5.0 WATERSHED-LEVEL ASSESSMENT OF 2004 RESULTS

This is the main results section of the RAMP 2004 Technical report. Sections 5.1 to 5.9 of this chapter focus on watersheds in which oil sands developments were underway as of 2004, while Sections 5.10 to 5.13 focus on watersheds for which there has been little or no oil sands development to date.

Page Number Guide to Watersheds and RAMP Component Reports

	Athabasca Main Stem	Athabasa River Delta	Muskeg	Steepbank	Tar	MacKay	Miscellaneous Exposed Systems	Firebag	Calumet	Ells	Christina-Clearwater	Hangingstone	Miscellaneous Reference Systems
Climate and Hydrology	5-4	5-50	5-62	5-116	5-150	5-170	5-190	5-216	5-234	5-248	5-268	5-330	5-344
Water Quality	5-5	5-50	5-62	5-116	5-150	5-170	5-190	5-216	5-234	5-248	5-268	5-330	5-344
Sediment Quality	5-7	5-50	5-63	5-117	5-151	5-171	5-192	5-216	5-234	5-248	5-269	5-330	5-345
Benthic Invertebrate Communities	5-8	5-51	5-64	5-117	5-152	5-172	5-193	5-217	5-235	5-249	5-269	5-331	5-345
Fish Populations	5-8	5-51	5-67	5-118	5-153	5-173	5-194	5-217	5-235	5-249	5-270	5-331	5-345

Definitions for Monitoring Status

- ***exposed*** describes aquatic resources and physical locations (i.e., stations, reaches) that may be influenced by oil sands developments. This term does not imply that effects of oil sands developments are occurring or have occurred, but simply that data collected from these locations are to be designated as ***operational*** for the purposes of data analysis.

- ***reference*** describes 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.

- ***baseline*** is used to characterize data and information gathered from stations that are designated as reference.

- ***operational*** is used to characterize data and information gathered from stations that are designated as exposed.

5.1 ATHABASCA RIVER MAINSTEM

Summary of Results

Climate and Hydrology

	Assessment of Change			
	Negligible	Low	Moderate	High
Mean open-water season discharge	√			
Mean winter discharge	√			
Annual maximum daily discharge	√			
Minimum open-water season discharge	√			

Measurement endpoints were calculated to be from 0.2% to 1.7% lower in the operational than in the baseline hydrograph, indicating endpoints are less than what they would have been in the absence of oil sands development activities.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=7)	2004 Reference Stations (n=4)
Physical variables (3 endpoints)	0	0
Nutrients (5 endpoints)	8	0
Ions (5 endpoints)	0	0
Organic compounds (1 endpoint)	0	0
Selected metals (5 endpoints)	7	0

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 7 stations X 7 analytes)	2004 Reference Stations (n= 3 stations X 7 analytes)
Above 95th	13	6
Between 75th and 95th	12	7
Between median and 75th	9	5
Between 25th and median	7	1
Between 5th and 25th	7	2
Less than 5th	1	0

Based on available water quality and oil sands development information for 2004, there were no discernible or detectable water quality effects of oil sands development activities in the Athabasca River mainstem.

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=9)	2004 Reference Stations (n=3)
Physical variables (4 endpoints)	0	0
Total Hydrocarbons (8 endpoints)	2	1
PAHs (7 endpoints)	0	0

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 9 stations X 3 analytes)	2004 Reference Stations (n= 3 stations X 3 analytes)
Above 95th	1	1
Between 75th and 95th	6	2
Between median and 75th	9	2
Between 25th and median	7	4
Between 5th and 25th	3	0
Less than 5th	1	0

Sediment quality in the Athabasca River mainstem has been highly variable during RAMP sampling since 1997, both among stations in a given year and within stations among years. In 2004, sediment sampling along the banks of the Athabasca River mainstem was confounded relative to previous years due to the high (bankfull) river level, which resulted in sediment sampling in different locations than in 2003. Although highly variable, sediment quality in the Athabasca River in 2004 was within the range of previous years' observations.

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline					
	2004 Exposed Stations (n= 0)			2004 Reference Stations (n= 0)		
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD
Abundance						
Richness						
Diversity						
Evenness						
% EPT						

Benthic invertebrate communities were not monitored by RAMP in the Athabasca River mainstem in 2004.

Fish Populations

Fish Inventory	Little evidence that characteristics of key indicator fish populations have changed during increasing development in the oil sands region.
Sentinel Studies	Sentinel fish studies were not conducted in 2004.
Fish Tissue	Level of Risk
Human Health: Subsistence	
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	
Fish and Wildlife: Mercury	
Fish and Wildlife: Other Chemicals	

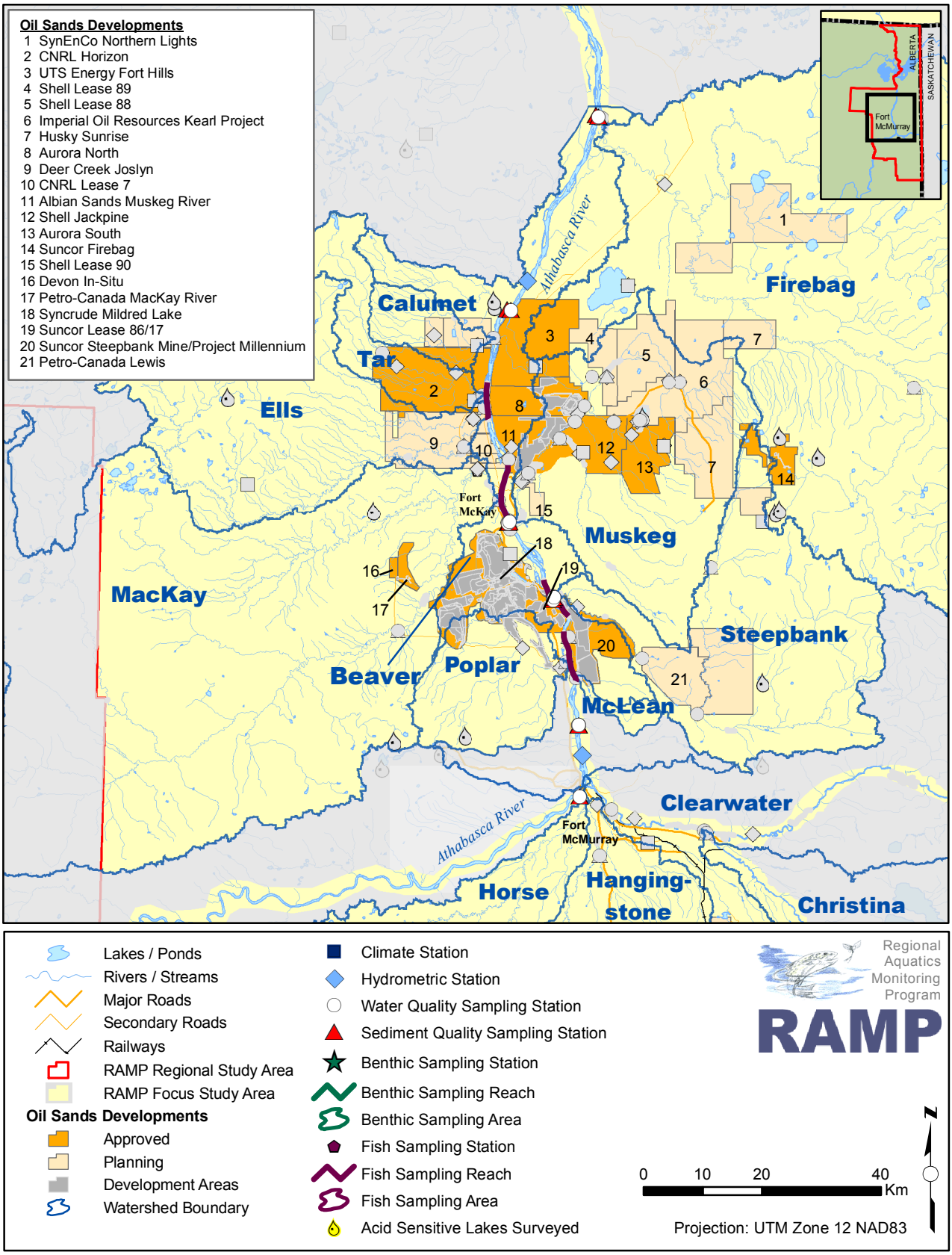
Fish tissue program was not conducted in the Athabasca River mainstem in 2004.

[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 mainstem.



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5.1.1 Hydrologic Conditions

Flows in the Athabasca River measured at WSC station 07DA001 (Athabasca River below Fort McMurray) in 2004 were slightly below normal, with a total annual volume of 90% of the long-term average (Figure 5.1-2). In the past decade, only two years—1996 and 1997—have been above the long-term average. Discharges in winter were very close to historical mean values, and in summer fluctuated between slightly above and well below the long-term average (Figure 5.1-2). The maximum daily discharge of 1960 m^3/s was well below the mean annual flood of 2490 m^3/s. The minimum open-water discharge of 375 m^3/s occurred on October 29, and was slightly lower than the long-term mean minimum discharge of 437 m^3/s. Discharges measured downstream of oil sands development at RAMP Station S24 were slightly higher than at the WSC station, as expected because of the intervening catchment area (Figure 5.1-3). Considering the uncertainty in both the WSC measurements and the RAMP measurements, the difference between the two is not significant.

Table 5.1-1 contains the parameters of the water balance model (Section 3.1.7) applied to the Athabasca River basin at RAMP Station S24 for calculating a baseline hydrograph for RAMP Station S24 to examine possible changes in the hydrologic measurement endpoints. The details of the water balance model as applied to the Athabasca River mainstem at RAMP Station S24 are:

- The baseline hydrograph is defined as the hydrograph that would have been observed at RAMP Station S24 in 2004 if no oil sands development had occurred. That hydrograph is obviously not natural because it includes the effects of a variety of upstream developments, but it is a baseline with respect to oil sands developments because it excludes the effects of oil sands development;
- Withdrawals from the Athabasca River by Syncrude, Albian and Suncor (Section 2, Figure 2.2-2 and Figure 2.2-3);
- Releases to the Athabasca River by Suncor (Section 2, Figure 2.2-2);
- Oil sands development effects on tributary flows, as discussed in subsequent sections of Chapter 5;
- Oil sands development effects on the local catchment of the Athabasca River, including catchments of smaller tributaries that are not specifically monitored; and
- The result of all of the upstream influences is the operational hydrograph measured at RAMP Station S24 in 2004.

The results of applying the water balance model are provided as a baseline hydrograph compared to the observed, operational hydrograph (Figure 5.1-3) and values of the measurement endpoints as calculated from the baseline and operational hydrographs (Table 5.1-2). All hydrologic measurement endpoints are calculated to be lower in the operational hydrograph than in the baseline hydrograph, 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% in the case of 2004 maximum daily discharge to -1.7% in the case of mean 2004 winter discharge, because the more or less constant withdrawals are proportionately larger during low-flow rather than high-flow periods. This must be regarded as a conservative estimate because clearing and de-watering did occur in some parts of the RAMP FSA in 2004 (Section 2) and this likely had an ameliorating effect on Athabasca mainstem flows. These changes would have been assessed as Negligible in most oil sands EIAs (Appendix A). Therefore, based on the available hydrologic and oils sands development information, it appears that changes in hydrologic conditions up to and including 2004 have been negligible in the Athabasca River mainstem.

5.1.2 Water Quality

In 2004, water quality samples were collected from a number of reference and exposed sites along the Athabasca River mainstem:

- Upstream of Fort McMurray (ATR-UFM) – reference;
- Upstream of Donald Creek (ATR-DC-CC, ATR-DC-W, ATR-DC-E) – reference;
- Upstream of the Steepbank River (ATR-SR-W, ATR-SR-E) – exposed;
- Upstream of the Muskeg River (ATR-MR-W, ATR-MR-E) – exposed;
- Downstream of all development (ATR-DD) – exposed;
- Upstream of mouth of Firebag River (ATR-FR) – exposed; and
- Upstream of the Embarras River (ATR-ER) – exposed.

Results of 2004 sampling for selected water quality measurement endpoints identified in Section 3.2.7 are shown in Table 5.1-3; results for selected measurement endpoints (1997 to 2004) relative to regional baseline conditions at stations along the Athabasca River mainstem are shown in Figure 5.1-4 to Figure 5.1-7.

Water quality in the Athabasca River mainstem in fall 2004 was influenced strongly by higher-than-average flows and associated increased sediment loads. Total suspended solids (TSS) were relatively high at all mainstem stations, although generally within historical fall values observed upstream of Fort McMurray at Alberta Environment long-term monitoring station ATR-UFM (Table 5.1-3). Other water quality variables typically associated with TSS, including total aluminum, total copper, total iron, total lead and total phosphorous, typically also were high at all stations in fall 2004, often exceeding CCME water quality guidelines for the protection of aquatic life (Table 5.1-3). Concentrations of these measurement endpoints were high at all stations in 2004, both upstream and downstream of oil sands developments. Dissolved species of these metals and nutrients did not occur at similarly high levels, indicating that these high total metal and total phosphorous values were related to high levels of suspended materials in the

river in 2004. In most instances, concentrations of selected measurement endpoints in fall 2004 were within the range of regional baseline conditions (Figure 5.1-4 to Figure 5.1-7).

Ion balance characteristics vary within a narrow range for all stations regardless of sampling year or longitudinal location along the river (Figure 5.1-8), with the exception of three observations: upstream of Donald Creek (east bank) (ATR-DC-E) in 2000 and 2003, and downstream of Fort Creek (east bank) (ATR-FC-E-D) 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, which exhibits much higher chloride concentrations and lower dissolved calcium than the Athabasca River upstream of Fort McMurray (Table 5.1-3 and Table 5.11-3). The shifted ion balance at ATR-DC-E observed in 2000 similarly may be a result of the influence of the Clearwater River. The shifted ion balance at ATR-FC-E-D in 1998 also may be related to influences of the upstream discharge of Fort Creek, although chloride concentrations in Fort Creek typically have been low (and dissolved calcium concentrations high) during previous RAMP sampling events (Appendix E).

In summary for 2004, there were no discernible or detectable water quality effects of oil sands development activities in the Athabasca River mainstem in 2004, based on available water quality and oil sands development information.

Long-term trends in Athabasca River water quality were examined through statistical trend analysis of Alberta Environment long-term monitoring data sets from upstream of Fort McMurray (RAMP ID ATR-UFM, 1976 to 2004 data) and downstream at Old Fort, at the head of the Athabasca delta (RAMP ID ATR-OF, 1987-2004 data). This analysis followed similar assessment of long-term trends at these stations undertaken in the RAMP 5-year report (Golder 2003).

Results of trend analysis for selected water quality measurement endpoints appear in Table 5.1-4. Results were similar to those found in the 5-year trend report, with trends found in several variables at the stations upstream of Fort McMurray, including: increases in various indicators of ion concentration, including pH, conductivity, alkalinity, sodium, chloride and sulphate; and small decreases in total suspended solids, total nitrogen, total Kjeldahl nitrogen, and total molybdenum. Increases in ion concentration at this station from 1976 to 2004 may be related to the commencement of several pulpmill discharges to the Athabasca River upstream of Fort McMurray over this period, as ion concentrations in pulpmill effluent typically are higher than ambient river concentrations; however this hypothesis is speculative.

Fewer trends were observed in water quality downstream of the oil sands development area at Old Fort, where only an increase in pH and a decrease in dissolved phosphorous were identified among the variables assessed. Inconsistencies between long-term trends in Athabasca River water quality upstream of Fort McMurray and at Old Fort may relate to the different time frames assessed for each station, or to contributing influences of other tributaries to water quality in the river mainstem downstream of Fort McMurray. The absence of corresponding increasing trends in ions at Old Fort relative to upstream of Fort McMurray likely is not related to oil sands activities, as oil-sands-related effects on

water quality have been predicted to potentially increase ion concentrations rather than decrease them.

Table 5.1-5 contains a list of all exceedances of CCME guidelines for protection of aquatic life observed in the Athabasca mainstem in 2004.

5.1.3 Sediment Quality

In 2004, sediment quality samples were collected from a number of reference and exposed sites along the Athabasca River mainstem:

- Upstream of Fort McMurray (ATR-UFM) – reference;
- Upstream of Donald Creek (ATR-DC-W, ATR-DC-E) – reference;
- Upstream of the Steepbank River (ATR-SR-W, ATR-SR-E) – exposed;
- Upstream of the Muskeg River (ATR-MR-W, ATR-MR-E) – exposed;
- Downstream of all development (ATR-DD-W, ATR-DD-E) – exposed;
- Upstream of mouth of Firebag River (ATR-FR-W, ATR-FR-E) – exposed; and
- Upstream of the Embarras River (ATR-ER) – exposed.

Results of 2004 sampling for sediment quality measurement endpoints identified in Section 3.2.7 are shown in Table 5.1-6; results for selected measurement endpoints (1997 to 2004) relative to regional baseline conditions are shown in Figure 5.1-9.

Sediment quality in the Athabasca River mainstem has been highly variable during RAMP sampling since 1997, among stations in a given year and within stations among years. In 2004, sediment sampling along the banks of the Athabasca River mainstem was confounded relative to previous years due to the high (bankfull) river level, which resulted in sediment sampling in different locations than in 2003, when the wetted banks of the river often were much further within the river channel.

Sediments in the Athabasca River mainstem typically are composed of high amounts of sand with variable amounts of silt and clay. Cluster analysis of sediment quality characteristics at mainstem stations from 1997 to 2004 (Appendix F) indicated that sediment characteristics—including particle size, organic carbon, metals and PAH concentrations—typically are highly variable between stations and between years. For example, since 1998 sediments from station ATR-DC-E (upstream of Donald Creek, east bank, a reference station for assessment of Athabasca River sediments further downstream) have exhibited both the highest and lowest total recoverable hydrocarbon (TRH) concentrations measured by RAMP in Athabasca River sediments, with no apparent trends with time.

Although highly variable, sediment quality in the Athabasca River in 2004 was within the range of previous years' observations. Carbon-normalized concentrations of total recoverable hydrocarbons, total PAHs and naphthalene have not exhibited any consistent trends in the Athabasca River since 1997 (Figure 5.1-9). CCME F3 hydrocarbons (i.e., those containing 16 to 34 carbon atoms) exceeded guidelines for surface soils at stations ATR-DC-E, ATR-SR-E (upstream of the Steepbank River, east bank), and ATR-DD-E (downstream of development, east bank); highest total PAH concentrations were found at ATR-DC-E and ATR-SR-E; predicted PAH toxicity was highest at ATR-SR-E (Table 5.1-6). Sublethal toxicity testing of Athabasca River mainstem sediments was not undertaken in 2004.

5.1.4 Benthic Invertebrate Communities

Information on benthic invertebrate communities has not been collected in the Athabasca River mainstem 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 of the Athabasca mainstem include tolerant chironomids and ceratopogonids. It is anticipated that water and sediment quality would have to be severely degraded before those effects would be detectable in the biota. The tributaries, on the other hand, have more diverse benthic assemblages, and would demonstrate effects long before the mainstem.

5.1.5 Fish Populations

The Fish Inventory activity was the only activity conducted in the Athabasca River mainstem in 2004.

5.1.5.1 Fish Inventory

Species Composition and Catch-Per-Unit-Effort

All 2004 Athabasca River fish inventory sampling was carried out using a boat electrofishing unit; no seine netting was included in the 2004 program. A total of 5,413 fish were captured or observed during the spring and fall fish inventory on the Athabasca River. During the spring sampling 1,506 fish of 17 species (Table 5.1-7) were captured or observed, while 3,907 fish of 16 species were recorded for the fall sampling (Table 5.1-8). Primary fish capture data from the 2004 Athabasca River inventory are compiled in the RAMP database available through the RAMP website (see Appendix C for further details concerning the RAMP database). Species composition (%) and catch-per-unit-effort (#fish/100 seconds) information for spring and fall electrofishing on the Athabasca River are also shown in Table 5.1-7 and Table 5.1-8, respectively.

The most abundant large-bodied species captured in the spring of 2004 (in declining order) were walleye, white sucker, goldeye, longnose sucker and northern pike (Table 5.1-7 and Table 5.1-8). This ranking is identical to that found in 2003 with the exception of goldeye that was ranked second in 2003, ahead of white sucker. During the fall sampling the most abundant large-bodied fish species were goldeye, walleye, lake whitefish, white sucker and northern pike. Again this ranking was generally consistent

with catch data from 2003. These results correspond to the known characteristics of the fish community utilizing the Athabasca River in the oil sands region (Figure 5.1-10). Large numbers of trout-perch (total 2,092 individuals spring and fall) were observed during electrofishing, although only about 22% were captured. In dramatic contrast to the spring survey (n=16 fish captured and observed), lake whitefish were highly abundant in the fall (total 1035 individuals observed and 58 captured to minimize mortality during holding period) due to the annual spawning migration for this species.

Percent catch composition (1995-2004 spring inventory) for selected large-bodied species is shown in Figure 5.1-10. Over the past eight years, numbers of northern pike have been the most consistent over time, representing approximately 5% of the fish captured. All large-bodied fish species showed a decrease in percent composition relative to 2003. Particularly dramatic declines were recorded for walleye and longnose sucker, with catches being approximately 50% and 25% of 2003 levels, respectively.

The combined catch-per-unit-effort (CPUE) (captured and observed) for the spring sampling on the Athabasca River decreased dramatically in 2004 after a substantial increase in 2003 (Figure 5.1-11). The combined CPUE in 2004 was the lowest recorded since initiation of the inventory program in 1995. CPUE of walleye in 2004 was similar to the 2003 level, although this species continues to slowly decline from high 1995 values (Figure 5.1-12). The abundance of longnose sucker and goldeye in 2004 continues to be lower relative to previous years, particularly 1997, but similar to results observed in 1995. A slight increase in white sucker CPUE was recorded in 2004 over the 2003 level. The CPUE of northern pike has remained consistently low since 1995.

Length-Frequency Analysis

Length-frequency histograms (1997-2004) for each key fish indicator species are presented in Figure 5.1-13 to Figure 5.1-18.

Walleye captured in 2004 were predominantly in the 401-450 mm length class. This class was also dominant in 1998. The dominant length class in all other years was 351-400 mm (Figure 5.1-13). Visually, there appeared to be little change in the length-frequency distribution for walleye in the Athabasca River in 2004, relative to historical inventory results. A statistical difference in length-frequency was found among years ($p<0.001$); however, no consistent pattern could be identified over time.

Inventory results for lake whitefish (fall only) in 2004 found the majority to be in the 401-450 m length range (Figure 5.1-14). This was also the dominant class in past years. A significant difference in length-frequency data among years was detected ($p=0.001$); however, there was no evidence of a directed shift towards any particular size class in the spawning population.

Goldeye captured during the 2004 spring and fall inventories were dominated by individuals in the 351-375 mm length class (Figure 5.1-15). Length-frequency distributions for previous survey data have been variable for goldeye, particularly in relation to the number of young fish captured. In 2004, a larger number of individuals in smaller length classes were captured than in 2003. These results are similar to 1997 and

1998 results, but differed from 1999 and 2000 results when lower numbers of small fish were captured. Statistical analysis found a significant difference in length-frequency among years ($p<0.001$).

The length-frequency distribution for longnose sucker has been quite variable among years (Figure 5.1-16). As was the case in 2003, two modes were observed in 2004 (151-200 mm and 401-450 mm length class) suggesting that small individuals, most likely juvenile, were present in comparatively large numbers. In past years, particularly 1997 and 1998, a single dominant mode was observed ranging from 350-500 mm. Length-frequency distributions were significantly different ($p<0.001$) among years.

The 2004 length-frequency distribution for northern pike was dominated by fish in a range of size classes from 301-600 mm (Figure 5.1-). Historically, the majority of individuals captured were between 400 and 600 mm long, with some shifting of the dominant 50 mm class between years (Figure 5.1-18). Smaller individuals were present in 2004, which contrasts with some years (e.g., 1999) when small fish were not collected. Overall, results from 2004 appear to be within the range of variation in length-frequency distributions seen in recent years. Though the distributions appear variable, there is no indication that the population is changing substantially over time. Statistical analyses found no significant difference ($p=0.18$) among years.

Trout-perch have been collected during inventory activities in the Athabasca River; however, they have not been included in RAMP monitoring as a key fish indicator until recently. In addition, the size-selective bias inherent in electrofishing limits the comparability of data. Low sample sizes in 1999 to 2002 (<20 fish per year) limited the comparison to results from 2003 ($n=361$) and 2004 ($n=451$). The majority of trout-perch collected in 2004 were in the 71-75 mm length class (Figure 5.1-18). This is a significant shift in average size compared to 2003 results when the dominant length class was 45-50 mm. Length-frequency relationships were significantly different between years ($p<0.001$); however, the limited sample size in 1997 relative to 2003 and 2004, most likely has a strong influence on the comparison.

Condition Factor

The relationship between body weight and fork length was examined for five of the six key indicator species. Trout-perch (which were not weighed prior to release) were not included in this analysis.

Comparisons of mean Fulton's Condition Factor (k) among years are presented for each species of interest in Figure 5.1-19 to Figure 5.1-23. There were no significant differences in condition ($p = 0.05$) among years for northern pike and walleye; however, a significant difference was shown for lake whitefish, longnose sucker and goldeye among specified years (Table 5.1-9).

Lake whitefish condition factor in 2004 was 6.8% higher relative to 1998 and almost 8% higher relative to 1999. Longnose sucker condition factor was significantly higher in 2004 relative to all previous years, ranging from 3.2% to 12.4%. Goldeye condition was significantly (i.e., 9.1%) higher in 2004 relative to 2002.

External Health

In 2004, mean external pathology index values ranged from 0.3% (walleye) to 1.4% (longnose sucker) (Table 5.1-10). As in previous years, abnormalities observed were primarily associated with fin erosion and injuries to the body surface (skin aberrations). The mean index values for fish collected in 2004 were within the range of values documented for previous years (Table 5.1-10). 2004 indices for walleye and white sucker were lower than all previous years.

Discussion

The 17 species recorded during the 2004 Athabasca spring inventory was in the mid-range of previous inventories (highest: 22 species in 1997; lowest: 13 species in 1999) (Golder 2003b). Of the 29 fish species known to inhabit the Athabasca River in the oil sands region, 22 species have previously been caught during RAMP fish inventory activities (Golder 2003a). In 2003, three species were captured that were known in the Athabasca River, but had not been previously captured under RAMP. These included cisco (electrofishing, spring and fall), pearl dace (spring seining, fall electrofishing), and longnose dace (spring seining). In 2004, the pearl dace was captured again during the spring electrofishing; however, cisco was not part of the catch in the spring or fall.

The total fishing effort and number of fish captured or observed in 2004 were similar to that recorded for 2003. In 2004, effort was highest in the spring sampling period, while the reverse was true for the 2003 inventory when the highest effort occurred during the fall sampling. In 2003, approximately equal numbers of fish were captured or observed during the spring and fall sampling efforts; in 2004, almost twice as many fish were captured or observed in fall relative to spring. This was primarily due to the comparatively large numbers of lake whitefish (whose annual spawning migration occurs in fall) and trout-perch observed. Actual fish capture data for the 2004 Athabasca River inventory were similar for both spring and fall (spring: 799; fall: 1,047).

With respect to overall fish catch and species diversity, it is important to note that during both the spring and fall inventory field programs in 2004 turbidity in the Athabasca River was comparatively high. This factor may have had a negative effect on the number of fish captured and observed during the inventory program.

Percent composition of all large-bodied fish species captured during the 2004 Athabasca River inventory (highlighted in the spring data) declined considerably relative to 2003 values. The result is more consistent with the apparent declining trend observed from recent pre-2003 data. Percent catch composition for walleye, northern pike and white sucker in 2004 were approximately one-half of the 2003 values, while values for goldeye and longnose sucker declined by about 60% and 80% from the previous year, respectively. Percent composition for all large-bodied fish species captured during the 2004 Athabasca River inventory was within the range of historical inventory results.

Combined CPUE for all species captured during the spring sampling period declined substantially from 2003 (approximately 4 in 2004 and 10 fish/100 s of electrofishing in 2003), and was the lowest value recorded since the beginning of the RAMP Athabasca inventory in 1995. However, combined CPUE in the fall of 2004 was greater than 14 fish/100 s, which was more than twice the rate recorded for the 2003 fall sampling effort. Comparatively high numbers of observed trout-perch, goldeye and flathead chub present in the 2004 sample were responsible for more than one-half of the combined CPUE for that sampling period. CPUE for migrating lake whitefish were similar in the fall of 2003 and 2004.

Historical relative abundance values, expressed as CPUE, for large-bodied fish species captured during the Athabasca River inventory indicate some level of variability between years. However, this has been attributed primarily to sampling variability, particularly with respect to time of the field programs (Golder 2003a). Relative abundance of lake whitefish shows the largest historical variability, although these differences can most likely be explained by the timing of the sampling effort with respect to the annual spawning migration on the Athabasca River. In general, overall species composition and relative abundance for large-bodied fish species in the Athabasca River have remained relatively constant over the RAMP inventory period. There has been some inter-annual variability for individual key fish indicator species, particularly a decline in walleye and lake white fish relative abundance in recent years. However, conducting a meaningful statistical analysis on the inventory data to determine whether this annual variability is significant or a significant trends exists is difficult given the variability in the sampling sites and timing of the field programs, as well as bias in the primary sampling method (e.g., electrofishing).

Examination of length-frequency distributions for key fish indicator species suggests that results have been generally consistent over time. Statistical differences in length-frequency distributions have been observed for some species over time; however, there were no consistent temporal trends that could be identified (Golder 2003). Given the large sample sizes (i.e., all fish caught from 1997-2004), comparisons had a high level of statistical power and could detect small differences in length-frequency. However, these differences did not appear to be ecologically relevant. Though some variability exists regarding the number of small or large individuals captured between years, in general, the dominant length classes have remained consistent over time. Effort should continue to collect sufficient number of individuals to allow appropriate comparison of length-frequency distributions (~100 per species per year would be optimal).

Overall there were no statistical differences in condition among years for any of the key indicator species studied. This suggests that the relationship between body weight and fork length has remained consistent over time. With the recent addition of trout-perch as a key fish indicator, it is recommended that weight information be collected to allow analysis of condition for this species as well.

Summary Assessment

As outlined in the statement of analytical framework for the RAMP fish component in Section 3, the Athabasca River fish inventory is generally considered to be a stakeholder-driven activity that is best suited for assessing general trends in abundance and

population parameters for large-bodied species, rather than fish community structure. Current and historical fish inventory data from the Athabasca River indicate some level of species-specific variability in designated measurement endpoints (e.g., relative abundance and condition factor). However, preliminary statistical analysis of the inventory data set has not demonstrated any significant trends in this regard. Additional inventory data gathered in a standardized fashion are needed to allow for appropriate trend analysis.

From the results of the Athabasca River inventory, there is little evidence to suggest that characteristics of key indicator fish populations (i.e., designated measurement endpoints) have changed during increasing development in the oil sands region.

Currently, all inventory fish sampling sites on the Athabasca River have been designated as exposed sites. In order to enhance the monitoring function of the inventory program it may be appropriate to include a reference site as part of the sampling regime. The reference, baseline site should be located in a reach of the Athabasca River that is situated upstream from oil sands development and has comparable habitat features. Temporal aspects of the Athabasca inventory (i.e., spring and fall sampling) are adequate but more sampling data are needed to assess variability due to factors relating to natural processes and those resulting from sampling methods.

5.1.5.2 Fish Tag Return Assessment

A total of 40 fish, consisting of five species (walleye, northern pike, white sucker, longnose sucker and lake whitefish), have been recorded in the tag return database between 1999 and 2001. All fish were tagged on one of three river systems in the oil sands area: the Athabasca River mainstem; Clearwater River; or, Muskeg River. Data generated from the tag returns are summarized in Table 5.1-11.

Walleye and northern pike returns were considerably higher than the other three species recorded in the database. This is not surprising since these species have been tagged in large numbers during the annual RAMP fish inventory programs on the Athabasca and Clearwater rivers and the are an important sportfish in the region. Numerous walleye and northern pike have also been tagged during the fish fence operations on the Muskeg River. In addition to having the largest number of returns, walleye also exhibited the longest overall distance traveled, with one fish captured over 715 km away from its original point of capture.

Figure 5.1-24 shows the start and finish points, as well as the most direct travel route, for the nine most traveled fish. Eight of the nine fish are walleye that were tagged on the Athabasca River mainstem during RAMP inventory activities. Most of the fish traveled downstream from their tagging locations in the vicinity of Fort McMurray to either Lake Athabasca or into the Peace River. However, the longest traveled fish was a walleye that moved upstream in the Athabasca River for a distance of over 700 km. This fish was tagged in May 1999 and recovered five years later in July 2004. Many of the tag returns have come from First Nations fishers operating out of Fort Chipewyan.

5.1.6 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; 2004 was no exception in this regard. In 2004 there were very small, negligible calculated changes in hydrologic conditions in the Athabasca River mainstem than would 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 development in the oil sands region. Any influences of oil sands development activities on the RAMP aquatic resources of the Athabasca River mainstem appear to be very minor and largely undetectable.

Figure 5.1-2 Athabasca River 2004 hydrograph at WSC Station 07DA001 and historical context.

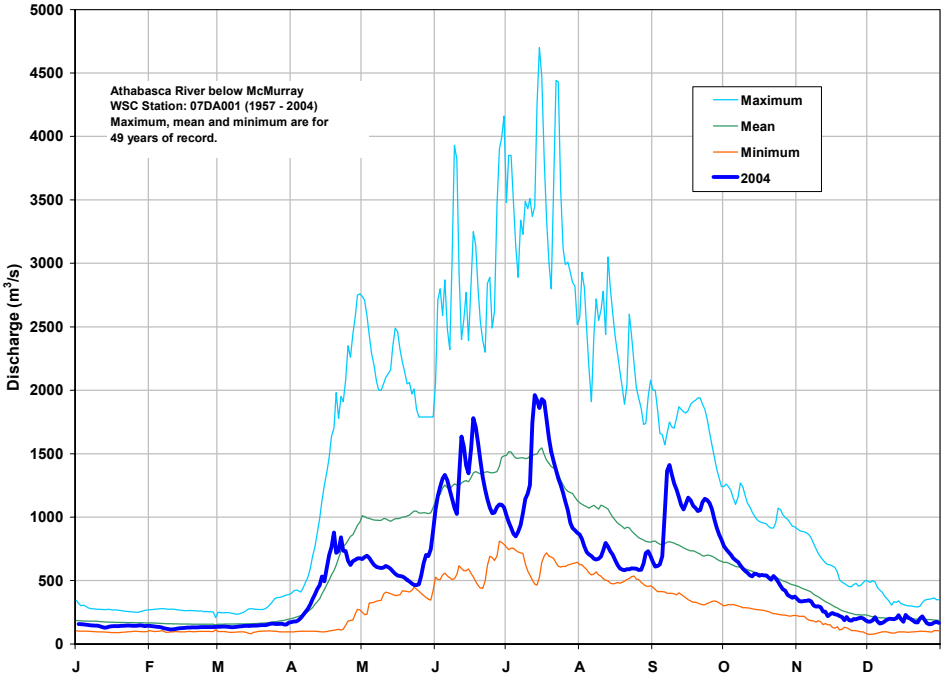


Figure 5.1-3 Athabasca River 2004 actual hydrograph for RAMP Station S24, historical context from WSC Station 07DA001, and estimated 2004 naturalized hydrograph.

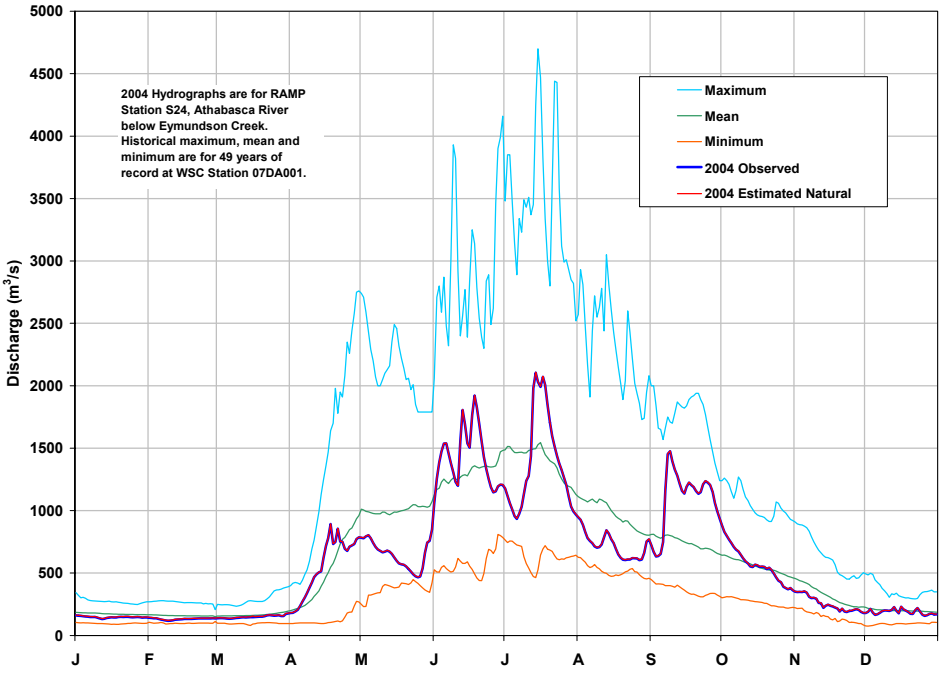


Table 5.1-1 Summary of parameter values for Athabasca River water balance calculation.

Component	Value	Basis / Data Source
Observed 2004 hydrograph[1]	Daily discharges	RAMP Station S24
natural runoff from active oil sands development areas, or intercepted by development	4% of the natural runoff from 360 km^2 in Syncrude Mildred Lake, 35 km^2 in Suncor Lease 86/17, and 150 km^2 in Suncor Steepbank / Millennium	Estimated area based on Figure 2.3-1
incremental runoff from areas that are cleared and areas that are dewatered	0	No information was available to estimate this parameter
water withdrawals from the watercourse in question by oil sands development activities	99 million m^3 for 2004, or 3.14 m^3/s	Daily 2004 Athabasca River withdrawal information from Suncor, Syncrude, Albian Sands
water releases to the watercourse in question by oil sands development activities	9.3 million m^3 for 2004, or 1.78 m^3/s	Daily 2004 Athabasca River discharge information from Suncor
the difference between naturalized and observed hydrographs on tributaries upstream of the station in question	Calculated from main Athabasca River tributaries upstream of RAMP Station S24	See Section 5 Climate and Hydrology sections for MacKay, Tar, Muskeg, and Steepbank River systems

[1]As measured at RAMP Station S24, Athabasca River below Eymundson Creek. Definitions and assumptions are discussed in Section 3.1.7.3.

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

Endpoint[1]	Baseline Value (Naturalized Hydrograph) (m^3/s)	Operational Value (Actual Hydrograph) (m^3/s)	Percent Change
Mean open-water season discharge	977	972	-0.5%
Mean winter discharge	177	174	-1.7%
Annual maximum daily discharge	2,110	2,100	-0.2%
Open-water season minimum daily discharge	366	362	-1.1%

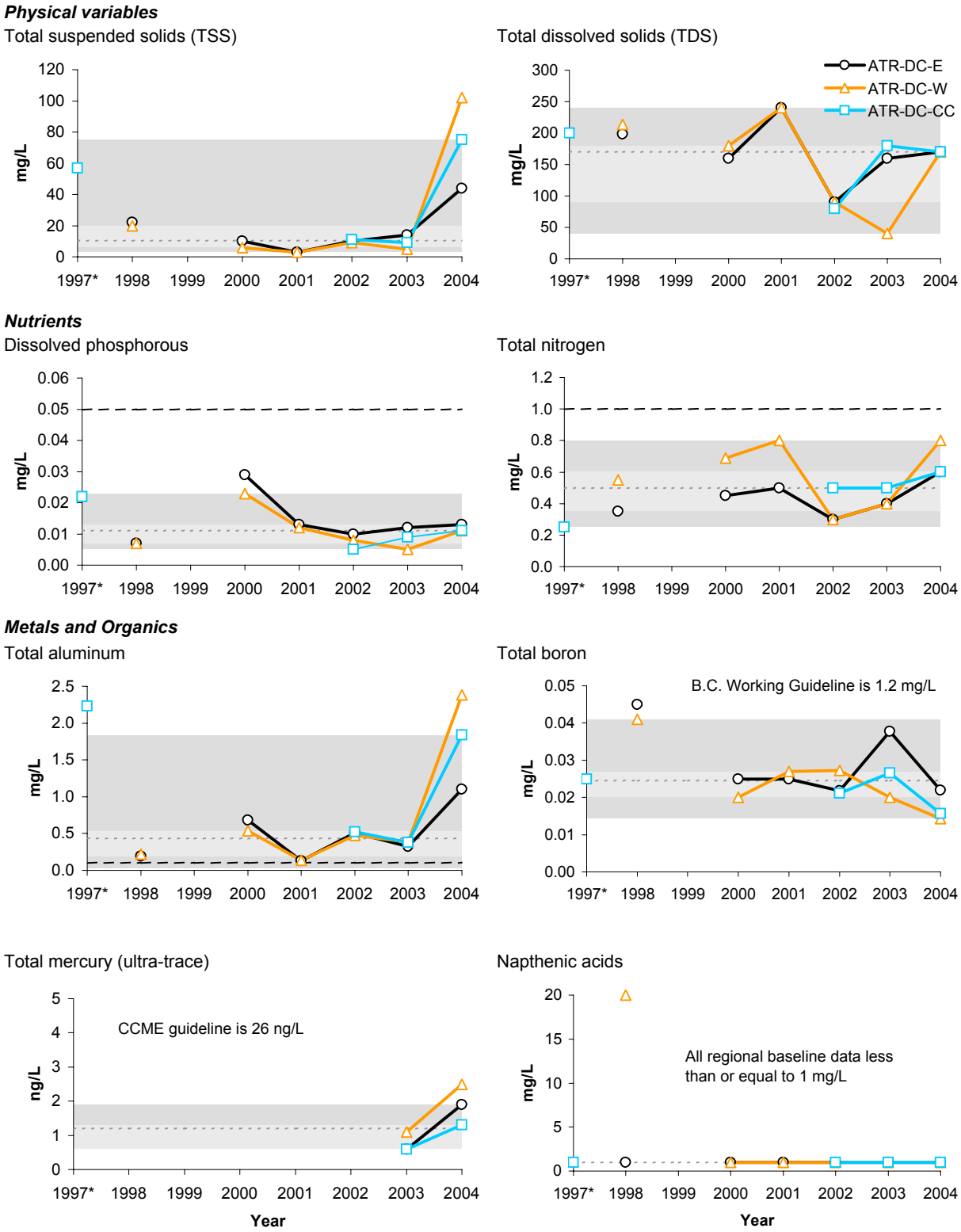
[1]As measured at RAMP Station S24, Athabasca River below Eymundson Creek. Definitions and assumptions are discussed in Section 3.1.7.3.

Table 5.1-3 Concentrations of water quality measurement endpoints, Athabasca River mainstem, fall 2004.

	Units	Guideline	Upstream of Fort McMurray				Upstream of Donald Creek			Upstream of Steepbank River		Upstream of Muskeg River		Downstream of Development	Upstream of Firebag River	Upstream of Embarras River
			n	Min	Mean	Max	E[3]	CC	W	E	W	E	W	M	M	M
Physical variables																
pH	pH units	6.5-9.0	176	7.07	7.95	8.53	8.1	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.1
Total suspended solids	mg/L	-					44	75	102	65	81	201	366	60	95	197
Conductivity	mg/L	-	162	150	306	670	218	202	202	209	205	224	228	218	204	230
Nutrients																
Total phosphorus	mg/L	0.05	182	0.002	0.11	2.5	**0.055**	**0.062**	**0.078**	**0.062**	**0.068**	**0.07**	**0.198**	**0.051**	**0.084**	**0.12**
Dissolved phosphorus	mg/L	0.05[1]	114	0.002	0.015	0.10	0.013	0.011	0.011	0.012	0.011	0.009	0.005	0.009	0.012	0.012
Total nitrogen*	mg/L	1.0	159	0.13	0.69	3.9	0.6	0.6	0.8	0.6	0.6	0.8	0.6	0.5	0.8	**1.5**
Nitrate+nitrite	mg/L	-	183	0.0005	0.079	0.84	<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	-	170	1	9	25	10	12	11	10	10	10	12	10	10	12
Ions																
Sodium	mg/L	-	180	4	12	40	18	9	8	12	7	13	10	10	10	10
Chloride	mg/L	230, 860[4]	180	0.3	4	19	20	5	3	11	3	10	5	6	7	9
Sulphate	mg/L	100[5]	176	11.8	31.0	93.5	10.4	15.9	16.9	14.1	17.6	15.5	20.2	17.2	15.1	13.9
Total dissolved solids	mg/L	-	80	108	189	414	170	170	170	170	170	190	190	200	170	170
Total alkalinity	mg/L	-	180	64	127	269	84	98	101	93	102	95	101	96	97	93
Organic compounds																
Naphthenic acids	mg/L	-	-	-	-	-	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
Selected metals																
Total aluminum	mg/L	0.1	35	0.005	0.8041	5.48	**1.1**	**1.84**	**2.38**	**1.4**	**1.85**	**2.23**	**4.1**	**1.61**	**2.18**	**3.03**
Dissolved aluminum	mg/L	0.1[1]	19	0.001	0.02633	0.149	0.0137	0.018	0.0101	0.0115	0.0117	0.0126	0.0112	0.0115	0.00834	0.0106
Total boron	mg/L	1.2[5]	29	0.0043	0.03214	0.053	0.022	0.0157	0.0143	0.0173	0.0126	0.0215	0.0204	0.0152	0.0153	0.0175
Total molybdenum	mg/L	0.073	74	0.00021	0.00191	0.018	0.00036	0.000495	0.000489	0.000521	0.000564	0.000384	0.000357	0.000504	0.0005	0.000401
Total mercury (ultra-trace)	ng/L	26	131[6]	0.00002	0.0001179	0.001	1.9	1.3	2.5	0.6	1.7	0.8	0.8	<0.6	1.5	1.1
Other variables that exceeded CCME/AENV guidelines in 2004																
Total phenols	mg/L	0.004	121[7]	0.0005	0.004	0.05	-	**0.006**	-	**0.005**	**0.006**	**0.006**	**0.01**	-	**0.005**	**0.009**
Total copper	mg/L	0.002-0.004[2]	85	0.00004	0.003	0.023	**0.00373**	**0.00281**	**0.00337**	**0.00249**	**0.00418**	**0.00326**	**0.00527**	**0.00252**	**0.00415**	**0.00501**
Total iron	mg/L	0.300	37	0.09	1.91	15.22	**1.51**	**2.17**	**2.87**	**1.94**	**2.4**	**3**	**5.55**	**1.9**	**2.74**	**4.07**
Total lead	mg/L	0.001-0.007[2]	43	0.000005	0.0024	0.0209	-	-	-	**-**	**-**	-	**0.00348**	-	-	**0.00257**

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.
* 2004 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. E=east bank; CC=cross-channel; W=west bank; M=mid-channel.
[4] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[5] B.C. Working Water Quality Guideline (B.C. 2003).
[6] 116 observations were below the detection limit.
[7] 47 observations were below the detection limit.

Figure 5.1-4 Concentrations of selected water quality measurement endpoints relative to regional baseline concentrations, Athabasca River mainstem upstream of Donald Creek (ATR-DC), fall 2004.

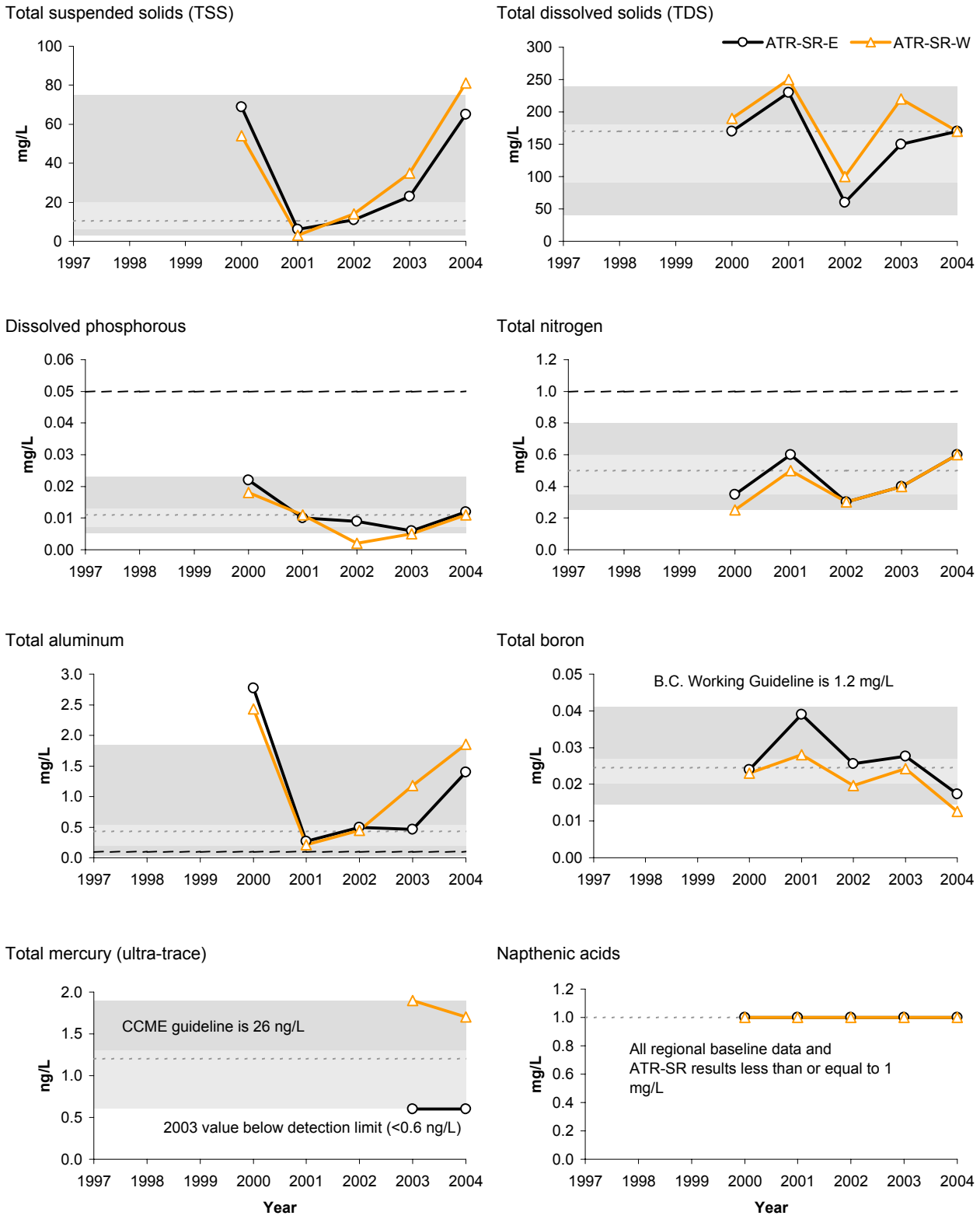


* 1997 ATR-DC-CC sample collected downstream of Donald Creek

[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 E for these regional baseline ranges.

Figure 5.1-5 Concentrations of selected water quality measurement endpoints relative to regional baseline concentrations, Athabasca River mainstem upstream of the Steepbank River (ATR-SR), fall 2004.

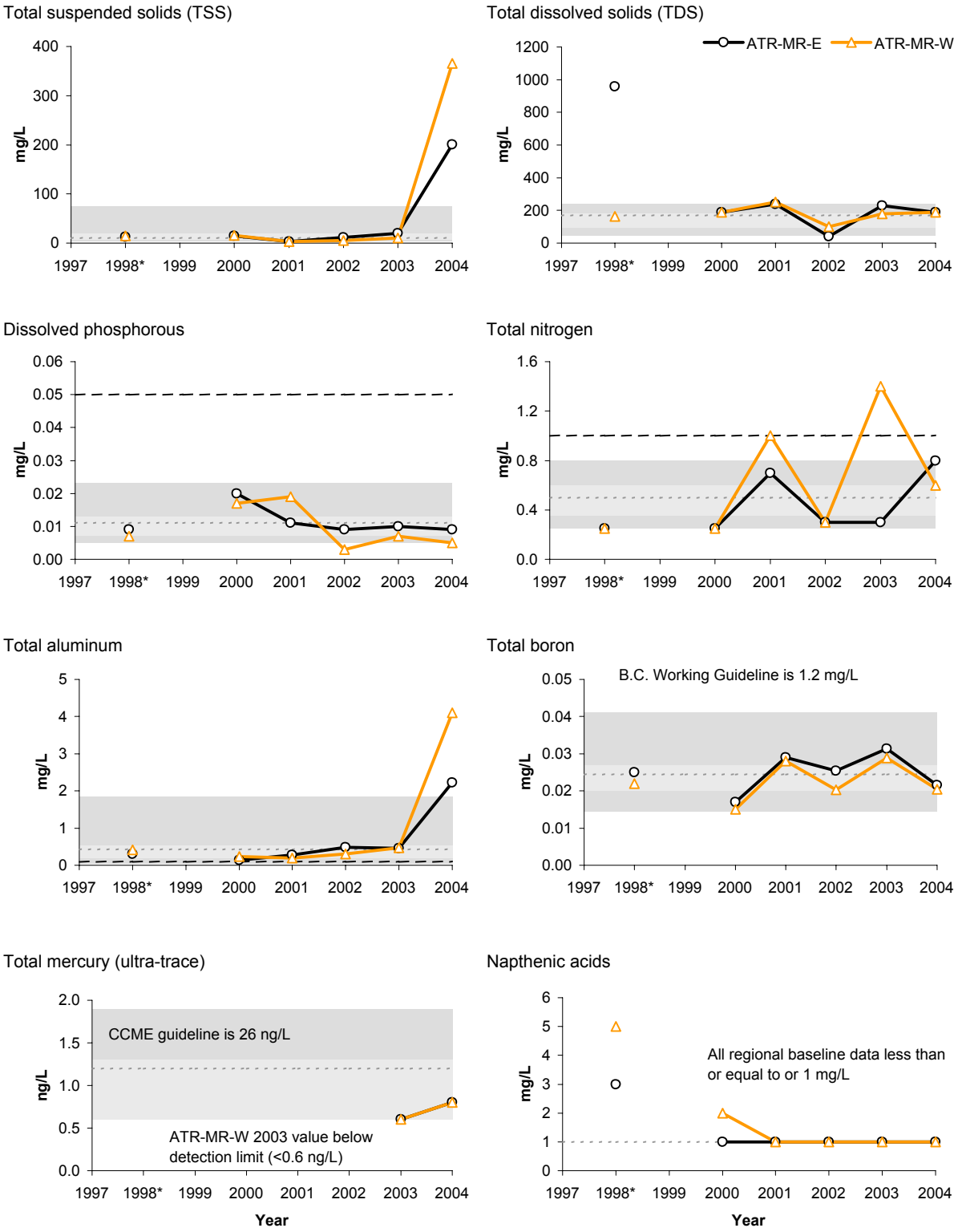
Physical variables



[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 E for these regional baseline ranges.

Figure 5.1-6 Concentrations of selected water quality measurement endpoints relative to regional baseline concentrations, Athabasca River mainstem upstream of the Muskeg River (ATR-MR), fall 2004.

Physical variables

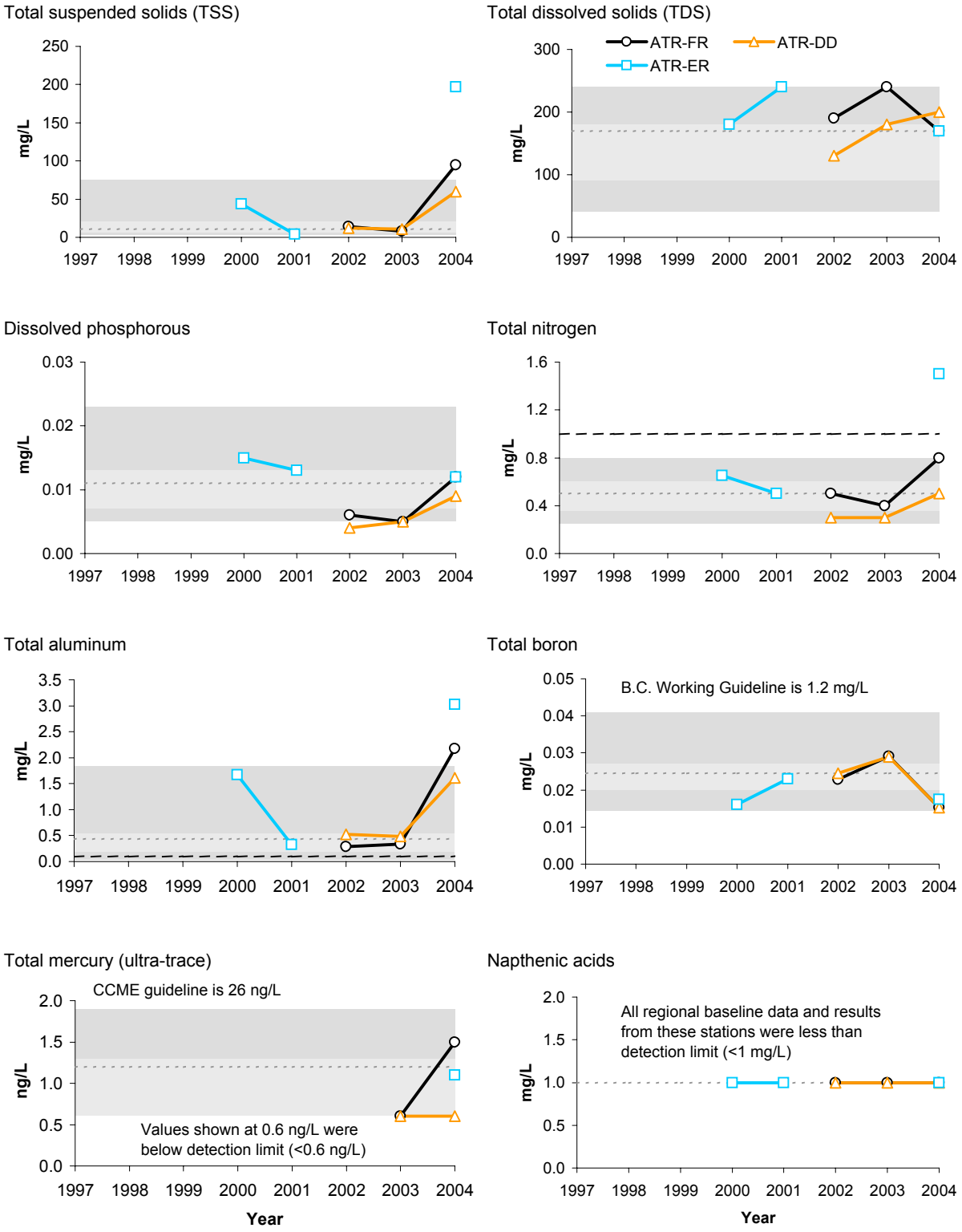


* 1998 samples collected downstream of the Muskeg River.

[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 E for these regional baseline ranges.

Figure 5.1-7 Concentrations of selected water quality measurement endpoints relative to regional baseline concentrations, Athabasca River mainstem downstream of development (ATR-DD), upstream of Firebag River (ATR-FR) and upstream of Embarras River (ATR-ER), fall 2004.

Physical variables



[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 E for these regional baseline ranges.

Figure 5.1-8 Piper diagram of ion concentrations in Athabasca River mainstem, fall 1997 to 2004.

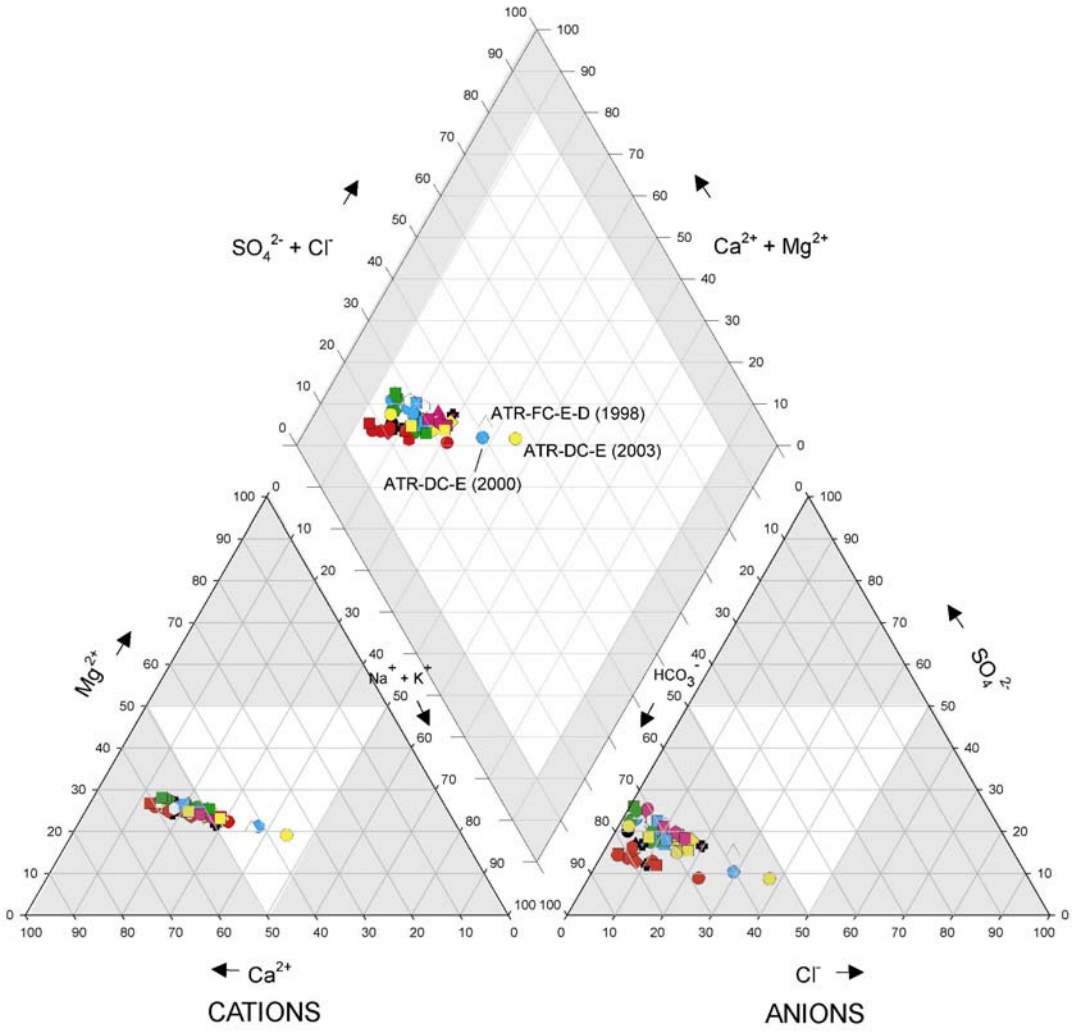


Table 5.1-4 Trend analysis of water quality measurement endpoints for Athabasca River mainstem.

Results of Seasonal Kendall Test for trend and Sen's slope estimate

		Upstream of Fort McMurray (ATR-UFM) 1976-2004				At Old Fort (ATR-OF) 1987-2004			
Parameter	**Units**	**n**	**Long-term mean**	**Significant trend (α=0.05)**	**Sen's slope (units per year)**	**n**	**Long-term mean**	**Significant trend (α=0.05)**	**Sen's slope (units per year)**
pH	pH units	176	7.95	↑	0.006	153	7.72	↑	0.02
conductivity	µS/cm	162	305.9	↑	2.8	153	318.5	-	-
total suspended solids	mg/L	194	100	↓	-0.2	177	70.64	-	-
dissolved organic carbon	mg/L	170	8.9	-	-	151	9.3	-	-
alkalinity	mg/L	180	126.9	↑	0.53	154	112.8	-	-
total dissolved solids	mg/L	80	188.9	↑	0.96	75	165.6	-	-
sodium	mg/L	180	11.9	↑	0.19	154	19.4	-	-
chloride	mg/L	180	3.8	↑	0.04	154	18.4	-	-
sulphate	mg/L	176	31.0	↑	0.38	154	24.4	-	-
total nitrogen	mg/L	159	0.69	↓	-0.010	146	0.59	-	-
total Kjeldahl nitrogen	mg/L	159	0.61	↓	-0.012	150	0.51	-	-
nitrate+nitrite	mg/L	183	0.08	-	-	152	0.07	-	-
total phosphorus	mg/L	182	0.11	-	-	151	0.08	-	-
dissolved phosphorus	mg/L	114	0.015	-	-	145	0.016	↓	-0.0002
total aluminum	mg/L	35	0.804	-	-	48	0.717	-	-
dissolved aluminum	mg/L	-	0.026	n/a	-	86	0.017	-	-
total boron	mg/L	29	0.0321	-	-	-	0.0359	n/a	-
total molybdenum	mg/L	74	0.0019	↓	-0.00003	43	0.0010	-	-
total mercury	mg/L	131	0.000179	-*	0	98	0.000097	-*	0

*: A statistcally significant trend was found with slope = 0. This finding is likely due to different detection limits used throughout the period of record.

n/a: insufficient data for analysis

↑ : upward trend (analyte level increased over time)

↓: downward trend (analyte level decreased over time)

Table 5.1-5 Seasonal exceedances of water quality guidelines in the Athabasca River mainstem (station ATR-DD), 2004.

Parameter	Units	Guideline	ATR-DD
Spring			
Total phosphorus	mg/L	0.05	**0.067**
Total aluminum	mg/L	0.100	**0.46**
Total copper	mg/L	0.002-0.004[1]	**0.00271**
Total iron	mg/L	0.300	**0.921**
Summer			
Total phosphorus	mg/L	0.05	**0.078**
Total aluminum	mg/L	0.100	**2.86**
Total copper	mg/L	0.002-0.004[1]	**0.0033**
Total iron	mg/L	0.300	**2.71**
Fall			
Total phosphorus	mg/L	0.05	**0.051**
Total aluminum	mg/L	0.100	**1.61**
Total copper	mg/L	0.002-0.004[1]	**0.00252**
Total iron	mg/L	0.300	**1.9**
Winter			
Total aluminum	mg/L	0.100	**0.142**
Dissolved iron	mg/L	0.300[2]	**0.716**
Total iron	mg/L	0.300	**1.08**
Total selenium	mg/L	0.0010	**0.0012**

Guidelines are CCME/AENV guidelines for the protection of aquatic life.
Note: Station ATR-DD was the only Athabasca River mainstem station sampled in seasons other than fall.
[1] Guideline is hardness dependent.
[2] Guideline is for total analyte (no guideline for dissolved species).

Table 5.1-6 Concentrations of fall 2004 sediment quality measurement endpoints, Athabasca River mainstem.

