5.0 WATERSHED-LEVEL ASSESSMENT OF 2005 RESULTS

This is the main results section of the RAMP 2005 Technical report. Sections 5.1 to 5.8 of this chapter focus on watersheds which had areas designated as *potentially influenced-oil sands* in 2005, while Sections 5.9 to 5.13 focus on watersheds which are designated as completely *reference* or *potentially influenced-other* in 2005.

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

	Athabasca River	Athabasca River Delta	Muskeg	Steepbank	Tar	MacKay	Calumet	Misc. Potentially Influenced-Oil Sands Watersheds	Firebag	Ells	Christina-Clearwater	Hangingstone	Miscellaneous Reference Watersheds
Climate and Hydrology	5-4	5-74	5-96	5-130	5-154	5-176	5-192	5-210	5-236	5-250	5-278	5-302	5-316
Water Quality	5-5	5-74	5-97	5-131	5-155	5-176	5-192	5-210	5-236	5-250	5-278	5-302	5-316
Sediment Quality	5-8	5-74	5-98	5-132	5-155	5-177	5-193	5-213	5-236	5-251	5-279	5-302	5-316
Benthic Invertebrate Communities	5-9	5-76	5-99	5-133	5-156	5-177	5-194	5-213	5-237	5-251	5-279	5-303	5-317
Fish Populations	5-9	5-76	5-101	5-134	5-157	5-178	5-195	5-214	5-237	5-252	5-280	5-303	5-317

Definitions for Monitoring Status

- ***Potentially influenced-oil sands*** is used in this report to describe aquatic resources and physical locations (i.e., stations, reaches) that may be influenced by oil sands developments. This term does not presume that effects of oil sands developments have occurred, but simply that data collected from these locations are to be designated as ***operational*** for the purposes of data analysis;

- ***Reference*** is used in this report to describe aquatic resources and physical locations that are not yet influenced by oil sands developments and that data on aquatic resources collected from these locations are to be designated as ***baseline*** for the purposes of data analysis;

- ***Potentially influenced-other*** is the term used to describe aquatic resources and physical locations that remain uninfluenced by oil sands activities, but are potentially influenced by other activities such as logging, quarrying, etc. Data on aquatic resources collected from these locations are designated as ***baseline*** for the purposes of data analysis;

- ***Baseline*** is the term used to characterize data and information gathered from stations that are designated as reference; and

- ***Operational*** is the term used to characterize data and information gathered from stations that are designated as *potentially influenced-oil sands*.

5.1 ATHABASCA RIVER

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge		√			Flows in the Athabasca River were slightly above normal in 2005. Based on available hydrologic and oils sands development information, changes in hydrologic conditions in the Athabasca River watershed up to and including 2005 have been negligible to low.
Mean winter discharge		√			
Annual maximum daily discharge		√			
Minimum open-water season discharge		√			

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	2005 ***Potentially Influenced-Oil Sands*** Stations (n=8)	2005 ***Reference*** Stations (n=3)	
Physical variables (max=8 for exp, 3 for ref)	0	0	No discernible or detectable effects of oil sands development activities on water quality in the Athabasca River were apparent in 2005, based on available water quality and oil sands development information.
Nutrients (max=24 for exp, 9 for ref)	2	1	
Ions (max=16 for exp, 6 for ref)	0	0	
Selected metals (max=40 for exp, 15 for ref)	8	3	
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2005 ***Potentially Influenced-Oil Sands*** Stations (n=8 stations X 8 endpoints)	2005 ***Reference*** Stations (n=3 stations X 8 endpoints)	
Greater than 95th percentile	1	1	
Between 5th and 95th percentiles	0	0	
Less than 5th percentile	0	0	

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	2005 ***Potentially Influenced-Oil Sands*** Stations (n=1)	2005 ***Reference*** Stations (n=0)	
Total Hydrocarbons (max = 4 for exp, 0 for ref)	0	No *reference* or *potentially influenced-other* stations were sampled in 2005.	Concentrations of all sediment quality measurement endpoints at the only station sampled for sediment quality in 2005 were below applicable CCME/ISQG guidelines in fall 2005. Concentrations of selected sediment quality measurement endpoints measured in fall 2005 were between the 5th and 95th percentile of reference baseline ranges, with the exception of carbon-normalized total hydrocarbon concentrations, which were less than the 5th percentile.
PAHs (max=1 for exp, 0 for ref)	0		
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[3]		
Percentile of Regional Baseline Values	2005 ***Potentially Influenced-Oil Sands*** Stations (n=3 stations X 3 endpoints)	2005 ***Reference*** Stations (n=0 stations X 3 endpoints)	
Greater than 95th percentile	0	No *reference* or *potentially influenced-other* stations were sampled in 2005.	
Between 5th and 95th percentiles	0		
Less than 5th percentile	1		

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline					
	2005 ***Potentially Influenced-Oil Sands*** Stations (n= 0)			2005 ***Reference*** Stations (n= 0)		
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above
Abundance	Benthic invertebrate communities were not sampled in the Atahbasca River in 2005					
Richness						
Diversity						
Evenness						
% EPT						

Fish Populations

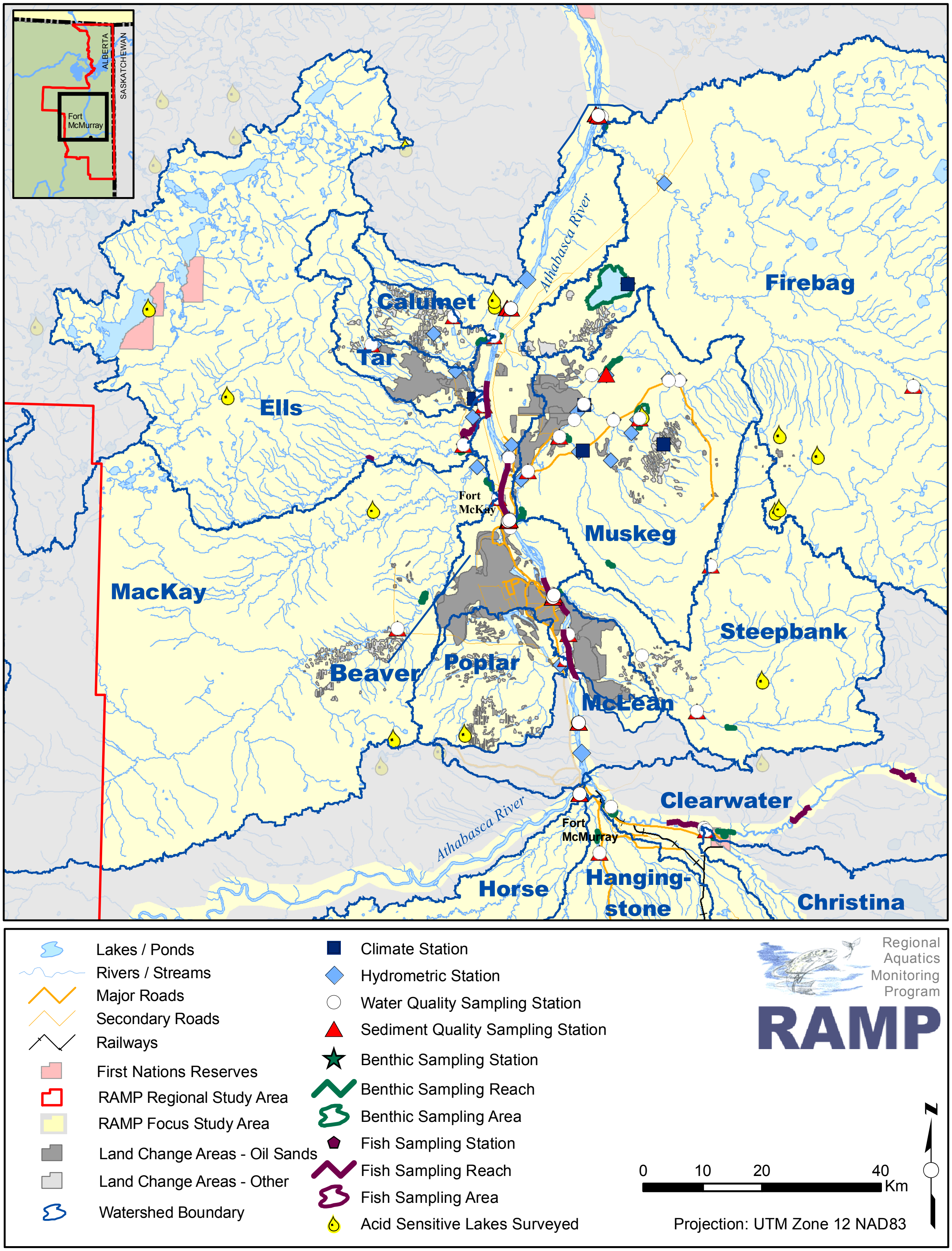
Fish Inventory	Little evidence that characteristics of key indicator fish populations have changed during increasing development in the oil sands region.	Based on the results to date for the Athabasca River, there is little evidence to suggest that characteristics of key indicator fish populations have changed during increasing oil sands development in the Athabasca oil sands area.
Sentinel Studies	No sentinel fish studies conducted in 2005.	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence	When considered in a regional context, mercury tissue concentrations in lake whitefish and walleye muscle from the Athabasca River are consistent with the natural range of concentrations observed in this region of northern Alberta.	
Human Health: Recreational Fishers		
Human Health: General Consumers		
Human Health: Tainting		

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.1-1 Athabasca River.



G:\DATA\PROJECTS\RAMP1166\GIS\RAMP1166_J_Mainstem_2006APR22.mxd

5.1.1 Development Status

For 2005, all the tributaries of the Athabasca River that are considered in this report and are upstream of the McLean Creek confluence are designated as *reference*, while many of the significant tributaries of the Athabasca River that are considered in this report and are downstream of the McLean Creek confluence (including McLean Creek) have areas designated as *potentially influenced-oil sands*. Therefore, for 2005, the confluence of McLean Creek with the Athabasca River is designated as the division between *reference* areas (upstream) and *potentially influenced-oil sands* (downstream). All data gathered from 2005 RAMP stations located on the Athabasca River downstream of the McLean Creek confluence are designated as operational, while all data gathered from 2005 RAMP stations located upstream of the McLean Creek confluence are designated as baseline.

5.1.2 Hydrologic Conditions

Flows in the Athabasca River measured at WSC station 07DA001 (Athabasca River below McMurray) were slightly above normal in 2005, with a total annual volume of 107% of the long-term average (Figure 5.1-2). Discharges in winter were very close to historical mean values, and during the open-water season fluctuated between slightly below and well above the long-term average. Following the spring runoff that resulted in above-normal flows in late April, several peaks in the hydrograph occurred at almost regular intervals. The maximum daily discharge of 2,420 m^3/s on July 3 was very close to the mean annual flood (the mean of the series of annual maximum daily discharges) of 2,490 m^3/s. The minimum daily discharge of 155 m^3/s was slightly greater than the historical average minimum value of 138 m^3/s.

As expected, discharges measured downstream of oil sands development at RAMP Station S24, Athabasca River below Eymundson Creek, were slightly higher than at WSC station 07DA001 below Fort McMurray because of the intervening catchment area (Figure 5.1-2).

Inputs to the water balance model for the Athabasca River used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints are provided in Table 5.1-1. Cumulative oil sands development in the Athabasca River watershed up to 2005 has resulted in the isolation of 208.0 km^2 of the watershed and clearing and/or drainage of an additional 75.2 km^2 (note: both figures pertain to areas within Poplar Creek, Beaver Creek, McLean Creek, and other minor Athabasca River tributaries from Fort McMurray to the mouth of the Firebag River). These land area changes were combined with:

- Total withdrawals for oils sands operations in 2005 estimated at 98.8 million $m^{3;}$
- Discharges by oil sands operations in 2005 estimated at 8.4 million m^3; and
- A calculated 800,000 m^3 incremental discharge into the Athabasca River in 2005 from Athabasca River tributaries designated as *potentially influenced-oil sands* (Tar, MacKay, Muskeg, and Steepbank Rivers) that would not have occurred without oil sands development activities on these watersheds.

The baseline hydrograph that would have occurred at RAMP Station S24 in the absence of oil sands development was estimated by removing these estimated influences of oil sands development from the operational hydrograph. All hydrologic measurement endpoints are calculated to be lower in the operational hydrograph than in the baseline hydrograph (Figure 5.1-2, Table 5.1-2), indicating these measurement endpoints are less than what the measurement endpoints would have been in the absence of oil sands development activities. This is largely because of water withdrawals and assumed decreased natural runoff from oil sands development areas. The percent change varies from -0.2% to -1.1% depending on the specific measurement endpoint and are similar to 2004 estimates (RAMP 2005a). The impact on low flows is greater in percentage terms than on high flows, because the more or less constant withdrawals are proportionately larger during low-flow than during high-flow periods. The reported changes in hydrologic measurement endpoints for 2005 would have been assessed as Negligible or Low in many oil sands EIAs (RAMP 2005b). Therefore, based on the available hydrologic and oils sands development information, it appears that changes in hydrologic measurement endpoints in the Athabasca River watershed up to and including 2005 have been negligible to low.

5.1.3 Water Quality

5.1.3.1 2005 Assessment

In 2005, water quality samples were collected under RAMP from the following locations in the Athabasca River:

- Upstream of Donald Creek (stations ATR-DC-CC, ATR-DC-W, ATR-DC-E, *reference*, baseline data available most years from 1997 to 2005);
- Upstream of the Steepbank River (stations ATR-SR-W, ATR-SR-E, *potentially influenced-oil sands*, operational data available from 2000 to 2005);
- Upstream of the Muskeg River (stations ATR-MR-W, ATR-MR-E, *potentially influenced-oil sands*, operational data available most years from 1998 to 2005);
- Downstream of all development (stations ATR-DD-CC, ATR-DD-W, ATR-DD-E, *potentially influenced-oil sands*, operational data available from 2002 to 2005); and
- Upstream of the Firebag River (station ATR-FR, *potentially influenced-oil sands*, operational data available from 2002 to 2005).

In addition, AENV conducted monthly water quality sampling upstream of Fort McMurray (station ATR-UFM, *reference*, baseline data available from 1997 to 2005).

Results of 2005 sampling for water quality measurement endpoints are presented in Table 5.1-3. Results for selected measurement endpoints (1997 to 2005) relative to regional baseline conditions at stations in the Athabasca River are shown in Figure 5.1-3 to Figure 5.1-6, and Table 5.1-4 contains all the water quality guideline exceedances observed in 2005 at stations ATR-DD-CC, ATR-DD-W, ATR-DD-E, the only stations in the Athabasca River which were sampled in all seasons in 2005.

Water quality in the Athabasca River in fall 2004 was influenced strongly by higher-than-average flows and associated increased sediment loads (RAMP 2005a). Flows in fall 2005 were more similar to historical average conditions, with the exception of a high flow event in late September (Figure 5.1-2), and water quality in the Athabasca River in fall 2005 reflected the more normal flow regime. Total suspended solids were lower in fall 2005 than in fall 2004 at all stations sampled. Concentrations of water quality analytes typically associated with TSS, including total aluminum, total iron, and total phosphorus, were also generally lower in 2005 than in 2004; an exception occurred at station ATR-DC-E, where higher concentrations of total iron and total phosphorus were observed in 2005. Previous studies have shown that water quality along the east bank at this station may be highly influenced by flows from the Clearwater River (RAMP 2004).

Overall, there were only 14 (12%) out of 121 possible exceedances in water quality guidelines at all the Athabasca River stations in fall 2005 (i.e., eleven of the selected water quality measurement endpoints have guidelines and water quality was sampled at a total of eleven locations on the Athabasca River in fall 2005, making for a total of 121 possible guideline exceedances, Table 5.1-3). Of these guideline exceedances, 11 were total aluminum, which exceeded its CCME/AENV guideline at every RAMP location sampled in fall 2005 despite its concentrations being generally lower in 2005 than in 2004. The remaining three guideline exceedances in fall 2005 were for total phosphorus, at stations ATR-DC-E, ATR-SR-E, and ATR-FR.

Fall 2005 results for most selected water quality measurement endpoints were within the range of regional baseline concentrations (Figure 5.1-3 to Figure 5.1-6), with the exceptions of dissolved phosphorus at station ATR-DC-E and naphthenic acids at station ATR-FR, both of which were higher than the 95th percentile of regional baseline values.

CCME/AENV guidelines for the protection of aquatic life for several water quality analytes were exceeded in all seasons at stations ATR-DD-CC, ATR-DD-W, and ATR-DD-E (Table 5.1-4). The highest number of guideline exceedances occurred in spring, when aluminum, chromium, cobalt, copper, iron, lead, and titanium exceeded guidelines (cobalt and titanium concentrations were screened against British Columbia Working Water Quality Guidelines). Higher concentrations of these metals in spring were likely associated with increased suspended sediment levels during the spring freshet.

Ion balance characteristics varied within a narrow range for all stations regardless of sampling year or longitudinal location along the river (Figure 5.1-7), with the exception of station ATR-DC-E in 2000, 2003, and 2005, and downstream of Fort Creek (east bank, station ATR-FC-E-D, *potentially influenced-oil sands*) in 1998. This range appears to be defined primarily by variation in concentrations of dissolved calcium, and to a lesser extent by chloride. Multivariate comparisons of water quality at ATR-DC-E in 2003 demonstrated that water at this station in that year was nearly identical in characteristics to lower Clearwater River water (RAMP 2004), and exhibited much higher chloride and lower dissolved calcium concentrations than the Athabasca River upstream of Fort McMurray (Table 5.1-3 and Table 5.11-3). The ion balance at ATR-DC-E observed in 2000 and 2005 similarly may be a result of the influence of the Clearwater River.

In summary, no discernible or detectable effects of oil sands development activities on water quality in the Athabasca River were apparent in 2005, based on available water quality and oil sands development information.

5.1.3.2 Long-Term Trends

Long-term trends in Athabasca River water quality were examined through statistical trend analysis of the AENV long-term Athabasca River monitoring dataset. Trends were assessed for the water quality measurement endpoints at the following Athabasca River locations: at the town of Athabasca (station ATR-ATH, *reference*), upstream of Fort

McMurray (station ATR-UFM, *reference*), and downstream at Old Fort, at the head of the Athabasca River Delta (ARD, station ATR-OF, *potentially influenced-oil sands*). The trend analysis was restricted to the same time period as the RAMP water quality data record (1997 to 2005) in order to assess potential trends in water quality related to oil sands development during this period. Restricting the trend analysis to this period also allowed a comparison of trends at different Athabasca River locations over a consistent period of time.

Results of trend analysis for selected water quality measurement endpoints are presented in Table 5.1-5 and Figure 5.1-8 to Figure 5.1-14, which show values of the measurement endpoints over time at each station as well as the relative concentrations of the measurement endpoints at the three stations listed above.

Fewer trends were found for the period 1997 to 2005 (Table 5.1-5) relative to previous assessments of trends over the period 1976 to 2004 (station ATR-UFM) and 1987 to 2004 (station ATR-OF) (RAMP 2005a).

- Upward trends in pH were found at all three Athabasca River stations (Figure 5.1-8), indicating that processes unrelated to oil sands development have been involved in contributing to this trend;
- A downward trend was found for specific conductance at station ATR-UFM (Figure 5.1-8);
- An upward trend in total Kjeldahl nitrogen concentration was found at station ATR-UFM, but not at station ATR-ATH or station ATR-OF (Figure 5.1-10);
- Downward trends were found for three ions: chloride concentrations decreased over time at station ATR-UFM, while calcium and magnesium concentrations decreased over time at station ATR-OF (Figure 5.1-11). Sodium and chloride concentrations at station ATR-OF were generally higher than at station ATR-ATH and station ATR-UFM, while concentrations of calcium, magnesium, and sulphate were generally lower at station ATR-OF than at the upstream stations;
- A downward trend was found in total molybdenum concentration at station ATR-ATH (Figure 5.1-14). While insufficient data were available to conduct seasonal Kendall tests for trend in the concentration of several metals, a downward trend in total molybdenum concentrations was also found at station ATR-OF using the Mann-Kendall test for trend; and
- A downward trend was found in total mercury (ultra-trace) at stations ATR-ATH and ATR-OF (Figure 5.1-14), but the length of the data record on which these trends were found is relatively short.

Differences in trends among stations located upstream of Fort McMurray and at Old Fort may be related to contributing influences of Athabasca River tributaries on water quality in the Athabasca River itself. Trend analysis of available water quality data indicate that oil sands development has not led to changes in concentrations of water quality measurement endpoints in the Athabasca River in the 1997-2005 period.

5.1.4 Sediment Quality

Measured sediment quality in the Athabasca River has been highly variable under RAMP since 1997, both among stations in a given year and at specific stations across years. Sediment sampling in the Athabasca River has been confounded by variable river levels, which can result in sediment sampling in different locations from year to year, as the locations of the wetted banks of the river change within the river channel under different flow conditions. In addition, the Athabasca River is not a truly depositional environment, making temporal studies of accumulated sediment quality inappropriate. For these reasons, sediment quality in the Athabasca River in 2005 was conducted only at Athabasca River upstream of the Embarras River at the head of the ARD (station ATR-ER, *potentially influenced-oil sands*, operational data from 2000 to 2005). Sediment quality sampling was also conducted in 2005 in the ARD, a depositional environment more likely than the Athabasca River itself to exhibit possible changes in sediment quality due to upstream processes. Results of sediment quality sampling in the ARD in 2005 are presented in Section 5.2.

Fall 2005 results for sediment quality measurement endpoints at station ATR-ER are shown in Table 5.1-6. Concentrations of selected water quality measurement endpoints observed at station ATR-ER over the period of RAMP sampling are shown relative to regional baseline levels in Figure 5.1-15, while Figure 5.1-16 and Figure 5.1-17 contain graphical temporal trends in selected sediment quality measurement endpoints.

Sediments at station ATR-ER in 2005 were dominated by sand, but included significant levels of fine sediment (44%) (Table 5.1-6). Hydrocarbon concentrations were similar to levels observed in 2004 (the first year of sampling for CCME four-fraction hydrocarbons), and were dominated by C16-C34 hydrocarbons. Overall, concentrations of all sediment quality measurement endpoints at station ATR-ER were below applicable CCME/ISQG guidelines in fall 2005.

Concentrations of selected sediment quality measurement endpoints measured in fall 2005 were between the 5th and 95th percentile of reference baseline ranges, with the exception of carbon-normalized total hydrocarbon concentrations, which were less than the 5th percentile (Figure 5.1-15).

PAHs at station ATR-ER appear to originate from both petrogenic and pyrogenic sources (M. MacKinnon, Syncrude Canada Ltd., *pers. comm.*, 2006), and are dominated by low-molecular-weight PAHs and alklyated PAHs (Figure 5.1-17). While concentrations of total PAHs increased between 2000 and 2003, total PAH levels in both 2004 and 2005 were lower than in 2003 (Figure 5.1-16). Concentrations of total PAHs normalized to TOC were relatively low compared to regional baseline median concentrations between 2000 and 2005 (Figure 5.1-15), but showed consistent increases over this period (Figure 5.1-15, Figure 5.1-16). However, the magnitude of the change over time relative to potential analytical error, and the absence of similar, increasing trends at stations in the ARD (Section 5.2) indicate that this pattern cannot be definitively linked to any human activity over the period of sampling. In addition, annual differences in sediment characteristics at station ATR-ER may be attributable to sampling of eroded bank material at this station, which has relatively steep, sandy banks. The complexity of the PAH assemblage, including its characteristics and source, and temporal patterns in PAH concentrations (Figure 5.1-17) may be related to physical processes such as river flow rates, bank erosion, and deposition (M. Evans, Environment Canada, *pers. comm.*, 2006).

5.1.5 Benthic Invertebrate Communities

Benthic invertebrate communities have not been sampled in the Athabasca River since 1998. The shifting sands of the river present a naturally harsh environment for benthic macroinvertebrates. The benthic animals that can tolerate the naturally harsh shifting-sand environment of the Athabasca River include tolerant chironomids and ceratopogonids. It is expected that water and sediment quality would have to be severely degraded before their effects would be detectable in benthic invertebrates. Athabasca River tributaries, on the other hand, have more diverse benthic assemblages, and would likely demonstrate effects long before the mainstem river.

5.1.6 Fish Populations

Fish population monitoring in 2005 within the Athabasca River included:

- Fish inventory (spring and fall);
- Fish tissue analyses of key fish indicator species; and
- Tag return assessment.

5.1.6.1 Fish Inventory

At the February 2005 RAMP Fish Group meeting, it was agreed that only inventory fish capture data would be used in the calculation of catch-per-unit-effort (CPUE) and catch composition, while both captured and observed data would be combined for species richness. In order to standardize CPUE and catch composition it was decided that fish inventory data will be used from only 9 of the 12 Athabasca River reaches that have been sampled consistently over the life of the RAMP Fish Population component (Figure 3.5-1). Furthermore, lake whitefish were excluded from the calculation of fall 2005 percent catch composition because of field collection limitations associated with this species and the large variability of the timing of the fall lake whitefish spawning migration.

Species Composition and Catch-Per-Unit-Effort

A total of 1,903 fish were captured during the spring and fall fish inventory on the Athabasca River, of which 922 fish comprised of 16 species were captured in the spring sampling (Table 5.1-7) and 981 fish comprised of 16 species, plus one observed species (burbot), were recorded in the fall sampling (Table 5.1-8). The combined seasonal captured and observed data totaled a species richness of 19, including a single bull trout captured in the spring (the bull trout is considered rare in this part of the province; this species has never been caught during the RAMP Athabasca River fish inventory program and there have only been two other reported catches of bull trout in this part of the oil sands region since 1977). This total is in the mid-range of previous inventories (highest: 22 species in 1997; lowest: 13 species in 1999, [Golder 2003b]).

Walleye, followed by goldeye, were the most abundant large-bodied species captured in spring (Table 5.1-7), while goldeye, followed by walleye, were the most abundant large-bodied species captured in fall (Table 5.1-8). With the exception of walleye, the percent composition of most large-bodied species in spring 2005 were similar to 2004 (i.e., <5% difference)(Figure 5.1-18). However, the catch of walleye increased by almost 15% relative to 2004, and approached the peak dominance of 51.3% recorded in 2002. The percentage of goldeye also increased slightly in 2005 and the proportion of longnose sucker captured in 2005 was the lowest recorded since 2003. The proportion of northern pike declined slightly over the last two years relative to 2003.

The total standardized CPUE for fish captured during the 2005 spring inventory was the highest recorded to date under the RAMP.(Figure 5.1-19). Walleye CPUE in 2005 was more than double that of 2004, and represented the highest standardized CPUE of any year included in the analysis. Similarly, the CPUE for northern pike in 2005 was also higher than previously recorded (Figure 5.1-20). Relative abundance of goldeye and white sucker in 2005, while not at historically high levels, were nevertheless higher than the previous three to four years (Figure 5.1-20).

Length-Frequency Analysis

Length-frequency histograms (1997-2005) for Key Indicator Resource (KIR) species are presented in Figure 5.1-21 to Figure 5.1-25. Key features with respect to each KIR are as follows:

- The dominant length class of walleye captured in the 2005 inventory was 401-450 mm (Figure 5.1-21). This class was also dominant in 1998 and 2004. In all other years, the 351-400 mm length class dominated the population size distribution. Visually, there is little change in the length-frequency distribution for walleye in the Athabasca River in 2005 relative to historical inventory results, or in length-frequency distributions throughout the historical record;

- The dominant length class of goldeye captured in the 2005 inventory was 376-400 mm (Figure 5.1-21). The data record is characterized by few individuals in the smaller size classes with the exception of 1998;

- No single clear dominant size class mode was present for longnose sucker in the 2005 inventory, although more individuals were in the 351-400 mm length class than in any other class (Figure 5.1-23). Variability in the longnose sucker length-frequency distribution is very high in the data record;

- The dominant length class of northern pike captured in the 2005 inventory was 501-550 mm (Figure 5.1-24). Variability in the northern pike length-frequency distribution is also very high in the data record; in most other years, the dominant captured length-class was between 400 and 600 mm, with some shifting of the dominant length class among years. Smaller individuals (<150 mm) were present only in the 2003 inventory, indicating a general absence of young fish during the other years. This was even more obvious in 1999, when no fish under 350 mm were captured; and

- The dominant length class of trout-perch captured in the 2005 inventory was 66-70 mm, surrounded by sub-dominant length classes of 61-65 and 71-75 mm (Figure 5.1-25). These results were similar to 2004, but considerably different from those in 1999 and 2003 when the dominant length class was considerably smaller (low sample sizes in 1998 to 2002 (<20 fish per year) limited the comparison to results to 1997 and 2003 to 2005.

Recruitment to the Sport Fishery

The ratio of under-size to legal-size captured walleye (an index of recruitment to the sport fishery) in 2005 was 1.1. This ratio has fluctuated in the data record from 0.8 to 1.8, and has shown little large-scale change over time (Figure 5.1-21). Northern pike ratios have been consistently higher and wider ranging (2.4 to 6.3), and have shown a slight increasing trend over the length of the data record (Figure 5.1-27). These ratios suggest that there has been no degradation of recruitment to the sport fishery for walleye, but that recruitment by northern pike to the sport fishery may in fact have decreased over time.

Condition Factor

Values of mean condition factor (body weight vs. fork length) from 1997 to 2005 are presented in Table 5.1-9 and Figure 5.1-28.

No significant differences in condition factor were present among years for walleye in spring ($p = 0.98$) or northern pike ($p = 0.99$). Mean walleye condition factor has remained consistent over time, ranging from 0.94 (2003) to 1.02 (2004) (Figure 5.1-28). Northern pike condition factor has ranged from 0.65 in 1997 to 0.79 in 2005, and has generally increased over the period of the data record (Figure 5.1-28).

In fall 2005, the mean condition factor of lake whitefish was 1.60 (Table 5.1-9). Although Figure 5.1-28 suggests that condition factor of lake whitefish has increased over the period of the data record, no significant differences were found among years ($p = 0.99$).

Significant differences were observed in condition factor of longnose sucker among years ($p < 0.001$). The condition of sucker was 8.5% lower in 1998 relative to 1997, while condition was 7.6% higher in 2004 relative to 2003. Overall, there has been a slight increase in the condition of longnose sucker over time (Figure 5.1-28).

External Abnormality Assessment

In 2005, 7.3% (75 of 1027) of fish examined during the Athabasca River fish inventory had some type of external abnormality. Abnormalities observed were primarily associated with minor skin or body surface aberrations and fin erosion. The 2005 health assessment index scores for KIR species (Table 5.1-10) were within the range of values documented in previous years.

Summary Assessment

As outlined in RAMP (2005b), the Athabasca River fish inventory is generally 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 detailed fish community structure. Standardized current and historical fish inventory data from the Athabasca River indicate some level of species-specific variability in relative abundance, length-frequency distribution, and condition factor. However, statistical analysis of the inventory data collected to date has demonstrated limited significant differences among years with no clear trends.

Based on the results to date for the Athabasca River inventory, there is little evidence to suggest that characteristics of key indicator fish populations have changed during increasing oil sands development in the Athabasca oil sands area.

Overall, additional inventory data obtained using a standardized approach is required to permit appropriate trend analysis, and determination of the natural variability associated with designated measurement endpoints. Once the range of natural variability has been estimated, appropriate criteria can be developed for determining the presence of a significant change. Ongoing assessment/evaluation of the data gathering and analysis procedures used in the Athabasca River fish inventory should result in substantial enhancements to the component, particularly with respect to its monitoring function.

5.1.6.2 Fish Tissue Analysis

Fish tissue samples were analyzed individually for mercury, while metals and tainting compounds were measured in separate size-specific composite samples prepared for each sex of the target species (walleye, lake whitefish).

Whole-Organism Metrics

In 2005, a total of 29 walleye (9 females, 16 males and 4 unsexed) and 26 lake whitefish (11 females and 15 males) from the Athabasca River (Muskeg and Steepbank areas) were collected for fish tissue analysis in conjunction with the fall inventory. Walleye ranged from a 212 mm immature fish to a 635 mm adult female, while lake whitefish ranged from 354 mm to 538 mm (Table 5.1-11).

The mean length of male and female lake whitefish was very close (436 mm and 445 mm, respectively), while mean female weight was approximately 15% greater relative to the male average. In contrast, sampled female walleye were on average longer (+38.6%) and heavier (+63%) than sampled males. As expected for pre-spawning lake whitefish, relative gonad size (i.e., GSI) of females was approximately 10-fold higher than for males. Relative liver size (LSI) was moderately smaller for male compared to female whitefish. In walleye, GSI and LSI for females was approximately 2–fold greater than for males.

Results from the external and internal fish health assessment for lake whitefish and walleye are summarized in Table 5.1-12. In order to provide an overview of fish health, the percent of fish affected by abnormalities was calculated. This calculation included all observations with the exception of those related to food availability and storage, such as levels of mesenteric fat, gall bladder colour and fatty livers (Table 5.1-12). Overall, occurrence of abnormalities was approximately 81.5% when observations for lake whitefish (male and female) and walleye (male, female and immature) were combined. The most prevalent condition in both species was the presence of few to moderate internal parasites. However, these data should be interpreted with some caution due to the relatively small sample sizes and lack of regional reference data characterizing the natural variability in the frequency of abnormalities.

Mercury

Total mercury concentrations in muscle of individual walleye and lake whitefish collected from the Athabasca River in 2005 are presented in Table 5.1-11. Concentrations in walleye ranged from a high of 0.765 mg/kg in a 470 mm male, to a low of 0.070 mg/kg in a 212 mm immature fish. Mean mercury concentration was higher in adult female walleye (0.516 mg/kg) relative adult males (0.352 mg/kg); however, concentrations did not differ significantly by sex in 2005 ($p>0.05$). The lowest mean mercury concentration was present in immature walleye (0.118 mg/kg).

In comparison, the range of mercury concentrations in lake whitefish was smaller, with a maximum of 0.170 mg/kg measured in a 474 mm male, and a minimum concentration of 0.034 mg/kg in a 371 mm male. Mean mercury concentration was greater in adult female lake whitefish (0.106 mg/kg) relative adult male fish (0.081 mg/kg). Again, these concentrations did not differ significantly by sex in 2005 ($p>0.05$).

Similarly, mercury concentrations in the 2005 composite samples were 0.738 mg/kg (female) and 0.574 mg/kg (male) for walleye, and 0.099 mg/kg (female) and 0.079 mg/kg (male) for lake whitefish (Table 5.1-14).

Scatterplots of fork length, and total weight against mercury concentrations in muscle of individual fish are presented in Figure 5.1-29 and Figure 5.1-30. In 2005, these graphical representations indicated a positive relationship between fish size (length and weight) and mercury concentration for both lake whitefish and to a greater extend walleye. In previous years, scatterplot analysis has also included GSI and LSI; however, the relationships between mercury concentrations and these variables have been weak.

Rank correlations were used to further evaluate the relationship between mercury concentrations in fish muscle and whole-organism parameters (fork length, total weight, GSI and LSI) for combined and individual sexes when sample sizes were sufficient for both walleye and lake whitefish (Table 5.1-13). Overall, mercury concentrations were most positively correlated with walleye size (length, r_s=0.57; weight, r_s= 0.58). On the basis of sex, there was a stronger correlation between male walleye size (r_s>0.7) and mercury concentration, as well as in immature fish (r_s =1.0), while the relationship for females was not significant (r_s<0.3). Combined lake whitefish size did not correlate with mercury concentration with r_s>0.5. However, when analyzed by sex, male mercury concentration positively correlated with fork length (r_s=0.51). Correlations of mercury concentration with LSI and GSI were not statistically significant, for combined and individual sexes of walleye and lake whitefish.

Linear regression analysis was used to further evaluate the relationships between mercury concentration and fork length in walleye (male and immature) and lake whitefish (male only). In adult male walleye, length accounted for 47.2% of the variability in mercury concentrations (regression p=0.003). More variability in mercury was accounted for in immature walleye (84.1%), however the regression was significant only at p<0.10 (p=0.071). This may have been the result of a limited sample size for immature walleye (n=3 after outlier removal). Similar to immature walleye, the length-mercury concentration regression for male lake whitefish was significant at p<0.10 (p=0.089) and accounted for approximately 21% of the variability in mercury concentrations (Figure 5.1-31).

Other Chemicals

Concentrations of other chemicals in sex-specific composite muscle samples of walleye and lake whitefish from the Athabasca River are presented in Table 5.1-14. Concentrations of 9 of 28 metals (including arsenic) analyzed, plus 6 tainting compounds, were below analytical detection limits in both walleye and lake whitefish composites. The analsyses for arsenic had a detection limit higher than USEPA criteria; therefore, the presence/absence of exceedance for this metal in Athabasca River fish tissue samples could not be determined. Concentrations of other metals, including barium, copper, iron, manganese, selenium, titanium and zinc varied slightly between sex and species.

Discussion

Screening of Potential Effects on Human Health

Mercury

Tissue mercury concentrations from Athabasca River walleye and lake whitefish, were screened against USEPA and Health Canada human health criteria for fish consumption (Table 5.1-15). Mercury concentrations in lake whitefish do not appear to pose a potential risk to subsistence fishers (i.e., < 0.20 mg/kg) or general consumers (i.e., < 0.5 mg/kg). However, total mercury concentrations in larger walleye (~>400 mm or ~>0.5 kg) exceeded the Health Canada criteria for subsistence fishers (0.20 mg/kg), USEPA criteria for subsistence fishers (0.049 mg/kg), and USEPA Region III risk-based criteria (0.14 mg/kg) (Figure 5.1-30). Some walleye over 450 mm or ~>1 kg exceeded the Health Canada general consumer criteria of 0.5 mg/kg (Figure 5.1-29 and Figure 5.1-30).

Figure 5.1-32 provides a comparison of mercury concentrations in walleye and lake whitefish from the Athabasca River, monitored over 3 years as part of RAMP (2002, 2003 and 2005). Mean lake whitefish mercury concentrations in both male and female fish have remained consistent and below the Health Canada criteria for subsistence consumers. Composite mercury concentrations have remained relatively consistent over time, with no dramatic increases or decreases for walleye and lake whitefish. Mean mercury concentration in walleye has fluctuated more than lake whitefish, and consistently exceeded the Health Canada subsistence consumer criteria with the exception of smaller immature individuals in 2005. No consistent trend or relationship with time is evident for the increase or decline of mercury concentration in Athabasca River fish tissue.

When considered in a regional context, mercury tissue concentrations in lake whitefish and walleye muscle from the Athabasca River are consistent with the natural range of concentrations observed in this region of northern Alberta (RAMP 2003, 2004 and Grey *et al.* 1995).

Other Chemicals

In Table 5.1-14, metals and tainting compounds in walleye and lake whitefish from the Athabasca River are screened against several criteria to assess potential risks to human health. With the exception of mercury, the only other potential exceedance recorded in 2005 was arsenic. The arsenic concentrations for the 2005 walleye and lake whitefish composite samples (both male and female) were below the detection limit of the analyses; therefore, it is uncertain whether concentrations of these metals exceeded the USEPA screening criteria.

Overall, these results indicate that metals (other than mercury) and tainting compounds do not pose a risk to human health at current concentrations; however, arsenic concentrations represent an unknown potential health. Concentrations of metals and tainting compounds in fish from the Athabasca River have remained fairly consistent over time and are similar to those found in fish from the Muskeg River and other surrounding populations.

Screening of Potential Effects on Fish and Fish Health

Mercury

Mercury concentrations in individual lake whitefish and walleye samples were compared to criteria and thresholds for effects in fish (Table 5.1-16). Mercury concentrations did not exceed any of the effects (or no effects) thresholds for fish.

Other Chemicals

Concentrations of other contaminants in lake whitefish and walleye composite tissue samples from the Athabasca River were screened against the lowest thresholds for effects (and absence of effects) in fish (Table 5.1-17). Three metals, aluminum, silver, and vanadium exceeded the no effects thresholds for fish. Aluminum and silver were below analytical detection limits in most cases; however, the detection limits were above the lowest no-effects threshold. Because these metals were below, or only slightly above the lowest reported effects level, these results suggest that there is low potential for risk at these concentrations. Future tissue analyses should utilize lower detection limits to better assess potential risks to fish.

Effects on Palatability of Fish

The presence of elevated concentrations of tainting compounds can result in decreased palatability of fish due to the presence of an undesirable odor or flavor. All tainting compounds in Athabasca River fish tissue were present at concentrations well below 1 mg/kg (<0.01 mg/kg) indicating that fish palatability is not likely to be an issue.

Impact Analysis

Measurement endpoints used in the impact assessment for 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. Potential effects on human health were predicted from the individual and composite fish tissue analyses. None of the 2005 mercury concentrations for lake whitefish exceeded Health Canada or USEPA criteria for potential human health risks. In contrast, results for walleye analyzed from the Athabasca River indicate that, due to elevated concentrations of mercury, there is a potential risk from human consumption. The potential human health risks from consuming Athabasca River walleye pertain to all fishers, including subsistence, recreational and sensitive subpopulations (i.e., children, pregnant women) based on the 2005 results and those previously documented by RAMP. The ASRD Consumption Advisory for walleye from the Athabasca River applies to women of childbearing age and children under the age of 15. Analyses of the relationship between individual mercury concentration and walleye length indicate that larger individuals exceed human health criteria.

Other metals and tainting compounds do not appear to pose any human health risks; however, to effectively screen for human health risks, lower detection limits are needed for some analyses, particularly for arsenic, and should be employed in future sampling programs if possible.

Although mercury concentrations in Athabasca River walleye tissues exceeded Health Canada and USEPA guidelines, comparison with historical data from the Athabasca and Muskeg rivers, as well as other fish populations illustrates that these concentrations fall within the natural range of concentrations observed in this region of Alberta. Water and sediment concentrations of mercury presented in this document further support the assertion that mercury is naturally present in the oil sands region and that observed concentrations are unrelated to oil sands development.

Effects on fish palatability were not assessed with the 2005 data, given that concentrations of all measured tainting compounds were below detection limits and well below screening values.

Non-Lethal Biopsy Pilot

The development and application of non-lethal fish tissue sampling techniques was started during the 2004 Clearwater fish program and extended to the Athabasca River in 2005. This pilot assessment involves a comparison of mercury concentrations in samples acquired using a conventional lethal approach against those collected using a non-lethal dermal punch technique. As outlined in the methods section of this document, the biopsy needle used for tissue sample acquisition in 2004 was replaced by a dermal punch in 2005. Due to the small sample sizes acquired using the punch, special mercury testing procedures were needed. These procedures are not available at ETL, but are available at Flett Research Inc. in Winnipeg, MB. Therefore, fillet samples resulting from the lethal sampling approach were analyzed by both laboratories, while biopsy plug samples were tested only by Flett Research Inc. This allowed for an inter-laboratory comparison, in addition to the comparison of sampling techniques.

Reports from the field indicated that there were only minor problems encountered when using the dermal punch, and that adequate sample volumes were obtained from all fish included in the assessment. It was also noted that the dermal punch was easier to use in the field than the biopsy needle. Furthermore, the laboratory reported that sample weights provided from the field were adequate for testing. Therefore, it appears as though the mechanics of non-lethal tissue sample acquisition and testing can now be successfully completed. Mercury concentrations in fish fillets measured by ETL were lower than those from Flett Research (Figure 5.1-33). This is opposite to the pattern observed in the 2004 for the Clearwater River fish tissue program, in which ETL concentrations were higher than Flett concentrations with the exception of one fish.

A Wilcoxon paired-sample test (Zar 1984) determined that mercury concentrations measured in Athabasca River fish fillets were significantly different ($p<0.05$) between analytical laboratories, with an average difference of 0.035 mg/kg and a maximum difference of 0.107 mg/kg (Table 5.1-18). The same test determined no significant difference between mercury concentrations measured in samples collected using lethal and non-lethal methods (i.e., fillet versus dermal punch) as determined by Flett Research ($p>0.05$) (Table 5.1-18 and Figure 5.1-33).

Based on the 2005 field and analytical results on the Athabasca River, it is apparent that the non-lethal tissue sampling methods for mercury analysis using a dermal punch can be effectively incorporated into the RAMP fish tissue monitoring program. This is further supported by Baker *et al*. (2004) who conducted a field study for the application of non-lethal sampling methods involving northern pike and found no indications of effects on growth and survival based on recapture success. However, information on the potential effects of non-lethal sampling techniques on released fish is limited, and requires the collection of additional information. Results of further assessments may show that this technique is not suitable for all species due to different responses associated with capture/handling stress (e.g., lake whitefish).

Lethal sampling will remain necessary for the analysis of metals and tainting compounds since sample weights acquired using the dermal punch (or biopsy needle) are not sufficient for the testing of all required parameters.

5.1.6.3 Fish Tag Return Assessment

A total of 21 RAMP Floy Tags (indicating capture of 21 tagged fish) were submitted by anglers to the Alberta Sustainable Resources Development, Fort McMurray Office in 2005. Information provided with each tag return typically includes tag number, species, capture location, and date of capture.

Figure 5.1-34 shows the start and finish points, as well as the most direct travel route, for the 21 fish for which tags were returned in 2005. Of the 21 fish captured, three species were represented: walleye; northern pike; and white sucker. Walleye dominated tag returns relative to the two other species (Table 5.1-19). This species has been tagged in large numbers during the annual RAMP fish inventory programs on the Athabasca, Muskeg and Clearwater rivers and is actively sought by sport fishers. In addition to having the largest number of returns, walleye also exhibited the longest overall distance traveled between captures (317 km) (Table 5.1-19). All fish were tagged and re-captured in either the Athabasca River, Clearwater River or in Lake Athabasca, suggesting that these fish were resident in the lower section of the Athabasca river system. A cumulative summary of RAMP tags returned to date (1999 to 2005) is presented in Table 5.1-20.

As in 2004 (RAMP 2005a), the majority of the re-captured walleye remained in the lower section of the Athabasca River between Fort McMurray and Lake Athabasca. One walleye individual (Fish ID #742; Figure 5.1-34) traveled from the Clearwater River to Lake Athabasca. Captured northern pike and white sucker (two individuals per species) were all found virtually at the same point in the Athabasca River on both capture occasions, despite a two-year period between captures for three of the four fish (Figure 5.1-34).

5.1.7 Summary of Conditions

The large size and flow of the Athabasca River means that there is high year-to-year variation in RAMP aquatic resources, much of which is due to natural factors; 2005 was no exception in this regard. In 2005, as in 2004, there were very small calculated changes in hydrologic conditions in the Athabasca River that would not have been experienced had there been no oil sands development activities within its drainage basin. There were no discernable or detectable changes in water or sediment quality conditions that could be ascribed to oil sands development activities and there is little evidence to suggest that characteristics of key indicator fish populations have changed during increasing oil sands development in the RAMP FSA. Any influences of oil sands development activities on the RAMP aquatic resources of the Athabasca River appear to be very minor and largely undetectable.

Figure 5.1-2 Athabasca River: 2005 hydrograph and historical context.

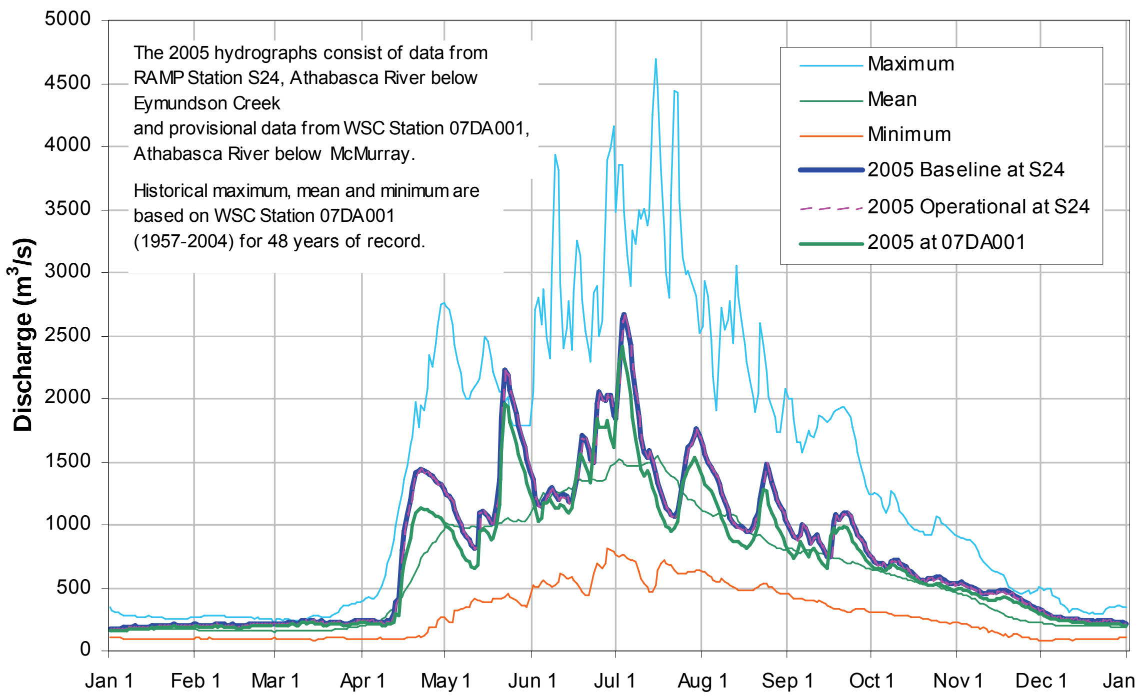


Table 5.1-1 Inputs for calculation of baseline hydrograph at RAMP Station S24, Athabasca River below Eymundson Creek.

Component	Annual Volume (dam^3)	Basis and Data Source
Observed hydrograph	24,600,000	Observed daily discharges obtained from RAMP Station S24, Athabasca River below Eymundson Creek
Natural runoff that would have occurred from active mine areas, or that is intercepted by development	34,600	208.0 km^2 estimated sum of oil sands-developed and oil sands-enclosed areas within: Poplar Creek; Beaver Creek; McLean Creek; and other minor Athabasca River tributaries from Fort McMurray to the mouth of the Firebag River (Table 2.4-1)
Incremental runoff from areas that are cleared and areas that are being dewatered	2,540	75.2 km^2 estimated sum of oil sands-cleared and oil sands-bare areas within Poplar Creek; Beaver Creek; McLean Creek; and other minor Athabasca River tributaries from Fort McMurray to the mouth of the Firebag River (Table 2.4-1)
Withdrawals from the Athabasca River by oil sands development activities	total of 98,765	
	48,000	Withdrawals by Suncor (annual total[1], Section 2.2.1.1)
	28,200	Withdrawals by Syncrude (annual total, Section 2.2.1.2)
	21,900	Withdrawals by Albian (daily values, Section 2.2.1.3)
	394	Withdrawals by CNRL (daily values, Section 2.2.1.5)
	271	Withdrawals by Fort Hills (daily values, Section 2.2.1.7)
Releases to the Athabasca River by oil sands development activities	total of 8,377	
	8,360	Releases by Suncor (partial annual totals, Section 2.2.1.1)
	17	Releases by CNRL (daily values, Section 2.2.1.5)
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	-800	Sum of results of hydrologic analyses from Muskeg, Steepbank, Tar, and MacKay Rivers

[1]Annual totals were prorated to daily estimates using 2004 daily data.

Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.1-2 Calculated changes in hydrologic measurement endpoints for the Athabasca River.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	1,200	1,200	-0.4%
Mean winter discharge	266	263	-1.1%
Annual maximum daily discharge	2,660	2,660	-0.2%
Open-water season minimum daily discharge	529	526	-0.7%

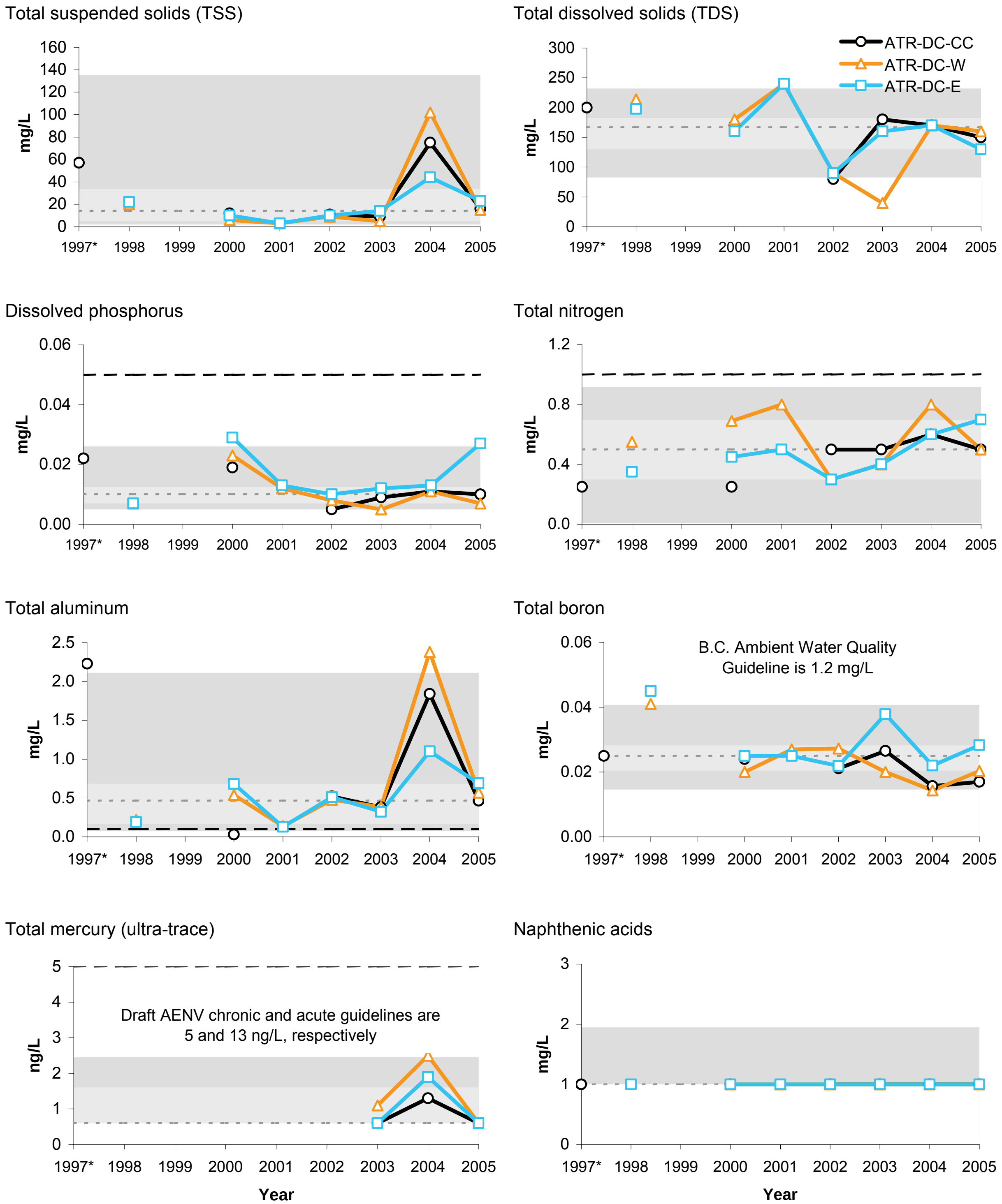
Note: As measured at RAMP Station S24, Athabasca River below Eymundson Creek.

Table 5.1-3 Concentrations of water quality measurement endpoints, Athabasca River mainstem, fall 2005.

	Units	Guideline	Upstream of Fort McMurray (ATR-UFM, fall AENV data, 1976-2005)				Upstream of Donald Creek (ATR-DC-CC, ATR-DC-W, ATR-DC-E)			Upstream of Steepbank R. (ATR-SR-W, ATR-SR-E)		Upstream of Muskeg R. (ATR-MR-W, ATR-MR-E)		Downstream of Development (ATR-DD-CC, ATR-DD-W, ATR-DD-E)			Upstream of Firebag River (ATR-FR)
			n	Min	Mean	Max	East[3]	Cross-channel	West	East	West	East	West	East	Cross-channel	West	Cross-channel
Physical variables																	
pH	pH units	6.5-9.0	50	7.28	8.025	8.45	7.7	8.2	8.3	8	8.2	8.1	8.2	8.2	8.2	8.3	8.2
Total suspended solids	mg/L	-	52	0.4	7.2	344	23	16	15	<3	16	5	3	25	24	22	27
Conductivity	mg/L	-	47	150	292	467	206	269	291	239	264	250	262	261	261	262	276
Nutrients																	
Total phosphorus	mg/L	0.05	49	0.006	0.02	0.35	**0.068**	0.035	0.031	**0.057**	0.033	0.04	0.031	0.045	0.05	0.05	**0.052**
Dissolved phosphorus	mg/L	0.05[1]	29	0.003	0.007	0.03	0.027	0.01	0.007	0.018	0.007	0.014	0.011	0.01	0.011	0.012	0.016
Total nitrogen*	mg/L	1.0	44	0.133	0.425	1.903	0.7	0.5	0.5	0.5	0.4	0.5	0.4	0.5	0.5	0.5	0.6
Nitrate+nitrite	mg/L	-	51	0.001	0.005	0.843	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	45	2.5	8	25	14	8	7	10	8	11	8	10	10	11	10
Ions																	
Sodium	mg/L	-	47	4	10	20	17	10	9	12	9	13	10	12	12	11	13
Calcium	mg/L	-	42	19	35	57	17.7	33.2	37.1	27.4	33.4	28.4	33.2	30.7	30.5	30.9	31.7
Magnesium	mg/L	-	42	5	9	16	5.7	9.4	10.4	7.8	9.3	8.5	9.4	8.8	8.7	8.8	8.8
Chloride	mg/L	230, 860[4]	51	1.0	3	10.3	21	6	3	10	4	11	6	8	8	7	11
Sulphate	mg/L	100[5]	50	13	28.8	63.9	6.4	23.6	27.2	18	25.4	18.9	24.9	20.8	20.2	21.1	21
Total dissolved solids	mg/L	-	22	123	182	288	130	150	160	140	150	170	170	150	160	170	170
Total alkalinity	mg/L	-	51	64	122	195	66	107	119	90	107	93	105	99	100	101	103
Organic compounds																	
Naphthenic acids	mg/L	-	-	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	3
Selected metals																	
Total aluminum	mg/L	0.1	8	0.07	0.1765	1.18	**0.69**	**0.467**	**0.57**	**0.611**	**0.683**	**0.548**	**0.414**	**0.92**	**0.889**	**1.08**	**0.944**
Dissolved aluminum	mg/L	0.1[1]	5	0.004	0.00812	0.02	0.00972	0.00968	0.0101	0.0113	0.0129	0.013	0.0113	0.0107	0.0116	0.0103	0.0119
Total boron	mg/L	1.2[5]	7	0.01	0.0281	0.04	0.0283	0.017	0.0203	0.0203	0.0204	0.0251	0.018	0.0255	0.025	0.023	0.027
Total molybdenum	mg/L	0.073	16	0.00066	0.001	0.018	0.000202	0.000618	0.000701	0.000435	0.000633	0.0005	0.000566	0.000577	0.000586	0.000586	0.000622
Total mercury (ultra-trace)	ng/L	5, 13[6]	3	0.6	0.6	2.4	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Other variables that exceeded CCME/AENV guidelines in 2005																	
Total phenols	mg/L	0.004	32	<0.001	0.002	0.011	**0.006**	-	-	-	-	-	-	**0.005**	**0.005**	-	-
Total cobalt	mg/L	0.0009[7]	10	<0.0003	<0.001	0.003	-	-	-	-	-	-	-	**0.00142**	**0.00177**	**0.0017**	-
Dissolved iron	mg/L	0.3[2]	9	<0.01	0.06	0.17	**0.668**	-	-	-	-	-	-	-	-	-	-
Total iron	mg/L	0.3	6	0.17	0.32	2.42	**1.9**	**0.789**	**0.601**	**1.2**	**0.707**	**0.872**	**0.588**	**1.12**	**1.08**	**1.15**	**1.0**

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.
* total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] Guideline is hardness dependent.
[3] Denotes sampling location. East=east bank; West=west bank.
[4] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[5] B.C. Ambient Water Quality Guideline (B.C. 2000, B.C. 2003).
[6] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).
[7] B.C. Working Water Quality Guideline (2001).

Figure 5.1-3 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem upstream of Donald Creek (ATR-DC).

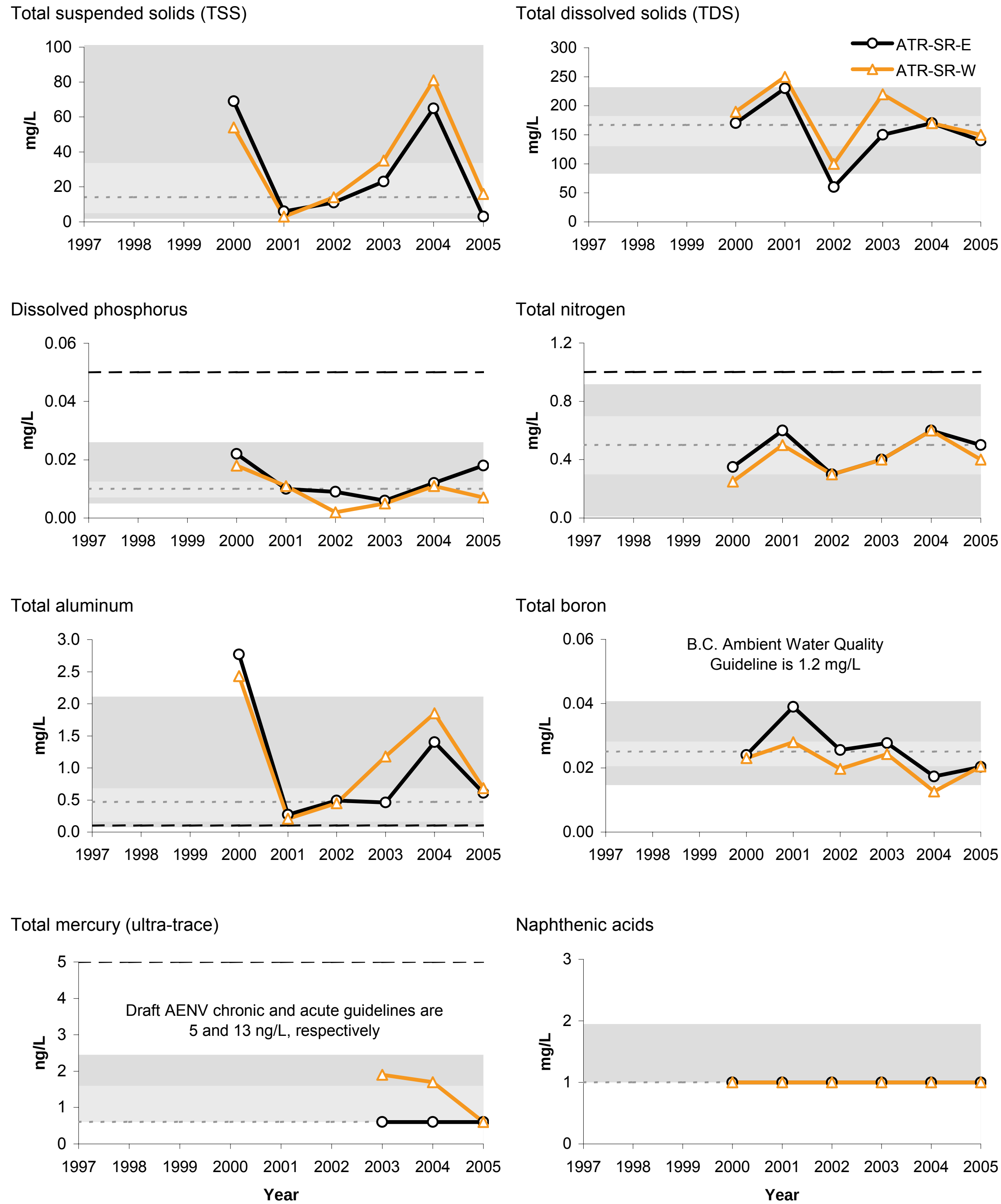


* 1997 ATR-DC-CC sample collected downstream of Donald Creek.

Non-detectable values are shown at the detection limit.

[1] 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.

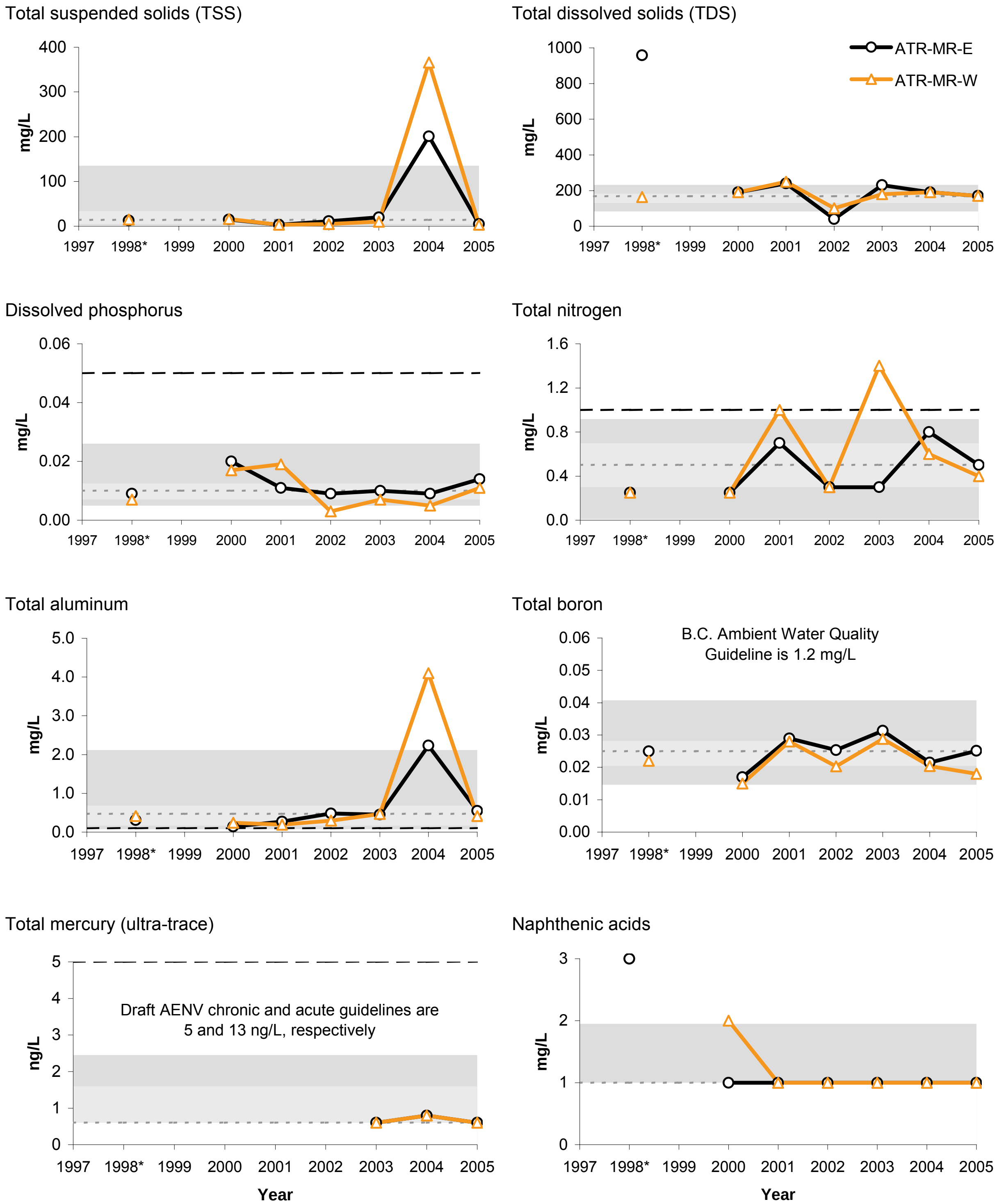
Figure 5.1-4 Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem upstream of the Steepbank River (ATR-SR).



Non-detectable values are shown at the detection limit.

[1] 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 5.1-5 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).

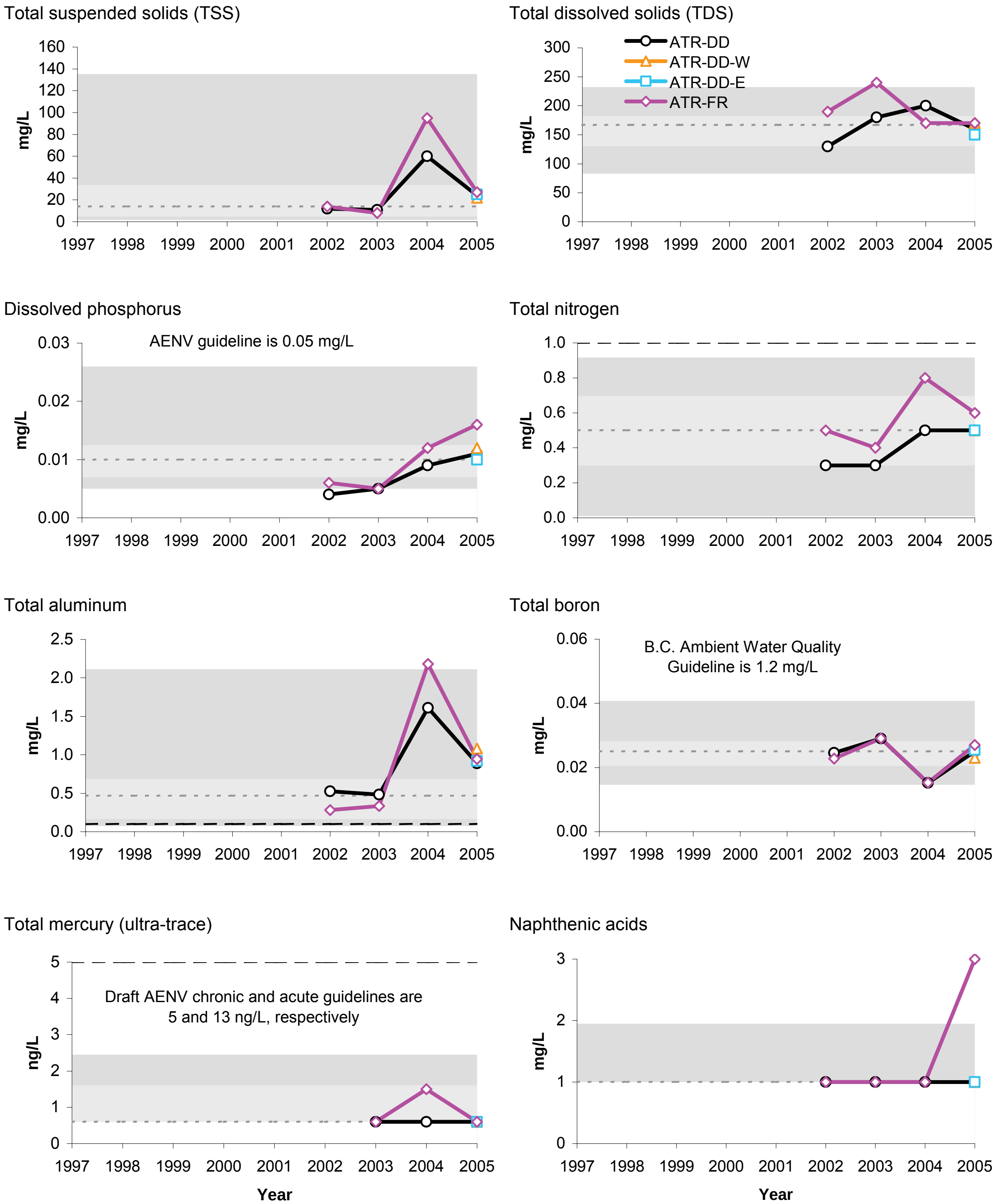


* 1998 samples collected downstream of Muskeg River.

Non-detectable values are shown at the detection limit.

[1] 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 5.1-6 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 Firebag River (ATR-FR).



ATR-DD and ATR-FR samples collected as cross-channel composites.

Non-detectable values are shown at the detection limit.

[1] 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.

Table 5.1-4 Seasonal exceedances of water quality guidelines in the Athabasca River mainstem (station ATR-DD), 2005.

Parameter	Units	Guideline*	ATR-DD-CC	ATR-DD-E	ATR-DD-W
Winter					
Dissolved phosphorus	mg/L	0.05[1]	**0.1**	**0.089**	**0.101**
Total phosphorus	mg/L	0.05	**0.116**	**0.093**	**0.102**
Total aluminum	mg/L	0.1	**0.209**	**0.217**	**0.21**
Total iron	mg/L	0.3	**0.491**	**0.698**	**0.525**
Spring					
Total phosphorus	mg/L	0.05	**0.163**	**0.233**	**0.267**
Total phenols	mg/L	0.004	**0.008**	**0.012**	**0.008**
Total aluminum	mg/L	0.1	**4.89**	**7.31**	**8.34**
Total chromium	mg/L	0.001-0.0089[2]	**-**	**0.00929**	**0.00985**
Total cobalt	mg/L	0.0009[3]	**0.00195**	**0.00315**	**0.00283**
Total copper	mg/L	0.002-0.004[4]	**0.00466**	**0.0062**	**0.0062**
Total iron	mg/L	0.3	**4.11**	**7.08**	**6.52**
Total lead	mg/L	0.001-0.007[4]	**0.00397**	**0.00494**	**0.00473**
Total titanium	mg/L	0.1[3]	**-**	**0.101**	**0.133**
Summer					
Total phenols	mg/L	0.004	**-**	**-**	**0.007**
Total aluminum	mg/L	0.1	**4.97**	**4.51**	**4.58**
Total cobalt	mg/L	0.0009[3]	**0.00177**	**0.00142**	**0.0017**
Total copper	mg/L	0.002-0.004[4]	**0.00481**	**0.00389**	**0.0047**
Total iron	mg/L	0.3	**4.36**	**3.71**	**4.2**
Total lead	mg/L	0.001-0.007[4]	**0.00336**	**0.00255**	**0.00317**
Fall					
Total phosphorus	mg/L	0.05	**-**	**-**	**-**
Total phenols	mg/L	0.004	**0.005**	**0.005**	**-**
Total aluminum	mg/L	0.1	**0.889**	**0.92**	**1.08**
Total cobalt	mg/L	0.0009[3]	**0.00177**	**0.00142**	**0.0017**
Dissolved iron	mg/L	0.3[1]	**-**	**-**	**-**
Total iron	mg/L	0.3	**1.08**	**1.12**	**1.15**

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

ATR-DD-CC, ATR-DD-E, ATR-DD-W were sampled in winter, spring, summer, fall 2005; all other stations sampled only in fall 2005.

ns = not sampled.

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

[2] Guidelines are for chromium VI (0.001 mg/L) and chromium III (0.0089 mg/L).

[3] B.C. Working Water Quality Guideline (2001).

[4] Guideline is hardness-dependent.

Figure 5.1-7 Piper diagram of ion concentrations in Athabasca River mainstem, fall 1997 to 2005.

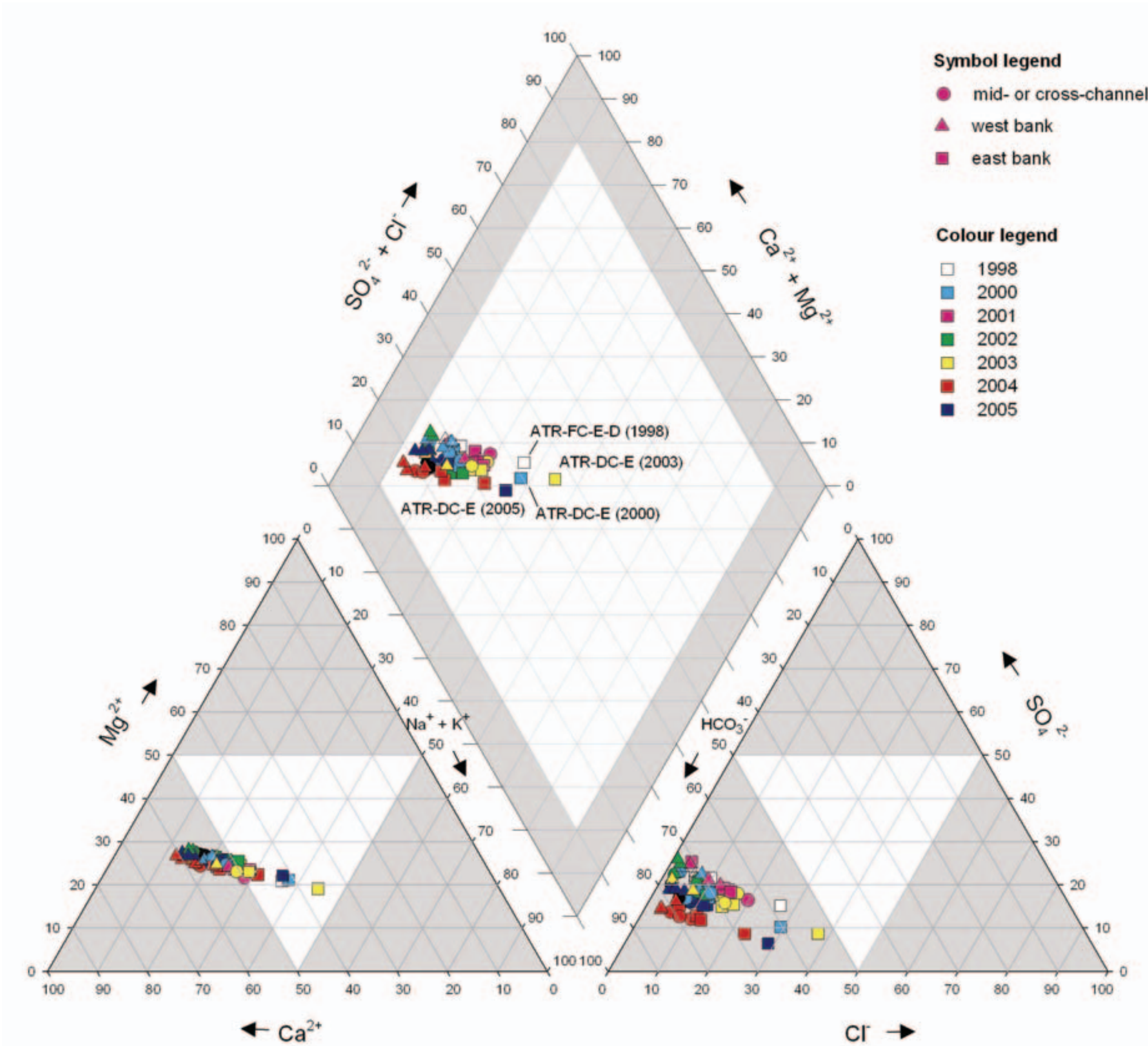


Table 5.1-5 Trend analysis of water quality measurement endpoints for Athabasca River mainstem.

AENV Analyte	At town of Athabasca 1997-2005 (station ATR-ATH)			Upstream of Fort McMurray 1997 - 2005 (station ATR-UFM)			At Old Fort 1997 - 2005 (station ATR-OF)		
	n	Trend Direction	Slope Estimate[1] (units per year)	n	Trend Direction	Slope Estimate[1] (units per year)	n	Trend Direction	Slope Estimate[1] (units per year)
Physical variables									
pH	110	up	0.04342	62	up	0.01993	66	up	0.06015
Total suspended solids	115	-	-	71	-	-	66	-	-
Specific conductance	111	-	-	54	down	-13.6	66	-	-
Nutrients									
Total phosphorus	112	-	-	65	-	-	63	-	-
Total dissolved phosphorus	112	-	-	65	-	-	60	-	-
Total nitrogen	115	-	-	65	-	-	64	-	-
Nitrate+nitrite	115	-	-	65	-	-	65	-	-
Total Kjeldahl nitrogen	115	-	-	65	up	0.02586	63	-	-
Dissolved organic carbon	115	-	-	70	-	-	64	-	-
Ions									
Sodium	110	-	-	62	-	-	66	-	-
Calcium	111	-	-	62	-	-	66	down	-0.4639
Magnesium	110	-	-	62	-	-	66	down	-0.1011
Chloride	110	-	-	62	down	-0.2967	66	-	-
Sulphate	110	-	-	62	-	-	66	-	-
Total dissolved solids (calculated)	110	-	-	62	-	-	66	-	-
Total dissolved solids (filtrable residue)	109	-	-	67	-	-	66	-	-
Alkalinity (as $CaCO_3$)	110	-	-	62	-	-	66	-	-
Selected metals									
Total aluminum	54	-	-	38	-	-	39[2]	-	-
Dissolved aluminum[1]	27	-	-	21[2]	-	-	15[2]	-	-
Total boron	33	-	-	31	-	-	27[2]	-	-
Total molybdenum	35	down	-0.0000511	27*	-	-	28[2]	down	0
Total mercury	26[2]	-	-	26	-	-	18[2]	-	-
Total mercury (ultra-trace)	11[2]	-	-	7[2]	-	-	10[2]	-	-

* Trend analyzed from 1999 to 2005 due to high detection limits in 1997 and 1998.

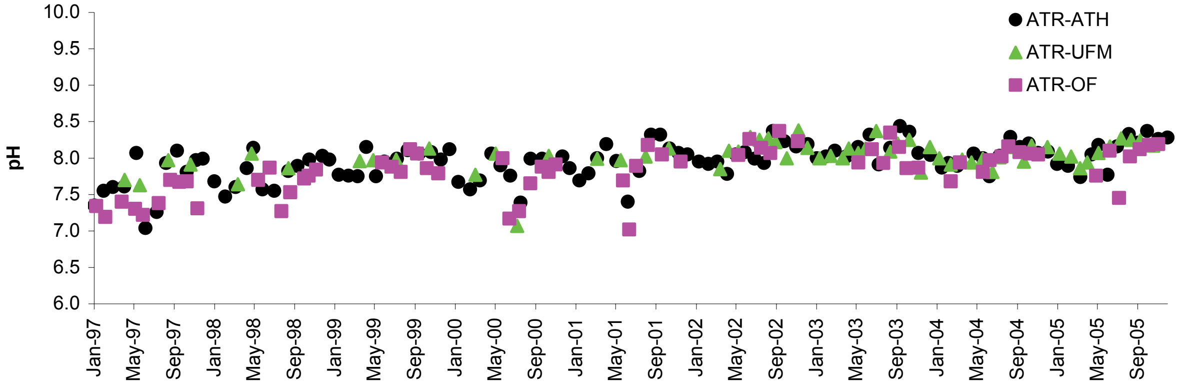
[1] Reported slope is the median of slopes estimated for individual season (Seasonal Kendall test) or individual time periods (Sen's slope estimate).

[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.

Figure 5.1-8 Water quality measurement endpoints (physical variables), 1997-2005 AENV data, Athabasca River mainstem stations.

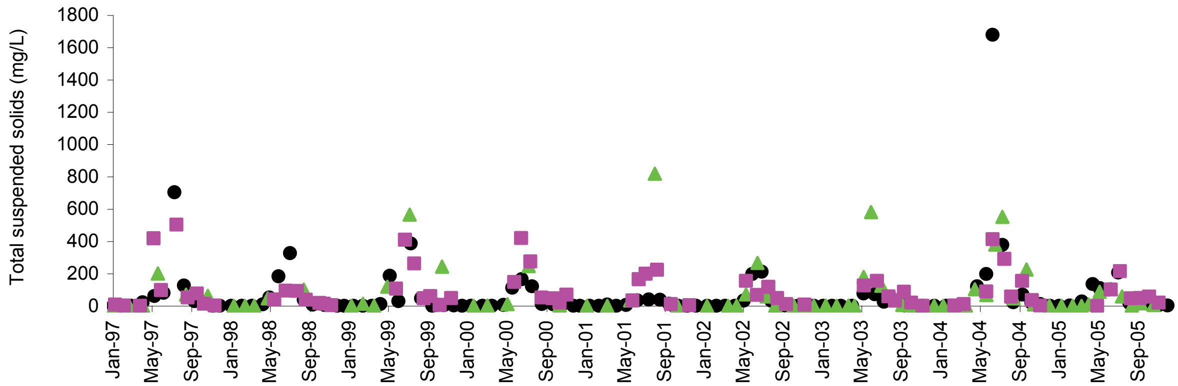
pH

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



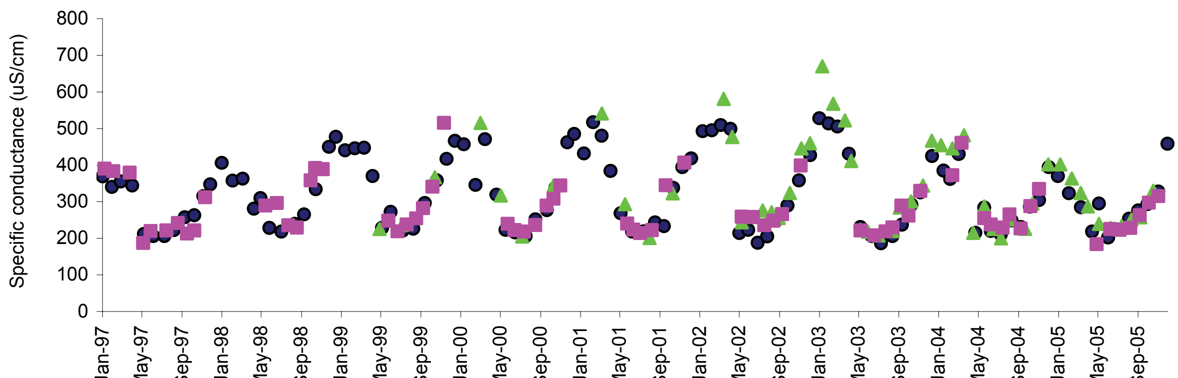
Total suspended solids

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



Specific conductance

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

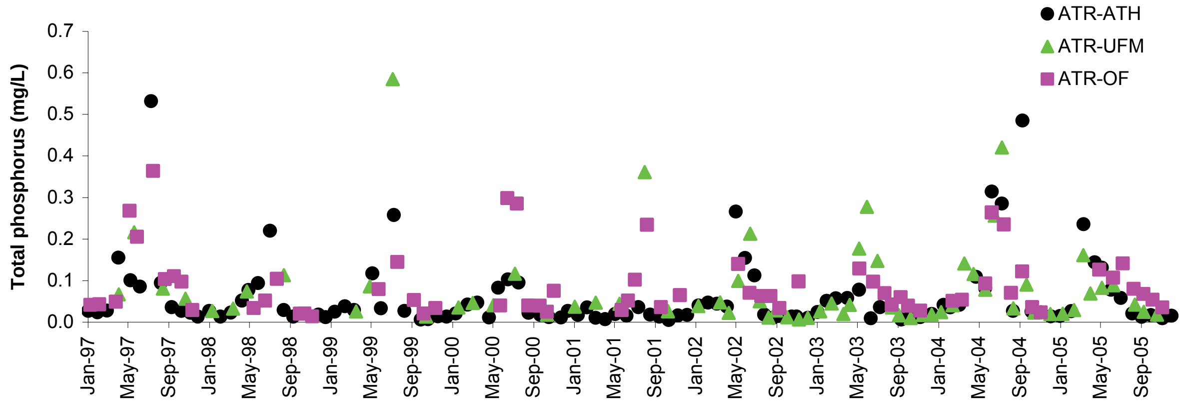


Non-detectable results are shown at the detection limit.

Figure 5.1-9 Water quality measurement endpoints (nutrients, set No. 1), 1997-2005 AENV data, Athabasca River mainstem stations.

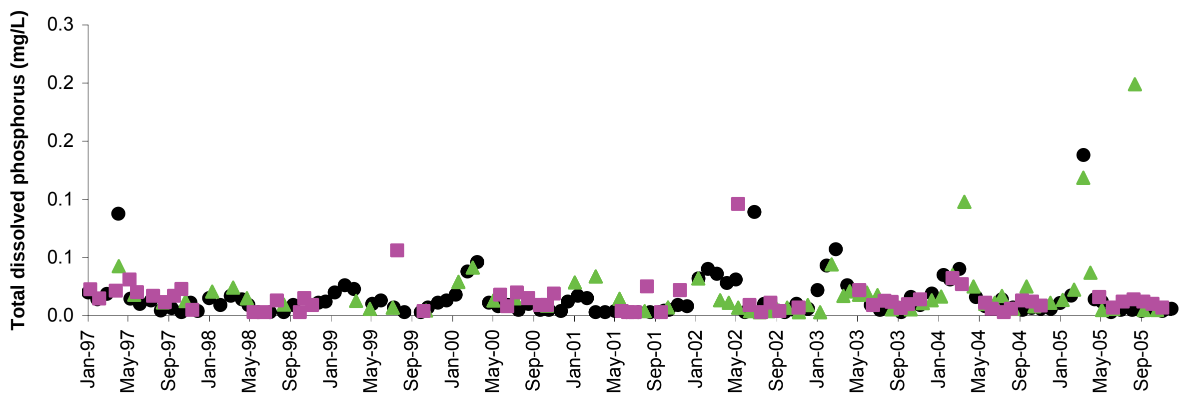
Total phosphorus

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



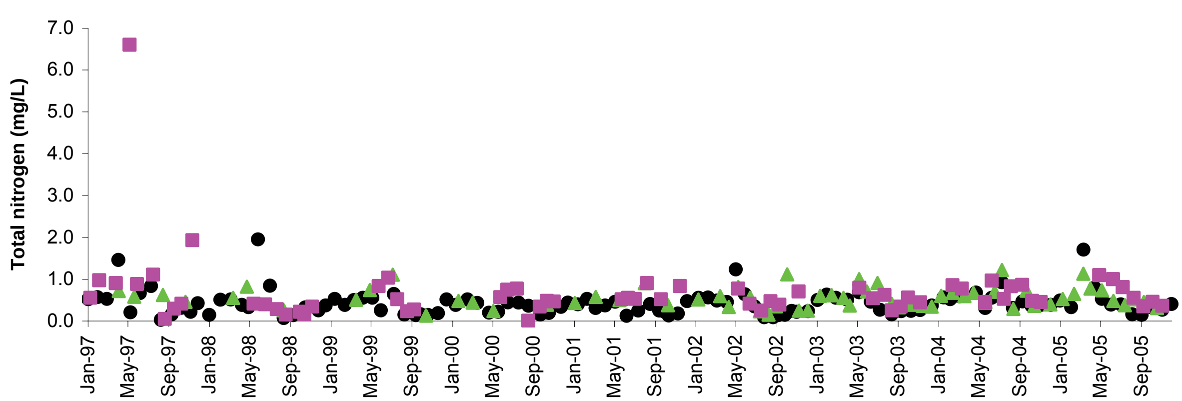
Total dissolved phosphorus

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



Total nitrogen

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

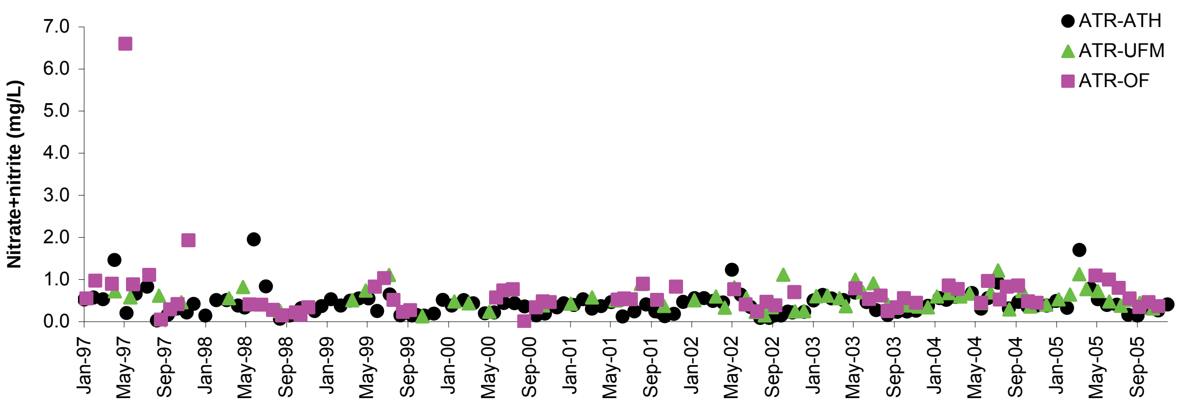


Non-detectable values are shown at the detection limit.

Figure 5.1-10 Water quality measurement endpoints (nutrients, set No. 2), 1997-2005 AENV data, Athabasca River mainstem stations.

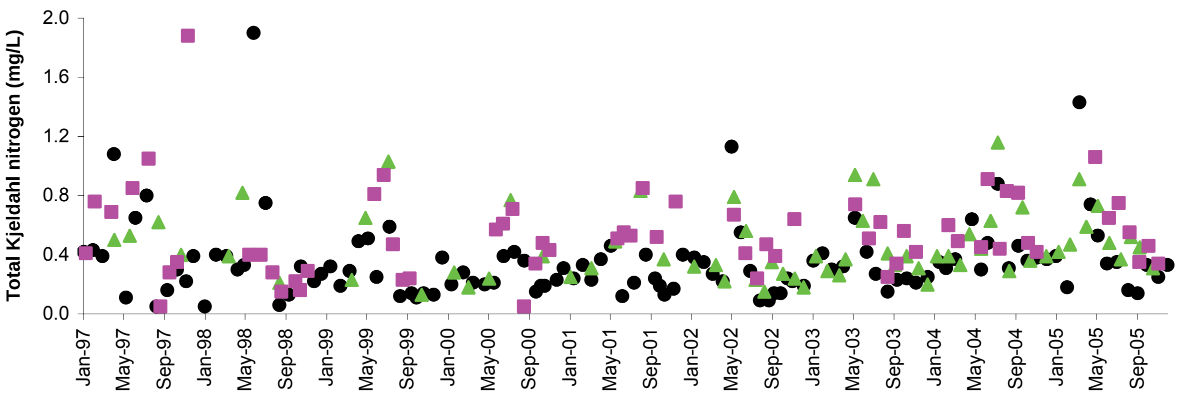
Nitrate + Nitrite

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



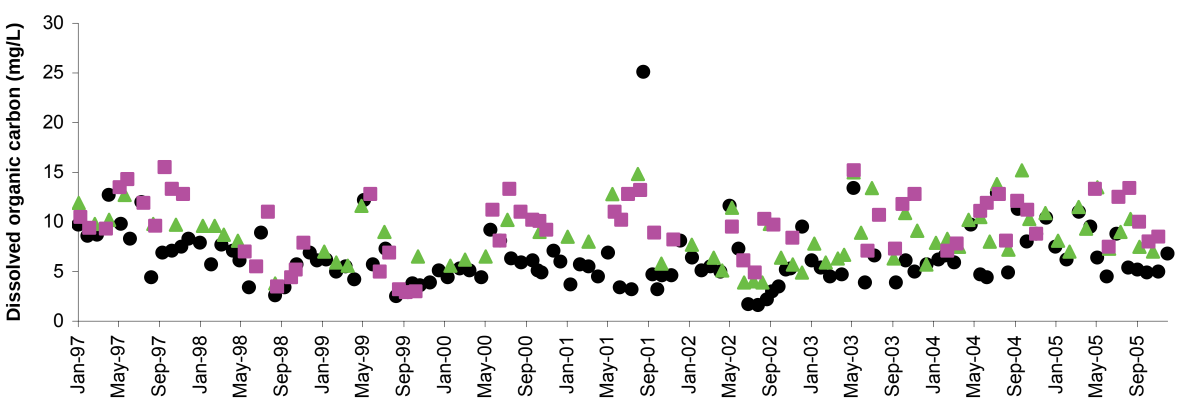
Total Kjeldahl nitrogen

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



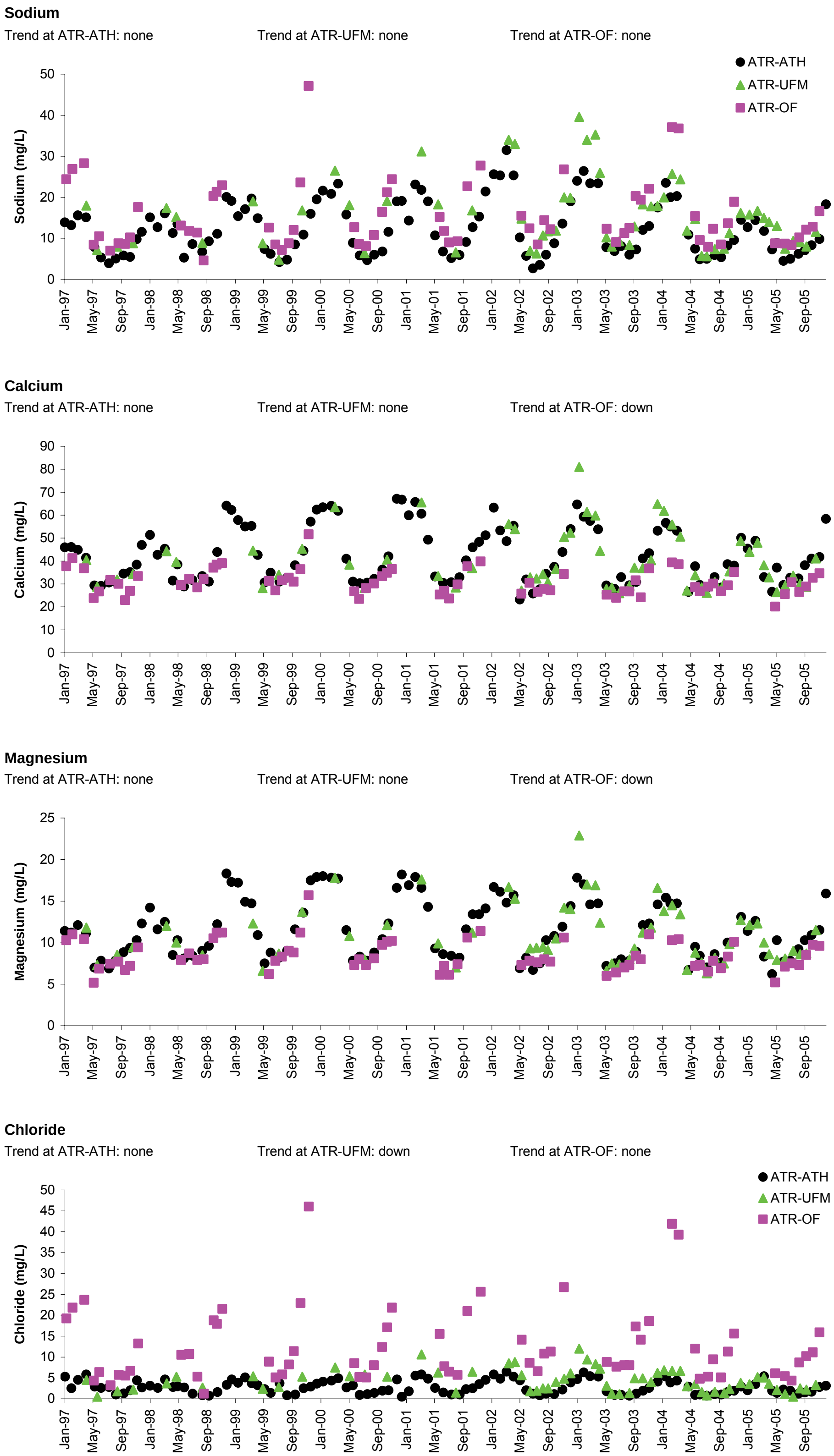
Dissolved organic carbon

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



Non-detectable values are shown at the detection limit.

Figure 5.1-11 Water quality measurement endpoints (ions, set No. 1), 1997-2005 AENV data, Athabasca River mainstem stations.

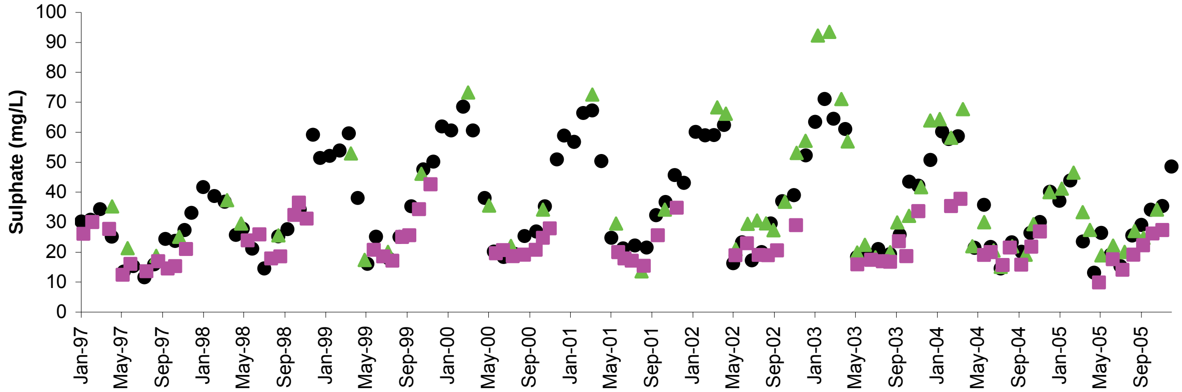


Non-detectable values are shown at the detection limit.

Figure 5.1-12 Water quality measurement endpoints (ions, set No. 2), 1997-2005 AENV data, Athabasca River mainstem stations.

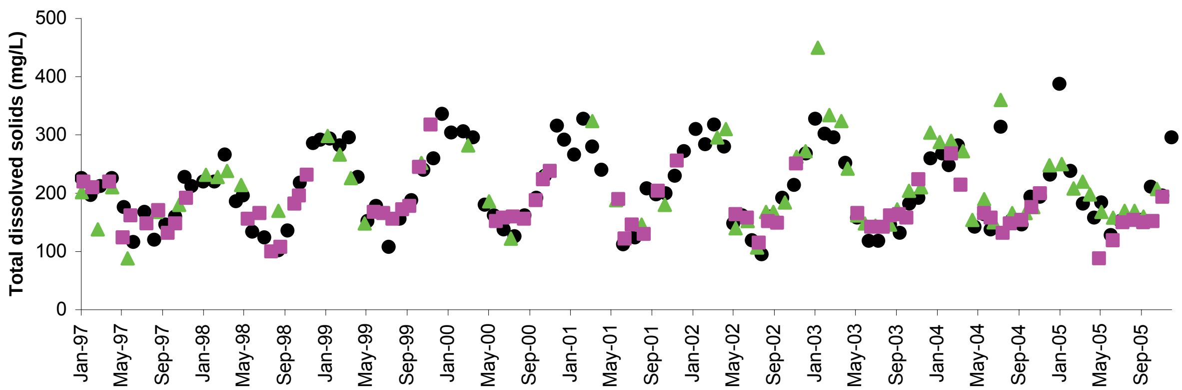
Sulphate

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



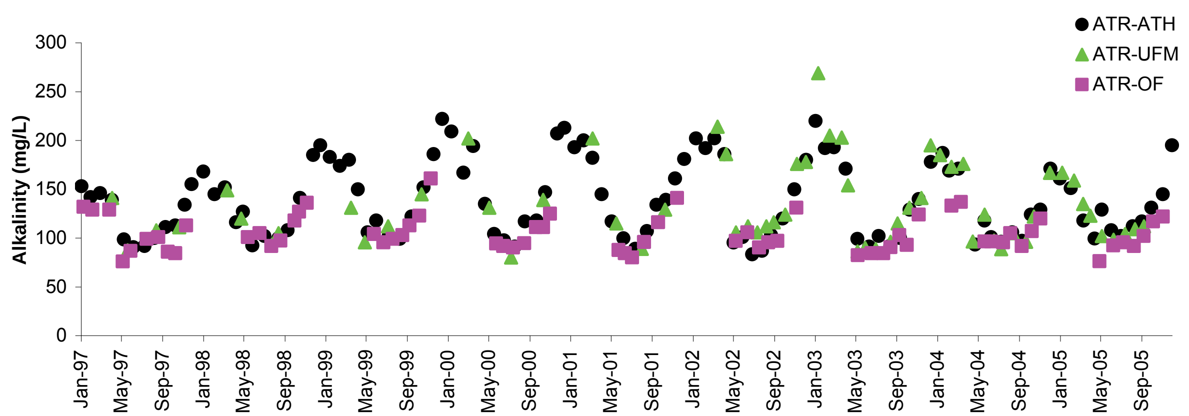
Total dissolved solids

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



Alkalinity (as $CaCO_3$)

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

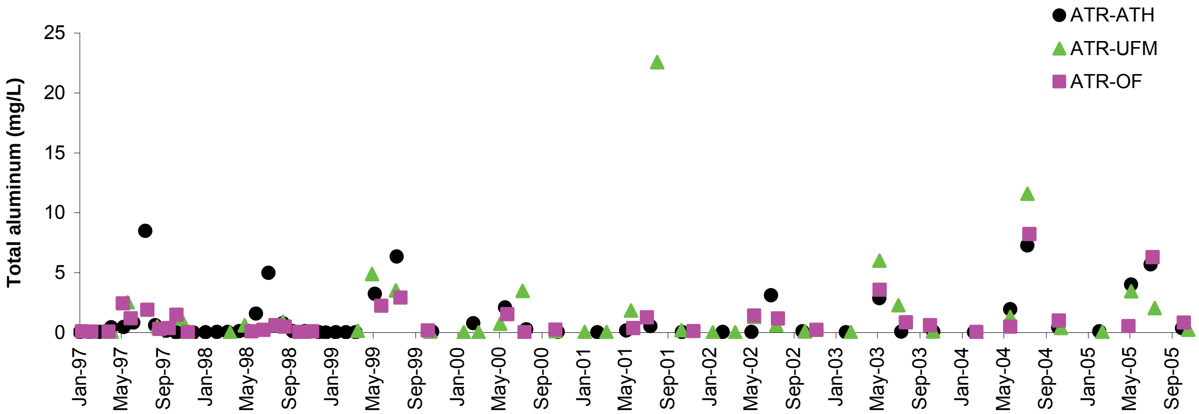


Non-detectable values are shown at the detection limit.

Figure 5.1-13 Water quality measurement endpoints (metals, set No. 1), 1997-2005 AENV data, Athabasca River mainstem stations.

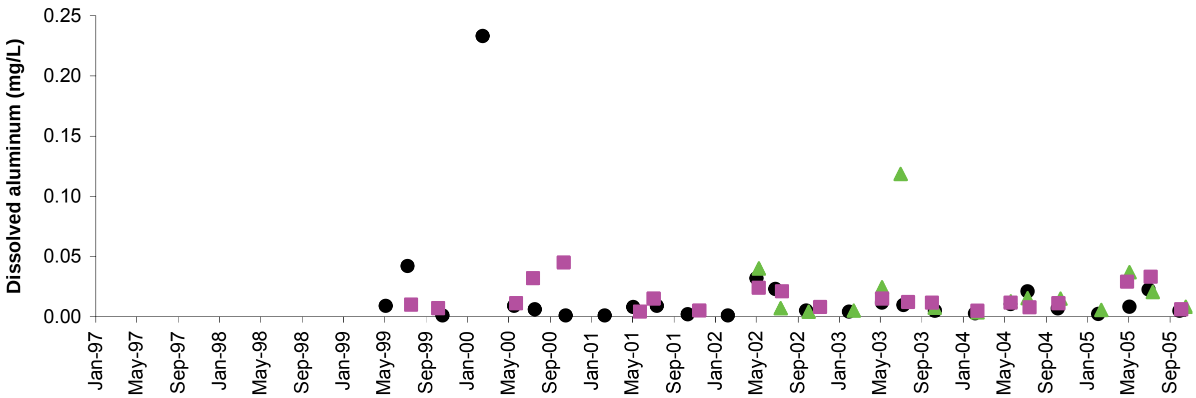
Total aluminum

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



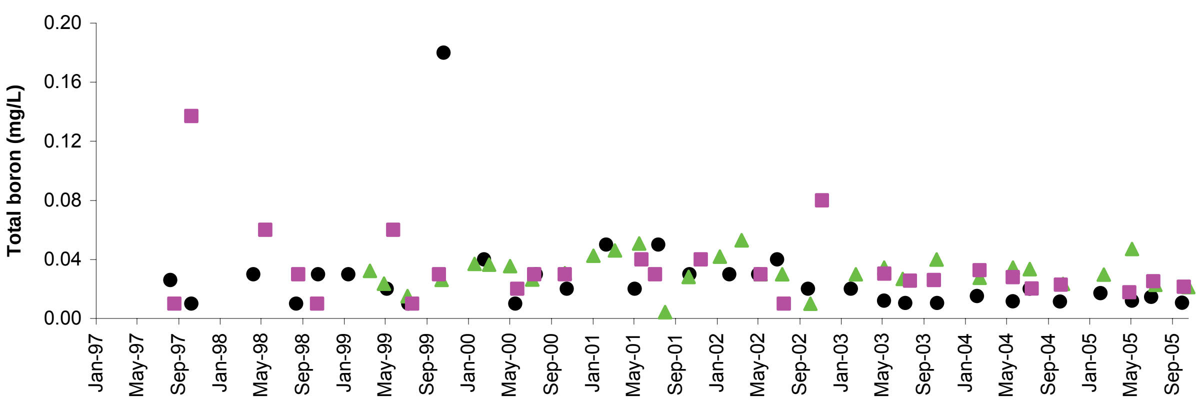
Dissolved aluminum

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



Total boron

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

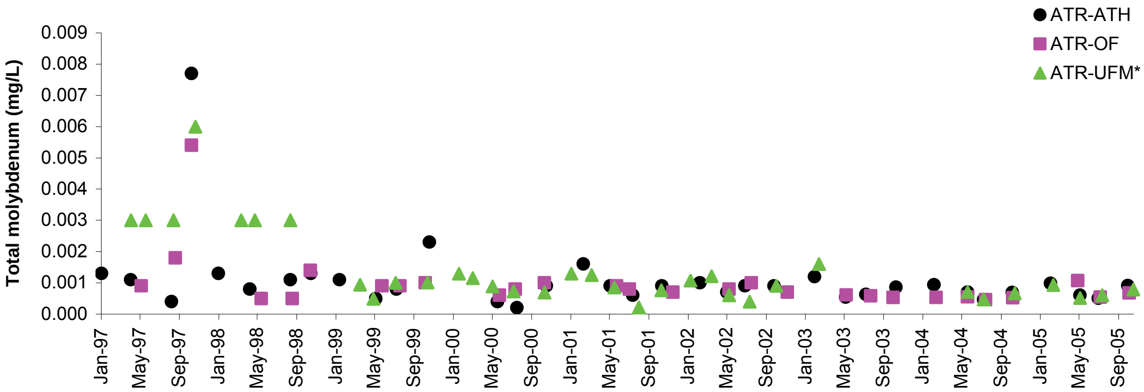


Non-detectable values are shown at the detection limit.

Figure 5.1-14 Water quality measurement endpoints (metals, set No. 2), 1997-2005 AENV data, Athabasca River mainstem stations.

Total molybdenum

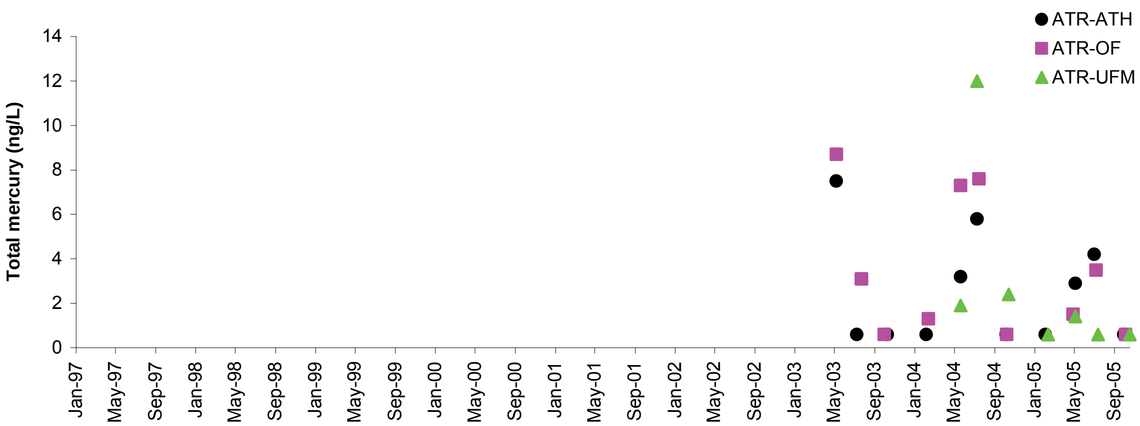
Trend at ATR-ATH: down Trend at ATR-UFM: none Trend at ATR-OF: down



* ATR-UFM data analyzed from 1999-2005 due to a higher detection limit in 1997 and 1998.

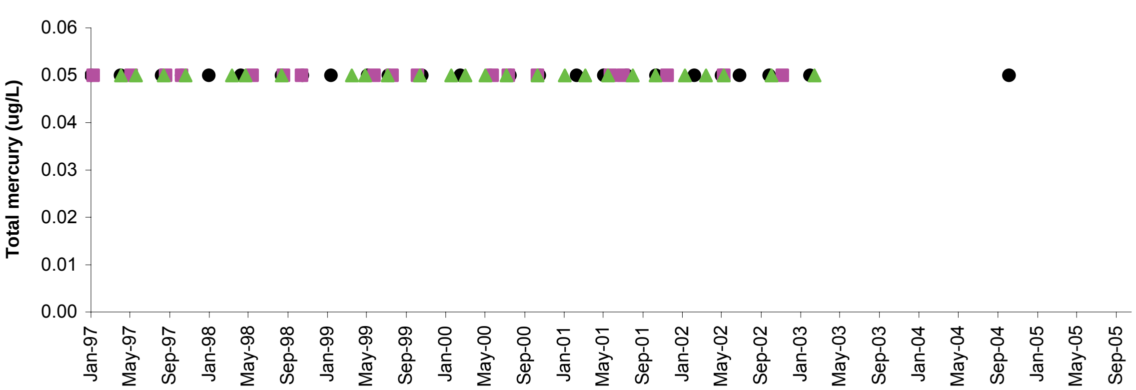
Total mercury (ultra-trace)

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



Total mercury*

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



* Data shown are screened to the highest detection limit.
Non-detectable values are shown at the detection limit.

