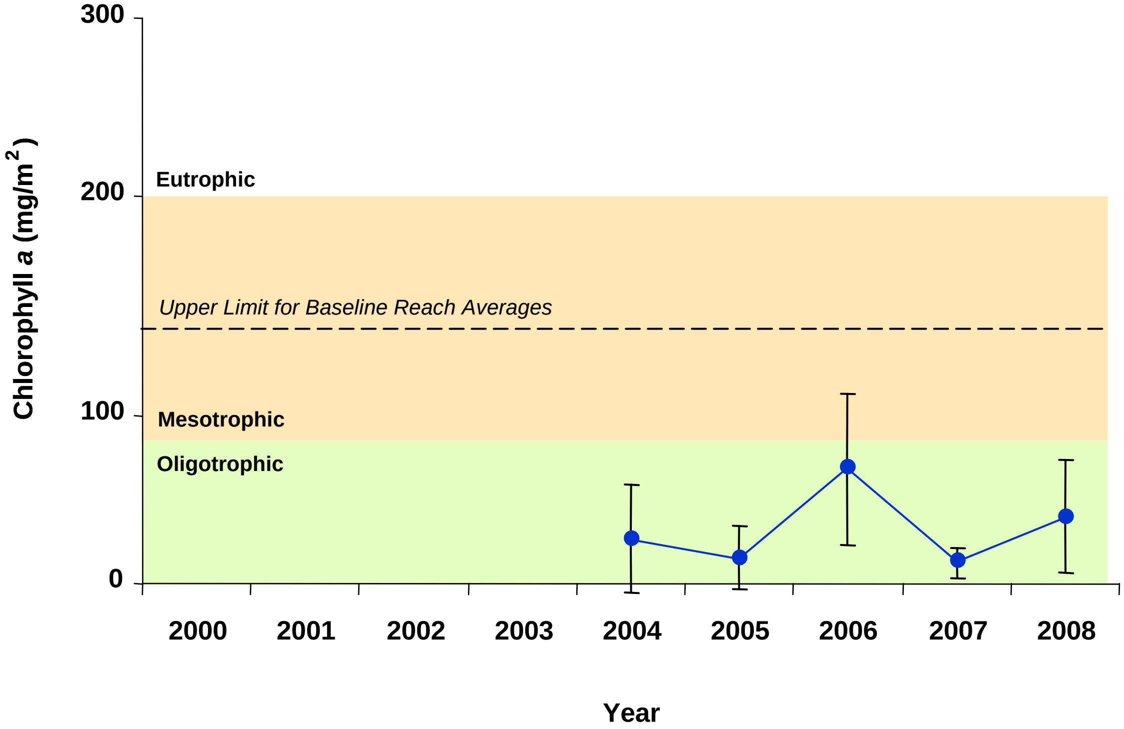
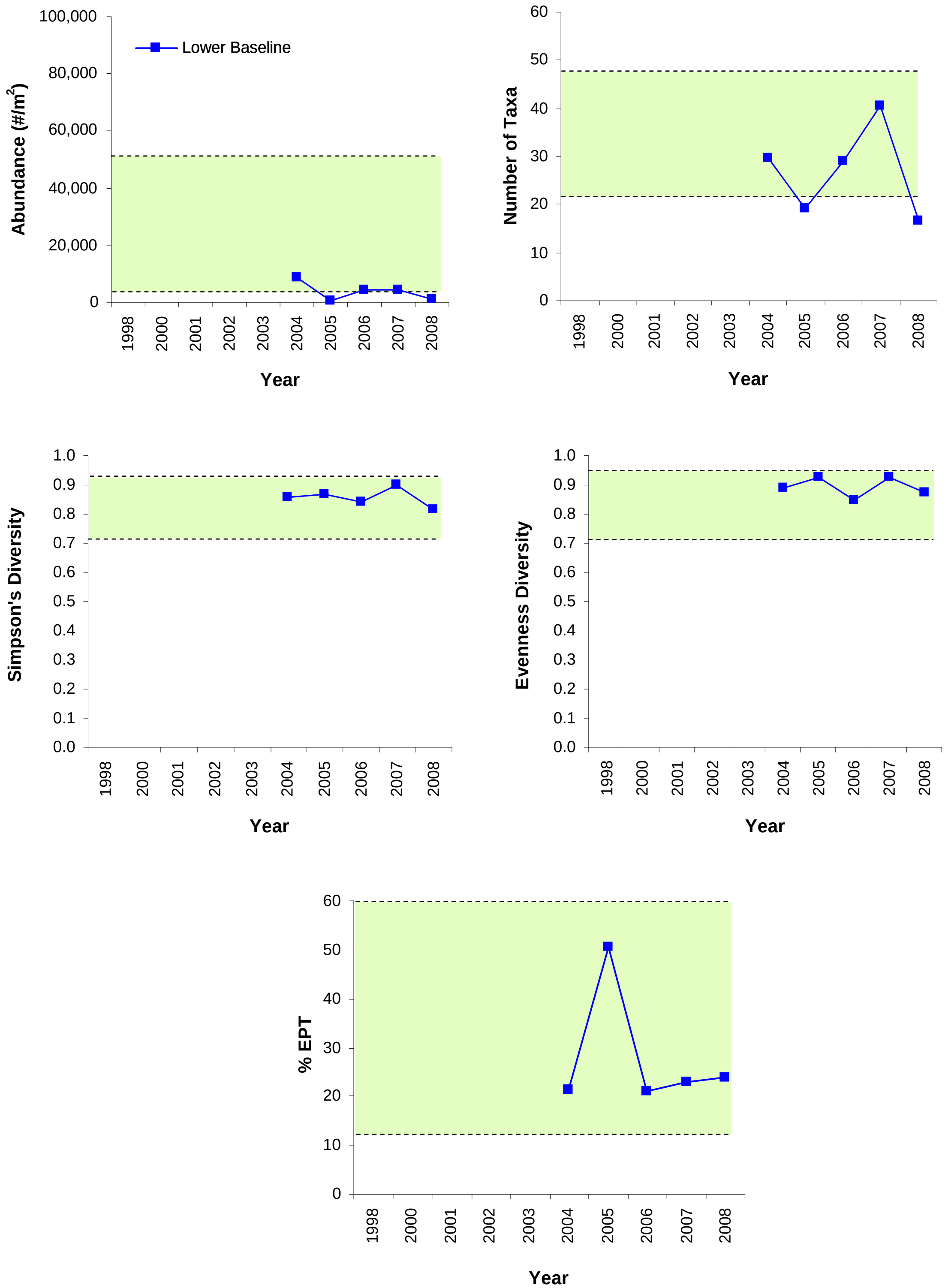


Table 5.10-6 Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the lower reach of the Hangingstone River (reach HAR-E-1).

Taxon	Percent Major Taxa Enumerated in Each Year				
	Reach HAR-E-1				
	2004	2005	2006	2007	2008
Anisoptera	<1	1	<1	1	2
Athericidae	<1	3	1	<1	3
Bivalvia	<1			1	<1
Ceratopogonidae	<1	<1	<1	<1	2
Chironomidae	33	14	40	30	31
Coleoptera	<1	<1	<1	<1	
Collembola		<1			<1
Copepoda	<1	<1		1	<1
Dolichopodidae				1	
Empididae	2	2	4	1	1
Enchytraeidae	1	2	1	2	<1
Ephemeroptera	16	34	11	13	7
Gastropoda	<1			3	<1
Hydra		1		<1	
Hydracarina	6	13	5	7	27
Naididae	24	3	25	13	6
Nematoda	6	2	2	4	1
Ostracoda	5		<1	15	1
Plecoptera	3	10	2	2	1
Simuliidae		3			
Tabanidae	<1				
Tipulidae		<1		<1	<1
Trichoptera	4	12	8	8	17
Tubificidae	<1	<1	<1	1	<1
Benthic Invertebrate Community Measurement Endpoints					
Total Abundance (No./m^2)	8,560	773	4,255	4,187	1,152
Richness	30	19	29	40	17
Simpson's Diversity	0.86	0.87	0.84	0.90	0.82
Evenness	0.89	0.92	0.85	0.93	0.87
% EPT	21	50	21	23	24

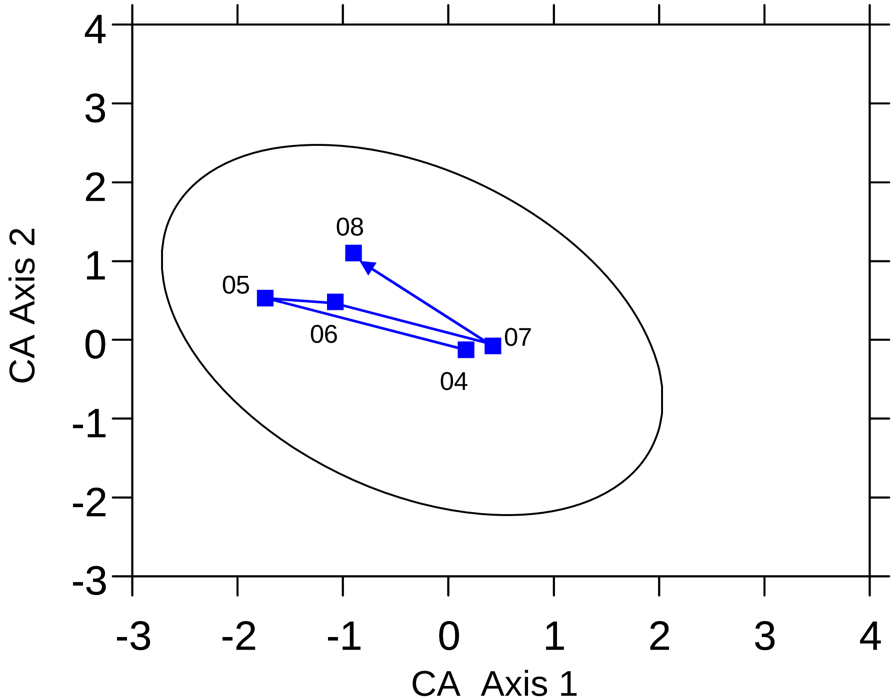
Figure 5.10-7 Variation in benthic invertebrate community measurement endpoints in the lower reach of the Hangingstone River (reach HAR-E-1).

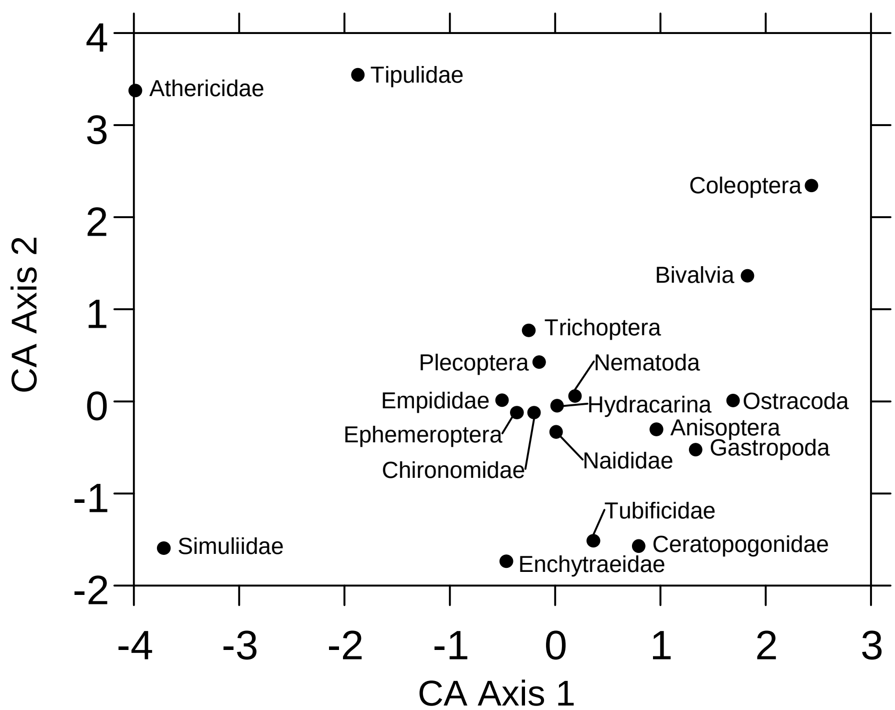


Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* erosional reaches in the RAMP FSA.

Note: Lower *Baseline* - HAR-E-1

Figure 5.10-8 Ordination (Correspondence Analysis) of erosional river benthic communities showing the lower reach of the Hangingstone River.





Note: the upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for *baseline* erosional reaches in the RAMP FSA.

Note: the numbers in the upper panel refer to sampling year for each data point.

5.11 MISCELLANEOUS AQUATIC SYSTEMS

Table 5.11-1 Summary of results for miscellaneous aquatic systems.

Miscellaneous Aquatic Systems	Summary of 2008 Conditions										
	Lakes					*Tributaries*					
Climate and Hydrology[1]											
Criteria	**S25** Susan Lake Outlet	**L3** Isadore's Lake				**S11** Poplar Creek at Highway 63	**S12** Fort Creek at Highway 63				**S6** Mills Creek at Highway 63
Mean open-water season discharge	not measured	not measured				High	Moderate				Moderate
Mean winter discharge	not measured	not measured				not measured	not measured				not measured
Annual maximum daily discharge	not measured	not measured				Negligible - Low	Moderate				Moderate
Minimum open-water season discharge	not measured	not measured				High	Moderate				Moderate
Water Quality											
Criteria	no station sampled	**ISL-1** Isadore's Lake	**SHL-1** Shipyard Lake	no station sampled	no station sampled	**POC-1** Poplar Creek at the mouth	**FOC-1** Fort Creek at the mouth	**BER-1** Beaver River at the mouth	**BER-2** upper Beaver River	**MCC-1** McLean Creek at the mouth	no station sampled
Water Quality		Negligible - Low	Negligible - Low			Negligible - Low	Negligible - Low	Moderate	Negligible - Low	Negligible - Low	
Benthic Invertebrate Community and Sediment Quality											
Criteria	no reach sampled	**ISL-1** Isadore's Lake	**SHL-1** Shipyard Lake	no reach sampled	no reach sampled	**POC-D-1** Poplar Creek lower reach	**FOC-D-1** Fort Creek lower reach	no reach sampled	**BER-D-2** Beaver River upper reach	no reach sampled	no reach sampled
Benthic Invertebrate Community		Moderate	Negligible - Low			Moderate	High		Negligible - Low		
Sediment Quality		Negligible - Low	Moderate			Negligible - Low	Negligible - Low		Negligible - Low		

Fish Populations

Criteria	Big Island Lake				Gardiner Lake				no reaches sampled
	Sp.[2]	Size[3]	Sub.	Gen.[4]	Sp.[2]	Size[3]	Sub.	Gen.[4]	
Human Health	WALL	>600mm	High	Moderate	WALL	>500mm	High	Moderate	
	NRPK	(all sizes)	Negligible - Low	Negligible - Low	NRPK	>700mm	High	Moderate	
	LKWH	(all sizes)	Negligible - Low	Negligible - Low	LKWH	(all sizes)	Negligible - Low	Negligible - Low	
Fish Palatability	not measured				not measured				
Fish Health	All species: Negligible - Low				All species: Negligible - Low				

Legend: Negligible - Low (yellow circle); Moderate (orange circle); High (brown circle); baseline (green shading); test (blue shading)

[1] For Climate and Hydrology, results are reported for station at the mouth of each watershed

[2] Species (Sp.): WALL=walleye; NRPK=northern pike; LKWH=lake whitefish

[3] The classification of risk to human health was Negligible-Low below the size class specified.

[4] Sub. refers to subsistence fishers; Gen. refers to general consumers as defined by Health Canada (see Section 3.4.7.3)

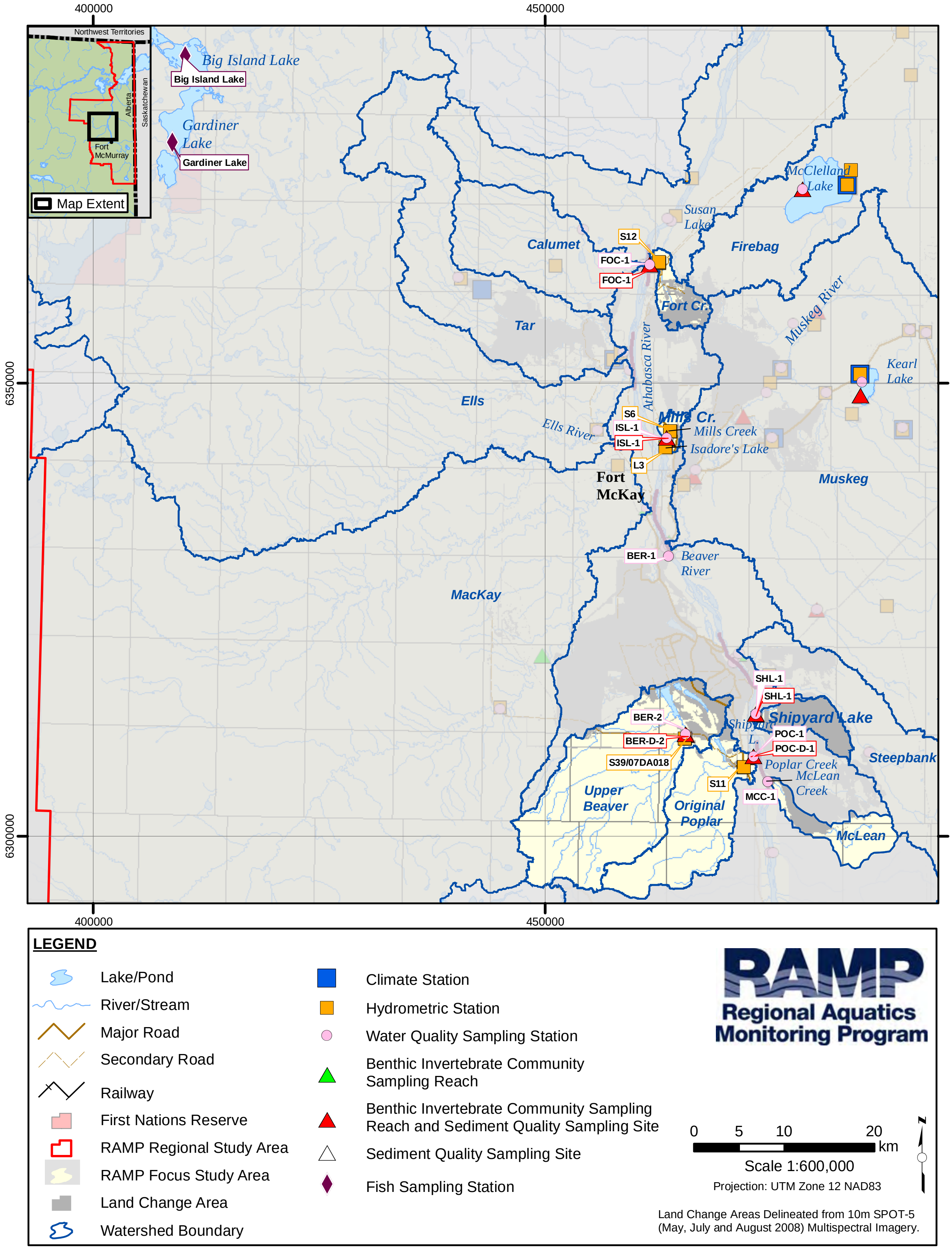
Hydrology: Measurement endpoints calculated on differences between observed *test* and estimated *baseline* hydrographs: ± 5% - Negligible-Low; ± 15% - Moderate; > 15% - High.

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.

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.

Fish Populations: Uses various USEPA and Health Canada criteria for risks to human health, fish health, and tainting from fish tissue concentrations of various substances, see Section 3.4.7.3 for a detailed description of the classification methodology.

Figure 5.11-1 Miscellaneous aquatic systems.



K:\Data\Project\RAMP1393\GIS_MXD\E_TechReport\RAMP1393_K11_Misc_20090420.mxd

Figure 5.11-2 Representative monitoring stations for miscellaneous aquatic systems, fall 2008.

Water Quality Station ISL-1:
Isadore's Lake, aerial view

Water Quality Station SHL-1:
Shipyard Lake, aerial view

Water Quality Station BER-1 (Beaver River):
right downstream bank, facing downstream

Water Quality Station FOC-1 (Fort Creek):
left downstream bank, facing downstream

Water Quality Station MCC-1 McLean Creek):
right downstream bank, facing downstream

Water Quality Station POC-1 (Poplar Creek):
left downstream bank, facing downstream

5.11.1 Summary of 2008 Conditions

This section includes 2008 results from the following aquatic systems, each with a specific status:

- Mills Creek, Poplar Creek, McLean Creek, Fort Creek, Beaver River, Isadore's Lake, and Shipyard Lake are designated as *test*. Land change as of 2008 comprises approximately 3.1% of the original Poplar Creek watershed, slightly more than 62% of the Fort Creek watershed, almost 25% of the McLean Creek watershed, approximately 11% of the Mills Creek watershed, 93% of the original watershed draining into Shipyard Lake[1], and approximately 9.4% of the Upper Beaver watersheds (Table 2.4-2); and
- The Susan Lake outlet is designated as *baseline* for 2008 in addition to the two regional lakes where fish tissue studies were conducted, Big Island and Gardiner lakes).

Table 5.11-1 contains a summary of the 2008 assessment for the miscellaneous aquatic systems in the RAMP FSA, Figure 5.11-1 is a detailed map of these miscellaneous aquatic systems, indicating the location of the monitoring stations for each RAMP component and the area of land change for 2008, while Figure 5.11-2 contains a series of pictures from 2008 of a number of the monitoring stations located in the miscellaneous aquatic systems in the RAMP FSA.

Mills Creek The differences in the Mills Creek watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Moderate** for all calculated hydrology measurement endpoints.

Isadore's Lake The water level of Isadore's Lake was just above the historical minimum until early in the year, but it rose well above its historical median level in April and continued to rise above the historical maximum levels for most of June. Water levels remained above the historical median values until the middle of December.

While significant increases have been measured in concentrations of calcium, magnesium and sulphate over the period of monitoring, differences in water quality in fall 2008 in Isadore's Lake as compared to regional *baseline* conditions are assessed as **Negligible-Low**.

The differences in benthic invertebrate communities between Isadore's Lake and *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes) are classified as **Moderate**. While the average values of taxa richness, diversity, evenness, and %EPT are significantly lower in Isadore's Lake as compared to the *baseline* lakes in the RAMP FSA and the time trends in diversity and evenness are significantly different in Isadore's Lake than in the *baseline* lakes, taxa richness was the only measurement endpoint in fall 2008 that was lower than the range of natural variability.

Differences in sediment quality in fall 2008 in Isadore's Lake as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Sediment quality in Isadore's Lake in 2008 was generally consistent with that of previous years, and largely within historical and regional *baseline* ranges of concentrations. Although concentrations of some sediment quality measurement endpoints were above the range of regional *baseline* values (i.e.,

[1] The boundary of the original Shipyard Lake watershed was estimated on an overlay of watershed boundaries prepared by CEMA with the 1:50,000 NTDB water and contour layers.

total hydrocarbons, some PAH species, and several metals), these relatively high concentrations were related to the consistently high organic carbon and fine sediments present in this lake. When total PAH concentrations were corrected for bioavailability and presented as predicted PAH toxicity, the 2008 value of 0.08 was among the lowest observed for any RAMP sediment monitoring location since 1997.

Poplar Creek and Beaver River The differences in the Poplar Creek watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **High** for mean open-water season discharge and minimum open-water season discharge, and **Negligible-Low** for the annual maximum daily discharge.

Differences in water quality in fall 2008 in the lower Beaver River as compared to regional *baseline* conditions are assessed as **Moderate**, largely as a result of relatively high concentrations of a number of ions and total dissolved solids. Differences in water quality in fall 2008 in the upper Beaver River, designated as *baseline*, as well as in lower Poplar Creek, designated as *test*, as compared to regional *baseline* conditions are assessed as **Low-Negligible**.

The differences in the benthic invertebrate community in lower Poplar Creek, designated as *test* in 2008, as compared to benthic invertebrate communities in *baseline* depositional reaches, represented by the upper Beaver River are classified as **Moderate**. Lower Poplar Creek had significantly lower Simpson's Diversity and evenness as compared to the upper Beaver River. Also, the diversity was below and taxa richness and %EPT were near lower end of their normal range of variation for *baseline* depositional reaches in the RAMP FSA.

Differences in sediment quality at both lower Poplar Creek and the upper Beaver River as compared to regional *baseline* conditions are assessed as **Negligible-Low**, although concentrations of some metals exceeded regional *baseline* ranges at *test* reach POC-D-1. No sediment quality variables exceeded relevant guidelines at either station.

McLean Creek Differences in water quality in fall 2008 in lower McLean Creek as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Water quality in McLean Creek in 2008 was generally consistent with regional *baseline* characteristics, although concentrations of several water quality variables were outside their previously measured ranges, including total dissolved phosphorus, dissolved organic carbon, and ultra-trace mercury (highs), and conductivity, sodium, calcium, magnesium, and sulphate (lows).

Fort Creek The differences in the Fort Creek watershed between the observed hydrograph and the estimated *baseline* hydrograph are assessed as **Moderate** for open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge.

Differences in water quality in fall 2008 in lower Fort Creek as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Water quality in lower Fort Creek has remained consistent since RAMP initiated monitoring in this waterbody in 2000.

The differences in the benthic invertebrate community in lower Fort Creek between the period it was designated as *baseline* and the period it has been designated as *test* are classified as **High**. Both total abundance and taxa richness are lower in the years lower Fort Creek has been designated as *test* as compared to the years it was designated as *baseline,* and total abundance, taxa richness, and Simpson's diversity were less than the normal range of variation for these measurement endpoints in *baseline* depositional reaches in the RAMP FSA in fall 2008. Stoneflies (Plecoptera) and caddisflies (Trichoptera), two insect groups typically associated with water and physical habitat of high and undisturbed quality (Bode et al., 1998), were absent in 2008.

Differences in sediment quality in fall 2008 in lower Fort Creek as compared to regional *baseline* conditions are assessed as **Negligible-Low**. Concentrations of sediment quality measurement endpoints in lower Fort Creek in 2008 were largely within previously measured and regional *baseline* ranges, although sediments contained more sand and less organic carbon in fall 2008 than in previous years.

Shipyard Lake Differences in water quality in fall 2008 in Shipyard Lake as compared to regional *baseline* conditions are assessed as **Negligible-Low**. However, slow but statistically-significant increases in concentrations of several ions (sodium, magnesium, potassium, and boron) and a related shift in ion balance in the lake, suggest water quality is changing in Shipyard Lake, with waters becoming more saline.

The differences in benthic invertebrate communities between Shipyard Lake and *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes) are classified as **Negligible-Low**. Differences in values of benthic invertebrate community measurement endpoints between Shipyard Lake and *baseline* lakes in the RAMP FSA are statistically-weak, no measurement endpoints in Shipyard Lake in fall 2008 were at values below the lower limit of their normal range of variability in *baseline* lakes in the RAMP FSA, and the benthic invertebrate community of Shipyard Lake has as high or higher diversity, with about as many or more sensitive taxa (i.e., %EPT) compared to *baseline* lakes in the RAMP FSA.

Differences in sediment quality in fall 2008 in Shipyard Lake as compared to regional *baseline* conditions are assessed as **Moderate**. Sediment quality in Shipyard Lake in 2008 was generally consistent with that of previous years, but regionally high concentrations of some PAH and metal species likely were related primarily to the very high organic carbon and proportion of fine materials in this lake relative to other lakes and stream reaches sampled by RAMP. When these concentrations were normalized to organic carbon or percent fines, resulting concentrations were similar to those at other RAMP sampling locations.

Big Island Lake and Gardiner Lake The measurement endpoint used in the assessment of the results from the Big Island and Gardiner lakes fish tissue sampling program is mercury concentration in fish tissue with potential effects on human health and fish health predicted from the fish tissue analyses.

The average mercury concentration across size classes in lake whitefish and northern pike from Big Island Lake were below the subsistence fish consumption guideline indicating a **Negligible-Low** risk to human health for subsistence fishers and general consumers. The average mercury concentration in walleye greater than 600 mm from Big Island Lake exceeded the subsistence fisher consumption guideline indicating a **High** risk to subsistence fishers and a **Moderate** risk to general consumers for consumption of fish of that size or greater. The average mercury concentration across size classes in lake whitefish from Gardiner Lake was below the subsistence fish consumption guideline indicating a **Negligible-Low** risk to human health. The average mercury concentration in northern pike, with the exception of one individual greater than 700 mm, was below the subsistence fish consumption guideline indicating a Negligible-Low risk to human health for subsistence fishers and general consumers. The average mercury concentration in walleye greater than 500 mm exceeded the subsistence fisher consumption guideline indicating a High risk to subsistence fishers and a **Moderate** risk on human health to general consumers for consumption of fish of that size or greater. Comparisons with historical regional fish tissue mercury data indicated that mercury concentrations from walleye, lake whitefish and northern pike in Gardiner and Big Island lakes were within the range of mercury concentrations observed in this region of Alberta.

Fish tissue results for Gardiner Lake in 2008 suggest **Negligible-Low** potential risk to fish health given mercury concentrations did not exceed the lethal and non-lethal effects or no effects thresholds.

5.11.2 Mills Creek and Isadore's Lake

Monitoring was conducted in the Mills Creek watershed in 2008 for the Climate and Hydrology component. Isadore's Lake is part of the Mills Creek watershed and receives flow from Mills Creek. Monitoring was conducted in Isadore's Lake in 2008 for the Climate and Hydrology, Water Quality, Benthic Invertebrate Community, and Sediment Quality components.

5.11.2.1 Hydrologic Conditions

2008 Hydrologic Conditions: Mills Creek Discharge in Mills Creek, as measured at RAMP Station S6, Mills Creek at Highway 63, did not exceed historical median values until late April but then remained above historical median values for the majority of 2008, with the exception of the late September period. A maximum daily discharge of 0.206 m^3/s was recorded in the middle of August (Figure 5.11-3), and the mean daily discharge for the 2008 data record was 0.038 m^3/s.

Differences Between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph The estimated water balance for Mills Creek for 2008 is provided in Table 5.11-2. As of 2008, the area of closed-circuited and not closed-circuited land change was 2.52 km^2 and 0 km^2, respectively, in the Mills Creek watershed (Table 2.4-1), the estimated net effects of which were decreased inflows to Mills Creek by 0.141 million m^3 in 2008[2].

The *baseline* hydrograph that would have occurred at RAMP Station S6, Mills Creek at Highway 63 was estimated by adding the 0.141 million m^3 of flow to the station's *test* hydrograph recorded for 2008; the resulting estimated *baseline* hydrograph is presented in Figure 5.11-3. The effect on the hydrologic measurement endpoints of the difference between the observed *test* and estimated *baseline* hydrograph for RAMP Station S6, Mills Creek at Highway 63 is a 10.6% decrease in mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge (Figure 5.11-3, Table 5.11-3).

2008 Hydrologic Conditions: Isadore's Lake The water level of Isadore's Lake was just above the historical minimum until early in the year, but it rose well above its historical median level in April and continued to rise above the historical maximum levels for most of June (Figure 5.11-4). Water levels remained above the historical median values until the middle of December.

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[2] For the purposes of this analysis, it is assumed that RAMP Station S6, Mills Creek at Highway 63, is at the mouth of Mills Creek as it enters Isadore's Lake. In reality, RAMP Station S6, Mills Creek at Highway 63, is located approximately 650 m upstream of the inlet of Mills Creek to Isadore's Lake. Therefore, while the estimated incremental discharge, expressed as a total volume, is conservative, the estimated incremental discharge, expressed as a percentage, is more reliable, as much of the land change in the Mills Creek watershed is distributed more or less evenly from north to south along the eastern side of the watershed (Figure 5.11-1).

Summary Differences in the Mills Creek watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at RAMP Station S6, Mills Creek at Highway 63 have been Moderate for all calculated hydrologic measurement endpoints: mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge (Table 5.11-1).

5.11.2.2 Water Quality

Water quality samples were collected from Isadore's Lake in summer and fall 2008 at *test* station ISL-1.