	Units	Guideline	ATR-UFM Upstream of Fort McMurray	ATR-DC Upstream of Donald Creek		ATR-SR Upstream of Steepbank River		ATR-MR Upstream of Muskeg River		ATR-DD Downstream of Development		ATR-FR Upstream of Firebag River		ATR-ER Upstream of Embarras River
				E[4]	W	E	W	E	W	E	W	E	W	
Physical variables														
Clay	%	-	10	13	3	20	11	21	23	16	9	6	3	10
Silt	%	-	21	29	7	48	36	45	40	36	16	25	10	29
Sand	%	-	69	58	90	32	53	34	37	48	75	69	87	61
Total organic carbon	%	-	0.6	1.3	0.2	1.6	0.9	1.7	2.1	1.4	0.2	0.6	0.5	0.8
Total hydrocarbons														
CCME variables														
BTEX	mg/kg	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fraction 2 (C10-C16)	mg/kg	150[2]	34	45	15	54	23	26	10	39	10	24	14	28
Fraction 3 (C16-C34)	mg/kg	400[2]	180	**1100**	51	**540**	130	310	120	**420**	75	92	85	220
Fraction 4 (C34-C50)	mg/kg	2800[2]	130	710	39	350	81	180	71	270	44	88	69	190
AEP Tier 1 variables														
TVH (C5-C10)	mg/kg	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
TEH (C11-C30)	mg/kg	-	210	2700	19	7	<5	480	130	340	91	<5	16	61
TRH	mg/kg	-	400	11600	<100	600	900	600	400	900	200	300	200	500
Polycyclic Aromatic Hydrocarbons (PAH)														
Total PAHs	mg/kg	-	1.18	9.60	0.30	6.15	1.44	2.45	1.44	2.45	0.64	0.61	0.31	1.11
Total HMW PAHs	mg/kg	-	0.41	3.40	0.10	2.30	0.43	0.78	0.47	0.65	0.19	0.21	0.11	0.38
Total LMW PAHs	mg/kg	-	0.77	6.20	0.20	3.85	1.01	1.67	0.97	1.80	0.45	0.40	0.20	0.72
Total dibenzothiophenes	mg/kg	-	0.042	0.13	0.012	0.13	0.035	0.076	0.1	0.074	0.022	0.020	0.010	0.034
Naphthalene	mg/kg	0.0346[3]	0.0085	0.0041	0.0033	0.0140	0.0088	0.0120	0.030	0.0140	0.0063	0.0049	0.0028	0.0091
Retene	mg/kg	-	0.214	2.67	0.046	2.15	0.22	0.53	0.17	0.42	0.097	0.15	0.061	0.22
Predicted PAH toxicity[1]	H.I.	-	1.5	0.43	1.5	5.1	0.87	2.2	1.9	1.6	1.6	1.0	0.73	1.1
Metals that exceeded CCME guidelines in 2004														
Arsenic	mg/kg	5.9	-	-	-	**6.6**	-	-	**6.2**	-	-	-	-	-

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.

Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

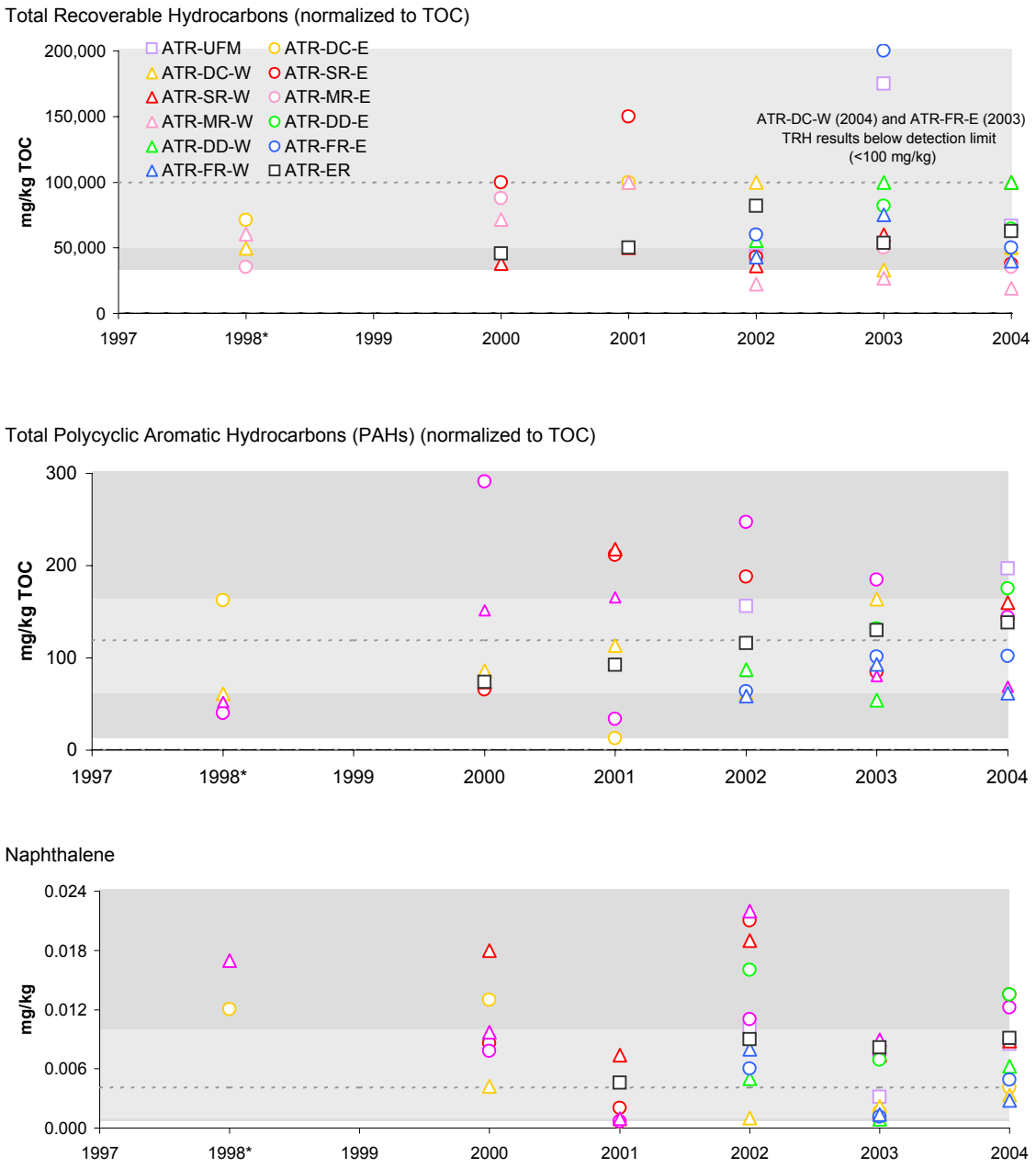
[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

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

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

[4] Denotes sampling location. E=east bank; W=west bank.

Figure 5.1-9 Concentrations of selected sediment quality measurement endpoints, Athabasca River mainstem, fall 2004, relative to regional baseline concentrations. [1]



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

* Sediment sampled downstream of tributary mouths in 1998.

Table 5.1-7 Fish inventory results from electrofishing on the Athabasca River, spring 2004.

Spring Results (total effort = 38,398 s)					
Species	**Total Captured**	**Total Observed**	**Total (obs.+cap.)**	**Species Composition (% Total)**	**CPUE (#/100 s)**
Arctic Grayling	1	0	1	0.07	0.00
Brook stickleback	1	0	1	0.07	0.00
Emerald shiner	31	8	39	2.59	0.11
Flathad chub	80	12	92	6.11	0.26
Fathead minnow	3	0	3	0.20	0.01
Goldeye	64	25	89	5.91	0.25
Lake chub	11	0	11	0.73	0.03
Lake whitefish	15	1	16	1.06	0.04
Longnose sucker	42	6	48	3.19	0.13
Mountain whitefish	1	2	3	0.20	0.01
Northern pike	25	10	35	2.32	0.10
Pearl Dace	3	0	3	0.20	0.01
Spottail shiner	23	0	23	1.53	0.06
Trout-perch	143	565	708	47.01	1.97
Walleye	253	56	309	20.52	0.86
White sucker	101	22	123	8.17	0.34
Yellow perch	2	0	2	0.13	0.01
TOTAL	**799**	**707**	**1,506**	**100**	**4.20**

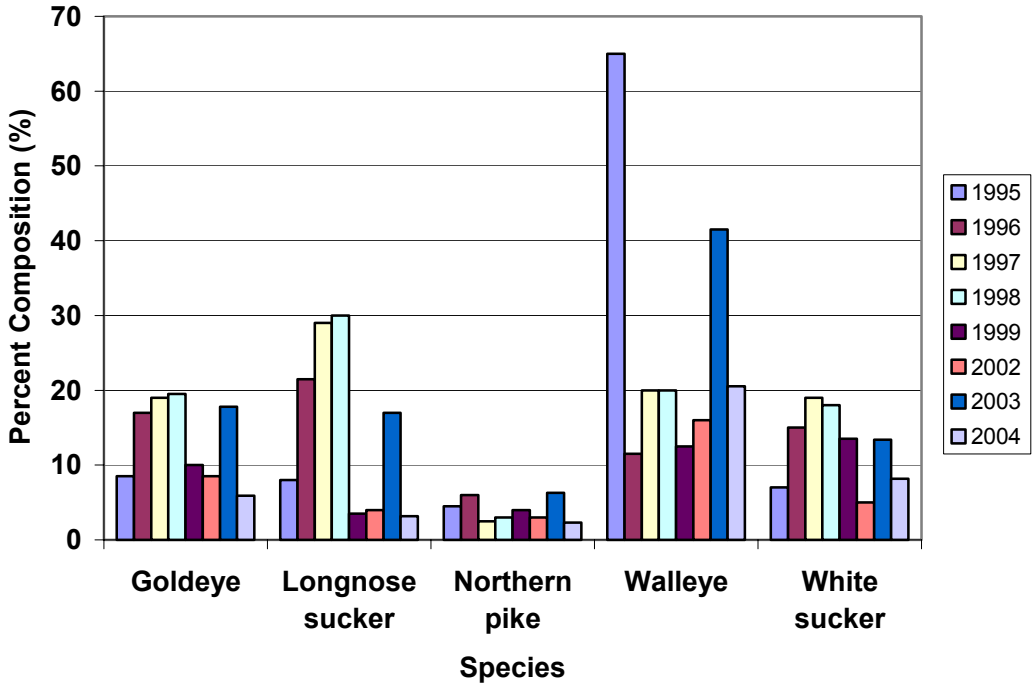
Table 5.1-8 Fish inventory results from electrofishing on the Athabasca River, fall 2004.

Fall Results (total effort = 27,400 s)					
Species	**Total Captured**	**Total Observed**	**Total (obs.+cap.)**	**Species Composition (% Total)**	**CPUE (#/100 s)**
Brook stickleback	1	0	1	0.03	0.00
Emerald shiner	7	6	13	0.33	0.05
Flathad chub	186	202	388	9.93	1.42
Fathead minnow	4	0	4	0.10	0.01
Goldeye	227	426	653	16.71	2.38
Lake chub	14	7	21	0.54	0.08

Table 5.1-8 (cont'd.)

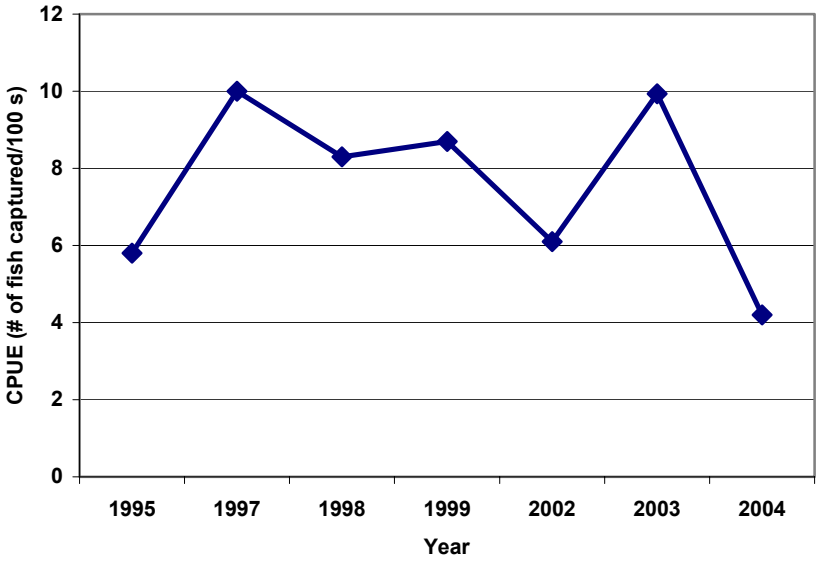
Fall Results (total effort = 27,400 s)					
Species	**Total Captured**	**Total Observed**	**Total (obs.+cap.)**	**Species Composition (% Total)**	**CPUE (#/100 s)**
Lake whitefish	58	1035	1093	27.98	3.99
Longnose sucker	14	25	39	1.00	0.14
Mountain whitefish	3	0	3	0.08	0.01
Northern pike	31	30	61	1.56	0.22
River shiner	5	0	5	0.13	0.02
Spottail shiner	2	0	2	0.05	0.01
Trout-perch	315	1069	1384	35.42	5.05
Walleye	124	41	165	4.22	0.60
White sucker	48	19	67	1.71	0.24
Yellow perch	8	0	8	0.20	0.03
TOTAL	**1047**	**2,860**	**3,907**	**100**	

Figure 5.1-10 Percent composition for common large-bodied species, Athabasca River spring inventory, 1995 to 2004.



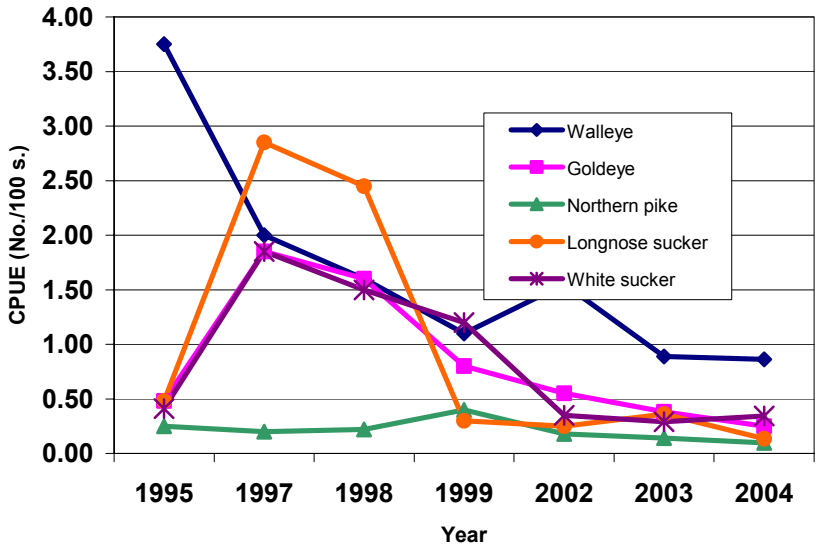
Note: Figure reproduced from Golder (2003b) with 2003-2004 data added. Figure based on fish captured and observed.

Figure 5.1-11 Catch-per-unit-effort (CPUE) for all species combined, Athabasca River spring electrofishing inventory, 1995 to 2004.



Note: figure reproduced from Golder (2003b) with 2003-2004 data added. Figure based on fish captured and observed.

Figure 5.1-12 Catch-per-unit-effort (CPUE) for key indicator species combined, Athabasca River spring electrofishing inventory, 1995 to 2004.



Note: Figure reproduced from Golder (2003b) with 2003-2004 data added. Figure based on fish captured and observed.

Figure 5.1-13 Length-frequency distributions for walleye captured in the Athabasca River, spring and fall, 1997 to 2004.

Note: Frequency = number of fish caught per size class in mm.

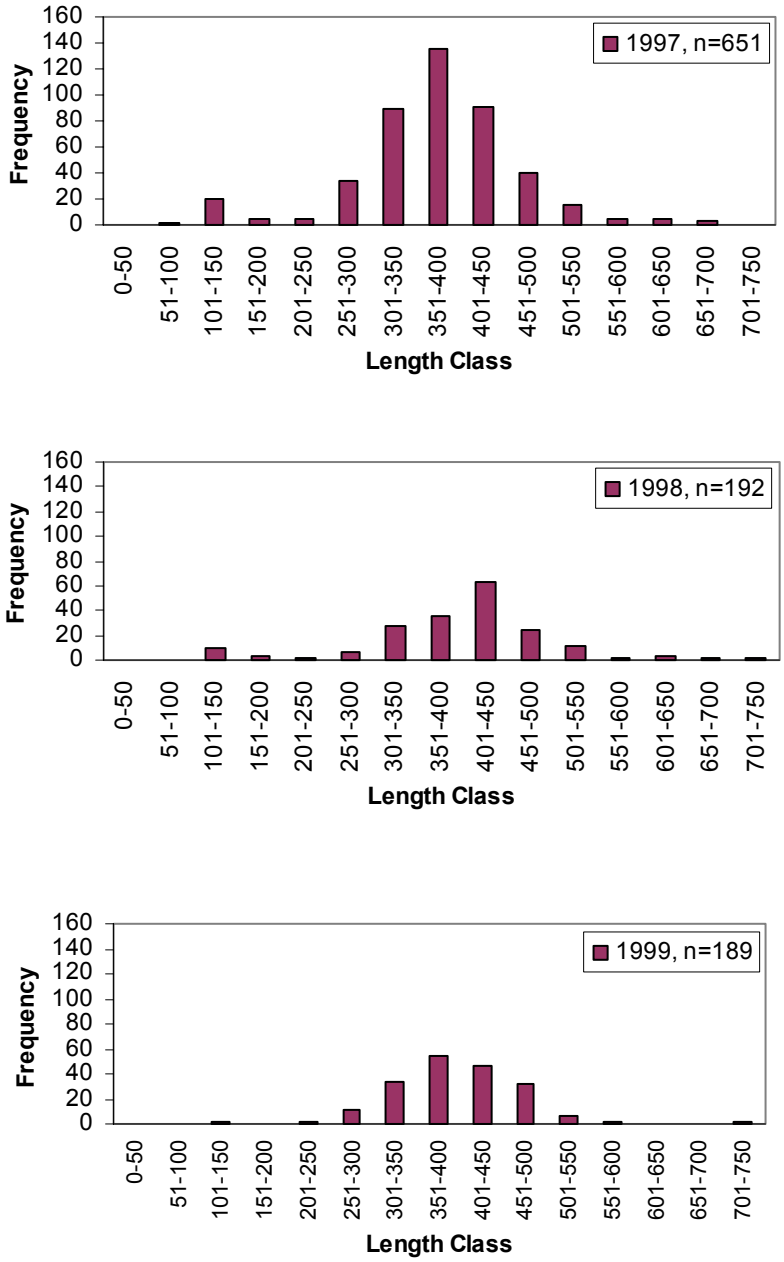


Figure 5.1-13 (cont'd.)

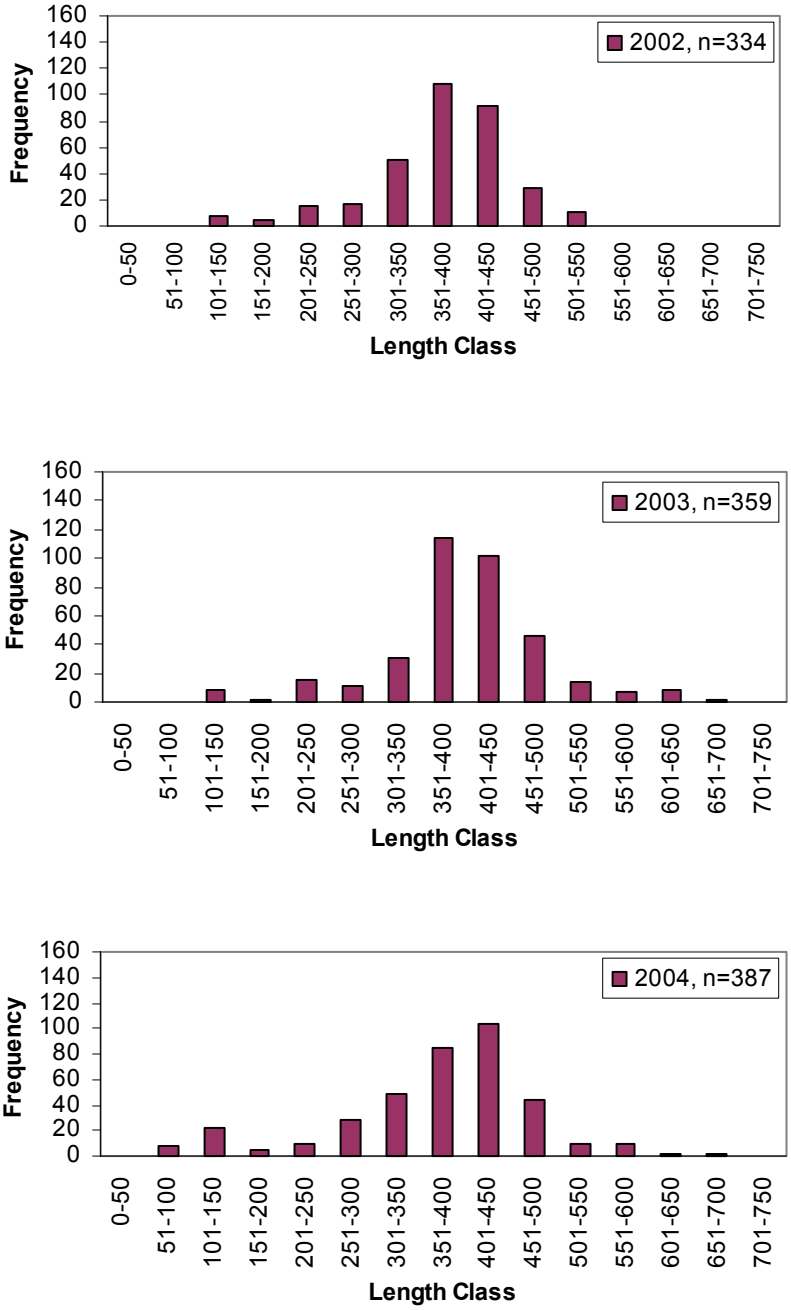
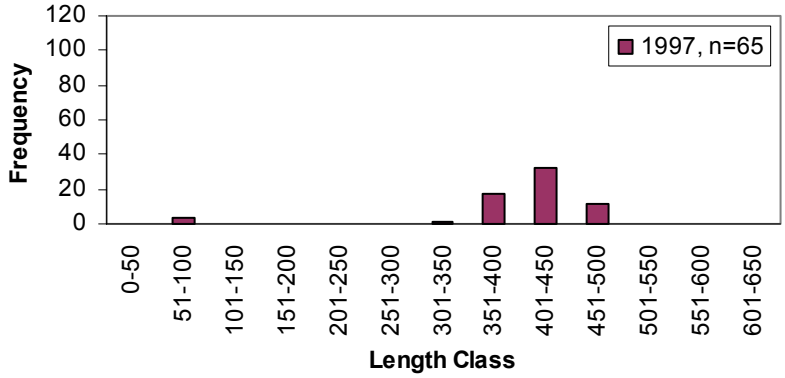
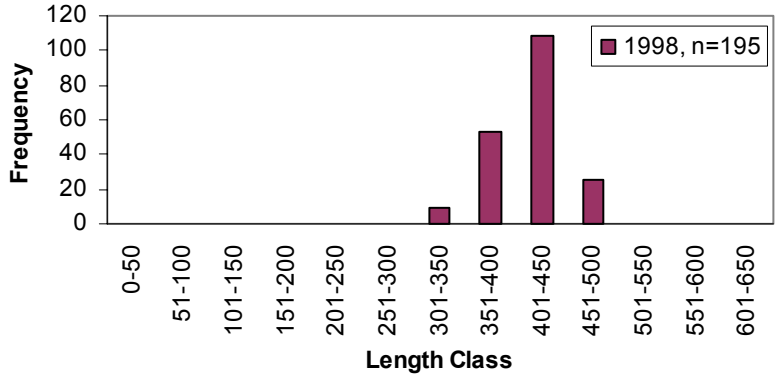


Figure 5.1-14 Length-frequency distributions for lake whitefish captured in the Athabasca River, fall, 1997 to 2004.

Note: Frequency = number of fish caught per size class in mm.





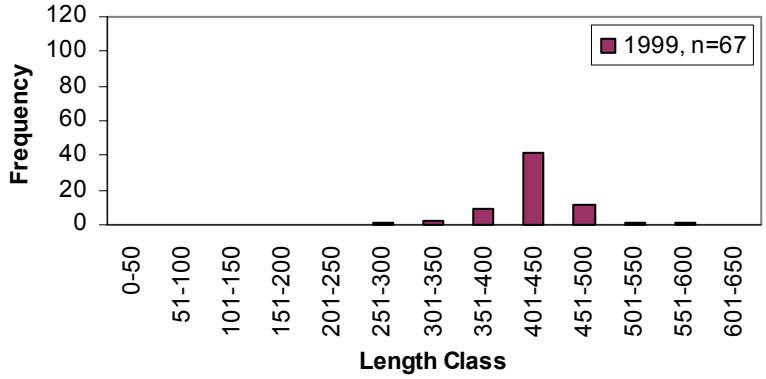


Figure 5.1-14 (cont'd.)

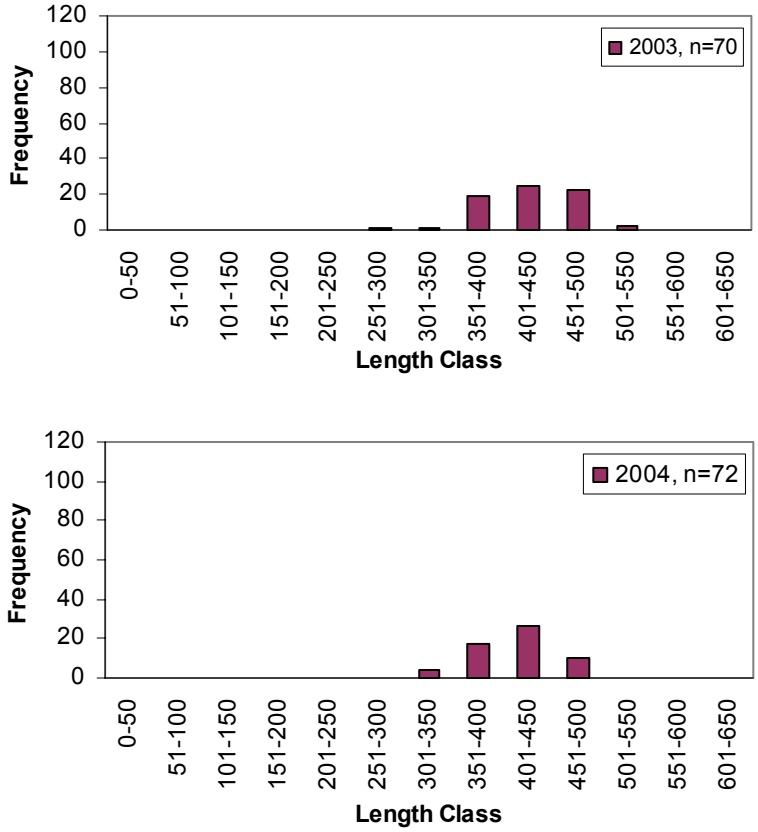


Figure 5.1-15 Length-frequency distributions for goldeye captured in the Athabasca River, spring and fall, 1997 to 2004.

Note: Frequency = number of fish caught per size class in mm.

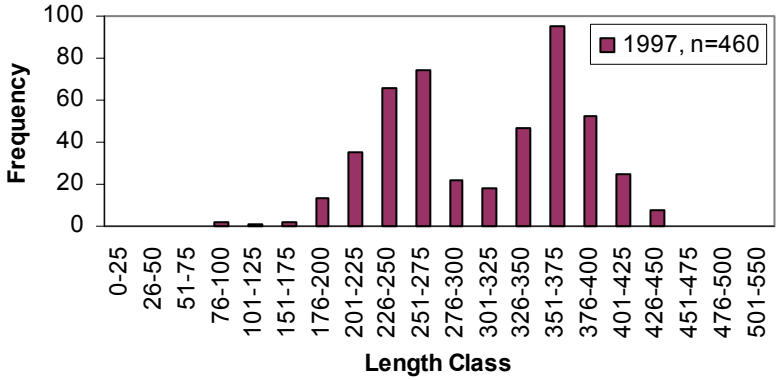


Figure 5.1-15 (cont'd.)

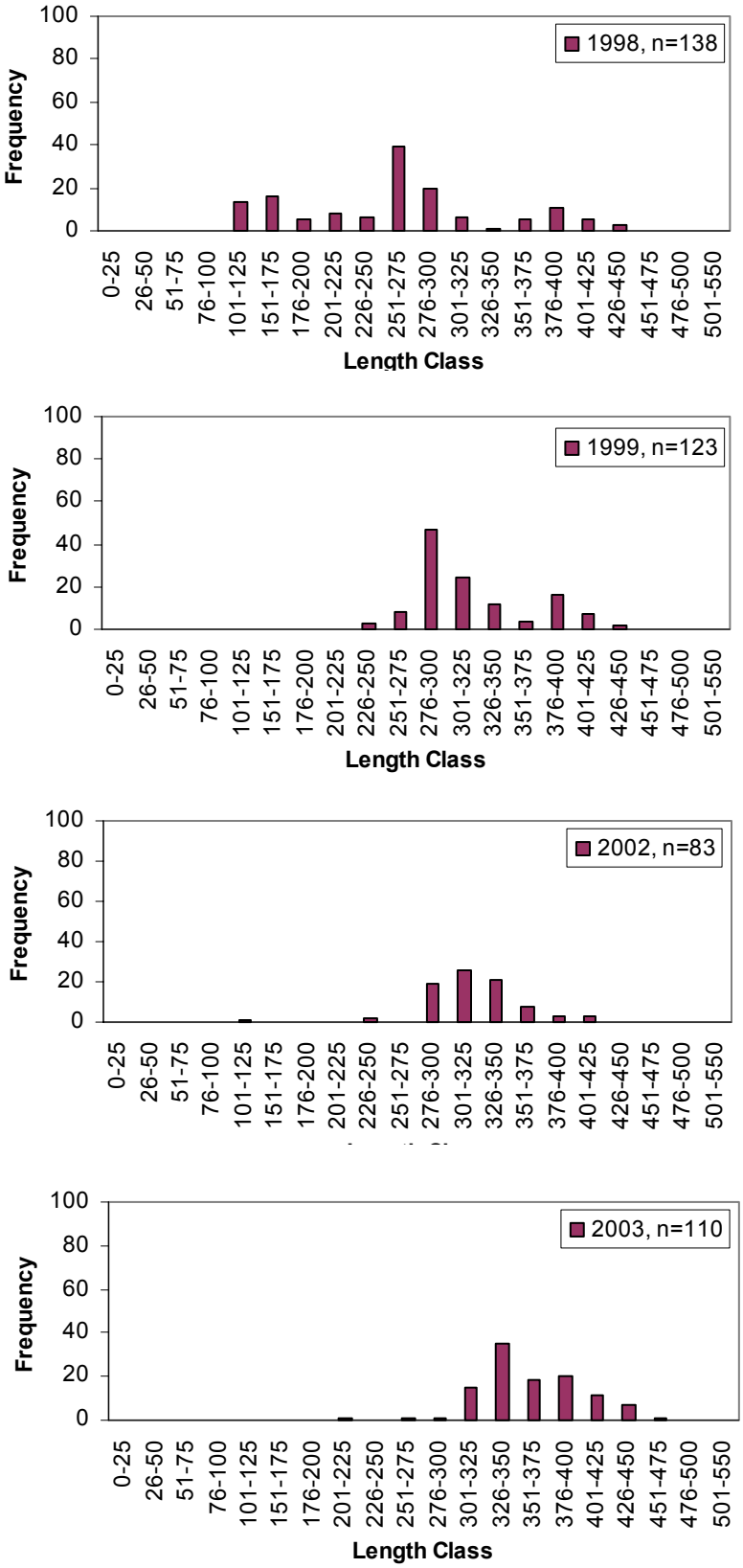


Figure 5.1-15 (cont'd.)

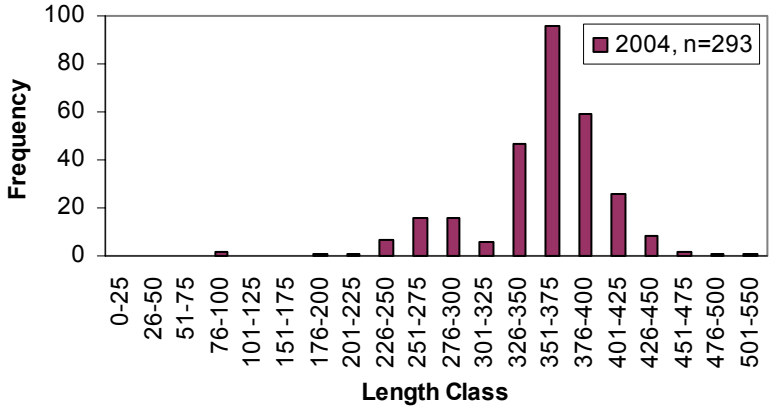
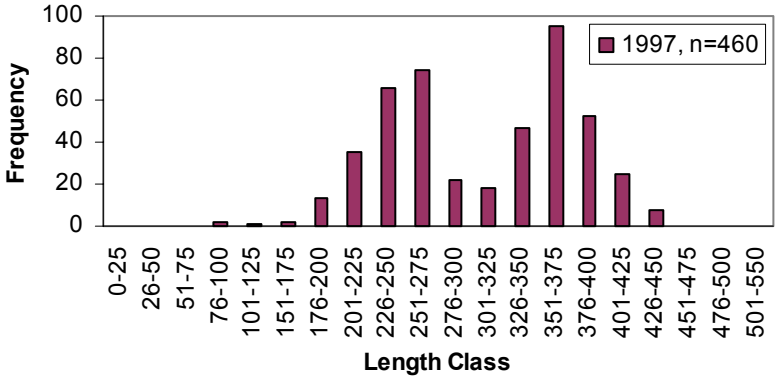


Figure 5.1-16 Length-frequency distributions for longnose sucker captured in the Athabasca River, spring and fall, 1997 to 2004.

Note: Frequency = number of fish caught per size class in mm.



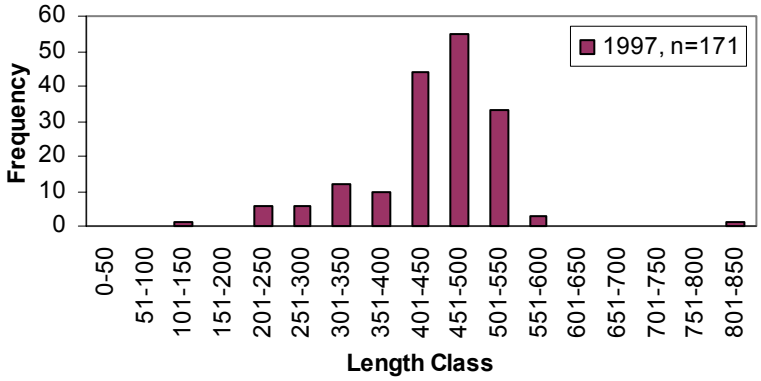
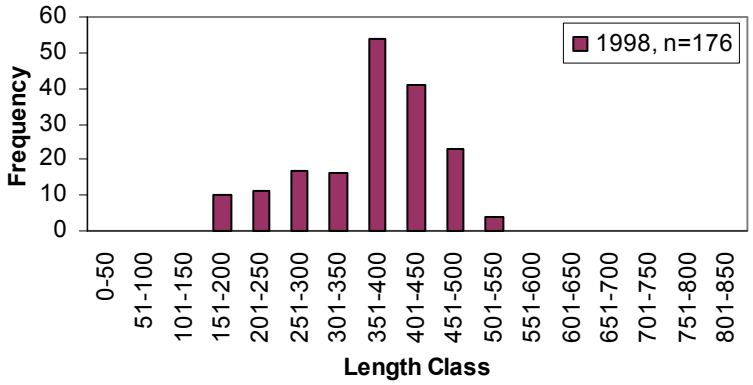
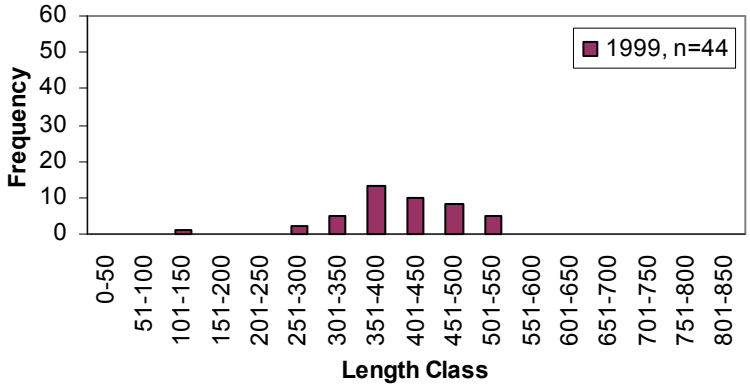


Figure 5.1-16 (cont'd.)





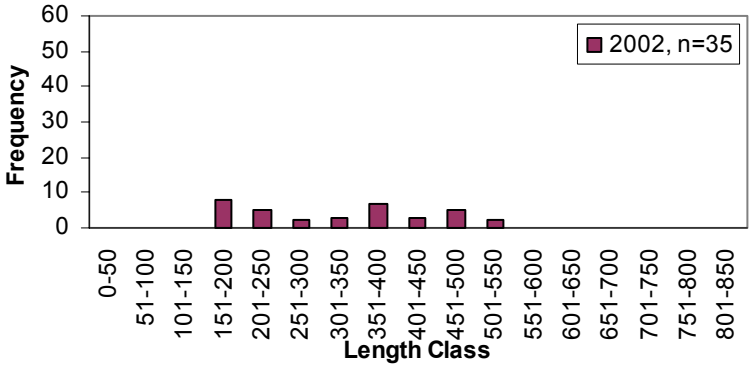


Figure 5.1-16 (cont'd.)

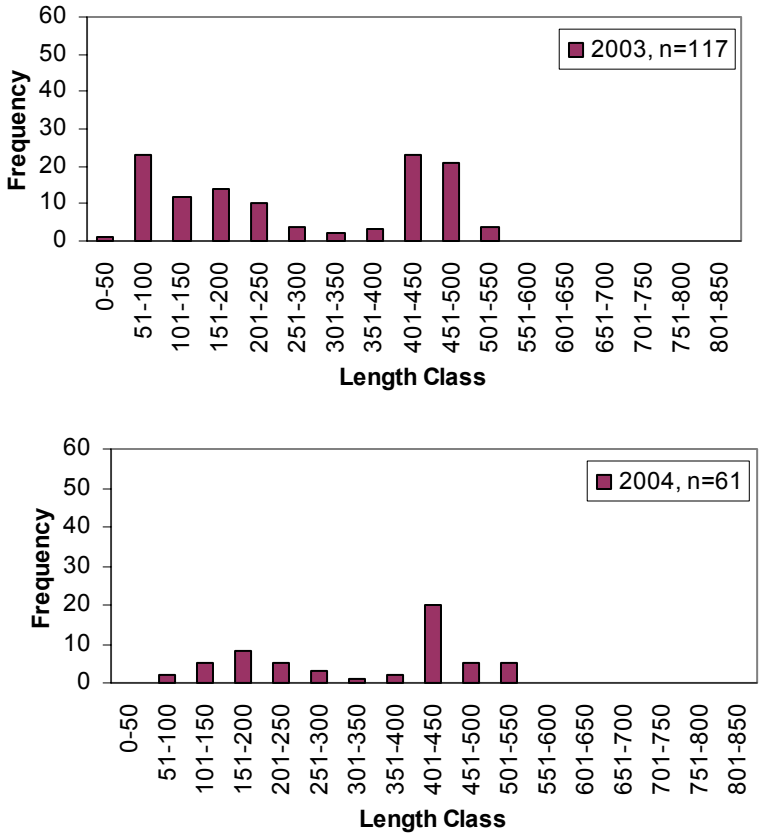


Figure 5.1-17 Length-frequency distributions for northern pike captured in the Athabasca River, spring and fall, 1997 to 2004.

Note: Frequency = number of fish caught per size class in mm.

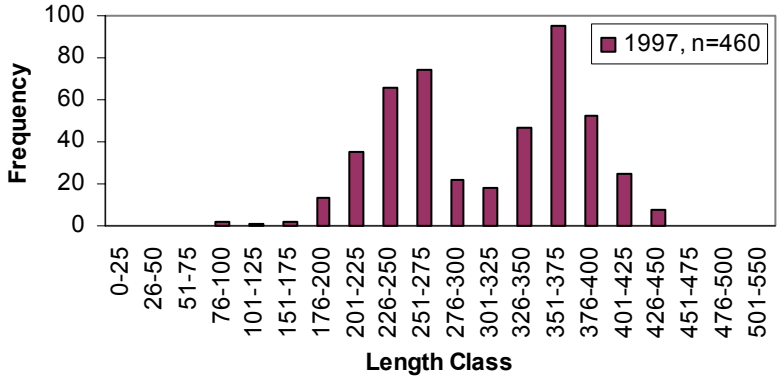
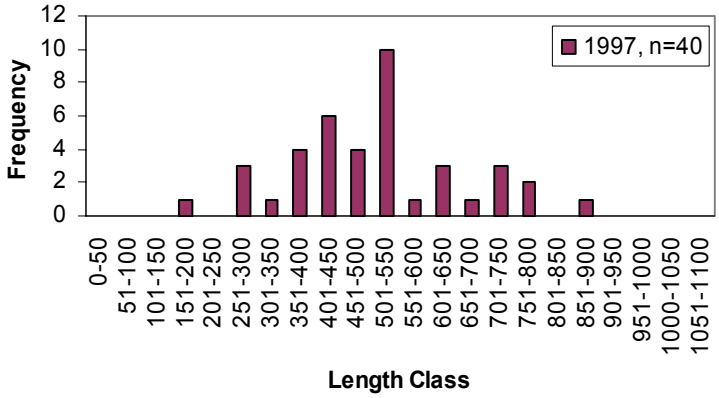
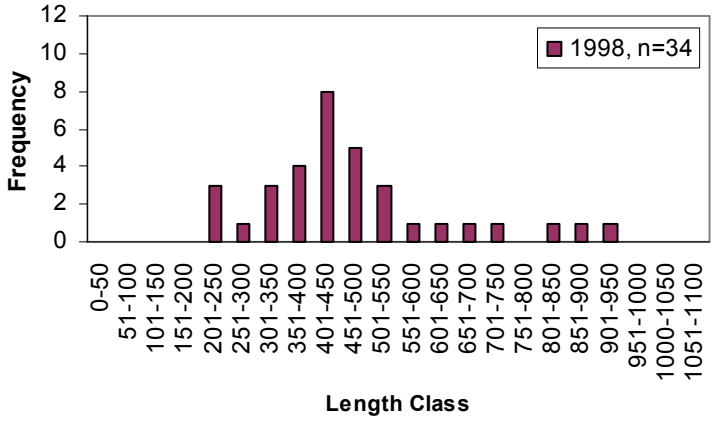


Figure 5.1-17 (cont'd.)





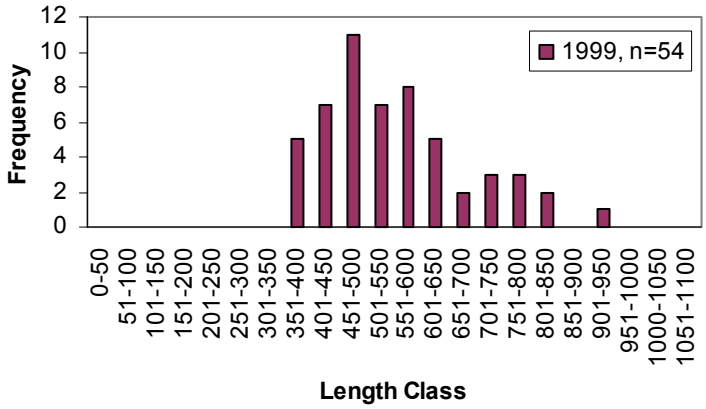
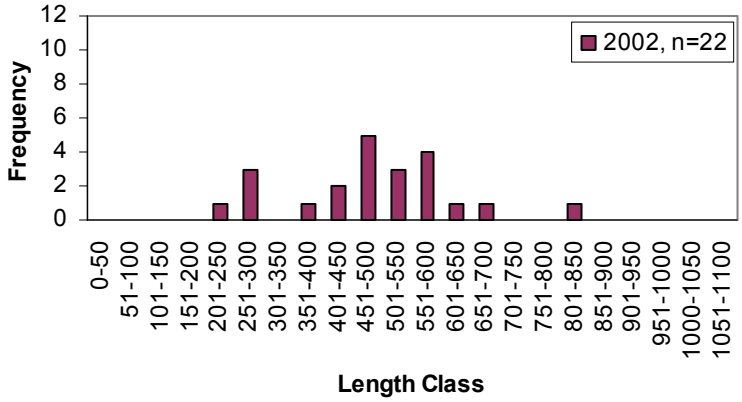
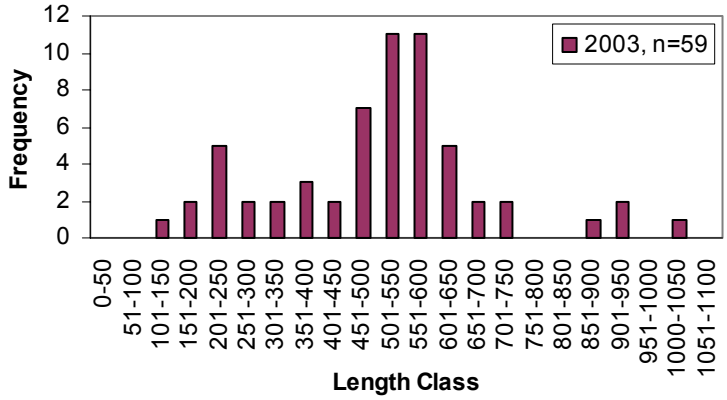


Figure 5.1-17 (cont'd.)





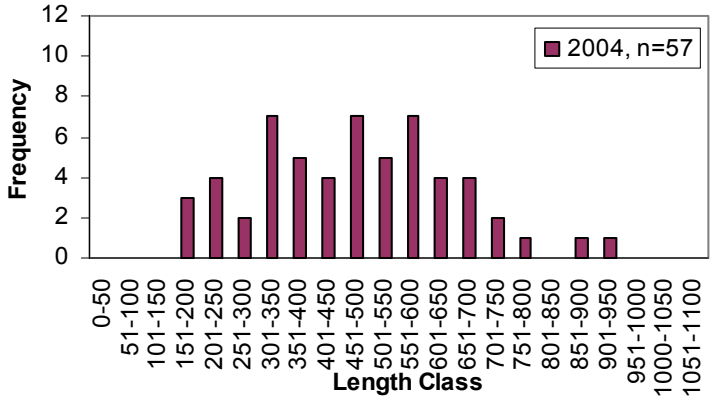


Figure 5.1-18 Length-frequency distributions for trout-perch captured in the Athabasca River, Spring and Fall, 1997 to 2004.

Note: Frequency = number of fish caught per size class in mm.

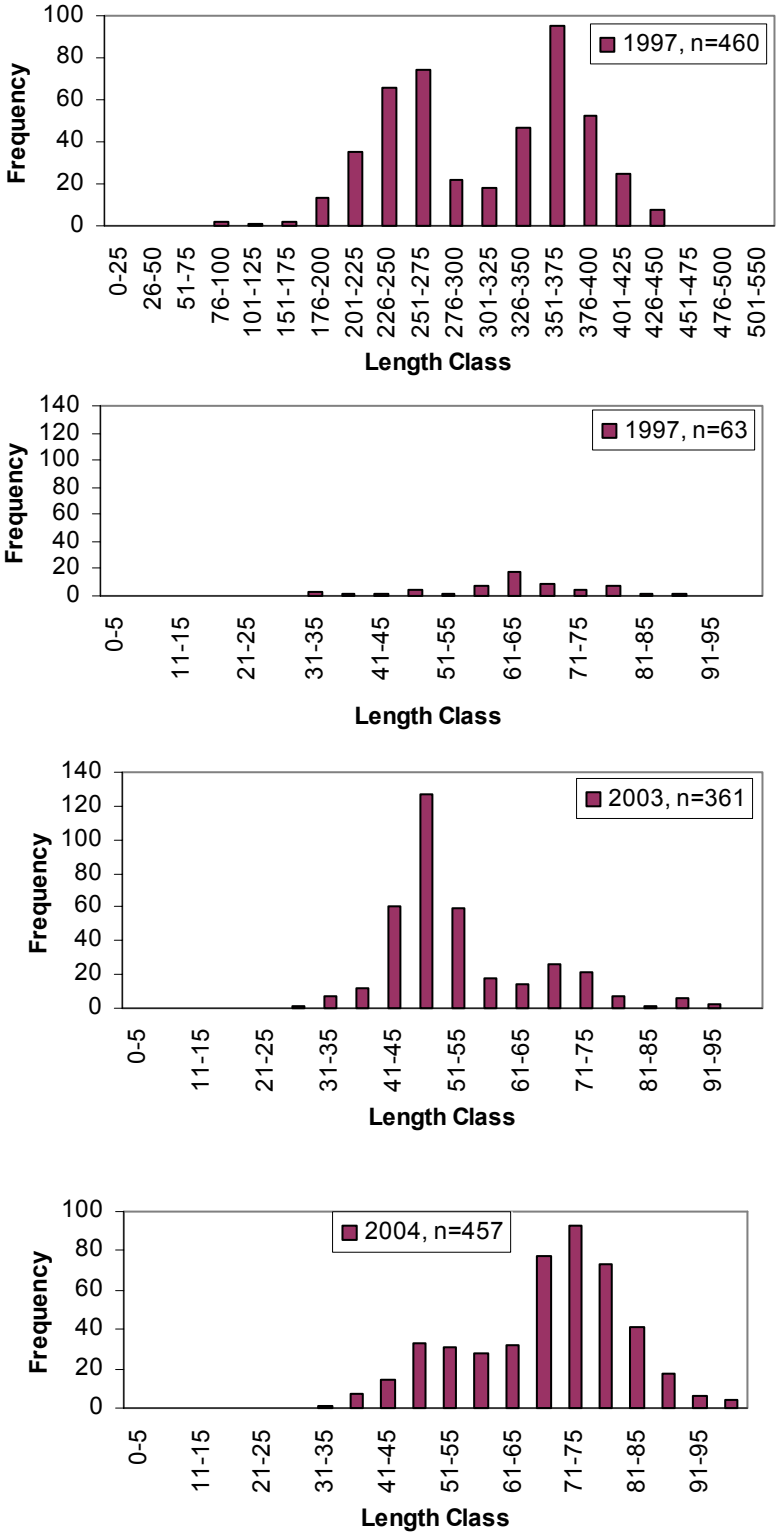


Table 5.1-9 Results of multi-year (1997-2004) comparisons of weight-length relationship (condition) for key fish indicator species, Athabasca River.

Species[2]		Year 1997	1998	1999	2002	2003	2004
Lake whitefish							
	n	60	181	62	-	67	62
	Mean[1]	1.636 A	1.448 B	1.429 B	-	1.585 A	1.553 A
	SE	0.025	0.014	0.015	-	0.023	0.021
Longnose sucker							
	n	130	6	26	17	23	25
	Mean[1]	1.274 A	1.172 A	1.295 A	1.269 A	1.203 A	1.338 B
	SE	0.012	0.045	0.024	0.029	0.024	0.022
Goldeye							
	n	149	11	12	36	46	58
	Mean[1]	1.092 B	1.167 AB	1.172 AB	1.072 B	1.101 AB	1.179 A
	SE	0.128	0.058	0.101	0.055	0.08	0.095

[1] Means within a row that bear the same letter are not significantly different at p = 0.05.

[2] Size restrictions: Goldeye ≥ 300 mm, lake whitefish and longnose sucker ≥ 350 mm.

Figure 5.1-19 Mean condition factor (± SE) and sample size for walleye in the oil sands region of the Athabasca River, 1997-2004.

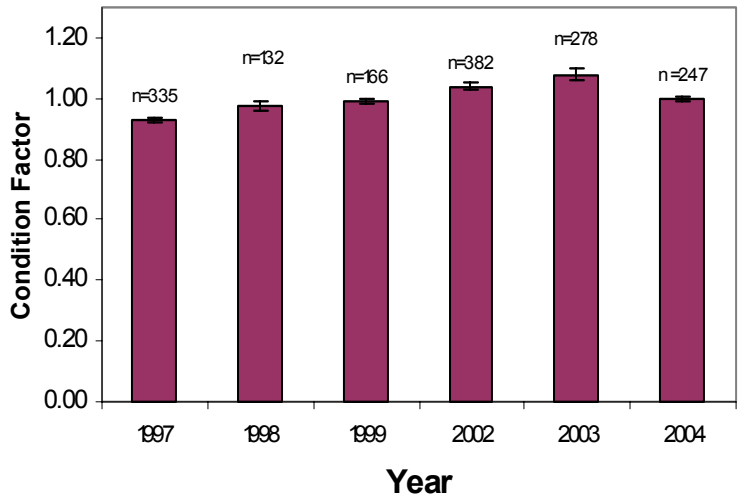


Figure 5.1-20 Mean condition factor (± SE) and sample size for lake whitefish in the oil sands region of the Athabasca River, 1997-2004.

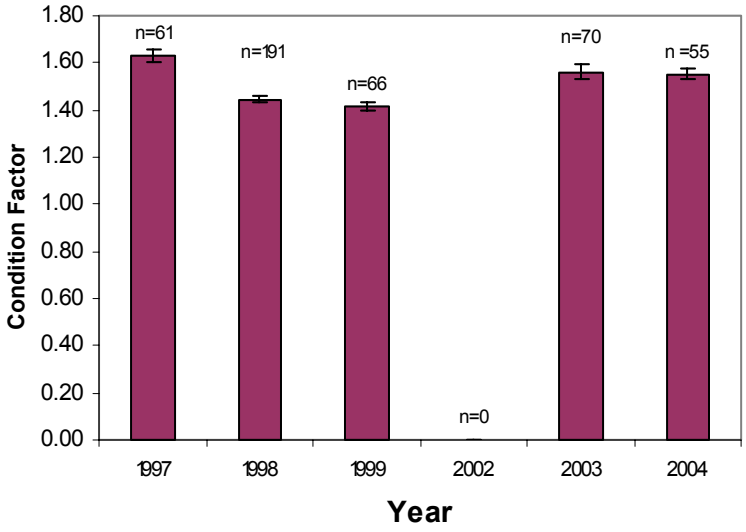


Figure 5.1-21 Mean condition factor (± SE) and sample size for longnose sucker in the oil sands region of the Athabasca River, 1997-2004.

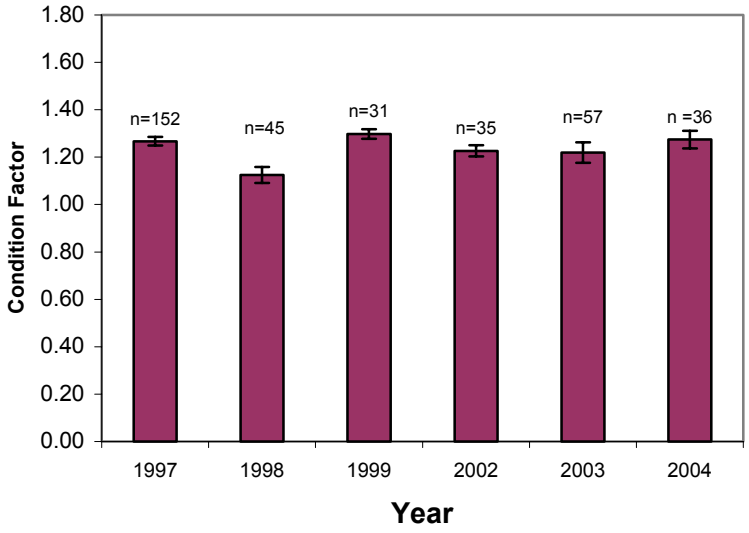


Figure 5.1-22 Mean condition factor (± SE) and sample size for goldeye in the oil sands region of the Athabasca River, 1997-2004.

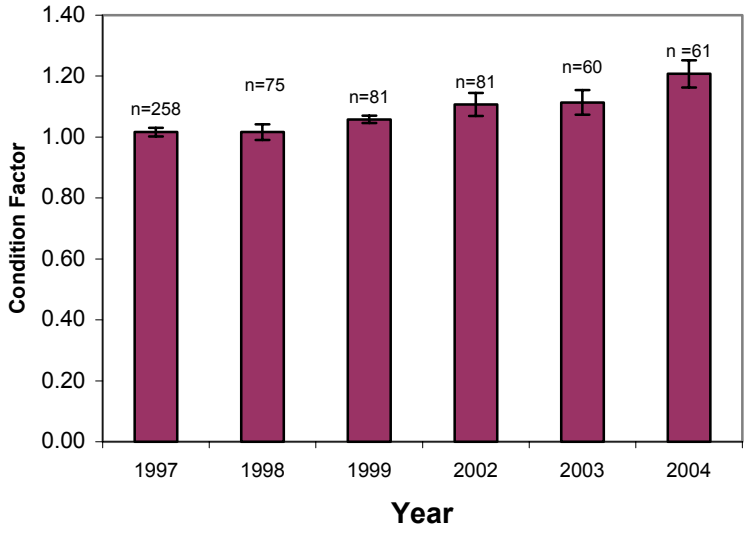


Figure 5.1-23 Mean condition factor (± SE) and sample size for northern pike in the oil sands region of the Athabasca River, 1997-2004.

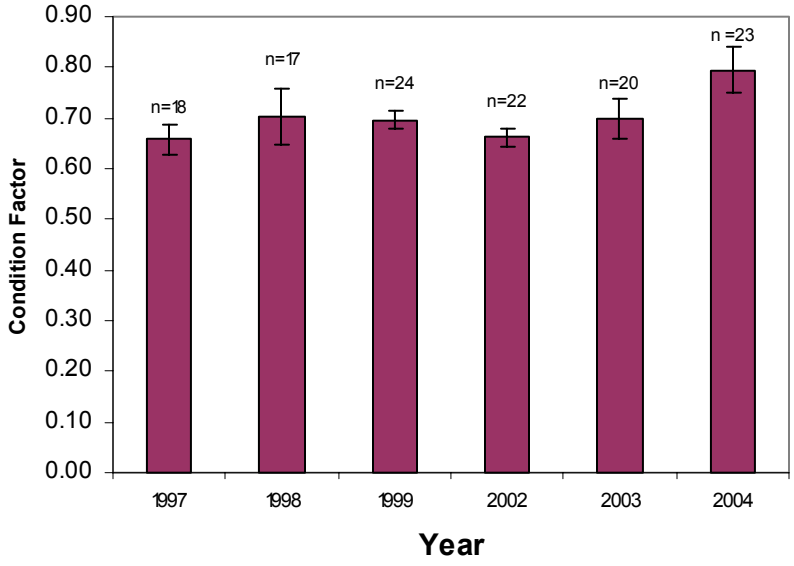


Figure 5.1-24 Fish tag recovery locations.

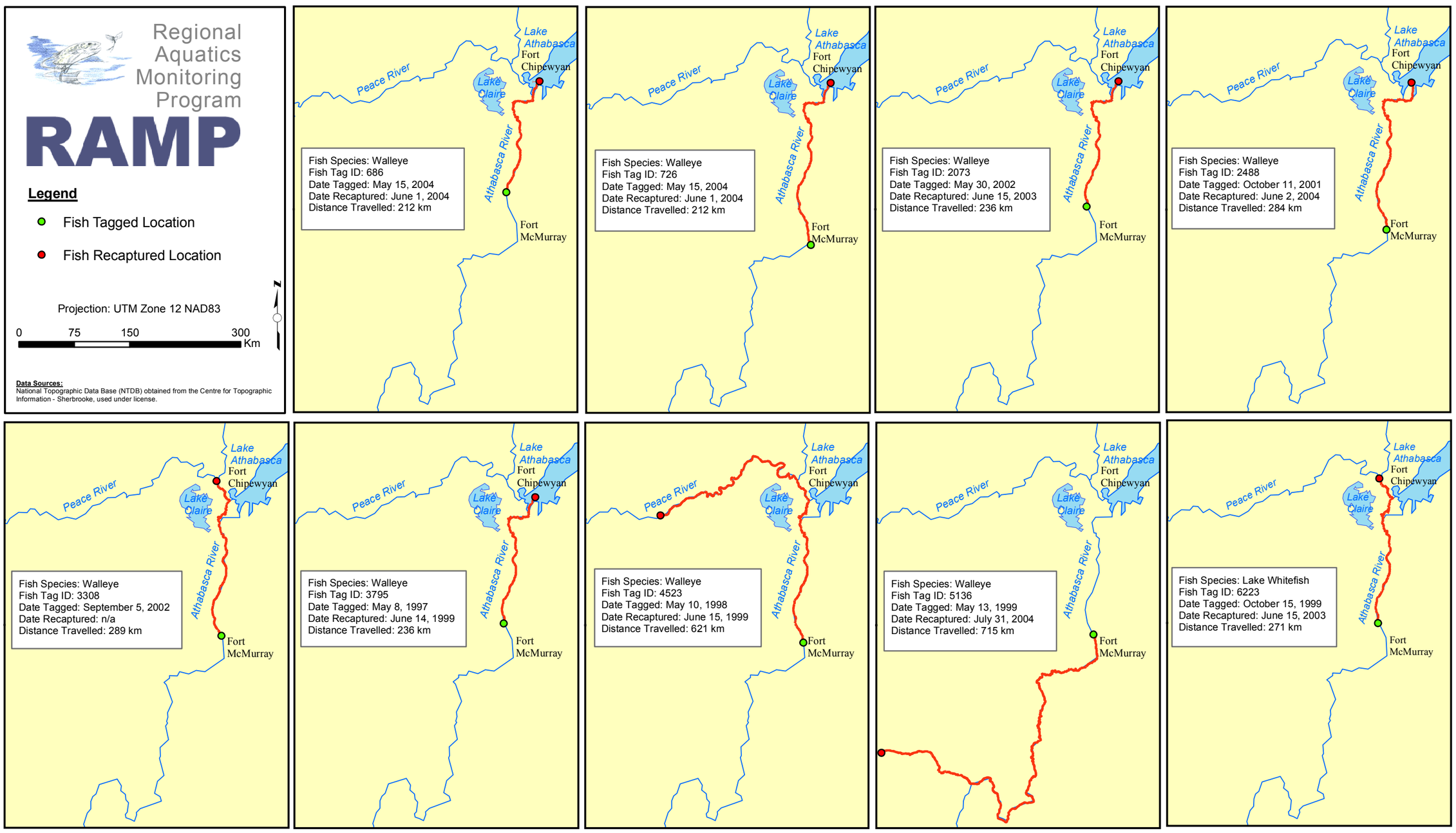


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Table 5.1-10 Summary of external pathology indices, Athabasca River inventories, 1995-2004.

Species	Mean External Pathology Index						
	1995	1997	1998	1999	2002	2003	2004
Goldeye	9.6	4.3	0.5	3.7	0.4	1.9	0.4
Longnose sucker	11	5.8	3.5	4.1	0.9	0.5	1.3
Walleye	2.8	1.5	2.1	18.3	1.4	1.1	0.3
White sucker	18.6	3.2	9.6	5.7	0.6	7.1	0.4

Note: summary is based on data for fish caught in spring only.

Table 5.1-11 Results of RAMP fish tag return analysis, 1999 to 2004.

Parameter	Fish Species				
	Lake Whitefish	Longnose Sucker	Northern Pike	Walleye	White Sucker
No. of Fish Recaptured	1	2	6	30	1
Min. Distance Traveled (km)	270.7	5.3	0	0	240.5
Max. Distance Traveled (km)	270.7	236.3	56.5	715.1	240.5

5.2 ATHABASCA RIVER DELTA

Summary of Results

Climate and Hydrology

	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge Mean winter discharge Annual maximum daily discharge Minimum open-water season discharge	Because of the absence of hydrometric stations in the ARD, there was no estimate made of the hydrological changes in relation to oil sands development activities.				The general characteristics of Athabasca River discharges at the ARD may be assumed to be similar to those on the mainstem in the Fort McMurray vicinity, as discussed in Section 5.1.1.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=1)	2004 Reference Stations (n=0)	
Physical variables (3 endpoints)	0	No water quality sampling stations were designated as reference in the ARD in 2004.	High concentrations of a number of variables were observed. Concentrations of a number of endpoints that exceeded CCME guidelines may have been dominated by the particulate form; dissolved phosphorous and aluminum were at concentrations that have been typical of historically normal levels. High total analyte concentrations are likely related to high levels of suspended materials in the ARD in 2004. High TSS concentrations in the Athabasca River in fall 2004 likely were a result of the high flow in the river at the time of sampling. Historically, ion balance characteristics at ARD-1 have varied within a relatively narrow range.
Nutrients (5 endpoints)	2		
Ions (5 endpoints)	0		
Organic compounds (1 endpoint)	0		
Selected metals (5 endpoints)	1		

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 1 station X 7 analytes)	2004 Reference Stations (n= 0 stations)	
Above 95th	3	No water quality sampling stations were designated as reference in the ARD in 2004.	
Between 75th and 95th	0		
Between median and 75th	1		
Between 25th and median	2		
Between 5th and 25th	1		
Less than 5th	0		

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n= 0)	2004 Reference Stations (n= 0)
Physical variables (4 endpoints) Total Hydrocarbons (8 endpoints) PAHs (7 endpoints)	Sediment quality was not monitored by RAMP in the Athabasca River delta in 2004.	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 0 stations)
Above 95th Between 75th and 95th Between median and 75th Between 25th and median Between 5th and 25th Less than 5th	Sediment quality was not monitored by RAMP in the Athabasca River delta in 2004.	

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline						
	2004 Exposed Stations (n= 3)			2004 Reference Stations (n= 0)			
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD	
Abundance	0	3	0	No benthic invertebrate community sampling stations were designated as reference in the ARD in 2004.			Benthic communities of the Athabasca River delta were in generally good condition in 2004 with relatively high diversity for a shifting-sand environment; there was no evidence of undue deleterious effects on benthic invertebrate communities.
Richness	0	3	0				
Diversity	0	3	0				
Evenness	0	3	0				
% EPT	0	2	1				

Fish Populations

Fish Inventory	No fish inventory studies conducted in the Athabasca River delta in 2004.	
Sentinel Studies	Sentinel fish studies were not conducted in 2004.	
Fish Tissue	Level of Risk	
Human Health: Subsistence Human Health: Recreational Fishers Human Health: General Consumers Human Health: Tainting Fish and Wildlife: Mercury Fish and Wildlife: Other Chemicals	Fish tissue program was not conducted in the Athabasca River delta in 2004.	

[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 Hydrologic Conditions

Athabasca River discharges are not monitored downstream of RAMP Station S24. However, the incremental catchment area between RAMP Station S24 and the Athabasca River Delta (ARD) is relatively small, so that the general characteristics of Athabasca River discharges at the ARD may be assumed to be similar to those on the main stem in the Fort McMurray vicinity, as discussed in Section 5.1.1.

5.2.2 Water Quality

Water quality samples were collected in the fall of 2004 from Big Point Channel (ARD-1), which has been designated an exposed station since RAMP began water quality sampling there in 1999.

Relative to previous years, high concentrations of a number of water quality variables were observed (Table 5.2-1). Total phosphorus, total nitrogen and total aluminum exceeded CCME guidelines for the protection of aquatic life. Both total phosphorus and total aluminum had exceeded these guidelines in previous years of RAMP sampling. TSS, total nitrogen, and total aluminum were above the 95th percentile of regional baseline concentrations in fall 2004 (Figure 5.2-2) and in all cases higher than previous maxima recorded for these variables during the limited RAMP water quality sampling conducted at ARD-1. Other selected water quality variables were within normal regional baseline levels for ARD-1 (Figure 5.2-2).

Correlation analysis of the 1997 to 2004 RAMP dataset indicated that total phosphorous and total aluminum are correlated with TSS in regional waters (Appendix E). This suggests that concentrations of these measurement endpoints may have been dominated by the particulate form. This is supported by the fact that dissolved phosphorous and aluminum at this station in fall 2004 were at historically typical concentrations (Table 5.2-1), indicating that these high total concentrations were related to high levels of suspended materials in the ARD in 2004. High suspended solids in the Athabasca River in fall 2004 likely were a result of the high flow in the river at the time of sampling (Section 4, Figure 4.1.4).