Table 5.1-6 Concentrations of selected sediment quality measurement endpoints, Athabasca River upstream of the Embarras River (ATR-ER), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	12	5	10	16	22
Silt	%	-	32	5	29	34	42
Sand	%	-	56	5	36	50	61
Total organic carbon	%	-	1	5	0.8	1.1	1.3
Total hydrocarbons							
CCME variables							
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]	11	1	-	-	28
Fraction 3 (C16-C34)	mg/kg	400[2]	260	1	-	-	220
Fraction 4 (C34-C50)	mg/kg	2800[2]	180	1	-	-	190
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0082	5	0.0046	0.009	0.037
Retene	mg/kg	-	0.0512	5	0.033	0.0399	0.081
Total dibenzothiophenes	mg/kg	-	0.29	5	0.09	0.22	0.35
Total PAHs	mg/kg	-	1.43	5	0.82	1.11	1.69
Total HMW PAHs	mg/kg	-	0.59	5	0.41	0.45	0.54
Total LMW PAHs	mg/kg	-	0.85	5	0.40	0.68	1.15
Predicted PAH toxicity[1]	H.I.	-	0.95	5	0.92	1.25	1.54
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	3	7	7.4	8
Chironomus growth - 10d	mg/organism	-	-	3	2.1	2.2	3.5
Hyallela survival - 14d	# surviving	-	-	1	-	-	10
Hyallela growth - 14d	mg/organism	-	-	1	-	-	0.09

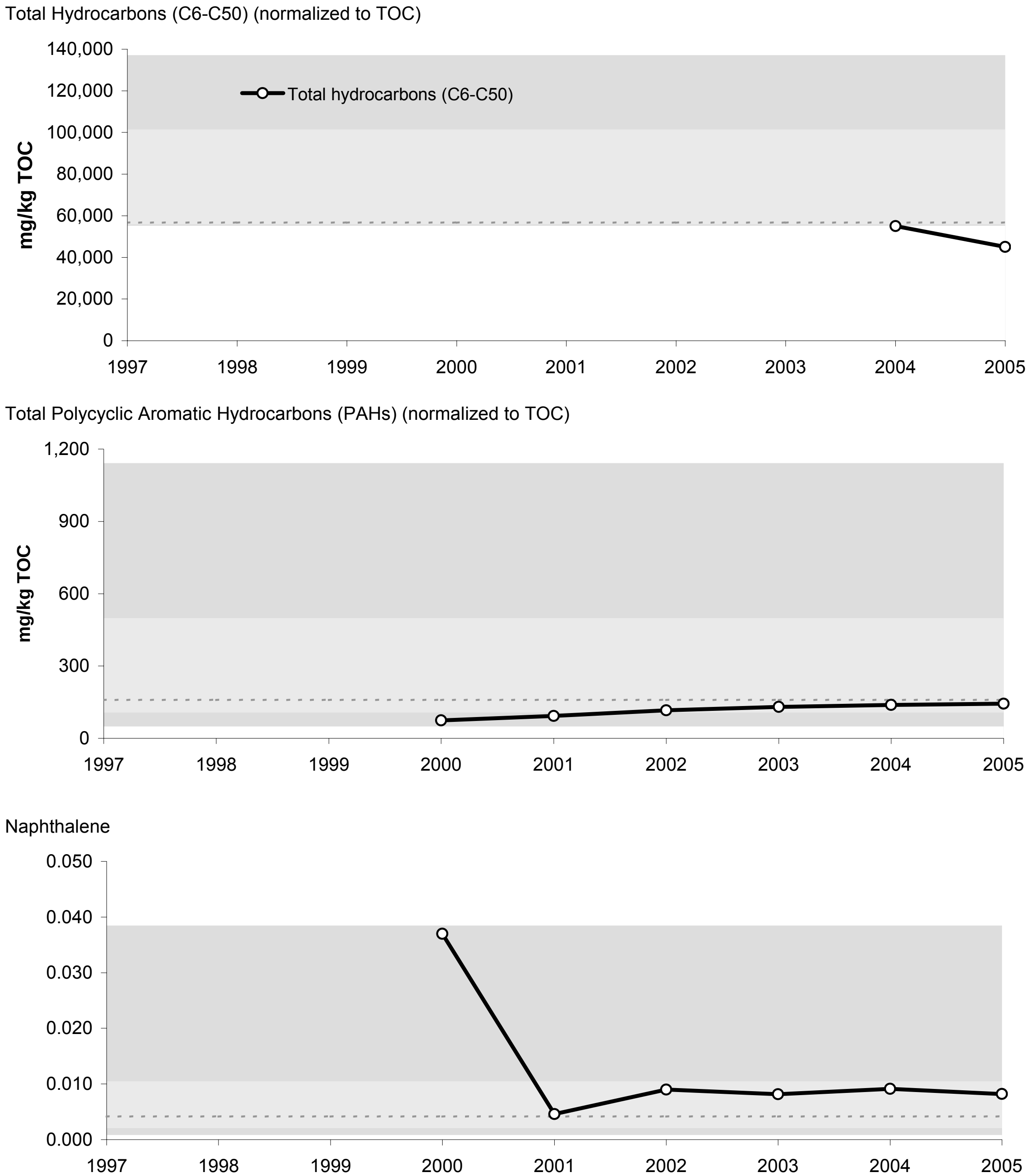
Values in **bold** indicate concentrations exceeding guidelines.

[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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

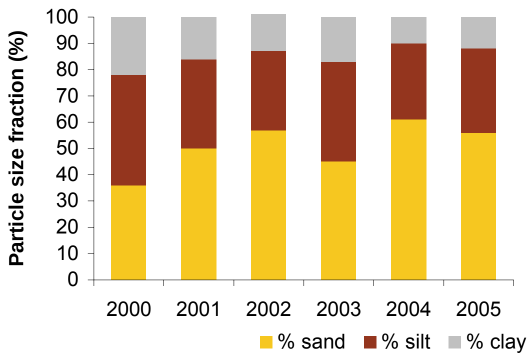
Figure 5.1-15 Selected sediment quality measurement endpoints in the Athabasca River (ATR-ER) (fall data) relative to regional baseline fall concentrations.



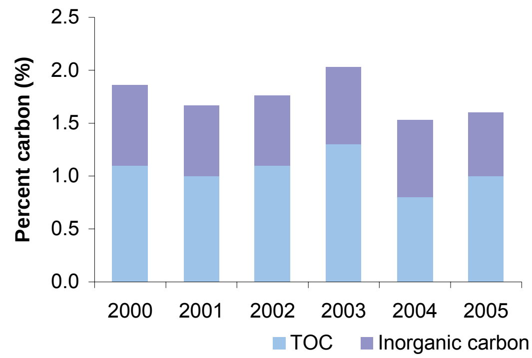
[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

Figure 5.1-16 Characteristics of sediment collected in the Athabasca River upstream of Embarras River (ATR-ER), 2000-2005 (fall data only).

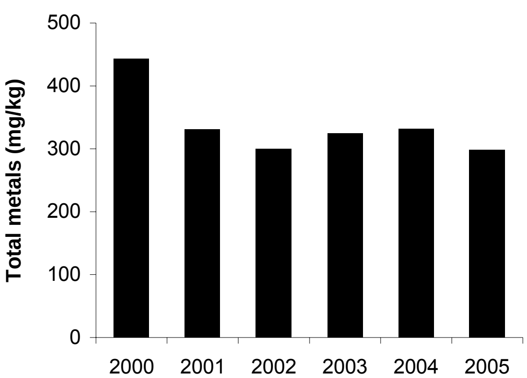
Particle size distribution



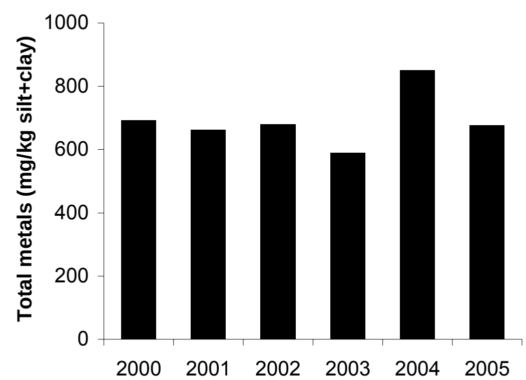
Carbon content



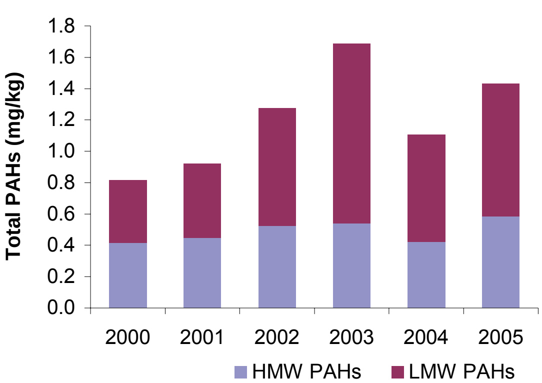
Total metals*



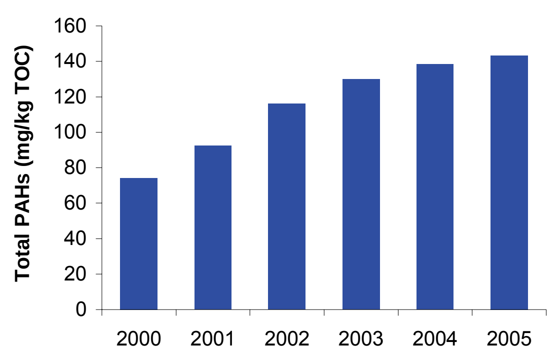
Total metals* normalized to percent fine sediments (i.e., % silt+clay)



Total PAHs



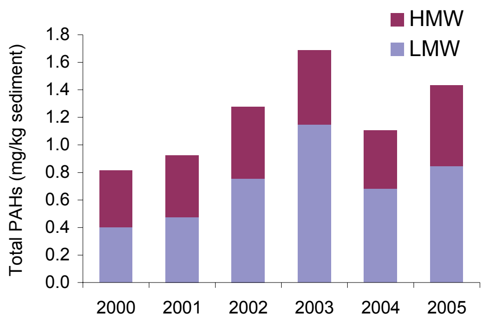
Total PAHs normalized to TOC



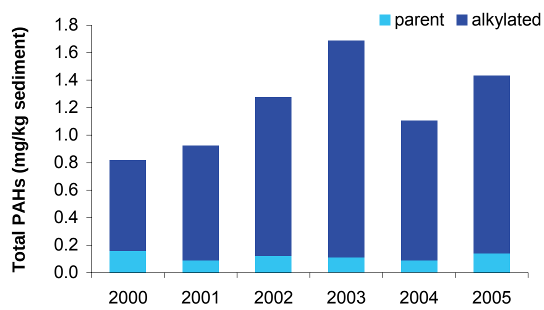
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Sr, Tl, U, V, Zn (measured in all years).

Figure 5.1-17 Sediment PAH concentrations, Athabasca River upstream of Embarras River (ATR-ER), 2000-2005 (fall data only).

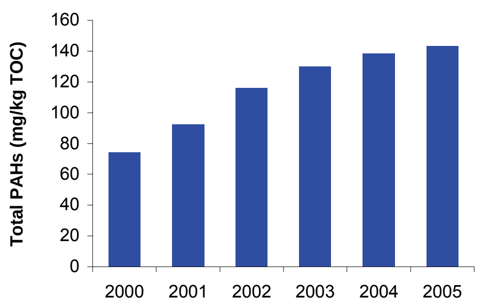
Total LMW and HMW PAHs



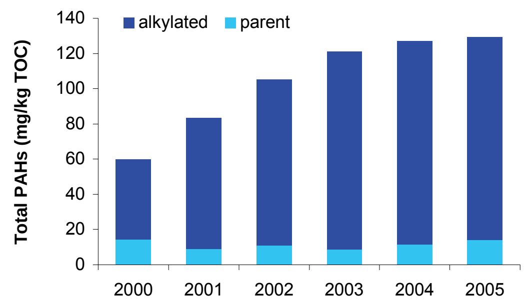
Total parent and alkylated PAHs



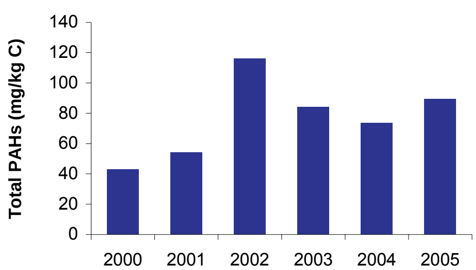
Total PAHs normalized to TOC



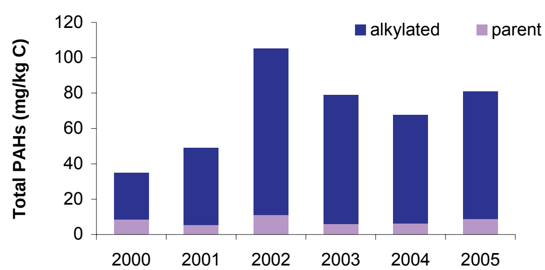
Total alkylated and parent PAHs normalized to TOC



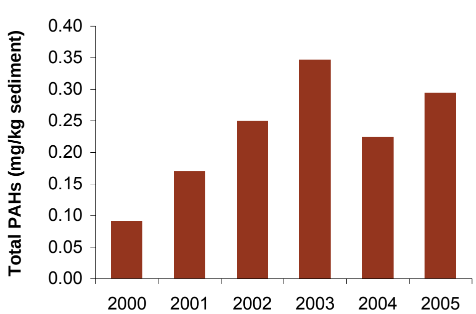
Total PAHs normalized to total carbon



Total alkylated and parent PAHs normalized to total carbon



Total dibenzothiophenes



Total dibenzothiophenes normalized to total carbon

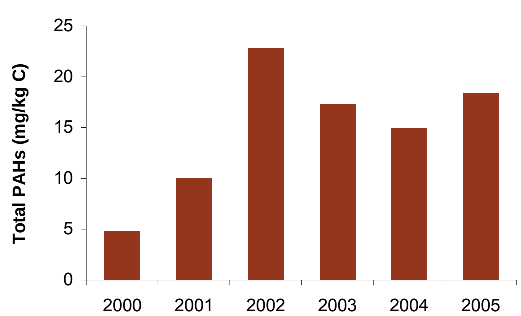


Table 5.1-7 Fish inventory results from electrofishing on the Athabasca River, Spring 2005.

Species	Total Spring Electrofishing Effort = 26,231 s		
	Total Captured	Species Composition (% of total)	CPUE (#/100s)
Bull trout	1	0.11	0.004
Yellow perch	1	0.11	0.004
Lake whitefish	2	0.22	0.008
Mountain whitefish	2	0.22	0.008
Spottail shiner	4	0.43	0.015
Burbot	6	0.65	0.023
Emerald shiner	8	0.87	0.03
Pearl dace	10	1.08	0.038
Lake chub	22	2.39	0.084
Northern pike	14	1.52	0.053
Longnose sucker	41	4.45	0.156
Flathead chub	96	10.4	0.366
White sucker	101	10.9	0.385
Trout-perch	110	11.9	0.419
Goldeye	108	11.7	0.412
Walleye	396	42.9	1.51
TOTAL	**922**		**3.515**

Table 5.1-8 Fish inventory results from electrofishing on the Athabasca River, Fall 2005.

Species	Total Fall Electrofishing Effort = 29,388 s		
	Total Captured	Species Composition (% of total)	CPUE (#/100s)
Spottail shiner	1	0.11	0.004
Sculpin sp.	4	0.55	0.015
Pearl dace	3	0.33	0.011
Mountain whitefish	5	0.55	0.019
Yellow perch	6	0.78	0.026
Emerald shiner	11	1.33	0.041
Longnose sucker	30	3.66	0.112
Cisco	34	3.77	0.127
Northern pike	32	3.77	0.119
Lake chub	38	4.32	0.142
White sucker	38	4.66	0.142
Trout-perch	125	14.8	0.465
Lake whitefish	113	--	0.421
Flathead chub	148	16.5	0.551
Walleye	165	19.6	0.659
Goldeye	228	25.3	0.849
TOTAL	**981**		**3.653**

[1] Lake whitefish were excluded from the CPUE calculation due to bias sampling associated with the fall spawning run of this species.

Figure 5.1-18 Percent composition of captured large-bodied species, Athabasca River spring inventory 1995 to 2005.

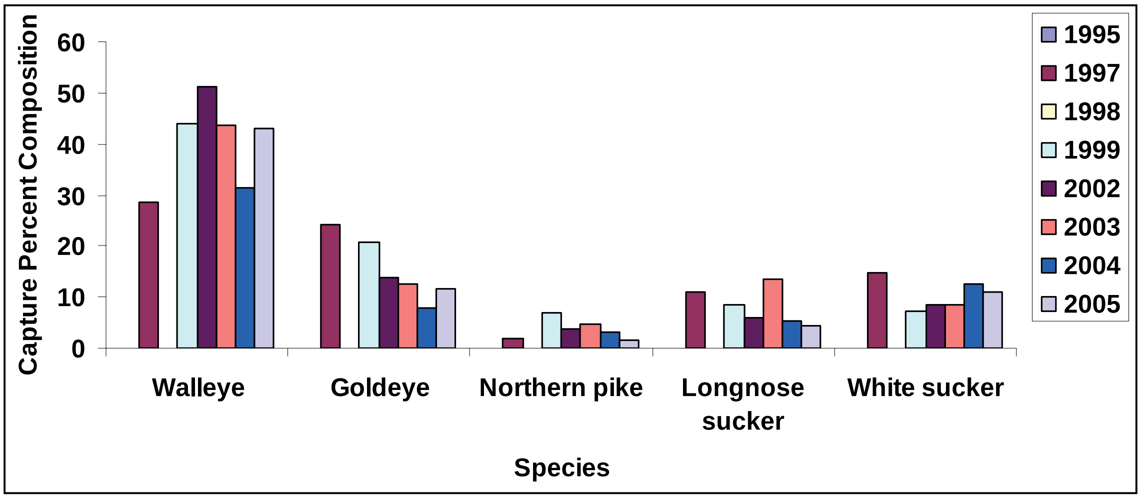


Figure 5.1-19 Catch-per-unit-effort (CPUE) for captured fish of all species combined, Athabasca River spring electrofishing inventory, 1995 to 2005.

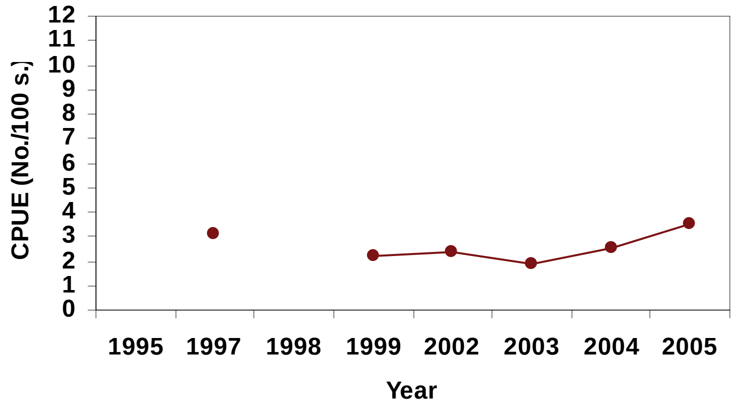


Figure 5.1-20 Catch-per-unit-effort (CPUE) for key indicator species, Athabasca River spring electrofishing inventory, 1995 to 2005.

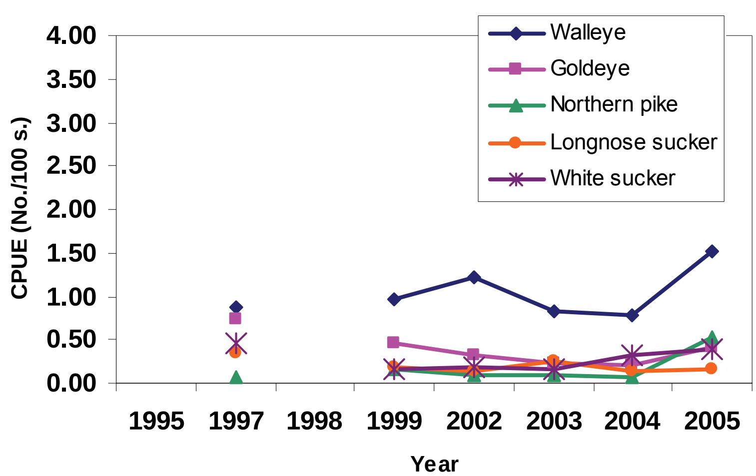
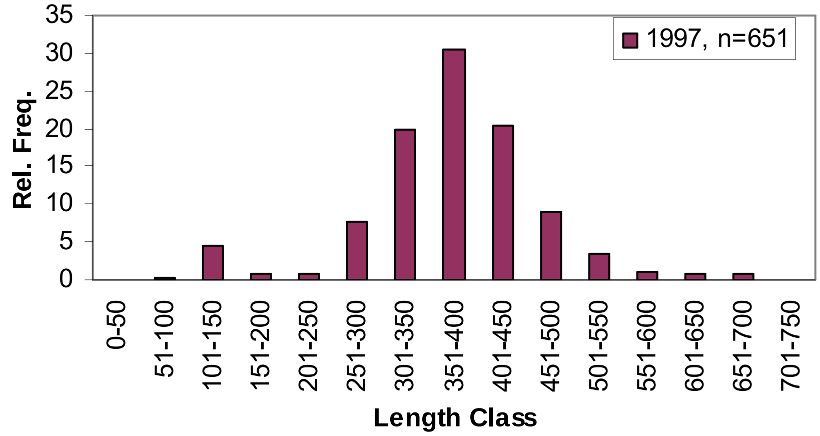
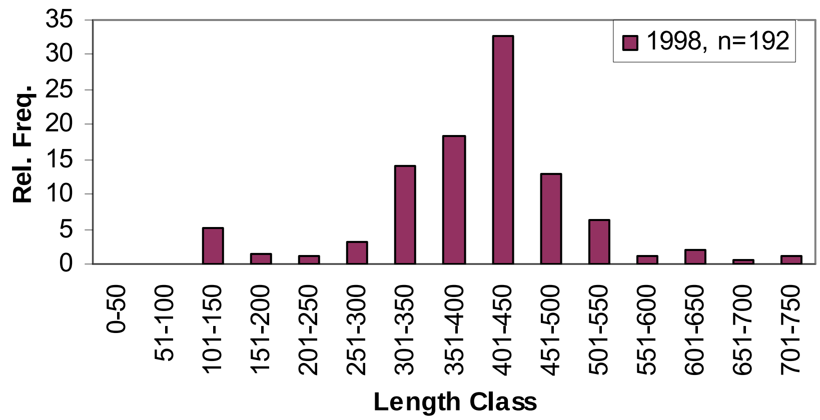


Figure 5.1-21 Relative length-frequency distributions for walleye captured in the Athabasca River, spring and fall, 1997 to 2005.





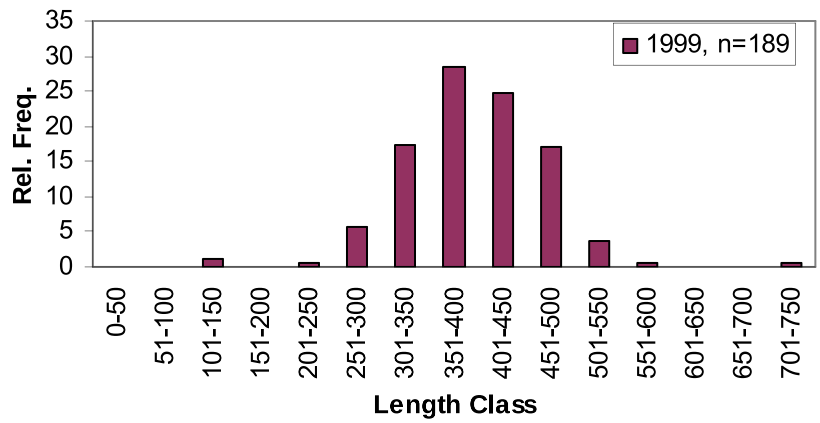


Figure 5.1-21 (Cont'd.)

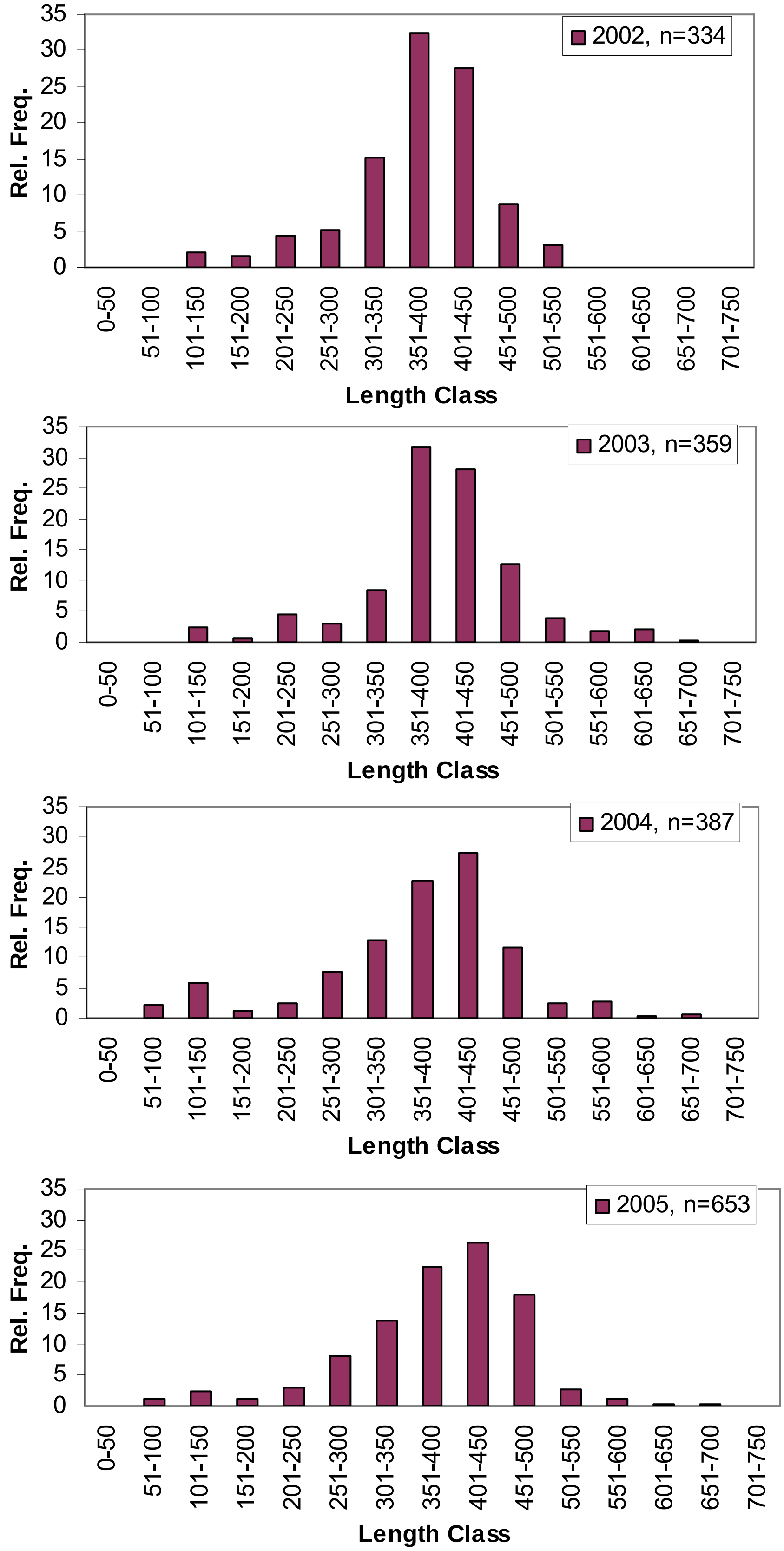
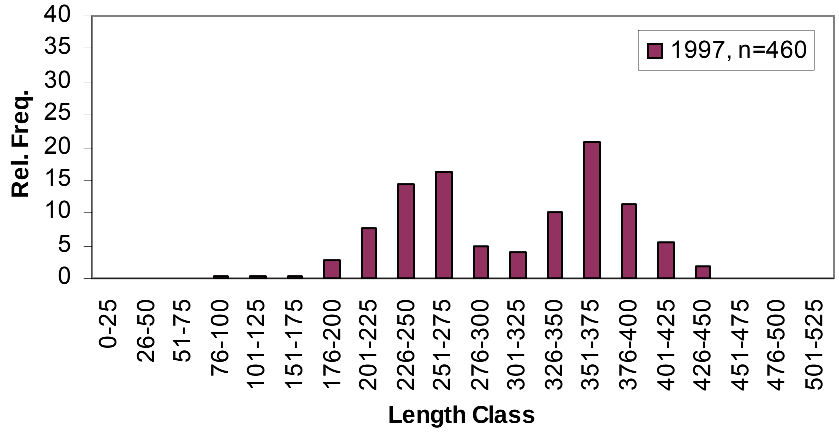
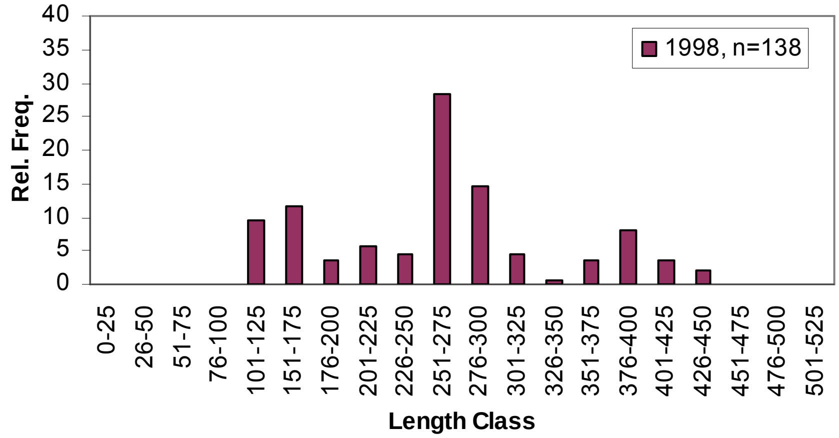


Figure 5.1-22 Relative length-frequency distributions for goldeye captured in the Athabasca River, spring and fall, 1997 to 2005.





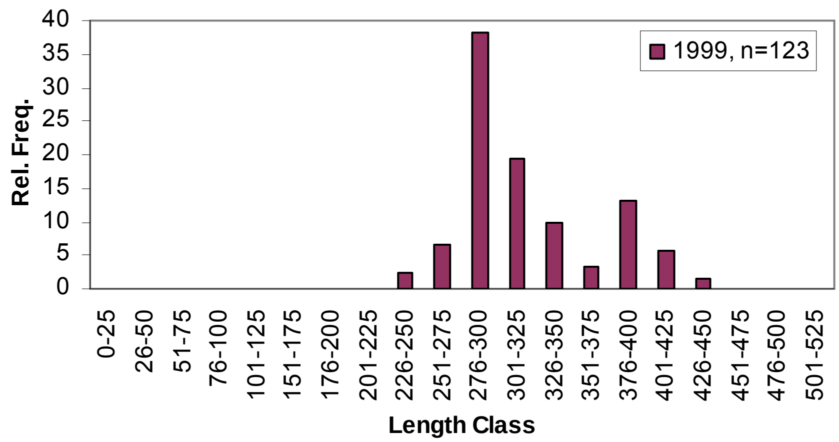


Figure 5.1-22 (Cont'd.)

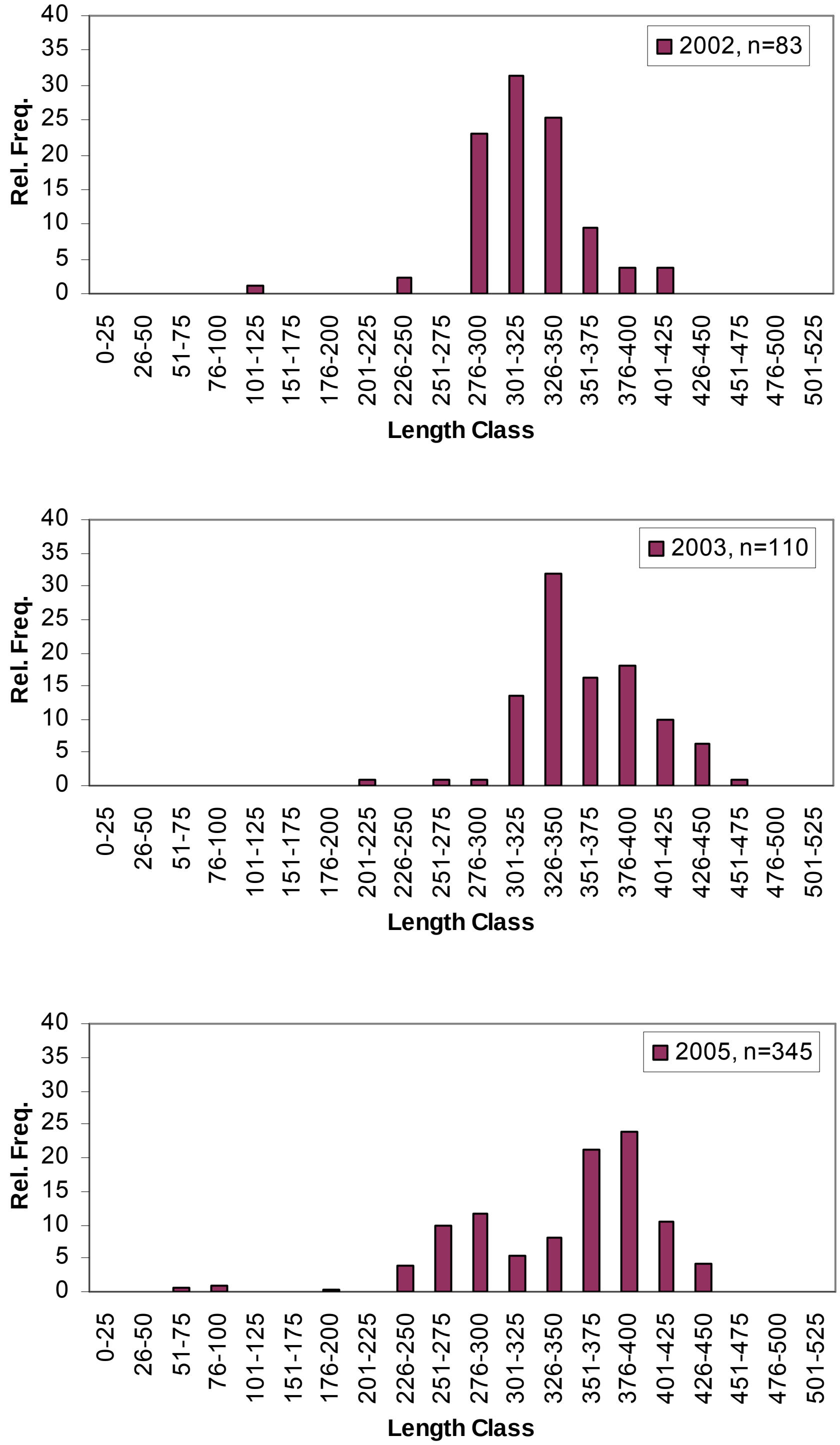


Figure 5.1-23 Relative length-frequency distributions for longnose sucker captured in the Athabasca River, spring and fall, 1997 to 2005.

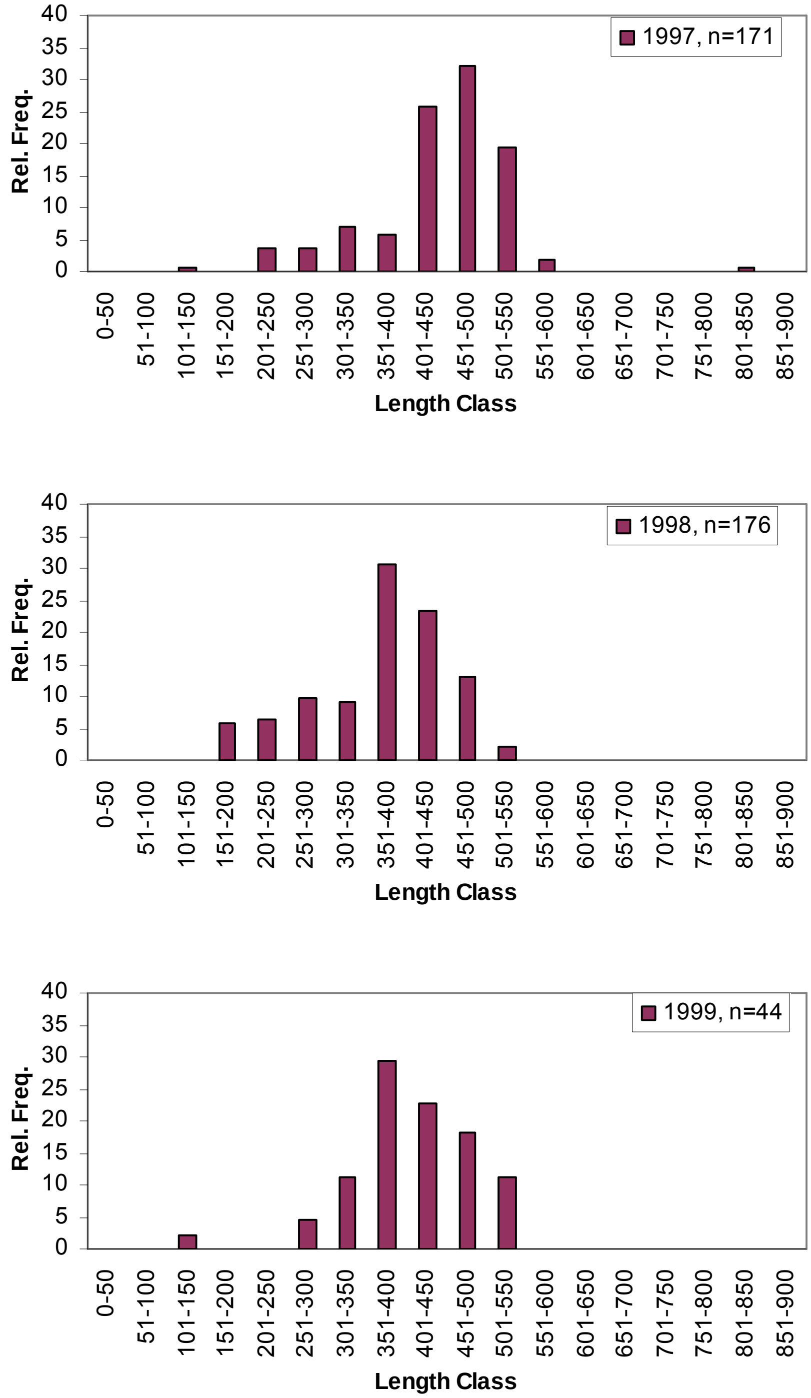


Figure 5.1-23 (Cont'd.)

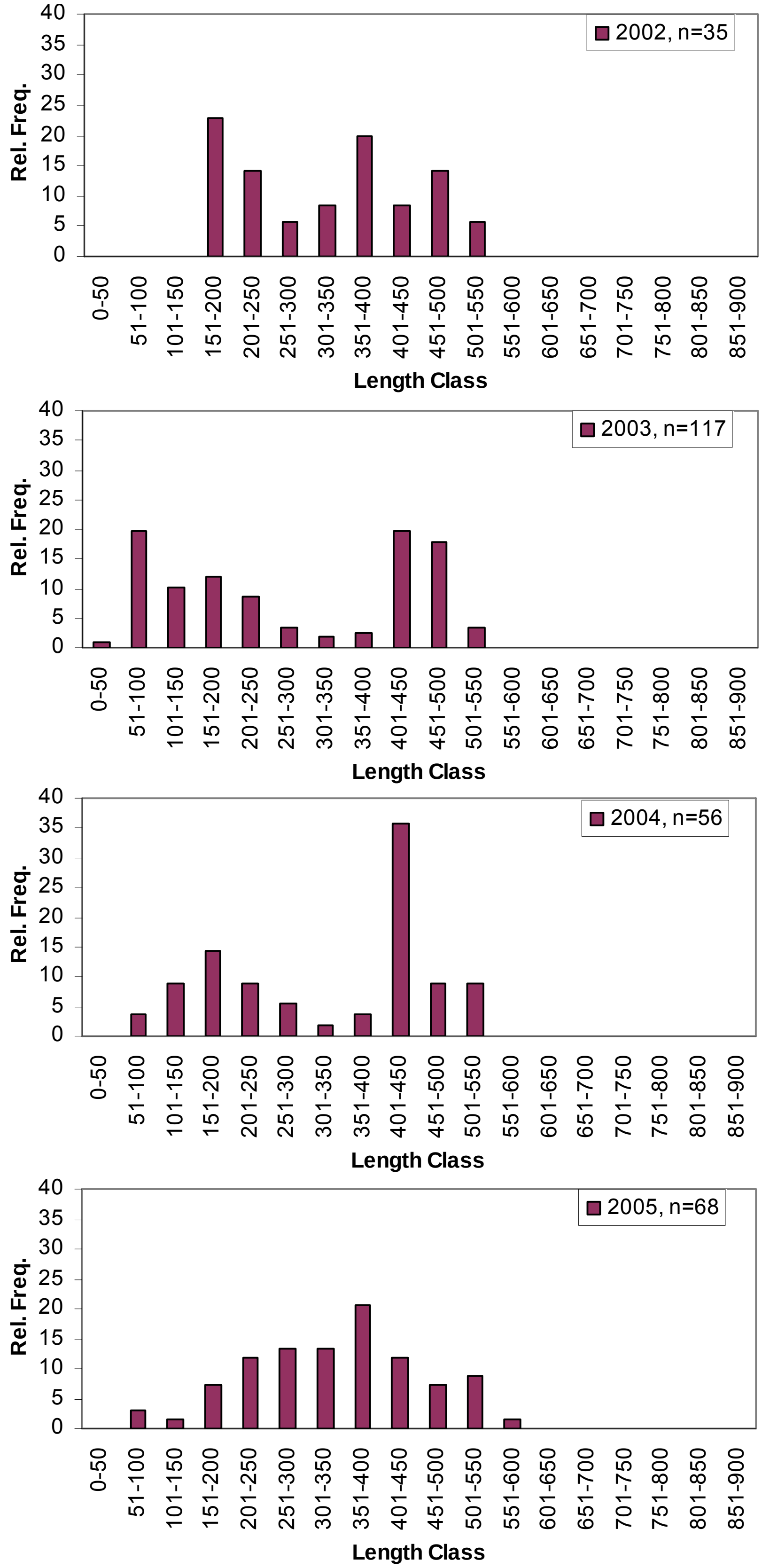


Figure 5.1-24 Relative length-frequency distributions for northern pike captured in the Athabasca River, spring and fall, 1997 to 2005.

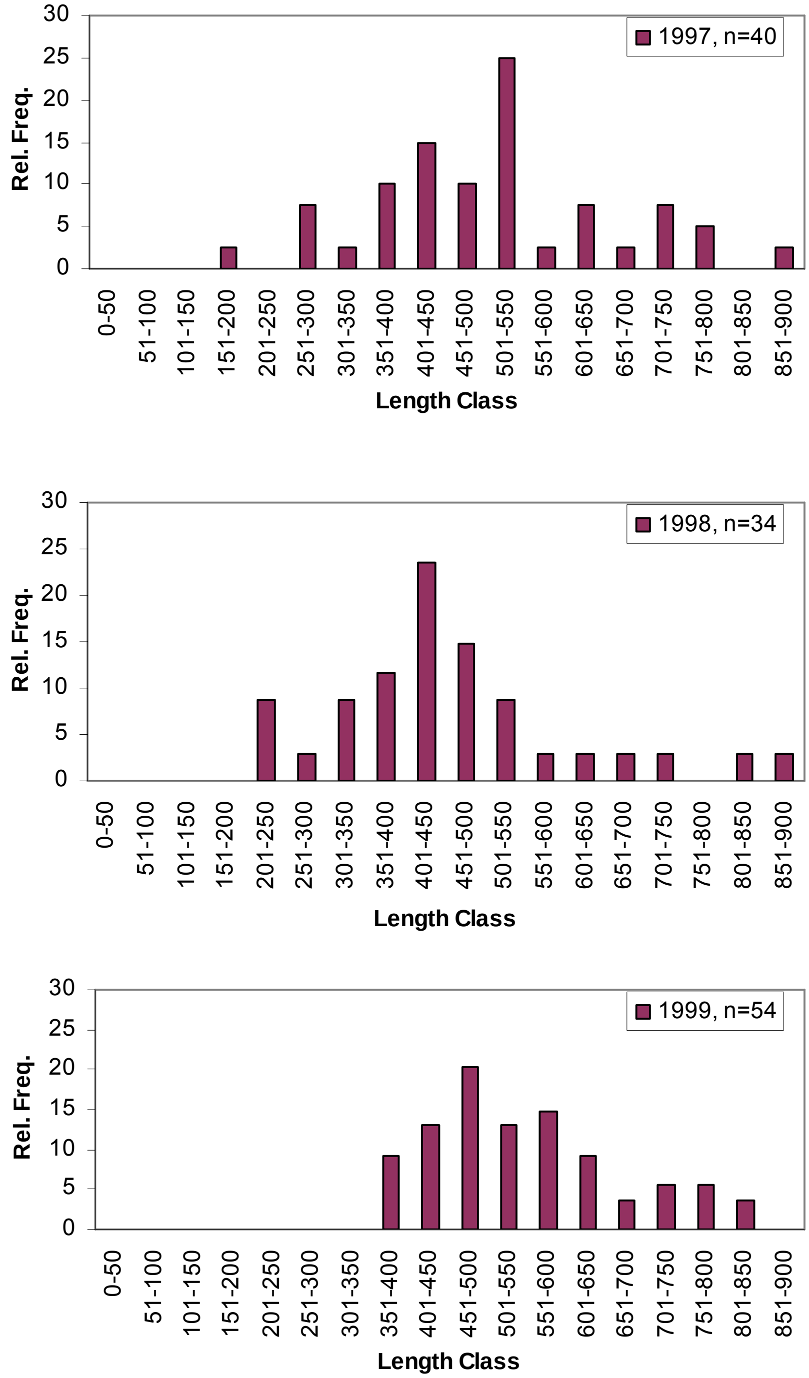


Figure 5.1-24 (Cont'd.)

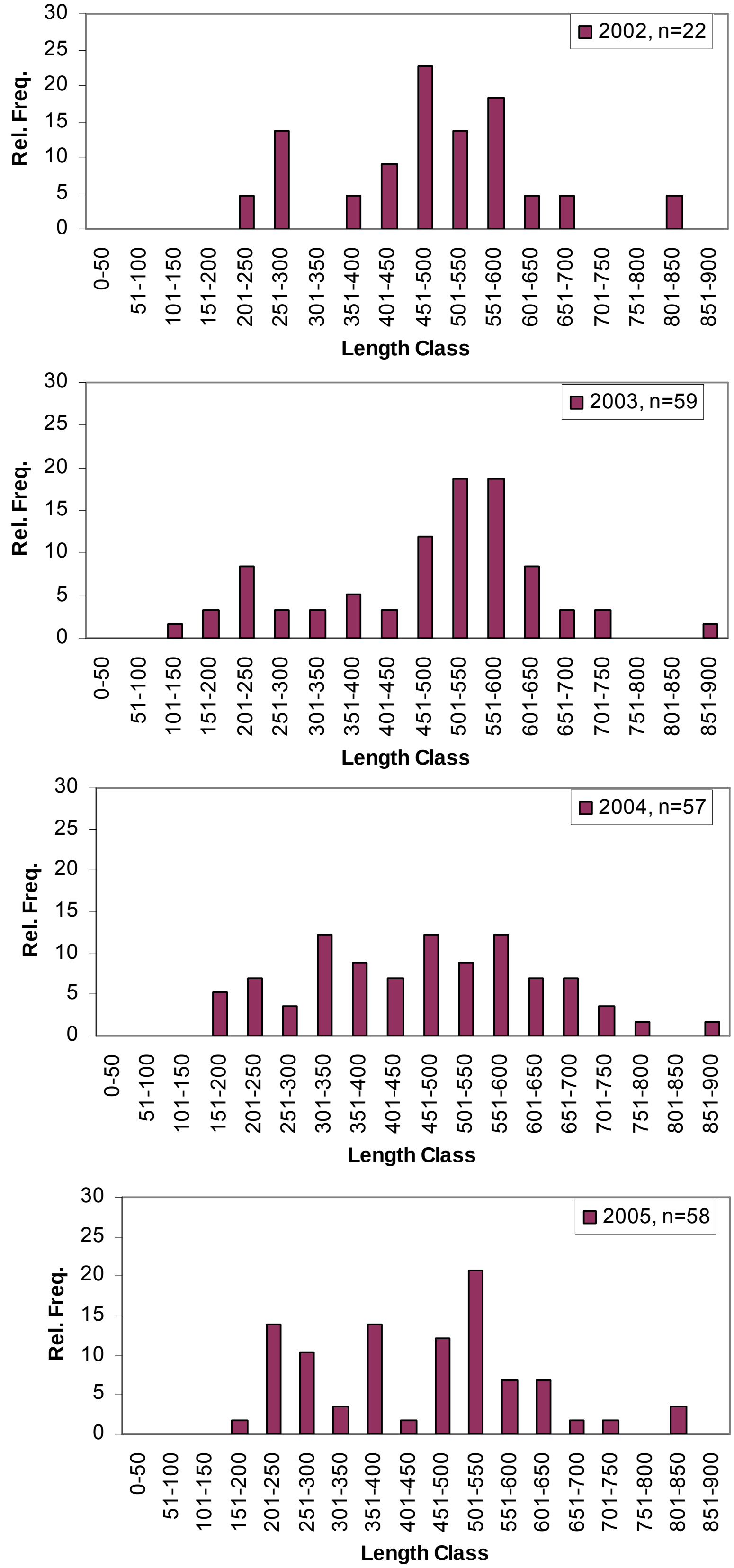
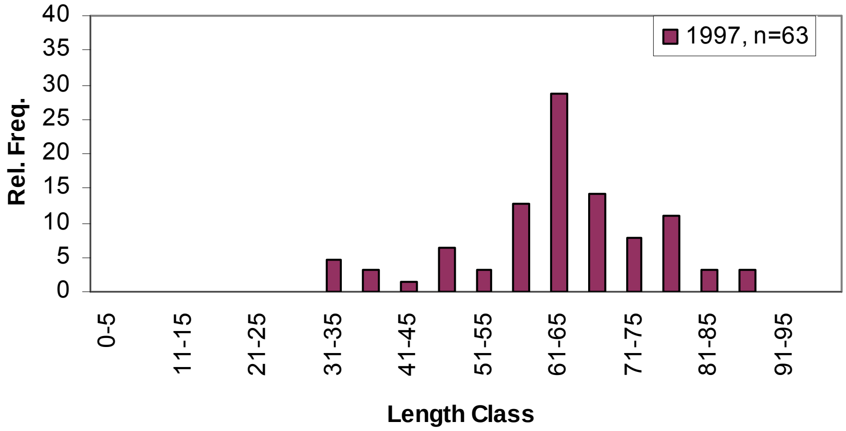
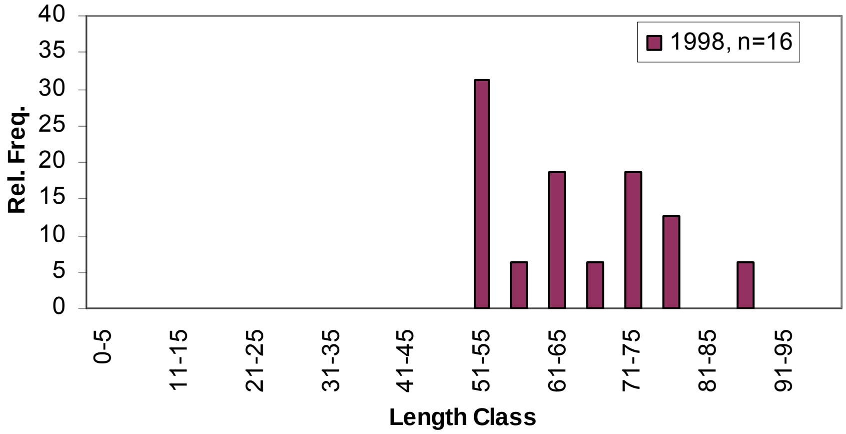


Figure 5.1-25 Relative length-frequency distributions for trout-perch captured in the Athabasca River, spring and fall, 1997 to 2005.





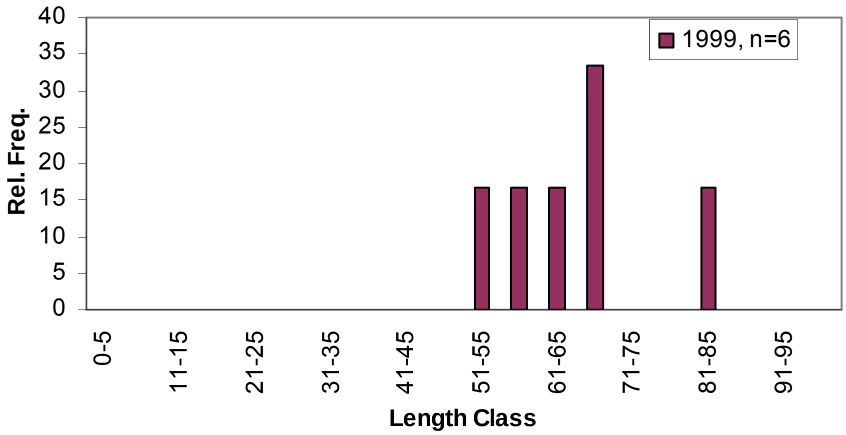


Figure 5.1-25 (Cont'd.)

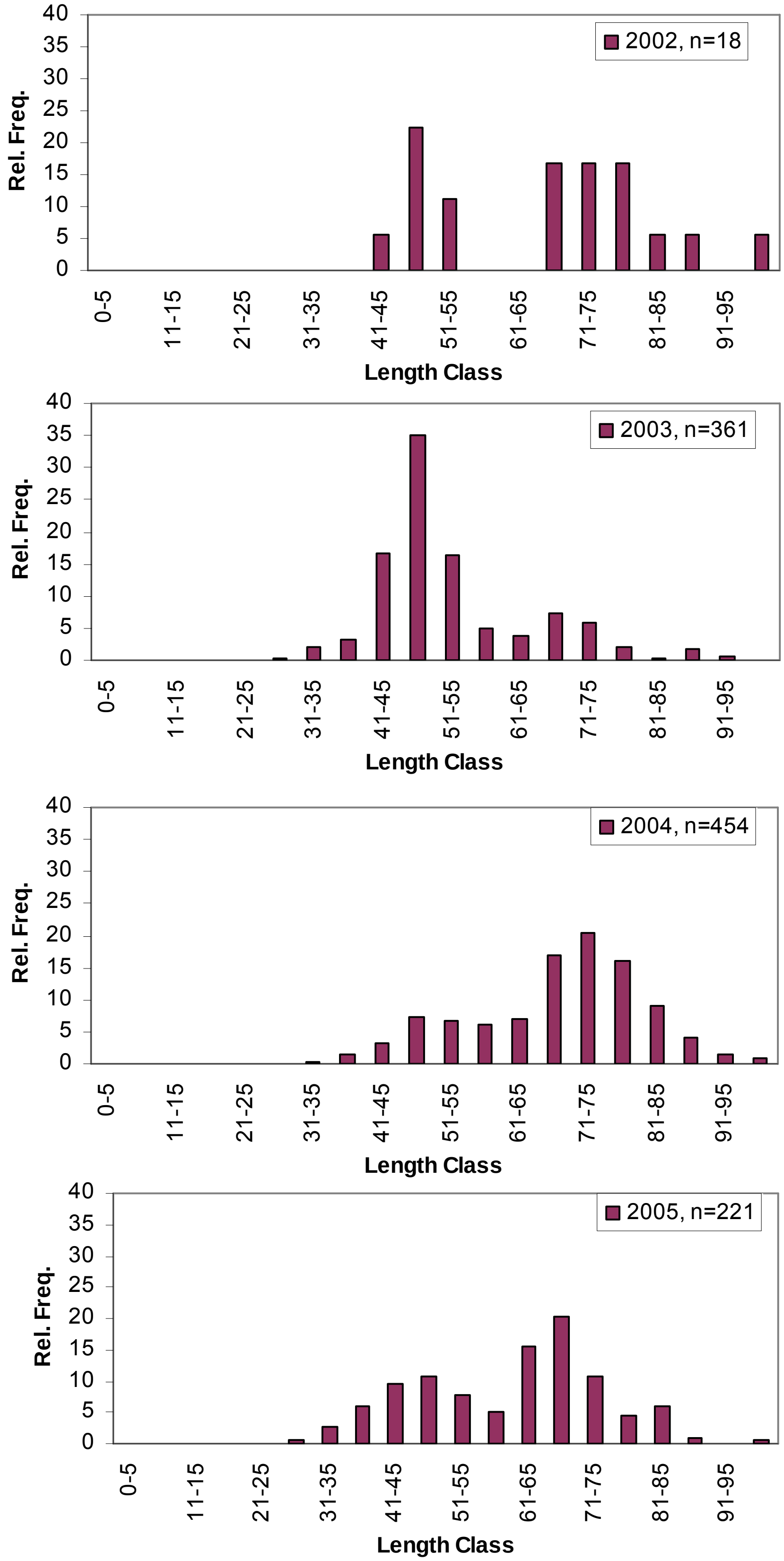


Figure 5.1-26 Ratio of undersize to legal size walleye captured from the Athabasca River, spring 2005.

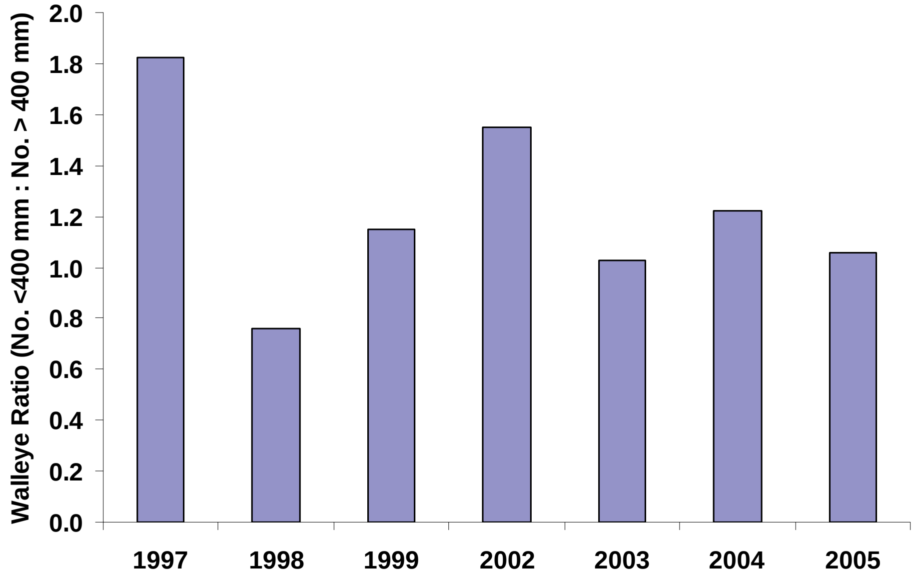


Figure 5.1-27 Ratio of undersize to legal size northern pike captured from the Athabasca River, spring 2005.

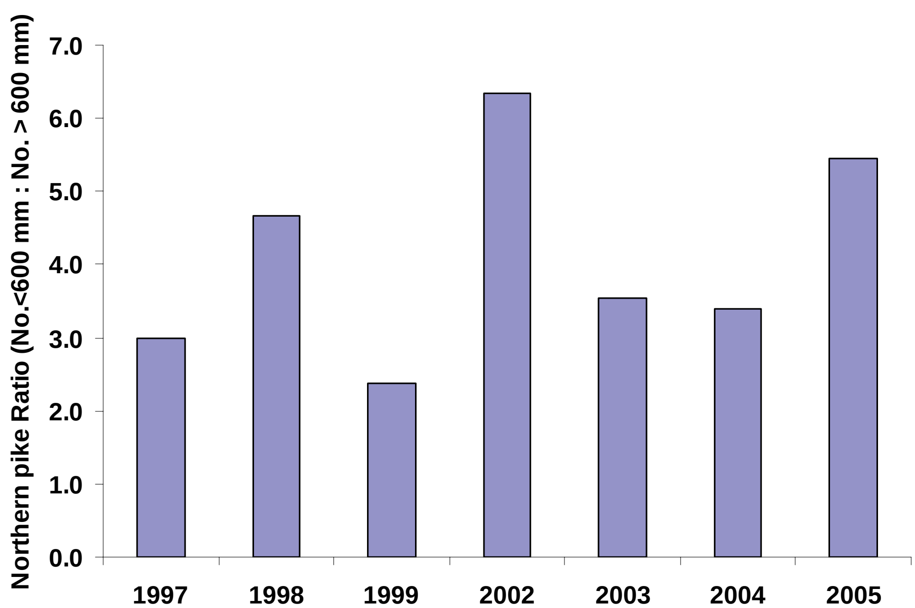


Table 5.1-9 Results of multi-year (1997-2005) comparisons of weight-length relationship (condition) for key indicator fish species, Athabasca River.

Species		Year						
		1997	1998	1999	2002	2003	2004	2005
Walleye	n =	121	81	76	130	67	144	246
	Mean	0.980	0.986	0.999	0.995	0.939	1.017	1.002
	SE	0.011	0.014	0.009	0.011	0.018	0.011	0.012
Northern pike	n =	14	7	20	17	12	13	16
	Mean	0.647	0.653	0.698	0.659	0.705	0.793	0.745
	SE	0.033	0.022	0.019	0.022	0.056	0.061	0.043
Longnose sucker	n =	132	14	26	17	23	27	18
	Mean	1.262	1.156	1.295	1.27	1.203	1.294	1.369
	SE	0.015	0.021	0.024	0.03	0.024	0.047	0.102
Goldeye	n =	149	20	12	34	42	61	55
	Mean	1.089	1.135	1.172	1.074	1.098	1.172	1.097
	SE	0.011	0.041	0.029	0.01	0.013	0.017	0.016
Lake whitefish	n =	60	181	62	-	42	51	136
	Mean	1.636	1.449	1.429	-	1.554	1.552	1.604
	SE	0.025	0.014	0.015	-	0.029	0.021	0.018

Figure 5.1-28 Mean condition factor (± 1 SE) for key indicator fish species in the oil sands region of the Athabasca River, 1997-2005.

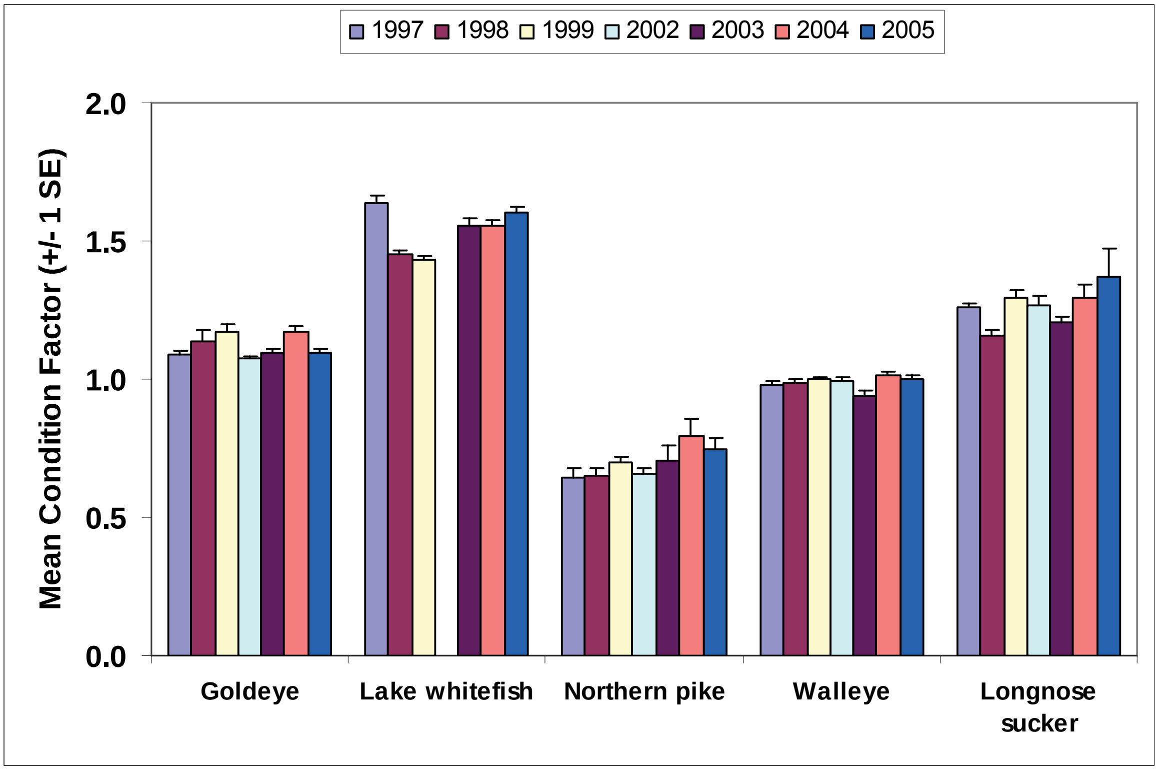


Table 5.1-10 Summary of external pathology indices, Athabasca River inventories, 1995-2005.

Species	Mean Pathology Index							
	1995	1997	1998	1999	2002	2003	2004	2005
Goldeye	9.6	4.3	0.5	3.7	0.4	1.9	0.4	0.7
Longnose sucker	11	5.8	3.5	4.1	0.9	0.5	1.4	1.1
Walleye	2.8	1.5	2.1	18.3	1.4	1.1	0.3	1.5
White sucker	18.6	3.2	9.6	5.7	0.6	7.1	0.4	2.5

Table 5.1-11 Metrics and mercury concentrations in lake whitefish and walleye collected from the Athabasca River, Fall 2005.

Species	Sex	FishID	Stage	Fork Length (mm)	Total Weight (g)	LSI	GSI	Mercury Concentration (mg/kg)
Lake whitefish	**Female**	ATR-SR-39	Adult	393	873.5	0.87	21.61	0.091
		ATR-MR-16	Adult	405	1045.3	1.80	17.90	0.062
		ATR-SR-25	Adult	411	1132.6	1.52	31.42	0.074
		ATR-SR-43	Adult	415	1087.3	1.62	20.04	0.106
		ATR-SR-26	Adult	421	1071.4	1.53	18.97	0.064
		ATR-SR-37	Adult	430	1552.8	1.48	23.21	0.16
		ATR-SR-52	Adult	447	1378.1	2.04	22.36	0.148
		ATR-MR-13	Adult	470	1768.6	1.72	25.37	0.159
		ATR-MR-12	Adult	499	2156.5	2.92	22.81	0.058
		ATR-SR-36	Adult	501	2062.9	2.64	20.16	0.105
		ATR-SR-49	Adult	503	2227.6	1.82	22.34	0.141
	Mean			445	1487.0	1.81	22.38	0.106
	SD			41.5	495.3	0.56	0.23	0.04
	Male	ATR-SR-33	Adult	354	571	0.58	1.55	0.068
		ATR-SR-24	Adult	366	663.2	0.61	1.13	0.081
		ATR-SR-23	Adult	371	664.3	0.64	1.86	0.034
		ATR-MR-15	Adult	400	962.4	0.71	1.43	0.049
		ATR-SR-38	Adult	401	909.9	0.70	1.28	0.102
		ATR-SR-21	Adult	403	914	0.59	1.58	0.062
		ATR-MR-14	Adult	415	1164.7	1.30	2.69	0.049
		ATR-SR-42	Adult	422	1000.6	0.69	1.81	0.073
		ATR-SR-54	Adult	447	1595.5	1.03	1.95	0.055
		ATR-SR-53	Adult	469	1632.5	0.83	1.62	0.071
		ATR-SR-50	Adult	474	1627	0.84	1.86	0.17
		ATR-MR-11	Adult	484	1672.4	1.19	1.69	0.099
		ATR-MR-10	Adult	494	1813	1.12	2.49	0.147
		ATR-SR-32	Adult	496	1661.9	0.81	1.79	0.083
		ATR-SR-34	Adult	538	2546.9	1.04	2.40	0.074
	Mean			436	1288.1	1.81	0.85	0.081
	SD			55.0	548.3	0.44	0.23	0.037

GSI = gonad somatic index; LSI = liver somatic index

Table 5.1-11 (Cont'd.)

Species	Sex	FishID	Stage	Fork Length (mm)	Total Weight (g)	LSI	GSI	Mercury Concentration (mg/kg)
Walleye	**Female**	ATR-MR-2	Adult	508	1541.4	2.73	4.42	0.464
		ATR-SR-29	Adult	514	1405.8	1.48	2.59	0.542
		ATR-MR-8	Adult	559	1994	1.73	3.64	0.391
		ATR-SR-48	Adult	565	1678	5.07	3.91	0.516
		ATR-MR-6	Adult	568	2242	2.84	5.47	0.440
		ATR-SR-31	Adult	593	2590.8	2.22	4.95	0.677
		ATR-SR-51	Adult	604	2924.8	2.15	5.48	0.404
		ATR-SR-47	Adult	635	3060	2.26	6.62	0.694
		ATR-MR-2	Adult	508	1541.4	2.73	4.42	0.464
	Mean			568.3	2179.6	2.56	4.63	0.516
	SD			43.12	631.95	1.11	1.26	0.116
	Male	ATR-MR-1	Immature	461	1090	1.19	0.19	0.173
		ATR-MR-3	Adult	412	740.6	0.95	1.65	0.234
		ATR-MR-4	Adult	459	1172	1.65	1.65	0.526
		ATR-MR-5	Adult	488	1205	1.09	2.38	0.317
		ATR-MR-7	Adult	467	1205	1.01	2.73	0.617
		ATR-MR-9	Immature	235	115	nd	nd	0.094
		ATR-MR-17	Immature	366	496.2	1.18	0.32	0.193
		ATR-SR-19	Adult	384	550	1.03	1.98	0.220
		ATR-SR-22	Adult	501	1344.3	1.20	1.69	0.737
		ATR-SR-27	Immature	225	115.6	0.87		0.078
		ATR-SR-28	Immature	337	402.2	1.62	0.32	0.152
		ATR-SR-30	Adult	399	672.4	0.78	2.14	0.216
		ATR-SR-35	Adult	470	1138.7	1.06	2.13	0.765
		ATR-SR-40	Adult	429	759.3	1.11	2.33	0.284
		ATR-SR-44	Adult	451	1038	1.80	1.67	0.709
		ATR-SR-45	Adult	473	1192.3	0.98	2.02	0.311
	Mean			409.8	827.3	1.17	1.66	0.352
	SD			83.7	402.7	0.30	0.81	0.237
	Immature	ATR-SR-46	Immature	212	91	1.34	n/d	0.070
		ATR-MR-18	Immature	262	201.5	1.05	n/d	0.102
		ATR-SR-41	Immature	302	278	1.28	n/d	0.119
		ATR-SR-20	Immature	322	304.6	0.66	n/d	0.180
	Mean			274.5	218.8	1.08	n/d	0.118
	SD			48.6	95.7	0.31	n/d	0.046

nd = no data

GSI = gonad somatic index; LSI = liver somatic index

Table 5.1-12 External and internal abnormalities for adult lake whitefish and walleye from the Athabasca River, September 2005.

Exam	Observation		Lake whitefish		Walleye	
			Female (n=11)	Male (n=15)	Female (n=8)	Male (n=16)
External	Fin Erosion	Light	0	0	1	3
		Moderate	0	0	0	0
		Severe	0	0	0	0
	Skin aberration	Mild	1	1	0	0
		Moderate	0	0	0	0
		Severe	0	0	0	0
	Eye	Opaque	0	0	0	0
		Swollen	0	0	0	0
		Bleeding	0	1	0	2
		Missing	0	0	0	0
		Other	0	0	0	0
	Opercle shortening	Mild	0	0	0	0
		Moderate	0	0	0	0
		Severe	1	0	0	0
Internal	Pseudobranchs	Swollen	0	0	0	0
		Lithic	0	0	0	0
		Swollen & lithic	0	0	0	0
		Inflamed	0	0	0	0
	Gills	Frayed	0	0	0	0
		Clubbed	0	0	0	0
		Marginate	1	1	1	1
		Pale	0	0	0	0
		Other	0	0	0	0
	Thymus hemorrhage	Mild	1	1	0	0
		Moderate	0	0	0	0
		Severe	0	0	0	0
	Mesenteric fat	<50%	2	5	3	7
		50%	0	1	0	2
		>50%	0	1	5	5
		Complete	0	0	0	1
	Parasites	Few	7	9	3	7
		Moderate	0	0	2	3
		Numerous	0	0	1	0

Table 5.1-12 (Cont'd.)

Exam	Observation		Lake whitefish Female (n=11)	Lake whitefish Male (n=15)	Walleye Female (n=8)	Walleye Male (n=16)
Internal Cont'd.	Liver	Fatty	0	3	2	8
		Cysts/nodules	0	0	0	0
		Focal discolouration	0	1	0	1
		General discolouration	0	0	1	3
	Kidney	Swollen	0	0	0	0
		Mottled	0	0	0	0
		Granular	0	0	0	0
		Urolithiasis	0	0	0	0
	Spleen	Granular	1	2	2	1
		Nodular	0	0	0	0
		Enlarged	1	0	0	0
	Hindgut	Slightly inflamed	4	3	0	0
		Moderately inflamed		1	0	0
	Gall Bladder	Yellow full	7	8	2	3
		Light to grass green	0	0	0	0
		Dark green to blue-green	0	0	0	0
	Other		0	0	0	0
# of different abnormalities observed[1]			8	8	8	8
% fish with one or more abnormalities[1]			100	73	100	75

[1] Level of mesenteric fat, gall bladder colour and presence of fatty livers excluded from calculation as they relate to food availability and storage. An individual fish may exhibit more than one observed abnormality.

Figure 5.1-29 Scatterplots of mercury concentration in lake whitefish and walleye muscle versus length, Athabasca River, 2005.

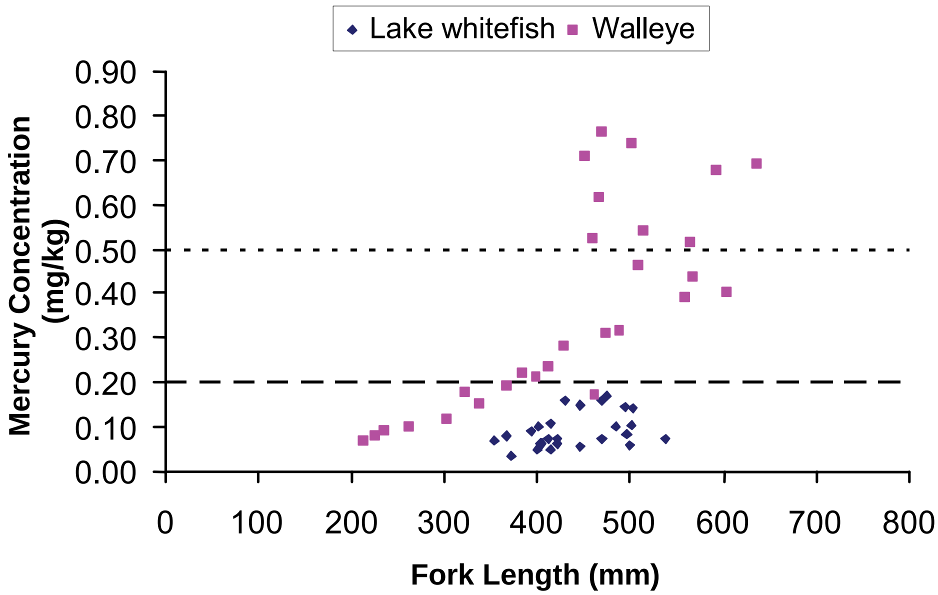


Figure 5.1-30 Scatterplots of mercury concentration in lake whitefish and walleye muscle versus weight, Athabasca River, 2005.

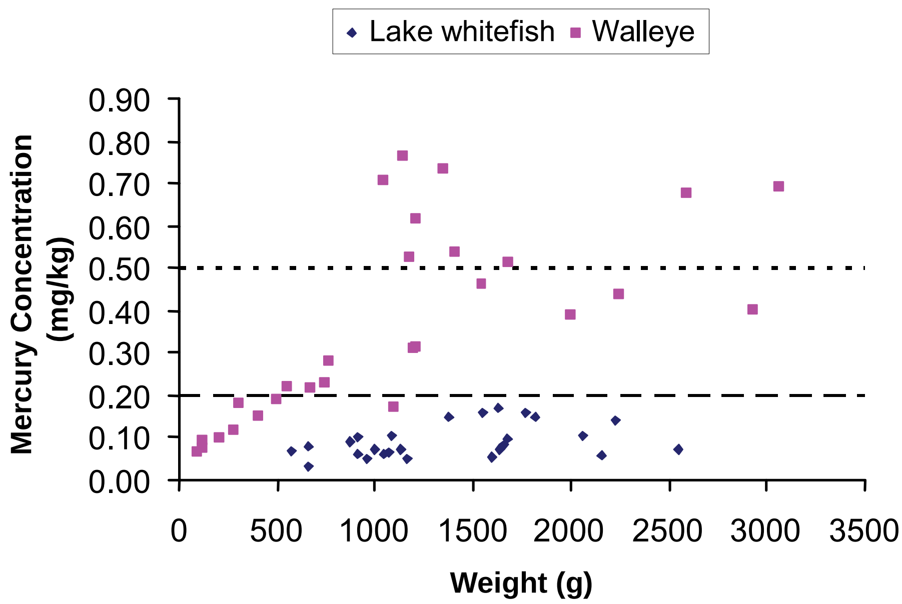


Table 5.1-13 Rank correlations between mercury concentration in fish muscle from Athabasca River lake whitefish and walleye versus length, weight, LSI and GSI.

Organism Metric	Rank Correlation with Mercury Concentrations (r_s)					
	Lake whitefish			Walleye		
	Male n=15	Female n=11	Combined n=26	Male n=11	Female n=9	Combined n=20
Fork length	**0.506**	0.309	0.403	**0.719**	0.286	**0.573**
Total Weight	0.425	0.300	0.372	**0.741**	0.143	**0.581**
GSI	-0.054	0.400	0.337	0.108	0.119	0.433
LSI	0.236	-0.182	0.314	0.487	0.190	0.372

Bold values indicate a strong correlation.

Figure 5.1-31 Regression analysis of mercury concentration in fish muscle from Athabasca River male lake whitefish and male walleye versus length, 2005.

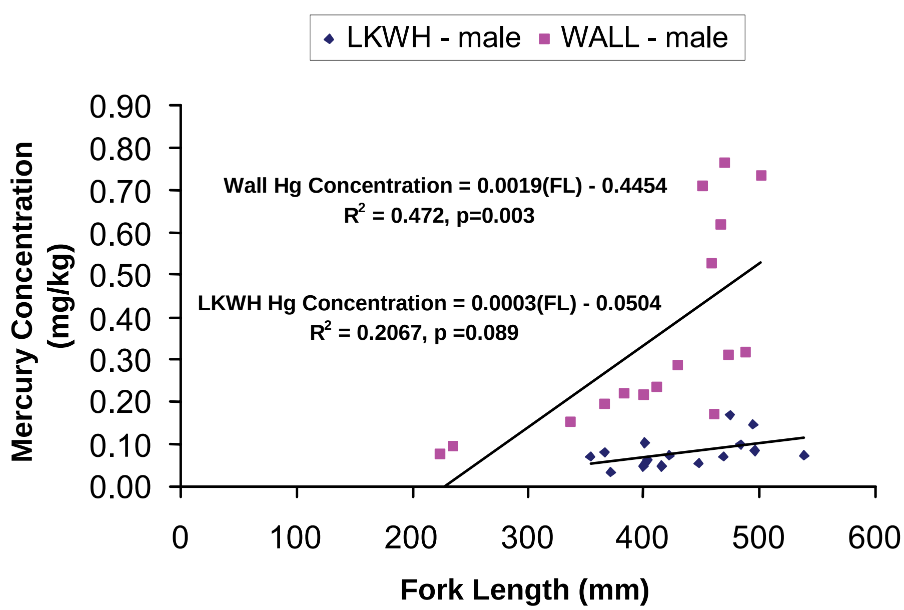


Table 5.1-14 Screening of metals and tainting compounds in lake whitefish and walleye composite samples collected from the Athabasca River against criteria fish consumption for the protection of human health.

	UNITS	DL	Composite				Health Canada Criteria[1]		National USEPA		Region III USEPA[2]
			WALL		LKWH						
			Female	Male	Female	Male	General	Subsistence	Recreational	Subsistence	Risk-based Criteria
Total Metals											
Aluminum (Al)	mg/kg	2	<2	<2	<2	<2	nc	nc	nc	nc	nc
Antimony (Sb)	mg/kg	0.04	<0.04	<0.04	<0.04	<0.04	nc	nc	nc	nc	0.54
Arsenic (As)	mg/kg	0.05	***<0.05***	***<0.05***	***<0.05***	***<0.05***	nc	nc	0.026	0.00327	0.0021
Barium (Ba)	mg/kg	0.08	0.12	0.11	0.1	0.35	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	10	70	90	50	70	nc	nc	nc	nc	nc
Chromium (Cr)	mg/kg	0.05	0.17	0.13	0.13	0.14	nc	nc	nc	nc	4.1
Cobalt (Co)	mg/kg	0.08	<0.08	<0.08	<0.08	<0.08	nc	nc	nc	nc	nc
Copper (Cu)	mg/kg	0.05	0.29	0.31	0.46	0.35	nc	nc	nc	nc	54
Iron (Fe)	mg/kg	2	5	5	7	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	2	287	273	258	251	nc	nc	nc	nc	nc
Manganese (Mn)	mg/kg	0.04	0.09	0.1	0.07	0.17	nc	nc	nc	nc	190
Mercury (Hg)-Total	mg/kg	0.004	***0.738***	***0.574***	***0.099***	***0.079***	0.5	0.2	0.4	0.049	0.14
Molybdenum (Mo)	mg/kg	0.04	<0.04	0.39	<0.04	0.05	nc	nc	nc	nc	6.8
Nickel (Ni)	mg/kg	0.01	0.1	0.08	0.37	0.1	nc	nc	nc	nc	27
Phosphorus (P)	mg/kg	2	2300	2370	2430	2240	nc	nc	nc	nc	nc
Potassium (K)	mg/kg	2	4220	4370	4390	4520	nc	nc	nc	nc	nc

value = exceeds USEPA screening value for subsistence fishers; ***value*** = exceeds Region III risk-based criteria

value = exceeds USEPA screening criteria for recreational fishers; nc = no criterion

[1] last updated 15 December 2005; found at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html

[2] last updated April 2006; found at http://www.epa.gov/reg3hwmd/risk/human/index.htm

Table 5.1-14 (Cont'd.)

	UNITS	DL	Composite				Health Canada Criteria[1]		National USEPA		Region III USEPA[2]
			WALL		LKWH						
			Female	Male	Female	Male	General	Subsistence	Recreational	Subsistence	Risk-based Criteria
Total Metals Cont'd.											
Selenium (Se)	mg/kg	0.06	0.46	0.6	0.45	0.38	nc	nc	20	2.457	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	2	210	212	377	208	nc	nc	nc	nc	nc
Strontium (Sr)	mg/kg	0.04	0.22	0.17	0.29	4.03	nc	nc	nc	nc	810
Thallium (Tl)	mg/kg	0.04	<0.04	<0.04	<0.04	<0.04	nc	nc	nc	nc	0.095
Tin (Sn)	mg/kg	0.08	<0.08	<0.08	<0.08	<0.08	nc	nc	nc	nc	810
Titanium (Ti)	mg/kg	0.05	0.16	<0.05	<0.05	0.2	nc	nc	nc	nc	Nc
Vanadium (V)	mg/kg	0.006	0.03	0.028	0.031	0.071	nc	nc	nc	nc	1.4
Zinc (Zn)	mg/kg	0.2	5.2	5.4	4.9	5.2	nc	nc	nc	nc	410
Tainting Compounds											
Thiophene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	nc
Toluene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	110
m+p-Xylenes	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc	nc
o-Xylene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01					
1,3,5-Trimethylbenzene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01					
Naphthalene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01					
1,2-Dichloroethane d4	%		98	99	98	97					
Toluene d8	%		107	107	97	98					
4-Bromofluorobenzene	%		91	88	104	107					

value = exceeds USEPA screening value for subsistence fishers; ***value*** = exceeds Region III risk-based criteria

value = exceeds USEPA screening criteria for recreational fishers; nc = no criterion

[1] last updated 15 December 2005; found at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives_e.html

[2] last updated April 2006; found at http://www.epa.gov/reg3hwmd/risk/human/index.htm

Table 5.1-15 Screening of mercury concentrations in lake whitefish and walleye from the Athabasca River (September 2005) against criteria for fish consumption for the protection of human health.

Mercury Screening Criteria		Mercury Concentration (mg/kg)
Health Canada	*General Consumer*	0.50
	Subsistence Fishers	0.20
Region III USEPA Risk-Based Criterion[1]		0.14
National USEPA Criteria[2]	Recreational Fishers	0.40
	Subsistence Fishers	0.049
Mercury Concentrations in Athabasca River Fish Muscle Tissue		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Lake whitefish	Female	0.091
		0.062
		0.074
		0.106
		0.064
		0.16
		0.148
		0.159
		0.058
		0.105
		0.141
	Male	0.068
		0.081
		0.034
		0.049
		0.102
		0.062
		0.049
		0.073
		0.055
		0.071
		0.17
		0.099
		0.147
		0.083
		0.074

[1] Region III USEPA risk-based criteria for fish consumption are based on a 70 kg individual consuming 54 g of fish per day over a 30-year period (USEPA 2003). Criterion is for methyl mercury. Criteria last updated April 2006.

[2] National USEPA screening values for recreational fishers are based on a 70 kg individual consuming 17.5 g of fish per day over a 70-year period; screening values for subsistence fishers are based on a 142.4 kg individual consuming 17.5 g of fish per day over a 70-year period (USEPA 2000). Criterion is for methyl mercury.

Table 5.1-15 (Cont'd.)

Mercury Concentrations in Athabasca River Fish Muscle Tissue		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Walleye	Female	0.464
		0.542
		0.391
		0.516
		0.440
		0.677
		0.404
		0.694
		0.464
	Male	0.173
		0.234
		0.526
		0.317
		0.617
		0.094
		0.193
		0.220
		0.737
		0.078
		0.152
		0.216
		0.765
		0.284
		0.709
		0.311
	Immature	0.070
		0.102
		0.119
		0.180

[1] Region III USEPA risk-based criteria for fish consumption are based on a 70 kg individual consuming 54 g of fish per day over a 30-year period (USEPA 2003). Criterion is for methyl mercury. Criteria last updated April 2006.

[2] National USEPA screening values for recreational fishers are based on a 70 kg individual consuming 17.5 g of fish per day over a 70-year period; screening values for subsistence fishers are based on a 142.4 kg individual consuming 17.5 g of fish per day over a 70-year period (USEPA 2000). Criterion is for methyl mercury.

Table 5.1-16 Screening of mercury concentrations in lake whitefish and walleye from the Athabasca River (September 2005) against criteria for the protection of fish.

Effects Thresholds for Fish[1]		Mercury Concentration (mg/kg)
No effects – lethal		1.91
No effects – sublethal		2.28
Effects - lethal		6.2
Effects - sublethal		8.6
Mercury Concentrations in Athabasca River Fish Muscle Tissue		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Lake whitefish	Female	0.091
		0.062
		0.074
		0.106
		0.064
		0.16
		0.148
		0.159
		0.058
		0.105
		0.141
	Male	0.068
		0.081
		0.034
		0.049
		0.102
		0.062
		0.049
		0.073
		0.055
		0.071
		0.17
		0.099
		0.147
		0.083
		0.074

[1] Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Table 5.1-16 (Cont'd.)

Mercury Concentrations in Athabasca River Fish Muscle Tissue		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Walleye	Female	0.464
		0.542
		0.391
		0.516
		0.440
		0.677
		0.404
		0.694
		0.464
	Male	0.173
		0.234
		0.526
		0.317
		0.617
		0.094
		0.193
		0.220
		0.737
		0.078
		0.152
		0.216
		0.765
		0.284
		0.709
		0.311
	Immature	0.070
		0.102
		0.119
		0.180

Table 5.1-17 Screening of metals and tainting compounds in lake whitefish and walleye composite samples collected from the Athabasca River against criteria for the protection of fish.

Analyte	UNITS	DL	Composite				Thresholds for the Protection of Fish			
			WALL		LKWH		Lowest no-effects Thresholds		Lowest Effects Thresholds	
			Female	Male	Female	Male	Lethal (mg/kg)	Sublethal (mg/kg)	Lethal (mg/kg)	Sublethal (mg/kg)
Total Metals										
Aluminum (Al)	mg/kg	2	<2	<2	<2	<2	1.0	nc	20	nc
Antimony (Sb)	mg/kg	0.04	<0.04	<0.04	<0.04	<0.04	5	nc	9	nc
Arsenic (As)	mg/kg	0.05	<0.05	<0.05	<0.05	<0.05	2.6	0.9	11.2	3.1
Barium (Ba)	mg/kg	0.08	0.12	0.11	0.1	0.35	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
Chromium (Cr)	mg/kg	0.05	0.17	0.13	0.13	0.14	nc	nc	nc	nc
Cobalt (Co)	mg/kg	0.08	<0.08	<0.08	<0.08	<0.08	nc	nc	nc	nc
Copper (Cu)	mg/kg	0.05	0.29	0.31	0.46	0.35	0.5	3.4	0.5	nc
Iron (Fe)	mg/kg	2	5	5	7	5	nc	nc	nc	nc
Lead (Pb)	mg/kg	0.02	<0.02	<0.02	<0.02	<0.02	4.0	nc	nc	nc
Manganese (Mn)	mg/kg	0.04	0.09	0.1	0.07	0.17	nc	nc	nc	nc
Molybdenum (Mo)	mg/kg	0.04	<0.04	0.39	<0.04	0.05	nc	nc	nc	nc
Nickel (Ni)	mg/kg	0.01	0.1	0.08	0.37	0.1	0.82	nc	118.1	nc
Selenium (Se)	mg/kg	0.06	***0.46***	***0.6***	***0.45***	***0.38***	0.28	0.08	0.92	0.32

value = exceeds lethal or sublethal no effects threshold; effects have not been observed at this concentration.

value **=** exceeds lethal or sublethal effects threshold; effects have been observed at this concentration.

nc = no criteria

[1]Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Table 5.1-17 (Cont'd.)

Analyte	UNITS	DL	Composite				Thresholds for the Protection of Fish			
			WALL		LKWH		Lowest no-effects Thresholds		Lowest Effects Thresholds	
			Female	Male	Female	Male	Lethal (mg/kg)	Sublethal (mg/kg)	Lethal (mg/kg)	Sublethal (mg/kg)
Total Metals Cont'd.										
Silver (Ag)	mg/kg	0.02	*0.02*	*<0.02*	*<0.02*	*0.02*	0.003	0.003	nc	nc
Sodium (Na)	mg/kg	2	210	212	377	208	nc	nc	nc	nc
Strontium (Sr)	mg/kg	0.04	0.22	0.17	0.29	4.03	nc	nc	nc	nc
Thallium (Tl)	mg/kg	0.04	<0.04	<0.04	<0.04	<0.04	nc	nc	nc	nc
Tin (Sn)	mg/kg	0.08	<0.08	<0.08	<0.08	<0.08	nc	nc	nc	nc
Titanium (Ti)	mg/kg	0.05	0.16	<0.05	<0.05	0.2	nc	nc	nc	nc
Vanadium (V)	mg/kg	0.006	*0.03*	*0.028*	*0.031*	*0.071*	5.33	0.02	nc	0.41
Zinc (Zn)	mg/kg	0.2	5.2	5.4	4.9	5.2	60	60	nc	nc
Tainting Compounds										
Thiophene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc
Toluene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc
m+p-Xylenes	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc
o-Xylene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc
1,3,5-Trimethylbenzene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc
Naphthalene	mg/kg	0.01	<0.01	<0.01	<0.01	<0.01	nc	nc	nc	nc
1,2-Dichloroethane d4	%		98	99	98	97	nc	nc	nc	nc
Toluene d8	%		107	107	97	98	nc	nc	nc	nc
4-Bromofluorobenzene	%		91	88	104	107	nc	nc	nc	nc

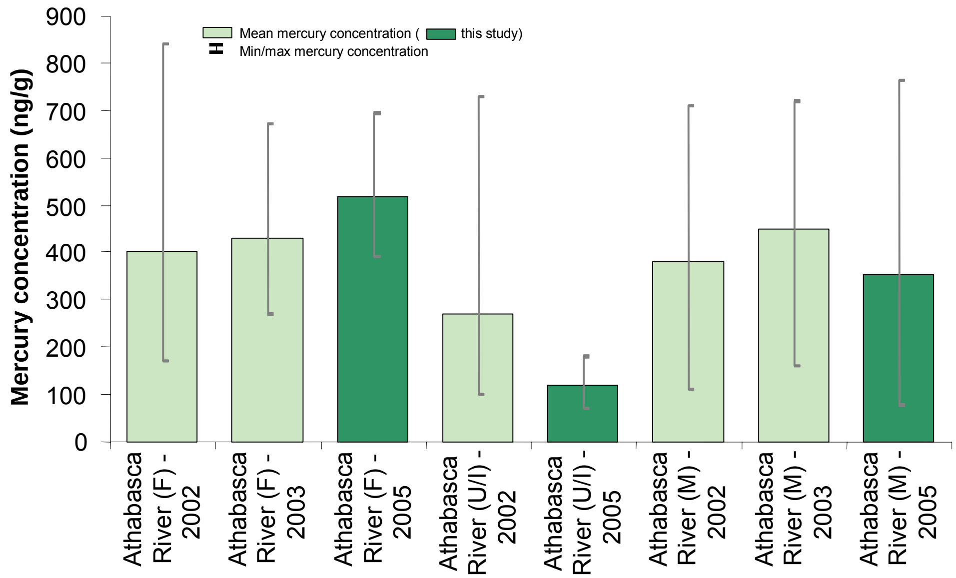
value = exceeds lethal or sublethal no effects threshold; effects have not been observed at this concentration.

***value* =** exceeds lethal or sublethal effects threshold; effects have been observed at this concentration.

nc = no criteria

[1]Threshold values were derived from effects data presented in Jarvinen and Ankley (1999).

Figure 5.1-32 Temporal comparison of mercury concentration in walleye and lake whitefish from the Athabasca River.



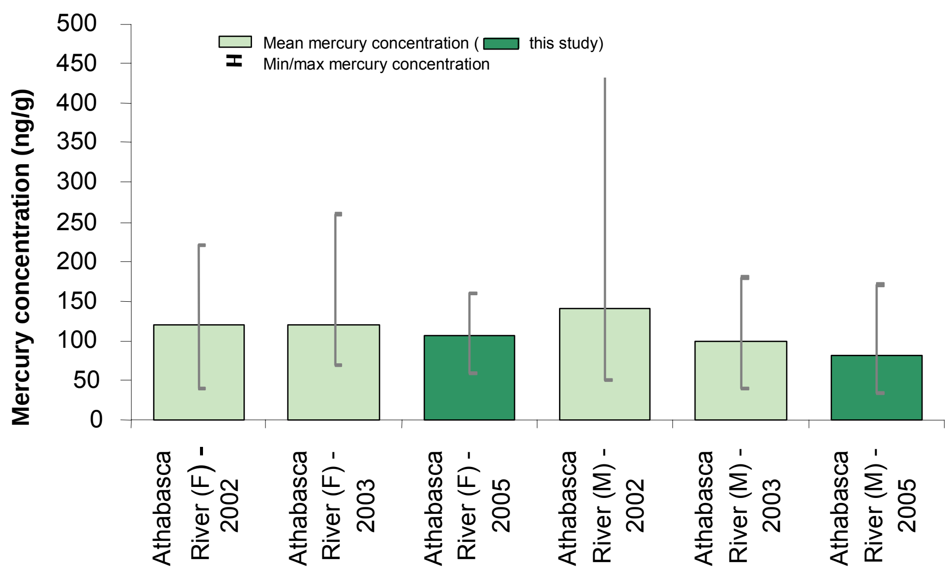


Figure 5.1-33 Results of inter-laboratory analysis and method comparison of mercury concentration in Athabasca River fish muscle tissue, September 2005.

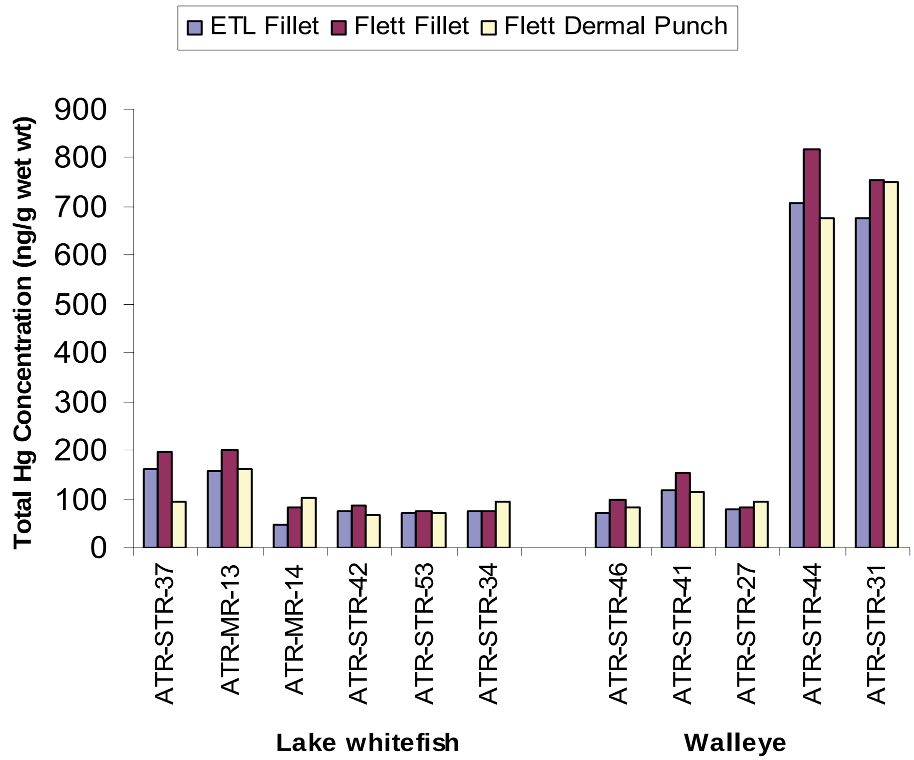


Table 5.1-18 Differences in mercury concentrations in Athabasca River lethal and non-lethal fish tissue samples.

Sample ID	Fish Species	ETL Fillet - Flett Fillet Difference (mg/kg wet weight)	Flett Fillet - Flett Plug Difference (mg/kg wet weight)
ATR-STR-37	LKWH	-0.036	0.1036
ATR-MR-13	LKWH	-0.04	0.037
ATR-MR-14	LKWH	-0.0328	-0.0222
ATR-STR-42	LKWH	-0.0146	0.0208
ATR-STR-53	LKWH	-0.0029	0.0037
ATR-STR-34	LKWH	-0.0025	-0.0184
ATR-STR-46	WALL	-0.0294	0.0151
ATR-STR-41	WALL	-0.035	0.039
ATR-STR-27	WALL	-0.0053	-0.0114
ATR-STR-44	WALL	-0.107	0.141
ATR-STR-31	WALL	-0.076	0.003

Figure 5.1-34 Fish tag recovery locations, 2005.

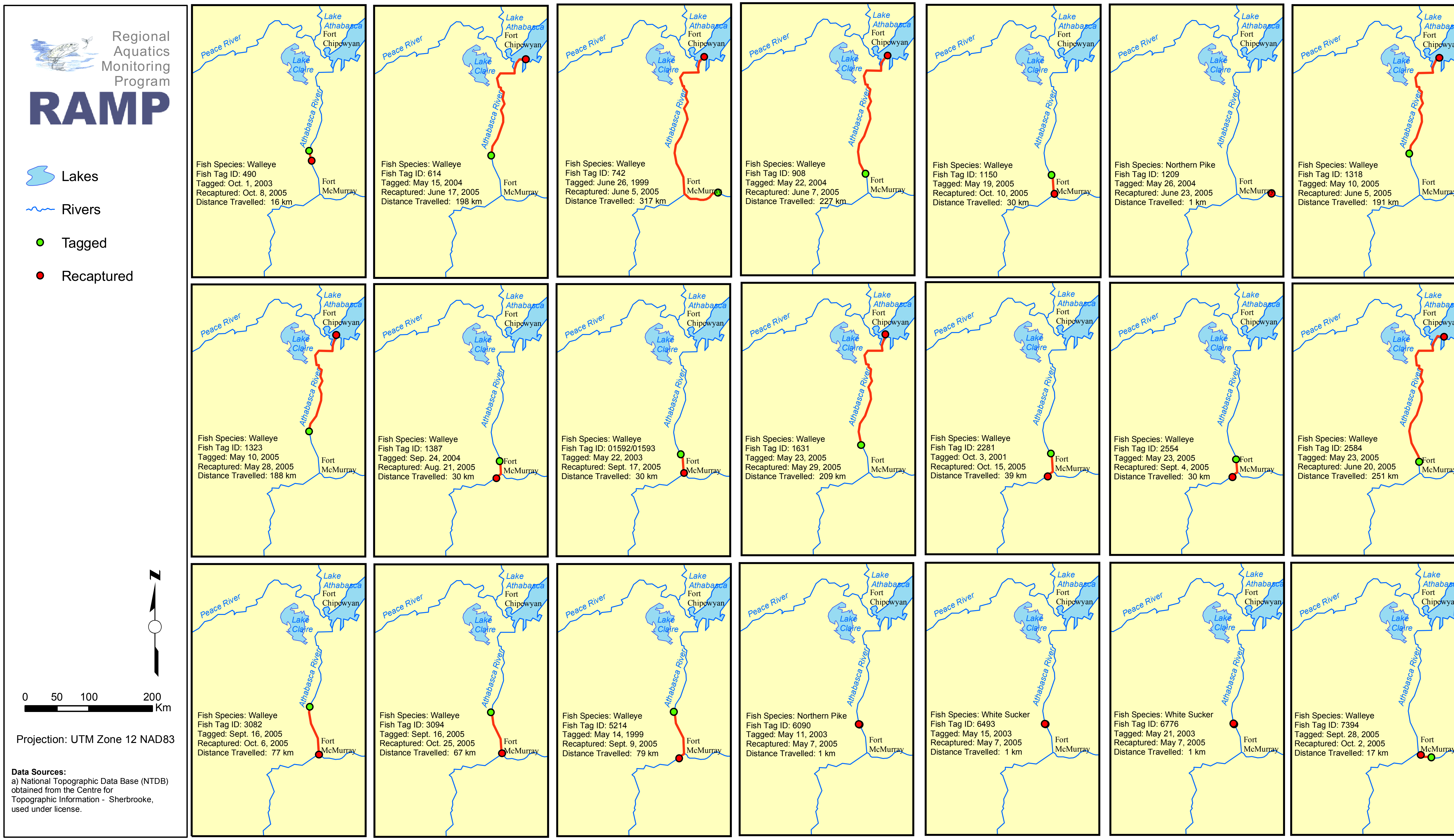


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Table 5.1-19 Results of RAMP fish tag return analysis, 2005.

Parameter	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
No. of Fish Recaptured	0	0	2	17	2
Min. Distance Traveled (km)	-	-	1	16	1
Max. Distance Traveled (km)	-	-	1	317	1

Table 5.1-20 Results of RAMP fish tag return analysis, 1999 to 2005.

Parameter	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
No. of Fish Recaptured	1	2	8	47	3
Min. Distance Traveled (km)	271	5.3	0	0	1
Max. Distance Traveled (km)	271	236	57	715	241

5.2 ATHABASCA RIVER DELTA

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	The general characteristics of Athabasca River discharges at the ARD may be assumed to be similar to those at RAMP Station S24, as discussed in Section 5.1.2.
Mean open-water season discharge	Because of the absence of hydrometric stations in the ARD, this was no estimate made of the hydrologic changes in relation to oil sands development activities.				
Mean winter discharge					
Annual maximum daily discharge					
Minimum open-water season discharge					

Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005[1]**		AENV has conducted monthly water quality sampling at Old Fort (ATR-OF); these data are presented and discussed in Section 5.1.3.
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=8)**	**2005 *Reference* Stations (n=0)**	
Physical variables	The 2005 RAMP Water Quality component did not include any activities in the ARD.		
Nutrients			
Ions			
Selected metals			
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 8 endpoints)**	**2005 *Reference* Stations (n=0 stations X 8 endpoints)**	
Greater than 95th percentile	The 2005 RAMP Water Quality component did not include any activities in the ARD.		
Between 5th and 95th percentiles			
Less than 5th percentile			

Sediment Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005[1]**		While there was large spatial variability in sediment quality measurement endpoints throughout the ARD in 2005, the analysis of 2005 information revealed no apparent effects of oil sands activities in the RMAP FSA for 2005.
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=11)**	**2005 *Reference* Stations (n=0)**	
Total Hydrocarbons (max=44)	2	No *reference* or *potentially influenced-other* stations were sampled in 2005.	
PAHs (max=11)	0		
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[3]**		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=11 stations X 3 endpoints)**	**2005 *Reference* Stations (n=0 stations X 3 endpoints)**	
Greater than 95th percentile	2	No *reference* or *potentially influenced-other* stations were sampled in 2005.	
Between 5th and 95th percentiles	31		
Less than 5th percentile	0		

Benthic Invertebrate Communities							
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline**						Benthic communities in the ARD were in generally good condition in 2005 with relatively high diversity for a shifting-sand environment; there was no evidence of undue deleterious effects on ARD benthic invertebrate communities.
	2005 *Potentially Influenced-Oil Sands* Stations (n=3)			**2005 *Reference* Stations (n=0)**			
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance		3		No *reference* or *potentially influenced-other* stations were sampled in 2005.			
Richness		3					
Diversity		3					
Evenness		3					
% EPT	1	2					

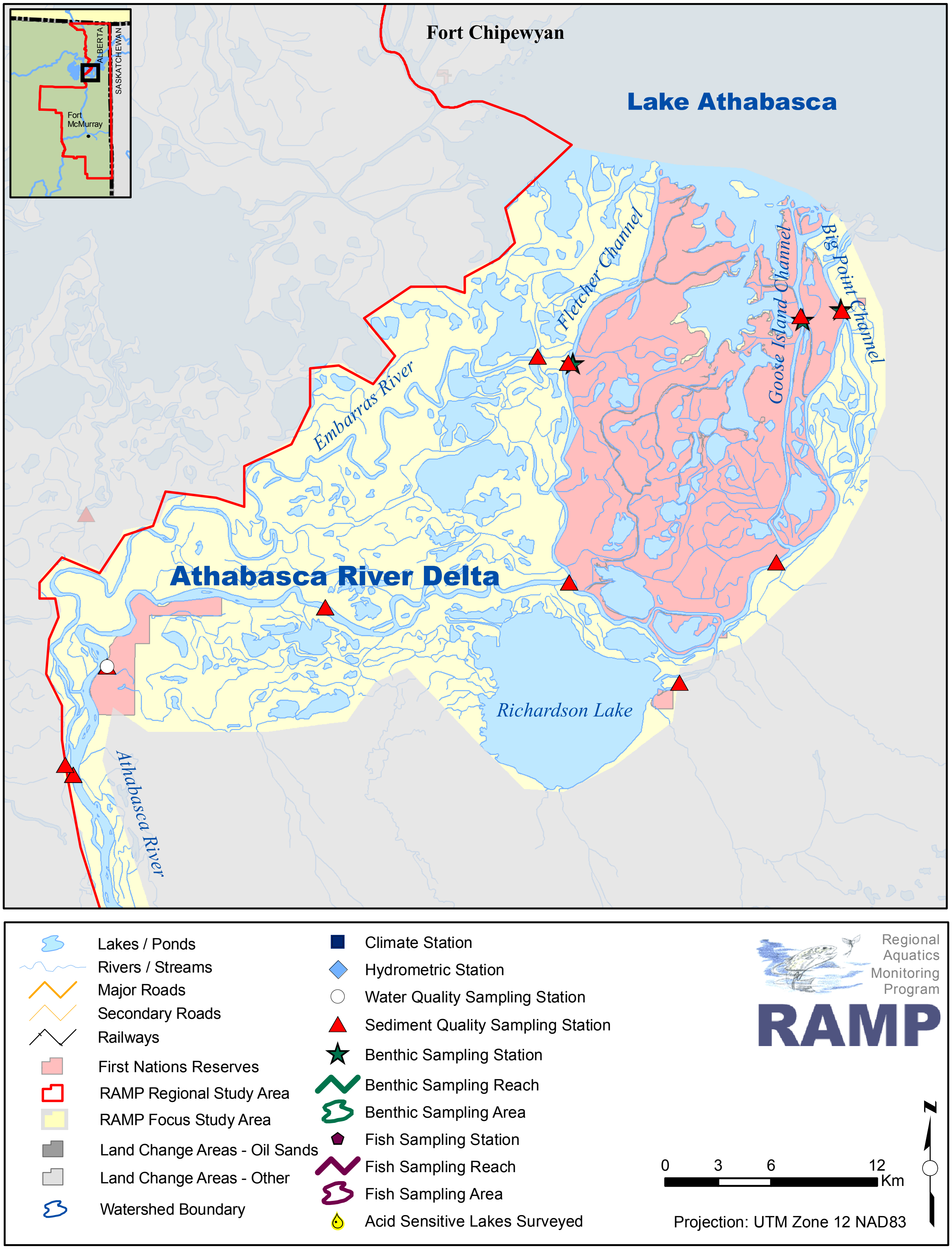
Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2005.
Sentinel Studies	No sentinel fish studies conducted in 2005.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.2-1 Athabasca River Delta.



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5.2.1 Development Status

The Athabasca River Delta (ARD) is designated as a *potentially influenced-oil sands* portion of the RAMP FSA because it is downstream of all oil sands development activities within the RAMP FSA. Therefore, all RAMP stations located in the ARD (Figure 5.2-1) are also designated as *potentially influenced-oil sands* for 2005 and all data gathered at these stations are designated as operational data.

5.2.2 Hydrologic Conditions

Athabasca River discharges are not monitored downstream of RAMP Station S24. However, the incremental catchment area between RAMP Station S24 and the ARD is relatively small, so that the general characteristics of Athabasca River discharges at the ARD may be assumed to be similar to those at RAMP Station S24, as discussed in Section 5.1.2.

5.2.3 Water Quality

The 2005 RAMP water quality component did not include any activities in the ARD. AENV has conducted monthly water quality sampling at Old Fort (ATR-OF); these data are presented and discussed in Section 5.1.3.

5.2.4 Sediment Quality

Sediments were sampled in the ARD in 2005 from the following locations:

- Embarras River at the head (EMR-1) and mouth (EMR-2);
- Cree Creek (CRC);
- Athabasca River near Old Fort (ATR-OF);
- Athabasca River between Old Fort and Richardson Lake (ARD-2);
- Big Eddy Channel (BEC);
- Fletcher Channel (FLC);
- Jackfish Creek (JFC);
- Big Point Channel downstream of Richardson Lake (BPC-2) and near Lake Athabasca (BPC); and
- Goose Island Channel (GIC).

Sediments were also sampled from the Athabasca River upstream of the Embarras River (station ATR-ER); a discussion of sediment quality at this station is found in Section 5.1.4. Results of fall 2005 sediment sampling are presented in Table 5.2-1 (stations EMR-1, EMR-2, CRC, ATR-OF, ARD-2, BEC, BPC-2, and JFC), Table 5.2-2 (station BPC), Table 5.2-3 (station FLC), and Table 5.2-4 (GIC). Concentrations of selected sediment quality measurement endpoints for individual stations are shown relative to pooled ARD data in Figure 5.2-2.

In 2005, ARD sediments were dominated by fine particle sizes (i.e., silt and clay), reflective of deposition of fine sediments from upstream areas. An exception was station ATR-OF (Athabasca River at Old Fort), which consisted of 70% sand. In general, sand content decreased with increasing distance downstream (Figure 5.2-3). Organic carbon content, although low in all ARD sediments, was generally higher at downstream stations relative to station ATR-ER (Athabasca River upstream of the Embarras River) and ATR-OF (Athabasca River at Old Fort) (Figure 5.2-4).

Concentrations of hydrocarbons in ARD sediments were low relative to sediments sampled in the Muskeg River watershed, western tributaries to the Athabasca River, and the Steepbank River, and were dominated by C16-C34 (CCME fraction 3) and C34-C50 (CCME fraction 4) hydrocarbon fractions at all stations (Figure 5.2-5). CCME fraction 2 hydrocarbons (C10-C16) were highest at stations ATR-OF, EMR-1, FLC, and CRC. Total hydrocarbon concentrations normalized to organic carbon content at stations ATR-OF and FLC were greater than the 95th percentile of pooled ARD concentrations (Figure 5.2-2). Hydrocarbon concentrations generally decreased longitudinally through the ARD (Figure 5.2-5).

No spatial patterns in total PAH concentrations throughout the ARD were apparent (Figure 5.2-8, Figure 5.2-9). Pooled total PAH concentrations normalized to organic carbon content within the ARD fall within a narrow range, and all 2005 ARD concentrations of normalized PAHs were within this range. Similarly, naphthalene concentrations in all 2005 ARD samples were between the 5th and 95th percentile concentrations of pooled ARD naphthalene results (Figure 5.2-2). Total metal concentrations were slightly higher at downstream stations relative to stations ATR-ER and ATR-OF (Figure 5.2-6); however, total metal concentrations normalized to fine sediment content were highest at stations ATR-ER and ATR-OF, and lower and very similar at all other stations (Figure 5.2-7).