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations of all water quality measurement endpoints in Isadore's Lake were within previously measured minimum and maximum concentrations with the exception of calcium, magnesium, chloride, sulphate, conductivity, and total dissolved solids, the concentrations of which all exceeded previously measured maximum concentrations (Table 5.11-4).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions Concentrations of all water quality measurement endpoints in Isadore's Lake in fall 2008 were within the range of regional *baseline* concentrations (Figure 5.11-5) with the exception of calcium, magnesium and sulphate, whose concentration was greater than the 95th percentile of regional *baseline* concentrations, and dissolved phosphorus, whose concentration was less than the 5th percentile of regional *baseline* concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Sulphate was the only water quality measurement endpoint whose concentration exceeded its water quality guideline in Isadore's Lake in fall 2008 (Table 5.11-4).

Comparison of Other Water Quality Variables to Water Quality Guidelines Concentrations of the following other water quality variables exceeded water quality guidelines in Isadore's Lake in 2008 (Table 5.11-4): total phenols in summer and fall; and sulphide in fall.

Ion Balance Over the period of RAMP monitoring in Isadore's Lake, ion balance has shifted toward a greater proportion sulphate and a decreasing proportion of bicarbonate (Figure 5.11-6).

Trend Analysis The statistically-significant trends detected in water quality in Isadore's Lake at *test* station ISL-1 over the RAMP sampling period ($\alpha = 0.05$) were:

- increasing concentrations of sodium, magnesium and chloride; and
- decreasing concentration of total arsenic, although this may be due to changing analytical detection limits after 2002 (Figure 5.11-5).

Water Quality Index A WQI value of 87.6 for Isadore's Lake in 2008 indicates a Negligible-Low difference from regional *baseline* conditions (Table 5.11-1 and Table 5.11-29). As mentioned above, concentrations of calcium, magnesium and sulphate all fell above the range of regional *baseline* values.

Summary While significant increases have been measured in concentrations of calcium, magnesium and sulphate over the period of monitoring, differences in water quality in fall 2008 in Isadore's Lake as compared to regional *baseline* conditions are assessed as Negligible-Low.

5.11.2.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2008 in Isadore's lake (*test* station ISL-1, depositional, sampled since 2006).

2008 Habitat Conditions The substrate of the Isadore's Lake was dominated by silt and clay; the water was slightly alkaline and had a high conductivity (Table 5.11-6). The amount of total organic carbon in the lake sediments was higher in fall 2008 than in fall 2007.

Relative Abundance of Benthic Invertebrate Community Taxa The benthic invertebrate taxa of Isadore's Lake in fall 2008 were dominated by nematode worms (49%), chironomids (19%) and copepods (11%), with water mites (Hydracarina, 8%) and dragonflies (Anisoptera, <1%) subdominant (Table 5.11-7). The nematode worms were more dominant in Isadore's Lake in fall 2008 than in fall 2007 (32%, RAMP 2008). It must be noted that, due to field sampling problems, benthic invertebrate communities was sampled in Isadore's Lake from 8 m of water, not in shallower (2 to 3 m) water as in previous years, and as in the *baseline* lakes. A difference of 5 to 6 m of water has the potential to substantially alter the kind of benthos found (Kilgour *et al.* 2008). Regardless, a lake such as Isadore's would normally have fingernail clams in water 2 to 8 m deep, as well as amphipods and gastropods. Isadore's Lake also does not contain mayflies or caddisflies, two insect Orders that are considered to be sensitive to a variety of pollutants.

The time trends in the benthic invertebrate community measurement endpoints for Isadore's Lake (Figure 5.11-7) have the following characteristics:

- Total abundance, while decreasing continuously since RAMP sampling began at *test* lake ISL-1 in 1998, remained within the range of natural variability in total abundance in *baseline* lakes in fall 2008;
- The number of taxa has decreased continuously since RAMP sampling began at *test* lake ISL-1 in 1998, and in fall 2008 was lower than the range of natural variability in number of taxa in *baseline* lakes;
- Both diversity and evenness in fall 2008 remained within the range of natural variability in *baseline* lakes, and similar to 2007 conditions which represented an increase from diversity and evenness levels in fall 2006 that were below the range of natural variability in these measurement endpoints in *baseline* lakes; and
- %EPT taxa remained at very low levels in fall 2008 and at the lower end of the range of natural variability for %EPT taxa in *baseline* lakes.

The results of the Correspondence Analysis indicate that Isadore's Lake in fall 2008 had a benthic invertebrate community composition that was outside the normal range of expected composition based on what has been observed in *baseline* lakes in the RAMP FSA (Figure 5.11-8).

Linear contrasts were used to test for:

- a difference in the average value of the benthic invertebrate community measurement endpoints between Isadore's Lake, designated as *test*, and the *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes), designated as "BT" in Table 5.11-8; and

- differences in time trends (designated as "T" in Table 5.11-8) between Isadore's Lake and the *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes) that would occur if the benthic invertebrate community in Isadore's Lake was continuing to degrade (designated as "BT x T" in Table 5.11-8).

The average values of taxa richness, diversity, evenness, and %EPT were significantly lower in Isadore's Lake as compared to the *baseline* lakes in the RAMP FSA, while the test for differences in time trends (BT x T) was significant for diversity and evenness (Table 5.11-8). In addition, the benthic invertebrate community of Isadore's Lake generally had lower (more negative) CA Axis 1 scores (Table 5.11-8), reflecting a higher proportion of the benthic invertebrate community in Isadore's Lake as naidid worms and mites and a relative absence of fingernail clams and amphipods (Table 5.11-7), compared to *baseline* lakes which were more numerically-dominated by amphipods, fingernail clams and tubificid worms.

Sediment Quality

Sediment quality in fall 2008 was sampled in Isadore's Lake (ISL-1, *test*) at the same location at which sampling of benthic invertebrate communities was undertaken in fall 2008.

2008 Results and Historical Ranges of Concentration As in previous years, sediment composition in Isadore's Lake was dominated by silt, with lower quantities of silt and sand (Table 5.11-9). Levels and concentration of more than half of the sediment quality measurement endpoints in fall 2008 were outside their previously measured ranges (Table 5.11-9):

- Levels or concentrations of silt, total organic carbon, Fraction 3 and Fraction 4 hydrocarbons, total dibenzothiophene, total alkylated PAHs, total PAHs, *Chironomus* survival, and *Hyalella* growth in the sediments of Isadore's Lake in fall 2008 were higher than previously measured maximum; and

- Concentrations of Fraction 2 hydrocarbons and predicted PAH toxicity in fall 2008, as well as *Hyalella* survival were below previously measured minima.

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines Concentrations of four sediment quality measurement endpoints in Isadore's Lake in fall 2008 were greater than sediment quality guidelines: F3 and F4 hydrocarbons; mercury; and arsenic.

Sediment Quality Index A SQI value of 85.7 was calculated for sediments in Isadore's Lake in 2008, indicating Negligible-Low difference from regional *baseline* conditions, although greater difference than was observed in many benthic reaches in 2008, where SQI values of over 90 were common (Table 5.11-34). Sediment quality variables that fell above the range of regional *baseline* values included total hydrocarbons (F3, F4 and total), some PAH species, and several metals. However, Isadore's Lake sediments contain high proportions of organic carbon and fine materials. As discussed in Section 6.3.2.1, when these hydrocarbon, PAH and metals data are normalized to organic carbon or percent-fines in sediment, concentrations of these variables fall within the range of observations at other *baseline* and *test* stations. Sediment quality data from ISL-1 since monitoring began in 2001 has been consistent, with SQI values ranging from 82.3 to 86.5.

Summary

The differences in benthic invertebrate communities between Isadore's Lake, designated as *test* throughout the period for which it has been sampled under RAMP, and *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes) are classified as Moderate (Table 5.11-1) on the basis that:

- the average values of taxa richness, diversity, evenness, and %EPT are significantly lower in Isadore's Lake as compared to the *baseline* lakes in the RAMP FSA, and the time trends in diversity and evenness are significantly different in Isadore's Lake than in the *baseline* lakes; and
- taxa richness in 2008 was lower than the range of natural variability from *baseline* lakes, and this was the first year in which this was the case.

In addition, Isadore's Lake in fall 2008 had a benthic invertebrate community composition that was outside the normal range of expected composition based on what has been observed in *baseline* lakes in the RAMP FSA.

Differences in sediment quality in fall 2008 in Isadore's Lake as compared to regional *baseline* conditions are assessed as Negligible-Low. Sediment quality in Isadore's Lake in 2008 was generally consistent with that of previous years, and largely within historical and regional *baseline* ranges of concentrations. Although concentrations of some sediment quality measurement endpoints were above the range of regional *baseline* values (i.e., total hydrocarbons, some PAH species, and several metals), these relatively high concentrations were related to the consistently high organic carbon and fine sediments present in this lake. When total PAH concentrations were corrected for bioavailability and presented as predicted PAH toxicity, the 2008 value of 0.08 was among the lowest observed for any RAMP sediment monitoring location since 1997. In sediment toxicity tests, midges and amphipods exhibited similar survival and greater growth in Isadore's Lake sediments relative to laboratory controls (Table 5.11-1).

5.11.3 Poplar Creek and Beaver River

Monitoring was conducted in the Poplar Creek and Beaver River watersheds in 2008 for the Climate and Hydrology, Water Quality, Benthic Invertebrate Community, and Sediment Quality components.

5.11.3.1 Hydrologic Conditions

2008 Hydrologic Conditions: Poplar Creek Flow in Poplar Creek as measured at RAMP Station S11, Poplar Creek at Highway 63 (07DA007) for 2008, including releases from the Poplar Creek spillway, was 20.8 million m^3 in the monitored period of May 14 to October 14, 2008 (Figure 5.11-9). The maximum-recorded discharge was 5.54 m^3/s, about two-thirds the mean annual flood of 8.2 m^3/s, but it is possible that the 2008 maximum daily discharge occurred before May 14. The minimum measured open-water discharge of 0.175 m^3/s was slightly greater than the historical average minimum discharge of 0.14 m^3/s.

Differences between Observed *Test* Hydrograph and Estimated *Baseline* Hydrograph: Poplar Creek The estimated water balance at RAMP Station S11, Poplar Creek at Highway 63 (07DA007) for the 2008 data record period is provided in Table 5.11-10. As of 2008, the area of closed-circuited and not closed-circuited land change was 2.99 km^2 and 1.27 km^2, respectively, in the Poplar Creek watershed (Table 2.4-1). In addition, water release to Poplar Creek via the Poplar Creek spillway in 2008 during the monitored period is estimated at 9.98 million m^3 as reported by Syncrude. Of this volume, 9.68 million m^3 is due to the diversion of Beaver River, and the remainder is attributed to water release to Ruth Channel by upstream focal projects. Discharge from the Poplar Creek spillway represented 48% of the total flow measured at RAMP Station S11 (07DA007) (Table 5.11-10), and removal of this diversion from Poplar Creek flows from the calculation of the *baseline* hydrograph has a significant influence on the values of the hydrologic measurement endpoints.

The *baseline* hydrograph that would have occurred at RAMP Station S11, Poplar Creek at Highway 63 (07DA007) is presented in Figure 5.11-9. The effect on the hydrologic measurement endpoints of the difference between the observed *test* and estimated *baseline* hydrograph for RAMP Station S11 (07DA007) is a 40% increase in mean open-water season discharge, little or no change to the annual maximum daily discharge, and the existence of discharge every day during the open-water season in contrast to the estimated *baseline* hydrograph for which the minimum open-water season discharge is estimated to be 0 m^3/s (Table 5.11-11).

Summary The differences in the Poplar Creek watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at RAMP Station S11 (07DA007) have been High for mean open-water season discharge and minimum open-water season discharge, and Negligible-Low for the annual maximum daily discharge (Table 5.11-1).

5.11.3.2 Water Quality

In fall 2008, water quality samples were collected from:

- near the mouth of the Beaver River (*test* station BER-1, sampled from 2003 to 2008);
- on the Beaver River upstream of all focal project developments (*baseline* station BER-2, and initiated as a new RAMP station in 2008); and
- near the mouth of Poplar Creek (*test* station POC-1, sampled from 2000 to 2008).

Seasonal sampling was conducted at *baseline* station BER-2 in spring, summer, and fall 2008; winter sampling was attempted, but not possible due to the absence of flowing water below ice at the station.

During the development of Syncrude's Mildred Lake in the 1970s, the upper Beaver River (including *baseline* station BER-2) was rerouted into reservoirs that drain to the Athabasca River via Poplar Creek, with much of the lower reach of Beaver River impounded within the Syncrude site or routed around it. The remaining mainstem of Beaver River is a constructed channel known as the West Interception Ditch, which bounds the western edge of Mildred Lake.

Beaver River

2008 Results and Historical Ranges of Concentration In fall 2008, at *test* station BER-1, concentrations or values of five water quality measurement endpoints were greater than their previously measured maxima: total suspended solids; ultra-trace mercury; total arsenic; total aluminum and pH (Table 5.11-12). Because station BER-2 was first sampled in 2008, no historical data were available for comparison with 2008 results (Table 5.11-13).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions In fall 2008, concentrations of several water quality measurement endpoints in the Beaver River were less than or greater than the range of their regional *baseline* concentrations (Figure 5.11-10):

- *Test* station BER-1: concentrations of sodium, chloride, total dissolved solids and ultra-trace mercury exceeded their 95th percentile of regional *baseline* concentrations; and

- *Baseline* station BER-2: concentrations of total boron and ultra-trace mercury exceeded their 95th percentile of regional *baseline* concentrations, and concentrations of calcium and potassium were less than their 5th percentile of *baseline* regional concentrations.

With few exceptions, concentrations of selected water quality measurement endpoints were higher at *test* station BER-1 relative to *baseline* station BER-2 (Figure 5.11-10).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines The following water quality guideline exceedances were measured in the Beaver River in fall 2008 (Table 5.11-12, Table 5.11-13):

- Concentrations of total nitrogen and total aluminum at both *test* station BER-1 and *baseline* station BER-2;

- Ultra-trace mercury at *test* station BER-1 which exceeded the water quality guideline for chronic exposure of aquatic life, but was below the water quality guideline for acute exposure; and

- Total dissolved phosphorus at *baseline* station BER-2.

The concentration of total aluminum also exceeded its water quality guideline at *baseline* station BER-1 in spring and summer 2008, and the concentration of ultra-trace mercury exceeded its water quality guideline (for chronic exposure) at *baseline* station BER-2 in spring 2008.

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded relevant water quality guidelines in the Beaver River in 2008 (Table 5.11-5):

- sulphide, total phosphorus, total nitrogen, dissolved iron, total iron, and total phenols at *baseline* station BER-2 in spring 2008;

- sulphide, total dissolved phosphorus, total phosphorus, dissolved iron, total aluminum, total phenols, and total iron at *baseline* station BER-2 in summer 2008;

- sulphide, total phosphorus, dissolved iron, total iron, and total phenols at both *test* station BER-1 and *baseline* station BER-2 in fall 2008; and

- total titanium at *test* station BER-1 in fall 2008.

Ion Balance In fall 2008, the composition of anions in sampled water was dominated by bicarbonate at *baseline* station BER-2 and by chloride and sulphate at *test* station BER-1 (Figure 5.11-11); the composition of cations in water sampled at both stations was dominated by calcium, sodium, and potassium. The ionic characteristics of water sampled at *test* station BER-1 were consistent with previous years (Figure 5.11-11).

Water Quality Index The WQI value of 67.5 for lower Beaver River (BER-1) in 2008 indicates a Moderate difference from regional *baseline* conditions (Table 5.11-29). As mentioned above, concentrations of several ions and other dissolved constituents of water quality typically fell above the range of regional *baseline* values at BER-1. In contrast, the upper Beaver River (BER-2) exhibited a WQI of 92.2, indicating a Negligible-Low difference from regional *baseline* conditions.

Summary Differences in water quality in fall 2008 in the lower Beaver River, designated as *test*, as compared to regional *baseline* conditions, are assessed as Moderate, largely as a result of relatively high concentrations of a number of ions and total dissolved solids. Differences in water quality in fall 2008 in the upper Beaver River, designated as *baseline*, as compared to regional *baseline* conditions are assessed as Negligible-Low. Concentrations of total nitrogen and total aluminum exceeded water quality guidelines at these stations, and total mercury also exceeded the AENV chronic water quality guideline in the lower Beaver River.

Poplar Creek

2008 Results and Historical Ranges of Concentration Concentrations of all water quality measurement endpoints at *test* station POC-1 in fall 2008 were within previously measured ranges of concentration at this station with the exception of total strontium, which had a measured concentration in fall 2008 that was below its previously measured minimum concentration (Table 5.11-14).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions In fall 2008, concentrations of all selected water quality measurement endpoints were within the range of regional *baseline* concentrations at *test* station POC-1 except total boron, which was greater than the 95th percentile of its *baseline* regional concentrations (Figure 5.11-10). This is in contrast to fall 2007, when the concentration of total boron at *test* station POC-1 was below the 5th percentile of its regional *baseline* concentrations (Figure 5.11-10).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines The concentrations of total aluminum and total nitrogen in fall 2008 were greater than their water quality guidelines at *test* station POC-1 (Table 5.11-14).

Other Water Quality Guideline Exceedances Concentrations of sulphide, total iron and total phenols were greater than their water quality guidelines at *test* station POC-1 in fall 2008 (Table 5.11-5).

Ion Balance There has been high year-to-year variation in the ion balance at *test* station POC-1 (Figure 5.11-11). In fall 2008, the ionic composition of water sampled at *test* station POC-1 was characterized by a relative bicarbonate concentration near its highest measured level and the relative composition of cations being within the range of historical measurements (Figure 5.11-11).

Trend Analysis The time series of data for *test* station POC-1 is sufficiently long and consistent to enable statistical trend analysis of fall water quality data (n=9). The only significant trend detected in the statistical trend analysis was a decrease in the concentration of total suspended solids (α=0.05).

Water Quality Index The WQI value of 96.1 for lower Poplar Creek in 2008 was similar to that observed at upstream BER-2, and indicates a Negligible-Low difference from regional *baseline* conditions (Table 5.11-29).

Summary Differences in water quality in fall 2008 in lower Poplar Creek, designated as *test*, as compared to regional *baseline* conditions are assessed as Negligible-Low (Table 5.11-1).

5.11.3.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in 2008 at *baseline* reach BER-D-2 (depositional, sampled for the first time in fall 2008) and *test* reach POC-D-1 (depositional, sampled for the first time in fall 2008). Data obtained from *baseline* reach BER-D-2 are used as a *baseline* against which data obtained from *test* reach POC-D-1 can be assessed.

2008 Habitat Conditions *Baseline* reach BER-D-2 in fall 2008 had a substrate dominated by sand, with minor amounts of silt and clay (Table 5.11-15). The water depth of the channel was about 0.7 m, and flow velocity was about 0.2 m/s. The water of the channel was slightly alkaline, and conductivity was measured at 312 µS/cm. *Test* reach POC-D-1 also had fine-grained sediments, but with a greater proportion of silt and clay than *baseline* reach BER-D-2. The substrate at *test* reach POC-D-1 had about four times the organic content as *baseline* reach BER-D-2 (Table 5.11-15). The conductivity of *test* reach POC-D-1 was higher than at *baseline* reach BER-D-2, suggesting a higher concentration of dissolved solids.

Relative Abundance of Benthic Invertebrate Community Taxa The species composition of the benthic invertebrate community of *test* reach POC-D-1 in fall 2008 was indicative of degraded habitat conditions (Table 5.11-16), with tubificid worms being the most dominant group comprising 72% of the collected individuals. Chironomidae were the next most dominant group (21%) and were comprised largely of *Cryptochironomus*, *Polypedilum* and *Paralauterborniella*. A single mayfly (Ephemeroptera, *Caenis*) and a single caddisfly (Trichoptera, *Oecetis*) were found among all the samples in *test* reach POC-D-1 in fall 2008.

The benthic invertebrate community of *baseline* reach BER-D-2 was dominated by taxa typically associated with sandy environments (Table 5.11-16). Chironomids were the single most dominant group accounting for an average of 84% of the fauna. Numerically-important chironomids included the generalist genus *Polypedilum*, as well as *Paracladopelma*, and several additional genera belonging to the sub-families Chironomini, Tanytarsini and Orthocladiinae. Sensitive taxa included the caddisflies (Trichoptera) *Brachycentrus* and *Lepidostoma*, and the mayflies (Ephemeroptera) *Hexagenia limbata*, *Caenis* and *Baetisca*, taxa that are frequently associated with sand environments.

The values of all benthic invertebrate community measurement endpoints for *baseline* reach BER-D-2 in fall 2008 were within the range of natural variation for depositional reaches in the RAMP FSA (Figure 5.11-12). In particular, almost 3% of the benthic invertebrate fauna collected at *baseline* reach BER-D-2 in fall 2008 were EPT taxa, well within the normal range of variation of this measurement endpoint for *baseline* depositional reaches. In contrast, at *test* reach POC-D-1, the values of both Simpson's diversity and evenness were below their normal range of variation for *baseline* depositional reaches in the RAMP FSA, and both taxa richness and %EPT were at the lower end of their normal range of variation for *baseline* depositional reaches in the RAMP FSA (Figure 5.11-12). Taxa richness, Simpson's Diversity, Evenness and %EPT were all lower at *test* reach POC-D-1 than at *baseline* reach BER-D-2 (Figure 5.11-12).

The results of the Correspondence Analysis indicate species composition at both *test* reach POC-D-1 and *baseline* reach BER-D-2 in fall 2008 was similar to what has been observed at *baseline* depositional reaches in the RAMP FSA (Figure 5.11-13).

Test reach POC-D-1 had significantly lower Simpson's Diversity and evenness and significantly different Correspondence Analysis axis scores as compared to *baseline* reach BER-D-2, but there were no statistical differences in total abundance, taxa richness, or %EPT between the two reaches (Table 5.11-17).

Sediment Quality

Sediment quality was sampled in fall 2008 at *baseline* reach BER-D-2 (depositional, sampled for the first time in fall 2008) and *test* reach POC-D-1 (depositional, sampled for the first time in fall 2004) at the same locations at which benthic invertebrate community sampling was undertaken in fall 2008 on these watercourses.

2008 Results and Historical Ranges of Concentration: Beaver River Given sediment quality in the upper Beaver River (BER-D-2) was sampled for the first time by RAMP in fall 2008, there are no historical data available for comparison. Sediments at BER-D-2 in 2008 were generally sandy, and exhibited low concentrations of total organic carbon and PAHs (Table 5.11-18).

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines: Beaver River In fall 2008, no sediment quality measurement endpoints exceeded sediment quality guidelines at *baseline* station BER-D-2 (Table 5.11-18).

2008 Results and Historical Ranges of Concentration: Poplar Creek In fall 2008, concentrations and levels of total organic carbon, naphthalene, retene, total parent PAHs, predicted PAH toxicity, *Chironomous* growth, and *Hyalella* survival were greater than their previously measured maxima at *test* station POC-D-1, while concentrations of Canadian Council of Ministers of the Environment (CCME) F2, F3, and F4 hydrocarbons as well as *Chironomous* survival were lower than their previously measured minima (Table 5.11-19).

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines: Poplar Creek In fall 2008, no sediment quality measurement endpoints exceeded sediment quality guidelines at *test* station POC-D-1 (Table 5.11-19).

Sediment Quality Index In fall 2008, a SQI value of 87.4 was calculated for POC-D-1 (Table 5.11-34); sediment quality observations at POC-D-1 from 1997 to 2004 (n=4) yielded SQI values from 87.3 to 100. For upper Beaver River reach BER-D-2, a value of 100 was calculated, indicating all observations in 2008 fell within the range of regional *baseline* conditions (Table 5.11-34). Several metals showed deviations from regional *baseline* conditions at POC-D-1 in 2008, including barium, chromium, cobalt, copper, lead, magnesium, mercury, nickel, strontium, thallium, and vanadium. As discussed in Section 6.3.2.1, lower Poplar Creek exhibited the highest absolute concentration of total metals of all RAMP reaches surveyed in 2008, and the second highest when normalized to percent fines.

Summary

The differences in the benthic invertebrate community in lower Poplar Creek, designated as *test* in 2008, as compared to benthic invertebrate communities in *baseline* depositional reaches, represented by the upper Beaver River are classified as Moderate (Table 5.11-1) on the basis that:

- *test* reach POC-D-1 in lower Poplar Creek had significantly lower Simpson's Diversity and evenness as compared to *baseline* reach BER-D-2 in the upper Beaver River; and
- at *test* reach POC-D-1, the values of both diversity measurement endpoints were below and both taxa richness and %EPT were at the lower end of their normal range of variation for *baseline* depositional reaches in the RAMP FSA.

At both *baseline* reach BER-D-2 and *test* reach POC-D-1, sediment quality showed a Negligible-Low difference from regional *baseline* conditions, although concentrations of some metals exceeded regional *baseline* ranges at POC-D-1. No sediment quality variables exceeded relevant guidelines at either station (Table 5.11-1).

5.11.4 McLean Creek

Monitoring was conducted in the McLean Creek watershed in 2008 for the Water Quality component.

5.11.4.1 Water Quality

In fall 2008, water quality samples were collected from near the mouth of McLean Creek (station MCC-1, *test* station, sampled from 1999 to 2008).

2008 Results and Historical Ranges of Concentration In fall 2008 at *test* station MCC-1, concentrations of three water quality measurement endpoints were greater than their previously measured maxima: total dissolved phosphorus, dissolved organic carbon, and ultra-trace mercury. Concentrations and levels of conductivity, sodium, calcium, magnesium, sulphate, and total alkalinity were lower than their previously measured minima (Table 5.11-20).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions In fall 2008, there were two water quality measurement endpoints that fell outside of the *baseline* range of natural variation at *test* station MCC-1 (Figure 5.11-10): the concentration of ultra-trace mercury was greater than the 95th percentile of regional *baseline* concentrations; and the concentration of total boron was below the 5th percentile of regional *baseline* concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Concentrations of total nitrogen and total aluminum exceeded their water quality guidelines at *test* station MCC-1 in fall 2008 (Table 5.11-20).

Other Water Quality Guideline Exceedances Concentrations of Sulphide, total phosphorus, total Kjeldahl nitrogen, dissolved iron, total iron, and total phenols were greater than their water quality guidelines at *test* station MCC-1 in fall 2008 (Table 5.11-5).

Ion Balance There has been high year-to-year variability in the ion composition at *test* station MCC-1 over the RAMP sampling period (Figure 5.11-11). While there was greater relative proportion of bicarbonate and calcium ions in fall 2008 compared to fall 2006 and 2007, the overall ion balance in fall 2008 was within the range in ion balance measured at *test* station MCC-1 over the RAMP sampling period.

Trend Analysis The time series of data for *test* station MCC-1 is sufficiently long and consistent to enable statistical trend analysis of fall water quality data (n=10). Only a decreasing trend in arsenic was observed over the period of record (α=0.05); although this may be due to changing analytical detection limits after 2002 (Figure 5.11-10).

Water Quality Index Based on a WQI value of 96.1 for fall 2008, water quality in McLean Creek showed Negligible-Low differences from regional *baseline* characteristics (Table 5.11-29).

Summary Differences in water quality in fall 2008 in lower McLean Creek, designated as *test*, as compared to regional *baseline* conditions, are assessed as Negligible-Low. Water quality in McLean Creek in 2008 was generally consistent with regional *baseline* characteristics, although concentrations of several water quality variables were outside their previously measured ranges for this station, including total dissolved phosphorus, dissolved organic carbon, and ultra-trace mercury (highs), and conductivity, sodium, calcium, magnesium, and sulphate (lows) (Table 5.11-1).

5.11.5 Fort Creek

Monitoring was conducted in the Fort Creek watershed in 2008 for the Climate and Hydrology, Water Quality, Benthic Invertebrate Community, and Sediment Quality components.

5.11.5.1 Hydrologic Conditions

2008 Hydrologic Conditions Fort Creek flows, as measured at RAMP Station S12, Fort Creek at Highway 63, were below historical median values for the first part of June and most of July (Figure 5.11-14). At the beginning of August, daily flow increased above the upper quartile for most of the remainder of the open water season. The maximum observed daily discharge was 0.249 m^3/s in late October and minimum summer flow was 0.018 in m^3/s in July. The mean daily flow for the 2008 record was 0.107 m^3/s.

Differences between Observed *Test* Hydrograph and Estimated Baseline Hydrograph The estimated water balance for Fort Creek at RAMP Station S12, Fort Creek at Highway 63 is provided in Table 5.11-21. As of 2008, the area of closed-circuited and not closed-circuited land change was 0.30 km^2 and 19.5 km^2, respectively, in the Fort Creek watershed (Table 2.4-1), the estimated net effects of which were increased inflows to Fort Creek by 0.149 million m^3 over the data record in 2008 (Table 5.11-21).

The *baseline* hydrograph that would have occurred at RAMP Station S12 was estimated by adding the 0. 149 million m^3 of flow to the station's observed *test* hydrograph recorded over the 2008 data record; the resulting estimated *baseline* hydrograph is presented in Figure 5.11-14. The effect on the hydrologic measurement endpoints of the difference between the observed *test* and estimated *baseline* hydrograph for RAMP Station S12, Fort Creek at Highway 63 is an 11.3% increase in mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge (Figure 5.11-14, Table 5.11-22).

Summary The differences in the Fort Creek watershed between the observed *test* hydrograph and the estimated *baseline* hydrograph as measured at RAMP Station S12, Fort Creek at Highway 63 have been Moderate for open-water season discharge, annual maximum daily discharge, and, open-season minimum daily discharge (Table 5.11-1).

5.11.5.2 Water Quality

In fall 2008, water quality samples were collected from near the mouth of Fort Creek (*test* station FOC-1, first sampled in 2000, sampled intermittently from 2002 to 2008).

2008 Results and Historical Ranges of Concentration In fall 2008, at *test* station FOC-1, the concentration of all water quality measurement endpoints were within their previously measured ranges at this station except conductivity and sulphate which were at levels that were greater than their previously measured historical maxima (Table 5.11-23).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Regional Baseline Conditions All but three water quality measurement endpoints were within the range of regional *baseline* concentrations at *test* station FOC-1 in fall 2008 (Figure 5.11-15): the concentration of calcium exceeded its 95^{th} percentile of regional *baseline* concentrations; and concentrations of total arsenic and dissolved phosphorus were lower than their 5^{th} percentile of regional *baseline* concentrations.

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines Total aluminum was the only selected water quality measurement endpoint at *test* station FOC-1 to exceed its water quality guideline in fall 2008 (Table 5.11-23).

Other Water Quality Guideline Exceedances Concentrations of sulphide, total iron, and total phenols were greater than their water quality guidelines at *test* station FOC-1 in fall 2008 (Table 5.11-23).

Ion Balance There was an increase in the relative proportion of sulphate in the ionic composition of water sampled at *test* station FOC-1 in fall 2008 relative to previous years (Figure 5.11-16), but this did not materially change the basic ionic composition of water at *test* station FOC-1 of being dominated by calcium and bicarbonate.

Trend Analysis The time series of data for *test* station FOC-1 is sufficiently long and consistent to enable statistical trend analysis of fall water quality data (n=8). There were no significant trends in water quality measurement endpoints at this station (α=0.05).

Water Quality Index A WQI value of 92.2 was calculated for Fort Creek in fall 2008, indicating Negligible-Low differences from regional *baseline* characteristics (Table 5.11-29).

Summary Differences in water quality in fall 2008 in lower Fort Creek, designated as *test*, as compared to regional *baseline* conditions, are assessed as Negligible-Low. Water quality in lower Fort Creek has remained consistent since RAMP initiated monitoring in this waterbody in 2000 (Table 5.11-1).

5.11.5.3 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate community samples were collected in fall 2008 from a lower reach of Fort Creek (reach FOC-D-1, sampled since 2001). This depositional reach was designated as *baseline* from 2001 to 2004, and as *test* from 2005 to present.

2008 Habitat Conditions Fort Creek at *test* reach FOC-D-1 in fall 2008 had a wetted width of about 2 m, a water depth of about 0.5 m, no macrophytes, and a substrate that was dominated by sand (Table 5.11-24). Total organic carbon content was almost 2%, reflecting high woody debris content. Water was slightly alkaline, and had a high conductivity and dissolved oxygen content.