Ion balance at ARD-1 in fall 2004 was similar to that observed in 2000 (Figure 5.2-3), a year that also exhibited higher-than-average Athabasca River flows (RAMP 2001). Nevertheless, ion balance characteristics at ARD-1 have varied within a relatively narrow range regardless of sampling year (Figure 5.2-3), suggesting that water quality in the ARD is dominated much more by natural factors than by upstream oil sands development activities.

5.2.3 Sediment Quality

Delta sediments were not sampled by RAMP in 2004. Previous monitoring of delta sediments by RAMP has indicated that these sediments are characterized by fine particle sizes (reflective of deposition of fine sediments from upstream areas), and moderately high metal, PAH and hydrocarbon levels, consistent with other regional sediments with similar particle size distributions.

5.2.4 Benthic Invertebrate Communities

Benthic invertebrate community samples were collected from three depositional stations in the delta in fall 2004 (all designated as exposed), namely Fletcher Channel (FTC), Goose Island Channel (GIC) and Big Point Channel (BPC).

The three channels of the ARD selected for analysis of benthic invertebrate samples in 2004 were similar in terms of habitat characteristics (Table 5.2-2). All three stations were in depositional habitats with water depths of 0.6 to 1.1 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 in that chironomids were dominant in each channel. Trichopterans were dominant in Big Point Channel, whereas Ephemeropterans and the Ceratopogonidae were abundant in Fletcher Channel (Table 5.2-3). Nematodes were co-dominant, and tubificids and coleopterans were abundant in Goose Island Channel. Total invertebrate abundance in Fletcher Channel was approximately half that of the other two channels in 2004.

There was a high level of correspondence between CA axis scores for the three delta channels and regional reference conditions for depositional habitats (Figure 5.2-4). All delta samples from 2002 to 2004 fell within the 95% confidence limits for expected conditions in depositional habitats.

Moreover, when individual benthic invertebrate community indices for the three channels in the delta were compared to regional reference conditions for depositional habitats, the measurement endpoints were all found to be within expected ranges of reference environments (Figure 5.2-5). The only exception to this trend was for Big Point Channel in 2004, which tended to have slightly above-average percent EPT (Ephemeroptera-Plecoptera-Trichoptera) taxa relative to other stations and years and whose mean was slightly greater than the criterion of 2 standard deviations above the regional baseline mean for depositional stations. There were no obvious trends in any of the benthic invertebrate community indices across the three channels or through time.

Based on the analysis of the benthic invertebrate community measurement endpoints collected at Fletcher Channel, Goose Island Channel, and Big Point Channel stations for 2004, it may be concluded that delta benthic communities were in generally good condition in 2004 with relatively high diversity for a shifting-sand environment; there was no evidence of undue deleterious effects on ARD benthic invertebrate communities.

5.2.5 Fish Populations

The 2004 RAMP fish program did not include any activities in the Athabasca delta.

5.2.6 Summary of Assessment

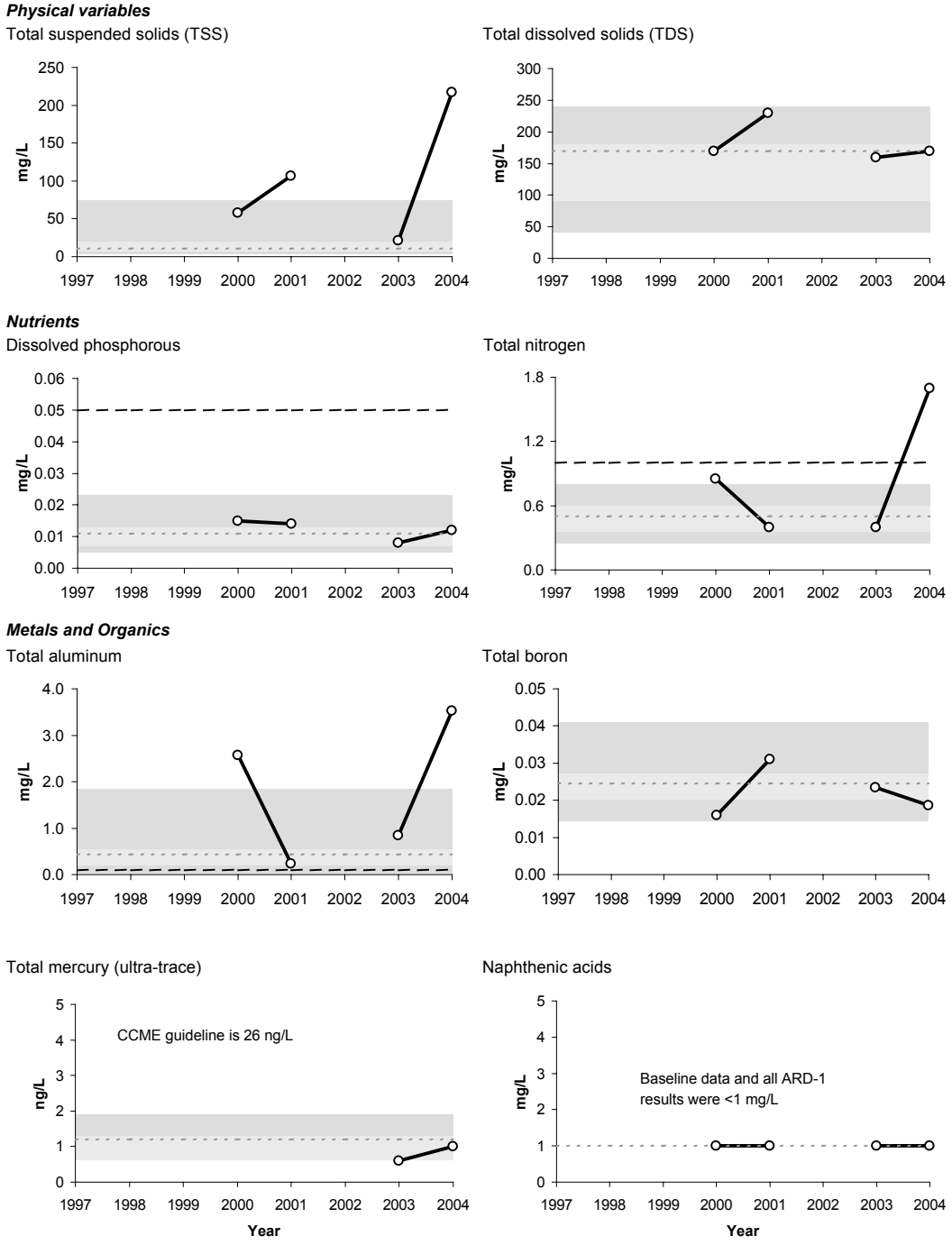
The Athabasca delta is the part of the RAMP FSA that is furthest downstream from oil sands development activities and the status of all RAMP aquatic resources measured in the ARD in 2004 is ascribed to the specific hydrologic conditions that characterized the sampling period of 2004, as well as inherent natural conditions of the delta environment. No influences of oil sands development activities were detected in the delta in 2004.

Table 5.2-1 Concentrations of water quality measurement endpoints, Athabasca River delta (ARD-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	7.9	8.1	8.1
Total suspended solids	mg/L	-	217	3	21	58	107
Conductivity	µS/cm	-	225	3	257	275	353
Nutrients							
Total phosphorous	mg/L	0.05	**0.15**	3	0.027	0.03	**0.056**
Dissolved phosporous	mg/L	0.05[1]	0.012	3	0.008	0.014	0.015
Total nitrogen*	mg/L	1.0	**1.7**	3	0.4	0.4	0.9
Nitrate+nitrite	mg/L	-	<0.1	3	0.05	0.1	0.1
Dissolved organic carbon	mg/L	-	11	3	5	6	9
Ions							
Sodium	mg/L	-	9	3	11	17	20
Chloride	mg/L	230, 860[3]	7	3	7	16	22
Sulphate	mg/L	100[4]	13.4	3	21.5	21.7	28.1
Total dissolved solids	mg/L	-	170	3	160	170	230
Total alkalinity	mg/L	-	92	3	92	101	114
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.100	**3.5**	3	**0.24**	**0.84**	**2.6**
Dissolved aluminum	mg/L	0.100[1]	0.011	3	0.008	0.01	**0.31**
Total boron	mg/L	1.2[4]	0.019	3	0.016	0.023	0.031
Total molybdenum	mg/L	0.073	0.000401	3	0.0007	0.0008	0.0009
Total mercury (ultra-trace)	ng/L	26	1	1	<0.6	<0.6	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.012**	3	<0.001	<0.001	0.002
Total copper	mg/L	0.002-0.004[2]	**0.005**	3	0.003	0.004	**0.005**
Total iron	mg/L	0.3	**4.5**	3	**0.46**	**0.71**	**2.0**
Total lead	mg/L	0.001-0.007[2]	**0.003**	3	<0.0001	0.0007	0.002

Note: unless otherwise indicated, 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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[4] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.2-2 Concentrations of selected water quality measurement endpoints for the Athabasca River delta (ARD-1) relative to regional baseline concentrations, fall 2004.



[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 E for these regional baseline ranges.

Figure 5.2-3 Piper diagram of ion concentrations in Athabasca River delta waters, fall 2004.

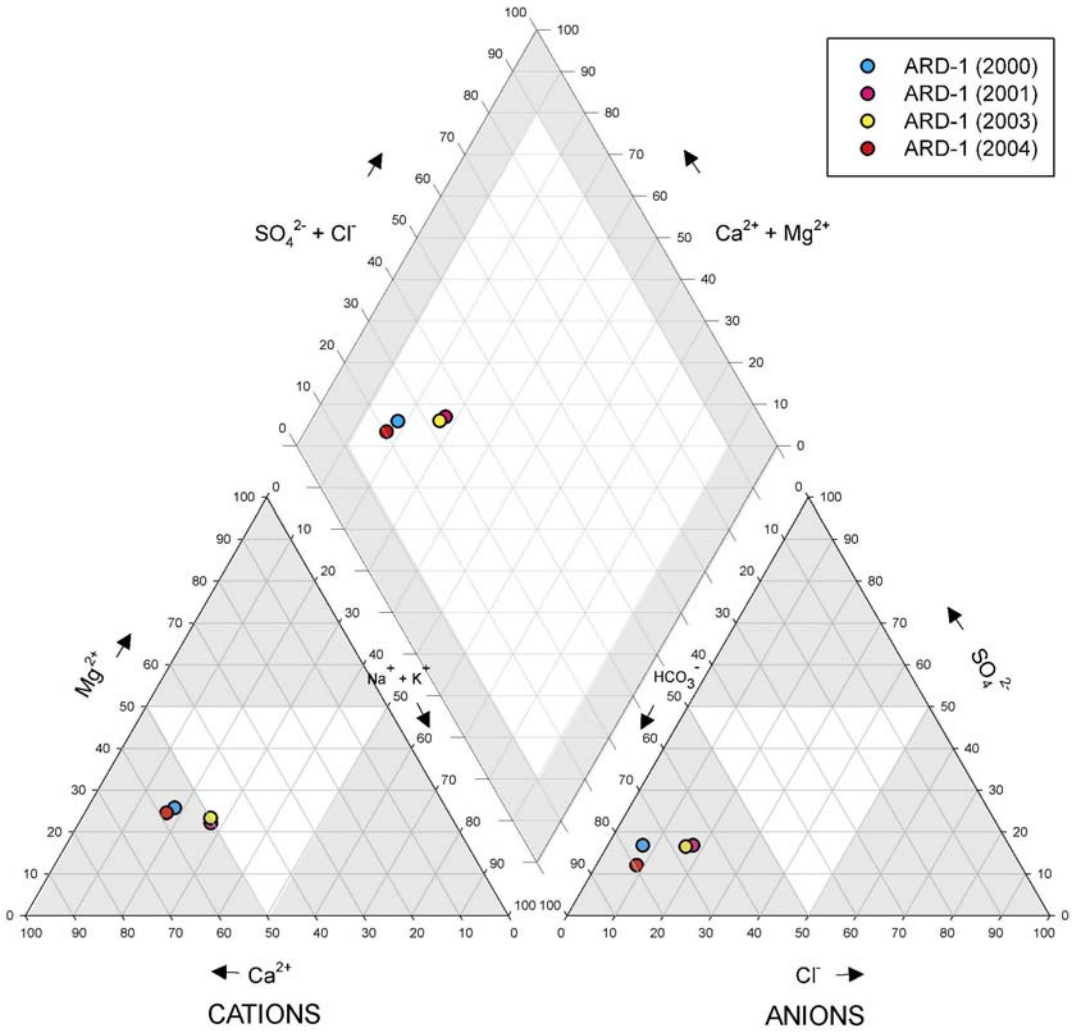


Table 5.2-2 Average habitat characteristics of Athabasca River delta benthic invertebrate sampling stations, fall 2004.

Variable	Units	Big Point Channel	Fletcher Channel	Goose Island Channel
Sample date	-	Sept. 15, 2004	Sept. 15, 2004	Sept. 15, 2004
Habitat	-	Depositional	Depositional	Depositional
Water depth	m	1.1	1.0	0.6
Current velocity	m/s	0	0	0
Field Water Quality				
Dissolved oxygen	mg/L	10.0	8.6	10.0
Conductivity	µS/cm	161.3	160.2	163.5
pH	-	8.0	8.0	7.8
Water temperature	°C	10.3	10.1	10.6
Sediment Composition				
Sand	%	32.0	24.4	27.8
Silt	%	49.4	55.2	52.4
Clay	%	18.6	20.6	19.8
Total Organic Carbon	%	1.4	1.7	1.4

Table 5.2-3 Summary of major taxon abundances and key indices of composition among stations in the Athabasca River Delta (ARD).

Taxon	Big Point Channel			Fletcher Channel			Goose Island Channel		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Nematoda	759	1,305	4.3	34	0	0.5	4,931	0	29.7
Erpobdellidae	603	0	3.4	0	0	0	0	0	0
Naididae	612	884	3.5	345	249	4.6	172	0	1.0
Tubificidae	638	591	3.6	440	290	5.8	2,207	2,999	13.3
Lumbriculidae	86	0	0.5	0	0	0	0	0	0
Ostracoda	233	316	1.3	284	530	3.8	466	991	2.8
Amphipoda	216	0	1.2	0	0	0	0	0	0
Gastropoda	95	41	0.5	198	640	2.6	172	145	1.0
Ephemeroptera	517	0	2.9	1931	0	25.5	319	1,067	1.9
Trichoptera	4,750	7,896	26.9	181	0	2.4	0	0	0
Anisoptera	155	0	0.9	9	0	0.1	17	0	0.1
Coleoptera	371	179	2.1	310	673	4.1	2,009	4,677	12.1
Heteroptera	690	0	3.9	1638	0	21.6	0	0	0
Ceratopogonidae	1,483	1,469	8.4	121	173	1.6	1,526	2,428	9.2
Chironomidae	6,336	2,837	35.9	2086	786	27.5	4,698	1,166	28.3
Megaloptera	172	0	1.0	0	0	0	0	0	0
Total Abundance	**17,629**	**7,481**	**-**	**7,578**	**5,859**	**-**	**16,603**	**12,170**	**-**
Richness	11.6	0.9	-	9.2	2.9	-	11.4	1.3	-
Simpson's Diversity	0.712	0.151	-	0.623	0.127	-	0.677	0.148	-
Evenness	0.780	0.167	-	0.713	0.172	-	0.742	0.158	-

Figure 5.2-4 Biplot of benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances.

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

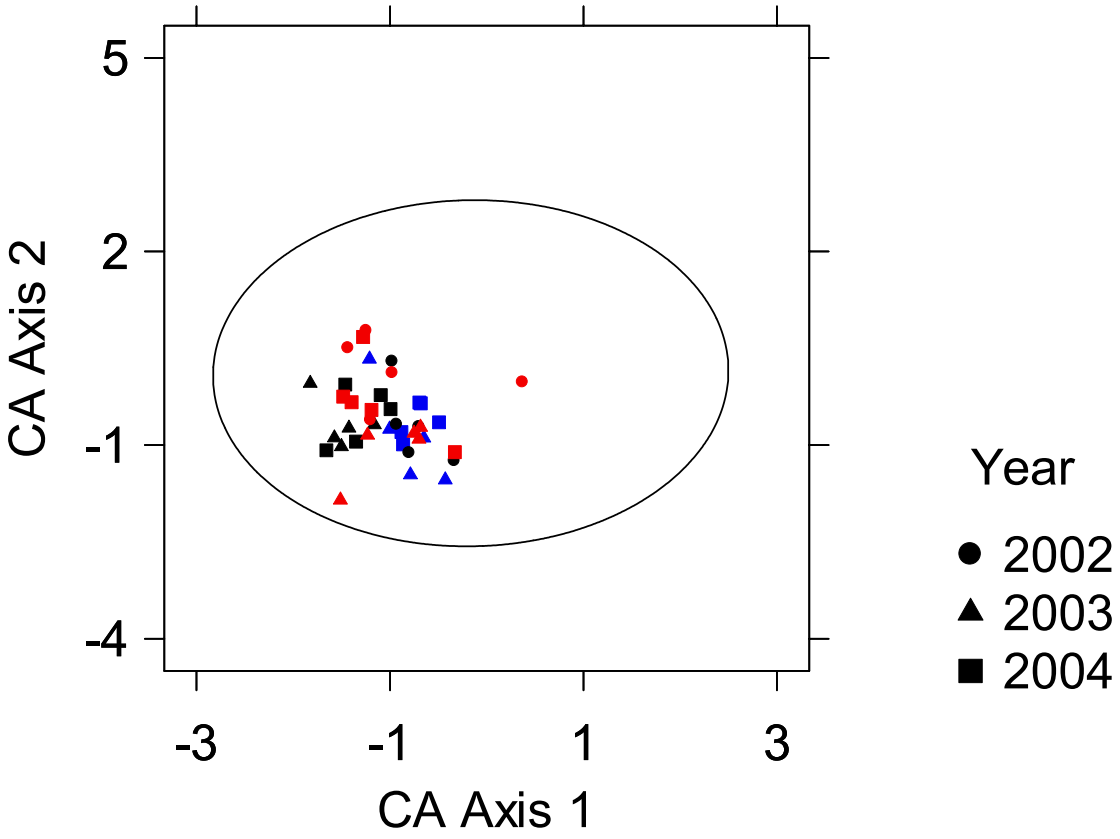
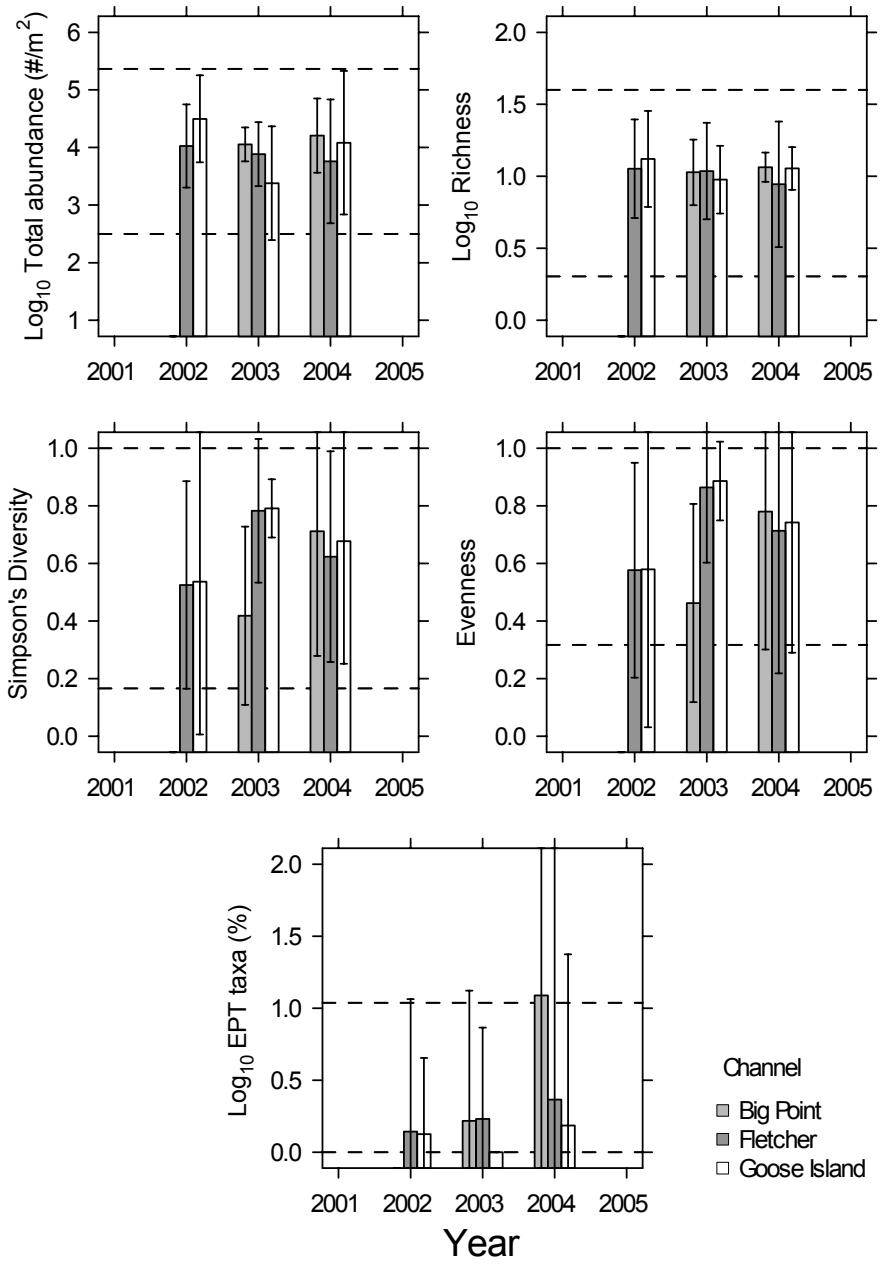


Figure 5.2-5 Variations in benthic invertebrate community measurement endpoints in the Athabasca River Delta between 2002 and 2004.

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



5.3 MUSKEG RIVER SYSTEM

Summary of Results

Climate and Hydrology

	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge		√			Mean winter discharge and other endpoints were estimated to be 2% and 7% lower, respectively, relative to estimated conditions in the absence of oil sands development. A 7% change would have been assessed as Low in most oil sands EIAs.
Mean winter discharge		√			
Annual maximum daily discharge		√			
Minimum open-water season discharge		√			

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=2)	2004 Reference Stations (n=4)	
Physical variables (3 endpoints)	0	0	With the exception of Stanley Creek in 2003, it appears that there has been little observable change in the concentrations of water quality variables measured by RAMP since oil sands operations commenced in the Muskeg River watershed in 1996.
Nutrients (5 endpoints)	0	0	
Ions (5 endpoints)	0	0	
Organic compounds (1 endpoint)	0	0	
Selected metals (5 endpoints)	0	0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 2 stations X 7 endpoints)	2004 Reference Stations (n= 4 stations X 7 endpoints)
Above 95th	0	0
Between 75th and 95th	2	4
Between median and 75th	2	4
Between 25th and median	5	13
Between 5th and 25th	3	5
Less than 5th	2	2

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=3)	2004 Reference Stations (n=1)	
Physical variables (4 endpoints)	0	0	Current oil sands development in the Muskeg River basin has not had a substantial effect on sediment quality. Hydrocarbon compounds were found in sediments throughout the watershed, including the reference station on Jackpine Creek.
Total Hydrocarbons (8 endpoints)	4	1	
PAHs (7 endpoints)	0	0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 3 stations X 3 endpoints)	2004 Reference Stations (n= 1 station X 3 endpoints)
Above 95th	1	0
Between 75th and 95th	2	2
Between median and 75th	3	1
Between 25th and median	1	0
Between 5th and 25th	2	0
Less than 5th	0	0

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline						
	2004 Exposed Stations (n= 2)			2004 Reference Stations (n= 1)			
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD	
Abundance		2			1		Benthic communities in the mid and lower reaches have demonstrated time trends consistent with subtle development-related effects. Despite these subtle trends, benthic communities in the Muskeg River are in very good condition with high diversity, and numerous examples of sensitive fauna.
Richness		2			1		
Diversity		2			1		
Evenness		2			1		
% EPT		2			1		

Fish Populations

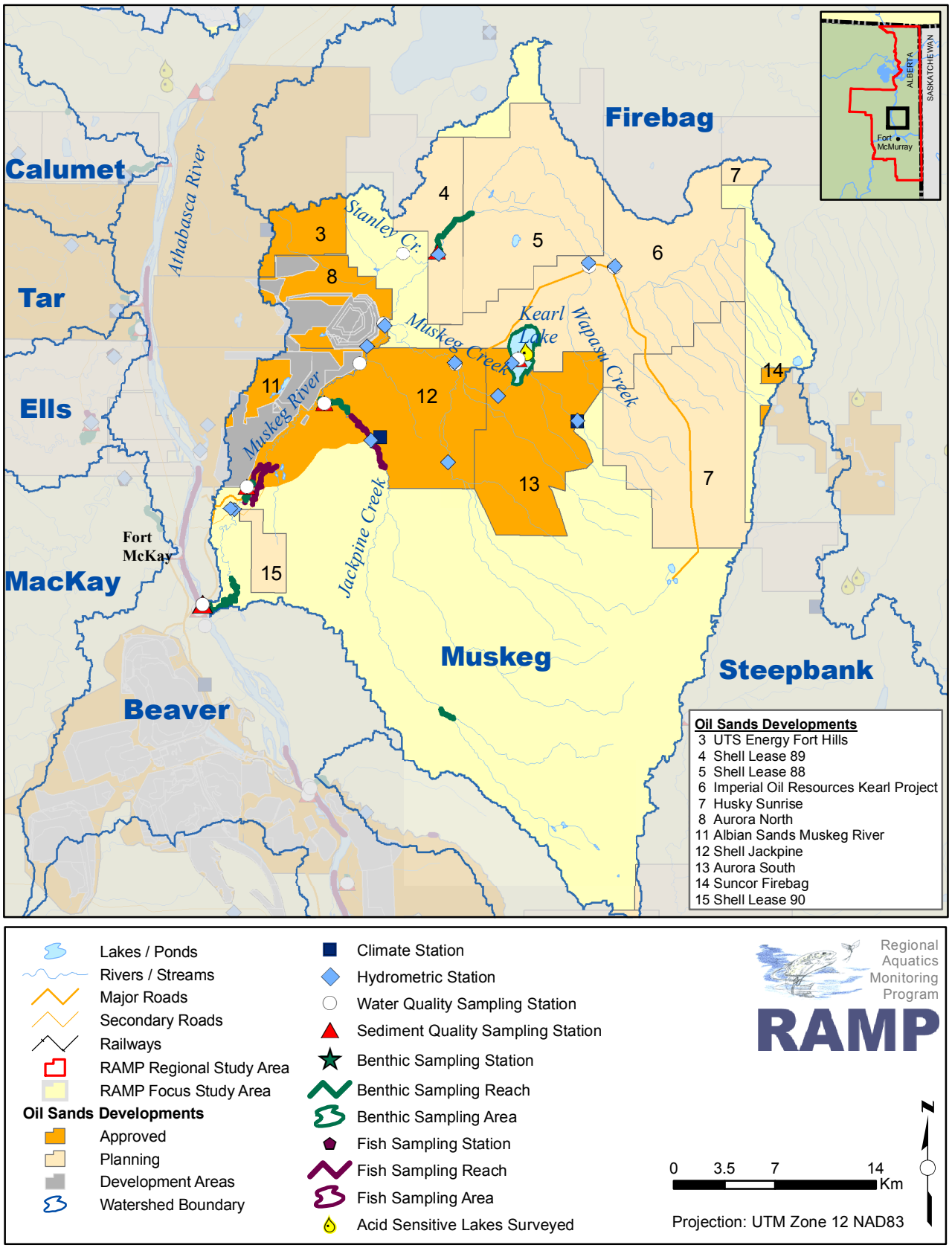
Fish Inventory	Little evidence that characteristics of key indicator fish populations have changed during increasing development in the oil sands region.	
Sentinel Studies		Sentinel species studies showed a sharp decline in the relative frequency of YOY in the population from August to October, indicating high mortality. Predictions of a weak 2004 age class can be made, suggesting a failure in two consecutive years. Chronic or repetitive year class failure would warrant further studies.
Fish Tissue	Level of Risk	
Human Health: Subsistence	High	
Human Health: Recreational Fishers	None	
Human Health: General Consumers	None	
Human Health: Tainting	Low	
Fish and Wildlife: Mercury	High	
Fish and Wildlife: Other Chemicals	Low	

[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.



5.3.1 Hydrologic Conditions

Total runoff in the Muskeg River basin in 2004, as measured at RAMP Station S7, was well below normal, at only 64% of the long-term average. However, more severe droughts have occurred seven times over the past thirty years. Discharges were close to normal in spring, peaked early in June (exceeding seasonal mean values for the month) in response to rainfall, and then subsided to near record low levels for the rest of the summer and fall (Figure 5.3-2). The June peak was 20% less than the mean annual flood.

The control or naturalized hydrograph that would have occurred at S7 in the absence of oil sands development can be estimated by removing known or estimated influences of development from the observed hydrograph. Parameters of the water balance model used to estimate the naturalized hydrograph are summarized in Table 5.3-1; results of applying the water balance model are provided in Table 5.3-2 and Figure 5.3-2. The combined development area related to the Aurora North and Albian Sands operations is approximately 100 km^2, or 6.8% of the Muskeg River drainage basin. Neither mine withdraws water from the Muskeg River; however, Aurora does discharge clean water into Stanley Creek (Section 2), which empties into the Muskeg River. Albian has no releases to local waterbodies. Based on this information, the mean winter discharge was estimated to be reduced by 2%, while the other hydrological endpoints were estimated to be reduced by 7% relative to what the measurement endpoints would have been in the absence of oil sands development in the basin (Table 5.3-2, Figure 5.3-2). There is some uncertainty regarding these estimates, particularly with respect to the accuracy of the total area estimated to be developed/cleared for each oil sands operation. The developed area for Aurora North was estimated using best professional judgment and information provided regarding the extent of active mine areas. The amount of developed area affects the amount of water that is intercepted by the oil sand activities, an important parameter for the water balance model. A 7% change would have been assessed as a Low change in many oil sands EIAs (Appendix A). It will be important to obtain detailed mining development area information for the 2005 program to minimize uncertainty related to parameters used in the model and to confirm or revise the 2004 assessment.

5.3.2 Water Quality

In 2004, mainstem water quality samples were collected from the upper Muskeg River (station MUR-6) and at the mouth of the Muskeg River (MUR-1), downstream of active oil sands operations. Station MUR-6 is a reference station located upstream of oil sands activities, while MUR-1 was designated as an exposed station. Results for the fall survey indicated that most measurement endpoints identified in Section 3.2.7 were within historical ranges recorded for 1997 to 2003 (Table 5.3-3, Table 5.3-4). The exception was pH, which was slightly higher than historically observed values at both MUR-1 (i.e., 8.4 relative to a previous historical high of 8.3) and MUR-6 (i.e., 8.3 relative to a previous historical high of 8.2). Selected water quality variables plotted against regional baseline ranges indicated Muskeg River water quality was within this regional baseline range (Figure 5.3-3). The concentration of total phenols at MUR-6 was the only endpoint found to exceed CCME/AENV guidelines established to protect aquatic life, but within historical range.

Ion balance in the Muskeg River mainstem has exhibited some variability since 1997 (Figure 5.3-4), but has been very consistent in the upper river (i.e., MUR-6). Ion balance

in the lower river (i.e., MUR-1) has been generally consistent among years, 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 suggested that higher sulphate concentrations in the lower Muskeg River in these years was relate to discharges from the Alsands Drain (previous RAMP station ALD-1), discharges to which were discontinued in late 2002.

Several tributaries of the Muskeg River were also monitored during the fall 2004 survey. Concentrations of all key water quality variables in Jackpine Creek (JAC-1), Muskeg Creek (MUC-1), Stanley Creek (STC-1) and Wapasu Creek (WAC-1) were within historically observed ranges (Table 5.3-5, Table 5.3-6, Table 5.3-7, Table 5.3-8, Figure 5.3-5). Total iron concentrations exceeded CCME guidelines in Jackpine Creek, Muskeg Creek and Wapasu Creek, but were within historically observed ranges. High iron concentrations in these creeks, associated with relatively high concentrations of total dissolved solids (TDS), dissolved organic carbon, manganese and colour, likely are related to the drainage from muskeg peatlands that enters these tributaries.

In 2003, Stanley Creek exhibited historically high concentrations of various ions, TDS, phenols and other variables, which exceeded regional baseline values (Figure 5.3-6). Ion balance also was clearly different in Stanley Creek in 2003 relative to other years (Figure 5.3-4). This change in water quality in 2003 likely was associated with commencement of Aurora North's Clean Water Discharge to this creek in May 2003 (RAMP 2004). However, this discharge was re-routed from Stanley Creek into ponds on the Aurora North site in February 2004, which likely resulted in the observed reversion of water quality in 2004 to values similar to those measured in 2001 and 2002.

Ion balance in Muskeg River tributaries generally has been consistent across years, and similar to that of the Muskeg River mainstem (Figure 5.3-4), with the exception of Shelley Creek (SHC-1, monitored once by RAMP in 1999), which exhibited higher chloride and sodium and lower calcium than other streams in the watershed.

Table 5.3-9 contains a list of all exceedances of CCME guidelines for protection of aquatic life observed in the Muskeg River system in 2004.

With the exception of Stanley Creek in 2003, it appears that since oil sands operations commenced in the Muskeg River watershed in 1996, there has been little observable change in the concentrations of water quality variables measured by RAMP.

5.3.3 Sediment Quality

Sediments were sampled in the Muskeg River watershed in 2004 at four stations: MUR-1 (Muskeg River mouth); MUR-2 (upstream of the Muskeg River mouth); MUR-D2 (upstream of Jackpine Creek); and JAC-1 (Jackpine Creek). Station JAC-1 was considered a reference station, whereas the remaining stations were designated as exposed stations. Generally, 2004 results for selected sediment measurement endpoints identified in Section 3.3.7 were within historical ranges at all stations, and within the defined regional baseline range (Table 5.3-10, Table 5.3-11, Table 5.3-12, Table 5.3-13, Figure 5.3-7). Sediment composition at all stations was dominated by sand. Hydrocarbons were common in sediments throughout the watershed, with highest concentrations of total hydrocarbons and total PAHs found at MUR-2, followed by JAC-1. At all stations,

CCME total hydrocarbon profiles were dominated by larger compounds (i.e., F3 (C16-C34) and F4 (C35-C50)); F3 hydrocarbons exceeded CCME surface soil guidelines at all stations while F2 hydrocarbons (C10-C16) hydrocarbons also exceeded surface soil guidelines at MUR-2.

Carbon-normalized trends in total recoverable hydrocarbons (TRH), total PAHs and naphthalene did not indicate trends over time in Muskeg watershed sediments, with the possible exception of a declining trend in naphthalene at the mouth of the Muskeg River (MUR-1) (Figure 5.3-7). Concentrations of naphthalene at MUR-2 have exceeded the regional baseline range in two of three years of sampling (2000, 2004), and may be related to a higher concentration of total F2 (C10-C16) hydrocarbons observed at this station relative to others.

No sediment metal concentrations in the Muskeg River watershed exceeded CCME guidelines for the protection of aquatic life except total zinc at MUR-D2, which was markedly higher in 2004 (i.e., 222 mg/kg) than in its previous year of sampling in 2003 (39 mg/kg).

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. Hydrocarbons compounds were found in sediments throughout the watershed, including the reference station on Jackpine Creek.

5.3.4 Benthic Invertebrate Communities

5.3.4.1 Muskeg River Reaches

In 2004, benthic invertebrate community samples were collected from three reaches: a lower reach near the Muskeg River mouth (MUR-E1), a low to mid reach near the Canterra Road crossing (MUR-D1) and an upper reach located upstream of the Albian Sands lease (MUR-D2). The upper reach is considered a reference reach, whereas the middle and lower reach were designated as exposed reaches. The lower reach of the Muskeg River is erosional in nature, shallow (0.2 m), has high current velocity (0.5 m/s) and low macrophyte cover. Benthic algal biomass was low (8.9 mg/m^2) at this station and dissolved oxygen was high (Table 5.3-14). By comparison, the lower-to-mid reach and the upper reach of the Muskeg River were depositional in nature, had deeper water with slower current velocities, and detectable macrophyte cover. Dissolved oxygen at the upper reference reach of the Muskeg River was low (5.0 mg/L), and below the Canadian Environmental Quality Guideline range for the protection of aquatic life of 5.5-9.0 mg/L (Canadian Council of Ministers of the Environment 1999). Conductivity was lowest at the lower reach of the Muskeg River, whereas pH and water temperature were similar at the three reaches. Substrate in the lower erosional reach consisted mostly of gravel and cobble; lower-to-mid-reach sediments were dominated by sand; upper reach sediments were dominated by sand/silt/clay. Total organic carbon was low in the lower to mid reach and high in the upper reach.

The benthic invertebrate community of the lower reach of the Muskeg River was heavily dominated by chironomids (60%), followed by plecopterans (11.5%), trichopterans (7.1%), and coleopterans (5.5%) (Table 5.3-15). Chironomids (26%) were also most abundant in the lower to mid reach of the Muskeg River, along with the Ceratopogonidae (23.0%),

and copepods (17.4%). Tubificids, the Naididae, and nematodes were also abundant in the lower to mid reach. The upper reach of the Muskeg River was dominated by tubificids (23.3%) and chironomids (20%). Nematodes, amphipods, and coleopterans were also abundant in the upper reach.

Benthic invertebrates in the lower reach of the Muskeg River have been sampled regularly since 1998 and community composition has consistently reflected the expected community composition based on regional reference data for erosional habitats (Figure 5.3-8). Moreover, community indices generally have fallen within expected reference ranges for erosional habitats (Figure 5.3-9).

An analysis of variance with planned comparisons was used to test for differences in time trends between lower and upper, and between mid and upper reaches. By comparing time trends between lower (erosional) and upper (depositional) reaches, we assume that the time trends in those two habitat types would be similar. Time trends in these two habitat types might be naturally different. By comparing the index values from the lower erosional site to values from regional reference erosional reaches, we are comfortable that a comprehensive assessment of condition is being carried out. Further, the upstream reference reach (though it is a depositional habitat) reflects factors occurring in the headwaters of the system, and give the best opportunity to reflect site-specific temporal factors that might influence the lower reach of the Muskeg River. Given these considerations, there was only a weakly significant (p=0.05) increase in abundance between 2002 and 2004 (the years when both reaches were sampled)(Table 5.3-16). Taxonomic richness differed significantly between the two reaches with higher richness in the lower, erosional reach. There was also a significant decline in richness in both reaches between 2002 and 2004. Diversity declined significantly in the lower reach between 2002 and 2004, whereas it stayed the same, or increased slightly, in the upper reach of the Muskeg River over the same time period (significant time × reach interaction). Overall, diversity was significantly higher in the lower reach than in the upper reach, reflecting typical differences between erosional and depositional habitats. Patterns in evenness matched those of diversity. Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa were more abundant in the lower reach of the Muskeg River as anticipated for an erosional habitat, and increased significantly between 2002 and 2004 in both lower and upper reaches; the increase was more pronounced in the upper reach than the lower reach.

Community composition of the lower to mid reach of the Muskeg River has also, for the most part, fallen within expected ranges for regional reference data for depositional habitats (Figure 5.3-10). Benthic community indices in the lower to mid and upper reaches of the Muskeg River, although sampled less frequently than the lower reach, also have generally fallen within expected ranges for depositional habitats in the region (Figure 5.3-11).

Analysis of variance of total invertebrate abundance between the lower to mid and upper reaches of the Muskeg River revealed a significant time × reach interaction for 2002 – 2004, corresponding to a decline in abundance at the lower to mid reach and no change in abundance at the upper reach (Table 5.3-17). There was no significant difference in abundance between reaches in 2004. Richness declined significantly over time in both reaches over the period when both reaches were sampled (2002 to 2004). There were weakly significant ($0.05 < p < 0.10$) differences between reaches and in the time × reach

interaction, corresponding to slightly higher richness overall and a steeper decline in richness between 2002 and 2004 in the lower to mid reach compared to the upper reach. Diversity and evenness in the lower to mid reach both declined between 2002 and 2004, whereas it increased in the upper reach over the same time period, corresponding to a significant time × reach interaction. EPT taxa also declined in the lower to mid reach and increased in the upper reach between 2002 and 2004 and there were significant differences in EPT taxa between reaches in 2004 (Table 5.3-17).

Benthic communities in the mid and lower reaches of the Muskeg River have demonstrated time trends that are consistent with subtle development-related effects. Despite these subtle trends, benthic communities in the Muskeg River are in very good condition with high diversity, and numerous examples of sensitive fauna. Further, despite the differences in time trends exhibited relative to the upper reference reaches, benthic communities of the lower and mid reaches of the Muskeg River have produced indices of composition that are within the ranges of values produced by regional reference reaches. Effects, therefore, if at all present are very subtle.

5.3.4.2 Jackpine Creek

Benthic invertebrate community samples were collected from two reaches on the Jackpine Creek: a lower reach near the mouth (JAC-E1) and an upper reach (JAC-E2). Both reaches are considered reference reaches and contribute to the collection of baseline data for this watercourse. The lower and upper reaches of Jackpine Creek are depositional habitats with shallow water depths, no measurable current, and low macrophyte cover (Table 5.3-18). Water quality at the two reaches in 2004 was similar in terms of dissolved oxygen, conductivity, pH and water temperature. Sediments at both reaches were dominated by sand, although the upper reach had more silt and clay in the sediments than the lower reach.

The benthic invertebrate communities of the lower and upper reaches of Jackpine Creek were both heavily dominated by chironomids (Table 5.3-19). Nematodes, tubificids, and the Chydoridae were also abundant in the lower reach, whereas nematodes and Ceratopogonidae were abundant in the upper reach.

The benthic invertebrate community of the lower reach of Jackpine Creek has been sampled yearly since 2002 and community composition has, for the most part, reflected regional reference conditions for depositional habitats. There were three samples in the lower reach in 2003 that had higher than expected CA Axis 2 scores, but only one "unusual" sample in each of 2002 and 2004. High CA Axis 2 scores reflect high abundance in samples of the Tipulidae and, to a lesser extent, copepods.

Benthic invertebrate community indices for both the lower and upper reaches of Jackpine Creek have consistently fallen within expected ranges based on regional reference sites for depositional habitats (Figure 5.3-12). Analysis of variance followed by planned contrasts revealed very few differences in community indices between reaches; the most common trend, detected in total abundance, diversity, evenness, and EPT taxa, was an overall difference in indices between years at both reaches (Table 5.3-20). In general, there was an increase in abundance and EPT taxa and a decrease in diversity and evenness at both reaches between 2003 and 2004. A significant time × reach interaction

for richness reflects an increase in richness at the lower reach between 2003 and 2004 and no change in richness at the upper reach during the same time period.

In general, data from Jackpine Creek have demonstrated a benthic community consistent with expectations from regional reference reaches.

5.3.5 Fish Populations

Fish population monitoring within the Muskeg River watershed included:

- Fish inventory of the lower Muskeg River and Jackpine Creek;
- Fish tissue analyses of key fish indicator species in the lower Muskeg River; and
- Sentinel Species Monitoring in the lower Muskeg River.

For all components of the fish population assessment in the Muskeg River, the lower reaches of the watershed were designated as exposure reaches. Inventory work in Jackpine Creek was conducted to further develop the baseline database prior to future development adjacent to this watercourse. In addition, Jackpine Creek provides part of the available erosional habitat that is dominant in the lower Muskeg River. Accordingly, potential changes in the fish community of the lower Muskeg may also be evident in Jackpine Creek as well.

5.3.5.1 Muskeg/Jackpine Fish Inventory

Muskeg River Inventory

Species Composition and Catch-Per-Unit-Effort

A total of 37 fish of 5 species were captured during the August 2004 fish inventory on the Muskeg River (Table 5.3-21). A total of 21 fish species have been reported to occur in the Muskeg River mainstem (Golder 2004). Fish were caught using a combination of boat and backpack electrofishing methods; no fish were captured in minnow traps. Total fish catch from electrofishing from the Muskeg River was substantially lower in 2004 than 2002, when 117 fish were captured (plus an additional 88 observed and two fish captured in gill nets, for a total of 207; fish that only were observed and not captured during the 2004 inventory were not recorded).

Relative abundance, as percent catch composition, for fish species captured in the 2004 inventory, along with catch-per-unit-effort information is provided in Table 5.3-21. The most abundant large bodied species captured (in declining order) were northern pike, followed by white sucker and longnose sucker. This ranking was essentially reversed from the 2002 Muskeg River inventory results. Many of the large bodied fish (particularly northern pike and longnose sucker) found in the Muskeg River in 2004 were juveniles, which may highlight the importance of this system for rearing. Comparatively low numbers of small-bodied fish were captured during the 2004 inventory. In 2002, overall inventory numbers for small-bodied fish species were higher than in 2004, but this was due in large part to the inclusion of fish observed in the 2002 total.

Percent catch composition for the major fish species captured in RAMP Muskeg River inventories is shown in Figure 5.3-14 for the years 1997, 2001, 2002 and 2004. When compared to previous RAMP inventories on the Muskeg River, the 2004 results were most similar to those observed in 2001, although a number of differences are evident, particularly with respect to northern pike that made up a far larger portion of the 2004 sample.

Catch-per-unit effort (CPUE) from electrofishing on the Muskeg River in 1997, 2001, 2002 and 2004 has been highly variable across years for all species (Figure 5.3-15). In 2004, CPUE for all species except northern pike and pearl dace was lower than 2002, and generally lower than the other two years of sampling. Arctic grayling have been absent in the RAMP Muskeg River inventory catch since 1997.

None of the fish species captured during the 2004 Muskeg River inventory were taken in sufficient numbers to permit more detailed analyses of population parameters (e.g., length-frequency analysis).

Condition Factor

Mean condition factors for key fish indicator species captured during the 2004 Muskeg River inventory are compared to historical values (1997, 2001 and 2002) in Figure 5.3-16. Condition factor for longnose sucker in 2004 was very similar to historical values, while condition factors for both northern pike and white sucker were notably higher in 2004 than in previous years (i.e., fish of a given length were heavier). Mountain whitefish were not captured during the 2004 Muskeg River inventory.

Discussion

In the 2004 fish inventory of the lower Muskeg River, overall catch size and species diversity was down notably from previous years, particularly relative to 2002 results. Data from 2004 indicated that the summer fish community was dominated by large-bodied species, including northern pike and suckers. Important fish indicator species, including goldeye, mountain whitefish and walleye were not present in the catch. Some differences in relative abundance were evident for some species in 2004 compared to previous RAMP data and historical reports. Arctic grayling were neither captured nor observed in the 2004 inventory, as was the case in 2001 and 2002. Results from the Muskeg River fish fence in spring 2003 indicated that Arctic grayling do use the Muskeg River watershed for spawning. However, summer inventory results from 2004 did not find any evidence of grayling rearing or feeding activity in the lower Muskeg River.

Sample sizes in 2004 were too small for the analysis of population parameters; however, a cursory examination of the length-weight data for northern pike and white sucker showed a range of sizes similar to those recorded in previous RAMP inventory years. A comparative assessment of condition factors for key fish indicator species showed minor historical variability, and values that are comparable to those recorded for these species in the Athabasca and Clearwater rivers.

Jackpine Creek Inventory

A total of 308 fish of 9 species were captured during the August 2004 fish inventory on Jackpine Creek (Table 5.3-22). Due to difficulties in field identification, sculpin captured

during the inventory were not separated by species, despite knowledge that both slimy and spoonhead sculpin are present in the Muskeg/Jackpine watershed. Work is ongoing within RAMP to refine diagnostic procedures for field identification of these two species. Mountain whitefish were caught in small numbers in both 2001 and 2002, but were not present in the 2004 sample. A total of 15 fish species have been reported to occur in Jackpine Creek (Golder 2004). Fish were caught using a combination of backpack electrofishing methods and minnow traps. Fish observed during the 2004 inventory were not recorded. Total fish catch from all fishing methods in 2004 was substantially higher relative to the 2002 inventory on the Jackpine Creek, when 133 fish were captured and observed.

Relative abundance, as percent catch composition, for fish species captured in the 2004 inventory, along with CPUE information is provided in Table 5.3-22 for electrofishing and Table 5.3-23 for minnow trapping. As in previous years, results from the 2004 inventory showed that the fish community in Jackpine Creek consists mainly of small-bodied species, including pearl dace and sculpin. Almost 98% of the total electrofishing catch on Jackpine Creek was composed of these two species.

Percent composition for the major fish species captured in the Jackpine Creek inventory is shown in Figure 5.3-17 for the years 2001, 2002 and 2004. When compared to previous RAMP inventories on the Jackpine, the 2004 results were most similar to those observed in 2002, although a number of differences are evident, particularly with respect to the lack of lake chub found in 2004, and a large number of sculpin in the 2004 sample.

CPUE from electrofishing on the Jackpine Creek in 2001, 2002 and 2004 has been highly variable across years for all species (Figure 5.3-18). With the exception of lake chub, CPUE for all species increased in 2004 relative to historical values.

Examination of population parameters (length frequency, condition factor) was not conducted for any large-bodied species due to small sample sizes.

Discussion

Species diversity and overall catch results from the 2004 RAMP Jackpine Creek inventory were high when compared to data from previous RAMP inventories. As in previous years, the 2004 summer fish community in Jackpine Creek was dominated by small-bodied fish species, and to a much lesser extent, by juvenile large-bodied fish. Historically, Arctic grayling have been known to use Jackpine Creek for spawning (O'Neil *et al*. 1982), but none were caught or observed in the 2004 inventory.

Impact Analysis (Muskeg/Jackpine Inventory)

The objective of the Muskeg River/Jackpine Creek fish inventory is to monitor and assess temporal and spatial changes in fish species presence, relative abundance and population parameters. In addition periodic fish inventories in the Muskeg watershed, supplementary data on fish populations also is being generated from the RAMP fish counting fence, which is scheduled to operate again in spring 2005.

Possible measurement endpoints identified for the fish inventory on the Muskeg/Jackpine system include relative abundance and condition factor. Current and historical fish inventory data from the Muskeg/Jackpine inventory indicate some level of

species-specific variability in designated endpoints. However, preliminary statistical analysis on the inventory data set has not demonstrated any significant trends in this regard.

Additional inventory data gathered in a standardized fashion are needed to allow for appropriate trend analysis. It is generally accepted that seven years of data are required for an effective trend analysis. In this regard, at least three more years of inventory data collection will be needed to provide an adequate data set for statistical or trend analysis of any designated measurement endpoints. Additional data also will contribute to establishing the level of natural variability in measurement endpoints, which will eventually allow for the determination of associated impact criteria.

From the results of the Muskeg/Jackpine inventory, there is little evidence to suggest that characteristics of key indicator fish populations (i.e., designated endpoints) have changed during increasing development in the Muskeg River watershed. Given the overall monitoring objective of the Muskeg/Jackpine inventory, it appears as though the spatial and temporal sampling approach is appropriate. Currently, the lower Muskeg sampling area is designated as an exposure site, while the Jackpine inventory area is considered a reference site. Habitat conditions in these two streams are quite different (although both are known to have spawning habitat for suckers and grayling); therefore, inventory results are reported separately and are generally not comparable. There is a need to be more rigorous in the application of sampling effort and methods, and possibly in the formulation of long-term monitoring objectives for the Muskeg River watershed, particularly in light of future large-scale oil sands development activities.

5.3.5.2 Fish Tissue Analysis

During the 2004 fish sampling program on the Muskeg River a total of 14 northern pike were captured. Of this total, only five (three males and two females) met the established size criteria for tissue testing. Tissues used for mercury testing were analyzed individually, while metals and tainting compounds were measured in separate composite samples prepared for males and females.

Mercury

Total mercury concentrations in individual northern pike collected from the Muskeg River in 2004 are presented in Table 5.3-24. The range of values was narrow, with concentrations between a high of 0.25 mg/kg in the largest female fish to a low of 0.19 mg/kg in the smallest male included in the sample.

Mercury concentrations in the composite samples, which were 0.23 mg/kg for the female composite and 0.21 mg/kg for the male sample (Table 5.3-25), were virtually identical to the mean value calculated for the individual fish.

The 2004 Muskeg River sample size was not adequate to establish relationships between tissue mercury concentrations and whole organism parameters (i.e., fork length, total weight and age).

Other Chemicals

Concentrations of other chemicals in composite muscle samples of walleye and northern pike from the Muskeg River are presented in Table 5.3-25. Concentrations of 18 of 30 metals analyzed (as well as the four tainting compounds) were below analytical detection limits. Concentrations of the remaining metals, including barium, copper, iron, manganese, selenium, strontium, titanium and zinc were low, and varied little between sexes and species. Arsenic and thallium have detection limits higher than the Region II USEPA risk-based criteria; therefore exceedances for these metals in Muskeg River fish tissue samples could not be determined.

Discussion

Effect on Human Health

Mercury

Tissue mercury concentrations from Muskeg River northern pike were screened against USEPA and Health Canada human health criteria for fish consumption (Table 5.3-26). Total mercury concentrations in pike, which ranged from 0.19 to 0.25 mg/kg, were greater than 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); mercury concentrations do not appear to pose a potential risk to recreational fishers (i.e., < 0.40 mg/kg) or general consumers (i.e., < 0.5 mg/kg).

Sample sizes for the 2004 Muskeg River fish tissue analysis were small, which limits meaningful statistical analysis and comparison with other RAMP data sets. However, in 2002, fish tissue collected from Muskeg River northern pike of similar size to those sampled in 2004 had mercury concentrations ranging from 0.17 to 0.21 mg/kg (Golder 2003b).

Other Chemicals

In Table 5.3-25, metals and tainting compounds in northern pike from the Muskeg River are screened against several criteria to assess potential risks to human health. With the exception of mercury, only two potential exceedances were recorded. Arsenic and thallium concentrations were below the detection limit of the analyses; therefore, it is uncertain whether concentrations of these metals exceeded the USEPA screening criteria.

Table 5.3-27 provides a comparison of metals concentrations from Muskeg River northern pike collected in 2001, 2002 and 2004. These parameters are the only ones that were detected in both the 2001 and 2002 samples. No consistent trend or relationship with time is evident for these parameters in Muskeg River fish tissue. However, concentrations measured in 2004 generally were slightly lower than those measured in previous years, although these differences were not significant.

Overall, these results indicate that metals (other than mercury) and tainting compounds do not pose a risk to human health at current levels; however, arsenic levels are seen as a potential health risk to subsistence fishers in the oil sands area, depending on individual consumption habits. Concentrations of metals and tainting compounds in fish from the Muskeg River are similar to those found in fish from the Athabasca River. Results from

both the Athabasca River and the Muskeg River indicate that fish tissue quality has remained the same or improved since 2002.

Effects on Fish and Wildlife

Mercury

In Table 5.3-28, total mercury concentrations in individual northern pike samples are screened against criteria and thresholds for effects in fish and wildlife. All mercury concentrations exceeded the CCME criteria for the protection of piscivorous wildlife (0.033 mg/kg) by up to 8-fold, indicating that there are potential risks to wildlife that consume fish. Mercury concentrations did not exceed any of the effects (or no effects) thresholds for fish.

Other Chemicals

Concentrations of other contaminants in composite tissue samples from Muskeg River northern pike were screened against lowest effect thresholds in fish (Table 5.3-29). Of the 30 metals measured in the fish tissue samples effects thresholds were available for only 11 metals. Two metals—cadmium and silver—exceeded no-effects thresholds for fish. Both of these metals were below analytical detection limits; however, 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 for silver 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 presence of an undesirable odor or flavor. All tainting compounds in Muskeg River fish tissue were present at concentrations well below 1 mg/kg (<0.02 mg/kg) indicating that fish palatability is not likely to be an issue.

Impact Analysis

The assessment of potential effects related to fish tissue measurement endpoints from the Muskeg River is provided in Table 5.3-30. It should be noted that only one species, northern pike, was included in the tissue testing and that the sample size was comparatively small (n=5).

Potential effects on human health were predicted from the fish tissue analyses. Results indicate that, due to the presence of elevated concentrations of mercury, there is potential risk to humans consuming target fish species (northern pike) from the Muskeg River. There are potential human health risks from consuming northern pike for subsistence fishers and sensitive subpopulations (i.e., children, pregnant women). 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 analytes, and should be employed in future sampling programs if possible.

Although mercury concentrations in Muskeg River fish tissues were high relative to guidelines, comparison with historical data from the Muskeg and Athabasca rivers shows

that these concentrations fall within the natural range of concentrations observed in this region. 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 health were not predicted from the screening against literature-based thresholds for effects. The fish health assessment also indicated that chemical-related effects were not evident in fish collected from the Muskeg River. However, based on comparisons with CCME criterion for wildlife, there are potential risks to wildlife that consume fish from the Muskeg River.

Effects on fish palatability are not suggested by the 2004 data, given concentrations of all measured tainting compounds were below detection limits and screening values.

Fish tissue chemistry has only been monitored within the Muskeg River watershed for three years (2001, 2002 and 2004) under RAMP. Furthermore, sample sizes of target fish species in 2004 and other years were small. Given the difficulty in capturing sufficient numbers of specific key indicator species in the Muskeg River, the rationale for continuing the assessment on northern pike may need to be revisited.

5.3.5.3 Sentinel Species Monitoring

One of the two exposure sites included in the 2004 sentinel species monitoring program was located on the lower Muskeg River. However, the summary of results from the sentinel species work is provided in Section 5.4.5 on the Steepbank River, where both an exposure and a reference site were located. Reference sites were also situated on the Horse and Dunkirk Rivers.

5.3.6 Summary of Conditions

Monitoring activities in the Muskeg River basin in 2004 were extensive, including hydrology, water and sediment quality, a benthic invertebrate survey, fish inventories, fish tissue chemical analyses and sentinel fish species monitoring. Comparison of the 2004 hydrograph for the Muskeg River to an estimated naturalized hydrograph (i.e., if there were no oil sands operations in the watershed) indicated a decrease of as much as 7% in several hydrologic measurement endpoints. Some uncertainty exists regarding the extent of land disturbance and the amount of water intercepted by oil sands operations. However, more detailed information will be obtained in 2005 to confirm or revise the estimated change in hydrologic conditions. Regardless, there has been little observable change in the concentrations of water and sediment quality variables; most measurement endpoints for water quality and sediment quality in 2004 were within normal ranges of baseline concentrations. Benthic invertebrate communities in the Muskeg River and Jackpine Creek exhibited characteristics within the range recorded for regional reference reaches.

From the results of fish inventories in the watershed, there was little evidence suggesting that characteristics of key indicator fish populations have changed during increasing oil sands development in the watershed. Elevated concentrations of total mercury were found in muscle tissue from northern pike, which could pose a potential risk to human consumers. The 2004 levels fall within the naturally elevated range of concentrations

observed in the region. No other metals or tainting compounds were present at concentrations that would pose a risk for humans.

Sentinel fish species monitoring using slimy sculpin was also conducted on the lower Muskeg River and Steepbank River (see Section 5.4, Steepbank River System, for details). Regarding the Muskeg River, there was evidence of reduced recruitment and missing year classes (i.e., cohorts). This was also observed at the Horse River, which is designated as a reference river. The Muskeg River population has experienced recruitment failure in two consecutive sampling years and warrants further detailed study to identify causes for this failure.

Figure 5.3-2 Muskeg River 2004 hydrograph and historical context.

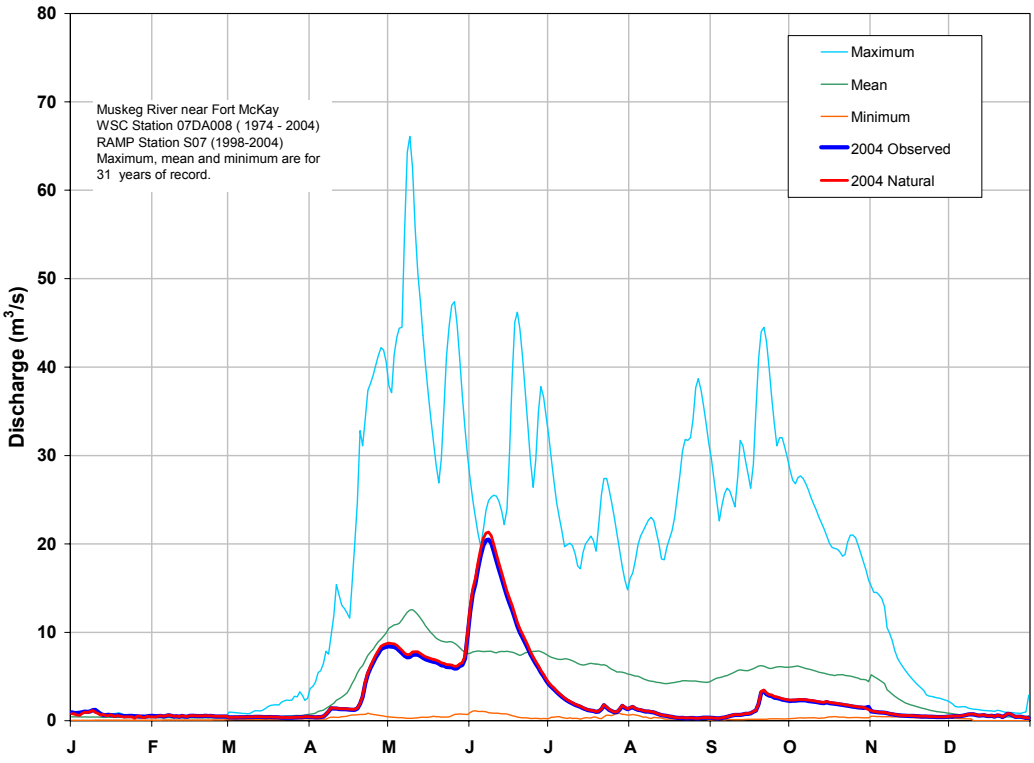


Table 5.3-1 Summary of parameter values for Muskeg River water balance calculation.

Component	Value	Basis / Data Source
Observed hydrograph at S7	Daily discharges	RAMP / WSC monitoring
Natural runoff that would have occurred from active mine areas, or that is intercepted by development	70 km^2 (Syncrude Aurora)	Estimated based on Figure 2.2-1
	30 km^2 (Albian Muskeg River)	Estimated based on Figure 2.2-1
Incremental runoff from areas that are cleared and areas that are being dewatered	Cleared area of 227 ha at Albian	Albian
	Cleared area of 300 ha at Syncrude Aurora	Best Professional Judgment
Withdrawals from Muskeg River	Zero	None reported
Releases to Muskeg River	Aurora Clean Water Diversion daily discharges to Stanley Creek	Syncrude
	Zero release from Albian polishing ponds to Muskeg River	Albian
The difference between observed and naturalized hydrographs on tributary streams	Not applicable	No tributaries were analyzed separately.

* As measured at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008). Definitions and assumptions are discussed in Section 3.1.7.3.

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

Endpoint	Control Value (m^3/s)	Treatment Value (m^3/s)	Percent Change
Mean open-water season discharge	4.56	4.26	-7%
Mean winter discharge	0.574	0.562	-2%
Annual maximum daily discharge	22.0	20.5	-7%
Open-water season minimum daily discharge	0.289	0.270	-7%

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

Table 5.3-3 Concentrations of water quality measurement endpoints, Muskeg River mouth (MUR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	7	7.4	8.0	8.3
Total suspended solids	mg/L	-	6	7	3	3	70
Conductivity	µS/cm	-	338	7	220	359	671
Nutrients							
Total phosphorus	mg/L	0.05	0.012	7	0.008	0.022	**0.072**
Dissolved phosphorus	mg/L	0.05[1]	0.004	7	0.005	0.014	0.030
Total nitrogen*	mg/L	1.0	0.6	7	0.4	0.8	**1.2**
Nitrate+nitrite	mg/L	-	<0.1	7	0.05	0.1	0.1
Dissolved organic carbon	mg/L	-	15	7	15.7	21	24
Ions							
Sodium	mg/L	-	15	7	8	12	64
Chloride	mg/L	230, 860[2]	9	7	1	3	36
Sulphate	mg/L	100[3]	2.1	7	3.5	8.3	91
Total dissolved solids	mg/L	-	280	7	184	280	405
Total alkalinity	mg/L	-	235	7	105	177	313
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.100	0.027	7	0.027	0.090	**1.2**
Dissolved aluminum	mg/L	0.100[1]	0.0021	7	0.0025	0.01	0.03
Total boron	mg/L	1.2[3]	0.051	7	0.032	0.042	0.15
Total molybdenum	mg/L	0.073	0.0001	7	0.0001	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	26	0.8	1	<0.6	<0.6	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
none	-	-	-	-	-	-	-

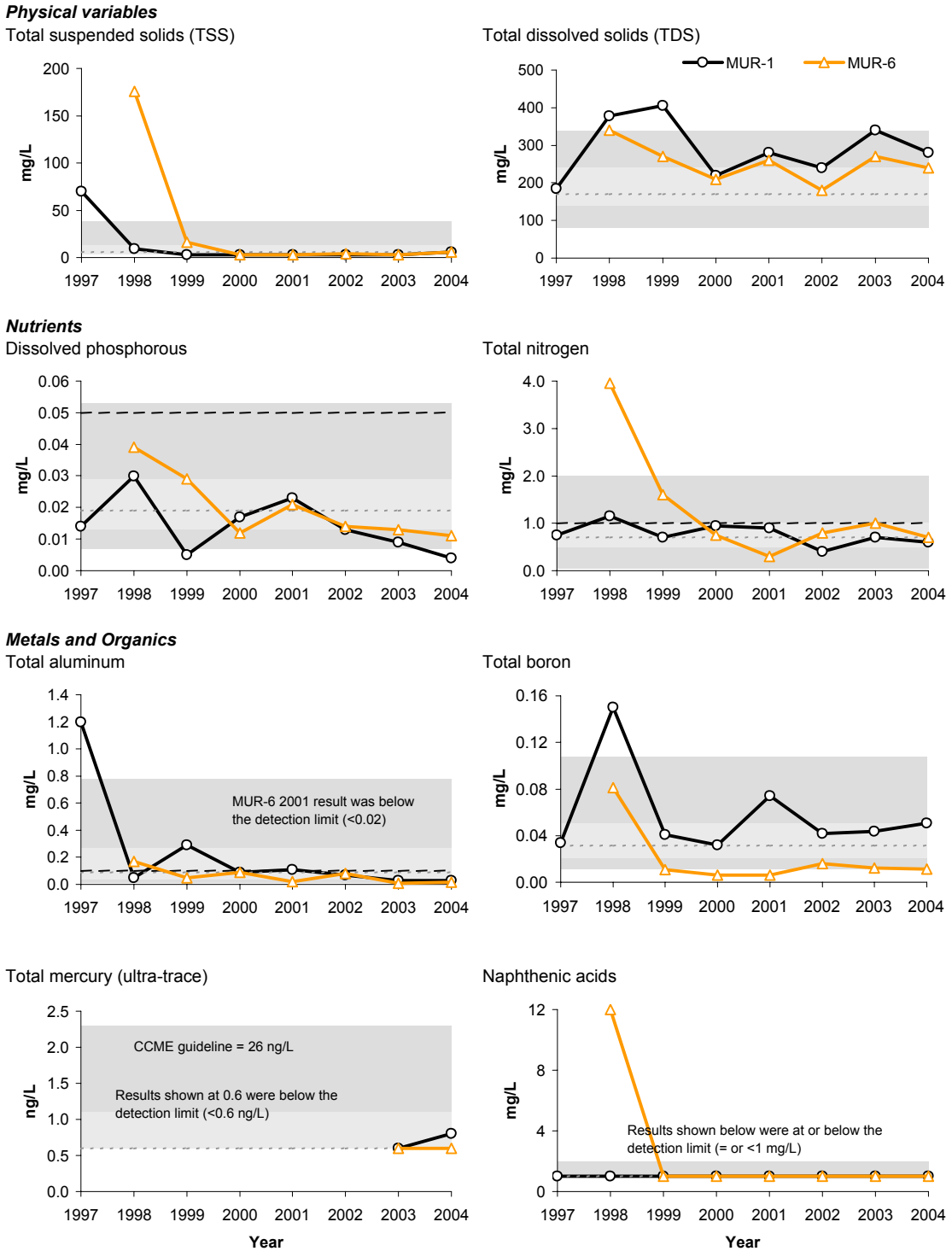
Note: unless otherwise indicated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.3-4 Concentrations of water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (MUR-6), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	7	7.0	7.7	8.2
Total suspended solids	mg/L	-	6	7	3	4	176
Conductivity	µS/cm	-	289	7	233	337	556
Nutrients							
Total phosphorus	mg/L	0.05	0.018	7	0.014	0.021	**2.31**
Dissolved phosphorus	mg/L	0.05[1]	0.011	7	0.012	0.021	0.039
Total nitrogen*	mg/L	1.0	0.7	7	0.3	1.0	**4.0**
Nitrate+nitrite	mg/L	-	<0.1	7	0.05	0.1	0.1
Dissolved organic carbon	mg/L	-	14	7	17	19	24
Ions							
Sodium	mg/L	-	3	7	3	5	9
Chloride	mg/L	230, 860[2]	2	7	<1	<1	3
Sulphate	mg/L	100[3]	1.6	7	3.0	5.1	6.6
Total dissolved solids	mg/L	-	240	7	180	270	340
Total alkalinity	mg/L	-	202	7	120	187	318
Organic compounds							
Naphthenic acids	mg/L	-	<1	7	<1	<1	<2
Selected metals							
Total aluminum	mg/L	0.1	0.02	7	0.009	0.08	**0.2**
Dissolved aluminum	mg/L	0.1[1]	0.002	7	0.006	0.01	0.08
Total boron	mg/L	1.2[3]	0.011	7	0.006	0.011	0.081
Total molybdenum	mg/L	0.073	0.0001	7	<0.0001	0.0001	0.0003
Total mercury (ultra-trace)	ng/L	26	<0.6	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.006**	7	<0.001	0.003	**0.01**

Note: unless otherwise indicated, 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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

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



[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 E for these regional baseline ranges.