Station GIC (Goose Island Channel) has been sampled by RAMP annually since 2001 (with the exception of 2004) (Figure 5.2-10). Relative to previous years' data, sediment at GIC was composed of slightly higher clay and lower sand content, and slightly higher organic carbon and total carbon content (Table 5.2-4). Total metals concentrations (normalized to fine sediment content, and unnormalized concentrations) were higher in 2005 than previous observations; the concentration of arsenic exceeded the CCME guideline in fall 2005. Concentrations of PAHs, including all PAH sediment quality measurement endpoints, were higher in 2005 than previous results; however, total PAH concentrations normalized to organic carbon content were similar to results obtained in 2001.

Station FLC (Fletcher Channel) has also been sampled by RAMP annually since 2001 (with the exception of 2004) (Figure 5.2-11). In 2005, sediment at FLC was higher in silt content and lower in sand content than in previous years (Table 5.2-3); fine sediments appear to have increased at this station since 2001. While organic carbon content in 2005 was the same as in 2003, total carbon content appears to have increased at this station over time. Total metals and total PAHs were slightly higher in 2005 than in previous years; however, normalized concentrations were lower than previous results. Total low molecular weight PAHs were higher in 2005 than in previous years, while high molecular weight PAHs were within the range of previous observations.

At station BPC (Big Point Channel), fall 2005 concentrations of most sediment quality measurement endpoints were within the range of concentrations previously observed at this station (Table 5.2-2). Total dibenzothiophenes were the only exception, and were slightly higher in 2005 than in previous years. No trends in physical properties, total metals, or total PAHs were apparent (Figure 5.2-12).

In summary, while there was large spatial variability in sediment quality measurement endpoints throughout the ARD in 2005, the analysis of 2005 information revealed no apparent effects of oil sands activities in the RAMP FSA for 2005.

5.2.5 Benthic Invertebrate Communities

Benthic invertebrate community samples were collected from three depositional stations in the ARD in fall 2005: Fletcher Channel (FLC), Goose Island Channel (GIC) and Big Point Channel (BPC).

The three channels of the ARD selected for analysis of benthic invertebrate samples in 2005 were similar in terms of habitat characteristics (Table 5.2-5). All three stations were in depositional habitats with water depths of 0.3 to 0.4 m and sediments consisting predominantly of sand, silt, and clay. Field water quality measures (dissolved oxygen, conductivity, pH, and temperature) were similar among stations.

The benthic invertebrate communities of three channels of the ARD were similar (Table 5.2-6), and dominated by tubificid worms and chironomids, with bivalves (Sphaeriidae), gastropods (*Probythinella*) and ceratopogonids less dominant. A variety of other groups such as nematodes, ostracods, larger insects including Ephemeroptera (*Hexagenia limbata*), Plecoptera (*Isoperla*) and Trichoptera (principally *Neureclipsis*) were present, but in low numbers. The worms were not identified below the Family level, but the high numbers of tubificids is not uncommon because of the characteristic shifting-sand environment of the ARD (Barton and Locke, 1979). The dominant chironomids were *Polypedilum* and *Procladius.*

Indices of composition have not indicated any significant negative trends in habitat quality since sampling started in 2002 (Table 5.2-6; Figure 5.2-13). The number of distinct taxa has averaged about 10 to 11 per sample while the number of animals per square meter has fluctuated widely from 5,000 to 105,000 individuals/m^2. Simpson's Diversity and evenness are not exceptionally high ranging between 0.4 and 0.7 (Figure 5.2-13), but these are normal values for these measurement endpoints in shifting-sand environments. Similarly, the %EPT (mayflies, stoneflies and caddisflies) has generally been low in the ARD, but that is not atypical for shifting-sand environments.

The ordination of the benthic invertebrate community data supports these findings for specific measurement endpoints, indicating that benthic invertebrate community conditions in 2005 continued to be well within the normal range observed from *reference* and *potentially influenced-other* reaches (Figure 5.2-14).

Based on the analysis of the benthic invertebrate community measurement endpoints collected at stations FLC, GIC, and BPC for 2005, we conclude that benthic communities in the ARD were in generally good condition in 2005 with relatively high diversity for a shifting-sand environment; there was no evidence of undue deleterious effects on ARD benthic invertebrate communities.

5.2.6 Fish Populations

The 2005 RAMP fish population component did not include any activities in the ARD.

5.2.7 Summary of Conditions

The ARD is the part of the RAMP FSA that is furthest downstream from oil sands development activities and the status of all RAMP aquatic resources measured in the ARD in 2005 is ascribed to the specific hydrologic conditions that characterized the sampling period of 2005, as well as inherent natural conditions of the dynamic environment of the ARD. There was large spatial variability in sediment quality measurement endpoints throughout the ARD in 2005, including both guideline exceedances and concentrations of measurement endpoints that were either below the 5th or above the 95th percentile for reference baseline ranges. In addition, the characteristics of benthic invertebrate community measurement endpoints in 2005 were similar to those of previous years. Therefore no influences of oil sands development activities were detected in the ARD in 2005.

Table 5.2-1 Concentrations of sediment quality measurement endpoints, Athabasca River Delta, fall 2005.

	Units	Guideline	September 2005							
			ATR-OF	ARD-2	BEC	EMR-1	CRC	EMR-2	JFC	BPC-2
Physical variables										
Clay	%	-	13	22	19	19	17	43	19	24
Silt	%	-	17	44	53	46	45	53	34	52
Sand	%	-	70	34	28	35	38	4	47	23
Total organic carbon	%	-	1.1	1.6	1.5	1.7	1.8	2.6	1.4	1.7
Total hydrocarbons										
CCME variables										
BTEX	mg/kg	-	<5	<5	<5	<5	<5	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	<5	<5	<5	<5	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	44	<5	<5	22	12	<5	<5	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	**620**	350	290	360	290	390	320	280
Fraction 4 (C34-C50)	mg/kg	2800[2]	450	240	190	240	210	190	200	180
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	mg/kg	0.0346[3]	0.0069	0.011	0.011	0.013	0.011	0.018	0.011	0.012
Retene	mg/kg	-	0.0643	0.074	0.108	0.073	0.056	0.13	0.039	0.046
Total dibenzothiophenes	mg/kg	-	0.24	0.51	0.32	0.29	0.31	0.49	0.20	0.30
Total PAHs	mg/kg	-	1.20	2.05	1.66	1.56	1.67	2.63	1.09	1.65
Total HMW PAHs	mg/kg	-	0.47	0.65	0.63	0.56	0.66	0.95	0.38	0.60
Total LMW PAHs	mg/kg	-	0.73	1.40	1.03	1.01	1.01	1.68	0.72	1.05
Predicted PAH toxicity[1]	H.I.	-	0.34	1.05	1.07	0.77	0.99	1.37	0.62	1.05
Metals that exceed CCME guidelines in 2005										
Arsenic	mg/kg	-	**-**	**-**	**-**	-	**-**	**8.2**	**-**	**-**
Chronic toxicity										
Chironomus survival - 10d	# surviving	-	**-**	-	**-**	**-**	**-**	**-**	-	**-**
Chironomus growth - 10d	mg/organism	-	**-**	-	**-**	**-**	**-**	**-**	-	**-**
Hyallela survival - 14d	# surviving	-	**-**	-	**-**	**-**	**-**	**-**	-	**-**
Hyallela growth - 14d	mg/organism	-	**-**	-	**-**	**-**	**-**	**-**	-	**-**

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 2001).

3 Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.2-2 Concentrations of sediment quality measurement endpoints, Big Point Channel (BPC), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	17	5	10	22	32
Silt	%	-	44	5	26	51	64
Sand	%	-	39	5	10	23	64
Total organic carbon	%	-	1.1	5	<0.1	1.2	1.76
Total hydrocarbons							
CCME variables							
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	400[2]	190	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	120	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0115	5	0.005	0.012	0.024
Retene	mg/kg	-	0.0527	4	0.041	0.058	0.0957
Total dibenzothiophenes	mg/kg	-	0.27	5	0.15	0.21	0.24
Total PAHs	mg/kg	-	1.40	5	1.05	1.25	1.54
Total HMW PAHs	mg/kg	-	0.52	5	0.25	0.50	0.73
Total LMW PAHs	mg/kg	-	0.88	5	0.50	0.81	1.00
Predicted PAH toxicity[1]	H.I.	-	1.34	5	0.91	1.11	1.46
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-					
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	5	3.2	7	9
Chironomus growth - 10d	mg/organism	-	-	5	0.89	2	3.6
Hyallela survival - 14d	# surviving	-	-	1	-	-	9
Hyallela growth - 14d	mg/organism	-	-	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 2001).

3 Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.2-3 Concentrations of sediment quality measurement endpoints, Fletcher Channel (FLC), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	16	3	12	14	18
Silt	%	-	49	3	18	35	38
Sand	%	-	35	3	44	51	70
Total organic carbon	%	-	1.3	3	0.6	1	1.3
Total hydrocarbons							
CCME variables							
BTEX	mg/kg	-	<5	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	18	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**430**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	280	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0114	3	0.0047	0.007	0.0094
Retene	mg/kg	-	0.0444	3	0.021	0.0371	0.048
Total dibenzothiophenes	mg/kg	-	0.26	3	0.15	0.17	0.19
Total PAHs	mg/kg	-	1.28	3	0.84	1.02	1.21
Total HMW PAHs	mg/kg	-	0.50	3	0.33	0.47	0.58
Total LMW PAHs	mg/kg	-	0.78	3	0.44	0.50	0.74
Predicted PAH toxicity[1]	H.I.	-	0.52	3	0.49	0.78	0.91
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	3	6	6	7
Chironomus growth - 10d	mg/organism	-	-	3	2.6	2.8	3.6
Hyallela survival - 14d	# surviving	-	-	1	-	-	9.6
Hyallela growth - 14d	mg/organism	-	-	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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.2-4 Concentrations of sediment quality measurement endpoints, Goose Island Channel (GIC), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	28	3	20	20	22
Silt	%	-	56	3	46	51	58
Sand	%	-	17	3	22	29	32
Total organic carbon	%	-	2.1	3	1.2	1.7	1.8
Total hydrocarbons							
CCME variables							
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	400[2]	360	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	200	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0146	3	0.0051	0.009	0.0106
Retene	mg/kg	-	0.0781	3	0.027	0.0439	0.054
Total dibenzothiophenes	mg/kg	-	0.41	3	0.21	0.22	0.26
Total PAHs	mg/kg	-	2.16	3	1.24	1.24	1.54
Total HMW PAHs	mg/kg	-	0.80	3	0.53	0.58	0.64
Total LMW PAHs	mg/kg	-	1.36	3	0.59	0.71	0.96
Predicted PAH toxicity[1]	H.I.	-	1.15	3	0.98	1.14	1.18
Metals that exceed CCME guidelines in 2005							
Arsenic (As)	mg/kg	5.9	**6.6**	3	4.5	4.7	4.8
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	3	4	7	8
Chironomus growth - 10d	mg/organism	-	-	3	2.6	2.7	4.2
Hyallela survival - 14d	# surviving	-	-	1	-	-	9
Hyallela growth - 14d	mg/organism	-	-	1	-	-	0.11

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

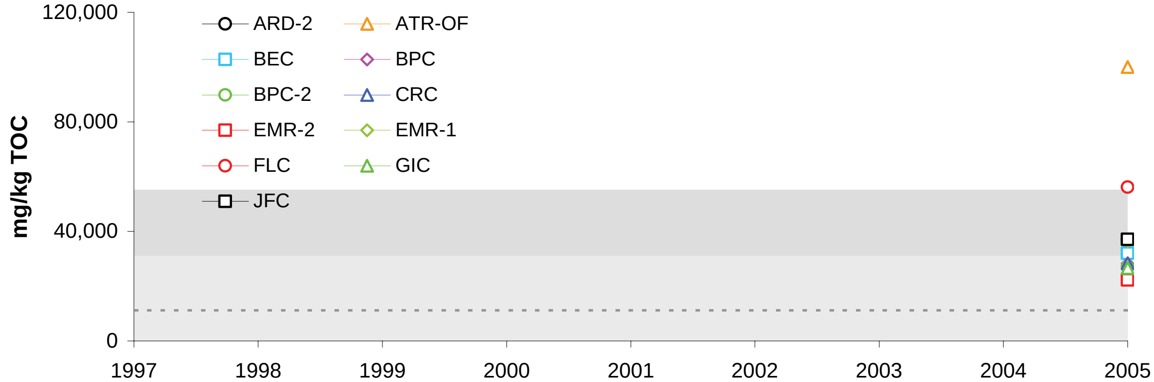
1 Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

2 Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

3 Interim sediment quality guideline (ISQG) (CCME 2003).

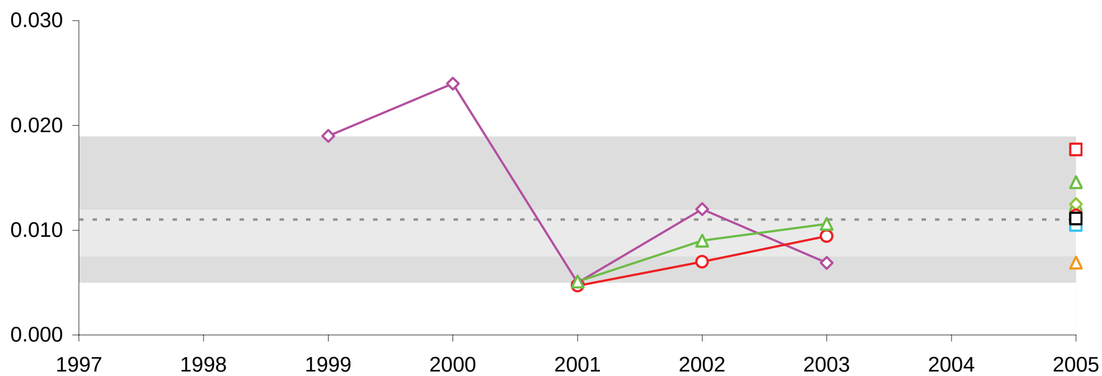
Figure 5.2-2 Concentrations of selected sediment quality measurement endpoints for the Athabasca River Delta (fall data) relative to regional baseline fall concentrations.

Total Hydrocarbons (C6-C50) (normalized to TOC)



Total Polycyclic Aromatic Hydrocarbons (PAHs) (normalized to TOC)

Naphthalene



[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

Figure 5.2-3 Particle size distribution of Athabasca River Delta sediments, fall 2005.

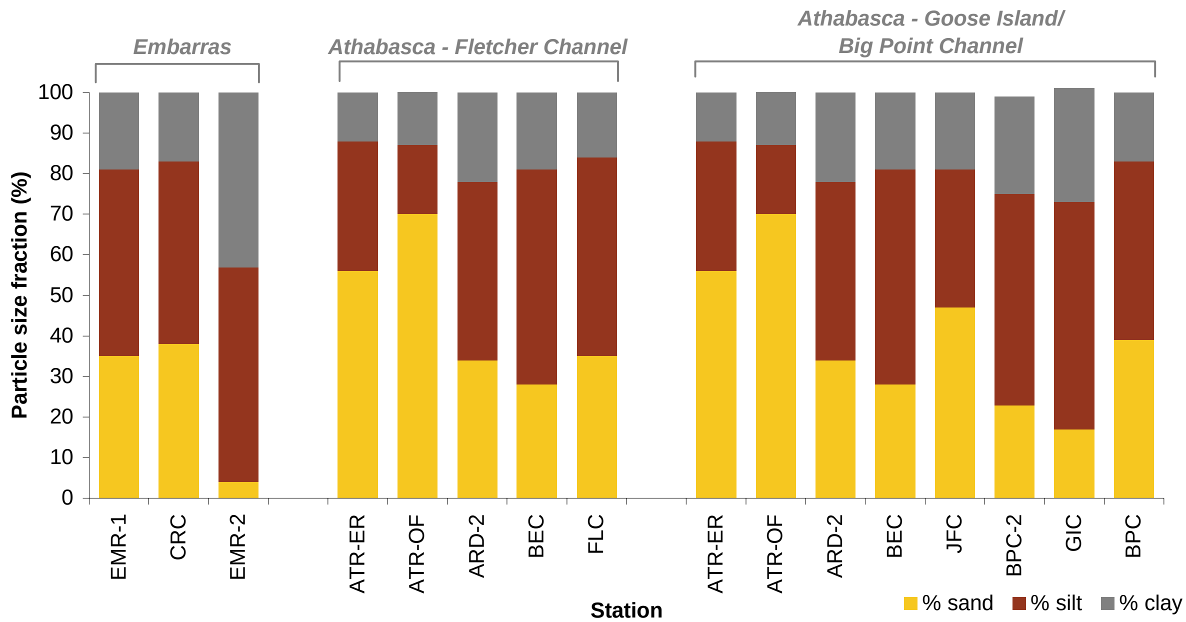


Figure 5.2-4 Carbon content of Athabasca River Delta sediments, fall 2005.

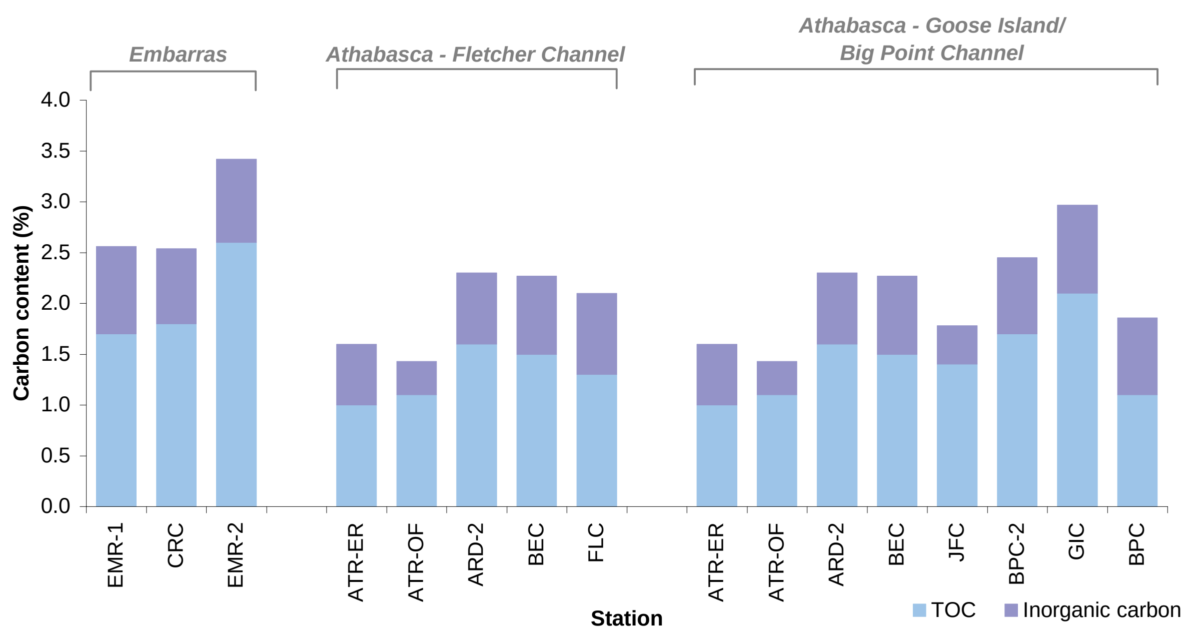


Figure 5.2-5 CCME hydrocarbon fractions in Athabasca River Delta sediments, fall 2005.

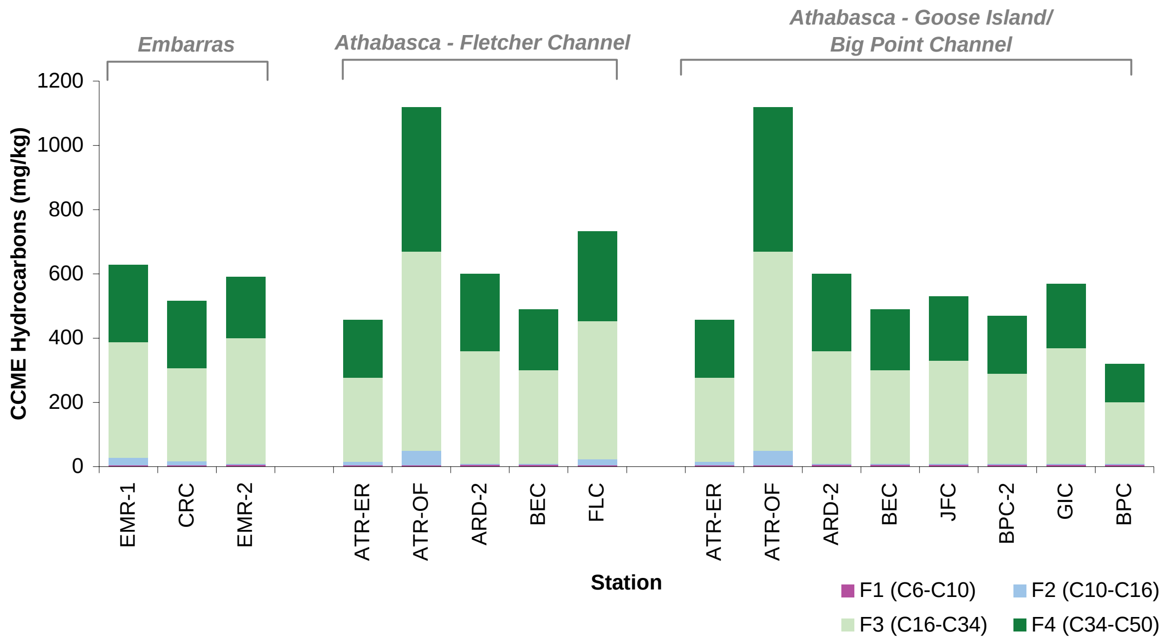


Figure 5.2-6 Total metals concentrations in Athabasca River Delta sediments, fall 2005.

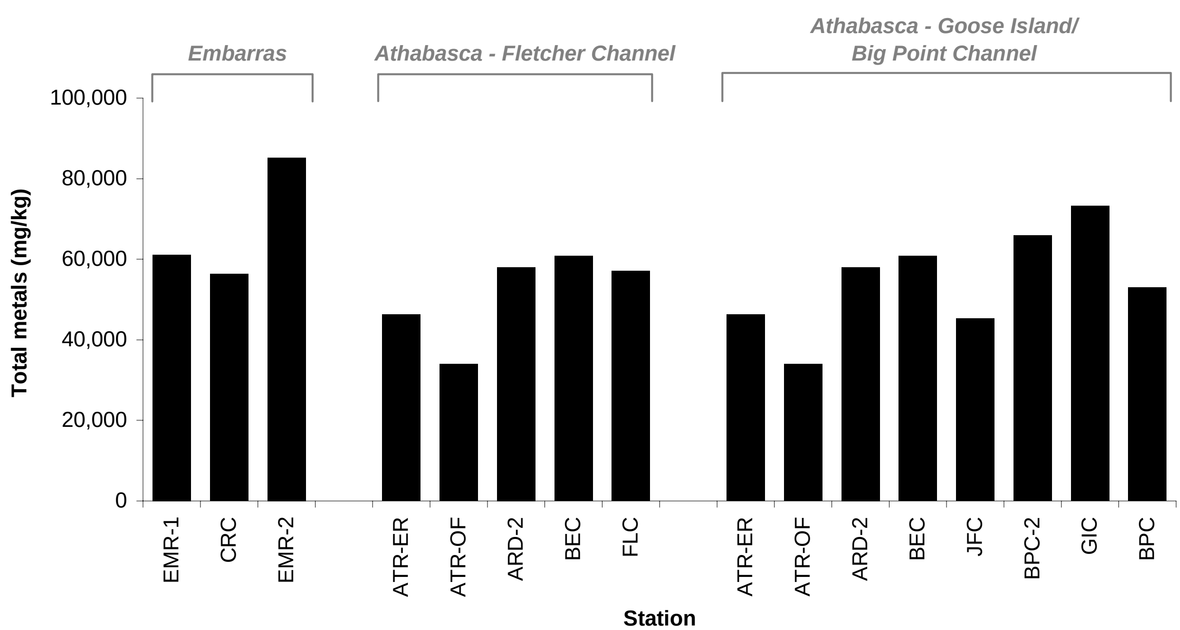


Figure 5.2-7 Total metals concentrations (normalized to fine sediment content) in Athabasca River Delta sediments, fall 2005.

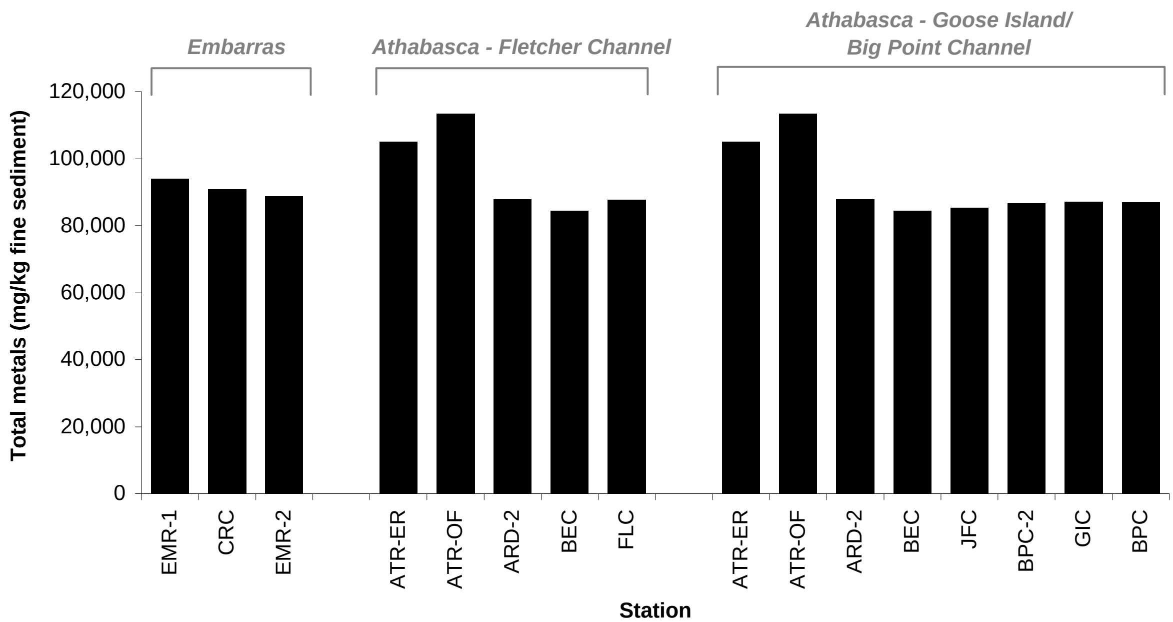


Figure 5.2-8 Total PAH concentrations in Athabasca River Delta sediments, fall 2005.

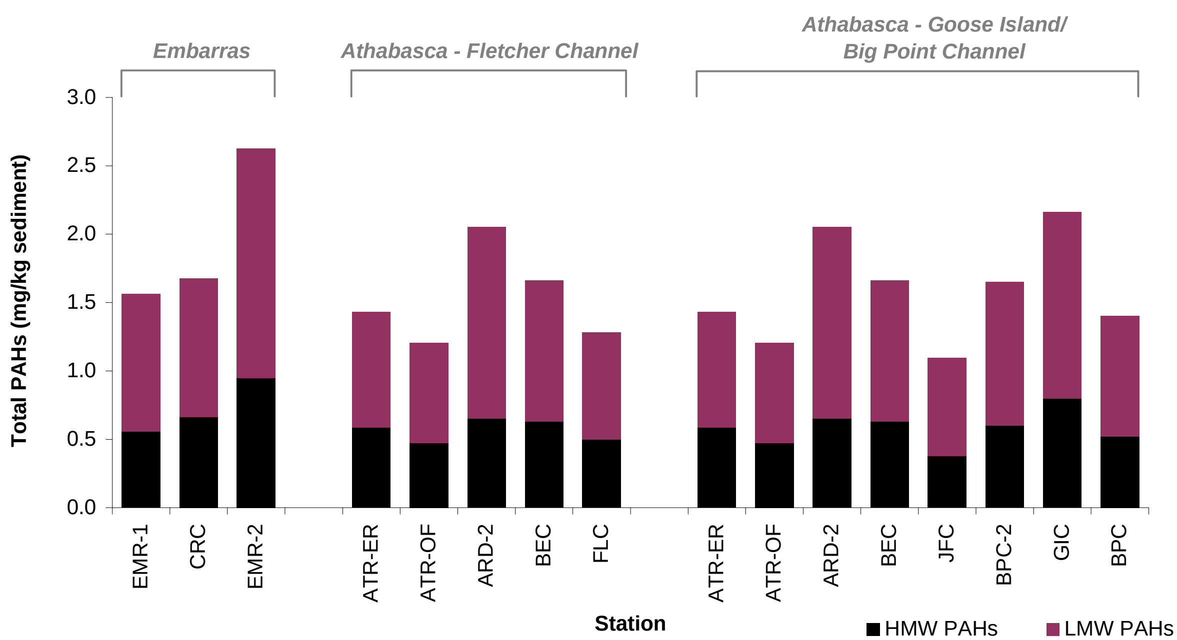


Figure 5.2-9 Total PAH concentrations (normalized to total organic carbon in Athabasca River Delta fine sediments, fall 2005.

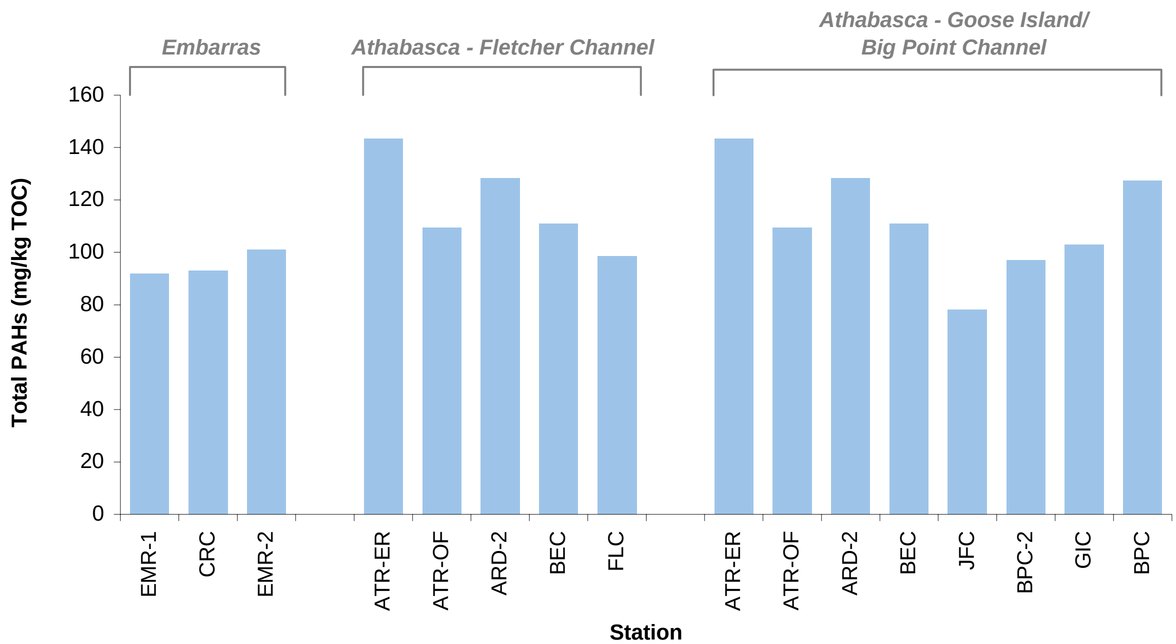
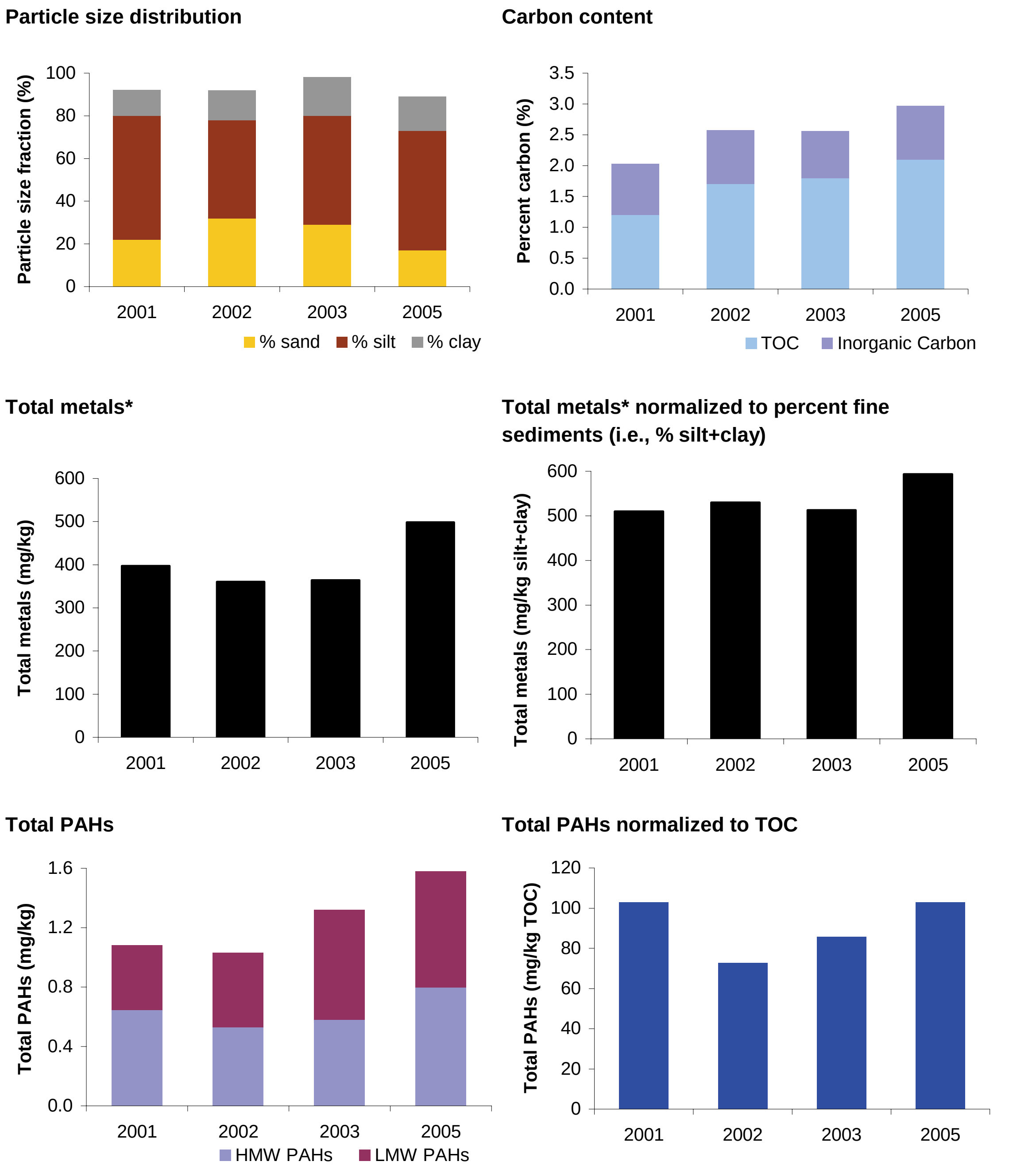


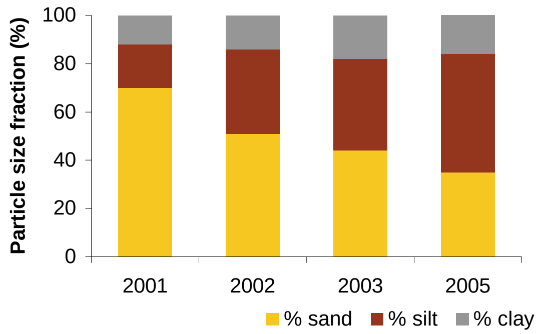
Figure 5.2-10 Characteristics of sediment at Goose Island Channel (GIC), 2001 - 2005 (fall data only).



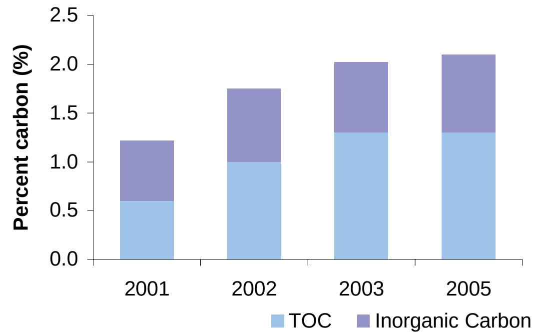
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Sr, Tl, U, V, Zn (measured in all years).

Figure 5.2-11 Characteristics of sediment at Fletcher Channel (FLC), 2001-2005 (fall data only).

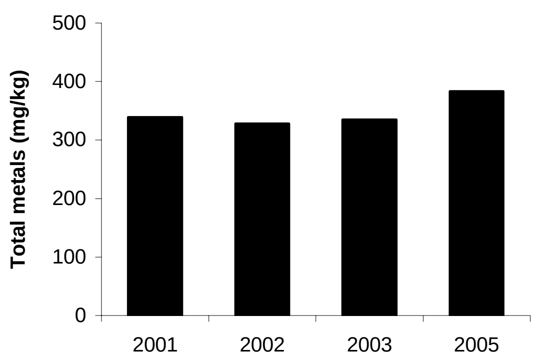
Particle size distribution



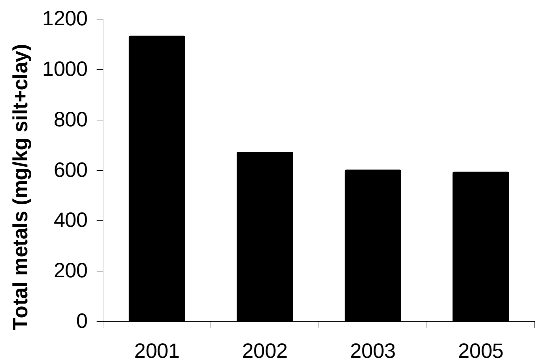
Carbon content



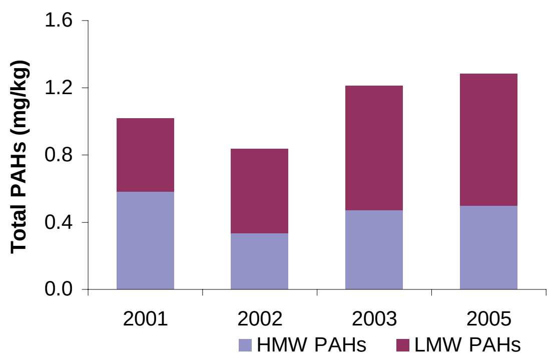
Total metals*



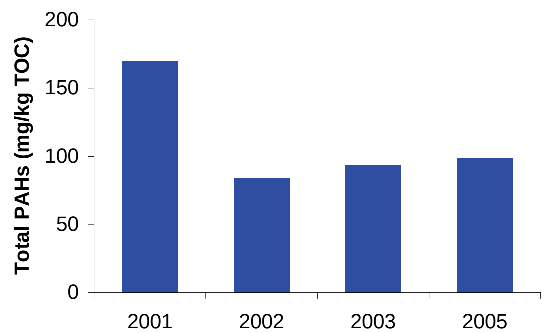
Total metals* normalized to percent fine sediments (i.e., % silt+clay)



Total PAHs



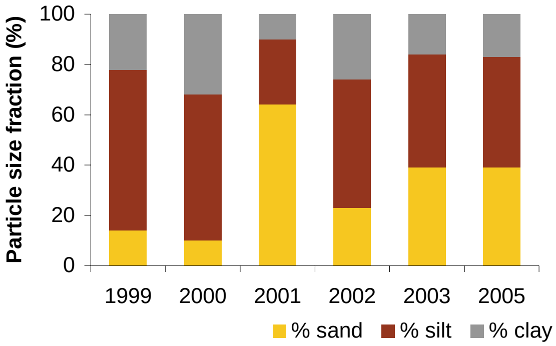
Total PAHs normalized to TOC



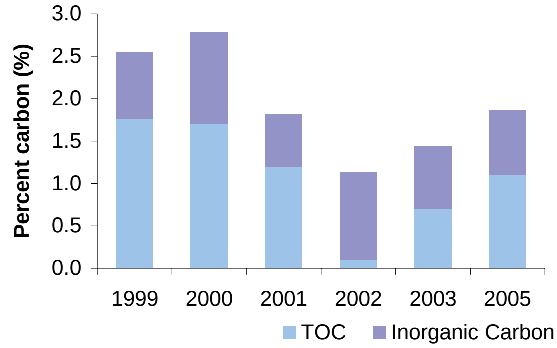
* Total metals include: As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Sr, Tl, U, V, Zn (measured in all years).
** Non-detectable level of total organic carbon in 2002 (<0.1%).

Figure 5.2-12 Characteristics of sediment at Big Point Channel (BPC), 1999-2005 (fall data only).

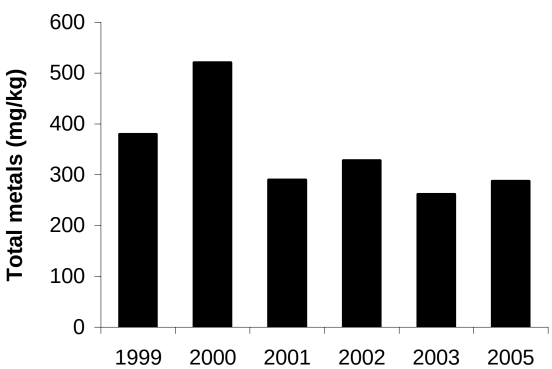
Particle size distribution



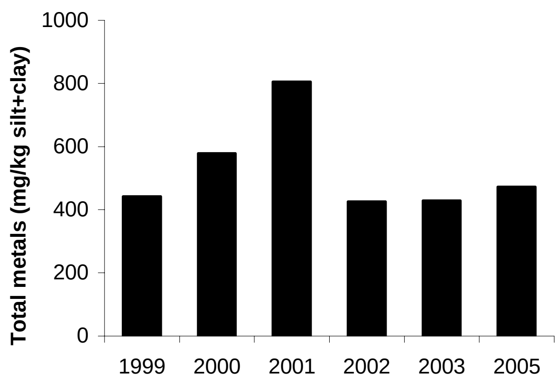
Carbon content



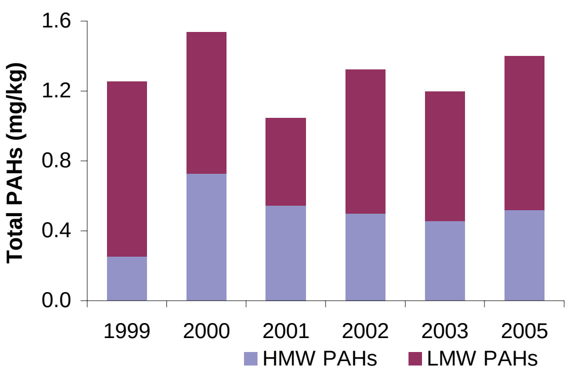
Total metals*



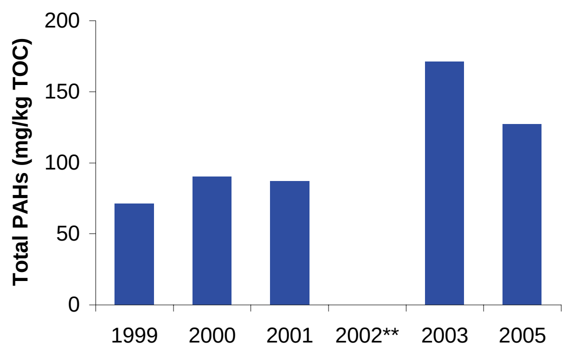
Total metals* normalized to percent fine sediments (i.e., % silt+clay)



Total PAHs



Total PAHs normalized to 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%).

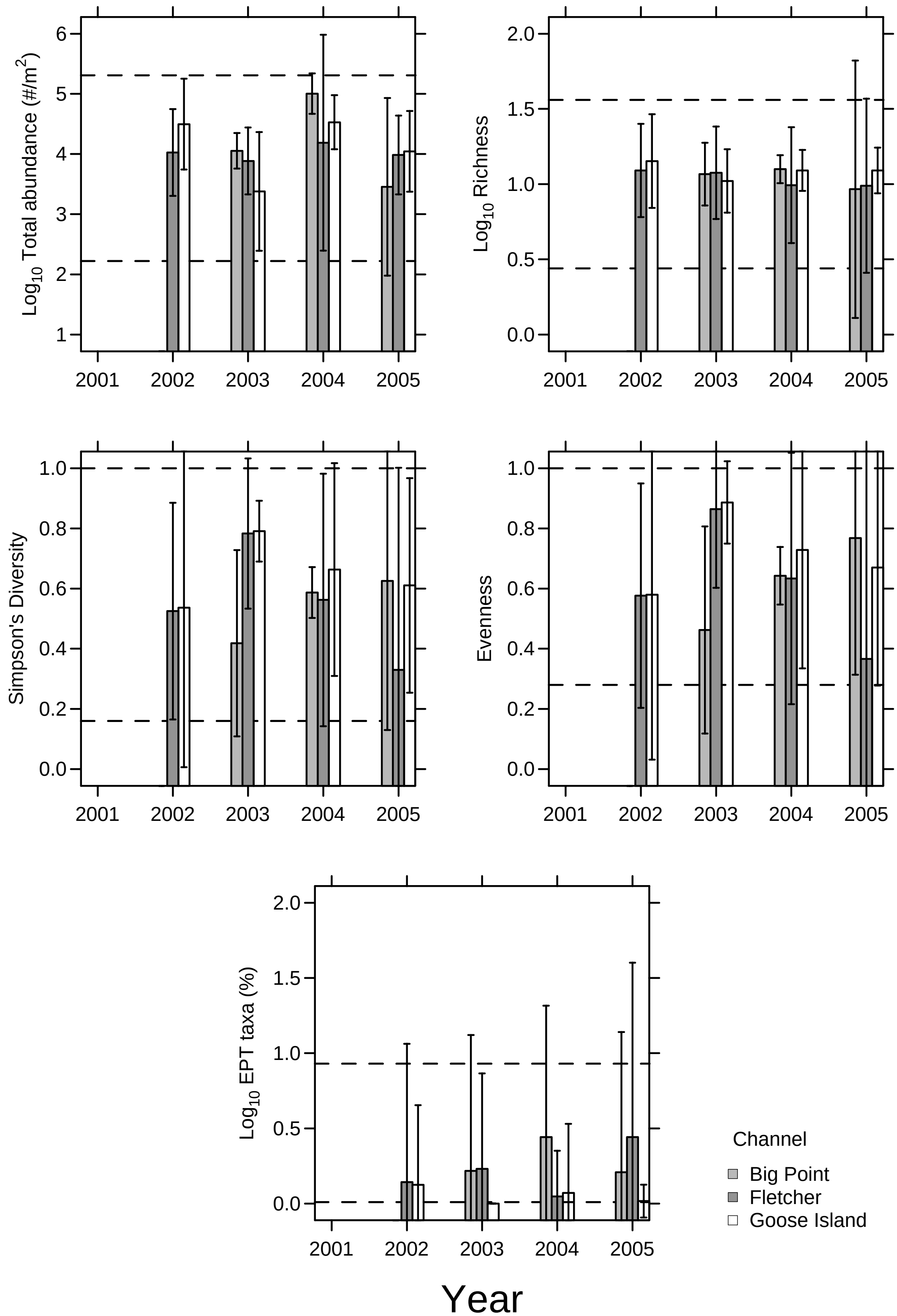
Table 5.2-5 Average habitat characteristics of benthic invertebrate community sampling sites among stations in the Athabasca River Delta.

Variable	Units	Big Point Channel	Fletcher Channel	Goose Island Channel
Sample date	-	Sept. 13, 2005	Sept. 13, 2005	Sept. 13, 2005
Habitat	-	Depositional	Depositional	Depositional
Water depth	m	0.4	0.3	0.3
Current velocity	m/s	0	0	0
Field Water Quality				
Dissolved oxygen	mg/L	n/a	n/a	n/a
Conductivity	µS/cm	n/a	n/a	n/a
pH	-	8.0	7.5	7.8
Water temperature	°C	12.3	12.5	11.6
Sediment Composition				
Sand	%	39	35	17
Silt	%	44	49	56
Clay	%	17	16	28
Total Organic Carbon	%	1.1	1.3	2.1

Table 5.2-6 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of the Athabasca River Delta.

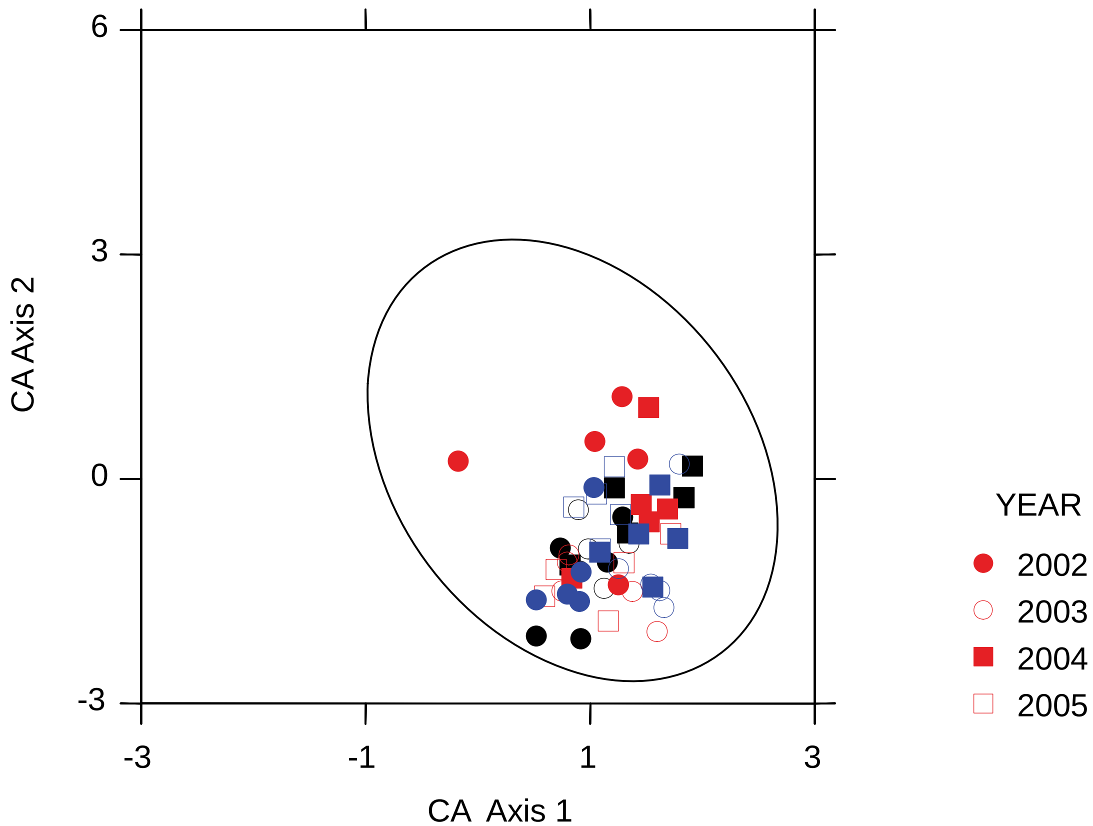
Taxon	Big Point Channel			Fletcher Channel				Goose Island Channel			
	2003	2004	2005	2002	2003	2004	2005	2002	2003	2004	2005
Nematoda	<1	<1	1	5	5	<1	<1	5	0	<1	2
Erpobdellidae	0	<1	0	0	0	0	0	0	0	0	0
Naididae	1	<1	2	<1	15	3	0	0	0	<1	7
Tubificidae	75	52	46	2	26	58	81	<1	27	27	62
Lumbriculidae	0	0	0	0	0	0	0	0	<1	<1	0
Hydracarina	<1	0	0	0	0	0	<1	<1	<1	0	<1
Ostracoda	<1	2	2	3	2	4	4	1	9	3	8
Copepoda	0	0	0	0	0	0	0	<1	0	0	1
Macrothricidae	0	0	0	<1	0	0	<1	<1	2	0	2
Amphipoda	0	<1	2	0	0	0	0	0	0	0	0
Bivalvia	10	1	8	1	13	3	3	13	4	2	3
Gastropoda	4	<1	1	1	14	<1	2	5	11	<1	<1
Ephemeroptera	<1	<1	1	<1	1	<1	<1	0	0	<1	<1
Plecoptera	0	0	0	0	0	0	<1	0	0	0	0
Trichoptera	1	2	1	0	<1	<1	2	<1	0	0	0
Anisoptera	<1	<1	<1	0	<1	<1	<1	<1	<1	<1	0
Heteroptera	<1	<1	0	0	<1	<1	0	0	<1	0	0
Tipulidae	<1	0	0	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	<1	0	0	0	0	0	0
Empididae	0	0	0	<1	0	0	0	0	0	0	0
Ceratopogonidae	1	<1	7	2	10	5	2	1	17	3	2
Chironomidae	6	40	31	86	13	27	4	74	28	64	13
Megaloptera	0	<1	0	0	0	0	0	0	0	0	0
Total Abundance (No./m^2)	11,552	103,983	4,757	11,897	8,328	27,207	10,843	36,000	2,914	35,776	12,243
Richness	11	12	10	12	11	9	10	14	10	11	11
Simpson's Diversity	0.42	0.59	0.63	0.53	0.78	0.56	0.33	0.54	0.79	0.66	0.61
Evenness	0.46	0.64	0.77	0.58	0.86	0.63	0.37	0.58	0.89	0.73	0.67
% EPT	1	2	1	1	1	<1	3	<1	0	<1	<1

Figure 5.2-13 Variation in benthic invertebrate community measurement endpoints in the Athabasca River Delta between 2002 and 2005.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites.

Figure 5.2-14 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for stations GIC, FLC, and BPC.



Notes: Black = Goose Island Channel; blue = Big Point Channel; Red = Fletcher Channel; ellipse describes reference conditions (95% confidence ellipse) for depositional reaches.

5.3 MUSKEG RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge		√			Total runoff in the Muskeg River basin in 2005 almost 166% of the long-term average. Oil sands activities are predicted to have decreased hydrologic measurement endpoints by 1.7% to 2.9%.
Mean winter discharge		√			
Annual maximum daily discharge		√			
Minimum open-water season discharge		√			

Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005[1]**		
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=2)**	**2005 *Reference* Stations (n=4)**	
Physical variables (max = 2 for exp, 4 for ref)	0	0	Influences of oil sands development activities in 2005 were relatively minor. While many water quality measurement endpoints in Stanley Creek were outside previously recorded ranges due to CWD, this did not result in increased guideline exceedence and was not reflected in Muskeg River water quality. There were few guideline exceedances in 2005 and fall concentrations of most measurement endpoints were within regional baseline ranges.
Nutrients (max = 6 for exp, 12 for ref)	0	0	
Ions (max = 4 for exp, 8 for ref)	1	0	
Selected metals (max=10 for exp, 20 for ref)	0	0	
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=2 stations X 8 endpoints)**	**2005 *Reference* Stations (n=4 stations X 8 endpoints)**	
Greater than 95th percentile	1	0	
Between 5th and 95th percentiles	14	32	
Less than 5th percentile	1	0	

Sediment Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005[1]**		
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=3)**	**2005 *Reference* Stations (n=0)**	
Total Hydrocarbons(max=12 for exp,0 for ref)	3	No *reference* or *potentially influenced-other* stations were sampled in 2005	Based on the available sediment quality data, it appears that current oil sands development in the Muskeg River basin has not had a substantial influence on sediment quality conditions, although the relatively small samples sizes and the resulting high variability for many sediment quality measurement endpoints make the detection and interpretation of differences and trends difficult.
PAHs (max=3 for exp, 0 for ref)	0		
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[3]**		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=3 stations X 3 endpoints)**	**2005 *Reference* Stations (n= station X 3 endpoints)**	
Greater than 95th percentile	1	No *reference* or *potentially influenced-other* stations were sampled in 2005	
Between 5th and 95th percentiles	8		
Less than 5th percentile	0		

Benthic Invertebrate Communities							
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline**						
	2005 *Potentially Influenced-Oil Sands* Stations (n= 1)			**2005 *Reference* Stations (n= 4)**			
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance		1			4		There are no indications of an impaired benthic community in reaches exposed to oil sands development activities.
Richness		1			4		
Diversity		1			4		
Evenness		1			4		
% EPT		1			4		

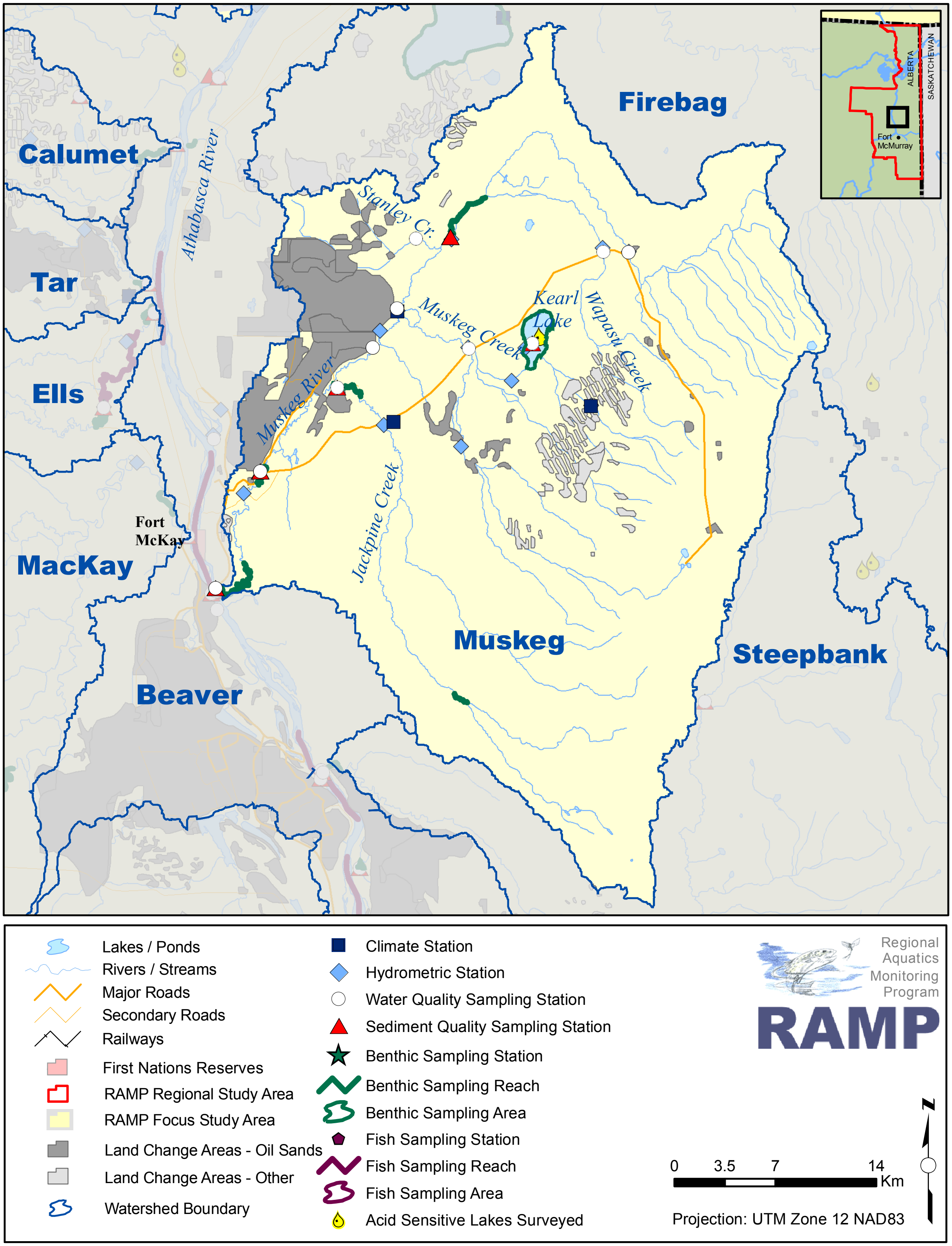
Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2005.
Sentinel Studies	No sentinel fish studies conducted in 2005.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.3-1 Muskeg River watershed.



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5.3.1 Development Status

Approximately 6% of the Muskeg River watershed has undergone land change as a result of oil sands development activities (Table 2.4-2). The designations of specific areas of the Muskeg River watershed are as follows:

- The Muskeg River downstream of its confluence with Stanley Creek, as well as all parts of the Stanley Creek drainage and all lands within the Muskeg River and Aurora North mine leases (Figure 2.4-1) are designated as *potentially influenced-oil sands*. All data gathered from 2005 RAMP stations located in this area of the watershed are designated as operational data;

- The Muskeg Creek and Wapasu Creek drainages are designated as *potentially influenced-other* because of the logging activities that have taken place in the upper parts of both these drainages, particularly in the Aurora South Lease (Figure 2.4-1). All data gathered from the 2005 RAMP stations located in this area of the watershed are designated as baseline data; and

- The remainder of the watershed is designated as *reference*, and all data gathered from the 2005 RAMP stations located in these parts of the watershed are designated as baseline data.

5.3.2 Hydrologic Conditions

Total runoff in the Muskeg River basin in 2005, as measured at RAMP Station S7, Muskeg River near Fort McKay (07DA008), was well above normal at almost 166% of the long-term average (Figure 5.3-2). Discharges were well above normal in spring and peaked on April 27 due to rapid snowmelt. Discharge peaks were also observed in July, August and September in response to rainfall, and then the river subsided to near average levels at the end of October. Mid-April and early August discharges were close to record values for those dates. The annual maximum daily discharge of 33.8 m^3/s was 30% greater than the mean annual flood of 26 m^3/s. The minimum winter discharge of 0.19 m^3/s was almost exactly equal to the historical average minimum flow.

Inputs to the water balance model for the Muskeg River watershed used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints are provided in Table 5.3-1. Cumulative oil sands development in the Muskeg River watershed up to 2005 has resulted in the isolation of 56 km^2 of the watershed and clearing and/or drainage of an additional 29.5 km^2. These land changes, combined with total releases of 271,000 m^3 from the Aurora Clean Water Diversion discharge to Stanley Creek, are predicted to have decreased mean open-water season discharge by 2%, decreased mean winter discharge by 1.7%, decreased annual maximum daily discharge by 2.9%, and decreased open-season minimum daily discharge by 2.0% (Table 5.3-2, Figure 5.3-2). These calculated hydrologic effects are considerably lower than was estimated for 2004, primarily because the current estimate of the hydrologically isolated area within the catchment has been reduced from 100 km^2 to 56 km^2 (using satellite imagery, Section 2). The reported changes in hydrologic measurement endpoints for 2005 would have been assessed as Negligible or Low in many oil sands EIAs (RAMP 2005b). Therefore, based on the available hydrologic and oils sands development information, it appears that changes in hydrologic conditions in the Muskeg River watershed up to and including 2005 have been negligible to low.

5.3.3 Water Quality

In 2005, water quality samples were collected from the following stations:

- mouth of the Muskeg River (station MUR-1, *potentially influenced-oil sands*, operational data available from 1997 to 2005);
- Muskeg River upstream of Wapasu Creek (station MUR-6, *reference*; baseline data available from 1998 to 2005);
- Stanley Creek (station STC-1, *potentially influenced-oil sands*, operational data, first sampled in 1998 and sampled every year since 2001);
- Muskeg Creek (station MUC-1, *potentially influenced-other*, baseline data available from 1998 to 2005);
- Jackpine Creek (station JAC-1, *reference*, baseline data available from 1998 to 2005); and
- Wapasu Creek (WAC-1, *potentially influenced-other*, baseline data available intermittently from 1998 to 2005).

Muskeg River

Results of 2005 sampling for water quality measurement endpoints are presented in Table 5.3-3 and Table 5.3-4. Results for selected measurement endpoints (1997 to 2005) relative to regional baseline conditions are shown in Figure 5.3-3, while Table 5.3-5 contains all the water quality guideline exceedances observed in 2005.

Overall, there were no guideline exceedances of the selected water quality measurement endpoints at either of the two Muskeg River stations in fall 2005 (Table 5.3-3 and Table 5.3-4). A number of other water quality variables, total phenols and total and dissolved iron at station MUR-1, exceeded CCME/AENV guidelines in fall 2005. Most measurement endpoints were within previously recorded ranges at both stations (Table 5.3-3, Table 5.3-4), with the exceptions of total dissolved solids and total molybdenum at station MUR-1 and total suspended solids sodium, and total dissolved solids at station MUR-6 being at or below historical (1997-2004) minimum recorded values, and dissolved organic carbon at station MUR-1 being at or above historical (1997-2004) maximum recorded values. All selected water quality measurement endpoints were within regional baseline concentrations at stations MUR-1 and MUR-6 in fall 2005 (Figure 5.3-3).

Ion balance at station MUR-1 has been generally consistent over the period of RAMP sampling, with the exceptions of 1998 and 1999, when higher sulphate and lower calcium concentrations were observed (Figure 5.3-4). The RAMP 5-year report (Golder 2003a) suggested that higher sulphate concentrations in the lower Muskeg River in these years was related to discharges from the Alsands Drain (previous RAMP station ALD-1), which were discontinued in late 2002. Ion balance has been very consistent at station MUR-6 from 1998 to 2005.

Muskeg River Tributaries

Results of 2005 sampling for water quality measurement endpoints in the Muskeg River tributaries are presented in Table 5.3-6 to Table 5.3-9. Results for selected measurement endpoints (1997 to 2005) relative to regional baseline conditions are shown in Figure 5.3-5 and Figure 5.3-6.

Overall, there was a single guideline exceedance (sulphate at station STC-1) of the selected water quality measurement endpoints at any of the four Muskeg River tributary stations in fall 2005. A number of other water quality variables at these stations exceeded CCME/AENV guidelines in fall 2005: total phenols at stations JAC-1 and WAC-1; dissolved iron at station JAC-1; and total iron at stations JAC-1 and MUC-1.

A considerable number of measurement endpoints were either above or below previously recorded fall maximum or minimum concentrations in fall 2005, particularly at station STC-1 (3 at or below previously recorded minima and 9 at or above previously recorded maxima out of a total of 21 measurement endpoints, Table 5.3-6) and station WAC-1 (9 at or below previously recorded minima and 3 at or above previously recorded maxima, Table 5.3-7). With respect to station STC-1, previous maximum concentrations of total dissolved solids and various ions occurred in 2003 and were attributed to Aurora North's Clean Water Discharge (CWD) to Stanley Creek in May 2003. Although the CWD did not flow to Stanley Creek in 2004 (RAMP 2005a), this discharge did occur again to Stanley Creek in 2005 (Section 5.3.2), and is the likely cause of increases in concentrations of various ions and other dissolved constituents of water quality at station STC-1 in fall 2005.

With respect to station WAC-1, logging has recently taken place in the upper parts of the Wapasu Creek watershed (Figure 2.4-1) and this may have influenced water quality conditions at station WAC-1. Logging has also occurred in the areas of the Muskeg River watershed that eventually drain into Muskeg Creek, and six water quality measurement endpoints at station MUC-1 in fall 2005 were below previously recorded minima and one endpoint (DOC) above previously recorded maxima, respectively (Table 5.3-8).

Despite the large number of historically high or low concentrations of water quality measurement endpoints in fall 2005, only two selected measurement endpoints were either below the 5th percentile or above the 95th percentile of fall regional baseline concentrations: total dissolved solids at station STC-1 being above the 95th percentile and total aluminum at station STC-1 being below the 5th percentile.

Ion balance at stations STC-1, MUC-1, WAC-1, and JAC-1 has been relatively consistent across years, and generally similar to stations MUR-1 and MUR-6 (Figure 5.3-4), although stations MUC-1 and JAC-1 have exhibited slightly more sodium/potassium cationic character.

In summary, the influences of oil sands development activities on water quality in the Muskeg River watershed in 2005 were relatively minor. While many water quality measurement endpoints in Stanley Creek were outside previously recorded ranges and this was likely caused by oil sands development activities, this did not result in increased guideline exceedences in Stanley Creek and was not reflected in water quality in the Muskeg River itself. There were few guideline exceedances throughout the Muskeg River watershed in 2005 and fall concentrations of practically all selected water quality measurement endpoints in fall 2005 were within regional baseline ranges.

5.3.4 Sediment Quality

Sediments were sampled in the Muskeg River watershed in 2005 at three stations:

- Muskeg River mouth (station MUR-1, *potentially influenced-oil sands*, operational data available from 1997 to 2005);

- Upstream of Canterra Road Crossing (station MUR-2, *potentially influenced-oil sands*, first sampled in 2000, sampled every year since 2002); and
- Upstream of Stanley Creek (station MUR-D2, *potentially influenced-oil sands*, operational data from 1-2002 to 2005).

Results of 2005 sampling for sediment quality measurement endpoints are presented in Table 5.3-10 to Table 5.3-12 and results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.3-7.

Overall, there was one out of five possible guideline exceedances of the selected sediment quality measurement endpoints at each of the stations in fall 2005 (i.e., five of the selected sediment quality measurement endpoints have CCME/ISQG guidelines [Table 5.3-10 to Table 5.3-12]). All three guideline exceedances were for Fraction 3 (C16-C34) hydrocarbons. No metals exceeded CCME guidelines in 2005 at any of the stations. A considerable number of sediment quality measurement endpoints were either above or below previously recorded fall maximum or minimum concentrations in fall 2005 at all stations, although these results should be interpreted with caution as there are very few observations in the data record for a number of the sediment quality measurement endpoints (Table 5.3-10 to Table 5.3-12). Concentrations of 20% of all selected sediment quality measurement endpoints at station MUR-D-2 were at or below previously recorded minima, whereas 45% of all endpoints were at or above previously recorded maxima. In addition, survival and growth of *Chironomus* and *Hyellela* in sediment toxicity tests were generally higher or lower than previously recorded values; these pattern was consistent across all three stations Table 5.3-10 to Table 5.3-12.

All selected sediment quality measurement endpoints were within regional baseline concentrations at all three stations in 2005 with the exception of total hydrocarbons at station MUR-D-2, which were above the 95th percentile of regional baseline concentrations (Figure 5.3-7).

Based on the available sediment quality data, it appears that current oil sands development in the Muskeg River basin has not had a measurable influence on sediment quality conditions. The relatively small samples sizes and the resulting high variability for many sediment quality measurement endpoints make the detection and interpretation of differences and trends difficult at this time.

5.3.5 Benthic Invertebrate Communities

5.3.5.1 Muskeg River Reaches

In 2005, benthic invertebrate community samples were collected from three reaches on the Muskeg River:

- A lower reach near the Muskeg River mouth (reach MUR-E-1, erosional, *potentially influenced-oil sands*, operational data available from 2000 to 2005);
- A middle reach near the Canterra Road crossing (reach MUR-D-2, depositional, *potentially influenced -oil sands*, operational data available from 2000 to 2005); and
- An upper reach located upstream of the Muskeg River and Aurora North oil sands developments (reach MUR-D-3, depositional, *potentially influenced-other*, baseline data available from 2002 to 2005).

Only two sites were sampled at reach MUR-E-1 in 2005 because of high flows. Reach MUR-E-1 is shallow (0.3 m), and had high current velocity (0.7 m/s) and low macrophyte cover at the time of sampling. Benthic algal biomass (measured as chlorophyll *a*) was low (7.0 mg/m²) and dissolved oxygen was high (8 mg/L; Table 5.3-13). Substrate was comprised of gravel and cobble at the two sites sampled. By comparison, reach MUR-D-2 and reach MUR-D-3 had deeper water with slower current velocities, and with higher macrophyte cover. Dissolved oxygen at reach MUR-D-3 was lower (6.5 mg/L) and conductivity was higher (330 µS/cm) than the other two reaches. Substrate at reach MUR-E-1 consisted mostly of gravel and cobble; sediments at reach MUR-D-2 were dominated by sand while reach MUR-D-3 sediments were dominated by sand/silt/clay.

Chironomids (20%), empidids (dance flies, 22%), mayflies (21%) and mites (10%) dominated reach MUR-E-1 (Table 5.3-14). Stoneflies were also prevalent (8%), while a number of worms (tubificids, naidids), bivalves (Sphaeriidae fingernail clams), caddisflies, and beetles (Coleoptera) were present in lower abundances. Benthic invertebrates have been sampled regularly at reach MUR-E-1 since 1998 and community composition (based on indices and multivariate descriptors) has consistently reflected the expected community composition based on regional baseline data for erosional habitats (Figure 5.3-8, Figure 5.3-9). Abundance measured about 3,000 individuals/m² in 2005, and has historically varied between 5,000 and 70,000 individuals/m². The number of taxa (richness) has been close to 30 for the past six years, while diversity has been very high (>0.8) for the past five years. Percent EPT was high (31%) in 2005, compared to historical ranges for the lower reach of between 14 and 57%. Some of the more sensitive taxa found in reach MUR-E-1 included the empidid (dance fly) *Hemerodromia*, the caddisfly *Brachycentrus*, and the stoneflies *Isogenoides* and *Claasenia sabulosa*. *C. sabulosa* was collected from the lower Muskeg River in the late 1970s by Barton (1980). That species has interesting potential as an indicator of habitat quality because it has at least a three-year life cycle with eggs hatching throughout the year (Barton, 1980).

Reach MUR-D-2 in 2005 was numerically dominated by chironomids (44%), naidids worms (11%), tubificids worms (10%), ostracods (6%), Nematoda (6%) and biting midges (Ceratopogonidae, 4%). Of the chironomids, the generalists *Polypedilum* and *Pagastiella* were the most common. A large variety of other benthic groups were present at reach MUR-D-2 including Mollusca (both clams and snails), cold-water stoneflies (Plecoptera), caddisflies (Trichoptera), dragonflies (Anisoptera), beetles, and miscellaneous dipteran flies. Total abundance in reach MUR-D-2 was lower in 2005 (12,000 individuals/m²) compared to previous years (up to 60,000 individuals/m² in previous years), but the number of taxa (average of 17), and diversity (mean of 0.78) in 2005 were similar to the long-term average for this reach (Figure 5.3-10). Percent EPT (5%) was higher in 2005 in this reach compared to previous years (1 to 2%). The stoneflies *Isoperla* and *Taeniopteryx* were the most sensitive taxa found in reach MUR-D-2 of the Muskeg River.

Reach MUR-D-3 in 2005 was dominated by chironomids (79%) including *Polypedilum* and *Cryptochironomus*). Other relatively dominant groups included Nematoda, worms (Naididae, Tubificidae), fingernail clams (Bivalvia) and mayflies (Ephemeroptera). Total abundances in reach MUR-D-3 were higher in 2005 than in previous years (16,000 individuals/m²), while the number of taxa (average of 11), diversity (0.75), and %EPT were all within historical ranges (Table 5.3-14).

For reach MUR-E-1 the time x reach interaction in an analysis of variance (ANOVA) was the most relevant contrast for testing an effect related to oil sands development activities (other contrasts between these two reaches would only confirm that the benthic communities are different, which they should be naturally given their different benthic habitat types). The time x reach interaction was significant only for richness ($p < 0.001$; Table 5.3-15). Richness in reach MUR-E-1 has averaged close to 30 since about 2000, and has been well within the range of normal variability from regional baseline locations (Figure 5.3-8). There are no indications of an impaired benthic community in reach MUR-E-1.

Relevant ANOVA testing contrasts between reach MUR-D-2 and MUR-D-3 are the time x reach interaction, as well as those relating to differences between reaches. The time x reach interaction was significant for Simpson's Diversity and Evenness (Table 5.3-16) though variations in both measurement endpoints between 2002 and 2005 have been within the range of values observed from regional baseline reaches (Figure 5.3-10). Total abundances have generally been higher in reach MUR-D-2 relative to the reach MUR-D-3 ($p = 0.041$), but no different in 2005 ($p = 0.98$; Table 5.3-16). Richness has generally decreased with time in both reaches ($p = 0.003$), while richness has typically been higher in reach MUR-D-2 ($p = 0.003$), even in 2005 ($p = 0.02$). Variations in %EPT have not been related to year or reach, though there was a significantly higher %EPT in reach MUR-D-2 in 2005 ($p = 0.027$). All of the observed variations in measurement endpoints in reach MUR-D-2 were within the normal range of variability observed in baseline depositional reaches. Differences between reach MUR-D-2 and reach MUR-D-3 infer higher habitat quality (i.e., higher diversity and richness) at reach MUR-D-2.

5.3.5.2 Jackpine Creek

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

- A lower reach near the mouth (reach JAC-D-1, depositional, *reference*, baseline data available from 2002 to 2005); and
- An upper reach (reach JAC-D-2, depositional, *reference*, baseline data available from 2003 to 2005).

Both reaches have shallow depths, no measurable current, and minimal macrophyte cover (Table 5.3-17). Water quality at the two reaches in 2005 was similar with respect to dissolved oxygen (9.5 mg/L), conductivity (205 to 210 µS/cm), and pH (7.5 to 8). Sediments at both reaches were dominated by sand, although reach JAC-D-2 had more silt and clay in the sediments than reach JAC-D-1.

The benthic invertebrate communities of both reaches were heavily dominated by chironomids (Table 5.3-18). Nematoda, Hydracarina (mites), ostracods (seed shrimps), caddisflies (Trichoptera), and Empididae (dance flies) were also abundant in both reaches. Ephemeroptera (mayflies) were present in both reaches, but in low numbers (1% on average). *Baetis*, *Caenis* and *Leptophlebia*, none of which are considered overly sensitive, represented the mayfly fauna in Jackpine Creek. Jackpine Creek does not generally contain fauna considered sensitive to disturbance.

Temporal variation in measurement endpoints is illustrated in Figure 5.3-11.

5.3.6 Fish Populations

The only activity planned under the 2005 RAMP fish program for the Muskeg River system was a spring fish counting fence program (see Section 5.3.2). However, as discussed in Section 3.5, this activity was not carried out due to prohibitively high discharges in the Muskeg River that corresponded with the proposed timing (May 2005) of fence installation and operation. During the month of May river discharge reached a maximum of 35 m³/s, four times the safety threshold of 9 m³/s specified in the RAMP fish fence installation and operation protocol. The purpose of conducting the fish fence study is to characterize spring spawning migration of fish entering from the Athabasca River; at no time were conditions suitable for fence installation during the spring spawning period. The Muskeg River fish fence program is currently scheduled for spring 2006, pending suitable spring river discharge conditions.

5.3.7 Summary of Conditions

There was evidence of effects of oil sands development activities in 2005, but these appear to be subtle and minor. Cumulative oil sands development in the Muskeg River watershed up to 2005 has decreased mean open-water season discharge by 2%, decreased mean winter discharge by 1.7%, decreased annual maximum daily discharge by 2.9%, and decreased open-season minimum daily discharge by 2.0%. These effects are considerably lower than was estimated for 2004 because the use of satellite imagery to estimate land change has reduced the estimate of the hydrologically-isolated area within the catchment for 2005 as compared to 2004. There were oil sands development effects on water quality in Stanley Creek, but this was not manifested in Muskeg River water quality, and fall concentrations of most selected water quality measurement endpoints in 2005 were within regional baseline ranges. Similar conclusions can be made for sediment quality, although the sediment quality data record for the Muskeg River is still relatively limited and characterized by very high variability. There is no evidence of an impaired benthic community in those parts of the Muskeg River designated as *potentially influenced-oil sands*.

Figure 5.3-2 Muskeg River: 2005 hydrograph and historical context.

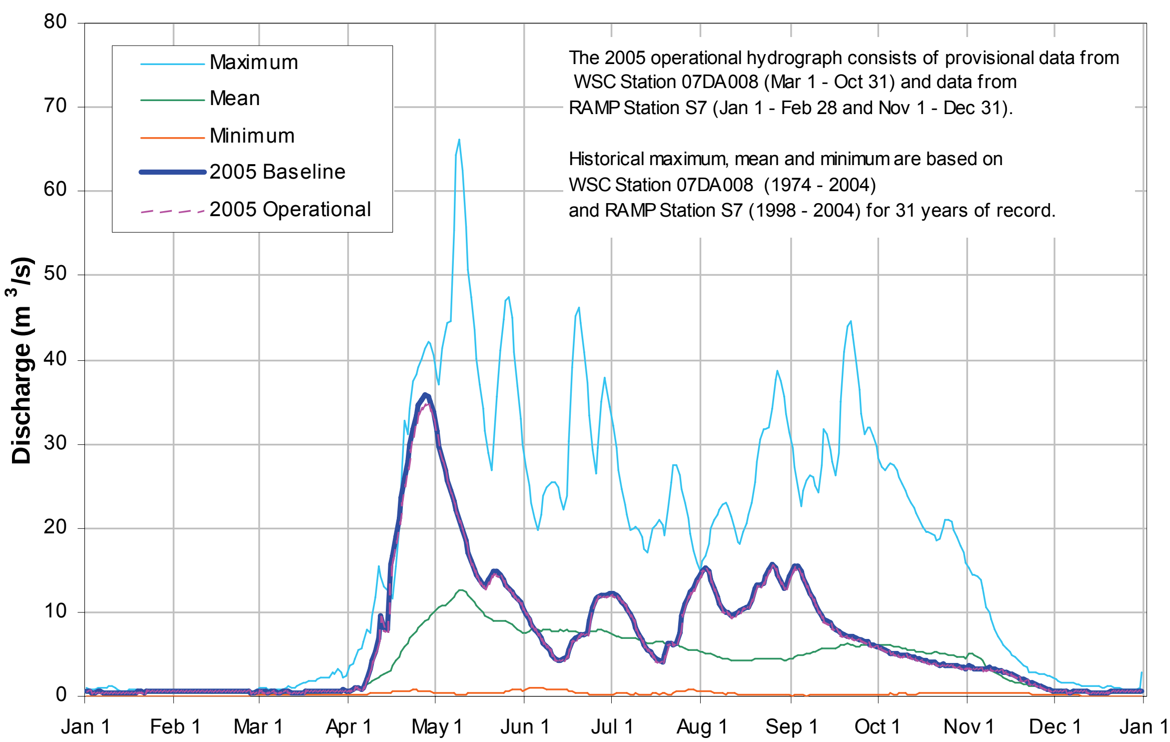


Table 5.3-1 Inputs for calculation of baseline hydrograph at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008).

Component	Annual Volume (dam^3)	Basis and Data Source
Observed hydrograph	212,000	Observed daily discharges obtained from RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008)
Natural runoff that would have occurred from active mine areas, or that is intercepted by development	6,350	56 km^2 estimated sum of oil sands-developed and oil sands-enclosed areas within watershed (Table 2.4-1)
Incremental runoff from areas that are cleared and areas that are being dewatered	2,220	29.5 km^2 estimated sum of oil sands-cleared and oil sands-bare areas within watershed (Table 2.4-1)
Withdrawals from the Muskeg River by oil sands development activities	0	Unknown but assumed to be negligible
Releases to the Muskeg River by oil sands development activities	271	Aurora Clean Water Diversion discharges to Stanley Creek – annual total; data provided by Syncrude
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No significant upstream oil sands developments

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.3-2 Calculated changes in hydrologic measurement endpoints for the Muskeg River watershed.

Measurement Endpoint[1]	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	10.1	9.91	-1.5
Mean winter discharge	0.892	0.908	-1.7
Annual maximum daily discharge	34.7	34.7	-2.9
Open-water season minimum daily discharge	3.22	3.18	-2.0

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

Table 5.3-3 Concentrations of selected water quality measurement endpoints, Muskeg River mouth (MUR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	8	7.4	8.1	8.4
Total suspended solids	mg/L	-[1]	<3	8	<3	3	70
Conductivity	µS/cm	-	269	8	220	349	671
Nutrients							
Total phosphorus	mg/L	0.05	0.023	8	0.008	0.022	**0.072**
Total dissolved phosphorus	mg/L	0.05[2]	0.015	8	0.004	0.014	0.03
Total nitrogen*	mg/L	1.0	0.9	8	0.4	0.7	**1.2**
Nitrate+nitrite	mg/L	-	<0.1	8	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	25	8	15	21	24
Ions							
Sodium	mg/L	-	10	8	8	13	64
Calcium	mg/L	-	37.5	8	28.8	51	108
Magnesium	mg/L	-	9.8	8	7.1	13	18.9
Chloride	mg/L	230, 860[3]	3	8	1	4	36
Sulphate	mg/L	100[4]	5.4	8	2.1	6.8	91
Total dissolved solids	mg/L	-	170	8	184	280	405
Total alkalinity	mg/L		136	8	105	179	313
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.078	8	0.027	0.079	**1.2**
Dissolved aluminum	mg/L	0.1[2]	0.0061	8	0.002	<0.01	0.03
Total boron	mg/L	1.2[4]	0.037	8	0.032	0.043	0.15
Total molybdenum	mg/L	0.073	0.000066	8	0.00008	<0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	0.8
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.008**	8	<0.001	<0.001	**0.005**
Dissolved iron	mg/L	0.3[2]	**0.38**	8	0.14	0.30	**1.02**
Total iron	mg/L	0.3	**0.63**	8	0.29	**0.76**	**1.81**

Note: Guideline values are CCME/AENV guidelines 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 1999).

4 B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.3-4 Concentrations of selected water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (MUR-6), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	8	7.0	7.8	8.3
Total suspended solids	mg/L	-[1]	<3	8	<3	5	176
Conductivity	µS/cm	-	263	8	233	332	556
Nutrients							
Total phosphorus	mg/L	0.05	0.018	8	0.014	0.021	**2.31**
Total dissolved phosphorus	mg/L	0.05[2]	0.014	8	0.011	0.018	0.039
Total nitrogen*	mg/L	1.0	0.8	8	0.3	0.9	**4.0**
Nitrate+nitrite	mg/L	-	<0.1	8	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	22	8	14	19	24
Ions							
Sodium	mg/L	-	3	8	3	4.5	9
Calcium	mg/L	-	36	8	31	51	85
Magnesium	mg/L	-	12.8	8	11.6	17	23
Chloride	mg/L	230, 860[3]	2	8	<1	1.1	3
Sulphate	mg/L	100[4]	2.9	8	1.6	4.9	6.6
Total dissolved solids	mg/L	-	180	8	180	265	340
Total alkalinity	mg/L		138	8	120	195	318
Organic compounds							
Naphthenic acids	mg/L	-	<1	8	<1	<1	12
Selected metals							
Total aluminum	mg/L	0.1	0.021	8	0.009	0.065	**0.17**
Dissolved aluminum	mg/L	0.1[2]	0.0051	8	0.002	0.01	0.08
Total boron	mg/L	1.2[4]	0.0146	8	0.006	0.01115	0.081
Total molybdenum	mg/L	0.073	0.000084	8	0.000075	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
none	-	-	-	-	-	-	-

Note: Guideline values are CCME/AENV guidelines 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.

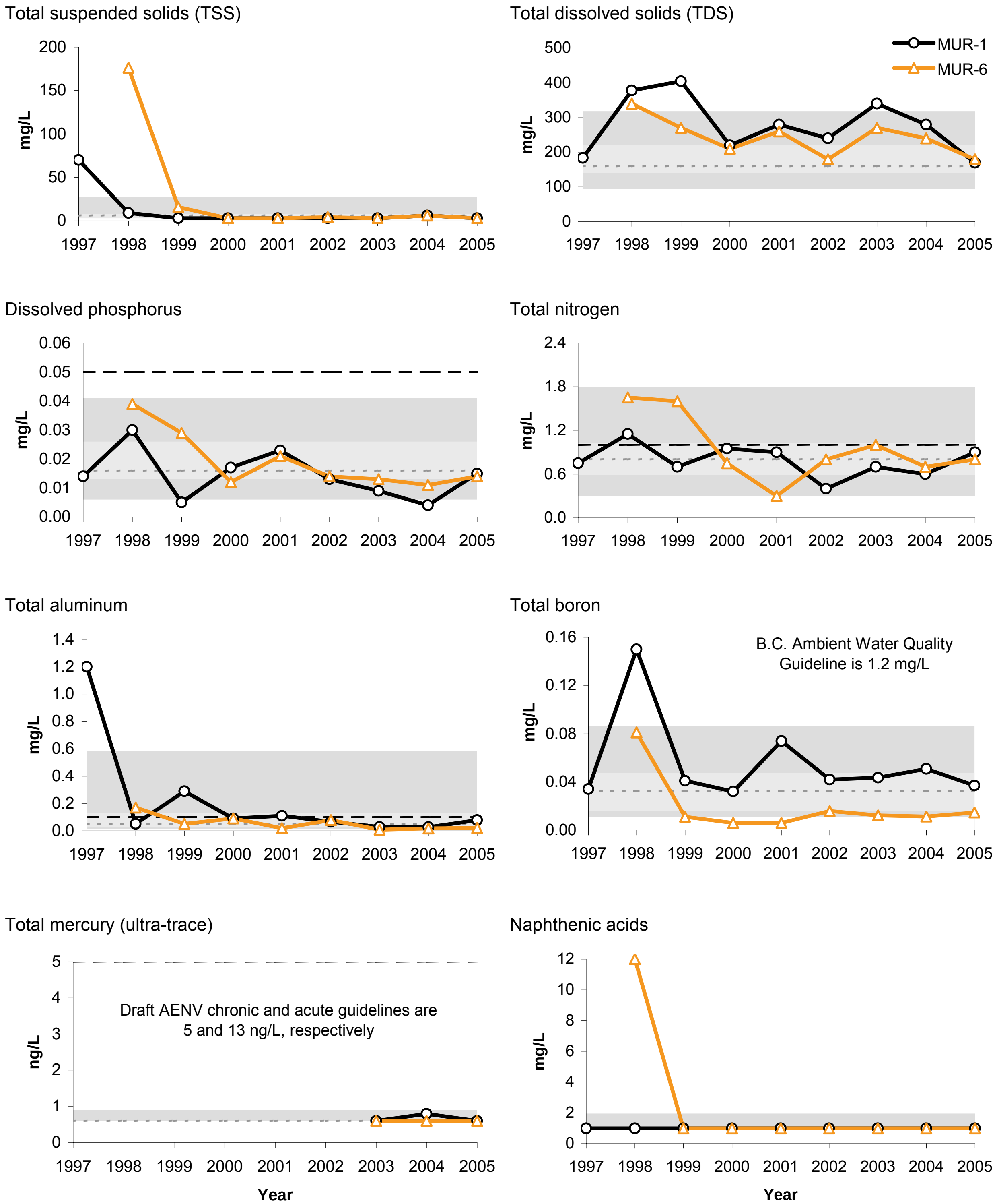
[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Figure 5.3-3 Concentrations of selected water quality measurement endpoints, Muskeg River at the mouth (MUR-1) and upstream of Wapasu Creek (MUR-6), fall 2005, relative to regional fall baseline concentrations.



Note: Non-detectable values are shown at the detection limit.

[1] 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.

Table 5.3-5 List of all 2005 water quality guideline exceedances, Muskeg River.

Parameter	Units	Guideline*	MUR-1	MUR-6	MUC-1	JAC-1	STC-1	WAC-1
Spring								
Total phenols	mg/L	0.004	ns	ns	ns	ns	**0.008**	ns
Summer								
Sulphate	mg/L	100[1]	ns	ns	ns	ns	**103**	ns
Dissolved oxygen	mg/L	5.0[2]	ns	ns	ns	ns	**3.39**	ns
Fall								
Sulphate	mg/L	100[1]	-	-	-	-	**126**	-
Total phenols	mg/L	0.004	**0.008**	-	-	**0.007**	-	**0.008**
Dissolved iron	mg/L	0.3[3]	**0.376**	-	-	**0.411**	-	-
Total iron	mg/L	0.3	**0.625**	-	**0.301**	**0.591**	-	-

STC-1 sampled in spring, summer, and fall 2005; all other stations sampled only in fall 2005.

ns = not sampled.

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

[1] B.C. Approved Water Quality Guideline (2001).

[2] Alberta acute guideline for dissolved oxygen; guideline is a minimum value.

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

Figure 5.3-4 Piper diagram of fall ion concentrations in the Muskeg River and its tributaries, 1997 to 2005.

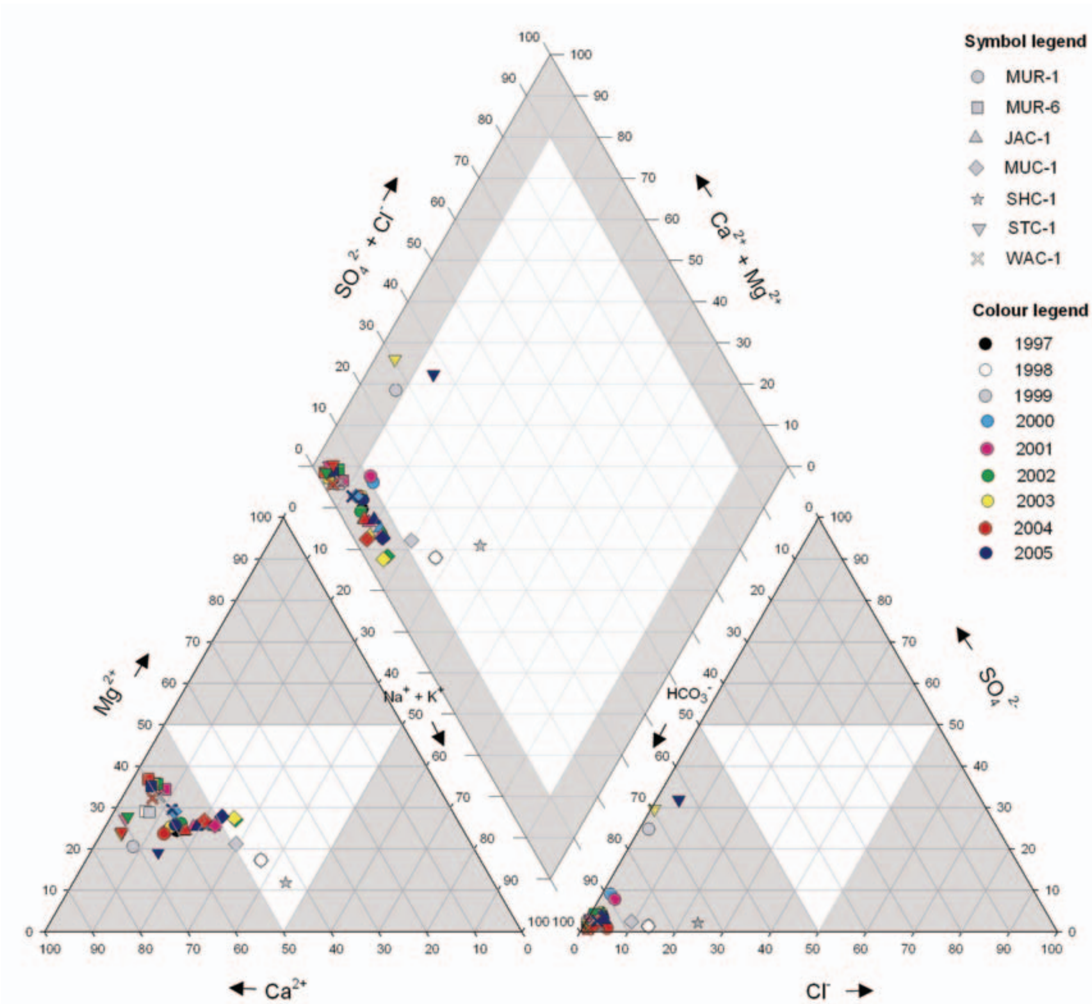


Table 5.3-6 Concentrations of selected water quality measurement endpoints, Stanley Creek (STC-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	4	7.6	7.85	8.1
Total suspended solids	mg/L	-[1]	<3	4	<3	<3	6
Conductivity	µS/cm	-	760	4	271	301	617
Nutrients							
Total phosphorus	mg/L	0.05	0.016	5	0.017	0.026	**0.08**
Total dissolved phosphorus	mg/L	0.05[2]	0.012	5	0.01	0.012	0.03
Total nitrogen*	mg/L	1.0	0.3	5	0.3	0.6	**2.1**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	9	4	6	7	8
Ions							
Sodium	mg/L	-	26	4	2	3	6
Calcium	mg/L	-	112	4	45.4	51	103
Magnesium	mg/L	-	19.7	4	11.1	11.3	20.5
Chloride	mg/L	230, 860[3]	14	4	<1	1.5	2
Sulphate	mg/L	100[4]	**126**	4	2.4	5.2	98.5
Total dissolved solids	mg/L	-	480	4	200	200	400
Total alkalinity	mg/L		260	4	157	167	240
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.000994	5	0.002	0.011	0.02
Dissolved aluminum	mg/L	0.1[2]	0.000424	5	0.0004	0.0016	0.02
Total boron	mg/L	1.2[4]	0.0871	5	0.018	0.023	0.025
Total molybdenum	mg/L	0.073	0.0000769	5	0.00004	<0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
none	-	-	-	-	-	-	-

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

[6] B.C. Approved Water Quality Guideline (2001).

Table 5.3-7 Concentrations of selected water quality measurement endpoints in Wapasu Creek (WAC-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	3	7.4	7.7	8.2
Total suspended solids	mg/L	-[1]	<3	3	3	3	23
Conductivity	µS/cm	-	220	3	284	339	524
Nutrients							
Total phosphorus	mg/L	0.05	0.016	3	0.02	0.03	**0.06**
Total dissolved phosphorus	mg/L	0.05[2]	0.012	3	0.014	0.014	0.016
Total nitrogen*	mg/L	1.0	1	3	0.5	0.8	1
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	26	3	11	17	18
Ions							
Sodium	mg/L	-	7	3	6	6	8
Calcium	mg/L	-	31	3	44	54	72
Magnesium	mg/L	-	10	3	15	17	25
Chloride	mg/L	230, 860[3]	2	3	1.4	2	2
Sulphate	mg/L	100[4]	3.1	3	1.9	5.2	7.6
Total dissolved solids	mg/L	-	160	3	240	250	300
Total alkalinity	mg/L		114	3	176	197	292
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.015	3	0.018	0.02	0.05
Dissolved aluminum	mg/L	0.1[2]	0.0062	3	0.0037	<0.01	0.05
Total boron	mg/L	1.2[4]	0.0208	3	0.014	0.0246	0.081
Total molybdenum	mg/L	0.073	0.0000328	3	0.000050	<0.0001	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.008**	3	0.002	**0.006**	**0.006**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.3-8 Concentrations of selected water quality measurement endpoints in Muskeg Creek (MUC-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	7	7.4	7.7	8.2
Total suspended solids	mg/L	-[1]	3	7	<3	4	9
Conductivity	µS/cm	-	184	7	188	297	671
Nutrients							
Total phosphorus	mg/L	0.05	0.022	7	0.017	0.028	**0.066**
Total dissolved phosphorus	mg/L	0.05[2]	0.013	7	0.013	0.018	0.03
Total nitrogen*	mg/L	1.0	1.0	7	0.4	0.9	**1.2**
Nitrate+nitrite	mg/L	-	<0.1	7	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	28	7	20	22	26
Ions							
Sodium	mg/L	-	11	7	7	17	64
Calcium	mg/L	-	21	7	23	34	71
Magnesium	mg/L	-	7	7	8	10	17
Chloride	mg/L	230, 860[3]	2	7	<1	3	36
Sulphate	mg/L	100[4]	3.4	7	2	4.6	8
Total dissolved solids	mg/L	-	140	7	150	230	378
Total alkalinity	mg/L		93	7	93	153	313
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.0407	7	0.031	0.05	0.09
Dissolved aluminum	mg/L	0.1[2]	0.0078	7	0.0029	<0.01	0.03
Total boron	mg/L	1.2[4]	0.0479	7	0.024	0.057	0.15
Total molybdenum	mg/L	0.073	0.0000482	7	0.0000479	0.0001	0.0064
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total iron	mg/L	0.3	**0.301**	7	**0.30**	**1.16**	**1.81**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.3-9 Concentrations of selected water quality measurement endpoints in Jackpine Creek (JAC-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	6	7.8	8.0	8.2
Total suspended solids	mg/L	-[1]	8	6	<3	6	8
Conductivity	µS/cm	-	197	6	183	220	413
Nutrients							
Total phosphorus	mg/L	0.05	0.022	6	0.018	0.021	0.042
Total dissolved phosphorus	mg/L	0.05[2]	0.018	6	0.006	0.013	0.026
Total nitrogen*	mg/L	1.0	0.9	6	0.7	0.8	**1.5**
Nitrate+nitrite	mg/L	-	<0.1	6	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	28	6	19	22	24
Ions							
Sodium	mg/L	-	10	6	10	12	18
Calcium	mg/L	-	25.8	6	22.2	28	56.6
Magnesium	mg/L	-	7.2	6	6.6	8	14.2
Chloride	mg/L	230, 860[3]	3	6	1	2	5.6
Sulphate	mg/L	100[4]	2.9	6	2.6	3.6	4.3
Total dissolved solids	mg/L	-	160	6	110	215	234
Total alkalinity	mg/L		100	6	93	112	227
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	1	1
Selected metals							
Total aluminum	mg/L	0.1	0.062	6	0.038	0.086	**0.12**
Dissolved aluminum	mg/L	0.1[2]	0.011	6	0.004	0.009	**0.17**
Total boron	mg/L	1.2[4]	0.0353	6	0.033	0.042	0.066
Total molybdenum	mg/L	0.073	0.000070	6	0.000071	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	-0.6	-	-0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.007**	6	<0.001	**0.0045**	**0.014**
Dissolved iron	mg/L	0.3[2]	**0.41**	6	0.19	0.26	**0.70**
Total iron	mg/L	0.3	**0.59**	6	**0.38**	**0.58**	**1.57**

Note: Guideline values are CCME/AENV guidelines 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.

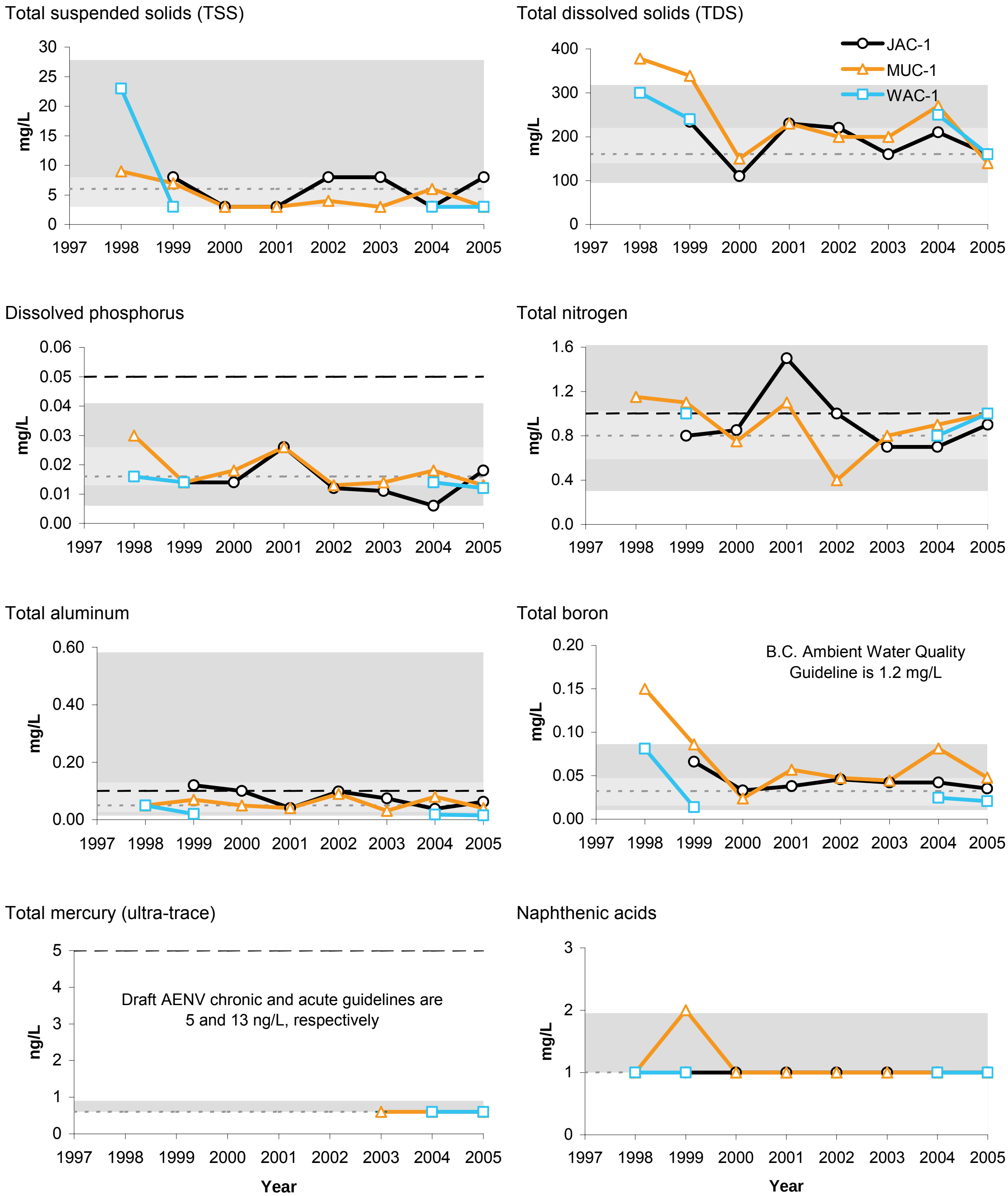
[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

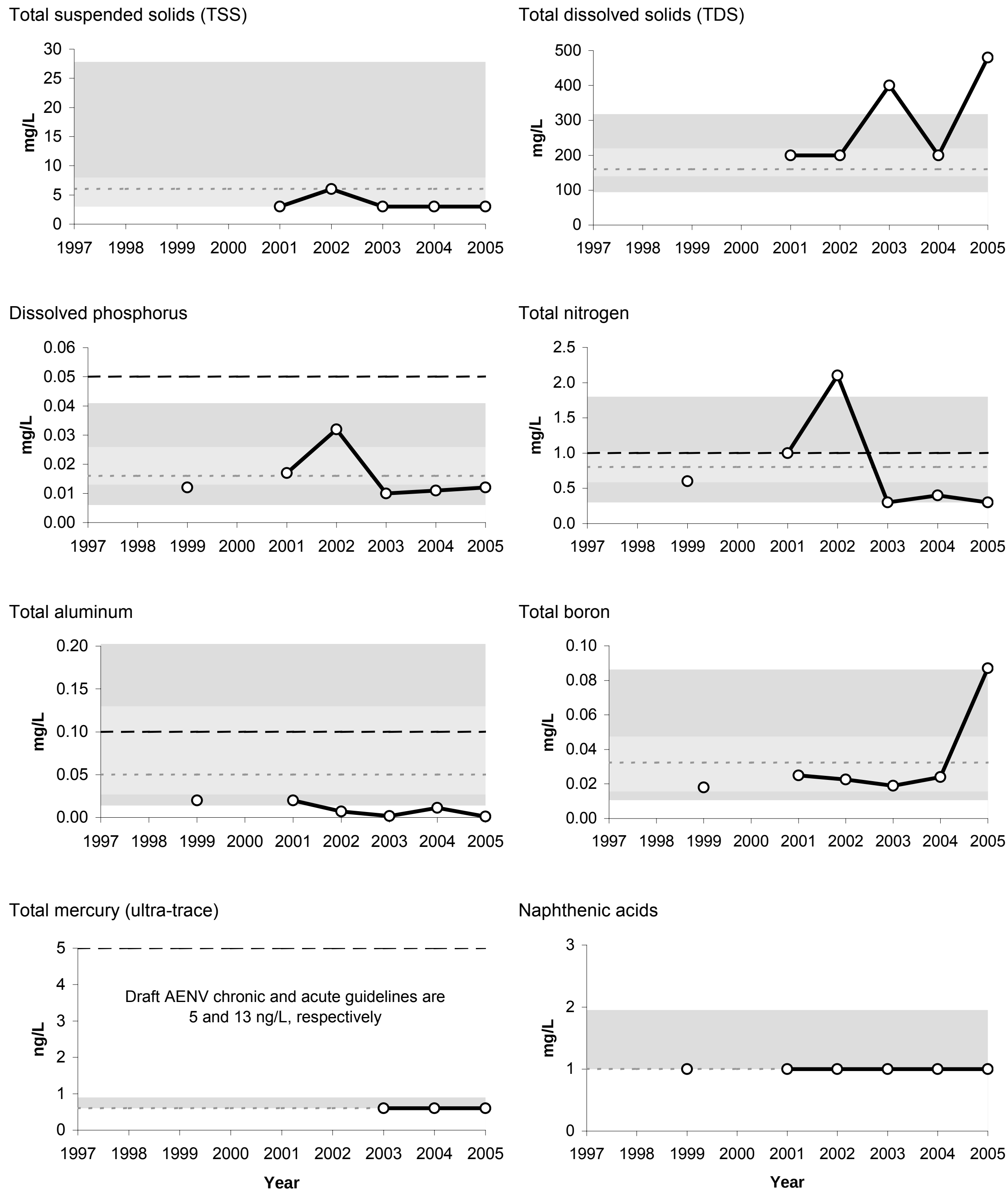
Figure 5.3-5 Concentrations of selected water quality measurement endpoints in Muskeg River tributaries (Jackpine Creek, Muskeg Creek and Wapasu Creek), fall 2005, relative to regional baseline fall concentrations.



Note: Non-detectable values are shown at the detection limit.

[1] 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 5.3-6 Concentrations of selected water quality measurement endpoints in Stanley Creek (STC-1), fall 2005, relative to regional baseline fall concentrations.



Note: Non-detectable values are shown at the detection limit.

[1] 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.

Table 5.3-10 Concentrations of selected sediment quality measurement endpoints, Muskeg River mouth (MUR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	16	7	2	6	16
Silt	%	-	28	7	4	13	27
Sand	%	-	56	7	58	85	90
Total organic carbon	%	-	2.1	8	0.5	1.35	2.98
Total hydrocarbons							
CCME variables							
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]	12	1	-	-	29
Fraction 3 (C16-C34)	mg/kg	400[2]	**660**	1	-	-	**670**
Fraction 4 (C34-C50)	mg/kg	2800[2]	630	1	-	-	590
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0123	9	<0.003	0.0085	0.018
Retene	mg/kg	-	0.0394	5	0.003	0.013	0.0627
Total dibenzothiophenes	mg/kg	-	0.42	9	0.02	0.14	0.58
Total PAHs	mg/kg	-	1.57	9	0.27	0.81	1.93
Total HMW PAHs	mg/kg	-	0.51	9	0.08	0.41	0.87
Total LMW PAHs	mg/kg	-	1.06	9	0.09	0.42	1.32
Predicted PAH toxicity[1]	H.I.	-	0.36	8	0.16	0.31	0.60
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	4	5	7.5	8.8
Chironomus growth - 10d	mg/organism	-	2.2	4	1.2	2.08	2.8
Hyallela survival - 14d	# surviving	-	9	2	5	-	8
Hyallela growth - 14d	mg/organism	-	0.26	2	0.1	-	0.14

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 2001).

3 Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.3-11 Concentrations of selected sediment quality measurement endpoints, Muskeg River upstream of mouth (MUR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	-	3	4	8	12
Silt	%	-	-	3	13	16	22
Sand	%	-	-	3	72	74	79
Total organic carbon	%	-	29.6	3	2.1	2.7	2.8
Total hydrocarbons							
CCME variables							
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	-	-	**160**
Fraction 3 (C16-C34)	mg/kg	400[2]	**2900**	1	-	-	**1800**
Fraction 4 (C34-C50)	mg/kg	2800[2]	1600	1	-	-	1400
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0049	3	0.0016	0.0171	0.02
Retene	mg/kg	-	0.285	3	<0.21	0.144	0.183
Total dibenzothiophenes	mg/kg	-	6.06	3	3.28	5.33	10.63
Total PAHs	mg/kg	-	20.90	3	14.27	15.33	30.44
Total HMW PAHs	mg/kg	-	5.78	3	3.40	3.92	9.63
Total LMW PAHs	mg/kg	-	15.12	3	10.87	11.40	20.81
Predicted PAH toxicity[1]	H.I.	-	1.40	3	1.18	1.67	1.75
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	7	2	6	-	7
Chironomus growth - 10d	mg/organism	-	0.68	2	2.5	-	2.5
Hyallela survival - 14d	# surviving	-	8	2	8	-	8
Hyallela growth - 14d	mg/organism	-	0.35	2	0.11	-	0.18

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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.3-12 Concentrations of selected sediment quality measurement endpoints, Muskeg River upstream of Stanley Creek (MUR-D2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	5	2	6	-	7
Silt	%	-	10	2	14	-	15
Sand	%	-	85	2	79	-	80
Total organic carbon	%	-	1.7	1	-	-	5.5
Total hydrocarbons							
CCME variables							
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]	130	1	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	**1900**	1	-	-	**540**
Fraction 4 (C34-C50)	mg/kg	2800[2]	1400	1	-	-	210
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0145	2	0.0031	-	0.0039
Retene	mg/kg	-	0.398	2	0.156	-	0.498
Total dibenzothiophenes	mg/kg	-	0.12	2	0.10	-	0.13
Total PAHs	mg/kg	-	1.26	2	0.67	-	1.12
Total HMW PAHs	mg/kg	-	0.51	2	0.20	-	0.31
Total LMW PAHs	mg/kg	-	0.75	2	0.47	-	0.82
Predicted PAH toxicity[1]	H.I.	-	0.15	2	0.32	-	0.56
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	2	3	-	7
Chironomus growth - 10d	mg/organism	-	1.43	2	1.8	-	2.2
Hyallela survival - 14d	# surviving	-	7	2	7	-	8
Hyallela growth - 14d	mg/organism	-	0.34	2	0.11	-	0.2

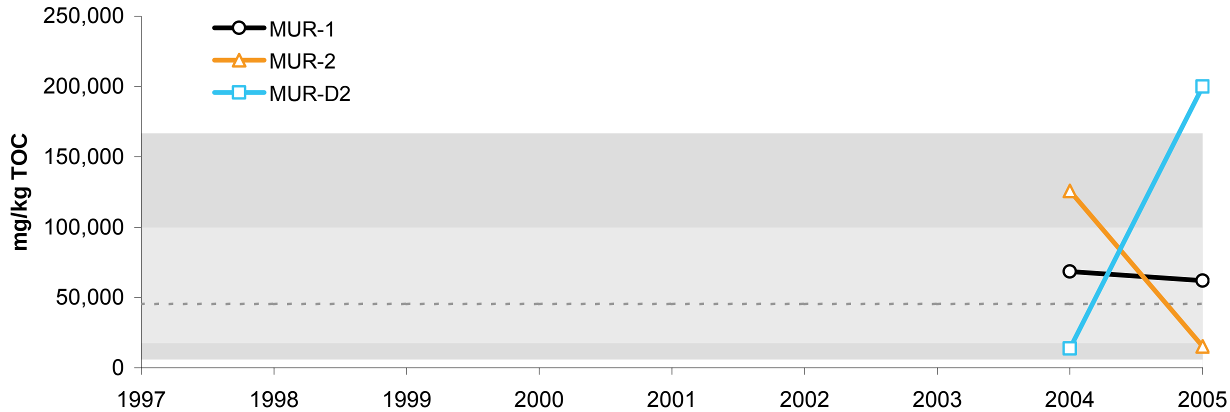
Values in **bold** indicate concentrations exceeding guidelines.