Relative Abundance of Benthic Invertebrate Community Taxa The composition of the benthic invertebrate community of lower Fort Creek at reach FOC-D-1 has typically been dominated by chironomids (68% in 2008) (Table 5.11-25). Subdominant groups in 2008 included tubificid worms (22%), snails (Gastropoda, 3%), and nematode worms (3%). Mayflies (Ephemeroptera: *Baetis*) were present, but in low relative abundance (1%). Stoneflies (Plecoptera) and caddisflies (Trichoptera) were absent in 2008 and, together with Ephemeroptera, have remained at low levels since the beginning of benthic invertebrate community sampling by RAMP in Fort Creek in 2001 (Table 5.11-25). Fingernail clams were also absent in 2008, and have been at less than 1% relative abundance every year since 2001 except for 2001 and 2005 (Table 5.11-25).

The time trends in the benthic invertebrate community measurement endpoints for lower Fort Creek at reach FOC-D-1 (Figure 5.11-17) have the following characteristics:

- Total abundance, taxa richness, and Simpson's diversity were less than the normal range of variation for these measurement endpoints in *baseline* depositional reaches in the RAMP FSA in fall 2008; and

- Evenness and %EPT were within the normal range of variation for these measurement endpoints in *baseline* depositional reaches in the RAMP FSA in fall 2008. %EPT has typically been low in reach FOC-D-1, even during the period that it was designated as *baseline*.

The results of the Correspondence Analysis indicate that the species composition of the benthic invertebrate community at reach FOC-D-1 has been similar to those found in *baseline* depositional reaches in the RAMP FSA since benthic invertebrate community sampling began there in 2001 (Figure 5.11-18).

Linear contrasts were used to *test* for differences in values of benthic invertebrate community measurement endpoints between the period that reach FOC-D-1 was designated as *baseline* and the period it has been designated as *test* ("Before to After" in Table 5.11-26). Both total abundance and taxa richness were lower in the years reach FOC-D-1 has been designated as *test* as compared to the years it was designated as *baseline*, while there is no difference in diversity, evenness, or %EPT between these two periods (Table 5.11-26). In addition, the non-effect-related variation ("Remainder" in Table 5.11-26) was insignificant for all benthic invertebrate community measurement endpoints.

Sediment Quality

Sediment quality was sampled in fall 2008 at *test* station FOC-D-1 at the same location at which benthic invertebrate community sampling was undertaken in fall 2008 on lower Fort Creek.

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations and levels of CCME F2, F3, and F4 hydrocarbons, retene, total dibenzothiophenes, and %sand were all greater than their previously measured maxima at *test* station FOC-D-1, while concentrations and levels of total organic carbon, %silt, and naphthalene were lower than their previously measured minima (Table 5.11-27).

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines In fall 2008, concentrations of CCME F2 and F3 hydrocarbons exceeded CCME soil-quality guidelines at FOC-D-1 (Table 5.11-27).

Sediment Quality Index A SQI value of 95.0 was calculated for Fort Creek in fall 2008, indicating a Negligible-Low difference from regional *baseline* characteristics (Table 5.11-34). In 2008, a small number of PAH species in Fort Creek sediments fell slightly above the regional range of natural variability. SQI values for Fort Creek have been variable since RAMP began monitoring sediment quality in this creek in 2000, ranging from 76.5 to 100 (n=5).

Summary

The differences in the benthic invertebrate community in lower Fort Creek, represented by reach FOC-D-1, between the period the reach was designated as *baseline* and the period it has been designated as *test* are classified as High (Table 5.11-1) on the basis that:

- both total abundance and taxa richness were lower in the years reach FOC-D-1 has been designated as *test* as compared to the years it was designated as *baseline*; and
- total abundance, taxa richness, and Simpson's diversity were less than the normal range of variation for these measurement endpoints in *baseline* depositional reaches in the RAMP FSA in fall 2008.

Differences in sediment quality in fall 2008 in lower Fort Creek, designated as *test*, as compared to regional *baseline* conditions, are assessed as Negligible-Low. Concentrations of sediment quality measurement endpoints in Fort Creek in 2008 were largely within previously measured and regional *baseline* ranges, although sediments contained more sand and less organic carbon in fall 2008 than in previous years (Table 5.11-1).

5.11.6 Shipyard Lake

Monitoring was conducted in Shipyard Lake in 2008 for the Water Quality, and the Benthic Invertebrate Community and Sediment Quality components.

5.11.6.1 Water Quality

Water quality samples were collected from Shipyard Lake in summer and fall 2008 at station SHL-1 (*test*, sampled every year since 1998).

2008 Results and Historical Ranges of Concentration At Shipyard Lake (station SHL-1), fall 2008 concentrations of all water quality measurement endpoints were within previously measured historical ranges with the exception of sodium, chloride and total boron, which had concentrations in fall 2008 that exceeded previously measured maxima, and total aluminum, which had a concentration in fall 2008 that was below its previously measured minimum concentration (Table 5.11-28).

Comparison of Water Quality Measurement Endpoints to Natural Variation in Baseline Conditions At *test* station SHL-1 in fall 2008, concentrations of all water quality measurement endpoints were within the range of regional *baseline* concentrations with the exception of dissolved phosphorus which was below the 5^{th} percentile of regional *baseline* concentrations (Figure 5.11-5).

Comparison of Water Quality Measurement Endpoints to Water Quality Guidelines No water quality measurement endpoints in Shipyard Lake in fall 2008 had measured concentrations that exceeded water quality guidelines (Table 5.11-28).

Other Water Quality Guideline Exceedances Concentrations of the following other water quality variables exceeded relevant water quality guidelines in 2008 in Shipyard Lake (Table 5.11-5): sulphide and total phenols in summer; and sulphide, total phenols and total iron in fall.

Ion Balance Relative concentrations in major ions in Shipyard Lake have shifted in the past two years to a greater proportion of sodium and chloride and a decreasing proportion of calcium and bicarbonate (Figure 5.11-6).

Trend Analysis The time series of data for *test* station SHL-1 is sufficiently long and consistent to enable statistical trend analysis of fall water quality data (n=11). Significant trends in the following water-quality measurement endpoints were observed at *test* station SHL-1 over the RAMP sampling period ($\alpha = 0.05$):

- Increasing concentration of sodium, magnesium, potassium, and total boron; and
- Decreasing concentration of arsenic, although this likely was due to improved (decreased) analytical detection limits after 2002.

Water Quality Index A WQI value of 100 for Shipyard Lake in 2008 indicates a Negligible-Low difference from regional *baseline* characteristics (Table 5.11-29).

Summary Differences in water quality in fall 2008 in Shipyard Lake, designated as *test*, as compared to regional *baseline* conditions, are assessed as Negligible-Low (Table 5.11-1). However, slow but statistically significant increases in concentrations of several ions (sodium, magnesium, potassium, and boron) and a related shift in ion balance in the lake, suggest water quality is changing in Shipyard Lake, with waters becoming more saline.

As a component of a fish-habitat compensation agreement related to Shipyard Lake, Suncor administers a Shipyard Lake Integrated Management Plan, which aims to maintain water levels and ecological function in the lake during mining operations. Although augmentation of lake water levels using Athabasca River water is contemplated in the agreement, up to 2008, water levels in the lake were within historical norms and therefore, no such augmentation has occurred to date (P. McEachern, Alberta Environment, *pers. comm.*, March 2009).

5.11.6.2 Benthic Invertebrate Communities and Sediment Quality

Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in fall 2008 in Shipyard Lake (*test* station ISL-1, depositional, sampled since 2000).

2008 Habitat Conditions Shipyard Lake in fall 2008 was characterized by high macrophyte cover (74%), high conductivity, and a substrate comprised mostly of clay and silt, with high total organic carbon content (Table 5.11-30).

Relative Abundance of Benthic Invertebrate Community Taxa The composition of the benthic invertebrate community of Shipyard Lake at *test* station SHL-1 in fall 2008 was dominated by chironomids (40%), ostracods (22%), and copepods (16%, Table 5.11-31).

Mayflies (Ephemeroptera, 6%), and caddisflies (Trichoptera, < 1%), and amphipods (1%) were present in lower abundances.

The time trends in the benthic invertebrate community measurement endpoints for Shipyard Lake at *test* station SHL-1 indicate that the benthic invertebrate community of the lake has a composition similar to what would be expected for a lake in the RAMP FSA designated as *baseline* (Figure 5.11-19). Total abundance, taxa richness, evenness, and %EPT in fall 2008 were close to, and Simpson's Diversity was above, the defined upper limit of the normal range of variability for these measurement endpoints in *baseline* lakes in the RAMP FSA. High diversity and %EPT suggest a benthic invertebrate community in relatively good condition (Plafkin *et al.* 1989).

The results of the Correspondence Analysis indicate that the species composition of the benthic invertebrate community in Shipyard Lake has been similar to those found in *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes) since benthic invertebrate community sampling began there in 2000 (Figure 5.11-20).

Linear contrasts were used to test for:

- a difference in the average value of the benthic invertebrate community measurement endpoints between Shipyard Lake, designated as *test*, and the *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes), designated as "BT" in Table 5.11-32; and
- differences in time trends (designated as "T" in Table 5.11-8) between Shipyard Lake and the *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes) that would occur if the benthic invertebrate community in Shipyard Lake was continuing to degrade (designated as "BT x T" in Table 5.11-32).

The average values of total abundance, diversity, and evenness were significantly different in Shipyard Lake as compared to the *baseline* lakes in the RAMP FSA, implying higher abundance and lower diversity and evenness in Shipyard Lake compared to the two *baseline* lakes, while the test for differences in time trends (BT x T) was significant for taxa richness and evenness (Table 5.11-32). The "remainder" term, representing non-effect-related variation; however, accounted for a substantially higher fraction of the variability in benthic invertebrate community measurement endpoints (except CA Axis 1) than did either of the tests described and reported above, and so the statistical differences described above are not strong. Shipyard Lake samples generally had lower (more negative) CA Axis 1 scores than those of *baseline* lakes (i.e., McClelland and Kearl lakes), suggesting that the benthic invertebrate community of Shipyard Lake is more numerically-dominated by naidid worms, mites and mayflies compared to *baseline* lakes in the RAMP FSA, which are more numerically-dominated by amphipods, fingernail clams and tubificid worms.

Sediment Quality

Sediment quality in fall 2008 was sampled in Shipyard Lake (SHL-1, *test*, sampled every year since 2001 except 2005) at the same locations at which benthic invertebrate community sampling was undertaken in fall 2008.

2008 Results and Historical Ranges of Concentration In fall 2008, concentrations of CCME F3 and F4 hydrocarbons, total alkylated PAHs, and naphthalene were greater than their previously measured maxima in Shipyard Lake (Table 5.11-33). In addition, *Chironomus* growth and *Hyalella* growth exceeded their previously measured maximum at *test* station SHL-1.

Comparison of Sediment Quality Measurement Endpoints to Sediment Quality Guidelines In fall 2008, CCME F3 hydrocarbons were the only sediment quality measurement endpoint to exceed sediment or soil-quality guidelines in Shipyard Lake (Table 5.11-33).

Sediment Quality Index A SQI value of 73.6 was calculated for sediments in Shipyard Lake in 2008, indicating Moderate difference from regional *baseline* conditions (Table 5.11-34). Several sediment-quality variables fell above the range of regional *baseline* values, included several PAH species and numerous metals. However, Shipyard Lake sediments contain high proportions of organic carbon (nearly 17%) and fine materials (>95% silt+clay). As discussed in Section 6.3.2.1, when these PAH and metals data are normalized to organic carbon or percent-fines in sediment, concentrations of these variables in Shipyard Lake fall within the range of observations at other *baseline* and *test* stations. When PAH concentrations were normalized for expected bioavailability as predicted PAH toxicity, this value was generally lower in Shipyard Lake than in other stream reaches sampled by RAMP in 2008. Sediment quality data from SHL-1 since monitoring began in 2001 has been consistent, with SQI values ranging from 71.3 to 95.6.

Summary

The differences in benthic invertebrate communities between Shipyard Lake, designated as *test* throughout the period for which it has been sampled under RAMP, and *baseline* lakes in the RAMP FSA (i.e., McClelland and Kearl lakes) are classified as Negligible-Low on the basis that (Table 5.11-1):

- differences in values of benthic invertebrate community measurement endpoints between Shipyard Lake and *baseline* lakes in the RAMP FSA are statistically-weak;
- no measurement endpoints in Shipyard Lake in fall 2008 were at values below the lower limit of their normal range of variability in *baseline* lakes in the RAMP FSA; and
- the benthic invertebrate community of Shipyard Lake has as high or higher diversity, with about as many ore more sensitive taxa (i.e., %EPT) compared to *baseline* lakes in the RAMP FSA.

Differences in sediment quality in fall 2008 in Shipyard Lake, designated as *test*, as compared to regional *baseline* conditions, are assessed as Moderate (Table 5.11-1). Sediment quality in Shipyard Lake in 2008 was generally consistent with that of previous years, but regionally high concentrations of some PAH and metal species likely were related primarily to the very high organic carbon and proportion of fine materials in this lake relative to other lakes and stream reaches sampled by RAMP. When these concentrations were normalized to organic carbon or percent fines, resulting concentrations were similar to those at other RAMP sampling locations. In sediment toxicity tests, midges and amphipods exhibited similar survival and greater growth in Shipyard Lake sediments relative to laboratory controls.

5.11.7 Susan Lake Outlet

Monitoring was conducted at the Susan Lake outlet in 2008 for the Climate and Hydrology component.

5.11.7.1 Hydrologic Conditions

2008 Hydrologic Conditions Flow in the Susan Lake Outlet was consistent with 2007 flow at the end of June and early July but dropped to near zero flow for the remainder of the month. The majority of flow was recorded in August with the three largest events occurring in this month. Discharge generally increased to the end of the recorded data period (Figure 5.11-21).

5.11.8 Big Island Lake and Gardiner Lake

The Fish Population component for miscellaneous aquatic systems consisted of tissue analyses on target fish species in two regional lakes in fall 2008: Big Island Lake and Gardiner Lake.

5.11.8.1 Big Island Lake

Whole-Organism Metrics

A total of 16 lake whitefish (6 female and 5 male and 5 unsexed), 12 northern pike (6 female and 6 male), and 20 walleye (8 female, 9 male and 3 unsexed) from Big Island Lake were sampled for fish tissue (muscle) analysis. The sizes of fish sampled were:

- Lake whitefish: 206 mm immature unsexed to 478 mm mature female. Males (average fork length: 452 mm) were larger than females (average fork length: 428 mm). The average length of all sampled fish was 382 mm;
- Northern pike: 434 mm, age 3, mature female to 649 mm, age 5, mature female. Females (average fork length: 563 mm, average age: 4 years) were larger than males (average fork length: 551 mm, average age: 5 years). The average length of all sampled fish was 557 mm and the average age was 5 years; and
- Walleye: 271 mm, age 2, immature male to 623 mm (age unknown) mature female. Females (average fork length: 447 mm, average age: 7 years) were larger than males (average fork length: 343 mm, average age: 5 years). The average length of all sampled fish was 375 mm and the average age was 6 years.

Mercury Concentrations

Total mercury concentrations in muscle of individual walleye, northern pike and lake whitefish collected from Big Island Lake in 2008 are presented in Table 5.11-35. Mercury concentrations in lake whitefish tissue ranged from a low of 0.01 mg/kg in a 265 mm immature unsexed individual to a high of 0.06 mg/kg in a 478 mm mature female. Mercury concentrations in northern pike tissue ranged from 0.05 mg/kg in a 434 mm mature female to 0.11 mg/kg in a 581 mm mature male and walleye tissue mercury concentrations ranged from 0.03 mg/kg in a 274 mm immature male to 0.25 mg/kg in a 623 mm mature female. Mercury concentrations by size class for lake whitefish, walleye and northern pike are presented in Figure 5.11-22. Mercury concentrations by age for walleye and northern pike are presented in Figure 5.11-23. Mercury concentrations in lake whitefish and walleye increased with size class while mercury in northern pike tissue did not show a consistent trend with size class. Mercury concentrations in walleye and northern pike increased with age.

Regressions between mercury concentrations and fork length (log_{10}-transformed) were significant and strongly positive for lake whitefish and walleye ($p < 0.01$; fork length adjusted $R^2 = 0.66$ for lake whitefish, and 0.81 for walleye) but not significant for northern pike and weakly correlated, possibly due to the small size range of captured fish of this species (p = 0.12; R^2 = 0.17) (Table 5.11-36, Figure 5.11-24).

Results from the 2008 Big Island Lake fish tissue program were compared to results from regional studies in northern Alberta as reported in Grey *et al*. (1995), RAMP (2004), Golder (2004), RAMP (2005), and RAMP (2008); results are provided in Figure 5.11-25 to Figure 5.11-27. Given that the size of fish may be an important determinant of the concentration of mercury in fish (INAC 2003) and may confound comparisons among waterbodies, mercury concentrations were standardized to fish weight[3]. When standardized to fish weight, 2008 mercury concentrations in male and female walleye in Big Island Lake were within the low to mid-range of mercury concentrations in walleye from regional waterbodies (Figure 5.11-25). Male and female mean mercury concentrations in northern pike from Big Island Lake in 2008 were very low relative to other waterbodies in the region (Figure 5.11-26); and weight standardized mercury concentrations in lake whitefish from Big Island Lake in 2008 were also very low relative to other waterbodies in the region (Figure 5.11-27).

Potential Risks of Mercury in Fish Tissue to Human Health

2008 walleye, northern pike and lake whitefish muscle mercury concentrations from Big Island Lake were screened against United States Environmental Protection Agency (USEPA) and Health Canada human health criteria for fish consumption (Table 5.11-35); a summary of the results is as follows:

- The mean mercury concentration (0.025 mg/kg) in lake whitefish did not exceed any criteria for fish consumption and no lake whitefish exceeded the Health Canada guideline for general consumers and subsistence fishers or the USEPA criteria for recreational fishers;
- The overall mean mercury concentration (0.08 mg/kg) in northern pike exceeded the USEPA criteria for subsistence fishers (0.049 mg/kg), but did not exceed the Health Canada criteria for subsistence (0.2 mg/kg) and recreational fishers (0.5 mg/kg). Eleven of the twelve northern pike captured exceeded the National USEPA guideline for subsistence fishers; and
- The overall mean mercury concentration (0.08 mg/kg) in walleye exceeded the USEPA criteria for subsistence fishers (0.049 mg/kg). Twelve of the twenty walleye captured exceeded the USEPA criteria for subsistence fishers (0.49 mg/kg) and one of the twenty captured walleye exceeded the Health Canada guideline for subsistence fishers (0.2 mg/kg).

Potential Risks of Mercury in Fish Tissue to Fish and Fish Health

Mercury concentrations in muscle of walleye, northern pike and lake whitefish from Big Island Lake did not exceed any of the effects (or no effects) thresholds for fish and fish health based on methylmercury concentration ranges described in Table 3.4-9.

Summary Assessment

The measurement endpoint used in the assessment of the results of the Big Island Lake fish tissue sampling program is mercury concentration in fish tissue, and potential effects on human health and fish health were predicted from the fish tissue analyses.

[3] Mercury concentrations are measured in mg/kg of fish tissue; therefore, concentrations were standardized to a 1 kg fish.

Results for lake whitefish from Big Island Lake indicate very little risk to subsistence and recreational fishers, or general consumers (0% of sampled fish exceeding any relevant Health Canada guidelines; 6% [one of 16] of sampled fish exceeded the more stringent USEPA subsistence guideline[4]). The average mercury concentration in lake whitefish from Big Island Lake across all size classes was below the subsistence fisher guideline indicating a Negligible-Low risk to human health (Table 5.11-1).

Results for Big Island Lake walleye indicate a small risk to subsistence fishers characterized by 60% of fish analyzed with mercury concentrations exceeding the USEPA guideline and of that proportion, 5% exceeding the Health Canada guideline. The average mercury concentration in walleye greater than 600 mm from Big Island Lake was above the subsistence fisher guideline indicating a High risk to subsistence fishers and a Moderate risk to human health for general consumers for consumption of fish of this size (Table 5.11-1). For fish less than 600mm in length, the risk to human health was classified as Negligible-Low.

Results for Big Island Lake northern pike indicate a risk to subsistence fishers characterized by 92% of fish analyzed with mercury concentrations exceeding USEPA guidelines, but little risk to recreational fishers and general consumers given no fish sampled fish exceeded the relevant guidelines. The average mercury concentration across all size classes in northern pike from Big Island Lake was below the subsistence fisher guideline indicating a Negligible-Low risk to human health for subsistence fishers and general consumers (Table 5.11-1).

Although mercury concentrations in Big Island Lake walleye, northern pike and lake whitefish often exceeded the USEPA subsistence guideline, comparisons with historical regional data indicated that these concentrations were within the range of mercury concentrations observed in this region of Alberta and are generally below any Health Canada consumption guidelines (Grey *et al*. 1995, RAMP 2004, Golder 2004, RAMP 2005, RAMP 2008).

Fish tissue results for Big Island Lake in 2008 suggest Negligible-Low risk to fish health given mercury concentrations did not exceed the effects or no effects lethal (survival) and non-lethal (growth, reproduction) thresholds (Table 5.11-1).

5.11.8.2 Gardiner Lake

Whole-Organism Metrics

A total of 14 lake whitefish (3 female, 7 male and 4 unsexed), 12 northern pike (8 female, 3 male and 1 unsexed), and 31 walleye (13 female and 16 male and 2 unsexed) from Gardiner Lake were sampled for fish tissue (muscle) analysis. The sizes of fish sampled were:

- Lake whitefish: 333 mm immature unsexed to 485 mm mature male. Males (average fork length: 446 mm) were slightly larger than females (average fork length: 442 mm). The average length of all sampled fish was 414 mm;
- Northern pike: 524 mm, age 4, mature female to 767 mm, age 9, mature male. Males (average fork length: 666 mm; average age: 15 years) were larger than females (average fork length: 633 mm; average age: 5 years). The average length of all sampled fish was 642 mm; the average age was 6 years; and

[4] The USEPA guidelines are based on a daily consumption rate of 142.4 g/day of fish for subsistence fishers and 17.5 g/day of fish for recreational fishers for a 70kg person; the Health Canada guidelines are based on a daily consumption rate of 40 g/day for subsistence fishers and 22 g/day for general consumers for a 60 kg person.

- Walleye: 206 mm, age 2, immature unsexed to 674 mm mature female. Females (average fork length: 487 mm; average age: 12 years) were larger than males (average fork length: 460 mm; average age 11 years). The average length of all sampled fish was 456 mm; the average age was 12 years.

Mercury Concentrations

Total mercury concentrations in muscle of individual walleye, northern pike and lake whitefish collected from Gardiner Lake in 2008 are presented in Table 5.11-37. Mercury concentrations in lake whitefish tissue ranged from a low of 0.04 mg/kg in a 333 mm immature unsexed individual to a high of 0.12 mg/kg in a 465 mm mature male. Mercury concentrations in northern pike tissue ranged from 0.10 mg/kg in a 524 mm mature female to 0.34 mg/kg in a 613 mm mature female and walleye tissue mercury concentrations ranged from 0.06 mg/kg in a 206 mm immature unsexed individual to 0.60 mg/kg in a 590 mm mature male. Mercury concentrations by size class for lake whitefish, walleye and northern pike are presented in Figure 5.11-28; for all three species, mercury concentrations increased with size class. Mercury concentrations by age for walleye and northern pike are presented in Figure 5.11-29; generally, mercury concentrations increased with age for both species.

Regressions between mercury concentrations and fork length (log_{10}-transformed) were significant and strongly positively correlated for lake whitefish and walleye ($p < 0.01$; fork length adjusted $R^2 = 0.61$ for lake whitefish, and 0.80 for walleye), but not significant and weakly positively correlated for northern pike, possibly due to the small size range of sampled fish of this species ($p = 0.12$; $R^2 = 0.06$) (Figure 5.11-30, Table 5.11-38).

Results from the 2008 Gardiner Lake fish tissue program were compared to results from regional studies in northern Alberta as reported in Grey *et al*. (1995), RAMP (2004), Golder (2004), RAMP (2005), and RAMP (2008); results are provided in Figure 5.11-25 to Figure 5.11-27. Given that the size of fish may be an important determinant of the concentration of mercury in fish (INAC 2003) and may confound comparisons among waterbodies, mercury concentrations were standardized to fish weight. Weight standardized mercury concentrations in lake whitefish from Gardiner Lake in 2008 were within mid-range relative to other waterbodies in the region (Figure 5.11-25). Male and female mean mercury concentrations in northern pike from Gardiner Lake in 2008 were low relative to other waterbodies in the region (Figure 5.11-26). When standardized to fish weight, 2008 mercury concentrations in male and female walleye in Gardiner Lake were within the mid to high-range of mercury concentrations in walleye from regional waterbodies (Figure 5.11-27).

Potential Risks of Mercury in Fish Tissue to Human Health

2008 walleye, northern pike and lake whitefish muscle mercury concentrations from Gardiner Lake were screened against USEPA and Health Canada human health criteria for fish consumption (Table 5.11-35); a summary of the results is as follows:

- The mean mercury concentration (0.07 mg/kg) in lake whitefish exceeded the USEPA consumption guideline for subsistence fishers (0.049 mg/kg), but did not exceed the Health Canada guideline for subsistence fishers (0.2 mg/kg) and general consumers (0.4 mg/kg) or the USEPA criteria for recreational fishers (0.4 mg/kg). Ten of the fourteen lake whitefish captured exceeded the USEPA guideline for subsistence fishers;

- The mean mercury concentration (0.19 mg/kg) in northern pike exceeded the USEPA criteria for subsistence fishers (0.049 mg/kg), but did not exceed the Health Canada criteria for subsistence and recreational fishers. Eleven of the twelve northern pike captured exceeded the USEPA guideline for subsistence fishers and of those eleven, five northern pike exceeded the Health Canada guideline for subsistence fishers; and
- The mean mercury concentration (0.29 mg/kg) in walleye exceeded the USEPA criteria for subsistence fishers (0.049 mg/kg) and the Health Canada subsistence criteria (0.2 mg/kg). All walleye captured exceeded the USEPA criteria for subsistence fishers (0.049 mg/kg); sixteen walleye captured exceeded the Health Canada guideline for subsistence fishers (0.2 mg/kg); and of those sixteen walleye, eight walleye exceeded the Health Canada general consumer criteria (0.5 mg/kg).

Potential Risks of Mercury in Fish Tissue to Fish and Fish Health

Mercury concentrations in muscle of walleye, northern pike and lake whitefish from Gardiner Lake did not exceed any of the lethal (survival) or non-lethal (reproduction/growth) effects (or no effects) thresholds for fish and fish health based on methylmercury concentration ranges described in Table 3.4-9.

Summary Assessment

The measurement endpoint used in the assessment of the results from the Gardiner Lake fish tissue sampling program is mercury concentration in fish tissue with potential effects on human health and fish health predicted from the fish tissue analyses.

Results for lake whitefish from Gardiner Lake indicate little risk to subsistence, and recreational fishers, or general consumers according to the Health Canada criteria (0% of sampled fish exceeding any relevant Health Canada guidelines); however 71% [10 of 14] of sampled fish exceeded the more stringent USEPA subsistence guideline. The average mercury concentration across all size classes in lake whitefish in Gardiner Lake was below the subsistence fisher guideline indicating a Negligible-Low risk to human health (Table 5.11-1).

Results for Gardiner Lake walleye indicate a Moderate risk to subsistence fishers characterized by 52% of fish analyzed with mercury concentrations exceeding the Health Canada (all fish exceeded the USEPA guideline). There is Moderate risk to general consumers given that of that proportion of fish exceeding the Health Canada subsistence guideline, 50% exceeded the Health Canada general consumer guideline (0.5 mg/kg). The average concentration of mercury in walleye greater than 500 mm exceeded the subsistence fisher guideline but was below the general consumer guideline indicating a High human health risk to subsistence fishers and a Moderate human health risk to general consumers for consumption of fish of that size (Table 5.11-1). The risk to human health from walleye less than 500mm in length was classified as Negligible-Low.

Results for Gardiner Lake northern pike indicate a Negligible-Low risk to subsistence fishers characterized by 42% of fish analyzed with mercury concentrations exceeding Health Canada guidelines (all fish exceeded the USEPA subsistence guideline), but an average concentration below the subsistence fisher guideline and little risk to recreational fishers and general consumers given no fish sampled fish exceeded the relevant guidelines (Table 5.11-1). The average mercury concentration of one northern pike greater than 700 mm in length exceeded the subsistence fisher guideline but the low sample size (n=1) does not represent the population of northern pike in this size class.

Although mercury concentrations in lake whitefish from Gardiner Lake, walleye and northern pike often exceeded the USEPA and Health Canada consumption guidelines, comparisons with historical regional data show that these concentrations were within the range of mercury concentrations observed in this region of Alberta (Grey *et al*. 1995, RAMP 2004, Golder 2004, RAMP 2005, RAMP 2008).

Fish tissue results for Gardiner Lake in 2008 suggest Negligible-Low potential risk to fish health given mercury concentrations did not exceed the lethal and non-lethal effects or no effects thresholds (Table 5.11-1).

Figure 5.11-3 Mills Creek: 2008 hydrograph and historical context.

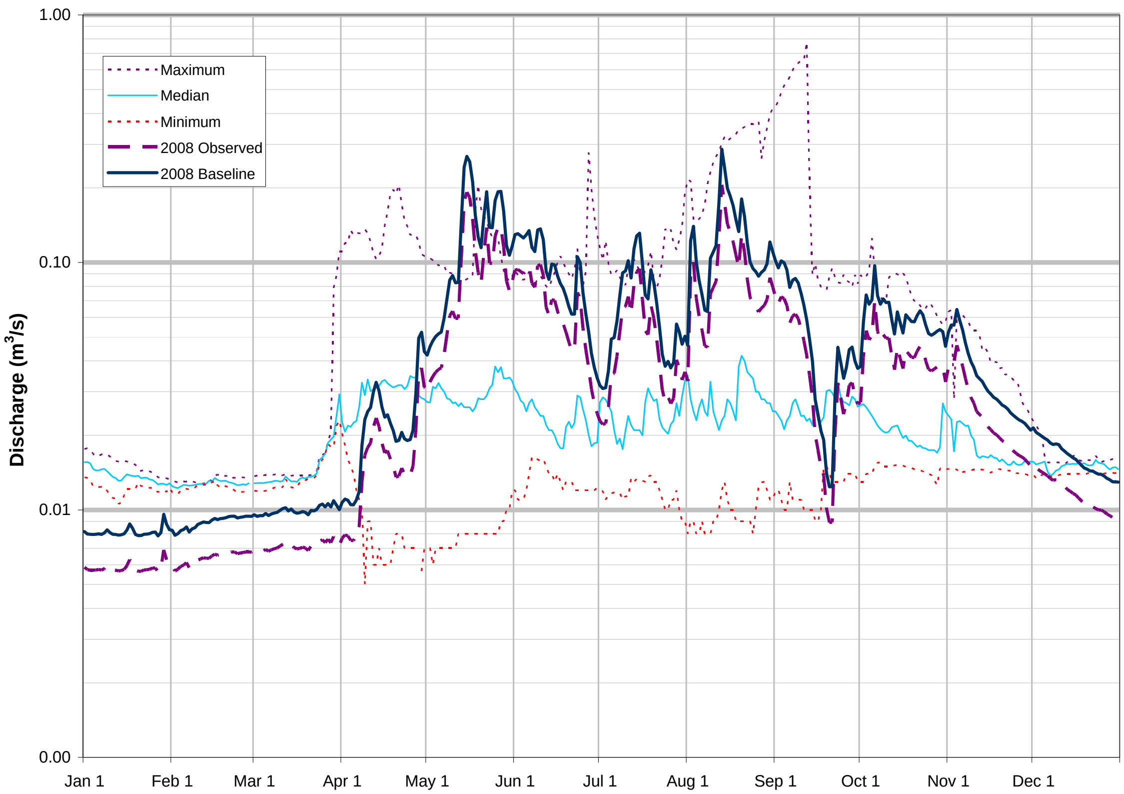


Table 5.11-2 Estimated water balance at RAMP Station S6, Mills Creek at Highway 63, in 2008.