Figure 5.3-4 Piper diagram of fall ion concentrations in the Muskeg River and its tributaries, 1997 to 2004.

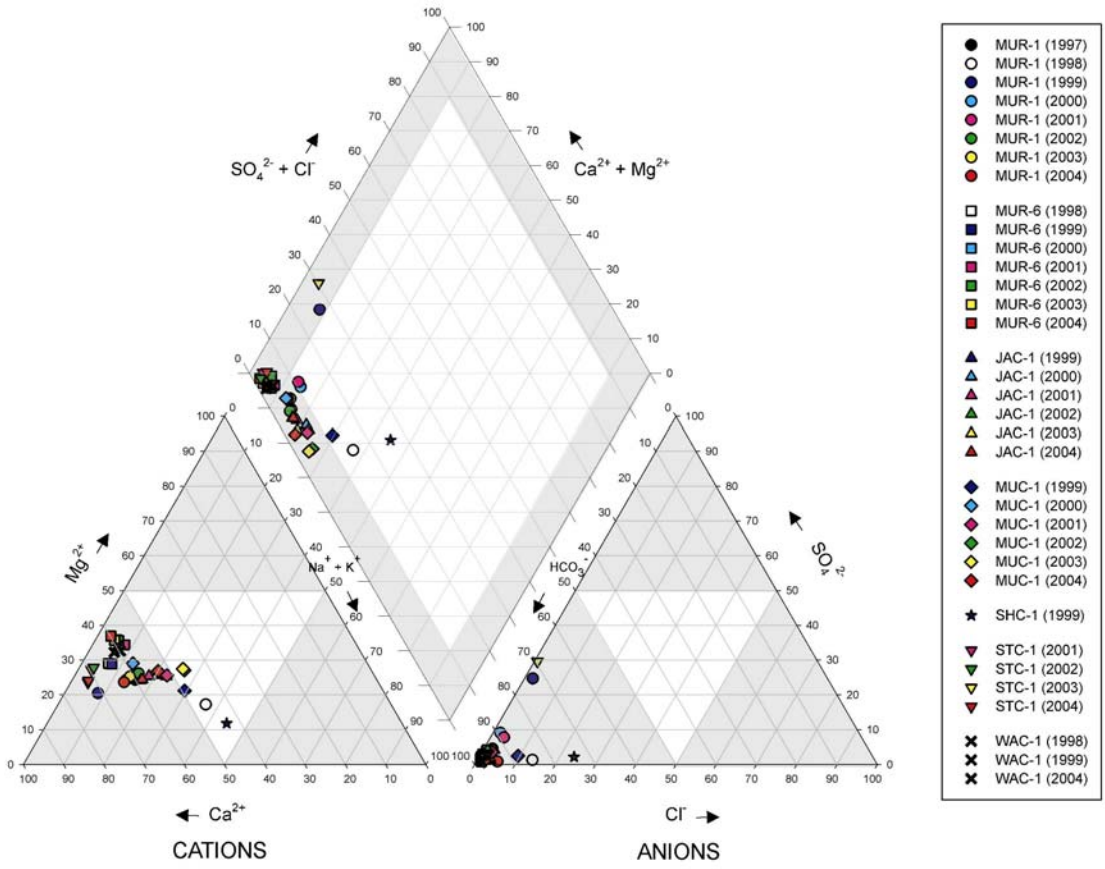


Table 5.3-5 Water quality in Stanley Creek (STC-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	7.6	7.7	8.0
Total suspended solids	mg/L	-	<3	3	<3	<3	6
Conductivity	µS/cm	-	271	3	294	307	617
Nutrients							
Total phosphorus	mg/L	0.05	0.02	4	0.02	0.03	**0.08**
Dissolved phosphorus	mg/L	0.05[1]	0.01	4	0.01	0.01	0.03
Total nitrogen*	mg/L	1.0	0.4	4	0.3	0.8	**2.1**
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	7	3	6	7	8
Ions							
Sodium	mg/L	-	3	3	2	2	6
Chloride	mg/L	230, 860[2]	2	3	<1	1	2
Sulphate	mg/L	100[3]	5.3	3	2.4	5.1	98.5
Total dissolved solids	mg/L	-	200	3	200	200	400
Total alkalinity	mg/L	-	164	3	157	170	240
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.01	4	0.002	0.01	0.02
Dissolved aluminum	mg/L	0.1[1]	0.0004	4	0.001	0.006	0.02
Total boron	mg/L	1.2[3]	0.02	4	0.02	0.02	0.03
Total molybdenum	mg/L	0.073	0.00005	4	<0.6	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	26	<0.6	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
none	-	-	-	-	-	-	-

Note: unless otherwise indicated, 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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.3-6 Water quality in Wapasu Creek (WAC-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	7.4	-	7.7
Total suspended solids	mg/L	-	3	2	3	-	23
Conductivity	µS/cm	-	284	2	339	-	524
Nutrients							
Total phosphorus	mg/L	0.05	0.03	2	0.02	-	0.06
Dissolved phosphorus	mg/L	0.05[1]	0.01	2	0.01	-	0.02
Total nitrogen*	mg/L	1.0	0.8	2	0.5	-	1.0
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	17	2	11	-	18
Ions							
Sodium	mg/L	-	6	2	6	-	8
Chloride	mg/L	230, 860[2]	2	2	1.4	-	2
Sulphate	mg/L	100[3]	1.9	2	5.2	-	7.6
Total dissolved solids	mg/L	-	250	2	240	-	300
Total alkalinity	mg/L	-	197	2	176	-	292
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	<1
Selected metals							
Total aluminum	mg/L	0.1	0.02	2	0.02	-	0.05
Dissolved aluminum	mg/L	0.1[1]	0.004	2	<0.01	-	0.05
Total boron	mg/L	1.2[3]	0.02	2	0.01	-	0.08
Total molybdenum	mg/L	0.073	0.00005	2	0.0001	-	0.0004
Total mercury (ultra-trace)	ng/L	26	<0.6	-	-	-	-
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.006**	2	0.002	-	**0.006**
Total iron	mg/L	0.3	**0.5**	2	**0.6**	-	**2.1**

Note: unless otherwise indicated, 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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.3-7 Water quality in Muskeg Creek (MUC-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	7.5	7.7	8.1
Total suspended solids	mg/L	-	6	5	<3	3	7
Conductivity	µS/cm	-	302	5	188	251	585
Nutrients							
Total phosphorus	mg/L	0.05	0.04	5	0.02	0.02	0.04
Dissolved phosphorus	mg/L	0.05[1]	0.02	5	0.01	0.01	0.03
Total nitrogen*	mg/L	1.0	0.9	5	0.4	0.8	**1.1**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	22	5	20	23	26
Ions							
Sodium	mg/L	-	21	5	7	14	44
Chloride	mg/L	230, 860[2]	3	5	<1	2	23
Sulphate	mg/L	100[3]	2	5	2.8	4.6	8
Total dissolved solids	mg/L	-	270	5	150	200	339
Total alkalinity	mg/L	-	210	5	93	123	297
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	<1	2
Selected metals							
Total aluminum	mg/L	0.1	0.08	5	0.03	0.05	0.09
Dissolved aluminum	mg/L	0.1[1]	0.003	5	0.005	0.01	0.011
Total boron	mg/L	1.2[3]	0.081	5	0.024	0.0474	0.086
Total molybdenum	mg/L	0.073	0.00005	5	0.00006	0.0001	0.0064
Total mercury (ultra-trace)	ng/L	26	<0.6	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.009**	5	0.001	**0.005**	**0.013**
Total iron	mg/L	0.3	**1.2**	5	0.30	**0.63**	**1.81**

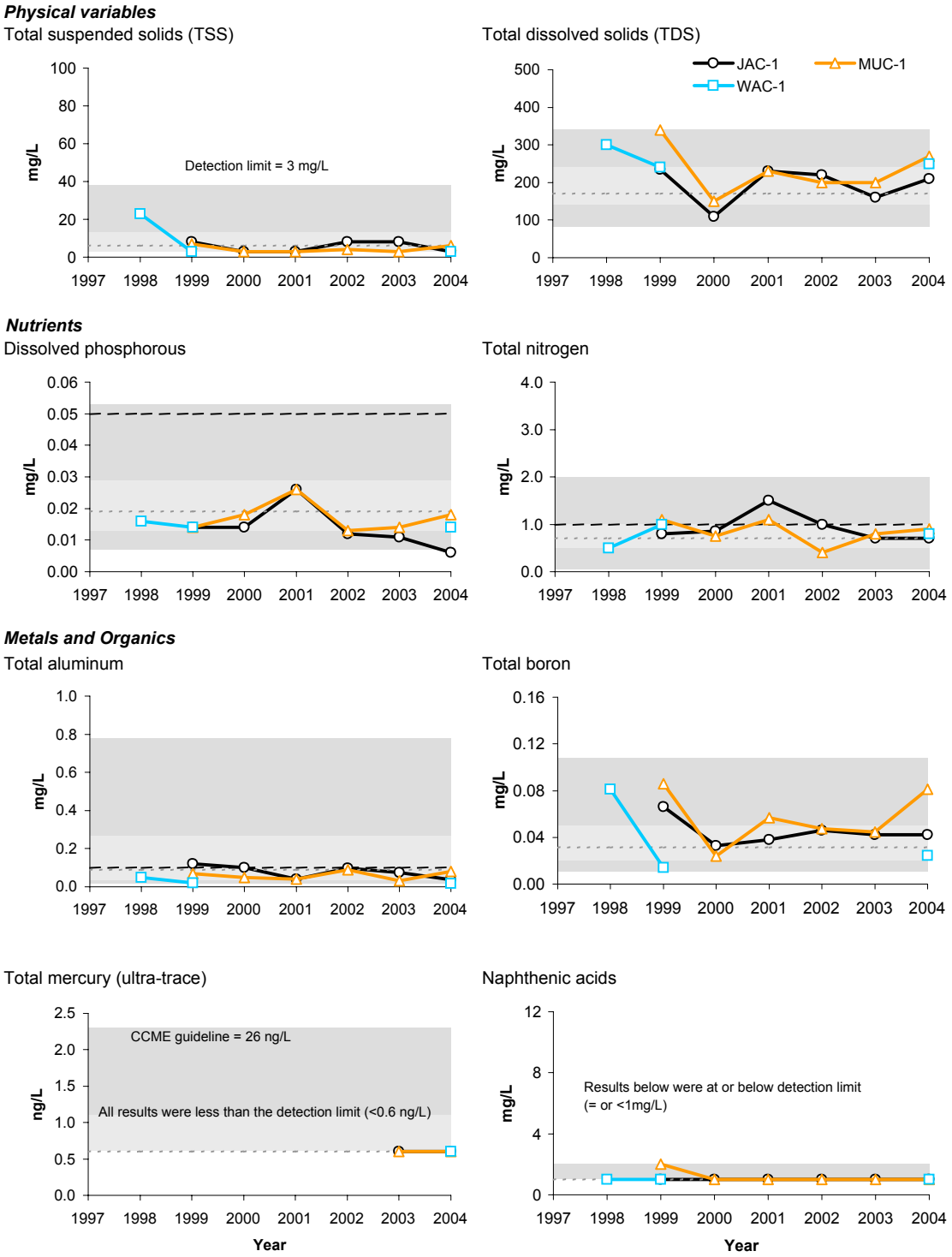
Note: unless otherwise indicated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.3-8 Water quality in Jackpine Creek (JAC-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	5	7.8	7.92	8.2
Total suspended solids	mg/L	-	<3	5	<3	8	8
Conductivity	µS/cm	-	242	5	183	197	413
Nutrients							
Total phosphorus	mg/L	0.05	0.018	5	0.019	0.021	0.042
Dissolved phosphorus	mg/L	0.05[1]	0.006	5	0.011	0.014	0.026
Total nitrogen*	mg/L	1.0	0.7	5	0.7	0.9	**1.5**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	21	5	19	22	24
Ions							
Sodium	mg/L	-	12	5	10	11	18
Chloride	mg/L	230, 860[2]	3	5	1	2	5.6
Sulphate	mg/L	100[3]	2.6	5	2.6	4.1	4.3
Total dissolved solids	mg/L	-	210	5	110	220	234
Total alkalinity	mg/L	-	138	5	93	97	227
Organic compounds							
Naphthenic acids	mg/L	-	1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.038	5	0.04	0.098	**0.12**
Dissolved aluminum	mg/L	0.1[1]	0.004	5	0.006	0.009	**0.17**
Total boron	mg/L	1.2[3]	0.042	5	0.033	0.042	0.066
Total molybdenum	mg/L	0.073	0.0001	5	0.0001	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	26	<0.6	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.006**	5	0.001	0.004	**0.014**
Total iron	mg/L	0.3	**0.72**	5	**0.38**	**0.45**	**1.6**

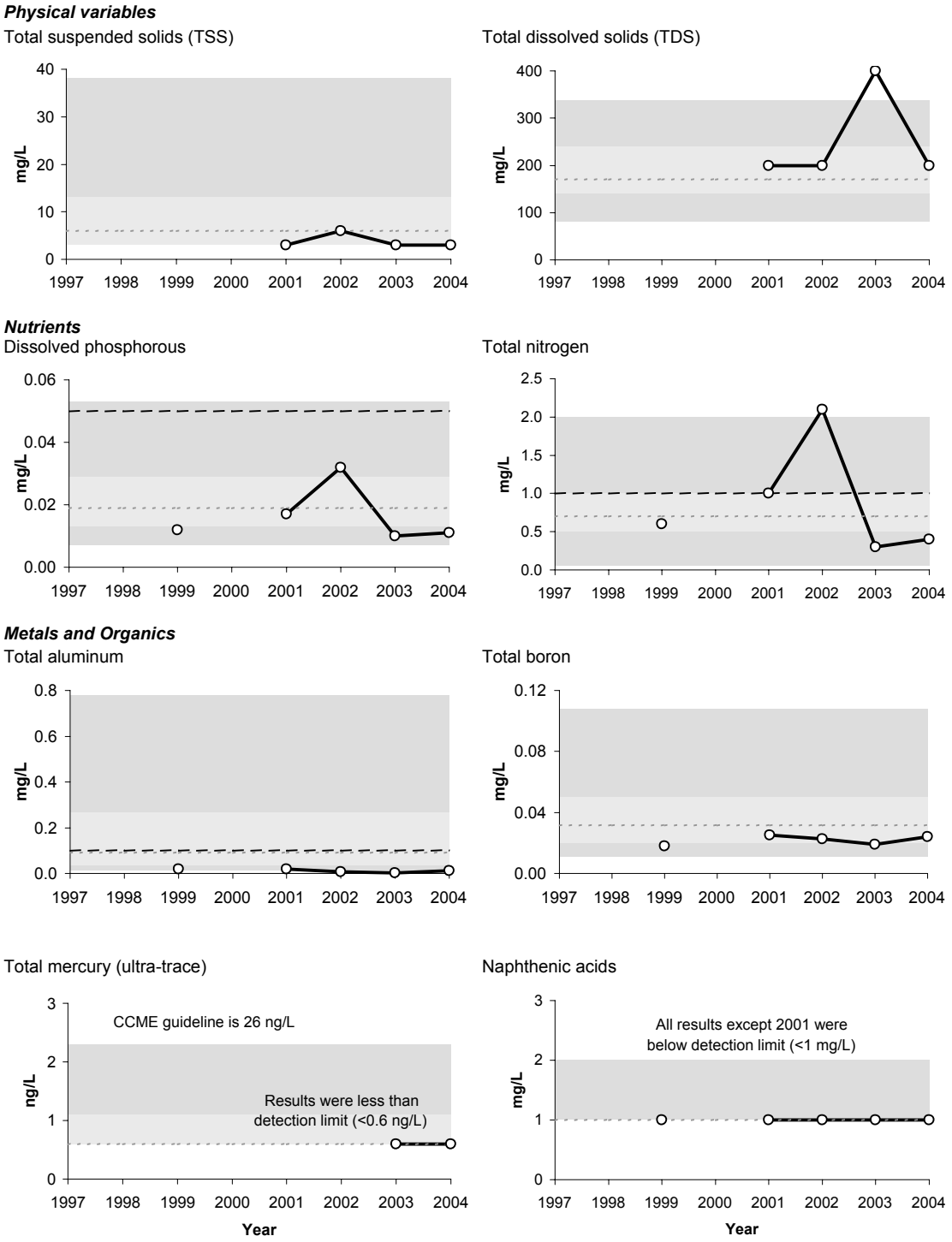
Note: unless otherwise indicated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.3-5 Concentrations of selected water quality measurement endpoints in Muskeg River tributaries (Jackpine Creek, Muskeg Creek and Wapasu Creek) relative to regional baseline concentrations, fall 2004.



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 E for these regional baseline ranges.

Figure 5.3-6 Concentrations of selected water quality measurement endpoints in Stanley Creek, relative to regional baseline concentrations, fall 2004.



[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 E for these regional baseline ranges.

Table 5.3-9 List of all 2004 water quality guideline exceedances, Muskeg River system.

Parameter	Units	Guideline	MUR-1	MUR-6	JAC-1	MUC-1	STC-1	WAC-1
Spring [1]								
Total iron	mg/L	0.300	ns	ns	**0.313**	-	**0.512**	ns
Total zinc	mg/L	0.030	ns	ns	-	-	**0.0363**	ns
Summer								
Total phenols	mg/L	0.004	ns	ns	**0.006**	**0.01**	-	ns
Total aluminum	mg/L	0.100	ns	ns	-	**0.194**	-	ns
Total iron	mg/L	0.300	ns	ns	**0.761**	**1.03**	**1.3**	ns
Dissolved iron	mg/L	0.300[2]	ns	ns	**0.496**	**0.547**	**0.582**	ns
Total phosphorus	mg/L	0.05	ns	ns	-	-	**0.104**	ns
Fall								
Total phenols	mg/L	0.004	-	**0.006**	**0.006**	**0.009**	-	**0.006**
Total iron	mg/L	0.300	-	-	**0.717**	**1.17**	-	**0.513**
Dissolved iron	mg/L	0.300[2]	-	-	**0.529**	**0.639**	-	**0.344**

Guidelines are CCME/AENV guidelines for the protection of aquatic life.
[1]: No stations sampled in winter; MUR-1, MUR-6, and WAC-1 sampled only in fall.
[2]: Guideline is for total analyte (no guideline for dissolved species).
ns: not sampled.

Table 5.3-10 Selected sediment quality measurement endpoints, Muskeg River mouth (MUR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	2	6	4.7	8	16
Silt	%	-	13	6	4	15	27
Sand	%	-	85	6	58	77.5	90
Total organic carbon	%	-	1.9	7	0.5	1.2	3.0
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]	29	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**670**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	590	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	4	0.5	0.5	0.5
TEH (C11-C30)	mg/kg	-	180	4	5	131	395
TRH	mg/kg	-	2400	7	800	1900	3440
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.002	8	0.0009	0.010	0.02
Retene	mg/kg	-	0.03	4	0.003	0.011	0.063
Total dibenzothiophenes	mg/kg	-	0.43	7	0.048	0.14	0.58
Total PAHs	mg/kg	-	1.8	7	0.27	0.81	1.9
Total HMW PAHs	mg/kg	-	0.52	7	0.12	0.41	0.87
Total LMW PAHs	mg/kg	-	1.2	7	0.09	0.53	1.3
Predicted PAH toxicity[1]	H.I.	-	0.36	7	0.15	0.24	0.49
Metals that exceed CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	7	2	8	-	8.8
Chironomus growth	mg/organism	-	2.8	2	1.2	-	1.36
Hyallela survival	# surviving	-	5	2	8	-	8.4
Hyallela growth	mg/organism	-	0.14	2	0.09	-	0.1

Note: unless otherwise stated, guidelines values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV 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 Selected sediment quality measurement endpoints, Muskeg River upstream of mouth (MUR-2), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4	2	8	-	12
Silt	%	-	22	2	13	-	16
Sand	%	-	74	2	72	-	79
Total organic carbon	%	-	2.7	2	2.1	-	2.8
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]	**160**	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**1800**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	1400	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	2	0.5	-	0.5
TEH (C11-C30)	mg/kg	-	720	2	370	-	1600
TRH	mg/kg	-	7900	2	6000	-	11300
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.02	2	0.002	-	0.02
Retene	mg/kg	-	0.2	2	0.1	-	0.2
Total dibenzothiophenes	mg/kg	-	3.3	2	5.3	-	10.6
Total PAHs	mg/kg	-	14.3	2	15.3	-	30.4
Total HMW PAHs	mg/kg	-	5.2	2	3.9	-	9.6
Total LMW PAHs	mg/kg	-	9.1	2	11.4	-	20.8
Predicted PAH toxicity[1]	H.I.	-	1.0	2	1.3	-	1.5
Metals that exceed CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	7	-	-	-	-
Chironomus growth	mg/organism	-	2.5	-	-	-	-
Hyallela survival	# surviving	-	8	-	-	-	-
Hyallela growth	mg/organism	-	0.18	-	-	-	-

Note: unless otherwise stated, guidelines values are CCME/AENV guidelines.

Values in **bold** indicate concentrations exceeding CCME/AENV 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 Selected sediment quality measurement endpoints, Muskeg River upstream of Stanley Creek (MUR-D2), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	6	1	-	-	7
Silt	%	-	15	1	-	-	14
Sand	%	-	80	1	-	-	79
Total organic carbon	%	-	5.5	-	-	-	-
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]	**540**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	210	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	1	-	-	<0.5
TEH (C11-C30)	mg/kg	-	470	1	-	-	150
TRH	mg/kg	-	1000	1	-	-	3600
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.003	1	-	-	0.004
Retene	mg/kg	-	0.16	1	-	-	0.50
Total dibenzothiophenes	mg/kg	-	0.13	1	-	-	0.10
Total PAHs	mg/kg	-	0.67	1	-	-	1.1
Total HMW PAHs	mg/kg	-	0.33	1	-	-	0.31
Total LMW PAHs	mg/kg	-	0.34	1	-	-	0.82
Predicted PAH toxicity[1]	H.I.	-	0.37	1	-	-	0.20
Metals that exceeded CCME guidelines in fall 2004							
Total Zinc (Zn)	mg/kg	123[3]	**222**	1	-	-	39
Chronic toxicity							
Chironomus survival	# surviving	-	7	-	-	-	-
Chironomus growth	mg/organism	-	2.2	-	-	-	-
Hyallela survival	# surviving	-	7	-	-	-	-
Hyallela growth	mg/organism	-	0.2	-	-	-	-

Note: unless otherwise stated, guidelines values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV 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 5.3-13 Selected sediment quality measurement endpoints, Jackpine Creek (JAC-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3	1	-	-	18.7
Silt	%	-	11	1	-	-	0.3
Sand	%	-	87	1	-	-	81
Total organic carbon	%	-	1.1	1	-	-	2
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]	17	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**450**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	530	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	-	-	-	-
TEH (C11-C30)	mg/kg	-	180	-	-	-	-
TRH	mg/kg	-	2600	1	-	-	5660
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	<0.00258	1	-	-	0.003
Retene	mg/kg	-	0.06		-	-	-
Total dibenzothiophenes	mg/kg	-	1.6	1	-	-	0.72
Total PAHs	mg/kg	-	4.5	1	-	-	2.1
Total HMW PAHs	mg/kg	-	1.5	1	-	-	0.49
Total LMW PAHs	mg/kg	-	3.0	1	-	-	1.6
Predicted PAH toxicity[1]	H.I.	-	0.86	1	-	-	0.17
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	7	-	-	-	-
Chironomus growth	mg/organism	-	3.2	-	-	-	-
Hyallela survival	# surviving	-	7	-	-	-	-
Hyallela growth	mg/organism	-	0.14	-	-	-	-

Note: unless otherwise stated, guidelines values are CCME/AENV guidelines.

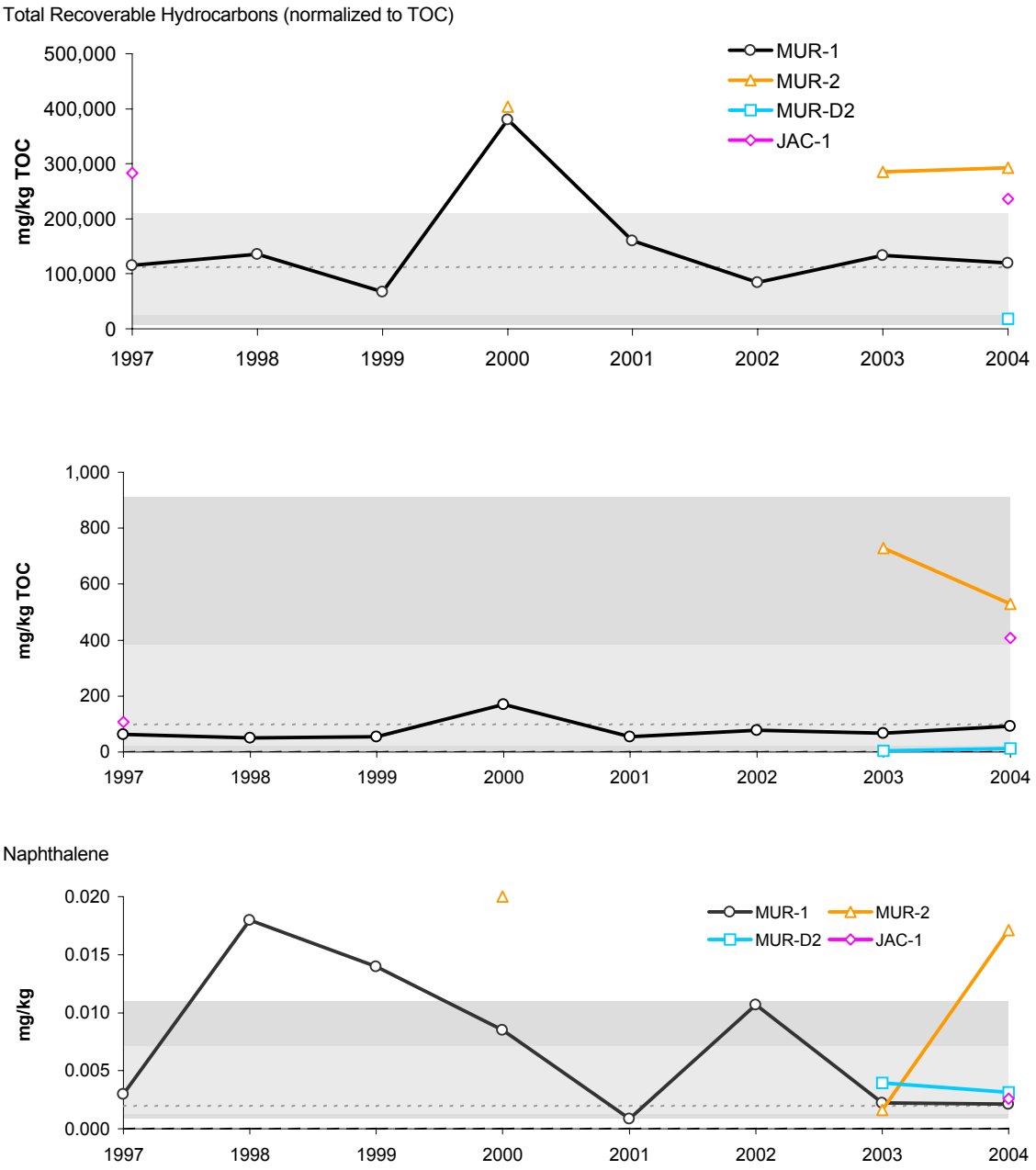
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

[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 Selected sediment quality measurement endpoints in the Muskeg River and its tributaries, relative to regional baseline concentrations, fall 2004.



[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 F for these regional baseline ranges.

Table 5.3-14 Average habitat characteristics of benthic invertebrate sampling stations in the Muskeg River, fall 2004.

Variable	Units	Lower Reach of the Muskeg River	Lower to Mid Reach of the Muskeg River	Upper Reach of the Muskeg River
Sample date	-	Sept. 8, 2004	Sept. 9, 2004	Sept. 15, 2004
Habitat	-	Erosional	Depositional	Depositional
Water depth	m	0.2	0.5	0.9
Current velocity	m/s	0.50	0.0	0.0
Macrophyte cover	%	0.3	10.0	19
Benthic algae	Mg/m^2	8.9	n/a	n/a
Field Water Quality				
Dissolved oxygen	mg/L	11.3	8.0	5.0
Conductivity	µS/cm	293	466	489
pH	-	8.3	8.2	7.9
Water temperature	°C	8.8	8.7	7.7
Sediment Composition				
Sand	%	n/a	93.5	35
Silt	%	n/a	5.7	22
Clay	%	n/a	2.1	44
Total Organic Carbon	%	n/a	1.5	30
Small gravel	%	11.1	n/a	n/a
Large gravel	%	37.7	n/a	n/a
Small cobble	%	36.3	n/a	n/a
Large cobble	%	18.6	n/a	n/a
Boulder	%	6.3	n/a	n/a
Bedrock	%	5.0	n/a	n/a

Table 5.3-15 Summary of major taxon abundances and key indices of composition among stations in the Muskeg River.

Taxon	Lower Reach of the Muskeg River			Lower to Mid Reach of the Muskeg River			Upper Reach of the Muskeg River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Nematoda	143	240	1.2	1,402	2,736	7.5	1,868	9,151	10.1
Glossiphoniidae	0	0	0	0	0	0	201	1,524	1.1
Erpobdellidae	0	0	0	0	0	0	575	2,438	3.1
Enchytraeidae	51	48	0.4	236	524	1.3	14	91	0.1
Naididae	321	599	2.7	1,302	7,144	6.9	514	0	2.8
Tubificidae	302	337	2.5	1,471	1,817	7.8	4,319	9,499	23.3
Lumbriculidae	11	106	0.1	0	0	0	29	0	0.2
Hydracarina	0	0	0	26	213	0.1	52	427	0.3
Ostracoda	0	0	0	57	0	0.3	287	1,013	1.6
Copepoda	14	41	0.1	3,270	21,599	17.4	132	272	0.7
Chydoridae	0	0	0	0	0	0	316	658	1.7
Daphniidae	0	0	0	468	2,972	2.5	115	453	0.6
Amphipoda	0	0	0	43	152	0.2	1,635	3,058	8.8
Gastropoda	0	0	0	0	0	0	371	988	2.0
Ephemeroptera	346	223	2.9	218	1,280	1.2	802	1,972	4.3
Plecoptera	1,376	510	11.5	0	0	0	0	0	0
Trichoptera	849	421	7.1	6	0	0.0	897	1,519	4.8
Anisoptera	254	276	2.1	0	0	0	287	0	1.6
Coleoptera	655	474	5.5	471	693	2.5	1,325	1,560	7.1
Heteroptera	0	0	0	0	0	0	32	274	0.2
Tipulidae	86	87	0.7	115	0	0.6	0	0	0
Dolichopodidae	0	0	0	66	108	0.4	3	0	0.0
Tabanidae	6	0	0.1	92	0	0.5	759	7,071	4.1
Empididae	348	609	2.9	106	737	0.6	0	0	0
Ceratopogonidae	44	102	0.4	4,322	9,173	23.0	287	498	1.6
Chironomidae	7,125	1,545	59.7	4,868	1,758	25.9	3,716	1,879	20.0
Psychodidae	0	0	0	259	305	1.4	0	0	0
Total Abundance	**11,932**	**6,640**	**-**	**18,799**	**18,073**	**-**	**18,534**	**18,759**	**-**
Richness	30.8	4.0	-	9.9	3.1	-	8.9	4.3	-
Simpson's Diversity	0.854	0.079	-	0.677	0.177	-	0.703	0.130	-
Evenness	0.883	0.082	-	0.763	0.200	-	0.809	0.120	-

Figure 5.3-8 **Biplot of benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for the lower Muskeg River (erosional habitats).**

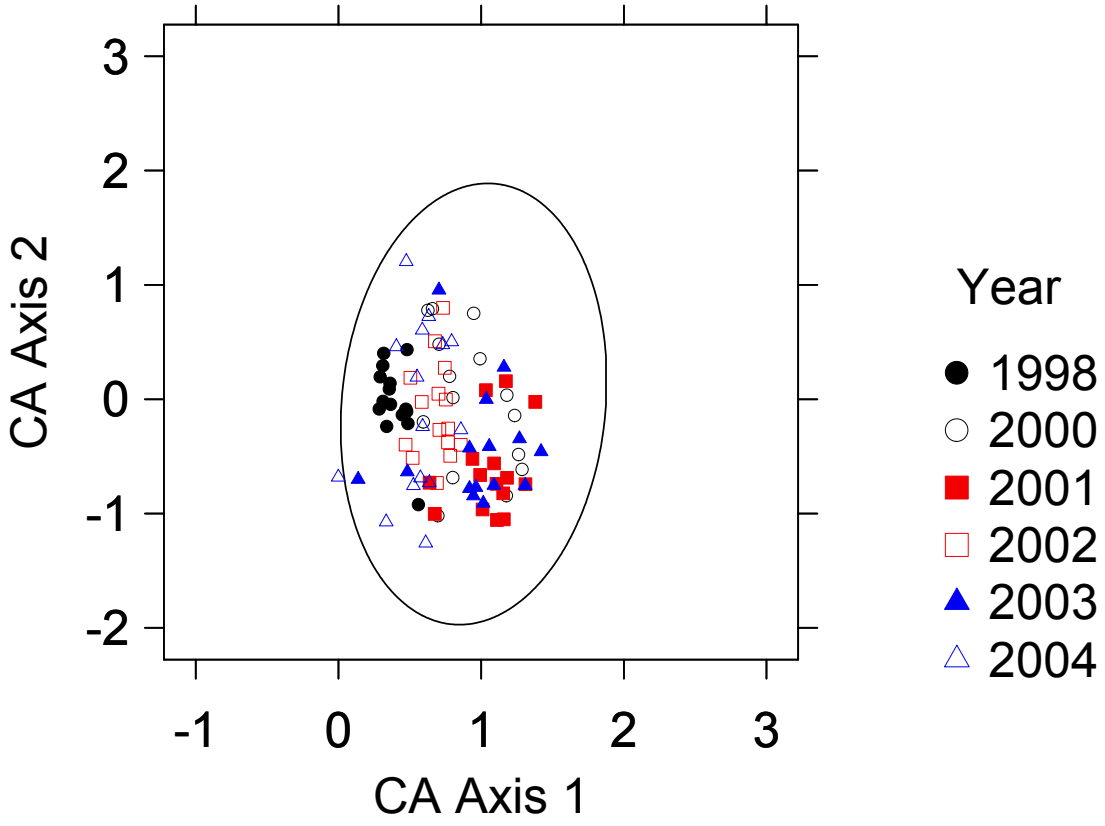


Figure 5.3-9 Variations in indices of benthic invertebrate community composition in the lower reach of the Muskeg River (erosional).

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

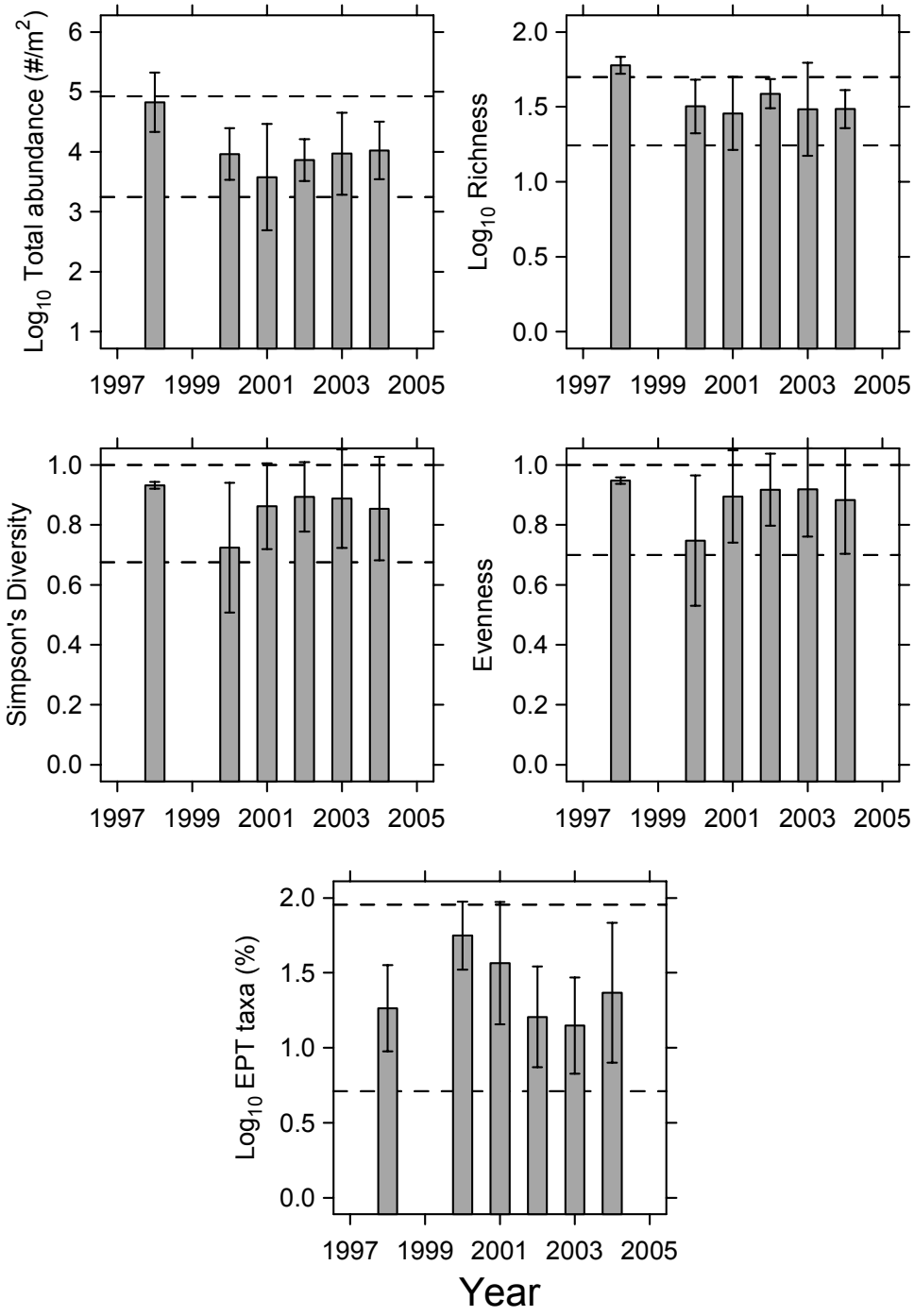


Table 5.3-16 Results of analysis of variance between lower (exposed) and upper (reference) reach of Muskeg River.

Source	SS	df	F	P
Log_{10} Abundance				
Reach-Year	4.925	8	6.507	<0.001
Time (2002-2004)	*0.368*	*1*	*3.888*	*0.051*
Reach	*0.070*	*1*	*0.736*	*0.393*
Time × Reach	*<0.001*	*1*	*0.002*	*0.965*
Reach (2004)	*0.042*	*1*	*0.444*	*0.506*
Error	10.785	114		
Log_{10} Richness				
Reach-Year	7.041	8	42.7	<0.001
Time (2002-2004)	*0.271*	*1*	*13.3*	*<0.001*
Reach	*4.975*	*1*	*241.4*	*<0.001*
Time × Reach	*0.016*	*1*	*0.778*	*0.380*
Reach (2004)	*2.497*	*1*	*121.2*	*<0.001*
Error	2.349	114		
Simpson's Diversity				
Reach	0.998	8	14.61	<0.001
Time (2002-2004)	*0.002*	*1*	*0.187*	*0.667*
Reach	*0.646*	*1*	*75.72*	*<0.001*
Time × Reach	*0.036*	*1*	*4.275*	*0.041*
Reach (2004)	*0.171*	*1*	*20.03*	*<0.001*
Error	0.973	114		
Evenness				
Reach	0.705	8	10.76	<0.001
Time (2002-2004)	*0.018*	*1*	*2.210*	*0.140*
Reach	*0.317*	*1*	*38.65*	*<0.001*
Time × Reach	*0.070*	*1*	*8.560*	*0.004*
Reach (2004)	*0.042*	*1*	*5.136*	*0.025*
Error	0.934	114		
Log_{10} EPT %				
Reach	38.04	8	46.11	<0.001
Time (2002-2004)	*1.641*	*1*	*15.91*	*<0.001*
Reach	*17.86*	*1*	*173.2*	*<0.001*
Time × Reach	*0.433*	*1*	*4.194*	*0.043*
Reach (2004)	*5.540*	*1*	*53.72*	*<0.001*
Error	11.76	114		

Figure 5.3-10 Biplot of benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for the lower-to-mid reach of the Muskeg River.

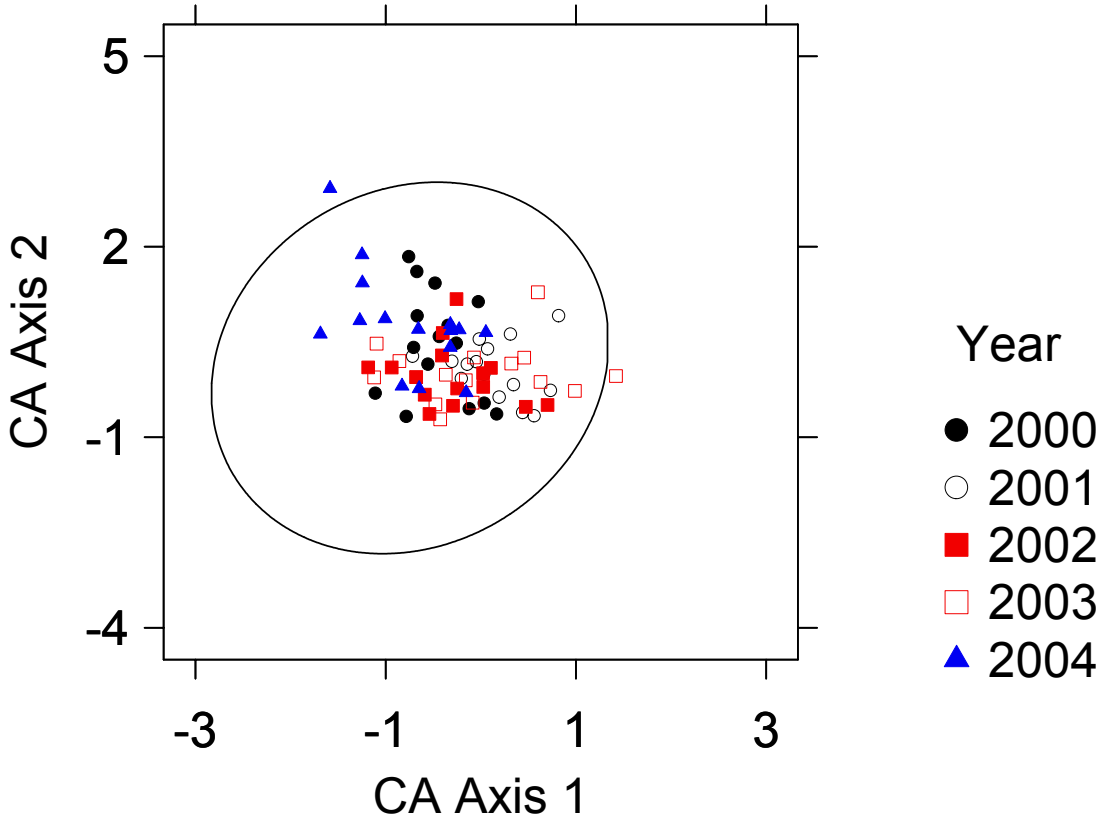


Figure 5.3-11 Variations in indices of benthic invertebrate community composition in lower-to-mid and upper reaches of the Muskeg River.

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

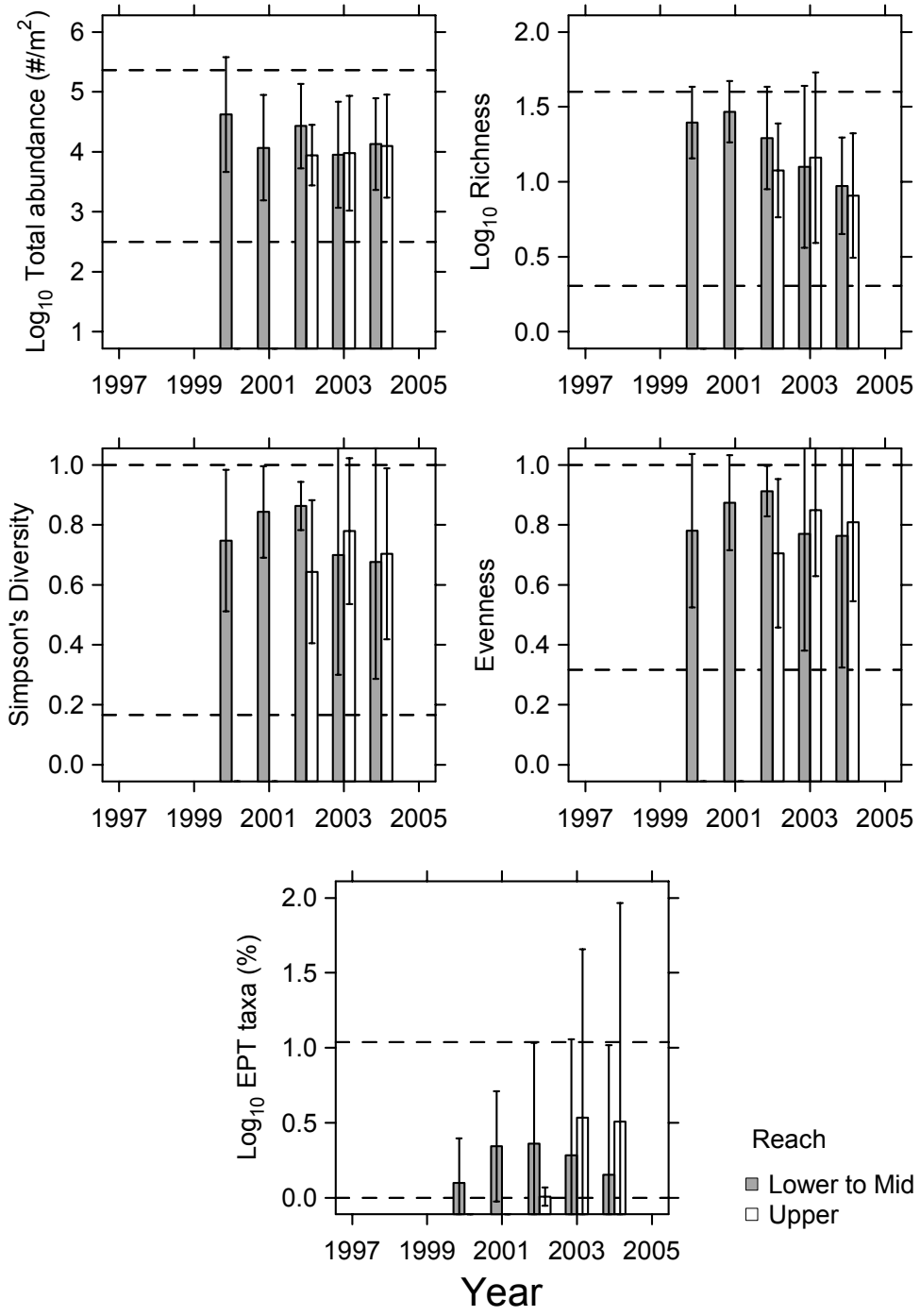


Table 5.3-17 Analysis of variance between Lower to Mid (exposed) and Upper (references) reaches of the Muskeg River.

Source	SS	df	F	P
Log_{10} Abundance				
Reach-Year	6.357	7	6.407	<0.001
Time (2002-2004)	*0.081*	*1*	*0.570*	*0.452*
Reach	*0.598*	*1*	*4.221*	*0.042*
Time × Reach	*0.770*	*1*	*5.430*	*0.022*
Reach (2004)	*0.008*	*1*	*0.054*	*0.817*
Error	15.87	112		
Log_{10} Richness				
Reach-Year	4.134	7	18.89	<0.001
Time (2002-2004)	*0.892*	*1*	*28.52*	*<0.001*
Reach	*0.119*	*1*	*3.812*	*0.053*
Time × Reach	*0.087*	*1*	*2.767*	*0.099*
Reach (2004)	*0.032*	*1*	*1.007*	*0.318*
Error	3.502	112		
Simpson's Diversity				
Reach	0.653	7	6.045	<0.001
Time (2002-2004)	*0.060*	*1*	*3.916*	*0.050*
Reach	*0.032*	*1*	*2.076*	*0.152*
Time × Reach	*0.227*	*1*	*14.73*	*<0.001*
Reach (2004)	*0.005*	*1*	*0.347*	*0.557*
Error	1.729	112		
Evenness				
Reach	0.475	7	4.204	<0.001
Time (2002-2004)	*0.008*	*1*	*0.493*	*0.484*
Reach	*0.017*	*1*	*1.073*	*0.302*
Time × Reach	*0.239*	*1*	*14.79*	*<0.001*
Reach (2004)	*0.015*	*1*	*0.945*	*0.333*
Error	1.808	112		
Log_{10} EPT %				
Reach	3.748	7	3.815	0.001
Time (2002-2004)	*0.321*	*1*	*2.291*	*0.133*
Reach	*0.158*	*1*	*1.128*	*0.290*
Time × Reach	*1.881*	*1*	*13.41*	*<0.001*
Reach (2004)	*0.943*	*1*	*6.720*	*0.011*
Error	15.72	112		

Table 5.3-18 Average habitat characteristics of benthic invertebrate sampling stations in Jackpine Creek, fall 2004.

Variable	Units	Lower Reach of Jackpine Creek	Upper Reach of Jackpine Creek
Sample date	-	Sept 13 2004	Sept 20 2004
Habitat	-	Depositional	Depositional
Water depth	m	0.2	0.2
Current velocity	m/s	0	0
Macrophyte cover	%	1	1
Field Water Quality			
Dissolved oxygen	mg/L	9.4	10.2
Conductivity	µS/cm	211	224
pH	-	8.1	8.0
Water temperature	°C	8.5	6.8
Sediment Composition			
Sand	%	91.4	81.4
Silt	%	6.7	10.7
Clay	%	2.5	8.0
Total Organic Carbon	%	1.0	1.0

Table 5.3-19 Summary of major taxon abundances and key indices of composition among stations in Jackpine Creek, fall 2004.

Taxon	Lower Reach of Jackpine Creek			Upper Reach of Jackpine Creek		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Hydra	86	0	0.3	0	0	0
Nematoda	1,974	4,049	6.6	4,313	12,426	19.9
Enchytraeidae	6	0	0.0	181	508	0.8
Naididae	195	498	0.7	351	922	1.6
Tubificidae-	1,693	3,565	5.7	773	2,479	3.6
Hydracarina	66	323	0.2	69	0	0.3
Ostracoda	63	398	0.2	75	671	0.3
Copepoda	1,376	7,715	4.6	55	141	0.3
Chydoridae	1,931	2,230	6.5	279	0	1.3
Daphniidae	0	0	0	75	0	0.3
Amphipoda	1,195	12,070	4.0	0	0	0
Collembola	0	0	0	3	0	0.0
Gastropoda	46	179	0.2	0	0	0
Ephemeroptera	707	1,076	2.4	454	2,864	2.1
Trichoptera	440	2,342	1.5	575	1,219	2.7
Anisoptera	497	1,655	1.7	0	0	0

Table 5.3-19 (cont'd.)

Taxon	Lower Reach of Jackpine Creek			Upper Reach of Jackpine Creek		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Coleoptera	124	301	0.4	951	2,076	4.4
Heteroptera	46	0	0.2	0	0	0
Tipulidae	468	656	1.6	756	956	3.5
Dolichopodidae	34	149	0.1	247	531	1.1
Tabanidae	273	832	0.9	417	1,076	1.9
Empididae	661	1,524	2.2	23	122	0.1
Ephydridae	0	0	0	184	0	0.9
Ceratopogonidae	1201	3,061	4.0	2,060	1,825	9.5
Chironomidae	16,756	4,400	56.2	9,787	7,740	45.3
Total Abundance	29,839	14,789	-	21,626	19,021	-
Richness	15.5	4.9	-	10.1	2.9	-
Simpson's Diversity	0.743	0.105	-	0.696	0.168	-
Evenness	0.799	0.102	-	0.778	0.180	-

Figure 5.3-12 Biplot of benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances, Jackpine Creek.

Note: Ellipse describes reference data.

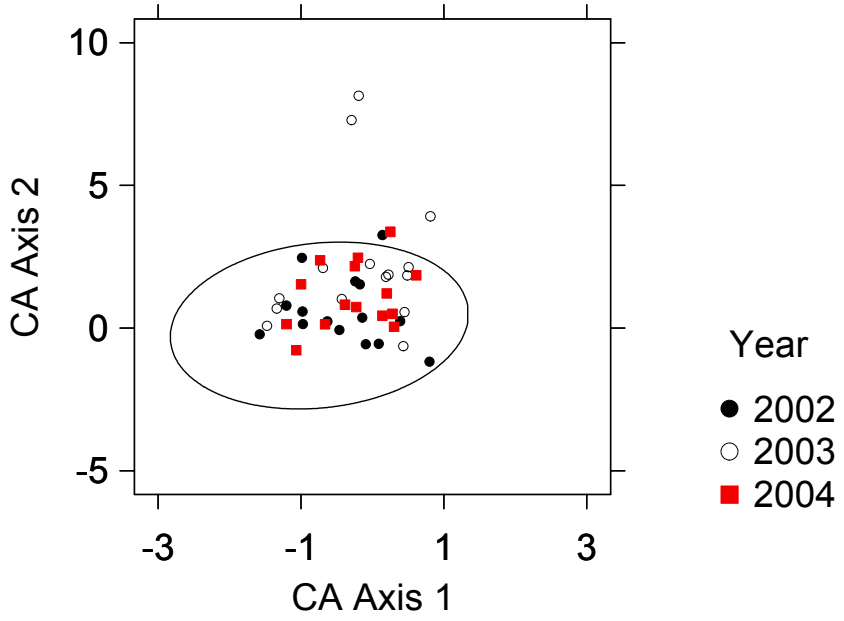


Figure 5.3-13 Variation in selected measurement endpoints of benthic invertebrate community composition in Jackpine Creek.

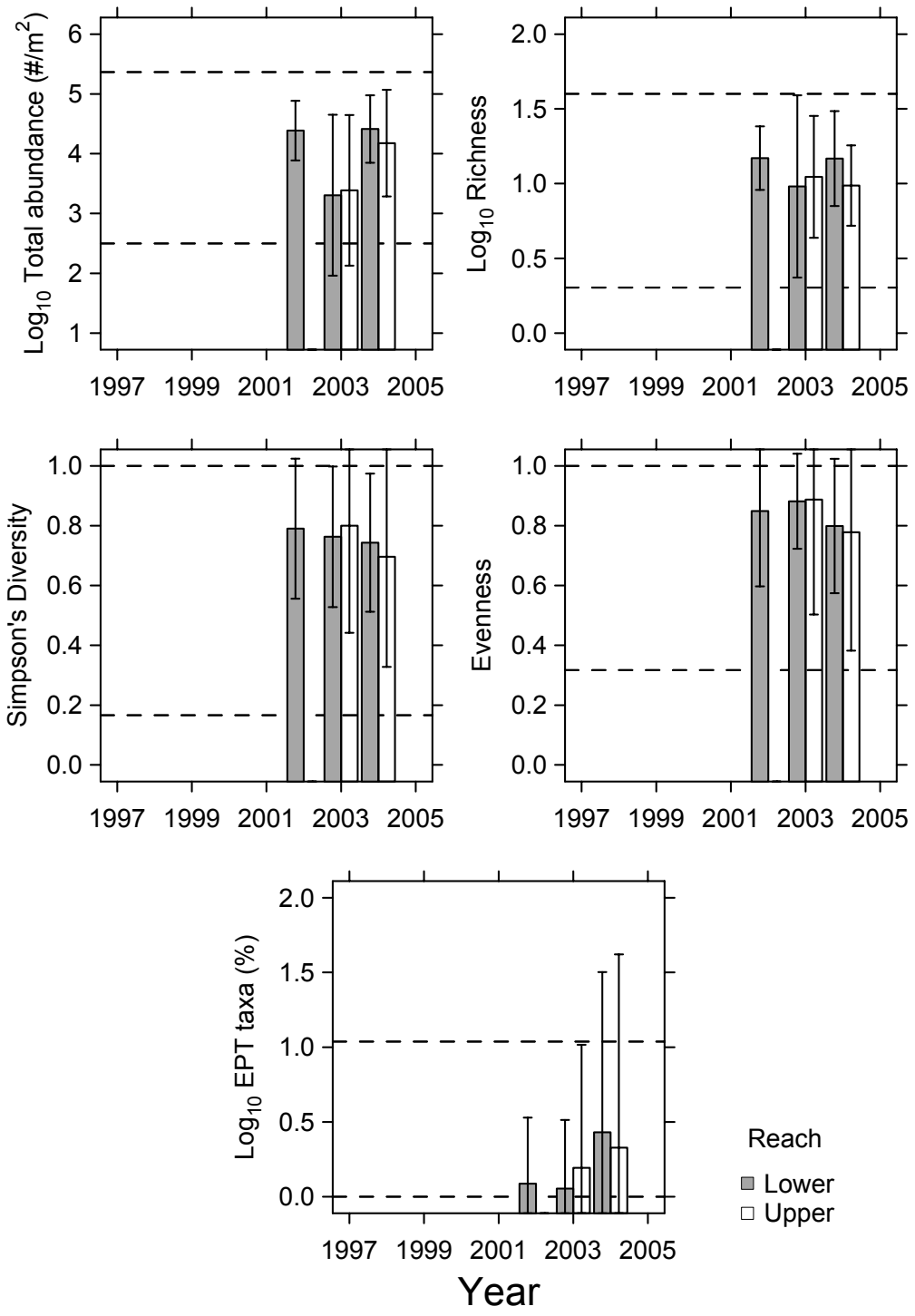


Table 5.3-20 Results of analysis of variance between lower (exposed) and upper (reference) reaches of Jackpine Creek.

Source	SS	df	F	P
Log_{10} Abundance				
Reach-Year	17.83	4	22.55	<0.001
Time (2003-2004)	*13.49*	*1*	*68.28*	*<0.001*
Reach	*0.091*	*1*	*0.462*	*0.499*
Time × Reach	*0.382*	*1*	*1.933*	*0.169*
Reach (2004)	*0.423*	*1*	*2.142*	*0.148*
Error	13.834	70		
Log_{10} Richness				
Reach-Year	0.524	4	4.169	0.004
Time (2003-2004)	*0.062*	*1*	*1.967*	*0.165*
Reach	*0.052*	*1*	*1.645*	*0.204*
Time × Reach	*0.223*	*1*	*7.111*	*0.010*
Reach (2004)	*0.245*	*1*	*7.798*	*0.007*
Error	2.199	70		
Simpson's Diversity				
Reach	0.103	4	1.445	0.228
Time (2003-2004)	*0.057*	*1*	*3.209*	*0.078*
Reach	*<0.001*	*1*	*0.022*	*0.883*
Time × Reach	*0.026*	*1*	*1.483*	*0.227*
Reach (2004)	*0.017*	*1*	*0.932*	*0.338*
Error	1.243	70		
Evenness				
Reach	0.143	4	1.947	0.112
Time (2003-2004)	*0.138*	*1*	*7.489*	*0.008*
Reach	*0.001*	*1*	*0.049*	*0.825*
Time × Reach	*0.003*	*1*	*0.148*	*0.702*
Reach (2004)	*0.003*	*1*	*0.184*	*0.669*
Error	1.289	70		
Log_{10} EPT %				
Reach	1.528	4	2.355	0.062
Time (2003-2004)	*0.981*	*1*	*6.046*	*0.016*
Reach	*0.005*	*1*	*0.028*	*0.868*
Time × Reach	*0.220*	*1*	*1.355*	*0.248*
Reach (2004)	*0.081*	*1*	*0.497*	*0.483*
Error	11.36	70		

Table 5.3-21 Fish inventory results from electrofishing on the Muskeg River, August 2004.

Total effort = 13,807 s			
Species	**Total**	**Species Composition (% Total)**	**CPUE (#/100 s)**
Longnose sucker	6	16.2	0.04
Northern pike	14	37.8	0.10
Pearl dace	7	18.9	0.05
Trout-perch	1	2.7	0.01
White sucker	9	24.3	0.07
Total	**37**	**100**	**0.27**

Figure 5.3-14 Comparison of species relative abundance, RAMP Muskeg River fish inventories 1997, 2001, 2002 and 2004.

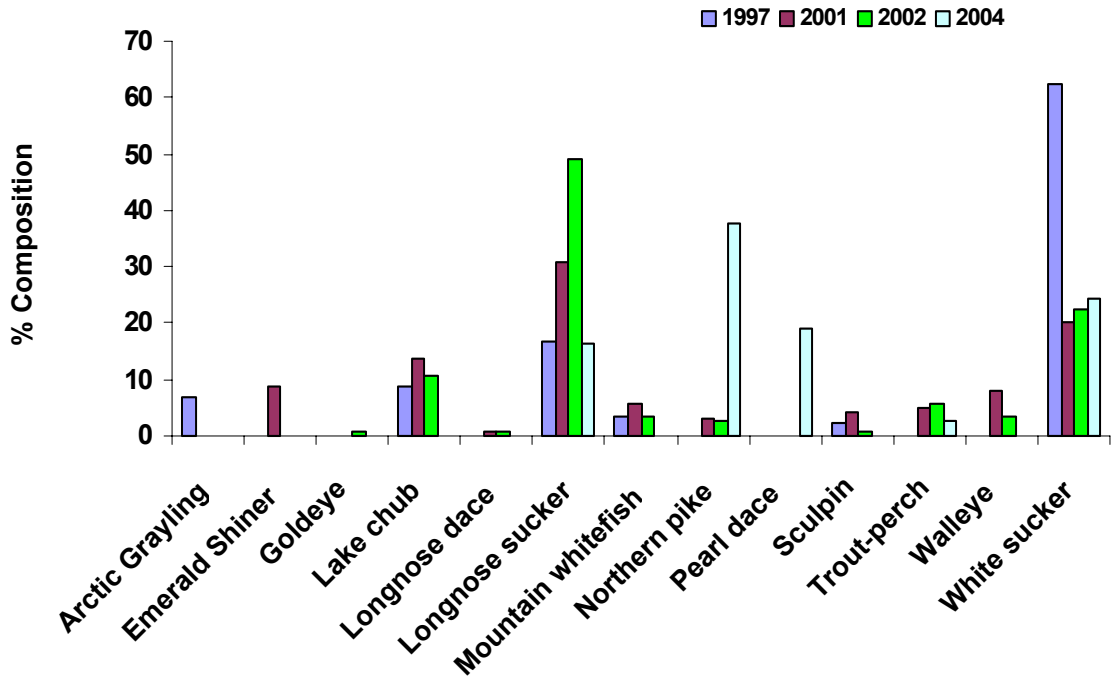


Figure 5.3-15 Electrofishing catch-per-unit-effort for RAMP Muskeg River fish, summer inventory, 1997, 2001, 2002 and 2004.

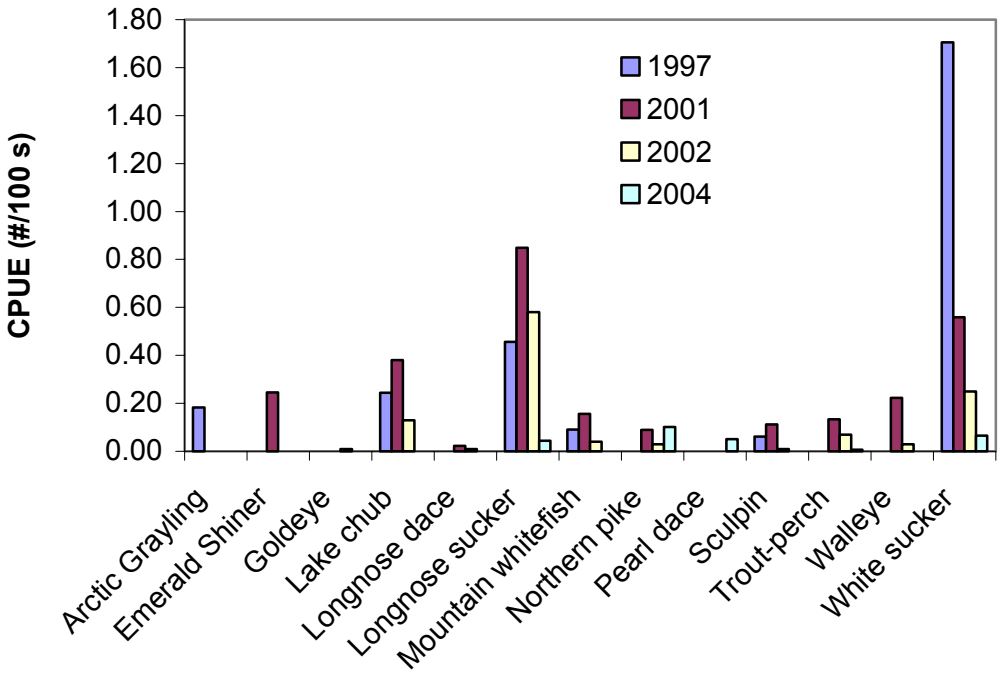


Figure 5.3-16 Mean condition factor (±SE) for key fish indicator species in the Muskeg River, 1997, 2001, 2002 and 2004.