[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.

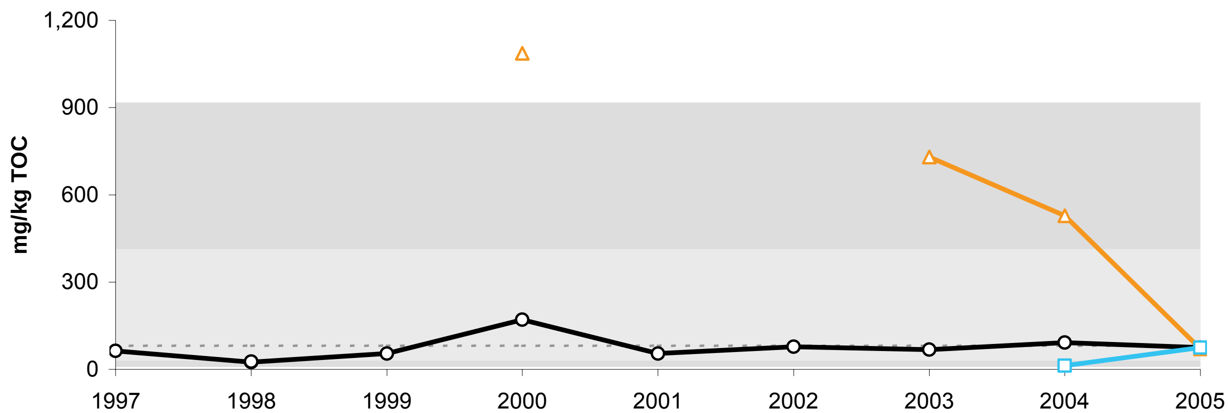
[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

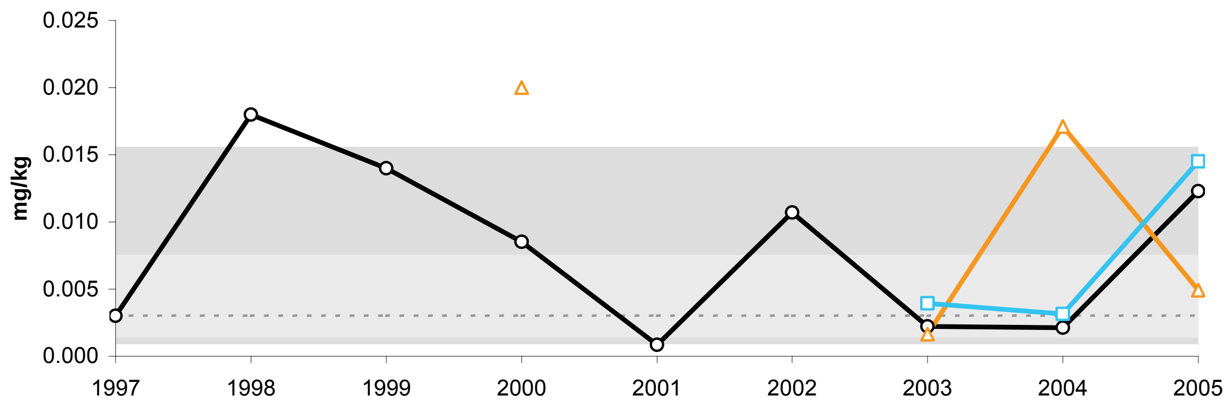
Figure 5.3-7 Concentrations of selected sediment quality measurement endpoints in the Muskeg River, fall 2005, relative to regional baseline fall concentrations.



Total Polycyclic Aromatic Hydrocarbons (PAHs) (normalized to TOC)



Naphthalene



[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

Table 5.3-13 Average habitat characteristics of benthic invertebrate community sampling reaches in the Muskeg River, fall 2005.

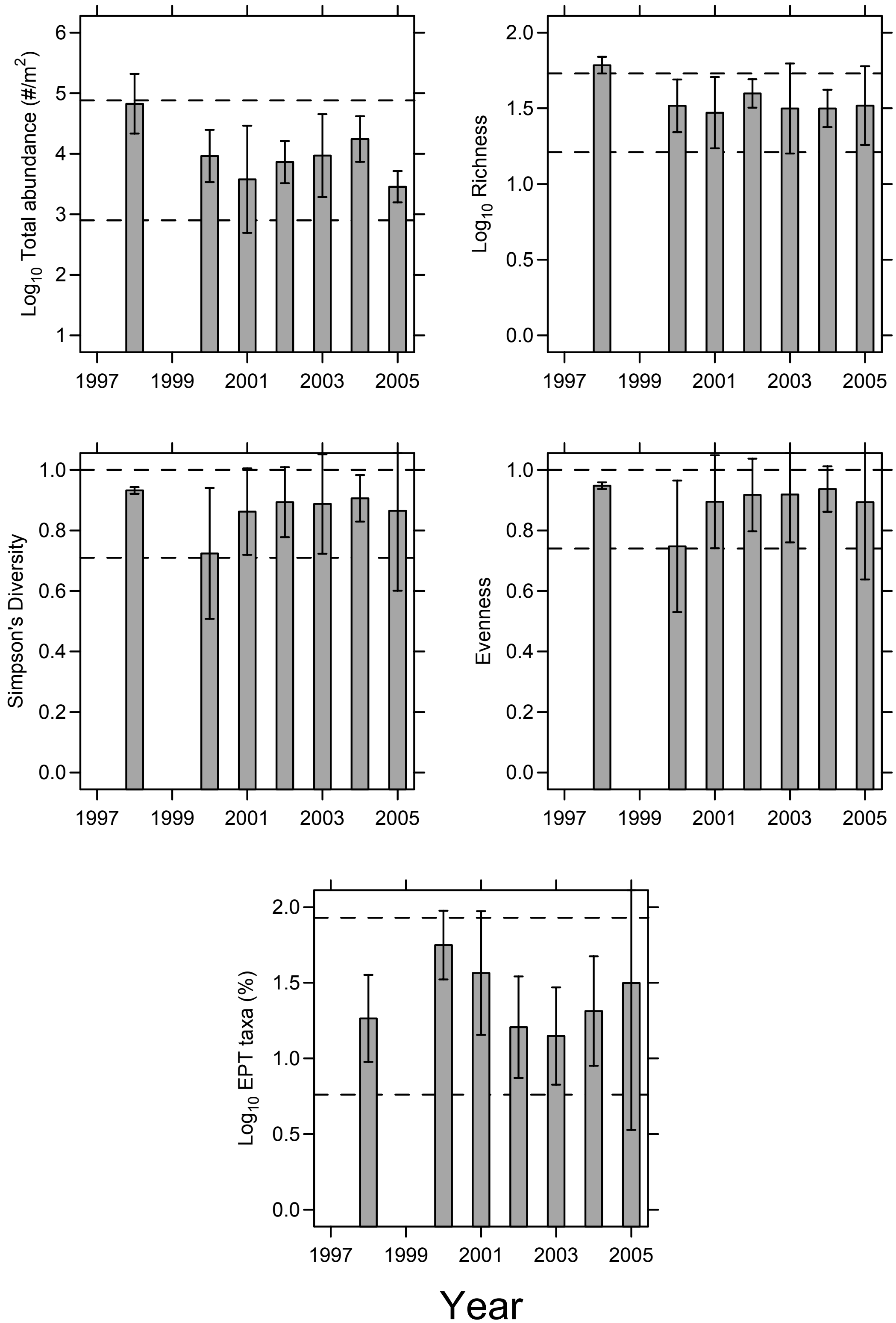
Variable	Units	Reach MAR-E-1	Reach MAR-D-2	Reach MAR-D-3
Sample date	-	Sept. 8, 2005	Sept. 8, 2005	Sept. 10, 2005
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.3	1.0	1.2
Current velocity	m/s	0.72	0.24	0.20
Macrophyte cover	%	n/a	46	4
Benthic algae[1]	mg/m^2	7	n/a	n/a
Field Water Quality				
Dissolved oxygen	mg/L	8.3	7.4	6.5
Conductivity	μS/cm	260	257	330
pH	-	7.8	7.8	7.3
Water temperature	°C	6.5	12.6	12.7
Sediment Composition				
Sand	%	n/a	70	82
Silt	%	n/a	21	8
Clay	%	n/a	9	14
Total Organic Carbon	%	n/a	4	17
Small gravel	%	63	n/a	n/a
Large gravel	%	28	n/a	n/a
Small cobble	%	10	n/a	n/a
Large cobble	%	n/a	n/a	n/a
Boulder	%	n/a	n/a	n/a
Bedrock	%	n/a	n/a	n/a

[1] Measured as chlorophyll *a*

Table 5.3-14 Summary of major taxon abundances and benthic invertebrate community measurement endpoints among reaches in the Muskeg River.

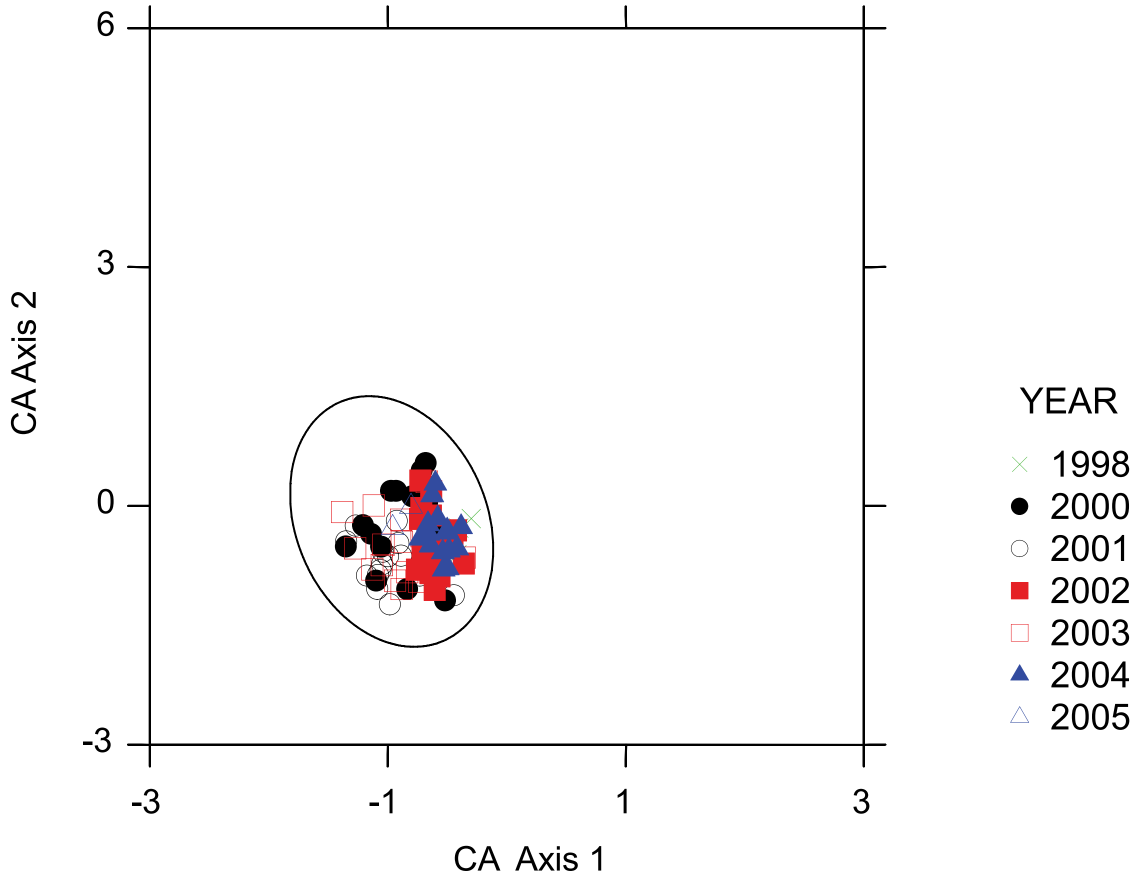
Taxon	Reach MAR-E-1							Reach MAR-D-2						Reach MAR-D-3			
	1998	2000	2001	2002	2003	2004	2005	2000	2001	2002	2003	2004	2005	2002	2003	2004	2005
Hydra	0	<1	<1	<1	0	0	0	<1	<1	0	0	0	<1	0	0	0	<1
Nematoda	2	<1	4	2	3	5	2	2	1	6	3	3	6	1	2	6	3
Glossiphoniidae	0	0	0	<1	0	0	0	<1	<1	<1	<1	0	0	<1	1	1	<1
Erpobdellidae	0	0	0	<1	0	0	0	<1	<1	<1	<1	0	<1	<1	<1	<1	<1
Enchytraeidae	<1	<1	1	<1	<1	1	1	<1	1	2	2	3	3	0	<1	1	<1
Naididae	5	1	6	14	3	3	1	2	1	<1	2	1	11	<1	1	1	2
Tubificidae	5	<1	<1	1	1	13	5	10	<1	3	2	8	10	<1	2	15	2
Lumbriculidae	0	0	0	<1	<1	<1	0	1	<1	<1	1	0	<1	0	<1	1	0
Hydracarina	14	6	15	13	13	0	10	1	1	2	1	<1	<1	<1	1	<1	<1
Ostracoda	3	1	<1	3	<1	0	0	1	2	5	0	<1	10	4	1	7	1
Copepoda	<1	<1	<1	2	<1	<1	1	<1	1	<1	<1	1	<1	0	1	3	1
Amphipoda	0	<1	0	<1	<1	0	0	0	<1	<1	1	<1	<1	<1	1	5	<1
Bivalvia	6	1	3	5	1	3	2	4	1	3	1	1	<1	28	17	18	8
Gastropoda	3	<1	<1	<1	<1	0	0	<1	3	1	<1	0	<1	<1	1	2	<1
Ephemeroptera	12	50	28	5	5	9	21	<1	1	2	1	<1	6	0	5	5	2
Plecoptera	4	6	5	5	3	8	8	<1	<1	<1	<1	0	<1	0	0	0	0
Trichoptera	2	1	8	5	4	4	2	<1	<1	<1	<1	<1	1	<1	<1	<1	1
Anisoptera	<1	<1	2	1	1	2	<1	<1	<1	<1	<1	0	<1	0	<1	<1	0
Coleoptera	5	1	2	1	3	10	5	<1	<1	<1	0	<1	1	0	<1	<1	0
Heteroptera	<1	0	0	0	0	0	0	<1	0	0	0	0	0	0	<1	<1	0
Tipulidae	<1	<1	<1	<1	<1	<1	0	1	<1	0	0	<1	0	0	0	0	0
Tabanidae	0	<1	<1	0	0	<1	0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Empididae	4	<1	2	2	3	6	22	<1	<1	<1	<1	1	1	0	0	0	0
Ceratopogonidae	1	<1	<1	1	0	<1	<1	1	1	2	3	7	4	<1	2	2	1
Chironomidae	32	31	23	37	58	37	20	75	84	69	81	74	44	66	65	27	79
Simuliidae	<1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	<1
Total Abundance (No./m^2)	68,374	9,983	4,953	7,754	11,343	18,757	2,849	59,328	64,032	34,672	12,635	10,440	11,948	9,905	13,566	7,190	15,887
Richness	60	32	29	39	32	31	32	26	30	21	14	10	17	12	17	9	11
Simpson's Diversity	0.93	0.72	0.86	0.89	0.89	0.91	0.87	0.75	0.84	0.86	0.70	0.68	0.78	0.64	0.78	0.71	0.75
Evenness	0.95	0.75	0.89	0.92	0.92	0.94	0.89	0.78	0.87	0.91	0.77	0.77	0.83	0.71	0.85	0.81	0.83
% EPT	18	57	39	16	14	21	31	<1	1	2	2	<1	5	<1	6	5	2

Figure 5.3-8 Variations in benthic invertebrate community measurement endpoints in reach MUR-E-1 (erosional).



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional sites.

Figure 5.3-9 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for reach MUR-E-1.

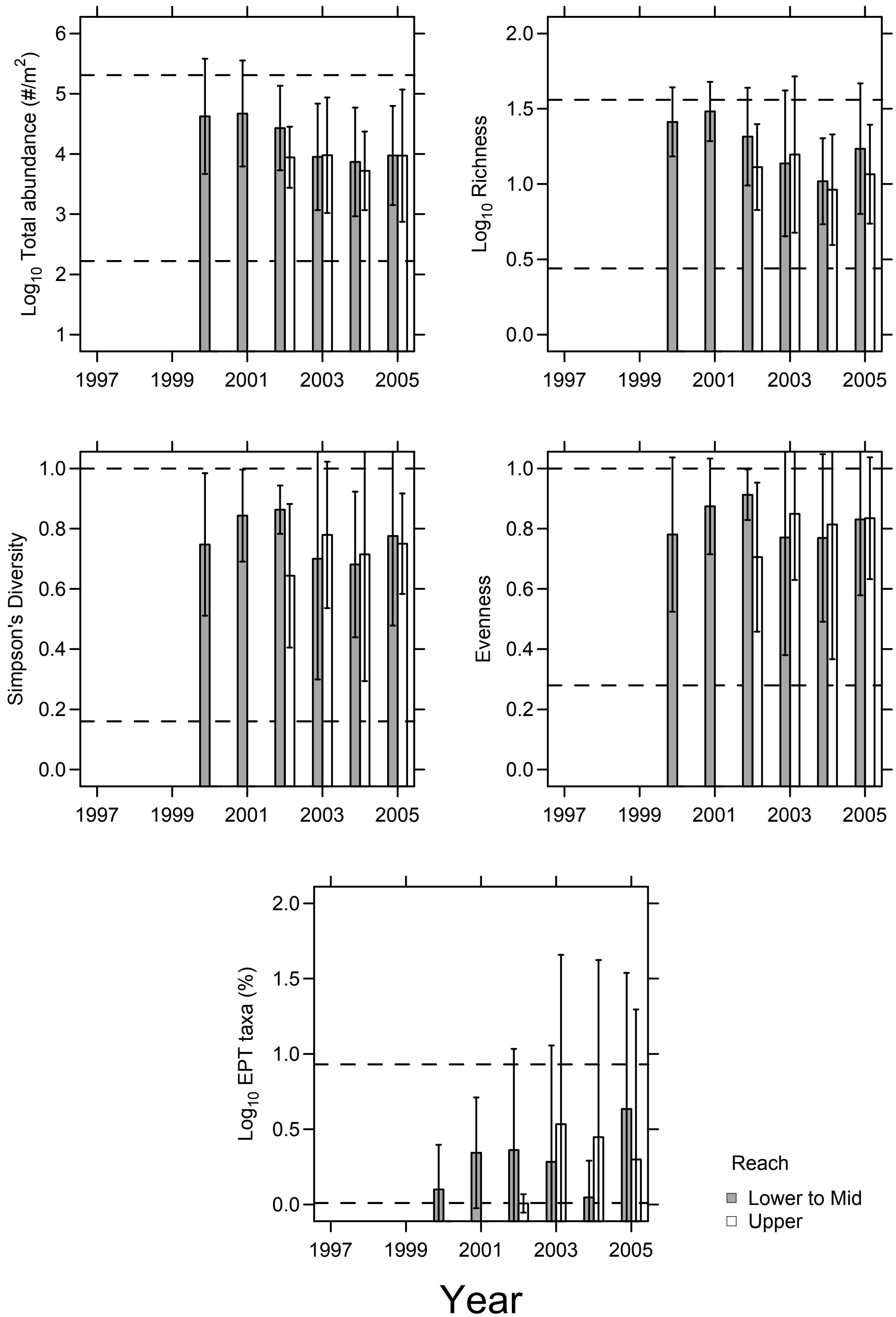


Note: ellipse is for the baseline erosional reaches.

Table 5.3-15 Results of analysis of variance (ANOVA) between reach MUR-E-1 and reach MUR-D-3, Muskeg River.

Source	SS	df	F	p
Log$_{10}$ Abundance				
Reach-Year	7.019	10	7.47	<0.001
Time	0.007	1	0.08	0.781
Reach	0.035	1	0.38	0.540
Time × Reach	0.173	1	1.85	0.177
Reach (2005)	0.445	1	4.74	0.031
Error	124	11.64		
Log$_{10}$ Richness				
Reach-Year				
Time	7.118	10	40.72	<0.001
Reach	0.074	1	4.27	0.040
Time × Reach	3.163	1	180.9	<0.001
Reach (2005)	0.341	1	19.55	<0.001
Error	2.167	124		
Simpson's Diversity				
Reach	1.126	10	11.36	<0.001
Time	0.003	1	0.39	0.535
Reach	0.441	1	44.53	<0.001
Time × Reach	0.010	1	1.08	0.300
Reach (2005)	0.022	1	2.23	0.137
Error	1.228	124		
Evenness				
Reach	0.807	10	7.67	<0.001
Time	0.011	1	1.11	0.293
Reach	0.213	1	20.31	<0.001
Time × Reach	0.020	1	1.90	0.170
Reach (2005)	0.005	1	0.54	0.464
Error	1.305	124		
Log$_{10}$ EPT %				
Reach	43.65	10	49.12	<0.001
Time	0.48	1	5.44	0.021
Reach	15.05	1	169.32	<0.001
Time × Reach	0.02	1	0.22	0.637
Reach (2005)	2.39	1	26.97	<0.001
Error	11.02	124		

Figure 5.3-10 Variations in benthic invertebrate community measurement endpoints in reach MUR-D-2 and reach MUR-D-3.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites.

Table 5.3-16 Analysis of variance (ANOVA) between reach MUR-D-2 and reach MUR-D-3.

Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	14.77	9	11.36	<0.001
Time	0.89	1	6.19	0.014
Reach	0.61	1	4.26	0.041
Time × Reach	0.39	1	2.69	0.104
Reach (2005)	<0.001	1	<0.001	0.982
Error	18.78	130		
Log_{10} Richness				
Reach-Year	3.78	9	16.07	<0.001
Time	0.23	1	8.84	0.003
Reach	0.23	1	8.84	0.003
Time × Reach	0.001	1	0.06	0.812
Reach (2005)	0.143	1	5.50	0.020
Error	3.39	130		
Simpson's Diversity				
Reach	0.639	9	4.78	<0.001
Time	0.001	1	0.09	0.767
Reach	0.029	1	1.96	0.163
Time × Reach	0.072	1	4.90	0.028
Reach (2005)	0.003	1	0.22	0.637
Error	1.931	130		
Evenness				
Reach	0.477	9	3.40	0.001
Time	0.002	1	0.13	0.714
Reach	0.010	1	0.68	0.411
Time × Reach	0.094	1	6.06	0.015
Reach (2005)	<0.001	1	<0.01	0.938
Error	2.025	130		
Log_{10} EPT %				
Reach	5.20	9	5.14	<0.001
Time	0.406	1	3.616	0.059
Reach	0.002	1	0.02	0.882
Time × Reach	0.021	1	0.191	0.663
Reach (2005)	0.562	1	5.01	0.027
Error	14.59	130		

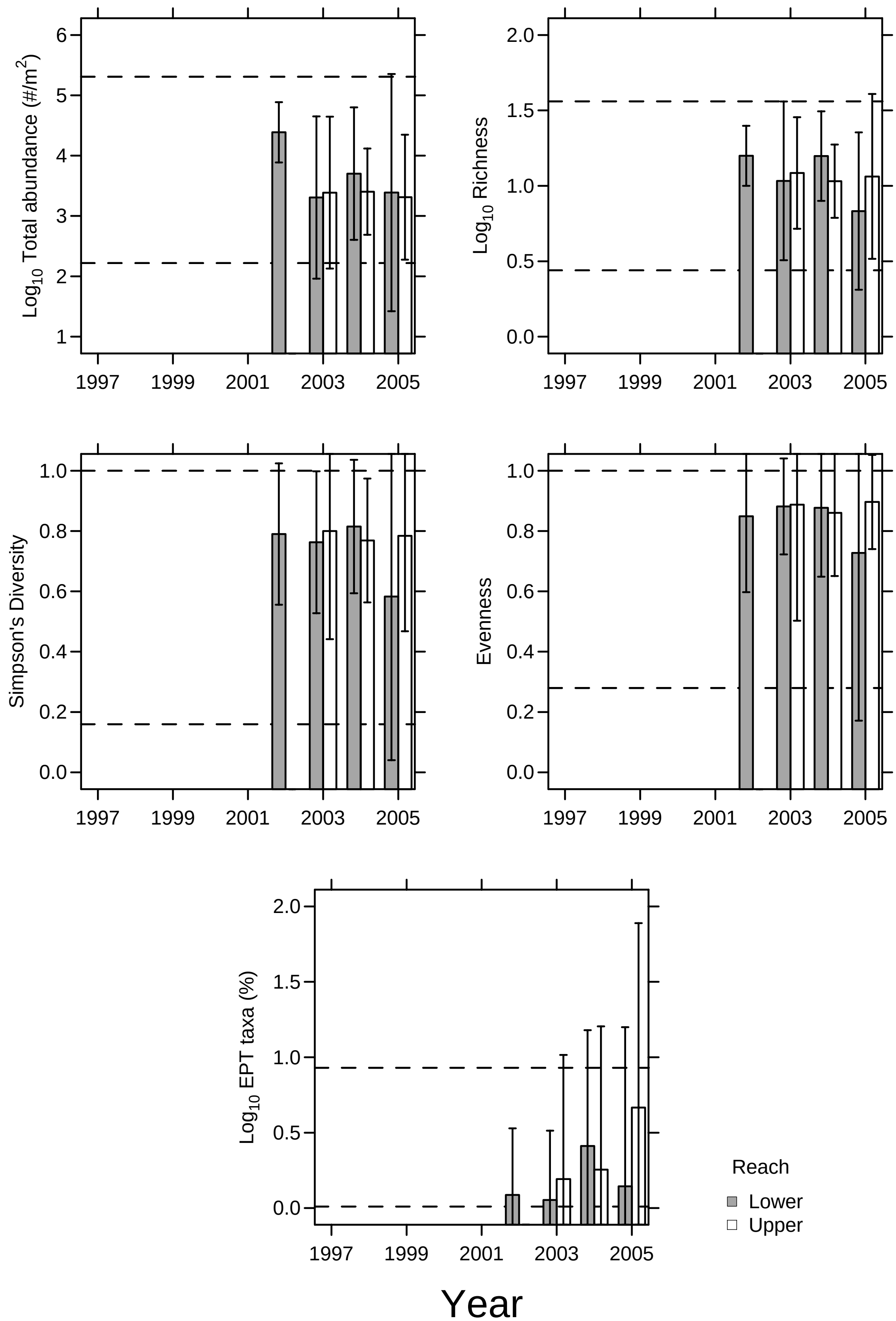
Table 5.3-17 Average habitat characteristics of benthic invertebrate community sampling reaches in Jackpine Creek, fall 2005.

Variable	Units	Reach JAC-D-1	Reach JAC-D-2
Sample date	-	Sept 8 2005	Sept 16 2005
Habitat	-	Depositional	Depositional
Water depth	m	0.5	0.3
Current velocity	m/s	3.3	0.2
Macrophyte cover	%	5	2
Field Water Quality			
Dissolved oxygen	mg/L	9.5	9.5
Conductivity	µS/cm	204	210
pH	-	7.5	8.3
Water temperature	°C	12.6	6.8
Sediment Composition			
Sand	%	91	76
Silt	%	7	14
Clay	%	2	10
Total Organic Carbon	%	0.8	1.8

Table 5.3-18 Summary of major taxon abundances and benthic invertebrate community measurement endpoints between reaches in Jackpine Creek, fall 2005.

Taxon	Reach JAC-D-1				Reach JAC-D-2		
	2002	2003	2004	2005	2003	2004	2005
Hydra	0	0	<1	0	0	0	0
Nematoda	5	6	1	4	6	4	2
Glossiphoniidae	0	<1	0	0	0	0	0
Enchytraeidae	<1	4	<1	0	10	1	1
Naididae	<1	2	2	0	3	1	1
Tubificidae	<1	<1	1	5	2	5	1
Hydracarina	1	1	1	8	<1	<1	18
Ostracoda	<1	0	2	4	<1	1	3
Copepoda	<1	10	6	1	0	2	3
Chydoridae	0	0	8	0	0	<1	0
Amphipoda	0	<1	<1	0	0	0	0
Bivalvia	1	3	<1	<1	<1	<1	<1
Gastropoda	<1	0	<1	0	0	0	<1
Ephemeroptera	<1	0	2	1	<1	2	1
Plecoptera	0	0	0	0	<1	0	0
Trichoptera	<1	<1	<1	3	<1	1	7
Anisoptera	<1	<1	<1	0	0	0	<1
Coleoptera	0	<1	<1	0	6	3	6
Tipulidae	<1	2	1	1	1	13	4
Tabanidae	<1	<1	<1	<1	1	2	<1
Empididae	<1	2	2	4	1	<1	3
Ephydridae	0	<1	0	0	<1	<1	0
Ceratopogonidae	2	2	4	0	1	31	4
Chironomidae	88	66	69	69	67	30	44
Total Abundance (No./m^2)	28172	4017	9230	7417	4787	3448	2957
Richness	15	11	15	7	12	10	12
Simpson's Diversity	0.79	0.76	0.81	0.58	0.80	0.77	0.78
Evenness	0.85	0.88	0.88	0.73	0.89	0.86	0.90
% EPT	<1	<1	2	3	2	2	7

Figure 5.3-11 Variation in benthic invertebrate community measurement endpoints in Jackpine Creek.



Notes: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional reaches.
Lower: reach JAC-D-1; upper: reach JAC-D-2.

5.4 STEEPBANK RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				The Steepbank River watershed produced 40% more runoff than the historical mean in March to October 2005. Measurement endpoint differences between calculated 2005 baseline hydrograph and observed, operational hydrograph were 0.1%.
Mean winter discharge	[a]				
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Water Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=1)	2005 *Reference* Stations (n=3)	
Physical variables (max = 1 for exp, 3 for ref)	0	0	Water quality in the Steepbank River in 2005 was similar to historical water quality conditions. There was no evidence of effects of oil sands development activities in the concentrations and observed ranges of selected measurement endpoints in 2005.
Nutrients (max = 3 for exp, 9 for ref)	0	1	
Ions (max = 2 for exp, 6 for ref)	0	0	
Selected metals (max=5 for exp, 15 for ref)	1	0	
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=1 station X 8 endpoints)	2005 *Reference* Stations (n=3 stations X 8 endpoints)	
Greater than 95th percentile	0	0	
Between 5th and 95th percentiles	8	24	
Less than 5th percentile	0	0	

Sediment Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=1)	2005 *Reference* Stations (n=1)	
Total Hydrocarbons(max=4 for exp,4 for ref)	2	0	Measurement endpoints at all stations were similar to results observed at those stations in previous years.
PAHs (max=1 for exp, 1 for ref)	0	0	
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[3]		
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=1 station X 3 endpoints)	2005 *Reference* Stations (n=1 station X 3 endpoints)	
Greater than 95th percentile	2	0	
Between 5th and 95th percentiles	1	3	
Less than 5th percentile	0	0	

Benthic Invertebrate Communities							
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline						
	2005 *Potentially Influenced-Oil Sands* Stations (n=1)			2005 *Reference* Stations (n=1)			
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance		1			1		2005 data suggest differences in benthic community composition in reach STR-E-1, downstream of oil sands development activities. However, measurement endpoints for this reach were within expected ranges for regional baseline conditions, and there were a number of sensitive benthic taxa present also.
Richness		1			1		
Diversity		1			1		
Evenness		1			1		
% EPT		1			1		

Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2005.
Sentinel Studies	No sentinel fish studies conducted in 2005.
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

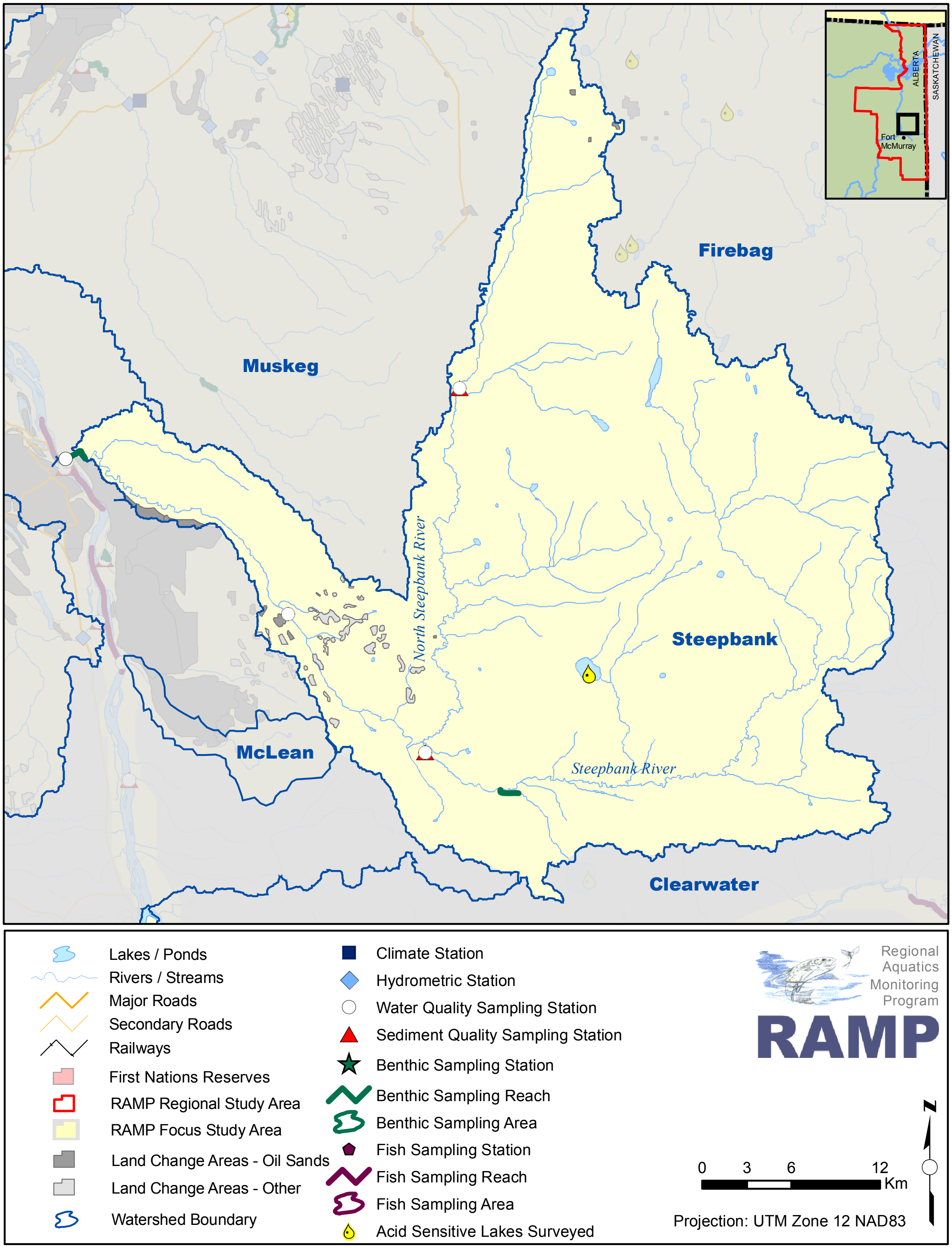
[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

[a] Could not be calculated from partial 2005 hydrograph

Figure 5.4-1 Steepbank River watershed.



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5.4.1 Development Status

While only approximately 0.3% of the Steepbank River watershed has undergone land change as a result of oil sands development activities (Table 2.4-2), much of this land change is concentrated in the lower portion of the watershed. There has been little other land change in the watershed to date, with slightly less than 0.5% of the area of the watershed designated as being changed by other activities such as logging (Table 2.4-2), although these land changes are concentrated between the oil sands development in the lower watershed and the confluence of the North Steepbank River confluence. The designations of specific areas of the watershed are as follows:

- The Steepbank River watershed downstream of the Suncor Steepbank and Millennium oil sands developments (Figure 2.4-1) is designated as *potentially influenced-oil sands*. All data gathered from 2005 RAMP stations located in this area of the watershed are designated as operational data;

- The Steepbank River watershed between the Suncor Steepbank and Millennium oil sands developments and the confluence of the North Steepbank River with the Steepbank River is designated as *potentially influenced-other*. All data gathered from 2005 RAMP stations located in this area of the watershed are designated as operational data; and

- The remainder of the watershed is designated as *reference*, and all data gathered from the 2005 RAMP stations located in these parts of the watershed are designated as baseline data.

5.4.2 Hydrologic Conditions

The Steepbank River basin produced 163 mm of runoff in March to October 2005, about 40% more than the historical mean runoff of 115 mm (Figure 5.4-2). The highest discharges occurred in April in response to rapid snowmelt, and several high flow events occurred during the summer in response to rainfall. Discharges were above the historical average for most of the open-water season. However, in mid-September, discharges fell to below average values and remained below average until the end of the monitoring season on October 31. The April maximum daily discharge was 40.0 m^3/s, 14% higher than the mean annual flood. The minimum open-water discharge of 2.35 m^3/s occurred on October 29, and was 23% higher than the historical average minimum discharge of 1.90 m^3/s.

Inputs to the water balance model for the Steepbank River watershed used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints are provided in Table 5.4-1. Cumulative oil sands development in the Steepbank River watershed up to 2005 has resulted in the isolation of 2.39 km^2 of the watershed and clearing and/or drainage of an additional 1.21 km^2. There were no reported withdrawals from or discharges to the Steepbank River by oil sands development activities in 2005. The calculated 2005 Steepbank River baseline hydrograph is predicted to be practically identical to the observed, operational hydrograph (Figure 5.4-2), with only 0.1% to 0.2% difference in hydrologic measurement endpoints (Table 5.4-2). These changes would be assessed as Negligible in many oil sands EIAS, or Low in the cases of the EIAs that did not define a Negligible category (RAMP 2005b).

5.4.3 Water Quality

In 2005, water quality samples were collected from four stations within the Steepbank watershed:

- Near the mouth of the Steepbank River (station STR-1, *potentially influenced-oil sands*, operational data, data available from 1997 to 2005);
- Upstream of Suncor's Millennium/Steepbank oil sands developments (station STR-2, *potentially influenced-other*, baseline data available from 2002 to 2005);
- Upper Steepbank River (STR-3, *reference*, baseline data from 2004 and 2005); and
- North Steepbank River (NSR-1, *reference*, baseline data from 2002 to 2005).

All stations were sampled in fall 2005; station STR-3 and station NSR-1 were also sampled in spring and summer to collect data on seasonal baseline conditions. Attempts to sample these two stations in winter were unsuccessful because these streams were frozen to depth.

Fall 2005 results for water quality measurement endpoints are shown in Table 5.4-3 for station STR-1, Table 5.4-4 for station STR-2, Table 5.4-5 for station STR-3, and Table 5.4-6 for station NSR-1. Concentrations of selected water quality measurement endpoints observed at the four stations over the period of RAMP sampling are shown relative to regional baseline levels in Figure 5.4-3, while Table 5.4-7 contains all the water quality guideline exceedances observed in 2005.

Overall, there were only 2 (5%) out of 44 possible exceedances in water quality guidelines at all the stations in fall 2005 (i.e., eleven of the selected water quality measurement endpoints have guidelines and water quality was sampled at four stations on the Steepbank River in fall 2005, making for a total of 44 possible guideline exceedances, Table 5.4-3 to Table 5.4-6). The guideline exceedances were total aluminum at station STR-1 and total phosphorus at station STR-3. Total phenols, total iron, and dissolved iron also exceeded guidelines in fall 2005 at all four stations.

Fall 2005 concentrations of most water quality measurement endpoints were within previously recorded fall ranges at stations STR-1, STR-2, and NSR-1 (Table 5.4-3, Table 5.4-4, and Table 5.4-6) (station STR-3 was not included in this particular analysis as water quality has only been sampled there since 2004 and historical minima and maxima of water quality measurement endpoint concentrations would therefore be based on too small a sample size to be meaningful). Of the total fall measurement endpoint-station combinations, 20% were at or below historical minima or at or above historical maxima; most of these were recorded at station NSR-1 (Table 5.4-6).

All selected water quality measurement endpoints were within regional baseline concentrations at all stations (Figure 5.4-3). Ionic character at all Steepbank River watershed stations was dominated by a calcium-bicarbonate system (Figure 5.4-4). Station NSR-1 is more highly dominated by calcium than the other stations, which appear to have very similar ionic characteristics that have changed little over the period of RAMP sampling (with the exception of station STR-1 in 1998).

In summary, water quality in the Steepbank River in 2005 was similar to historical water quality conditions. There was no evidence of effects of oil sands development activities in the concentrations and observed ranges of selected measurement endpoints in 2005.

5.4.4 Sediment Quality

Sediment quality was sampled in the Steepbank River watershed in 2005 at three stations:

- Near the mouth of the Steepbank River (station STR-1, *potentially influenced-oil sands*, operational data available intermittently from 1997 to 2005) (collection of representative sediment samples was difficult at station STR-1 in 2005 as in previous years, as the river is naturally heavily embedded and channelized);
- Upstream of Suncor's Millennium/Steepbank oil sands developments (station STR-2, *potentially influenced-other*, baseline data available intermittently from 1997 to 2005);
- Upper Steepbank River (STR-3, *reference*, baseline data, sampled in 2005 for the first time); and
- North Steepbank River (NSR-1, *reference*, baseline data from 2002 to 2005).

Fall 2005 results for sediment quality measurement endpoints are shown in Table 5.4-8 for station STR-1, Table 5.4-9 for station STR-2, Table 5.4-10 for station STR-3, and Table 5.4-11 for station NSR-1. Concentrations of selected water quality measurement endpoints observed at the four stations over the period of RAMP sampling are shown relative to regional baseline levels in Figure 5.4-5.

Sediments at all stations were dominated by sand, with the highest proportion of silt and clay (19%) found at station NSR-1. Organic carbon content was low (<1%) at all stations. Station STR-1 exhibited the highest concentration of hydrocarbons, with C16-C34 hydrocarbons comprising the largest fraction. Overall, concentrations of only two sediment quality measurement endpoints at all the stations, Fraction 2 (C10-C16) and Fraction 3 (C16-C34) hydrocarbons at station STR-1, exceeded CCME/ISQG guidelines in fall 2005. No metals exceeded CCME guidelines in 2005 at any of the stations.

Fall 2005 concentrations of most sediment quality measurement endpoints were within previously recorded fall ranges at stations STR-1 and NSR-1 (Table 5.4-8, Table 5.4-11) (stations STR-2 and STR-3 were not included in this particular analysis because of sample size issues). Of the total fall sediment quality measurement endpoint-station combinations, 14% were at or below historical minima or at or above historical maxima; most of these were recorded at station STR-1 (Table 5.4-8).

Levels of PAHs at stations STR-1, STR-2, and NSR-1 were similar to levels found in previous years. PAHs at station STR-3 had not been analyzed prior to 2005; however, PAH levels at this station were similar to levels found at stations STR-2 and NSR-1 and lower than at station STR-1.

Concentrations of selected sediment quality measurement endpoints measured in fall 2005 in the Steepbank River were between the 5th and 95th percentile of reference baseline ranges, with the exception of carbon-normalized hydrocarbon concentrations (> 95th percentile) and carbon-normalized total PAHs (> 95th percentile) at station STR-1 (Figure 5.4-5).

In summary, sediment quality measurement endpoints at *potentially influenced-oil sands* station STR-1 were similar in 2005 to results observed in previous years at this station, suggesting that while collection of sediment samples representative of river sediments is difficult, sediment quality samples have been consistent over the period of RAMP sampling. In addition, concentrations of sediment quality measurement endpoints at the other three stations were also similar to previous years.

5.4.5 Benthic Invertebrate Communities

In 2005, benthic invertebrate community samples were collected from a lower operational reach near the mouth of the Steepbank River (reach STR-E-1, erosional, *potentially influenced-oil sands*, operational data, data available intermittently from 1998 to 2005) and from an upper reach well upstream of the North Steepbank confluence (reach STR-E-2, erosional, *reference*, baseline data, data available for 2004 and 2005). Both reach STR-E-1 and reach STR-E-2 are typical of erosional habitats with high flow velocities (0.5 to 2 m/s) and coarse substrate consisting of gravel and cobble (Table 5.4-12). Macrophytes were generally absent, while benthic algal chlorophyll *a* was very high in reach STR-E-2 (77 mg/m^2) and lower (18 mg/m^2) in reach STR-E-1, consistent with previous years sampling results.

Mayflies (38%) and chironomids (25%) dominated the benthic invertebrate community of reach STR-E-1 that was sampled in 2005, with empidids, mites and worms (Enchytraeidae, Naididae) sub-dominant (Table 5.4-13). Stoneflies, caddisflies, dragonflies and blackfly larvae were also present in reach STR-E-1 (Table 5.4-13). Abundance in reach STR-E-1 was about 3,000 individuals/m^2, which is near to the long-term average for this reach. The average number of taxa was 17, which is the lowest average observed to date for reach STR-E-1, and relatively low considering the normal range of variability for baseline erosional reaches (Figure 5.4-6). Diversity and %EPT, however, were relatively high. Correspondence analysis results for reach STR-E-1 (Figure 5.4-7) indicate this reach in 2005 remained within the range of normal variability for erosional reaches designated as *reference* or *potentially influenced-other.*

Chironomids (32%), caddisflies (24%) and mayflies (23%) dominated reach STR-E-2 (Table 5.4-13), with empidids, worms (Naididae), mites, and various other flies (Tipulid craneflies, athericids, tabanids) sub-dominant. Abundance was high in 2005, about 17,000/m^2, probably reflecting the high chlorophyll *a* biomass (Table 5.4-12). The number of taxa and other benthic community measurement endpoints were within expected ranges for baseline erosional reaches (Figure 5.4-6).

A variety of sensitive taxa were present in both the upper and lower reaches including the mayflies *Ephemerella* and *Drunella grandis*, the stoneflies *Zapada*, *Skwala*, and *Pteronarcys*, the caddisfly *Brachycentrus*, the empidid *Hemerodromia*, and the dragonfly *Ophiogomphus*. The most common mayflies were *Baetis*, which is a complex genus comprising several species including both tolerant and sensitive forms. Chironomids were dominated by a variety of groups, but principally *Rheotanytarsus* and members of the *Cricotopus/Orthocladius* complex.

Analysis of variance (ANOVA) of benthic invertebrate community measurement endpoints between the reach STR-E-1 and STR-E-2 was limited to data collected in 2004 and 2005. Abundance, richness and Simpson's Diversity were significantly lower in reach STR-E-1 than at reach STR-E-2 (Table 5.4-14), perhaps as a result of oil sands development activities occurring upstream of this reach, but more likely reflecting the lower benthic algal biomass there (Table 5.4-12). There were no significant differences in evenness, or %EPT between reach STR-E-1 and STR-E-2 in 2005.

In general, the 2005 data suggest differences in benthic community composition in reach STR-E-1, downstream of oil-sands development activities. However, benthic invertebrate community measurement endpoints in 2005 for reach STR-E-1 were within the expected ranges for regional baseline conditions, and there were a number of sensitive benthic taxa present in this reach. There was, therefore, little evidence in 2005 of negative impacts of oil sands development activities on the benthic invertebrate community in the Steepbank River.

5.4.6 Fish Populations

The 2005 RAMP fish program did not include any activities in the Steepbank River system.

5.4.7 Summary of Assessment

Monitoring activities within the Steepbank River basin included hydrology (Water Survey of Canada station), water and sediment quality, and benthic invertebrate community surveys.

Although the oil sands development located adjacent to the Steepbank River commenced in 1997, there is little evidence to suggest that oil sands developments have influenced current hydrologic, water quality, sediment quality, and benthic invertebrate community conditions. While some shifts in the benthic invertebrate community were observed at the *potentially influenced-oil sands* reach of the Steepbank River relative to the *reference* upstream reach, benthic invertebrate community measurement endpoints were generally within the expected ranges for regional reference conditions.

Figure 5.4-2 Steepbank River: 2005 hydrograph and historical context.

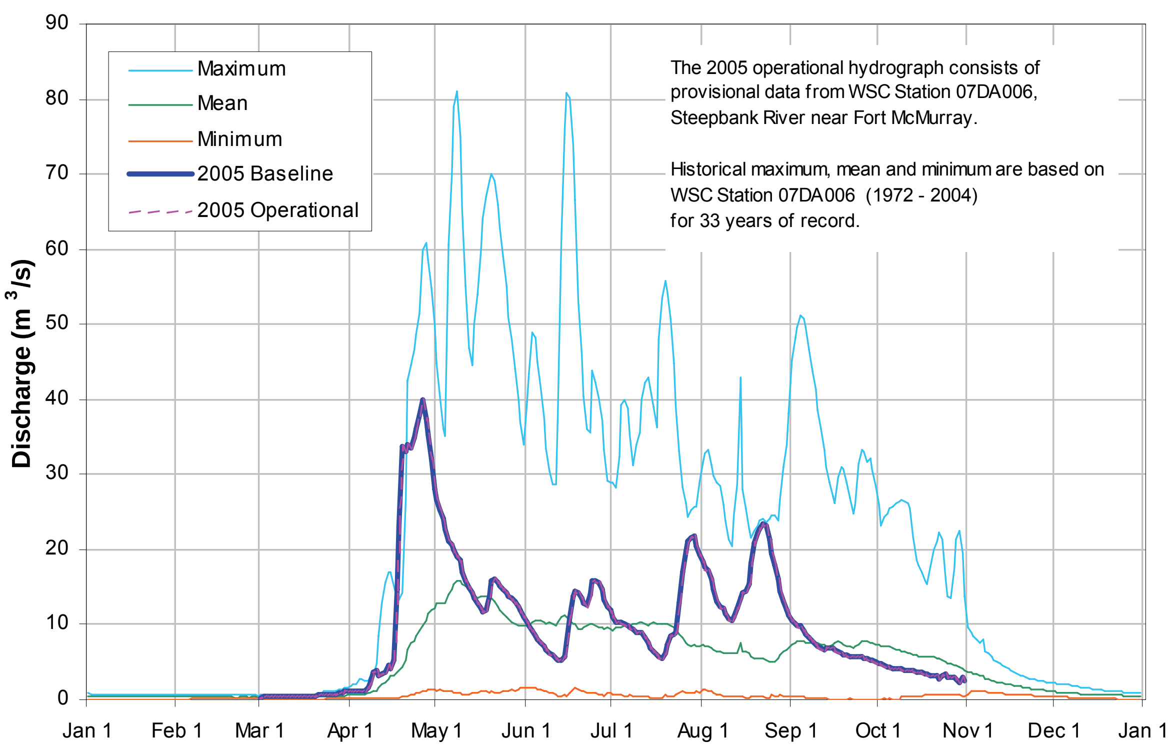


Table 5.4-1 Inputs for calculation of the baseline hydrograph at WSC Station 07DA006, Steepbank River near Fort McMurray.

Component	Annual Volume (dam^3)	Basis and Data Source
Observed hydrograph	215,000	Observed daily discharges, obtained from WSC Station 07DA006, Steepbank River near Fort McMurray
Natural runoff that would have occurred from active mine areas, or that is intercepted by development	354	2.39 km^2 estimated sum of oil sands-developed and oil sands-enclosed areas within watershed (Table 2.4-1)
Incremental runoff from areas that are cleared and areas that are being dewatered	39.8	1.21 km^2 estimated sum of oil sands-cleared and oil sands-bare areas within watershed (Table 2.4-1)
Withdrawals from the Steepbank River	0	None reported, assumed to be negligible
Releases to the Steepbank River	0	None reported, assumed to be negligible
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No significant upstream oil sands developments

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.4-2 Calculated change in hydrologic measurement endpoints for the Steepbank River watershed for 2005.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Percent Change
Mean open-water season discharge	10.8	10.7	-0.1%
Mean winter discharge	not monitored	not monitored	-
Annual maximum daily discharge	40.0	40.0	-0.2%
Open-water season minimum daily discharge	2.35	2.35	-0.1%

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

Table 5.4-3 Concentrations of water quality measurement endpoints in the lower Steepbank River (STR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	7	7.7	8.3	8.4
Total suspended solids	mg/L	-[1]	<3	7	<3	8	60
Conductivity	µS/cm	-	189	7	141	247	516
Nutrients							
Total phosphorus	mg/L	0.05	0.039	7	0.008	0.04	**0.054**
Total dissolved phosphorus	mg/L	0.05[2]	0.028	7	0.006	0.018	0.032
Total nitrogen*	mg/L	1.0	0.8	7	0.3	0.7	**2.4**
Nitrate+nitrite	mg/L	-	<0.1	7	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	24	7	11	16	26
Ions							
Sodium	mg/L	-	10	7	6	13	38
Calcium	mg/L	-	24.4	7	17.2	31.2	50.3
Magnesium	mg/L	-	7.2	7	5.4	9.5	16.2
Chloride	mg/L	230, 860[3]	3	7	1	2	8
Sulphate	mg/L	100[4]	4.2	7	4.6	5.3	12.3
Total dissolved solids	mg/L	-	140	7	120	220	320
Total alkalinity	mg/L		94	7	63	121	263
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.164**	7	0.04	**0.12**	**2.73**
Dissolved aluminum	mg/L	0.1[2]	0.0148	7	<0.01	0.018	0.099
Total boron	mg/L	1.2[4]	0.047	7	0.025	0.076	0.2
Total molybdenum	mg/L	0.073	0.000155	7	0.00015	0.0002	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.008**	7	<0.001	0.002	**0.006**
Dissolved iron	mg/L	0.3[2]	**0.52**	7	0.19	0.29	**0.55**
Total iron	mg/L	0.3	**0.81**	7	**0.47**	**0.83**	**2.28**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.4-4 Concentrations of water quality measurement endpoints in the Steepbank River upstream of Steepbank Mine/Project Millennium (STR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	7.8	8.0	8.3
Total suspended solids	mg/L	-[1]	<3	3	8	14	28
Conductivity	µS/cm	-	178	3	121	142	274
Nutrients							
Total phosphorus	mg/L	0.05	0.047	3	0.035	0.037	0.045
Total dissolved phosphorus	mg/L	0.05[2]	0.038	3	0.01	0.02	0.02
Total nitrogen*	mg/L	1.0	0.8	3	0.6	0.7	**1.5**
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	25	3	14	22	29
Ions							
Sodium	mg/L	-	8	3	5	6	16
Calcium	mg/L	-	23.7	3	16.8	19.1	35.9
Magnesium	mg/L	-	7	3	5.3	5.7	10.8
Chloride	mg/L	230, 860[3]	2	3	1	2	3
Sulphate	mg/L	100[4]	3.2	3	3.5	3.5	5.5
Total dissolved solids	mg/L	-	150	3	140	160	200
Total alkalinity	mg/L		91	3	61	71	155
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.086	3	**0.243**	**0.421**	**0.536**
Dissolved aluminum	mg/L	0.1[2]	0.0146	3	0.0056	0.0178	0.0294
Total boron	mg/L	1.2[4]	0.0456	3	0.0227	0.0292	0.0969
Total molybdenum	mg/L	0.073	0.00016	3	0.0001	0.00014	0.00026
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	2.3
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.007**	3	<0.001	0.001	**0.007**
Dissolved iron	mg/L	0.3[2]	**0.54**	3	**0.35**	**0.39**	**0.41**
Total iron	mg/L	0.3	**0.78**	3	**0.84**	**1.03**	**1.07**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.4-5 Concentrations of water quality measurement endpoints in the upper Steepbank River (STR-3), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	1	-	-	8.3
Total suspended solids	mg/L	-[1]	<3	1	-	-	<3
Conductivity	µS/cm	-	196	1	-	-	276
Nutrients							
Total phosphorus	mg/L	0.05	**0.052**	1	-	-	**0.051**
Total dissolved phosphorus	mg/L	0.05[2]	0.041	1	-	-	0.027
Total nitrogen*	mg/L	1.0	0.8	1	-	-	0.6
Nitrate+nitrite	mg/L	-	<0.1	1	-	-	<0.1
Dissolved organic carbon	mg/L	-	25	1	-	-	14
Ions							
Sodium	mg/L	-	9	1	-	-	15
Calcium	mg/L	-	25.5	1	-	-	37.9
Magnesium	mg/L	-	7.7	1	-	-	11.1
Chloride	mg/L	230, 860[3]	2	1	-	-	2
Sulphate	mg/L	100[4]	3.4	1	-	-	3.2
Total dissolved solids	mg/L	-	140	1	-	-	210
Total alkalinity	mg/L		100	1	-	-	165
Organic compounds							
Naphthenic acids	mg/L	-	<1	1	-	-	1
Selected metals							
Total aluminum	mg/L	0.1	0.041	1	-	-	0.0389
Dissolved aluminum	mg/L	0.1[2]	0.0175	1	-	-	0.0040
Total boron	mg/L	1.2[4]	0.0584	1	-	-	0.0943
Total molybdenum	mg/L	0.073	0.00015	1	-	-	0.00024
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.005**	1	-	-	0.004
Dissolved iron	mg/L	0.3[2]	**0.69**	1	-	-	**0.55**
Total iron	mg/L	0.3	**0.94**	1	-	-	**0.92**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.4-6 Concentrations of water quality measurement endpoints in the North Steepbank River (NSR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	3	7.5	8.0	8.1
Total suspended solids	mg/L	-[1]	<3	3	4	5	8
Conductivity	µS/cm	-	142	3	110	143	175
Nutrients							
Total phosphorus	mg/L	0.05	0.046	3	0.027	0.028	0.032
Total dissolved phosphorus	mg/L	0.05[2]	0.037	3	0.015	0.016	0.02
Total nitrogen*	mg/L	1.0	0.7	3	0.4	0.5	0.7
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	20	3	13	16	18
Ions							
Sodium	mg/L	-	3	3	2	3	3
Calcium	mg/L	-	23.2	3	16.5	20.9	26.9
Magnesium	mg/L	-	6.5	3	4.9	6.1	7.6
Chloride	mg/L	230, 860[3]	2	3	<1	1	2
Sulphate	mg/L	100[4]	5.2	3	1.2	1.8	2.2
Total dissolved solids	mg/L	-	130	3	120	150	160
Total alkalinity	mg/L		72	3	55	73	98
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	0.035	3	0.028	0.050	**0.129**
Dissolved aluminum	mg/L	0.1[2]	0.0117	3	0.0050	0.0125	0.0148
Total boron	mg/L	1.2[4]	0.0131	3	0.0109	0.0126	0.0173
Total molybdenum	mg/L	0.073	0.00018	3	0.00015	0.0002	0.00031
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.006**	3	<0.001	**0.007**	**0.008**
Dissolved iron	mg/L	0.3[2]	**0.61**	3	0.28	**0.43**	**0.50**
Total iron	mg/L	0.3	**0.90**	3	**0.51**	**0.58**	**0.79**

Note: Guideline values are CCME/AENV guidelines 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.

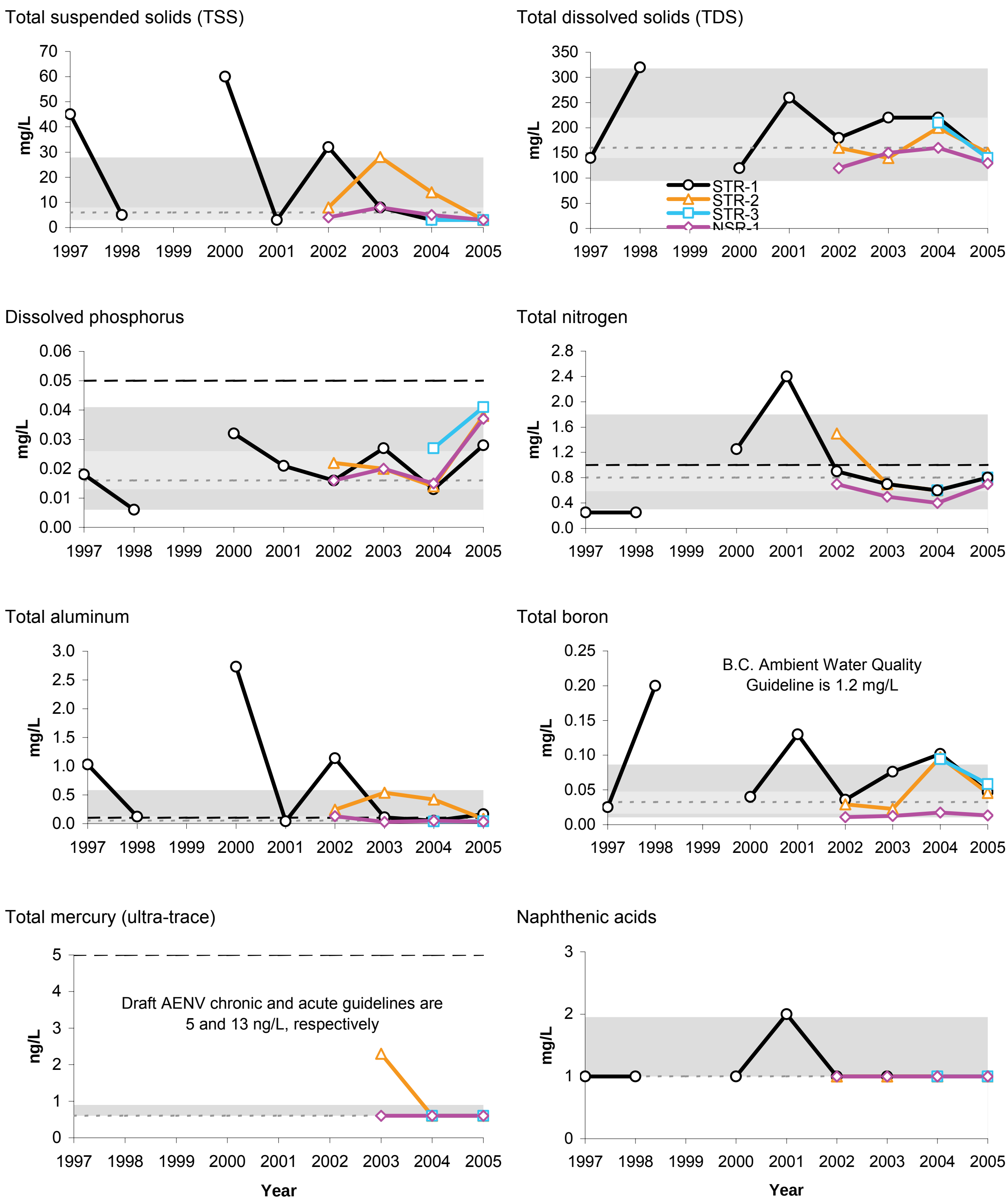
2 Guideline is for total analyte (no guideline for dissolved species).

3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Figure 5.4-3 Concentrations of selected water quality measurement endpoints in the Steepbank River watershed (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

[1] 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.

Table 5.4-7 List of water quality guideline exceedances, Steepbank River watershed, 2005.

Parameter	Units	Guideline*	STR-1	STR-2	STR-3	NSR-1
Spring						
Total phenols	mg/L	0.004	ns	ns	**0.011**	**0.007**
Total iron	mg/L	0.3	ns	ns	**0.323**	**0.326**
Summer						
Dissolved phosphorus	mg/L	0.05[1]	ns	ns	**0.053**	**-**
Total phosphorus	mg/L	0.05	ns	ns	**0.07**	**-**
Dissolved iron	mg/L	0.3[1]	ns	ns	**0.566**	**0.429**
Total iron	mg/L	0.3	ns	ns	**0.911**	**0.841**
Fall						
Total phosphorus	mg/L	0.05	**-**	**-**	**0.052**	**-**
Total phenols	mg/L	0.004	**0.008**	**0.007**	**0.005**	**0.006**
Total aluminum	mg/L	0.1	**0.164**	**-**	**-**	**-**
Dissolved iron	mg/L	0.3[1]	**0.517**	**0.538**	**0.687**	**0.605**
Total iron	mg/L	0.3	**0.809**	**0.784**	**0.935**	**0.897**

STR-1 and STR-2 were sampled only in fall 2005; no winter sampling was conducted at these stations.

ns = not sampled.

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

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

Figure 5.4-4 Piper diagram of ion balance in waters of the Steepbank River watershed, fall 1997-2005.

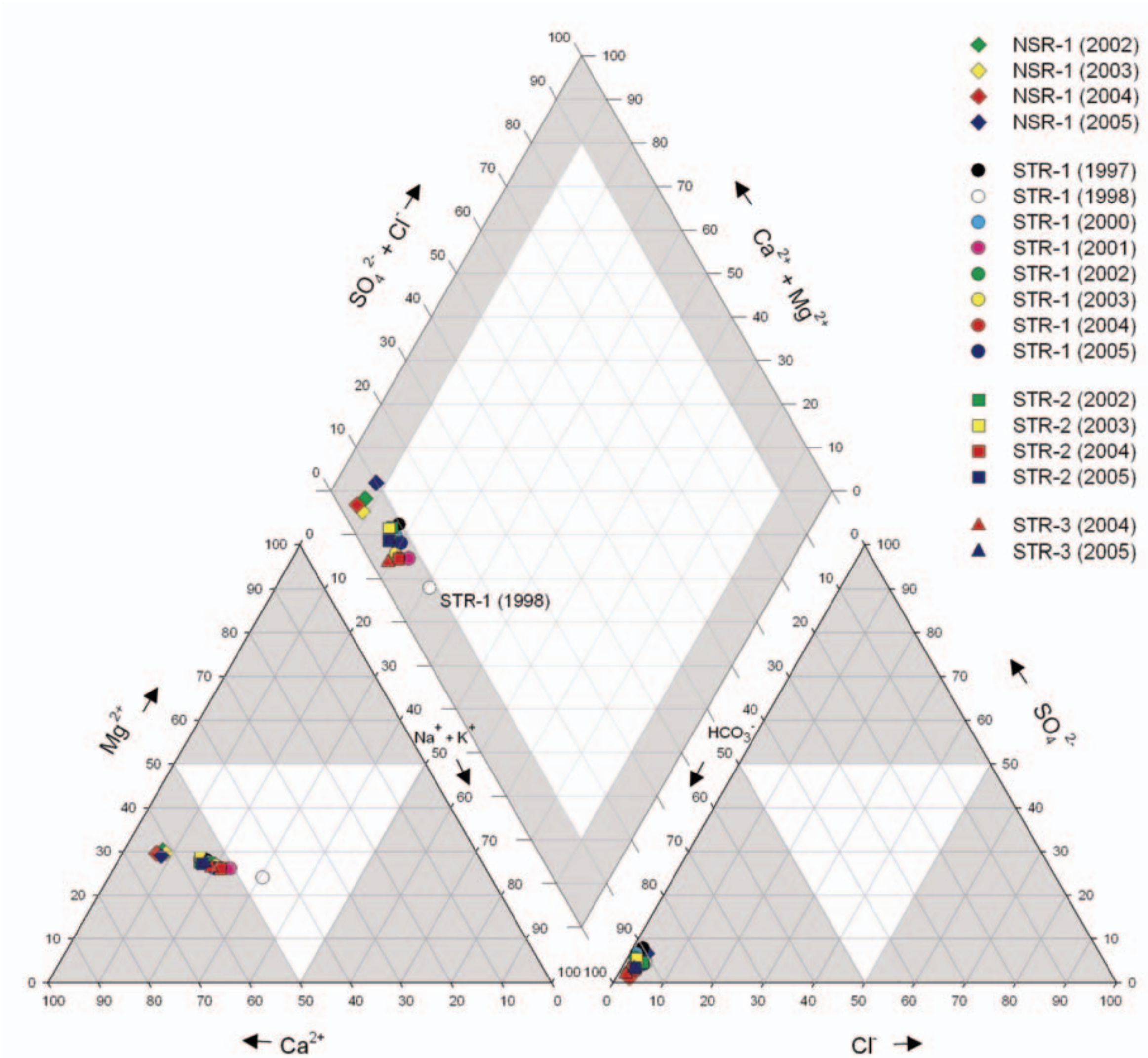


Table 5.4-8 Concentrations of sediment quality measurement endpoints, mouth of Steepbank River (STR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4	3	5.7	10	11
Silt	%	-	3	3	1.3	14	15
Sand	%	-	93	3	74	76	93
Total organic carbon	%	-	0.9	3	0.86	1.85	1.9
Total hydrocarbons							
CCME variables							
BTEX	mg/kg	-	<5	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	**300**	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**3100**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	1700	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.00369	3	<0.003	0.01	0.015
Retene	mg/kg	-	0.243	1	-	-	0.715
Total dibenzothiophenes	mg/kg	-	11.20	3	3.48	5.91	36.20
Total PAHs	mg/kg	-	28.50	3	14.36	14.40	84.22
Total HMW PAHs	mg/kg	-	7.21	3	1.00	2.38	15.08
Total LMW PAHs	mg/kg	-	21.29	3	12.03	13.35	69.15
Predicted PAH toxicity[1]	H.I.	-	1.69	3	0.89	1.31	3.47
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	1	-	-	1
Chironomus growth - 10d	mg/organism	-	0.88	1	-	-	0.4
Hyallela survival - 14d	# surviving	-	2	-	-	-	-
Hyallela growth - 14d	mg/organism	-	0.15	-	-	-	-

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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.4-9 Concentrations of sediment quality measurement endpoints, Steepbank River upstream of the Steepbank Mine/Project Millennium (STR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4	1	-	-	7
Silt	%	-	1	1	-	-	6
Sand	%	-	95	1	-	-	88
Total organic carbon	%	-	0.1	1	-	-	0.5
Total hydrocarbons							
CCME variables							
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	400[2]	<5	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	6	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.00367	1	-	-	0.0009
Retene	mg/kg	-	0.0076	1	-	-	0.018
Total dibenzothiophenes	mg/kg	-	0.004	1	-	-	0.002
Total PAHs	mg/kg	-	0.072	1	-	-	0.085
Total HMW PAHs	mg/kg	-	0.032	1	-	-	0.050
Total LMW PAHs	mg/kg	-	0.039	1	-	-	0.035
Predicted PAH toxicity[1]	H.I.	-	1.40	1	-	-	0.65
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	1	-	-	7
Chironomus growth - 10d	mg/organism	-	1.91	1	-	-	1.9
Hyallela survival - 14d	# surviving	-	2	-	-	-	-
Hyallela growth - 14d	mg/organism	-	0.16	-	-	-	-

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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.4-10 Concentrations of sediment quality measurement endpoints, upper Steepbank River (STR-3), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2	-	-	-	-
Silt	%	-	<1	-	-	-	-
Sand	%	-	98	-	-	-	-
Total organic carbon	%	-	0.1	-	-	-	-
Total hydrocarbons							
CCME variables							
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	400[2]	23	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	14	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.00237	-	-	-	-
Retene	mg/kg	-	0.00918	-	-	-	-
Total dibenzothiophenes	mg/kg	-	0.001731	-	-	-	-
Total PAHs	mg/kg	-	0.0438533	-	-	-	-
Total HMW PAHs	mg/kg	-	0.010996	-	-	-	-
Total LMW PAHs	mg/kg	-	0.0328573	-	-	-	-
Predicted PAH toxicity[1]	H.I.	-	0.36	-	-	-	-
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	9	-	-	-	-
Chironomus growth - 10d	mg/organism	-	2.15	-	-	-	-
Hyallela survival - 14d	# surviving	-	3	-	-	-	-
Hyallela growth - 14d	mg/organism	-	0.32	-	-	-	-

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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

* STR-3 not sampled prior to 2005.

Table 5.4-11 Concentrations of sediment quality measurement endpoints, upper North Steepbank River (NSR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	8	3	1	3	11
Silt	%	-	11	3	2	8	26
Sand	%	-	81	3	63	89	98
Total organic carbon	%	-	0.9	2	0.2	-	1.7
Total hydrocarbons							
CCME variables							
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	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	150	1	-	-	15
Fraction 4 (C34-C50)	mg/kg	2800[2]	94	1	-	-	9
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0054	3	0.0013	0.0017	0.002
Retene	mg/kg	-	0.0153	3	0.0019	0.0943	0.749
Total dibenzothiophenes	mg/kg	-	0.005	3	0.002	0.012	0.021
Total PAHs	mg/kg	-	0.082	3	0.025	0.222	0.924
Total HMW PAHs	mg/kg	-	0.021	3	0.005	0.043	0.088
Total LMW PAHs	mg/kg	-	0.061	3	0.021	0.179	0.836
Predicted PAH toxicity[1]	H.I.	-	0.12	3	0.17	0.55	12.30
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	2	7	-	8
Chironomus growth - 10d	mg/organism	-	-	2	1.9	-	3.1
Hyallela survival - 14d	# surviving	-	-	1	-	-	10
Hyallela growth - 14d	mg/organism	-	-	1	-	-	0.13

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

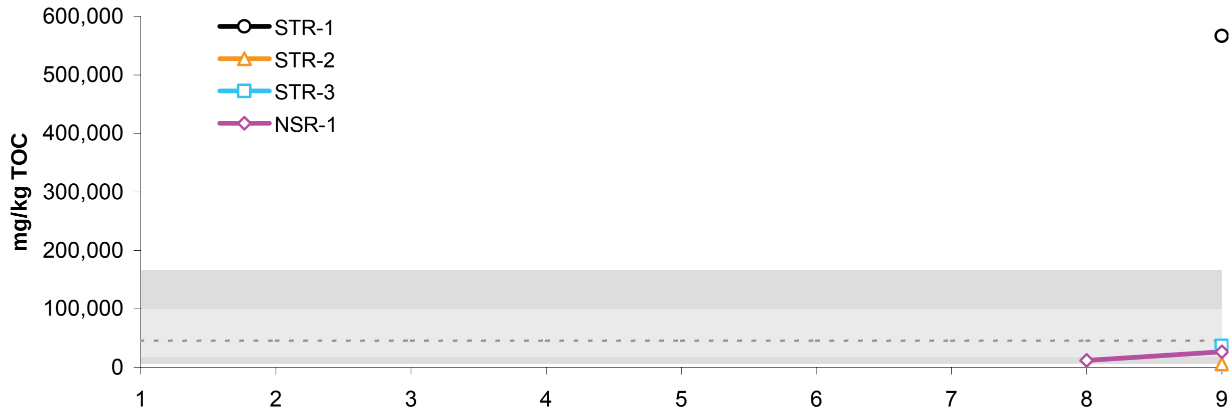
[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

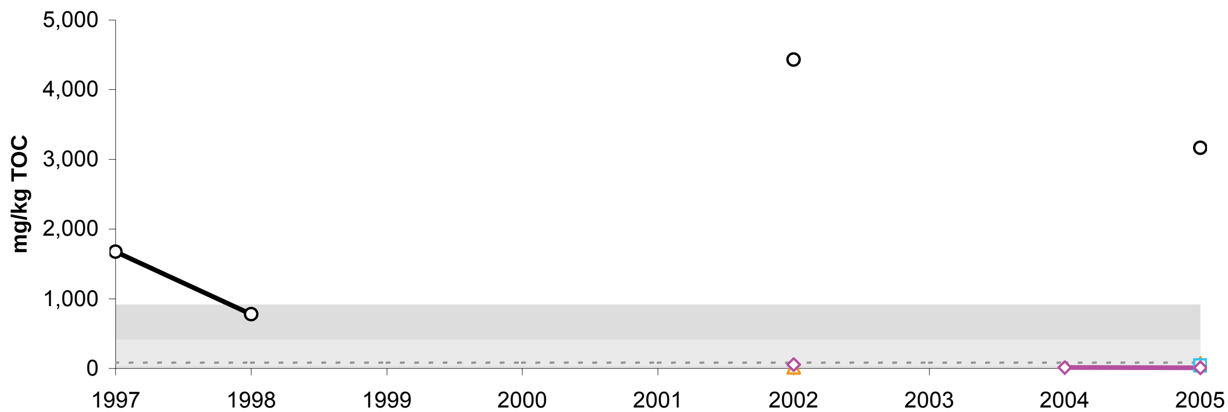
[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Figure 5.4-5 Concentrations of selected sediment quality measurement endpoints in the Steepbank River watershed (fall data) relative to regional baseline fall concentrations.

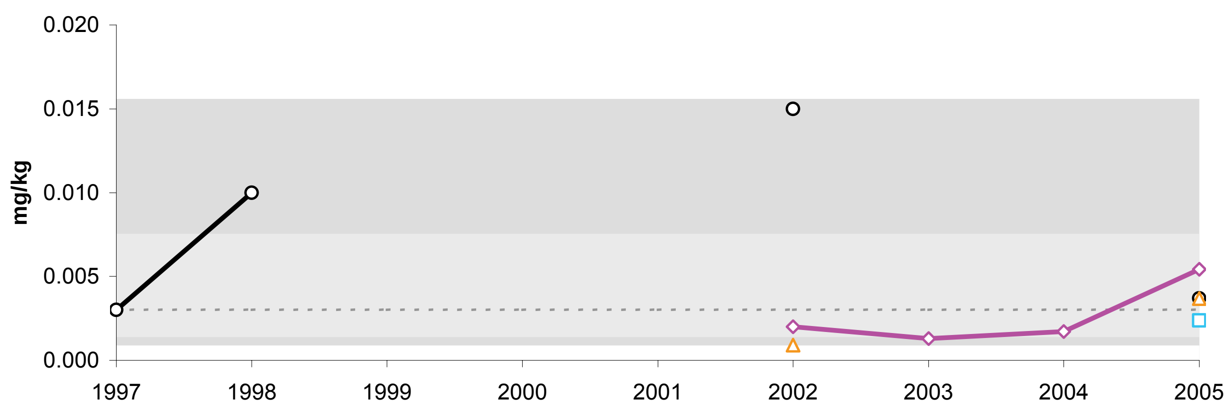
Total Hydrocarbons (C6-C50) (normalized to TOC)



Total Polycyclic Aromatic Hydrocarbons (PAHs) (normalized to TOC)



Naphthalene



[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

Table 5.4-12 Average habitat characteristics of benthic invertebrate community reaches in the Steepbank River, Fall 2005.

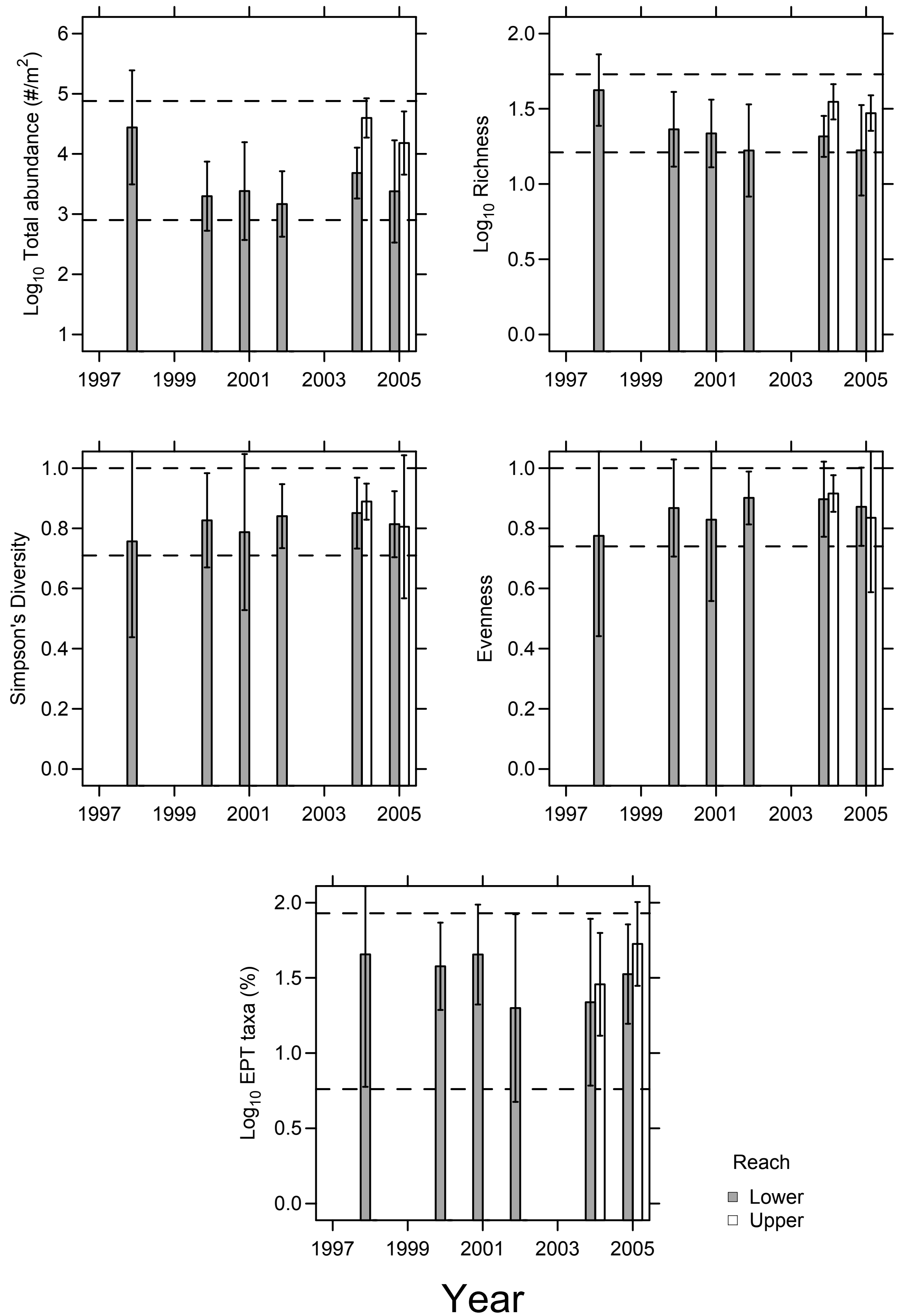
Variable	Units	Reach STR-E-1	Reach STR-E-2
Sample date	-	Sept 10, 2005	Sept 18, 2005
Habitat	-	Erosional	Erosional
Water depth	m	0.4	<1
Current velocity	m/s	1.0	1.6
Macrophyte cover	%	0	0
Benthic algae[1]	mg/m^2	18	77
Field Water Quality			
Dissolved oxygen	mg/L	10.1	n/a
Conductivity	µS/cm	197	n/a
pH		7.8	n/a
Water temperature	°C	5.0	6.9
Sediment Composition			
Sand/Silt/Clay	%	5	0
Small gravel	%	15	13
Large gravel	%	21	33
Small cobble	%	38	32
Large cobble	%	21	12
Boulder	%	1	1
Bedrock	%	0	0

[1]measured as chlorophyll *a*

Table 5.4-13 Summary of major taxon abundances and benthic invertebrate community measurement endpoints between reaches sampled in the Steepbank River, fall 2005.

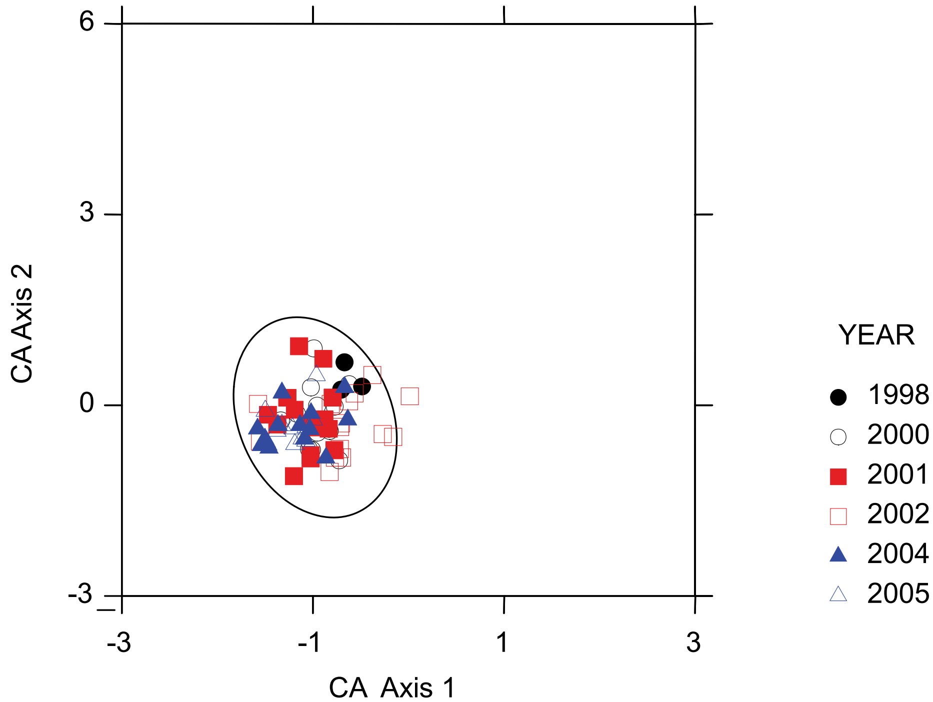
Taxon	Reach STR-E-1						Reach STR-E-2	
	1998	2000	2001	2002	2004	2005	2004	2005
Nematoda	1	2	2	2	1	<1	3	1
Enchytraeidae	1	11	10	9	6	9	<1	1
Naididae	2	21	2	2	21	5	2	2
Tubificidae	2	1	<1	10	<1	1	<1	
Lumbriculidae		<1			<1			
Hydracarina	6	3	6	4	4	9	7	3
Ostracoda	1	<1	<1	<1			1	
Copepoda	<1	<1	<1	<1		<1	4	<1
Cladocera	1							
Chydoridae		<1					4	
Collembola	<1	<1					<1	
Bivalvia				<1				<1
Gastropoda	<1	<1	<1	<1	<1			
Ephemeroptera	51	42	51	19	23	38	18	23
Plecoptera	<1	1	<1	1	1	<1	2	4
Trichoptera	1	<1	<1	1	1	1	9	24
Anisoptera	<1	<1	<1	1	<1	<1	<1	<1
Heteroptera		<1	<1	<1				
Lepidoptera		<1		<1				
Tipulidae	<1	<1					1	1
Brachycera		<1						
Athericidae		<1	<1	<1	<1	<1	<1	3
Dolichopodidae							<1	
Tabanidae	<1	<1			<1		<1	<1
Empididae	2	1	2	6	4	9	2	6
Ceratopogonidae	<1		<1	<1	<1			
Chironomidae	31	15	25	43	38	25	46	32
Psychodidae		<1						
Simuliidae	3	<1	<1	1	<1	3	<1	1
Total Abundance (No./m^2)	29,87	2,321	3,156	1,725	5,259	3,105	41,844	17,317
Richness	41	23	21	17	20	17	34	29
Simpson's Diversity	0.76	0.83	0.79	0.84	0.85	0.81	0.89	0.81
Evenness	0.78	0.87	0.83	0.90	0.90	0.87	0.92	0.83
% EPT	47	39	47	23	24	34	29	54

Figure 5.4-6 Variations in benthic invertebrate community measurement endpoints in the Steepbank River.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional reaches. Lower – reach STR-E-1; upper – reach STR-E-2.

Figure 5.4-7 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for reach STR-E-1.



Note: Ellipse is for reference baseline data for erosional reaches.

Table 5.4-14 Analysis of variance (ANOVA) between reach STR-E-1 and reach STR-E-2.

Source	SS	df	F	P
Log_{10} Abundance				
Reach-Year	25.27	7	51.42	<0.001
Reach	*8.936*	*1*	*127.26*	*<0.001*
Error	6.319	90		
Log_{10} Richness				
Reach-Year	1.359	7	20.02	<0.001
Reach	*0.625*	*1*	*64.42*	*<0.001*
Error	0.873	90		
Simpson's Diversity				
Reach-Year	0.112	7	3.04	0.006
Reach	*0.033*	*1*	*6.422*	*0.013*
Error	0.474	90		
Evenness				
Reach-Year	0.121	7	3.07	0.006
Reach	*0.011*	*1*	*2.05*	*0.155*
Error	0.507	90		
Log_{10} EPT %				
Reach-Year	2.064	7	8.00	<0.001
Reach	*3.317*	*1*	*0.747*	*0.389*
Error	3.317	90		

5.5 TAR RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge		√			May to October runoff volume was 11% above historical average. Oil sands activities are predicted to have increased mean open-water season discharge by 1.6%, increased annual maximum daily discharge by 1.4% and increased open-season minimum daily discharge by 2%.
Mean winter discharge		√			
Annual maximum daily discharge		√			
Minimum open-water season discharge		√			

Water Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=1)	2005 *Reference* Stations (n=1)	
Physical variables (max=1 for exp, 1 for ref)	0	0	Overall, there were four (36%) out of 11 possible guideline exceedances of the water quality measurement endpoints at each station. Guideline exceedances occurred in all seasons of sampling at both stations. Most water quality measurement endpoints were within historical regional baseline ranges. Ion balance at station TAR-2 exhibited higher calcium and magnesium cationic character in 2005, while at TAR-1, anion balance was more highly dominated by chloride.
Nutrients (max=3 for exp, 3 for ref)	3	2	
Ions (max=2 for exp, 2 for ref)	0	0	
Selected metals (max=5 for exp, 5 for ref)	1	1	
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=1 station X 8 endpoints)	2005 *Reference* Stations (n=1 station X 8 endpoints)	
Greater than 95th percentile	1	0	
Between 5th and 95th percentiles	5	5	
Less than 5th percentile	2	3	

Sediment Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=1)	2005 *Reference* Stations (n=1)	
Total Hydrocarbons (max=4 for exp, 4 for ref)	1	0	Hydrocarbons at both stations were dominated by C16-C34 hydrocarbons and were higher in 2005 than 2004. Total PAH concentrations at TAR-1 were within the range of historical results, and were generally slightly higher at TAR-2 in 2005 than 2004. Concentrations of selected sediment quality measurement endpoints remained within the range of historical baseline conditions.
PAHs (max=1 for exp, 1 for ref)	0	0	
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[3]		
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=1 station X 3 endpoints)	2005 *Reference* Stations (n=1 station X 3 endpoints)	
Greater than 95th percentile	0	0	
Between 5th and 95th percentiles	3	3	
Less than 5th percentile	0	0	

Benthic Invertebrate Communities							
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline						
	2005 *Potentially Influenced-Oil Sands* Stations (n=1)			2005 *Reference* Stations (n=1)			
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance		1			1		Benthic invertebrate community indices have trended lower over time in reach TAR-D-1; average index values in 2005 are close to the limits of the normal ranges in reference and exposed-other depositional reaches. Analysis of variance reveals significant differences in time trends between reaches.
Richness		1			1		
Diversity		1			1		
Evenness		1			1		
% EPT	1				1		

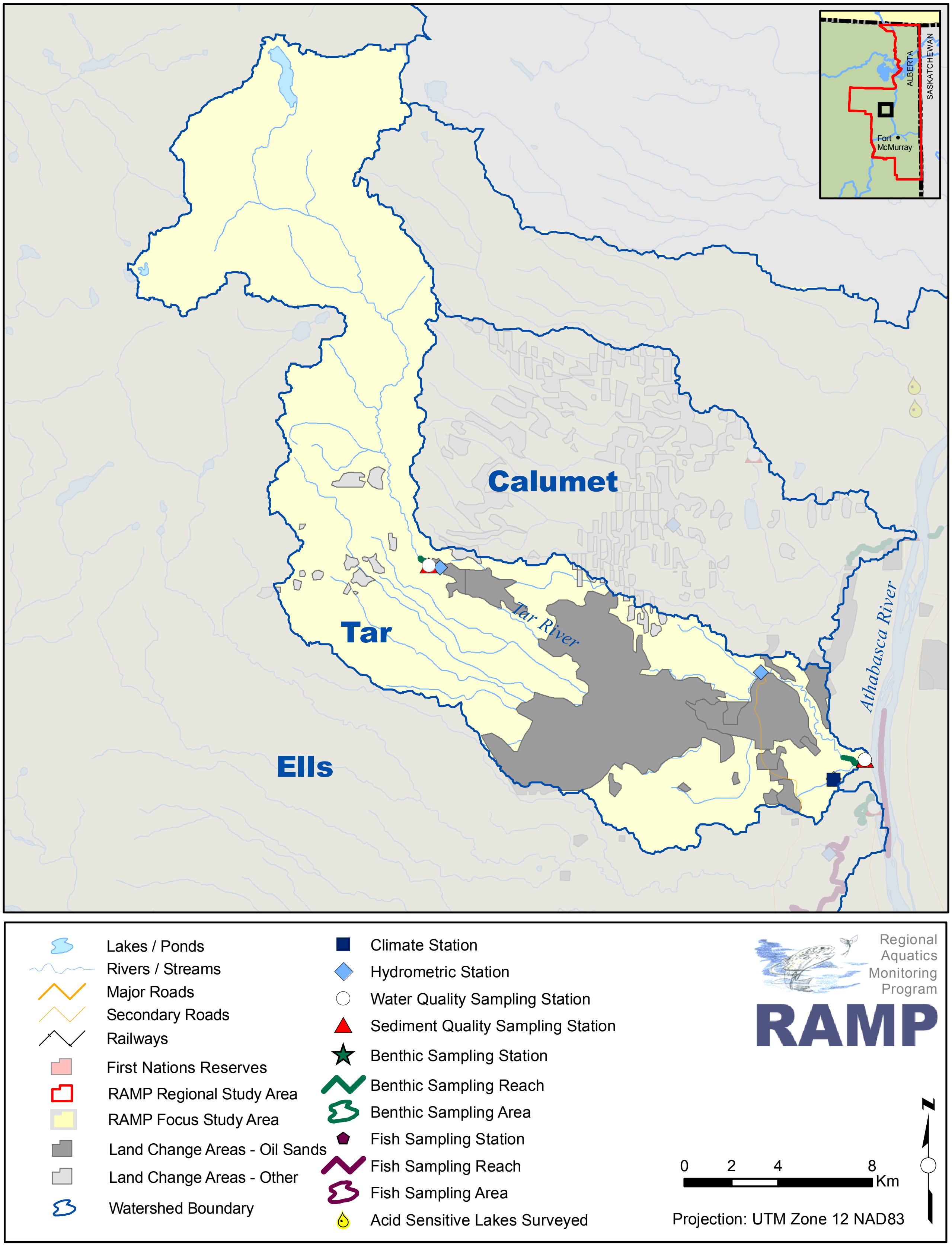
Fish Populations	
Fish Inventory	No RAMP fish inventory studies conducted in 2005.
Sentinel Studies	No RAMP sentinel fish studies conducted in 2005.
Fish Tissue	Level of Risk
Human Health: Subsistence	RAMP fish tissue program was not conducted in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.5-1 Tar River watershed.



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5.5.1 Development Status

Approximately 18% of the Tar River watershed has undergone land change as a result of oil sands development activities (Table 2.4-2). The designations of specific areas of the watershed are as follows:

- The lower Tar River drainage is designated as *potentially influenced-oil sands*. All data gathered from the 2005 RAMP stations located in this area of the watershed are designated as operational data; and

- The westernmost ¼ of Oil Sands Lease 18 and all areas of the Tar River drainage upstream are designated as *reference*. Slightly less than 1% of the watershed is designated having land change from other developments; this consists of logging activities in the far upper areas of the drainage (Figure 2.4-1). All data gathered from the 2005 RAMP stations located in this area of the watershed are designated as baseline data.

5.5.2 Hydrologic Conditions

The observed May to October runoff volume in the Tar River watershed system, as measured at S15, Tar River near the Mouth (07DA015), was 11% above the historical average in 2005 (Figure 5.5-2). A significant spring runoff peak of 3.66 m^3/s was recorded on April 27, the day that the monitoring equipment was installed. However, the highest flow of the year occurred during a rainfall-runoff event on May 20. The maximum daily discharge of 6.23 m^3/s was 30% higher than the mean annual flood of 4.8 m^3/s. The minimum observed open-water discharge was 0.37 m^3/s, which is slightly higher than the average minimum open-water discharge of 0.31 m^3/s.

Inputs to the water balance model for the Tar River watershed used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints are provided in Table 5.5-1. Cumulative oil sands development in the Tar River watershed up to 2005 has resulted in the isolation of an estimated 9.1 km^2 of the watershed and clearing and drainage of an estimated additional 51.9 km^2. These land changes, combined with no known surface water withdrawals or releases from oil sands development projects in the Tar River watershed are predicted to have increased mean open-water season discharge by 1.6%, increased annual maximum daily discharge by 1.4% and increased open-season minimum daily discharge by 2% (Table 5.5-2, Figure 5.5-2). The calculated hydrologic effects would have been assessed as Low for these hydrologic measurement endpoints in many oil sands EIAs (RAMP 2005b).

The differences between the observed operational hydrograph at RAMP/WSC Station S15 and the calculated baseline hydrograph would have likely been greater without the D-7 drainage ditch constructed in 2004. This ditch was used to convey runoff generated from site drainage and muskeg dewatering to the Tar River below RAMP/WSC Station S15. This flow is not included in the operational hydrograph observed at RAMP/WSC Station S15. Therefore, based on the available hydrologic and oils sands development information, it appears that changes in hydrologic conditions in the lower Tar River watershed up to and including 2005 have been low to moderate.

5.5.3 Water Quality

In 2005, water quality samples were collected from the mouth of the Tar River (station TAR-1, *potentially influenced-oil sands*, operational data, established in 2000), and upstream of the CNRL Horizon Project (station TAR-2, *reference*, baseline data, established in 2004). Results of 2005 sampling for water quality measurement endpoints are presented in Table 5.5-3 and Table 5.5-4; results for selected measurement endpoints (1997 to 2005) relative to regional baseline conditions are shown in Figure 5.5-3. Seasonal sampling was undertaken at both stations in 2005, but water samples could not be collected from either station in winter, given the river was frozen to depth in both reaches.

Overall, there were four (36%) out of 11 possible guideline exceedances of the selected water quality measurement endpoints at each station (i.e., eleven of the selected water quality measurement endpoints have guidelines [Table 5.5-3 and Table 5.5-4]). At station TAR-1, total dissolved phosphorus, total nitrogen, total Kjeldahl nitrogen, dissolved organic carbon, dissolved aluminum, dissolved iron, and total phenols all exhibited historically high concentrations in fall 2005, while total mercury concentrations were lower than previously observed at this station. As in 2002 and 2004, total aluminum concentrations at station TAR-1 exceeded the 95th percentile of regional baseline concentrations, while the concentration of total dissolved phosphorus in 2005 was nearly equal to the 95th percentile of regional baseline concentrations. Several water quality measurement endpoints – including total suspended solids, total dissolved solids, total boron, total mercury, and naphthenic acids - were comparable to or lower in 2005 than in years prior to designation as an *potentially influenced-oil sands* station (i.e., before 2004). Total nitrogen concentrations were higher in 2004 and 2005 than in previous years, but were still within the range of regional baseline concentrations.

Concentrations of nutrients, aluminum, and iron were generally higher at station TAR-2 in 2005 than in 2004, while ions and related analytes, total boron, total molybdenum, and total mercury were lower. Some of these annual differences may be due to the fact that the location of station TAR-2 changed between 2004 and 2005. The concentration of total boron in 2005 was less than the 5th percentile of regional baseline concentrations. Exceedances of water quality guidelines occurred in all seasons of sampling (spring, summer, fall) at both stations (Table 5.5-5).

The ion balance at station TAR-2 exhibited higher calcium and magnesium cationic character in 2005 than in 2004, while at station TAR-1, anion balance was more highly dominated by chloride than in previous years (Figure 5.5-4).

These results indicate that water quality conditions in the Tar River watershed in 2005 exhibited little signs of influence from oil sands activities.

5.5.4 Sediment Quality

In 2005, sediment quality samples were collected from the mouth of the Tar River (station TAR-1, *potentially influenced-oil sands*, operational data, established in 1998, sampling every year since 2002), and upstream of the CNRL Horizon Project (station TAR-2, *reference*, baseline data, established in 2004). Results of 2005 sampling for selected sediment quality measurement endpoints are shown in Table 5.5-6 and Table 5.5-7; results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.5-5.

Sediments sampled at both stations were dominated by sand, although silt and clay comprised a higher proportion of sediments at station TAR-1 (Table 5.5-6, Table 5.5-7). Hydrocarbons at both stations were dominated by C16-C34 hydrocarbons and were higher in 2005 than in 2004, when hydrocarbons were non-detectable at station TAR-2. As in 2004, C10-C50 hydrocarbons were higher at station TAR-1 than at station TAR-2; these results are likely related to the higher proportion of fine sediments and organic carbon found at station TAR-1. Fall 2005 total PAH concentrations at station TAR-1 were within the range of historically observed results, while PAH concentrations at station TAR-2 were, in general, slightly higher in 2005 than in 2004. No trends in total carbon-normalized PAH or naphthalene concentrations are apparent over the period of RAMP sampling and concentrations of the selected sediment quality measurement endpoints remained within the range of historical baseline conditions (Figure 5.5-5). Based on available sediment quality data, oil sands development does not appear to have affected sediment quality at station TAR-1.

5.5.5 Benthic Invertebrate Communities

In 2005, benthic invertebrate community samples were collected from a depositional reach near the mouth of the Tar River (reach TAR-D-1, *potentially influenced-oil sands*, operational data from 2004 onwards) and from an erosional upper reach upstream of the CNRL Horizon Project (reach TAR-E-2, *reference*, baseline data).

Reach TAR-D-1 was deeper than reach TAR-E-2, with no measurable water current or macrophyte cover. In contrast, current velocity in reach TAR-E-2 was moderate, while biomass of periphyton chlorophyll *a* was low (typically non-detectable < 1 mg/L, but with an average of 9 mg/m^2; Table 5.5-8). Dissolved oxygen was high (> 9 mg/L) in both reaches, while water temperatures were cooler in reach TAR-E-2 (6^{o}C) than reach TAR-D-1 (13^{o}C). Samples were collected on different days, so the difference in air temperature may have also been a factor in the different water temperatures. Sediments in reach TAR-D-1 were principally sand, while substrates in reach TAR-E-2 were dominated by cobble and gravel.

Chironomids, tubificid worms, ceratopogonids and ostracods were dominant in reach TAR-D-1, with a few bivalves (Sphaeriidae), tipulids (craneflies) and tabanids (horse flies) (Table 5.5-9). The chironomids included the ubiquitous *Polypedilum* and the fine-sand-preferring *Cryptochironomus*. Mayflies, stoneflies and caddisflies, that were typically present in reach TAR-D-1 in previous years, were absent in 2005, as were naidids worms, and empidids (dance flies). Numbers of animals per m^2 in reach TAR-D-1 was also lower (average of 660 m^2) than in previous years and was lower by a factor of 100 compared to 2002 when 70,000 organisms/m^2 were estimated; Table 5.5-9). The richness in 2005 was 4, compared to previous years that ranged between 11 and 22 (Figure 5.5-6). A large part of the reduction in number of taxa was related to chironomids that were much less diverse in 2005 than in previous years.

Mayflies, stoneflies and caddisflies comprised about 60% of the benthic fauna in reach TAR-E-2, with chironomids (33%) and simuliids (blackflies; 2%) and empidids (2%) being sub-dominant. Other taxa present in low numbers included worms (Enchytraeidae, Naididae, Tubificidae, Lumbriculidae), mites, and various other fly larvae. Total abundance in reach TAR-E-2 (2,200 organisms/m^2) were marginally lower than in previous years (5,000 to 7,000 organisms/m^2), as was the richness (17 in 2005 compared to more than 20 in previous years). Diversity and evenness were marginally lower in 2005 compared to the previous two years (Figure 5.5-7).

Benthic invertebrate community indices have trended lower over time in reach TAR-D-1 to the point that average index values in 2005 are close to the limits of the normal ranges observed in *reference* and *potentially influenced-other* depositional reaches (Figure 5.5-6). Analysis of variance demonstrated that there were significant differences in time trends between the reach TAR-D-1 and reach TAR-E-2 (Table 5.5-10). Those differences in time trends were consistent with the commencement of oil sands development operations in the watershed Analysis of variance indicate statistically significant differences for the Before to After x Reach interaction terms for abundance, richness and %EPT (Table 5.5-10). The temporal declines for those indices (Figure 5.5-6, compared to Figure 5.5-7) was consistent with degrading habitat. Ordination results (Figure 5.5-8) indicated that the benthic community was mostly within expected conditions for *reference* and *potentially influenced-other* reaches in this 2005 survey, but there has been an apparent shift in composition of the community from pre-operational years (2002, 2003) to 2005. The absence of mayflies (*Baetis*, *Callibaetis*), caddisflies (*Brachycentrus*), stoneflies and empidids (all of which are generally more sensitive to degraded conditions than other fauna) in 2005 indicates some level of habitat degradation. Several chironomid taxa found in previous inventories of the lower reach (e.g., *Paralauterbourniella*, *Saetheria*, *Micropsectra*/*Tanytarsus*, *Heterotrissocladius*) were absent in 2005. Reach TAR-D-1 will be monitored in 2006, and data obtained in 2006 will be useful for confirming the presence/absence of significant alterations in habitat quality.

5.5.6 Fish Populations

The 2005 RAMP Fish Population component did not include any activities in the Tar River watershed.

5.5.7 Summary of Conditions

Monitoring activities in the Tar River watershed in 2005 included hydrology, water quality, sediment quality, and benthic invertebrate communities. The Tar River watershed in 2005 showed some changes in RAMP aquatic resources from previous years. The effects of oil sands activities on hydrologic conditions in 2005 was assessed as low based on effects criteria used in oil sands EIAs for mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge. Water quality and sediment quality conditions in 2005 were generally within regional ranges of concentrations for baseline conditions. Finally, generally lower values of benthic invertebrate community measurement endpoints in 2005, and recent downward trends in a number of these measurement endpoints coinciding with the commencement of significant oil sands development activities indicate the possible effects of these activities on benthic invertebrate communities in the lower parts of the Tar River watershed.

Figure 5.5-2 Tar River: 2005 hydrograph and historical context.

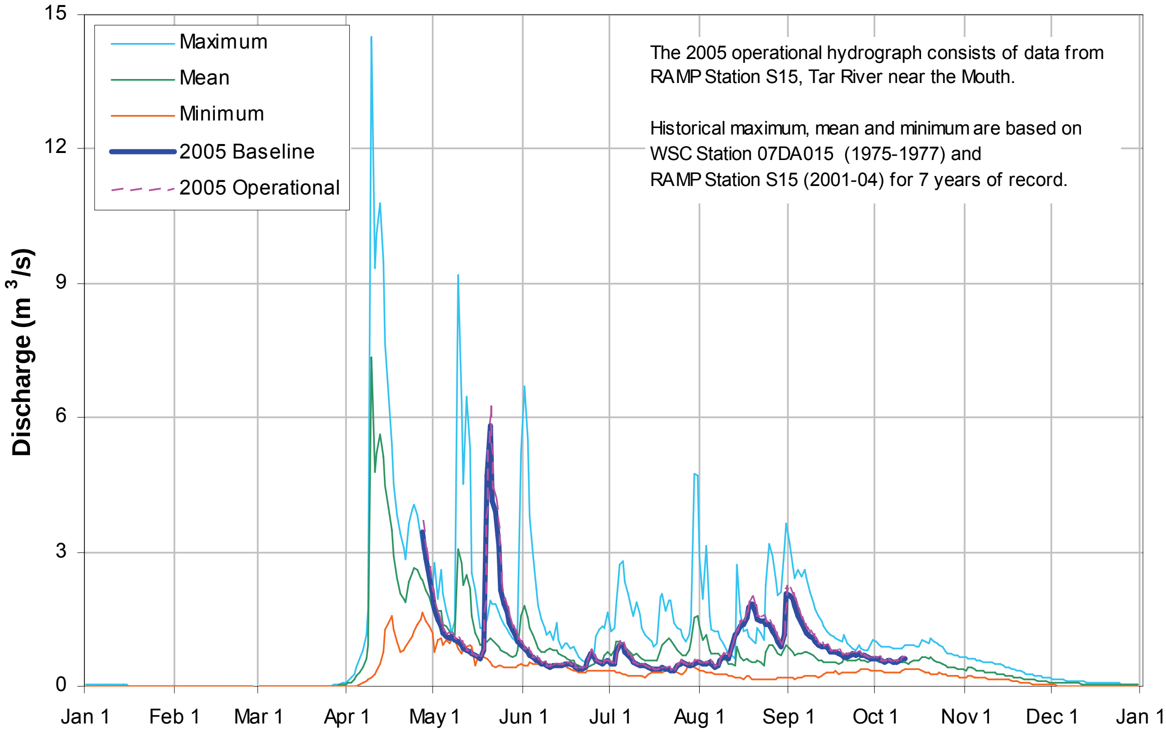


Table 5.5-1 Summary of inputs to the calculation of the Tar River baseline hydrograph at RAMP/WSC Station S15, Tar River near the Mouth (07DA015).

Component	Annual Volume (dam^3)	Basis and Data Source
Observed hydrograph	15,100	Observed daily discharges obtained from RAMP/WSC Station S15, Tar River near the Mouth (07DA015)
Natural runoff that would have occurred from active mine areas, or that is intercepted by development	314	9.05 km^2 estimated sum of oil sands-developed and oil sands-enclosed areas within watershed (Table 2.4-1)
Incremental runoff from areas that are cleared and areas that are being dewatered	547	51.9 km^2 estimated sum of oil sands-cleared and oil sands-bare areas within watershed (Table 2.4-1)
Withdrawals from the Tar River by oil sands development activities	0	Unknown but assumed to be negligible
Releases to the Tar River by oil sands development activities	0	Unknown but assumed to be negligible
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No significant upstream oil sands developments

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.5-2 Calculated change in hydrologic measurement endpoints for the Tar River watershed.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	0.978	0.994	+1.6%
Mean winter discharge	not measured	not measured	
Annual maximum daily discharge	6.15	6.23	+1.4%
Open-water season minimum daily discharge	0.367	0.374	+2.0%

Note: As measured at and calculated for RAMP/WSC Station S15, Tar River near the Mouth (07DA015).

Table 5.5-3 Concentrations of water quality measurement endpoints, lower Tar River (TAR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	4	8.1	8.15	8.2
Total suspended solids	mg/L	-[1]	36	4	15	55.5	214
Conductivity	µS/cm	-	326	4	302	366	493
Nutrients							
Total phosphorus	mg/L	0.05	**0.166**	4	**0.057**	**0.084**	**0.232**
Total dissolved phosphorus	mg/L	0.05[2]	**0.067**	4	0.015	0.017	0.05
Total nitrogen*	mg/L	1.0	**1.3**	4	0.5	0.63	1
Nitrate+nitrite	mg/L	-	0.2	4	<0.05	<0.1	0.2
Dissolved organic carbon	mg/L	-	21	4	12	13.5	16
Ions							
Sodium	mg/L	-	17	4	15	23	32
Calcium	mg/L	-	38.8	4	38	45.45	52.3
Magnesium	mg/L	-	11.4	4	11.3	13.7	16.5
Chloride	mg/L	230, 860[3]	4	4	1.7	3	5
Sulphate	mg/L	100[4]	38.1	4	20.4	30.4	42
Total dissolved solids	mg/L	-	220	4	170	290	330
Total alkalinity	mg/L		121	4	139	171	210
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**1.39**	4	**0.47**	**0.719**	**3.95**
Dissolved aluminum	mg/L	0.1[2]	0.0255	4	0.0047	0.0123	0.02
Total boron	mg/L	1.2[4]	0.0535	4	0.05677	0.0843	0.145
Total molybdenum	mg/L	0.073	0.00084	4	0.00037	0.0014	0.002
Total mercury (ultra-trace)	ng/L	5, 13[5]	0.6	2	0.9	-	2.8
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total Kjeldahl nitrogen	mg/L	1.0[6]	**1.1**	4	0.4	0.55	**0.9**
Total phenols	mg/L	0.004	**0.008**	4	<0.001	0.0015	0.007
Total cobalt	mg/L	0.0009[7]	**0.00**	4	0.00035	**0.00**	**0.0023**
Dissolved iron	mg/L	0.3[2]	**0.95**	4	**0.148**	**0.39**	**0.625**
Total iron	mg/L	0.3	**2.49**	4	1.46	2.1595	7.03

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

[6] Guideline is for total nitrogen.

[7] B.C. Working Water Quality Guideline (2001).

Table 5.5-4 Concentrations of water quality measurement endpoints, upper Tar River (TAR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	1	-	-	8.3
Total suspended solids	mg/L	-[1]	6	1	-	-	7
Conductivity	µS/cm	-	233	1	-	-	297
Nutrients							
Total phosphorus	mg/L	0.05	**0.081**	1	-	-	**0.053**
Total dissolved phosphorus	mg/L	0.05[2]	**0.058**	1	-	-	0.024
Total nitrogen*	mg/L	1.0	0.5	1	-	-	0.5
Nitrate+nitrite	mg/L	-	<0.1	1	-	-	<0.1
Dissolved organic carbon	mg/L	-	14	1	-	-	8
Ions							
Sodium	mg/L	-	6	1	-	-	16
Calcium	mg/L	-	31.4	1	-	-	45.6
Magnesium	mg/L	-	8.8	1	-	-	13.7
Chloride	mg/L	230, 860[3]	2	1	-	-	2
Sulphate	mg/L	100[4]	20	1	-	-	29.9
Total dissolved solids	mg/L	-	160	1	-	-	280
Total alkalinity	mg/L		100	1	-	-	159
Organic compounds							
Naphthenic acids	mg/L	-	1	1	-	-	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.708**	1	-	-	0.0865
Dissolved aluminum	mg/L	0.1[2]	0.0165	1	-	-	0.008
Total boron	mg/L	1.2[4]	0.0347	1	-	-	0.0663
Total molybdenum	mg/L	0.073	0.00083	1	-	-	0.0014
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	1	-	-	1.4
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Dissolved iron	mg/L	0.3[2]	**0.8**	1	-	-	**0.403**
Total iron	mg/L	0.3	**1.590**	1	-	-	0.922

Note: Guideline values are CCME/AENV guidelines 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.