Component	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total discharge)	1.19	**Observed discharge, obtained from RAMP Station S6, Mills Creek at Highway 63**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+0.141	2.52 km^2 within Mills Creek drainage estimated to have been closed-circuited by oil sands development projects as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	0.000	0 km^2 within Mills Creek drainage estimated to have undergone land change by oil sands development projects as of 2008, but are not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from Mills Creek by focal projects	0	Unknown, none reported, assumed to be negligible
Amount by which discharge would be lower without releases to Mills Creek by focal projects	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Mills Creek not accounted for in figures contained in this table
***Baseline* hydrograph (total discharge)**	1.33	**Estimated *baseline* discharge at RAMP Station S6, Mills Creek at Highway 63**
Incremental flow (change in total discharge)	-0.141	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total discharge)	-10.6%	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Rounding of results occurs due to the use of a maximum of three significant digits

Table 5.11-3 Calculated change in hydrologic measurement endpoints for the Mills Creek watershed for 2008.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.071	0.063	-10.6%
Mean winter discharge	0.013	0.011	-10.6%
Annual maximum daily discharge	0.230	0.206	-10.6%
Open-water season minimum daily discharge	0.010	0.009	-10.6%

Note: As measured at RAMP Station S6, Mills Creek at Highway 63.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Figure 5.11-4 Isadore's Lake: 2008 hydrograph and historical context.

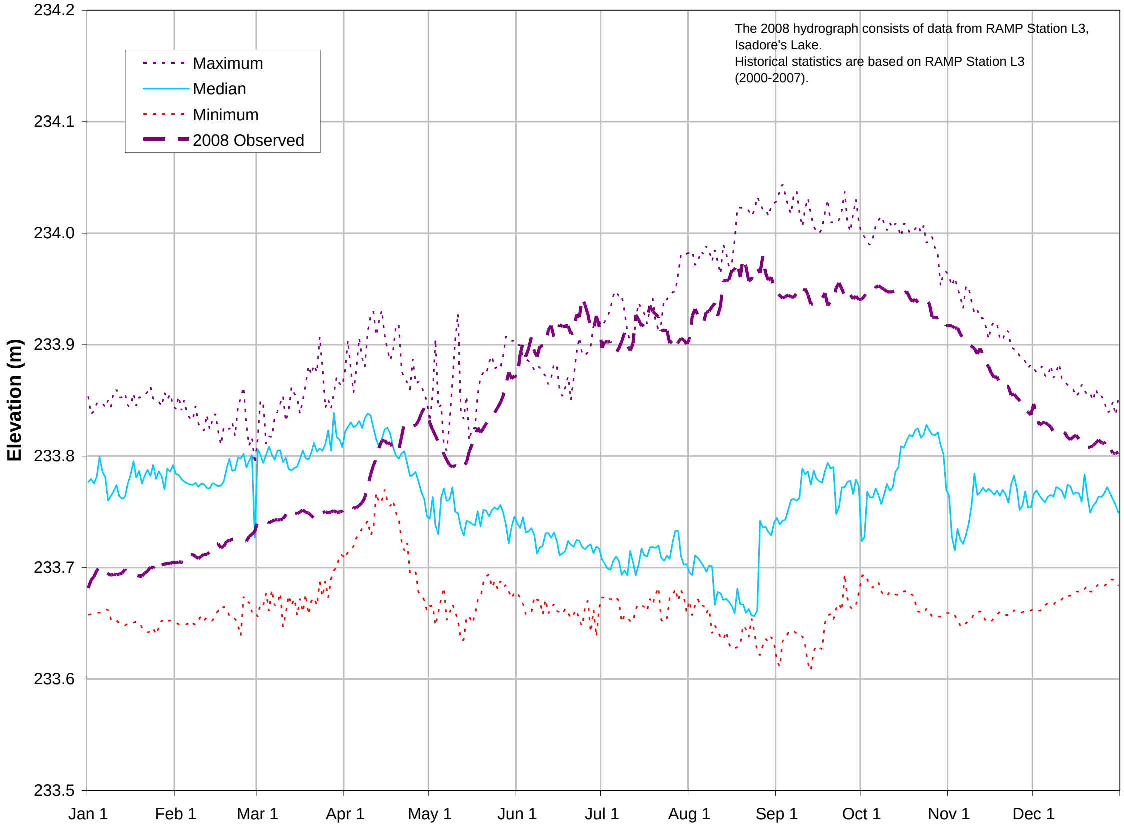


Table 5.11-4 Concentrations of water quality measurement endpoints, Isadore's Lake (ISL-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	6	7.7	8.15	8.3
Total Suspended Solids	mg/L	-[1]	4	6	<3	5.5	10
Conductivity	µS/cm	-	672	6	353	517.5	588
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.007	6	0.004	0.009	**0.067**
Total nitrogen*	mg/L	1.0	0.8	6	0.3	0.95	**1.25**
Nitrate+Nitrite	mg/L	1.0	<0.1	6	<0.1	<0.1	0.3
Dissolved organic carbon	mg/L	-	12	6	8	10.5	12
Ions							
Sodium	mg/L	-	11	6	6	9.5	13
Calcium	mg/L	-	85.4	6	37	54.85	72.2
Magnesium	mg/L	-	36	6	25.6	29	33.2
Chloride	mg/L	230, 860[3]	19	6	4	10	16
Sulphate	mg/L	100[4]	**148**	6	63.9	92.75	**109**
Total Dissolved Solids	mg/L	-	456	6	250	331.5	380
Total Alkalinity	mg/L	-	181	6	122	158.5	227
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0056	6	<0.02	0.028	**0.182**
Dissolved aluminum	mg/L	0.1[2]	<0.001	6	<0.01	<0.0002	0.020
Total arsenic	mg/L	0.005	0.0005	6	<0.001	0.0006	0.0012
Total boron	mg/L	1.2[5]	0.0483	6	0.0350	0.0404	0.0491
Total molybdenum	mg/L	0.073	0.00001	6	<0.0001	0.00002	0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	4	<1.2	<1.2	1.4
Total strontium	mg/L	-	0.244	6	0.162	0.208	0.238
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.012**	6	**0.003**	**0.0075**	**0.015**
Total phenols	mg/L	0.004	**0.005**	6	<0.001	0	**0.007**

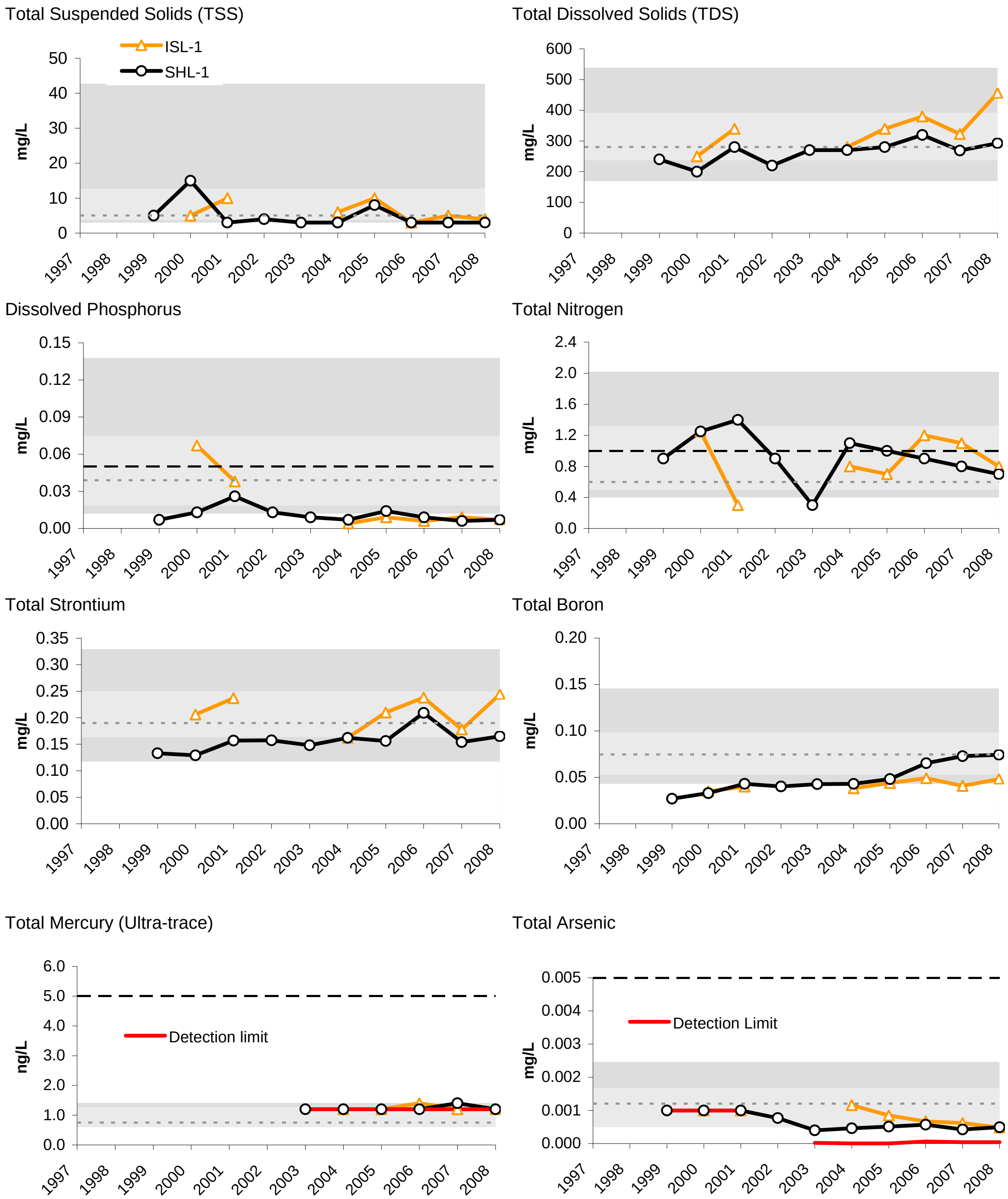
Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

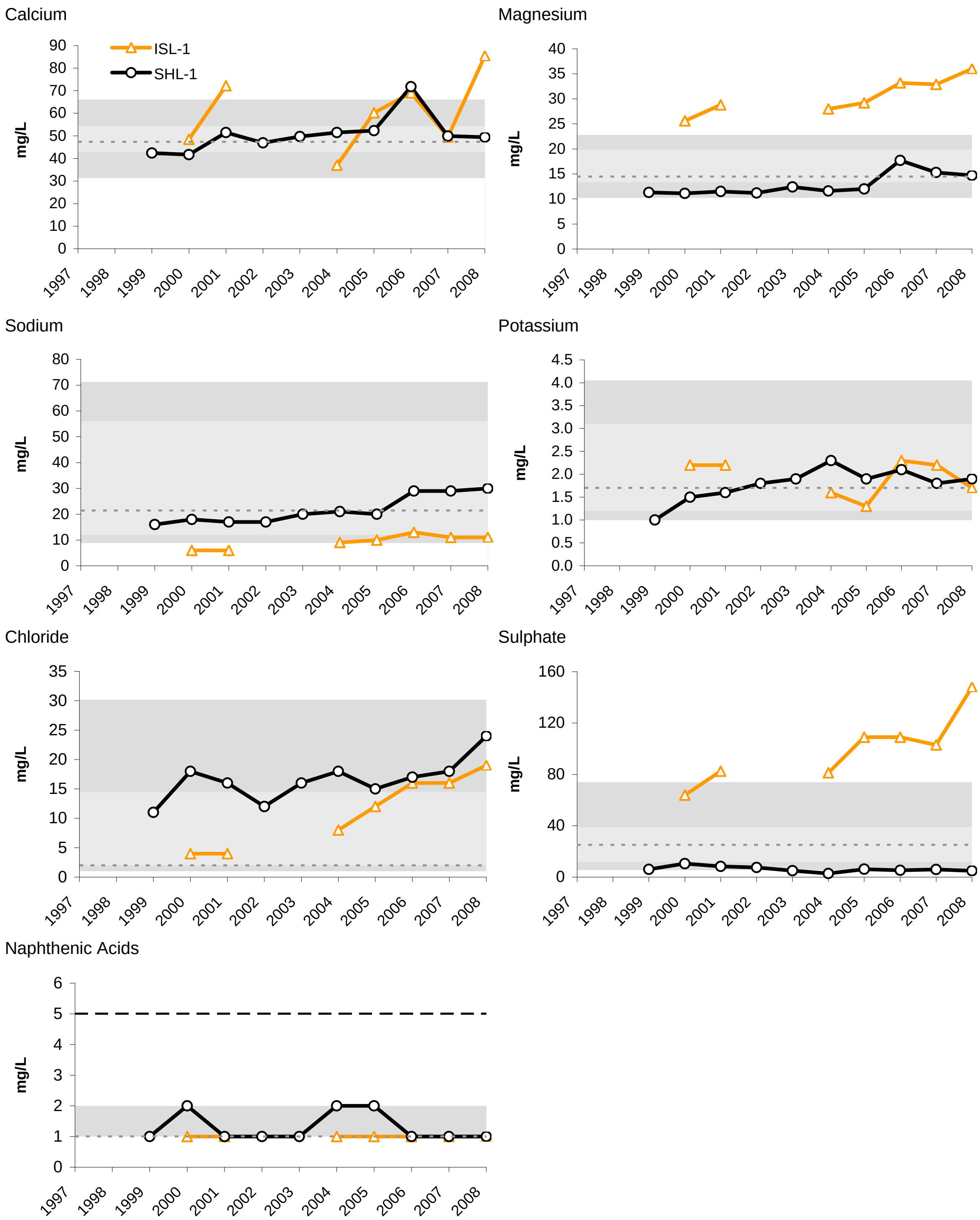
[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.
[2] Guideline is for total analyte (no guideline for dissolved species).
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).
[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).
[5] B.C. ambient water quality guideline for boron (B.C. 2003).
[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).
[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Figure 5.11-5 Concentrations of selected fall water quality measurement endpoints, Isadore's Lake (ISL-1) and Shipyard Lake (SHL-1) (fall 2008), relative to regional fall baseline concentrations.



Non-detectable values are shown at the detection limit.
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.
See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.11-5 (Cont'd.)



Non-detectable values are shown at the detection limit.
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.
See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Table 5.11-5 Water quality guideline exceedances in the Beaver River (station BER-1), Poplar Creek (station POC-1), McLean Creek (station MCC-1), Isadore's Lake (stations ISL-1), Shipyard Lake (stations SHL-1), and Fort Creek (station FOC-1) 2008.

Variable	Units	Guideline*	POC-1	BER-1	BER-2	MCC-1	ISL-1	SHL-1	FOC-1
Spring									
Sulphide	mg/L	0.002[2]	ns	ns	**0.011**	ns	ns	ns	ns
Total phosphorus	mg/L	0.05	ns	ns	**0.145**	ns	ns	ns	ns
Total Kjeldahl nitrogen	mg/L	1.0	ns	ns	**2.6**	ns	ns	ns	ns
Total nitrogen	mg/L	1.0	ns	ns	**2.7**	ns	ns	ns	ns
Total aluminum	mg/L	0.1	ns	ns	**2.98**	ns	ns	ns	ns
Dissolved iron	mg/L	0.3[3]	ns	ns	**0.655**	ns	ns	ns	ns
Total iron	mg/L	0.3	ns	ns	**3.33**	ns	ns	ns	ns
Total phenols	mg/L	0.004	ns	ns	**0.01**	ns	ns	ns	ns
Mercury (ultra-trace)	ng/L	5, 13[4]	ns	ns	**5.6**	ns	ns	ns	ns
Summer									
Sulphate	mg/L	100[1]	ns	ns	-	ns	**135**	-	ns
Sulphide	mg/L	0.002[2]	ns	ns	**0.01**	ns	-	**0.006**	ns
Total dissolved phosphorus	mg/L	0.05	ns	ns	**0.06**	ns	-	-	ns
Total phosphorus	mg/L	0.05	ns	ns	**0.093**	ns	-	-	ns
Dissolved iron	mg/L	0.3[3]	ns	ns	**0.877**	ns	-	-	ns
Total aluminum	mg/L	0.1	ns	ns	**0.179**	ns	-	-	ns
Total phenols	mg/L	0.004	ns	ns	**0.007**	ns	**0.005**	**0.005**	ns
Total iron	mg/L	0.3	ns	ns	**1.5**	ns	-	-	ns
Fall									
Sulphate	mg/L	100[1]	-	-	-	-	**148**	-	-
Sulphide	mg/L	0.002[2]	**0.004**	**0.038**	**0.017**	**0.018**	**0.012**	**0.012**	**0.005**
Total dissolved phosphorus	mg/L	0.05	-	-	**0.074**	-	-	-	-
Total phosphorus	mg/L	0.05	-	**0.128**	**0.102**	**0.072**	-	-	-
Total Kjeldahl nitrogen	mg/L	1.0	**1.2**	**1.1**	**1.2**	**1.3**	-	-	-
Total nitrogen	mg/L	1.0	**1.3**	**1.2**	**1.3**	**1.4**	-	-	-
Total aluminum	mg/L	0.1	**0.401**	**5.13**	**0.266**	**0.346**	-	-	**0.105**
Dissolved iron	mg/L	0.3[3]	-	**0.465**	**1.16**	**0.396**	-	-	-
Total iron	mg/L	0.3	**0.713**	**5.88**	**1.79**	**1.06**	-	**0.312**	**1.04**
Total phenols	mg/L	0.004	**0.008**	**0.009**	**0.008**	**0.012**	**0.005**	**0.006**	**0.008**
Mercury (ultra-trace)	ng/L	5, 13[4]	-	**8.1**	-	-	-	-	-
Total titanium	mg/L	0.100	-	**0.15**	-	-	-	-	-

BER-1, MCC-1, POC-1, and FOC-1 were sampled only in fall 2008. ISL-1 and SHL-1 were sampled in summer and fall 2008.

BER-2 was sampled in spring, summer, and fall 2008.

ns = not sampled

* Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

[1] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[2] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[3] Guideline is for total metal (no guideline for dissolved species).

[4] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

Figure 5.11-6 Piper diagram of fall ion balance in Isadore's Lake and Shipyard Lake, 1999-2008.

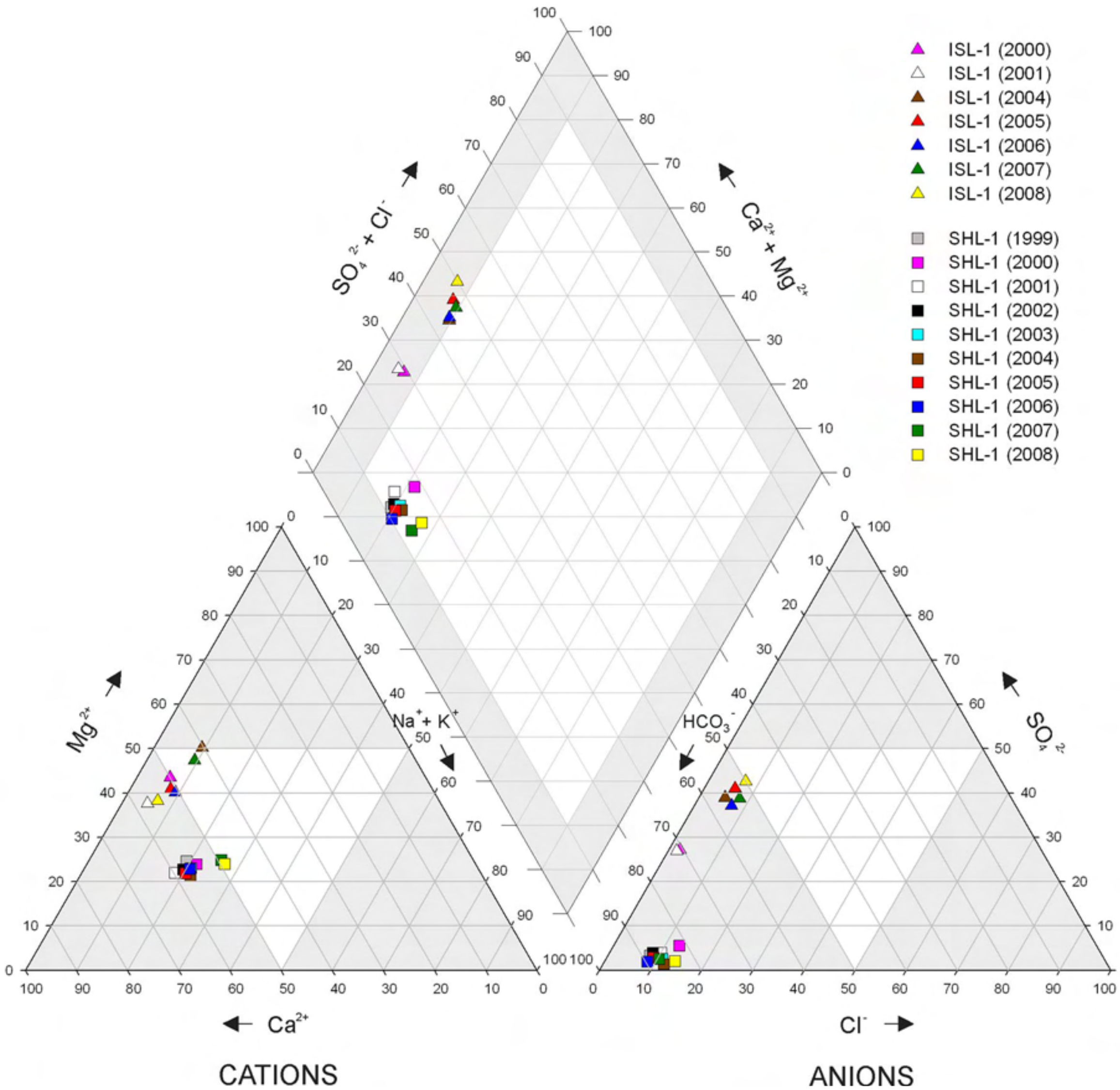


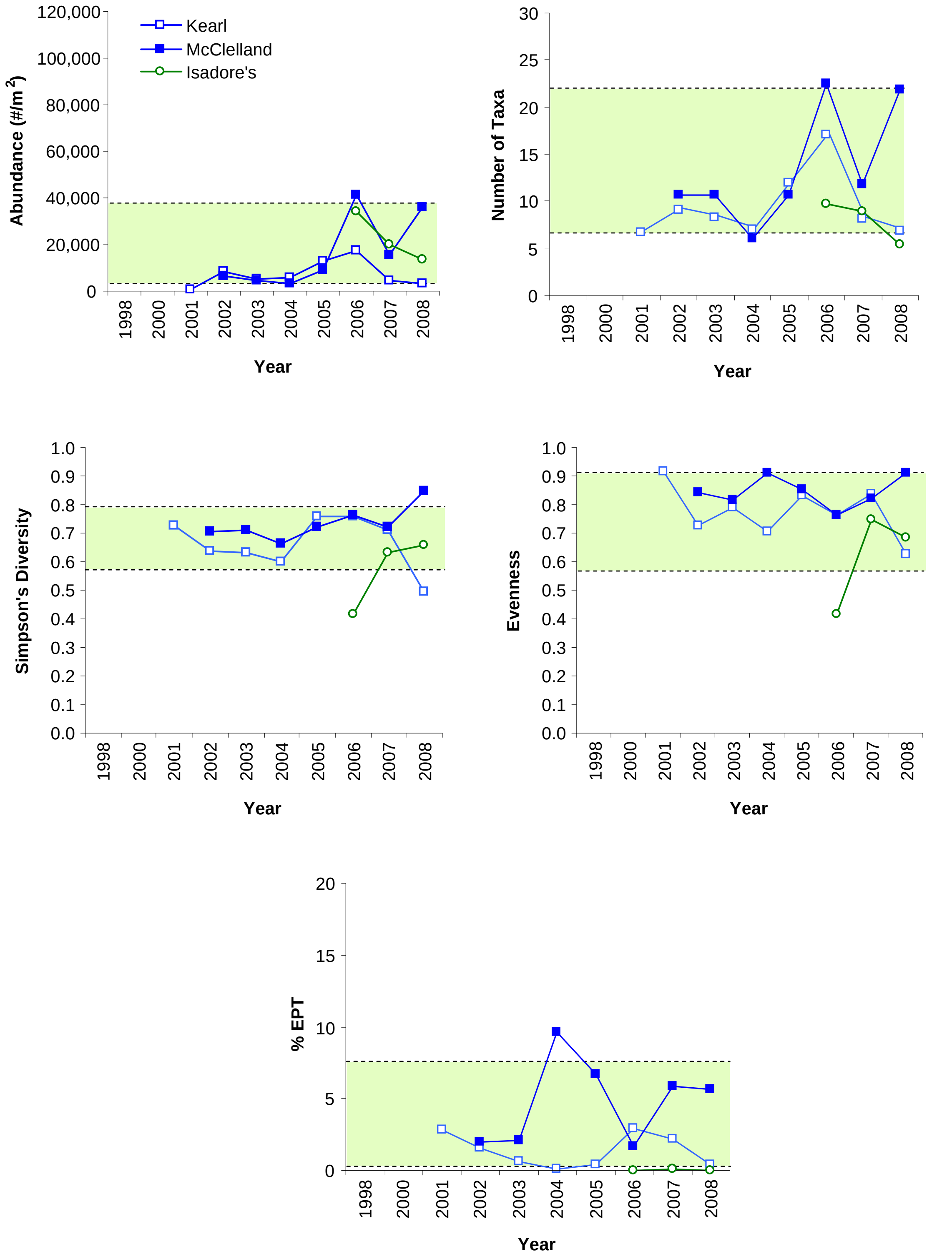
Table 5.11-6 Average habitat characteristics of benthic invertebrate sampling locations in Isadore's Lake.

Variable	Units	Isadore's Lake (ISL-1)
Sample date	-	Sept 7, 2008
Habitat	-	Depositional
Water depth	m	8
Macrophyte cover	%	n/a
Field Water Quality		
Dissolved oxygen	mg/L	11.3
Conductivity	µS/cm	660
pH	pH units	8.1
Water temperature	°C	13.4
Sediment Composition		
Sand	%	15
Silt	%	60
Clay	%	25
Total Organic Carbon	%	6

Table 5.11-7 Major taxon percent abundances and benthic invertebrate community measurement endpoints in Isadore's Lake.

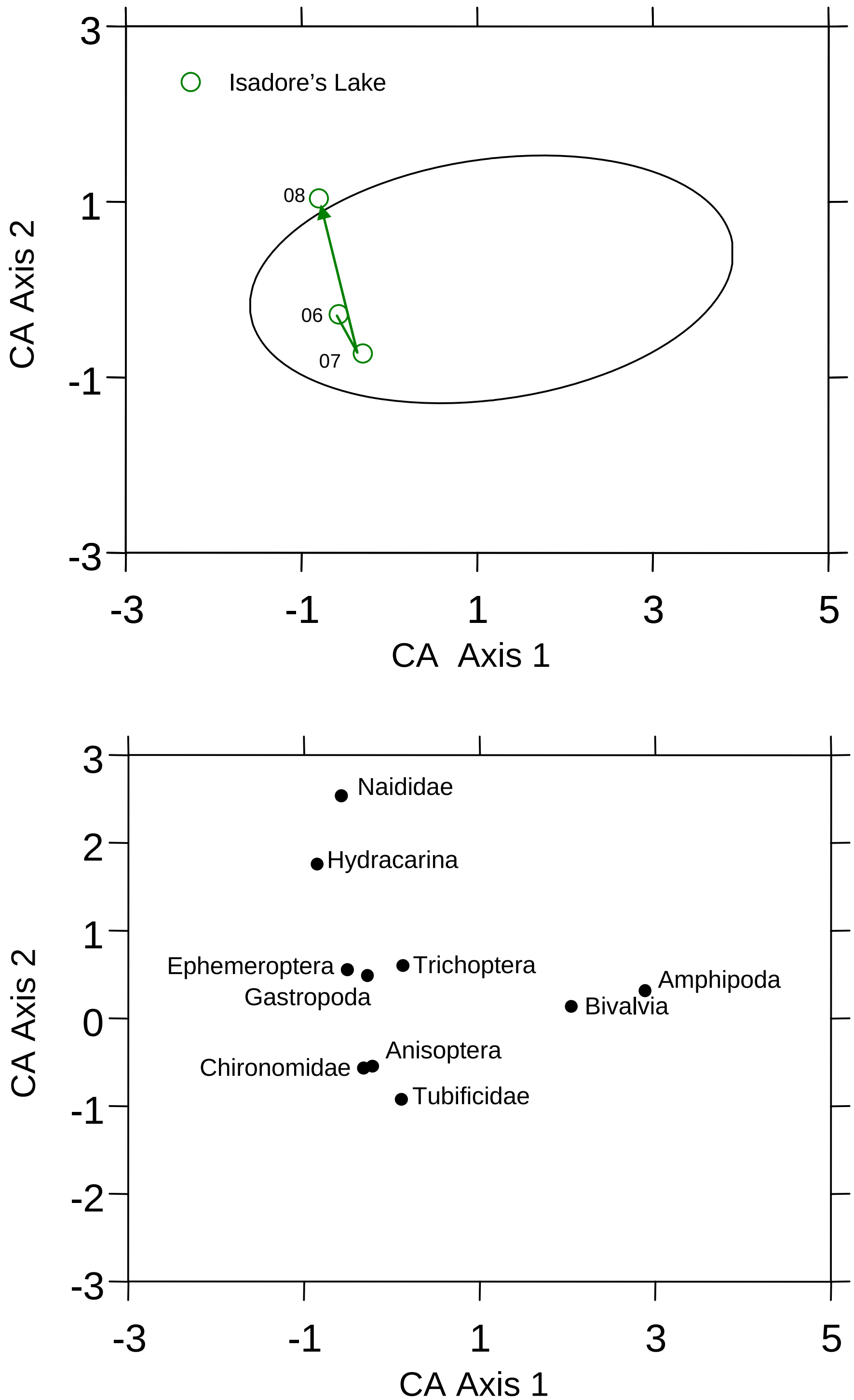
Taxon	Percent Major Taxa Enumerated in Each Year		
	2006	2007	2008
Amphipoda	<1		
Anisoptera			<1
Bivalvia			
Ceratopogonidae	<1		
Chaoboridae	<1		
Chironomidae	2	57	19
Cladocera		4	
Copepoda	3	4	11
Ephemeroptera		1	
Erpobdellidae			
Gastropoda			
Glossiphoniidae			
Hydracarina			8
Lumbriculidae			
Naididae	4	1	6
Nematoda	72	32	49
Ostracoda	1	2	7
Trichoptera			
Tubificidae			
Zygoptera			
Benthic Invertebrate Community Measurement Endpoints			
Total Abundance (No./m^2)	33,987	20,110	13,870
Richness	10	9	6
Simpson's Diversity	0.41	0.63	0.66
Evenness	0.42	0.75	0.69
% EPT	0	1	0

Figure 5.11-7 Variation in benthic invertebrate community measurement endpoints in Isadore's Lake (*test*) relative to *baseline* lakes in the RAMP FSA.



Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in Kearl and McClelland lakes, both designated as *baseline*.

Figure 5.11-8 Ordination (Correspondence Analysis) of lake benthic invertebrate communities in Isadore's Lake.



Note: the upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is generated from the benthic invertebrate community data from the *baseline* Kearl and McClelland lakes.

Note: the numbers in the upper panel refer to the sampling year for each data point.

Table 5.11-8 Results of analysis of variance (ANOVA) *test*ing for differences in benthic invertebrate community measurement endpoints in Isadore's Lake (ISL-1) relative to *baseline* lakes.