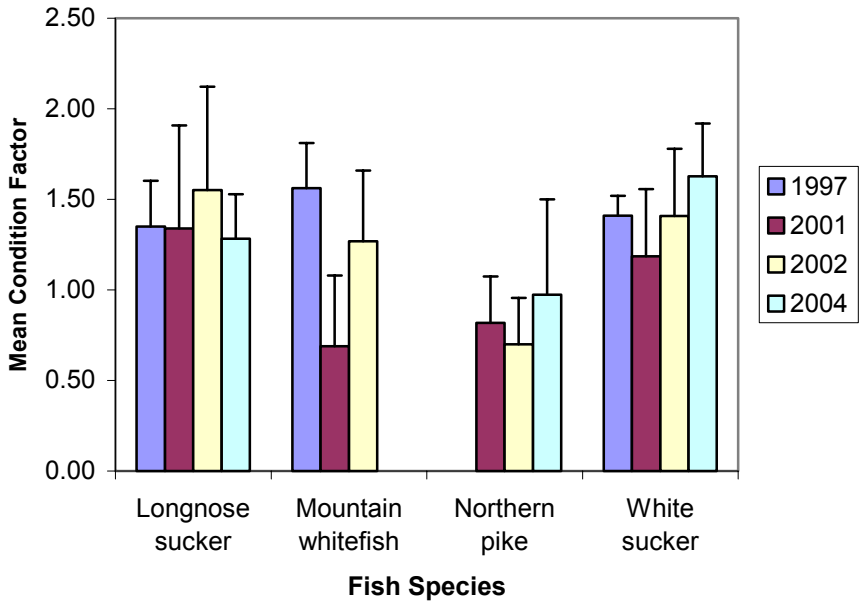


Table 5.3-22 Fish inventory results from electrofishing in Jackpine Creek, August 2004.

Electrofishing (Total effort 7,303 s)			
Species	**Total**	**Species Composition (% Total)**	**CPUE (#/100 s)**
Brook stickleback	2	0.78	0.03
Longnose dace	2	0.78	0.03
Longnose sucker	2	0.78	0.03
Pearl dace	73	28.52	1.00
Sculpin sp.	176	68.75	2.41
White sucker	1	0.39	0.01
Total	**256**		**3.51**

Note: Spoonhead and slimy sculpin numbers combined due to difficulties associated with field identification.

Table 5.3-23 Fish inventory results from minnow trapping in Jackpine Creek, August 2004.

Minnow Trapping (Total Effort 48 trap hrs)		
Species	**Total Number Caught**	**CPUE (# / trap hr)**
Lake chub	5	0.10
Northern red belly dace	6	0.13
Northern pike	1	0.02
Pearl dace	39	0.81
Sculpin	1	0.02
Total	**52**	**1.08**

Note: Spoonhead and slimy sculpin numbers combined due to difficulties associated with field identification.

Figure 5.3-17 Comparison of species relative abundance, Jackpine Creek inventories 2001, 2002 and 2004.

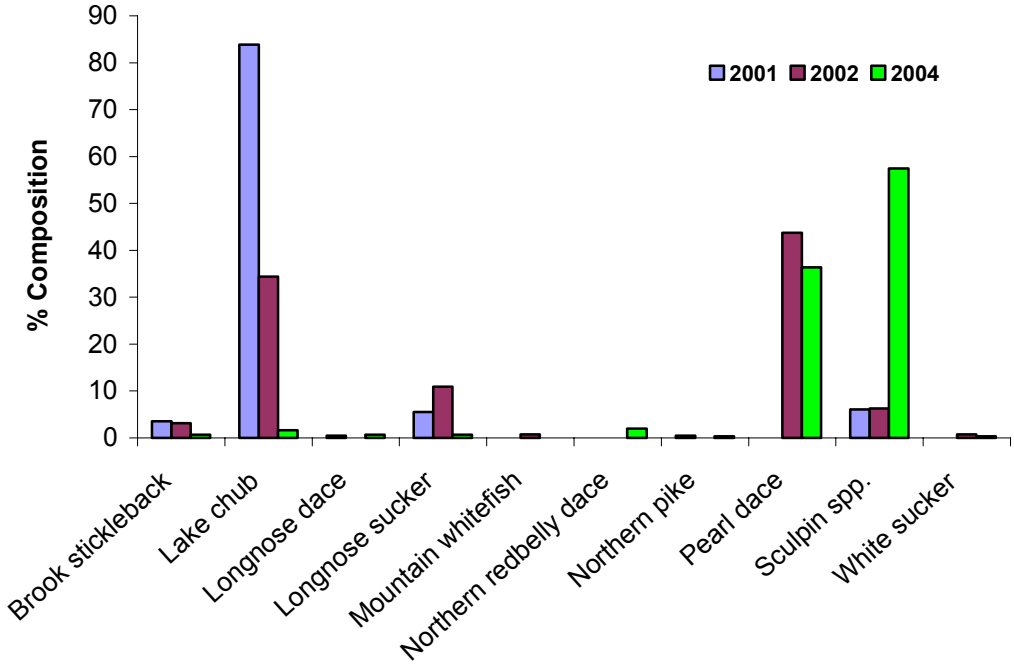


Figure 5.3-18 Electrofishing catch-per-unit-effort for Jackpine Creek fish, summer inventory, 2001, 2002 and 2004.

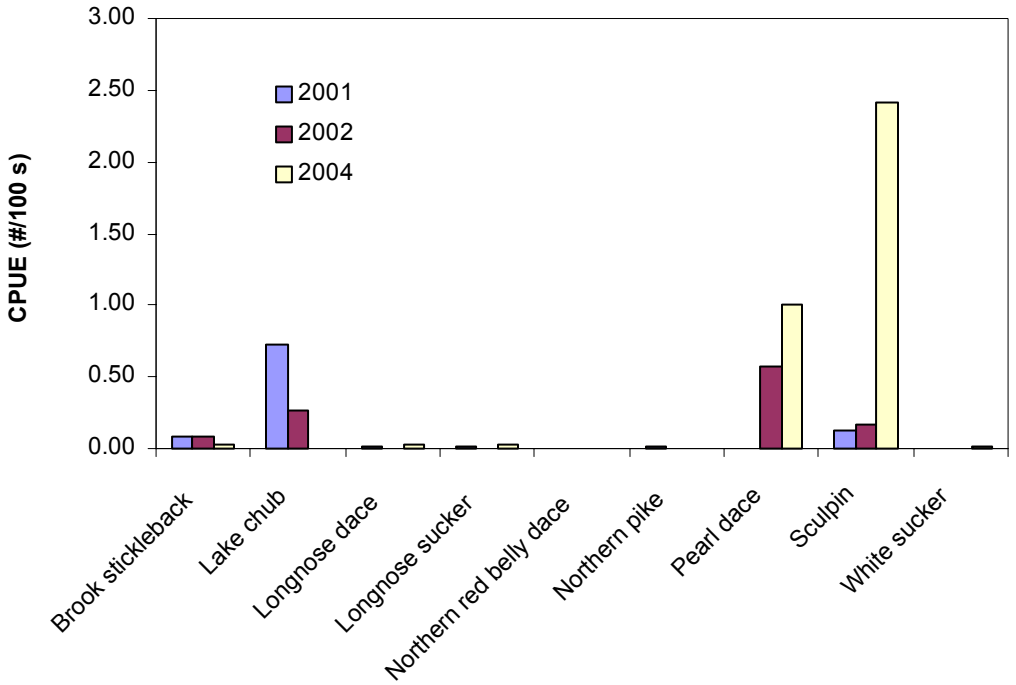


Table 5.3-24 Mercury concentrations in muscle tissue taken from Muskeg River northern pike, August 2004.

Fish ID	Fork Length (mm)	Total Weight (g)	Sex	Maturity	Age	Mercury Concentration (mg/kg)
NRPK319MUR04	548	1,000	Male	Mature	2	0.20
NRPK320MUR04	510	1,000	Male	Mature	2	0.24
NRPK328MUR04	511	975	Male	Mature	4	0.19
NRPK329MUR04	551	1,350	Female	Mature	4	0.25
NRPK330MUR04	606	1,575	Female	Mature	3	0.20
Mean	545	1,180			3	0.22
SD	39	270			1.0	0.03

Table 5.3-25 Screening of average metals and tainting compounds in composite northern pike muscle tissue samples from the Muskeg River (August 2004) against risk-based fish consumption criteria for the protection of human health.

Analyte	Concentration (mg/kg)		Health Canada Criteria		National USEPA	Region III USEPA	
	Male n=3	Female n=2	General Consumer	Subsistence Fishers	Recreational Fishers	Subsistence Fishers	Risk-based Criteria
Total Metals							
Aluminum (Al)	<4	<4	nc	nc	nc	nc	1400
Antimony (Sb)	<0.04	<0.04	nc	nc	nc	nc	0.54
Arsenic (As)	***<0.2***	***<0.2***	nc	nc	0.026	0.00327	0.002
Barium (Ba)	<0.08	0.23	nc	nc	nc	nc	95
Beryllium (Be)	<0.2	<0.2	nc	nc	nc	nc	2.7
Boron (B)	<2	<2	nc	nc	nc	nc	270
Cadmium (Cd)	<0.08	<0.08	nc	nc	4	0.491	1.4
Calcium (Ca)	90	90	nc	nc	nc	nc	nc
Chromium (Cr)	<0.2	<0.2	nc	nc	nc	nc	4.1
Cobalt (Co)	<0.08	<0.08	nc	nc	nc	nc	27
Copper (Cu)	0.28	0.20	nc	nc	nc	nc	54
Iron (Fe)	5	3	nc	nc	nc	nc	410
Lead (Pb)	<0.04	<0.04	nc	nc	nc	nc	nc
Lithium (Li)	<0.5	<0.5	nc	nc	nc	nc	27
Magnesium (Mg)	258	253	nc	nc	nc	nc	nc
Manganese (Mn)	0.18	0.16	nc	nc	nc	nc	190
Mercury (Hg)	***0.21***	***0.23***	0.5	0.2	0.4	0.049	0.14
Molybdenum (Mo)	<0.04	<0.04	nc	nc	nc	nc	6.8
Nickel (Ni)	0.09	<0.08	nc	nc	nc	nc	27
Phosphorus (P)	2210	2090	nc	nc	nc	nc	nc
Potassium (K)	3990	4000	nc	nc	nc	nc	nc
Selenium (Se)	<0.2	<0.2	nc	nc	20	2.457	6.8
Silver (Ag)	<0.08	<0.08	nc	nc	nc	nc	6.8
Sodium (Na)	266	248	nc	nc	nc	nc	nc
Strontium (Sr)	0.07	0.12	nc	nc	nc	nc	810
Thallium (Tl)	***<0.04***	***<0.04***	nc	nc	nc	nc	0.09
Tin (Sn)	<0.08	<0.08	nc	nc	nc	nc	810
Titanium (Ti)	5.26	2.60	nc	nc	nc	nc	5400
Vanadium (V)	<0.08	<0.08	nc	nc	nc	nc	0.41
Zinc (Zn)	2.9	2.6	nc	nc	nc	nc	410
Tainting Compounds (PAHs)							
Thiophene	<0.03	<0.03	nc	nc	nc	nc	nc
Toluene	<0.02	<0.02	nc	nc	nc	nc	270
Mesitylene	<0.01	<0.01	nc	nc	nc	nc	nc
M+P-Xylene	<0.01	<0.01	nc	nc	nc	nc	270

value = exceeds USEPA screening value for subsistence fishers

value = exceeds Region II risk-based criteria

value = exceeds USEPA screening criteria for recreational fishers

nc = no criterion

Table 5.3-26 Screening of mercury concentrations in northern pike from Muskeg River (August, 2004) against criteria for fish consumption for the protection of human health.

Mercury Screening Criteria		**Hg (mg/kg)**
Health Canada Criteria	*General Consumer*	0.50
	Subsistence Fishers	0.20
Region III USEPA Risk-Based Criterion[1]		0.14
National USEPA Screening Values[2]	*Recreational Fishers*	0.40
	Subsistence Fishers	0.049

Mercury Concentrations in Muskeg River Northern Pike Muscle Tissue

Fish ID	Sex	Mercury Concentration (mg/kg)
NRPK319MUR04	Male	0.20
NRPK320MUR04	Male	**0.24**
NRPK328MUR04	Male	0.19
NRPK329MUR04	Female	**0.25**
NRPK330MUR04	Female	0.20

All values exceed the USEPA screening values for subsistence fishers and the Region II USEPA risk-based criterion.

value = exceeds Heath Canada screening value for subsistence fishers.

[1]Region III USEPA risk- based criterion 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 methylmercury.

[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 70 kg individual consuming 142.4 g of fish per day over a 70-year period; USEPA 2000).Criterion is for methylmercury.

Table 5.3-27 Comparison of metals concentrations in northern pike from the Muskeg River for 2001, 2002 and 2004.

	Metal Concentration (mg/kg)				
	2001		**2002**	**2004**	
Analyte	**Female**	**Male**	**Male**	**Female**	**Male**
Barium	0.09	<0.08	0.10	0.23	<0.08
Calcium	550	310	120	90	90
Copper	0.29	1.18	0.24	0.20	0.28
Iron	4	6	4	3	5
Magnesium	313	324	334	253	258
Manganese	0.42	0.30	0.17	0.16	0.18
Mercury	0.14	0.12	0.19	0.23	0.21
Phosphorus	2,240	2,120	2,680	2,090	2,210
Potassium	3,770	4,020	4,370	4,000	3,990
Sodium	266	297	314	248	266
Strontium	0.37	.0.2	0.06	0.12	0.07
zinc	6.4	7.2	5.6	2.6	2.9

Table 5.3-28 Screening of mercury concentrations in northern pike from Muskeg River (August, 2004) against criteria for protection of fish and wildlife.

Mercury Screening Criteria		Hg (mg/kg)
CCME criteria for the protection of wildlife[1]		0.033
Effects thresholds for fish[2]	No effects - lethal	1.91
	No effects sublethal	2.28
	Effects lethal	6.2
	No effects sub-lethal	8.6

Mercury Concentrations in Muskeg River Northern Pike Muscle Tissue		
Fish ID	**Sex**	**Mercury Concentration (mg/kg)**
NRPK319MUR04	Male	0.20
NRPK320MUR04	Male	0.24
NRPK328MUR04	Male	0.19
NRPK329MUR04	Female	0.25
NRPK330MUR04	Female	0.20

value = exceeds CCME criteria for piscivorous wildlife; potential risk to animals consuming fish.

value **=** exceeds lethal effects thresholds; potential risk to fish.

Thresholds and criteria are for methylated forms of mercury.

[1]Canadian Councils of Ministers of the Environment (CCME) criteria for the protection of wildlife that consume fish (CCME 2001b).

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

Table 5.3-29 Screening of metals and tainting compounds in northern pike composite samples collected from the Muskeg River (Muskeg, 2004) against criteria for the protection of fish.

			Thresholds for the Protection of Fish[1]			
	Muskeg River Northern Pike		Lowest no-effects thresholds		Lowest effects thresholds	
Analyte	**Composite 1 Male n=3**	**Composite 2 Female n=2**	**Lethal (mg/kg)**	**Sublethal (mg/kg)**	**Lethal (mg/kg)**	**Sublethal (mg/kg)**
Total Metals						
Aluminum (Al)	**<4**	**<4**	1.0	nd	20	nd
Antimony (Sb)	<0.04	<0.04	5	nd	9	nd
Arsenic (As)	<0.2	<0.2	2.6	0.9	11.2	3.1
Barium (Ba)	<0.08	0.23	nd	nd	nd	nd
Beryllium (Be)	<0.2	<0.2	nd	nd	nd	nd
Boron (B)	<2	<2	nd	nd	nd	nd
Cadmium (Cd)	**<0.08**	**<0.08**	0.02	0.09	0.14	0.12
Calcium	90	90	nd	nd	nd	nd
Chromium (Cr)	<0.2	<0.2	nd	nd	nd	nd
Cobalt (Co)	<0.08	<0.08	nd	nd	nd	nd

Table 5.3-29 (cont'd.)

Analyte	Muskeg River Northern Pike		Thresholds for the Protection of Fish[1]			
			Lowest no-effects thresholds		Lowest effects thresholds	
	Composite 1 Male n=3	Composite 2 Female n=2	Lethal (mg/kg)	Sublethal (mg/kg)	Lethal (mg/kg)	Sublethal (mg/kg)
Copper (Cu)	0.28	0.20	0.5	3.4	0.5	Nd
Iron (Fe)	5	3	nd	nd	nd	nd
Lead (Pb)	<0.04	<0.04	4.0	nd	nd	nd
Lithium (Li)	<0.5	<0.5	nd	nd	nd	nd
Manganese (Mn)	258	253	nd	nd	nd	nd
Molybdenum (Mo)	0.18	0.16	nd	nd	nd	nd
Nickel (Ni)	0.21	0.23	0.82	nd	118.1	nd
Phosphorus (P)	2210	2090	nd	nd	nd	nd
Potassium (K)	3990	4000	nd	nd	nd	nd
Selenium (Se)	<0.2	<0.2	0.28	0.08	0.92	0.32
Silver (Ag)	<0.08	<0.08	0.003	0.003	nd	nd
Sodium (Na)	266	248	nd	nd	nd	nd
Strontium (Sr)	0.07	0.12	nd	nd	nd	nd
Thallium (Tl)	0.04	0.04	nd	nd	nd	nd
Tin (Sn)	<0.08	<0.08	nc	nc	nc	nc
Titanium (Ti)	5.26	2.60	nc	nc	nc	nc
Vanadium (V)	<0.08	<0.08	5.33	0.02	nd	0.41
Zinc (Zn)	2.9	2.6	60	60	nc	nc
Tainting Compounds						
Thiophene	<0.03	<0.03	nc	nc	nc	nc
Toluene	<0.02	<0.02	nc	nc	nc	nc
Mesitylene	<0.01	<0.01	nc	nc	nc	nc
M+P-Xylenes	<0.01	<0.01	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

nd = no data available

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

Table 5.3-30 Assessment of potential effects related to fish tissue measurement endpoint, Muskeg River 2004.

Parameter	Potential for Effects
Protection of Human Health	High - Subsistence
Protection of Fish Health	Negligible – Low[1]
Protection of Wildlife	Moderate - High
Tainting	Negligible - Low

[1] Metals with detection limits above criteria were excluded from this rating.

5.4 STEEPBANK RIVER SYSTEM

Summary of Results

Climate and Hydrology

	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				Although a small portion of the basin is disturbed by oil sands activities, there were no known water withdrawals, releases, or development-related catchment changes. Oil sands activities in the Steepbank basin had a negligible effect on hydrology.
Mean winter discharge	√				
Annual maximum daily discharge	√				
Minimum open-water season discharge	√				

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=1)	2004 Reference Stations (n=3)	
Physical variables (3 endpoints)	0	0	Concentrations of total and dissolved iron exceeded the CCME guideline for total iron in fall 2004 at all stations. At STR-1, no other water quality parameter concentrations exceeded relevant guidelines. 2004 results for selected water quality measurement endpoints were also within the range of regional baseline conditions. Based on these findings, oil sands developments within the Steepbank River watershed do not appear to have impacted water quality at the mouth of the Steepbank River.
Nutrients (5 endpoints)	8	1	
Ions (5 endpoints)	0	0	
Organic compounds (1 endpoint)	0	0	
Selected metals (5 endpoints)	7	0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 1 station X 7 analytes)	2004 Reference Stations (n= 3 stations X 7 analytes)
Above 95th	0	0
Between 75th and 95th	1	4
Between median and 75th	1	3
Between 25th and median	3	11
Between 5th and 25th	1	2
Less than 5th	1	1

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=1)	
Physical variables (4 endpoints)	Sediment quality was not monitored by RAMP in the Steepbank River watershed in 2004.	0	2004 sediment quality in the North Steepbank River was similar to that observed in 2002 and 2003, and similar to sediment quality in comparable tributaries sampled by RAMP. Sediments were characterized by coarse particle sizes, low organic carbon, and low concentrations of metals, hydrocarbons, and PAHs. The lower Steepbank River near the mouth is naturally heavily embedded and channelized, making collection of representative sediment samples difficult; sediment quality sampling was not conducted in this area in 2004.
Total Hydrocarbons (8 endpoints)		0	
PAHs (7 endpoints)		0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 1 station X 3 analytes)
Above 95th	Sediment quality was not monitored by RAMP in the Steepbank River watershed in 2004.	0
Between 75th and 95th		0
Between median and 75th		0
Between 25th and median		2
Between 5th and 25th		1
Less than 5th		0

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline						
	2004 Exposed Stations (n= 1)			2004 Reference Stations (n= 1)			
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD	
Abundance		1			1		In general, the 2004 data suggest subtle shifts in benthic community composition in the lower reach of the Steepbank River adjacent to the oil-sands development area. However, indices of community composition were generally within the expected ranges for regional-reference conditions.
Richness		1			1		
Diversity		1			1		
Evenness		1			1		
% EPT		1			1		

Fish Populations

Fish Inventory	No fish inventory studies were conducted in the Steepbank River in 2004.
Sentinel Studies	Sentinel fish species monitoring using slimy sculpin was conducted on the lower Steepbank River. There was evidence of reduced recruitment and very low abundance of young-of-the-year (YOY) sculpin. Negligible to low impact on condition factor was identified.

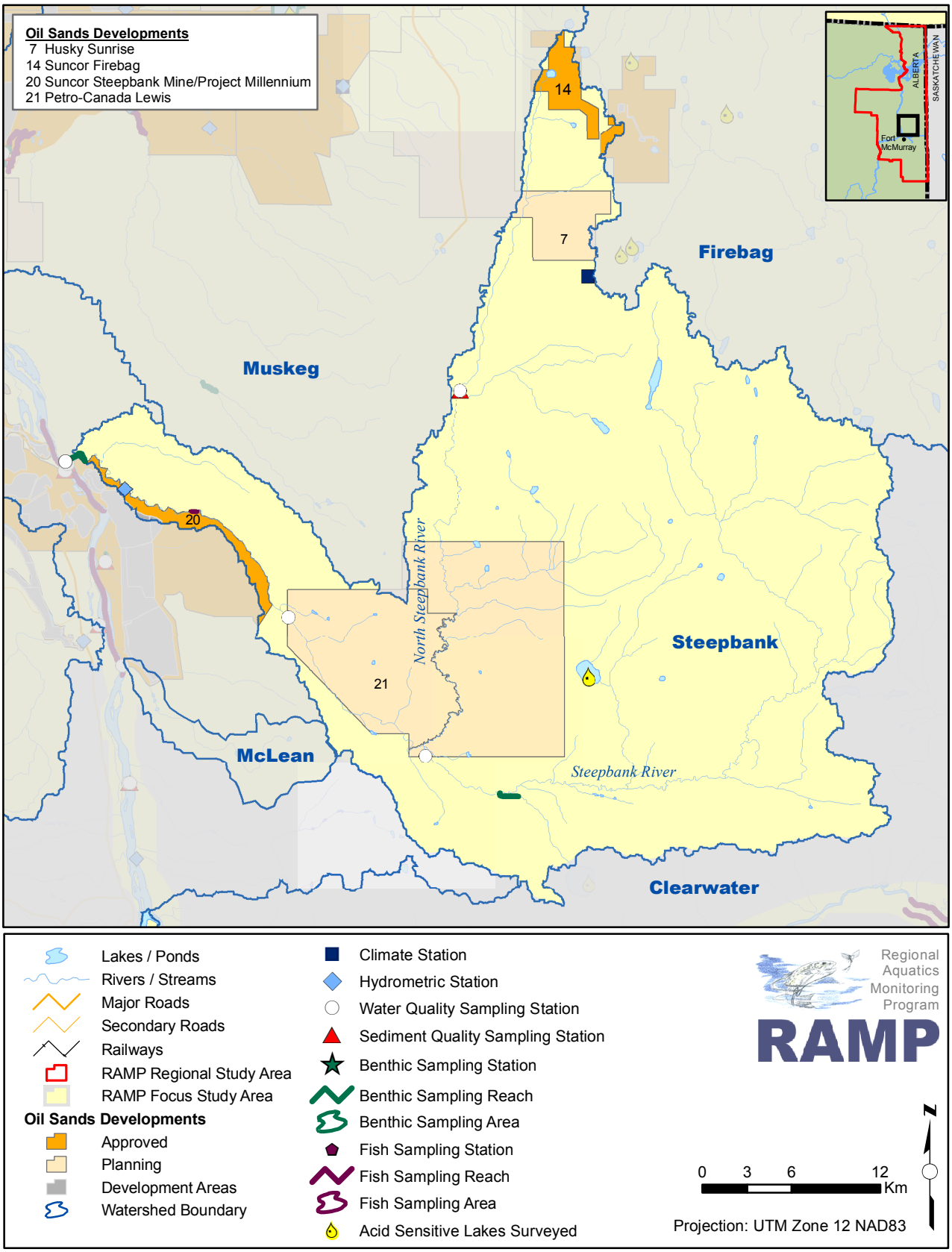
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in the Steepbank River in 2004.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	
Fish and Wildlife: Mercury	
Fish and Wildlife: Other Chemicals	

[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 5.4-1 Steepbank River watershed.



RAMP1110\GIS\2004_STEEPBANK.MXD

5.4.1 Hydrologic Conditions

The Steepbank River basin was somewhat drier in 2004 than historical norms, based on runoff volume at WSC Station 07DA006, which, at 102 mm, was 10% below the historical mean runoff of 114 mm. Discharges were near historical normal values until early June, when rainfall caused a substantial increase in discharge (Figure 5.4-2). By early July, river flows were below normal, and for the remainder of the summer, flows were close to record low values. Discharges rose again in September, but still ended the open-water season below normal. The June maximum daily discharge was 48.9 m^3/s and almost 40% higher than the mean annual flood. The minimum open-water discharge of 0.79 m^3/s occurred on September 2 and was substantially lower than the historical average minimum discharge of 1.90 m^3/s.

Due to the close proximity with the Suncor Steepbank Mine/Project Millennium, the lower Steepbank River was designated as exposed. Parameters evaluated for the application of the water balance model for the purposes of creating a naturalized hydrograph to examine possible changes in hydrology are provided in Table 5.4-1. Although a small portion of the mining development area is within the Steepbank basin, there were no known water withdrawals, releases, or development-related catchment changes in 2004. Consequently, the naturalized hydrograph was not considered significantly different from the observed hydrograph, and the change in measurement endpoints was estimated to be zero (Table 5.4-2). Oil sands activities in the Steepbank River watershed are therefore assessed to have had a negligible influence on hydrologic conditions in 2004.

5.4.2 Water Quality

In 2004, water quality samples were collected near the mouth of the Steepbank River (STR-1, designated as exposed) and from three reference stations: upstream of the Steepbank Mine/Project Millennium operations (STR-2), upstream of the planned Petro-Canada Lewis lease area (STR-3, new station in 2004) and on the upper North Steepbank River (NSR-1). STR-1 was designated as exposed to oil sands development for the entire period of record for RAMP water quality monitoring (i.e., 1997-2004). All stations were sampled in fall 2004; STR-3 and NSR-1 were sampled in additional seasons to determine seasonal baseline conditions.

Fall 2004 results for selected water quality measurement endpoints are shown in Table 5.4-3 (STR-1), Table 5.4-4 (STR-2, STR-3), and Table 5.4-5 (NSR-1), while concentrations of selected water quality variables observed at the four stations over the period of RAMP sampling are shown relative to regional baseline levels in Figure 5.4-3. Parameters exceeding water quality guidelines in the four sampling seasons are shown in Table 5.4-6. Figure 5.4-4 displays the ionic characteristics at the four stations over the period of RAMP sampling.

Concentrations of total and dissolved iron exceeded the CCME guideline for total iron in fall 2004 at all stations. At STR-1, no other water quality parameter concentrations exceeded relevant guidelines. Concentrations of sodium, chloride, and sulphate ions at STR-1 in 2004 were within the range previously observed and have been relatively constant over the period of RAMP sampling (Figure 5.4-4). While the concentration of total dissolved solids (TDS) was higher at STR-1 than at other Steepbank River watershed

stations in fall 2004, the level observed was within the range found under regional baseline conditions. 2004 results for other selected water quality measurement endpoints were also within the range of regional baseline conditions (Figure 5.4-3). Based on these findings, oil sands developments within the Steepbank River watershed do not appear to have influenced water quality at the Steepbank River mouth in any significant way.

Fall 2004 water quality at STR-2, STR-3, and NSR-1 was generally similar to that observed at STR-2 and NSR-1 in previous years of fall RAMP sampling. Because only two years of previous data are available for STR-2 and NSR-1, the full range of baseline conditions has not been established at these stations; the concentrations of many selected water quality parameters in fall 2004 were thus outside the range observed in previous years of data (Table 5.4-4, Table 5.4-5).

Concentrations of total phenols, total and dissolved iron, and total phosphorus exceeded relevant guidelines at STR-3 and NSR-1 in summer 2004; other guideline exceedances occurred in spring (STR-3, NSR-1) and winter (STR-3). Ionic character at all Steepbank River watershed stations is dominated by a calcium-bicarbonate system (Figure 5.4-4). Station NSR-1 is more highly dominated by calcium than the other stations (Figure 5.4-4), which appear to have very similar ionic characteristics that have changed little over the period of RAMP sampling (with the exception of STR-1 in 1998).

5.4.3 Sediment Quality

Sediment quality was measured in the Steepbank River in 2004 from the North Steepbank River (NSR-1). Other stations in the Steepbank River watershed have been sampled in past RAMP programs; the lower Steepbank River near its mouth is naturally heavily embedded and channelized, making collection of representative sediment samples difficult.

Sediment quality in the North Steepbank River was similar in 2004 to previous years of sampling (i.e., 2002 and 2003), and also to most smaller headwater tributaries sampled by RAMP. Sediments were characterized by coarse particle sizes (i.e., 98% sand), low organic carbon, and low concentrations of metals, hydrocarbons and PAHs (Table 5.4-7). No sediment quality measurement endpoints exceeded CCME ISQG guidelines at station NSR-1 in fall 2004. Concentrations of PAHs and hydrocarbons at NSR-1 in 2004 were generally below concentrations observed at this station in 2002 and 2003 (Figure 5.4-5).

2004 sediment quality data collected on the North Steepbank River represents the third year of baseline data for this watercourse.

5.4.4 Benthic Invertebrate Communities

In 2004, benthic community samples were collected from a lower exposed reach near the mouth of the Steepbank River (STR-E-1-15) and from an upper reference reach (STR-E-16-30) well upstream of the North Steepbank confluence. The lower and upper reaches of the Steepbank River are typical of erosional habitats, with shallow depths and fast currents (Table 5.4-8). There were little to no macrophytes and benthic algae present at the lower reach, where some macrophytes and a large biomass of benthic algae were measured at the upper reach in September 2004. Dissolved oxygen was similar and high at both reaches. Conductivity in the lower reach was nearly double the conductivity of

the upper reach; pH was very high in the upper reach relative to the lower reach; water temperature was similar in both reaches. Sediment composition in each reach also was similar, although the upper reach was dominated by slightly larger substrate (cobble) than the lower reach (large gravel).

The benthic invertebrate community of the lower reach of the Steepbank River was heavily dominated by chironomids, followed by Ephemeroptera, the Empididae, and Hydracarina. Chironomids were also dominant in the upper reach of the Steepbank River, followed by the EPT taxa (Ephemeroptera, Trichoptera, and Plecoptera) and Coleoptera (Table 5.4-9).

Benthic invertebrates in the lower reach of the Steepbank River have been sampled regularly since 1998 and with the exception of two sample locations from 1998 and one sample location from 2002, community composition of all samples fell within 95% confidence limits describing regional reference community composition for erosional reaches (Figure 5.4-6). There has been no clear trend in community composition data for the lower reach of the Steepbank River.

Total abundance and richness in the Steepbank River has generally been at the lower extreme of the 95% confidence limits for regional reference data since 2000; data collected in 2004 increased to values more typical of the regional reference reaches. By comparison, the upper reach of the Steepbank River, sampled for the first time in 2004 and considered to be a reference reach, had community index values that were well within the expected range for regional reference reaches (Figure 5.4-7).

Analysis of variance of benthic community indices between the lower and upper reaches of the Steepbank River was limited to data collected in 2004 (the first year the upper Steepbank was sampled). Abundance, richness, and EPT taxa were all significantly lower at the lower reach than at the upper reach (Table 5.4-10), likely reflecting the lower benthic algal biomass there (Table 5.4-8). There were no significant differences in evenness or diversity between the upper and lower reaches in 2004.

In general, the 2004 data suggest subtle shifts in benthic community composition in the lower reach of the Steepbank River adjacent to the oil-sands development area. However, indices of community composition were generally within the expected ranges for regional reference conditions.

5.4.5 Fish Populations

Fish population monitoring in the Steepbank River focused on a sentinel fish species survey using slimy sculpin. The exposed monitoring site was located on the lower Steepbank River adjacent to the Steepbank Mine/Project Millennium operations. Reference populations of slimy sculpin were also sampled from an upper reach of the Steepbank River, as well as reference sites on the Horse River and Dunkirk River. In addition, slimy sculpin were sampled at an exposure site on the lower Muskeg River, downstream of the Aurora North and Albian Sands oil sands operations. Reference populations from the Steepbank, Horse and Dunkirk rivers were used for comparison against exposed sculpin populations from both the lower Steepbank and Muskeg rivers. Consequently, results related to the lower Muskeg River are presented here rather than in Section 5.3.6.

5.4.5.1 Sentinel Species Monitoring

Field Sampling Results

A survey of available fish habitat at each site was conducted at each sampling site in August 2004. Major habitat characteristics for each site are summarized in Table 5.4-11. Detailed results of habitat assessments are provided in Appendix H. Fish habitat at the five sentinel sampling sites was generally comparable (e.g., gradient, substrate characteristics, average water velocity); the only exception was the Horse River site, where water velocity (and discharge) was much lower in fall 2004 relative to other sites. There were no differences observed in water quality variables (measured in August) between exposure and reference sites (Appendix H).

The number of sculpin collected at each sampling station ranged from 96 to 111 in the summer sampling and 94 to 108 in the fall (Table 5.4-12). Typically, one full day of electrofishing was required to collect 100 sculpin (the minimum recommended number for sentinel species studies) during summer and fall sampling efforts. A second day of effort was required at several stations, particularly in October.

Sculpin density varied from 0.028 fish/m^2 at the Horse River reference site to 0.072 fish/m^2 at the Dunkirk River reference site. Note that density may be underestimated slightly due to the preference of sculpin for areas with high flow and large substrate size, which are difficult to sample accurately.

Population Distribution

A "pairwise" statistical approach was used to compare sculpin length-frequency distributions between all combinations of sampling sites (reference and exposure). Length-frequency distributions for Steepbank River reference and exposure populations were significantly different in both August ($p<0.001$) and October ($p<0.001$) (Table 5.4-13). In August, the only pair-wise comparison that was not significantly different was the Dunkirk River reference site versus the Steepbank River exposure site (Figure 5.4-8), meaning that the sculpin populations were similar in their range (and abundance) of fish of various body lengths.

The range of lengths and number of individuals for each length class differed among sites sampled in 2004. This was particularly evident in both August and October at the lower Steepbank River site, where young-of-the-year (YOY) individuals were either present in very low numbers or were not captured (Figure 5.4-9 and Figure 5.4-10).

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, within-site length-frequency distributions between August and October were significantly different ($p<0.05$) (i.e., sculpin in all five populations grew between sampling events). Mean sculpin size (both length and weight) increased between the August and October sampling events at all five sites (Figure 5.4-11 and Figure 5.4-12).

In August, mean length was greatest for sculpin from the Steepbank River and Muskeg River exposure sites and the Dunkirk reference site (Table 5.4-14). This may be partially

reflective of the comparatively low numbers of YOY fish caught at these sites (especially at the Steepbank River exposure site).

Figure 5.4-13 and Figure 5.4-14 illustrate the amount of growth in length for YOY fish between August and October sampling trips. Shifts in older age classes can also be identified, although they are generally less pronounced. Gray *et al*. (2002) stated that age validation would be required as sculpin of different age classes may overlap in size (i.e., length). With increasing age, growth in length may be influenced by shifts in energy allocation to reproductive development (in contrast to YOY fish, which devote their energy to somatic growth).

The growth rate for YOY fish was estimated for the period from August to October (standardized at 65 days). Of all populations sampled, the Horse River population had the lowest YOY growth rate (0.13 mm/day) (Table 5.4-15). YOY in the other three populations (Dunkirk, Muskeg and upper Steepbank) exhibited slightly higher growth rates (0.19 to 0.23 mm/day) (Table 5.4-15). Estimation of young sculpin growth at the Steepbank River exposure site was not possible due to the low numbers of YOY captured.

Reproductive performance and short-term survival for a population can be estimated by examining the proportion of a population composed of YOY individuals. The percentage of YOY in each population varied widely, from approximately 1% of the population at the Steepbank River exposure site to almost 75% of the population at the Horse River reference site (Table 5.4-16). Reasons for the low percentage of YOY collected at the Steepbank River exposure site are unknown; sampling methods and amount of effort were comparable to other 2004 sentinel sampling sites.

Energy Storage

Condition factor is a common measurement endpoint that is calculated for each fish as a ratio of the fish's length and weight (i.e., how fat a fish is). Consequently, condition factor provides a measure of energy storage (in lethal sentinel studies liver size is also used to estimate energy storage).

Overall, ANCOVA analysis (comparing intercepts of regression lines between length and weight) found a significant interaction ($p<0.05$), indicating that sample populations in the Steepbank River appeared to be growing at different rates (i.e., unequal slopes) in reference and exposed sites (Figure 5.4-15). Equality of slopes is an assumption of the ANCOVA model and, if this assumption is not satisfied, further statistical consideration is not valid (i.e., fish must be growing at the same rate before differences in length-weight relationship can be examined).

It was recognized that the small number of YOY sculpin captured at some sites (lower Steepbank River exposed site, in particular) may exert a large influence on the ability to detect differences in condition factor between sites. To minimize this influence, YOY data were excluded and the analysis was re-run using only 1+ year or older fish. This subsequent analysis again found a significant interaction between populations using August results (ANCOVA, $p<0.05$); however, October results found condition of older (non-YOY) sculpin to be significantly different among populations (ANOVA, $p<0.001$). Specifically, condition was significantly greater at the Steepbank River reference site relative to all other populations, including both reference and exposure areas (Table 5.4-17).

Discussion

Direct comparison of 2004 non-lethal study results with results of previous RAMP sentinel species programs (1999 and 2001) was not possible for the following reasons: field sampling was not always conducted at the same time of year; some previous studies have focused on only adult sculpin (e.g., 1999); and the change in overall sentinel study methodology (i.e., non-lethal vs. lethal based endpoints). However, relevant historical data has been incorporated into the discussion below. It should be noted that results from future RAMP non-lethal sentinel studies will be directly comparable to 2004 results.

Sculpin sampled in 2001 and 2004 were longer at both exposure sites (Steepbank and Muskeg rivers) relative to sculpin from the reference Steepbank and Horse River sites. However, in 2004 no differences in mean sculpin length were observed between exposure sites and the Dunkirk River population, whereas in 2001, the Dunkirk River population was longer relative to sculpin at the Steepbank River exposure site. Sculpin at exposure sites were also significantly heavier, on average, in 2004, relative to those at two of three reference sites sampled (the Dunkirk River population excepted). Growth rates calculated for YOY (the most distinct size/age cohort between August and October) were similar among sites.

Observed differences in sculpin size, growth and condition can be interpreted as a collective indication of the environmental conditions present at a particular site over time, including, but not limited to, nutrient enrichment and/or metabolic disruption (Munkittrick *et al.* 2002). Significant differences in population distributions and comparatively low proportions of YOY sculpin captured at the Steepbank exposure and Dunkirk reference sites in 2004 may be the result of limited reproductive capacity in adults, elevated early life history mortality, or a combination of the two. In turn, this could result in an increase in mean age of a population (Gibbons and Munkittrick 1994), as was observed in 2001 for exposed male sculpin from the Steepbank River (Golder 2002). Interestingly, 2001 study results (using lethal methods) found significantly lower female gonad size and fecundity (# eggs/female) at the Muskeg River exposure site relative to reference sites by 10% to 13% and 27% to 40%, respectively (Golder 2002). Mean fecundity of the Steepbank River exposure population was 15% lower than for the Dunkirk River population; however, the same difference was not evident relative to the two other reference sites.

Impact Analysis

Measurement endpoints established for the lethal sentinel species monitoring approach established by Environment Canada (2002) include condition factor, relative gonad size (Gonad Somatic Index), and relative liver size (Liver Somatic Index). Currently, only condition factor can be applied as a measurement endpoint when the non-lethal approach is used. The impact criterion for condition factor defined by Environment Canada (2002) is a ± 10% difference between exposed and reference sites. A difference in condition that is greater than 10% indicates a population may be affected by some factor or factors.

A summary of condition factor responses of sculpin from the Steepbank and Muskeg exposure sites relative to the three reference sites in 2004 is provided in Table 5.4-18 and Table 5.4-19, respectively. For sculpin from the lower Steepbank River, a slight effect on

condition factor was identified relative to the Dunkirk River, although no effect was evident when compared to the reference Steepbank and Horse River sites, or to pooled reference sculpin. For exposed Muskeg River sculpin, the only effect on condition was when compared to reference sculpin from the Steepbank River. Overall, differences in condition were negligible to low.

The RAMP sentinel fish program is designed to identify differences in sculpin populations between reference and exposure sites in terms of growth, reproduction, and energy storage (condition) (Gray *et al*. 2002, Environment Canada 2004). At present, condition factor is the only non-lethal sentinel species measurement endpoint that has a numerical criterion for identifying an effect. Below is a modified list of possible indicators associated with non-destructive sampling (Environment Canada 2004):

Growth

- Length and/or weight of young-of-year at end of growth period;
- Length and/or weight of 1+ year old fish; and
- size-at-age (if possible to determine ages of fish captured).

Reproduction

- Relative abundance of young-of-year (i.e., % composition); and
- Young-of-year survival.

Survival

- Length frequency distribution – identification of missing size (age) cohorts.

Past events of possible recruitment failure in sculpin populations were identified through missing year classes (i.e., cohorts), in both a reference (Horse River) and exposure (lower Muskeg River) area. Furthermore, early life history bottlenecks in terms of YOY abundance, growth and survival were estimated from the magnitude of size (age) class shift over an identified period of time. Although no obvious differences were observed in YOY growth during 2004, factors such as initial size at hatch or time of hatching may require further investigation if differentiated growth was present among populations.

In August, lack of YOY individuals was most noticeable in the exposure population at the Steepbank River site. Similarly, in October few YOY individuals were present in either exposure population. In the Muskeg River, a sharp decline was observed in the proportion of YOY in the population from August to October, suggesting high mortality.

In both cases, predictions of a weak 2004-age class can be made, which in the case of the Muskeg River population would suggest a failure in two consecutive years. Chronic or repetitive year class failure within a population would indicate potential effects from environmental factors, and warrant more detailed study to identify the cause.

5.4.6 Summary of Assessment

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

Although the oil sands development located adjacent to the Steepbank River commenced in 1997, there is little evidence suggesting that mining operations have influenced current hydrologic and water quality conditions. Subtle shifts in benthic community composition were observed at the exposed reach of the Steepbank River relative to the upstream reference community; however, indices of community composition were generally within the expected ranges for regional-reference conditions.

Sentinel fish species monitoring using slimy sculpin was also conducted on the lower Steepbank River (and Muskeg River). There was evidence of reduced recruitment and very low abundance of young-of-the-year (YOY) sculpin in the Steepbank River. Negligible to low differences in condition factor were identified in scupling from exposed sites compared to sculpin from reference sites.

Table 5.4-1 Summary of parameter values for Steepbank River water balance calculation.

Component	Value	Basis / Data Source
Observed hydrograph	Daily discharges	WSC monitoring
Natural runoff that would have occurred from active mine areas, or that is intercepted by development	None – limited development in the basin	Development progress shown on Figure 5.4-1
Incremental runoff from areas that are cleared and areas that are being dewatered	None – limited development in the basin	Development progress shown on Figure 5.4-1
Withdrawals from the Steepbank River	None	None reported
Releases to the Steepbank River	None	None reported
The difference between observed and naturalized hydrographs on tributary streams	Not applicable	No tributaries were analyzed separately.

* As measured at WSC Station 07DA006, Steepbank River near Fort McMurray. Definitions and assumptions are discussed in Section 3.1.7.3.

Figure 5.4-2 Steepbank River 2004 hydrograph and historical context.

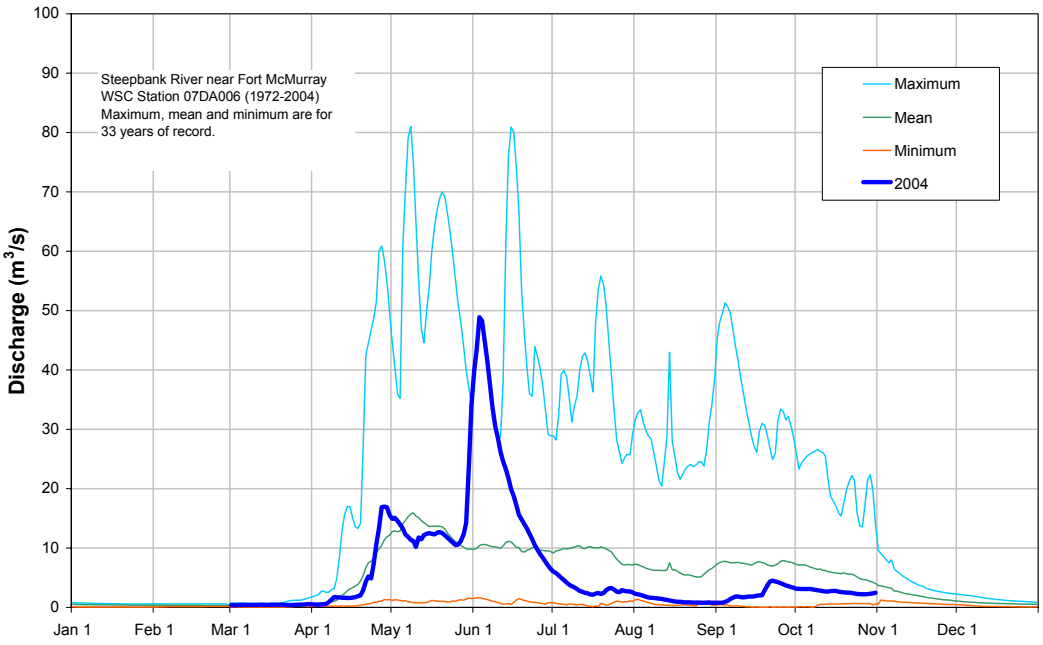


Table 5.4-2 Calculated change in hydrologic measurement endpoints for the Steepbank River watershed.

Endpoint	Control Value (m^3/s)	Treatment Value (m^3/s)	Percent Change
Mean open-water season discharge	7.61	7.61	0%
Mean winter discharge	Not measured	Not measured	na
Annual maximum daily discharge	48.9	48.9	0%
Open-water season minimum daily discharge	0.79	0.79	0%

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

Table 5.4-3 Water quality in the lower Steepbank River (STR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	6	7.7	8.1	8.4
Total suspended solids	mg/L	-	<3	6	3	20	60
Conductivity	mg/L	-	268	6	141	217	516
Nutrients							
Total phosphorus	mg/L	0.05	0.023	6	0.008	0.0405	**0.054**
Dissolved phosphorus	mg/L	0.05[1]	0.013	6	0.006	0.0195	0.032
Total nitrogen*	mg/L	1.0	0.6	6	<0.2	0.7	**2.3**
Nitrate+nitrite	mg/L	-	<0.1	6	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	15	6	11	18	26
Ions							
Sodium	mg/L	-	18	6	6	10.5	38
Chloride	mg/L	230, 860[2]	4	6	1	1.6	8.4
Sulphate	mg/L	100[3]	4.8	6	4.6	5.6	12.3
Total dissolved solids	mg/L	-	220	6	120	200	320
Total alkalinity	mg/L		167	6	63	104	263
Organic compounds							
Naphthenic acids	mg/L	-	<1	6	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	0.05	6	0.04	**0.58**	**2.7**
Dissolved aluminum	mg/L	0.1[1]	0.0044	6	0.010	0.024	0.099
Total boron	mg/L	1.2[3]	0.10	6	0.025	0.058	0.2
Total molybdenum	mg/L	0.073	0.0003	6	0.0002	0.0002	0.0005
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total iron (Fe)	mg/L	0.300	**0.6**	6	**0.5**	**1.2**	**2.3**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.4-4 Water quality in the upper Steepbank River (STR-2 and STR-3), fall 2004.

	Units	Guideline	September 2004		1997-2003 (STR-2 Fall data only)			
			STR-2	STR-3[2]	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.3	8.3	2	7.8	-	8.0
Total suspended solids	mg/L	-	14	<3	2	8	-	28
Conductivity	mg/L	-	274	276	2	121	-	142
Nutrients								
Total phosphorus	mg/L	0.05	0.04	**0.05**	2	0.04	-	0.05
Dissolved phosphorus	mg/L	0.05[1]	0.014	0.027	2	0.020	-	0.022
Total nitrogen*	mg/L	1.0	0.6	0.6	2	0.7	-	**1.5**
Nitrate+nitrite	mg/L	-	<0.1	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	14	14	2	22	-	29
Ions								
Sodium	mg/L	-	16	15	2	5	-	6
Chloride	mg/L	230, 860[3]	3	2	2	1	-	2
Sulphate	mg/L	100[4]	5.5	3.2	2	3.5	-	3.5
Total dissolved solids	mg/L	-	200	210	2	140	-	160
Total alkalinity	mg/L	-	155	165	2	61	-	71
Organic compounds								
Naphthenic acids	mg/L	-	1	1	2	<1	-	<1
Selected metals								
Total aluminum	mg/L	0.1	**0.42**	0.039	2	**0.24**	-	**0.54**
Dissolved aluminum	mg/L	0.1[1]	0.0056	0.0040	2	0.018	-	0.029
Total boron	mg/L	1.2[4]	0.097	0.094	2	0.023	-	0.029
Total molybdenum	mg/L	0.073	0.00026	0.00024	2	0.00010	-	0.00014
Total mercury (ultra-trace)	ng/L	26	<0.6	<0.6	1	-	-	2.3
Other variables that exceeded CCME/AENV guidelines in fall 2004								
Total iron (Fe)	mg/L	0.3	**1.03**	**0.92**	2	**0.84**	-	**1.07**

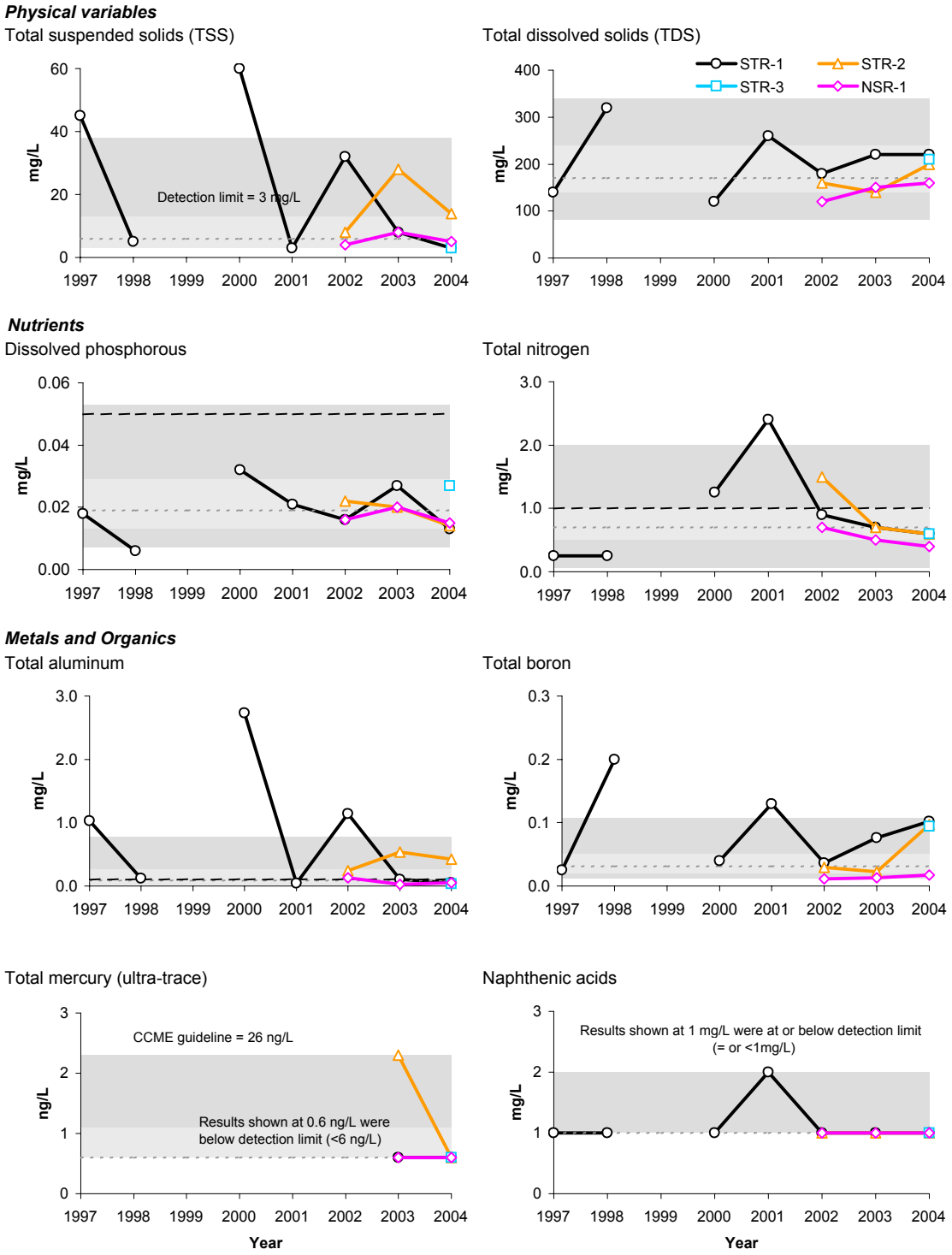
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] New station in 2004. No previous data are available.
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[4] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.4-5 Water quality in the North Steepbank River (NSR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	2	7.5	-	8.0
Total suspended solids	mg/L	-	5	2	4	-	8
Conductivity	mg/L	-	175	2	110	-	143
Nutrients							
Total phosphorus	mg/L	0.05	0.032	2	0.027	-	0.028
Dissolved phosphorus	mg/L	0.05[1]	0.015	2	0.016	-	0.02
Total nitrogen*	mg/L	1.0	0.4	2	0.5	-	0.7
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	0.1
Dissolved organic carbon	mg/L	-	13	2	16	-	18
Ions							
Sodium	mg/L	-	3	2	2	-	3
Chloride	mg/L	230, 860[2]	2	2	<1	-	1
Sulphate	mg/L	100[3]	1.2	2	1.8	-	2.2
Total dissolved solids	mg/L	-	160	2	120	-	150
Total alkalinity	mg/L	-	98	2	55	-	73
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	1
Selected metals							
Total aluminum	mg/L	0.1	0.050	2	0.028	-	0.13
Dissolved aluminum	mg/L	0.1[1]	0.005	2	0.013	-	0.015
Total boron	mg/L	1.2[3]	0.017	2	0.011	-	0.013
Total molybdenum	mg/L	0.073	0.0003	2	0.0002	-	0.0002
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Phenols (4AAP)	mg/L	0.004	**0.007**	2	0.001	-	<0.001
Total iron (Fe)	mg/L	0.300	**0.79**	2	**0.51**	-	**0.58**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.4-3 Concentrations of selected water quality variables in the Steepbank River watershed relative to relative to regional baseline concentrations, fall 1997-2004.



[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 E for these regional baseline ranges.

Table 5.4-6 Water quality guideline exceedances, Steepbank River watershed, 2004.

Parameter	Units	Guideline	STR-1	STR-2	STR-3	NSR-1
Winter [1]						
Total phosphorus	mg/L	0.05	ns	ns	**0.073**	ns
Total iron	mg/L	0.300	ns	ns	**0.896**	ns
Spring						
Total copper	mg/L	0.002-0.004[3]	ns	ns	**0.00345**	-
Dissolved copper	mg/L	0.002-0.004[2, 3]	ns	ns	**0.00255**	-
Total aluminum	mg/L	0.100	ns	ns	**0.203**	-
Total iron	mg/L	0.300	ns	ns	**0.668**	**0.423**
Dissolved iron	mg/L	0.300[2]	ns	ns	**0.317**	-
Summer						
Total phenols	mg/L	0.004	ns	ns	**0.005**	**0.005**
Total iron	mg/L	0.300	ns	ns	**1.03**	**1.09**
Dissolved iron	mg/L	0.300[2]	ns	ns	**0.712**	**0.774**
Total phosphorus	mg/L	0.05	ns	ns	**0.061**	**0.057**
Fall						
Total phenols	mg/L	0.004	-	-	-	**0.007**
Total aluminum	mg/L	0.100	-	**0.421**	-	-
Total iron	mg/L	0.300	**0.622**	**1.03**	**0.92**	**0.791**
Dissolved iron	mg/L	0.300[2]	**0.464**	**0.408**	**0.554**	**0.495**
Total phosphorus	mg/L	0.05	-	-	**0.051**	-

Guidelines are CCME/AENV guidelines for the protection of aquatic life.

[1]: Winter sampling: STR-3; spring and summer sampling: STR-3, NSR-1; fall sampling: STR-1, STR-2, STR-3, NSR-1.

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

[3]: Guideline is hardness dependent.

ns: not sampled.

Figure 5.4-4 Ion balance in waters of the Steepbank River watershed, fall 1997-2004.

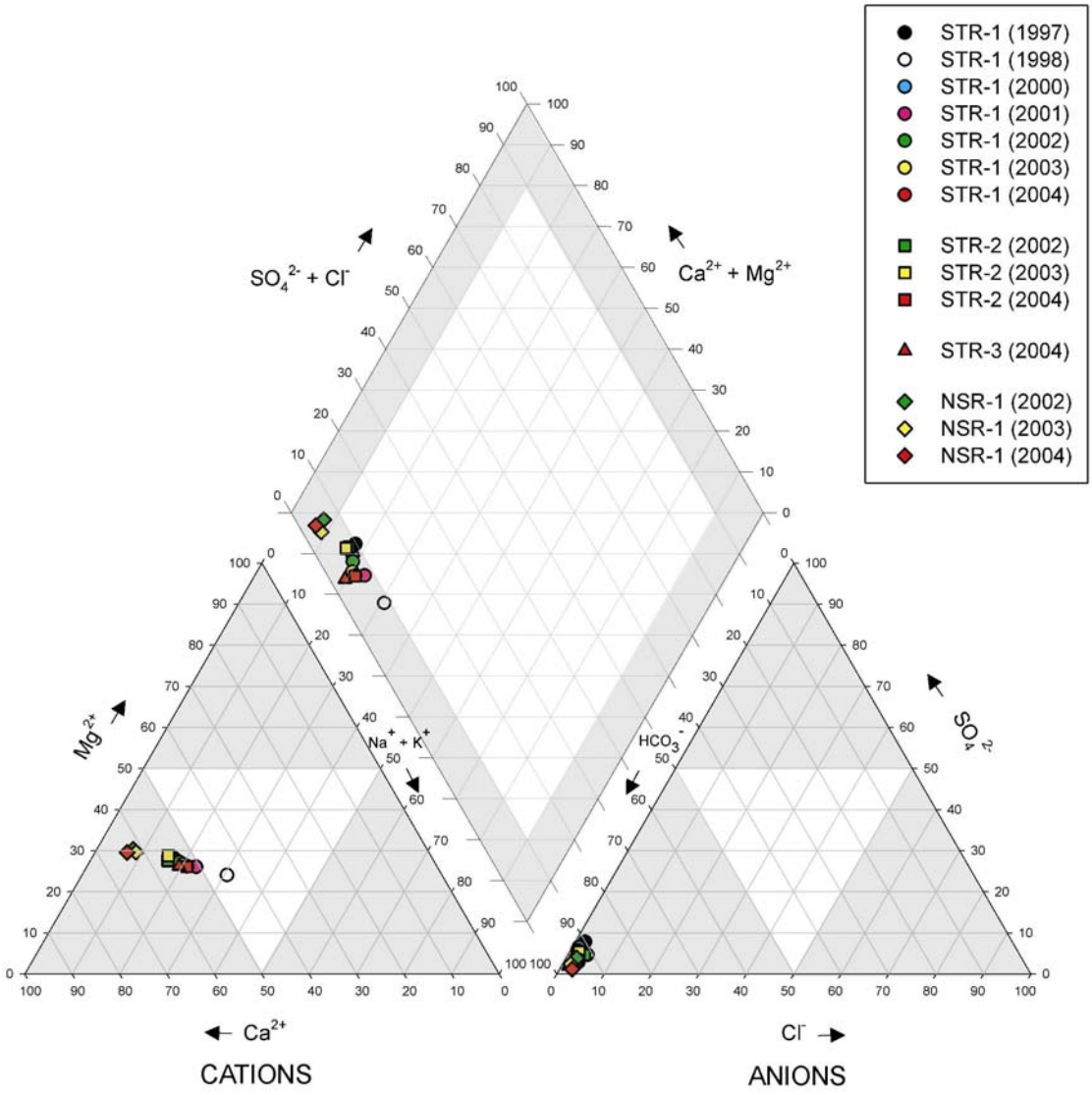


Table 5.4-7 Selected sediment quality measurement endpoints, North Steepbank River (NSR-1), fall 2004.

	Units	Guideline	September 2004 Value	n	1997-2003 (Fall data only) Min	Median	Max
Physical variables							
Clay	%	-	1	1	-	-	3
Silt	%	-	2	1	-	-	8
Sand	%	-	98	1	-	-	89
Total organic carbon	%	-	0.2	1	-	-	1.7
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]	15	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	9	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	1	-	-	13
TEH (C11-C30)	mg/kg	-	23	1	-	-	74
TRH	mg/kg	-	<100	1	-	-	100
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.002	2	0.001	-	0.002
Retene	mg/kg	-	0.002	2	0.09	-	0.75
Total dibenzothiophenes	mg/kg	-	0.002	2	0.012	-	0.021
Total PAHs	mg/kg	-	0.025	2	0.22	-	0.92
Total HMW PAHs	mg/kg	-	0.009	2	0.043	-	0.088
Total LMW PAHs	mg/kg	-	0.016	2	0.18	-	0.84
Predicted PAH toxicity[1]	H.I.	-	0.14	2	0.36	-	6.71
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	-	1	-	-	8
Chironomus growth	mg/organism	-	-	1	-	-	1.9
Hyallela survival	# surviving	-	-	1	-	-	9
Hyallela growth	mg/organism	-	-	1	-	-	0.1

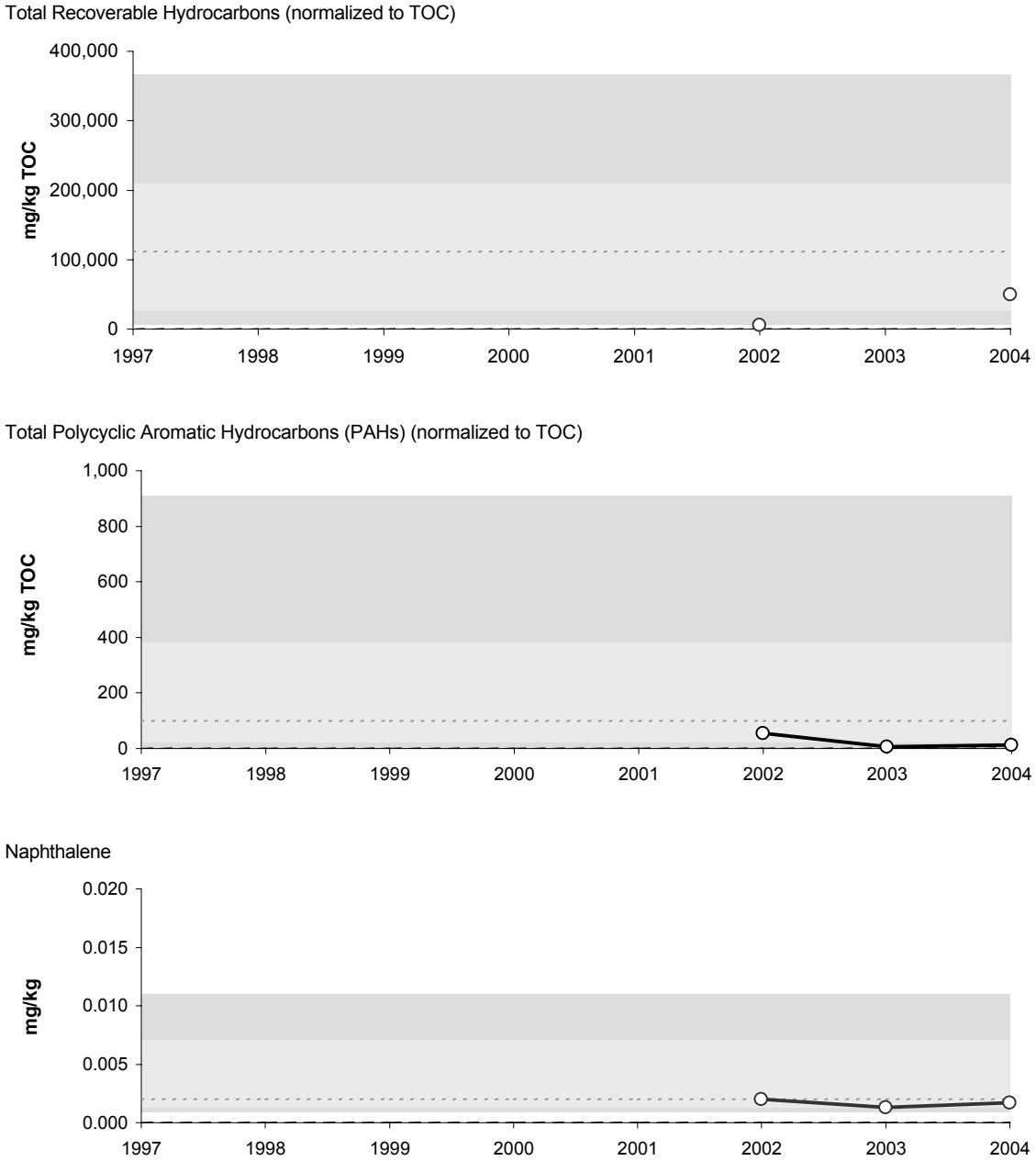
Note: unless otherwise noted, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

[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 Selected sediment quality measurement endpoints, North Steepbank River (NSR-1), 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 F for these regional baseline ranges.

Table 5.4-8 Average habitat characteristics of sites in the Steepbank River, Fall 2004.

Variable	Units	Lower Reach of the Steepbank River	Upper Reach of the Steepbank River
Sample date	-	Sept 19, 2004	Sept 19, 2004
Habitat	-	Erosional	Erosional
Water depth	m	0.2	0.3
Current velocity	m/s	0.7	0.6
Macrophyte cover	%	0	8.0
Benthic algae	mg/m^2	8.9	247
Field Water Quality			
Dissolved oxygen	mg/L	10.0	10.4
Conductivity	µS/cm	340	186
pH		8.5	12.9
Water temperature	°C	8.3	7.8
Sediment Composition			
Sand/Silt/Clay	%	8.6	1.0
Small gravel	%	15.7	6.0
Large gravel	%	33.6	12.3
Small cobble	%	32.1	39.3
Large cobble	%	9.6	36.7
Boulder	%	0.4	4.7
Bedrock	%	0	0

Table 5.4-9 Summary of major taxon abundances and key indices of composition among benthic invertebrate sampling reaches in the Steepbank River, fall 2004.