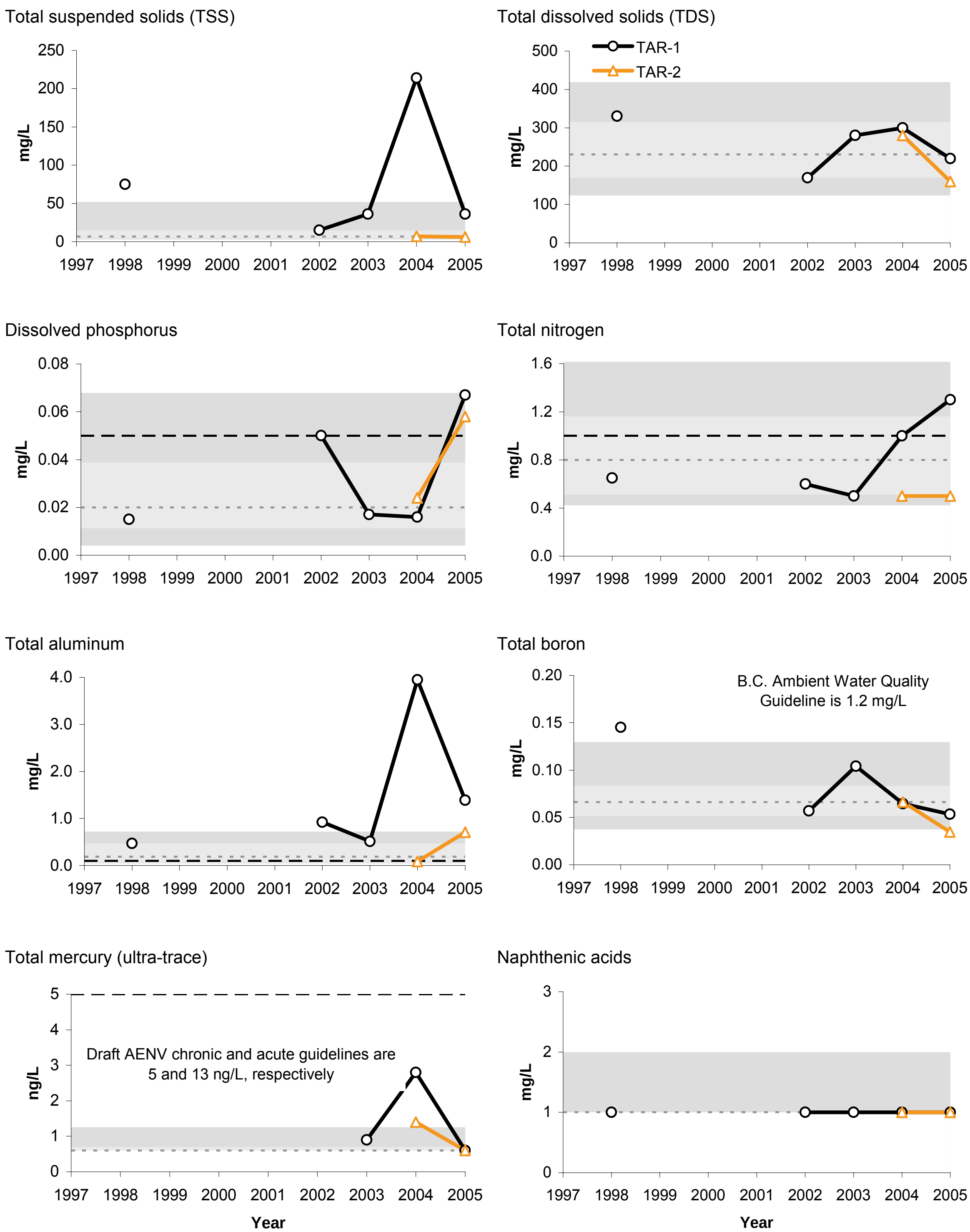
[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Figure 5.5-3 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.

[1] 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 5.5-4 Piper diagram of fall ion concentrations in the Tar River watershed.

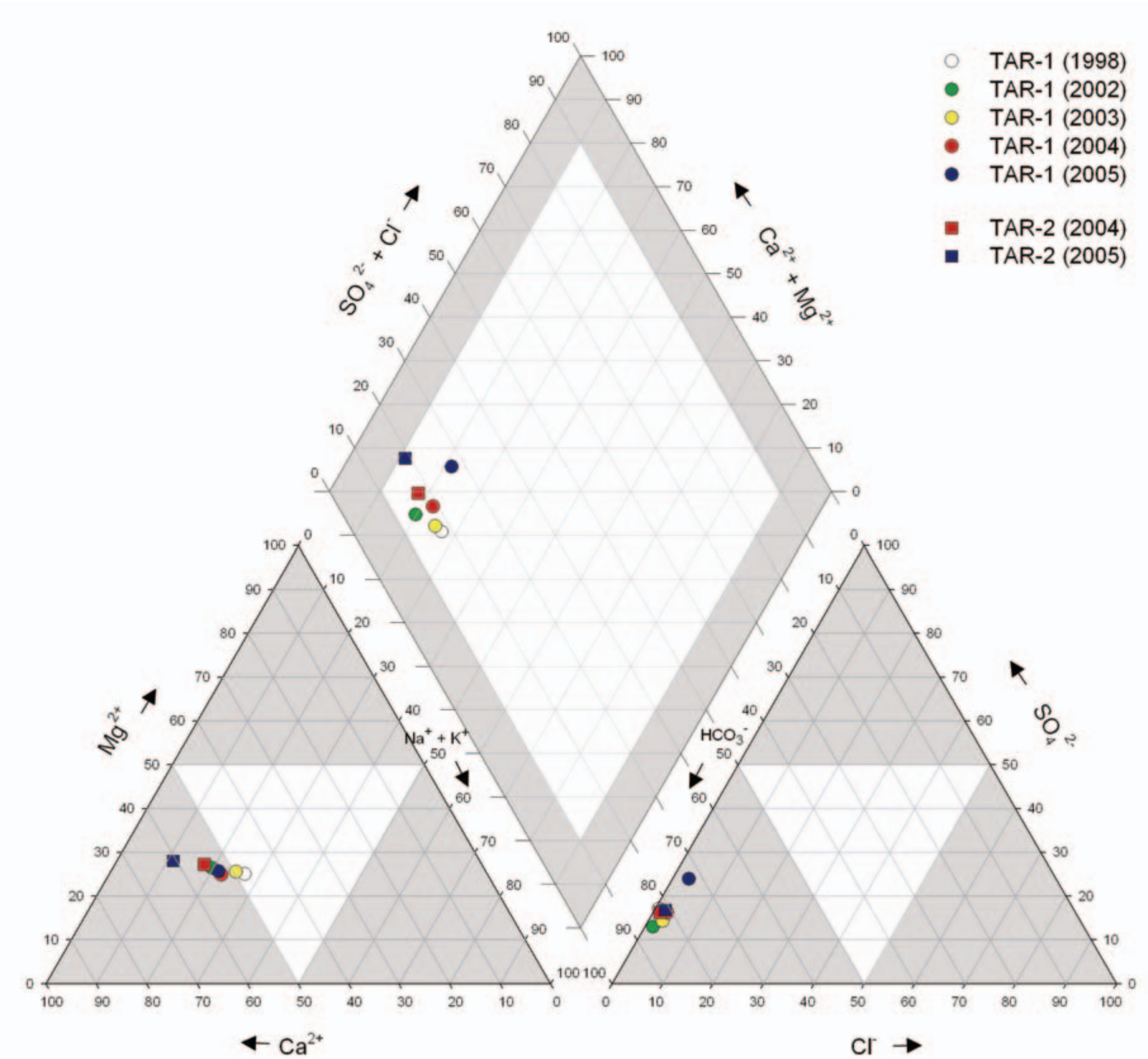


Table 5.5-5 List of all 2005 water quality guideline exceedances, Tar River.

Parameter	Units	Guideline*	TAR-1	TAR-2
Spring				
Total phosphorus	mg/L	0.05	**0.154**	**0.108**
Total phenols	mg/L	0.004	**0.012**	**0.009**
Total aluminum	mg/L	0.1	**2.34**	**1.82**
Total copper	mg/L	0.002-0.004[1]	**0.00279**	**-**
Dissolved iron	mg/L	0.3[2]	**0.566**	**0.31**
Total iron	mg/L	0.3	**3.1**	**2.04**
Total cobalt	mg/L	0.0009[3]	**0.00115**	**-**
Summer				
Dissolved phosphorus	mg/L	0.05[2]	**0.064**	**-**
Total phosphorus	mg/L	0.05	**0.124**	**0.072**
Total aluminum	mg/L	0.1	**0.62**	**0.218**
Dissolved iron	mg/L	0.3[2]	**0.886**	**0.476**
Total iron	mg/L	0.3	**2.42**	**1.02**
Fall				
Dissolved phosphorus	mg/L	0.05[2]	**0.067**	**0.058**
Total phosphorus	mg/L	0.05	**0.166**	**0.081**
Total Kjeldahl nitrogen	mg/L	1.0[4]	**1.1**	**-**
Total phenols	mg/L	0.004	**0.008**	**-**
Total aluminum	mg/L	0.1	**1.39**	**0.708**
Total cobalt	mg/L	0.0009[3]	**0.00115**	**-**
Dissolved iron	mg/L	0.3[2]	**0.947**	**0.816**
Total iron	mg/L	0.3	**2.49**	**1.59**

TAR-1 and TAR-2 not sampled in winter 2005.

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

[1] Guideline is hardness-dependent.

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

[3] B.C. Working Water Quality Guideline (2001).

[4] Guideline is for total nitrogen.

Table 5.5-6 Concentrations of sediment quality measurement endpoints, lower Tar River (TAR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	15	4	10	16	26
Silt	%	-	20	4	10	23.5	50
Sand	%	-	65	4	24	60.5	80
Total organic carbon	%	-	2.7	3	0.9	1.1	6.3
Total hydrocarbons							
CCME variables							
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]	59	1	-	-	100
Fraction 3 (C16-C34)	mg/kg	400[2]	**860**	1	-	-	810
Fraction 4 (C34-C50)	mg/kg	2800[2]	460	1	-	-	360
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0048	4	0.0013	0.0042	0.015
Retene	mg/kg	-	0.0687	3	0.0226	0.043	0.379
Total dibenzothiophenes	mg/kg	-	1.61	4	0.15	0.75	6.26
Total PAHs	mg/kg	-	4.42	4	0.62	2.34	19.14
Total HMW PAHs	mg/kg	-	0.83	4	0.10	0.63	2.17
Total LMW PAHs	mg/kg	-	3.59	4	0.52	1.71	16.97
Predicted PAH toxicity[1]	H.I.	-	0.96	4	0.21	2.15	5.44
Metals that exceed CCME guidelines in 2005							
Arsenic (As)	mg/kg	5.9	**6.3**	4	3.2	5.7	**9.5**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	2	5	-	7
Chironomus growth - 10d	mg/organism	-	-	2	2	-	4
Hyallela survival - 14d	# surviving	-	-	1	-	-	6.6
Hyallela growth - 14d	mg/organism	-	-	1	-	-	0.1

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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.5-7 Concentrations of sediment quality measurement endpoints, upper Tar River (TAR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	7	1	-	-	5
Silt	%	-	6	1	-	-	6
Sand	%	-	87	1	-	-	89
Total organic carbon	%	-	0.3	1	-	-	0.3
Total hydrocarbons							
CCME variables							
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	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	150	1	-	-	<5
Fraction 4 (C34-C50)	mg/kg	2800[2]	34	1	-	-	<5
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0030	1	-	-	0.0019
Retene	mg/kg	-	0.0152	1	-	-	0.0014
Total dibenzothiophenes	mg/kg	-	0.002	1	-	-	0.005
Total PAHs	mg/kg	-	0.114	1	-	-	0.097
Total HMW PAHs	mg/kg	-	0.066	1	-	-	0.054
Total LMW PAHs	mg/kg	-	0.048	1	-	-	0.043
Predicted PAH toxicity[1]	H.I.	-	0.20	1	-	-	0.11
Metals that exceed CCME guidelines in 2005							
Arsenic (As)	mg/kg	5.9	**13**	1	-	-	4.4
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	-	-	-	-
Chironomus growth - 10d	mg/organism	-	-	-	-	-	-
Hyallela survival - 14d	# surviving	-	-	-	-	-	-
Hyallela growth - 14d	mg/organism	-	-	-	-	-	-

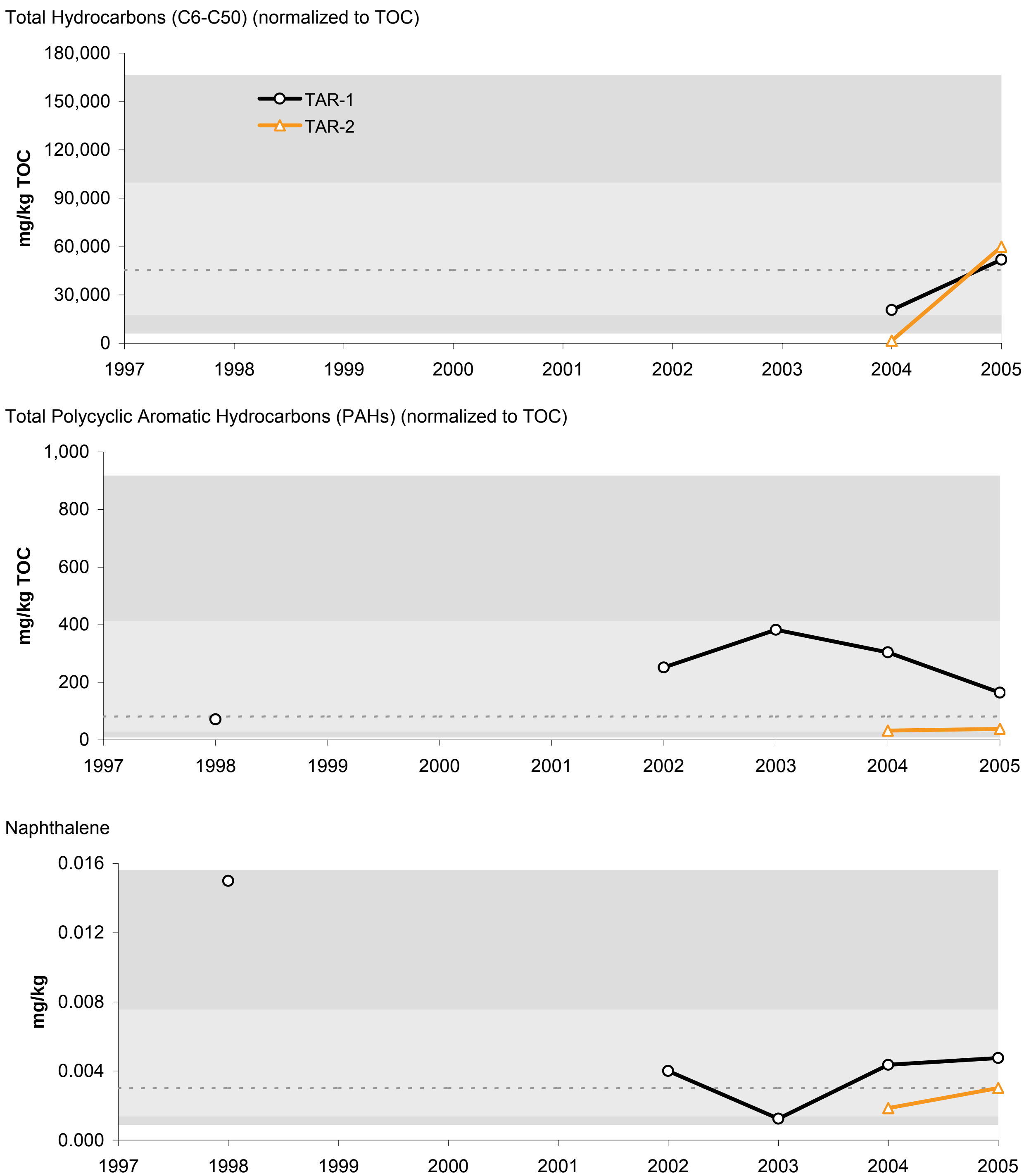
Values in **bold** indicate concentrations exceeding guidelines.

[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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Figure 5.5-5 Selected sediment quality measurement endpoints in the Tar River (fall data) relative to regional baseline fall concentrations.



[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

Table 5.5-8 Average habitat characteristics of benthic invertebrate community sampling reaches in the Tar River, fall 2005.

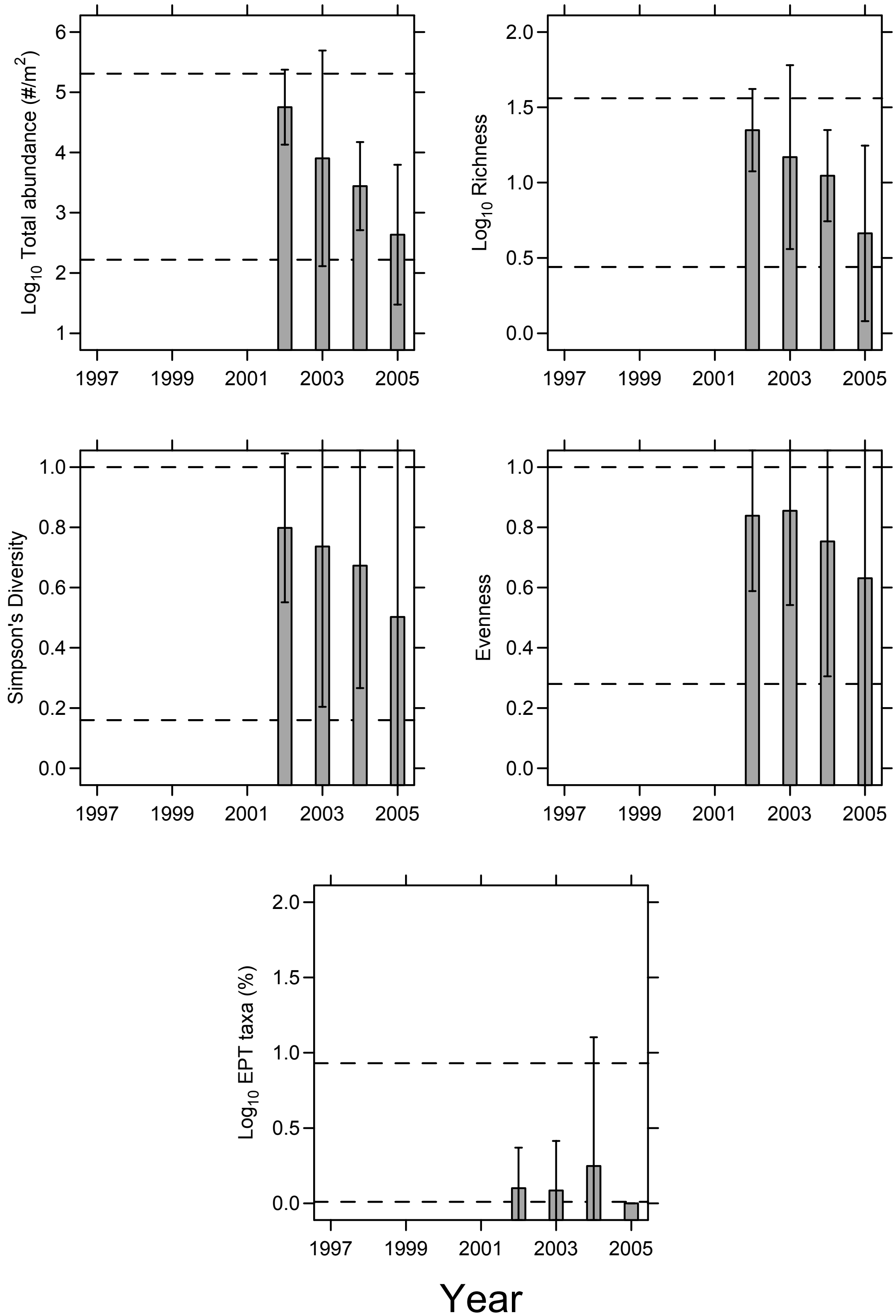
Variable	Units	Reach TAR-D-1	Reach TAR-E-2
Sample date	-	Sept 9, 2005	Sept 17, 2005
Habitat	-	Depositional	Erosional
Water depth	m	0.4	<1
Current velocity	m/s	0.2	1.4
Macrophyte cover	%	0	1
Benthic algae[1]	mg/m^2	n/a	9
Field Water Quality			
Dissolved oxygen	mg/L	9.2	11
Conductivity	µS/cm	n/a	n/a
pH		8.0	n/a
Water temperature	°C	13.2	6.1
Sediment Composition			
Sand	%	87	n/a
Silt	%	8	n/a
Clay	%	5	n/a
Total Organic Carbon	%	0.7	n/a
Sand/Silt/Clay	%	n/a	0
Small gravel	%	n/a	10
Large gravel	%	n/a	43
Small cobble	%	n/a	31
Large cobble	%	n/a	6
Boulder	%	n/a	0
Bedrock	%	n/a	0

[1] measured as chlorophyll *a*

Table 5.5-9 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of the Tar River, fall 2005.

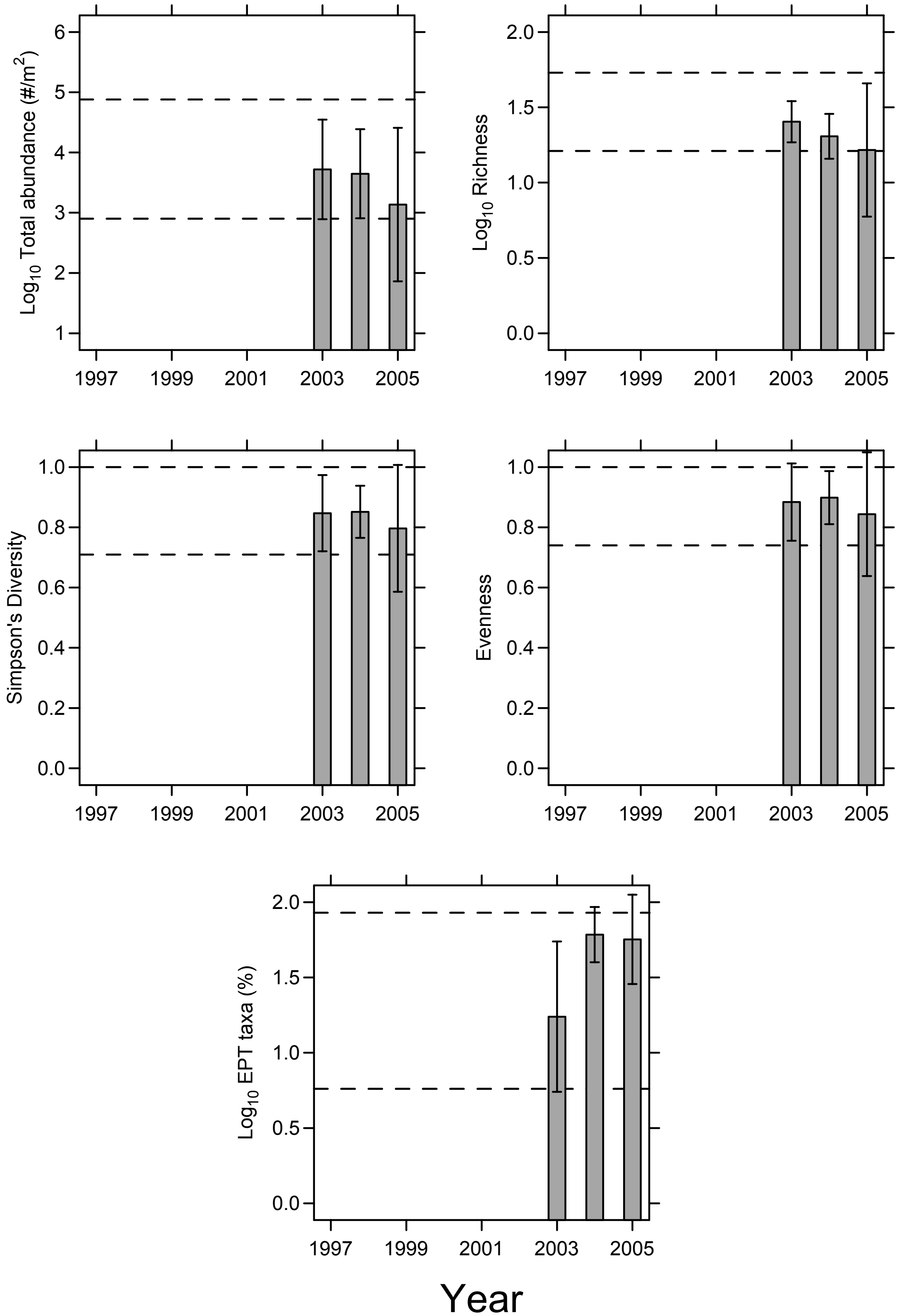
Taxon	Reach TAR-D-1				Reach TAR-E-2		
	2002	2003	2004	2005	2003	2004	2005
Nematoda	2	<1	4	1	2	<1	<1
Erpobdellidae	<1	<1	<1			<1	
Enchytraeidae			5	2	2	<1	<1
Naididae	<1	4	2		6	<1	<1
Tubificidae	7	1	6	28	1	1	1
Lumbriculidae					1		<1
Hydracarina	<1	1	1		1	2	<1
Ostracoda	2	<1	25	37			
Copepoda	<1	<1	2		1		<1
Chydoridae	<1	<1	<1				
Amphipoda	<1						
Collembola		<1					
Bivalvia	1	<1	<1	1			
Gastropoda	<1		1				
Ephemeroptera	<1	<1	1		5	38	45
Plecoptera	<1	<1	<1		8	13	12
Trichoptera	<1	<1	<1		2	10	3
Anisoptera	<1						
Zygoptera							
Coleoptera	<1		<1			<1	
Heteroptera					<1		
Lepidoptera							
Tipulidae	<1	<1	<1	3	1	<1	<1
Dolichopodidae			1			<1	
Tabanidae	<1	<1	<1	1			
Empididae	1	1	1		2	1	2
Ephydridae					<1		
Ceratopogonidae	1	1	16	8	<1	<1	
Chironomidae	86	90	33	20	67	21	33
Psychodidae					<1		<1
Simuliidae						13	2
Megaloptera						<1	
Total Abundance (No./m^2)	69,759	20,805	3,489	657	7,166	5,781	2,263
Richness	22	16	11	4	25	20	17
Simpson's Diversity	0.80	0.74	0.67	0.50	0.85	0.85	0.80
Evenness	0.84	0.85	0.75	0.87	0.88	0.90	0.86
% EPT	<1	<1	2	0	18	61	58

Figure 5.5-6 Variations in benthic invertebrate community measurement endpoints in the Tar River, reach TAR-D-1.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional reaches.

Figure 5.5-7 Variations in benthic invertebrate community measurement endpoints in the Tar River, reach TAR-E-2.

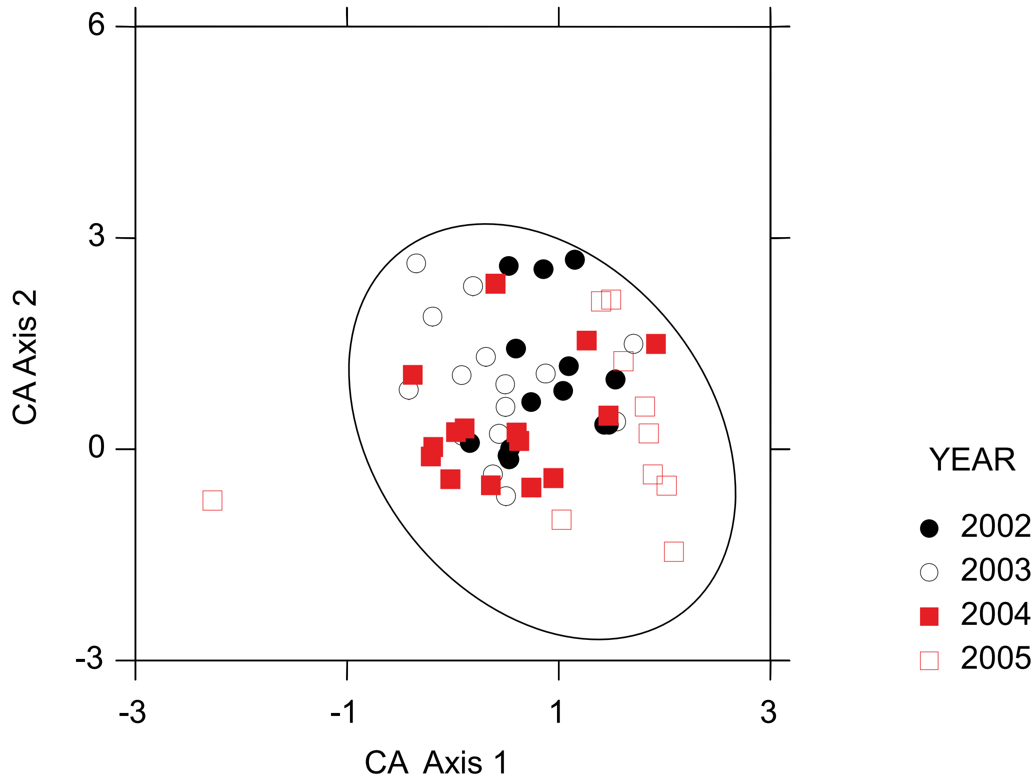


Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional reaches.

Table 5.5-10 Results of analysis of variance (ANOVA) on Tar River, reaches TAR-D-1 and TAR-E-2, with planned comparisons.

Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	32.76	6	23.42	<0.001
Before to After	6.56	1	28.14	<0.001
Reach	0.58	1	2.49	0.118
Before to After × Reach	1.34	1	5.73	0.019
Pre-Post lower reach	22.17	1	95.08	<0.001
Reach (2005)	1.25	1	5.36	0.023
Error	20.51	88		
Log_{10} Richness				
Reach-Year	4.370	6	24.82	<0.001
Before to After	0.963	1	32.84	<0.001
Reach	2.364	1	80.59	<0.001
Before to After × Reach	0.138	1	4.70	0.032
Pre-Post lower reach	2.178	1	74.24	<0.001
Reach (2005)	1.532	1	52.23	<0.001
Error	2.581	88		
Simpson's Diversity				
Reach	1.055	6	6.409	<0.001
Before to After	0.136	1	4.98	0.028
Reach	0.728	1	26.54	<0.001
Before to After × Reach	0.072	1	2.66	0.106
Pre-Post lower reach	0.430	1	15.68	<0.001
Reach (2005)	0.432	1	15.75	<0.001
Error	2.415	88		
Evenness				
Reach	0.482	6	2.87	0.013
Before to After	0.102	1	3.66	0.059
Reach	0.286	1	10.22	0.002
Before to After × Reach	0.089	1	3.20	0.077
Pre-Post lower reach	0.246	1	8.81	0.003
Reach (2005)	0.182	1	6.52	0.012
Error	2.460	88		
Log_{10} EPT %				
Reach	52.00	6	211.16	<0.001
Before to After	1.49	1	36.31	<0.001
Reach	42.30	1	1030.5	<0.001
Before to After × Reach	1.11	1	26.94	<0.001
Pre-Post lower reach	0.01	1	0.32	0.574
Reach (2005)	15.36	1	374.2	<0.001
Error	3.61	88		

Figure 5.5-8 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for reach TAR-D-1 (operational as of summer 2004).



Note: Ellipse is for *reference* and *potentially influenced-other* depositional reaches.

5.6 MACKAY RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				Streamflow was very close to historical average conditions in 2005. All hydrologic measurement endpoints are estimated to be essentially identical to what they would have been in the absence of oil sands development activities.
Mean winter discharge	√				
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=1)	2005 *Reference* Stations (n=1)	
Physical variables (max=1 for exp, 1 for ref)	0	0	In general, fall 2005 results for water quality variables were similar to those observed in previous years. Overall, there were three (27%) out of 11 possible guideline exceedances of the selected water quality measurement endpoints at each station. Ionic characteristics of the water sampled at both stations have been relatively constant, suggesting there has been little change in overall water quality conditions in the watershed since the beginning of RAMP sampling.
Nutrients (max=3 for exp, 3 for ref)	2	1	
Ions (max=2 for exp, 2 for ref)	0	0	
Selected metals (max=5 for exp, 5 for ref)	1	1	
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=1 station X 8 endpoints)	2005 *Reference* Stations (n=1 station X 8 endpoints)	
Greater than 95th percentile	0	0	
Between 5th and 95th percentiles	5	5	
Less than 5th percentile	3	3	

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]	
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=0)	2005 *Reference* Stations (n=0)
Total Hydrocarbons	No sediment quality sampling was conducted in 2005.	
PAHs		
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[3]**	
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 3 endpoints)	2005 *Reference* Stations (n=0 stations X 3 endpoints)
Greater than 95th percentile	No sediment quality sampling was conducted in 2005.	
Between 5th and 95th percentiles		
Less than 5th percentile		

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline						
	2005 *Potentially Influenced-Oil Sands* Stations (n=1)			2005 *Reference* Stations (n=1)			
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance		1			1		Differences in time trends of richness suggest the possibility of sublte changes in benthic invertebrate communities reaches designated as exposed-oil sands. Benthic communities in 2005 were in good condition with all indices continuing to fall within expected regional baseline ranges.
Richness		1			1		
Diversity		1			1		
Evenness		1			1		
% EPT		1			1		

Fish Populations

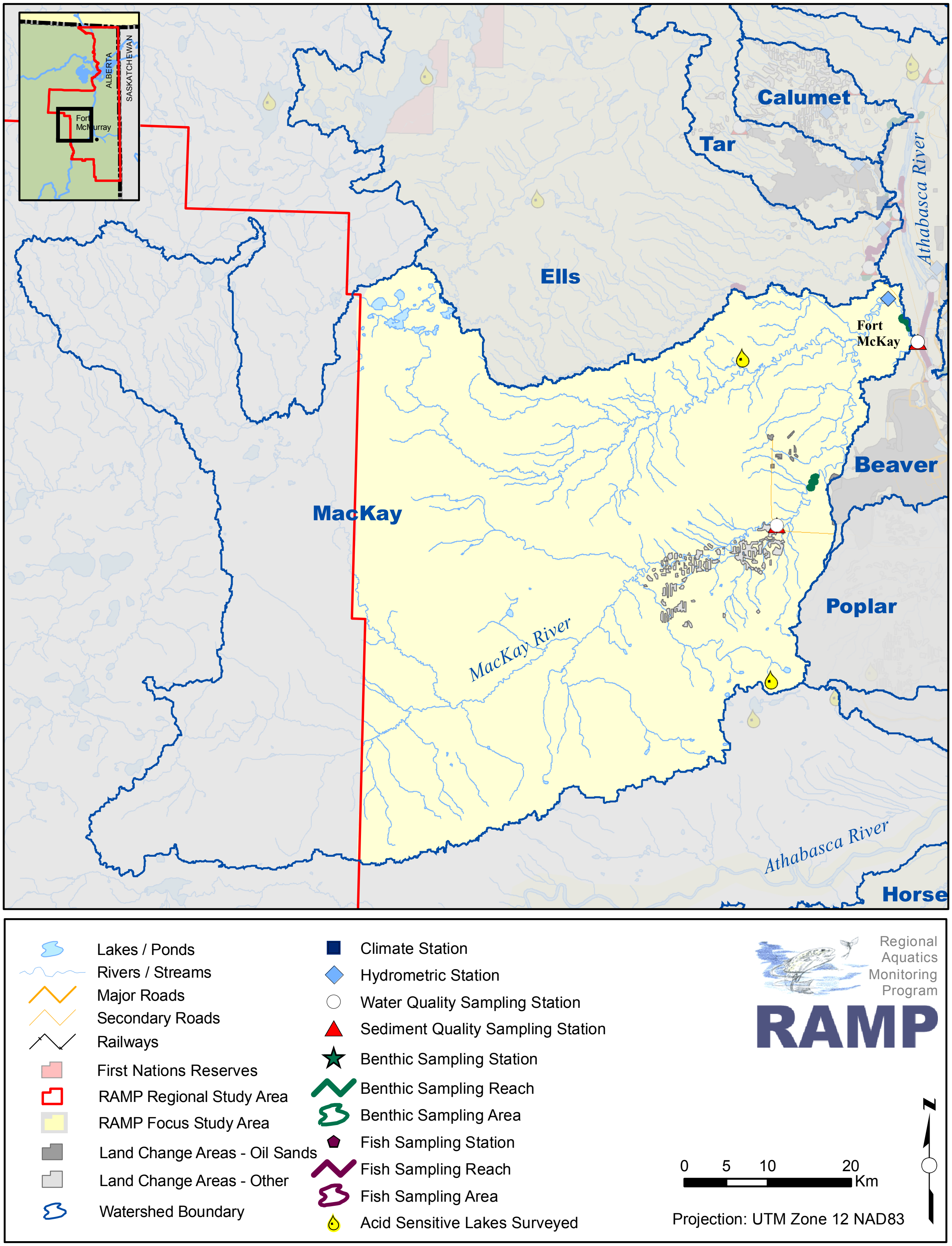
Fish Inventory	No fish inventory studies conducted in 2005.
Sentinel Studies	No sentinel fish studies conducted in 2005.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.6-1 MacKay River watershed.



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5.6.1 Development Status

Less than 1% of the MacKay River watershed has undergone land change as a result of oil sands development activities (Table 2.4-2). The designations of specific areas of the watershed are as follows:

- All areas and 2005 RAMP stations located downstream of the Petro-Canada MacKay River, Petro-Canada Devon *in situ* operations and that part of Syncrude's Mildred Lake operations in the MacKay River watershed (Figure 2.4-1) are designated as *potentially influenced-oil sands*. All data gathered from the 2005 RAMP stations located in this area of the watershed are designated as operational data;

- The area of the MacKay River drainage upstream of these *in situ* oil sands developments and the 2005 RAMP stations located in this part of the watershed are designated as *potentially influenced-other* because approximately 0.5% of the MacKay River drainage is designated as having land change from by other developments. These other developments consist of logging activities in the watershed upstream of the *in situ* oil sands projects (Figure 2.4-1). All data gathered from the 2005 RAMP stations located in this area of the watershed are designated as baseline data; and

- The Dover River drainage is designated as a *reference* area.

5.6.2 Hydrologic Conditions

Streamflow in the MacKay River basin, as measured at RAMP Station S26 and WSC Station 07DB001 (designated as *potentially influenced-oil sands*), was very close to historical average conditions in 2005 (Figure 5.6-2). The May to October runoff depth was 72 mm compared to the average of 67 mm; the maximum daily discharge for the year was 99.7 m^3/s compared to the mean annual flood of 114 m^3/s; and the minimum daily open-water discharge was 3.50 m^3/s compared to an average minimum of 3.58 m^3/s. The highest flow occurred in late April, and the flows fluctuated above and below long-term average values throughout the rest of the year.

Inputs to the water balance model for the MacKay River watershed used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints are provided in Table 5.6-1. The very small estimated area of the MacKay River watershed determined as having undergone land change from cumulative oil sands development activities up to 2005, combined with no known surface water withdrawals or releases known to have been made by the two active oil sands projects in the watershed, mean that all hydrologic measurement endpoints are estimated to be essentially identical to what they would have been in the absence of oil sands development activities (Table 5.6-2, Figure 5.6-2). This change would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b). Therefore, based on the available hydrologic and oils sands development information, it appears that changes in hydrologic conditions in the MacKay River watershed up to and including 2005 have been negligible.

5.6.3 Water Quality

In 2005, water quality samples were collected from the mouth of the MacKay River (station MAR-1, *potentially influenced-oil sands*, operational data, first sampled in 1998, fall sampling every year since 2000) and upstream of the Petro-Canada MacKay River and Petro-Canada Devon *in situ* developments (station MAR-2, *potentially influenced-other*, baseline data, first sampled in 2002). Results of 2005 sampling for selected water quality measurement endpoints are shown in Table 5.6-3 and Table 5.6-4. Figure 5.6-3 contains results for selected endpoints relative to regional baseline conditions.

Overall, there were three (27%) out of 11 possible guideline exceedances of the selected water quality measurement endpoints at each station (i.e., eleven of the selected water quality measurement endpoints have guidelines [Table 5.6-3 and Table 5.6-4]). Several ions and related analytes (i.e., conductivity), as well as total boron and molybdenum were slightly lower in fall 2005 than minimum values observed in previous years of sampling (1997-2004) for both stations MAR-1 and MAR-2. Dissolved organic carbon and total phenols were slightly higher in 2005 than historical maxima, and total phenols exceeded guidelines in fall 2005 at both stations. Dissolved and total iron, as well as total aluminum and total Kjeldahl nitrogen, also exceeded guidelines at both stations in fall 2005; concentrations of total aluminum and total nitrogen, however, were within historical ranges and within the range of regional baseline concentrations.

Ionic characteristics at both stations have been relatively constant over the period of sampling (Figure 5.6-4), with only a slight increase in calcium in fall 2005 at station MAR-2. This indicates there has been little observable change in water quality conditions since oil sands development activities commenced in the MacKay River watershed in 2002.

All exceedances of CCME/AENV guidelines observed in the MacKay River in 2005 are shown in Table 5.6-5.

5.6.4 Sediment Quality

The 2005 RAMP Sediment Quality component did not include any activities in the MacKay River watershed.

5.6.5 Benthic Invertebrate Communities

In 2005, benthic invertebrate community samples were collected from a reach near the mouth of the MacKay River (reach MAR-E-1, *potentially influenced-oil sands*, operational data from 2002 onwards), and upstream of the Petro-Canada MacKay River and Petro-Canada Devon *in situ* developments (reach MAR-E-3, *potentially influenced-other*, baseline data). Both reaches are erosional.

Both reach MAR-E-1 and reach MAR-E-3 are typical erosional habitats, with moderate current velocities (0.2 to 0.7 m/s) and shallow depths (<0.5 m) (Table 5.6-6). Periphyton chlorophyll *a* biomass was low in reach MAR-E-1 (5 mg/m^2) and relatively high in reach MAR-E-3 (48 mg/m^2). Chlorophyll *a* biomass was lower in reach MAR-E-1 than pre-operational levels of about 30+ mg/m^2. Macrophytes were rare in reach MAR-E-1 (1% cover, similar to baseline conditions) and more abundant in reach MAR-E-3 (11% cover). Water temperatures were cooler upstream (3ºC) than downstream (13ºC). Substrates were similar between the two reaches, although reach MAR-E-1 was composed of more fine material (gravel and sand/silt/clay) than reach MAR-E-3 (~50% cobble and boulder).

Chironomids, mayflies, mites and naidids worms dominated the communities of both reach MAR-E-1 and MAR-E-3 (Table 5.6-7). Sub-dominant groups were also similar and included a variety of larval flies (empidids, ceratopogonids, simuliids), sphaeriid clams, tubificids worms and nematodes. Caddisflies and stoneflies were also present. Both reaches contained a number of benthic taxa considered sensitive to degraded conditions including the mayflies *Ameletus* and *Ephemerella*, the stonefly *Isoperla*, the dragonfly *Ophiogomphus* and the empidid *Hemerodromia*. Reach MAR-E-1 also contained the sensitive stoneflies *Taeniopteryx*, and *Claassenia sabulosa*, while reach MAR-E-3 contained the sensitive caddisfly *Brachycentrus*.

Time trends of indices relative to baseline erosional reaches provided little evidence of effects on the benthic invertebrate community of reach MAR-E-1 (Figure 5.6-5). Analysis of variance results testing for time x reach contrasts since 2002 when reach MAR-E-1 was designated as *potentially influenced-oil sands* reveal a statistically significant decline in abundance and statistically significant increase in Simpson's Diversity and evenness (Table 5.6-8). Abundance and richness are statistically lower, and evenness and %EPT statistically higher in reach MAR-E-1; these differences are evident in the 2005 reach contrasts also (Table 5.6-8). Only richness differs significantly from baseline to operational periods, but the difference was marginal and average numbers are well within the normal range of *reference* and *potentially influenced-other* reaches in the RAMP FSA (Figure 5.6-5). Ordination results (Figure 5.6-6) provide supporting evidence that the benthic invertebrate community of reach MAR-E-1 is similar to benthic invertebrate communities from *reference* and *potentially influenced-other* erosional reaches in the RAMP FSA.

5.6.6 Fish Populations

The 2005 RAMP Fish Population component did not include any activities in the MacKay River watershed.

5.6.7 Summary of Conditions

Data collected in the MacKay River watershed in 2005 indicated negligible changes in hydrological conditions as a result of oil sand activities, little observable change in water quality; and little evidence of effects on benthic invertebrate communities. These 2005 results, plus the relatively small scale of oil sands development activities in the watershed to date indicates that oil sands development is having minor and negligible effects on RAMP aquatic resources.

Figure 5.6-2 MacKay River: 2005 hydrograph and historical context.

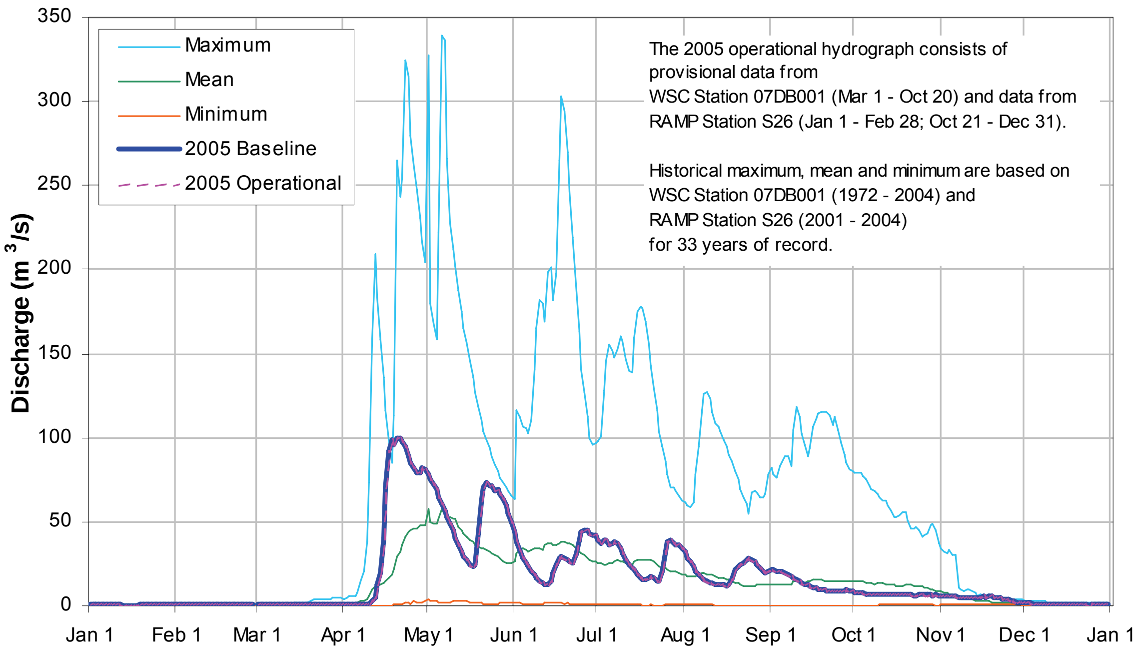


Table 5.6-1 Inputs to calculation of MacKay River baseline hydrograph at RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001).

Component	Annual Volume (dam^3)	Basis and Data Source
Observed hydrograph	559,000	Observed daily discharges obtained from RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001)
Natural runoff that would have occurred from active mine areas, or that is intercepted by development	151	1.71 km^2 isolated, equal to estimated sum of oil sands-developed and oil sands-enclosed areas within watershed (Table 2.4-1)
Incremental runoff from areas that are cleared and areas that are being dewatered	13	0.66 km^2 cleared, equal to estimated sum of oil sands-cleared and oil sands-bare areas within watershed (Table 2.4-1)
Withdrawals from the MacKay River by oil sands development activities	0	Water withdrawals are from groundwater
Releases to the MacKay River by oil sands development activities	0	Unknown but assumed to be negligible
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No significant upstream oil sands developments

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.6-2 Calculated change in hydrologic measurement endpoints for the MacKay River watershed.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	25.2	25.2	<0.025%
Mean winter discharge	2.75	2.75	<0.025%
Annual maximum daily discharge	99.8	99.7	<0.025%
Open-water season minimum daily discharge	3.50	3.50	<0.025%

Note: as measured at and calculated for RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001).

Table 5.6-3 Concentrations of water quality measurement endpoints, mouth of MacKay River (MAR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	6	7.6	8.2	8.6
Total suspended solids	mg/L	-[1]	<3	6	<3	8	26
Conductivity	µS/cm	-	217	6	233	296	576
Nutrients							
Total phosphorus	mg/L	0.05	**0.051**	6	0.011	0.036	**0.054**
Total dissolved phosphorus	mg/L	0.05[2]	0.039	6	0.004	0.016	0.047
Total nitrogen*	mg/L	1.0	**1.2**	6	0.4	**1.05**	**3.2**
Nitrate+nitrite	mg/L	-	<0.1	6	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	33	6	20	23	31
Ions							
Sodium	mg/L	-	15	6	17	23	60
Calcium	mg/L	-	24.7	6	25.1	28.8	44.7
Magnesium	mg/L	-	8.1	6	8.2	9.6	15.9
Chloride	mg/L	230, 860[3]	4	6	3	8	41
Sulphate	mg/L	100[4]	12.7	6	17.9	20.5	35.5
Total dissolved solids	mg/L	-	170	6	170	260	342
Total alkalinity	mg/L		96	6	100	122	202
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.238**	6	0.05	**0.234**	**0.501**
Dissolved aluminum	mg/L	0.1[2]	0.0237	6	0.01	0.0164	0.03
Total boron	mg/L	1.2[4]	0.0632	6	0.077	0.0997	0.14
Total molybdenum	mg/L	0.073	0.00023	6	0.00036	0.0004	0.0006
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total Kjeldahl nitrogen	mg/L	1.0[6]	**1.1**	6	0.3	0.95	**3.1**
Total phenols	mg/L	0.004	**0.009**	6	<0.001	0.0005	0.004
Dissolved iron	mg/L	0.3[2]	**0.57**	6	0.23	**0.39**	**0.6**
Total iron	mg/L	0.3	**0.95**	6	**0.31**	**0.92**	**23.3**

Note: Guideline values are CCME/AENV guidelines 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 1999).

4 B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

6 Guideline is for total nitrogen.

Table 5.6-4 Concentrations of water quality measurement endpoints, upper MacKay River (MAR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	3	7.8	8.1	8.3
Total suspended solids	mg/L	-[1]	3	3	<3	<3	10
Conductivity	µS/cm	-	182	3	202	237	249
Nutrients							
Total phosphorus	mg/L	0.05	0.047	3	0.014	0.046	**0.074**
Total dissolved phosphorus	mg/L	0.05[2]	0.035	3	0.008	0.028	0.039
Total nitrogen*	mg/L	1.0	**1.2**	3	0.8	**1.40**	**3.1**
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	32	3	22	25	31
Ions							
Sodium	mg/L	-	11	3	15	17	19
Calcium	mg/L	-	22.2	3	21.3	26.6	31.5
Magnesium	mg/L	-	6.9	3	7	9.0	10.1
Chloride	mg/L	230, 860[3]	2	3	1	2	2
Sulphate	mg/L	100[4]	11	3	15.4	17.6	23.7
Total dissolved solids	mg/L	-	160	3	190	200	240
Total alkalinity	mg/L		81	3	85	112	128
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.159**	3	0.0201	**0.201**	**0.468**
Dissolved aluminum	mg/L	0.1[2]	0.0233	3	<0.0002	0.0248	0.0251
Total boron	mg/L	1.2[4]	0.0514	3	0.05839	0.0738	0.105
Total molybdenum	mg/L	0.073	0.00023	3	0.00030	0.0004	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	0.7
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total Kjeldahl nitrogen	mg/L	1.0[6]	**1.1**	3	0.7	1.3	**3**
Total phenols	mg/L	0.004	**0.011**	3	<0.001	0.006	0.006
Dissolved iron	mg/L	0.3[2]	**0.52**	3	0.289	**0.53**	**0.587**
Total iron	mg/L	0.3	**0.81**	3	**0.386**	**0.92**	**1.277**

Note: Guideline values are CCME/AENV guidelines 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).

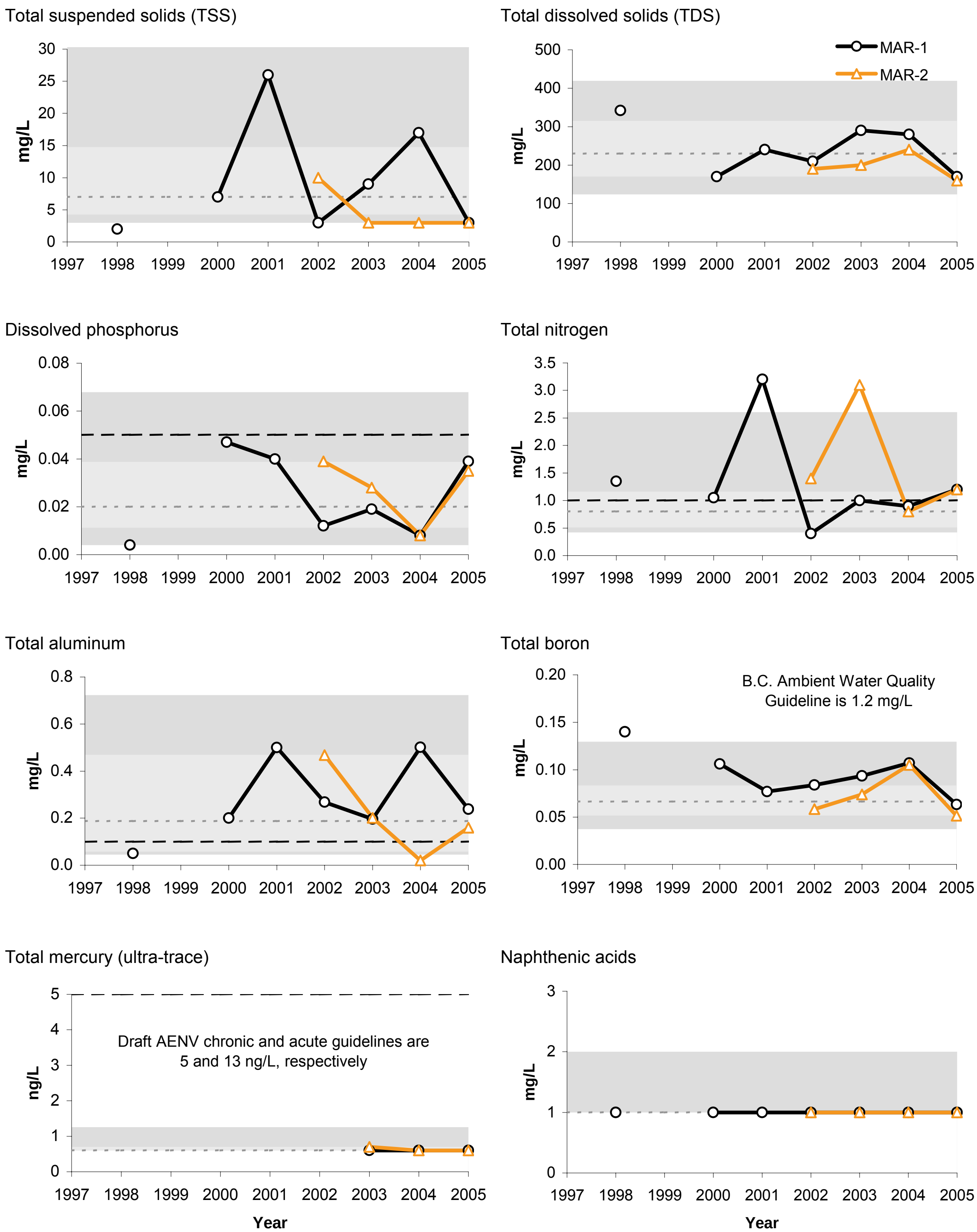
3 U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

4 B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

6 Guideline is for total nitrogen.

Figure 5.6-3 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.

[1] 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 5.6-4 Piper diagram of fall ion concentrations in the MacKay River watershed.

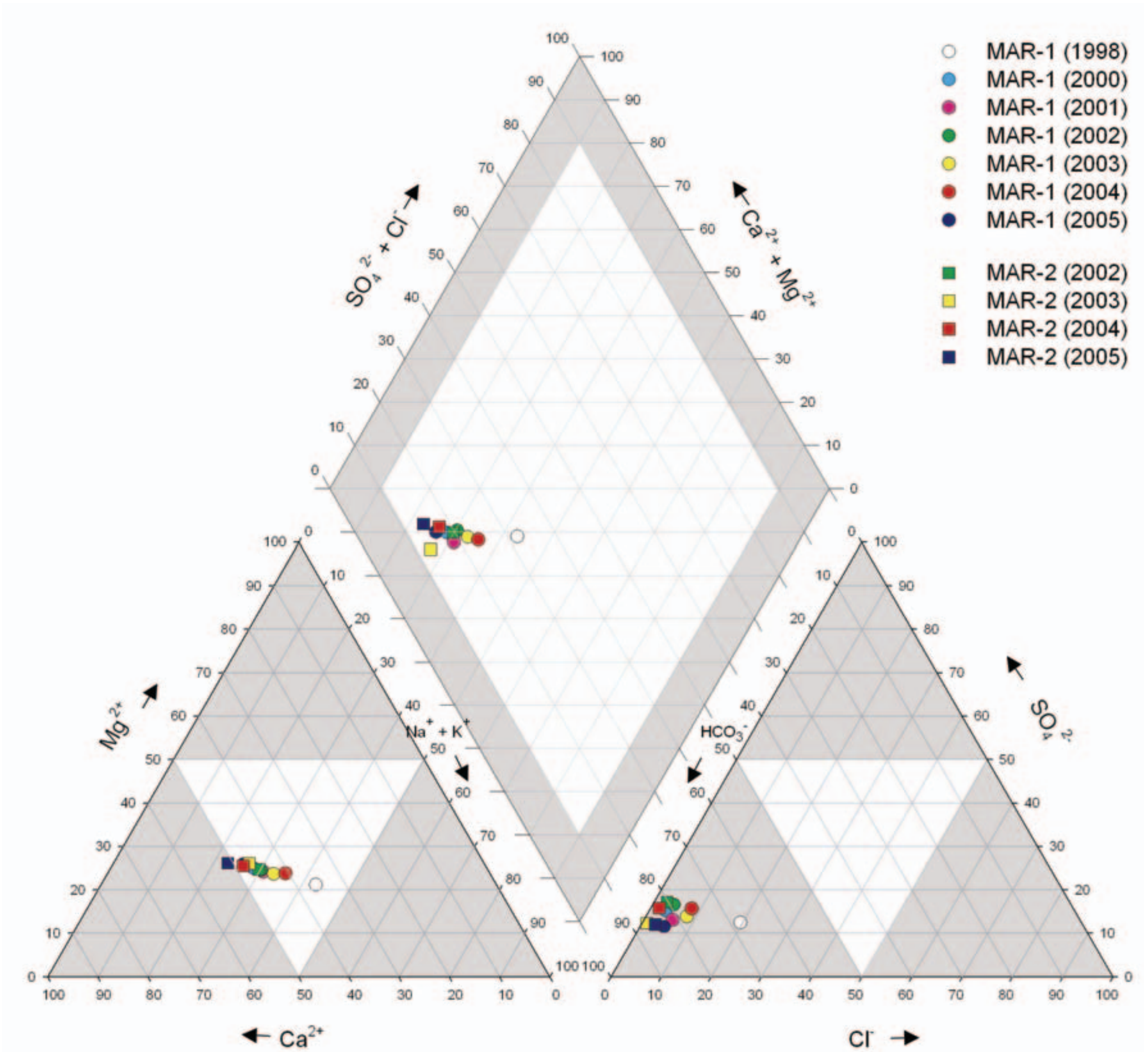


Table 5.6-5 Water quality guideline exceedances, MacKay River watershed, 2005.

Parameter	Units	Guideline*	MAR-1	MAR-2
Fall				
Total phosphorus	mg/L	0.05	**0.051**	-
Total Kjeldahl nitrogen	mg/L	1.0[1]	**1.1**	**1.1**
Total phenols	mg/L	0.004	**0.009**	**0.011**
Total aluminum	mg/L	0.1	**0.238**	**0.159**
Dissolved iron	mg/L	0.3[2]	**0.574**	**0.52**
Total iron	mg/L	0.3	**0.95**	**0.808**

MAR-1 and MAR-2 were sampled only in fall 2005.

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

[1] Guideline is for total nitrogen.

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

Table 5.6-6 Average habitat characteristics of benthic invertebrate community sampling reaches in the MacKay River, fall 2005.

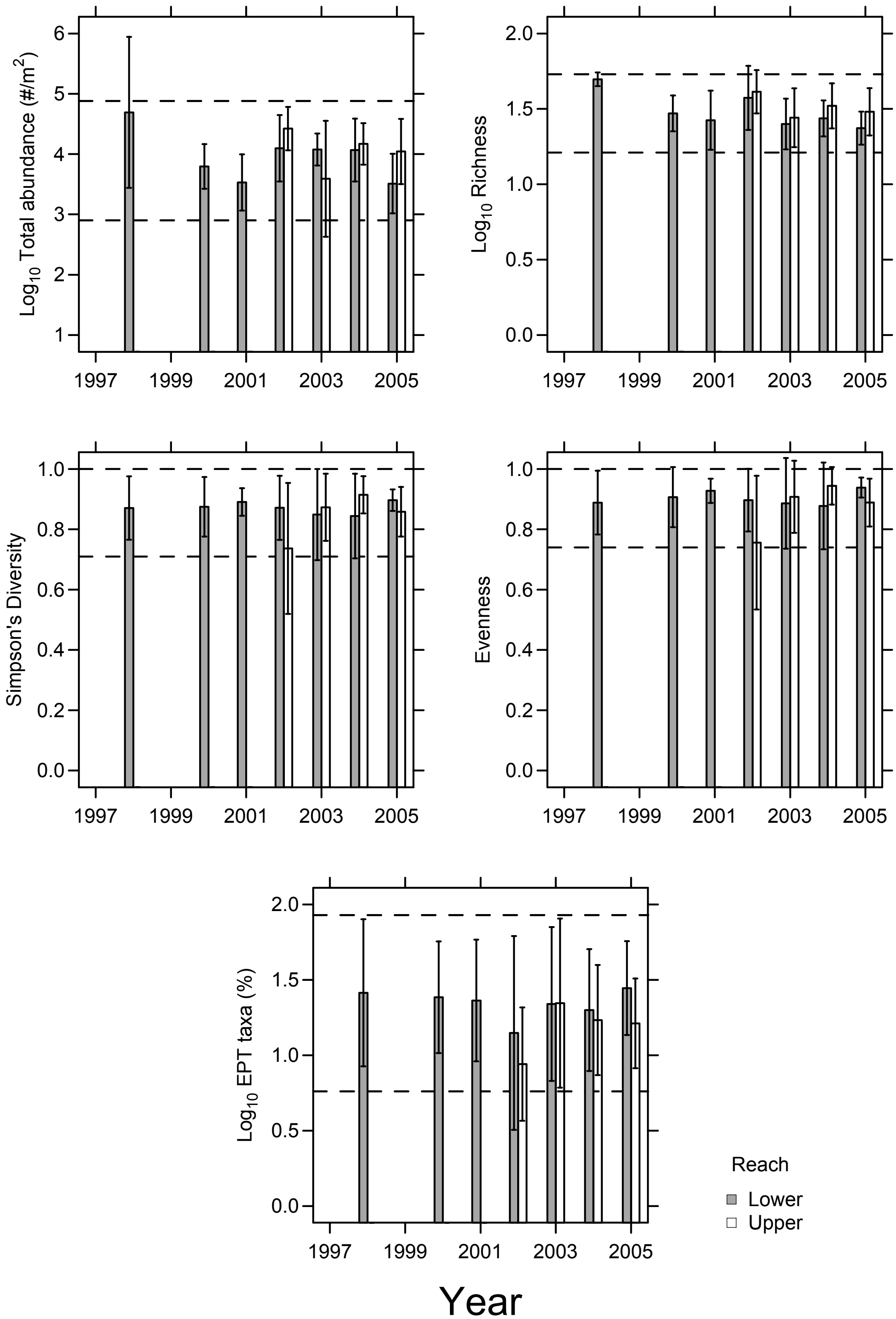
Variable	Units	Reach MAR-E-1	Reach MAR-E-3
Sample date	-	Sept 11, 2005	Sept 15, 2005
Habitat	-	Erosional	Erosional
Water depth	m	0.4	0.2
Current velocity	m/s	0.2	0.7
Macrophyte cover	%	1	11
Benthic algae[1]	mg/m^2	5	48
Field Water Quality			
Dissolved oxygen	mg/L	8.9	9.2
Conductivity	µS/cm	195	n/a
pH		8.2	n/a
Water temperature	°C	13.5	3.0
Sediment Composition			
Sand/Silt/Clay	%	4	11
Small gravel	%	24	16
Large gravel	%	51	22
Small cobble	%	19	23
Large cobble	%	3	22
Boulder	%	0	7
Bedrock	%	0	0

[1] measured as chlorophyll *a*.

Table 5.6-7 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of the MacKay River, fall 2005.

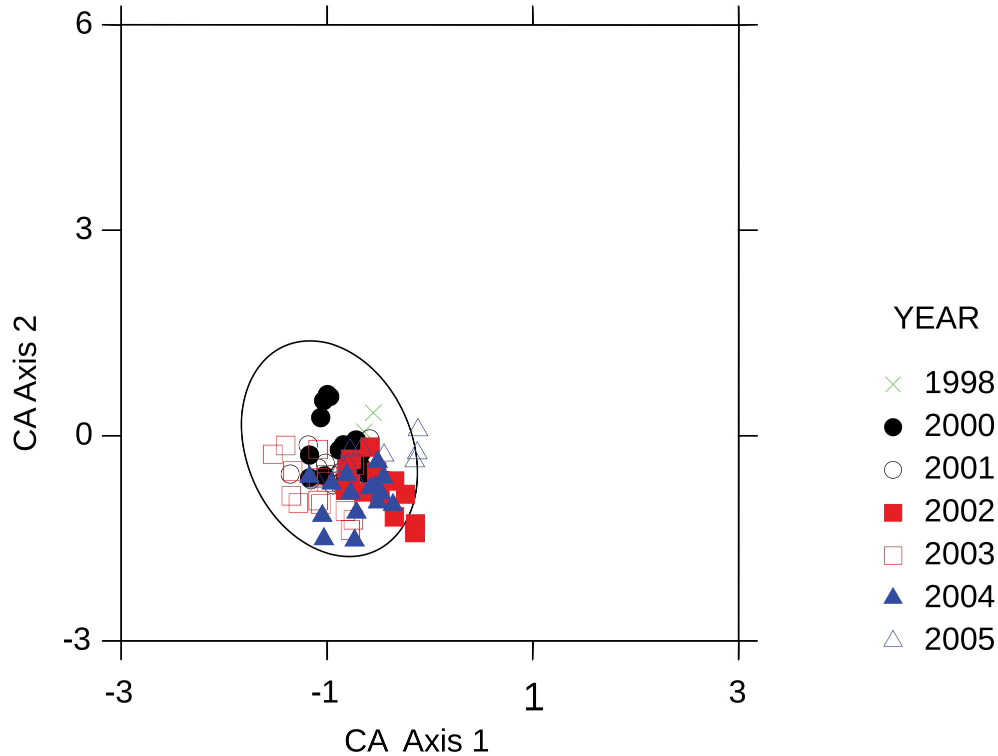
Taxon	Reach MAR-E-1							Reach MAR-E-3			
	1998	2000	2001	2002	2003	2004	2005	2002	2003	2004	2005
Hydra	<1			1	<1			<1			
Nematoda	2	2	8	6	1	3	1	3	1	3	1
Erpobdellidae						<1			<1		
Enchytraeidae	4	12	10	5	5	1	1	1	4	3	3
Naididae	2	17	2	24	8	3	11	48	15	4	15
Tubificidae	2	<1	1	2	<1	1	6	<1	<1	8	1
Lumbriculidae					<1				<1		<1
Hydracarina	1	4	6	3	18	6	10	7	21	4	9
Ostracoda	<1	1	1	6		<1		<1	<1	<1	
Copepoda	<1	<1	<1	<1				<1		<1	
Daphniidae				<1		<1					
Macrothricidae		<1		1							
Bivalvia		<1	<1	1	2	2	1	<1	4	1	<1
Gastropoda	<1	<1	1	2	<1	1		<1	<1	<1	<1
Ephemeroptera	26	21	18	12	19	13	25	2	14	11	10
Plecoptera	2	5	5	<1	1	3	3	<1	3	3	1
Trichoptera	<1	<1	3	3	2	5	<1	6	4	3	5
Anisoptera	1	1	2	1	1	3	2	<1	1	<1	<1
Coleoptera	<1	<1			<1	<1			<1	<1	<1
Heteroptera	<1		<1								
Tipulidae	<1	<1			<1			<1	<1	<1	
Dolichopodidae				<1				<1	<1		
Tabanidae					<1		1		<1		
Empididae	1	1	4	3	2	2	12	1	2	1	5
Ceratopogonidae	1	1	<1	1	<1	1	5	<1	<1	1	1
Chironomidae	57	34	40	31	40	57	20	31	30	59	49
Simuliidae	1	<1	<1	<1	<1		2		<1		<1
Total Abundance (No./m^2)	56,434	6,680	3,745	14,423	12,347	13,290	3,592	28,222	5,568	15,733	12,332
Richness	49	29	26	37	24	27	23	40	27	32	30
Simpson's Diversity	0.87	0.87	0.89	0.87	0.85	0.84	0.90	0.74	0.87	0.91	0.86
Evenness	0.89	0.91	0.93	0.90	0.89	0.88	0.94	0.76	0.91	0.94	0.89
% EPT	26	25	24	16	23	20	28	8	25	17	16

Figure 5.6-5 Variations in benthic invertebrate community measurement endpoints in the MacKay River, reaches MAR-E-1 and MAR-E-3.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for *reference* and *potentially influenced-other* erosional reaches. Lower reach: reach MAR-E-1; Upper reach: reach MAR-E-3.

Figure 5.6-6 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for reach MAR-E-1.



Note: Ellipse is for erosional reaches sampled in the RAMP FSA and designated as *reference* and *potentially influenced-other.*

Table 5.6-8 Results of analysis of variance (ANOVA) on MacKay River, reaches MAR-E-1 and MAR-E-3, with planned comparisons.

Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	13.25	10	23.79	<0.001
Time	1.16	1	20.74	<0.001
Reach	0.38	1	6.79	0.010
Time × Reach	0.63	1	11.22	0.001
Reach (2005)	1.42	1	25.43	<0.001
Pre-Post reach MAR-E-1	0.06	1	1.17	0.281
Error	7.30	131		
Log_{10} Richness				
Reach-Year	0.867	10	16.35	<0.001
Time	0.189	1	35.73	<0.001
Reach	0.125	1	23.56	<0.001
Time × Reach	0.019	1	3.70	0.056
Reach (2005)	0.059	1	11.09	0.001
Pre-Post reach MAR-E-1	0.101	1	19.07	<0.001
Error	0.694	131		
Simpson's Diversity Index				
Reach	0.312	10	10.54	<0.001
Time	0.068	1	22.99	<0.001
Reach	0.010	1	3.51	0.063
Time × Reach	0.036	1	12.02	<0.001
Reach (2005)	0.007	1	2.51	0.115
Pre-Post reach MAR-E-1	0.002	1	0.84	0.360
Error	0.388	131		
Evenness				
Reach	0.370	10	12.15	<0.001
Time	0.089	1	29.30	<0.001
Reach	0.017	1	5.72	0.018
Time × Reach	0.032	1	10.60	0.001
Reach (2005)	0.012	1	4.06	0.045
Pre-Post reach MAR-E-1	<0.001	1	0.30	0.586
Error	0.398	131		
Log_{10} EPT %				
Reach	2.763	10	6.82	<0.001
Time	0.604	1	14.91	<0.001
Reach	0.420	1	10.35	0.002
Time × Reach	0.010	1	0.25	0.617
Reach (2005)	0.275	1	6.78	0.010
Pre-Post reach MAR-E-1	0.088	1	2.17	0.143
Error	5.310	131		

5.7 CALUMET RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				All hydrologic measurement endpoints are estimated to be essentially identical to what they would have been in the absence of oil sands development activities.
Mean winter discharge	√				
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Measurement Endpoint	Summary of 2005 Conditions		
Water Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		If any influences of oil sands development have occurred in the Calumet River watershed are not seen in the water quality data gathered to date. There were few guideline exceedances throughout the Calumet River watershed in 2005 and fall concentrations of practically all selected water quality measurement endpoints in fall 2005 were within regional baseline ranges.
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=1)	2005 *Reference* Stations (n=1)	
Physical variables (max=1 for exp, 1 for ref)	0	0	
Nutrients (max=3 for exp, 3 for ref)	3	3	
Ions (max=2 for exp, 2 for ref)	0	0	
Selected metals (max=5 for exp, 5 for ref)	1	0	
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=1 station X 8 endpoints)	2005 *Reference* Stations (n=1 station X 8 endpoints)	
Greater than 95th percentile	0	1	
Between 5th and 95th percentiles	8	7	
Less than 5th percentile	0	0	

Measurement Endpoint	Summary of 2005 Conditions		
Sediment Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		It appears that current oil sands development has not had a measurable effect on sediment quality conditions. However, the relatively small samples sizes and the resulting high variability for many sediment quality measurement endpoints make the detection and interpretation of differences and trends difficult.
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=1)	2005 *Reference* Stations (n=1)	
Total Hydrocarbons (max=5 for exp, 5 for ref)	3	3	
PAHs (max=1 for exp, 1 for ref)	0	0	
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[3]		
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=1 station X 3 endpoints)	2005 *Reference* Stations (n=1 station X 3 endpoints)	
Greater than 95th percentile	1	1	
Between 5th and 95th percentiles	2	2	
Less than 5th percentile	0	0	

Measurement Endpoint	Summary of 2005 Conditions						
Benthic Invertebrate Communities							
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline						Benthic invertebrate community conditions in the Calumet River watershed in 2005 were not measurably affected by oil sands development.
	2005 *Potentially Influenced-Oil Sands* Stations (n=1)			2005 *Reference* Stations (n=1)			
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance		1			1		
Richness		1			1		
Diversity		1			1		
Evenness		1			1		
% EPT		1			1		

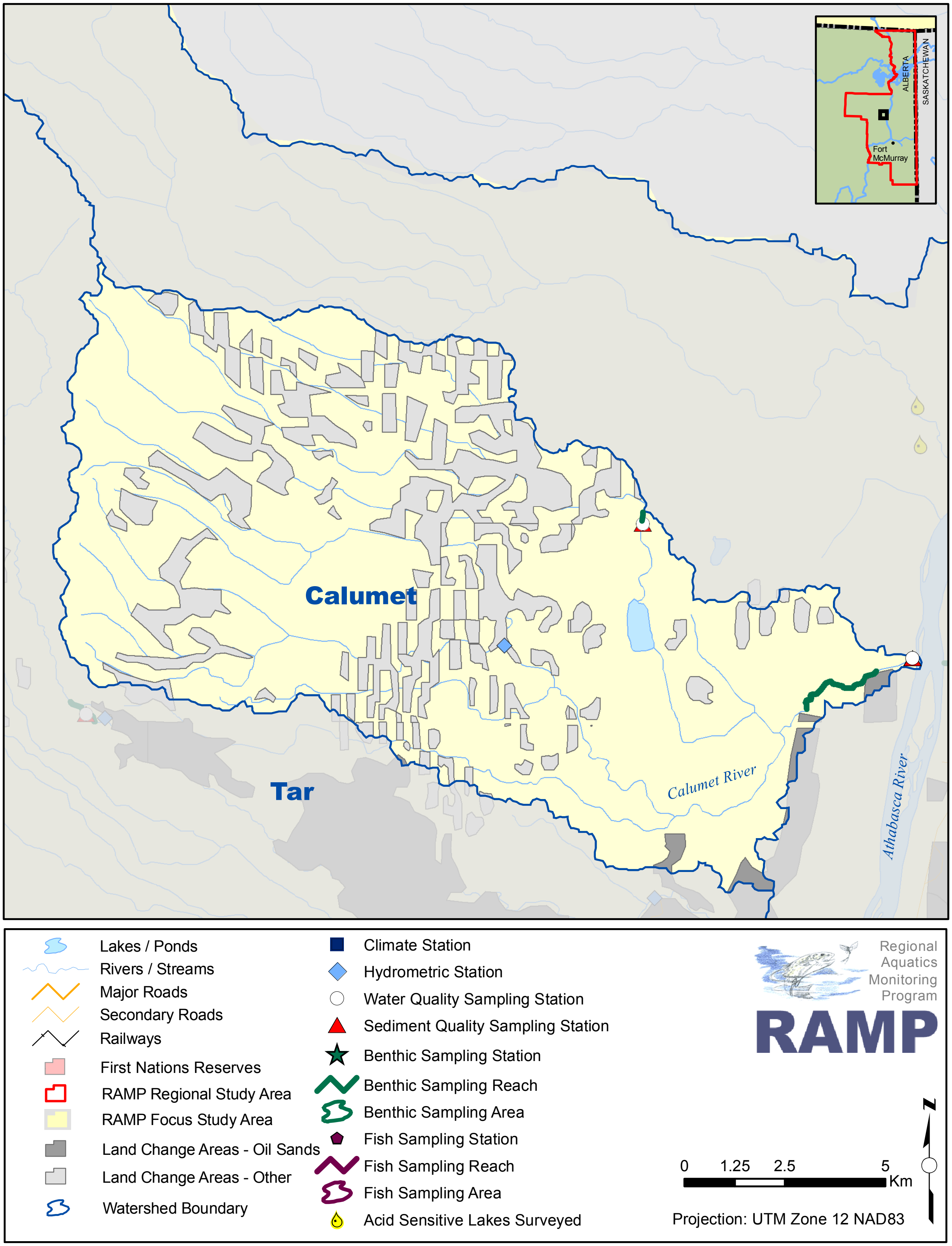
Measurement Endpoint	Summary of 2005 Conditions
Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2005.
Sentinel Studies	No sentinel fish studies conducted in 2005.
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.7-1 Calumet River watershed.



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5.7.1 Development Status

Approximately 1% of the Calumet River watershed has undergone land change as a result of oil sands development activities (Table 2.4-2), and most of this land change has occurred in the lower part of the watershed (Figure 5.7-1). The designations of specific areas of the watershed are as follows:

- The watershed downstream of the last major northerly bend in the Calumet River is designated as *potentially influenced-oil sands* as most of the land changes from oil sands activities as of 2005 were in this area. All data gathered from the 2005 RAMP stations located in this area of the watershed are designated as operational data; and

- All areas upstream of the last major bend in the Calumet River are designated as *potentially influenced-other*, as most of the 20% of the area that has undgone land change from other development activities, mostly logging, is located in this area (Figure 2.4-1). All data gathered from the 2005 RAMP stations located in this area of the watershed are designated as baseline data.

5.7.2 Hydrologic Conditions

The 2005 hydrograph for the Calumet River is presented in Figure 5.7-2.

Inputs to the water balance model for the Calumet River watershed used to create a baseline hydrograph for examining possible changes in the hydrologic measurement endpoints are provided in Table 5.7-1. The very small estimated area of the Calumet River watershed determined as having undergone land change from cumulative oil sands development activities up to 2005, combined with no known surface water withdrawals or releases known to have been made by oil sands projects in the watershed, mean that all hydrologic measurement endpoints are estimated to be essentially identical to what they would have been in the absence of oil sands development activities (Table 5.7-2, Figure 5.7-2). This change would have been assessed as Negligible in most oil sands EIAs (RAMP 2005b). Therefore, based on the available hydrologic and oils sands development information, it appears that changes in hydrologic conditions in the Calumet River watershed up to and including 2005 have been negligible.

5.7.3 Water Quality

In 2005, water quality samples were collected from the mouth of the Calumet River (station CAR-1, *potentially influenced-oil sands*, operational data, data available from 2002 to 2005) and upstream of the CNRL Horizon Project (station CAR-2, *potentially influenced-other*, baseline data, 2005 was the first year of sampling at this location). Seasonal sampling was conducted at both stations in 2005, although winter samples could not be collected from either station because both reaches were frozen to depth at the time of sampling.

Results of 2005 sampling for water quality measurement endpoints are presented in Table 5.7-3. Results for selected measurement endpoints (1997 to 2005) relative to regional baseline conditions are shown in Figure 5.7-3, while Table 5.7-4 contains all the water quality guideline exceedances observed in 2005.

Overall, there were 7 (32%) out of 22 possible guideline exceedances of the selected water quality measurement endpoints at either of the two Calumet River stations in fall 2005 (i.e., eleven of the selected water quality measurement endpoints have guidelines and water quality was sampled at two stations on the Calumet River in fall 2005, making for a total of 22 possible guideline exceedances, Table 5.7-3). A number of other water quality variables, total Kjeldahl nitrogen, total phenols, dissolved iron, and total iron, exceeded CCME/AENV guidelines at both stations in fall 2005 (Table 5.7-3). There were a considerable number of guidelines exceedances throughout 2005 at both stations (Table 5.7-4).

Most measurement endpoints at station CAR-1 were within previously recorded ranges (Table 5.7-3), with the exceptions of total phosphorus, sodium, chloride, and total boron being at or below historical (1997-2004) minimum recorded values, and pH being at or above historical (1997-2004) maximum recorded values. Such a comparison was not possible for station CAR-2 as 2005 was the first year under RAMP that water quality had been sampled at that location. All selected water quality measurement endpoints were within regional baseline concentrations at stations CAR-1 and CAR-2 in fall 2005 with the exception of dissolved aluminum, which exceeded its 95th percentile regional baseline concentration (Figure 5.7-3).

The ionic character of station CAR-2 appears to be somewhat different from and more dominated by chloride anions than station CAR-1 (Figure 5.7-4), where similar ionic character has been observed over the four years of sampling. The somewhat different ionic character of the water sampled at station CAR-2 may be due to logging that has recently taken place in the upper parts of the Calumet River watershed (Figure 2.4-1).

In summary, if any influences of oil sands development have occurred in the Calumet River watershed they are not seen in the water quality data gathered to date. There were few guideline exceedances throughout the Calumet River watershed in 2005 and fall concentrations of practically all selected water quality measurement endpoints in fall 2005 were within regional baseline ranges.

5.7.4 Sediment Quality

In 2005, sediment quality samples were collected from the mouth of the Calumet River (station CAR-1, *potentially influenced-oil sands*, operational data, data available from 2002 to 2005) and upstream of the CNRL Horizon Project (station CAR-2, *potentially influenced-other*, baseline data available from 2004 to 2005). Results of 2005 sediment quality sampling are provided in Table 5.7-5 and Table 5.7-6, while results for selected sediment quality measurement endpoints relative to regional baseline conditions are shown in Figure 5.7-5.

Overall, there were three out of five possible guideline exceedances of the selected sediment quality measurement endpoints at each of the stations in fall 2005 (i.e., five of the selected sediment quality measurement endpoints have CCME/ISQG guidelines [Table 5.7-5 and Table 5.7-6]). All three guideline exceedances at both stations were for Fraction 2 (C10-C16), Fraction 3 (C16-C34), and Fraction 4 (C34-C50) hydrocarbons.

A number of sediment quality measurement endpoints were either above or below previously recorded fall maximum or minimum concentrations in fall 2005 at all stations, although these results should be interpreted with caution as there are very few observations in the data record for a number of the sediment quality measurement endpoints (Table 5.7-5 and Table 5.7-6).

All selected sediment quality measurement endpoints were within regional baseline concentrations in 2005 with the exception of naphthalene at station CAR-2 and total hydrocarbons at station CAR-1, both of which were above the 95th percentile of regional baseline concentrations (Figure 5.7-5).

Based on the available sediment quality data, it appears that current oil sands development in the Calumet River watershed has not had a measurable effect on sediment quality conditions. However, the relatively small samples sizes and the resulting high variability for many sediment quality measurement endpoints make the detection and interpretation of differences and trends difficult.

5.7.5 Benthic Invertebrate Communities

In 2004, benthic invertebrate community samples were collected from a reach at the mouth of the Calumet River (reach CAR-D-1, depositional, *potentially influenced-oil sands*, data available from 2002 to 2005) and a reach on the upper Calumet River (reach CAR-D-2, depositional, *potentially influenced-other*, data available from 2003 to 2005).

Reach CAR-D-1 was shallow (0.4 m) with some macrophytes (3% cover, Table 5.7-7). Reach CAR-D-2 is pond-like and still, with no measurable current and higher macrophyte cover (40%). As in previous years, the dissolved oxygen levels were low (4 mg/L) in Reach CAR-D-2. Conductivity was quite high at both reaches (507 µS/cm in reach CAR-D-2 and 580 µS/cm in reach CAR-D-2). Sediments in reach CAR-D-1 were heavily dominated by sand, whereas sand, silt and clay were more evenly distributed at reach CAR-D-2. Total organic carbon was relatively high (compared to the Ontario Ministry of the Environment, 1993, guideline value of 10 mg/kg) in reach CAR-D-2.

Both reach CAR-D-1 and reach CAR-D-2 had similar benthic communities that were dominated by Chironomidae (>40%) and were diverse considering the depositional habitats. Reach CAR-D-1 had an average of 18 taxa, and over 17,000 individuals/m^2. The stonefly *Nemoura* was present, indicating high quality habitat, while there was only a single specimen of an immature leptophlebiid mayfly. Chironomids were diverse in reach CAR-D-1, but *Polypedilum* and *Stichtochironomus* were abundant in most samples. Other groups present in reach CAR-D-1 included Hydra, nematodes, worms (naidids, tubificids, enchytraeids), crustaceans (ostracods, copepods), sphaeriid clams, beetles and other miscellaneous fly larvae (tabanids, ceratopogonids). Benthic invertebrate community measurement endpoints in reach CAR-D-1 in 2005 were well within the regional baseline ranges for depositional habitats (Figure 5.7-6).

Reach CAR-D-2 was also diverse, especially considering the pond-like environment. That reach contained a variety of worms, crustaceans, clams, and fly larvae in addition to the chironomids. *Chaoborus*, a genus restricted almost entirely to lakes and ponds, were present in small numbers at reach CAR-D-2, reflecting the pond-like environment. The number of taxa (13) and number of animals (~13,000 individuals/m^2) were relatively high for depositional habitats (Figure 5.7-6).

In summary, benthic invertebrate community conditions in the Calumet River watershed in 2005 were not measurably affected by oil sands development.

5.7.6 Fish Populations

The 2005 RAMP Fish Population component did not include any activities in the Calumet River watershed.

5.7.7 Summary of Conditions

While 2005 was the first year that a portion of the Calumet River watershed was designated as *potentially influenced-oil sands*, RAMP aquatic resources were measured as being similar to previous years. Few measurement endpoints in 2005 exceeded existing environmental guidelines, and few selected measurement endpoints were outside the range of expected reference conditions for similar river systems and habitats in the RAMP FSA.

Figure 5.7-2 Calumet River: 2005 hydrograph and historical context.

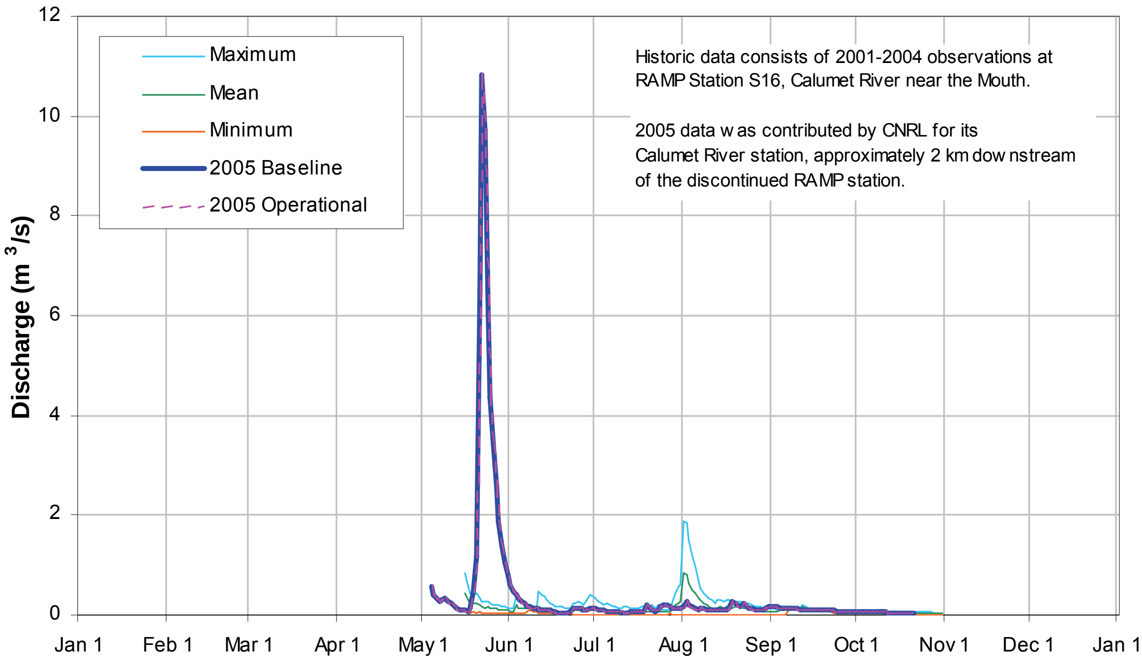


Table 5.7-1 Inputs to calculation of Calumet River baseline hydrograph at RAMP Station S16, Calumet River near the Mouth.

Component	Annual Volume (dam^3)	Basis and Data Source
Observed hydrograph	6,102	Observed daily discharges obtained from RAMP Station S16, Calumet River near the Mouth
Natural runoff that would have occurred from active mine areas, or that is intercepted by development	0	1.71 km^2 isolated, equal to estimated sum of oil sands-developed and oil sands-enclosed areas within watershed (Table 2.4-1)
Incremental runoff from areas that are cleared and areas that are being dewatered	11	1.2 km^2 cleared, equal to estimated sum of oil sands-cleared and oil sands-bare areas within watershed (Table 2.4-1)
Withdrawals from the Calumet River by oil sands development activities	0	Unknown but assumed to be negligible
Releases to the Calumet River by oil sands development activities	0	Unknown but assumed to be negligible
Diversions into or out of the watershed	0	None
The difference between operational and baseline hydrographs on tributary streams	0	No significant upstream oil sands developments

Note: Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.7-2 Calculated change in hydrologic measurement endpoints for the Calumet River watershed.

Measurement Endpoint	Baseline Value (m^3/s)	Operational Value (m^3/s)	Calculated Percent Change
Mean open-water season discharge	0.412	0.412	+0.2%
Mean winter discharge	Not monitored	Not monitored	
Annual maximum daily discharge	10.8	10.8	+0.2%
Open-water season minimum daily discharge	0.034	0.034	+0.2%

Note: as measured at and calculated for RAMP Station S16, Calumet River near the Mouth.

Table 5.7-3 Concentrations of water quality measurement endpoints, Calumet River (CAR-1 and CAR-2), fall 2005.

	Units	Guideline	September 2005		1997-2004 (CAR-1 fall data only)			
			CAR-1	CAR-2	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.4	7.8	3	8.1	8.2	8.2
Total suspended solids	mg/L	-[1]	11	<3	3	4	12	41
Conductivity	µS/cm	-	486	526	3	463	631	702
Nutrients								
Total phosphorus	mg/L	0.05	**0.075**	**0.19**	3	**0.081**	**0.089**	**0.099**
Total dissolved phosphorus	mg/L	0.05[2]	**0.055**	**0.129**	3	0.025	0.027	**0.076**
Total nitrogen*	mg/L	1.0	**1.2**	**2.0**	3	1.0	**1.2**	**1.4**
Nitrate+nitrite	mg/L	-	<0.1	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	32	47	3	29	30	34
Ions								
Sodium	mg/L	-	39	53	3	47	67	71
Calcium	mg/L	-	51	44	3	39	65	66
Magnesium	mg/L	-	16	18	3	13	20	22
Chloride	mg/L	230, 860[3]	12	14	3	14	30	34
Sulphate	mg/L	100[4]	12.3	45.3	3	11.2	11.9	13.5
Total dissolved solids	mg/L	-	320	370	3	300	460	480
Total alkalinity	mg/L		240	213	3	216	316	337
Organic compounds								
Naphthenic acids	mg/L	-	<1	2	3	<1	1	2
Selected metals								
Total aluminum	mg/L	0.1	**0.146**	0.062	3	0.05	**0.175**	**0.337**
Dissolved aluminum	mg/L	0.1[2]	0.0043	0.0132	3	0.0026	0.0051	0.0058
Total boron	mg/L	1.2[4]	0.0743	0.0817	3	0.0826	0.0904	0.117
Total molybdenum	mg/L	0.073	0.00018	0.000235	3	0.00018	0.00023	0.0003
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005								
Total Kjeldahl nitrogen	mg/L	1.0[6]	**1.1**	**1.9**	3	0.9	**1.1**	**1.3**
Total phenols	mg/L	0.004	**0.008**	**0.012**	3	<0.001	0.002	**0.010**
Dissolved iron	mg/L	0.3[2]	**0.49**	**0.37**	3	**0.34**	**0.49**	**0.61**
Total iron	mg/L	0.3	**0.94**	**0.72**	3	**0.60**	**1.48**	**3.14**

Note: Guideline values are CCME/AENV guidelines 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).

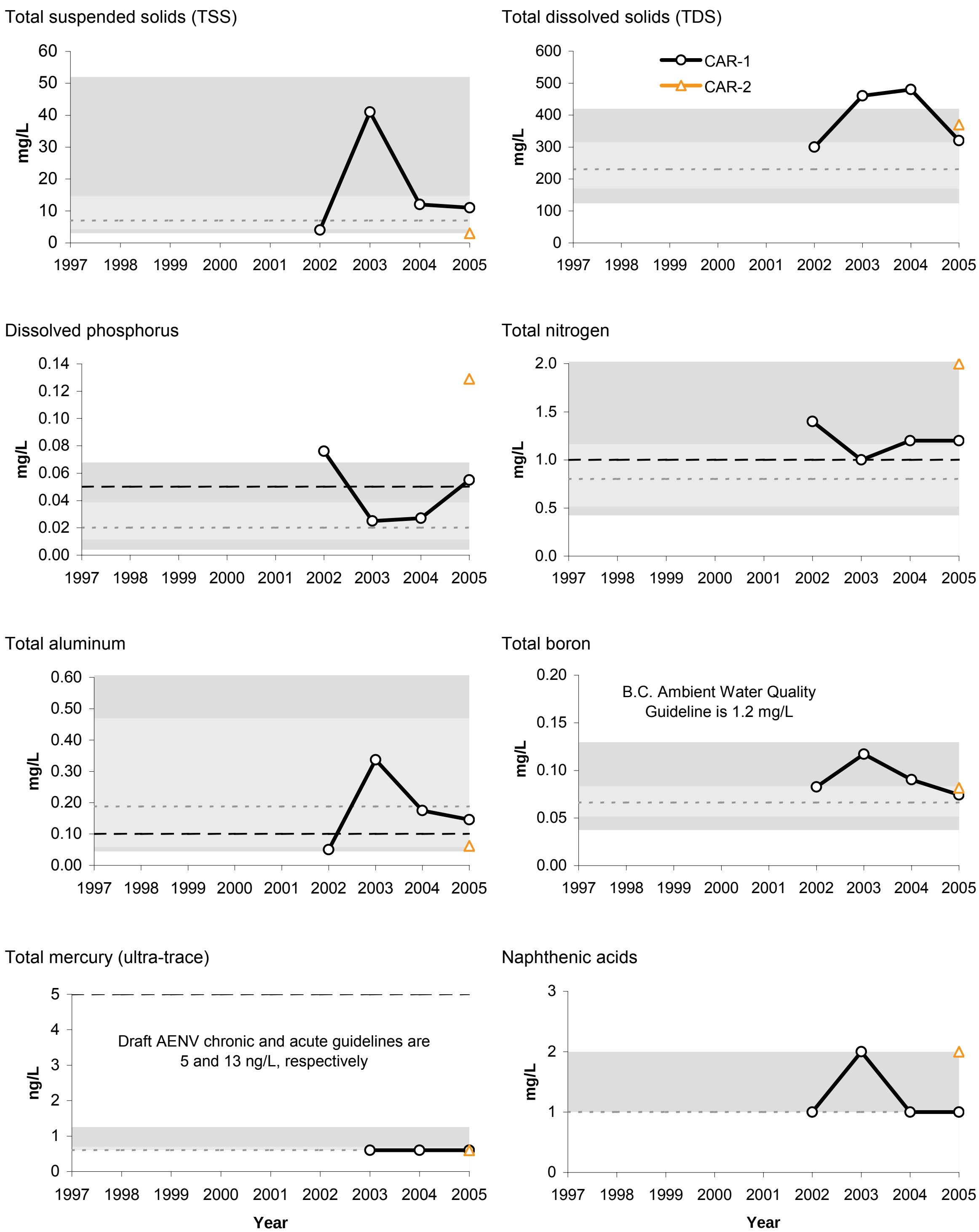
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

[6] Guideline is for total nitrogen.

Figure 5.7-3 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.

[1] 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 5.7-4 Piper diagram of fall ion concentrations in Calumet River watershed.

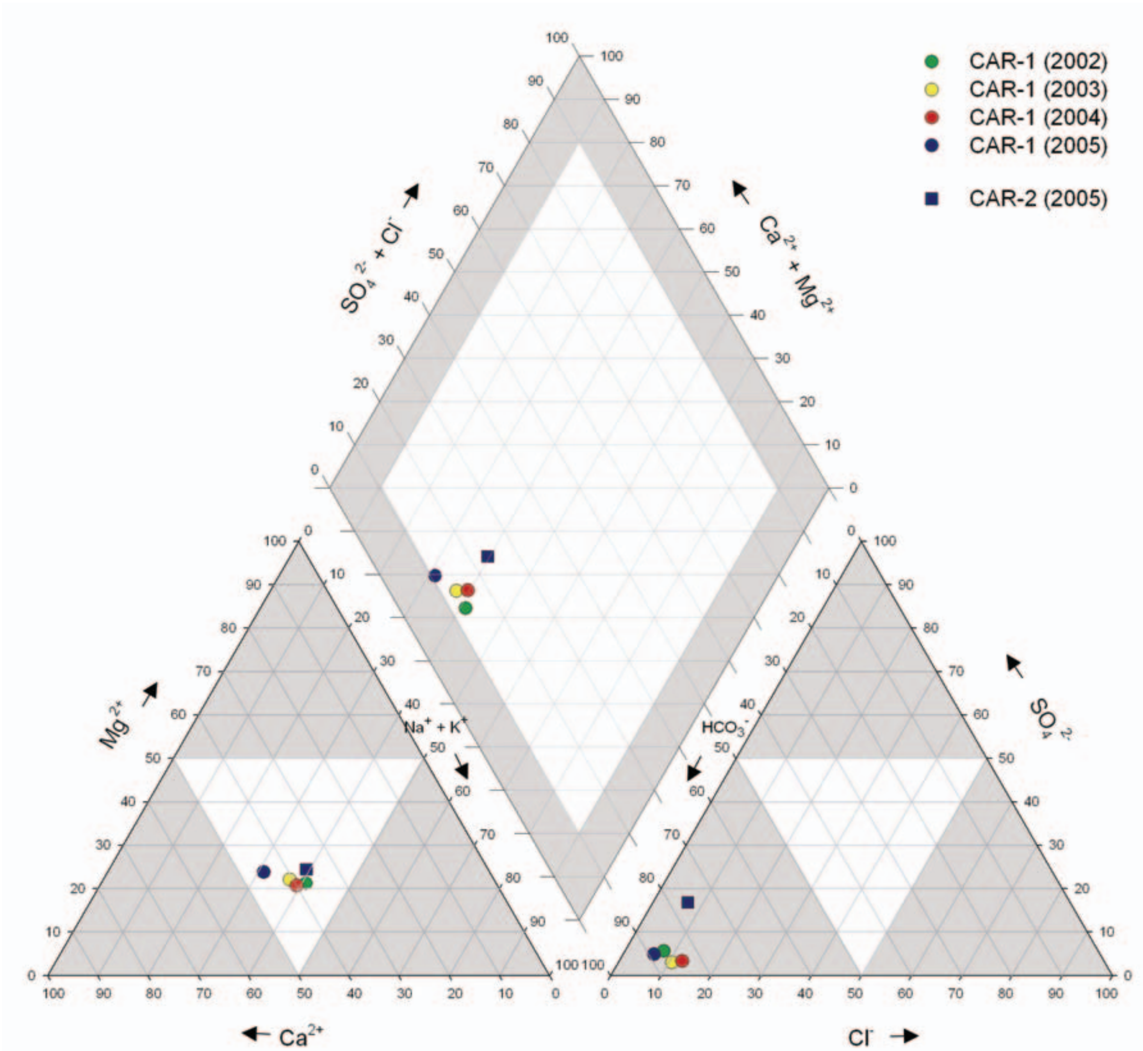


Table 5.7-4 List of all 2004 water quality guideline exceedances, Calumet River.

Parameter	Units	Guideline*	CAR-1	CAR-2
Spring				
Sulphate	mg/L	100[1]	-	**109**
Dissolved phosphorus	mg/L	0.05[2]	**0.092**	**0.129**
Total phosphorus	mg/L	0.05	**0.11**	**0.169**
Total Kjeldahl nitrogen	mg/L	1.0[3]	**1.5**	**1.7**
Total phenols	mg/L	0.004	**0.022**	**0.026**
Total aluminum	mg/L	0.1	**0.138**	**0.361**
Dissolved iron	mg/L	0.3[2]	**0.486**	**0.992**
Total iron	mg/L	0.3	**0.741**	**1.52**
Summer				
Dissolved phosphorus	mg/L	0.05[2]	**-**	**0.448**
Total phosphorus	mg/L	0.05	**-**	**0.53**
Total Kjeldahl nitrogen	mg/L	1.0[3]	**1.2**	**2.3**
Total aluminum	mg/L	0.1	**0.118**	**0.384**
Dissolved iron	mg/L	0.3[2]	**0.711**	**1.02**
Total iron	mg/L	0.3	**1.07**	**2.42**
Dissolved oxygen	mg/L	5.0[4]	**-**	**2.09**
Fall				
Dissolved phosphorus	mg/L	0.05[2]	**0.055**	**0.129**
Total phosphorus	mg/L	0.05	**0.075**	**0.19**
Total Kjeldahl nitrogen	mg/L	1.0[3]	**1.1**	**1.9**
Total phenols	mg/L	0.004	**0.008**	**0.012**
Total aluminum	mg/L	0.1	**0.146**	**-**
Dissolved iron	mg/L	0.3[2]	**0.492**	**0.369**
Total iron	mg/L	0.3	**0.935**	**0.721**

CAR-1 and CAR-2 were not sampled in winter 2005.

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

[1] B.C. Approved Water Quality Guideline (2001).

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

[3] Guideline is for total nitrogen.

[4] Alberta acute guideline for dissolved oxygen; guideline is a minimum value.

Table 5.7-5 Concentrations of sediment quality measurement endpoints, mouth of Calumet River (CAR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	21	2	10	-	18
Silt	%	-	9	2	26	-	30
Sand	%	-	70	2	52	-	67
Total organic carbon	%	-	3.8	2	0.6	-	4.1
Total hydrocarbons							
CCME variables							
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]	**640**	1	-	-	200
Fraction 3 (C16-C34)	mg/kg	400[2]	**7200**	1	-	-	3400
Fraction 4 (C34-C50)	mg/kg	2800[2]	**5300**	1	-	-	3000
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0048	2	0.0036	-	0.011
Retene	mg/kg	-	0.172	2	0.05	-	0.181
Total dibenzothiophenes	mg/kg	-	9.68	2	0.31	-	5.39
Total PAHs	mg/kg	-	26.98	2	1.54	-	17.46
Total HMW PAHs	mg/kg	-	5.94	2	0.54	-	6.07
Total LMW PAHs	mg/kg	-	21.04	2	1.00	-	11.40
Predicted PAH toxicity[1]	H.I.	-	0.60	2	0.78	-	2.02
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-				
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	1	-	-	9
Chironomus growth - 10d	mg/organism	-	1.27	1	-	-	1.8
Hyallela survival - 14d	# surviving	-	9	1	-	-	9
Hyallela growth - 14d	mg/organism	-	0.28	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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.7-6 Concentrations of sediment quality measurement endpoints, upper Calumet River (CAR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	-	-	-	-	-
Silt	%	-	-	-	-	-	-
Sand	%	-	-	-	-	-	-
Total organic carbon	%	-	20.5	-	-	-	-
Total hydrocarbons							
CCME variables							
BTEX	mg/kg	-	<5	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	**230**	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**6100**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	**3000**	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0201	-	-	-	-
Retene	mg/kg	-	0.353	-	-	-	-
Total dibenzothiophenes	mg/kg	-	0.04143	-	-	-	-
Total PAHs	mg/kg	-	1.92799	-	-	-	-
Total HMW PAHs	mg/kg	-	0.12054	-	-	-	-
Total LMW PAHs	mg/kg	-	1.80745	-	-	-	-
Predicted PAH toxicity[1]	H.I.	-	0.07	-	-	-	-
Metals that exceed CCME guidelines in 2005							
Arsenic (As)	mg/kg	5.9	**12.6**	-	-	-	-
Cadmium (Cd)	mg/kg	0.6	**0.8**	-	-	-	-
Zinc (Zn)	mg/kg	123	**129**	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	-	-	-	-
Chironomus growth - 10d	mg/organism	-	2.24	-	-	-	-
Hyallela survival - 14d	# surviving	-	6	-	-	-	-
Hyallela growth - 14d	mg/organism	-	0.44	-	-	-	-

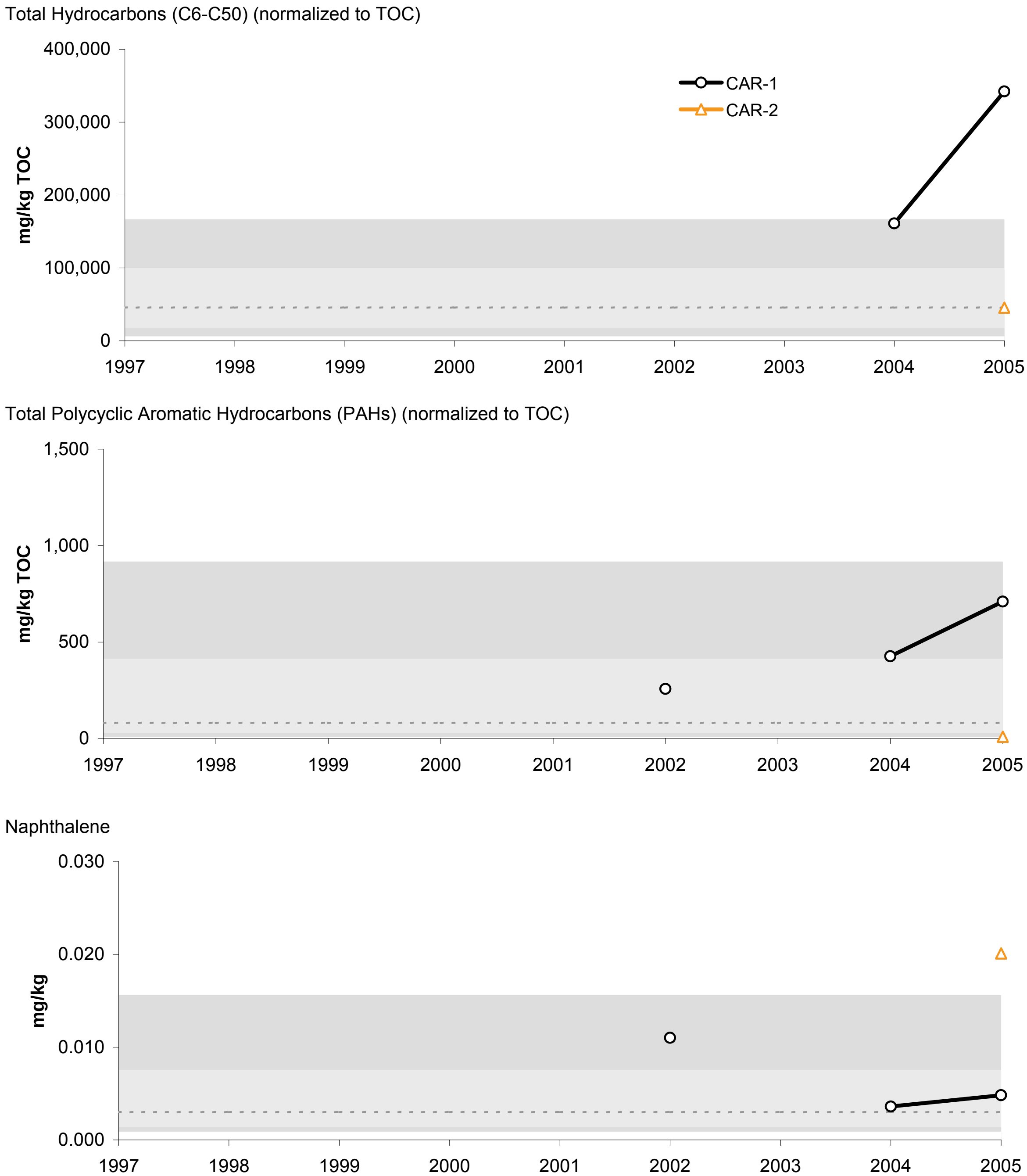
Values in **bold** indicate concentrations exceeding guidelines.

[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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Figure 5.7-5 Concentrations of selected sediment quality measurement endpoints in the Calumet River (fall data) relative to regional baseline concentrations.



[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

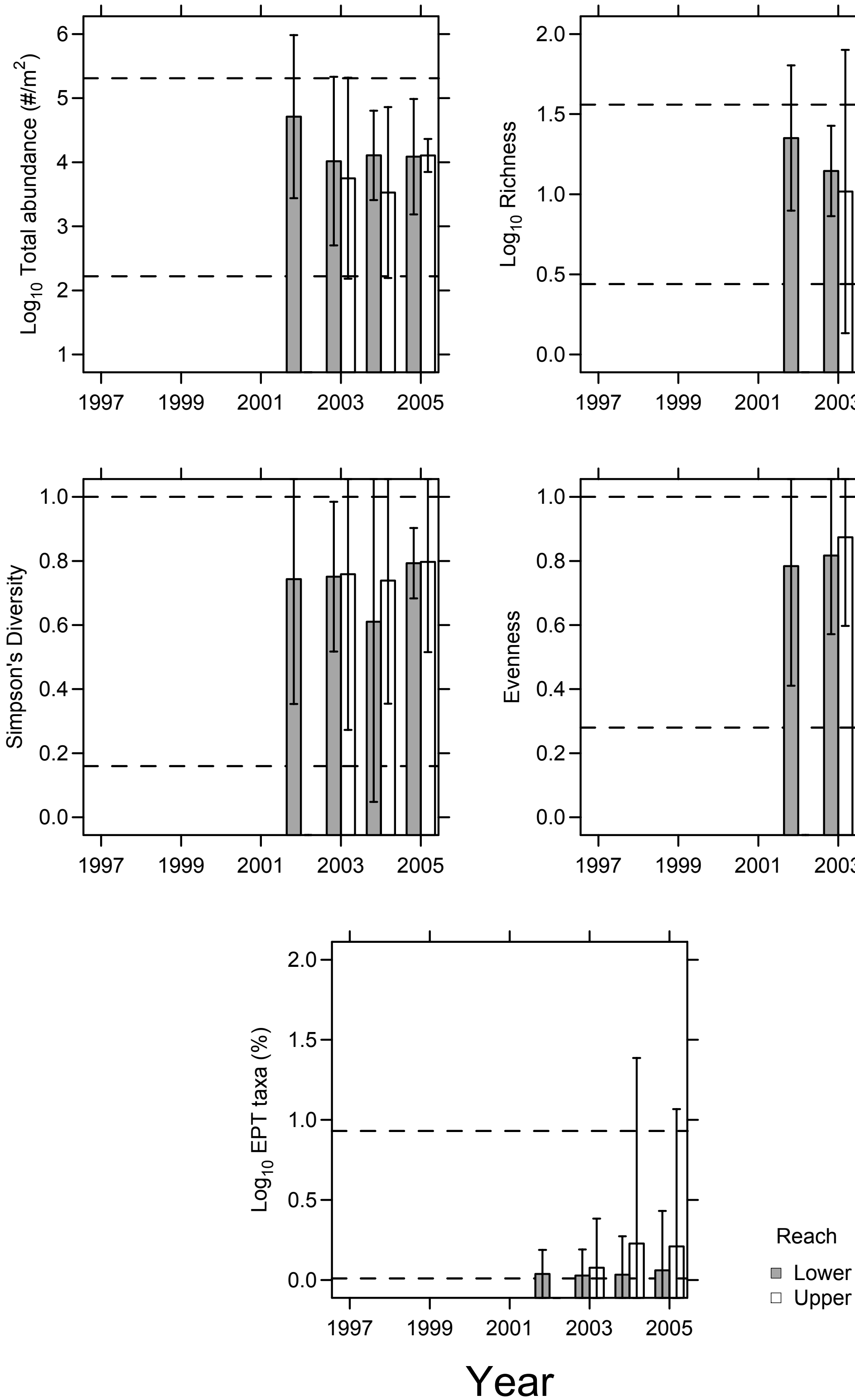
Table 5.7-7 Average habitat characteristics of benthic invertebrate community sampling reaches in the Calumet River, fall 2005.