Endpoint	Source	SS	df	MS	F-ratio	P
Log Abundance	Lake - Year	35.825	17	2.107	5.47	0.000
	Baseline vs Test (BT)	0.053	1	0.053	0.14	0.713
	Linear Time Trend (T)	6.761	1	6.761	17.54	0.000
	BT x T	0.005	1	0.005	0.01	0.907
	Remainder (noise)	29.007	14	2.072	5.38	0.022
	Error	62.045	161	0.385		
Log Richness	Lake - Year	5.241	17	0.308	5.42	0.000
	Baseline vs Test (BT)	0.887	1	0.887	15.57	0.000
	Linear Time Trend (T)	1.080	1	1.080	18.98	0.000
	BT x T	0.005	1	0.005	0.08	0.774
	Remainder (noise)	3.270	14	0.234	4.10	0.044
	Error	9.164	161	0.057		
Diversity	Lake - Year	1.485	17	0.087	3.27	0.000
	Baseline vs Test (BT)	0.546	1	0.546	20.40	0.000
	Linear Time Trend (T)	0.048	1	0.048	1.79	0.183
	BT x T	0.270	1	0.270	10.11	0.002
	Remainder (noise)	0.621	14	0.044	1.66	0.199
	Error	4.304	161	0.027		
Evenness	Lake - Year	2.089	17	0.123	4.67	0.000
	Baseline vs Test (BT)	0.549	1	0.549	20.85	0.000
	Linear Time Trend (T)	0.034	1	0.034	1.29	0.257
	BT x T	0.217	1	0.217	8.23	0.005
	Remainder (noise)	1.290	14	0.092	3.50	0.063
	Error	4.237	161	0.026		
Log %EPT	Lake - Year	6.39	17	0.38	2.87	0.000
	Baseline vs Test (BT)	1.95	1	1.95	14.89	0.000
	Linear Time Trend (T)	0.08	1	0.08	0.58	0.446
	BT x T	0.04	1	0.04	0.29	0.590
	Remainder (noise)	4.33	14	0.31	2.36	0.126
	Error	21.05	161	0.13		
CA Axis 1	Lake - Year	203.37	17	11.96	8.33	0.000
	Baseline vs Test (BT)	38.79	1	38.79	27.03	0.000
	Linear Time Trend (T)	1.09	1	1.09	0.76	0.384
	BT x T	0.02	1	0.02	0.01	0.913
	Remainder (noise)	163.5	14	11.676	8.13	0.005
	Error	228.24	159	1.44		
CA Axis 2	Lake - Year	49.72	17	2.92	3.25	0.000
	Baseline vs Test (BT)	0.25	1	0.25	0.28	0.600
	Linear Time Trend (T)	17.20	1	17.20	19.10	0.000
	BT x T	0.38	1	0.38	0.43	0.514
	Remainder (noise)	31.89	14	2.28	2.53	0.114
	Error	143.20	159	0.90		

Table 5.11-9 Concentrations of sediment quality measurement endpoints, Isadore's Lake (ISL-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only, station ISL-1)			
			Value	n	Min	Median	Max
Physical variables[5]							
Clay	%	-	25.1	3	20.6	26	29.4
Silt	%	-	60	3	54	55.3	56.1
Sand	%	-	15	3	15.4	20	23.3
Total organic carbon	%	-	5.5	3	1.3	2.9	3.3
Total hydrocarbons							
BTEX	mg/kg	-	<5	2	<5	<7.5	<10
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	2	<5	<7.5	<10
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	2	16	19.5	23
Fraction 3 (C16-C34)	mg/kg	300[2]	**4600**	2	150	**470**	**790**
Fraction 4 (C34-C50)	mg/kg	2800[2]	**3500**	2	89	314.5	540
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.008	3	0.006	0.006	0.009
Retene	mg/kg	-	0.07	3	0.056	0.066	0.071
Total dibenzothiophenes	mg/kg	-	0.26	3	0.14	0.15	0.24
Total PAHs	mg/kg	-	2.06	3	1.28	1.28	1.52
Total Parent PAHs	mg/kg	-	0.18	3	0.14	0.17	0.37
Total Alkylated PAHs	mg/kg	-	1.88	3	1.11	1.14	1.14
Predicted PAH toxicity[1]	H.I.	-	0.08	3	0.32	0.56	1.38
Metals that exceed CCME guidelines in 2008							
Arsenic	mg/kg	5.9, 17[4]	**7.30**	-	-	-	-
Mercury	mg/kg	0.17,0.486[4]	**0.21**	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	2	7	7	7
Chironomus growth - 10d	mg/organism	-	2.4	2	1.9	2.3	2.6
Hyalella survival - 14d	# surviving	-	8	2	10	10	10
Hyalella growth - 14d	mg/organism	-	0.4	2	0.2	0.3	0.3

Values in **bold** indicate concentrations exceeding guidelines.

1 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.

2 Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

3 Interim sediment quality guideline (ISQG) (CCME 2002).

4 CCME interim sediment quality guideline and probable effects level, respectively.

5 Value is calculated from an average of 10 replicates.

Figure 5.11-9 Poplar Creek: 2008 hydrograph and historical context.

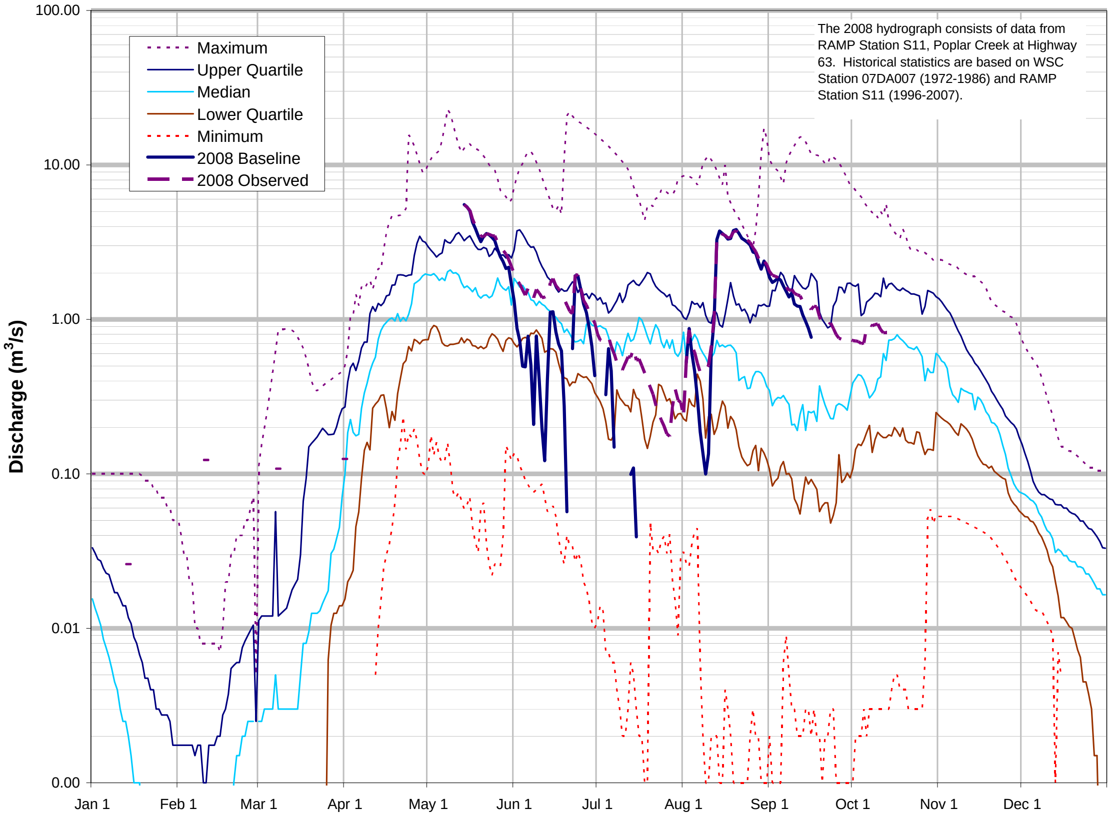


Table 5.11-10 Estimated water balance at RAMP Station S11, Poplar Creek at Highway 63 (07DA007) for 2008.

Component	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total discharge)	**20.8**	**Observed daily discharges, obtained from RAMP Station S11, Poplar Creek at Highway 63 (07DA007)**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+0.295	2.99 km^2 within Poplar Creek drainage estimated to have been closed-circuited by oil sands development projects as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.025	1.27 km^2 within Poplar Creek drainage estimated to have undergone land change by oil sands development projects as of 2008, but are not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from Poplar Creek by focal projects	0	Unknown, none reported, assumed to be negligible
Amount by which discharge would be lower without releases to Poplar Creek by focal projects	-0.250	Releases to Ruth Channel from Suncor
Diversions into or out of the watershed	-9.68	Diversion from original upper Beaver River catchment area into Poplar Creek; daily releases from the Poplar Creek Spillway minus the releases to Ruth Channel from Suncor
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Poplar Creek not accounted for in figures contained in this table
Baseline hydrograph (total discharge)	**14.9**	**Estimated baseline discharge at RAMP Station S11, Poplar Creek at Highway 63 (07DA007)**
Incremental flow (change in total discharge)	5.90	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total discharge)	40%	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Note: Data in the table is for the monitored period May 14 – October 14.

Note: Seasonal volumes presented in the table do not balance, because daily runoff values computed to be less than zero (when reported Poplar Creek spillway releases were greater than observed S11 discharges) were set to zero.

Table 5.11-11 Calculated change in hydrologic measurement endpoints for the Poplar Creek watershed for 2008.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	1.12	1.56	40%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	5.54	5.54	-0.1%
Open-water season minimum daily discharge	0.000	0.175	-

Note: As measured at RAMP Station S11, Poplar Creek at Highway 63.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.11-12 Concentrations of water quality measurement endpoints, lower Beaver River (*test* station BER-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	5	8.0	8.1	8.2
Total Suspended Solids	mg/L	-[1]	35	5	<3	5	26
Conductivity	µS/cm	-	871	5	566	1070	1430
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.015	5	0.004	0.005	0.022
Total nitrogen*	mg/L	1.0	**1.2**	5	0.7	0.9	**1.4**
Nitrate+Nitrite	mg/L	1.0	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	34	5	15	26	52
Ions							
Sodium	mg/L	-	77	5	53	118	181
Calcium	mg/L	-	63.5	5	49.1	79.7	91.4
Magnesium	mg/L	-	19.1	5	15.5	24.6	27.9
Chloride	mg/L	230, 860[3]	94	5	55	105	221
Sulphate	mg/L	100[4]	69.2	5	54	79	**117**
Total Dissolved Solids	mg/L	-	650	5	450	659	830
Total Alkalinity	mg/L	-	221	5	158	266	294
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	1	3
Selected metals							
Total aluminum	mg/L	0.1	**5.13**	5	0.0314	**0.238**	**0.318**
Dissolved aluminum	mg/L	0.1[2]	0.0303	5	0.0017	0.0031	0.0445
Total arsenic	mg/L	0.005	0.0021	5	0.0007	0.0009	0.0013
Total boron	mg/L	1.2[5]	0.107	5	0.088	0.149	0.169
Total molybdenum	mg/L	0.073	0.0004	5	0.0002	0.0003	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[6]	**8.1**	5	<1.2	<1.2	1.3
Total strontium	mg/L	-	0.233	5	0.233	0.315	0.425
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.038**	5	**<0.003**	**0.018**	**0.035**
Total phosphorus	mg/L	0.05	**0.128**	5	0.016	0.024	0.041
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.1**	5	0.6	0.8	**1.3**
Dissolved iron	mg/L	0.3[2]	**0.465**	5	0.046	0.298	**1.87**
Total iron	mg/L	0.3	**5.88**	5	**1.79**	**2.39**	**3.72**
Total phenols	mg/L	0.004	**0.009**	4	0.002	**0.0055**	**0.009**
Total titanium	mg/L	0.100	**0.15**	5	0.0012	0.0069	**0.0104**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[8] Guideline is for total nitrogen.

Table 5.11-13 Concentrations of water quality measurement endpoints, upper Beaver River (*baseline* station BER-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008 Value
Physical variables			
pH	pH units	6.5-9.0	8.3
Total Suspended Solids	mg/L	-[1]	6
Conductivity	µS/cm	-	315
Nutrients			
Total dissolved phosphorus	mg/L	0.05[2]	**0.074**
Total nitrogen*	mg/L	1.0	**1.3**
Nitrate+Nitrite	mg/L	1.0	<0.1
Dissolved organic carbon	mg/L	-	34
Ions			
Sodium	mg/L	-	31
Calcium	mg/L	-	29.7
Magnesium	mg/L	-	10.3
Chloride	mg/L	230, 860[3]	2
Sulphate	mg/L	100[4]	15.3
Total Dissolved Solids	mg/L	-	238
Total Alkalinity	mg/L	-	151
Organic compounds			
Naphthenic acids	mg/L	-	<1
Selected metals			
Total aluminum	mg/L	0.1	**0.266**
Dissolved aluminum	mg/L	0.1[2]	0.0272
Total arsenic	mg/L	0.005	0.0014
Total boron	mg/L	1.2[5]	0.163
Total molybdenum	mg/L	0.073	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.5
Total strontium	mg/L	-	0.175
Other variables that exceeded CCME/AENV guidelines in fall 2008			
Sulphide	mg/L	0.002[7]	**0.017**
Total phosphorus	mg/L	0.05	**0.102**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.2**
Dissolved iron	mg/L	0.3[2]	**1.16**
Total iron	mg/L	0.3	**1.79**
Total phenols	mg/L	0.004	**0.008**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

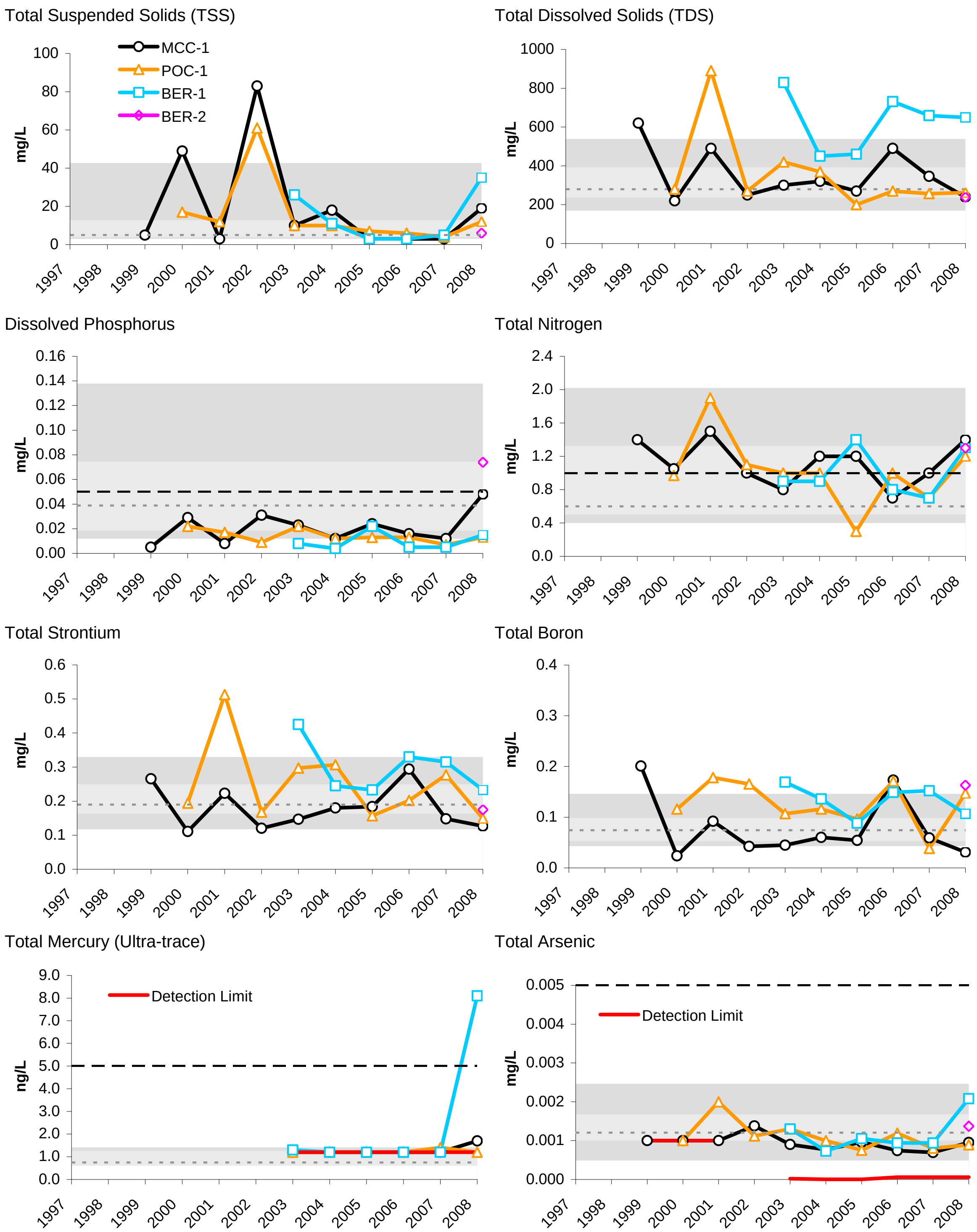
5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

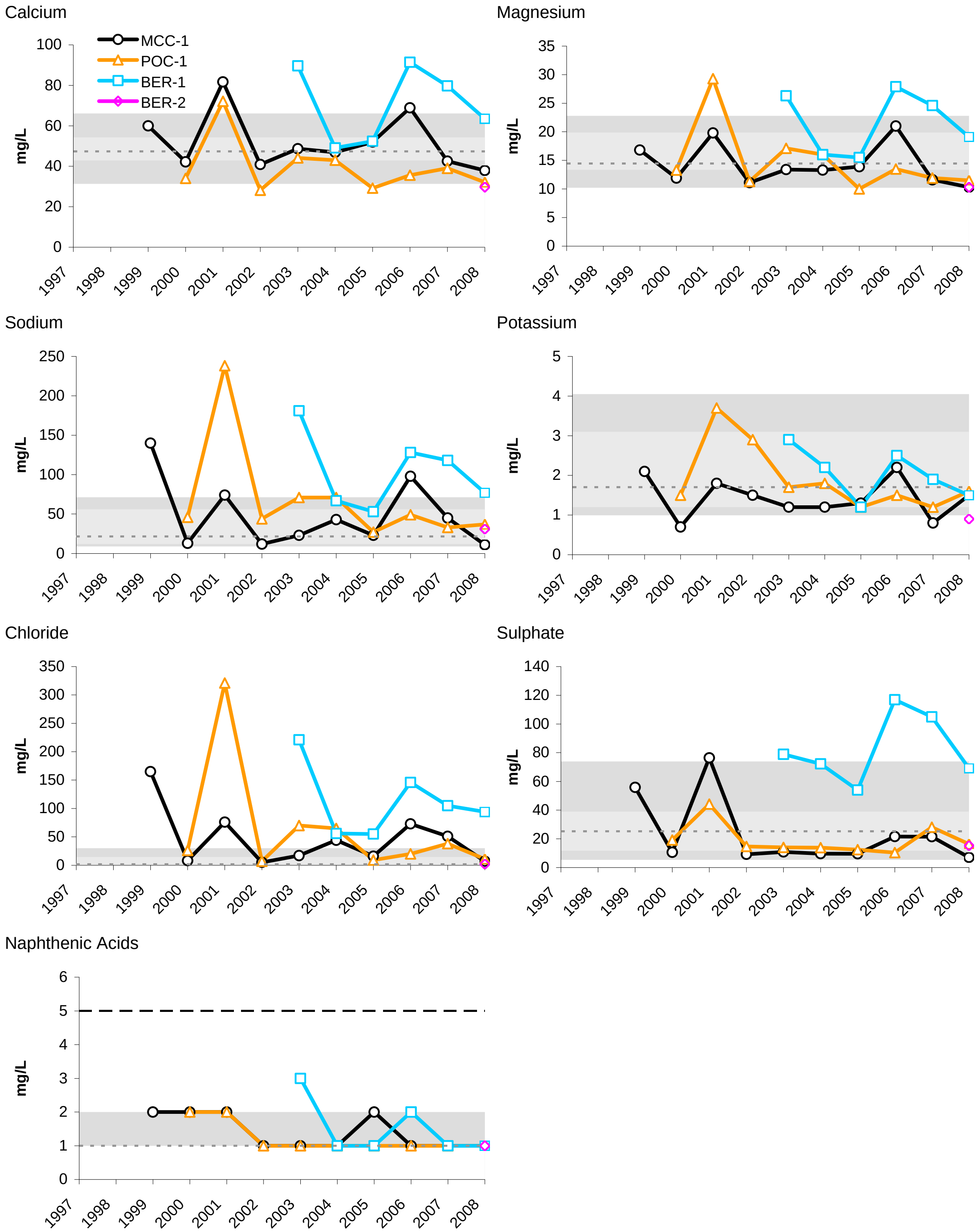
8 Guideline is for total nitrogen.

Figure 5.11-10 Concentrations of selected water quality measurement endpoints in the Beaver River (station BER-1), Poplar Creek (station POC-1), and McLean Creek (station MCC-1) (fall 2008) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.
See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.11-10 (Cont'd.)



Non-detectable values are shown at the detection limit.
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.
See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.11-11 Piper diagram of fall ion balance at *test* station BER-1, *baseline* station BER-2, *test* station POC-1, and *test* station McLean Creek (MCC-1), 1999-2008.

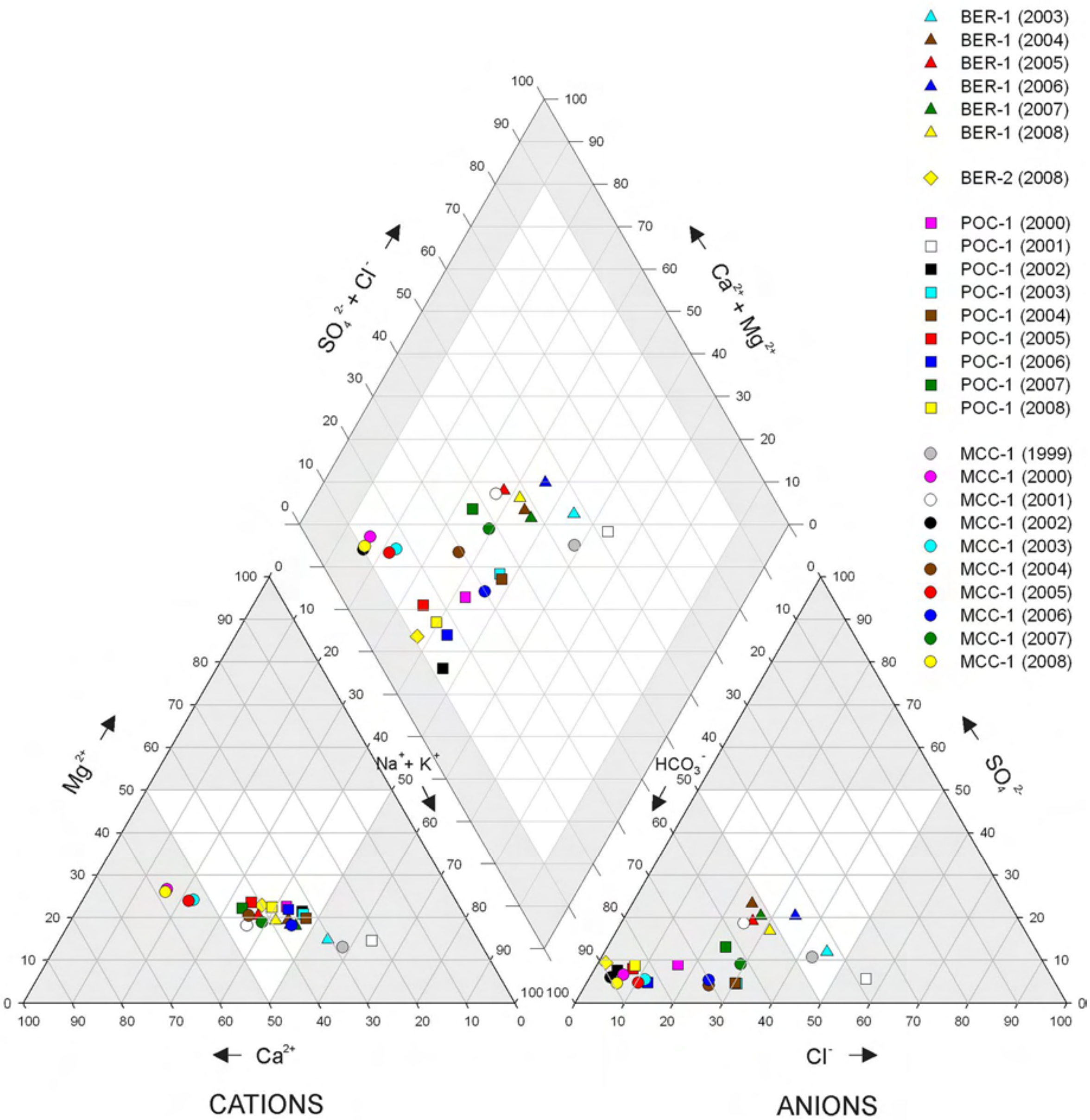


Table 5.11-14 Concentrations of water quality measurement endpoints, Poplar Creek (station POC-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	8	7.9	8.25	8.4
Total Suspended Solids	mg/L	-[1]	12	8	4	10	61
Conductivity	µS/cm	-	362	8	308	451	1590
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.013	8	0.007	0.013	0.022
Total nitrogen*	mg/L	1.0	**1.3**	8	0.3	1	**1.9**
Nitrate+Nitrite	mg/L	1.0	<0.1	8	<0.1	<0.1	0.1
Dissolved organic carbon	mg/L	-	26	8	10	23.5	32
Ions							
Sodium	mg/L	-	37	8	27	47.5	238
Calcium	mg/L	-	32.1	8	28.2	37.3	72.1
Magnesium	mg/L	-	11.5	8	10	13.4	29.3
Chloride	mg/L	230, 860[3]	11	8	7	32	**321**
Sulphate	mg/L	100[4]	16.4	8	10.4	14.4	44.2
Total Dissolved Solids	mg/L	-	262	8	200	275	890
Total Alkalinity	mg/L	-	163	8	135	183.5	304
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.401**	8	**0.207**	**0.291**	**1.44**
Dissolved aluminum	mg/L	0.1[2]	0.0019	8	<0.01	0.0063	0.0121
Total arsenic	mg/L	0.005	0.0009	8	<0.001	0.0011	0.002
Total boron	mg/L	1.2[5]	0.147	8	0.039	0.116	0.178
Total molybdenum	mg/L	0.073	0.0002	8	0.0002	0.0003	0.0007
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	1.4
Total strontium	mg/L	-	0.149	8	0.157	0.240	0.513
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.004**	8	**<0.003**	**0.007**	**0.009**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.2**	8	<0.2	0.9	**1.8**
Total iron	mg/L	0.3	**0.713**	8	**0.698**	**1.39**	**3.63**
Total phenols	mg/L	0.004	**0.008**	8	<0.001	**0.0045**	**0.019**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

1 AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

4 B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

5 B.C. ambient water quality guideline for boron (B.C. 2003).

6 Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

7 B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

8 Guideline is for total nitrogen.

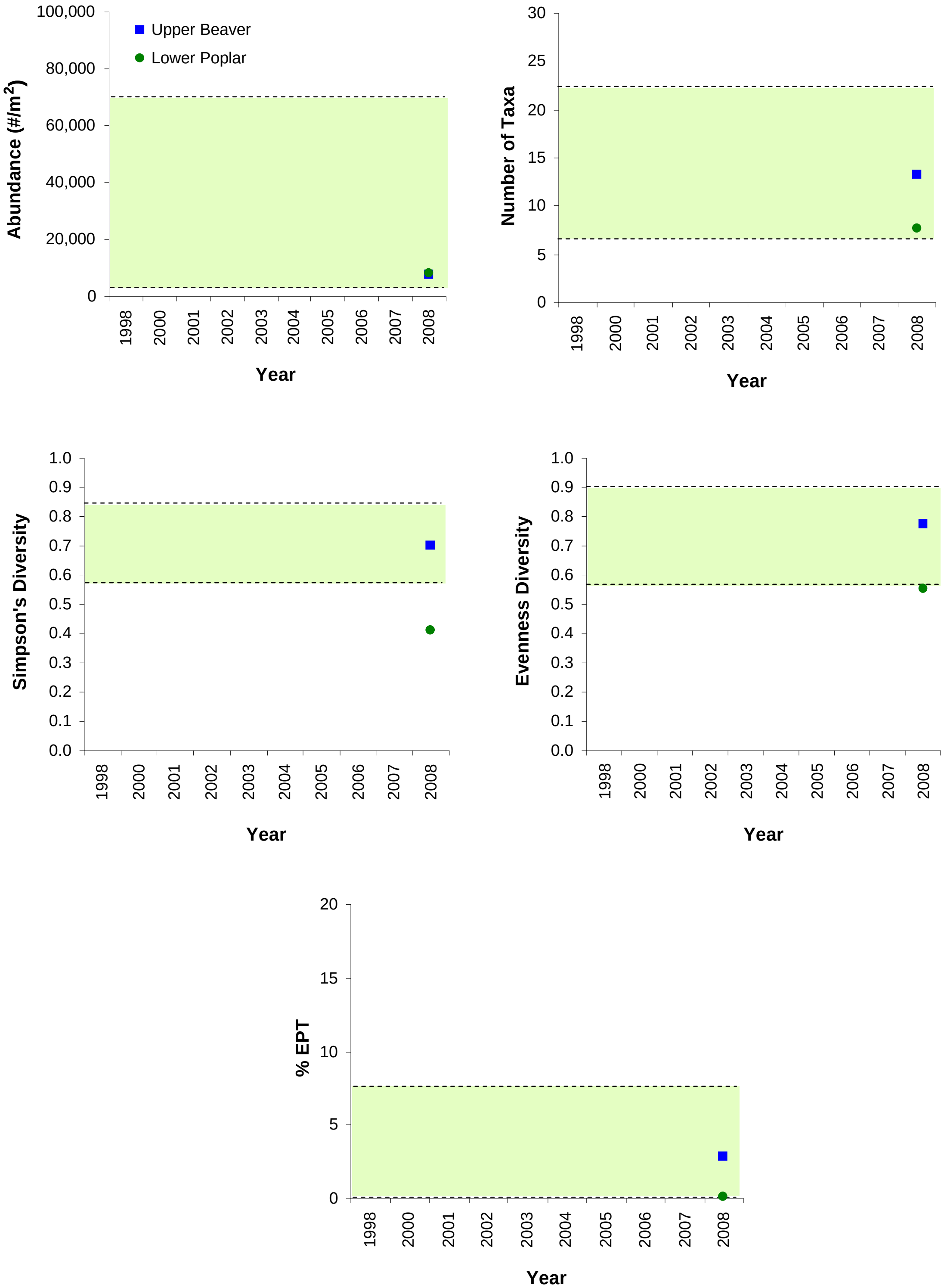
Table 5.11-15 Average habitat characteristics of benthic invertebrate sampling locations in the Beaver River and Poplar Creek.

Variable	Units	BER-D-2 Upper Reach of the Beaver River	POC-D-1 Lower Reach of Poplar Creek
Sample date	-	Sept 5, 2008	Sept 4, 2008
Habitat	-	Depositional	Depositional
Water depth	m	0.7	0.5
Current velocity	m/s	0.2	0.4
Field Water Quality			
Dissolved oxygen	mg/L	8.0	8.2
Conductivity	µS/cm	312	356
pH	pH units	8.0	8.5
Water temperature	°C	9.8	12.6
Sediment Composition			
Sand	%	85	62
Silt	%	8	25
Clay	%	7	13
Total Organic Carbon	%	0.6	2.4

Table 5.11-16 Major taxon percent abundances and benthic invertebrate community measurement endpoints for the upper Beaver River (*baseline* reach BER-D-2) and lower Poplar Creek (*test* reach POC-D-1).