Taxon	Lower Reach of the Steepbank River			Upper Reach of the Steepbank River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Nematoda	55	154	0.8	83	87	0.6
Enchytraeidae	113	107	1.6	63	152	0.5
Naididae	100	160	1.4	229	228	1.8
Tubificidae	75	212	1.1	4	6	0.0
Lumbriculidae	4	0	0.1	0	0	0
Hydracarina	533	2,150	7.7	47	82	0.4
Ostracoda	0	0	0	94	163	0.7
Copepoda	0	0	0	1,439	2,658	11.2
Chydoridae	0	0	0	35	38	0.3
Collembola	0	0	0	3	6	0.0
Gastropoda	22	0	0.3	0	0	0
Ephemeroptera	1,049	482	15.2	1,072	394	8.3
Plecoptera	195	154	2.8	987	389	7.7
Trichoptera	164	163	2.4	1,628	584	12.7
Anisoptera	202	362	2.9	92	461	0.7
Coleoptera	0	0	0	156	579	1.2
Tipulidae	0	0	0	618	590	4.8
Athericidae	11	106	0.2	597	732	4.6
Dolichopodidae	0	0	0	1	0	0.0
Tabanidae	1	0	0.0	4	0	0.0
Empididae	708	589	10.3	222	159	1.7
Ceratopogonidae	103	612	1.5	0	0	0
Chironomidae	3,518	876	51.1	4,955	1,289	38.6
Simuliidae	34	207	0.5	516	2,102	4.0
Total Abundance	**6,887**	**3,028**	**-**	**12,845**	**5,403**	**-**
Richness	19.9	3.0	-	34.5	4.5	-
Simpson's Diversity	0.795	0.117	-	0.841	0.062	-
Evenness	0.838	0.124	-	0.867	0.064	-

Figure 5.4-6 Biplot of benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for the Lower Steepbank (exposed erosional).

Ellipse is for reference data.

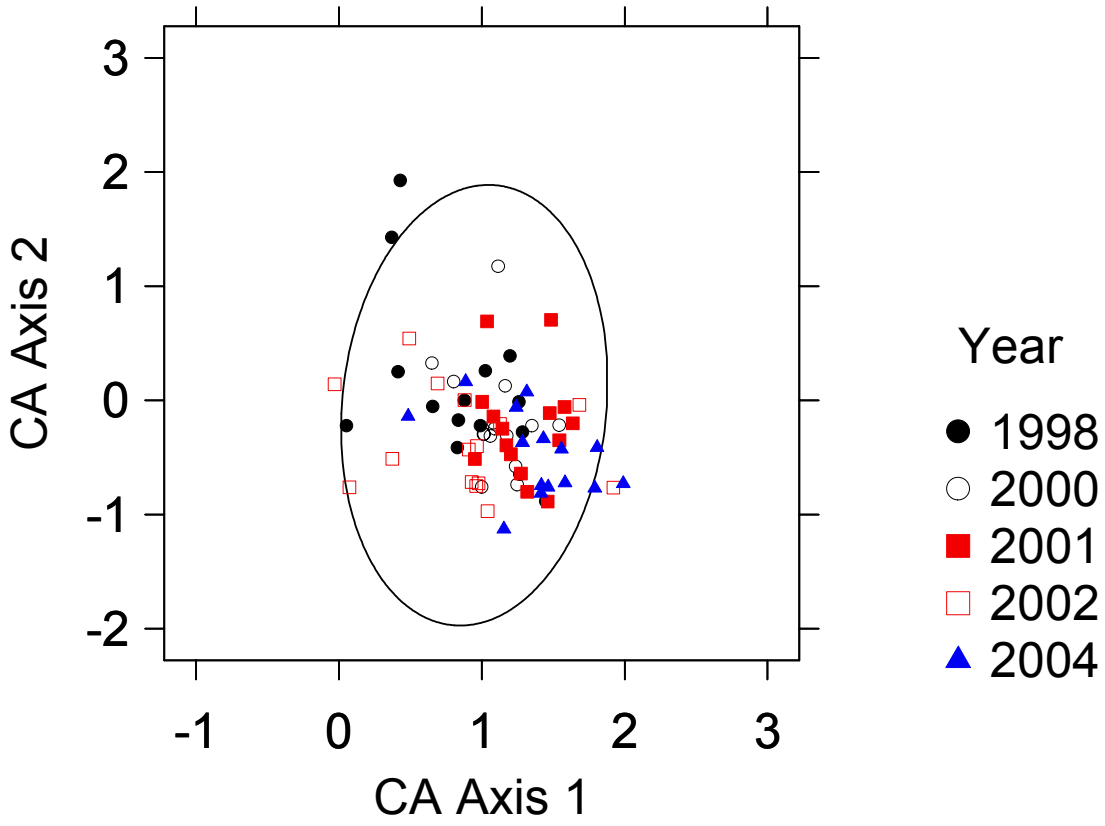


Figure 5.4-7 Variations in indices of benthic invertebrate community composition in the Steepbank River, lower and upper reaches.

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

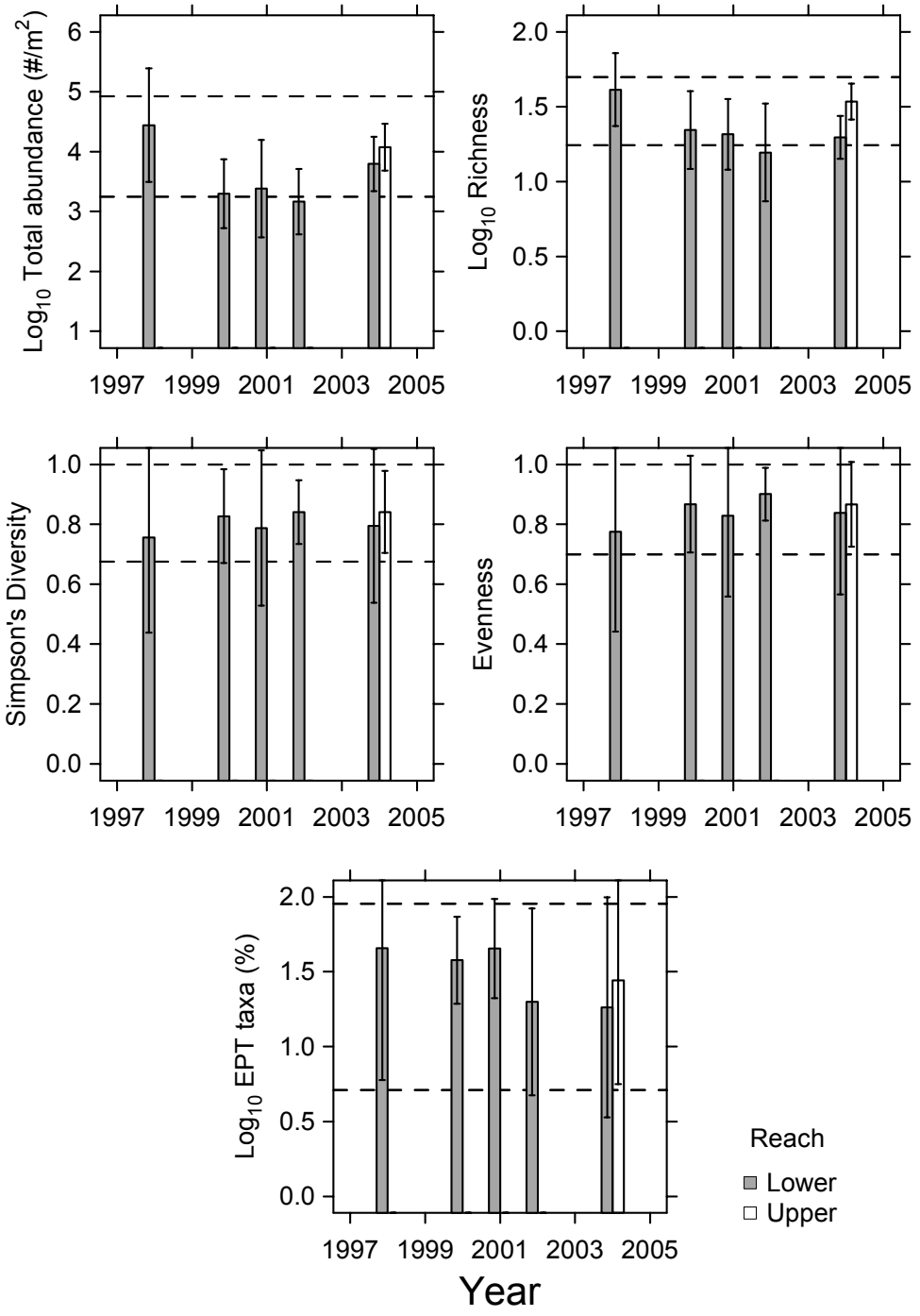


Table 5.4-10 Analysis of variance between lower (exposed) and upper (reference) reaches of the Steepbank River.

Source	SS	df	F	P
Log_{10} Abundance				
Reach-Year	10.93	5	32.32	<0.001
Reach (2004)	*0.587*	*1*	*8.672*	*0.004*
Error	4.870	72		
Log_{10} Richness				
Reach-Year	1.143	5	21.18	<0.001
Reach (2004)	*0.429*	*1*	*39.74*	*<0.001*
Error	0.777	72		
Simpson's Diversity				
Reach-Year	0.050	5	1.296	0.275
Reach (2004)	*0.016*	*1*	*2.095*	*0.152*
Error	0.556	72		
Evenness				
Reach-Year	0.070	5	1.694	0.147
Reach (2004)	*0.006*	*1*	*0.764*	*0.385*
Error	0.594	72		
Log_{10} EPT %				
Reach-Year	1.868	5	5.674	<0.001
Reach (2004)	*0.244*	*1*	*3.710*	*0.058*
Error	4.741	72		

Table 5.4-11 Summary of habitat characteristics of sentinel species monitoring sites, August 2004.

Parameter	Steepbank River Exposure Site	Steepbank River Reference Site	Muskeg River Exposure Site	Dunkirk River Reference Site	Horse River Reference Site
Channel Morphology	Riffle-Pool	Riffle-Pool	Riffle-Pool	Riffle-Pool	Riffle-Pool
Gradient (%)	1.5	1.5	1.5	1.0	1.0
Avg. Channel Width (m)	21.3	28.2	21.6	26.8	17.1
Avg. Wetted Width (m)	12.6	21.4	10.9	26.5	14.2
Avg. Water Velocity (m/s)	Riffle: 0.84 Glide: 0.41	Riffle: 0.51 Glide: 0.22	Riffle: 0.79 Glide: 0.53	Riffle: 0.79 Glide: 0.41	Riffle: 0.29 Glide: 0.14
Substrate	Gravel / Cobble	Cobble / Boulder	Gravel / Cobble	Gravel / Cobble	Cobble / Gravel
Cover Type	Pool / Boulder	Boulder / Pool	Pool / Boulder	Boulder / LWD	Boulder / Over Veg.

Table 5.4-12 Results of fish sampling efforts during August and October 2004 sentinel species monitoring program.

Site	August 2004 Sampling					October 2004
	Enclosure Area (m^2)	Fish Caught in Enclosure	Density ($\#/m^2$)	Total Fish Caught	Young-of-Year	Total Fish Caught
Muskeg River Exposure	872	27	0.031	102	25	94
Steepbank River Reference	1027	55	0.054	96	49	102
Steepbank River Exposure	920	64	0.070	103	1	110
Horse River Reference	568	16	0.028	111	83	104
Dunkirk River Reference	1325	95	0.072	108	19	101

Table 5.4-13 Statistical comparison of length-frequency distributions between Steepbank sites and other sentinel species sites, 2004.

Site Comparison	Kolmogorov-Smirnov Two-Sample Test	
Steepbank River Reference verses:	**August**	**October**
Steepbank River Exposure	<0.0001	<0.0001
Dunkirk River Reference	<0.0001	<0.0001
Horse River Reference	<0.0001	0.268
Muskeg River Exposure	<0.0001	<0.0001
Steepbank River Exposure verses:		
Dunkirk River Reference	0.113	0.016
Horse River Reference	<0.0001	<0.0001
Muskeg River Exposure	<0.0001	<0.0001
Dunkirk River Reference vs. Horse River Reference	<0.0001	<0.0001
Dunkirk River Reference vs. Muskeg River Exposure	<0.0001	<0.0001
Horse River Reference vs. Muskeg River Exposure	<0.0001	<0.0001

Figure 5.4-8 Cumulative length-frequency distributions for the Horse, Dunkirk and Muskeg rivers, August and October 2004.

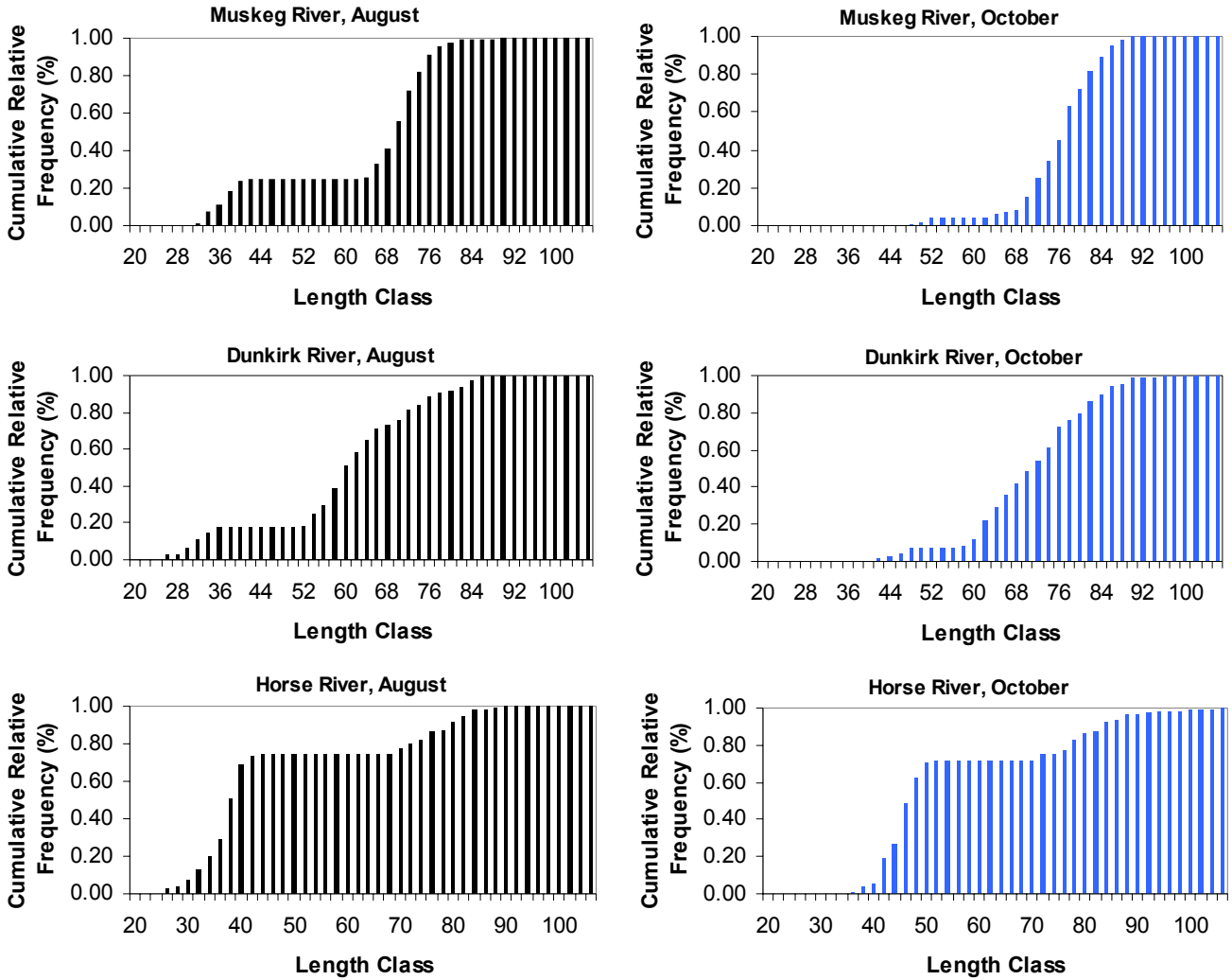
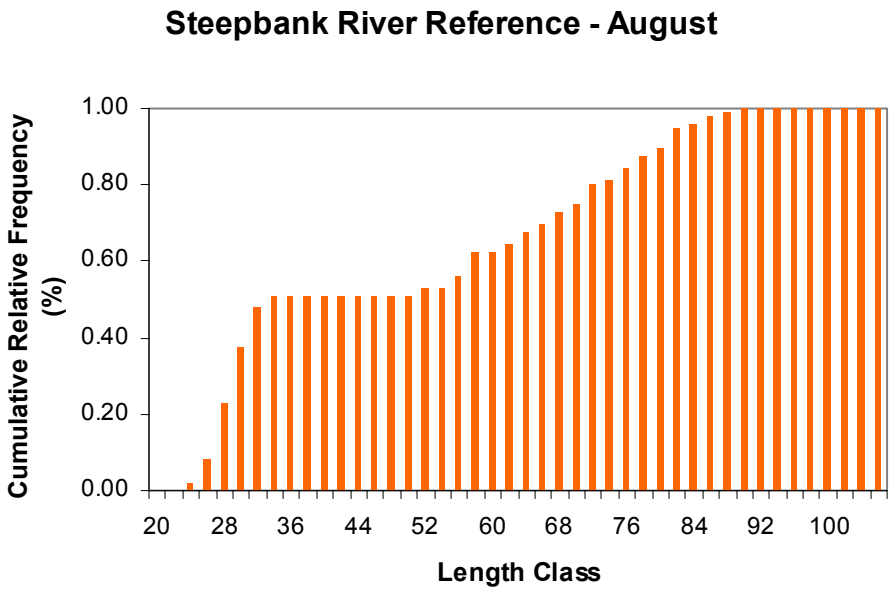


Figure 5.4-9 Cumulative length-frequency distributions for exposure and reference Steepbank River sculpin populations, August 2004.



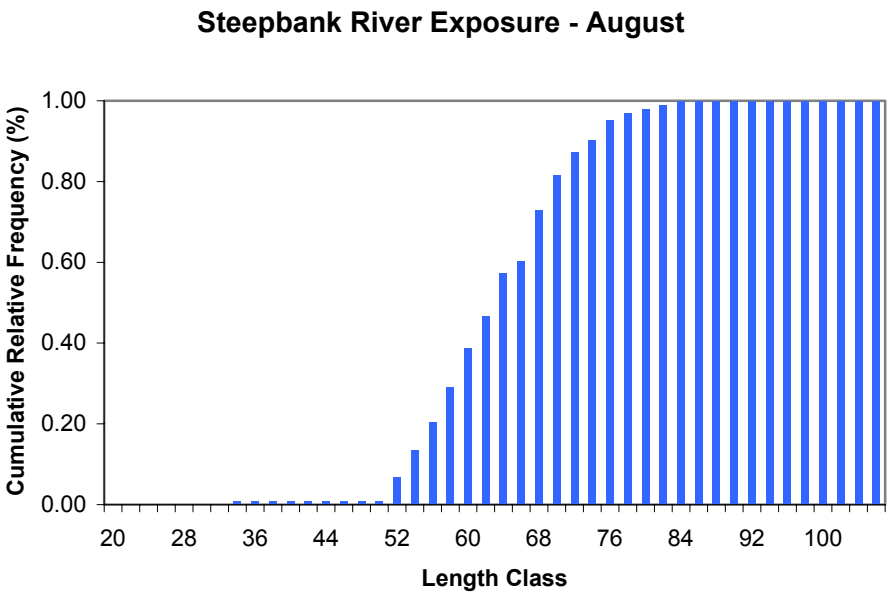
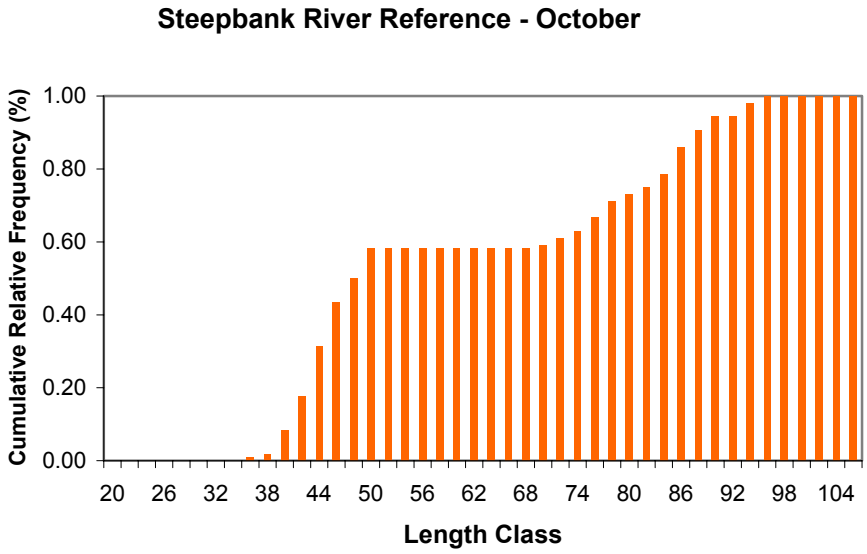


Figure 5.4-10 Cumulative length-frequency distributions for Steepbank River sculpin, October 2004.



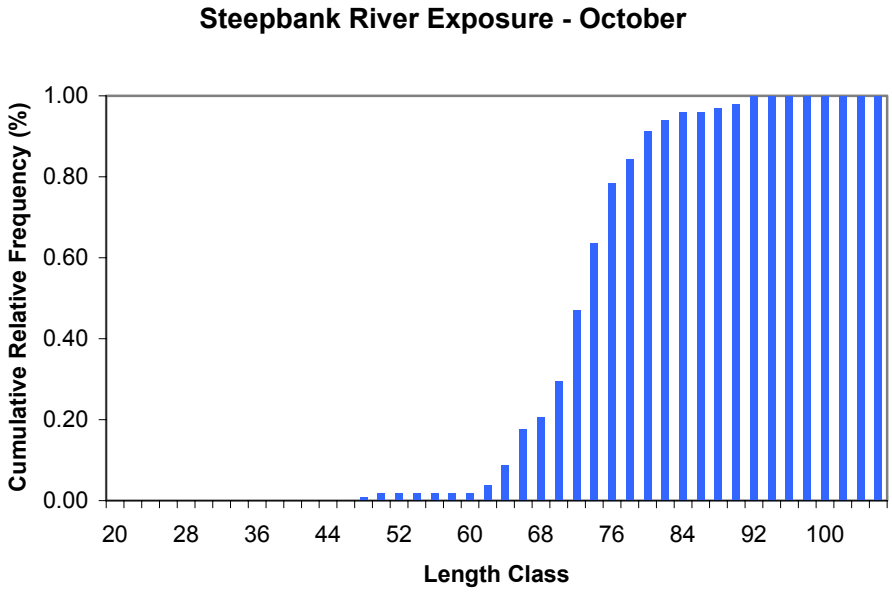


Figure 5.4-11 Mean length of sculpin captured during the 2004 sentinel species program.

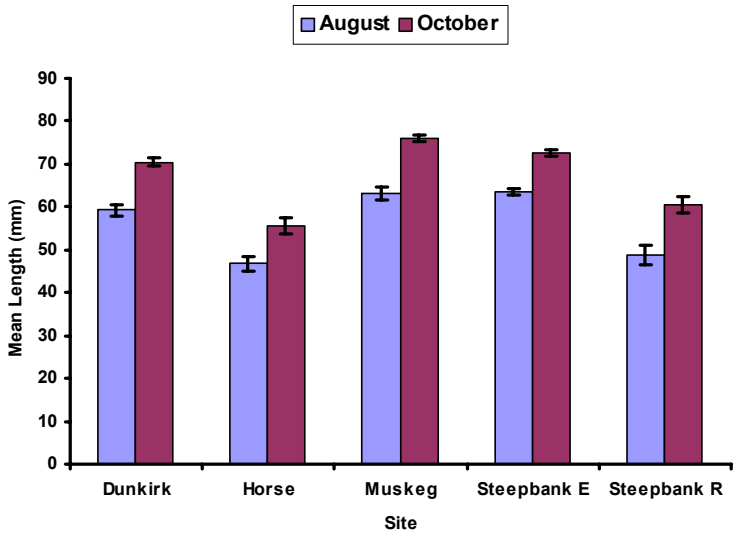


Figure 5.4-12 Mean weight of sculpin captured during the 2004 sentinel species program.

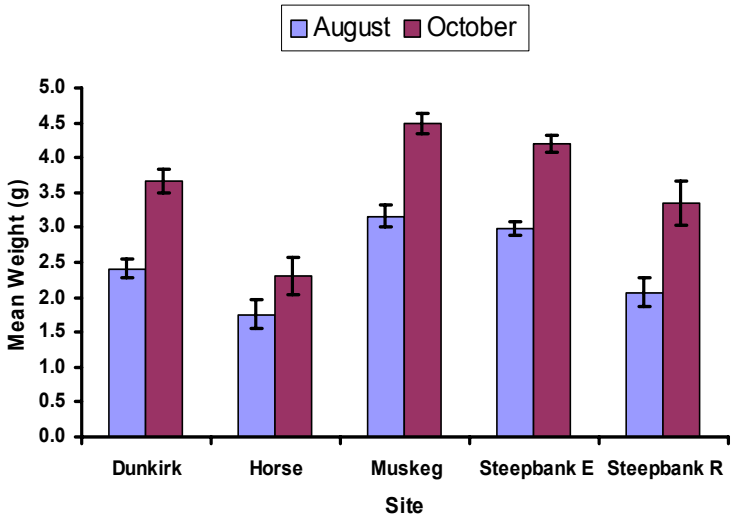
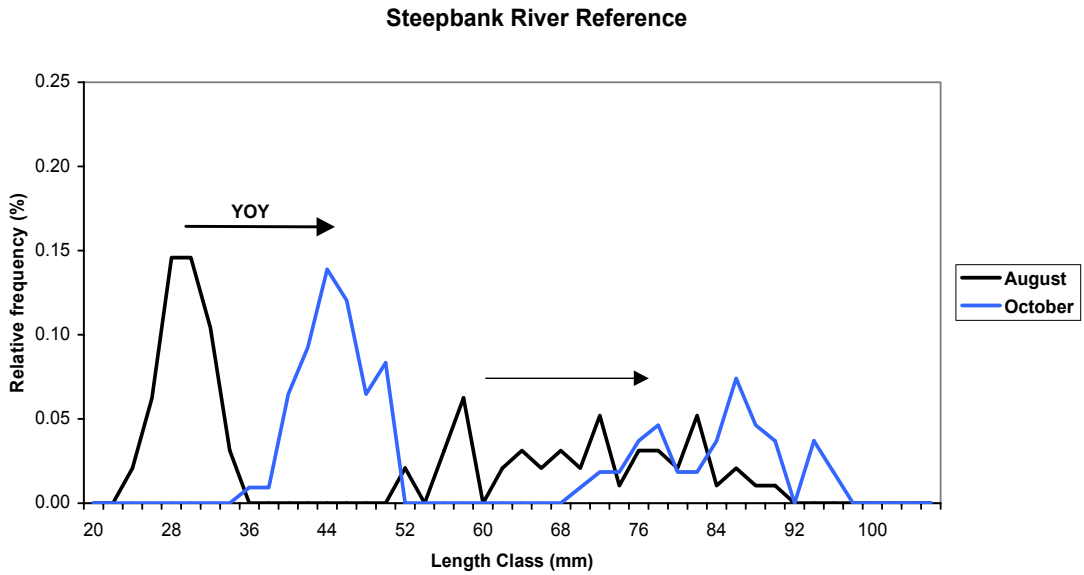


Table 5.4-14 Seasonal comparison of size of sculpin captured from exposure and reference sites, August and October 2004.

		Steepbank River		Dunkirk	Horse	Muskeg
		Reference	Exposure	River	River	River
August	**Sample Size**	96	103	108	111	102
Length (mm)	Mean	48.9 AC	63.5 BD	59.2 AB	46.8 C	63.1 D
	SE	2.25	0.80	1.50	1.76	1.56
	Min	24.0	33.0	25.0	25.0	31.0
	Max	90.0	83.0	86.0	89.0	89.0
Weight (g)	Mean	2.07 B	2.98 AC	2.42 A	1.75 B	3.17 AC
	SE	0.21	0.10	0.13	0.21	0.16
	Min	0.13	0.39	0.21	0.19	0.29
	Max	7.18	6.62	6.28	8.45	6.02
October	**Sample Size**	108	102	101	104	94
Length (mm)	Mean	60.6 B	72.7 AC	70.5 A	55.6 B	76.1 AC
	Standard Error	1.92	0.68	1.10	1.73	0.81
	Minimum	35.00	47	41.0	36.0	48.0
	Maximum	95.00	92	95.0	106.0	90.0
Weight (g)	Mean	3.35 AD	4.20 ACD	3.66 A	2.31 B	4.49 AC
	Standard error	0.31	0.12	0.17	0.27	0.14
	Minimum	0.36	0.88	0.57	0.40	1.05
	Maximum	10.45	8.16	8.37	16.00	8.56

* Those values bearing different letters indicate a significant difference between sites as determined through ANOVA ($p<0.05$) and Bonferroni adjusted multiple comparisons. Sites with the same letter were not significantly different from each other; sites with different letters were significantly different from each other.

Figure 5.4-13 Length-frequency (%) distributions of slimy sculpin from the Steepbank River, August and October 2004.



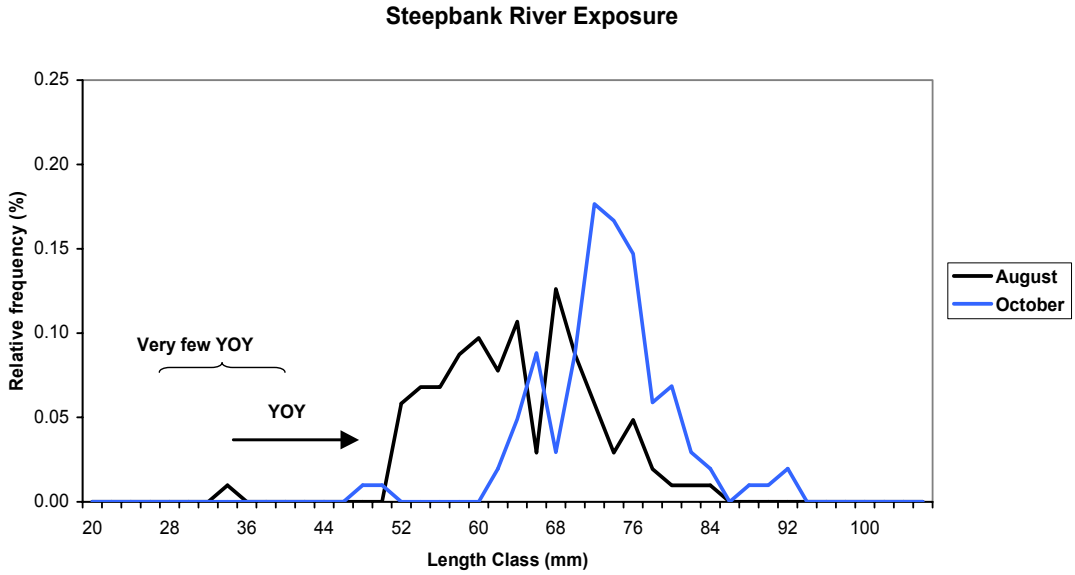


Figure 5.4-14 Length-frequency (%) distributions of slimy sculpin from the Dunkirk, Horse and Muskeg rivers, August and October 2004.

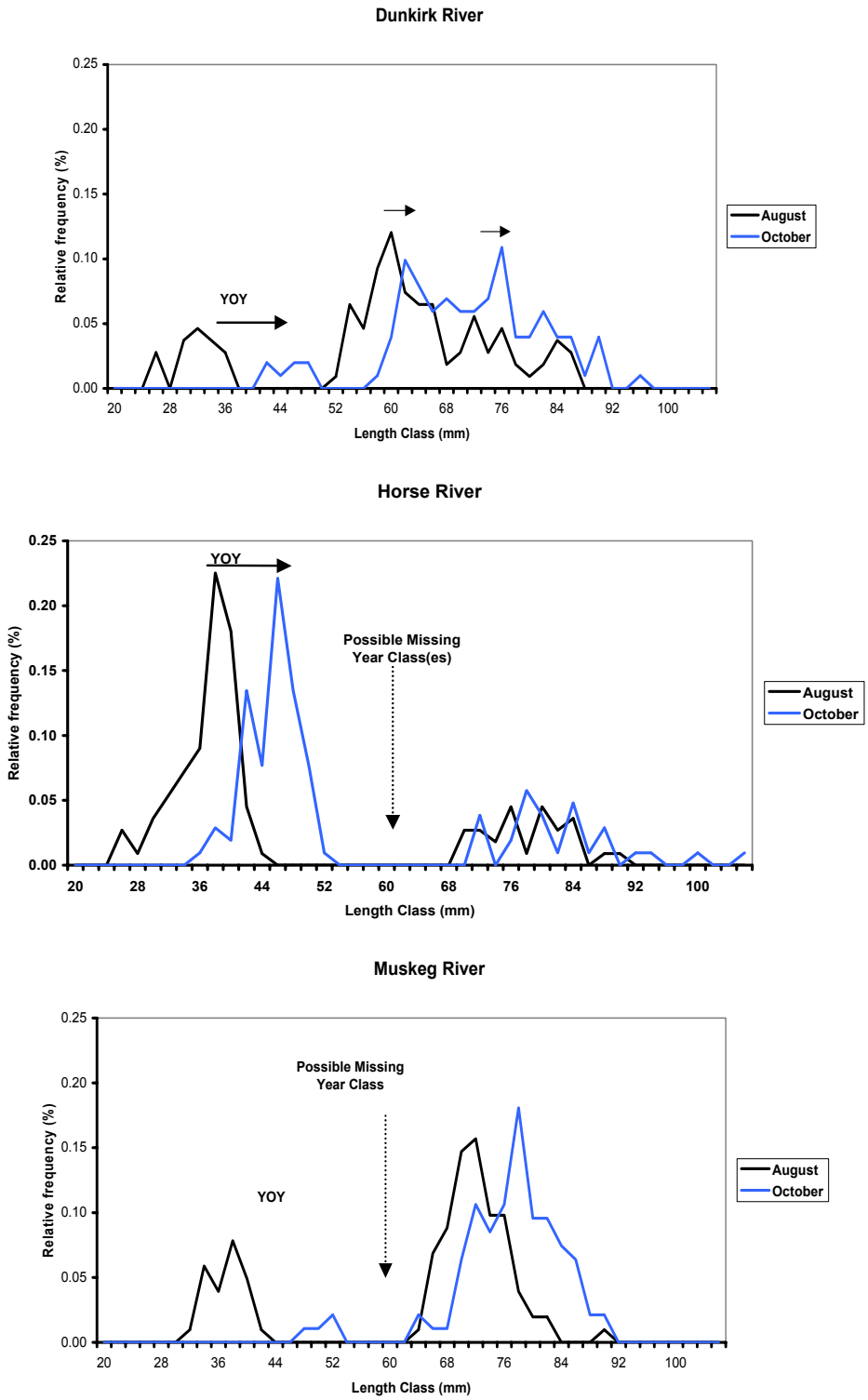


Table 5.4-15 Estimated growth rates (mm/day) of young-of-the-year sculpin from exposure and reference populations, 2004.

Site	Mean Length (mm) August	Mean Length (mm) October	Difference	Estimated Growth (mm/day)
Steepbank River Exposure	na[1]	na	na	na
Steepbank River Reference	29.6	44.3	14.7	0.23
Muskeg River Exposure	36.5	49.8	13.2	0.20
Dunkirk River Reference	32.1	44.6	12.5	0.19
Horse River Reference	36.4	44.8	8.5	0.13

[1] - na - not applicable–only one young of the year captured in exposed area of the Steepbank River

Table 5.4-16 Proportion of sculpin populations represented by young-of-year individuals, August 2004.

Site	Total Sculpin Caught	No. Young-of-Year	% Young-of-Year
Steepbank River Exposure	103	1	1.0
Steepbank River Reference	96	49	51.0
Muskeg River Exposure	102	25	24.5
Dunkirk River Reference	108	19	17.6
Horse River Reference	111	83	74.8

Figure 5.4-15 Condition factor for Steepbank River sculpin captured during the October 2004 sentinel species program.

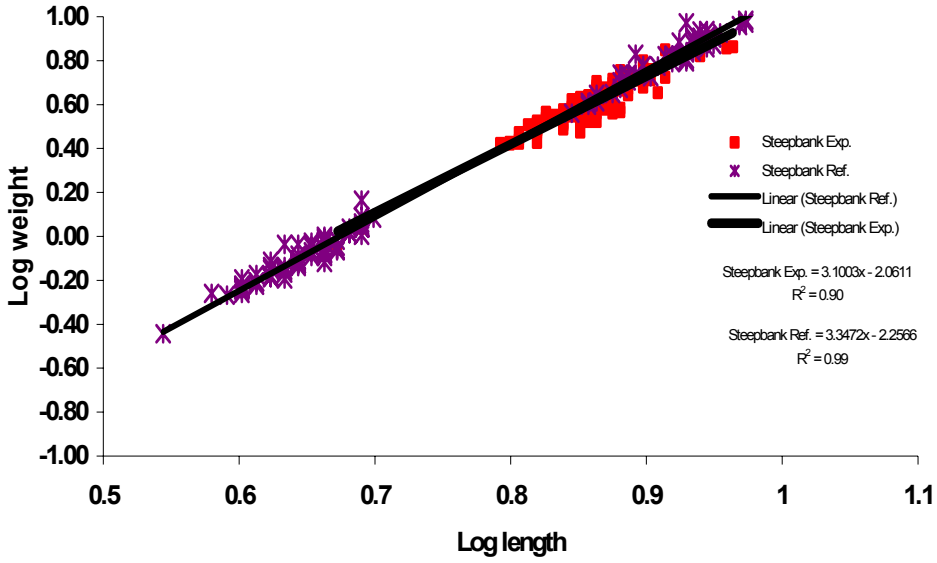


Table 5.4-17 Mean condition factor of sculpin (excluding YOY fish) from reference and exposures sites, October 2004.

Estimate	Steepbank River		Dunkirk	Horse	Muskeg
	Reference	Exposure	River	River	River
Sample Size	45	100	94	30	90
Mean	1.16 C	1.069 B	0.968 A	1.038 AB	0.983 A
SE	0.015	0.01	0.01	0.02	0.01

Values with different letters indicate significant differences between sites as determined through ANOVA ($p<0.05$) and Bonferroni adjusted multiple comparisons. Sites with the same letter were not significantly different from each other; sites with different letters were significantly different from each other.

Table 5.4-18 Effect summary for condition factor[1] of sculpin from the Steepbank River exposure site relative to reference sites, October 2004.

Reference Site	Effect[2]	% Difference[3]
Steepbank River	No-	-7.8
Dunkirk River	Yes	+10.4
Horse River	No	+3.0 ns
Mean of all Reference Sites[4]	No	+1.3 ns

[1] Condition Factor = (weight)/(length^3) * 10^5
[2] Effect when condition > ± 10% of reference mean.
[3] Percent difference of exposed site relative to reference site; ns = not significantly different.
[4] Note significant differences present among reference sites.

Table 5.4-19 Effect summary for condition factor[1] of sculpin from the Muskeg River exposure site relative to reference sites, October 2004.

Reference Site	Effect[2]	% Difference[3]
Steepbank River	Yes	-15.3
Dunkirk River	No	+1.5 ns
Horse River	No	-5.3 ns
Mean of all Reference Sites[4]	No	-6.9

[1] Condition Factor = (weight)/(length^3) * 10^5
[2].Effect when condition > ± 10% of reference mean.
[3] Percent difference of exposed site relative to reference site; ns = not significantly different.
[4] Note significant differences present among reference sites.

5.5 TAR RIVER SYSTEMS

Summary of Results

Climate and Hydrology

	Assessment of Change			
	Negligible	Low	Moderate	High
Mean open-water season discharge	√			
Mean winter discharge	√			
Annual maximum daily discharge	√			
Minimum open-water season discharge	√			

Oil sands development activities began in September 2004, but were considered to have had negligible effect on 2004 discharges. Therefore, the effect of oil sands activities on hydrologic conditions in 2004 is determined to be negligible.

Water Quality

Guideline Exceedances

	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=1)	2004 Reference Stations (n=1)
Physical variables (3 endpoints)	0	0
Nutrients (5 endpoints)	1	1
Ions (5 endpoints)	0	0
Organic compounds (1 endpoint)	0	0
Selected metals (5 endpoints)	1	0

Comparison to Regional Baselines

	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 1 station X 7 endpoints)	2004 Reference Stations (n= 1 station X 7 endpoints)
Above 95th	2	0
Between 75th and 95th	2	0
Between median and 75th	1	4
Between 25th and median	2	2
Between 5th and 25th	0	1
Less than 5th	0	0

A number of measurement endpoints in fall 2004, notably total phosphorus and total aluminum, were above the 95th percentile of regional baseline concentrations. However, general ion balance was not notably different in 2004 than in previous years, indicating that water quality in 2004 was likely related to increased suspended particulates rather than changes in the dissolved component of water quality. Water quality conditions in 2004 may have been due to both oil sands activities that commenced in the Tar watershed in the latter half of 2004 and natural environmental conditions on the 2004 sampling day.

Sediment Quality

Guideline Exceedances

	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=1)	2004 Reference Stations (n=1)
Physical variables (4 endpoints)	0	0
Total Hydrocarbons (8 endpoints)	1	0
PAHs (7 endpoints)	0	0

Comparison to Regional Baselines

	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 1 station X 3 endpoints)	2004 Reference Stations (n= 1 station X 3 endpoints)
Above 95th	0	0
Between 75th and 95th	0	2
Between median and 75th	3	1
Between 25th and median	0	0
Between 5th and 25th	0	0
Less than 5th	0	0

At TAR-1, fraction 3 hydrocarbons exceeded CCME guidelines. Predicted PAH toxicity was the highest observed at any RAMP station in 2004, and among the highest of any RAMP sediment sample since 1997. Fraction 2 and Fraction 4 hydrocarbon concentrations were much higher at TAR-1 than at TAR-2. However, hydrocarbon, naphthalene and PAH concentrations at TAR-1 from 1998 to 2004 do not indicate any apparent trends over time, suggesting that the high 2004 values may be related to finer sediments and the organic carbon content of the 2004 sample.

Benthic Invertebrate Communities

Comparison to Regional Baselines

	Endpoints in 2004 Compared to Regional Baseline					
	2004 Exposed Stations (n= 1)			2004 Reference Stations (n= 1)		
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD
Abundance		1			1	
Richness		1			1	
Diversity		1			1	
Evenness		1			1	
% EPT		1			1	

While potentially subtle shifts in benthic community composition occurred in 2004 that correspond with the commencement of oil sands development activities, indices of community composition have to date remained generally within the expected ranges for regional baseline conditions.

Fish Populations

Fish Inventory

No fish inventory studies were conducted in the Tar River in 2004.

Sentinel Studies

Sentinel fish studies were not conducted in 2004.

Fish Tissue

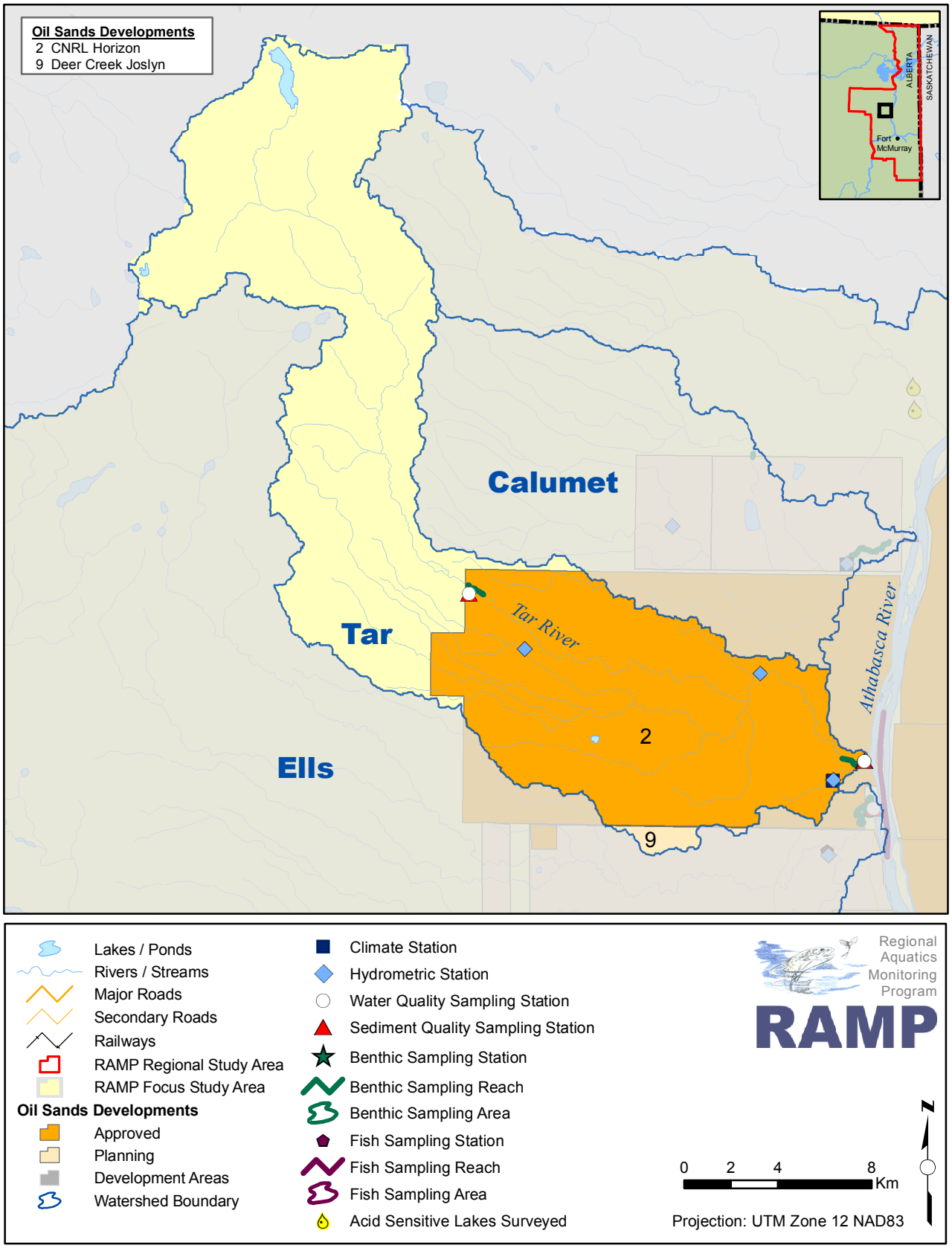
	Level of Risk
Human Health: Subsistence	
Human Health: Recreational Fishers	
Human Health: General Consumers	Fish tissue program was not conducted in the Tar River in 2004.
Human Health: Tainting	
Fish and Wildlife: Mercury	
Fish and Wildlife: Other Chemicals	

[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 Hydrologic Conditions

Runoff in the Tar River system, as measured near the mouth at S15, Tar River (07DA015, designated as an exposed location from summer 2004), was below the historical average. Using the natural drainage area of 301 km^2, the total runoff for the year was 23 mm, compared to the historical mean of 41 mm. However, the drainage area contributing to the gauge has been reduced by upstream diversions, as discussed below. The only significant flow occurred in June, as shown in Figure 5.5-2. The maximum daily discharge of 6.7 m^3/s was almost exactly equal to the mean annual flood of 6.6 m^3/s. The minimum observed open-water discharge was 0.15 m^3/s, which is less than half of the seven-year mean minimum discharge of 0.31 m^3/s.

CNRL constructed two stream diversions in the Tar River basin in 2004 (Section 2). The D-6 diversion in the upper catchment was constructed in May and June; it transfers water from two tributaries of the Tar River to the main stem. That diversion had no effect on the hydrograph at Station S15. The D-7 diversion, constructed between May and September, removes water from a Tar River tributary upstream of the plant site and returns it to the Tar River downstream of S15. The D-7 diversion therefore reduces the discharge observed at S15.

Parameters used for the application of the water balance model to the Tar River basin in order to examine possible changes in the hydrologic measurement endpoints are provided in Table 5.5-1. Clearing and muskeg dewatering began in the second half of 2004, but specific areas cleared and dewatered in 2004 were not known at the time of report preparation. Construction activities for CNRL Horizon have only just begun and there are negligible areas of oil sands developments that would have intercepted runoff in the CNRL Horizon project in 2004. In addition, an estimated 5,220 m^3 of water was withdrawn from the Tar River by the CNRL Horizon Project in 2004. This Tar River withdrawal was a very small portion of the total Tar River discharge measured at Station S15. In addition, the D-7 diversion and muskeg dewatering are expected to influence streamflows in the Tar River in 2005, but are considered to have had negligible effect on 2004 discharges. Therefore, based on data from S15, the overall effect of oil sands activities on hydrologic conditions in 2004 is determined to be negligible.

5.5.2 Water Quality

In 2004, water quality samples were collected from the mouth of the Tar River (station TAR-1), where sampling has occurred since 2000, and upstream of the CNRL Horizon Project (station TAR-2, newly established in 2004) in September. Station TAR-1 is designated as an exposed station from summer 2004 onwards, while station TAR-2 is designated as a reference water quality station. Results of 2004 sampling for selected water quality measurement endpoints identified in Section 3.2.7 are shown in Table 5.5-2; results for selected measurement endpoints (1997 to 2004) relative to regional baseline conditions are shown in Figure 5.5-3.

Several water quality variables were higher in the Tar River at its mouth (TAR-1, exposed) in fall 2004 relative in previous years. Water quality measurement endpoints were below CCME guidelines for protection of aquatic life except for total phosphorous and total aluminum (Table 5.5-2). However, these two variables, as well as TSS, total iron

and total copper exhibited historically high concentrations in fall 2004. The CNRL Horizon project began clearing and draining of land in 2004; site drainage to the lower Tar River just upstream of TAR-1 was observed in fall 2004. On the specific day of sampling, heavy rain may have contributed to the volume of discharge from this drainage to the Tar River, which in turn may have contributed to the historically high TSS value observed at TAR-1 in fall 2004 relative to previous years (i.e., 214 mg/L vs. 15 to 75 mg/L, respectively) (Table 5.5-2, Figure 5.5-3). Many of the other water quality variables that exhibited historical highs at TAR-1 in 2004 are known to be related to suspended material. A number of these measurement endpoints in fall 2004, notably total phosphorous and total aluminum, were above the 95th percentile of regional concentrations for reference sites (Figure 5.5-3). However, general ion balance at TAR-1 was not notably different in 2004 than in previous years (Figure 5.5-4), supporting the notion that much of the change in water quality at TAR-1 in 2004 was related to increased suspended particulate matter rather than changes in the dissolved component of water quality.

Water quality in the upper Tar River (TAR-2, reference) in fall 2004 for most measurement endpoints was within ranges observed at TAR-1 prior to 2004 (Table 5.5-2). In fall 2004, all water quality measurement endpoints observed at station TAR-2 were below CCME guidelines for protection of aquatic life except for total phosphorous. The ion balance at station TAR-2 in fall 2004 was similar to the ion balance to the lower Tar River (station TAR-1) in 2004 and earlier years (Figure 5.5-4), suggesting that this new upstream location is an appropriate reference site for assessing changes at TAR-1 which is now designated as exposed. Concentrations of all water quality variables at station TAR-2 were within the normal range of regional concentrations for reference stations (Figure 5.5-3).

Based on available water quality information, it appears that the water quality conditions measured in 2004 may have been due to a combination of oil sands development activities that commenced in the Tar River watershed in the latter half of 2004 and natural environmental conditions on the specific day that 2004 sampling occurred.

Table 5.5-3 contains a list of all exceedances of CCME guidelines for protection of aquatic life observed in the Tar River in 2004.

5.5.3 Sediment Quality

In 2004, sediment quality samples were collected from the mouth of the Tar River (station TAR-1), where sampling occurred once in 1998 and every year since 2002, and upstream of the CNRL Horizon Project (station TAR-2, newly established in 2004) in September 2004. Sediment quality station TAR-1 is designated as an exposed station from summer 2004 onwards, while station TAR-2 is designated as a reference sediment quality station. Results of 2004 sampling for selected sediment quality measurement endpoints identified in Section 3.2.7 are shown in Table 5.5-4; results for selected measurement endpoints (1997 to 2004) relative to regional baseline conditions are shown in Figure 5.5-5.

In 2004, sediments in the lower Tar River (TAR-1, exposed) exhibited finer particle sizes, higher organic carbon, higher hydrocarbons, and relatively high metals and PAHs than in previous years (Table 5.5-4). CCME Fraction 3 (C16-C34) hydrocarbons exceeded

CCME ISQG surface soil guidelines. Predicted PAH toxicity at this station (i.e., a Hazard Index of 4.84) was the highest observed at any RAMP station in 2004, and among the highest calculated for any sediment sample collected by RAMP since 1997. In addition, concentrations of Fraction 2 (C10-C16) and Fraction 4 (C34-C50) hydrocarbons, while not above CCME ISQG guidelines, were much higher at station TAR-1 than at station TAR-2. However, carbon-normalized hydrocarbon, naphthalene and PAH concentrations at this station from 1998 to 2004 do not indicate any apparent trend in these compounds over time (Figure 5.5-5), suggesting that the high values observed in 2004 may be related to the finer sediments and higher organic carbon content of the sample collected in 2004 relative to previous years. It is not known if the finer sediments and higher organic carbon content observed were due to natural conditions or conditions created in part by the commencement of oil sands development activities in the watershed in 2004.

Sediment quality in the upper Tar River (TAR-2, reference) was typical of headwater tributaries in the RAMP study area, namely very sandy, low in organic carbon, and low in metal, hydrocarbon and PAH concentrations (Table 5.5-4). None of the sediment quality measurement endpoints sampled at station TAR-2 in fall 2004 had concentrations that exceeded CCME ISQG surface soil guidelines.

Based on available sediment quality information, it appears that the sediment quality conditions measured in 2004 were within regional ranges of concentrations for reference conditions, with the exception of some of the CCME total hydrocarbon variables. Future sampling will obviously be required to determine the significance of elevated CCME variables noted in 2004 and to ascertain the reasons for any continued elevation in these measurement endpoints.

5.5.4 Benthic Invertebrate Communities

In 2004, benthic invertebrate community samples were collected from a reach near the mouth of the Tar River (reach TAR-D 1-15, depositional) and upstream of the CNRL Horizon Project (reach TAR-E 1-15, erosional). Reach TAR-D 1-15 is designated as an exposed reach and sampling area from summer 2004, while site TAR-E 1-15 remains designated as a reference reach and a baseline benthic invertebrate community sampling site.

Reach TAR-D 1-15 is deeper than reach TAR-E 1-15, with no measurable water current, macrophyte cover, or benthic algae. In contrast, current velocity in reach TAR-E 1-15 was moderate, a few macrophytes were evident and a small community of benthic algae was measured on substrata (Table 5.5-5). Dissolved oxygen, conductivity and pH were similar between the two reaches, whereas water temperatures were much warmer in the lower reach than the upper reach. Sediments in the lower reach were heavily dominated by sand, while substrates in the upper reach were dominated by cobble and gravel.

Chironomids formed approximately 1/3 of the benthic communities in both the lower and upper reaches (Table 5.5-6). In reach TAR-D 1-15, Ostracoda, Nematoda, and Ceratopogonidae were also abundant. By comparison, the EPT taxa (Ephemeroptera, Plecoptera, Trichoptera) combined represented nearly half of the benthic invertebrates present in TAR-E 1-15. Hydracarina was also abundant in reach TAR-E 1-15.

Community composition (based on Correspondence Analysis) of the lower reach of the Tar River (TAR-D 1-15) has for the most part been within expected regional reference conditions for depositional habitats since benthic invertebrate community data collection began on the lower Tar River in 2002 with the exceptions of a sampling location in 2002 and one sampling location in 2004 (Figure 5.5-6).

Benthic invertebrate community measurement endpoints have also been within expected values for regional reference conditions for depositional habitats near the mouth of the Tar River at reach TAR-D 1-15 (Figure 5.5-7). Richness and Simpson's Diversity declined slightly whereas percent EPT taxa increased slightly over the three year sampling period, but these shifts have been well within the range of normal natural variability exhibited in regional reference reaches. Although the upper erosional reach (reach TAR-E 1-15) has only been sampled for two years, richness and diversity decreased and percent EPT increased between 2003 and 2004 (Figure 5.5-8). As expected, benthic community indices for the upper reach of the Tar River were all within the expected regional reference condition ranges for erosional habitats.

Given that reach TAR-D 1-15 was designated as an exposed reach beginning in the summer of 2004 and, given that reach TAR-E 1-15 was sampled in 2003 and 2004, it was possible to compare conditions in both reaches both pre and post impact with planned comparisons following an analysis of variance (Table 5.5-7). Differences in the lower reach between the pre-impact period (2002-2003) and the post-impact period (2004) were also tested. As with the Muskeg River system (Section 5.3.4), both erosional and depositional habitats were expected to have similar trends over time because they are in the same basin, even though the absolute measurement endpoint values are expected to be naturally different. In general, while benthic invertebrate community indices differed between years (2003 and 2004) and between reaches, the time trends were generally similar between upper and lower reaches (Table 5.5-7). The exceptions to this pattern were evenness, where there was a drop in the lower reach but not in the upper reach between 2003 and 2004, and % EPT taxa, where increases were detected in both reaches between 2003 and 2004, the increase in the upper reach being more pronounced than in the lower reach.

In summary, the analysis suggests that, while potentially subtle shifts in benthic community composition have occurred that correspond with the commencement of oil sands development activities, indices of community composition have to date remained generally within the expected ranges for regional baseline conditions.

5.5.5 Fish Populations

The 2004 RAMP fish program did not include any activities in the Tar River system.

5.5.6 Summary of Conditions

Monitoring activities in the Tar River watershed in 2004 included hydrology, water and sediment quality (with reference water quality and sediment quality stations established in the upper Tar River in 2004), and a benthic invertebrate survey during a period when part of the watershed became designated as exposed. The Tar River watershed in 2004 showed some changes in RAMP aquatic resources from previous years. The overall

effect of oil sands activities on hydrologic conditions in 2004 is determined to be negligible. Water quality conditions measured in 2004 may have been due to a combination of oil sands development activities that commenced in the Tar River watershed in the latter half of 2004 and natural environmental conditions on the specific day that 2004 sampling occurred. Sediment quality conditions measured in 2004 were within regional ranges of concentrations for reference conditions, with the exception of some of the CCME variables. Finally, while potentially subtle shifts in benthic community composition may have occurred with the commencement of oil sands development activities, indices of community composition to date remain generally within the expected ranges for regional baseline sediment quality conditions.

Figure 5.5-2 Tar River 2004 hydrograph and historical context.

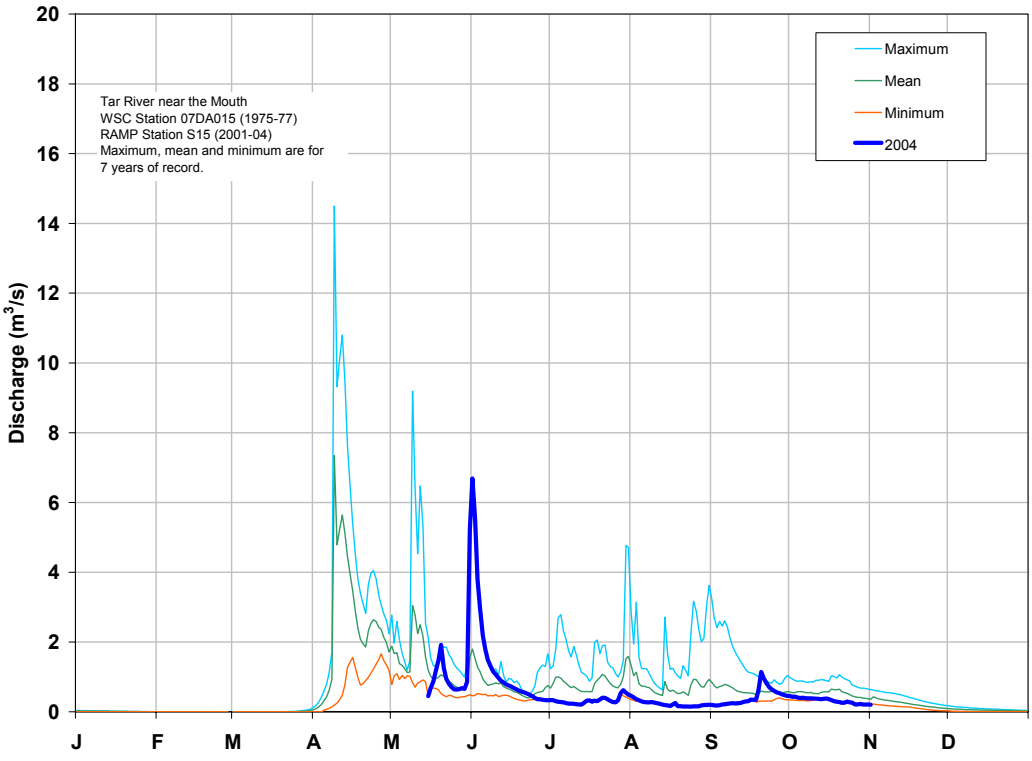


Table 5.5-1 Summary of parameter values for Tar River water balance calculation.

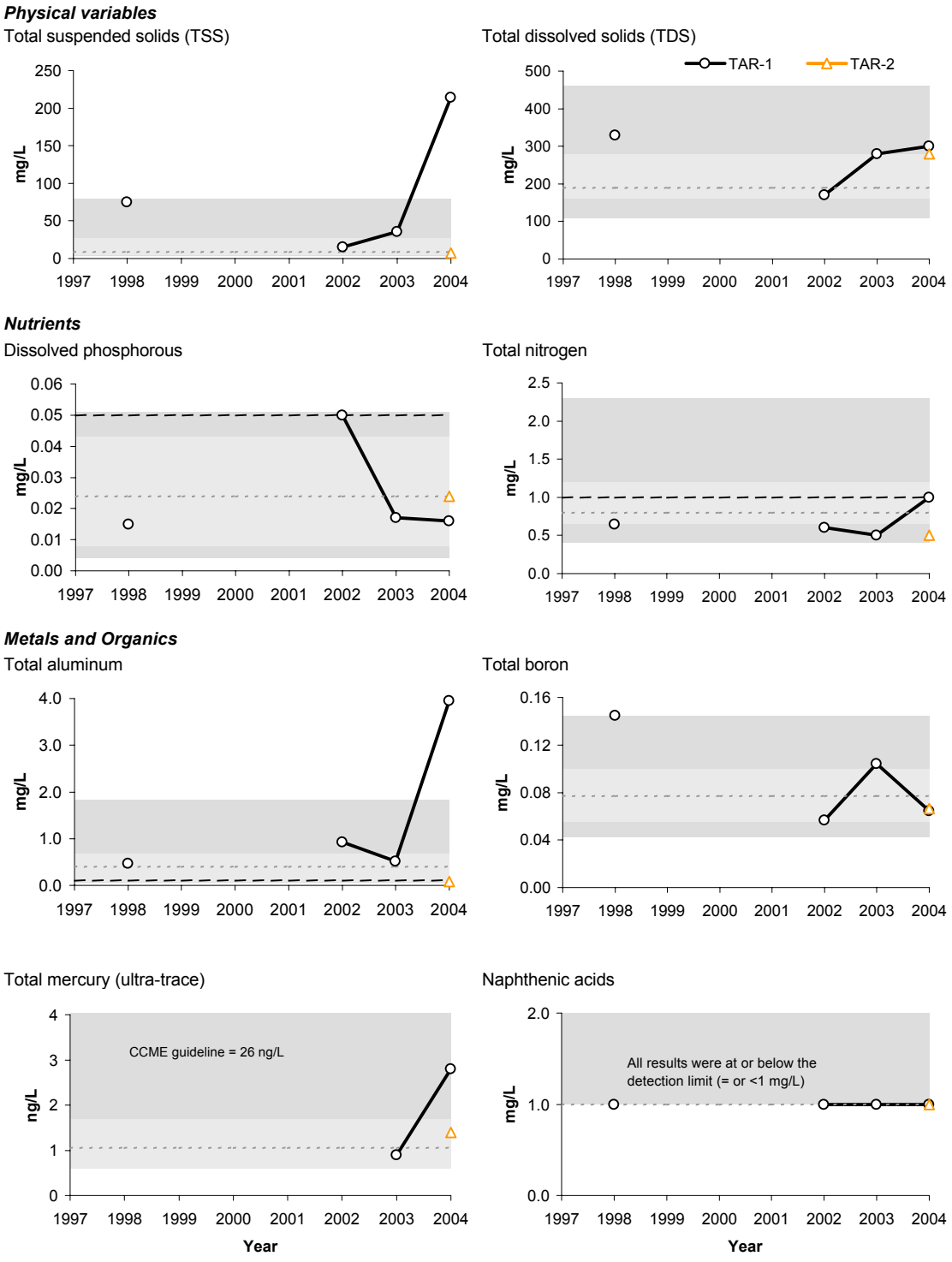
Component	Value	Basis / Data Source
Observed 2004 hydrograph	Daily discharges	Hydrometric Stations S15 and 07DA015
natural runoff from active oil sands development areas, or intercepted by development	0	Construction activities for CNRL Horizon have only just begun and are assumed negligible for 2004
incremental runoff from areas that are cleared and areas that are dewatered	No estimate	Clearing and de-watering occurred in the CNRL Horizon project in 2004 (Section 2) but estimates of areas cleared and dewatered in the second half of 2004 were not available
water withdrawals from the watercourse in question by oil sands development activities	Estimated total of 5220 m^3	Information obtained from CNRL Horizon project
water releases to the watercourse in question by oil sands development activities	0	Based on location of diversion
the difference between naturalized and observed hydrographs on tributaries upstream of the station in question	none	No significant upstream developments

Table 5.5-2 Selected water quality variables in the lower and upper Tar River, fall 2004.

	Units	Guideline	September 2004		1997-2003 (TAR-1, fall data only)			
			TAR-1	TAR-2[3]	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.2	8.3	3	8.1	8.1	8.2
Total suspended solids	mg/L	-	214	7	3	15	36	75
Conductivity	mg/L	-	304	297	3	302	427	493
Nutrients								
Total phosphorus	mg/L	0.05	**0.232**	**0.053**	3	**0.057**	**0.082**	**0.085**
Dissolved phosphorus	mg/L	0.05[1]	0.016	0.024	3	0.015	0.017	0.05
Total nitrogen*	mg/L	1.0	1.0	0.5	3	0.5	0.6	0.7
Nitrate+nitrite	mg/L	-	0.1	<0.1	3	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	16	8	3	12	13	14
Ions								
Sodium	mg/L	-	19	16	3	15	27	32
Chloride	mg/L	230, 860[4]	4	2	3	2	2	5
Sulphate	mg/L	100[5]	29.3	29.9	3	20.4	31.5	42
Total dissolved solids	mg/L	-	300	280	3	170	280	330
Total alkalinity	mg/L		153	159	3	139	189	210
Organic compounds								
Naphthenic acids	mg/L	-	1	<1	3	<1	<1	<1
Selected metals								
Total aluminum	mg/L	0.1	**3.95**	0.087	3	**0.470**	**0.514**	**0.924**
Dissolved aluminum	mg/L	0.1[1]	0.0145	0.008	3	0.0047	0.0101	0.02
Total boron	mg/L	1.2[5]	0.0646	0.0663	3	0.0568	0.104	0.145
Total molybdenum	mg/L	0.073	0.0004	0.0014	3	0.0012	0.0017	0.002
Total mercury (ultra-trace)	ng/L	26	2.8	1.4	1	-	-	0.9
Other variables that exceeded CCME/AENV guidelines in fall 2004								
Total phenols	mg/L	0.004	**0.007**	-	3	0.001	0.001	0.004
Total copper	mg/L	0.002-0.004[2]	**0.0044**	-	3	0.0015	0.0021	0.004
Total iron	mg/L	0.300	**7.03**	**0.92**	3	**1.46**	**1.69**	**2.63**

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] New station in 2004. No previous data are available.
[4] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[5] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.5-3 Concentrations of selected water quality measurement endpoints in the Tar River relative to regional baseline concentrations.