Variable	Units	Reach CAR-D-1	Reach CAR-D-2
Sample date	-	Sept. 9, 2005	Sept. 17, 2005
Habitat	-	Depositional	Depositional
Water depth	m	0.4	n/a
Current velocity	m/s	0.2	0.0
Macrophyte cover	%	3	40
Field Water Quality			
Dissolved oxygen	mg/L	9.5	3.8
Conductivity	µS/cm	507	580
pH	pH units	7.8	6.5
Water temperature	°C	5.9	8.5
Sediment Composition			
Sand	%	82	5
Silt	%	12	49
Clay	%	6	47
Total Organic Carbon	%	3.8	19.3

Table 5.7-8 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches in the Calumet River, fall 2005.

Taxon	Reach CAR-D-1				Reach CAR-D-2		
	2002	2003	2004	2005	2003	2004	2005
Hydra				1			
Nematoda	1	<1	3	1	4	16	5
Erpobdellidae	<1	<1	<1			<1	<1
Enchytraeidae	<1	<1	<1	<1			
Naididae	<1	4	2	<1	9	6	6
Tubificidae	1	1	37	6		1	
Hydracarina	<1	<1	<1	<1	3		2
Ostracoda	3	2	4	3		12	7
Copepoda	1	2	<1	1	4	3	4
Daphniidae	<1	<1	<1		3		
Macrothricidae	<1	<1	<1				
Amphipoda	<1		<1		3	2	
Bivalvia	1	2	1	1	1	10	<1
Gastropoda	<1	<1	<1		13	5	1
Ephemeroptera	<1	<1	<1	<1	<1	1	1
Plecoptera	<1		<1	1			
Trichoptera	<1	<1			<1	<1	<1
Anisoptera	<1	<1	<1		<1	<1	1
Coleoptera	<1	<1	1	<1			
Heteroptera	<1	<1	<1				
Dolichopodidae		<1	<1				
Tabanidae	<1	1	1	<1			
Chaoboridae					3	1	2
Ceratopogonidae	1	2	2	<1	3		4
Chironomidae	91	85	48	86	54	42	67
Total Abundance (No./m^2)	73,983	19,664	16,954	17,096	10,302	4,612	12,957
Richness	23	14	11	18	12	8	13
Simpson's Diversity	0.74	0.75	0.61	0.79	0.76	0.74	0.80
Evenness	0.78	0.82	0.67	0.85	0.87	0.88	0.87
% EPT	<1	<1	<1	<1	<1	2	1

Figure 5.7-6 Variations in benthic invertebrate community measurement endpoints in the Calumet River, reach CAR-D-1 and reach CAR-D-2.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites.
Lower: reach CAR-D-1; upper: reach CAR-D-2

5.8 MISCELLANEOUS AQUATIC SYSTEMS POTENTIALLY INFLUENCED BY OIL SANDS DEVELOPMENTS

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge	No estimate was made of the hydrologic changes in relation to oil sands development activities.				Isadore's Lake: rose throughout the summer to levels higher than observed since 2000. Mills Creek: Runoff well above normal for almost entire year. Poplar Creek: observed discharges were also above normal.
Mean winter discharge					
Annual maximum daily discharge					
Minimum open-water season discharge					

Water Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005**[1]		
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=5)**	**2005 *Reference* Stations (n=0)**	Some exceedances of CCME/AENV guidelines for the protection of aquatic life occurred in 2005. Concentrations of some variables were higher or lower in 2005 than previously observed maxima or minima; no consistent patterns were evident. Most measurement endpoints were within the range of regional baseline conditions. Exceptions included total dissolved solids in Beaver River and Isadore's Lake, total nitrogen in Poplar Creek, and naphthenic acids in Shipyard Lake.
Physical variables (max=5)	0	No *reference* or *potentially influenced-other* stations were sampled in 2005.	
Nutrients (max=15)	2		
Ions (max=10)	1		
Selected metals (max=25)	4		
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline**[2]		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=5 stations X 8 endpoints)**	**2005 *Reference* Stations (n=0 stations X 8 endpoints)**	
Greater than 95th percentile	4	No *reference* or *potentially influenced-other* stations were sampled in 2005.	
Between 5th and 95th percentiles	25		
Less than 5th percentile	11		

Sediment Quality			
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005**[1]		
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=1)**	**2005 *Reference* Stations (n=0)**	There were few exceedances of CCME ISQG guidelines for the protection of aquatic life, although some selected measurement endpoints exceeded the normal range of regional baseline conditions.
Total Hydrocarbons (max=4)	2	No *reference* or *potentially influenced-other* stations were sampled in 2005.	
PAHs (max=1)	0		
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline**[3]		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=1 station X 3 endpoints)**	**2005 *Reference* Stations (n=0 stations X 3 endpoints)**	
Greater than 95th percentile	1	No *reference* or *potentially influenced-other* stations were sampled in 2005.	
Between 5th and 95th percentiles	2		
Less than 5th percentile	0		

Benthic Invertebrate Communities							
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline**						
	2005 *Potentially Influenced-Oil Sands* Stations (n=1)			**2005 *Reference* Stations (n=2)**			There are indications of degraded habitat quality in Shipyard Lake: i.e., dominance by taxonomic groups tolerant of degraded conditions. The community has high richness, diversity, evenness relative to Kearl, McClelland Lakes and contains sensitive groups including representative mayflies, caddisflies.
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance		1			2		
Richness		1			2		
Diversity		1			2		
Evenness		1			2		
% EPT		1			2		

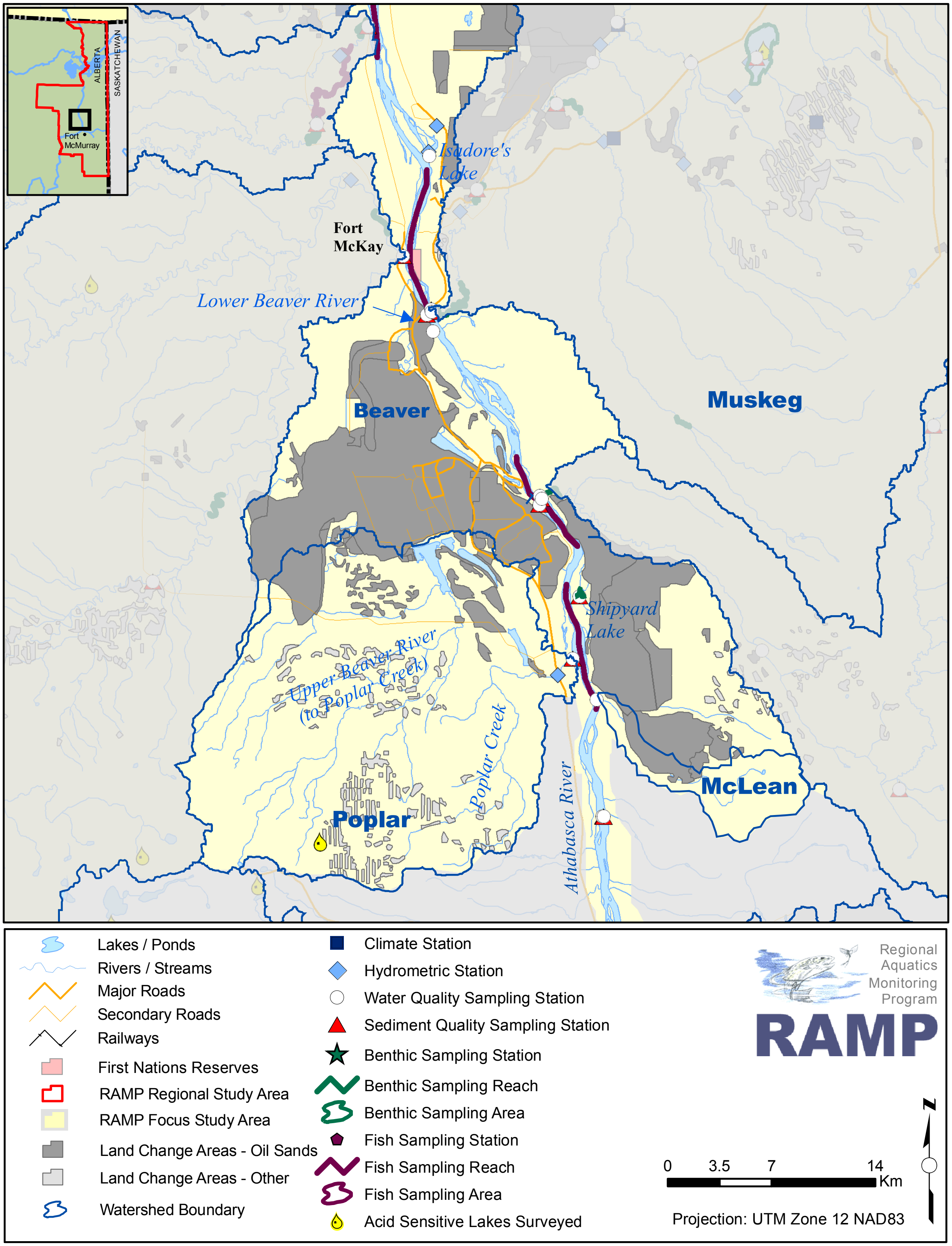
Fish Populations	
Fish Inventory	No fish inventory studies conducted in these aquatic systems in 2005.
Sentinel Studies	No sentinel fish studies conducted in these aquatic systems in 2005.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	No fish tissue programs conducted in these aquatic systems in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.8-1 Miscellaneous aquatic systems with areas potentially influenced by oil sands developments.



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5.8.1 Development Status

This section includes 2005 results from the following aquatic systems: Mills Creek; Poplar Creek; McLean Creek; Beaver River; Isadore's Lake; and Shipyard Lake. All these aquatic systems and RAMP stations are designated as *potentially influenced-oil sands*, and all data gathered at these stations are designated as operational data. To date, land changes from oil sands activities has covered 61% of the Beaver River watershed, almost 7% of the Poplar River watershed, and 18% of the McLean Creek watershed (Table 2.4-2).

5.8.2 Hydrologic Conditions

In 2005, hydrologic monitoring was undertaken on Isadore's Lake, Mills Creek, and Poplar Creek, and not on McLean Creek, Beaver River, or Shipyard Lake.

Water levels on Isadore's Lake have behaved fairly consistently over the past five years. There is typically a small rise in water level in April, but very little variation in level during the rest of the year. In 2005, however, the water level rose in March, somewhat earlier than usual (Figure 5.8-2). Water levels subsided in April, but then rose throughout the summer to levels higher than have been observed since monitoring began in 2000. The total range in lake levels since 2000 has been approximately 0.4 m.

Runoff in Mills Creek was well above normal for almost the entire year in 2005 (Figure 5.8-3). The total runoff for the catchment was 57 mm, compared to a long-term average of 31 mm. The peak flow for the year of 0.21 m^3/s occurred in mid-May, and was very close to the mean annual flood of 0.19 m^3/s. The minimum open-water discharge was 0.026 m^3/s, compared to the 8-year average minimum discharge of 0.019 m^3/s.

Observed discharges in Poplar Creek were also above normal in 2005 (Figure 5.8-4). The maximum observed daily discharge of 15.7 m^3/s occurred in April and was almost double the mean annual flood of 8.16 m^3/s. However, a large component of the runoff volume was contributed by releases from the Poplar Creek Spillway, which releases diversions from the Beaver River watershed upstream of Syncrude's Mildred Lake Mine. The baseline hydrograph, calculated by subtracting the Poplar Creek spillway releases from the observed hydrograph, was actually below the historical average discharge for most of the monitored period. A portion of the 2005 record is missing because of vandalism damage to the monitoring station.

5.8.3 Water Quality

Water quality samples were collected from the following aquatic systems designated as *potentially influenced-oil sands*: Beaver River; Poplar Creek, McLean Creek; Shipyard Lake; and Isadore's Lake.

5.8.3.1 Beaver River

The lower Beaver River drains the outer perimeter of the Syncrude Mildred Lake Project; the upper reaches of this river were diverted into Poplar Creek in fall 1975, given the development of the Mildred Lake facility in the lower Beaver River watershed (Noton and Chymo 1977). Syncrude requested RAMP to begin monitoring of Beaver River in 2003 to assess the potential for seepage from adjacent tailings ponds at the Mildred Lake facility to affect water quality in the lower Beaver River (station BER-1, *potentially influenced-oil sands*). Monitoring in 2003 found very high ion concentrations and conductivity relative to other RAMP stations, suggesting a potential effect of tailing pond seepages on water quality (RAMP 2004). In contrast, water quality at station BER-1 in fall 2004 fell within regional baseline ranges; the potential effects of seepage on Beaver River water quality may have been attenuated by higher water flows in 2004 relative to flows in 2003 (RAMP 2005a).

Fall ion concentrations at station BER-1 in 2005 were relatively low, with concentrations of several analytes (i.e., sodium, magnesium, chloride, sulphate, total alkalinity, conductivity) lower than results from 2003 or 2004 (Table 5.8-1). The concentration of total dissolved solids in 2005 was, as in 2003 and 2004, greater than the 95th percentile of regional baseline concentrations (Figure 5.8-5). Fall 2005 concentrations of some analytes (i.e., total dissolved phosphorus, total nitrogen, dissolved aluminum and iron) at station BER-1 were higher than previously observed concentrations. Concentrations of total boron, molybdenum, and naphthenic acids in fall 2005, however, were lower than the historical minimum observed at this station. A compilation of all water quality guideline exceedences in 2005 for station BER-1 (as well as for all miscellaneous aquatic systems sampled in 2005) is provided in Table 5.8-2.

Ion balance from station BER-1 water differed clearly between 2003 and 2004, particularly with respect to chloride and sodium (Figure 5.8-6). Ionic characteristics in 2005 were most similar to characteristics observed in 2004, particularly with respect to anionic character.

5.8.3.2 Poplar Creek

The Poplar Creek watershed includes the upper Beaver River, which was diverted away from the Syncrude Mildred Lake facility in fall 1975 (Noton and Chymo 1977). A ponded Poplar Reservoir was created in the watershed adjacent to the Mildred Lake facility; the lower Poplar River also was channelized. It is possible that water quality in lower Poplar Creek may be influenced by site drainage from the southern perimeter of Syncrude Mildred Lake site, by traffic and related activities on Highway 63, which it flows under, and by local natural saline seepages (M. MacKinnon, Syncrude Canada Ltd., *pers. comm*. 2004).

Water quality in fall 2005 in lower Poplar Creek (station POC-1, *potentially influenced-oil sands*) was generally similar to historical water quality at this station (Table 5.8-3), although a number of analyte concentrations (ions and related analytes, total boron and molybdenum) were lower than previously observed levels. Total nitrogen in fall 2005 was below the 5th percentile of regional baseline concentrations. Total aluminum, total iron, and total phenols concentrations exceeded CCME/AENV guidelines in fall 2005. Water quality at this station has shown high interannual variability, including highly variable ion balance among years (Figure 5.8-6).

5.8.3.3 McLean Creek

McLean Creek receives intermittent site drainage discharges from Suncor operations and therefore exhibits highly variable flow throughout the year. Water quality (station MCC-1, *potentially influenced-oil sands*) in McLean Creek also has been highly variable over seven years of sampling by RAMP. Water quality at station MCC-1 in fall 2005 was, with the exception of dissolved organic carbon, within the historical range of water quality at this station (Table 5.8-4) and within regional baseline values (Figure 5.8-5). Guidelines for several metals, including aluminum, chromium, cobalt, copper, iron, and lead, were exceeded in summer 2005 (Table 5.8-2). Ion balance at this station has been highly variable over the seven years of RAMP sampling, possibly reflecting the influence of the Suncor site drainage waters (Figure 5.8-6).

5.8.3.4 Shipyard Lake

Shipyard Lake (station SHL-1, *potentially influenced-oil sands*) is located adjacent to the Suncor Steepbank/Project Millennium lease area. Conductivity, total dissolved solids, total alkalinity, calcium, and dissolved organic carbon were higher in fall 2005 than previous years, and the concentration of total boron was also higher in 2005 than the previous maximum concentration (Table 5.8-5). A statistically significant upward trend in total boron concentrations (1999-2005) was found using the Mann-Kendall test for trend (n=7, slope=0.003 mg/L/year), although all concentrations of total boron measured to date have been within the range of regional baseline concentrations (Figure 5.8-7). Total and dissolved aluminum concentrations in fall 2005 were below the previously observed minimum concentrations. CCME/AENV guidelines for total phenols and total and dissolved iron were exceeded in fall 2005, while total iron also exceeded the guideline in summer 2005 (Table 5.8-2). Ion balance at Shipyard Lake has been relatively consistent since RAMP sampling of this water body commenced in 1999 (Figure 5.8-8).

5.8.3.5 Isadore's Lake

Isadore's Lake (station ISL-1, *potentially influenced-oil sands*) is located adjacent to the Muskeg River Mine project area. Water quality in this lake in fall 2005 was generally similar to that observed in previous years, although concentrations of several ions and some metals exhibited historical highs, including sodium, magnesium, chloride, sulphate, total aluminum, and total boron (Table 5.8-6, Figure 5.8-7). The concentration of total phosphorus was lower in fall 2005 than previous years. Total aluminum and sulphate concentrations in fall 2005 exceeded guidelines for the protection of aquatic life (Table 5.8-2). Sulphate concentrations in Isadore's Lake in fall 2005 were the highest recorded by RAMP since monitoring began. Ion balance in Isadore's Lake has been somewhat variable among sampling years (Figure 5.8-8), with ion balance in 2005 more highly dominated by chloride and sulphate anions than in previous years.

5.8.3.6 Summary

These smaller aquatic systems potentially influenced by oil sands development activities exhibited a range of water quality conditions in 2005. With respect to the water quality measurement endpoints:

- Some exceedances of CCME/AENV guidelines for the protection of aquatic life occurred in 2005 (Table 5.8-2);
- Some concentrations of ions, nutrients, and metals were higher or lower in 2005 than previously observed maxima or minima, respectively. Few consistent patterns were evident, although ions, total boron, and total molybdenum were lower than historical values in both Beaver River and Poplar Creek; and
- Most of the measurement endpoints in fall 2005 were within the range of regional baseline conditions for reference water bodies and watercourses. Exceptions included total dissolved solids in Beaver River and Isadore's Lake, total nitrogen in Poplar Creek, and naphthenic acids in Shipyard Lake.

5.8.4 Sediment Quality

In 2005, sediment quality samples were collected from McLean Creek; the other miscellaneous aquatic systems potentially influenced by oil sands developments were not monitored for sediment quality in 2005.

Sediment quality in McLean Creek in 2005 (station MCC-1, *potentially influenced-oil sands*) was similar to that observed in previous years (Table 5.8-7). Sediments at station MCC-1 were predominantly sandy, with lower levels of organic carbon (1.5%) than previously observed. Total hydrocarbons in sediments at MCC-1 were dominated by fraction 3 (C16-C34) hydrocarbons. Total PAH concentrations in fall 2005 were similar to levels observed previously, although total PAH concentrations normalized to organic carbon exceeded previous normalized concentrations as well as the 95th percentile of regional baseline concentrations (Figure 5.8-9). Survival and growth of *Chironomus tentans* were slightly higher than previously observed values. In summary, there were few exceedances of CCME ISQG guidelines in 2005, although some selected measurement endpoints exceeded the normal range of regional baseline conditions.

5.8.5 Benthic Invertebrate Communities

Benthic invertebrate communities were sampled in 2005 at Shipyard Lake (station SHL-1, *potentially influenced-oil sands*, operational data, sampling since 2000). Data obtained from station SHL-1 were compared with data obtained from two lakes designated as *potentially influenced-other* in 2005: Kearl Lake (station KEL-1, *potentially influenced-other*, baseline data, sampling since 2001); and McClelland Lake (station MCL-1, *potentially influenced-other*, baseline data, prior sampling in 2002 and 2003). Sampling locations in the three lakes had similar water depths (1 to 2 m; Table 5.8-8), and water temperatures were similar to previous years (11^{o}C). The sediments of Shipyard Lake were similar to those of Kearl Lake and consisted primarily of silt and clay, with low sand content.

Chironomidae (48%) dominated the benthic communities at the two stations designated as *potentially influenced-other* (KEL-1 and MCL-1, Table 5.8-9). Sub-dominant forms at station KEL-1 included sphaeriid bivalves, amphipods (mostly *Gammarus lacustris* and some *Hyalella azteca*) and copepods. Other minor groups at station KEL-1 included nematodes, worms (Naididae, Tubificidae), ostracods and caddisflies (*Mystacides*, *Agrypnea*, *Polycentropus*). *Dicrotendipes*, *Paratanytarsus* and *Procladius* were the most common chironomids at station KEL-1, although there were several other chironomid taxa that co-occurred. The number of taxa at station KEL-1 was 12, with over 12,000 individuals per m^2.

In addition to chironomids (62%), the benthic invertebrate community at station MCL-1 was sub-dominated by worms (Naididae), Ostracoda (6%) and amphipods (mostly *Hyalella azteca* and some *Gammarus lacustris*, Table 5.8-9). Other forms that were present included *Hydra*, nematodes, mites, sphaeriid clams, snails (the ubiquitous *Gyraulus*), caddisflies (*Oxyethira*) and dragonflies (*Somatochlora*, *Leucorrhina*). *Pagastiella* and *Procladius* were the two prevalent chironomid taxa found in every sample; other chironomids were much less frequently and abundantly found. The number of taxa at station MCL-1 was 11, while the number per m^2 was higher than in previous years (~9,000 m^2).

Benthic invertebrate communities at station SHL-1 were dominated by ostracods and chironomids (mostly *Chironomus* and *Einfeldia*), while nematodes, naidid and tubificids worms, copepods, daphnids, gastropods (*Armiger crista*, *Gyraulus*, *Valvata sincera*, *Valvata* *tricarinata*), amphipods (*Hyalella azteca* only), and chaoborids were sub-dominant (Table 5.8-9). Station SHL-1 averaged 15 taxa per sample (higher than at stations KEL-1 and MCL-1), and had almost 30,000 animals per m² (also higher than at stations KEL-1 and MCL-1).

There were conflicting indicators of the condition of the benthic invertebrate community at station SHL-1. As in 2004, the dominance of the benthic invertebrate community by ostracods at station SHL-1 in 2005 (Table 5.8-9) is a little unusual and suggests some degree of impaired habitat quality. The relative abundance of ostracods in 2005 was lower than in 2004, but they were still a major component of the benthic invertebrate communities at station SHL-1 (Table 5.8-9). Time trends differed significantly between station SHL-1 and stations KEL-1 and MCL-1 for abundance, richness and evenness (Time x Lake interactions; Table 5.8-10), but those measures of composition have generally stayed within the normal range of variability as defined by stations KEL-1 and MCL-1 (Figure 5.8-10). Abundance and richness were higher at station SHL-1 in 2005 than at stations KEL-1 and MCL-1, but neither measure exceeded the normal range of variability as defined by stations KEL-1 and MCL-1 (Figure 5.8-10). The ordination of the benthic invertebrate community data (Figure 5.8-11) also indicates that the benthic invertebrate community at station SHL-1 has remained within the normal range of variability based on stations KEL-1 and MCL-1

The dominance of the chironomid community by the genera *Chironomus* and *Einfeldia* is another indicator of potential stress at station SHL-1; both genera are considered indicators of degraded water quality, with *Chironomus* being a classic indicator of anoxic conditions. In addition, the continued presence of chaoborids (*Chaoborus*) in the benthic invertebrate community at station SHL-1 is noteworthy, as this group has never been observed in either stations KEL-1 and MCL-1 (Table 5.8-9). The distribution of *Chaoborus* can depend on whether fish are present. *Chaoborus americanus*, for example, occurs only in lakes without fish, while *Chaoborus punctipennis* occurs only in lakes with fish (von Elde, 1979). In the future, it would be useful, but not critical, to identify *Chaoborus* down to the species level.

5.8.6 Fish Populations

The 2005 RAMP Fish Population component did not include any activities in Shipyard Lake, Isadore's Lake, Beaver River, Poplar Creek, or McLean Creek.

5.8.7 Summary of Conditions

The various miscellaneous aquatic systems in the RAMP FSA potentially influenced by oil sands developments that were sampled in 2005 exhibited a range of conditions. While water quality in these aquatic systems in 2005 exhibited some exceedances of CCME guidelines for the protection of aquatic life, most selected measurement endpoints were within the normal range of regional baseline conditions for reference water bodies and watercourses. There were few sediment quality exceedances in 2005 of CCME ISQG guidelines for the protection of aquatic life, although some selected measurement endpoints exceeded the normal range of regional baseline conditions for reference water bodies and watercourses. Benthic invertebrate communities in Shipyard Lake in 2005 were dominated by taxa tolerant of degraded conditions such as *Chironomus*, *Einfeldia* and ostracods. The community does, however, have a relatively high number of taxa, diversity and evenness relative to Kearl Lake and McClelland Lake, and does contain sensitive groups including representative mayflies and caddisflies.

Figure 5.8-2 Isadore's Lake: 2005 hydrograph and historical context.

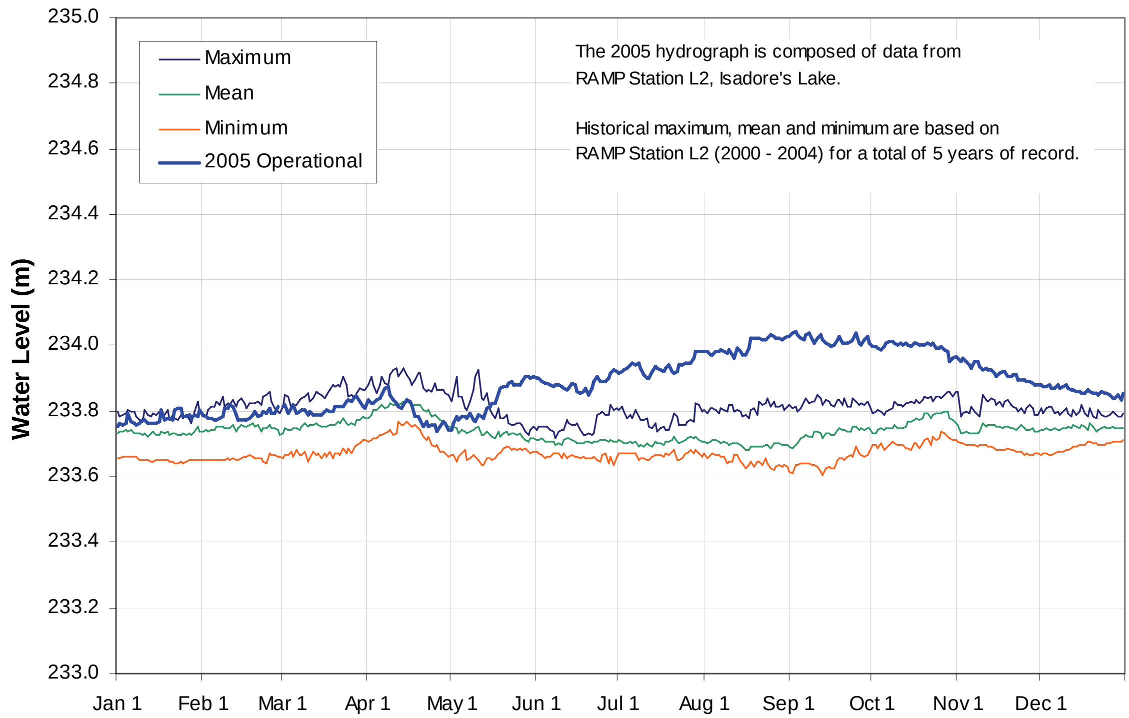


Figure 5.8-3 Mills Creek: 2005 hydrograph and historical context.

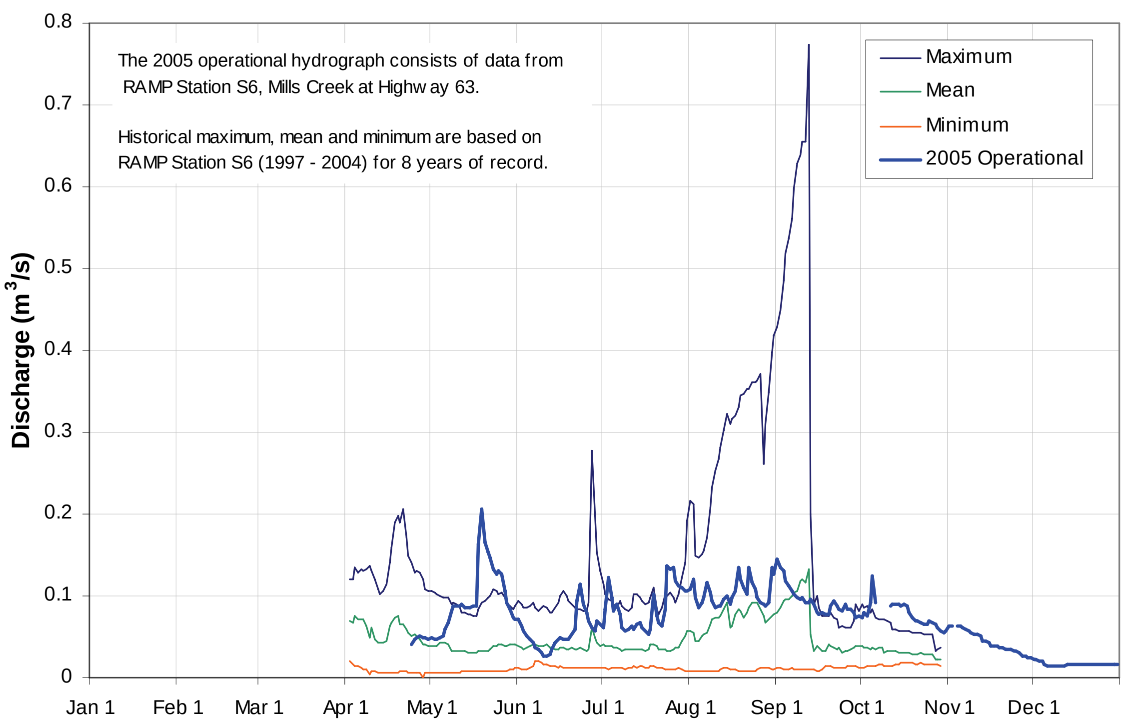


Figure 5.8-4 Poplar Creek: 2005 hydrograph and historical context.

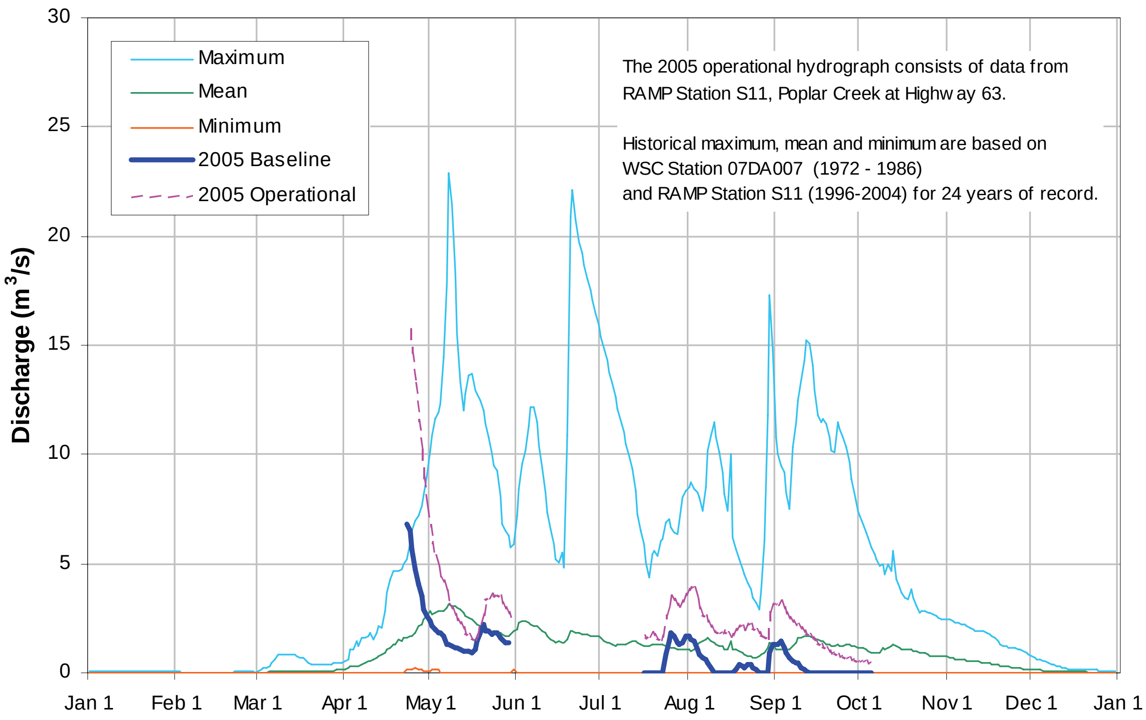


Table 5.8-1 Concentrations of water quality measurement endpoints, lower Beaver River, (BER-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8	2	8.0	-	8.2
Total suspended solids	mg/L	-[1]	<3	2	11	-	26
Conductivity	µS/cm	-	566	2	605	-	1430
Nutrients							
Total phosphorus	mg/L	0.05	0.029	2	0.019	-	0.041
Total dissolved phosphorus	mg/L	0.05[2]	0.022	2	0.004	-	0.008
Total nitrogen*	mg/L	1.0	**1.4**	2	0.9	-	0.9
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	52	2	21	-	31
Ions							
Sodium	mg/L	-	53	2	67	-	181
Calcium	mg/L	-	52	2	49	-	90
Magnesium	mg/L	-	16	2	16	-	26
Chloride	mg/L	230, 860[3]	55	2	56	-	221
Sulphate	mg/L	100[4]	54	2	72.3	-	78.9
Total dissolved solids	mg/L	-	460	2	450	-	830
Total alkalinity	mg/L		158	2	169	-	294
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	1	-	3
Selected metals							
Total aluminum	mg/L	0.1	**0.265**	2	**0.238**	-	**0.318**
Dissolved aluminum	mg/L	0.1[2]	0.0445	2	0.0017	-	0.0141
Total boron	mg/L	1.2[4]	0.088	2	0.136	-	0.169
Total molybdenum	mg/L	0.073	0.00019	2	0.00038	-	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	1.3
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total Kjeldahl nitrogen	mg/L	1.0[6]	**1.3**	2	0.8	-	0.8
Total phenols	mg/L	0.004	**0.009**	2	0.002	-	**0.005**
Dissolved iron	mg/L	0.3[2]	**1.87**	2	0.05	-	**0.86**
Total iron	mg/L	0.3	**2.39**	2	**1.79**	-	**3.72**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

[6] Guideline is for total nitrogen.

Table 5.8-2 Water quality guideline exceedances in miscellaneous aquatic systems potentially influenced by oil sands developments, 2005.

Parameter	Units	Guideline*	POC-1	BER-1	ISL-1	MCC-1	SHL-1
Spring							
Total phenols	mg/L	0.004	ns	ns	ns	**0.012**	ns
Total aluminum	mg/L	0.1	ns	ns	ns	**0.951**	ns
Total iron	mg/L	0.3	ns	ns	ns	**0.664**	ns
Summer							
Total Kjeldahl nitrogen	mg/L	1.0[1]	ns	**1.3**	-	**1.5**	-
Total phenols	mg/L	0.004	ns	-	**0.007**	-	-
Total aluminum	mg/L	0.1	ns	**0.669**	-	**6.09**	-
Total chromium	mg/L	0.001-0.0089[2]	ns	-	-	**0.00917**	-
Total cobalt	mg/L	0.0009[3]	ns	-	-	**0.00326**	-
Total copper	mg/L	0.002-0.004[4]	ns	-	-	**0.00641**	-
Dissolved iron	mg/L	0.3[5]	ns	**1.71**	-	-	-
Total iron	mg/L	0.3	ns	**2.72**	-	**5.15**	**0.527**
Total lead	mg/L	0.001-0.007[4]	ns	-	-	**0.00462**	-
Fall							
Dissolved phosphorus	mg/L	0.05[5]	-	-	-	-	-
Total Kjeldahl nitrogen	mg/L	1.0[1]	-	**1.3**	-	**1.1**	-
Total phenols	mg/L	0.004	**0.008**	**0.009**	-	**0.007**	**0.01**
Sulphate	mg/L	100[6]	-	-	**109**	-	-
Total aluminum	mg/L	0.1	**0.262**	**0.265**	**0.182**	**0.226**	-
Total cobalt	mg/L	0.0009[3]	-	-	-	-	-
Dissolved iron	mg/L	0.3[5]	-	**1.87**	-	-	**0.438**
Total iron	mg/L	0.3	**0.729**	**2.39**	-	**0.569**	**0.733**

BER-1, ISL-1, SHL-1 not sampled in winter or spring 2005; POC-1 sampled only in fall 2005.

ns = not sampled.

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

[1] Guideline is for total nitrogen.

[2] Guidelines are for chromium VI (0.001 mg/L) and chromium III (0.0089 mg/L).

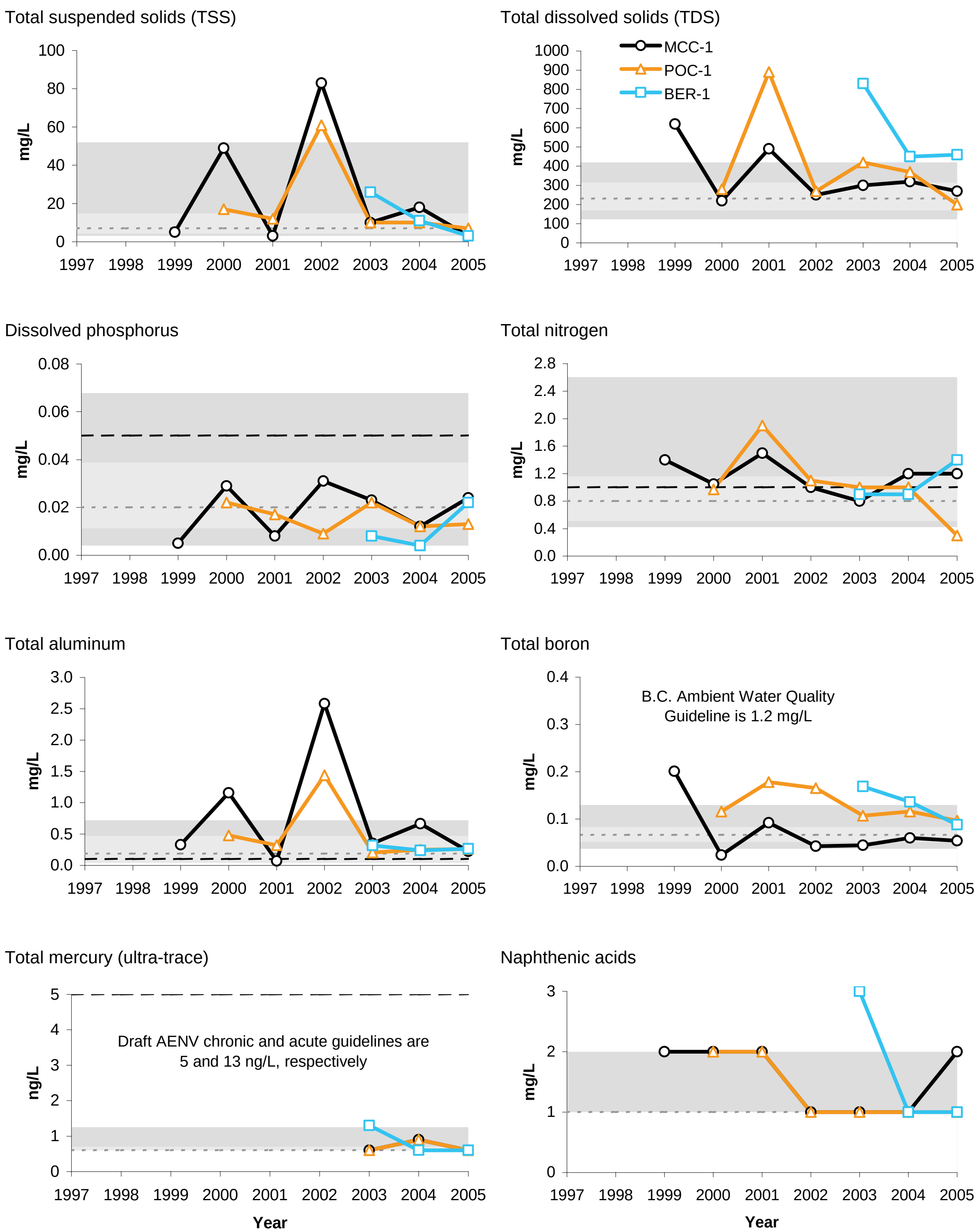
[3] B.C. Working Water Quality Guideline (2001).

[4] Guideline is hardness-dependent.

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

[6] B.C. Approved Water Quality Guideline (2001).

Figure 5.8-5 Concentrations of selected water quality measurement endpoints in McLean Creek (MCC-1), Beaver River (BER-1), and Poplar Creek (POC-1) (fall data) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

[1] 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 5.8-6 Piper diagram of ion balance in McLean Creek, Beaver River and Poplar Creek, 1999-2005.

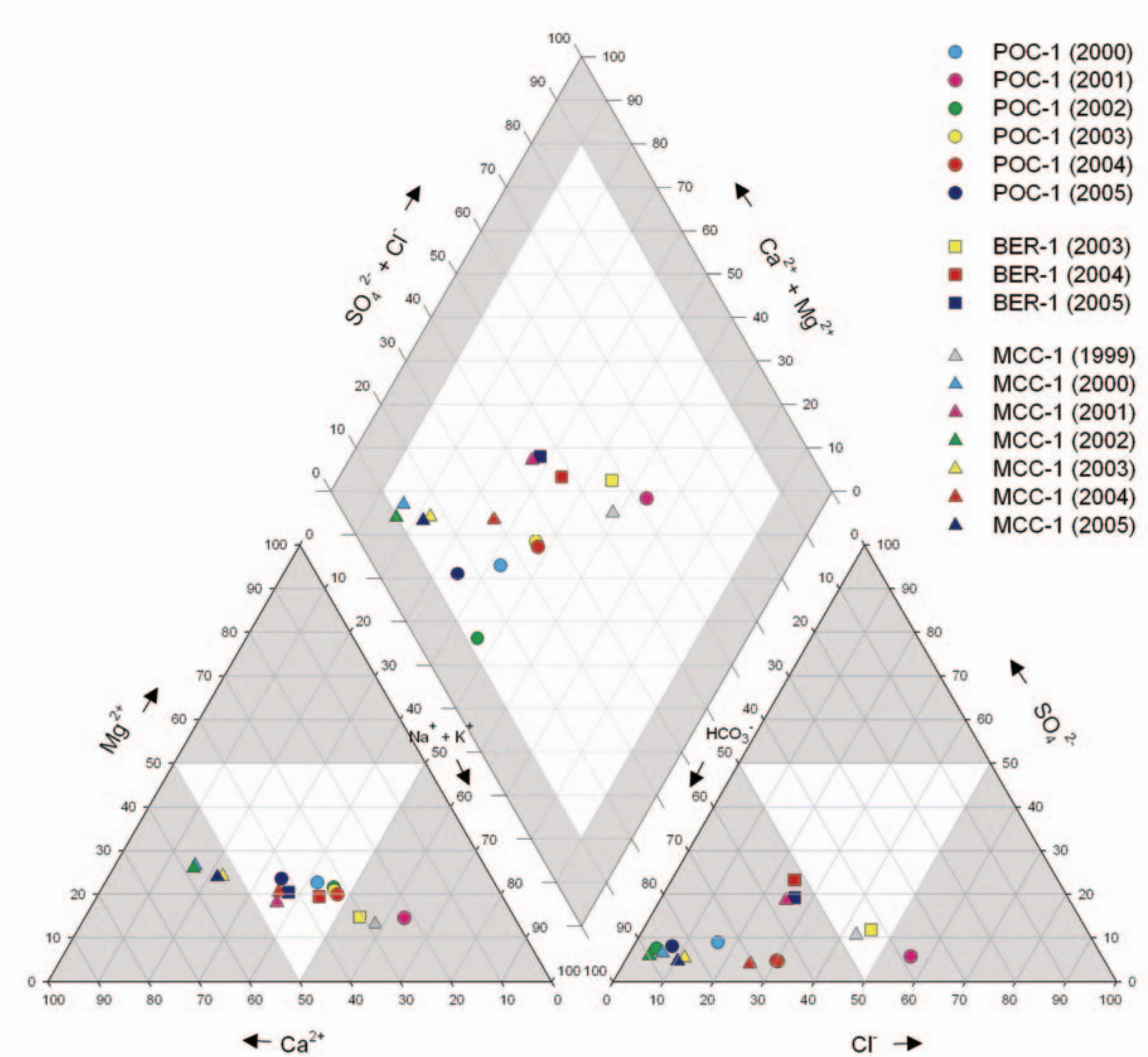


Table 5.8-3 Concentrations of water quality measurement endpoints, Poplar Creek (POC-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	7.9	8.2	8.3
Total suspended solids	mg/L	-[1]	7	5	10	12	61
Conductivity	µS/cm	-	308	5	374	529	1590
Nutrients							
Total phosphorus	mg/L	0.05	0.035	5	0.03	0.032	**0.06**
Total dissolved phosphorus	mg/L	0.05[2]	0.013	5	0.009	0.017	0.022
Total nitrogen*	mg/L	1.0	0.3	5	0.97	1	**1.9**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.1	0.07	0.1
Dissolved organic carbon	mg/L	-	28	5	21	24	32
Ions							
Sodium	mg/L	-	27	5	44	71	238
Calcium	mg/L	-	29	5	28	43	72
Magnesium	mg/L	-	10	5	11	16	29
Chloride	mg/L	230, 860[3]	9	5	7	65	**321**
Sulphate	mg/L	100[4]	12.5	5	13.8	14.7	44.2
Total dissolved solids	mg/L	-	200	5	270	370	890
Total alkalinity	mg/L		135	5	166	198	304
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	**0.26**	5	**0.21**	**0.32**	**1.44**
Dissolved aluminum	mg/L	0.1[2]	0.0054	5	<0.01	0.0071	0.0121
Total boron	mg/L	1.2[4]	0.096	5	0.107	0.116	0.178
Total molybdenum	mg/L	0.073	0.00020	5	0.00023	0.0003	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	0.9
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.008**	5	<0.001	0.002	**0.007**
Total iron	mg/L	0.3	**0.73**	5	**1.21**	**1.57**	**3.63**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.8-4 Concentrations of water quality measurement endpoints, McLean Creek (MCC-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	6	8.0	8.3	8.4
Total suspended solids	mg/L	-[1]	<3	6	<3	14	83
Conductivity	µS/cm	-	402	6	300	389	1000
Nutrients							
Total phosphorus	mg/L	0.05	0.04	6	0.008	0.042	**0.07**
Total dissolved phosphorus	mg/L	0.05[2]	0.024	6	0.005	0.018	0.031
Total nitrogen*	mg/L	1.0	**1.2**	6	0.8	**1.1**	**1.5**
Nitrate+nitrite	mg/L	-	<0.1	6	<0.05	<0.1	<1
Dissolved organic carbon	mg/L	-	34	6	14	22	28
Ions							
Sodium	mg/L	-	23	6	12	33	140
Calcium	mg/L	-	52	6	40.9	47.8	81.7
Magnesium	mg/L	-	13.9	6	11.1	13.4	19.8
Chloride	mg/L	230, 860[3]	16	6	5	31	165
Sulphate	mg/L	100[4]	9.6	6	9.2	10.8	76.4
Total dissolved solids	mg/L	-	270	6	220	310	620
Total alkalinity	mg/L		188	6	144	175	251
Organic compounds							
Naphthenic acids	mg/L	-	2	6	<1	1.5	2
Selected metals							
Total aluminum	mg/L	0.1	**0.226**	6	0.07	**0.51**	**2.58**
Dissolved aluminum	mg/L	0.1[2]	0.0085	6	0.0080	0.01	0.0157
Total boron	mg/L	1.2[4]	0.0542	6	0.024	0.052	0.201
Total molybdenum	mg/L	0.073	0.00023	6	0.0001	0.0002	0.0005
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	0.9
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total Kjeldahl nitrogen	mg/L	1.0[6]	**1.1**	6	0.4	0.95	**1.4**
Total phenols	mg/L	0.004	**0.007**	6	<0.001	<0.001	**0.008**
Total iron	mg/L	0.3	**0.57**	6	**0.36**	**0.77**	**3.46**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.8-5 Concentrations of water quality measurement endpoints, Shipyard Lake (SHL-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	6	7.7	8.0	8.1
Total suspended solids	mg/L	-[1]	8	6	<3	3.5	15
Conductivity	µS/cm	-	421	6	358	379	394
Nutrients							
Total phosphorus	mg/L	0.05	0.019	6	0.015	0.018	0.031
Total dissolved phosphorus	mg/L	0.05[2]	0.014	6	0.007	0.011	0.026
Total nitrogen*	mg/L	1.0	1.0	6	0.3	1.0	**1.4**
Nitrate+nitrite	mg/L	-	<0.1	6	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	24	6	17	20	22
Ions							
Sodium	mg/L	-	20	6	16	18	21
Calcium	mg/L	-	52.3	6	41.7	48	51.5
Magnesium	mg/L	-	12	6	11.1	11	12.4
Chloride	mg/L	230, 860[3]	15	6	11	16	18
Sulphate	mg/L	100[4]	6.2	6	2.8	6.8	10.5
Total dissolved solids	mg/L	-	280	6	200	255	280
Total alkalinity	mg/L		201	6	159	173	189
Organic compounds							
Naphthenic acids	mg/L	-	2	6	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	0.0041	6	0.006	0.027	**0.14**
Dissolved aluminum	mg/L	0.1[2]	0.0005	6	0.0015	0.0064	<0.01
Total boron	mg/L	1.2[4]	0.048	6	0.027	0.041	0.043
Total molybdenum	mg/L	0.073	0.000089	6	0.000046	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[5]	0.7	2	<0.6	-	1
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.010**	6	<0.001	0.0025	**0.012**
Dissolved iron	mg/L	0.3[2]	**0.44**	6	<0.01	0.19	**0.86**
Total iron	mg/L	0.3	**0.73**	6	0.27	**0.60**	**1.48**

Note: Guideline values are CCME/AENV guidelines 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 1999).

4 B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.8-6 Concentrations of water quality measurement endpoints, Isadore's Lake (ISL-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	7.7	8.1	8.2
Total suspended solids	mg/L	-[1]	10	3	5	6	10
Conductivity	µS/cm	-	526	3	353	462	551
Nutrients							
Total phosphorus	mg/L	0.05	0.035	3	0.039	**0.075**	**0.098**
Total dissolved phosphorus	mg/L	0.05[2]	0.009	3	0.004	0.038	**0.067**
Total nitrogen*	mg/L	1.0	0.7	3	0.3	0.8	**1.3**
Nitrate+nitrite	mg/L	-	<0.1	3	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	10	3	8	9	11
Ions							
Sodium	mg/L	-	10	3	6	6	9
Calcium	mg/L	-	60	3	37	48.5	72.2
Magnesium	mg/L	-	29	3	25.6	28	28.8
Chloride	mg/L	230, 860[3]	12	3	4	4	8
Sulphate	mg/L	100[4]	**109**	3	63.9	81.3	82.5
Total dissolved solids	mg/L	-	340	3	250	280	340
Total alkalinity	mg/L		146	3	122	173	227
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.182**	3	<0.02	0.04	0.0634
Dissolved aluminum	mg/L	0.1[2]	0.00059	3	0.00203	<0.01	0.02
Total boron	mg/L	1.2[4]	0.0439	3	0.035	0.038	0.04
Total molybdenum	mg/L	0.073	0.000018	3	<0.0001	0.0001	0.000125
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
none	-	-	-	-	-	-	-

Note: Guideline values are CCME/AENV guidelines 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).

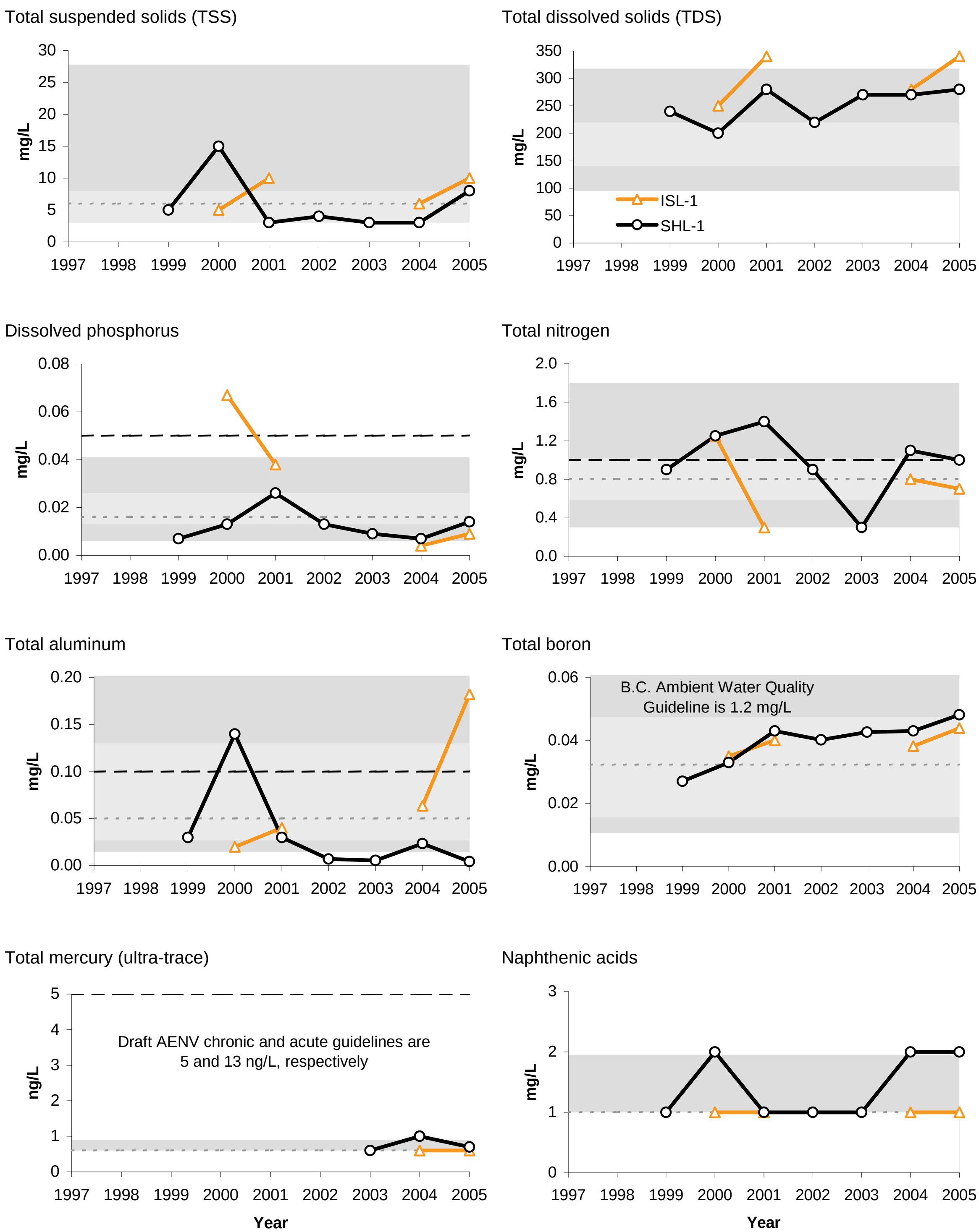
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

[6] B.C. Approved Water Quality Guideline (2001).

Figure 5.8-7 Concentrations of selected fall water quality measurement endpoints, Shipyard Lake (SHL-1) and Isadore's Lake (ISL-1) (fall data), relative to regional fall baseline concentrations.



Non-detectable values are shown at the detection limit.

[1] 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 5.8-8 Piper diagram of ion balance in Shipyard Lake and Isadore's Lake, 1999-2005.

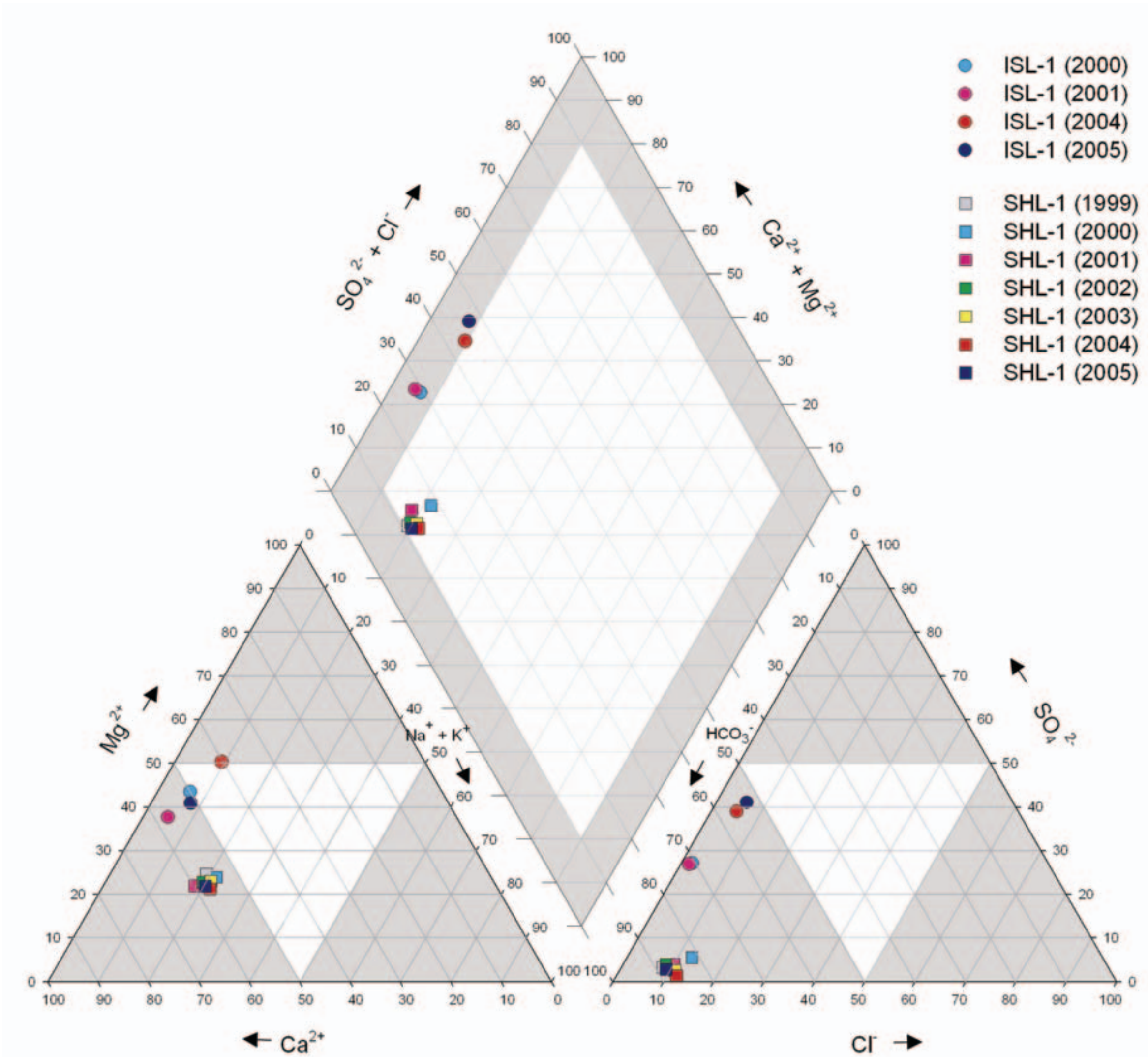


Table 5.8-7 Concentrations of sediment quality measurement endpoints in McLean Creek (MCC-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	9	4	4	15.5	30
Silt	%	-	8	4	5	14.5	60
Sand	%	-	83	4	10	74	84
Total organic carbon	%	-	1.5	4	2.3	3.3	5.6
Total hydrocarbons							
CCME variables							
BTEX	mg/kg	-	<5	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	**390**	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**3700**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	2200	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.0035	4	0.0042	0.0155	0.027
Retene	mg/kg	-	0.265	3	0.33	0.385	1.1
Total dibenzothiophenes	mg/kg	-	10.70	4	0.23	14.35	24.81
Total PAHs	mg/kg	-	29.57	4	1.77	40.04	77.99
Total HMW PAHs	mg/kg	-	8.70	4	0.37	11.26	38.04
Total LMW PAHs	mg/kg	-	20.88	4	1.40	28.78	39.96
Predicted PAH toxicity[1]	H.I.	-	1.42	4	1.09	1.22	2.99
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	3	0	6.4	6.6
Chironomus growth - 10d	mg/organism	-	1.19	2	0.44	-	1.1
Hyallela survival - 14d	# surviving	-	7	-	-	-	-
Hyallela growth - 14d	mg/organism	-	0.21	-	-	-	-

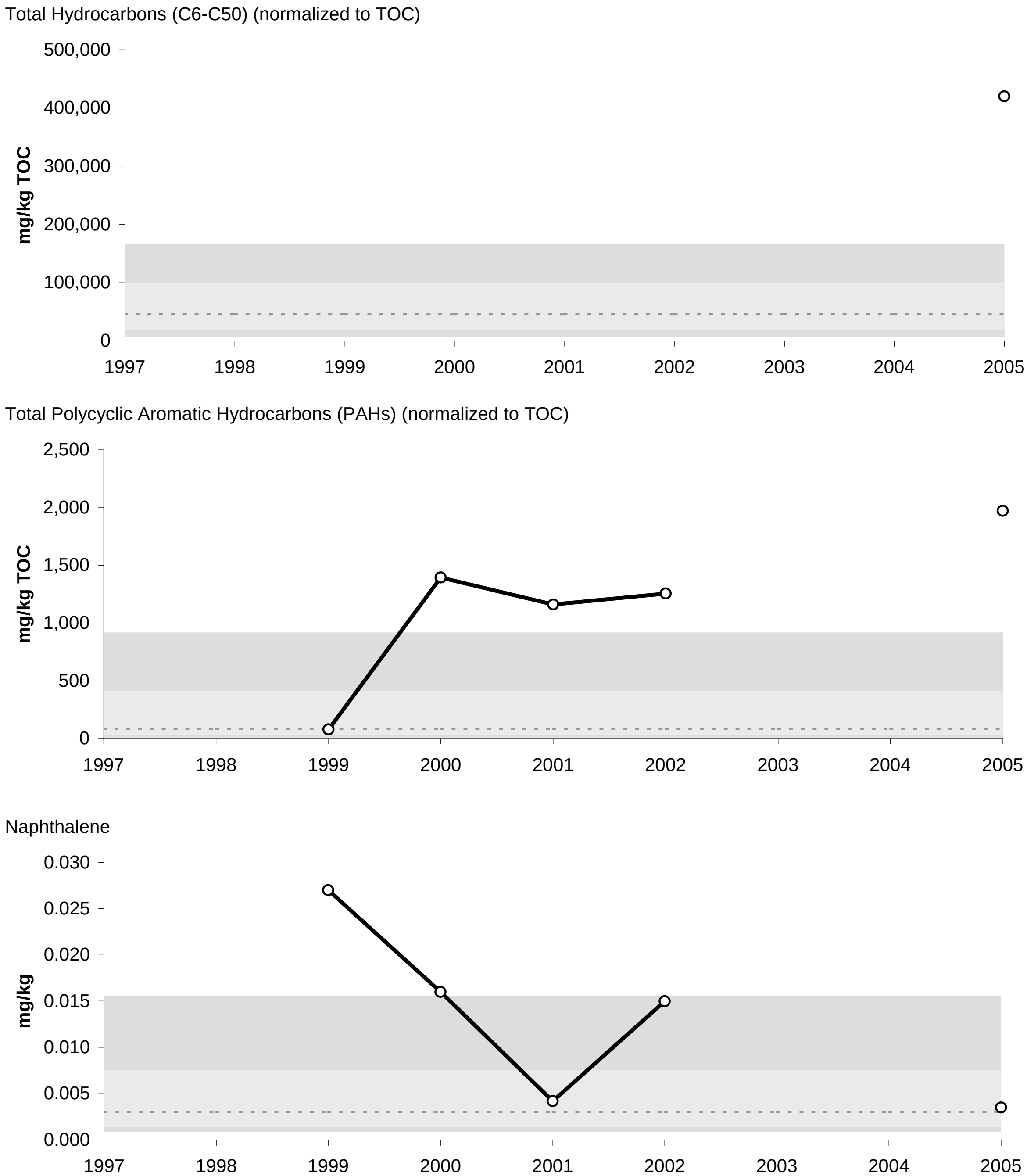
Values in **bold** indicate concentrations exceeding guidelines.

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 2001).

3 Interim sediment quality guideline (ISQG) (CCME 2003).

Figure 5.8-9 Concentrations of selected sediment quality measurement endpoints, McLean Creek (MCC-1) (fall data) relative to regional baseline fall concentrations.



[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

Table 5.8-8 Average habitat characteristics of benthic invertebrate sampling locations in Kearl, McClelland, and Shipyard Lakes, fall 2005.

Variable	Units	Kearl Lake	McClelland Lake	Shipyard Lake
Sample date	-	Sept 14, 2005	Sept 17, 2005	Sept 24, 2005
Habitat	-	Depositional	Depositional	Depositional
Water depth	m	1.2	2.2	2.2
Macrophyte cover	%	2	16	22
Field Water Quality				
Dissolved oxygen	mg/L	n/a	n/a	6.5
Conductivity	µS/cm	n/a	n/a	n/a
pH	-	n/a	8.2	n/a
Water temperature	°C	n/a	11	11
Sediment Composition				
Sand	%	6	52	35
Silt	%	36	34	34
Clay	%	58	14	31
Total Organic Carbon	%	39	26	13

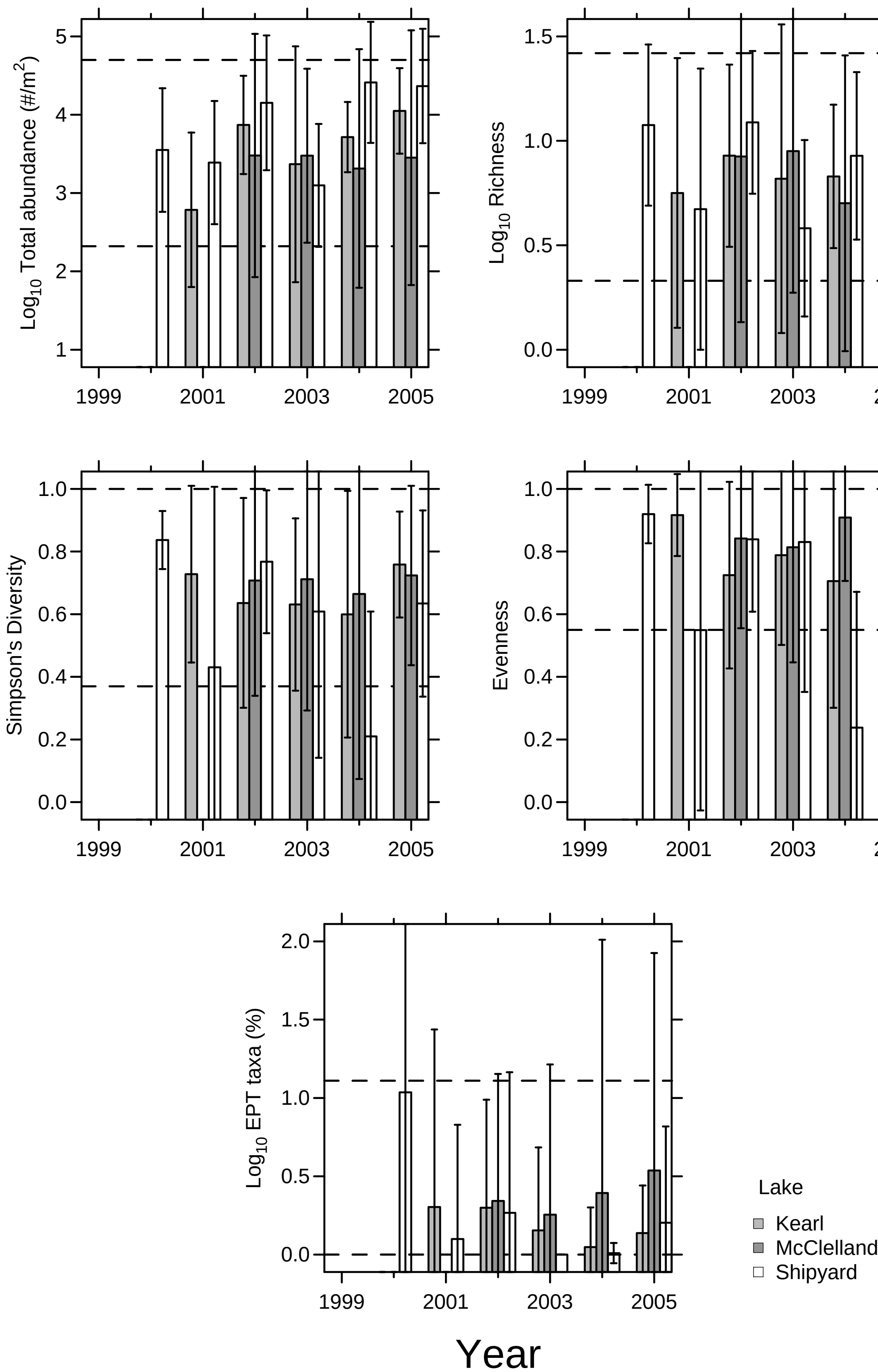
Table 5.8-9 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of Kearl, McClelland, and Shipyard Lakes, fall 2005.

Taxon	KEL-1					MCL-1				SHL-1					
	2001	**2002**	**2003**	**2004**	**2005**	**2002**	**2003**	**2004**	**2005**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Hydra				1			<1		<1						
Nematoda					1	2	1	8	1			1	3	2	1
Glossiphoniidae	1	<1	<1	<1							1	<1	<1		
Erpobdellidae					<1	2	<1	<1							
Naididae		1	5	7	1	14	17	5	12	6	1	4		7	8
Tubificidae					1		1	1		1		<1	3	<1	3
Lumbriculidae							<1	<1	<1						<1
Hydracarina	1		<1			1	<1		1		<1	<1		<1	2
Ostracoda	9	5	2	4	<1	10	4	13	6	7	3	23	7	86	46
Copepoda	1	<1		2	15			11	2	1	1		11	1	3
Chydoridae	2		<1	1	2	<1		2	<1	2					1
Daphniidae			<1	<1	3				<1					<1	3
Macrothricidae					1				<1						
Amphipoda	16	44	30	52	24	6	8	13	5	9		2	5		2
Bivalvia	5	3	6	8	4	1	10	3	3	8	<1	8	3	<1	<1
Gastropoda	2	<1				<1	<1		1	15	3	7	7	1	2
Ephemeroptera	1	1				2	3	9	7	21	3	3			<1
Trichoptera	2	1	1	<1	<1	2		2	<1	2	<1	<1		<1	1
Anisoptera								<1	<1	<1	1	<1			<1
Zygoptera							<1			4		<1		<1	
Coleoptera										<1					
Heteroptera										<1					
Chaoboridae	8									3	43	<1	29	1	<1
Ceratopogonidae		<1	<1						<1		<1	<1	1		
Chironomidae	55	46	55	25	48	61	55	32	62	22	43	49	31	2	29
Total Abundance (No./m^2)	891	8,706	5,366	5,690	12,691	6,352	4,823	3,504	8,874	4,552	3,284	19,780	1,530	30,867	27,930
Richness	7	9	8	7	12	11	11	6	11	13	6	13	4	9	15
Simpson's Diversity	0.73	0.64	0.63	0.60	0.76	0.71	0.71	0.66	0.72	0.84	0.43	0.77	0.61	0.21	0.63
Evenness	0.92	0.72	0.79	0.71	0.83	0.84	0.81	0.91	0.85	0.92	0.55	0.84	0.83	0.24	0.69
% EPT	3	2	1	<1	<1	2	2	10	7	19	1	2		<1	1

Table 5.8-10 Results of analysis of variance (ANOVA) on benthic invertebrate community dataset; time contrasts are for station KEL-1 versus station SHL-1, 2001 to 2005.

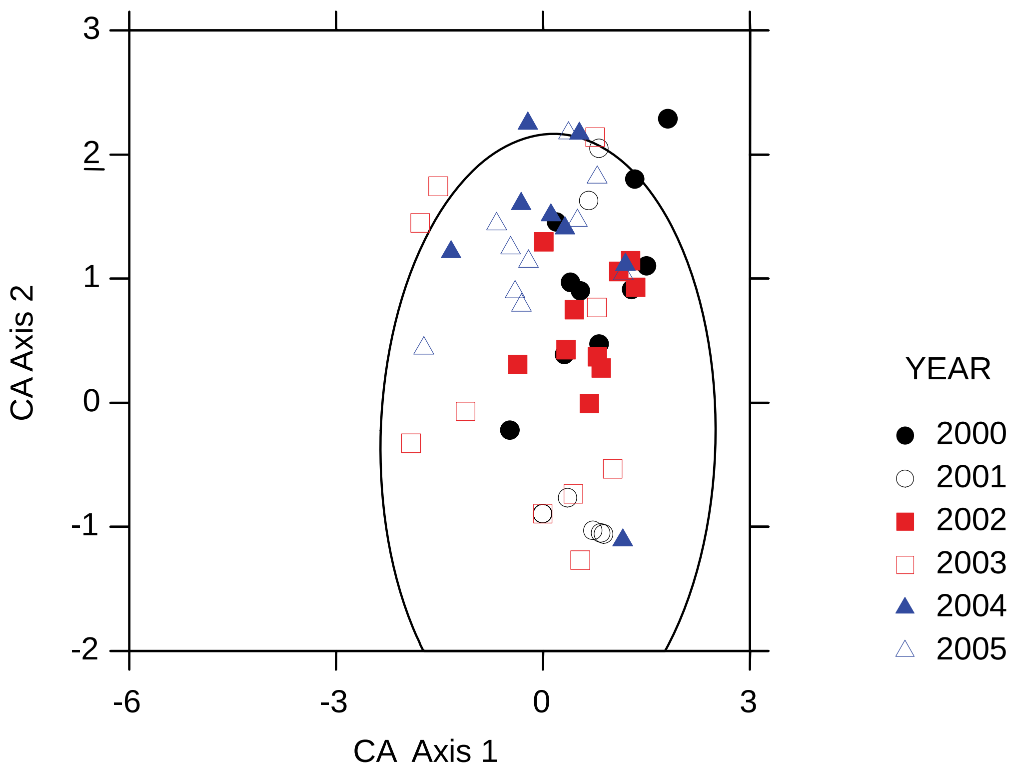
Source	SS	df	F	P
Log_{10} Abundance				
Lake-Year	27.81	14	9.71	<0.001
Time	1.64	1	8.03	0.005
Lake	4.44	1	21.73	<0.001
Time × Lake	7.07	1	34.57	<0.001
Shipyard vs others in 2005	2.53	1	12.37	0.001
Error	27.01	132		
Log_{10} Richness				
Lake-Year	3.822	14	4.73	<0.001
Time	0.078	1	1.36	0.244
Lake	0.045	1	0.79	0.376
Time × Lake	0.317	1	5.49	0.020
Shipyard vs others in 2005	0.144	1	2.50	0.115
Error	7.618	132		
Simpson's Diversity				
Lake-Year	2.867	14	8.12	<0.001
Time	0.071	1	2.836	0.094
Lake	0.394	1	15.61	<0.001
Time × Lake	0.014	1	0.591	0.443
Shipyard vs others in 2005	0.076	1	3.018	0.084
Error	3.331	132		
Evenness				
Lake-Year	3.758	14	13.57	<0.001
Time	0.140	1	7.107	0.008
Lake	0.654	1	33.09	<0.001
Time × Lake	0.088	1	4.49	0.035
Shipyard vs others in 2005	0.161	1	8.165	0.004
Error	2.610	132		
Log_{10} EPT %				
Lake-Year	9.22	14	4.35	<0.001
Time	<0.01	1	<0.01	0.977
Lake	0.58	1	3.85	0.052
Time × Lake	0.32	1	2.10	0.150
Shipyard vs others in 2005	0.12	1	0.79	0.374
Error	19.98	132		

Figure 5.8-10 Variation in benthic invertebrate community measurement endpoints in Kearl, McClelland and Shipyard Lakes.



Note: Error bars are ± 2 standard deviations for observations from the Kearl and McClelland lakes, designated as *potentially influenced- other*.

Figure 5.8-11 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for Kearl, Shipyard and McClelland Lakes.



Note: Ellipse is for baseline data (i.e., McClelland Lake and Kearl Lake).

5.9 FIREBAG RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				Total runoff was well above average in 2005. Flows were above average for almost the entire year, with maximum daily and minimum open-water discharge much higher than the mean annual flood and mean annual minimum discharge, respectively.
	Negligible	Low	Moderate	High	
Mean open-water season discharge	The Firebag River watershed was designated as a *reference* watershed for 2005.				
Mean winter discharge					
Annual maximum daily discharge					
Minimum open-water season discharge					

Water Quality			
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		Water quality measurement endpoints were generally consistent with results from previous years. Some analytes were slightly higher in 2005 than historical results. Exceedances of CCME/AENV guidelines occurred in all seasons, and ionic characteristics of the water sampled have been consistent from 2002 to 2005.
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=0)**	**2005 *Reference* Stations (n=2)**	
Physical variables (max=2)	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.	0	
Nutrients (max=6)		4	
Ions (max=4)		0	
Selected metals (max=10)		1	
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 8 endpoints)**	**2005 *Referenc* e Stations (n=2 stations X 8 endpoints)**	
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.	2	
Between 5th and 95th percentiles		9	
Less than 5th percentile		5	

Sediment Quality		
Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]	
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=0)**	**2005 *Reference* Stations (n=0)**
Total Hydrocarbons	No sediment quality sampling was conducted in 2005.	
PAHs		
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 3 endpoints)**	**2005 *Reference* Stations (n=0 stations X 3 endpoints)**
Greater than 95th percentile	No sediment quality sampling was conducted in 2005.	
Between 5th and 95th percentiles		
Less than 5th percentile		

Benthic Invertebrate Communities							
Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline						Benthic invertebrate community measurement endpoints were well within the expected regional reference values for erosional and depositional habitats in the lower and upper reaches of the Firebag River, respectively.
	2005 *Potentially Influenced-Oil Sands* Stations (n=0)			**2005 *Reference* Stations (n=2)**			
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance	No benthic invertebrate community sampling reaches were designated as *potentially influenced-oil sands* in 2005.				2		
Richness					2		
Diversity					2		
Evenness					2		
% EPT					2		

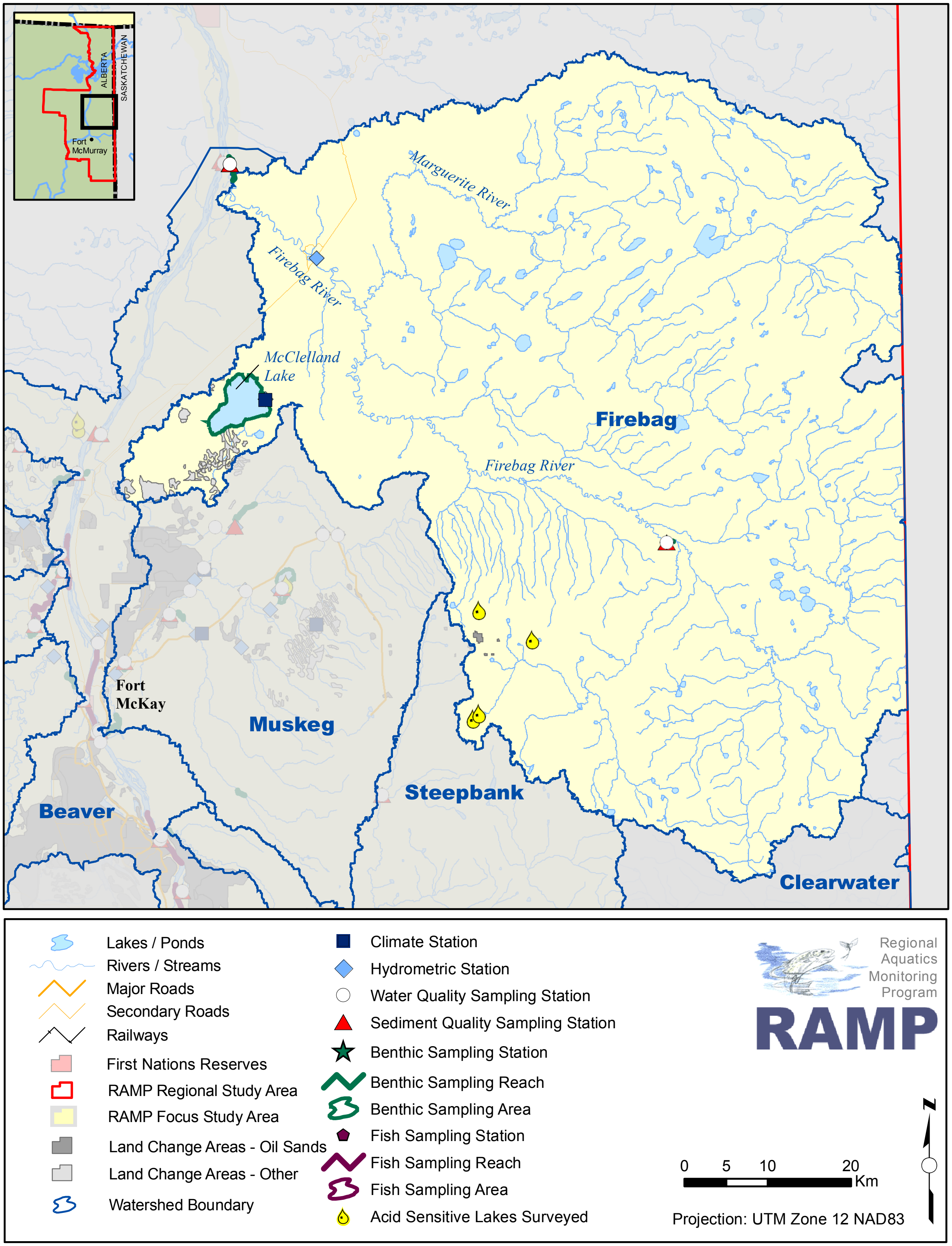
Fish Populations	
Fish Inventory	No fish inventory studies conducted in 2005.
Sentinel Studies	No sentinel fish studies conducted in 2005.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.9-1 Firebag River watershed.



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5.9.1 Development Status

All parts of the Firebag River watershed are designated as *reference* for 2005. To date, 0.2% of the area of the watershed has undergone land change from oil sands activities, while less than 0.2% of the area of the watershed has undergone land change from other activities (Section 2). Therefore, all RAMP stations in the Firebag River watershed in 2005 are designated as *reference* stations and all data gathered at these stations are designated as baseline data.

5.9.2 Hydrologic Conditions

Total runoff in the Firebag River watershed was well above average in 2005, with a May to October runoff depth of 155 mm compared to the long-term average of 114 mm. Flows were above average for almost the entire year (Figure 5.9-2). The maximum daily discharge of 192 m^3/s occurred on April 24, significantly exceeding previously recorded April discharges and amounting to 185% of the mean annual flood. The highest rainfall runoff occurred in late August. The minimum open-water discharge was 28.0 m^3/s on October 31, much higher than the mean annual minimum discharge of 15.2 m^3/s.

5.9.3 Water Quality

In 2005, water quality was assessed at the mouth of the Firebag River (station FIR-1, *reference*, baseline data, first sampled in 2002) and upstream of the Suncor Firebag project (station FIR-2, *reference*, baseline data, first sampled in 2002). Results of 2005 sampling for selected water quality measurement endpoints are shown in Table 5.9-1 and Table 5.9-2; results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.9-3.

Water quality measurement endpoints at stations FIR-1 and FIR-2 were generally consistent with results from previous years. Some analytes (total and total dissolved phosphorus, dissolved organic carbon, total and dissolved iron) were slightly higher in 2005 than historical results at both stations. Total and dissolved phosphorus and iron concentrations exceeded CCME/AENV guidelines in fall 2005 at both stations; dissolved phosphorus concentrations exceeded the 95th percentile of regional baseline concentrations (Figure 5.9-3). At station FIR-2, the concentrations of some ions and related analytes (sodium, calcium, magnesium, total dissolved solids, total alkalinity) were lower in 2005 than in previous years. Exceedances of CCME/AENV guidelines occurred in all seasons at both stations; in addition to exceedances of aluminum, iron, total phenols, and phosphorus guidelines, dissolved oxygen at station FIR-2 was below the AENV acute guideline in winter 2005 (Table 5.9-3).

Figure 5.9-4 indicates that ionic characteristics of the water sampled at both stations (FIR-1 and FIR-2) have been consistent from 2002 to 2005, suggesting there has been little change in overall water quality conditions in the Firebag River watershed since the beginning of RAMP sampling. These results continue to confirm that station FIR-2 will be a suitable reference station for station FIR-1 should further oil sands activities in the watershed lead to designation of station FIR-1 as *potentially influenced-oil sands.*

5.9.4 Sediment Quality

The 2005 RAMP Sediment Quality component did not include any activities in the Firebag River watershed.

5.9.5 Benthic Invertebrate Communities

In 2005, benthic invertebrate community samples were collected from a depositional reach near the mouth of the Firebag River (reach FIR-D-1, *reference*, first sampled in 2003) and an erosional reach upstream of the Suncor Firebag Project (reach FIR-E-2, *reference*, first sampled in 2003).

Reach FIR-D-1 is depositional, with moderate depths, slow current, and minor coverage by macrophytes (Table 5.9-4). In contrast, reach FIR-E-2 is erosional, with shallow depths, moderate current velocity, and moderate levels of benthic algae (chlorophyll *a*, 27 mg/m^2). Water quality at the two reaches was generally similar, although conductivity in reach FIR-D-1 was higher (207 µS/cm) than reach FIR-E-2 (175 µS/cm). Sediments of the reach FIR-D-1 were dominated by sand with very little total organic carbon. Substrates in reach FIR-E-2 were heterogeneous, and ranged from small gravel to large cobble.

Tubificid worms and chironomids dominated reach FIR-D-1, with a few additional types of fly larvae (ceratopogonids, tipulids), snails (*Physa*), sphaeriid clams and nematodes (Table 5.9-5). Stoneflies (*Pteronarcys*, *Skwala*), and caddisflies (*Neureclipsis*) were the most sensitive taxa present in the reach. The total abundance (~20,000/m^2) was approximately average and the number of taxa (6) slightly lower for baseline depositional reaches in the RAMP FSA (Figure 5.9-5).

Chironomids, mayflies and caddisflies dominated the benthic invertebrate communities of reach FIR-D-1 (Table 5.9-5), while mites (11%), beetles (Coleoptera), nematodes and naidids worms were sub-dominant. Other groups present in reach FIR-E-2 included Crustacea (ostracods, copepods, chydorids), springtails (Collembola), sphaeriid clams, and other miscellaneous fly larvae (tipulids, ceratopogonids). Several of the taxa found in reach FIR-E-2 indicate high quality benthic habitat including the stoneflies *Isogenoides*, *Isoperla*, *Skwala*, *Pteronarcys* and *Taeniopteryx*, the caddisfly *Brachcentrus*, the dragonfly *Ophiogomphus*, the empidid *Hemerodromia*, and several of the chironomids (e.g., *Cricotopus*/*Orthocladius*, *Tvetenia*, *Pottastia longimana*). The total abundance (~12,000/m^2), richness (38 taxa), diversity and evenness were all slightly higher than the average for baseline erosional reaches in the RAMP FSA indicating a high quality benthic environment in reach FIR-E-2 (Figure 5.9-6).

5.9.6 Fish Populations

The 2005 RAMP Fish Population component did not include any activities in the Firebag River watershed.

5.9.7 Summary of Conditions

RAMP aquatic resources of the Firebag River watershed, with all watershed areas designated as *reference* for 2005, were similar in 2005 relative to previous years. There were few exceedances of water quality environmental guidelines throughout 2005, and practically all measurement endpoints for RAMP aquatic resources that were sampled in 2005 were within the range of expected reference conditions for similar river systems and habitats in the RAMP FSA.

Figure 5.9-2 Firebag River: 2005 hydrograph and historical context.

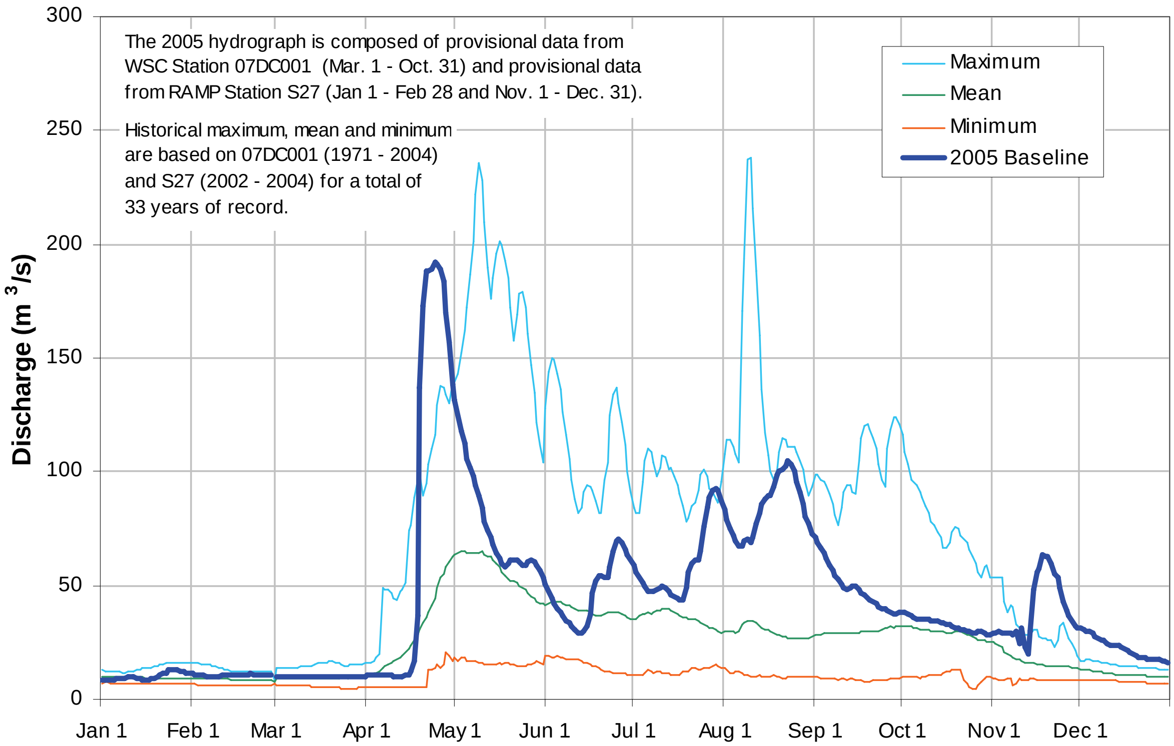


Table 5.9-1 Concentrations of water quality measurement endpoints, mouth of Firebag River (FIR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.9	2	8.1	-	8.1
Total suspended solids	mg/L	-[1]	3	2	<3	-	8
Conductivity	µS/cm	-	162	2	160	-	174
Nutrients							
Total phosphorus	mg/L	0.05	**0.134**	2	**0.068**	-	**0.087**
Total dissolved phosphorus	mg/L	0.05[2]	**0.10**	2	0.04	-	**0.06**
Total nitrogen*	mg/L	1.0	0.7	2	0.5	-	0.5
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	16	2	8	-	12
Ions							
Sodium	mg/L	-	3	2	4	-	4
Calcium	mg/L	-	22.9	2	25	-	25.7
Magnesium	mg/L	-	6.4	2	7.2	-	7.4
Chloride	mg/L	230, 860[3]	2	2	<1	-	2
Sulphate	mg/L	100[4]	2.8	2	1.9	-	2.9
Total dissolved solids	mg/L	-	110	2	120	-	150
Total alkalinity	mg/L		81	2	91	-	93
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	<1
Selected metals							
Total aluminum	mg/L	0.1	0.0289	2	0.0232	-	0.0359
Dissolved aluminum	mg/L	0.1[2]	0.0066	2	0.0031	-	0.0063
Total boron	mg/L	1.2[4]	0.0107	2	0.0134	-	0.0153
Total molybdenum	mg/L	0.073	0.00016	2	0.00015	-	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	1.1
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Dissolved iron	mg/L	0.3[2]	**0.89**	2	0.28	-	**0.41**
Total iron	mg/L	0.3	**1.39**	2	**0.53**	-	**0.68**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.9-2 Concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag project (FIR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	7.9	8.2	8.2
Total suspended solids	mg/L	-[1]	7	3	5	12	17
Conductivity	µS/cm	-	196	3	178	190	227
Nutrients							
Total phosphorus	mg/L	0.05	**0.093**	3	0.027	0.045	**0.07**
Total dissolved phosphorus	mg/L	0.05[2]	**0.057**	3	0.016	0.029	0.036
Total nitrogen*	mg/L	1.0	0.7	3	0.4	0.5	**1.7**
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	16	3	8	8	13
Ions							
Sodium	mg/L	-	4	3	3	4	4
Calcium	mg/L	-	27.4	3	25.2	30.2	31.3
Magnesium	mg/L	-	8.4	3	8.2	9.4	9.5
Chloride	mg/L	230, 860[3]	3	3	2	2	3
Sulphate	mg/L	100[4]	3.4	3	2.8	3.2	4.1
Total dissolved solids	mg/L	-	140	3	60	130	170
Total alkalinity	mg/L		98	3	87	110	112
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.175**	3	0.033	**0.262**	**0.292**
Dissolved aluminum	mg/L	0.1[2]	0.0087	3	0.0028	0.0054	0.0089
Total boron	mg/L	1.2[4]	0.0176	3	0.0140	0.0142	0.019
Total molybdenum	mg/L	0.073	0.00013	2	0.00011	-	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.005**	3	<0.001	<0.001	**0.007**
Dissolved iron	mg/L	0.3[2]	**0.5**	3	0.24	0.28	**0.40**
Total iron	mg/L	0.3	**1.1**	3	**0.39**	**0.71**	**1.05**

Note: Guideline values are CCME/AENV guidelines 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.

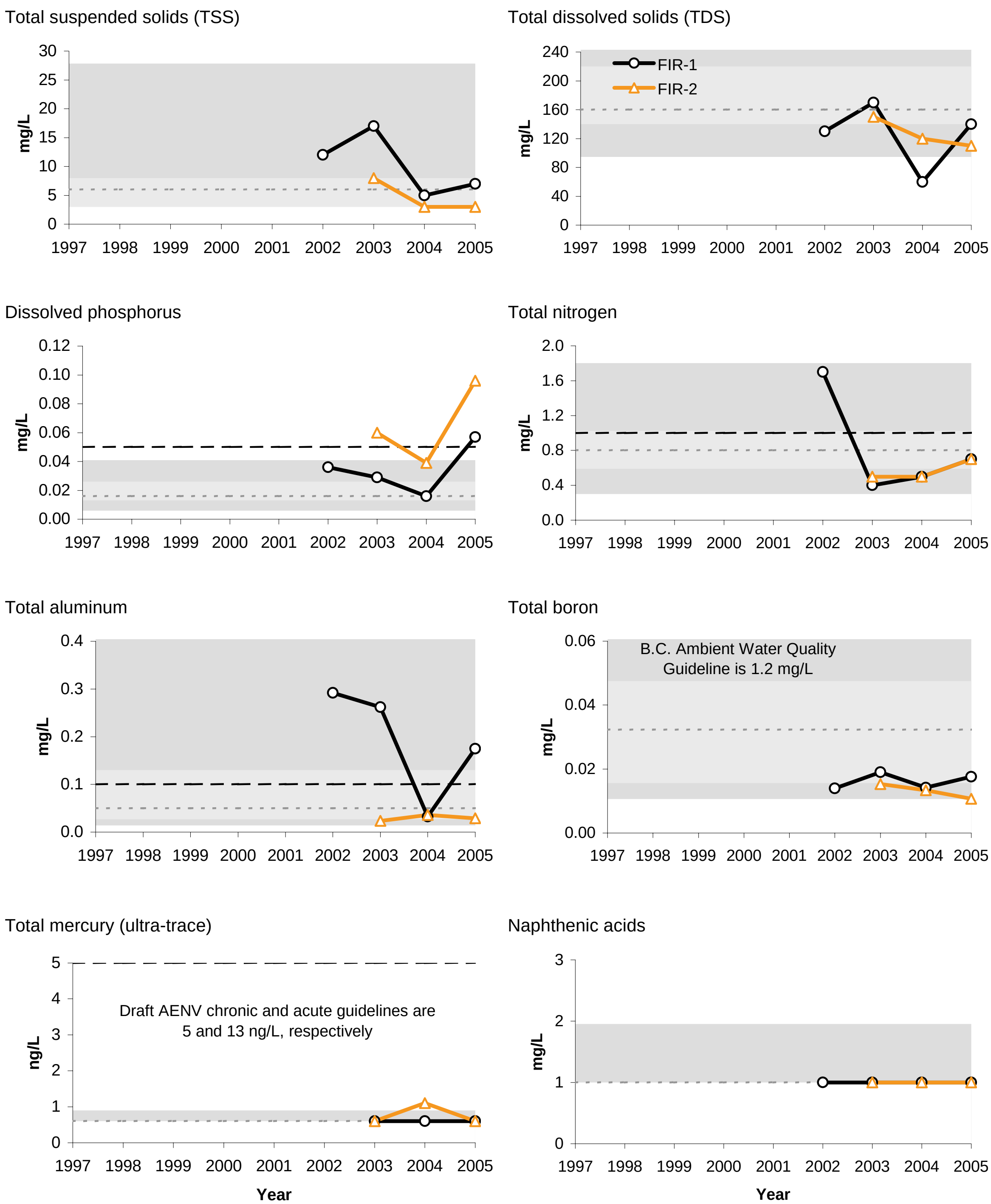
[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Figure 5.9-3 Concentrations of selected water quality measurement endpoints in the Firebag River watershed (fall 2005) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit

[1] 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 5.9-4 Piper diagram of fall 2005 ion concentrations in the Firebag River watershed.

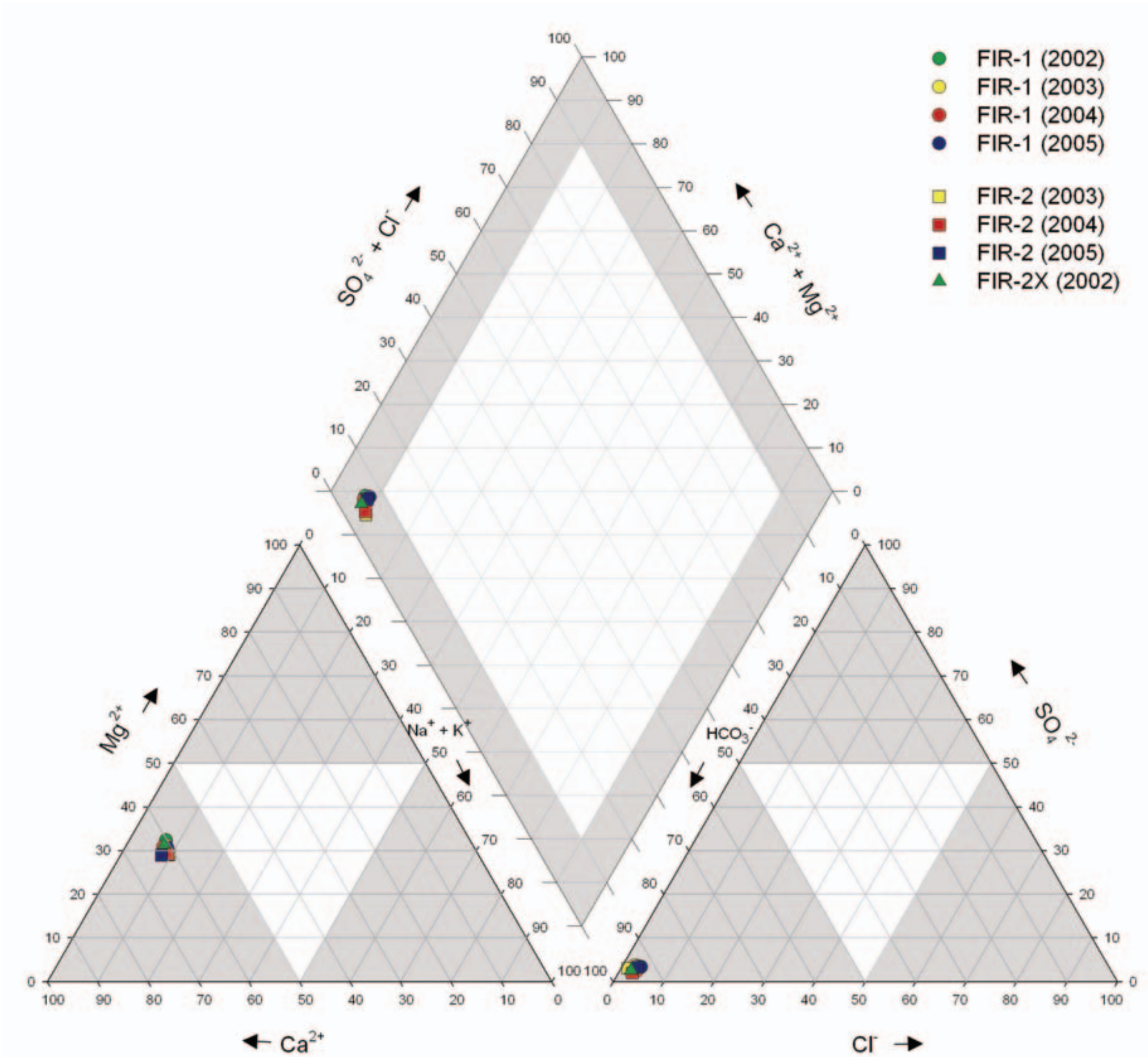


Table 5.9-3 List of all 2005 water quality guideline exceedances, Firebag River.

Parameter	Units	Guideline*	FIR-1	FIR-2
Winter				
Dissolved phosphorus	mg/L	0.05[1]	**-**	**0.061**
Total phosphorus	mg/L	0.05	**-**	**0.1**
Dissolved iron	mg/L	0.3[1]	-	**0.306**
Total iron	mg/L	0.3	**0.458**	**0.735**
Dissolved oxygen	mg/L	5.0[2]	**-**	**3.21**
Spring				
Total phosphorus	mg/L	0.05	**-**	**0.088**
Total phenols	mg/L	0.004	**0.008**	**0.006**
Total aluminum	mg/L	0.1	**0.167**	**-**
Total iron	mg/L	0.3	**0.581**	**0.707**
Summer				
Dissolved phosphorus	mg/L	0.05[1]	**-**	**0.109**
Total phosphorus	mg/L	0.05	**0.075**	**0.127**
Total aluminum	mg/L	0.1	**0.182**	**-**
Dissolved iron	mg/L	0.3[1]	**0.335**	**0.502**
Total iron	mg/L	0.3	**0.879**	**0.767**
Fall				
Dissolved phosphorus	mg/L	0.05[1]	**0.057**	**0.096**
Total phosphorus	mg/L	0.05	**0.093**	**0.134**
Total phenols	mg/L	0.004	**0.005**	**-**
Total aluminum	mg/L	0.1	**0.175**	**-**
Dissolved iron	mg/L	0.3[1]	**0.54**	**0.886**
Total iron	mg/L	0.3	**1.06**	**1.39**

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

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

[2] Alberta acute guideline for dissolved oxygen; guideline is a minimum value.

Table 5.9-4 Average habitat characteristics of benthic invertebrate community sampling reaches in the Firebag River, fall 2005.

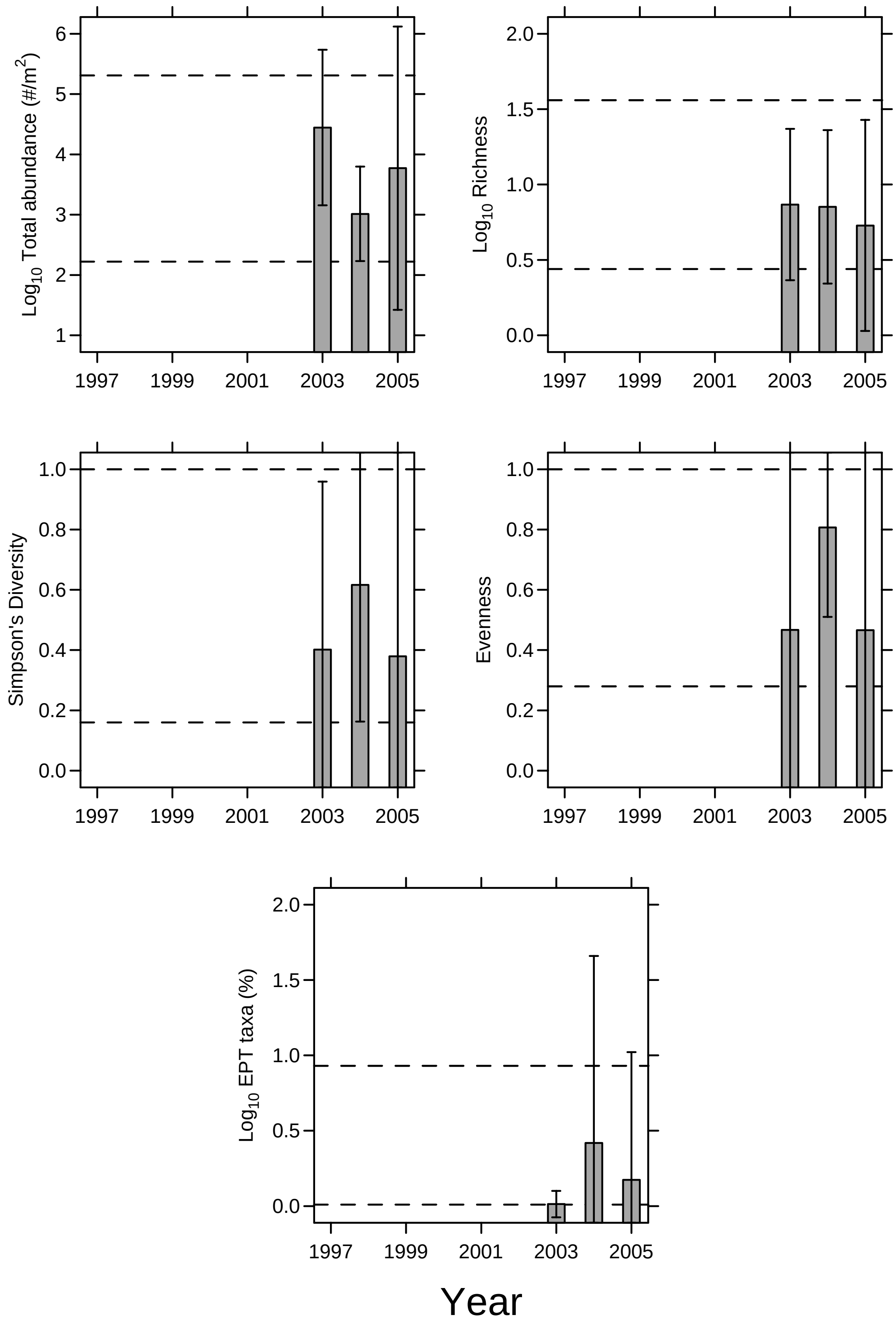
Variable	Units	Reach FIR-D-1	Reach FIR-E-2
Sample date	-	Sept. 11, 2005	Sept. 14, 2005
Habitat	-	Depositional	Erosional
Water depth	m	0.6	n/a
Current velocity	m/s	0.3	0.0
Macrophyte cover	%	1	1
Benthic algae[1]	mg/m^2	n/a	27
Field Water Quality			
Dissolved oxygen	mg/L	7.7	9.6
Conductivity	µS/cm	208	175
pH	pH units	7.7	7.8
Water temperature	°C	6.1	8.0
Sediment Composition			
Sand	%	81	n/a
Silt	%	18	n/a
Clay	%	5	n/a
Total Organic Carbon	%	1.3	n/a
Sand/Silt/Clay	%	n/a	0
Small gravel	%	n/a	8
Large gravel	%	n/a	29
Small cobble	%	n/a	43
Large cobble	%	n/a	21
Boulder	%	n/a	0
Bedrock	%	n/a	0

[1] measured as chlorophyll *a*

Table 5.9-5 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches in the Firebag River, fall 2005.

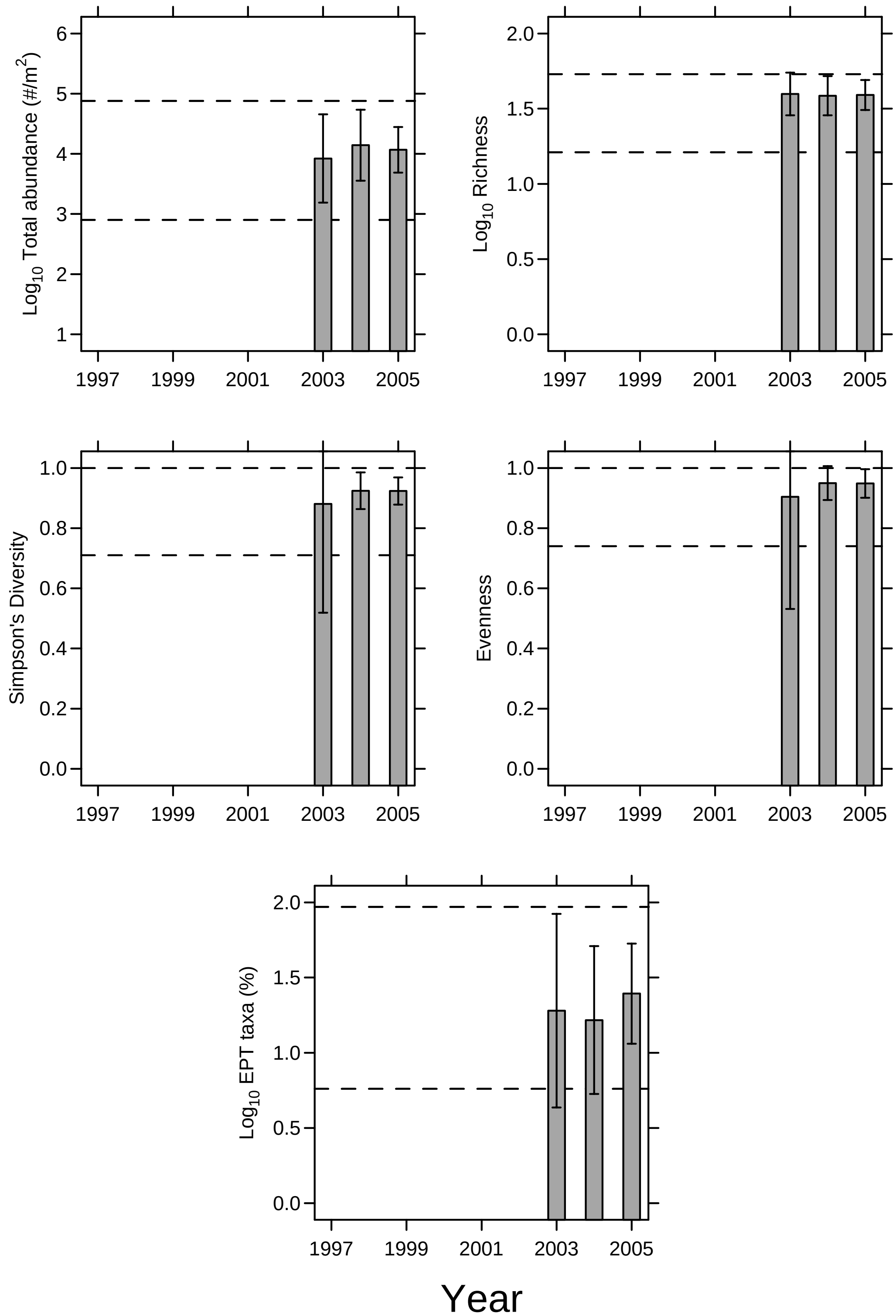
Taxon	Reach FIR-D-1			Reach FIR-E-2		
	2003	2004	2005	2003	2004	2005
Hydra				<1	<1	
Nematoda	<1	4	1	2	4	3
Glossiphoniidae				<1	<1	<1
Piscicolidae				<1		
Erpobdellidae					<1	
Enchytraeidae				1	<1	<1
Naididae	1	1		2	5	4
Tubificidae	1	28	60	1	1	1
Lumbriculidae		<1		<1		
Hydracarina		<1		5	10	11
Ostracoda		9		<1	<1	<1
Copepoda				1	1	<1
Chydoridae					<1	<1
Amphipoda				<1	<1	
Collembola					<1	<1
Bivalvia		4	1	3	3	2
Gastropoda			<1	1	<1	
Ephemeroptera	<1	3		9	12	15
Plecoptera	<1		<1	2	1	1
Trichoptera			1	5	7	10
Anisoptera	<1		<1	<1	<1	<1
Coleoptera				2	4	5
Heteroptera	1	<1		<1	<1	0
Tipulidae		9	<1	1	<1	<1
Tabanidae	<1			<1	<1	<1
Empididae	<1	2				
Ephydridae		3				
Ceratopogonidae	<1	2	1		<1	<1
Chironomidae	96	33	36	63	48	35
Simuliidae				<1	<1	<1
Megaloptera					<1	
Total Abundance (No./m^2)	62,517	1,391	19,722	11,930	16,024	12,335
Richness	7	7	6	39	38	38
Simpson's Diversity	0.40	0.62	0.38	0.88	0.92	0.92
Evenness	0.47	0.81	0.67	0.90	0.95	0.95
% EPT	<1	5	1	22	17	25

Figure 5.9-5 Variation in benthic invertebrate community measurement endpoints in the Firebag River, reach FIR-D-1, fall 2005.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites.