Taxon	Percent Major Taxa Enumerated in Each Year	
	Upper Beaver River (Reach BER-D-2)	Lower Poplar Creek (reach POC-D-1)
	2008	2008
Bivalvia	1	1
Ceratopogonidae	6	2
Chironomidae	84	21
Coleoptera		<1
Copepoda	<1	
Empididae	1	
Enchytraeidae	<1	
Ephemeroptera	4	<1
Gastropoda	<1	
Glossiphoniidae	<1	
Hydracarina	1	
Naididae	<1	<1
Nematoda	1	2
Ostracoda	1	1
Tabanidae		<1
Trichoptera	<1	<1
Tubificidae	1	72
Benthic Invertebrate Community Measurement Endpoints		
Total Abundance (No./m^2)	7,687	8345
Richness	13	8
Simpson's Diversity	0.70	0.41
Evenness	0.77	0.55
% EPT	3	<1

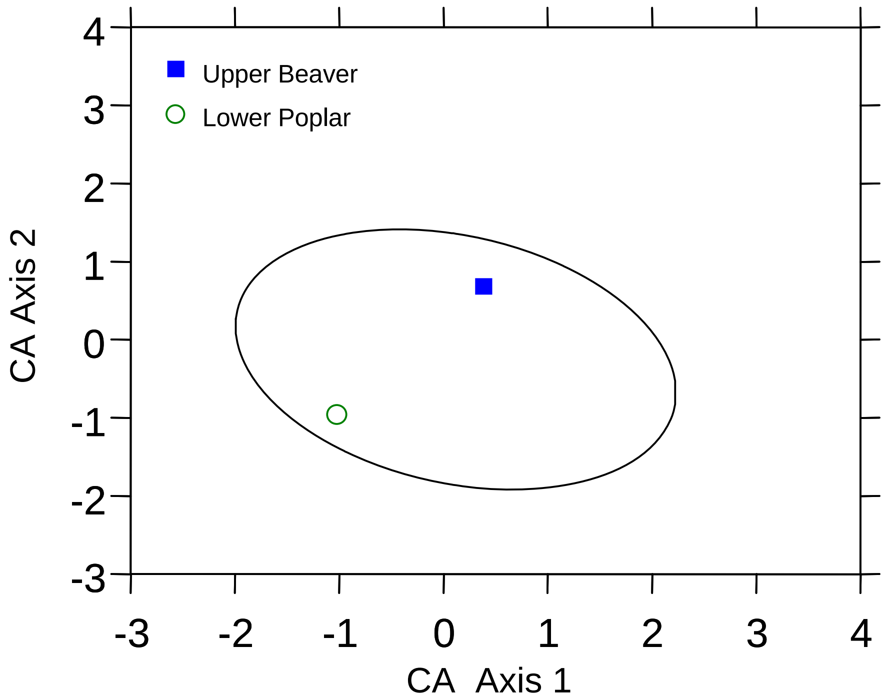
Figure 5.11-12 Variation in benthic invertebrate community measurement endpoints in the Beaver River and Poplar Creek.

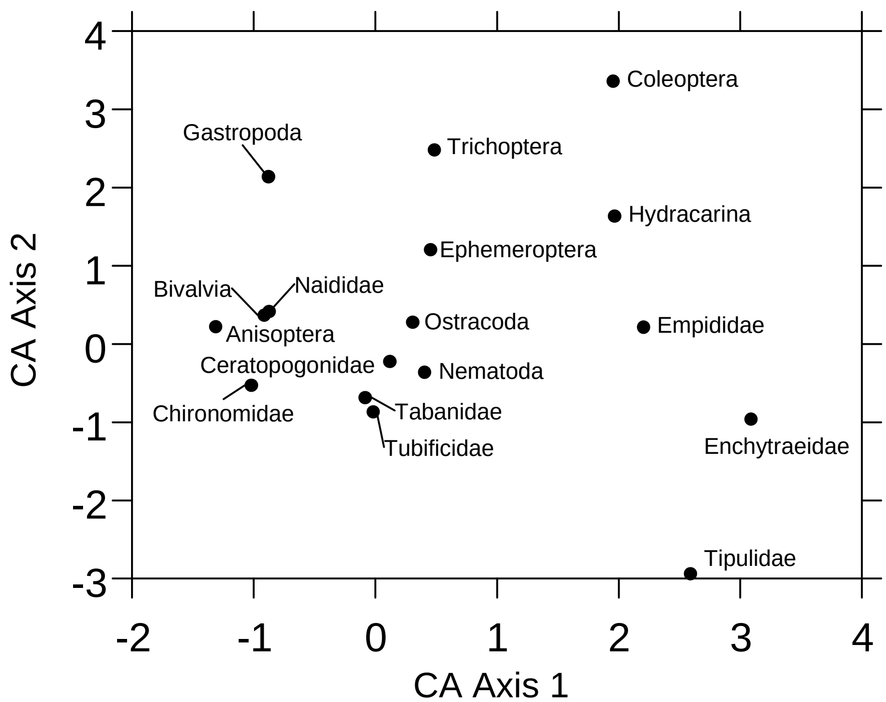


Note: Dotted lines and shaded ranges are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* depositional sites in the RAMP FSA.

Note: upper Beaver: *baseline* reach BER-D-2; lower Poplar: *test* reach POC-D-1

Figure 5.11-13 Ordination (Correspondence Analysis) of lake benthic invertebrate communities in the Beaver River and Poplar Creek.





Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the data for *baseline* depositional reaches in the RAMP FSA.

Note: Upper Beaver: *baseline* reach BER-D-2; lower Poplar: *test* reach POP-D-1

Table 5.11-17 Results of analysis of variance (ANOVA) between the lower Poplar Creek (*test* reach POC-D-1) and the upper Beaver River reach (*baseline* reach BER-D-2).

Endpoint	Source	SS	df	MS	F-ratio	P
Log Abundance	Reach	0.001	1	0.001	0.01	0.939
	Error	2.804	15	0.187		
Log Richness	Reach - Year	0.324	1	0.324	4.49	0.051
	Error	1.083	15	0.072		
Diversity	Reach - Year	0.338	1	0.338	12.69	0.003
	Error	0.400	15	0.027		
Evenness	Reach - Year	0.199	1	0.199	7.21	0.017
	Error	0.413	15	0.028		
Log %EPT	Reach - Year	0.45	1	0.45	3.96	0.065
	Error	1.70	15	0.11		
CA Axis 1	Reach - Year	8.52	1	8.52	27.01	0.000
	Error	4.73	15	0.32		
CA Axis 2	Reach - Year	11.05	1	11.05	7.86	0.013
	Error	21.08	15	1.41		

Table 5.11-18 Concentrations of sediment quality measurement endpoints, upper Beaver River (BER-D-2), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008 Value
Physical variables[6]			
Clay	%	-	7.4
Silt	%	-	7.6
Sand	%	-	85.1
Total organic carbon	%	-	0.64
Total hydrocarbons			
BTEX	mg/kg	-	na[4]
Fraction 1 (C6-C10)	mg/kg	30[2]	na[4]
Fraction 2 (C10-C16)	mg/kg	150[2]	na[4]
Fraction 3 (C16-C34)	mg/kg	300[2]	na[4]
Fraction 4 (C34-C50)	mg/kg	2800[2]	na[4]
Polycyclic Aromatic Hydrocarbons (PAHs)			
Naphthalene	mg/kg	0.0346[3]	0.00096
Retene	mg/kg	-	0.005
Total dibenzothiophenes	mg/kg	-	0.001
Total PAHs	mg/kg	-	0.018
Total Parent PAHs	mg/kg	-	0.004
Total Alkylated PAHs	mg/kg	-	0.014
Predicted PAH toxicity[1]	H.I.	-	[5]
Metals that exceed CCME guidelines in 2007			
none	mg/kg	-	-
Chronic toxicity			
Chironomus survival - 10d	# surviving	-	9
Chironomus growth - 10d	mg/organism	-	2.1
Hyalella survival - 14d	# surviving	-	10
Hyalella growth - 14d	mg/organism	-	0.4

Sediment quality was only sampled at BER-2 in fall 2008.

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Lab did not analyze sample for this variable, therefore no data is available.

[5] Hazard Index (H.I.) could not be calculated due to absence of total hydrocarbon data.

[6] Value is calculated from an average of 10 replicates.

na= not analyzed

Table 5.11-19 Concentrations of sediment quality measurement endpoints, lower Poplar Creek (POC-D-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	13.6	3	10	19.7	35
Silt	%	-	24.9	3	13.3	29	53
Sand	%	-	61.3	3	12	67	73
Total organic carbon	%	-	2.4	3	1.82	2.1	2.2
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	1	-	-	120
Fraction 3 (C16-C34)	mg/kg	300[2]	170	1	-	-	**1400**
Fraction 4 (C34-C50)	mg/kg	2800[2]	54	1	-	-	1400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0176	3	0.002	0.006	0.016
Retene	mg/kg	-	0.108	2	0.048	0.076	0.104
Total dibenzothiophenes	mg/kg	-	0.944	3	0.307	0.636	1.320
Total PAHs	mg/kg	-	3.400	3	1.753	2.177	4.828
Total Parent PAHs	mg/kg	-	0.209	3	0.148	0.189	0.201
Total Alkylated PAHs	mg/kg	-	3.191	3	1.605	1.976	4.640
Predicted PAH toxicity[1]	H.I.	-	4.32	3	0.159	0.467	0.654
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	1	-	-	9
Chironomus growth - 10d	mg/organism	-	2.4	1	-	-	1.7
Hyalella survival - 14d	# surviving	-	9	1	-	-	8
Hyalella growth - 14d	mg/organism	-	0.2	1	-	-	0.2

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 7 replicates.

Table 5.11-20 Concentrations of water quality measurement endpoints, McLean Creek (MCC-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	9	8.0	8.3	8.6
Total Suspended Solids	mg/L	-[1]	19	9	<3	5	83
Conductivity	µS/cm	-	290	9	300	407	1000
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.048	9	0.005	0.016	0.031
Total nitrogen*	mg/L	1.0	**1.4**	9	0.7	**1.05**	**1.5**
Nitrate+Nitrite	mg/L	1.0	<0.1	9	<0.05	<0.1	<1
Dissolved organic carbon	mg/L	-	35	9	14	22	34
Ions							
Sodium	mg/L	-	11	9	12	43	140
Calcium	mg/L	-	37.9	9	40.9	48.7	81.7
Magnesium	mg/L	-	10.3	9	11.1	13.4	21
Chloride	mg/L	230, 860[3]	7	9	5	44	165
Sulphate	mg/L	100[4]	7	9	9.2	10.9	76.4
Total Dissolved Solids	mg/L	-	239	9	220	320	620
Total Alkalinity	mg/L	-	141	9	144	176	319
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.346**	9	0.07	**0.33**	**2.58**
Dissolved aluminum	mg/L	0.1[2]	0.0074	9	<0.01	0.0085	0.0157
Total arsenic	mg/L	0.005	0.0010	9	<0.001	0.0007	0.0014
Total boron	mg/L	1.2[5]	0.0309	9	0.024	0.059	0.201
Total molybdenum	mg/L	0.073	0.0001	9	0.0001	0.0002	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[6]	1.7	5	<1.2	<1.2	<1.2
Total strontium	mg/L	-	0.127	9	0.111	0.180	0.294
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.018**	9	**<0.003**	**0.008**	**0.025**
Total phosphorus	mg/L	0.05	**0.072**	9	0.008	0.038	**0.07**
Total Kjeldahl nitrogen	mg/L	1.0[8]	**1.3**	9	0.4	0.9	**1.4**
Dissolved iron	mg/L	0.3[2]	**0.396**	9	0.04	0.228	**0.449**
Total iron	mg/L	0.3	**1.06**	9	**0.36**	**0.61**	**3.46**
Total phenols	mg/L	0.004	**0.012**	9	<0.001	<0.001	**0.011**

Guidelines are CCME (2007) or AENV (1999) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

[8] Guideline is for total nitrogen.

Figure 5.11-14 Fort Creek: 2008 hydrograph and historical context.

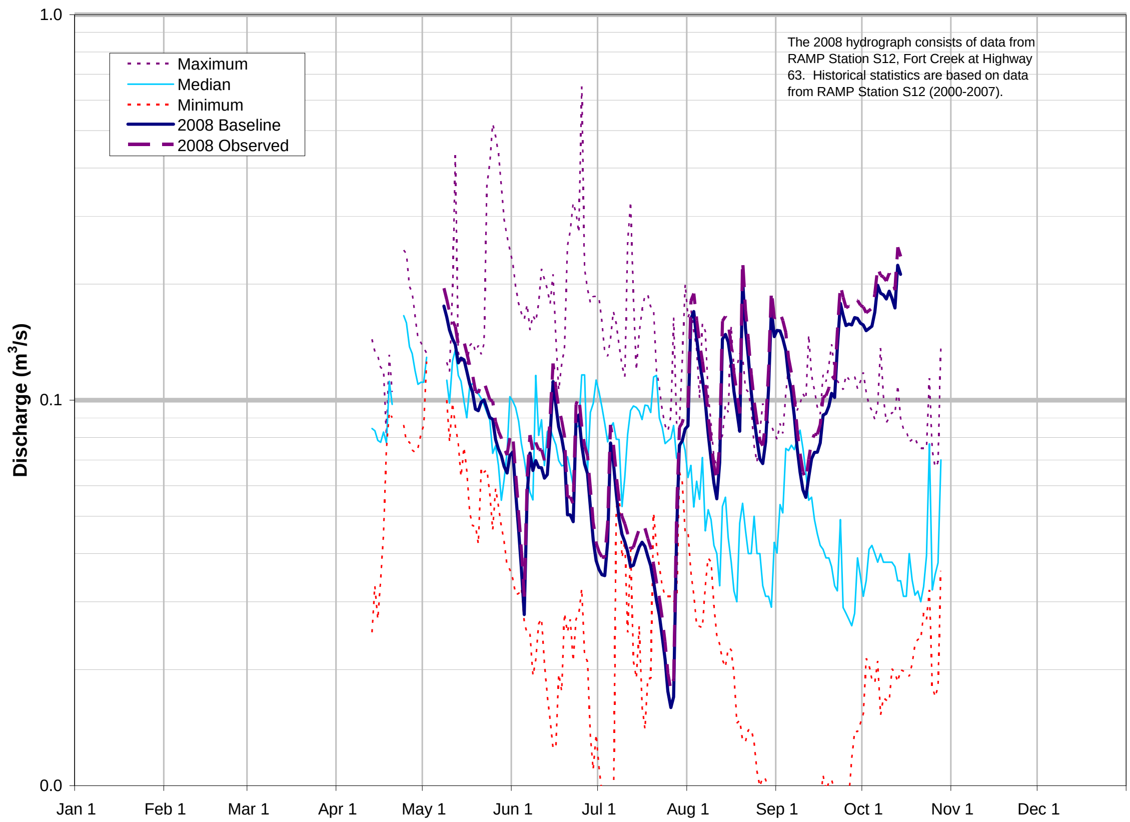


Table 5.11-21 Estimated water balance for RAMP Station S12, Fort Creek at Highway 63, in 2008.

Component	Volume (million m^3)	Basis and Source of Data
Observed *test* hydrograph (total discharge)	1.47	**Observed daily discharges, obtained from RAMP Station S12, Fort Creek at Highway 63**
Natural runoff that would have occurred from areas of land change that were closed-circuited as of 2008	+0.012	0.30 km^2 within Fort Creek drainage estimated to have been closed-circuited by oil sands development projects as of 2008 (Table 2.4-1)
Incremental runoff from areas of land change that were not closed-circuited as of 2008	-0.162	19.5 km^2 within Fort Creek drainage estimated to have undergone land change by oil sands development projects as of 2008, but are not closed-circuited (Table 2.4-1)
Discharge that would have occurred in the absence of water withdrawals from Fort Creek by focal projects	0	Unknown, none reported, assumed to be negligible
Amount by which discharge would be lower without releases to Fort Creek by focal projects	0	Unknown, none reported, assumed to be negligible
Diversions into or out of the watershed	0	None reported
The difference between *test* and *baseline* hydrographs on tributary streams	0	No focal projects or other oil sands projects on tributaries of Fort Creek not accounted for in figures contained in this table
***Baseline* hydrograph (total discharge)**	1.32	**Estimated baseline discharge at RAMP Station S12, Fort Creek at Highway 63**
Incremental flow (change in total discharge)	+0.149	Total discharge from observed *test* hydrograph less total discharge from estimated *baseline* hydrograph.
Incremental flow (% of observed total discharge)	+11.3%	Incremental flow as a percentage of total discharge of estimated *baseline* hydrograph.

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Note: Rounding of results occurs due to the use of a maximum of three significant digits

Table 5.11-22 Calculated change in hydrologic measurement endpoints for the Fort Creek watershed for 2008.

Measurement Endpoint	Value from *Baseline* Hydrograph (m^3/s)	Value from *Test* Hydrograph (m^3/s)	Relative Change
Mean open-water season discharge	0.096	0.107	+11.3%
Mean winter discharge	not measured	not measured	-
Annual maximum daily discharge	0.224	0.249	+11.3%
Open-water season minimum daily discharge	0.016	0.018	+11.3%

Note: As measured at RAMP Station S12, Fort Creek at Highway 63.

Note: Rounding of results occurs due to the use of a maximum of three significant digits.

Table 5.11-23 Concentrations of water quality measurement endpoints, lower Fort Creek (station FOC-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008 Value	1997-2007 (fall data only) n[8]	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	7	8.1	8.3	8.4
Total Suspended Solids	mg/L	-[1]	9	7	5	15	61
Conductivity	µS/cm	-	572	7	432	503	562
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.01	7	0.009	0.012	0.02
Total nitrogen*	mg/L	1.0	0.6	7	0.4	0.650	1.0
Nitrate+Nitrite	mg/L	1.0	<0.1	7	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	14	7	11	13	14
Ions							
Sodium	mg/L	-	11	7	8	10	18
Calcium	mg/L	-	85.1	7	69.4	77.9	89.6
Magnesium	mg/L	-	18.6	7	14.3	17.7	20.1
Chloride	mg/L	230, 860[3]	3	7	2	2.0	7
Sulphate	mg/L	100[4]	29.3	7	3.7	6.7	11.2
Total Dissolved Solids	mg/L	-	330	7	260	320	360
Total Alkalinity	mg/L	-	277	7	231	275	304
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.105**	7	0.04	0.057	**0.85**
Dissolved aluminum	mg/L	0.1[2]	0.0012	7	<0.01	0.002	0.090
Total arsenic	mg/L	0.005	0.0002	7	<0.001	0.0003	0.0007
Total boron	mg/L	1.2[5]	0.049	7	0.026	0.050	0.073
Total molybdenum	mg/L	0.073	0.0001	7	<0.0001	0.0000978	0.0001
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	3	<1.2	<1.2	1.4
Total strontium	mg/L	-	0.175	7	0.142	0.174	0.224
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.005**	7	**<0.003**	**0.004**	**0.006**
Total phenols	mg/L	0.004	**0.008**	7	<0.001	0.002	**0.027**
Total iron	mg/L	0.3	**1.04**	7	0.07	**0.71**	**1.94**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006)

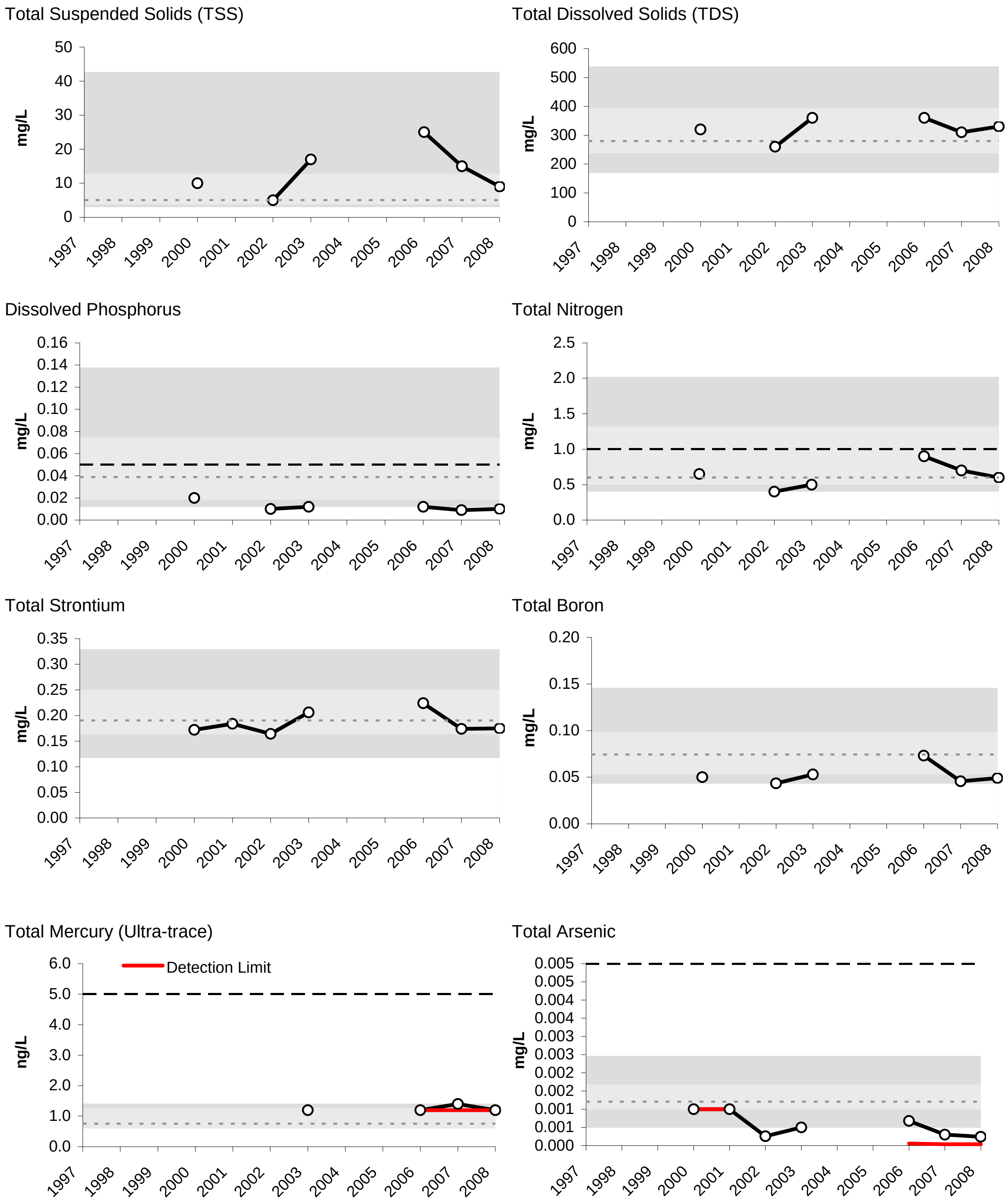
[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

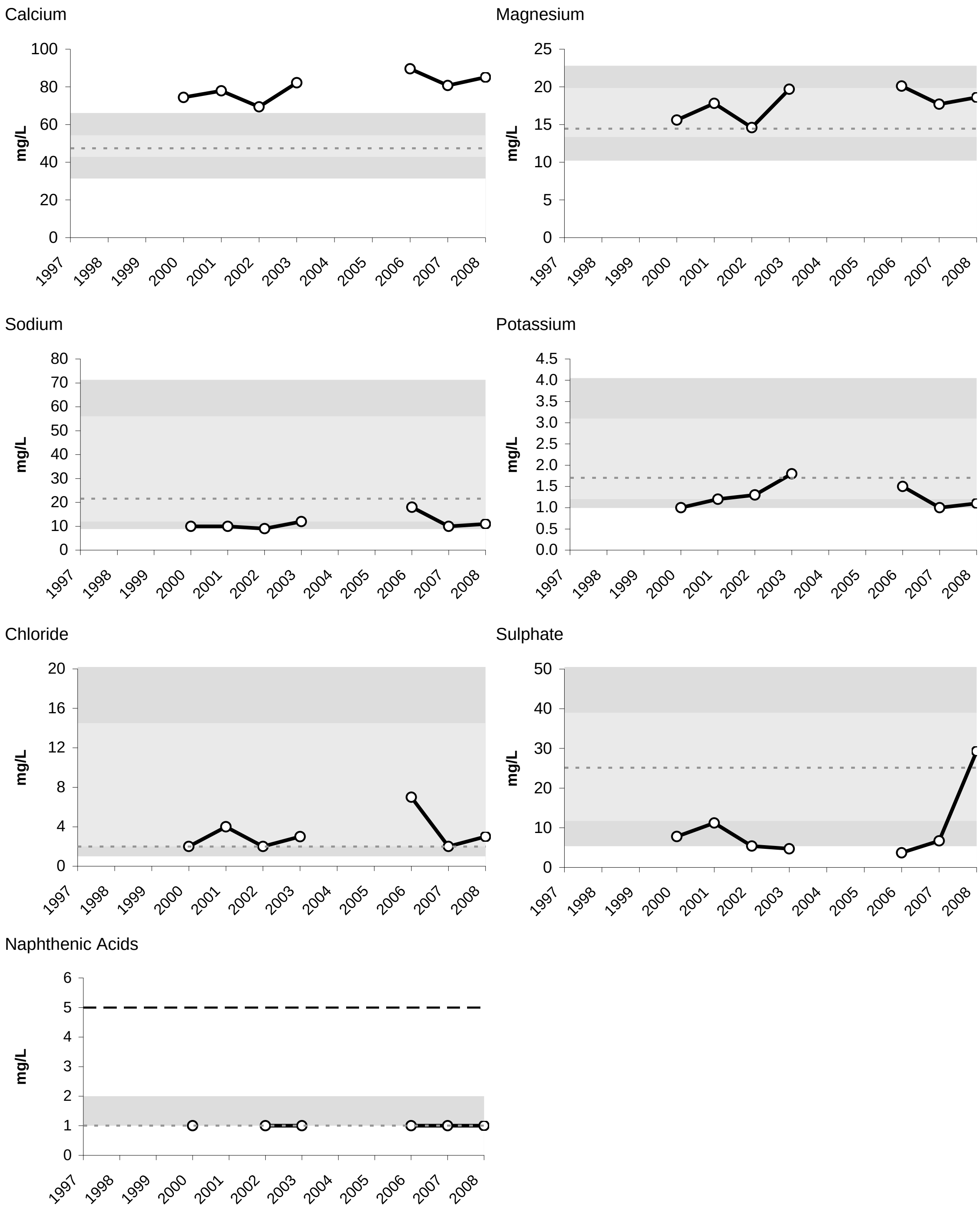
[8] FOC-1 was sampled in both September and October 2000.

Figure 5.11-15 Concentrations of selected water quality measurement endpoints in Fort Creek (fall 2008) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.
Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.
See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.11-15 (Cont'd.)



Non-detectable values are shown at the detection limit.

Regional baseline values reflect pooled results for all baseline stations with similar water quality, from all years of RAMP sampling.

See Sections 3.2.7.3 and 3.2.7.4, as well as Appendix D for a discussion of this approach.

Figure 5.11-16 Piper diagram of ion balance in Fort Creek, 2000-2008.

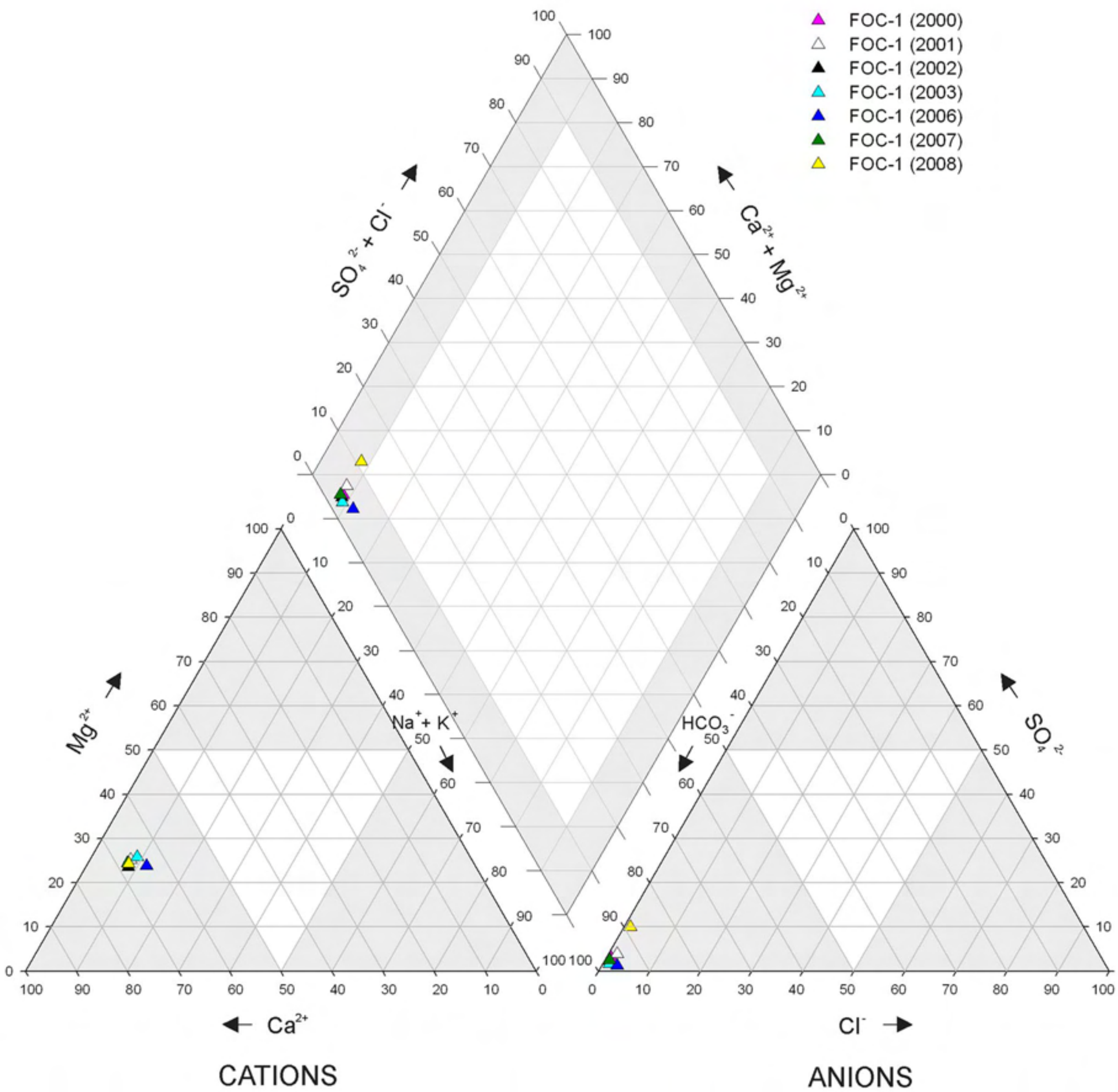


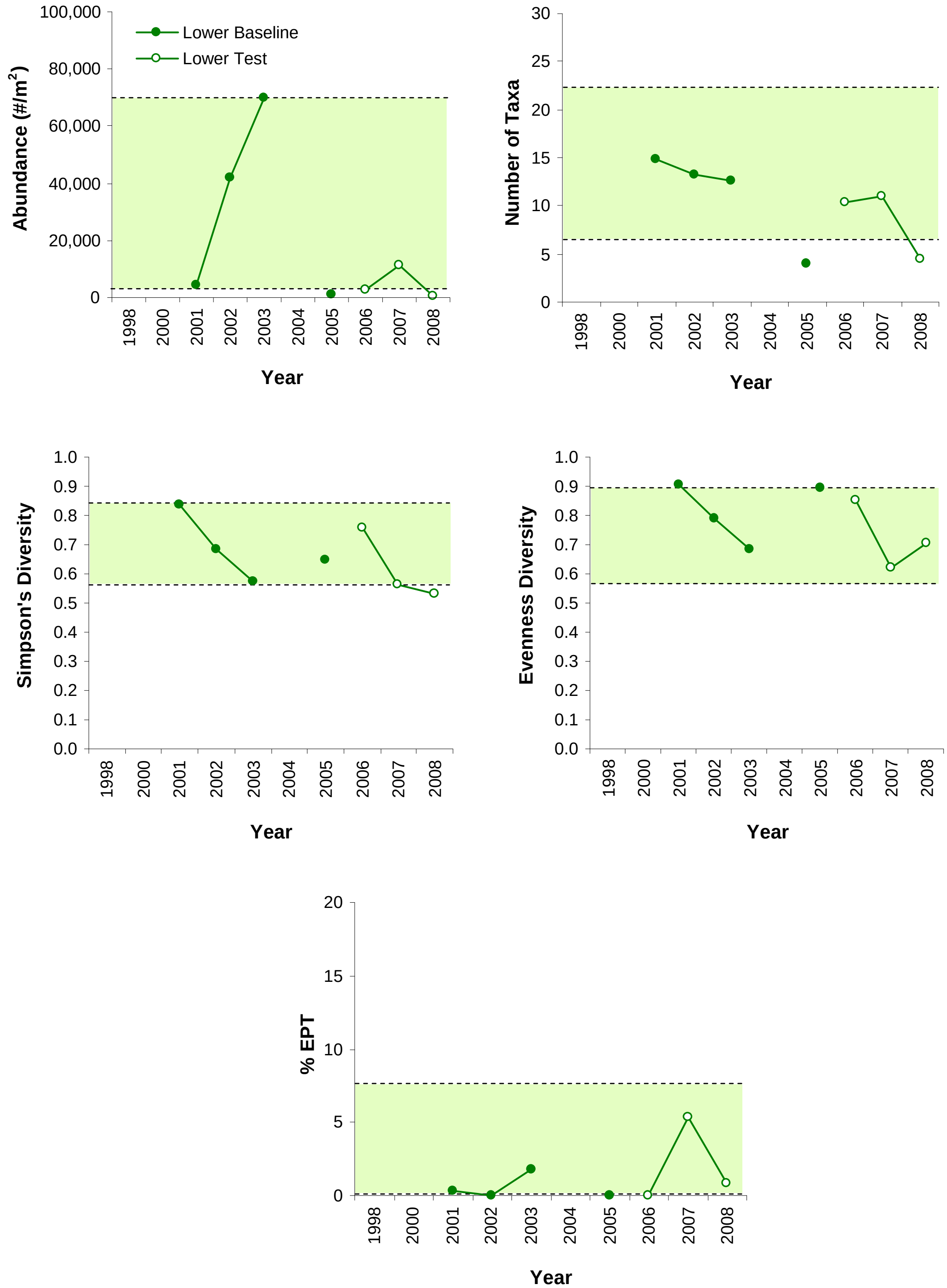
Table 5.11-24 Average habitat characteristics of lower Fort Creek (*test* reach FOC-D-1).