[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 E for these regional baseline ranges.

Figure 5.5-4 Ion composition of Tar River waters, fall 1998-2004.

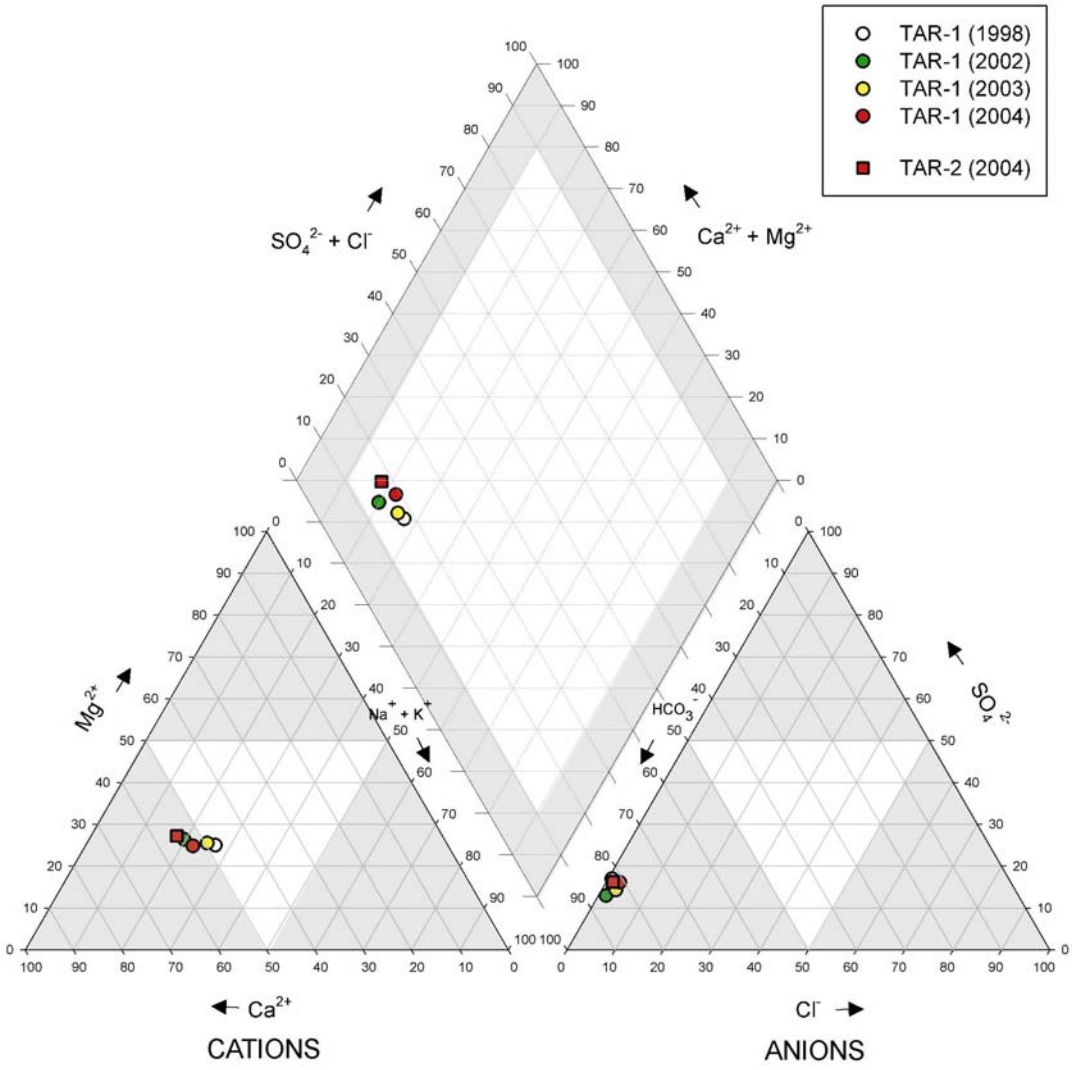


Table 5.5-3 List of all 2004 water quality guideline exceedances, Tar River.

Parameter	Units	Guideline	TAR-1	TAR-2
Winter [1]				
Total iron	mg/L	0.300	**1.22**	ns
Spring				
Total copper	mg/L	0.002-0.004[3]	**0.00246**	**0.00288**
Total aluminum	mg/L	0.100	**1.06**	**1.83**
Total iron	mg/L	0.300	**2.71**	**4.49**
Dissolved iron	mg/L	0.300[2]	**0.623**	**0.546**
Total phosphorus	mg/L	0.05	**0.101**	**0.204**
Summer				
Total aluminum	mg/L	0.100	**1.05**	**1.82**
Total iron	mg/L	0.300	**2.17**	**3.51**
Total phosphorus	mg/L	0.05	**0.089**	**0.154**
Fall				
Total phenols	mg/L	0.004	**0.007**	-
Total copper	mg/L	0.002-0.004[3]	**0.00441**	-
Total aluminum	mg/L	0.100	**3.95**	-
Total iron	mg/L	0.300	**7.03**	**0.92**
Dissolved iron	mg/L	0.300[2]	-	**0.403**
Total phosphorus	mg/L	0.05	**0.232**	**0.053**

Guidelines are CCME/AENV guidelines for the protection of aquatic life.
[1]: TAR-2 not sampled in winter.
[2]: Guideline is for total analyte (no guideline for dissolved species).
[3]: Guideline is hardness dependent.
ns: not sampled.

Table 5.5-4 Selected sediment quality measurement endpoints, Tar River, fall 2004.

	Units	Guideline	September 2004		1997-2003 (TAR-1, fall data only)			
			TAR-1	TAR-2	n	Min	Median	Max
Physical variables								
Clay	%	-	26	5	2	12	-	20
Silt	%	-	50	6	2	13	-	34
Sand	%	-	24	89	2	46	-	75
Total organic carbon	%	-	6.3	0.3	2	0.87	-	1.1
Total hydrocarbons								
CCME variables								
BTEX	mg/kg	-	<5	<5	-	-	-	-
Fraction 1 (C6-C10)	mg/kg	30[2]	<5	<5	-	-	-	-
Fraction 2 (C10-C16)	mg/kg	150[2]	100	<5	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**810**	<5	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	360	<5	-	-	-	-
AEP Tier 1 variables								
TVH (C5-C10)	mg/kg	-	<0.5	<0.5	1	-	-	2.9
TEH (C11-C30)	mg/kg	-	280	<5	1	-	-	720
TRH	mg/kg	-	2300	500	2	800	-	1820
Polycyclic Aromatic Hydrocarbons (PAH)								
Naphthalene	mg/kg	0.0346[3]	0.004	0.002	3	0.001	0.004	0.015
Retene	mg/kg	-	0.38	0.001	2	0.023	-	0.043
Total dibenzothiophenes	mg/kg	-	6.3	0.005	3	0.15	0.56	0.94
Total PAHs	mg/kg	-	19.1	0.10	3	0.62	1.9	2.8
Total HMW PAHs	mg/kg	-	5.5	0.02	3	0.10	0.62	0.64
Total LMW PAHs	mg/kg	-	13.7	0.07	3	0.52	1.3	2.1
Predicted PAH toxicity[1]	H.I.	-	4.8	0.09	3	0.20	1.6	1.8
Metals that exceed CCME guidelines in fall 2004								
Total Arsenic (As)	mg/kg	5.9[3]	**9.5**	-	2	3.2	-	5.2
Chronic toxicity								
Chironomus survival	# surviving	-	-	-	1	-	-	7
Chironomus growth	mg/organism	-	-	-	1	-	-	2
Hyallela survival	# surviving	-	-	-	1	-	-	9
Hyallela growth	mg/organism	-	-	-	1	-	-	0.1

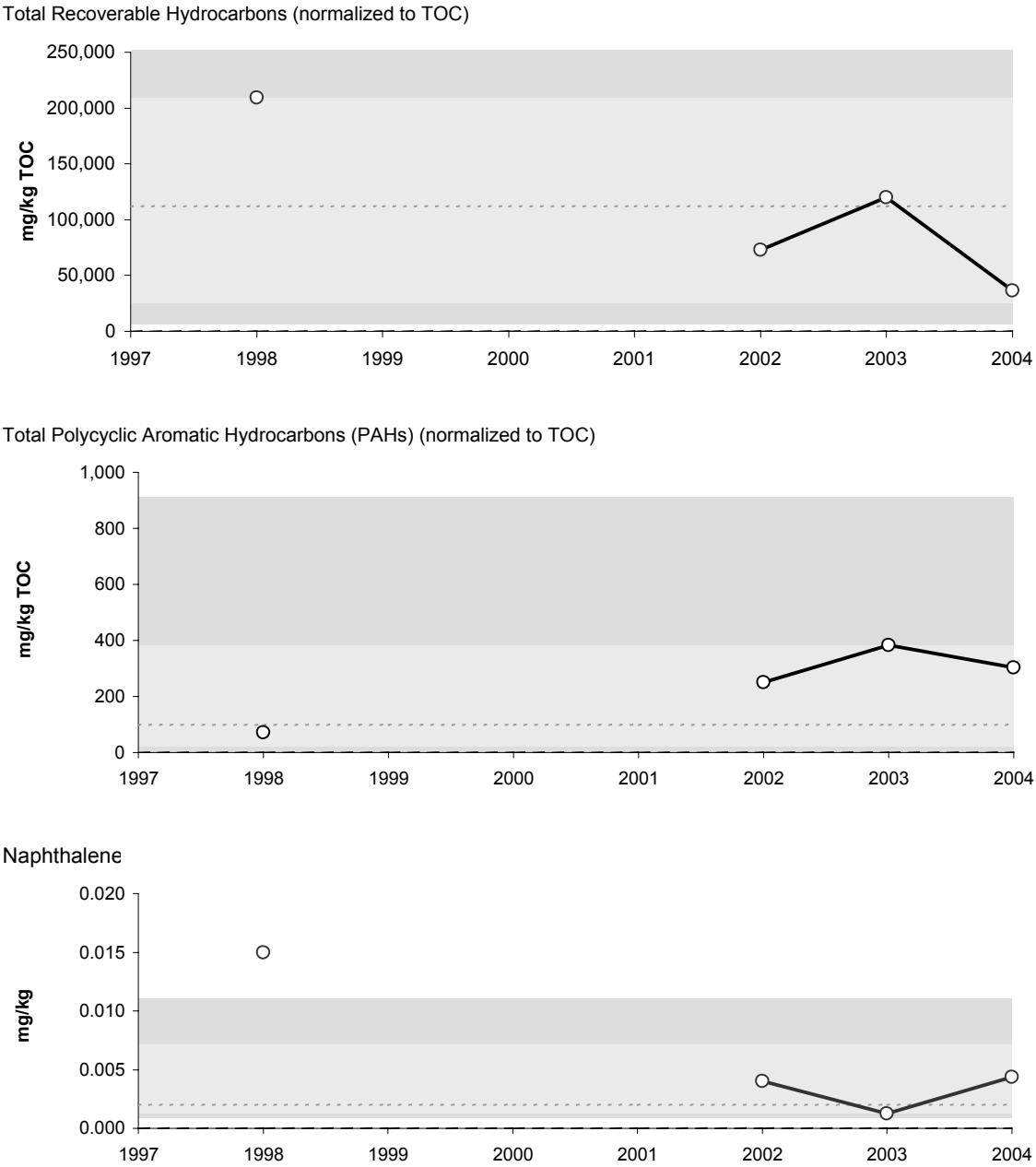
Note: unless otherwise noted, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

[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 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 F for these regional baseline ranges.

Table 5.5-5 Average habitat characteristics of benthic invertebrate sampling reaches in the Tar River, fall 2004.

Variable	Units	Lower Reach of the Tar River	Upper Reach of the Tar River
Sample date	-	Sept 16, 2004	Sept 10, 2004
Habitat	-	Depositional	Erosional
Water depth	m	0.6	0.2
Current velocity	m/s	0	0.5
Macrophyte cover	%	0	1.3
Benthic algae	mg/m^2	n/a	24
Field Water Quality			
Dissolved oxygen	mg/L	11	11.3
Conductivity	µS/cm	421	405
pH		8.4	8.3
Water temperature	°C	9.1	4.0
Sediment Composition			
Sand	%	92.3	n/a
Silt	%	3.5	n/a
Clay	%	4.1	n/a
Total Organic Carbon	%	0.4	n/a
Sand/Silt/Clay	%	n/a	5.3
Small gravel	%	n/a	7.3
Large gravel	%	n/a	13.7
Small cobble	%	n/a	33.7
Large cobble	%	n/a	28.7
Boulder	%	n/a	12
Bedrock	%	n/a	0

Table 5.5-6 Summary of major taxon abundances and key indices of composition among reaches in the Tar River, fall 2004.

Taxon	Lower Reach of the Tar River			Upper Reach of the Tar River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Nematoda	5,474	15,479	17.1	140	360	1.8
Erpobdellidae	1,149	4,267	3.6	29	0	0.4
Enchytraeidae	727	1,120	2.3	166	213	2.1
Naididae	175	190	0.5	22	93	0.3
Tubificidae	405	526	1.3	66	170	0.8
Hydracarina	782	2,031	2.4	729	1775	9.3
Ostracoda	5,825	17,818	18.1	0	0	0
Copepoda	270	427	0.8	0	0	0
Chydoridae	86	305	0.3	0	0	0
Gastropoda	816	4,385	2.5	0	0	0
Ephemeroptera	259	602	0.8	1,332	697	16.9
Plecoptera	718	0	2.2	987	440	12.6
Trichoptera	23	0	0.1	1,317	506	16.8
Coleoptera	40	199	0.1	1	0	0.0
Tipulidae	115	0	0.4	57	109	0.7
Dolichopodidae	233	1,074	0.7	1	0	0.0
Tabanidae	49	335	0.2	0	0	0
Empididae	316	1,539	1.0	154	295	2.0
Ceratopogonidae	2,509	3,528	7.8	100	0	1.3
Chironomidae	12,132	7,601	37.8	2,573	870	32.7
Simuliidae	0	0	0	171	555	2.2
Megaloptera	0	0	0	17	0	0.2
Total Abundance	**32,103**	**22,903**	**-**	**7,861**	**3,684**	**-**
Richness	10.6	3.3	-	19.5	3.1	-
Simpson's Diversity	0.612	0.183	-	0.823	0.050	-
Evenness	0.687	0.208	-	0.868	0.051	-

Figure 5.5-6 Biplot of benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for the Lower Tar (exposed as of summer 2004).

Ellipse is for reference data.

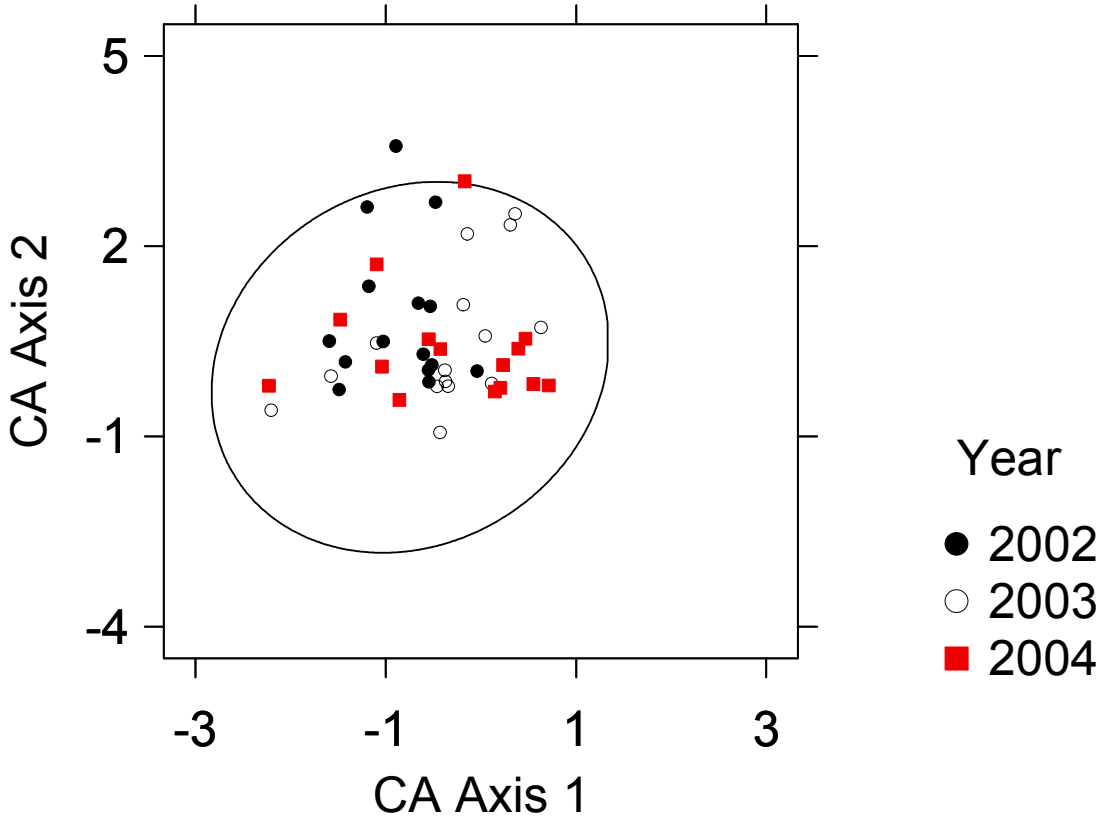
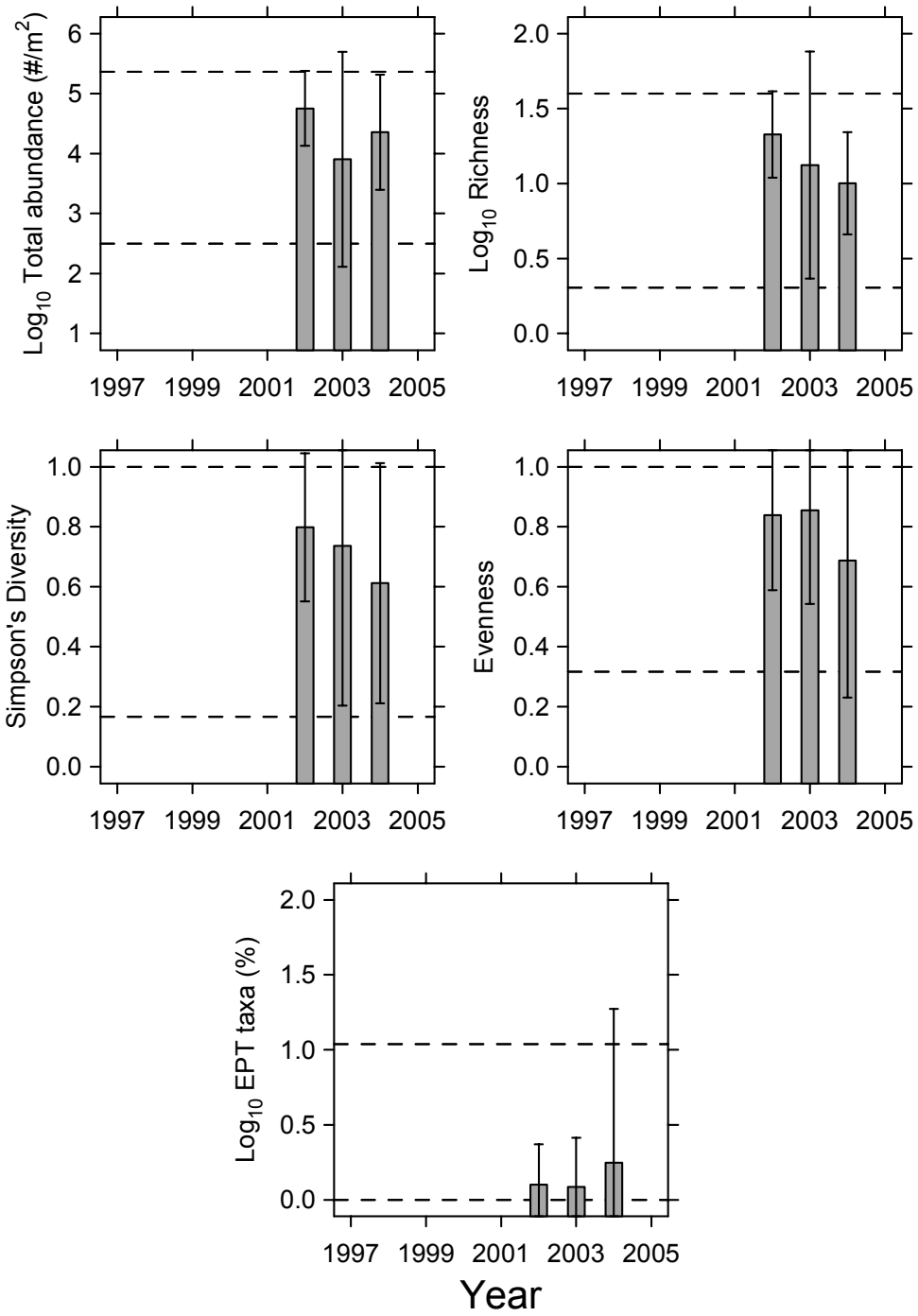
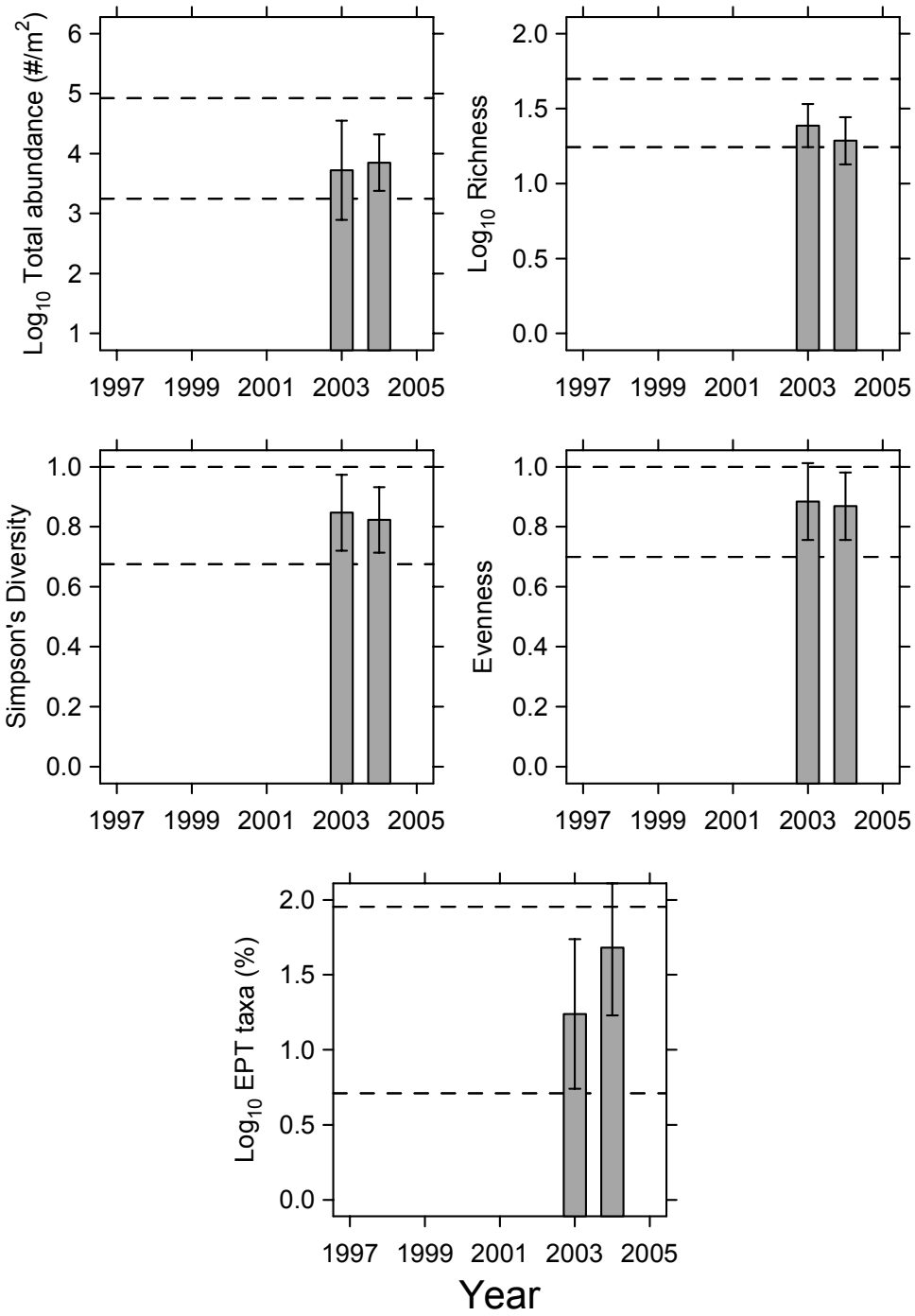


Figure 5.5-7 Variations in indices of benthic invertebrate community composition in the Tar River, lower reach (TAR-D 1-15).



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

Figure 5.5-8 Variations in indices of benthic invertebrate community composition in the Tar River, upper reach (TAR-E 1-15).



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

Table 5.5-7 Results of analysis of variance between lower and upper reaches of the Tar River for subset of benthic invertebrate community measurement endpoints.

Source	SS	df	F	P
Log_{10} Abundance				
Reach-Year	11.05	4	12.26	<0.001
Time (2003-2004)	1.267	1	5.622	0.020
Reach	1.787	1	7.930	0.006
Time × Reach	0.388	1	1.721	0.194
Pre-Post lower reach	0.007	1	0.032	0.859
Reach (2004)	1.919	1	8.520	0.005
Error	15.77	70		
Log_{10} Richness				
Reach-Year	1.503	4	11.08	<0.001
Time (2003-2004)	0.186	1	5.470	0.022
Reach	1.120	1	33.03	<0.001
Time × Reach	0.002	1	0.044	0.834
Pre-Post lower reach	0.498	1	14.68	<0.001
Reach (2004)	0.602	1	17.75	<0.001
Error	2.375	70		
Simpson's Diversity				
Reach	0.533	4	6.019	<0.001
Time (2003-2004)	0.084	1	3.780	0.056
Reach	0.388	1	17.55	<0.001
Time × Reach	0.038	1	1.719	0.194
Pre-Post lower reach	0.243	1	10.96	0.001
Reach (2004)	0.335	1	15.13	<0.001
Error	1.548	70		
Evenness				
Reach	0.382	4	5.770	<0.001
Time (2003-2004)	0.126	1	7.609	0.007
Reach	0.166	1	10.04	0.002
Time × Reach	0.087	1	5.269	0.025
Pre-Post lower reach	0.255	1	15.43	<0.001
Reach (2004)	0.247	1	14.93	<0.001
Error	1.157	70		
Log_{10} EPT %				
Reach	32.892	4	117.6	<0.001
Time (2003-2004)	1.374	1	19.641	<0.001
Reach	25.14	1	359.4	<0.001
Time × Reach	0.293	1	4.189	0.044
Pre-Post lower reach	0.239	1	3.423	0.069
Reach (2004)	15.43	1	220.6	<0.001
Error	4.895	70		

5.6 MACKAY RIVER SYSTEM

Summary of Results

Climate and Hydrology

	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge	√				All hydrologic measurement endpoints were estimated to be a maximum of 0.4% lower than what the measurement endpoints 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 2004[1]	
	2004 Exposed Stations (n=1)	2004 Reference Stations (n=1)
Physical variables (3 endpoints)	0	0
Nutrients (5 endpoints)	0	0
Ions (5 endpoints)	0	0
Organic compounds (1 endpoint)	0	0
Selected metals (5 endpoints)	1	0

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 1 station X 7 endpoints)	2004 Reference Stations (n= 1 station X 7 endpoints)
Above 95th	1	1
Between 75th and 95th	1	0
Between median and 75th	3	1
Between 25th and median	0	1
Between 5th and 25th	0	0
Less than 5th	2	4

In general, fall 2004 results for water quality variables were similar to those observed in previous years. Ionic characteristics of the water sampled at both stations have been relatively constant over the period of sampling, suggesting there has been little change in overall water quality conditions in the watershed since the beginning of RAMP sampling. Therefore, based on available water quality information, it appears that there has been little observable change in water quality conditions since oil sands development activities commenced in the MacKay River watershed in 2002.

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=1)	2004 Reference Stations (n=1)
Physical variables (4 endpoints)	0	0
Total Hydrocarbons (8 endpoints)	0	0
PAHs (7 endpoints)	0	0

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 1 station X 3 endpoints)	2004 Reference Stations (n= 1 station X 3 endpoints)
Above 95th	1	0
Between 75th and 95th	0	0
Between median and 75th	2	0
Between 25th and median	0	2
Between 5th and 25th	0	0
Less than 5th	0	1

Sediment quality in the upper and lower MacKay River in 2004 was within the range of observations from previous years. Based on the available sediment quality data, it appears that oil sands development activities that have occurred in the MacKay River watershed since 2002 have had no observable effects on sediment quality conditions within the watershed.

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline					
	2004 Exposed Stations (n= 1)			2004 Reference Stations (n= 1)		
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD
Abundance		1			1	
Richness		1			1	
Diversity		1			1	
Evenness		1			1	
% EPT		1			1	

Differences in time trends suggest the possibility of changes in benthic invertebrate communities in the years designated as operational relative to baseline conditions. Benthic communities were in good condition with all indices for all years falling within expected regional baseline ranges.

Fish Populations

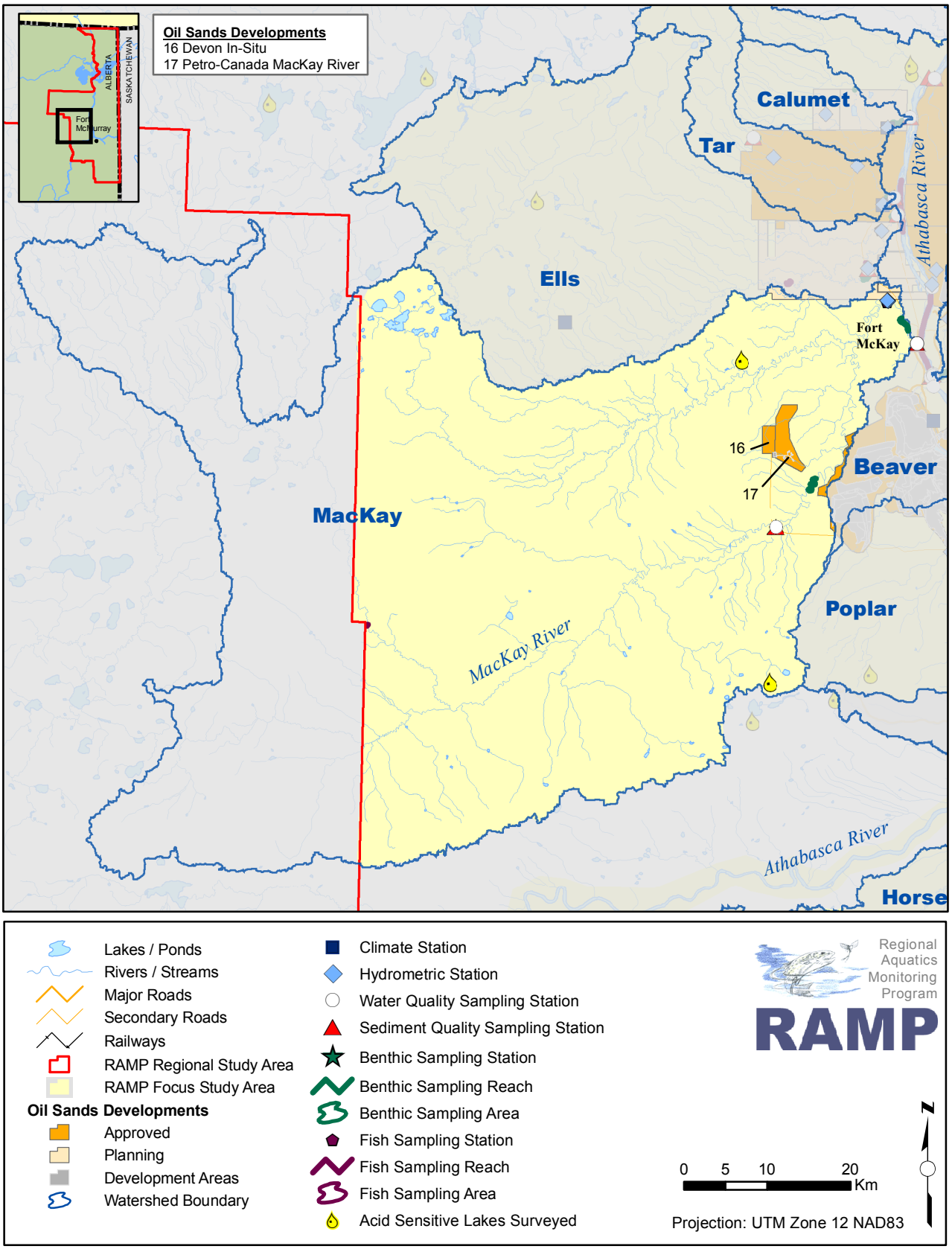
Fish Inventory	No fish inventory studies were conducted in the MacKay River in 2004.
Sentinel Studies	Sentinel fish studies were not conducted in the MacKay River in 2004.
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in the MacKay River in 2004.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	
Fish and Wildlife: Mercury	
Fish and Wildlife: Other Chemicals	

[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.



RAMP1110\GIS\2004_MACKAY.MXD

5.6.1 Hydrologic Conditions

The MacKay River basin was very dry in 2004, with a runoff volume of 29 mm, as measured at RAMP Station S26 and WSC Station 07DB001 (both of which have been designated as operational stations from 2002). For comparison, the average runoff depth in 33 years of record is 77 mm. Rainfall at the end of May and early in June did produce some runoff response in the river, but barely enough to raise the river above its normal discharge for that time of the year. Throughout the summer, the river was nearly dry, with discharges less than 3 m^3/s from early July until mid-September, as shown in Figure 5.6-2. The June maximum daily discharge of 44.9 m^3/s was only 36% of the mean annual flood of 126 m^3/s. The minimum open-water season discharge of 0.93 m^3/s occurred on September 3. In an average year, the minimum open-water discharge is 3.58 m^3/s.

Parameters used for the application of the water balance model for the MacKay River basin for the purposes of creating a naturalized hydrograph to examine possible changes in the hydrologic measurement endpoints are provided in; the results of applying the water balance model are provided in Table 5.6-2 and Figure 5.6-2. The combined lease area of the Petro-Canada and Devon operations, slightly more than 20 km2, represents approximately 0.36% of the entire MacKay River drainage basin. In addition, no surface water withdrawals or releases are known to have been made by the two projects. Therefore, all hydrologic measurement endpoints are estimated to be less than 0.4% less than what the measurement endpoints would have been in the absence of oil sands development activities (Table 5.6-2, Figure 5.6-2). This must also be regarded as a conservative estimate because the actual active oil sands development areas are much less than the total area of the lease boundaries; the amount of water intercepted by these oil sands development activities was likely much less than what was assumed for application of the water balance model. This change would have been assessed as Negligible in most oil sands EIAs (Appendix A). Therefore, based on the available hydrological and oils sands development information, it appears that changes in hydrological conditions up to and including 2004 have been negligible in the MacKay River watershed.

5.6.2 Water Quality

In 2004, water quality samples were collected from the mouth of the MacKay River (station MAR-1) and upstream of the Petro-Canada MacKay River development (station MAR-2) in September. Station MAR-1 is designated as an exposed station from 2002 onwards, while station MAR-2 remains designated as a reference water quality station. Results of 2004 sampling for selected water quality measurement endpoints identified in Section 3.2.7 are shown in Table 5.6-3 and Table 5.6-4; results for selected measurement endpoints (1997 to 2004) relative to regional baseline conditions are shown in Figure 5.6-3.

In general, fall 2004 results for water quality variables were similar to those observed in previous years. Water quality variables were below CCME guidelines for protection of aquatic life except for the following instances:

- At station MAR-1 (exposed):
  - While the concentration of total aluminum (September 2004) slightly exceeded the previously observed station maximum and was five times

higher than the CCME guideline for protection of aquatic life, the observed concentration was within the range observed in regional baseline watercourses;

  - Total iron concentration exceeded CCME guidelines, but was within the previously observed concentration range; and
  - Ion concentrations were above the historical (1998, 2000-2003) median, but was below relevant CCME guidelines and within the historical range.

- At upstream (reference) station MAR-2, total iron concentration exceeded CCME guidelines, but was below previously observed concentrations.

Figure 5.6-4 indicates that ionic characteristics of the water sampled at both stations have been relatively constant over the period of sampling, suggesting there has been little change in overall water quality conditions in the watershed since the beginning of RAMP sampling. Therefore, based on available water quality information, there has been little observable change in water quality conditions within the watershed since oil sands development activities commenced in the MacKay River watershed in 2002.

5.6.3 Sediment Quality

As with water quality, sediment quality samples were collected in September 2004 from the mouth of the MacKay River (station MAR-1, designated as exposed from 2002 onwards) and upstream of the Petro-Canada MacKay River development (station MAR-2, designated as reference). Results of 2004 sampling for selected sediment quality measurement endpoints identified in Section 3.3.7 are shown in Table 5.6-5 and Table 5.6-6; results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.6-5.

Sediment quality in the upper and lower MacKay River in 2004 was within the range of observations of previous years. All sediment quality variables at both stations in fall 2004 were below CCME ISQG and other guidelines. Visible amounts of bitumen and hydrocarbons were apparent in surface sediments during sampling at MAR-1 in 2004, although hydrocarbon and PAH concentrations in 2004 were well below those observed at this station in previous years, including 2001, when sediments from MAR-1 exhibited very high PAH concentrations (i.e., 31.4 mg/kg total PAH) and total hydrocarbons (i.e., TRH=11,300 mg/kg). Sediment characteristics at MAR-2 in 2004 were similar to 2003, the only other year of sampling at this station, and consisted primarily of sand with low concentrations of metals and hydrocarbons. Carbon-normalized concentrations of TRH, total PAHs and naphthalene did not exhibit any consistent trends over time at either station (Figure 5.6-5). As is the case in most smaller tributary systems monitored by RAMP, sediments in the upper MacKay River (MAR-2) exhibited coarser particle sizes, lower organic carbon, and lower metal and PAH concentrations than those near the mouth of the river (MAR-1). Based on the available sediment quality information, it appears that oil sands development activities that have occurred in the MacKay River watershed since 2002 have had no observable effects on sediment quality conditions within the watershed.

5.6.4 Benthic Invertebrate Communities

In 2004, benthic invertebrate community samples were collected from a reach near the mouth of the MacKay River (reach MAR-E 1-15) and upstream of the Petro-Canada MacKay River development (reach MAR-E 16-30). Reach MAR-E 1-15 is designated as an exposed reach and operational sampling area from 2002 onwards, while site MAR-E 16-30 remains designated as a reference reach and a baseline benthic invertebrate community sampling site. Both reaches are erosional.

The lower and upper reaches of the MacKay River system are typical of erosional habitats, with moderate to fast currents and shallow depths (Table 5.6-6). Macrophytes were rare and benthic algae was low at the lower reach and moderate at the upper reach of the MacKay River in September 2004. Dissolved oxygen, pH and water temperature were similar between the two reaches; conductivity in the lower reach was more than double that of the upper reach. Substrates were similar between the two reaches, although the lower reach was composed of more fine material (gravel and sand/silt/clay) than the upper reach.

The benthic community of the river's lower reach was dominated by chironomids (40%) and the EPT taxa (23%), followed by tubificids and gastropods. Benthic invertebrates in the upper reach were also dominated by Chironomids (63%) and the EPT taxa (22%) (Table 5.6-9).

Benthic invertebrate community indices in the lower reach of the MacKay River (MAR-E 1-15), sampled since 1998, have consistently remained within expected values based on regional baseline reaches from erosional habitats (Figure 5.6-6). There has been no clear trend in these measurement endpoints over time. Benthic invertebrate community indices for both the lower (MAR-E 1-15, exposed) and the upper (MAR-E 16-30, reference) reach of the MacKay River have fluctuated over time, but stayed within expected regional reference values for erosional habitats (Figure 5.6-6).

The following statistical comparisons were made for the benthic invertebrate community endpoints (Table 5.6-9):

- Lower reach (MAR-E 1-15) in 2002, 2003, and 2004 (operational data) with upper reach (MAR-E 16-30) during the same years (baseline data); and

- Lower reach (MAR-E 1-15) in 2002, 2003, and 2004 (operational data) with lower reach (MAR-E 1-15) in 1998, 2000, and 2001 (baseline data).

Total abundance varied significantly among operational years; a weakly significant interaction between reach and time (i.e., baseline vs. operational) reflected the fact that abundance in the lower, exposed reach (MAR-E 1-15) was similar from 2002 to 2004, while it declined slightly over the same period in the upper, reference reach (MAR-E 16-30). Significant time × reach interactions for diversity (Simpson's Diversity Index) and evenness reflect a decline in these two measurement endpoints at the lower reach (MAR-E 1-15) and a corresponding increase at the upper reach (MAR-E 16-30) between 2002 and 2004. EPT taxa slightly increased in the lower reach (MAR-E 1-15) between 2002 and 2004, but increased slightly more in the upper reach (MAR-E 16-30), reflecting the weakly significant interaction for EPT taxa. Richness was the only index that differed

significantly between reaches in 2004, with lower richness in the lower reach of the MacKay River (MAR-E 1-15). Richness, diversity, evenness, and EPT taxa in the lower reach all declined in the operational years relative to the baseline years. There was no change in total abundance between the two periods.

Differences in time trends in diversity and evenness suggest the possibility of subtle changes in benthic invertebrate communities in the MacKay River in the years designated as operational as compared to years designated as baseline. However, in general, MacKay River benthic invertebrate communities (both upper and lower reaches) were in good condition with all indices for all years falling within expected ranges for reference benthic invertebrate communities.

5.6.5 Fish Populations

Activities in the MacKay River basin in the Fish Population component consisted of fish fence reconnaissance work.

5.6.5.1 Fish Fence Reconnaissance

The MacKay River site was selected as a candidate for fish fence deployment based on the results of the topographic map and airphoto assessment of the watershed, as well as its proximity to existing hydrometric monitoring stations (RAMP S26 and Water Survey of Canada), which provided useful historical discharge information for the assessment. The site also was accessible by vehicle.

A cross-section of the MacKay River was assessed at the leftward curve (looking downstream) in the river, which exhibited a radius of approximately four times the wetted width (Figure 5.6-8). Average stream depth at the site was greater than 1 m at the time of the assessment, with visually assessed wetted and channel widths of roughly 25 m and 28 m, respectively. Substrate was composed mainly of cobble with a sub-dominant sand fraction. This substrate composition would allow relatively easy seating of the fence, but erosion/scouring, resulting in fence undercutting would be a concern.

The drainage area upstream of this site encompasses approximately 5,570 km^2. Spring discharge is high: MacKay River discharge on May 1 exceeded 25 m^3/s in both 2003 and 2004 (Figure 5.6-9). Although access to the proposed MacKay River site is generally good and accurate stream flow information is available from RAMP and WSC stations near the site, the unconsolidated nature of the channel substrate and high spring discharge make the site unsuitable for future fish fence operations using current RAMP fence method and technology.

As outlined in the RAMP Fish Fence Protocols for the Muskeg River (Appendix H), predicted discharge followed by a final on-site confirmation of flow are the determining factors for full fish fence installation. Flows above the designated cutoff point (greater than 9 m^3/s) may be appropriate for the deployment of a partial fence configuration.

5.6.5.2 Summary of Conditions

The MacKay River watershed in 2004 showed, at most, the following negligible and subtle changes in all RAMP aquatic resources from previous years:

- Slight changes in hydrological conditions (i.e., <0.4% in any measured end-point) relative to pre-development conditions;
- Little observable change in both water and sediment quality; and
- The possibility of small changes in benthic invertebrate communities.

The relatively small scale of oil sands development activities in the watershed to date suggests that, if oil sands development is having effects on RAMP aquatic resources in the MacKay River watershed, these effects are minor and insignificant at most.

Figure 5.6-2 MacKay River 2004 hydrograph and historical context.

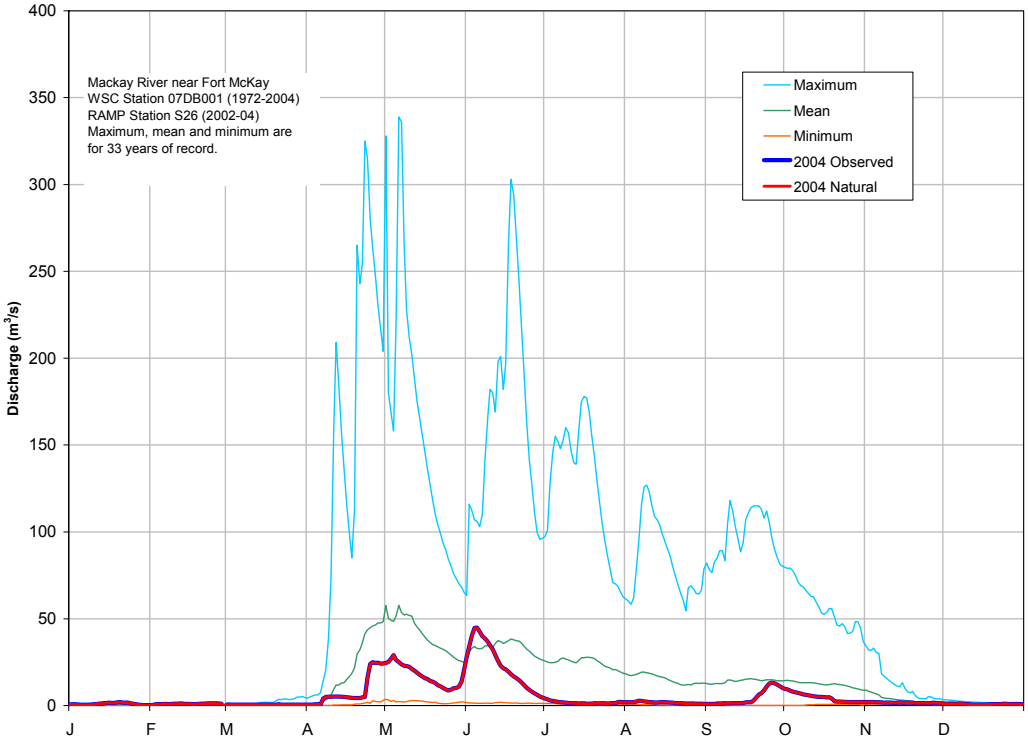


Table 5.6-1 Summary of parameter values for MacKay River water balance calculation.

Component	Value	Basis / Data Source
Observed 2004 hydrograph	Daily discharges	Hydrometric Stations S26 and 07DB001
natural runoff from active oil sands development areas, or intercepted by development	4% of the natural runoff from 20.3 km^2	Conservative estimate using total lease area of Devon *in-situ* and Petro-Canada MacKay River developments
incremental runoff from areas that are cleared and areas that are dewatered	0	Professional judgment based on fact that oil sands activities in river basin were in the operational phase and no clearing or dewatering occurred in 2004
water withdrawals from the watercourse in question by oil sands development activities	0	Water withdrawals are from groundwater
water releases to the watercourse in question by oil sands development activities	0	Unknown but assumed to be negligible
the difference between naturalized and observed hydrographs on tributaries upstream of the station in question	none	No significant upstream developments

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

Endpoint[1]	Baseline Value (Naturalized Hydrograph) (m^3/s)	Operational Value (Actual Hydrograph) (m^3/s)	Percent Change
Mean open-water season discharge	8.87	8.84	-0.34%
Mean winter discharge	0.97	0.962	-0.34%
Annual maximum daily discharge	45.05	44.9	-0.34%
Open-water season minimum daily discharge	0.93	0.93	-0.34%

[1]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 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	5	7.6	8.0	8.6
Total suspended solids	mg/L	-	17	5	2	7	26
Conductivity	mg/L	-	348	5	233	278	576
Nutrients							
Total phosphorus	mg/L	0.05	0.02	5	0.01	0.04	**0.05**
Dissolved phosphorus	mg/L	0.05[1]	0.008	5	0.004	0.019	0.047
Total nitrogen*	mg/L	1.0	0.9	5	0.4	**1.1**	**3.2**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	22	5	20	24	31
Ions							
Sodium	mg/L	-	35	5	17	20	60
Chloride	mg/L	230, 860[2]	12	5	3	6	41
Sulphate	mg/L	100[3]	30	5	18	20	36
Total dissolved solids	mg/L	-	280	5	170	240	342
Total alkalinity	mg/L	-	155	5	100	116	202
Organic compounds							
Naphthenic acids	mg/L	-	1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	**0.50**	5	0.05	**0.2**	**0.5**
Dissolved aluminum	mg/L	0.1[1]	0.01	5	0.01	0.02	0.03
Total boron	mg/L	1.2[3]	0.11	5	0.08	0.09	0.14
Total molybdenum	mg/L	0.073	0.0004	5	0.0004	0.0004	0.0006
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total iron (Fe)	mg/L	0.300	**1.0**	5	0.31	0.83	**23.3**

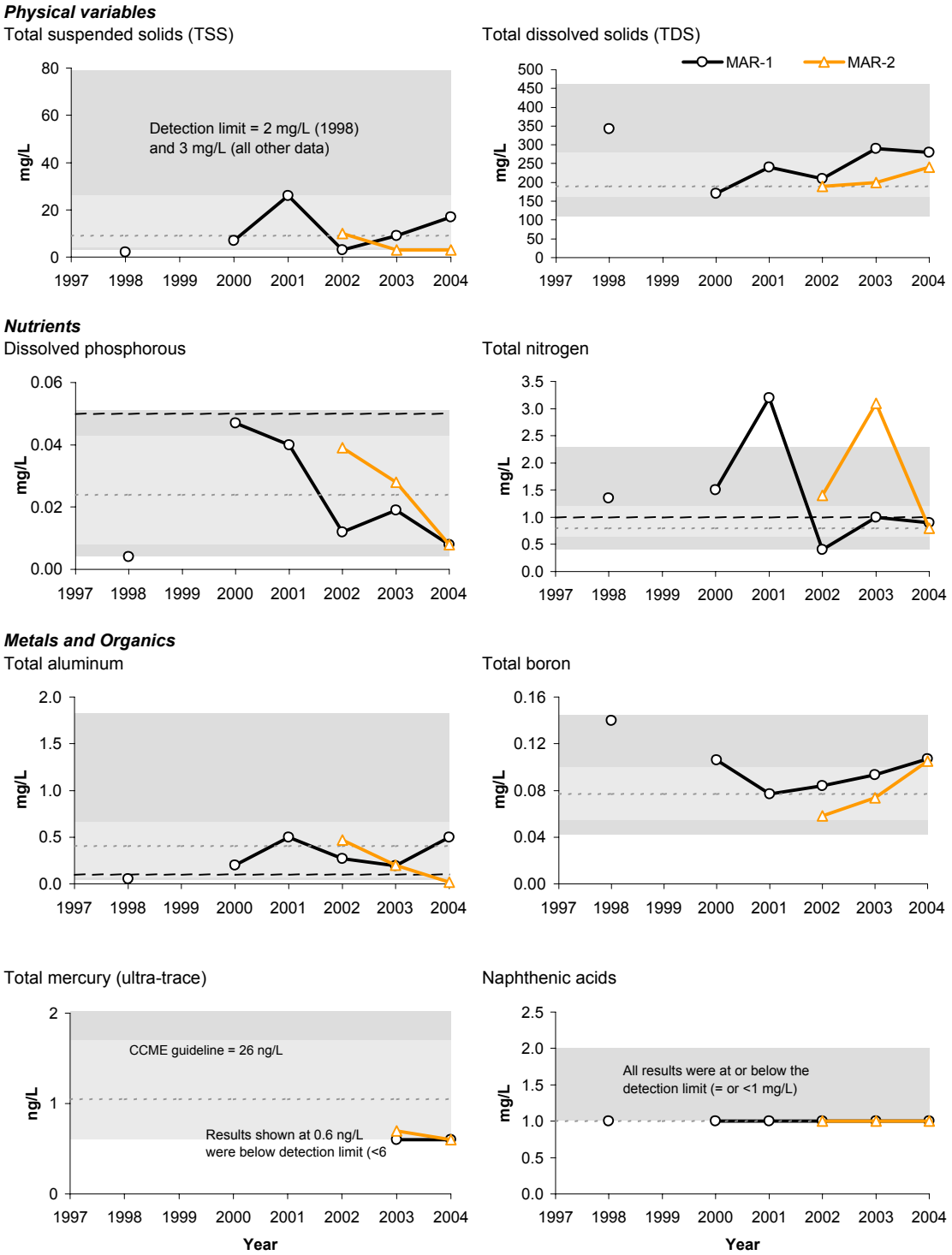
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.6-4 Concentrations of water quality measurement endpoints, upper MacKay River (MAR-2), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	2	7.8	-	8.1
Total suspended solids	mg/L	-	<3	2	<3	-	10
Conductivity	mg/L	-	249	2	202	-	237
Nutrients							
Total phosphorus	mg/L	0.05	0.01	2	0.05	-	**0.07**
Dissolved phosphorus	mg/L	0.05[1]	0.008	2	0.03	-	0.04
Total nitrogen*	mg/L	1.0	0.8	2	**1.4**	-	**3.1**
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	22	2	25	-	31
Ions							
Sodium	mg/L	-	19	2	15	-	17
Chloride	mg/L	230, 860[2]	2	2	1	-	2
Sulphate	mg/L	100[3]	24	2	15	-	18
Total dissolved solids	mg/L	-	240	2	190	-	200
Total alkalinity	mg/L	-	128	2	85	-	112
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	<1
Selected metals							
Total aluminum	mg/L	0.1	0.02	2	**0.2**	-	**0.5**
Dissolved aluminum	mg/L	0.1[1]	<0.0002	2	0.02	-	0.03
Total boron	mg/L	1.2[3]	0.105	2	0.06	-	0.07
Total molybdenum	mg/L	0.073	0.00054	2	0.0003	-	0.0004
Total mercury (ultra-trace)	ng/L	26	<0.6	1	0.7	-	0.7
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.006**	2	<0.001	-	**0.006**
Total iron	mg/L	0.300	**0.39**	2	**0.92**	-	**1.28**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.6-3 Concentrations of selected water quality measurement endpoints on the MacKay River, relative to regional baseline conditions, fall 1997-2004.



[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 E for these regional baseline ranges.

Figure 5.6-4 Piper diagram of fall ion concentrations in the MacKay River system.

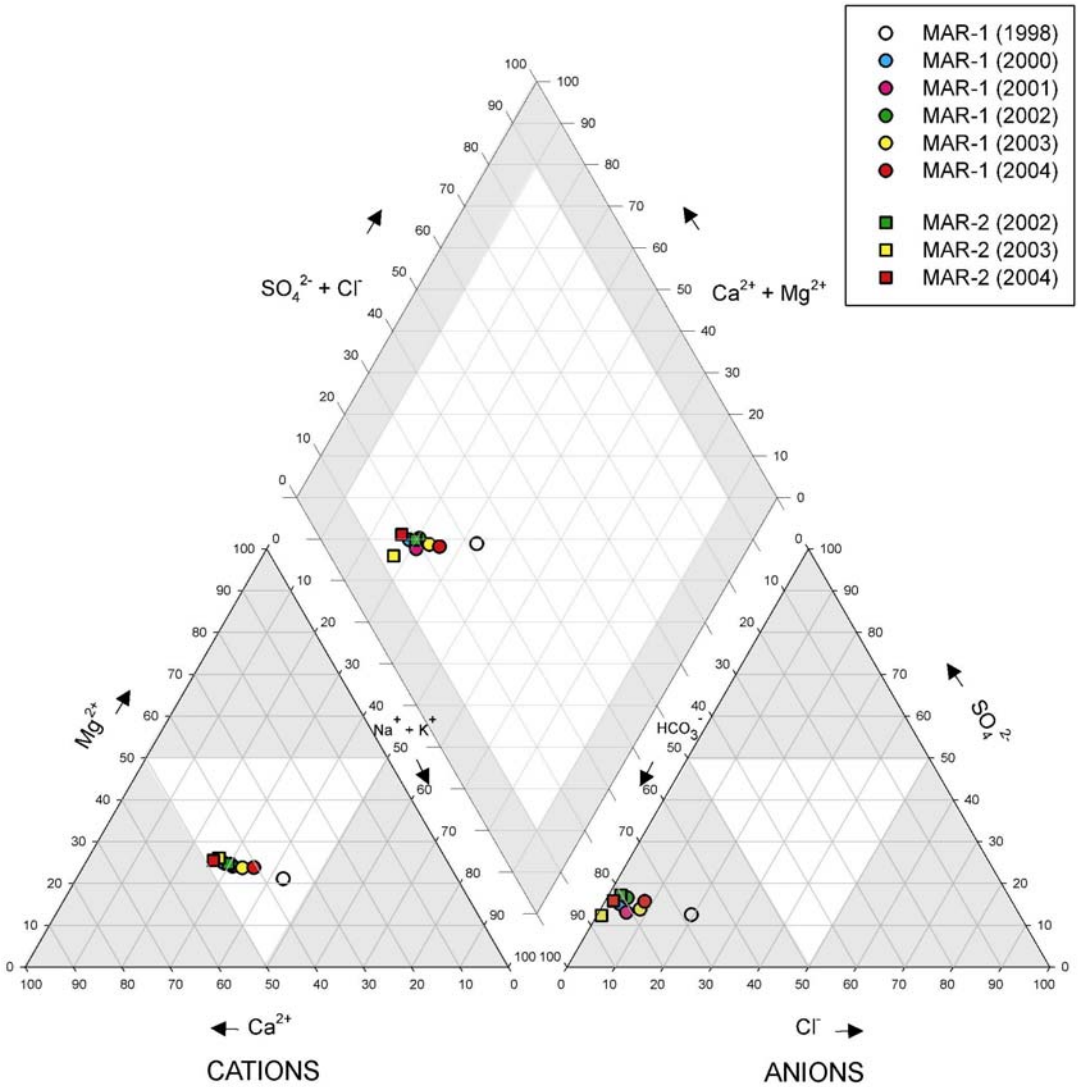


Table 5.6-5 Concentrations of sediment quality measurement endpoints, mouth of MacKay River (MAR-1), fall 2004.

	Units	Guideline	September 2004 Value	n	1997-2003 (Fall data only) Min	Median	Max
Physical variables							
Clay	%	-	26	4	5	18.35	37
Silt	%	-	48	4	6	18.65	48
Sand	%	-	25	4	15	63	89
Total organic carbon	%	-	2.1	4	1.37	1.73	2.67
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]	23	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	290	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	160	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	2	0.5	-	0.5
TEH (C11-C30)	mg/kg	-	580	2	1619	-	6600
TRH	mg/kg	-	1700	4	3300	5990	11300
Polycyclic Aromatic Hydrocarbons (PAH)							
Napthelene	mg/kg	0.0346[3]	0.011	4	0.008	0.011	0.02
Retene	mg/kg	-	0.07	2	0.13	-	0.42
Total dibenzothiophenes	mg/kg	-	0.9	4	1.2	4.3	12.9
Total PAHs	mg/kg	-	3.7	4	7.22	12.5	31.4
Total HMW PAHs	mg/kg	-	1.1	4	1.0	2.8	9.8
Total LMW PAHs	mg/kg	-	2.6	4	6.2	9.8	21.5
Predicted PAH toxicity[1]	H.I.	-	1.2	4	0.4	1.7	2.0
Metals that exceed CCME guidelines in fall 2004							
Total Arsenic (As)	mg/kg	5.9[3]	**7.2**	4	1.8	5	8.9
Chronic toxicity							
Chironimus survival	# surviving	-	8	1	-	-	6
Chironimus growth	mg/organism	-	2.5	1	-	-	1.8
Hyallela survival	# surviving	-	7	1	-	-	6
Hyallela growth	mg/organism	-	0.1	1	-	-	0.1

Note: unless otherwise noted, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV 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 5.6-6 Concentrations of sediment quality measurement endpoints, upper MacKay River (MAR-2), fall 2004.

	Units	Guideline	September 2004 Value	1997-2003 (Fall data only) n	Min	Median	Max
Physical variables							
Clay	%	-	2	1	-	-	4
Silt	%	-	3	1	-	-	6
Sand	%	-	95	1	-	-	90
Total organic carbon	%	-	<0.1	1	-	-	0.4
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]	6	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	<5	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	1	-	-	1.2
TEH (C11-C30)	mg/kg	-	10	1	-	-	64
TRH	mg/kg	-	<100	1	-	-	100
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.001	1	-	-	0.0007
Retene	mg/kg	-	0.004	1	-	-	0.02
Total dibenzothiophenes	mg/kg	-	0.01	1	-	-	0.01
Total PAHs	mg/kg	-	0.08	1	-	-	0.13
Total HMW PAHs	mg/kg	-	0.02	1	-	-	0.10
Total LMW PAHs	mg/kg	-	0.06	1	-	-	0.03
Predicted PAH toxicity[1]	H.I.	-	0.39	1	-	-	0.61
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	6	-	-	-	-
Chironomus growth	mg/organism	-	3.6	-	-	-	-
Hyallela survival	# surviving	-	9	-	-	-	-
Hyallela growth	mg/organism	-	0.2	-	-	-	-

Note: unless otherwise noted, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

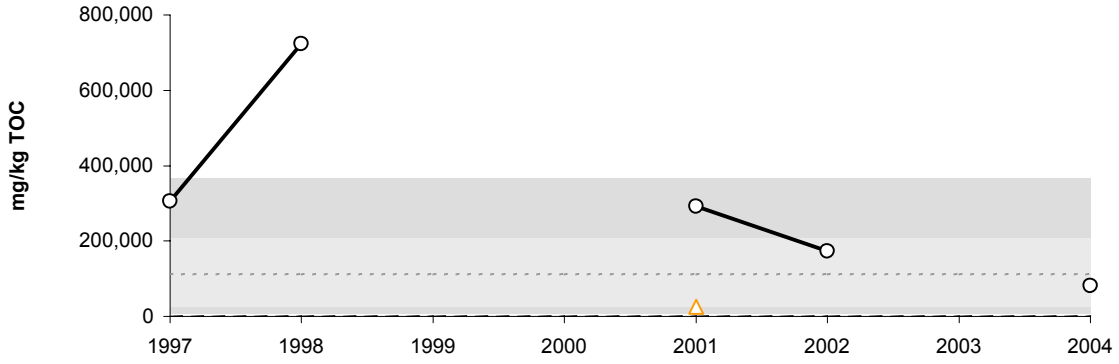
[1] Toxicity of PAH assemblage estimated using the equilibrium partitioning approach. A hazard index (H.I.) is calculated from individual PAH concentrations in sediment, values of K_{ow} (octanol-water partition coefficient), and chronic toxicity of the individual PAH species.

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

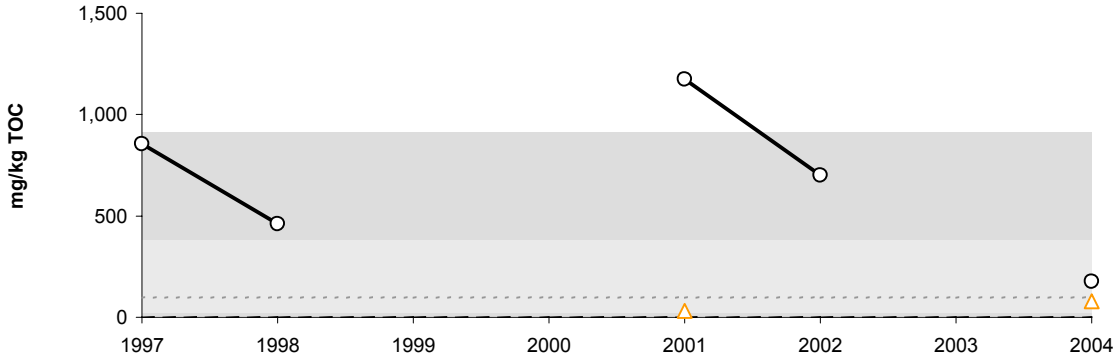
[3] Interim sediment quality guideline (ISQG) (CCME 2003).

Figure 5.6-5 Concentrations of fall 2004 selected sediment quality measurement endpoints in the MacKay River relative to regional baseline concentrations.

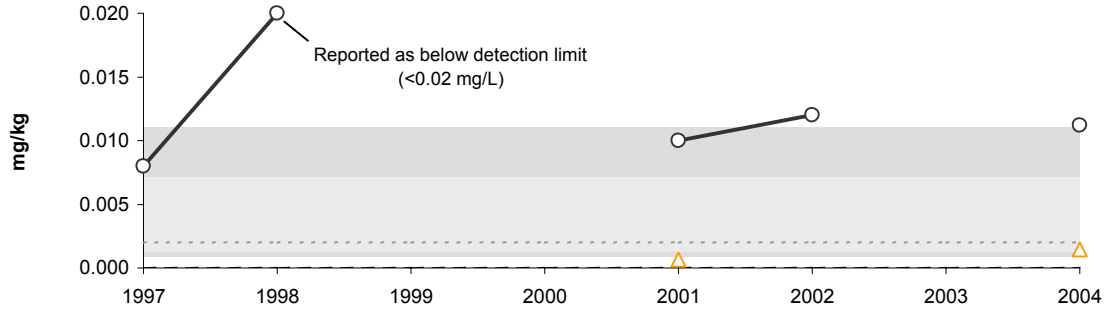
Total Recoverable Hydrocarbons (normalized to TOC)



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 F for these regional baseline ranges.

Table 5.6-7 Average habitat characteristics of benthic invertebrate sampling reaches in the Mackay River, fall 2004.

Variable	Units	Lower Reach of the MacKay River	Upper Reach of the MacKay River
Sample date	-	Sept 11-12, 2004	Sept 18, 2004
Habitat	-	Erosional	Erosional
Water depth	m	0.2	0.2
Current velocity	m/s	0.3	0.7
Macrophyte cover	%	1	0
Benthic algae	mg/m^2	15	58
Field Water Quality			
Dissolved oxygen	mg/L	10	10.7
Conductivity	µS/cm	440	195
pH		8.7	8.2
Water temperature	°C	7.9	7.8
Sediment Composition			
Sand/Silt/Clay	%	5	1.3
Small gravel	%	18	6.7
Large gravel	%	37	17.7
Small cobble	%	37	40.0
Large cobble	%	3	19.3
Boulder	%	0	5.3
Bedrock	%	0	0

Table 5.6-8 Summary of major taxon abundances and key indices of composition among stations in the MacKay River, Fall 2004.

Taxon	Lower Reach of the MacKay River			Upper Reach of the MacKay River		
	Abundance $\#/m^2$	SD	% Abundance	Abundance $\#/m^2$	SD	% Abundance
Nematoda	185	286	1.6	253	750	1.8
Erpobdellidae	14	0	0.1	0	0	0
Enchytraeidae	189	570	1.6	153	213	1.1
Naididae	335	669	2.8	125	98	0.9
Tubificidae	1082	3704	9.2	387	748	2.7
Hydracarina	349	715	3.0	76	361	0.5
Ostracoda	42	341	0.4	5	0	0.0
Copepoda	0	0	0	3	0	0.0
Daphniidae	63	0	0.5	0	0	0
Gastropoda	831	2065	7.0	160	853	1.1
Ephemeroptera	742	363	6.3	1300	821	9.1
Plecoptera	1189	1027	10.1	569	246	4.0
Trichoptera	781	1216	6.6	1272	827	8.9
Anisoptera	325	283	2.8	543	592	3.8
Coleoptera	440	1021	3.7	128	225	0.9
Tipulidae	0	0	0	140	0	1.0
Empididae	459	370	3.9	123	181	0.9
Ceratopogonidae	105	201	0.9	105	309	0.7
Chironomidae	4685	1198	39.6	8995	1279	62.7
Total Abundance	11819	4850		14336	6462	
Richness	26.5	3.5		32.5	5.0	
Simpson's Diversity	0.793	0.130		0.836	0.092	
Evenness	0.825	0.135		0.863	0.092	

Figure 5.6-6 Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for the lower MacKay (MAR-E 1-15).