Figure 5.9-6 Variation in indices of benthic invertebrate community measurement endpoints in the Firebag River, reach FIR-E-2, fall 2005.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional sites.

5.10 ELLS RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	
Mean open-water season discharge	The Ells River watershed was designated as a *reference* watershed for 2005.				Runoff volume was 14% above average in 2005, with a May to October runoff depth of 82 mm compared to the long-term average of 72 mm.
Mean winter discharge					
Annual maximum daily discharge					
Minimum open-water season discharge					

Water Quality

Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005[1]**		
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=0)**	**2005 *Reference* Stations (n=2)**	
Physical variables (max=2)	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.	0	Overall, there were six (14%) out of 22 possible guideline exceedances of water quality measurement endpoints in 2005. Concentrations of water quality measurement endpoints in fall 2005 were generally within the range of regional fall baselines with the exception of naphthenic acids (station ELR-1) and total aluminum (station ELR-2). Ion balance at station ELR-1 remained similar to previous years and ion balance at station ELR-2 remained generally similar to station ELR-1.
Nutrients (max=6)		2	
Ions (max=4)		0	
Selected metals (max=10)		1	
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 8 endpoints)**	**2005 *Reference* Stations (n=2 stations X 8 endpoints)**	
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.	2	
Between 5th and 95th percentiles		12	
Less than 5th percentile		2	

Sediment Quality

Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005[1]**		
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=0)**	**2005 *Reference* Stations (n=2)**	
Total Hydrocarbons (max=8)	No sediment quality stations were designated as *potentially influenced-oil sands* in 2005.	3	Total hydrocarbons were higher in 2005 than in 2004 (both stations) and were near or exceeded the 95th percentile of regional baseline concentrations of carbon-normalized total hydrocarbons. Concentrations of PAHs were higher in 2005 than previously observed (both stations), and carbon-normalized total PAH concentrations were in the upper range of regional baseline levels.
PAHs (max=2)		0	
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[3]**		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 3 endpoints)**	**2005 *Reference* Stations (n=2 stations X 3 endpoints)**	
Greater than 95th percentile	No sediment quality stations were designated as *potentially influenced-oil sands* in 2005.	0	
Between 5th and 95th percentiles		4	
Less than 5th percentile		2	

Benthic Invertebrate Communities

Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline**						
	2005 *Potentially Influenced-Oil Sands* Stations (n=0)			**2005 *Reference* Stations (n=2)**			
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance	No benthic invertebrate community sampling reaches were designated as *potentially influenced-oil sands* in 2005.				2		All benthic invertebrate community measurement endpoints (both reaches) were within the ranges for regional depositional baseline reaches. % EPT at reach ELR-D-1 was well below the average for baseline regional depositional reaches.
Richness					2		
Diversity					2		
Evenness					2		
% EPT					2		

Fish Populations

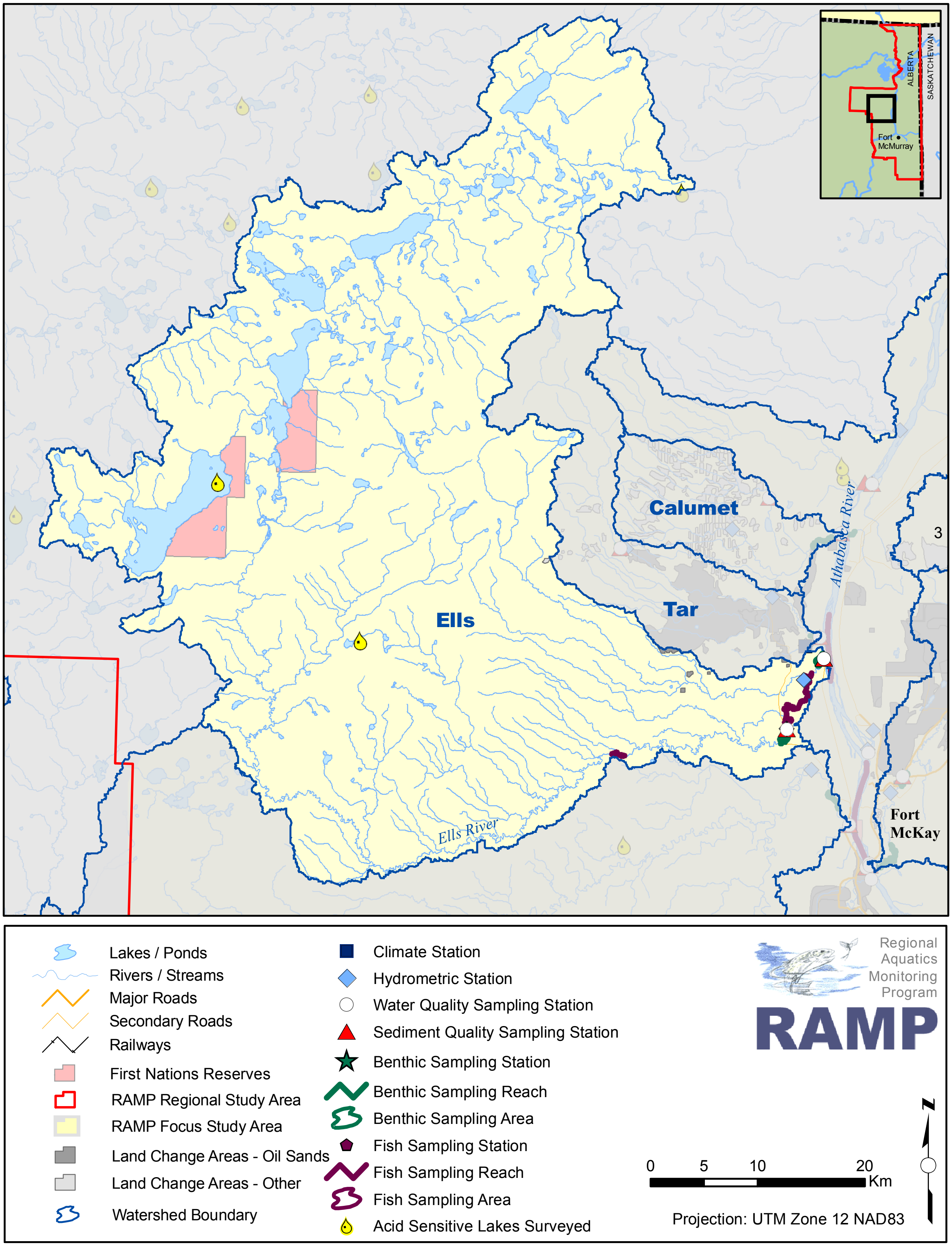
Fish Inventory	Ells River populations are typical of fish populations in other aquatic environments within the Athabasca oil sands area.	Catch-per-unit-effort was generally higher for most common species in 2005. Small-bodied species appear to dominate the Ells River summer fish community based on capture success in both 2004 and 2005. Overall mean size was significantly greater for longnose dace from the lower site relative to the upper site.
Sentinel Studies	The first year of sentinel species monitoring revealed significant baseline differences in measurement endpoints of populations sampled at the upper and lower reference sites.	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence	Fish tissue program was not conducted in 2005.	
Human Health: Recreational Fishers		
Human Health: General Consumers		
Human Health: Tainting		

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.10-1 Ells River watershed.



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5.10.1 Development Status

All of the Ells River watershed is designated as *reference* for 2005. To date, 0.1% of the watershed area has undergone land change as a result of oil sands activities, while approximately 0.01% of the watershed area has undergone land change as a result of other activities (Section 2, Figure 5.10-1). Therefore, all RAMP stations in the Ells River watershed in 2005 are designated as *reference* stations and all data gathered at these stations are designated as baseline data.

5.10.2 Hydrologic Conditions

Runoff volume in the Ells River basin, as measured at RAMP Station S14A, was 14% above average in 2005 (Figure 5.10-2), with a May to October runoff depth of 82 mm compared to the long-term average of 72 mm. The snowmelt runoff peak of 61 m^3/s in April was the highest flow measured during the year. Except for minor rainfall runoff peaks in May and late August to early September, discharges were close to historical average values for the remainder of the year (Figure 5.10-2). The April maximum daily discharge of 61 m^3/s was 25% higher than the mean annual flood of 49 m^3/s, and the minimum open-water discharge of 5.51 m^3/s on July 17 was significantly higher than the mean open-water minimum discharge of 2.96 m^3/s.

5.10.3 Water Quality

In 2005, water quality was sampled at the mouth of the Ells River (station ELR-1, *reference*, baseline data, established in 1998, sampled every year since 2002) and near the Fort McKay water supply intake, upstream of CNRL Lease 7 (ELR-2, *reference*, baseline data, established in 2000, sampled in 2004 and 2005). Fall 2005 results for water quality measurement endpoints are shown in Table 5.10-1 and Table 5.10-2; results for selected measurement endpoints (1997 to 2005) relative to regional baseline conditions are shown in Figure 5.10-3. Seasonal sampling of both stations was undertaken in 2005, although no samples could be collected from station ELR-2 in winter, because the stream was frozen to depth in this reach.

At station ELR-1, numerous ions and related analytes (e.g., conductivity) were equal to or lower in fall 2005 than the previously observed minimum results; these analytes were also lower in 2005 than in 2004 (the first year of sampling) at station ELR-2. Overall, there were six (14%) out of 22 possible guideline exceedances of the selected water quality measurement endpoints (i.e., eleven of the selected water quality measurement endpoints have guidelines and water quality was sampled at two stations on the Ells River in fall 2005, making for a total of 22 possible guideline exceedances [Table 5.10-1 and Table 5.10-2]). Nutrients were higher in fall 2005 than previously observed at stations ELR-1 and ELR-2; total phosphorus exceeded the AENV guideline at both stations. Concentrations of selected water quality measurement endpoints in fall 2005 were generally within the range of regional baseline fall concentrations (Figure 5.10-3) with the exception of naphthenic acids whose fall 2005 concentration at station ELR-1 was three times higher than in previous years (3 mg/L) and exceeded the regional baseline 95th percentile, and total aluminum at station ELR-2 whose fall 2005 concentration slightly exceeded the regional baseline 95th percentile. Total aluminum and total iron were higher at both stations in fall 2005 than in previous years and exceeded guidelines in all seasons at station ELR-1 and in spring, summer, and fall at station ELR-2 (Table 5.10-3). Ion balance at station ELR-1 has been relatively constant over the four years of RAMP sampling (Figure 5.10-4), and ion balance at station ELR-2 is generally similar to ion balance at station ELR-1.

5.10.4 Sediment Quality

Sediment quality samples were collected in fall 2005 from the mouth of the Ells River (station ELR-1) and upstream of CNRL Lease 7 (station ELR-2; Figure 5.10-1). 2005 results for sediment quality measurement endpoints are shown in Table 5.10-4 and Table 5.10-5; results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.10-5.

Sediments at station ELR-2 were dominated by sand as in 2004, but contained a much higher proportion of silt and clay in 2005 (Table 5.10-5). Sediments at station ELR-1 were dominated by silt, with approximately equal proportions of clay and sand. At both stations, hydrocarbons were dominated by the C16-C34 fraction. Total hydrocarbons were higher in 2005 than in 2004 at both stations, and were near or exceeded the 95^{th} percentile of regional baseline concentrations of carbon-normalized total hydrocarbons (Figure 5.10-5). Concentrations of PAHs were higher in 2005 than previously observed at both stations, and carbon-normalized total PAH concentrations were in the upper range of regional baseline levels.

Results of sediment toxicity tests at ELR-1 were inconsistent relative to previous years, with similar survival but lower growth of *Chironomus*, and lower survival but similar growth of *Hyallela,* relative to the two previous years in which sediment toxicity was assessed.

5.10.5 Benthic Invertebrate Communities

In 2005, benthic invertebrate community samples were collected from a depositional reach near the mouth of the Ells River (reach ELR-D-1) and from an erosional upper reach of the river (reach ELR-E-2; Figure 5.10-1).

Reach ELR-D-1 was typical of depositional habitats in the region with fine-grained sediments, shallow water and high dissolved oxygen concentrations (Table 5.10-6). Reach ELR-E-2 was typical of erosional habitats with substrate consisting of cobble and sand, and higher current velocities (0.8 m/s). Periphyton chlorophyll *a* biomass was relatively high (39 mg/m^2), while the water was cold (2^{o}C) (Table 5.10-6).

Tubificidae (57%), nematodes (17%) and chironomids (17%) dominated reach ELR-D-1 (Table 5.10-7). Other sub dominant taxa included ostracods, dragonflies and a variety of fly larvae (athericids, tabanids, ceratopogonids, simuliids). *Polypedilum* was the most abundant chironomid, while the broad group *Baetis* represented the mayflies, and the sensitive *Hemerodromia* represented the Ephydridae. All benthic invertebrate community measurement endpoints at reach ELR-D-1 were within the ranges for regional depositional baseline reaches, although % EPT was well below the average for baseline regional depositional reaches (Figure 5.10-6).

Diversity at reach ELR-E-2 was greater, with an average of 28 taxa from about 8,000 animals per m^2. Chironomids dominated the community (35%) with naidid worms (28%), mites (19%) and mayflies (7%) sub-dominant. Nematodes and other worms were found at reach ELR-E-2, as were ostracods, stoneflies, caddisflies, dragonflies, and a variety of fly larvae. Several sensitive groups were recorded including the mayflies

Ameletus, *Ephemerella*, several heptageniids, and *Tricorythodes*, the stoneflies *Isoperla* and *Taeniopteryx*, and the dragonfly *Ophiogomphus*. Chironomids diversity was high, with *Thiennemannimyia*, *Polypedilum*, *Micropsectra*/*Tanytarsus*, *Rheotanytarsus*, *Eukiefferiella* and *Tvetenia* being relatively common among all samples taken from reach ELR-E-2. All benthic invertebrate community measurement endpoints in both reaches were generally within the ranges for regional depositional baseline reaches (Figure 5.10-7).

5.10.6 Fish Populations

2005 RAMP Fish Population component activities in the Ells River watershed included a summer fish inventory, conducted in a lower reach of the river, and sentinel species monitoring (Figure 5.10-1), established following an Ells River fish inventory in fall 2004 that served as a sentinel species reconnaissance survey.

5.10.6.1 Fish Inventory

Species Composition and Catch-Per-Unit-Effort

A total of 261 fish from 9 species were captured during the August 2005 fish inventory on the Ells River. While sampling effort during the 2005 inventory was less than half of that expended in 2004 and although the total number of fish caught in 2005 (261) was less than in 2004 (348), catch-per-unit-effort was generally higher for most common species in 2005. Small-bodied species appear to dominate the Ells River summer fish community based on capture success in both 2004 and 2005 (Table 5.10-8). Longnose dace was the most abundant species in both years, representing approximately 59% of the total catch, while in 2005 lake chub was the second-most common species captured (20.31%) and all large-bodied species were present in comparatively low numbers (e.g., white sucker at 1.92%) (Table 5.10-8). The combined fish species richness from the 2004 and 2005 inventories is 13. Of the eight species captured in 2004, four were not included in the 2005 total of nine species.

Size and Condition Factor

The mean sizes for indicator fish species captured in sufficient numbers ($n \geq 5$) during the 2005 inventory are presented in Table 5.10-9, and a comparison of condition factors of species captured both during 2004 and 2005 is presented in Figure 5.10-8. Condition factor for lake chub was lower in 2005 than in 2004, but values for trout-perch and longnose dace were comparable between years. In general, morphometric results to date are typical of fish populations in other aquatic environments within the Athabasca oil sands area.

5.10.6.2 Sentinel Species Monitoring

Field Sampling Results

A survey of fish habitat at each site was conducted as part of the sentinel species monitoring activities. *In situ* measurements including dissolved oxygen (8 to 12 mg/L), conductivity (190 to 210), and pH (7.5 to 8.5) indicated suitable fish habitat at both sites during summer and fall.

Summer sampling efforts at the lower site occurred in stream sections comprised mainly of riffle habitat (60-70%) with a gradient typically of 2.5% and a wetted width of 25-30m. Similar conditions were present at the upper site, although the gradient was slightly lower and there was a larger glide section. At the upper site, river depth was similar across much of the channel at 0.8 to 1.0 m, with reduced visibility (~20 cm). River substrate at the upper site was predominantly sand with patches of gravel and scattered large woody debris. Riparian vegetation was mixed including some deciduous trees, and grasses.

The preference of longnose dace for high flow and large substrate size, made it difficult to accurately sample across the river channel during summer field program. Reduced visibility may have also influenced visual capture efficiency. In addition, elevated flows rarely permitted mid-channel sampling, the areas were fishing success appeared to be better than in margin habitats.

Fall sampling efforts and field observations indicate that the majority of longnose dace at the upper site were captured in water 0.4 to 0.7 m in depth with large angular cobble, and reduced water velocity relative to the lower site. In contrast, the majority of fish at the lower site were caught in a shallow riffle section with cover provided by medium to large boulders and instream algal growth. Fishing success was reduced in a section of the lower site that had little cobble or boulder cover. Similar to summer field program, poor water visibility may have reduced visual capture efficiency, particularly at the lower site.

The number of longnose dace collected at each Ells River sentinel sampling site ranged from 103 to 123 in the summer and 36 to 101 in the fall (Table 5.10-10). In all but one case the recommended minimum of 100 fish for the non-lethal sampling approach were captured. However, considerable effort (i.e., 2-3 days of electrofishing) was required to capture the required number of fish at each site, particularly in October 2005. Density estimates were not calculated for longnose dace, as the wetted width (35-40 m) and flow prevented the installation of barrier or block nets. CPUE declined during fall sampling relative to that recorded in summer at both the upper and lower sites (Table 5.10-10).

Population Distribution

A "pairwise" statistical approach was used to compare longnose dace length-frequency distributions between sampling sites (upper and lower) and sampling times within an area (August and October). Length-frequency distributions for Ells River upper and lower populations were significantly different in both August ($p<0.001$) and October ($p<0.001$) (Table 5.10-11, Figure 5.10-9 and Figure 5.10-10). Differences in the August population structures are evident by the different dominant lengths present at the upper (46-52 mm, Figure 5.10-11) and lower (56-64 mm, Figure 5.10-12) sites. Differences in population structures in October are evident by a strong size class at 46-52 mm at the upper site (Figure 5.10-11) and near complete absence of this size class at the lower site (Figure 5.10-12).

Growth

Growth was evaluated by measuring the magnitude of change in mean length of the youngest size class (YOY) if present between August and October. As would be expected with progressive seasonal growth (summer to fall) and shifts associated with both survival and mortality, within-site length-frequency distributions between August and October were significantly different ($p < 0.05$), but only at the upper site (lower site $p = 0.607$, Table 5.10-11). This may be partially influenced by the low numbers of fish caught at the lower site during fall sampling efforts.

In August and October, overall mean size (length and weight) was significantly greater ($p < 0.05$) for longnose dace from the lower site relative to the upper site (Table 5.10-12, Table 5.10-13). When considering only the YOY in August, only mean weight in August was significantly greater (t-test $p < 0.05$ using pooled variance) for those captured from the lower site relative to the upper site.

Summer growth for YOY longnose dace individuals ($\leq$ 26 mm in August) was estimated for the period from August to October (standardized at 65 days). The population at the upper site had YOY growth of 0.084mm/day compared to 0.046 mm/day for the population at the lower site. Although, there appears to be a clear difference, the precision of the estimate of young longnose dace growth at the lower site is uncertain given the low numbers of YOY captured there.

Reproductive performance and short-term survival of a population can be estimated by examining the proportion of a population composed of YOY individuals. In August, YOY longnose dace (<26 mm) represented 22% of the population at the upper site compared to 12% at the lower site (Table 5.10-14 and Figure 5.10-11). The proportion represented by YOY shifted and declined slightly in fall, at both the upper (13%) and lower sites (11%) (Table 5.10-14 and Figure 5.10-12). Reasons for the lower percentage of YOY longnose dace collected at the lower site are unknown.

Energy Storage

Overall seasonal analysis of covariance (ANCOVA) for all longnose dace captured showed a statistically significant difference ($p<0.05$) in the length-weight relationship, with condition being higher at the lower site in both August and October relative to the population at the upper site (Figure 5.10-13, Figure 5.10-14). The small number of longnose dace captured at the lower site in October may exert an influence on the differences in condition factor between sites and assessed seasonal growth and/or survival, and that results should be interpreted with some caution. A subsequent analysis, focusing on the YOY cohort and therefore excluding individuals larger than 26 mm in August found no significant difference in August condition ($p = 0.392$), but significantly higher condition at the lower site relative to upper site fish in October ($p < 0.05$, Figure 5.10-15, Figure 5.10-16).

Discussion

Significant differences in population distributions of longnose dace captured at the upper and lower sites of the Ells River may be the result of limited reproductive capacity in adults, elevated mortality, or a combination of these and/or additional factors such as seasonal movements or shifts in preferred habitat. However, similar to sculpin species, the longnose dace is suspected to have a limited home range.

Longnose dace are fractional spawners and will typically lay eggs multiple times within the open-water season. Accordingly, evaluating population changes using length-frequency analyses is challenging because distinctions among size classes become more difficult to identify as new cohorts are recruited into the population. Unfortunately alternate sentinel species in the Ells River are not available. Other procedures may need to be evaluated (e.g., marking individual fishes) to facilitate the identification and tracking of a single YOY cohort over time.

The lack of YOY individuals represented in both populations may have also resulted from disproportionate sampling of higher flow areas relative to stream margins. Shallower, calmer waters have been identified as preferred habitat for the early history stages of longnose dace (Scott and Crossman 1973) and will be sampled more aggressively in future longnose dace programs, and sentinel programs in general. There are also indications that this species is relatively slow growing (Scott and Crossman 1973), which may influence how future sentinel species studies are implemented on the Ells River.

Impact Analysis

Condition factor of longnose dace from the Ells River sentinel program indicate fish from the lower site were "fatter" relative to the upper site. Overall, differences in mean condition exceeded the Environment Canada impact criterion of 10% in both August (13.2%) and October (18%) (Table 5.10-12). More specifically, the mean YOY condition in October was significantly greater by approximately 23% at the lower site relative to the upper site. However caution is warranted in interpreting this result because of the limited fall capture success at the lower site (Table 5.10-10).

Based on the relative frequency distributions, it appears that over the summer at both the upper and lower sites, mortality events associated with the "older" or larger length classes may have occurred. Another possible explanation may be a seasonal movement out of the area by larger individuals prior to fall sampling. However, neither Scott and Crossman (1973) nor Nelson and Paetz (1992) identify the presence of seasonal movement patterns, with the exception of the transition from a pelagic larval stage in the stream margins to a benthic or bottom dwelling life style, which occurs four months post-hatch.

It has been documented that longnose dace have an increased ability to regulate swim bladder volume, and thus their buoyancy, relative to other minnow species. This permits longnose dace to remain on the bottom in faster flow areas without increased energy expenditure (Nelson and Paetz 1992). This may provide a means or basis for resource partitioning with other minnow species, particularly in smaller streams of fast flow and should be considered when conducting fish sampling during future programs involving the species.

Additional "gaps" or low representation of particular lengths in August and October for both upper and lower sites suggest possible recruitment limitations of longnose dace populations. A comparatively large number of size classes representing a low proportion of the population may suggest consecutive years of limited recruitment. Predictions for the 2005-age class and comparisons of potential early life history bottlenecks in terms of YOY abundance, growth and survival are difficult to make between areas due to the limited fall sample size at the lower site.

5.10.7 Summary of Conditions

Conditions in the Ells River in 2005 were generally similar to previous years. Although overall flow was higher, water quality, sediment quality, and benthic invertebrate community conditions were within the range of historical regional baseline conditions. The main exceptions were PAHs in sediments which were higher in 2005 and in the upper range of regional baseline levels. Fish inventory results indicate Ells River populations are typical of fish populations in other aquatic environments within the Athabasca oil sands area. The first year of sentinel species monitoring in the watershed, using the longnose dace, revealed significant baseline differences in population measurement endpoints of populations sampled at the upper and lower *reference* sites, including condition.

Figure 5.10-2 Ells River: 2005 hydrograph and historical context.

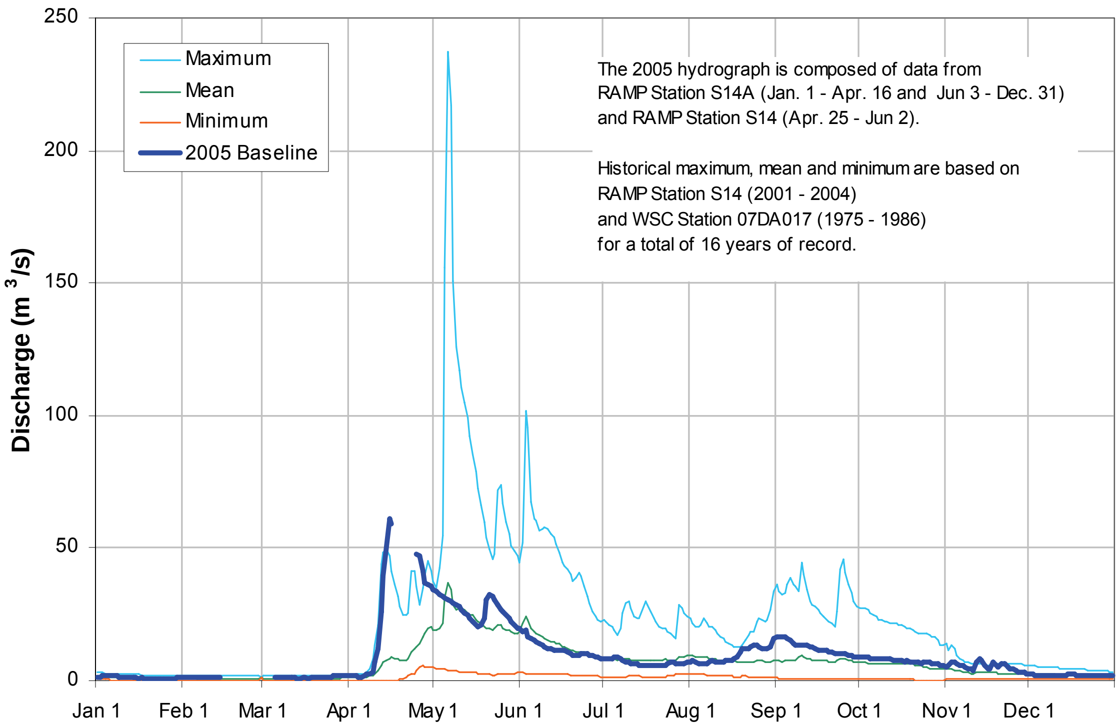


Table 5.10-1 Concentrations of water quality measurement endpoints, mouth of Ells River (ELR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.8	4	7.9	8.2	8.4
Total suspended solids	mg/L	-[1]	5	4	5	8	16
Conductivity	µS/cm	-	175	4	186	243	258
Nutrients							
Total phosphorus	mg/L	0.05	**0.055**	4	0.011	0.014	0.043
Total dissolved phosphorus	mg/L	0.05[2]	0.02	4	0.003	0.008	0.011
Total nitrogen*	mg/L	1.0	0.9	4	0.3	0.5	0.7
Nitrate+nitrite	mg/L	-	<0.1	4	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15	4	11	11.5	12
Ions							
Sodium	mg/L	-	8	4	8	14	18
Calcium	mg/L	-	21.6	4	24	26	30.4
Magnesium	mg/L	-	6.5	4	7.3	8	9.1
Chloride	mg/L	230, 860[3]	2	4	<0.5	1.5	4
Sulphate	mg/L	100[4]	12.3	4	15.4	20.1	27.9
Total dissolved solids	mg/L	-	110	4	140	167	220
Total alkalinity	mg/L		76	4	78	99	111
Organic compounds							
Naphthenic acids	mg/L	-	3	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.673**	4	0.060	**0.243**	**0.663**
Dissolved aluminum	mg/L	0.1[2]	0.017	4	0.008	0.030	0.078
Total boron	mg/L	1.2[4]	0.0444	4	0.0410	0.0660	0.0784
Total molybdenum	mg/L	0.073	0.00071	4	0.00064	0.00075	0.00084
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total iron	mg/L	0.3	**0.95**	4	**0.45**	**0.61**	**0.78**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.10-2 Concentrations of water quality measurement endpoints, upper Ells River (ELR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.7	1	-	-	7.8
Total suspended solids	mg/L	-[1]	4	1	-	-	<3
Conductivity	µS/cm	-	164	1	-	-	195
Nutrients							
Total phosphorus	mg/L	0.05	**0.062**	1	-	-	0.01
Total dissolved phosphorus	mg/L	0.05[2]	0.017	1	-	-	0.004
Total nitrogen*	mg/L	1.0	0.8	1	-	-	0.7
Nitrate+nitrite	mg/L	-	<0.1	1	-	-	<0.1
Dissolved organic carbon	mg/L	-	16	1	-	-	10
Ions							
Sodium	mg/L	-	6	1	-	-	13
Calcium	mg/L	-	20.5	1	-	-	24.8
Magnesium	mg/L	-	6.2	1	-	-	7.2
Chloride	mg/L	230, 860[3]	2	1	-	-	3
Sulphate	mg/L	100[4]	10.8	1	-	-	18.9
Total dissolved solids	mg/L	-	110	1	-	-	190
Total alkalinity	mg/L		73	1	-	-	110
Organic compounds							
Naphthenic acids	mg/L	-	1	1	-	-	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.735**	1	-	-	0.0515
Dissolved aluminum	mg/L	0.1[2]	0.0133	1	-	-	<0.0002
Total boron	mg/L	1.2[4]	0.0405	1	-	-	0.0836
Total molybdenum	mg/L	0.073	0.00065	1	-	-	0.0008
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total iron	mg/L	0.3	**0.92**	1	-	-	0.26

Note: Guideline values are CCME/AENV guidelines 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.

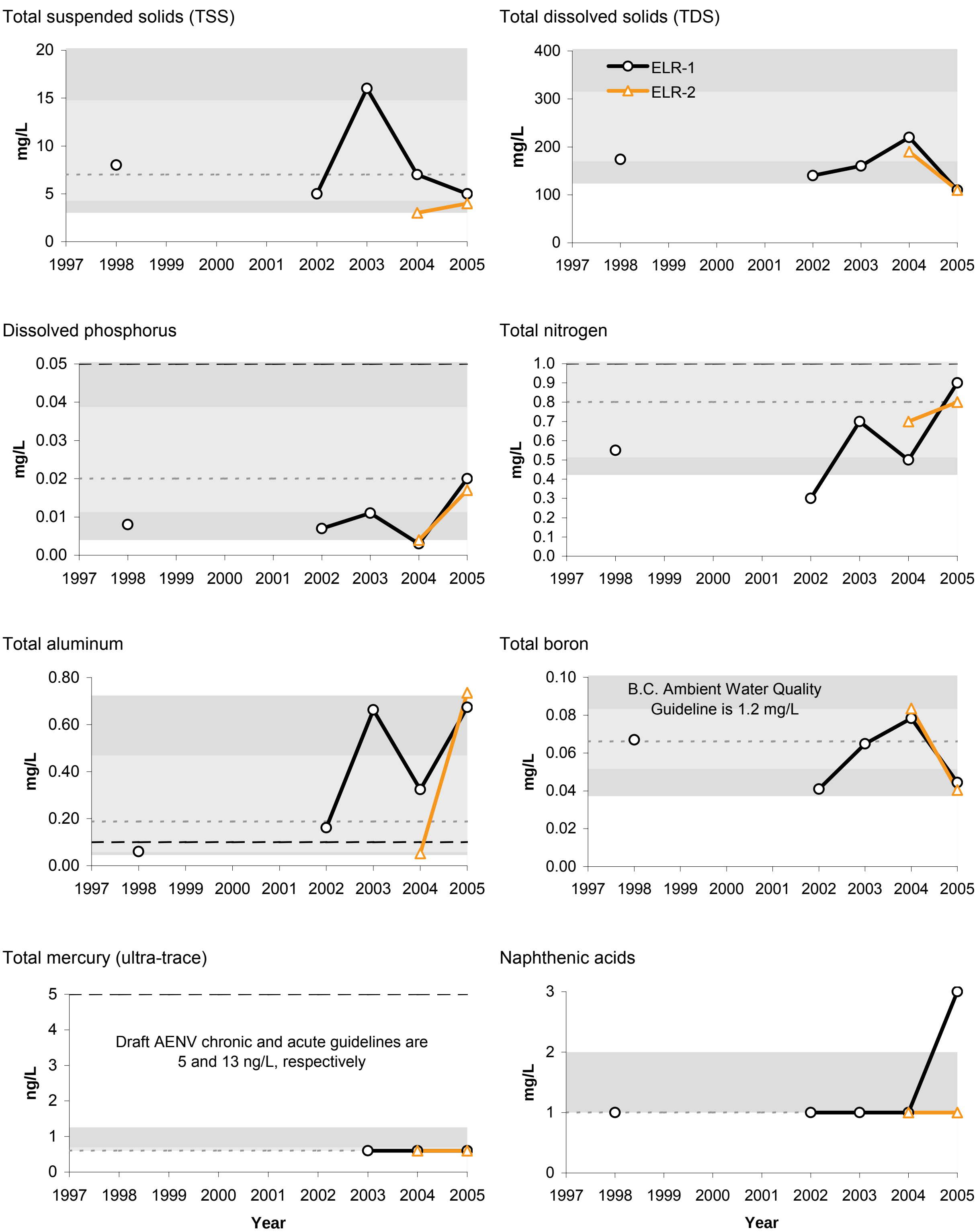
[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Figure 5.10-3 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.

[1] 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.

Table 5.10-3 Water quality guideline exceedances, Ells River watershed, 2005.

Parameter	Units	Guideline*	ELR-1	ELR-2
Winter				
Total aluminum	mg/L	0.1	**0.118**	ns
Total iron	mg/L	0.3	**0.442**	ns
Spring				
Total phosphorus	mg/L	0.05	**0.13**	**0.121**
Total phenols	mg/L	0.004	**0.009**	**-**
Total aluminum	mg/L	0.1	**2.86**	**3.11**
Total cobalt	mg/L	0.0009[1]	**0.00102**	**0.00143**
Total copper	mg/L	0.002-0.004[2]	**0.0029**	**0.00364**
Dissolved iron	mg/L	0.3[3]	**0.305**	**-**
Total iron	mg/L	0.3	**2.88**	**3.76**
Summer				
Total aluminum	mg/L	0.1	**0.352**	**0.329**
Total iron	mg/L	0.3	**0.698**	**0.527**
Fall				
Total phosphorus	mg/L	0.05	**0.055**	**0.062**
Total aluminum	mg/L	0.1	**0.673**	**0.735**
Total iron	mg/L	0.3	**0.945**	**0.922**

ELR-2 was not sampled in winter 2005.

ns = not sampled

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

[1] B.C. Working Water Quality Guideline (2001).

[2] Guideline is hardness-dependent.

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

Figure 5.10-4 Piper diagram of fall ion concentrations in Ells River system.

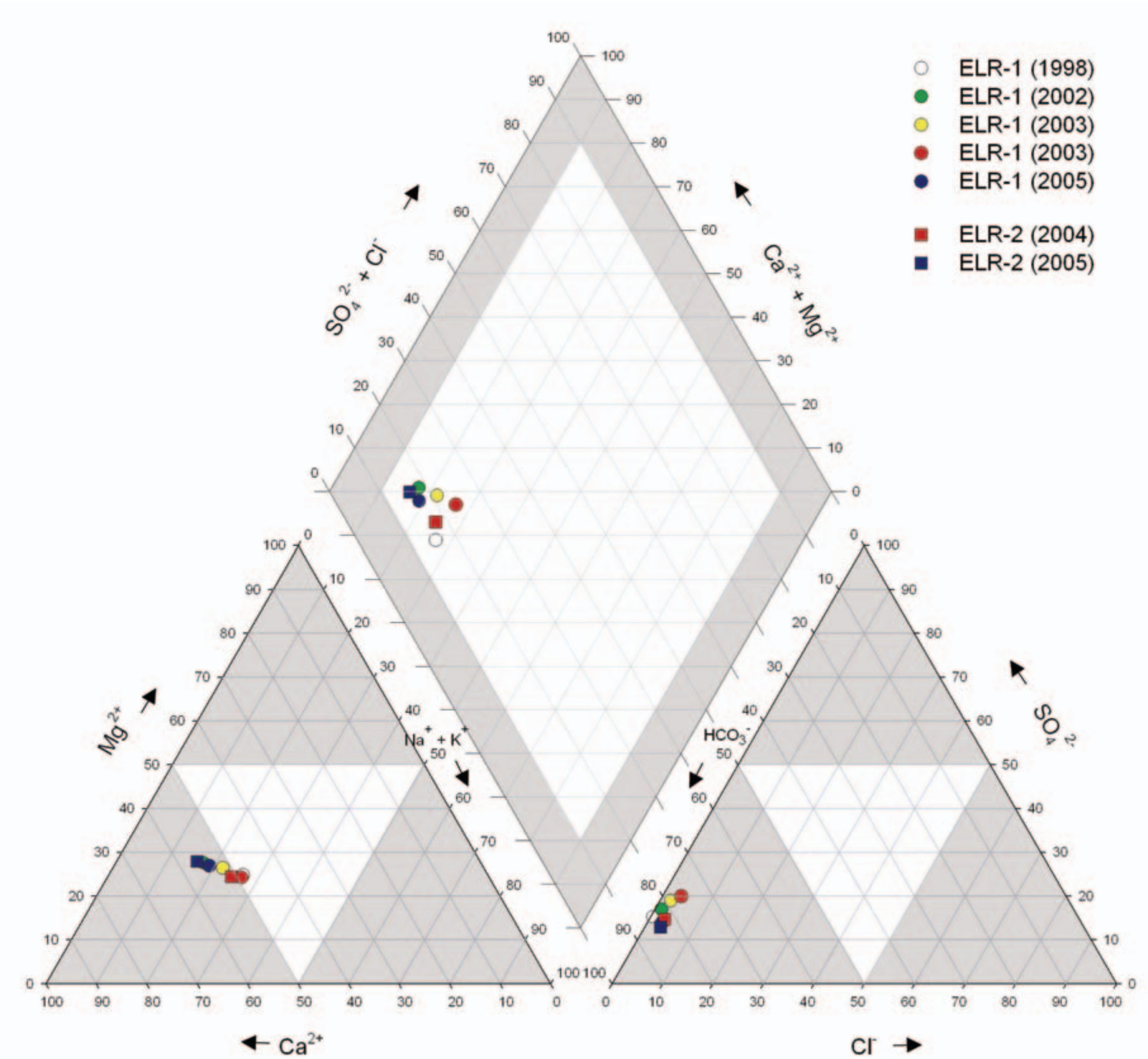


Table 5.10-4 Selected sediment quality measurement endpoints, mouth of Ells River (ELR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	26	4	5	7	18
Silt	%	-	51	4	8	13	38
Sand	%	-	23	4	44	81	85
Total organic carbon	%	-	2.7	4	0.7	1.325	2.8
Total hydrocarbons							
CCME variables							
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]	**320**	1	-	-	150
Fraction 3 (C16-C34)	mg/kg	400[2]	**3000**	1	-	-	**1500**
Fraction 4 (C34-C50)	mg/kg	2800[2]	1600	1	-	-	790
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.00939	4	0.0012	0.0043	<0.0061
Retene	mg/kg	-	0.293	3	0.067	0.19	0.212
Total dibenzothiophenes	mg/kg	-	9.88	4	1.28	3.66	5.84
Total PAHs	mg/kg	-	25.10	4	4.81	11.27	16.86
Total HMW PAHs	mg/kg	-	5.46	4	0.40	3.22	5.01
Total LMW PAHs	mg/kg	-	19.63	4	4.20	8.13	11.90
Predicted PAH toxicity[1]	H.I.	-	1.53	4	1.18	1.97	2.87
Metals that exceed CCME guidelines in 2005							
Arsenic (As)	mg/kg	5.9	**8**	4	1.7	3.7	**6.9**
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	6	2	5	-	7
Chironomus growth - 10d	mg/organism	-	1.31	2	2.1	-	2.8
Hyallela survival - 14d	# surviving	-	5	2	9	-	10
Hyallela growth - 14d	mg/organism	-	0.16	2	0.13	-	1.6

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 2001).

[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Table 5.10-5 Selected sediment quality measurement endpoints, upper Ells River (ELR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	14	1	-	-	1
Silt	%	-	26	1	-	-	2
Sand	%	-	60	1	-	-	97
Total organic carbon	%	-	2	1	-	-	1
Total hydrocarbons							
CCME variables							
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]	150	1	-	-	51
Fraction 3 (C16-C34)	mg/kg	400[2]	**2200**	1	-	-	**600**
Fraction 4 (C34-C50)	mg/kg	2800[2]	960	1	-	-	420
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.00602	1	-	-	<0.0013
Retene	mg/kg	-	0.17	1	-	-	0.0304
Total dibenzothiophenes	mg/kg	-	5.89	1	-	-	0.89
Total PAHs	mg/kg	-	14.76	1	-	-	3.28
Total HMW PAHs	mg/kg	-	3.09	1	-	-	1.25
Total LMW PAHs	mg/kg	-	11.66	1	-	-	2.03
Predicted PAH toxicity[1]	H.I.	-	1.33	1	-	-	1.44
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	-	1	-	-	7
Chironomus growth - 10d	mg/organism	-	-	1	-	-	3.6
Hyallela survival - 14d	# surviving	-	-	1	-	-	6
Hyallela growth - 14d	mg/organism	-	-	1	-	-	0.3

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

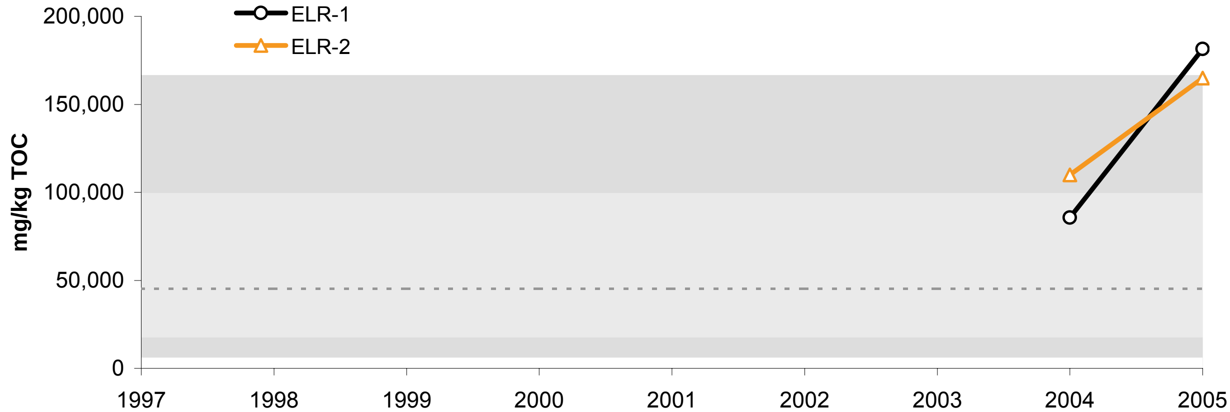
[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

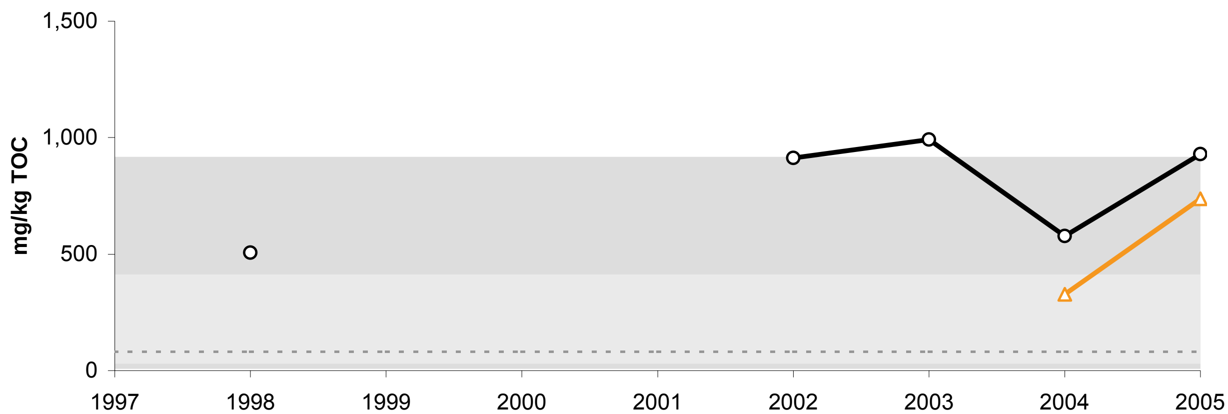
[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Figure 5.10-5 Concentrations of selected sediment quality measurement endpoints in the Ells River (fall data) relative to regional baseline fall concentrations.

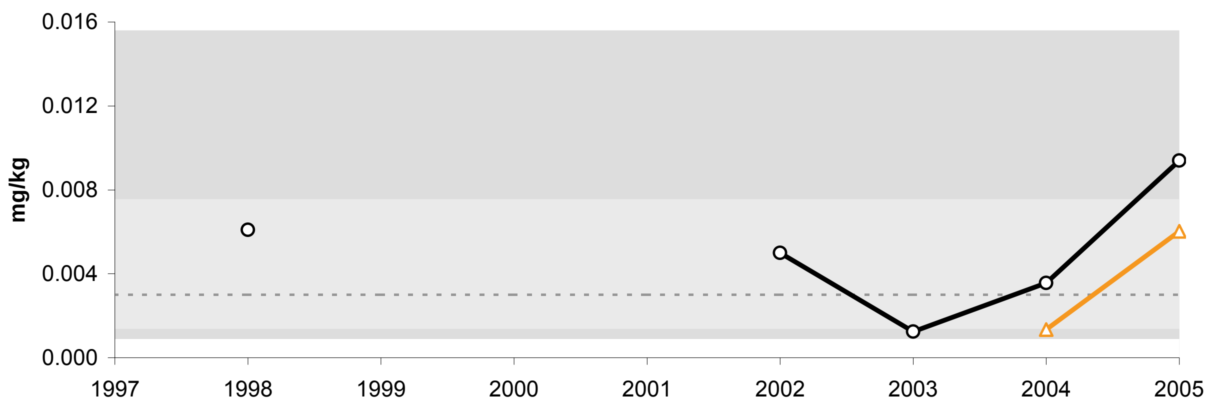
Total Hydrocarbons (C6-C50) (normalized to TOC)



Total Polycyclic Aromatic Hydrocarbons (PAHs) (normalized to TOC)



Naphthalene



[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

Table 5.10-6 Average habitat characteristics of benthic invertebrate sampling reaches in the Ells River, fall 2005.

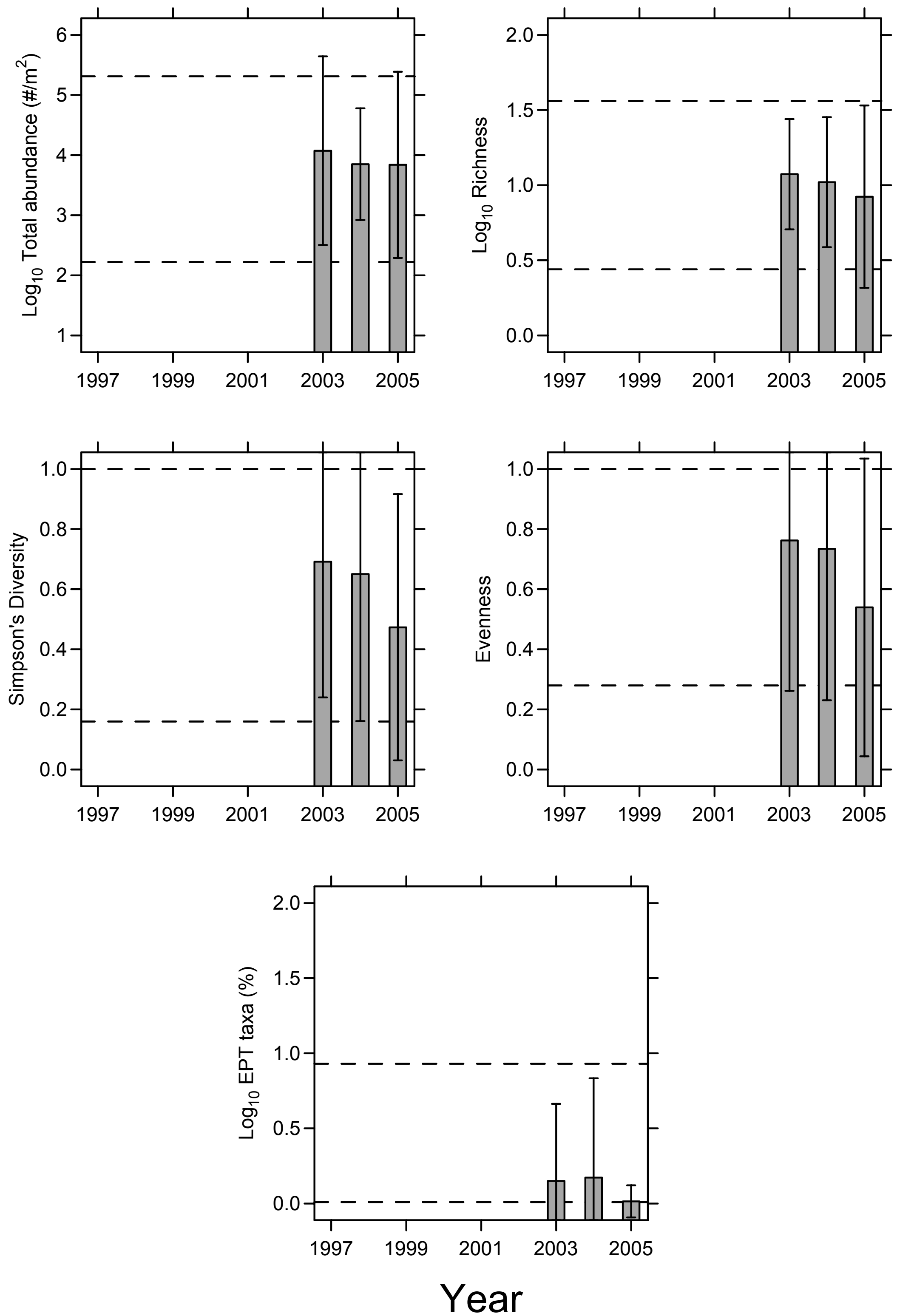
Variable	Units	Reach ELR-D-1	Reach ELR-E-2
Sample date	-	Sept 18, 2005	Sept 16, 2005
Habitat	-	Depositional	Erosional
Water depth	m	0.3	0.3
Current velocity	m/s	0.2	0.8
Macrophyte cover	%	2	<1
Benthic algae[1]	mg/m^2	n/a	39
Field Water Quality			
Dissolved oxygen	mg/L	10	n/a
Conductivity	µS/cm	180	n/a
pH	pH units	8.4	n/a
Water temperature	°C	10.0	2.1
Sediment Composition			
Sand	%	60	n/a
Silt	%	26	n/a
Clay	%	14	n/a
Total Organic Carbon	%	3.0	n/a
Sand/Silt/Clay	%	n/a	5
Small gravel	%	n/a	5
Large gravel	%	n/a	7
Small cobble	%	n/a	32
Large cobble	%	n/a	51
Boulder	%	n/a	0
Bedrock	%	n/a	0

[1] measured as chlorophyll *a*

Table 5.10-7 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of the Ells River, fall 2005.

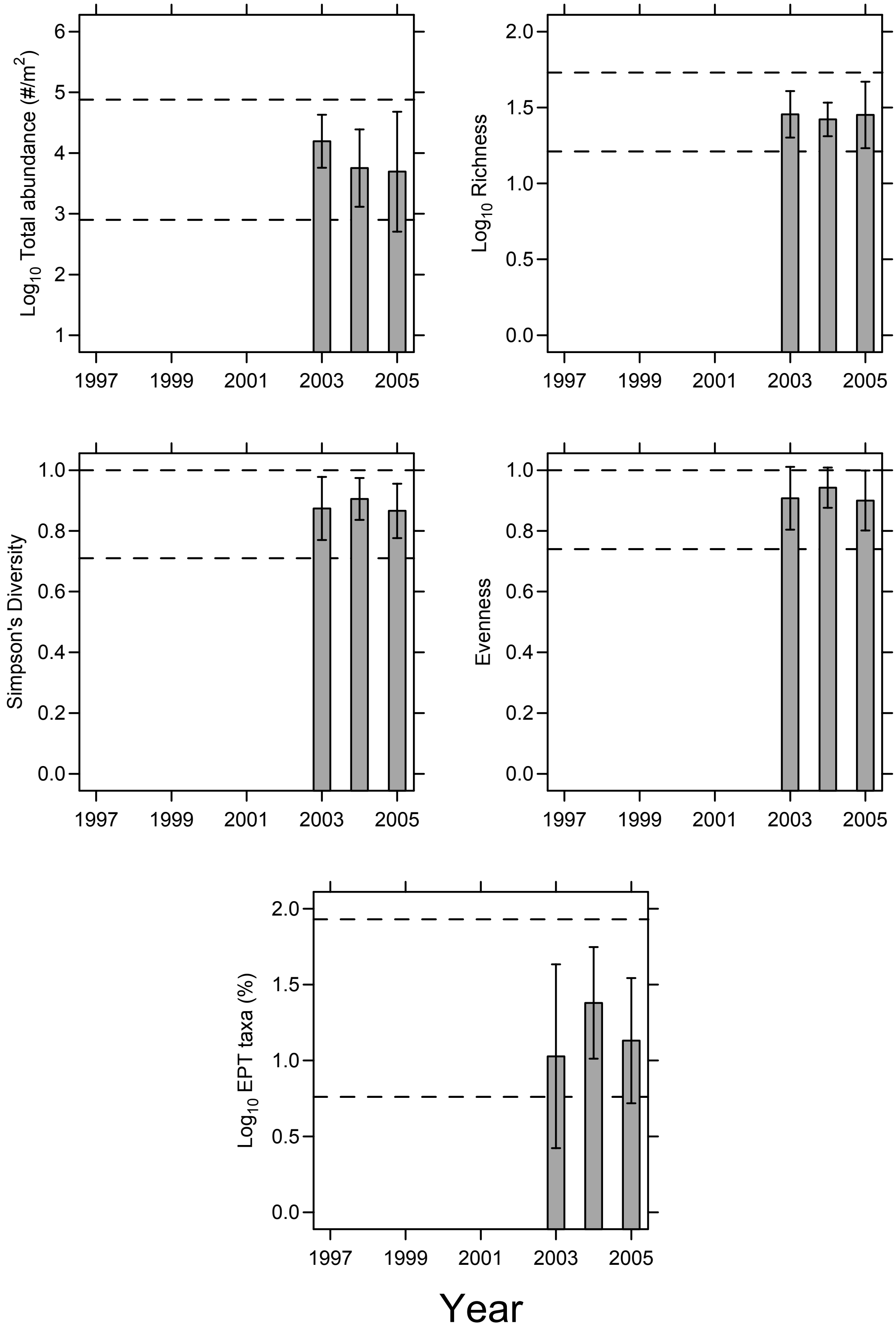
Taxon	Reach ELR-D-1			Reach ELR-E-2		
	2003	2004	2005	2003	2004	2005
Nematoda	<1	2	<1	1	4	<1
Enchytraeidae		<1		1	1	<1
Naididae	24	2	17	13	5	28
Tubificidae	52	55	57	<1	<1	1
Hydracarina	<1	<1		11	8	19
Ostracoda		<1	5	<1	<1	<1
Copepoda	<1				<1	
Bivalvia	<1	<1		<1	1	<1
Gastropoda	<1	<1		1	<1	<1
Ephemeroptera	<1	<1	<1	7	15	7
Plecoptera				1	6	3
Trichoptera	<1	<1		2	4	2
Anisoptera	<1	<1	<1	<1	2	<1
Zygoptera		<1				
Coleoptera		<1			<1	<1
Heteroptera	<1					
Lepidoptera						
Tipulidae		<1		<1		<1
Athericidae			<1	<1	<1	
Tabanidae	<1	1	<1	<1		<1
Empididae	<1	<1	<1	2	3	1
Ceratopogonidae	3	5	1	1	2	<1
Chironomidae	19	32	17	60	49	35
Simuliidae			2	<1	<1	1
Megaloptera						
Total Abundance (No./m^2)	30,917	11,129	12,939	17,207	6,779	7,592
Richness	12	10	9	28	26	28
Simpson's Diversity	0.69	0.65	0.47	0.87	0.91	0.87
Evenness	0.76	0.73	0.64	0.91	0.94	0.90
% EPT	1	1	<1	12	24	14

Figure 5.10-6 Variations in benthic invertebrate community measurement endpoints in the Ells River, reach ELR-D-1.



Note: lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional reaches.

Figure 5.10-7 Variations in benthic invertebrate community measurement endpoints in the Ells River, reach ELR-E-2.



Note: lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional reaches.

Table 5.10-8 Fish inventory results, Ells River, 2004 and 2005.

Species	August 2005 (total effort = 4,963 s)			September 2004 (total effort = 11,264 s)		
	No. Captured	Percent Composition	CPUE (No./100 s)	No. Captured	Percent Composition	CPUE (No./100 s)
Burbot	4	1.53	0.08	0	0	0
Emerald shiner	23	8.81	0.46	0	0	0
Flathead chub	1	0.38	0.02	0	0	0
Lake chub	53	20.31	1.07	8	2.30	0.07
Longnose dace	154	59.00	3.10	205	58.91	1.81
Longnose sucker	7	2.68	0.14	0	0	0
Trout-perch	11	4.21	0.22	34	9.77	0.30
Walleye	3	1.15	0.06	0	0	0
White sucker	5	1.92	0.10	41	11.78	0.36
Yellow perch	0	0	0	1	0.29	0.01
Northern pike	0	0	0	2	0.57	0.01
Pearl Dace	0	0	0	56	16.09	0.48
Spottail shiner	0	0	0	1	0.29	0.01
Total	**261**			**348**		

Table 5.10-9 Morphometric results (mean ± 1 SE) for common fish captured during the Ells River inventory, 2005.

Species	Sample Size	Length (mm)	Weight (g)
Emerald shiner	23	53.2 ± 4.53	2.23 ± 0.461
Lake chub	53	52.7 ± 2.37	1.92 ± 0.242
Longnose dace	154	38.9 ± 1.06	0.89 ± 0.072
Longnose sucker	7	62.3 ± 6.89	3.15 ± 0.930
Trout-perch	11	54.5 ± 4.13	1.84 ± 0.312
White sucker	5	119.6 ± 49.59	4.85 ± 2.066

Figure 5.10-8 Comparison of condition for common fish captured during the Ells River inventory, 2004 and 2005.

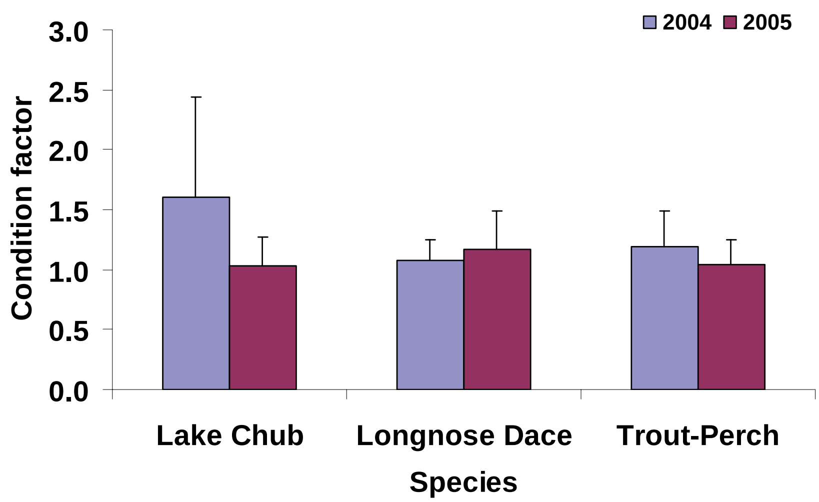


Table 5.10-10 Summary of longnose dace catch per unit effort and morphometric data (mean ± 1 SE), Ells River sentinel species program, 2005.

Month/Area	# of Fish Captured	Effort (s)	CPUE (# fish/100 s)	Length (mm)	Weight (g)	Condition
August						
Lower Site	123	2401	5.12	41.41 ± 1.43	0.989 ± 0.09	1.061 ± 0.026
Upper Site	103	4689	2.20	50.35 ± 1.72	1.912 ± 0.152	1.252 ± 0.091
October						
Lower Site	101	4993	2.02	46.24 ± 1.08	1.088 ± 0.074	0.949 ± 0.010
Upper Site	36	9275	0.13	53.22 ± 2.57	1.991 ± 0.207	1.120 ± 0.028

Notes: October upper site CPUE is based on 12 fish captured in 9,275 seconds, the 24 additional fish included were captured during an unknown amount of effort.

Table 5.10-11 Statistical comparison of longnose dace length-frequency distributions between upper and lower sites, Ells River, 2005.

Analysis	Upper-Lower Site (Between Areas)		Seasonal (August-October, within areas)	
	August	October	Lower Reach	Upper Reach
Kolomogorov-Smirnov two sample test	**<0.001**	**<0.001**	**0.002**	0.607

Note: values in **bold** indicate significant difference in longnose dace population size distribution.

Figure 5.10-9 Cumulative length-frequency distributions for lower and upper sites, Ells River, August 2005.

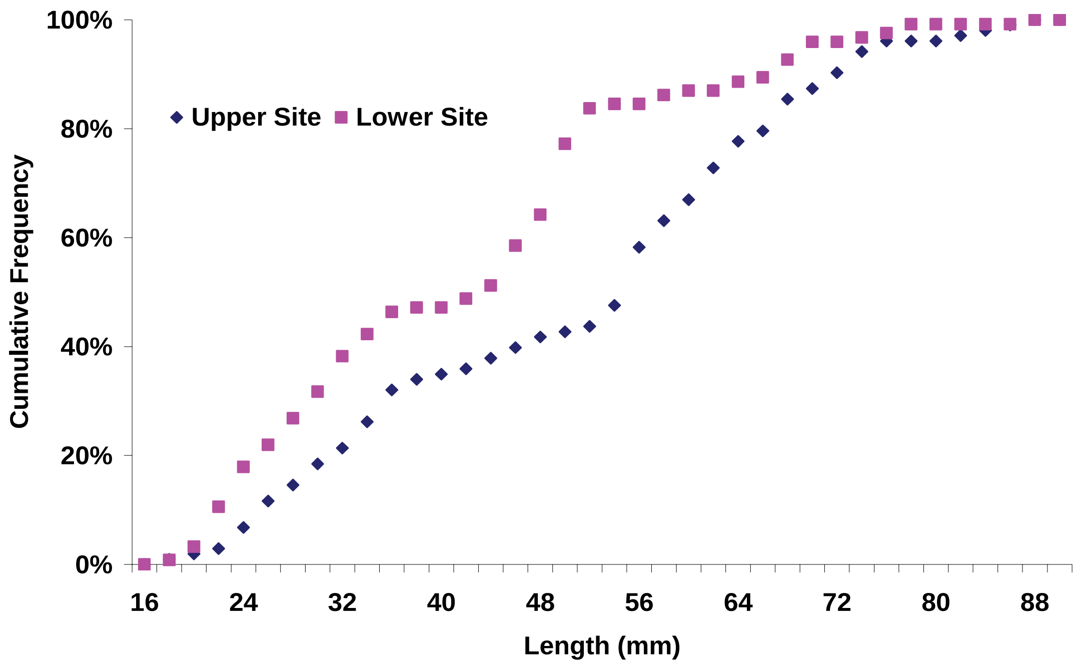


Figure 5.10-10 Cumulative length-frequency distributions for lower and upper sites, Ells River, October 2005.

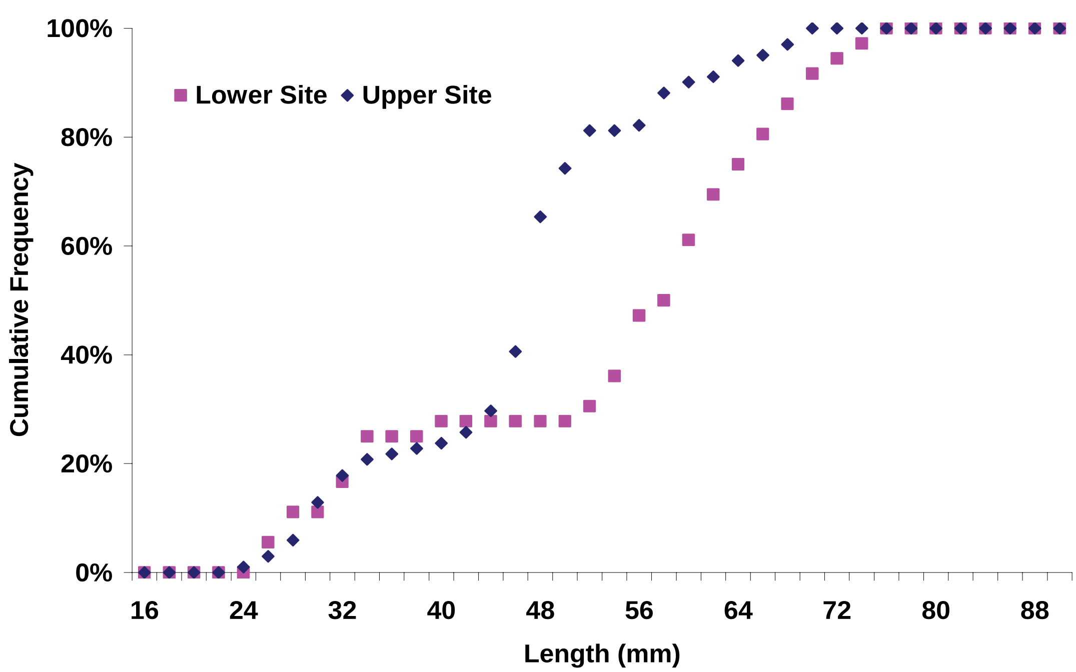


Figure 5.10-11 Seasonal relative length-frequency distributions of longnose dace from the upper site on the Ells River.

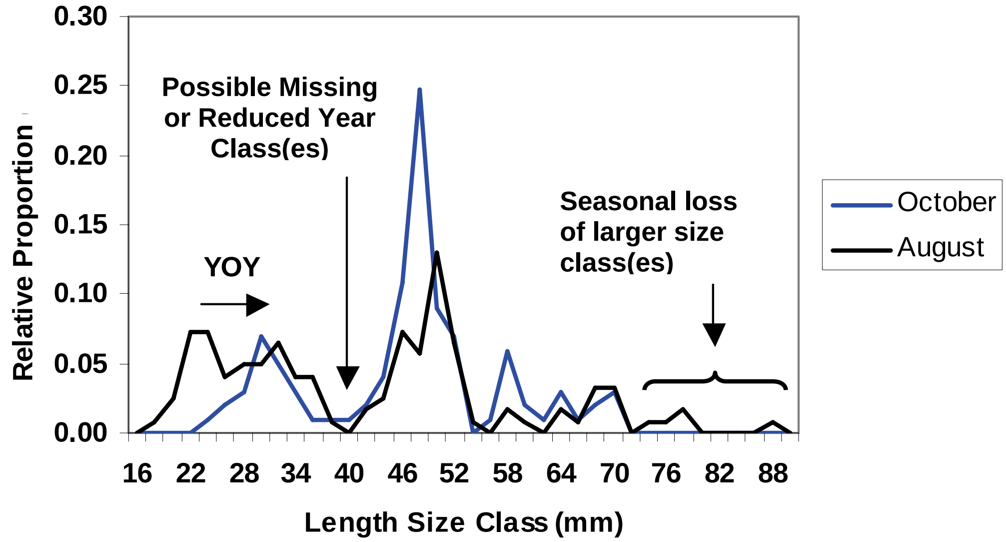


Figure 5.10-12 Seasonal relative length-frequency distributions of longnose dace from the lower site on the Ells River.

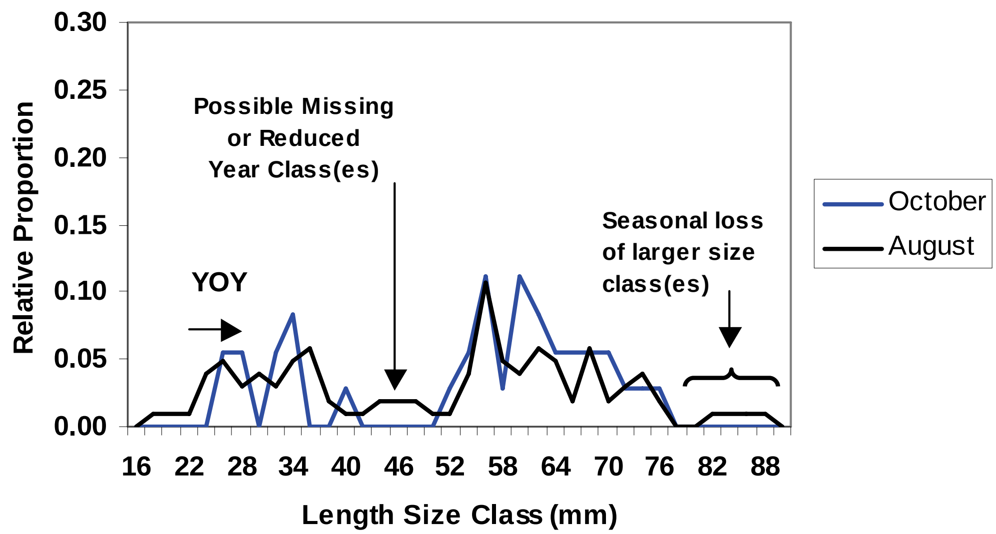


Table 5.10-12 Young-of-year (YOY) morpohometrics (mean ± 1 SE) for the upper and lower sites on the Ells River, August and October 2005.

Month/Area	# of YOY Captured (n=)	Length (mm)	Weight (g)	Condition
August				
Upper	27	22.54 ± 0.431	0.212 ± 0.009	1.292 ± 0.066
Lower	12	23.50 ± 0.821	0.150 ± 0.029	2.065 ± 0.741
October				
Upper	4	28.08 ± 0.537	0.226 ± 0.015	1.010 ± 0.034
Lower	13	26.50 ± 0.646	0.235 ± 0.027	1.245 ± 0.085

Table 5.10-13 Seasonal test results for comparison of longnose dace size between the upper and lower areas on the Ells River, August and October 2005.

Month/Area	df	Pooled Variance	Mean Difference	Probability
Adult				
August				
Length	224	4.027	8.935	**<0.001**
Weight	224	5.389	0.923	**<0.001**
October				
Length	135	2.941	6.985	**0.004**
Weight	135	5.220	0.909	**<0.001**
YOY				
August				
Length	37	1.074	0.907	0.29
Weight	37	2.656	0.012	**0.012**
October				
Length	15	-1.512	-1.577	0.15
Weight	15	0.287	0.009	0.78

Table 5.10-14 Relative proportion of longnose dace populations represented by young-of-year individuals, August and October 2005.

Site	Total Caught	No. Young-of-Year	%. Young-of-Year
August			
Upper	123	27	22%
Lower	103	12	12%
October			
Upper	101	4	13%
Lower	36	13	11%

Note: In August YOY were fish ≤26mm and in October ≤30mm.

Figure 5.10-13 Condition factor for Ells River longnose dace captured during sentinel species program, August 2005.

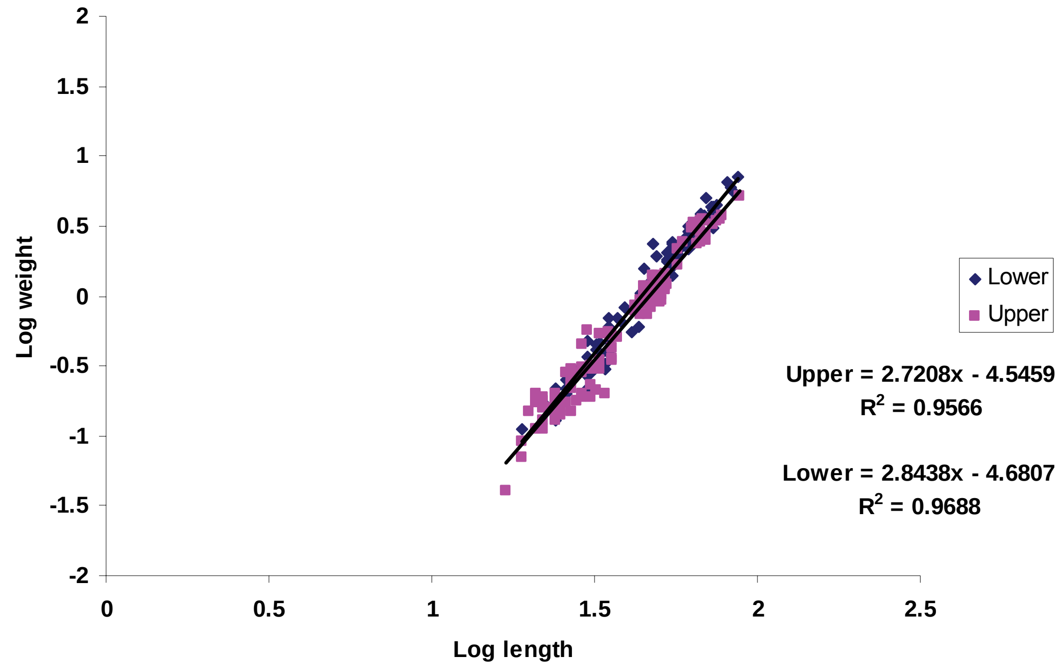


Figure 5.10-14 Condition factor for Ells River longnose dace captured during sentinel species program, October 2005.

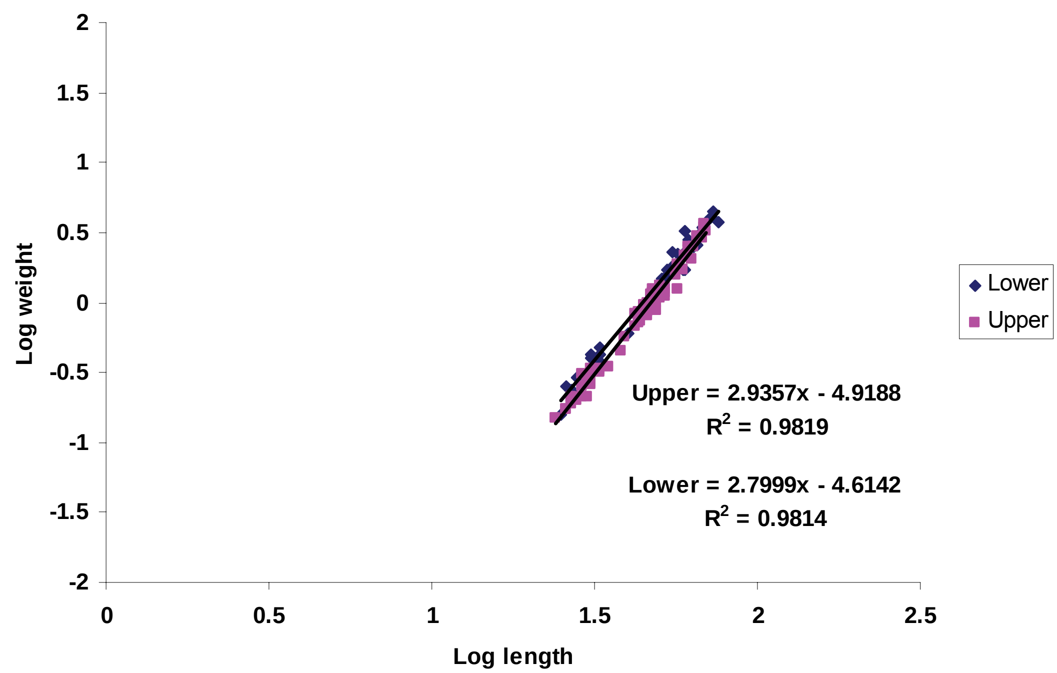


Figure 5.10-15 Condition factor for Ells River YOY longnose dace captured during sentinel species program, August 2005.

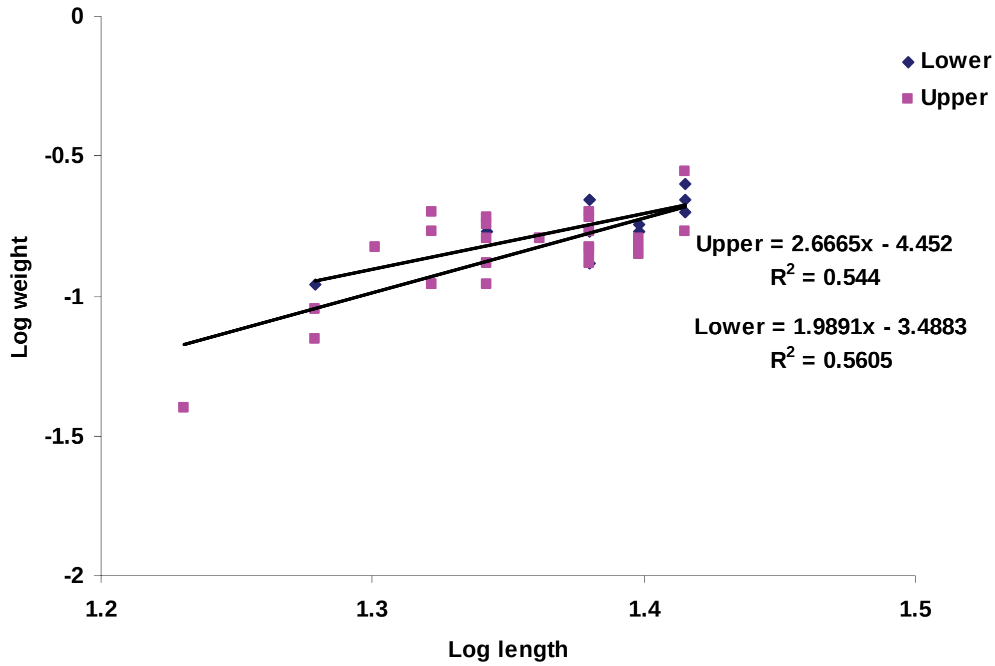
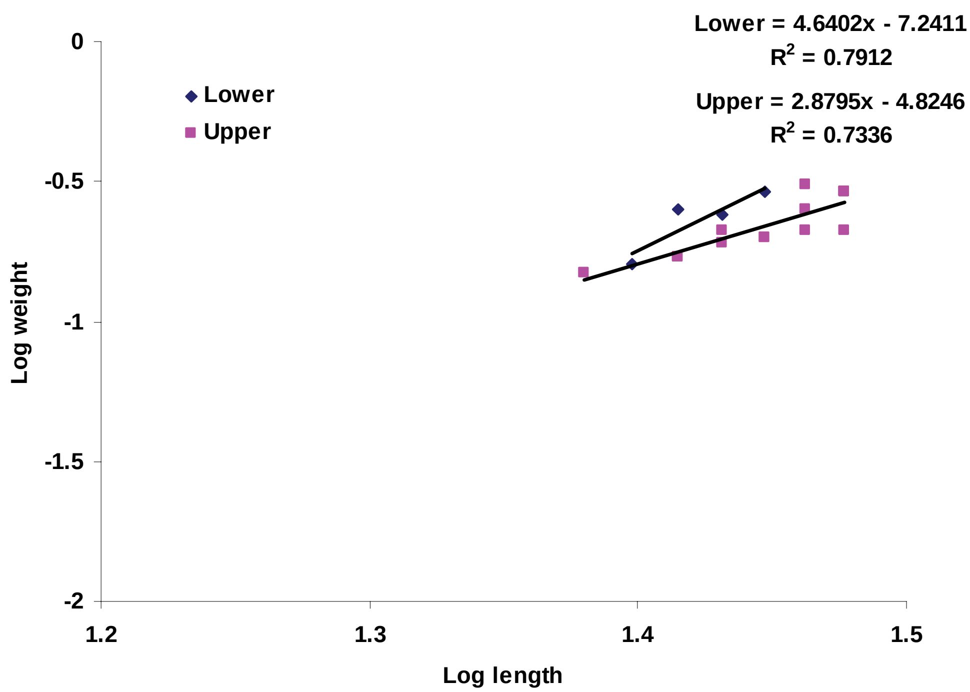


Figure 5.10-16 Condition factor for Ells River YOY longnose dace captured during sentinel species program, October 2005.



5.11 CLEARWATER-CHRISTINA RIVER SYSTEM

Summary of Results

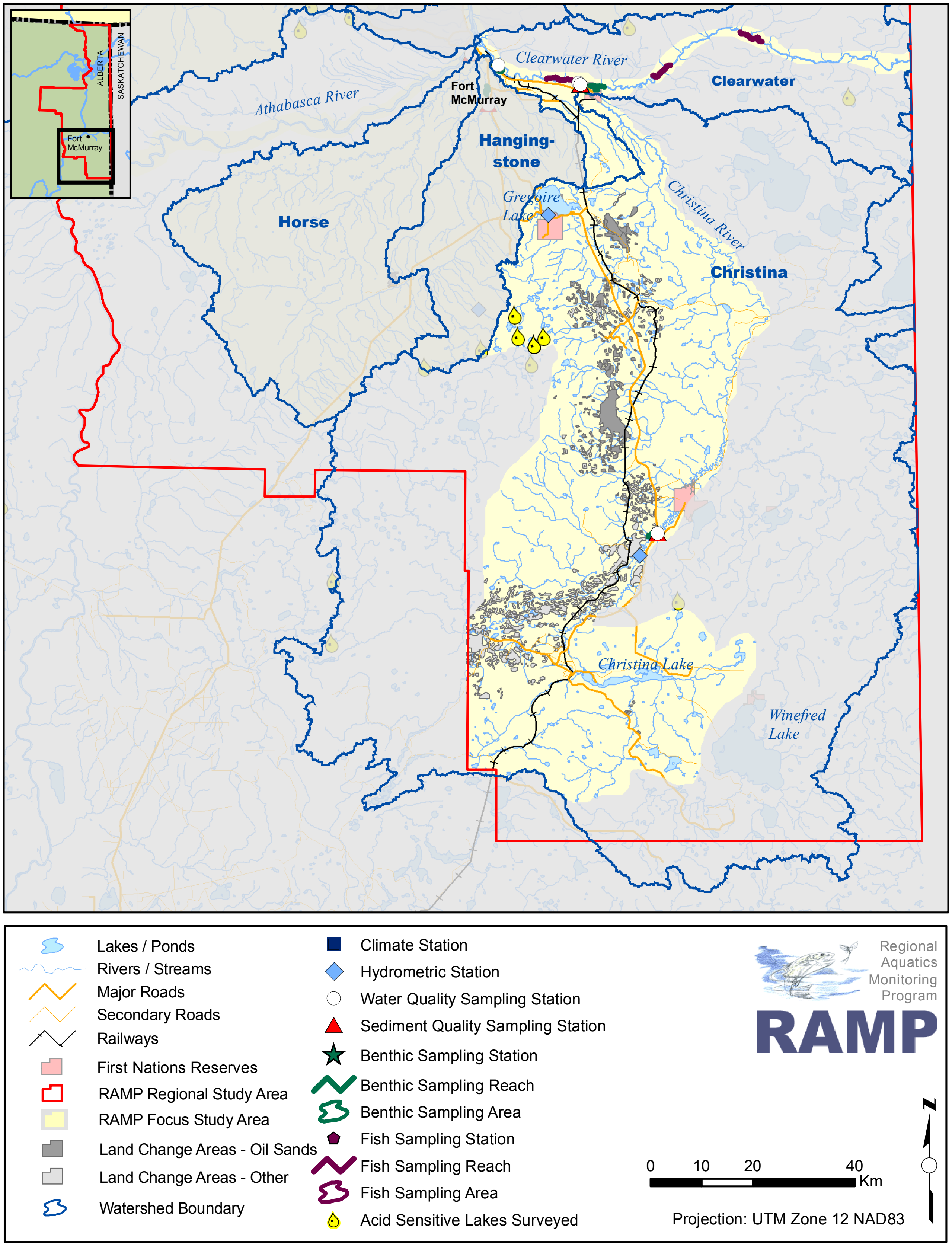
Measurement Endpoint	Summary of 2005 Conditions						
Climate and Hydrology							
	Assessment of Change						
	Negligible	**Low**		**Moderate**	**High**		
Mean open-water season discharge	The Clearwater and Christina watersheds were designated as *reference* watersheds for 2005.						Streamflows were much above normal in both the Clearwater and Christina Rivers in 2005.
Mean winter discharge							
Annual maximum daily discharge							
Minimum open-water season discharge							
Water Quality							
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005[1]**						Water quality was generally consistent between upstream and downstream stations on the Clearwater. On the Christina, TSS levels in fall 2005 were higher than previous and total phosphorus, aluminum, and iron exceeded guidelines in fall 2005. Some metals were elevated in 2005 at all stations. No consistent trends in ion balance have been apparent among any stations since the beginning of sampling at these locations.
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=0)**			**2005 *Reference* Stations (n=4)**			
Physical variables (max=4)	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.			0			
Nutrients (max=12)				7			
Ions (max=8)				0			
Selected metals (max=20)				4			
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[2]**						
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 8 endpoints)**			**2005 *Reference* Stations (n=4 stations X 8 endpoints)**			
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.			6			
Between 5th and 95th percentiles				25			
Less than 5th percentile				1			
Sediment Quality							
Guideline Exceedances	**Station-Endpoint Combinations Exceeding Guidelines in 2005[1]**						
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=0)**			**2005 *Reference* Stations (n=0)**			
Total Hydrocarbons	No sediment quality sampling was conducted in 2005.						
PAHs							
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[3]**						
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 3 endpoints)**			**2005 *Reference* Stations (n=0 stations X 3 endpoints)**			
Greater than 95th percentile	No sediment quality sampling was conducted in 2005.						
Between 5th and 95th percentiles							
Less than 5th percentile							
Benthic Invertebrate Communities							
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline**						All measurement endpoints were within ranges for regional depositional baseline reaches. **Christina:** richness and density were below average for regional depositional baseline reaches. **Clearwater:** richness, abundance, and diversity in reach CLR-D-1 were below average for depositional baseline reaches.
	2005 *Potentially Influenced-Oil Sands* Stations (n=0)			**2005 *Reference* Stations (n=4)**			
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance	No benthic invertebrate community sampling reaches were designated as *potentially influenced-oil sands* in 2005.				4		
Richness					4		
Diversity					4		
Evenness					4		
% EPT					4		
Fish Populations							
Fish Inventory	2005 results were generally similar to 2003 and 2004 results with respect to length-frequency indicators, condition, external health.						Fish catch was higher in 2005 than 2004, in both spring and fall. Species richness was equal to 2004 but less than 2003. Condition estimates from 2003-2005 are generally comparable with those obtained from the Athabasca River. Only 3.4% of fish in the spring inventory were found to have some type of external condition.
Sentinel Studies	No sentinel fish studies conducted in 2005.						
Fish Tissue	**Level of Risk**						
Human Health: Subsistence	Fish tissue program was not conducted in 2005.						
Human Health: Recreational Fishers							
Human Health: General Consumers							
Human Health: Tainting							

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.11-1 Clearwater-Christina River watershed.



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5.11.1 Development Status

All parts of the Christina-Clearwater watersheds within the RAMP FSA are designated as *reference* for 2005. To date, although a number of *in situ* oil sands projects are planned or are undergoing initial development within the Christina River watershed, less than 1% of the watershed area has undergone land change as a results of oil sands activities, while less than 2% of the watershed area has undergone land change as a result of other activities (Section 2). In addition, all parts of both the Horse and the Hangingstone watersheds are designated as *reference* (Section 2), and there has been no oil sands development in the Clearwater River watershed upstream of the Christina River confluence. Therefore, all RAMP stations in the Christina-Clearwater River watersheds in 2005 are designated as *reference* stations and all data gathered at these stations in 2005 are designated as baseline data.

5.11.2 Hydrologic Conditions

Streamflows were much above normal in both the Clearwater and Christina Rivers in 2005. The May-October runoff depth in the Clearwater River basin was 123 mm, 38% above average. The Christina River basin was even wetter, with a May – October runoff depth of 137 mm, nearly double its long-term average of 70 mm.

The Clearwater River runoff hydrograph contained four significant peaks in 2005 (Figure 5.11-2), with the highest peak occurring during snowmelt in April. That peak of 257 m^3/s was 27% higher than the mean annual flood, and was the highest discharge recorded since 1979. Streamflow remained at or above average during the entire monitored season. The minimum open-water discharge on the Clearwater River was 90.7 m^3/s on October 31, 50% higher than the mean annual minimum discharge of 60.9 m^3/s.

In the Christina River basin, the highest discharge of the year occurred in May in response to rainfall, and the snowmelt peak was the third highest event of five significant events during the year (Figure 5.11-3). The May maximum daily discharge of 116 m^3/s was 53% greater than the mean annual flood, and was the highest recorded since 1991. The minimum open-water season discharge was 10.3 m^3/s, 72% higher than average.

5.11.3 Water Quality

In 2005, water quality samples were collected from the Clearwater River upstream of Fort McMurray (CLR-1, *reference*, baseline data, first sampled in 2001) and upstream of the Christina River confluence (CLR-2, *reference*, baseline data, first sampled in 2001), and from the Christina River at the mouth (CHR-1, *reference*, baseline data, first sampled in 2002) and upstream of Janvier (CHR-2, *reference*, baseline data, first sampled in 2002) (Figure 5.11-1). Results of 2005 sampling for selected water quality measurement endpoints are shown in Table 5.11-1 and Table 5.11-2 for the Christina River, and in Table 5.11-3 and Table 5.11-4 for the Clearwater River. Results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.11-4, while all exceedances of CCME/AENV guidelines observed in the Clearwater and Christina Rivers in 2005 are shown in Table 5.11-5.

Water quality was generally consistent between the upstream and downstream stations on the Clearwater River (stations CLR-1 and CLR-2), with the exception of TSS (below detection limit at CLR-1, 36 mg/L at station CLR-2). At both stations, concentrations of total phosphorus, total aluminum, and total and dissolved iron exceeded CCME/AENV guidelines for the protection of aquatic life. Total aluminum concentrations at both stations exceeded the 95th percentile of regional baseline concentrations, and at both stations were higher than previously observed concentrations. Other analytes higher or lower in fall 2005 than previous results include pH (lower in 2005 than in previous years), total and dissolved phosphorus, dissolved organic carbon, total aluminum, total and dissolved iron, and, at station CLR-1, dissolved aluminum, total boron, total molybdenum, and naphthenic acids.

In the Christina River, the concentration of TSS in fall 2005 was higher than previously observed at both stations. Concentrations of total phosphorus, total aluminum, and total iron, analytes typically associated with TSS, exceeded guidelines at both stations in fall 2005. At both stations (CHR-1, CHR-2), concentrations of total phosphorus, total dissolved phosphorus, dissolved organic carbon, dissolved aluminum and dissolved iron were slightly higher than concentrations observed in previous RAMP sampling, while concentrations of total boron and total molybdenum were at or below previously observed minimum concentrations.

Total iron concentrations exceeded CCME/AENV guidelines for the protection of aquatic life in winter, spring, summer, and fall at all four stations in the Clearwater-Christina watershed, while total aluminum exceeded guidelines at all four stations in spring, summer, and fall. Dissolved iron exceeded guidelines (for total iron) in spring, summer, and fall but not in winter, while dissolved aluminum concentrations were below guidelines for total aluminum in all samples. Other metals exceeding guidelines include total cobalt, copper, and lead at stations CLR-1, CHR-1, and CHR-2 (spring). These results indicate that some metals are elevated at these stations under baseline conditions, and often have been lower at CLR-2 than CLR-1. This indicates that the Christina River has a clear effect on water quality in the lower Clearwater River, which limits direct comparisons between upstream (CLR-2) and downstream (CLR-1) Clearwater River stations, should other stations in this watershed become designated as operational.

Ion concentrations in the Christina River were low in fall 2005 relative to previous years, while ion concentrations in the Clearwater River were within historical ranges (Figure 5.11-4). The ionic composition of water samples collected in fall 2005 was similar to previous years at all stations (Figure 5.11-5). The ionic composition of Clearwater and Christina River samples collected by RAMP since 2001 indicates variation over a narrow range of characteristics for Clearwater River and lower Christina River stations, with inter-annual variation occurring primarily in chloride and calcium concentrations (Figure 5.11-5). Relative ion concentrations at the upper Christina River station (CHR-2) differ from these other stations, with consistently higher concentrations of calcium and consistently lower concentrations of chloride. No consistent trends in ion balance are apparent among these stations since the beginning of RAMP sampling at these locations.

5.11.4 Sediment Quality

The 2005 RAMP Sediment Quality component did not include any activities in the Clearwater-Christina watersheds.

5.11.5 Benthic Invertebrate Communities

In 2005, benthic invertebrate community samples were collected from reaches on the Clearwater River located downstream (CLR-D-1, *reference*, baseline data from 2001) and upstream (CLR-D-2, *reference*, baseline data from 2001) of the Christina River confluence, and from reaches on the Christina River located near the mouth (CHR-D-1, *reference*, baseline data from 2002) and upstream of Janvier (CHR-D-2, *reference*, baseline data from 2002) (Figure 5.11-1). Reach CHR-D-2 of the Christina River was moderately deep (0.6 m) with moderate current velocity (0.3 m/s) and no macrophyte cover (Table 5.11-6). In contrast, reach CHR-D-1 was shallower (0.4 m) with slower water (0.2 m/s) and some macrophyte cover (1%). The substrate in both reaches CHR-D-1 and CHR-D-2 was dominated by sand, with minor amounts of silt and clay. Total organic carbon content was also very minor with < 1 % in both sampled reaches ((Table 5.11-6). Habitats in reaches CLR-D-1 and CLR-D-2 in the Clearwater River were similar in being dominated by sand, with small amounts of silt and clay, and low total organic carbon content (≤ 1%) (Table 5.11-7). Reach CLR-D-2 was moderately deeper (0.6 m) than reach CLR-D-1 (0.3 m), while current velocities were similar (~ 0.2 to 0.3 m/s).

Chironomids and tubificids dominated the benthos of both reach CHR-D-1 and reach CHR-D-2, while EPT taxa, nematodes, other worms, and other fly larvae were sub-dominant (Table 5.11-8). Sphaeriid clams were present in reach CHR-D-1, but not reach CHR-D-2. Several pollution-sensitive taxa were common to both reaches and included the mayfly *Ametropus neavei*, the stonefly *Isoperla*, and the empidid *Hemerodromia*. *Polypedilum* was the most common chironomid in both reaches. All benthic invertebrate community measurement endpoints were within the ranges for regional depositional baseline reaches, while the number of taxa and numbers of individuals were just below average for other regional depositional baseline reaches in the RAMP FSA (Figure 5.11-6).

Chironomids and tubificids also dominated the benthos of the Clearwater River, with sub-dominant groups including other worms, flies and molluscs (sphaeriid clams, snails; Table 5.11-9). The empidid, *Hemerodromia*, was the most pollution-sensitive fly in reach CLR-D-1. *Heptagenia* and *Polypedilum* were the most common mayfly and chironomid, respectively. Pollution-sensitive taxa in reach CLR-D-2 included early instars of *Perlodidae* (stonefly), and the dragonfly *Ophiogomphus*. *Polypedilum* was most common chironomid, while *Baetis*, *Stenonema* and early instars of *Leptophlebiidae* represented the Ephemeroptera. While all benthic invertebrate community measurement endpoints in both reaches were generally within the ranges for regional depositional baseline reaches, the number of taxa (3), abundance (~15,000/m^2), and diversity (0.3) in reach CLR-D-1 were somewhat lower than average for depositional baseline reaches in the RAMP FSA (Figure 5.11-7).

5.11.6 Fish Populations

Fish population monitoring for 2005 in the Clearwater River/Christina River watersheds consisted of a spring and fall fish inventory on the Clearwater River at three locations: CR1; CR2; and CR3 (Figure 5.11-1).

During the spring sampling, a total of 593 fish were captured consisting of 12 different species. Fall sampling efforts resulted in the capture of 488 fish from 11 different species (Table 5.11-10 and Table 5.11-11). In total, 17 fish species were recorded (captured and observed) during the Clearwater River inventory in 2005. Species richness in 2005 was equal to that reported for 2004, but less than 2003 when 21 fish species were captured/observed. Although only 17 species of fish were identified during the 2005 Clearwater fish inventory, collectively over the past three years (spring and fall combined) a total of 22 different species have been captured and/or observed in the Clearwater River. This is the same total species richness reported in Golder (2003a), which listed eight sport species, two sucker species and twelve small-bodied forage species.

Percent species composition and catch-per-unit-effort for fish caught during the inventory are provided in Table 5.11-10 and Table 5.11-11. White sucker (19.22%) and goldeye (12.14%) were the two dominant large-bodied fish species captured in the spring, while pearl dace (23.44%) and trout-perch (2.70%) were the most common small-bodied fish species (Table 5.11-10). In the fall, white sucker was the dominant large-bodied species captured (32.38%) followed by northern pike (17.62%), while the spottail shiner (14.34%) and the pearl dace (11.89%) were the most common small-bodied species caught (Table 5.11-11).

No lake whitefish were captured during fall inventory activities on the Clearwater River in 2005, an identical result to 2003 and 2004 (although sampling effort was comparatively low during the fall 2003 and 2004 inventories). The absence of lake whitefish during the fall period in three consecutive years supports the possibility that the Clearwater River is not used by this species for the species annual spawning migration, unlike the Athabasca River. Jones et al. *(*1978) found neither lake whitefish spawning nor lake whitefish in spawning condition present in a fall study on the Clearwater River.

The total catch during the 2005 Clearwater River fish inventory was substantially higher than in 2004 (Table 5.11-12). However, in 2004 low, turbid water conditions and technical difficulties reduced the effectiveness of the fall inventory. Catch results for 2005 closely resembled those of 2003, while spring values have exhibited higher historical variability than fall values across the three-year data record.

Length-Frequency Analysis

Length-frequency distributions for indicator fish species captured during the 2005 Clearwater River inventory are shown in Figure 5.11-8 to Figure 5.11-12. Data were pooled to include fish captured in the spring and fall, and were compared to 2003 and 2004 results.

The dominant length class for walleye in 2005 was 401 to 450 mm (~31% of total number of walleye captured in 2005 Clearwater inventory), bordered by two sub-dominant size classes (351 to 400 mm and 451 to 500 mm, Figure 5.11-8). While this walleye size-class distribution pattern was similar to that observed in the 2004 Clearwater inventory for this species, the total relative percentage of smaller length size classes (<251 mm) was lower in 2005 relative to 2003 and 2004. The dominant length class was similar to historical length-frequency distributions for walleye observed in the Athabasca River from 1997 to 2005 (Figure 5.1-21).

The dominant length classes for goldeye in 2005 were 401 to 450 mm and 351 to 375 mm (Figure 5.11-9), which is identical to results from the 2004 Clearwater River fish inventory, and similar to Athabasca River goldeye sampled in 2004 (Figure 5.1-22).

Longnose sucker captured in the 2005 Clearwater River inventory were primarily small to mid-size individuals; the dominant length in the length-frequency distribution for this species was 201 to 250 mm (Figure 5.11-10). This was the same pattern observed in 2004, while the dominant size class for this species in 2003 was even smaller (101 to 150 mm). This contrasts with historical results (1997-1999) for the Athabasca River in which the dominant length class was typically 350 to 450 mm (Figure 5.1-23).

Northern pike sampled in 2005 were predominantly in the 501 to 550 mm and 551 to 600 mm length classes, with a smaller peak in the 351 to 400 mm length class (Figure 5.11-11). While these results are similar to 2003 and 2004 inventory results for the

Clearwater River, the relative abundance of larger northern pike length size classes was less than that for 2003 and 2004 in that no individuals over 651 mm were captured in 2005.

The co-dominant length classes for white sucker captured during the 2005 Clearwater River fish inventory were 351 to 400 mm and 401 to 450 mm (Figure 5.11-12). This is in contrast to 2004 when the dominant size class was 51 to 100 mm, but similar to 2003 when the largest number of fish were also in the 401 to 450 mm size.

Condition Factor

Mean condition factors for indicator fish species captured in the spring and fall of the 2005 Clearwater River inventory are shown in Figure 5.11-13 relative to 2003 and 2004 values. Lake whitefish (none captured in 2004) and trout-perch (body weight not measured) are not included. Although some variability has been observed, the magnitude of differences among years for each species has been limited.

External Fish Health

Only 20 of the 593 fish (3.4%) in the spring 2005 inventory were found to have some type of external abnormality. Abnormalities observed were primarily associated with minor skin or body surface aberrations (e.g., raised or missing scales) and old wounds/scars. The 2005 index scores for indicator fish species collected from the Clearwater River including goldeye, longnose sucker, walleye and white sucker, were similar or less than those recorded in the Athabasca River inventory (Table 5.11-13).

5.11.7 Summary of Conditions

Monitoring activities in the Clearwater River and Christina River watersheds in 2005 focused on expanding baseline datasets for hydrology, water quality, benthic invertebrate communities and fish populations.

Runoff volume and streamflows in both the Clearwater River and Christina River watersheds were above normal in 2005. Water quality measurement endpoints were generally within historical ranges and within the range for regional reference stations. Guideline exceedance of selected water quality measurement endpoints was restricted to nutrients and metals, with more than 50% of nutrient-endpoint combinations exceeding existing guidelines. Concentrations of water quality endpoints were often different from concentration at CLR-2, the designated reference station. Benthic invertebrate community measurement endpoints were within the range for the appropriate regional reference conditions, although density and richness indices in both sampled reaches of the Christina River and in the lower sampled reach of the Clearwater River were lower than the regional averages for these indices. These results, along with similar 2004 results for water quality and benthic invertebrate communities, indicate upper sampling stations and reaches in these watersheds may not be suitable as reference stations.

A third year of fish inventory work on the Clearwater River was conducted to expand the baseline dataset for this river. Fish community composition, length-frequency relationships external fish health indices, and condition factors were similar to what was found in 2003 and 2004, although there were some shifts in the length-frequency distributions for some species. These measurement endpoints were also similar in 2005 to what has been measured in the Athabasca River (with the exception of lake whitefish in the Athabasca River). Information obtained in 2005 provided additional evidence that lake whitefish do not use the Clearwater watershed for spawning migration.

Figure 5.11-2 Clearwater River: 2005 hydrograph and historical context.

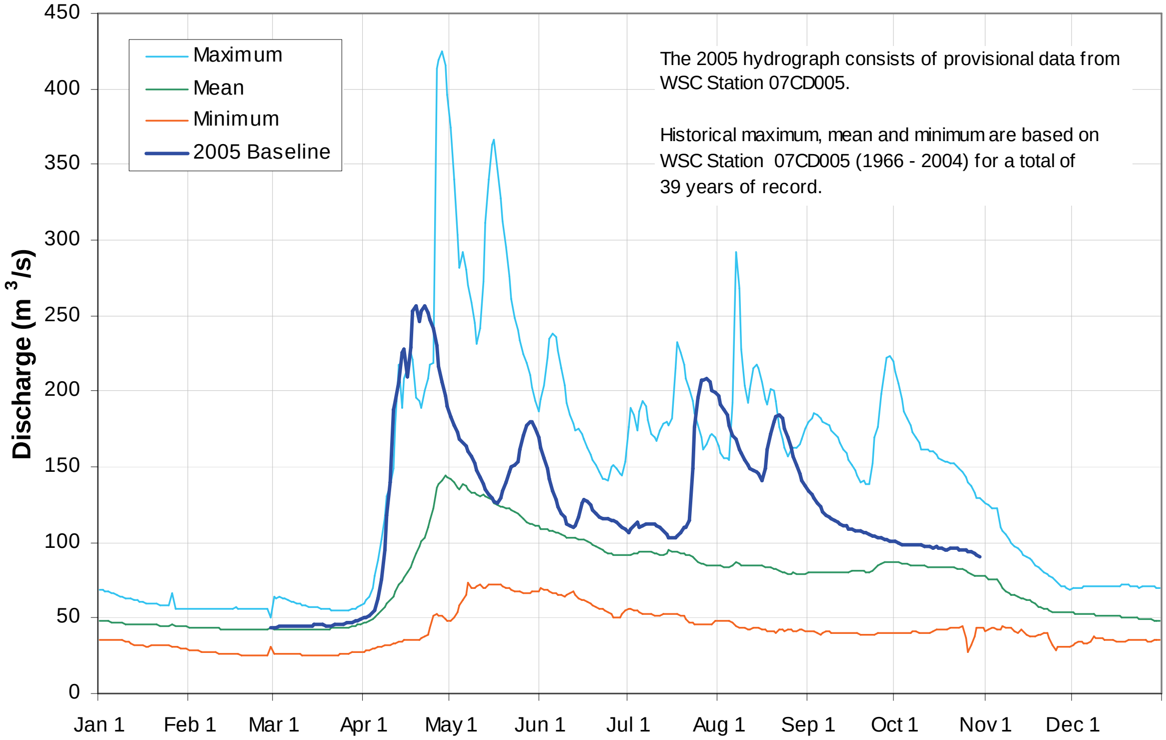


Figure 5.11-3 Christina River: 2005 hydrograph and historical context.

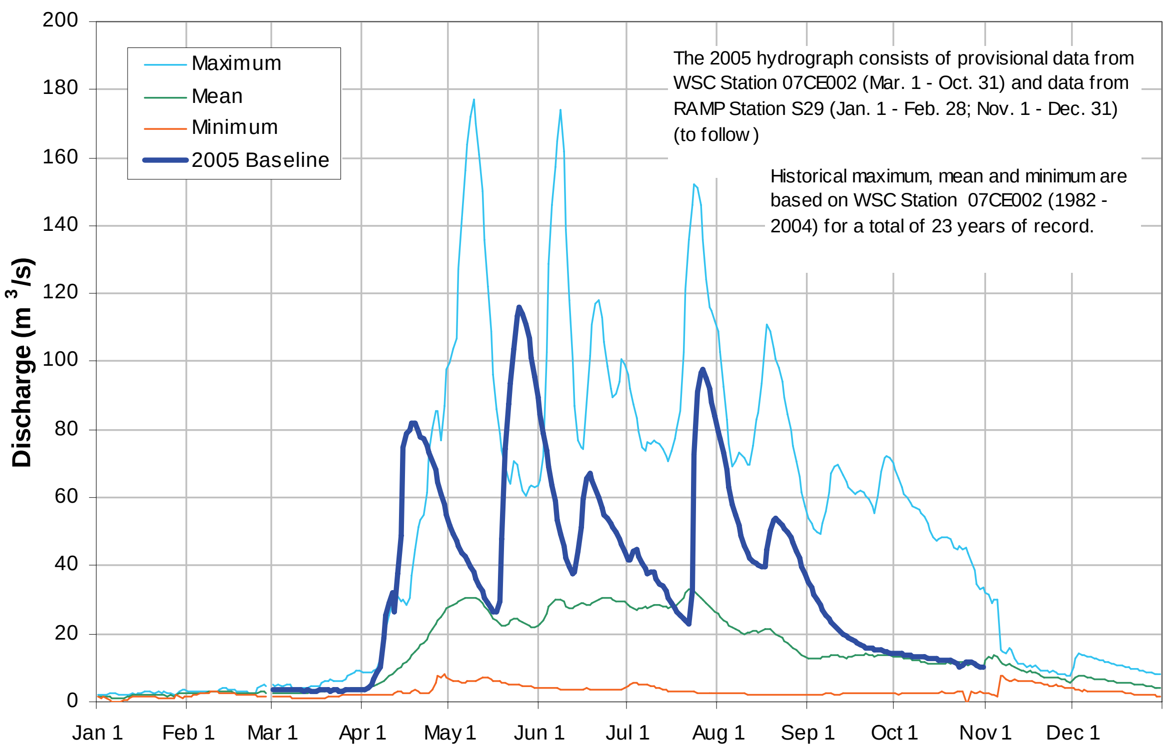


Table 5.11-1 Concentrations of water quality measurement endpoints, mouth of Christina River (CHR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	3	8.1	8.3	8.4
Total suspended solids	mg/L	-[1]	38	3	<3	10	26
Conductivity	µS/cm	-	269	3	291	295	375
Nutrients							
Total phosphorus	mg/L	0.05	**0.108**	3	0.049	**0.058**	**0.064**
Total dissolved phosphorus	mg/L	0.05[2]	0.03	3	0.021	0.023	0.025
Total nitrogen*	mg/L	1.0	**1.1**	3	0.6	0.7	**1.6**
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	22	3	14	16	16
Ions							
Sodium	mg/L	-	20	3	25	27	34
Calcium	mg/L	-	26	3	27	29	30
Magnesium	mg/L	-	7.8	3	8.5	8.7	9.1
Chloride	mg/L	230, 860[3]	21	3	24	30	41
Sulphate	mg/L	100[4]	6.8	3	6.9	7.4	7.9
Total dissolved solids	mg/L	-	160	3	140	240	250
Total alkalinity	mg/L		101	3	110	115	118
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.425**	3	**0.238**	**0.587**	**0.733**
Dissolved aluminum	mg/L	0.1[2]	0.0099	3	0.0066	0.0079	0.0092
Total boron	mg/L	1.2[4]	0.0271	3	0.0494	0.0536	0.0664
Total molybdenum	mg/L	0.073	0.00016	3	0.00035	0.00038	0.0004
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Dissolved iron	mg/L	0.3[2]	**0.71**	3	0.26	**0.34**	**0.49**
Total iron	mg/L	0.3	**1.5**	3	**0.78**	**1.11**	**1.60**

Note: Guideline values are CCME/AENV guidelines 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 1999).

4 B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.11-2 Concentrations of water quality measurement endpoints, upper Christina River (CHR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	3	8.1	8.2	8.3
Total suspended solids	mg/L	-[1]	13	3	8	8	9
Conductivity	µS/cm	-	197	3	211	226	266
Nutrients							
Total phosphorus	mg/L	0.05	**0.095**	3	0.048	**0.055**	**0.068**
Total dissolved phosphorus	mg/L	0.05[2]	**0.051**	3	0.026	0.033	0.038
Total nitrogen*	mg/L	1.0	**1.4**	3	0.6	0.8	**1.4**
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	20	3	14	15	18
Ions							
Sodium	mg/L	-	6	3	7	8	10
Calcium	mg/L	-	26	3	28.5	28.9	35
Magnesium	mg/L	-	8	3	8	9	11
Chloride	mg/L	230, 860[3]	2	3	<1	2	2
Sulphate	mg/L	100[4]	6.4	3	4.4	5.8	9.6
Total dissolved solids	mg/L	-	130	3	140	190	240
Total alkalinity	mg/L		97	3	106	113	138
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.237**	2	0.049	-	0.093
Dissolved aluminum	mg/L	0.1[2]	0.013	2	0.004	-	0.008
Total boron	mg/L	1.2[4]	0.0316	2	0.0367	-	0.0459
Total molybdenum	mg/L	0.073	0.00042	2	0.00042	-	0.0006
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	0.9
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total Kjeldahl nitrogen	mg/L	1.0[6]	**1.3**	3	0.5	0.7	**1.3**
Total phenols	mg/L	0.004	**0.006**	3	<0.001	**0.010**	**0.019**
Total copper	mg/L	0.002-0.004[7]	**0.00428**	2	0.0001	-	0.0004
Dissolved iron	mg/L	0.3[2]	**1.4**	2	**0.41**	-	**0.64**
Total iron	mg/L	0.3	**2.6**	2	**1.00**	-	**1.08**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

[6] Guideline is for total nitrogen.

[7] Guideline is hardness-dependent.