Variable	Units	Fort Creek
Sample date	-	Sept 10, 2008
Habitat	-	Depositional
Water depth	m	0.3
Current velocity	m/s	0.5
Macrophyte cover	%	0
Field Water Quality		
Dissolved oxygen	mg/L	9.9
Conductivity	µS/cm	532
pH	pH units	8.3
Water temperature	°C	8.2
Sediment Composition		
Sand	%	92
Silt	%	3
Clay	%	5
TOC	%	1.7

Table 5.11-25 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Fort Creek.

Taxon	Percent Major Taxa Enumerated in Each Year						
	Fort Creek (reach FOC-D-1)						
	2001	2002	2003	2005	2006	2007	2008
Bivalvia	5	1	<1	8		2	
Ceratopogonidae	<1	<1	1		2	8	1
Chironomidae	80	95	95	56	55	18	68
Copepoda	<1	1	1				
Empididae	1		<1				
Enchytraeidae	1	<1	1		<1	1	1
Ephemeroptera	<1					<1	1
Erpobdellidae		<1					
Gastropoda	<1		<1			1	3
Glossiphoniidae		<1					
Heteroptera			<1				
Hydracarina	<1		<1				
Macrothricidae		<1	<1				
Naididae	1	1	<1		1	2	
Nematoda	2	1	1	24	4	1	3
Ostracoda	1		<1	6	1	1	
Plecoptera						1	
Simuliidae			<1				
Tabanidae		<1			1		
Tipulidae	8	<1	<1		3		
Trichoptera			<1			<1	
Tubificidae		1	<1	6	29	66	22
Benthic Invertebrate Community Measurement Endpoints							
Total Abundance (No./m^2)	4,069	41,905	69,802	913	2,948	11,270	591
Richness	15	13	13	4	10	11	4
Simpson's Diversity	0.84	0.69	0.57	0.65	0.76	0.56	0.53
Evenness	0.91	0.79	0.68	0.9	0.77	0.62	0.70
% EPT	<1	0	2	0	0	9	<1

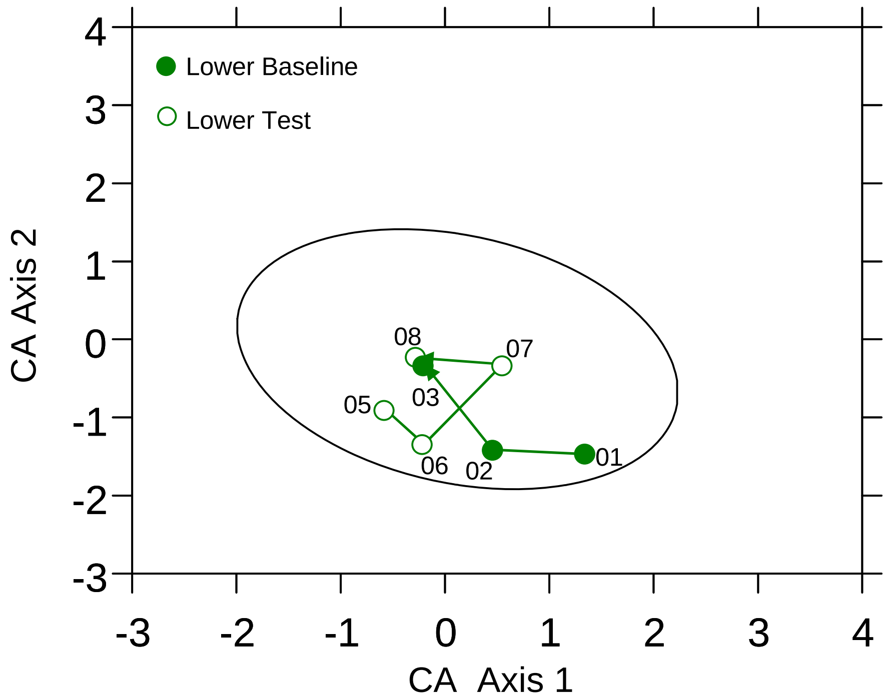
Figure 5.11-17 Variations in benthic invertebrate community measurement endpoints in Fort Creek, reach FOC-D-1.

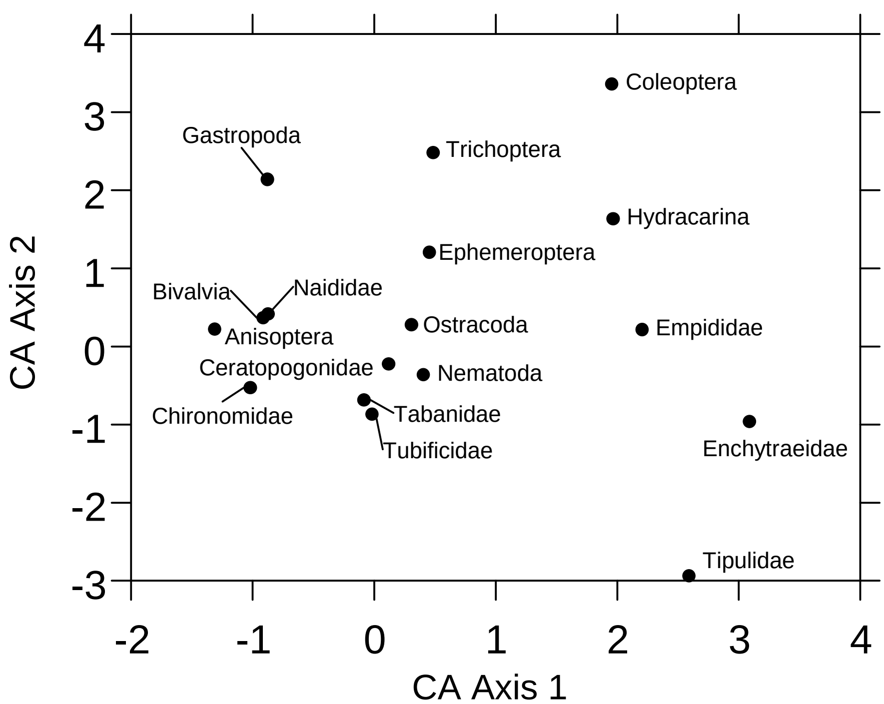


Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in *baseline* depositional sites in the RAMP FSA.

Note: lower *baseline* – reach FOC-D-1 from 2001 to 2003 when it was designated as *baseline*; lower *test* - reach FOC-D-1 from 2003 onwards when it was designated as *test*

Figure 5.11-18 Ordination (Correspondence Analysis) of depositional reaches, showing lower reach (FOC-D-1) of Fort Creek.





Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data for erosional river habitats in the RAMP FSA.

Note: lower *baseline* – reach FOC-D-1 from 2001 to 2003 when it was designated as *baseline*; lower *test* - reach FOC-D-1 from 2003 onwards when it was designated as *test*

Table 5.11-26 Results of analysis of variance (ANOVA) for lower Fort Creek (reach FOC-D-1).

Endpoint	Source	SS	df	MS	F-ratio	P
Log Abundance	Reach - Year	13.894	6	2.316	2.97	0.024
	Before to After	4.578	1	4.578	5.87	0.023
	Remainder (noise)	9.317	5	1.863	2.39	0.134
	Error	20.273	26	0.780		
Log Richness	Reach - Year	1.204	6	0.201	2.78	0.032
	Before to After	0.461	1	0.461	6.39	0.018
	Remainder (noise)	0.742	5	0.148	2.06	0.163
	Error	1.877	26	0.072		
Diversity	Reach - Year	0.294	6	0.049	1.67	0.169
	Before to After	0.004	1	0.004	0.14	0.708
	Remainder (noise)	0.290	5	0.058	1.97	0.172
	Error	0.764	26	0.029		
Evenness	Reach - Year	0.346	6	0.058	1.24	0.319
	Before to After	0.00	1	0.00	0.10	0.751
	Remainder (noise)	0.341	5	0.068	1.47	0.237
	Error	1.208	26	0.047		
Log %EPT	Reach - Year	1.40	6	0.23	1.89	0.120
	Before to After	0.07	1	0.07	0.60	0.445
	Remainder (noise)	1.33	5	0.27	2.15	0.155
	Error	3.21	26	0.12		
CA Axis 1	Reach - Year	138.60	24	5.78	5.23	0.000
	Before to After	0.79	1	0.79	0.71	0.399
	Remainder (noise)	137.8	23	5.992	5.42	0.020
	Error	1034.49	936	1.11		
CA Axis 2	Reach - Year	189.61	24	7.90	7.54	0.000
	Before to After	0.35	1	0.35	0.33	0.566
	Remainder (noise)	189.27	23	8.23	7.85	0.005
	Error	981.11	936	1.05		

Table 5.11-27 Concentrations of sediment quality measurement endpoints, lower Fort Creek (reach FOC-D-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only, station FOC-1)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	4.4	4	4	13.7	17.8
Silt	%	-	3.2	4	12	29.8	52.8
Sand	%	-	92.0	4	36.3	56.5	84
Total organic carbon	%	-	1.68	4	2	3.95	7.1
Total hydrocarbons							
BTEX	mg/kg	-	<5	1	-	-	<10
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	1	-	-	<10
Fraction 2 (C10-C16)	mg/kg	150[2]	**170**	1	-	-	16
Fraction 3 (C16-C34)	mg/kg	300[2]	**2600**	1	-	-	**440**
Fraction 4 (C34-C50)	mg/kg	2800[2]	1500	1	-	-	450
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0026	4	0.008	0.009	0.017
Retene	mg/kg	-	0.679	4	<0.38	0.044	0.629
Total dibenzothiophenes	mg/kg	-	3.22	4	0.16	1.36	3.10
Total PAHs	mg/kg	-	11.20	4	1.85	4.88	14.26
Total Parent PAHs	mg/kg	-	0.32	4	0.16	0.50	0.87
Total Alkylated PAHs	mg/kg	-	10.88	4	1.69	4.38	13.38
Predicted PAH toxicity[1]	H.I.	-	0.79	3	0.43	0.45	1.05
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	3	7	9	9
Chironomus growth - 10d	mg/organism	-	1.9	3	1.2	1.5	3.0
Hyalella survival - 14d	# surviving	-	10	2	6	7.5	9
Hyalella growth - 14d	mg/organism	-	0.3	2	0.1	0.2	0.3

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 5 replicates.

Table 5.11-28 Concentrations of water quality measurement endpoints, Shipyard Lake (SHL-1), fall 2008.

Measurement Endpoint	Units	Guideline	September 2008	1997-2007 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	9	7.7	8.1	8.2
Total Suspended Solids	mg/L	-[1]	<3	9	<3	3	15
Conductivity	µS/cm	-	465	9	358	389	509
Nutrients							
Total dissolved phosphorus	mg/L	0.05[2]	0.007	9	0.006	0.009	0.026
Total nitrogen*	mg/L	1.0	0.7	9	0.3	0.9	**1.4**
Nitrate+Nitrite	mg/L	1.0	<0.1	9	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	20	9	17	20	24
Ions							
Sodium	mg/L	-	30	9	16	20	29
Calcium	mg/L	-	49.4	9	41.7	49.9	71.8
Magnesium	mg/L	-	14.7	9	11.1	11.6	17.7
Chloride	mg/L	230, 860[3]	24	9	11	16	18
Sulphate	mg/L	100[4]	4.9	9	2.8	6	10.5
Total Dissolved Solids	mg/L	-	293	9	200	270	320
Total Alkalinity	mg/L	-	206	9	159	182	251
Organic compounds							
Naphthenic acids	mg/L	-	<1	9	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	<0.002	9	0.004	0.010	**0.140**
Dissolved aluminum	mg/L	0.1[2]	<0.001	9	<0.01	<0.001	0.00
Total arsenic	mg/L	0.005	0.0005	9	<0.001	0.0005	0.001
Total boron	mg/L	1.2[5]	0.0744	9	0.0270	0.0430	0.0728
Total molybdenum	mg/L	0.073	0.00003	9	<0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[6]	<1.2	5	<1.2	<1.2	1.4
Total strontium	mg/L	-	0.165	9	0.129	0.156	0.209
Other variables that exceeded CCME/AENV guidelines in fall 2008							
Sulphide	mg/L	0.002[7]	**0.012**	9	**<0.003**	**0.009**	**0.014**
Total iron	mg/L	0.3	**0.312**	9	0.27	**0.6**	**1.48**
Total phenols	mg/L	0.004	**0.006**	9	<0.001	**0.005**	**0.012**

Guidelines are CCME (2007) or AENV (1999b) unless otherwise noted.

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN);
Non-detectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[1] AENV guideline: TSS is not to be increased by more than 10 mg/L over background value.

[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 2006).

[4] B.C. maximum concentration guideline for sulphate (B.C. Approved Water Quality Guideline, B.C. 2006).

[5] B.C. ambient water quality guideline for boron (B.C. 2003).

[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999b).

[7] B.C. Working Water Quality Guideline for sulphide as H_2S (B.C. 2006).

Table 5.11-29 Water quality index (fall 2008) for Miscellaneous watershed stations.

Station Identifier	Location	2008 Designation	Water Quality Index	Classification
ISL-1	Isadore's Lake	*test*	92.2	Negligible-Low
SHL-1	Shipyard Lake	*test*	96.1	Negligible-Low
POC-1	Near the mouth of Poplar Creek	*test*	96.1	Negligible-Low
FOC-1	Near the mouth of Fort Creek	*test*	96.1	Negligible-Low
BER-1	Near the mouth of Beaver River	*test*	96.1	Moderate
BER-2	Upper Beaver River	*baseline*	96.1	Negligible-Low
MCC-1	Near the mouth of McLean Creek	*test*	96.1	Negligible-Low

Note: see Figure 5.11-1 for the locations of these water quality stations.

Note: see Section 3.2.7.4 for a description of the Water Quality Index.

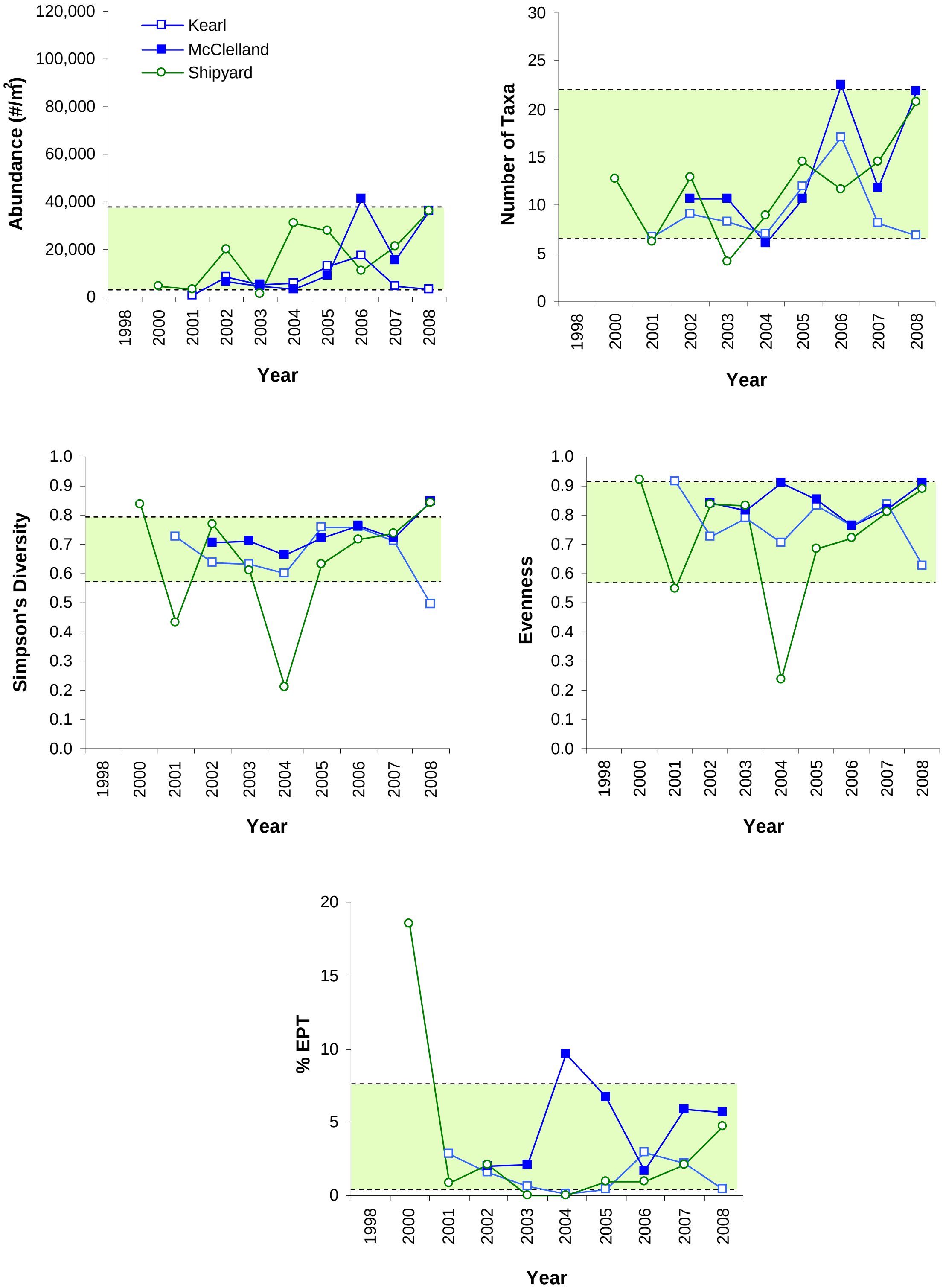
Table 5.11-30 Average habitat characteristics of benthic invertebrate sampling locations in Kearl, McClelland, and Shipyard Lakes.

Variable	Units	Shipyard Lake SHL-1
Sample date	-	Sept 6, 2008
Habitat	-	Depositional
Water depth	m	1.4
Macrophyte cover	%	74
Field Water Quality		
Dissolved oxygen	mg/L	n/a
Conductivity	µS/cm	473
pH	pH units	7.1
Water temperature	°C	14.9
Sediment Composition		
Sand	%	8
Silt	%	37
Clay	%	55
Total Organic Carbon	%	18.8

Table 5.11-31 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Shipyard Lake.

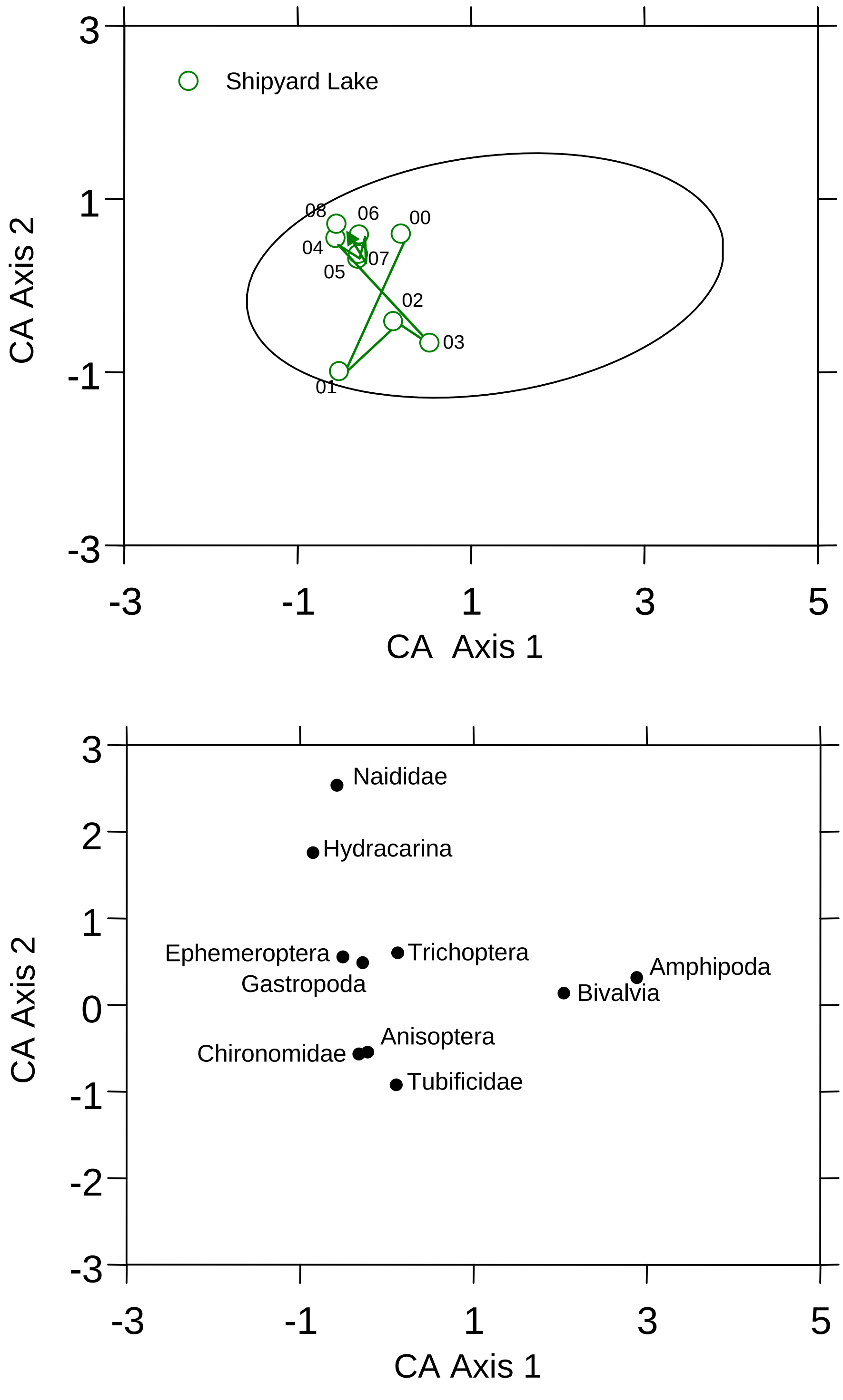
Taxon	Percent Major Taxa Enumerated in Each Year								
	Shipyard								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Amphipoda	7		2	3		2	2	2	1
Anisoptera	<1	1	<1			<1			<1
Bivalvia	7	<1	8	6	1	<1	2	1	1
Ceratopogonidae		1	<1	1			6		
Chaoboridae	3	53	1	32	1	<1	6		
Chironomidae	25	40	48	32	3	30	37	27	40
Cladocera	3				<1	2		1	3
Copepoda	1	<1		9	1	3	1	11	16
Ephemeroptera	16	1	2			<1	<1	3	6
Erpobdellidae							1		
Gastropoda	18	1	7	5	1	2	<1	3	2
Glossiphoniidae		<1	<1	<1					
Hydracarina		1	<1		<1	1		3	2
Lumbriculidae						<1			
Naididae	8	<1	3		4	9	16	6	5
Nematoda			3	2	2	1	1	1	1
Ostracoda	6	2	25	8	87	5	22	40	22
Trichoptera	2	1	<1		<1	1	1	1	<1
Tubificidae	1		1	3	1	7			<1
Zygoptera	3		1		<1				1
Benthic Invertebrate Community Measurement Endpoints									
Total Abundance (No./m^2)	4,552	3,284	19,780	1,530	30,867	27,930	10,647	21,305	36,328
Richness	13	6	13	4	9	15	12	15	21
Simpson's Diversity	0.84	0.43	0.77	0.61	0.21	0.63	0.72	0.74	0.84
Evenness	0.92	0.55	0.84	0.83	0.24	0.69	0.72	0.81	0.89
% EPT	19	1	2	<1	<1	1	<1	2	4

Figure 5.11-19 Variation in benthic invertebrate community measurement endpoints in Shipyard, Kearl, and McClelland lakes.



Note: lower and upper dotted lines are 5th and 95th percentile for each measurement endpoint based on the distribution of annual means in Kearl and McClelland lakes, both designated as *baseline*.

Figure 5.11-20 Ordination (Correspondence Analysis) of lake benthic invertebrate communities in Shipyard Lake (*test* station SHL-1).



Note: upper panel is the scatterplot of sample scores while the lower panel is the scatterplot of taxa scores. The ellipse in the upper panel is for the *baseline* data (i.e., Kearl and McClelland lakes).

Table 5.11-32 Results of analysis of variance (ANOVA) testing for differences in benthic invertebrate community measurement endpoints in Shipyard Lake (SHL-1) relative to Kearl and McClelland Lakes.

Endpoint	Source	SS	df	MS	F-ratio	P
Log Abundance	Lake - Year	54.082	23	2.351	9.76	0.000
	Baseline vs Test (BT)	5.335	1	5.335	22.14	0.000
	Linear Time Trend (T)	3.093	1	3.093	12.83	0.000
	BT x T	0.275	1	0.275	1.14	0.287
	Remainder (noise)	45.380	20	2.269	9.41	0.002
	Error	51.332	213	0.241		
Log Richness	Lake - Year	7.826	23	0.340	7.20	0.000
	Baseline vs Test (BT)	0.116	1	0.116	2.46	0.118
	Linear Time Trend (T)	0.945	1	0.945	20.00	0.000
	BT x T	0.200	1	0.200	4.23	0.041
	Remainder (noise)	6.565	20	0.328	6.94	0.009
	Error	10.065	213	0.047		
Diversity	Lake - Year	3.840	23	0.167	6.88	0.000
	Baseline vs Test (BT)	0.147	1	0.147	6.06	0.015
	Linear Time Trend (T)	0.358	1	0.358	14.74	0.000
	BT x T	0.091	1	0.091	3.76	0.054
	Residual (noise)	3.244	20	0.162	6.67	0.010
	Error	5.171	213	0.024		
Evenness	Lake - Year	4.384	23	0.191	8.67	0.000
	Baseline vs Test (BT)	0.276	1	0.276	12.56	0.001
	Linear Time Trend (T)	0.057	1	0.057	2.58	0.110
	BT x T	0.105	1	0.105	4.77	0.030
	Remainder (noise)	3.947	20	0.197	8.97	0.003
	Error	4.682	213	0.022		
Log %EPT	Lake - Year	12.58	23	0.55	3.76	0.000
	Baseline vs Test (BT)	0.39	1	0.39	2.69	0.102
	Linear Time Trend (T)	0.40	1	0.40	2.73	0.100
	BT x T	0.32	1	0.32	2.20	0.139
	Remainder (noise)	11.47	20	0.57	3.94	0.048
	Error	31.01	213	0.15		
CA Axis 1	Lake - Year	242.2	23	10.53	8.84	0.000
	Baseline vs Test (BT)	91.3	1	91.31	76.67	0.000
	Linear Time Trend (T)	15.4	1	15.44	12.97	0.000
	BT x T	0.1	1	0.12	0.10	0.750
	Remainder (noise)	135.3	20	6.765	5.68	0.018
	Error	252.5	212	1.19		
CA Axis 2	Lake - Year	64.98	23	2.83	3.18	0.000
	Baseline vs Test (BT)	0.05	1	0.05	0.06	0.805
	Linear Time Trend (T)	5.97	1	5.97	6.72	0.010
	BT x T	4.69	1	4.69	5.28	0.023
	Remainder (noise)	54.26	20	2.71	3.05	0.082
	Error	188.47	212	0.89		

Table 5.11-33 Concentrations of sediment quality measurement endpoints, Shipyard Lake (SHL-1), fall 2008.

Measurement Endpoints	Units	Guideline	September 2008	1997-2007 (fall data only, station SHL-1)			
			Value	n	Min	Median	Max
Physical variables[4]							
Clay	%	-	43.1	6	3	53.9	60
Silt	%	-	52.8	6	32.9	38.6	59
Sand	%	-	4.1	6	2	6.1	42.1
Total organic carbon	%	-	16.9	6	5.5	15.3	19.7
Total hydrocarbons							
BTEX	mg/kg	-	<5	3	<5	<5	<60
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	3	<5	<5	<60
Fraction 2 (C10-C16)	mg/kg	150[2]	<5	3	<5	<5	69
Fraction 3 (C16-C34)	mg/kg	300[2]	**2600**	3	290	**550**	**780**
Fraction 4 (C34-C50)	mg/kg	2800[2]	280	3	<5	117.5	230
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.025	4	0.011	0.017	0.022
Retene	mg/kg	-	0.124	6	0.046	0.088	0.199
Total dibenzothiophenes	mg/kg	-	2.31	6	0.26	0.45	2.62
Total PAHs	mg/kg	-	9.14	6	2.28	4.07	13.87
Total Parent PAHs	mg/kg	-	0.67	6	0.23	0.25	5.89
Total Alkylated PAHs	mg/kg	-	8.46	6	2.02	3.80	8.09
Predicted PAH toxicity[1]	H.I.	-	0.90	6	0.10	1.57	3.78
Metals that exceed CCME guidelines in 2008							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	4	7	8	8
Chironomus growth - 10d	mg/organism	-	2.6	4	1.5	2.0	2.3
Hyalella survival - 14d	# surviving	-	8	3	6	8	8
Hyalella growth - 14d	mg/organism	-	0.4	3	0.2	0.2	0.3

Values in **bold** indicate concentrations exceeding guidelines.

[1] 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.

[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2008).

[3] Interim sediment quality guideline (ISQG) (CCME 2002).

[4] Value is calculated from an average of 10 replicates.

Table 5.11-34 Sediment quality index (fall 2008) for miscellaneous watershed stations.

Station Identifier	Location	2008 Designation	Sediment Quality Index	Classification
ISL-1	Isadore's Lake	*test*	85.7	Negligible-Low
POC-D1	Mouth of Poplar Creek	*test*	87.4	Negligible-Low
FOC-D1	Mouth of Fort Creek	*test*	95.0	Negligible-Low
SHL-1	Shipyard Lake	*test*	73.6	Moderate
BER-D2	Upper Beaver River	*baseline*	100.0	Negligible-Low

Figure 5.11-21 Susan Lake Outlet: 2008 hydrograph.