Table 5.11-3 Concentrations of water quality measurement endpoints, mouth of Clearwater River (CLR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.5	4	7.7	8.0	8.2
Total suspended solids	mg/L	-[1]	<3	4	6	10	38
Conductivity	µS/cm	-	197	4	177	253	291
Nutrients							
Total phosphorus	mg/L	0.05	**0.063**	4	0.033	0.043	**0.051**
Total dissolved phosphorus	mg/L	0.05[2]	0.028	4	0.012	0.018	0.022
Total nitrogen*	mg/L	1.0	0.6	4	0.3	0.4	0.7
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	14	4	8	9.5	10
Ions							
Sodium	mg/L	-	17	4	16	26	31
Calcium	mg/L	-	16	4	15	18	18
Magnesium	mg/L	-	5.2	4	5.1	5.8	5.9
Chloride	mg/L	230, 860[3]	21	4	17	35	43
Sulphate	mg/L	100[4]	5.7	4	5.2	7.3	7.7
Total dissolved solids	mg/L	-	130	4	60	165	200
Total alkalinity	mg/L		63	4	59	68	71
Organic compounds							
Naphthenic acids	mg/L	-	2	4	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**1.46**	4	**0.14**	**0.34**	**0.72**
Dissolved aluminum	mg/L	0.1[2]	0.0148	4	0.0059	0.0078	<0.01
Total boron	mg/L	1.2[4]	0.0548	4	0.0275	0.0360	0.045
Total molybdenum	mg/L	0.073	0.00036	4	0.00016	0.00019	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Dissolved iron	mg/L	0.3[2]	**0.76**	4	0.16	0.25	**0.35**
Total iron	mg/L	0.3	**2.43**	4	**0.51**	**0.84**	**1.55**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Table 5.11-4 Concentrations of water quality measurement endpoints, upper Clearwater River (CLR-2), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.2	4	7.6	7.8	8.0
Total suspended solids	mg/L	-[1]	36	4	7	7	25
Conductivity	µS/cm	-	155	4	138	206	249
Nutrients							
Total phosphorus	mg/L	0.05	**0.074**	4	0.032	0.035	0.043
Total dissolved phosphorus	mg/L	0.05[2]	0.026	4	0.01	0.018	0.021
Total nitrogen*	mg/L	1.0	0.5	4	0.3	0.4	**1.2**
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	9	4	6	7	8
Ions							
Sodium	mg/L	-	15	4	13	22	29
Calcium	mg/L	-	11	4	10	12	13
Magnesium	mg/L	-	3.9	4	3.7	4.3	5
Chloride	mg/L	230, 860[3]	22	4	16	31	43
Sulphate	mg/L	100[4]	5	4	4.4	6.5	7.6
Total dissolved solids	mg/L	-	130	4	40	125	160
Total alkalinity	mg/L		44	4	39	45	49
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.70**	4	**0.13**	**0.19**	**0.50**
Dissolved aluminum	mg/L	0.1[2]	0.0093	4	0.005	0.0093	0.040
Total boron	mg/L	1.2[4]	0.0142	4	0.018	0.025	0.030
Total molybdenum	mg/L	0.073	0.000095	4	0.0001	0.000119	0.0002
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Dissolved iron	mg/L	0.3[2]	**0.67**	4	0.16	0.22	**0.33**
Total iron	mg/L	0.3	**2.1**	4	**0.56**	**0.70**	**1.17**

Note: Guideline values are CCME/AENV guidelines 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 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

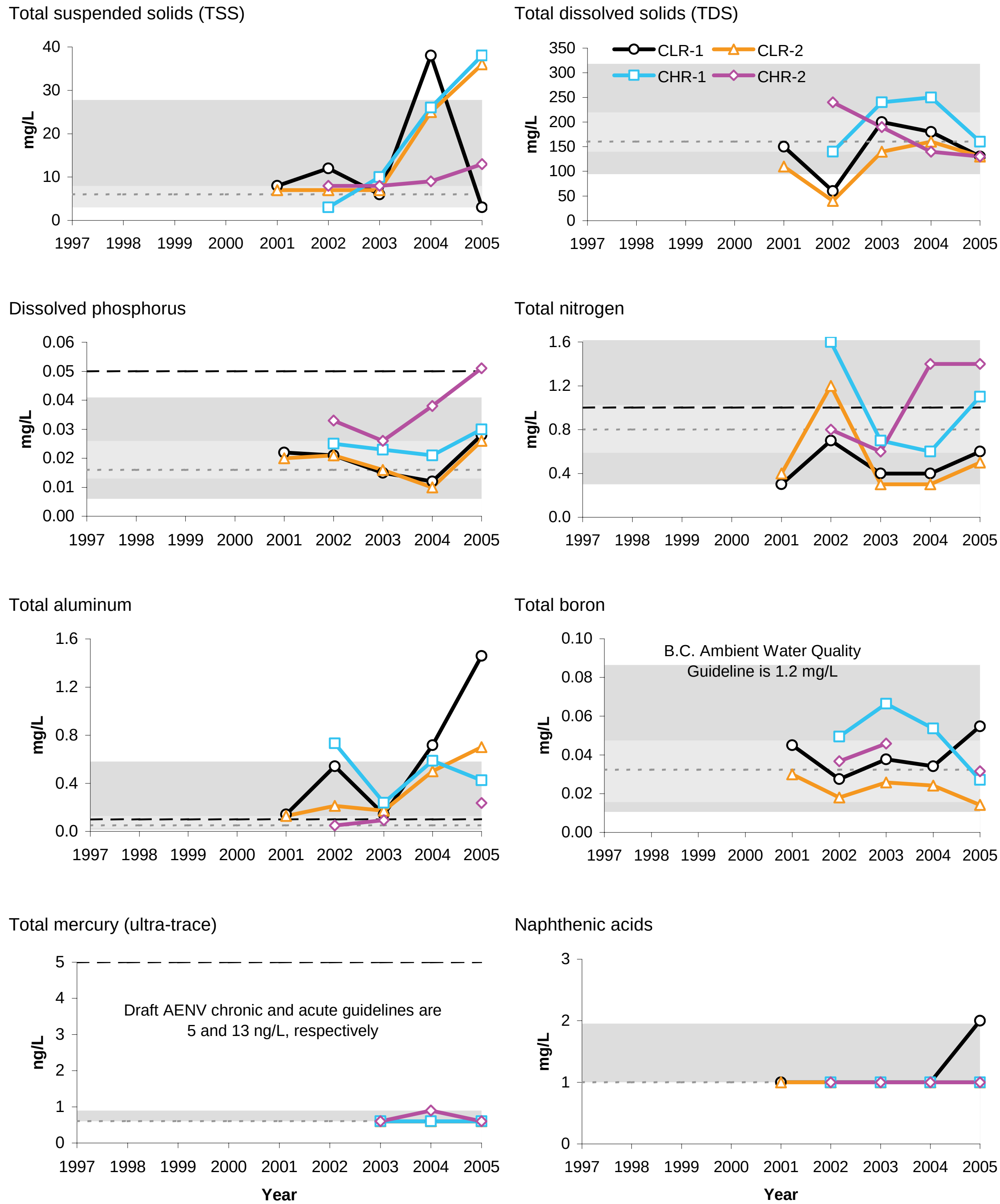
[5] Draft AENV guidelines for chronic and acute total mercury concentrations, respectively (AENV 1999).

Table 5.11-5 Water quality guideline exceedances, Clearwater-Christina River watersheds, 2005.

Parameter	Units	Guideline*	CLR-1	CLR-2	CHR-1	CHR-2
Winter						
Total phosphorus	mg/L	0.05	-	-	**0.051**	**0.054**
Total iron	mg/L	0.3	**0.77**	**0.779**	**0.996**	**0.946**
Spring						
Total phosphorus	mg/L	0.05	**0.242**	-	**0.322**	**0.279**
Total Kjeldahl nitrogen	mg/L	1.0[1]	-	-	**1.2**	-
Total phenols	mg/L	0.004	**0.008**	**0.005**	**0.008**	-
Total aluminum	mg/L	0.1	**3.39**	**0.79**	**5.45**	**2.31**
Total cobalt	mg/L	0.0009[2]	**0.00155**	-	**0.00285**	**0.0013**
Total copper	mg/L	0.002-0.004[3]	**0.00423**	-	**0.00605**	**0.00273**
Dissolved iron	mg/L	0.3[4]	**0.364**	-	**0.411**	**0.591**
Total iron	mg/L	0.3	**4.06**	**1.25**	**7.24**	**4.1**
Total lead	mg/L	0.001-0.007[3]	**0.00237**	-	**0.00464**	**0.00229**
Summer						
Dissolved phosphorus	mg/L	0.05[4]	-	-	-	**0.052**
Total phosphorus	mg/L	0.05	**0.065**	**0.056**	**0.113**	**0.133**
Total phenols	mg/L	0.004	-	-	-	**0.006**
Total aluminum	mg/L	0.1	**0.53**	**0.438**	**0.891**	**0.359**
Dissolved iron	mg/L	0.3[4]	**0.411**	**0.362**	**0.484**	**0.937**
Total iron	mg/L	0.3	**1.12**	**0.998**	**1.91**	**2.08**
Fall						
Dissolved phosphorus	mg/L	0.05[4]	-	-	-	**0.051**
Total phosphorus	mg/L	0.05	**0.063**	**0.074**	**0.108**	**0.095**
Total Kjeldahl nitrogen	mg/L	1.0[1]	-	-	-	**1.3**
Total phenols	mg/L	0.004	-	-	-	**0.006**
Total aluminum	mg/L	0.1	**1.46**	**0.701**	**0.425**	**0.237**
Total copper	mg/L	0.002-0.004[3]	-	-	-	**0.00428**
Dissolved iron	mg/L	0.3[4]	**0.756**	**0.672**	**0.711**	**1.41**
Total iron	mg/L	0.3	**2.43**	**2.07**	**1.49**	**2.62**

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.
[1] Guideline is for total nitrogen.
[2] B.C. Working Water Quality Guideline (2001).
[3] Guideline is hardness-dependent.
[4] Guideline is for total analyte (no guideline for dissolved species).

Figure 5.11-4 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.

[1] 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 5.11-5 Piper diagram of fall ion concentrations in Clearwater-Christina River system.

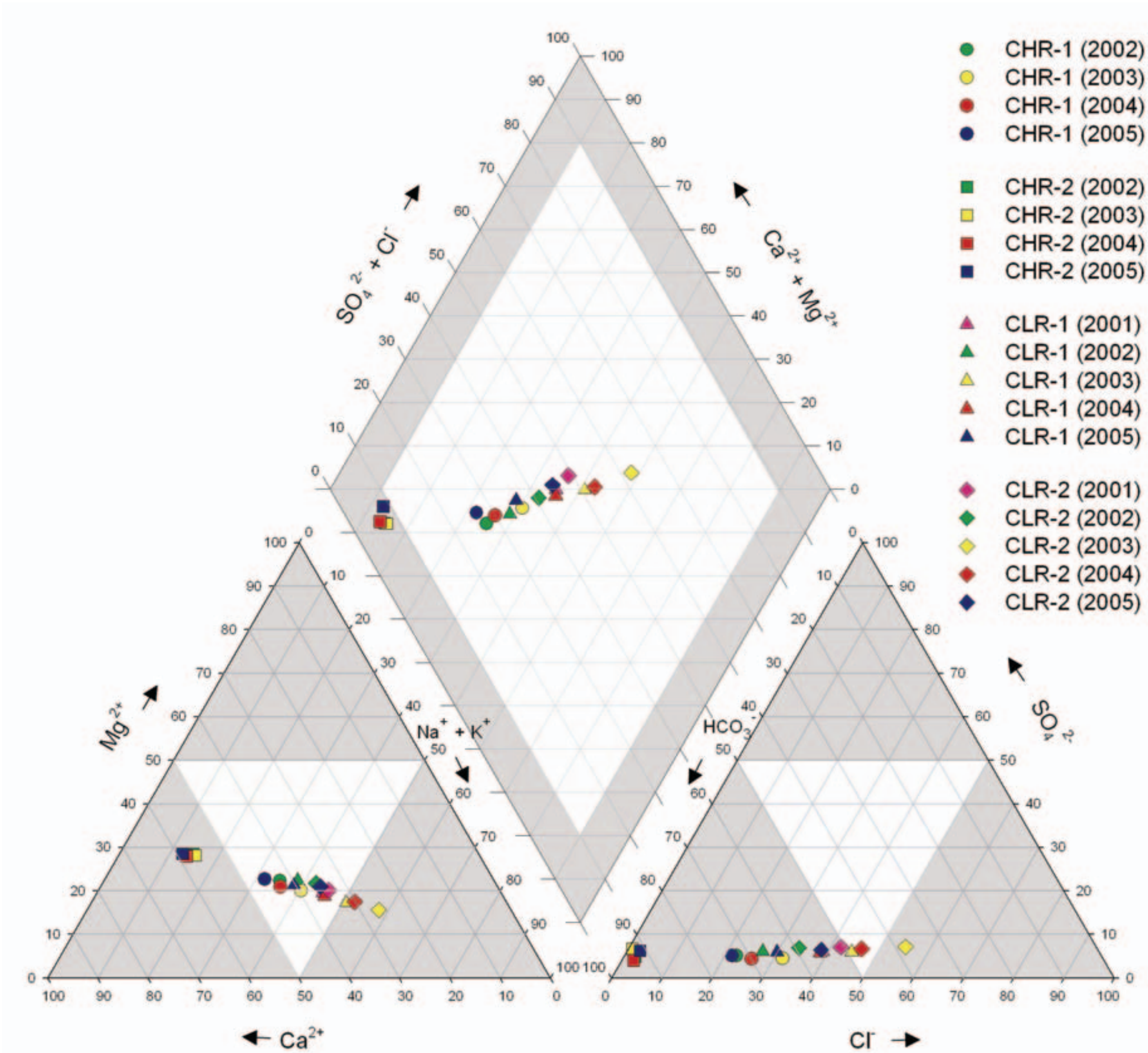


Table 5.11-6 Average habitat characteristics of benthic invertebrate community sampling reaches in the Christina River, fall 2005.

Variable	Units	Reach CHR-D-1	Reach CHR-D-2
Sample date	-	Sept. 13, 2005	Sept. 12, 2005
Habitat	-	Depositional	Depositional
Water depth	m	0.4	0.6
Current velocity	m/s	0.2	0.3
Macrophyte cover	%	1	0
Field Water Quality			
Dissolved oxygen	mg/L	n/a	n/a
Conductivity	µS/cm	n/a	n/a
pH	pH units	8.5	8.0
Water temperature	°C	11.9	12.5
Sediment Composition			
Sand	%	77	87
Silt	%	13	11
Clay	%	9	4
Total Organic Carbon	%	0.7	0.8

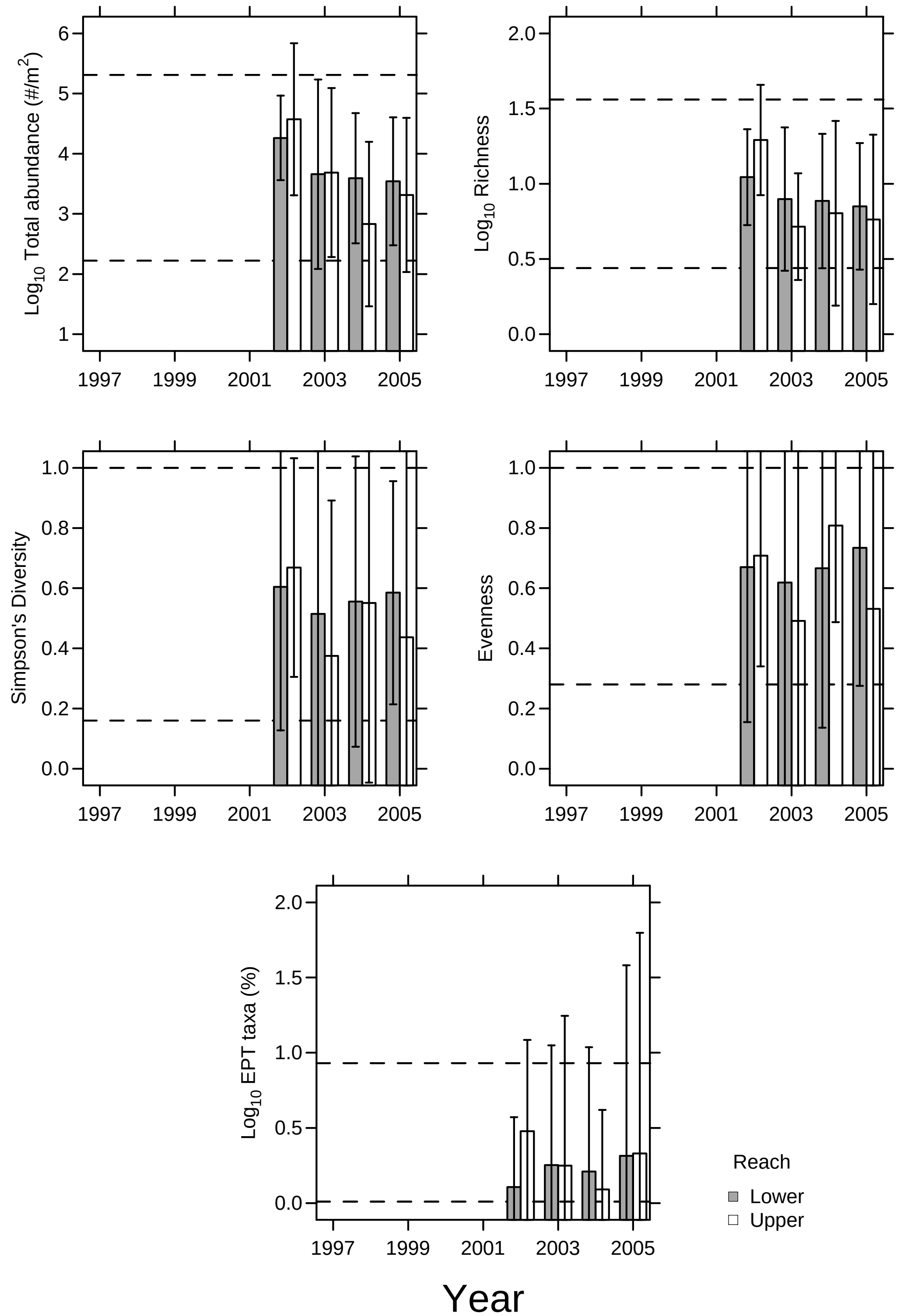
Table 5.11-7 Average habitat characteristics of benthic invertebrate community sampling reaches in the Clearwater River, fall 2005.

Variable	Units	Reach CLR-D-1	Reach CLR-D-2
Sample date	-	Sept. 15-16, 2005	Sept. 15, 2005
Habitat	-	Depositional	Depositional
Water depth	m	0.3	0.6
Current velocity	m/s	0.2	0.3
Macrophyte cover	%	n/a	n/a
Field Water Quality			
Dissolved oxygen	mg/L	n/a	n/a
Conductivity	µS/cm	235	n/a
pH	pH units	8.0	9.7
Water temperature	°C	11.6	10.4
Sediment Composition			
Sand	%	65	77
Silt	%	23	14
Clay	%	12	9
Total Organic Carbon	%	1.0	0.9

Table 5.11-8 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of the Christina River, fall 2005.

Taxon	Reach CHR-D-1				Reach CHR-D-2			
	2002	2003	2004	2005	2002	2003	2004	2005
Nematoda	1	1	2	1	1	<1	11	<1
Glossiphoniidae	<1				<1			
Erpobdellidae		<1	<1					
Enchytraeidae				<1			3	<1
Naididae	<1	5	1	2		<1	4	
Tubificidae	44	66	50	45	23	<1	33	4
Lumbriculidae		<1	<1					
Hydracarina						<1		
Ostracoda	2	<1	9		24	<1	2	
Copepoda	<1	<1			<1		<1	
Chydoridae					<1			
Macrothricidae					<1			
Bivalvia	11	1	1	<1	3	<1	7	
Gastropoda	2	<1			<1			
Ephemeroptera		1	1	1	2	<1	<1	<1
Plecoptera	<1	<1	<1	<1				<1
Trichoptera	<1	<1		<1	<1	<1		4
Anisoptera	<1	<1	<1	<1	<1	<1		<1
Coleoptera							<1	
Heteroptera		<1			<1			
Tipulidae			<1		<1		2	
Dolichopodidae			<1				4	
Tabanidae	<1	<1		<1	<1		<1	1
Empididae		<1	1	1	<1			1
Ephydridae			<1				4	
Ceratopogonidae	<1	1	7	3	2		2	1
Chironomidae	39	23	29	46	44	99	28	89
Total Abundance (No./m^2)	22,928	10,178	6,405	5,052	63,968	12,963	1,305	3,848
Richness	11	8	8	7	20	5	6	6
Simpson's Diversity	0.60	0.51	0.56	0.59	0.67	0.37	0.55	0.44
Evenness	0.67	0.62	0.67	0.73	0.71	0.49	0.81	0.63
% EPT	<1	2	2	6	3	3	1	7

Figure 5.11-6 Variation in benthic invertebrate community measurement endpoints in the Christina River, CHR-D-1 and CHR-D-2.

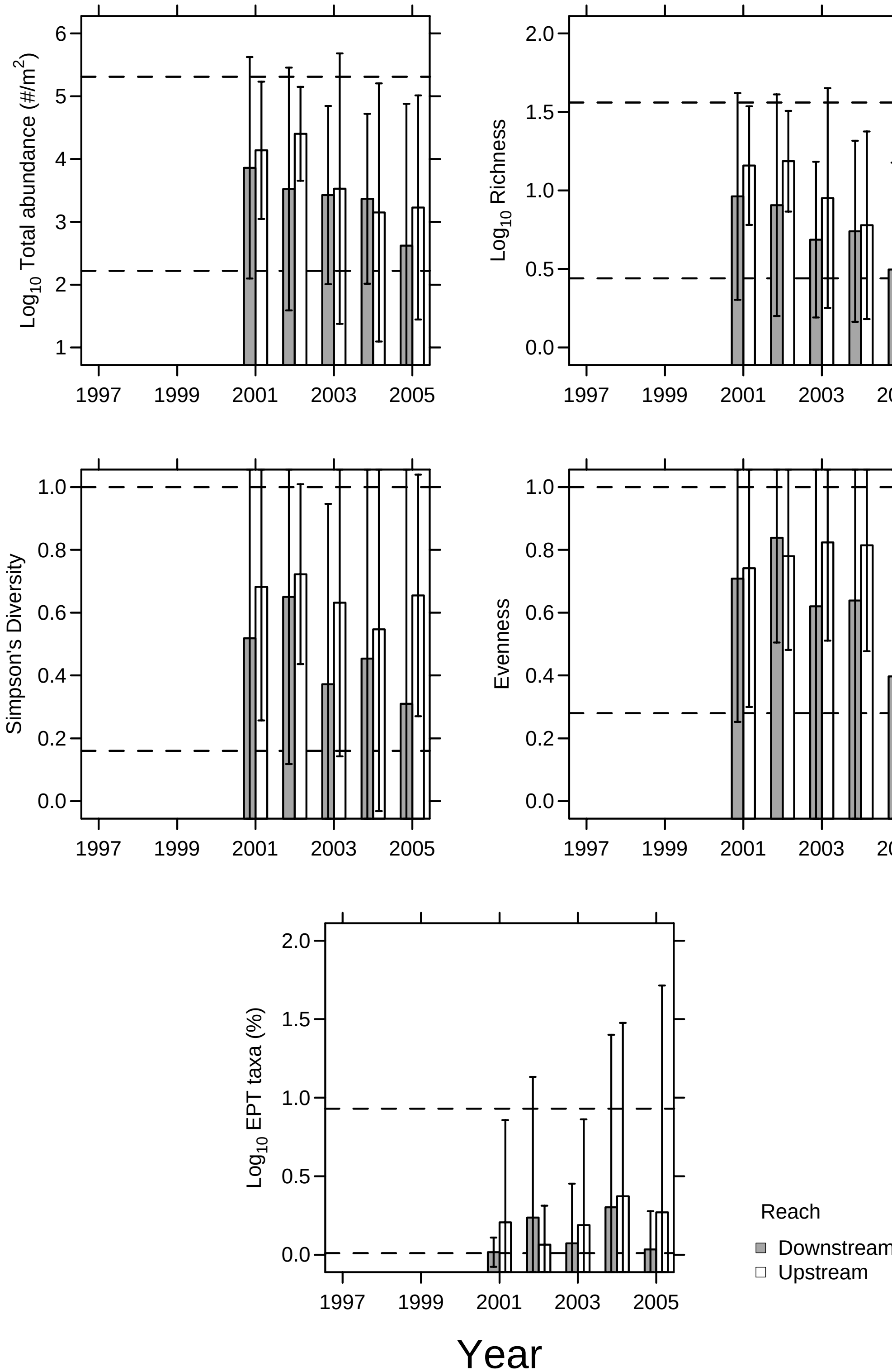


Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites. Lower reach: reach CHR-D-1; Upper reach: reach CHR-D-2.

Table 5.11-9 Summary of major taxon abundances and benthic invertebrate community measurement endpoints in reaches of the Clearwater River, fall 2005.

Taxon	Clearwater River downstream of Christina River					Clearwater River upstream of Christina River				
	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005
Nematoda	<1	<1	<1	<1	4	1	1	1	8	<1
Glossiphoniidae	<1					<1		<1	<1	
Erpobdellidae								<1	<1	
Enchytraeidae		2		<1		<1		1		1
Naididae	3	3	2	1	<1	21	5	10	1	1
Tubificidae	27	10	14	6	31	26	17	8	40	45
Lumbriculidae			<1				<1	<1	<1	
Hydracarina	<1			<1		<1	<1	<1		
Ostracoda	6	2				3	7	12	<1	
Copepoda						<1	<1		1	
Chydoridae	3			<1		1	<1	<1		
Macrothricidae							5	<1	<1	
Amphipoda						<1	<1	<1		
Bivalvia	20	6	1	1	<1	11	10	33	14	1
Gastropoda	<1	<1			<1	1	<1	<1		<1
Ephemeroptera	<1	2	<1	1	<1	1	<1	<1	1	1
Plecoptera		1		<1		<1		<1	<1	1
Trichoptera		1				<1	<1	<1		2
Anisoptera	1	1	<1	<1	<1	<1	<1	<1	1	2
Zygoptera	<1	<1				<1	<1		<1	
Coleoptera		<1		<1		<1	<1	<1		
Heteroptera	<1	0					<1	<1		
Lepidoptera		<1					<1			
Tipulidae							<1	<1	1	
Dolichopodidae								<1	<1	
Tabanidae	<1	<1				<1	<1		<1	<1
Empididae		1		<1	1	<1	<1		1	1
Ceratopogonidae	1	2	<1	1	6	1	1	4	<1	1
Chironomidae	38	68	80	87	57	34	51	27	32	44
Simuliidae		<1	2			<1	<1			
Megaloptera						<1				
Total Abundance (No./m^2)	2,060	1,014	5,126	4,991	1,522	2,184	3,249	1,431	5,572	6,443
Richness	10	9	4	5	3	14	15	10	6	8
Simpson's Diversity	0.52	0.65	0.37	0.45	0.31	0.68	0.72	0.63	0.55	0.65
Evenness	0.71	0.84	0.62	0.64	0.90	0.74	0.78	0.82	0.81	0.80
% EPT	<1	2	<1	3	<1	1	<1	8	4	8

Figure 5.11-7 Variation in benthic invertebrate community measurement endpoints in the Clearwater River, CLR-D-1 and CLR-D-2.



Note: Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional reaches. Downstream reach: reach CLR-D-1; Upstream reach: reach CLR-D-2.

Table 5.11-10 Results of the spring fish inventory on the Clearwater River, 2005.

Species	Spring Results (total effort = 14,592 s.)		
	Total Captured	Captured Species Composition (% of total)	CPUE (#/100s)
Brook stickleback	1	0.17	0.01
Flathead chub	9	1.52	0.06
Goldeye	72	12.14	0.49
Lake whitefish	16	2.70	0.11
Longnose sucker	9	1.52	0.06
Mountain whitefish	7	1.18	0.05
Northern pike	57	9.61	0.39
Pearl dace	139	23.44	0.95
Spottail shiner	91	15.35	0.62
Trout-perch	16	2.70	0.11
Walleye	62	10.46	0.42
White sucker	114	19.22	0.78
TOTAL	**593**	**100**	**4.06**

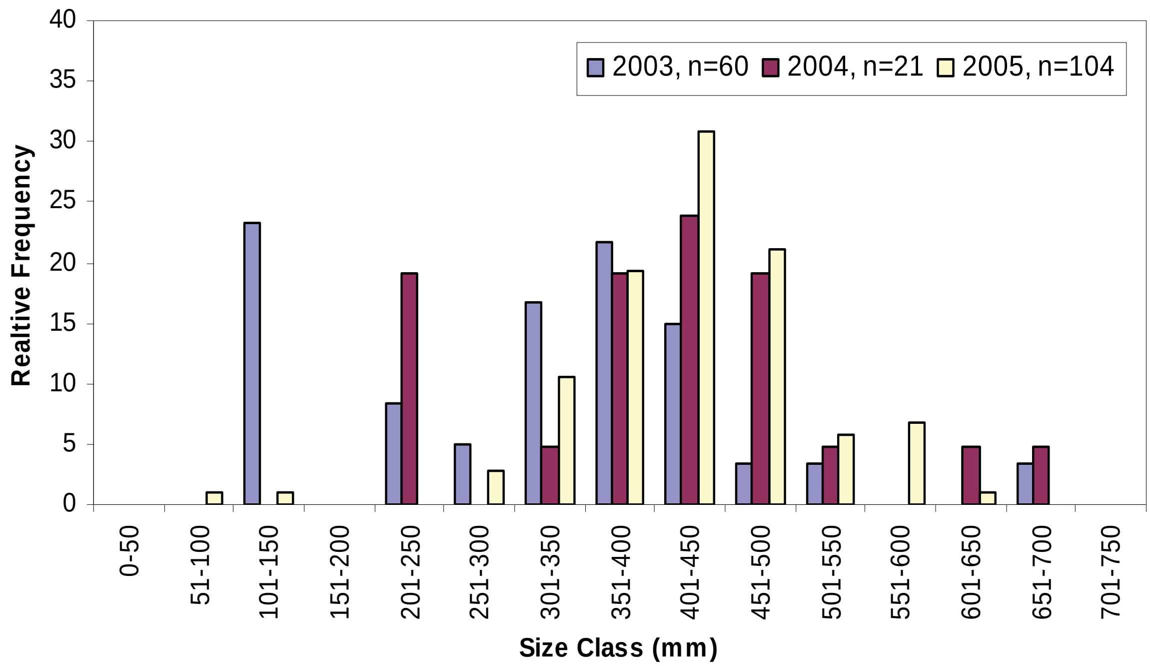
Table 5.11-11 Results of the fall fish inventory on the Clearwater River, 2005.

Species	Fall Results (total effort = 17,193 s)		
	Total Captured	Captured Species Composition (% of total)	CPUE (#/100s)
Arctic grayling	7	1.43	0.04
Burbot	1	0.20	0.01
Longnose sucker	31	6.35	0.18
Mountain whitefish	15	3.07	0.09
Northern pike	86	17.62	0.50
Pearl dace	58	11.89	0.34
Sculpin sp.	6	1.23	0.03
Spottail shiner	70	14.34	0.41
Trout-perch	14	2.87	0.08
Walleye	42	8.61	0.24
White sucker	158	32.38	0.92
TOTAL	**488**	**100**	**2.84**

Table 5.11-12 Seasonal comparison of total catch per unit effort (captured fish only) in the Clearwater River, 2003 to 2005.

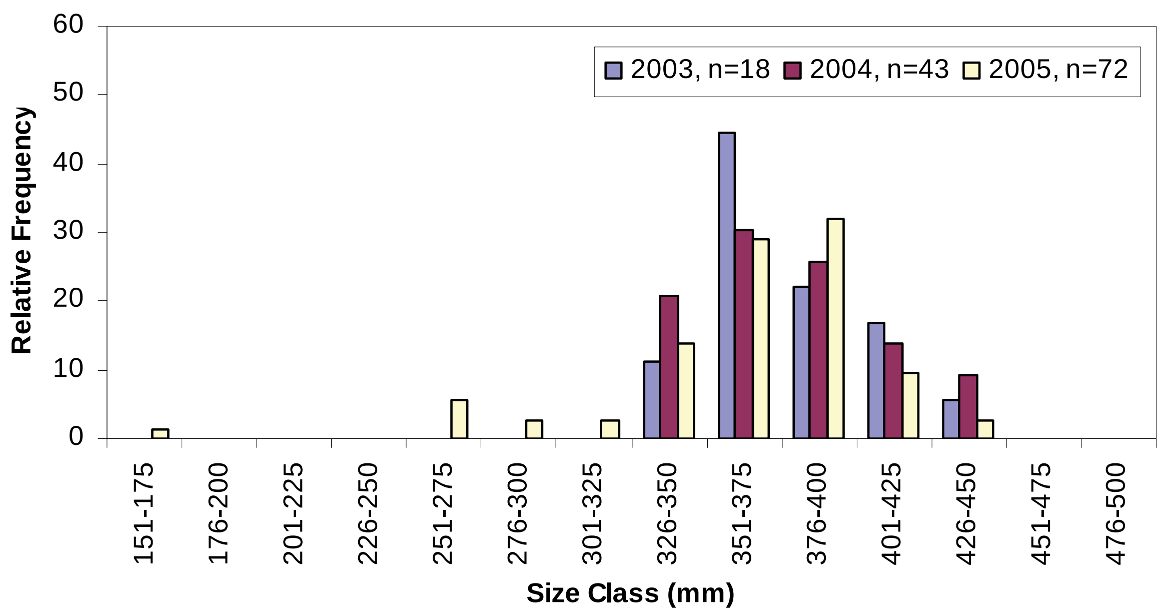
Year	Catch per unit effort (No. fish/100 s)	
	Spring	Fall
2003	1.68	2.59
2004	0.03	1.22
2005	5.37	2.84

Figure 5.11-8 Length-frequency distribution for walleye captured during fish inventories on the Clearwater River, spring and fall 2003 to 2005.



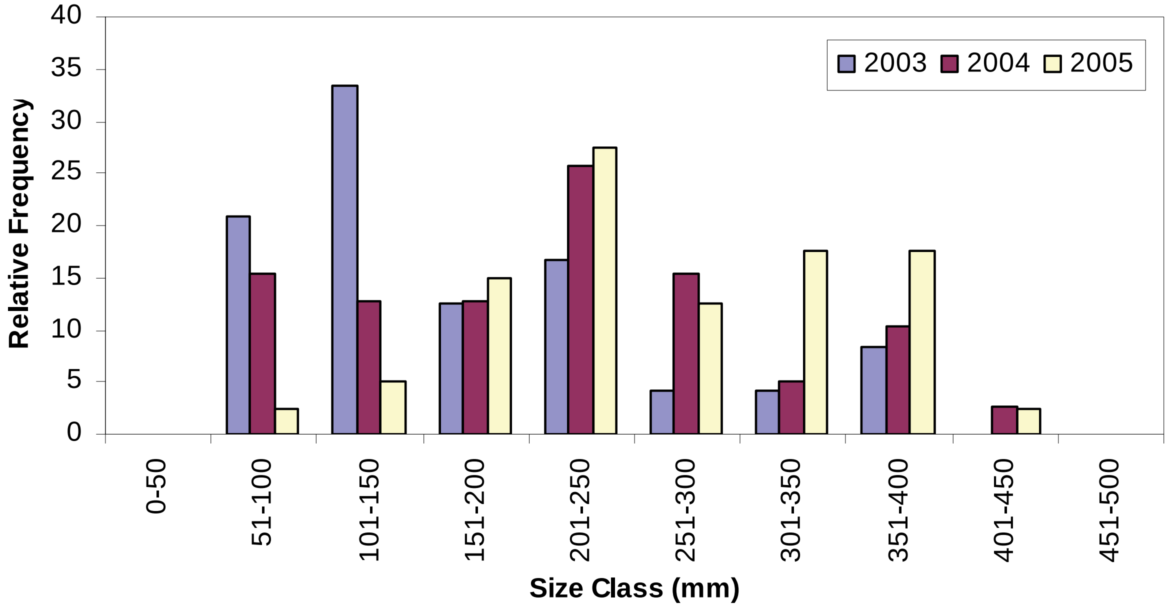
Note: Frequency is the number of fish caught per size class.

Figure 5.11-9 Length-frequency distribution for goldeye captured during fish inventories on the Clearwater River, spring and fall 2004 to 2005.



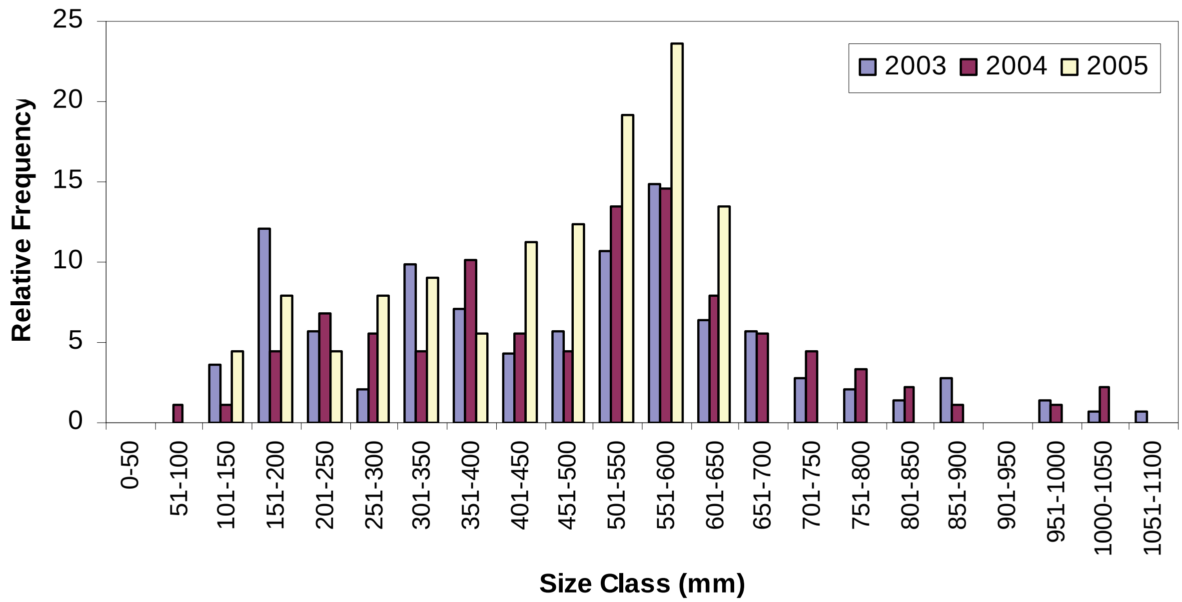
Note: Frequency is the number of fish caught per size class.

Figure 5.11-10 Length-frequency distribution for longnose sucker captured during fish inventories on the Clearwater River, spring and fall 2004 to 2005.



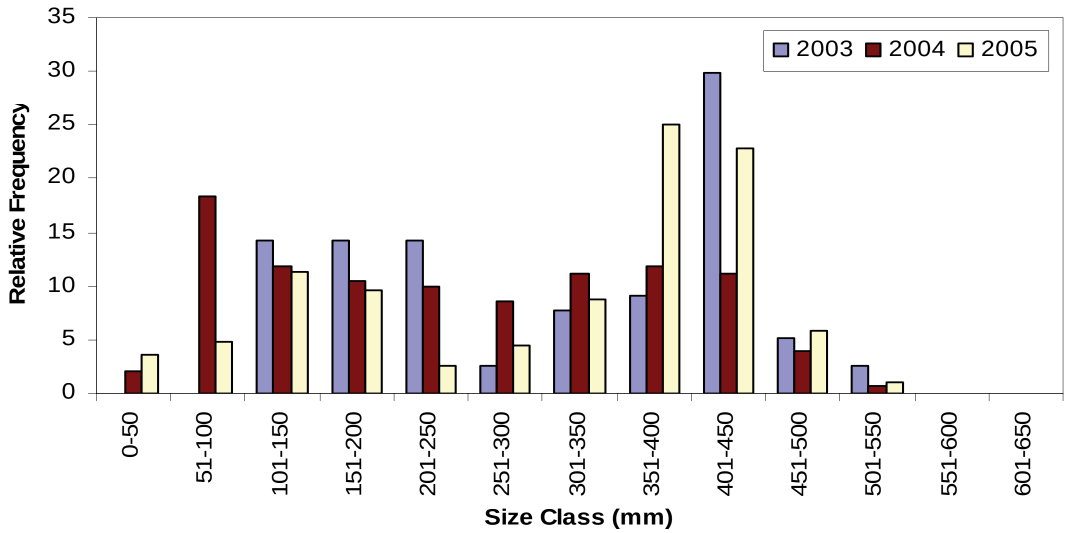
Note: Frequency is the number of fish caught per size class; length size class in millimeters (mm).

Figure 5.11-11 Length-frequency distribution for northern pike captured during fish inventories on the Clearwater River, spring and fall 2004 to 2005.



Note: Frequency is the number of fish caught per size class.

Figure 5.11-12 Length-frequency distributions for white sucker captured during fish inventories on the Clearwater River, spring and fall 2004 to 2005.



Note: Frequency is the number of fish caught per size class.

Figure 5.11-13 Mean condition factor (± 1 SE) key indicator fish species in the Clearwater River, spring 2004 and 2005.

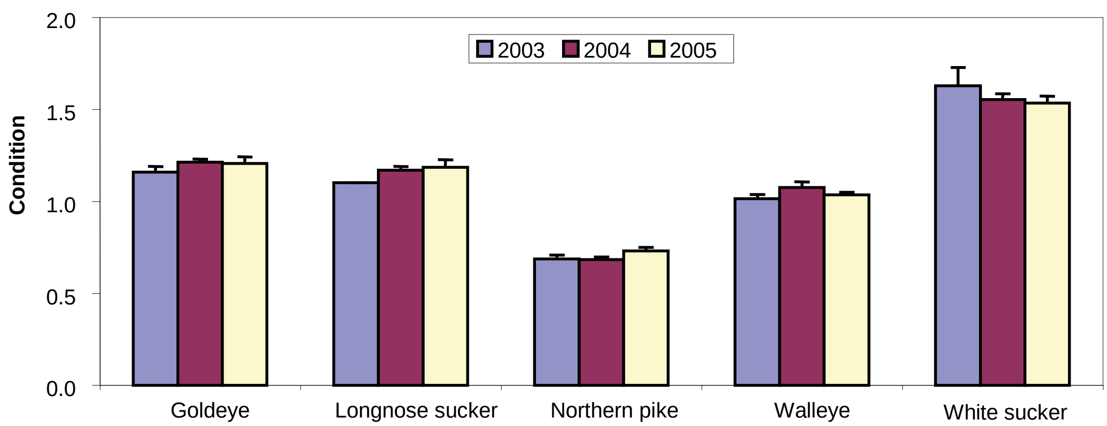


Table 5.11-13 Comparison of external pathology indices for fish captured during the Clearwater River and Athabasca River inventories.

	Athabasca River Pathology Results								Clearwater River Pathology results	
	1995	1997	1998	1999	2002	2003	2004	2005	2004	2005
Goldeye	9.6	4.3	0.5	3.7	0.4	1.9	0.7	0.8	0.2	0.4
Longnose sucker	11	5.8	3.5	4.1	0.9	0.5	1.3	1.1	0.3	1.1
Walleye	2.8	1.5	2.1	18.3	1.4	1.1	2.4	1.5	0.5	0.2
White sucker	18.6	3.2	9.6	5.7	0.6	7.1	3.4	2.5	0.7	0.8
Northern pike	nc	nc	nc	nc	nc	nc	1.2	2.5	2.3	2.5

nc – none caught

5.12 HANGINGSTONE RIVER WATERSHED

Summary of Results

Measurement Endpoint	Summary of 2005 Conditions				
Climate and Hydrology					
	Assessment of Change				
	Negligible	**Low**	**Moderate**	**High**	Total runoff volume in the Hangingstone basin was 21% above normal in 2005, but conditions were less extreme than in most of the other watersheds in the RAMP FSA.
Mean open-water season discharge	The Hangingstone River watershed was designated as a *reference* watershed for 2005.				
Mean winter discharge					
Annual maximum daily discharge					
Minimum open-water season discharge					

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=0)**	**2005 *Reference* Stations (n=1)**	Water quality in 2005 was most similar to that observed in western tributaries of the Athabasca River and other small watercourses, with relatively high concentrations of ions and a range of concentrations of total metals. 2005 concentrations of water quality measurement endpoints were very similar to concentrations observed in 2004, and were within the range of regional baseline conditions. Ion balance was consistent between 2004 and 2005.
Physical variables (max=1)	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.	0	
Nutrients (max=3)		1	
Ions (max=2)		0	
Selected metals (max=5)		1	
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 8 endpoints)**	**2005 *Reference* Stations (n=1 station X 8 endpoints)**	
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.	0	
Between 5th and 95th percentiles		8	
Less than 5th percentile		0	

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	**2005 *Potentially Influenced-Oil Sands* Stations (n=0)**	**2005 *Reference* Stations (n=1)**	In 2005, no concentrations of any of the sediment quality measurement endpoints exceeded CCME guidelines and concentrations of selected sediment quality measurement endpoints were all in the lower range and below the median of regional baseline concentrations.
Total Hydrocarbons (max=4)	No sediment quality stations were designated as *potentially influenced-oil sands* in 2005.	0	
PAHs (max=1)		0	
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[3]**		
Percentile of Regional Baseline Values	**2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 3 endpoints)**	**2005 *Reference* Stations (n=1 station X 3 endpoints)**	
Greater than 95th percentile	No sediment quality stations were designated as *potentially influenced-oil sands* in 2005.	0	
Between 5th and 95th percentiles		3	
Less than 5th percentile		0	

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline						
	2005 *Potentially Influenced-Oil Sands* Stations (n=0)			**2005 *Reference* Stations (n=1)**			Chironomids, mayflies, stoneflies, caddisflies and mites dominated the benthic community groups. All measurement endpoints were within the normal range of regional baseline values with the exception of total abundance which was was much lower in 2005 than in 2004.
Values in Relation to Reference Mean	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	**>2 SD below**	**w/i 2 SD**	**> 2 SD above**	
Abundance	No benthic invertebrate community sampling reaches were designated as *potentially influenced-oil sands* in 2005.			1			
Richness					1		
Diversity					1		
Evenness					1		
% EPT					1		

Fish Populations

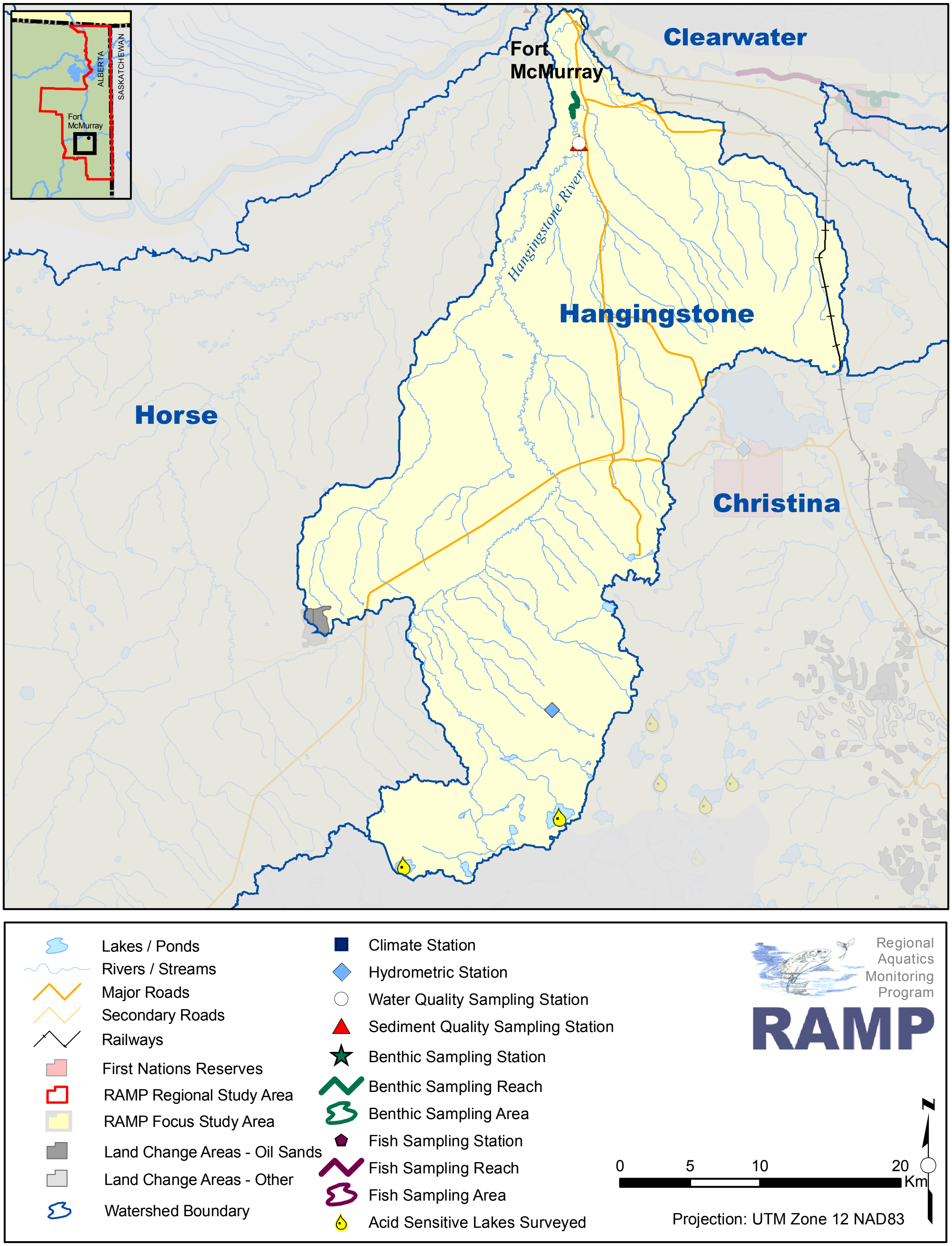
Fish Inventory	No fish inventory studies conducted in these aquatic systems in 2005.
Sentinel Studies	No sentinel fish studies conducted in these aquatic systems in 2005.
Fish Tissue	**Level of Risk**
Human Health: Subsistence	Fish tissue program was not conducted in 2005.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.12-1 Hangingstone River watershed.



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5.12.1 Development Status

All parts of the Hangingstone River watershed are designated as *reference* for 2005. To date, slightly more than 0.2% of the watershed area has undergone land change from oil sands activities, while practically none of the watershed has undergone land change from other activities (Section 2). Therefore, all RAMP stations in the Hangingstone River watershed in 2005 are designated as *reference* stations and all data gathered at these stations are designated as baseline data.

5.12.2 Hydrologic Conditions

Total runoff volume in the Hangingstone basin, as measured at WSC Station 07CD004, Hangingstone River at Fort McMurray, was 21% above normal in 2005, but conditions were less extreme than in most of the other watersheds in the RAMP FSA. The May to October runoff depth was 121 mm compared to the long-term average of 100 mm. Three rainfall-runoff events occurred during the year, producing discharges higher than the spring snowmelt peak (Figure 5.12-2). The highest maximum daily discharge of 35 m^3/s, which occurred on July 25, was less than the mean annual flood of 42.3 m^3/s. The lowest discharge of the open-water season was 0.72 m^3/s on October 22. That discharge compares to a mean annual minimum open-water discharge of 0.98 m^3/s.

5.12.3 Water Quality

In 2005, water quality sampling was conducted at the mouth of the Hangingstone River (station HAR-1, *reference*, baseline data, first sampled in 2004) in spring, summer, and fall. Winter sampling was attempted at this station, but was not possible because the creek was frozen to depth. Results of 2005 fall sampling for water quality measurement endpoints are shown in Table 5.12-1, and are shown for selected water quality measurement endpoints relative to regional baseline concentrations in Figure 5.12-3. Ionic characteristics of the Hangingstone River at station HAR-1 are shown in Figure 5.12-4.

Water quality at station HAR-1 in 2004 and 2005 was most similar to that observed in western tributaries of the Athabasca River and other small watercourses (Appendix D). In general, this group of stations has to date exhibited relatively high concentrations of ions and a range of concentrations of total metals.

In general, fall 2005 concentrations of water quality measurement endpoints were very similar to concentrations observed in 2004 (Table 5.12-1), and were within the range of regional baseline conditions (Figure 5.12-3). Concentrations of aluminum, iron, and total boron were higher in fall 2005 than in 2004, and total aluminum and total and dissolved iron concentrations exceeded CCME/AENV guidelines for the protection of freshwater aquatic life. Total molybdenum and mercury were lower in 2005 than in 2004. Numerous metals exceeded guidelines in spring and summer 2005, with concentrations of aluminum and iron particularly high in both seasons (Table 5.12-2). Ion balance was consistent between 2004 and 2005, with Hangingstone River water dominated by calcium-bicarbonate (Figure 5.12-4).

5.12.4 Sediment Quality

In 2005, sediments were sampled at the mouth of the Hangingstone River (station HAR-1, *reference*, baseline data, first sampled in 2004). Results of 2005 sampling for sediment quality measurement endpoints are shown in Table 5.12-3, and are compared to regional baseline sediment quality conditions in Figure 5.12-5.

As in 2004, sediments at HAR-1 were sandy, low in organic carbon, and low in hydrocarbon, PAH and metal concentrations (Table 5.12-3). No concentrations of any of the sediment quality measurement endpoints exceeded CCME guidelines (Table 5.12-3) and concentrations of selected sediment quality measurement endpoints were all in the lower range and below the median of regional baseline concentrations (Figure 5.12-5).

Toxicity of sediments to *Chironomus* and *Hyallela* was generally consistent with results observed in 2004, with lower survival of *Hyellela* than *Chironomus* (i.e., 30% relative to 80% survival, respectively).

5.12.5 Benthic Invertebrate Communities

In 2005, benthic invertebrate community sampling was conducted in the fall at an erosional reach in the lower Hangingstone River (reach HAR-E-1, *reference*, first sampled in 2004). The substrate in 2005 was dominated by cobble and boulder, with finer particles in the interstices. Current velocities were relatively high (0.6 m/s), while periphyton chlorophyll *a* biomass was marginally high (25 mg/m^2).

Similar to 2004 results, chironomids, mayflies, stoneflies, caddisflies and mites dominated the benthic community groups. Total abundance (~800/m^2) however, was much lower in 2005 than in 2004 (Table 5.12-5), and lower than the normal range of variability for *reference and potentially influenced-other* erosional reaches (Figure 5.12-6). A number of sensitive benthic taxa were found in 2005 including the mayfly *Ephemerella*, the stoneflies *Isogenoides*, *Isoperla*, *Skwala*, *Pteronarcys* and *Taeniopteryx*, the caddisfly *Brachcentrus*, the dragonfly *Ophiogomphus*, and the empidid *Hemerodromia*. Other mayflies included the large group *Baetis*, *Acentrella* and *Heptagenia*. Chironomids were diverse, with *Saetheria* and *Cricotopus*/*Orthocladius* about the most common.

5.12.6 Fish Populations

The 2005 RAMP Fish Population component did not include any activities in the Hangingstone River watershed.

5.12.7 Summary of Conditions

2005 results confirm that the Hangingstone River is a typical Athabasca River basin watershed, with RAMP aquatic resources in 2005 within the range of regional baseline conditions for similar watersheds and habitat types. 2005 sampling results confirm that the selected sampling stations are suitable for monitoring possible influences of upstream oil sands development activities.

Figure 5.12-2 Hangingstone River: 2005 hydrograph and historical context.

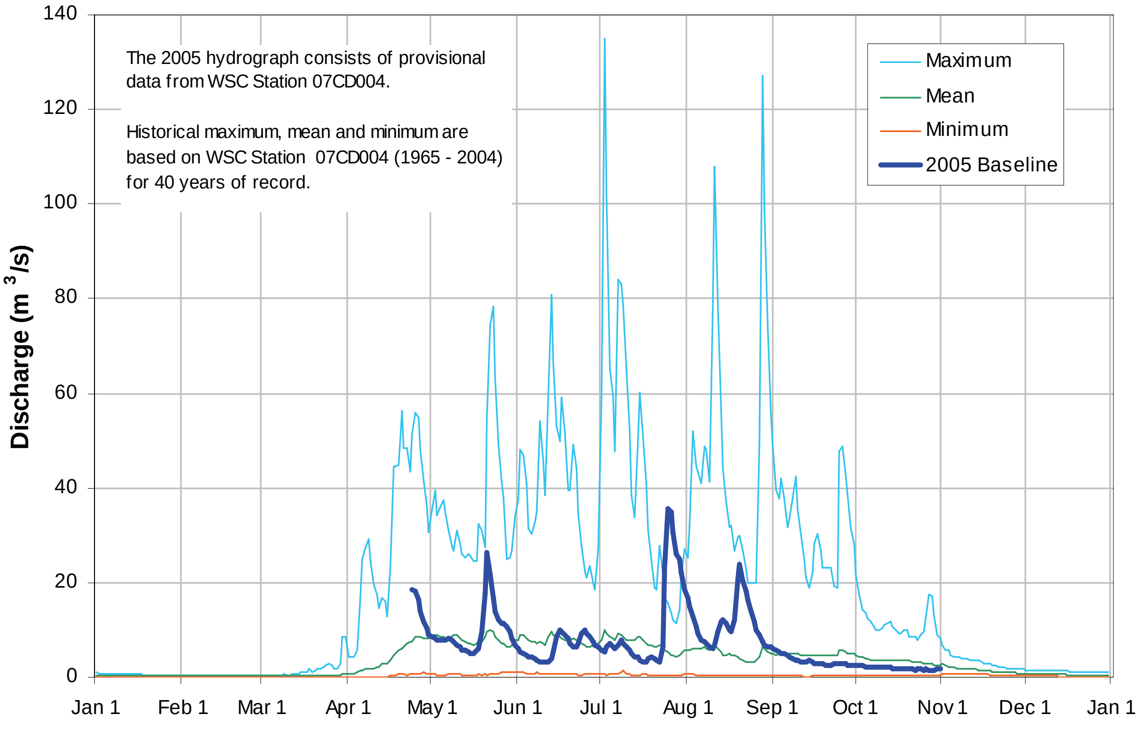


Table 5.12-1 Concentrations of water quality measurement endpoints, mouth of Hangingstone River (HAR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	1	-	-	8.2
Total suspended solids	mg/L	-[1]	12	1	-	-	5
Conductivity	µS/cm	-	231	1	-	-	233
Nutrients							
Total phosphorus	mg/L	0.05	**0.068**	1	-	-	**0.059**
Total dissolved phosphorus	mg/L	0.05[2]	0.046	1	-	-	0.038
Total nitrogen*	mg/L	1.0	0.9	1	-	-	0.9
Nitrate+nitrite	mg/L	-	<0.1	1	-	-	<0.1
Dissolved organic carbon	mg/L	-	28	1	-	-	21
Ions							
Sodium	mg/L	-	17	1	-	-	17
Calcium	mg/L	-	23.2	1	-	-	25.7
Magnesium	mg/L	-	7.2	1	-	-	7.4
Chloride	mg/L	230, 860[3]	13	1	-	-	9
Sulphate	mg/L	100[4]	10.4	1	-	-	10
Total dissolved solids	mg/L	-	170	1	-	-	190
Total alkalinity	mg/L		88	1	-	-	99
Organic compounds							
Naphthenic acids	mg/L	-	<1	1	-	-	1
Selected metals							
Total aluminum	mg/L	0.1	**0.421**	1	-	-	**0.166**
Dissolved aluminum	mg/L	0.1[2]	0.0296	1	-	-	0.0138
Total boron	mg/L	1.2[4]	0.066	1	-	-	0.0607
Total molybdenum	mg/L	0.073	0.00075	1	-	-	0.00099
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	1	-	-	1.22
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total phenols	mg/L	0.004	**0.010**	1	-	-	**0.011**
Dissolved iron	mg/L	0.3[2]	**0.79**	1	-	-	**0.74**
Total iron	mg/L	0.3	**1.38**	1	-	-	**1.13**

Note: Guideline values are CCME/AENV guidelines 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.

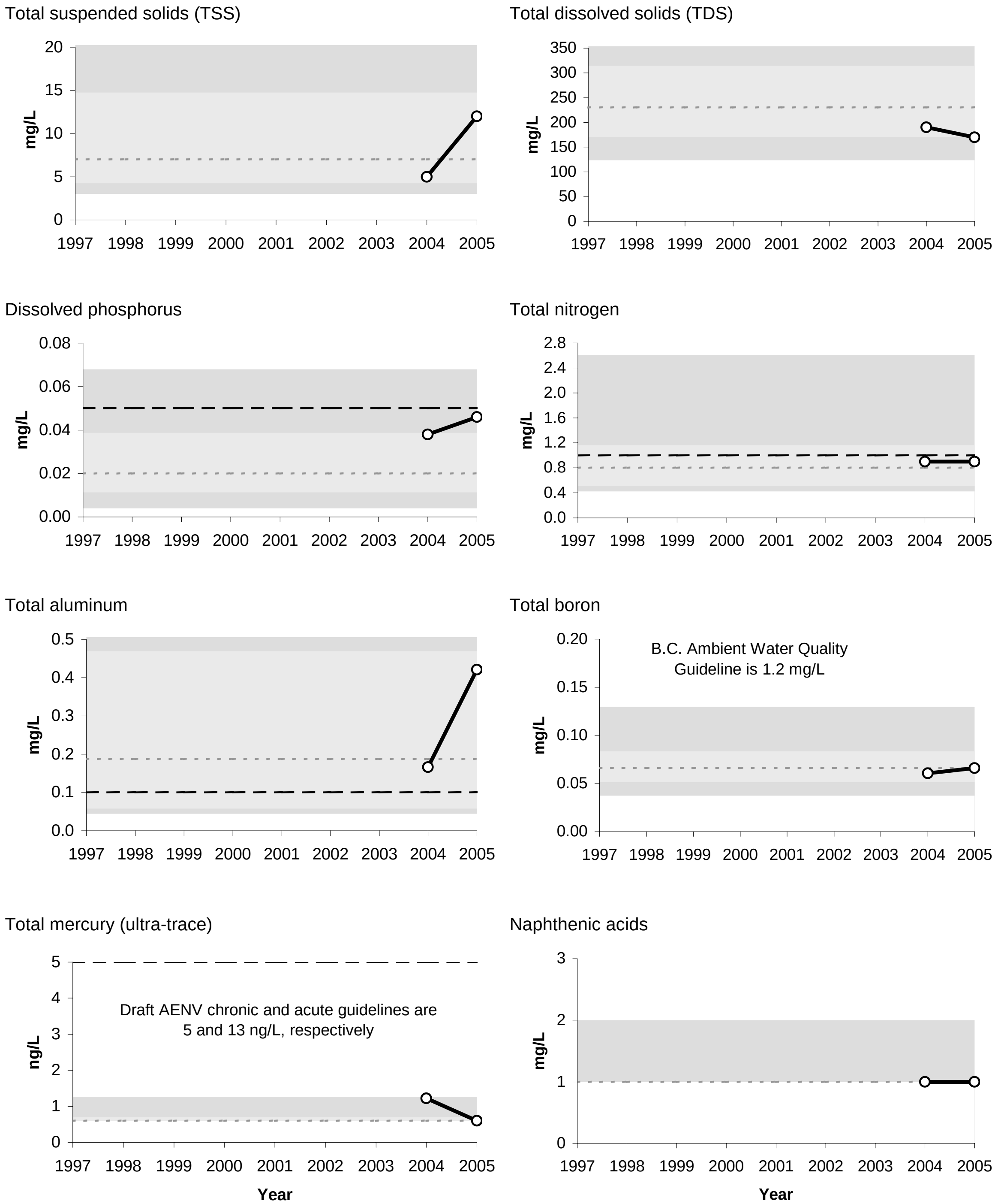
[2] Guideline is for total analyte (no guideline for dissolved species).

[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).

[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

Figure 5.12-3 Concentrations of selected water quality measurement endpoints at the mouth of Hangingstone River (HAR-1) (fall 2005) relative to regional baseline fall concentrations.



Non-detectable values are shown at the detection limit.

[1] 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 5.12-4 Piper diagram of fall 2005 ion concentrations in the Hangingstone River watershed.

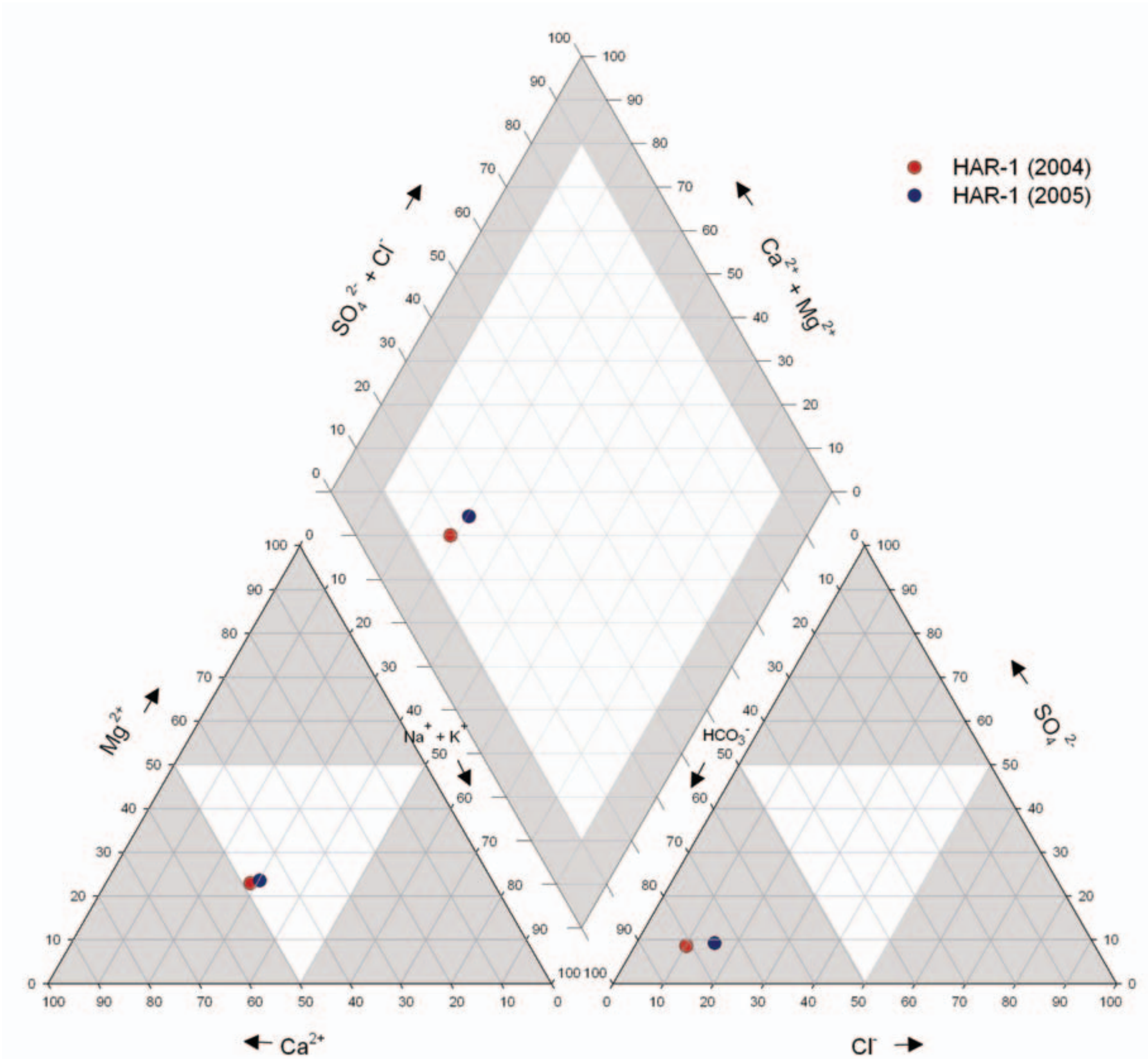


Table 5.12-2 List of all 2005 water quality guideline exceedances, Hangingstone River (HAR-1).

Parameter	Units	Guideline*	HAR-1
Spring			
Total phosphorus	mg/L	0.05	**0.301**
Total aluminum	mg/L	0.1	**4.98**
Total cobalt	mg/L	0.0009[1]	**0.00299**
Total copper	mg/L	0.002-0.004[2]	**0.0057**
Dissolved iron	mg/L	0.3[3]	**0.391**
Total iron	mg/L	0.3	**6.96**
Total lead	mg/L	0.001-0.007[2]	**0.00479**
Total titanium	mg/L	0.1[1]	**0.114**
Summer			
Total phosphorus	mg/L	0.05	**0.397**
Total Kjeldahl nitrogen	mg/L	1.0[4]	**1.6**
Total aluminum	mg/L	0.1	**4.92**
Total cobalt	mg/L	0.0009[1]	**0.00333**
Total copper	mg/L	0.002-0.004[2]	**0.004**
Dissolved iron	mg/L	0.3[3]	**0.746**
Total iron	mg/L	0.3	**7.03**
Fall			
Total phosphorus	mg/L	0.05	**0.068**
Total phenols	mg/L	0.004	**0.01**
Total aluminum	mg/L	0.1	**0.421**
Dissolved iron	mg/L	0.3[3]	**0.788**
Total iron	mg/L	0.3	**1.38**

HAR-1 sampled only in spring, summer, and fall 2005.

* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.

[1] B.C. Working Water Quality Guideline (2001).

[2] Guideline is hardness-dependent.

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

[4] Guideline is for total nitrogen.

Table 5.12-3 Concentrations of sediment quality measurement endpoints, mouth of Hangingstone River (HAR-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2	1	-	-	1
Silt	%	-	<1	1	-	-	2
Sand	%	-	98	1	-	-	98
Total organic carbon	%	-	0.2	1	-	-	0.1
Total hydrocarbons							
CCME variables							
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	-	-	<5
Fraction 3 (C16-C34)	mg/kg	400[2]	<5	1	-	-	12
Fraction 4 (C34-C50)	mg/kg	2800[2]	16	1	-	-	11
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	mg/kg	0.0346[3]	0.00337	1	-	-	0.000975
Retene	mg/kg	-	0.00231	1	-	-	0.00187
Total dibenzothiophenes	mg/kg	-	0.014	1	-	-	0.013
Total PAHs	mg/kg	-	0.079	1	-	-	0.067
Total HMW PAHs	mg/kg	-	0.031	1	-	-	0.028
Total LMW PAHs	mg/kg	-	0.048	1	-	-	0.039
Predicted PAH toxicity[1]	H.I.	-	0.88	1	-	-	0.42
Metals that exceed CCME guidelines in 2005							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival - 10d	# surviving	-	8	1	-	-	9
Chironomus growth - 10d	mg/organism	-	1.83	1	-	-	2.4
Hyallela survival - 14d	# surviving	-	3	1	-	-	5
Hyallela growth - 14d	mg/organism	-	0.39	1	-	-	0.3

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

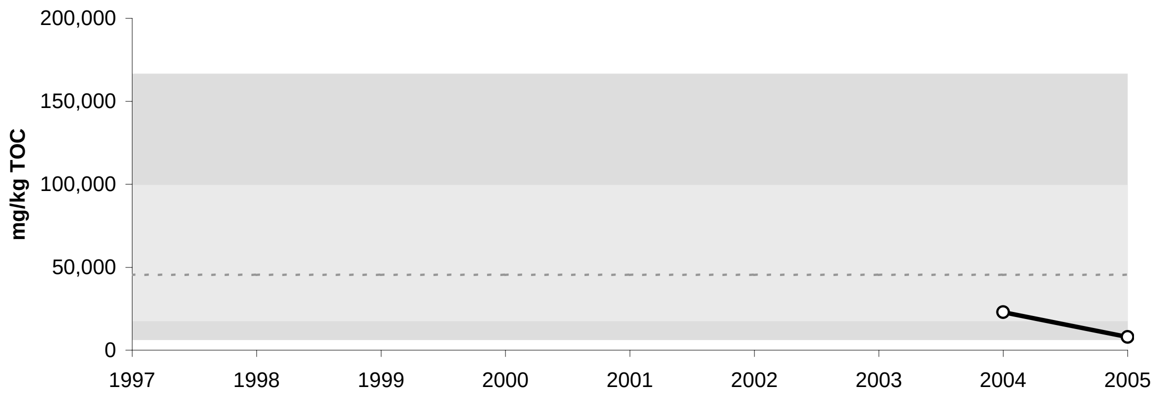
[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

[2] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2001).

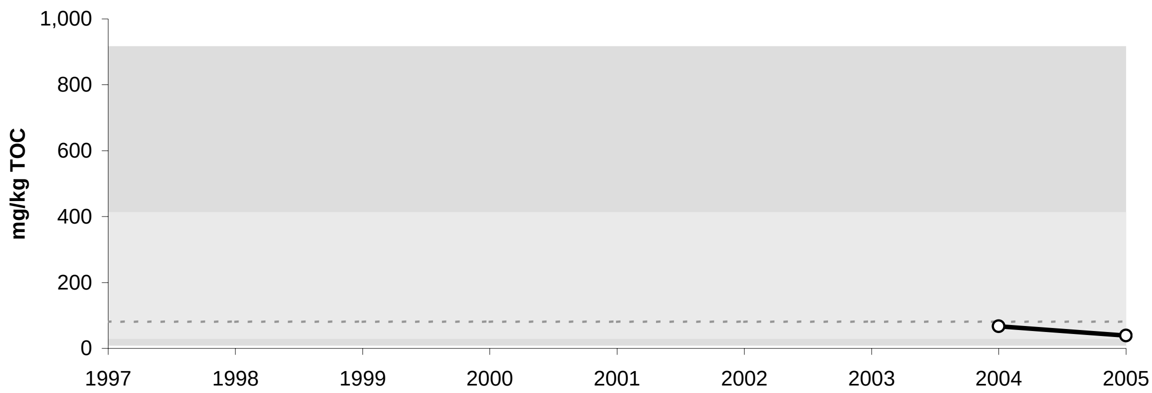
[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Figure 5.12-5 Concentrations of selected sediment quality measurement endpoints at the mouth of Hangingstone River (HAR-1) (fall 2005) relative to regional baseline fall concentrations.

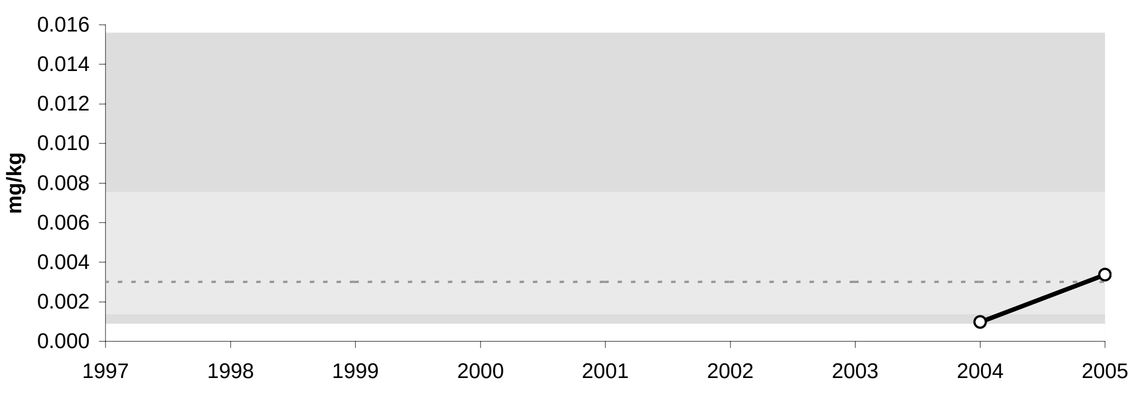
Total Hydrocarbons (C6-C50) (normalized to TOC)



Total Polycyclic Aromatic Hydrocarbons (PAHs) (normalized to TOC)



Naphthalene



[1] Regional baseline values reflect pooled results for all baseline stations with similar sediment quality, from all years of RAMP sampling. See Section 3.3.7 for a discussion of this approach, and Appendix E for these regional baseline ranges.

Table 5.12-4 Average habitat characteristics of benthic invertebrate community sampling station in the Hangingstone River, fall 2005.

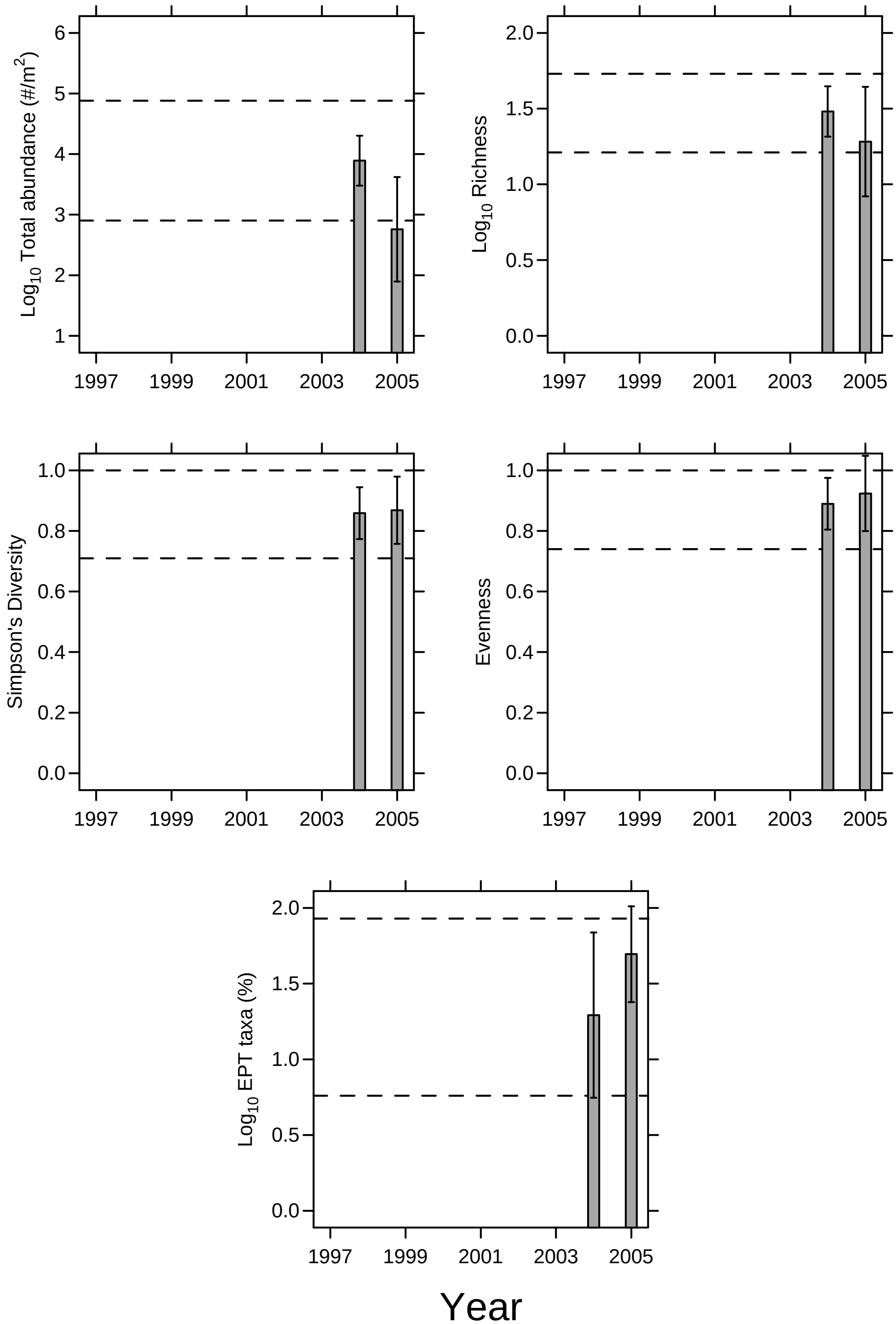
Variable	Units	Reach HAR-E-1
Sample date	-	Sept 7, 2005
Habitat	-	Erosional
Water depth	m	0.3
Current velocity	m/s	0.6
Macrophyte cover	%	0
Benthic algae[1]	mg/m^2	25
Field Water Quality		
Dissolved oxygen	mg/L	9
Conductivity	µS/cm	233
pH	pH units	7.7
Water temperature	°C	12.2
Sediment Composition		
Sand/Silt/Clay	%	11
Small gravel	%	1
Large gravel	%	4
Small cobble	%	10
Large cobble	%	31
Boulder	%	41
Bedrock	%	0

[1]measured as chlorophyll *a*

Table 5.12-5 Summary of major taxon abundances and measurement endpoints among benthic invertebrate community sampling stations in the Hangingstone River, fall 2005.

Taxon	Reach HAR-E-1	
	2004	2005
Hydra		1
Nematoda	6	2
Enchytraeidae	1	2
Naididae	24	3
Tubificidae	<1	<1
Hydracarina	6	13
Ostracoda	5	
Copepoda	<1	<1
Collembola		<1
Bivalvia	<1	
Gastropoda	<1	
Ephemeroptera	16	34
Plecoptera	3	10
Trichoptera	4	12
Anisoptera	<1	1
Coleoptera	<1	<1
Tipulidae		<1
Athericidae	<1	3
Dolichopodidae		
Tabanidae	<1	
Empididae	2	2
Ceratopogonidae	<1	<1
Chironomidae	33	14
Simuliidae		3
Total Abundance (No./m^2)	8,560	773
Richness	30	19
Simpson's Diversity	0.86	0.87
Evenness	0.89	0.92
% EPT	21	50

Figure 5.12-6 Variation in benthic invertebrate community measurement endpoints in the Hangingstone River.



Notes: lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional sites.

5.13 MISCELLANEOUS AQUATIC SYSTEMS NOT POTENTIALLY INFLUENCED BY OIL SANDS ACTIVITIES

Summary of Results

Climate and Hydrology

Measurement Endpoint	Summary of 2005 Conditions: Assessment of Change (Negligible / Low / Moderate / High)	
Mean open-water season discharge	The Clearwater and Christina watersheds were designated as *reference* watersheds for 2005.	Streamflows were much above normal in both the Clearwater and Christina Rivers in 2005.
Mean winter discharge		
Annual maximum daily discharge		
Minimum open-water season discharge		

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]		
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=0)	2005 *Reference* Stations (n=4)	
Physical variables (max=4)	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.	0	Water quality was generally consistent between upstream and downstream stations on the Clearwater. On the Christina, TSS levels in fall 2005 were higher than previous and total phosphorus, aluminum, and iron exceeded guidelines in fall 2005. Some metals were elevated in 2005 at all stations. No consistent trends in ion balance have been apparent among any stations since the beginning of sampling at these locations.
Nutrients (max=12)		7	
Ions (max=8)		0	
Selected metals (max=20)		4	
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[2]**		
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 8 endpoints)	2005 *Reference* Stations (n=4 stations X 8 endpoints)	
Greater than 95th percentile	No water quality sampling stations were designated as *potentially influenced-oil sands* in 2005.	6	
Between 5th and 95th percentiles		25	
Less than 5th percentile		1	

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2005[1]	
Measurement endpoints with guidelines	2005 *Potentially Influenced-Oil Sands* Stations (n=0)	2005 *Reference* Stations (n=0)
Total Hydrocarbons	No sediment quality sampling was conducted in 2005.	
PAHs		
Comparison to Regional Baselines	**Endpoints in 2005 Compared to Regional Baseline[3]**	
Percentile of Regional Baseline Values	2005 *Potentially Influenced-Oil Sands* Stations (n=0 stations X 3 endpoints)	2005 *Reference* Stations (n=0 stations X 3 endpoints)
Greater than 95th percentile	No sediment quality sampling was conducted in 2005.	
Between 5th and 95th percentiles		
Less than 5th percentile		

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2005 Compared to Regional Baseline						
	2005 *Potentially Influenced-Oil Sands* Stations (n=0)			2005 *Reference* Stations (n=4)			
Values in Relation to Reference Mean	>2 SD below	w/i 2 SD	> 2 SD above	>2 SD below	w/i 2 SD	> 2 SD above	
Abundance	No benthic invertebrate community sampling reaches were designated as *potentially influenced-oil sands* in 2005.				4		All measurement endpoints were within ranges for regional depositional baseline reaches. **Christina:** richness and density were below average for regional depositional baseline reaches. **Clearwater:** richness, abundance, and diversity in reach CLR-D-1 were below average for depositional baseline reaches.
Richness					4		
Diversity					4		
Evenness					4		
% EPT					4		

Fish Populations

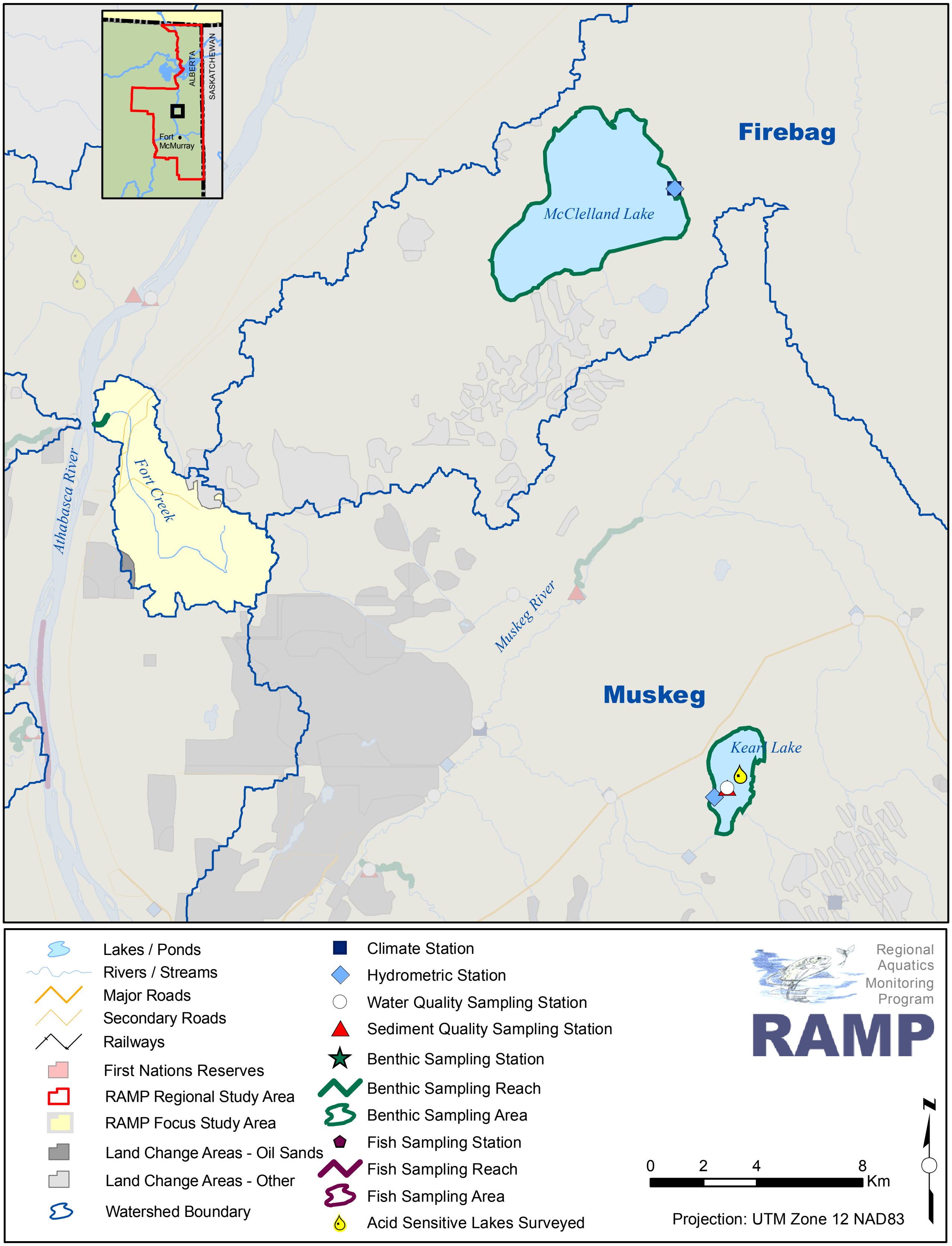
Fish Inventory	2005 results were generally similar to 2003 and 2004 results with respect to length-frequency indicators, condition, external health.	Fish catch was higher in 2005 than 2004, in both spring and fall. Species richness was equal to 2004 but less than 2003. Condition estimates from 2003-2005 are generally comparable with those obtained from the Athabasca River. Only 3.4% of fish in the spring inventory were found to have some type of external condition.
Sentinel Studies	No sentinel fish studies conducted in 2005.	
Fish Tissue	**Level of Risk**	
Human Health: Subsistence	Fish tissue program was not conducted in 2005.	
Human Health: Recreational Fishers		
Human Health: General Consumers		
Human Health: Tainting		

[1] Guidelines applied depend on analyte and include CCME/AENV guidelines for the protection of aquatic life, U.S. EPA Guidelines, and B.C. Working Water Quality Guidelines.

[2] Water Quality Measurement Endpoints: TSS; TDS; Dissolved phosphorous; Total nitrogen; Total aluminum; Total boron; Total mercury (ulta-trace); Naphthenic acids.

[3] Sediment Quality Measurement Endpoints: Total Recoverable Hydrocarbons; Total PAHs; Naphthalene.

Figure 5.13-1 Miscellaneous aquatic systems without potential influence from oil sands developments.



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5.13.1 Development Status

This section includes 2005 results from Kearl Lake, McClelland Lake, and Fort Creek. Both lakes were designated as *potentially influenced-other* waterbodies for 2005 because of logging activities in upstream areas (Section 2, Figure 5.13-1). Therefore, all RAMP stations in these two lakes in 2005 are designated as *potentially influenced-other* stations and all data gathered at these stations are designated as baseline data for oil sands operations. Fort Creek is designated as a *reference* waterbody for 2005; all RAMP stations in Fort Creek in 2005 are designated as *reference* stations and all data gathered at these stations are designated as baseline data for oil sands operations

5.13.2 Hydrologic Conditions

Water levels on Kearl Lake, as characterized by RAMP Station L2, were below normal during the winter of 2004 – 2005 (Figure 5.13-2). In April, the lake level rose almost 0.5 m in response to snowmelt and rainfall, falling to historical average levels by mid-June. The lake level fell in October to below historical average levels and continued to drop into the winter of 2005/2006. The total range in lake levels during 2005 was 0.6 m, and included the highest and lowest levels recorded on the lake since 1999. Estimates of normal and extreme conditions are somewhat uncertain because of the short and intermittent period of record for the lake. period and fluctuated during the summer (Figure 5.13-3).

McClelland Lake water levels rose slightly in the March to May rical average values in the early part of the year and above average after May. The range of lake levels observed in 2005 was less than 0.2 m, compared to a total average range of 0.6 m over eight years of monitoring.

5.13.3 Water Quality

Water quality samples were collected from Kearl Lake (station KEL-1, *potentially influenced-other*, baseline data, first sampled in 1998, sampled every fall since 2000) in summer and fall 2005. Water quality sampling was not conducted on McClelland Lake in 2005. Results of 2005 sampling for water quality measurement endpoints are shown in Table 5.13-1; results for selected measurement endpoints relative to regional baseline conditions for station KEL-1 are shown in Figure 5.13-4.

Overall, there was one (9%) out of 11 possible guideline exceedances of the selected water quality measurement endpoints in Kearl Lake (i.e., only eleven of the selected water quality measurement endpoints have guidelines [Table 5.13-1]). Conductivity, pH, and total alkalinity were lower in fall 2005 than previously observed, while the concentration of total dissolved solids in 2005 was in the lower range of regional baseline concentrations (Figure 5.13-4) and appears to have declined since 2000. Concentrations of dissolved phosphorus, total aluminum, total boron, total mercury, and naphthenic acids have been consistent between 2000 and 2005. Concentrations of total Kjeldahl nitrogen exceeded the AENV chronic total nitrogen guideline in summer and fall, while total copper exceeded the CCME guideline in the fall and was also slightly higher than the previously observed maximum concentration. Ion balance in Kearl Lake has been very consistent since the beginning of RAMP sampling.

5.13.4 Sediment Quality

The 2005 RAMP Sediment Quality component did not include any activities in either Kearl Lake or McClelland Lake in 2005.

5.13.5 Benthic Invertebrate Communities

In 2005, benthic invertebrate community samples were collected from Kearl Lake (station KEL-1, *potentially influenced-other,* baseline data, sampled since 2001) and from McClelland Lake (station MCL-1, *potentially influenced-other*, baseline data, sampled in 2002 and 2003). 2005 results are presented and discussed in the context of Shipyard Lake in Section 5.8. In general, benthic invertebrate communities in Kearl Lake and McClelland Lake are in relative good condition, with measurement endpoints that are within regional baseline ranges (Section 5.8.5).

In addition, in 2005, benthic invertebrate community samples were collected from a lower reach in Fort Creek (reach FOC-D-1, depositional, baseline data available from 2001 to 2005 with the exception of 2004). Reach FOC-E-1 is depositional, dominated by fine-grained sand and silt. Total organic carbon content was relatively high (4%; Table 5.13-3) reflecting high wood debris associated with beaver dams upstream. At low flow the creek is shallow with depths ~ 0.2 m, while the channel is quite wide (bankfull width of ~7 m and wetted width of ~ 4 m).

The benthic invertebrate community at reach FOC-D-1 has been dominated by Chironomidae, with a large variety of additional taxa including bivalves (fingernail clams, Sphaeriidae), nematodes, leeches, worms, mites, ostracods, and miscellaneous insect larvae (mayflies, caddisflies, other Diptera). Total numbers of animals was lower in 2005 (~900 individuals/m^2) compared to the previous years (4,000 to 70,000 individuals/m^2), while diversity was also significantly lower (Table 5.13-4; Figure 5.13-6). Very few taxa were present in 2005, being limited to nematodes, tubificids, ostracods, bivalves (Sphaeriidae) and chironomids (only three taxa, *Polypedilum, Brillia, Cricotopus/Orthocladius)*. The lack of fauna indicates a local impact, potentially related to a recent storm event that was in evidence by locally wind-felled trees.

5.13.6 Fish Populations

The 2005 RAMP Fish Population component did not include any activities in Kearl or McClelland Lakes.

5.13.7 Summary of Conditions

The RAMP aquatic resources of miscellaneous aquatic systems not potentially influenced by oil sands developments had similar conditions in 2005 to previous years, with the exception of Kearl Lake lake levels. All water quality measurement endpoints were within the range of expected reference conditions for aquatic systems in the RAMP FSA and there were very few exceedances of existing environmental guidelines.

Figure 5.13-2 Kearl Lake: 2005 water levels and historical context.

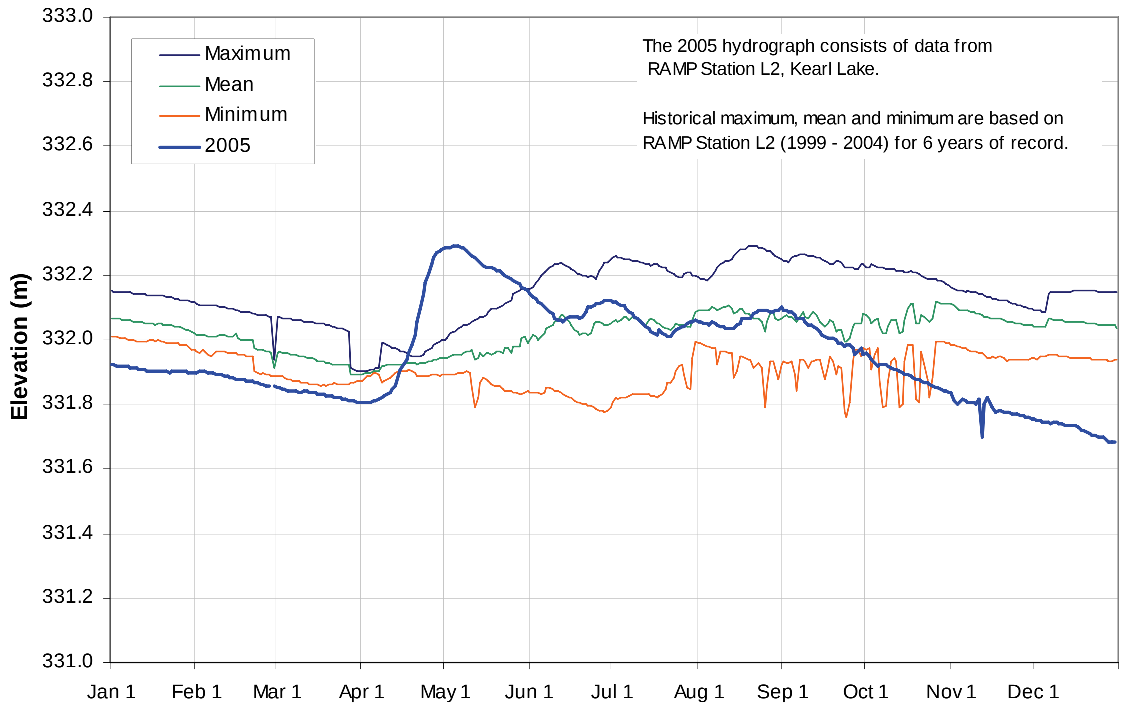


Figure 5.13-3 McClelland Lake: 2005 water levels and historical context.

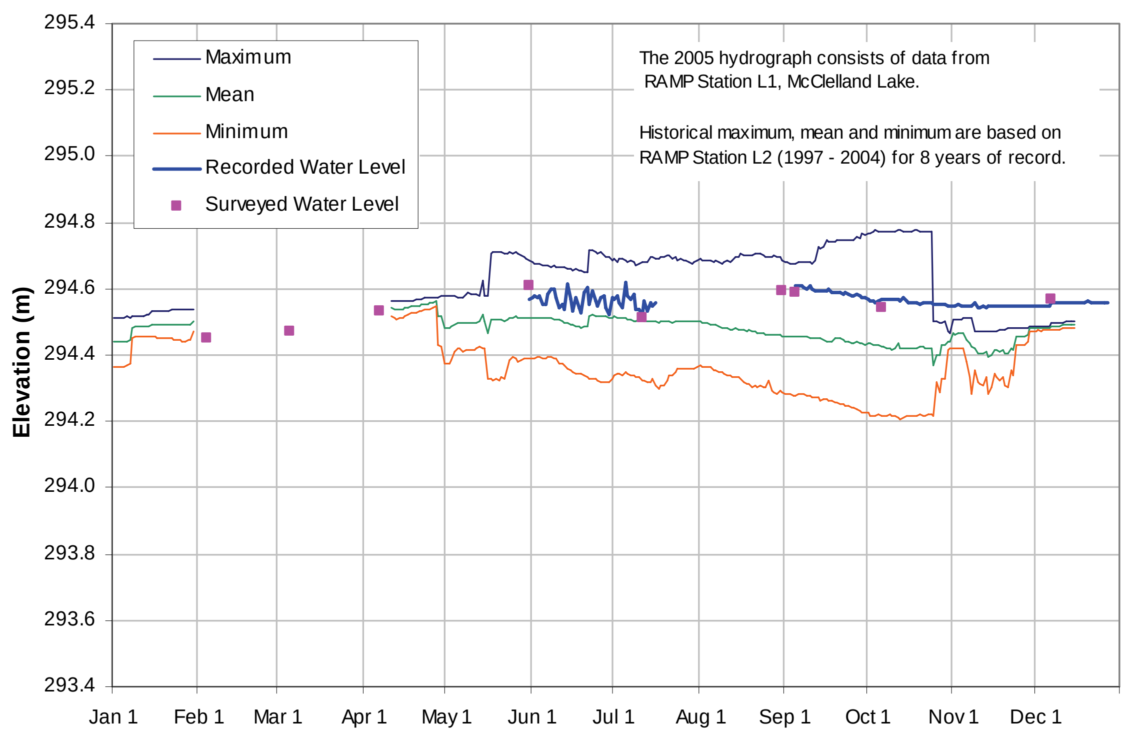


Table 5.13-1 Concentrations of water quality measurement endpoints, Kearl Lake (KEL-1), fall 2005.

	Units	Guideline	September 2005	1997-2004 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	7.6	6	7.7	8.0	8.1
Total suspended solids	mg/L	-[1]	7	6	<3	4	15
Conductivity	µS/cm	-	150	6	165	180	183
Nutrients							
Total phosphorus	mg/L	0.05	0.026	6	0.009	0.013	0.027
Total dissolved phosphorus	mg/L	0.05[2]	0.007	6	0.002	0.009	0.013
Total nitrogen*	mg/L	1.0	**1.4**	6	0.5	0.9	**1.8**
Nitrate+nitrite	mg/L	-	<0.1	6	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	23	6	15	20	24
Ions							
Sodium	mg/L	-	8	6	8	10	11
Calcium	mg/L	-	16.5	6	17.8	19.7	20.6
Magnesium	mg/L	-	6	6	6.5	7.0	7.6
Chloride	mg/L	230, 860[3]	2	6	<1	<1	2
Sulphate	mg/L	100[4]	5.3	6	2.7	4.8	5.7
Total dissolved solids	mg/L	-	100	6	94	150	220
Total alkalinity	mg/L		72	6	79	88	93
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.0178	6	0.011	0.033	**0.13**
Dissolved aluminum	mg/L	0.1[2]	0.0021	6	0.0014	0.0075	0.03
Total boron	mg/L	1.2[4]	0.0465	6	0.012	0.047	0.0493
Total molybdenum	mg/L	0.073	0.00011	6	0.00006	0.00010	0.0009
Total mercury (ultra-trace)	ng/L	5, 13[5]	<0.6	2	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2005							
Total Kjeldahl nitrogen	mg/L	1.0[6]	**1.3**	6	0.4	0.8	**1.7**
Total copper	mg/L	0.002-0.004[7]	**0.0023**	6	<0.001	0.0004	0.002

Note: Guideline values are CCME/AENV guidelines 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 1999).

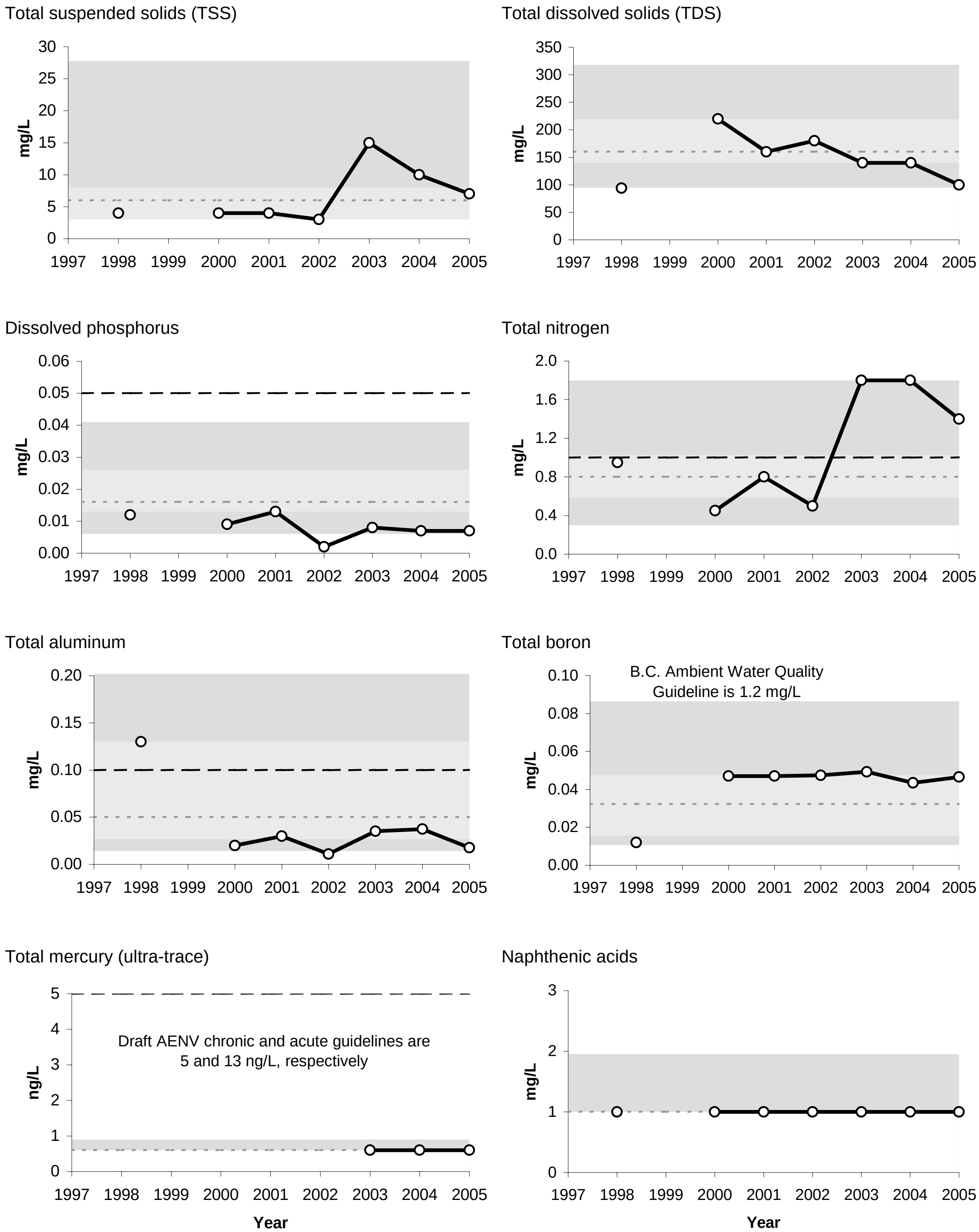
[4] B.C. Ambient Water Quality Guideline (B.C. 2000; B.C. 2003).

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

[6] Guideline is for total nitrogen.

[7] Guideline is hardness-dependent.

Figure 5.13-4 Concentrations of selected water quality measurement endpoints in Kearl Lake (fall data) relative to regional baseline fall conditions.



Non-detectable values are shown at the detection limit.

[1] 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 5.13-5 Piper diagram of fall ion concentrations in Kearl Lake.

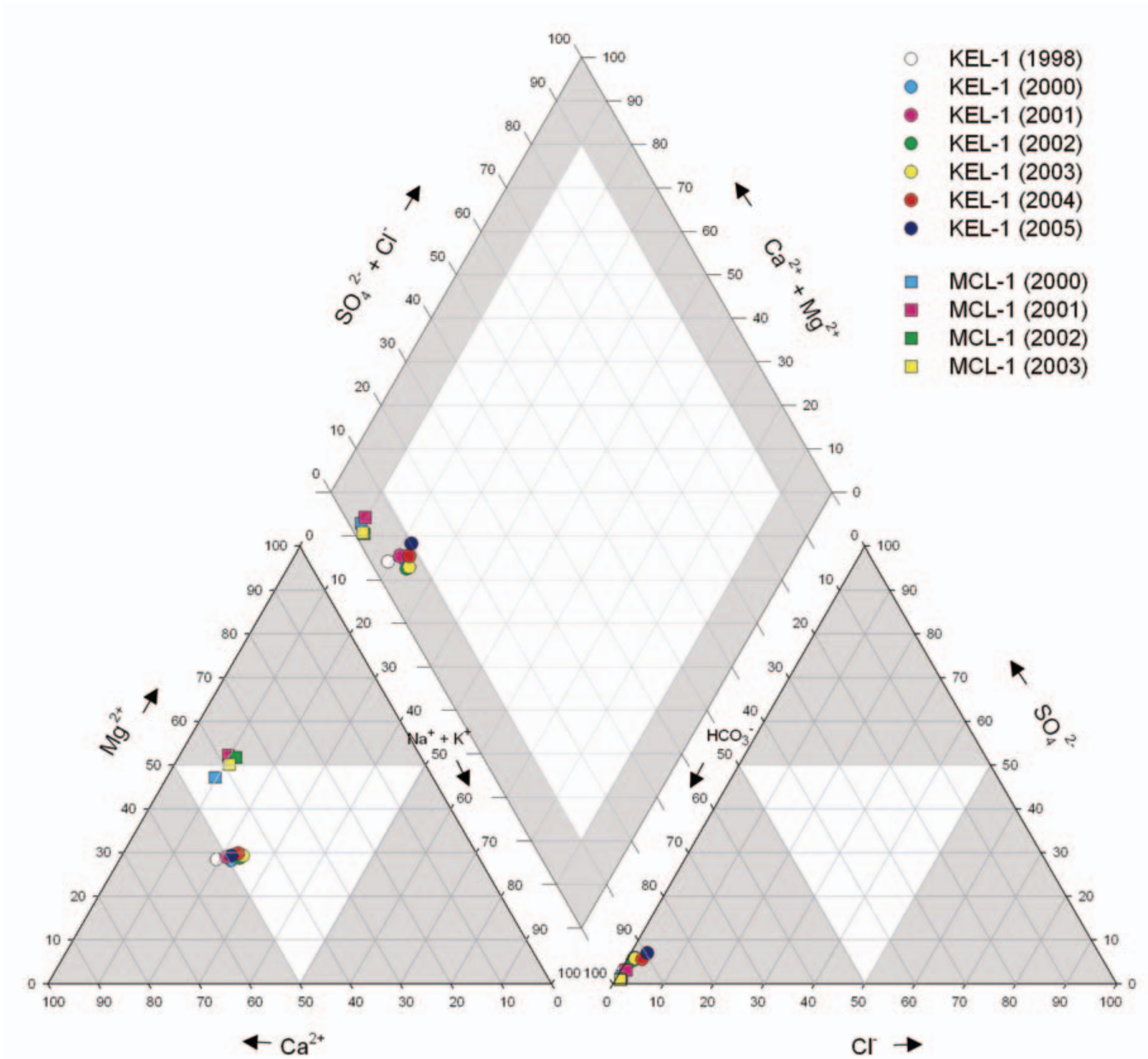


Table 5.13-2 Water quality guideline exceedances, Kearl Lake, 2005.

Parameter	Units	Guideline*	KEL-1
Summer			
Total Kjeldahl nitrogen	mg/L	1.0[2]	**1.2**
Fall			
Total Kjeldahl nitrogen	mg/L	1.0[2]	**1.3**
Total copper	mg/L	0.002-0.004[1]	**0.00232**

KEL-1 not sampled in winter or spring 2005.
* Guidelines are CCME (2003) or AENV (1999) unless otherwise noted.
[1] Guideline is hardness-dependent.
[2] Guideline is for total nitrogen.

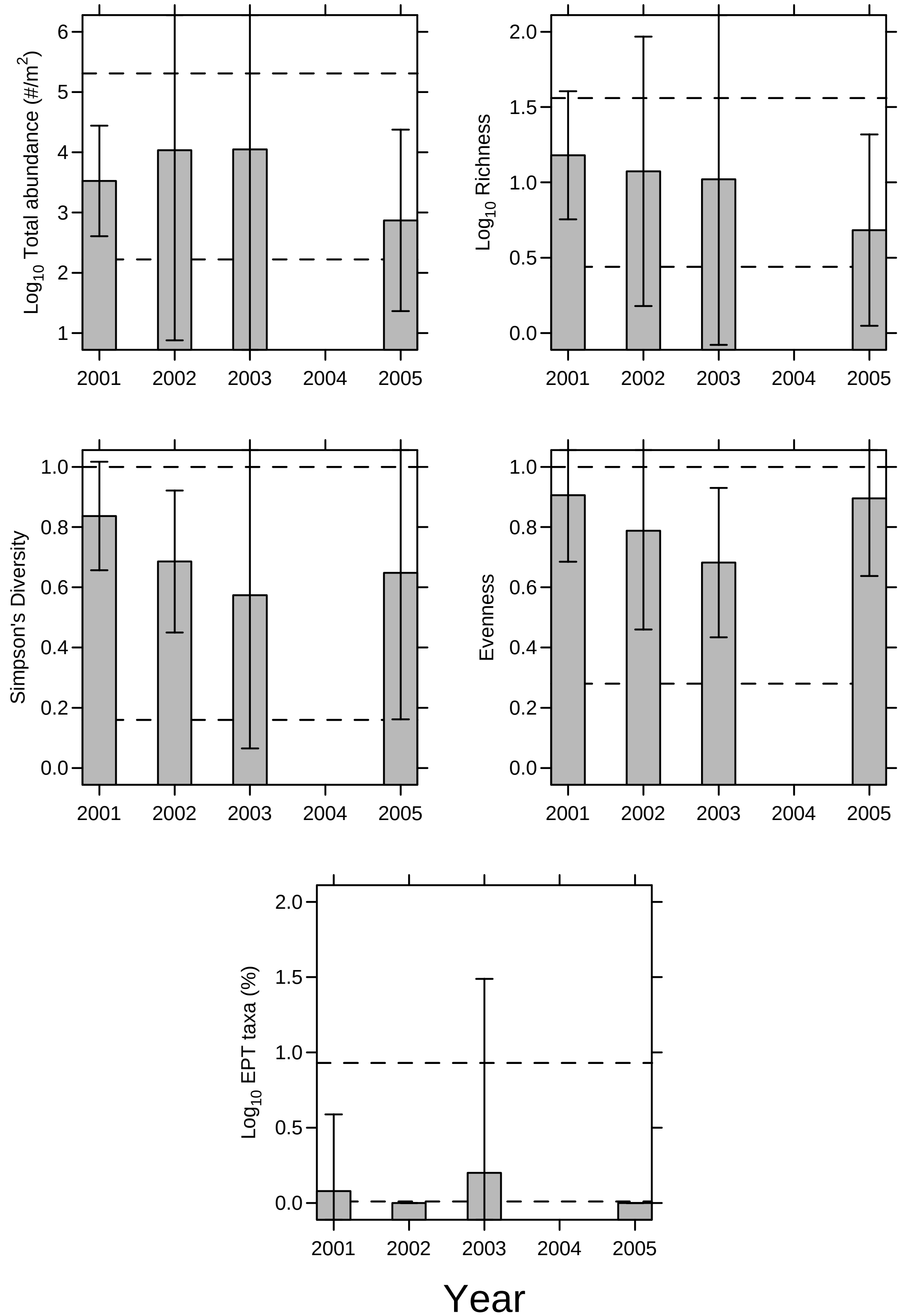
Table 5.13-3 Average habitat characteristics of reach FOC-D-1, Fort Creek, fall 2005.

Variable	Units	Reach FOC-D-1
Sample date	-	Sept. 9, 2005
Habitat	-	Depositional
Water depth	m	0.20
Current velocity	m/s	0.4
Macrophyte cover	%	0
Field Water Quality		
Dissolved oxygen	mg/L	9.4
Conductivity	µS/cm	340
pH	pH units	8.0
Water temperature	°C	14.0
Sediment Composition		
Sand	%	76
Silt	%	15
Clay	%	9
Total Organic Carbon	%	4.0

Table 5.13-4 Summary of major taxon abundances and benthic invertebrate community measurement endpoints, Fort Creek, 2001 to 2005.

Taxon	Fort Creek (reach FOC-D-1)			
	2001	2002	2003	2005
Nematoda	2	1	1	24
Glossiphoniidae		<1		
Erpobdellidae		<1		
Enchytraeidae	1	<1	1	
Naididae	1	1	<1	
Tubificidae		1	<1	6
Hydracarina	<1		<1	
Ostracoda	1		<1	6
Copepoda	<1	1	1	
Macrothricidae		<1	<1	
Bivalvia	5	1	<1	8
Gastropoda	<1		<1	
Ephemeroptera	<1			
Trichoptera			<1	
Heteroptera			<1	
Tipulidae	8	<1	<1	
Tabanidae		<1		
Empididae	1		<1	
Ceratopogonidae	<1	<1	1	
Chironomidae	80	95	95	56
Simuliidae			<1	
Total Abundance (No./m^2)	4,069	41,905	69,802	913
Richness	15	13	13	4
Simpson's Diversity	0.84	0.69	0.57	0.65
Evenness	0.91	0.79	0.68	0.90
% EPT	<1	0	2	0

Figure 5.13-6 Variations in benthic invertebrate community measurement endpoints in Fort Creek, each FOC-D-1.



Note: lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for depositional sites.