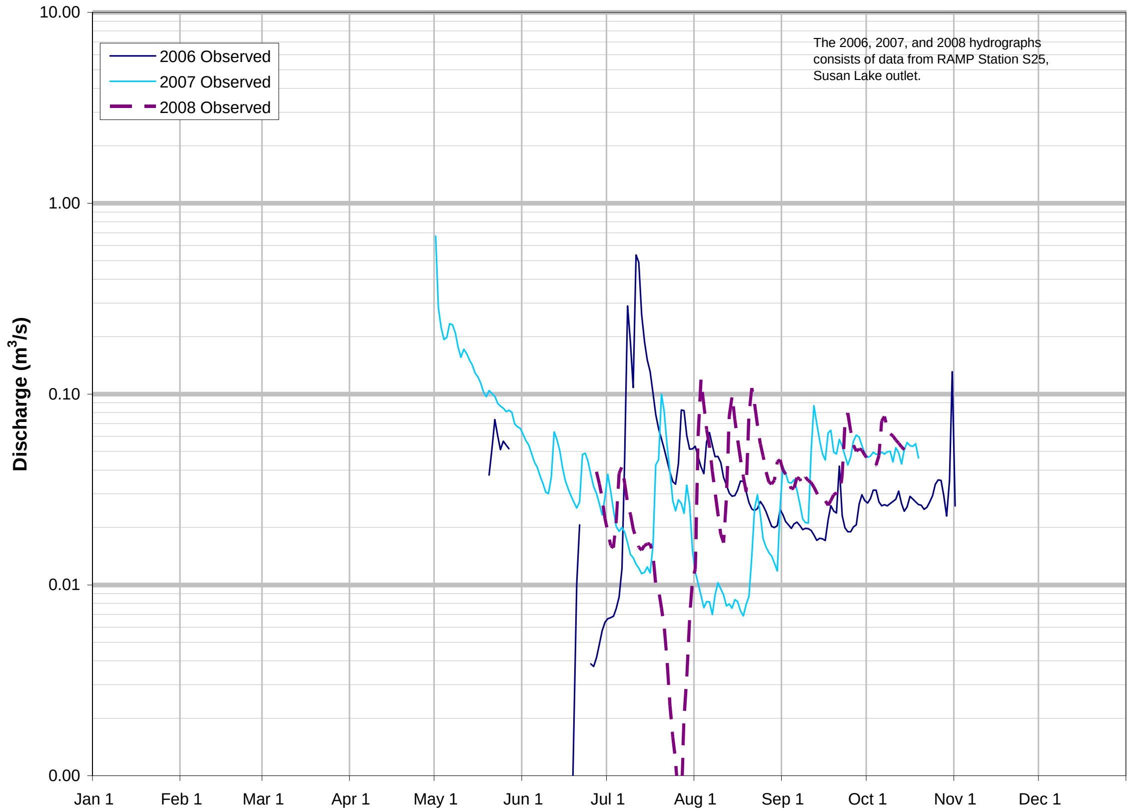


Table 5.11-35 Metrics and mercury concentrations of walleye, northern pike and lake whitefish from Big Island Lake, September 2008.

Species	Fish ID	Sex	Age	Stage	Length (mm)	Weight (g)	Hg (mg/kg)
Lake whitefish	BL-LKWH-01	F	-	M	446	1400	0.030
Lake whitefish	BL-LKWH-02	U	-	I	232	174	0.015
Lake whitefish	BL-LKWH-03	M	-	M	440	1125	0.032
Lake whitefish	BL-LKWH-04	M	-	M	467	1380	0.025
Lake whitefish	BL-LKWH-05	U	-	I	243	183	0.015
Lake whitefish	BL-LKWH-06	F	-	M	463	1325	0.036
Lake whitefish	BL-LKWH-07	F	-	M	460	1350	0.038
Lake whitefish	BL-LKWH-08	M	-	M	441	1200	0.028
Lake whitefish	BL-LKWH-09	U	-	I	265	280	0.012
Lake whitefish	BL-LKWH-10	M	-	M	468	1450	0.026
Lake whitefish	BL-LKWH-11	F	-	M	478	1700	0.055
Lake whitefish	BL-LKWH-12	F	-	M	463	1450	0.029
Lake whitefish	BL-LKWH-13	U	-	I	337	173	0.014
Lake whitefish	BL-LKWH-14	U	-	I	206	116	0.018
Lake whitefish	BL-LKWH-15	M	-	M	442	1300	0.022
Lake whitefish	BL-LKWH-16	F	-	I	259	250	0.013
Northern pike	BL-NRPK-01	M	8	M	577	1625	0.109
Northern pike	BL-NRPK-02	F	-	M	623	1800	0.067
Northern pike	BL-NRPK-03	M	5	M	527	1130	0.100
Northern pike	BL-NRPK-04	M	6	M	581	1370	0.112
Northern pike	BL-NRPK-05	F	5	M	649	2100	0.071
Northern pike	BL-NRPK-06	F	3	M	434	600	0.048
Northern pike	BL-NRPK-07	M	5	M	570	1390	0.073
Northern pike	BL-NRPK-08	M	4	M	511	1050	0.086
Northern pike	BL-NRPK-09	F	3	M	503	860	0.054
Northern pike	BL-NRPK-10	F	6	M	610	1550	0.083
Northern pike	BL-NRPK-11	M	4	M	539	1150	0.071
Northern pike	BL-NRPK-12	F	4	M	560	2820	0.057
Walleye	BL-WALL-01	U	-	I	290	263.6	0.041
Walleye	BL-WALL-02	F	5	M	483	3060	0.098
Walleye	BL-WALL-03	F	6	M	482	1355	0.090
Walleye	BL-WALL-04	F	3	I	285	243.6	0.041
Walleye	BL-WALL-05	M	-	I	298	277.1	0.037
Walleye	BL-WALL-06	F	7	I	456	1130	0.092
Walleye	BL-WALL-07	U	-	I	278	253.6	0.040

Table 5.11-35 (Cont'd.)

Species	Fish ID	Sex	Age	Stage	Length (mm)	Weight (g)	Hg (mg/kg)
Walleye	BL-WALL-08	F	14	M	458	3050	0.150
Walleye	BL-WALL-09	M	3	I	275	232.1	0.039
Walleye	BL-WALL-10	M	2	I	271	250	0.046
Walleye	BL-WALL-11	M	2	I	274	205.6	0.034
Walleye	BL-WALL-12	M	6	I	454	1250	0.080
Walleye	BL-WALL-13	M	7	M	365	680	0.095
Walleye	BL-WALL-14	U	-	I	277	223	0.047
Walleye	BL-WALL-15	F	7	I	453	1210	0.081
Walleye	BL-WALL-16	M	-	I	273	210	0.062
Walleye	BL-WALL-17	F	4	I	332	415	0.065
Walleye	BL-WALL-18	F	-	M	623	3350	0.251
Walleye	BL-WALL-19	M	8	M	415	860	0.102
Walleye	BL-WALL-20	M	7	M	458	1300	0.079

Sex: F-Female; M-Male; U-Undetermined; M-Mature.

Stage: M-Mature; I-Immature.

exceeds National USEPA Criterion for subsistence fishers (0.049 mg/kg)

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds National USEPA Criterion for recreational fishers (0.40 mg/kg)

exceeds Health Canada Criterion for general consumers (0.50 mg/kg)

Figure 5.11-22 Mean mercury concentration (+/- SE) by size class in lake whitefish, walleye and northern pike captured in Big Island Lake, September 2008.

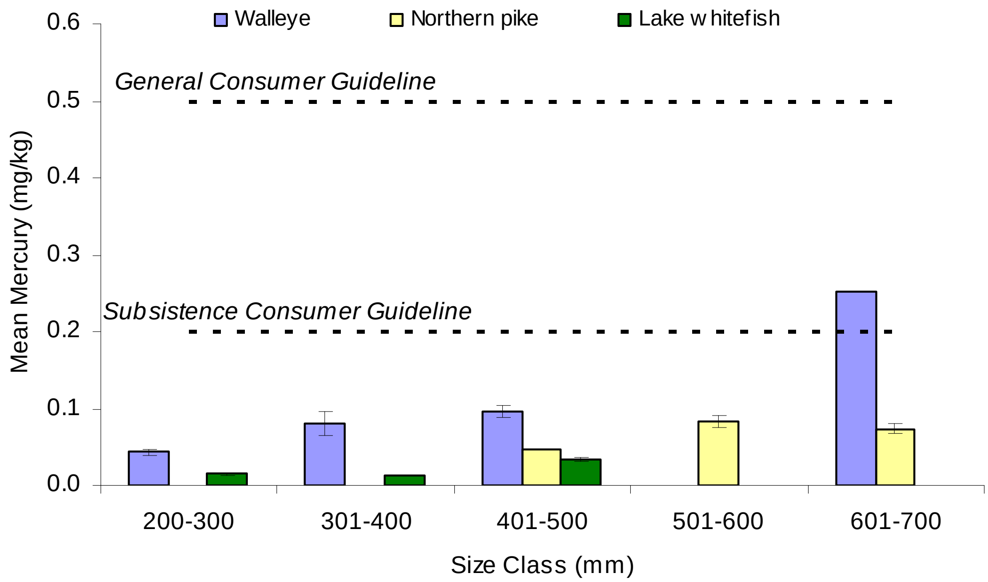
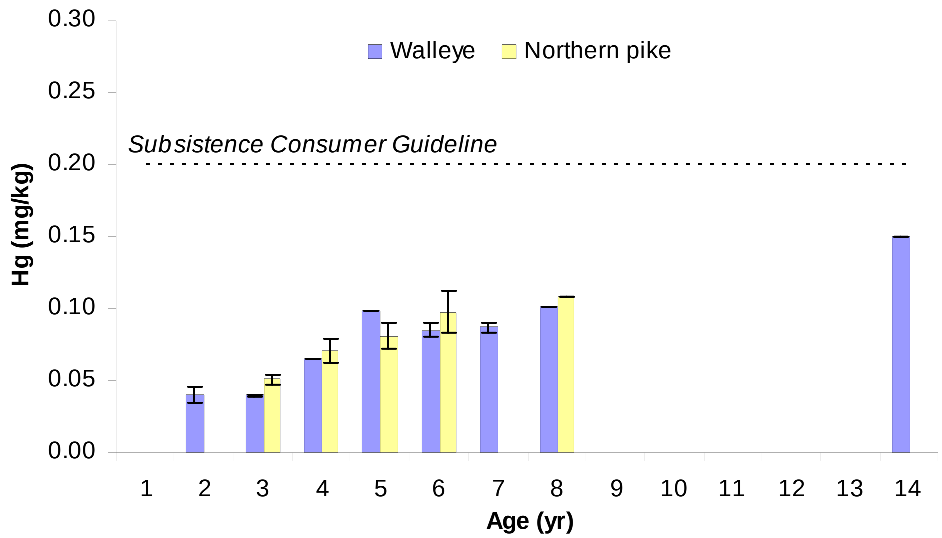


Figure 5.11-23 Mean mercury concentration by age in walleye and northern pike in Big Island Lake, September 2008.



Note: there is no ageing result for the 623 mm walleye with mercury fish tissue concentration of 0.25 mg/kg.

Table 5.11-36 Correlations between mercury concentration and fork length and body weight in walleye, northern pike and lake whitefish muscle tissue collected from Big Island Lake, September 2008.

Species	Sex	Sample Size	Metric	
			Fork Length	Total Weight
Lake whitefish	Male	5	-0.309	-0.676
	Female	6	**0.785**	**0.841**
	Combined	16	**0.757**	**0.817**
Northern pike	Male	6	0.373	0.440
	Female	6	**0.832**	0.347
	Combined	12	0.317	-0.014
Walleye	Male	9	**0.786**	**0.737**
	Female	8	**0.858**	**0.808**
	Combined	20	**0.858**	**0.855**

value = moderate correlation (0.5 < |r| < 0.75)
value = strong correlation (|r| > 0.75)
value = significant correlation (|r| > critical value)
critical values at α=0.1: n=5, |r|=0.900; n=6, |r|=0.829; n=16, |r|=0.429; n=12, |r|=0.503; n=9, |r|=0.600; n=8, |r|=0.643; and n=20, |r|=0.380

Figure 5.11-24 Regression analysis of mercury concentration in fish muscle versus length for walleye, northern pike and lake whitefish from Big Island Lake, fall 2008.

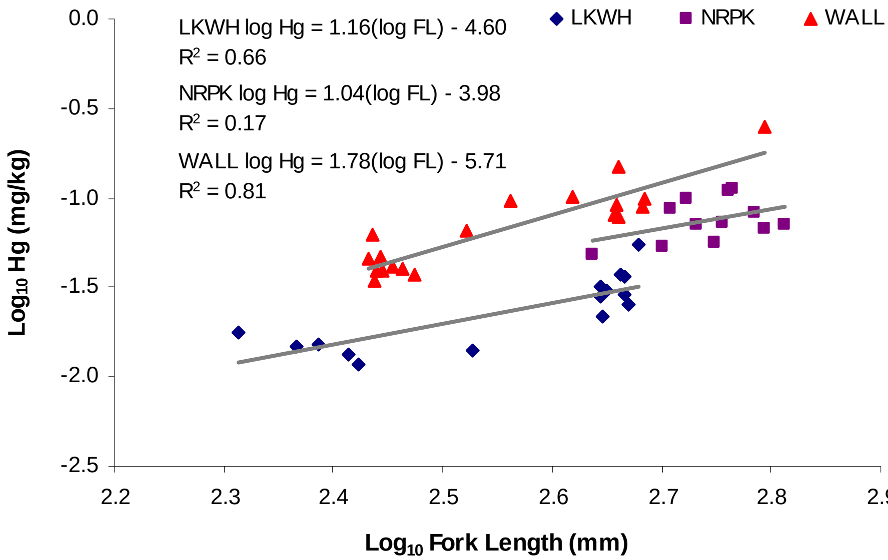
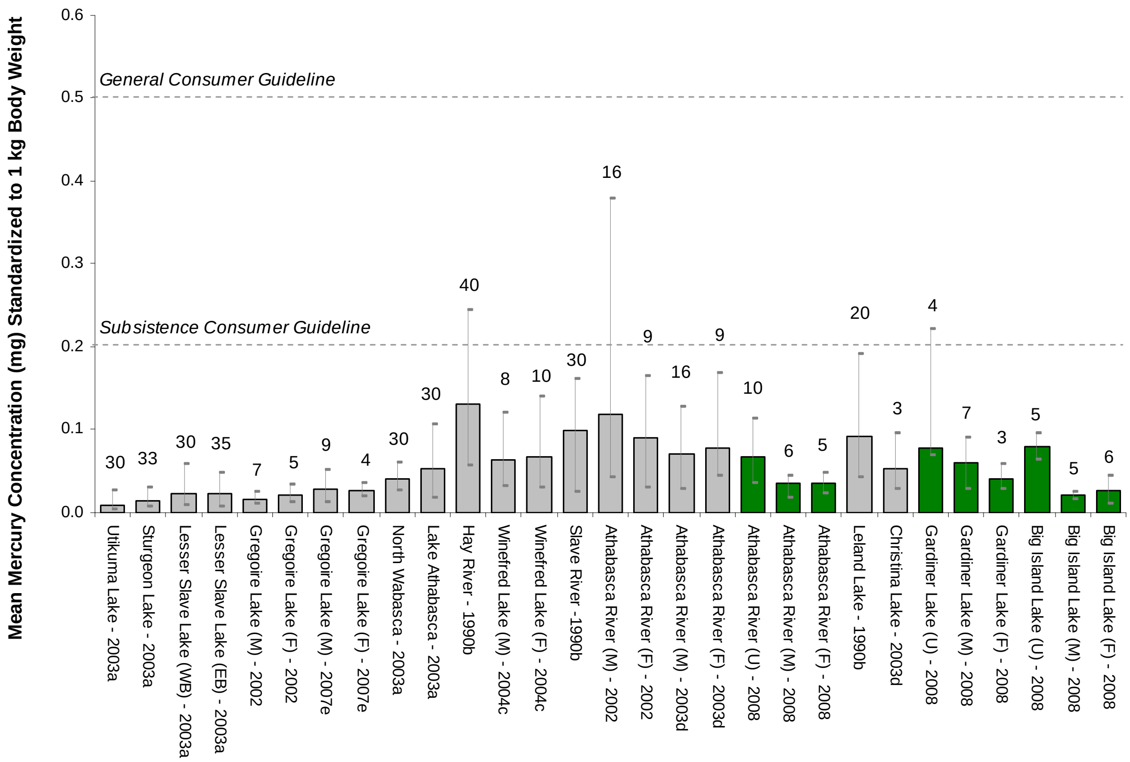
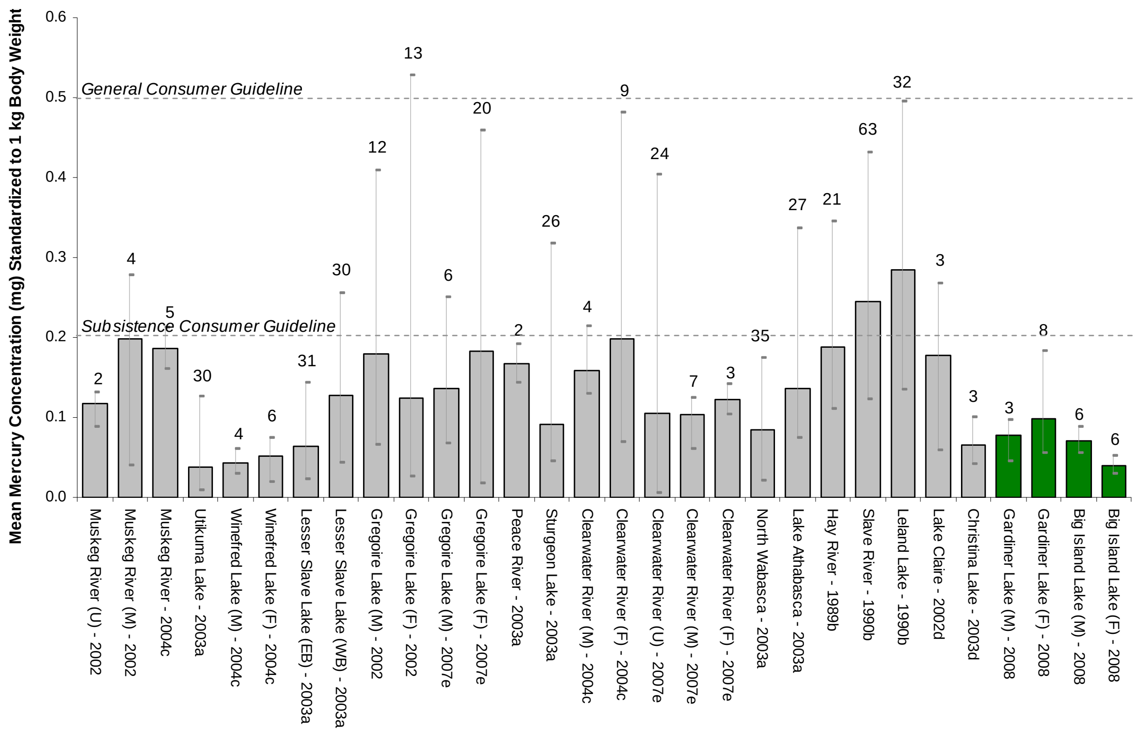


Figure 5.11-25 Mean mercury concentration in lake whitefish muscle tissue, standardized to 1 kg body weight, collected from regional waterbodies, 1989-2008.



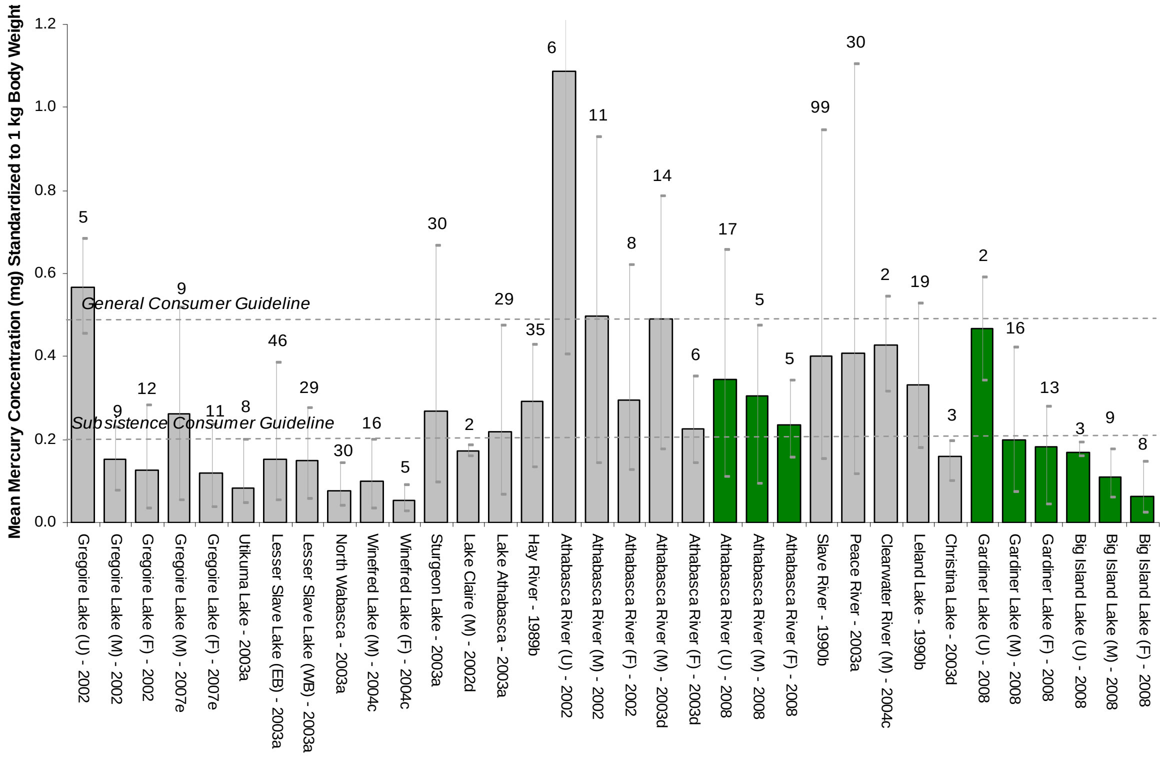
Note: Green bars indicate mercury concentrations from fish collected for the 2008 RAMP Fisheries Program. Years denoted with "a" - data from Golder (2004); Years denoted with "b" – data from Grey *et al*. (1995); Years denoted with "c" – data from RAMP (2004); Years denoted with "d" – data from RAMP (2003); Years denoted with "e" – data from RAMP (2008).

Figure 5.11-26 Mean mercury concentrations in northern pike muscle tissue, standardized to 1 kg body weight, collected from regional waterbodies, 1989-2008.



Note: Green bars indicate mercury concentrations from fish collected for the 2008 RAMP Fisheries Program. Years denoted with "a" - data from Golder (2004); Years denoted with "b" – data from Grey *et al*. (1995); Years denoted with "c" – data from RAMP (2004); Years denoted with "d" – data from RAMP (2003); Years denoted with "e" – data from RAMP (2008).

Figure 5.11-27 Mean mercury concentration in walleye muscle tissue, standardized to 1 kg body weight, collected from regional waterbodies, 1990-2008.



Note: Green bars indicate mercury concentrations from fish collected for the 2008 RAMP Fisheries Program. Years denoted with "a" - data from Golder (2004); Years denoted with "b" – data from Grey *et al*. (1995); Years denoted with "c" – data from RAMP (2004); Years denoted with "d" – data from RAMP (2003); Years denoted with "e" – data from RAMP (2008).

Table 5.11-37 Metrics and mercury concentrations in lake whitefish, northern pike and walleye collected from Gardiner Lake, September 2008.

Species	Fish ID	Sex	Age	Stage	Length	Weight	Hg (mg/kg)
Lake whitefish	GL-LKWH-01	M	-	M	430	1100	0.038
Lake whitefish	GL-LKWH-02	U	-	I	340	600	0.038
Lake whitefish	GL-LKWH-03	F	-	M	395	975	0.044
Lake whitefish	GL-LKWH-04	M	-	M	410	1050	0.055
Lake whitefish	GL-LKWH-05	M	-	M	465	1600	0.122
Lake whitefish	GL-LKWH-06	F	-	M	450	1725	0.055
Lake whitefish	GL-LKWH-07	U	-	I	333	525	0.055
Lake whitefish	GL-LKWH-08	F	-	M	480	1900	0.090
Lake whitefish	GL-LKWH-09	M	-	M	483	1625	0.112
Lake whitefish	GL-LKWH-10	U	-	I	333	525	0.036
Lake whitefish	GL-LKWH-11	M	-	M	480	1675	0.080
Lake whitefish	GL-LKWH-12	M	-	M	370	775	0.055
Lake whitefish	GL-LKWH-13	M	-	M	485	1600	0.097
Lake whitefish	GL-LKWH-14	U	-	I	348	550	0.042
Northern pike	GL-NRPK-01	F	4	M	613	1475	0.342
Northern pike	GL-NRPK-02	F	-	M	628	1685	0.206
Northern pike	GL-NRPK-03	F	-	M	671	2200	0.206
Northern pike	GL-NRPK-04	F	6	M	666	2175	0.151
Northern pike	GL-NRPK-05	F	4	M	524	1000	0.102
Northern pike	GL-NRPK-06	M	5	M	572	1500	0.221
Northern pike	GL-NRPK-07	F	6	M	660	2300	0.172
Northern pike	GL-NRPK-08	-	-	-	-	-	0.194
Northern pike	GL-NRPK-09	M	9	M	767	3550	0.240
Northern pike	GL-NRPK-10	F	5	M	652	2000	0.182
Northern pike	GL-NRPK-11	F	5	M	650	2150	0.112
Northern pike	GL-NRPK-12	M	12	M	659	2410	0.111
Walleye	GL-WALL-01	M	-	I	385	760	0.107
Walleye	GL-WALL-02	M	7	I	423	830	0.166
Walleye	GL-WALL-03	F	10	M	672	4240	0.528
Walleye	GL-WALL-04	M	-	I	329	400	0.105
Walleye	GL-WALL-05	F	-	M	674	3825	0.502
Walleye	GL-WALL-06	F	-	I	360	520	0.164
Walleye	GL-WALL-07	F	-	I	305	488	0.083
Walleye	GL-WALL-08	U	2	I	222	150	0.096
Walleye	GL-WALL-09	F	18	M	640	2089	0.511
Walleye	GL-WALL-10	F	17	M	606	2825	0.518
Walleye	GL-WALL-11	M	20	M	523	1920	0.534
Walleye	GL-WALL-12	F	2	I	228	125	0.094

Table 5.11-37 (Cont'd.)

Species	Fish ID	Sex	Age	Stage	Length	Weight	Hg (mg/kg)
Walleye	GL-WALL-13	M	-	M	560	1710	0.322
Walleye	GL-WALL-14	M	-	I	345	420	0.199
Walleye	GL-WALL-15	M	16	M	624	3075	0.416
Walleye	GL-WALL-16	F	19	M	670	3660	0.480
Walleye	GL-WALL-17	M	20	M	555	2300	0.398
Walleye	GL-WALL-18	F	-	M	625	3410	0.517
Walleye	GL-WALL-19	M	5	I	323	425	0.192
Walleye	GL-WALL-20	M	10	M	474	1400	0.190
Walleye	GL-WALL-21	M	-	M	502	1575	0.192
Walleye	GL-WALL-22	M	7	I	435	1150	0.124
Walleye	GL-WALL-23	F	3	I	247	225	0.125
Walleye	GL-WALL-24	M	19	M	542	2200	0.347
Walleye	GL-WALL-25	F	-	I	337	475	0.207
Walleye	GL-WALL-26	M	25	M	590	2475	0.599
Walleye	GL-WALL-27	U	2	I	206	175	0.055
Walleye	GL-WALL-28	M	19	M	521	1675	0.494
Walleye	GL-WALL-29	F	10	M	536	1725	0.505
Walleye	GL-WALL-30	M	-	I	227	450	0.115
Walleye	GL-WALL-31	F	7	I	435	980	0.223

Sex: F-Female; M-Male; U-Undetermined; M-Mature.

Stage: M-Mature; I-Immature.

exceeds National USEPA Criterion for subsistence fishers (0.049 mg/kg)

exceeds Health Canada Criterion for subsistence fishers (0.20 mg/kg)

exceeds National USEPA Criterion for recreational fishers (0.40 mg/kg)

exceeds Health Canada Criterion for general consumers (0.50 mg/kg)

Figure 5.11-28 Mercury concentration (+/- SE) by size class in lake whitefish, walleye and northern pike captured in Gardiner Lake, September 2008.

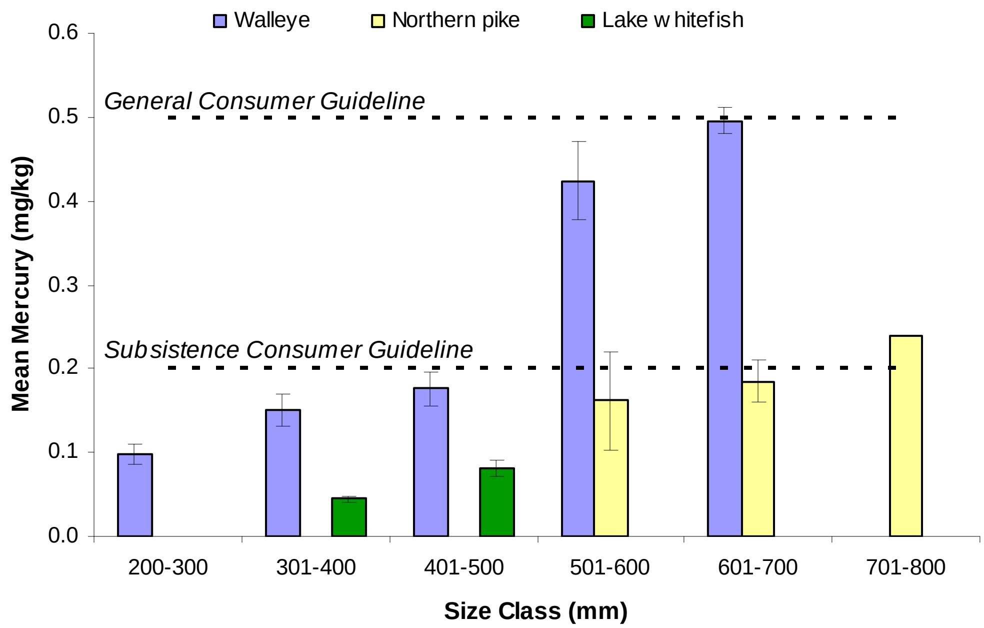


Figure 5.11-29 Mean mercury concentration by age in walleye and northern pike captured in Gardiner Lake, September 2008.

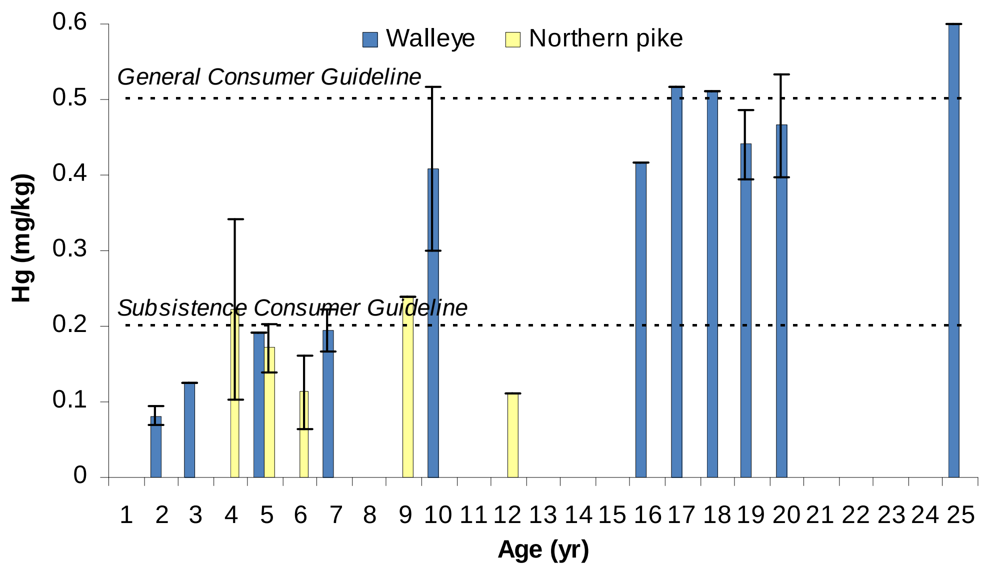


Table 5.11-38 Correlations between mercury concentration in lake whitefish, northern pike and walleye muscle from Gardiner Lake versus length and weight, September 2008.

Species	Sex	Sample Size	Metric	
			Fork length	Total weight
Lake whitefish	Male	7	**0.726**	0.635
	Female	3	**0.900**	0.330
	Combined	14	**0.777**	0.311
Northern pike	Male	3	0.198	0.200
	Female	8	0.152	-0.100
	Combined	11	0.163	0.030
Walleye	Male	16	**0.765**	**0.790**
	Female	13	**0.961**	**0.894**
	Combined	31	**0.883**	**0.855**

value = moderate correlation (0.5 < |r| < 0.75)

value = strong correlation (|r| > 0.75)

value = significant correlation (|r| > critical value)

critical values at α=0.1: n=3, |r|>0.900; n=7, |r|=0.714; n=13, |r|=0.484; n=14, |r|=0.464; n=16, |r|=0.429; n=8, |r|=0.643; and n=31, |r|<0.380

Figure 5.11-30 Regression analysis of mercury concentration in fish muscle versus length for lake whitefish, northern pike and walleye from Gardiner Lake, September 2008.