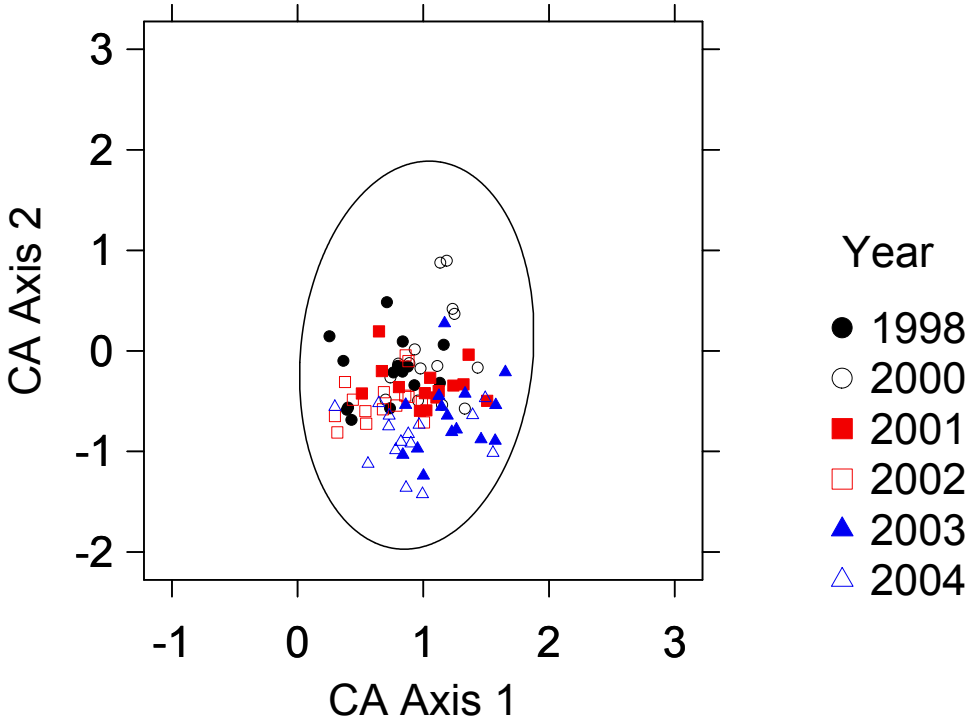
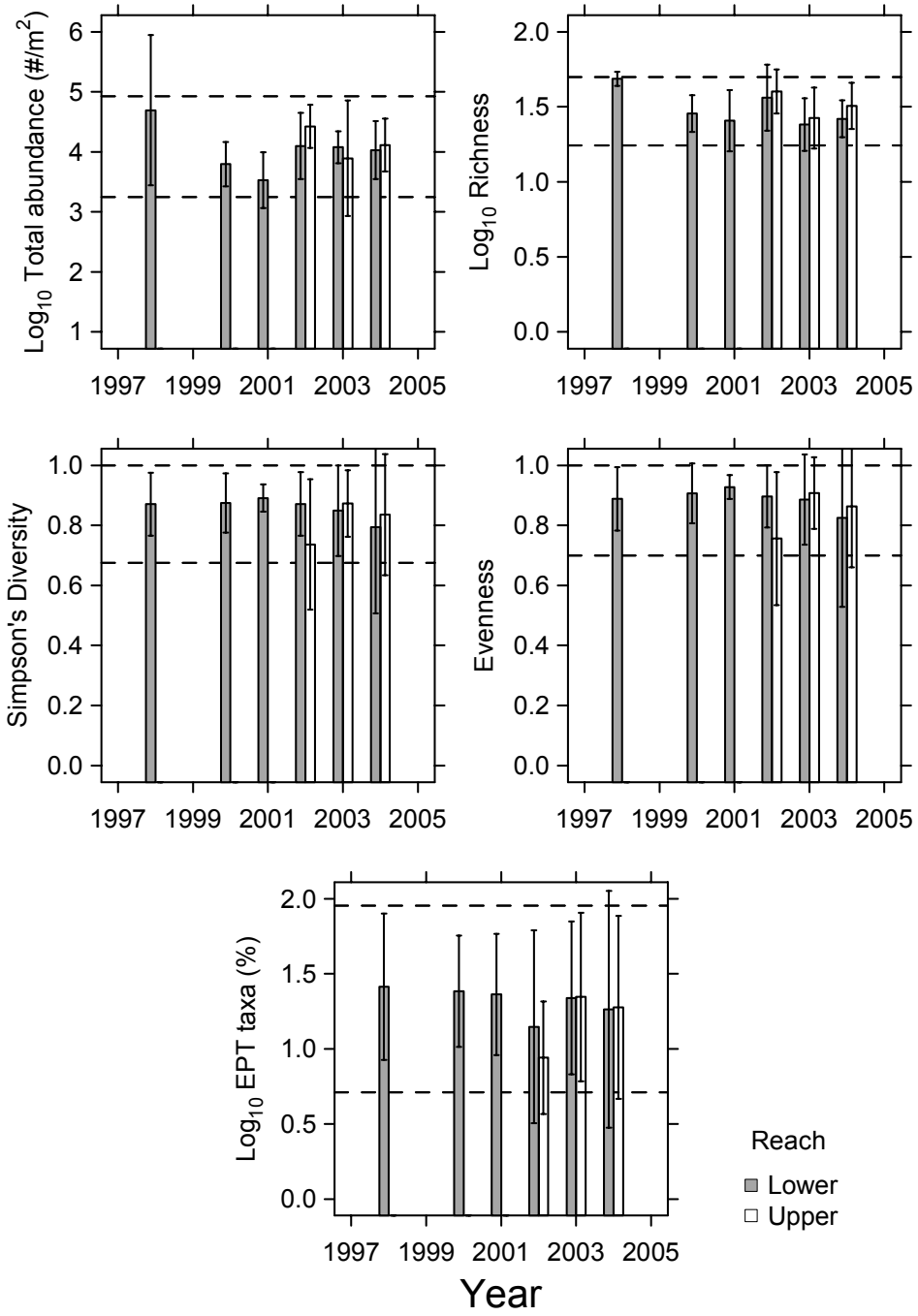


Figure 5.6-7 Variations in benthic invertebrate community measurement endpoints in the MacKay River, upper (MAR-E 16-30) and lower reaches (MAR-E 1-15).



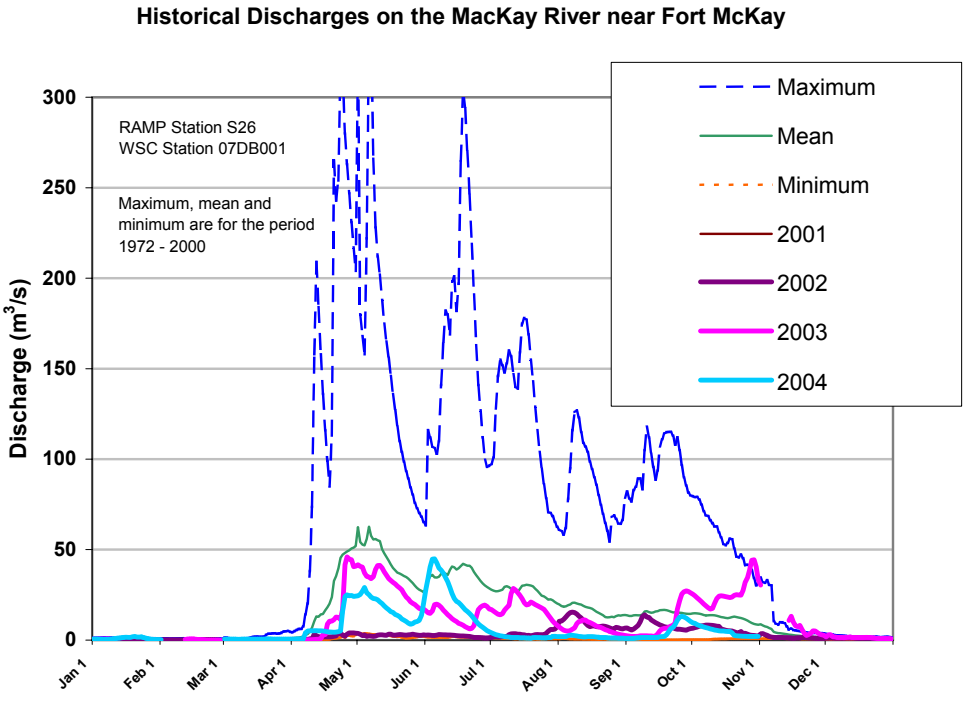
Lower and upper dotted lines represent ±2 SD of distribution of regional baseline values for erosional reaches.

Table 5.6-9 Results of analysis of variance on MacKay River upper and lower reaches with planned comparisons between: (i) baseline and operational years on lower reach; and (ii) operational years on lower and same baseline years on upper reach.

Source	SS	df	F	p
Log_{10} Abundance				
Reach-Year	8.430	8	18.28	<0.001
Time (2002-2004)	*0.532*	*1*	*9.224*	*0.003*
Reach	*0.130*	*1*	*2.258*	*0.136*
Time × Reach	*0.216*	*1*	*3.750*	*0.055*
Reach (2004)	*0.056*	*1*	*0.965*	*0.328*
Pre-Post lower reach	*0.050*	*1*	*0.872*	*0.352*
Error	6.514	113		
Log_{10} Richness				
Reach-Year	0.787	8	16.29	<0.001
Time (2002-2004)	*0.210*	*1*	*34.81*	*<0.001*
Reach	*0.073*	*1*	*12.12*	*0.001*
Time × Reach	*0.007*	*1*	*1.210*	*0.274*
Reach (2004)	*0.055*	*1*	*9.170*	*0.003*
Pre-Post lower reach	*0.052*	*1*	*8.614*	*0.004*
Error	0.682	113		
Simpson's Diversity Index				
Reach	0.282	8	5.997	<0.001
Time (2002-2004)	*0.002*	*1*	*0.296*	*0.588*
Reach	*0.012*	*1*	*1.989*	*0.161*
Time × Reach	*0.118*	*1*	*20.07*	*<0.001*
Reach (2004)	*0.014*	*1*	*2.309*	*0.131*
Pre-Post lower reach	*0.022*	*1*	*3.771*	*0.055*
Error	0.664	113		
Evenness				
Reach	0.331	8	6.779	<0.001
Time (2002-2004)	*0.005*	*1*	*0.779*	*0.379*
Reach	*0.016*	*1*	*2.691*	*0.104*
Time × Reach	*0.120*	*1*	*19.68*	*<0.001*
Reach (2004)	*0.011*	*1*	*1.781*	*0.185*
Pre-Post lower reach	*0.020*	*1*	*3.254*	*0.074*
Error	0.690	113		
Log_{10} EPT %				
Reach	2.379	8	4.780	<0.001
Time (2002-2004)	*0.769*	*1*	*12.36*	*0.001*
Reach	*0.089*	*1*	*1.430*	*0.234*
Time × Reach	*0.180*	*1*	*2.894*	*0.092*
Reach (2004)	*0.001*	*1*	*0.018*	*0.893*
Pre-Post lower reach	*0.250*	*1*	*4.021*	*0.047*
Error	7.028	113		

Figure 5.6-8 Upstream view of fish fence reconnaissance site on the MacKay River, April 2004.

Figure 5.6-9 Hydrograph of MacKay River measured near Fort McKay.



5.7 MISCELLANEOUS AQUATIC SYSTEMS EXPOSED TO RAMP OIL SANDS DEVELOPMENTS

Summary of Results

Climate and Hydrology

	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge Mean winter discharge Annual maximum daily discharge Minimum open-water season discharge	Because of limited development information, there was no estimate made of the hydrological changes in relation to oil sands development activities.				Isadore's Lake: In 2004, spring water level rose somewhat earlier and higher than usual. Mills Creek: Runoff was much below normal for almost the entire year. Poplar Creek: Discharges were below normal in 2004.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=5)	2004 Reference Stations (n=0)	
Physical variables (3 endpoints)	0	No water quality sampling stations were designated as reference in 2004.	A range of conditions was observed in miscellaneous aquatic systems exposed to oil sands development activities. Limited exceedances of water quality guidelines for the protection of aquatic life occurred in 2004. Concentrations of most water quality measurement endpoints were within the range of regional baseline conditions for reference waterbodies and watercourses.
Nutrients (5 endpoints)	2		
Ions (5 endpoints)	0		
Organic compounds (1 endpoint)	0		
Selected metals (5 endpoints)	2		

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 5 stations X 7 endpoints)	2004 Reference Stations (n= 0 stations)	
Above 95th	0	No water quality sampling stations were designated as reference in 2004.	
Between 75th and 95th	10		
Between median and 75th	10		
Between 25th and median	11		
Between 5th and 25th	3		
Less than 5th	1		

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=2)	2004 Reference Stations (n=0)	
Physical variables (4 endpoints)	0	No sediment quality sampling stations were designated as reference in 2004.	Limited exceedances of CCME sediment quality guidelines occurred in 2004. Sediment quality varied widely within the range of regional baseline conditions for reference waterbodies and watercourses.
Total Hydrocarbons (8 endpoints)	1		
PAHs (7 endpoints)	0		

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]		
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 2 stations X 3 endpoints)	2004 Reference Stations (n= 0 stations)	
Above 95th	2	No sediment quality sampling stations were designated as reference in 2004.	
Between 75th and 95th	1		
Between median and 75th	1		
Between 25th and median	2		
Between 5th and 25th	0		
Less than 5th	0		

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline						
	2004 Exposed Stations (n= 2)			2004 Reference Stations (n= 0)			
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD	
Abundance		2		No benthic invertebrate community sampling stations were designated as reference in miscellaneous exposed aquatic systems in 2004.			In general, Shipyard Lake is in relatively good condition, with a number of indices that are as good as what has been found at Kearl and McClelland Lakes. Trends suggest that the benthic community has been increasing in diversity in Shipyard Lake relative to Kearl Lake, but the trends to date have been quite subtle.
Richness		2					
Diversity		2					
Evenness		2					
% EPT		2					

Fish Populations

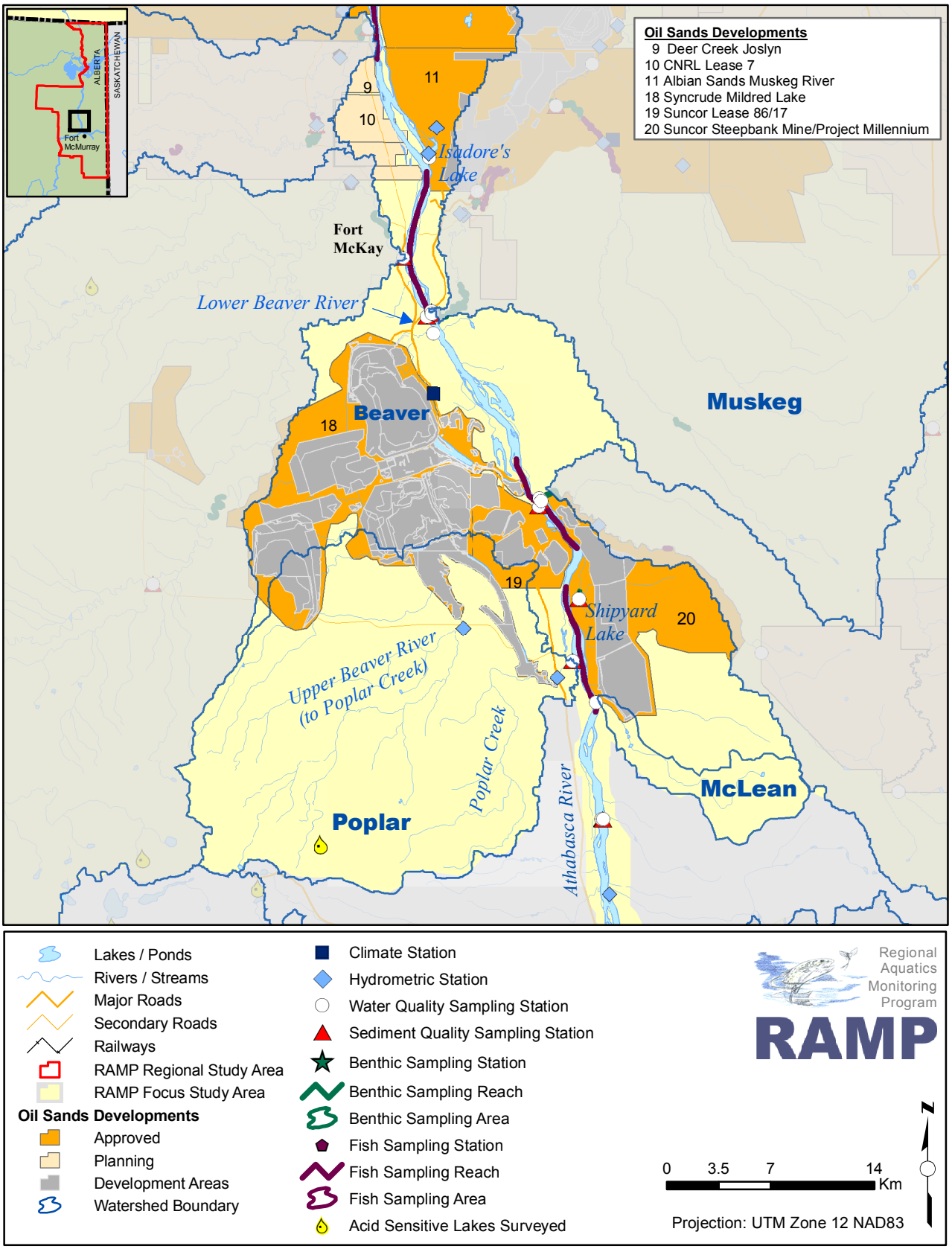
Fish Inventory	No fish inventory studies were conducted in McLean Creek, Beaver River, or Shipyard Lake in 2004.	
Sentinel Studies	Sentinel fish studies were not conducted in 2004.	
Fish Tissue	Level of Risk	
Human Health: Subsistence Human Health: Recreational Fishers Human Health: General Consumers Human Health: Tainting Fish and Wildlife: Mercury Fish and Wildlife: Other Chemicals	Fish tissue program was not conducted in these waterbodies in 2004.	

[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 Miscellaneous aquatic systems exposed to RAMP oil sands developments.



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This section includes 2004 results from the following aquatic systems: Mills Creek; Poplar Creek; McLean Creek; Beaver River; Isadore's Lake; and Shipyard Lake.

5.7.1 Hydrologic Conditions

Hydrologic conditions were examined on the following aquatic systems: Isadore's Lake; Mills Creek; and Poplar Creek.

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 2004, the spring water level rose somewhat earlier and higher than usual. Water levels were lower than normal in July and August, but the total range in lake levels was only approximately 0.2 m.

Runoff in Mills Creek was well below normal for almost all of 2004. Total runoff for the catchment was 13 mm, compared to a long-term average of 31 mm (Figure 5.7-2). The June rainfall that produced the annual peak flow on most of the streams in the area had very little effect on Mills Creek discharges. However, a mid-September rainfall did result in above-average flows for a few days. The annual maximum daily discharge was 0.075 m^3/s, compared to the mean annual flood of 0.192 m^3/s. The minimum open-water discharge was 0.011 m^3/s, compared to the 8-year average minimum discharge of 0.019 m^3/s.

Discharges in Poplar Creek were also below normal in 2004 (Figure 5.7-3). The total runoff volume for the year was 27% below normal, but most of the discharge occurred in June, while the rest of the year was much below normal. The June maximum daily discharge of 9.5 m^3/s was 14% higher than the mean annual flood, while the minimum daily open-water discharge of 0.084 was 34% below normal.

5.7.2 Water Quality

Water quality conditions were examined on the following aquatic systems designated as exposed to oil sands development: Beaver River; Poplar Creek, McLean Creek; Shipyard Lake; and Isadore's Lake.

5.7.2.1 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 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, exposed). 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).

By contrast, in fall 2004 water quality at BER-1 fell within regional baseline ranges (Table 5.7-1, Figure 5.7-4). Ion balance in Beaver River water differed clearly between 2003 and 2004, particularly with respect to chloride and sodium (Figure 5.7-5, Table 5.7-1). Water

level in this river was very high in 2004 relative to 2003 (when the river was extremely low and barely flowing). This higher water flow in 2004 may have attenuated any potential effects of seepage on Beaver River water quality in 2004.

5.7.2.2 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 lower Poplar Creek (station POC-1, exposed) in 2004 was within the range of historical observations at this station (Table 5.7-2), with moderately high conductivity and ion concentrations relative to other RAMP stations, within regional baseline ranges (Figure 5.7-4). Water quality at this station has shown high interannual variability, including highly variable ion balance among years (Figure 5.7-5).

5.7.2.3 McLean Creek

McLean Creek receives intermittent site drainage discharges from Suncor operations and therefore exhibits highly variable flow throughout the year. Water quality in McLean Creek also has been highly variable over six years of sampling by RAMP (station MCC-1, exposed). Water quality in McLean Creek in fall 2004 was within historical ranges and within regional baseline values (Figure 5.7-4); for several variables (e.g., conductivity, various ions), measured concentrations in 2004 were near the low end of the range of historical observations (Table 5.7-3).

5.7.2.4 Shipyard Lake

Shipyard Lake (station SHL-1, exposed) is located adjacent to the Suncor Steepbank/Project Millennium lease area. Golder (2003), in the RAMP 5-Year Report, reported increasing trends in total boron and sulphate in Shipyard Lake from 1995 to 2002. However, further data collection and analysis in 2003 did not corroborate these trends (RAMP 2004). Water quality data collected in 2004 supports the 2003 assessment, with low sulphate concentrations and historically typical boron concentrations observed in 2004 (Table 5.7-4, Figure 5.7-6). Other water quality variables also were within historical and regional baseline ranges. Ion balance at Shipyard Lake has been relatively consistent since RAMP sampling of this waterbody commenced in 1999 (Figure 5.7-7).

5.7.2.5 Isadore's Lake

Isadore's Lake (station ISL-1, exposed) is located adjacent to Albian Sands' Muskeg River Mine project area. Water quality in this lake in fall 2004 was generally similar to that observed in previous years, although concentrations of numerous variables exhibited historical lows, including conductivity, alkalinity, total and dissolved phosphorous, total dissolved solids and dissolved organic carbon (Table 5.7-5, Figure 5.7-6); some ions,

including sodium and chloride, as well as total zinc, exhibited historical highs in 2004 (Table 5.7-5). Ion balance in Isadore's Lake has been somewhat variable among sampling years (Figure 5.7-7).

5.7.2.6 Summary

The aquatic systems exposed to oil sands development activities that were monitored in 2004 exhibited a range of water quality conditions. With respect to the water quality measurement endpoints, however:

- there were limited exceedances of CCME guidelines for the protection of aquatic life in 2004; and
- most of the measurement endpoints were within the normal range of regional baseline conditions for reference waterbodies and watercourses.

Table 5.7-6 contains a list of all exceedances of CCME guidelines for protection of aquatic life observed in the miscellaneous aquatic systems exposed to oil sands developments sampled in 2004.

5.7.3 Sediment Quality

Sediment quality conditions were examined on Poplar Creek and Shipyard Lake, both of which are designated as exposed to oil sands development.

5.7.3.1 Poplar Creek

Sediment quality in lower Poplar Creek in 2004 (station POC-1, exposed) was similar to that observed in previous years (Table 5.7-7). Sediments at station POC-1 were predominantly sandy, with moderate levels of organic carbon (i.e., 2.1%), moderate to high total hydrocarbons (dominated by the F3 [C16-C34] fraction), and moderate PAH concentrations. No trends in these measurement quality endpoints are apparent over time (Figure 5.7-8). Values in 2004 values for these measurement endpoints were within regional baseline ranges for reference stations.

5.7.3.2 Shipyard Lake

In 2004, sediment quality measurement endpoint values in Shipyard Lake (station SHL-1, exposed) were similar to previous years (Table 5.7-8), with relatively high organic carbon, low to moderate hydrocarbons, and moderate metal and PAH concentrations. Carbon-normalized hydrocarbon and PAH concentrations do not suggest consistent trends over time in these variables (Figure 5.7-9). Total PAH and naphthalene concentrations in Shipyard Lake sediments were well above those observed in regional baseline stations (Figure 5.7-9). However, this regional baseline range was developed from historical data for the two baseline regional lakes monitored by RAMP, and included only three available historical observations (Appendix F).

5.7.3.3 Summary

Similar to water quality, the aquatic systems exposed to oil sands development activities that were monitored in 2004 exhibited a range of sediment quality conditions. With respect to the sediment quality measurement endpoints, however:

- there were limited exceedances of CCME ISQG guidelines for the protection of aquatic life in 2004; and
- there was wide variation in sediment quality measurement endpoints with respect to the range of regional baseline conditions for reference waterbodies and watercourses.

5.7.4 Benthic Invertebrate Communities

Benthic invertebrate communities were examined at Shipyard Lake (SHL-1-10, exposed) and Kearl Lake (KRL-1-10, reference) in 2004. Benthic data for McClelland Lake (MCL-1-10, reference) are shown to provide contrast to Shipyard Lake, since McClelland Lake is the reference lake against which Shipyard Lake should be compared.

Sampling stations were selected at consistent depths (mean depth range from 1.4 to 2.0 m; Table 5.7-9). Water temperature ranged between 10.6°C and 11.4°C in these lakes. pH was similar in both lakes (near 7.5). Conductivity in Shipyard Lake (280 µS) was about twice that of Kearl Lake (120 µS). Dissolved oxygen was low in Shipyard Lake, below the CCME guideline range for the protection of aquatic life, whereas dissolved oxygen was higher and above the recommended guidelines in Kearl Lake. The sediments of Shipyard Lake were similar to those of Kearl Lake and consisted primarily of silt and clay, with low sand content (13.5% to 17.1%). Sediments in the two lakes were predominantly sand and clay.

Chironomids were the dominant taxon in both Kearl and Shipyard Lakes in 2004. Amphipods and Naididae were also abundant in Kearl Lake, whereas Naididae, Chaoboridae, Ostracoda, and Gastropoda were abundant in Shipyard Lake (Table 5.7-10). There was very little separation between the exposed Shipyard Lake and the reference Kearl and McClelland lakes, based on a CA of reference data collected from all sample years (Figure 5.7-10). Four samples collected from Shipyard Lake between 2000 and 2004 fell outside the expected range of values for reference lakes, and these generally had high CA Axis 1 scores that corresponded to abundant Hydracarina, Chydoridae and Gastropods.

Benthic invertebrate community indices were generally similar among years and between lakes (Figure 5.7-11). Analysis of variance on each index, followed by planned contrasts to examine year and lake trends between 2001 and 2004 for Kearl and Shipyard lakes, revealed significant year × lake interactions for total abundance, diversity and evenness, indicating that patterns over time differed among lakes (Table 5.7-11). In 2001 and 2002, total numbers of benthic invertebrates were higher in Shipyard Lake than in Kearl Lake, but numbers were higher in Kearl Lake in 2003 and 2004. Simpson's diversity has been relatively consistent in Kearl Lake (~ 0.6 to 0.7), but has fluctuated more widely and increased over time in Shipyard Lake (0.4 to 0.8). Evenness has likewise generally increased in Shipyard Lake, while it has decreased in Kearl Lake. There were no

significant differences in any of the benthic invertebrate community measurement endpoints between Kearl and Shipyard lakes in 2004. There also were no significant differences in measurement endpoints among lakes when all indices were averaged over time.

In general, Shipyard Lake is in relatively good condition, with indices of composition and a diversity that is as good as what has been found at Kearl Lake and McClelland Lake. A variety of sensitive faunal groups were present in Kearl Lake including caddisflies (Trichoptera) and phantom midges (Chaoboridae). Trends over time indicate that the benthic community has been increasing in diversity in Shipyard Lake relative to Kearl Lake, but the trends to date have been quite subtle.

5.7.5 Fish Populations

Fish populations were not monitored in any of these waterbodies in 2004.

5.7.6 Summary of Conditions

The various miscellaneous waterbodies in the RAMP FSA sampled under the RAMP program in 2004 exhibited a range of conditions. The designated aquatic systems sampled for water quality in 2004 exhibited limited exceedances of CCME guidelines for the protection of aquatic life and had values of most of the measurement endpoints were within the normal range of regional baseline conditions for reference waterbodies and watercourses. Similarly, designated aquatic systems sampled for sediment quality in 2004 exhibited limited exceedances of CCME ISQG guidelines for the protection of aquatic life in 2004. However, there was a wide variation in the location of the sediment quality measurement endpoints with respect to the normal range of regional baseline conditions for reference waterbodies and watercourses. With respect to benthic invertebrate communities, Shipyard Lake is in relatively good condition, with indices of composition and a diversity that is as good as what has been found at Kearl Lake and McClelland Lake (both reference lakes). Trends over time indicate that benthic community diversity has been increasing in Shipyard Lake relative to Kearl Lake, but the trends to date have been quite subtle.

Figure 5.7-2 Mills Creek 2004 hydrograph and historical context.

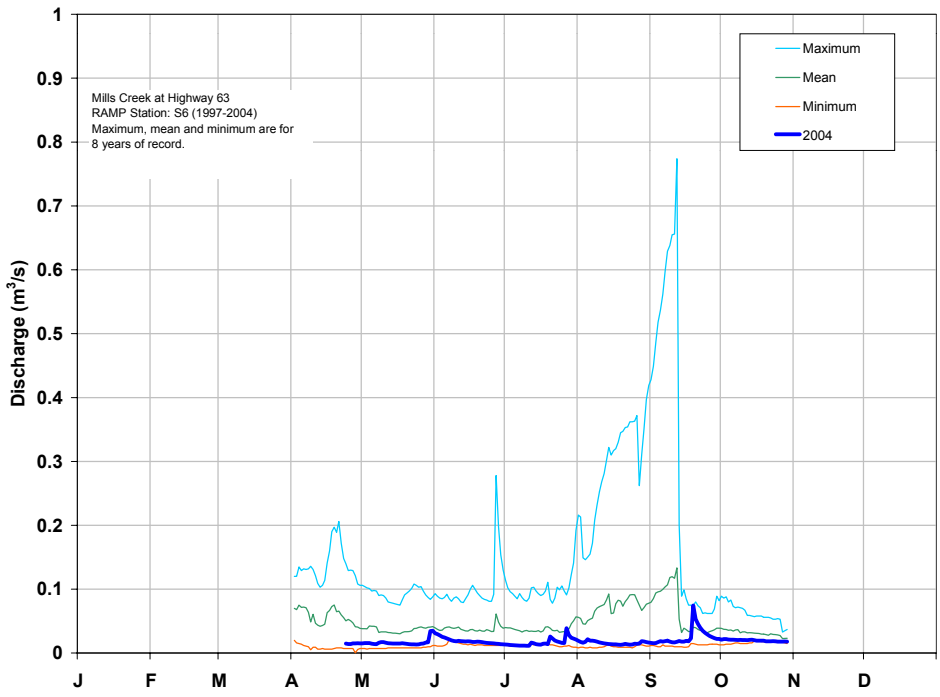


Figure 5.7-3 Poplar Creek 2004 hydrograph and historical context.

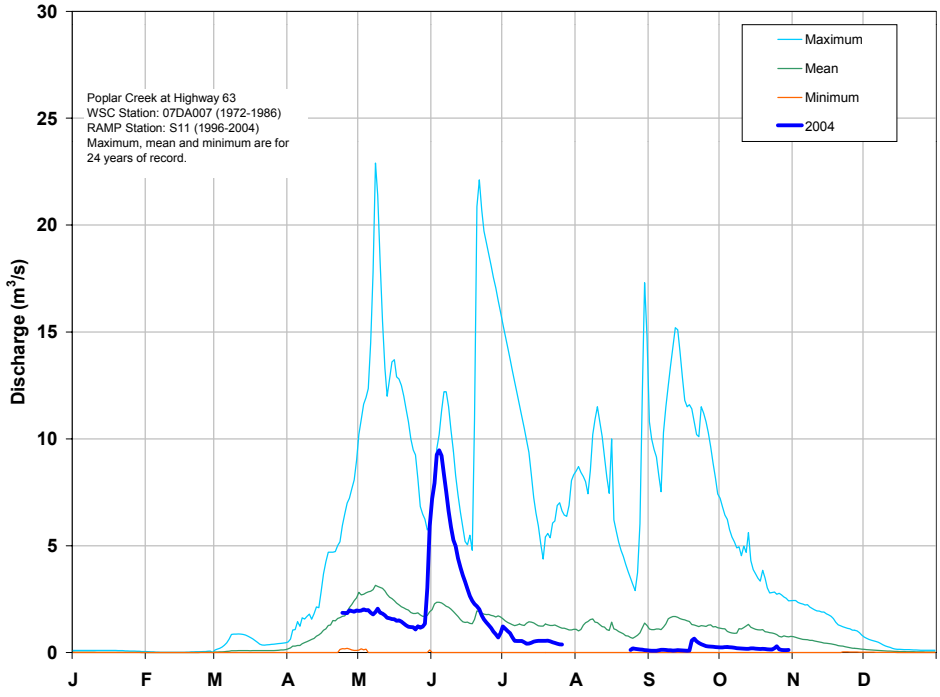
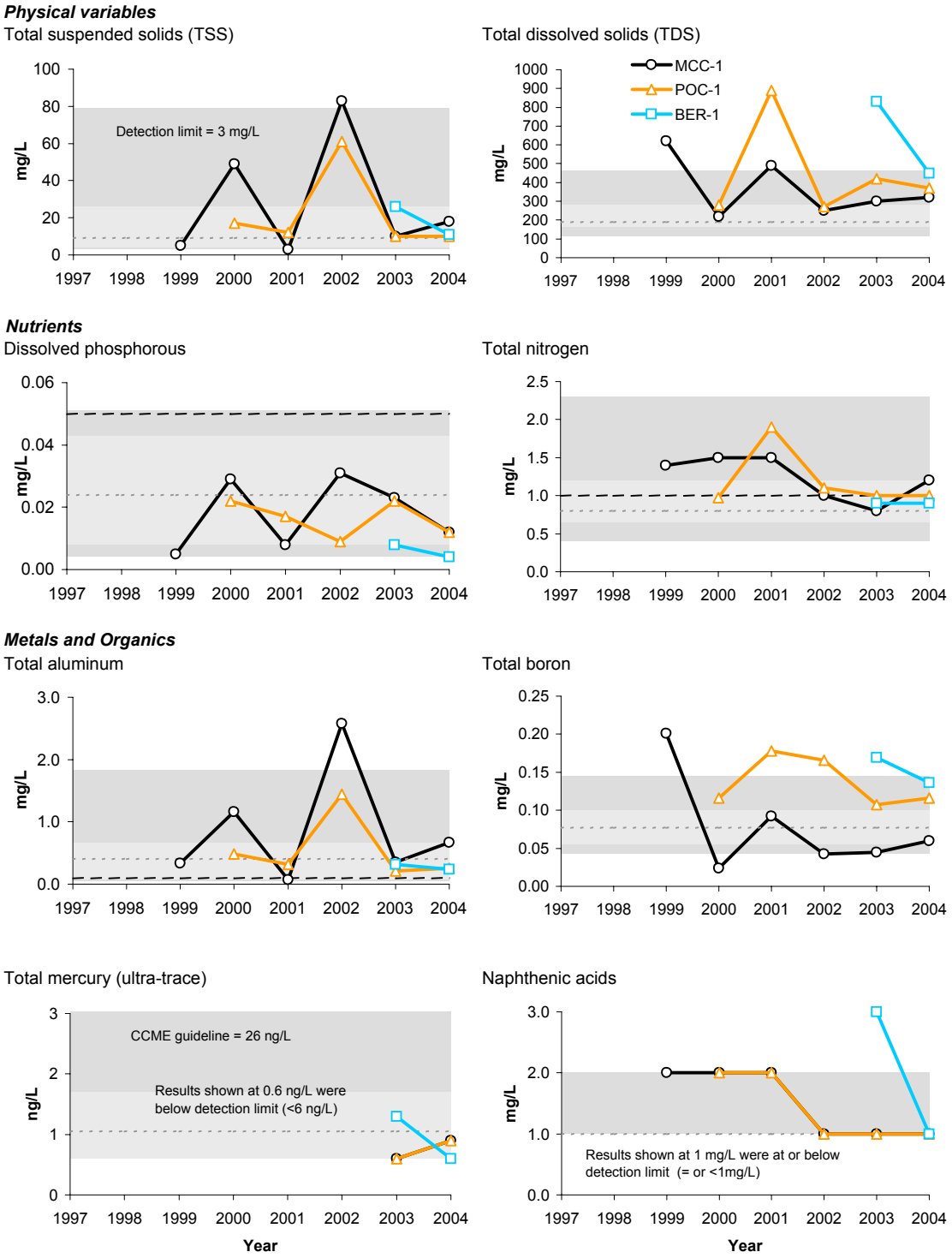


Table 5.7-1 Water quality measurement endpoints, lower Beaver Creek (BER-1).

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	1	-	-	8.0
Total suspended solids	mg/L	-	11	1	-	-	26
Conductivity	mg/L	-	605	1	-	-	1430
Nutrients							
Total phosphorus	mg/L	0.05	0.02	1	-	-	0.04
Dissolved phosphorus	mg/L	0.05[1]	0.004	1	-	-	0.008
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	-	31	1	-	-	21
Ions							
Sodium	mg/L	-	67	1	-	-	181
Chloride	mg/L	230, 860[2]	56	1	-	-	221
Sulphate	mg/L	100[3]	72	1	-	-	79
Total dissolved solids	mg/L	-	450	1	-	-	830
Total alkalinity	mg/L	-	169	1	-	-	294
Organic compounds							
Naphthenic acids	mg/L	-	1	1	-	-	3
Selected metals							
Total aluminum	mg/L	0.1	**0.238**	1	-	-	**0.318**
Dissolved aluminum	mg/L	0.1[1]	0.014	1	-	-	0.002
Total boron	mg/L	1.2[3]	0.14	1	-	-	0.17
Total molybdenum	mg/L	0.073	0.0004	1	-	-	0.0004
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	1.3
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.005**	1	-	-	0.002
Total iron	mg/L	0.300	**1.79**	1	-	-	**3.72**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.7-4 Selected fall water quality measurement endpoints in McLean Creek (MCC-1), Beaver Creek (BER-1) and Poplar Creek (POC-1), relative to regional baseline conditions.



[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 E for these regional baseline ranges.

Figure 5.7-5 Ion balance in McLean Creek, Beaver Creek and Poplar Creek, 1999-2004.

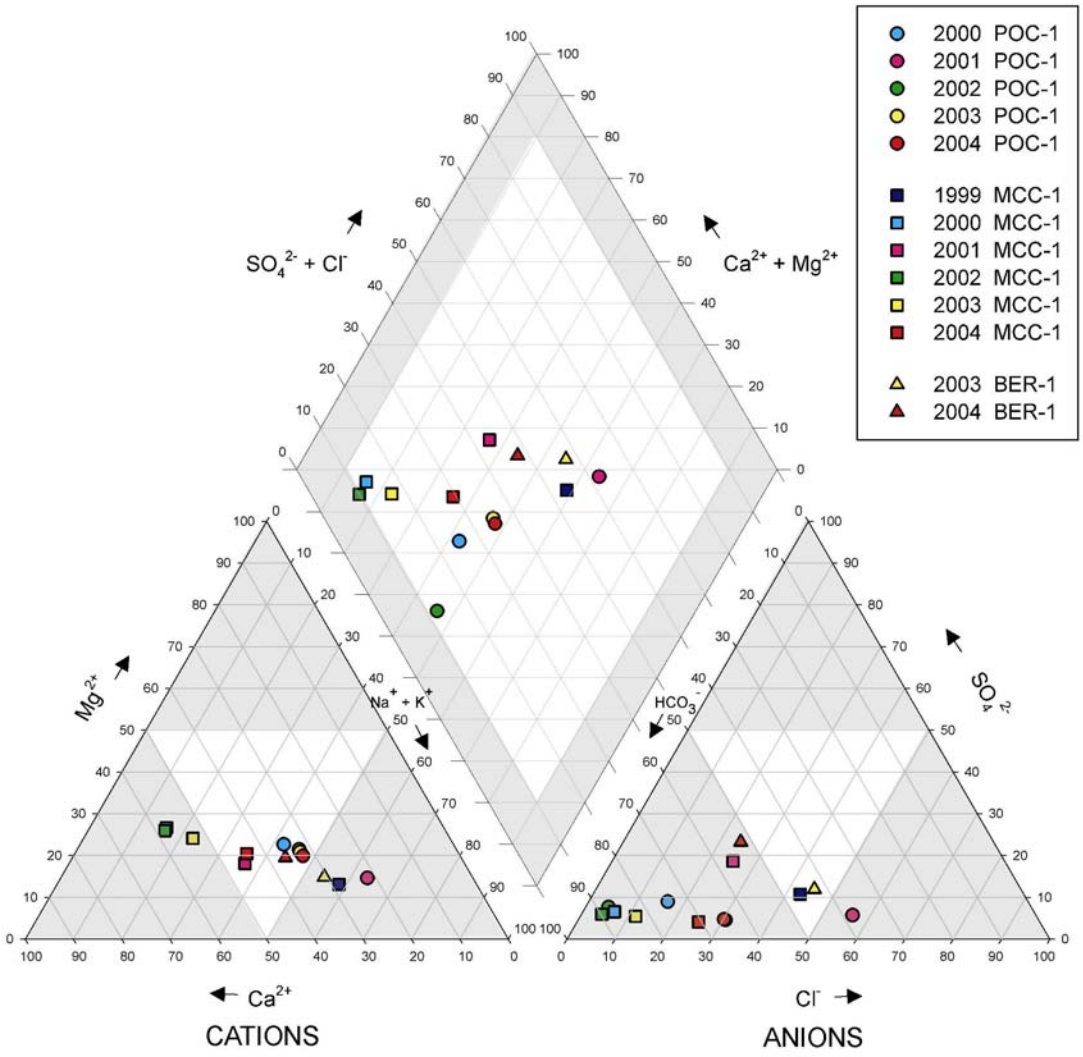


Table 5.7-2 Water quality measurement endpoints, Poplar Creek (POC-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	4	7.9	8.2	8.3
Total suspended solids	mg/L	-	10	4	10	14.5	61
Conductivity	mg/L	-	529	4	374	542	1590
Nutrients							
Total phosphorus	mg/L	0.05	0.03	4	0.031	0.036	**0.060**
Dissolved phosphorus	mg/L	0.05[1]	0.012	4	0.009	0.020	0.022
Total nitrogen*	mg/L	1.0	1.0	4	1.0	**1.1**	**1.9**
Nitrate+nitrite	mg/L	-	<0.1	4	<0.1	0.07	0.1
Dissolved organic carbon	mg/L	-	23	4	21	24	32
Ions							
Sodium	mg/L	-	71	4	44	59	238
Chloride	mg/L	230, 860[2]	65	4	7	48	**321**
Sulphate	mg/L	100[3]	14	4	14	17	44
Total dissolved solids	mg/L	-	370	4	270	350	890
Total alkalinity	mg/L	-	198	4	166	193	304
Organic compounds							
Naphthenic acids	mg/L	-	<1	4	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	0.3	4	**0.2**	**0.4**	**1.4**
Dissolved aluminum	mg/L	0.1[1]	0.009	4	0.007	<0.01	0.012
Total boron	mg/L	1.2[3]	0.12	4	0.11	0.14	0.18
Total molybdenum	mg/L	0.073	0.0003	4	0.0002	0.0003	0.0005
Total mercury (ultra-trace)	ng/L	26	0.9	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.007**	4	<0.001	0.0015	0.002
Total iron	mg/L	0.3	**1.57**	4	**1.21**	**1.81**	**3.63**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.7-3 Water quality measurement endpoints, McLean Creek (MCC-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.4	5	8.0	8.3	8.4
Total suspended solids	mg/L	-	18	5	3	10	83
Conductivity	mg/L	-	370	5	300	407	1000
Nutrients							
Total phosphorus	mg/L	0.05	0.037	5	0.008	0.047	**0.07**
Dissolved phosphorus	mg/L	0.05[1]	0.012	5	0.005	0.023	0.031
Total nitrogen*	mg/L	1.0	**1.2**	5	0.8	**1.1**	**1.5**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<1
Dissolved organic carbon	mg/L	-	22	5	14	21	28
Ions							
Sodium	mg/L	-	43	5	12	23	140
Chloride	mg/L	230, 860[2]	44	5	5	17	165
Sulphate	mg/L	100[3]	10	5	9	11	76
Total dissolved solids	mg/L	-	320	5	220	300	620
Total alkalinity	mg/L	-	176	5	144	174	251
Organic compounds							
Naphthenic acids	mg/L	-	<1	5	<1	2	2
Selected metals							
Total aluminum	mg/L	0.1	**0.7**	5	0.07	**0.4**	**2.6**
Dissolved aluminum	mg/L	0.1[1]	0.008	5	0.010	0.010	0.016
Total boron	mg/L	1.2[3]	0.06	5	0.02	0.04	0.20
Total molybdenum	mg/L	0.073	0.0002	5	0.0001	0.0002	0.0005
Total mercury (ultra-trace)	ng/L	26	0.9	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.008**	5	<0.001	<0.001	0.002
Total iron	mg/L	0.300	**0.89**	5	**0.36**	**0.66**	**3.46**

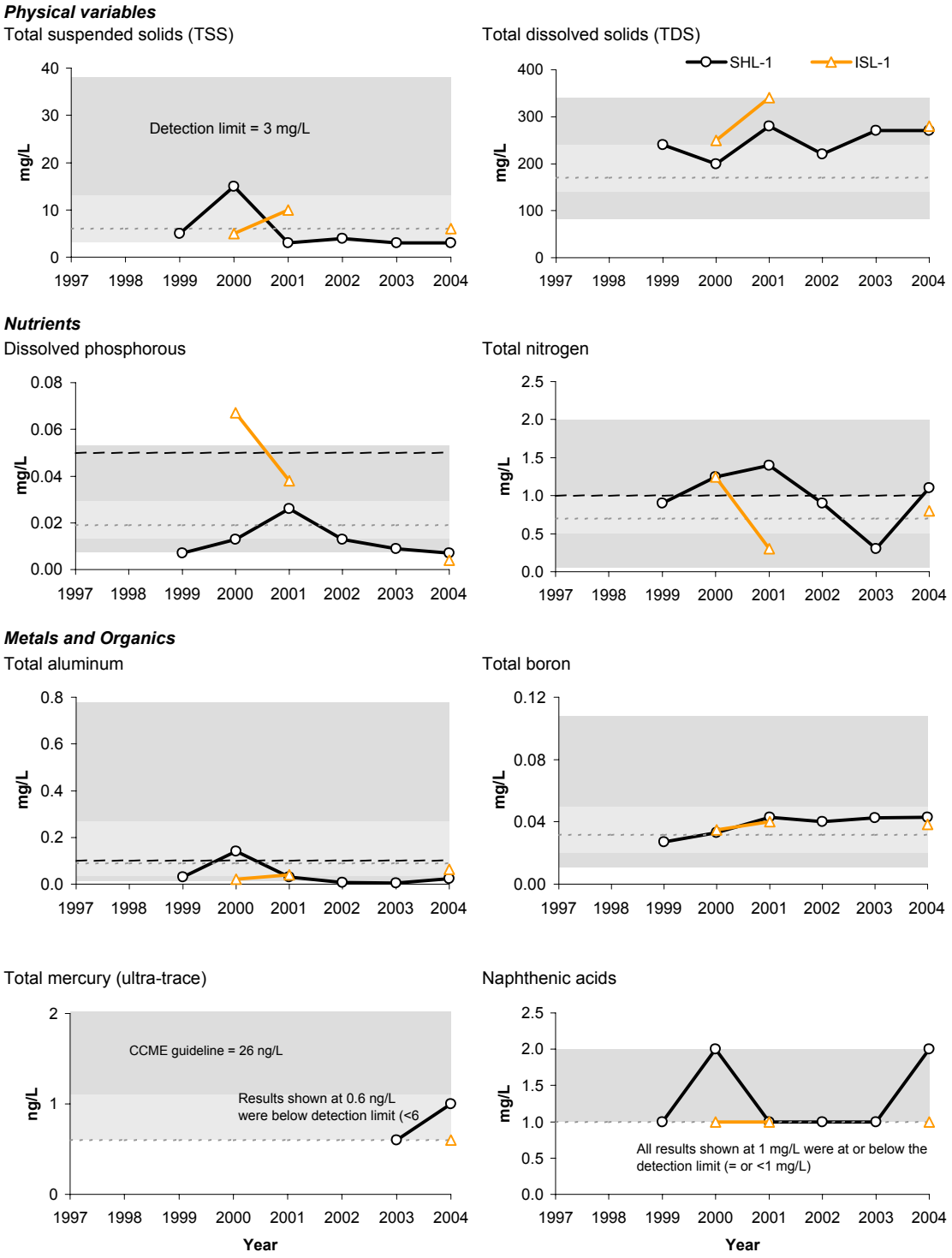
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.7-4 Water quality measurement endpoints, Shipyard Lake (SHL-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	5	7.7	7.8	8.1
Total suspended solids	mg/L	-	<3	5	<3	4	15
Conductivity	mg/L	-	389	5	358	378	394
Nutrients							
Total phosphorus	mg/L	0.05	0.02	5	0.02	0.02	0.03
Dissolved phosphorus	mg/L	0.05[1]	0.007	5	0.007	0.013	0.026
Total nitrogen*	mg/L	1.0	**1.1**	5	0.3	0.9	**1.4**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	22	5	17	19	22
Ions							
Sodium	mg/L	-	21	5	16	17	20
Chloride	mg/L	230, 860[3]	18	5	11	16	18
Sulphate	mg/L	100[4]	3	5	5	8	11
Total dissolved solids	mg/L	-	270	5	200	240	280
Total alkalinity	mg/L	-	182	5	159	171	189
Organic compounds							
Naphthenic acids	mg/L	-	2	5	<1	1	2
Selected metals							
Total aluminum	mg/L	0.1	0.02	5	0.006	0.030	**0.14**
Dissolved aluminum	mg/L	0.1[1]	0.001	5	0.002	0.01	0.01
Total boron	mg/L	1.2[4]	0.04	5	0.03	0.04	0.04
Total molybdenum	mg/L	0.073	0.00005	5	0.00007	0.0001	0.0002
Total mercury (ultra-trace)	ng/L	26	1	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.012**	5	<0.001	<0.001	**0.006**
Total copper	mg/L	0.002-0.004[2]	**0.0038**	5	0.00016	<0.001	0.004
Total iron	mg/L	0.30	**0.35**	5	0.27	**0.77**	**1.48**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[4] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.7-6 Selected fall water quality measurement endpoints, Shipyard Lake (SHL-1) and Isadore's Lake (ISL-1), relative to regional baseline conditions.



[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 E for these regional baseline ranges.

Figure 5.7-7 Ion balance in Shipyard Lake and Isadore's Lake, 1999-2004.

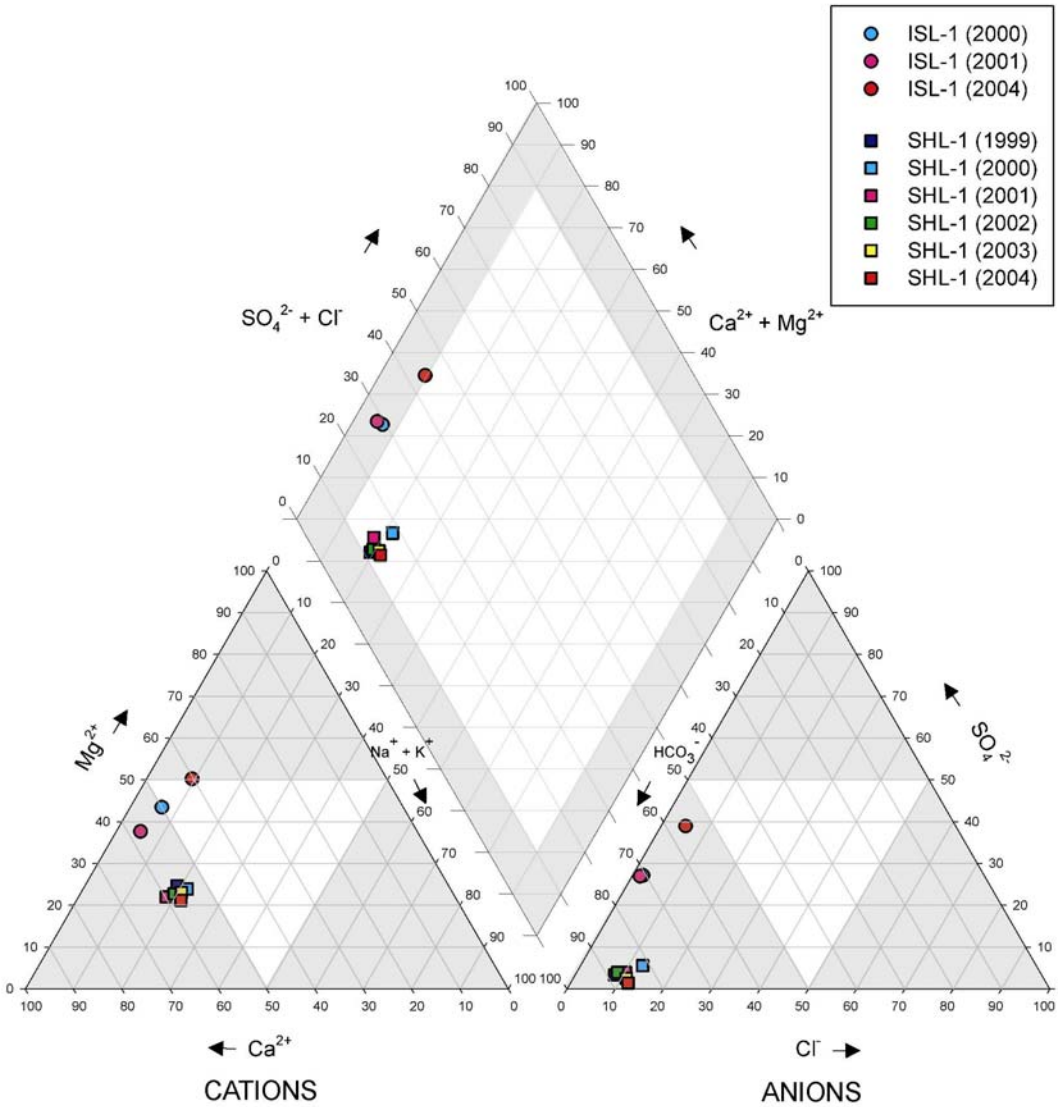


Table 5.7-5 Water quality measurement endpoints, Isadore's Lake (ISL-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	7.7	-	8.1
Total suspended solids	mg/L	-	6	2	5	-	10
Conductivity	mg/L	-	353	2	462	-	551
Nutrients							
Total phosphorus	mg/L	0.05	0.04	2	**0.08**	-	**0.10**
Dissolved phosphorus	mg/L	0.05[1]	0.004	2	0.038	-	**0.067**
Total nitrogen*	mg/L	1.0	0.8	2	0.3	-	**1.3**
Nitrate+nitrite	mg/L	-	<0.1	2	<0.05	-	<0.1
Dissolved organic carbon	mg/L	-	8	2	9	-	11
Ions							
Sodium	mg/L	-	9	2	6	-	6
Chloride	mg/L	230, 860[2]	8	2	4	-	4
Sulphate	mg/L	100[3]	81.3	2	63.9	-	82.5
Total dissolved solids	mg/L	-	280	2	250	-	340
Total alkalinity	mg/L	-	122	2	173	-	227
Organic compounds							
Naphthenic acids	mg/L	-	1	2	<1	-	<1
Selected metals							
Total aluminum	mg/L	0.1	0.063	2	<0.02	-	0.04
Dissolved aluminum	mg/L	0.1[1]	0.0020	2	<0.01	-	0.02
Total boron	mg/L	1.2[3]	0.038	2	0.035	-	0.040
Total molybdenum	mg/L	0.073	0.0001	2	<0.0001	-	0.0001
Total mercury (ultra-trace)	ng/L	26	<0.6	-	-	-	-
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total zinc	mg/L	0.030	**0.058**	2	**0.032**	-	**0.035**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.7-6 Water quality guideline exceedances in miscellaneous aquatic systems exposed to oil sands developments, 2004.

Parameter	Units	Guideline	ISL-1	SHL-1	BER-1
Summer [1]					
Total iron	mg/L	0.300	-	**0.630**	**2.78**
Dissolved iron	mg/L	0.300[2]	-	-	**1.58**
Fall					
Total phenols	mg/L	0.004	-	**0.012**	**0.005**
Total copper	mg/L	0.002-0.004[3]	-	**0.00380**	-
Dissolved copper	mg/L	0.002-0.004[2, 3]	-	**0.00367**	-
Total zinc	mg/L	0.030	**0.0578**	-	-
Dissolved zinc	mg/L	0.030[2]	**0.0385**	-	-

Guidelines are CCME/AENV guidelines for the protection of aquatic life.

[1]: Stations sampled only in summer and fall.

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

[3]: Guideline is hardness dependent.

Table 5.7-7 Sediment quality measurement endpoints, Poplar Creek (POC-1), fall 2004.

	Units	Guideline	September 2004		1997-2003 (Fall data only)		
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	10	2	19.7	-	35
Silt	%	-	17	2	13.3	-	53
Sand	%	-	73	2	12	-	67
Total organic carbon	%	-	2.1	2	1.82	-	2.2
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]	120	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**1400**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	1400	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	1	-	-	15
TEH (C11-C30)	mg/kg	-	150	1	-	-	900
TRH	mg/kg	-	6600	2	2200	-	6670
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.002	2	0.006	-	0.016
Retene	mg/kg	-	0.05	1	-	-	0.10
Total dibenzothiophenes	mg/kg	-	1.3	2	0.3	-	0.6
Total PAHs	mg/kg	-	4.8	2	1.8	-	2.2
Total HMW PAHs	mg/kg	-	1.5	2	0.4	-	0.8
Total LMW PAHs	mg/kg	-	3.3	2	1.4	-	1.4
Predicted PAH toxicity[1]	H.I.	-	0.38	2	0.12	-	0.52
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	8	1	-	-	9
Chironomus growth	mg/organism	-	1.8	1	-	-	1.7
Hyallela survival	# surviving	-	8	1	-	-	9
Hyallela growth	mg/organism	-	0.2	1	-	-	0.1

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV 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.

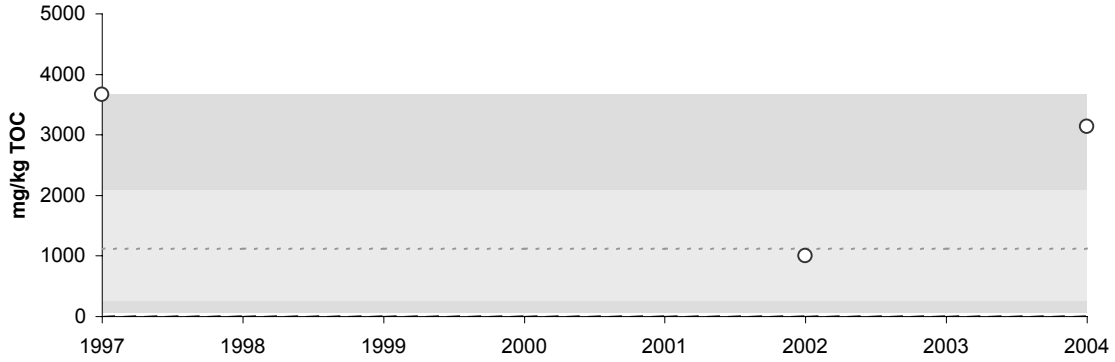
[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2001).

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

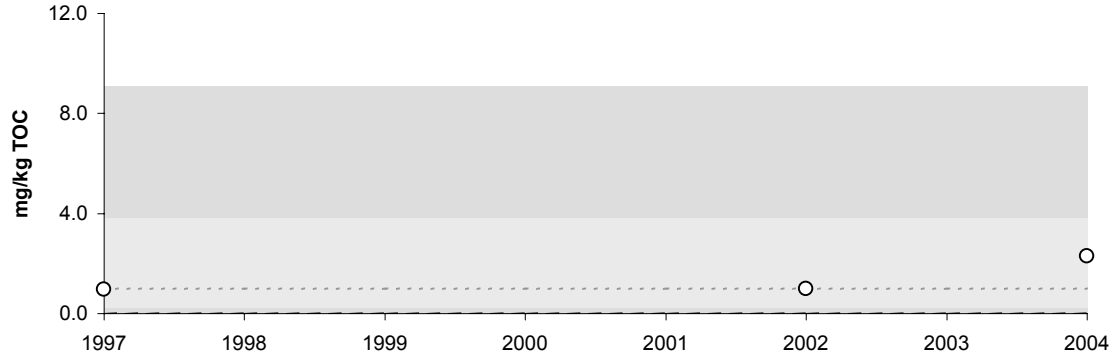
Figure 5.7-8 Selected sediment quality measurement endpoints, Poplar Creek (POC-1), relative to regional baseline concentrations.

Note : MCC-1, BER-1 not sampled in 2004

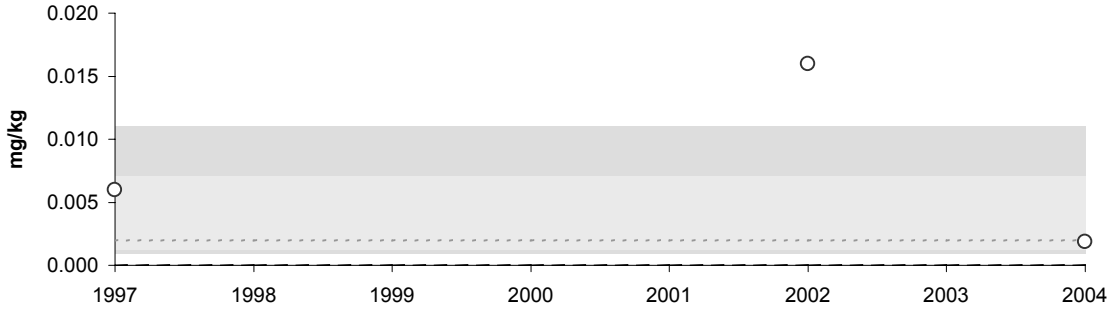
Total Recoverable Hydrocarbons (normalized to TOC)



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 F for these regional baseline ranges.

Table 5.7-8 Sediment quality measurement endpoints, Shipyard Lake (SHL-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	3	2	53	-	59
Silt	%	-	59	2	40	-	45
Sand	%	-	39	2	2	-	2
Total organic carbon	%	-	9.7	2	5.5	-	15.5
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]	69	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	290	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	130	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	2	1.7	-	7.9
TEH (C11-C30)	mg/kg	-	14	2	36	-	570
TRH	mg/kg	-		2	2300	-	3400
Polycyclic Aromatic Hydrocarbons (PAH)							
Napthelene	mg/kg	0.0346[3]	0.0186	2	0.011	-	0.0151
Retene	mg/kg	-	0.103	3	0.046	0.0821	0.094
Total dibenzothiophenes	mg/kg	-	0.682	3	0.265	0.411	0.470
Total PAHs	mg/kg	-	4.07	3	2.28	2.64	4.07
Total HMW PAHs	mg/kg	-	1.39	3	1.09	1.29	1.88
Total LMW PAHs	mg/kg	-	2.68	3	0.98	1.55	2.19
Predicted PAH toxicity[1]	H.I.	-		3	0.09	0.42	0.54
Metals that exceed CCME guidelines in fall 2004							
Total Arsenic (As)	mg/kg	5.9[3]	**7.3**	2	7.4	-	7.8
Chronic toxicity							
Chironimus survival	# surviving	-	8	1	-	-	7
Chironimus growth	mg/organism	-	2	1	-	-	1.5
Hyallela survival	# surviving	-	6	1	-	-	6
Hyallela growth	mg/organism	-	0.2	1	-	-	0.1

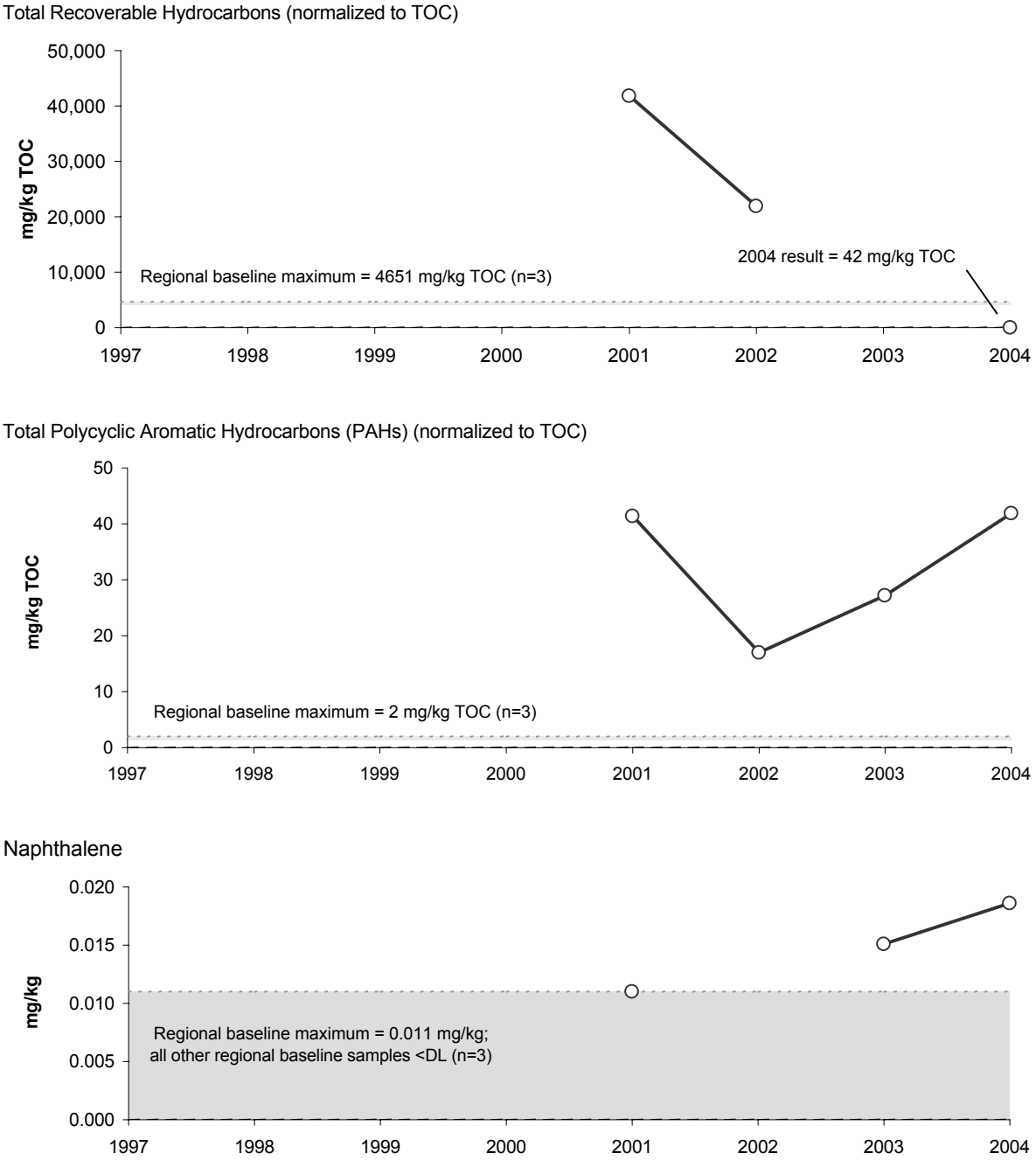
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

[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 5.7-9 Selected sediment quality measurement endpoints, Shipyard Lake (SHL-1), 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 F for these regional baseline ranges.

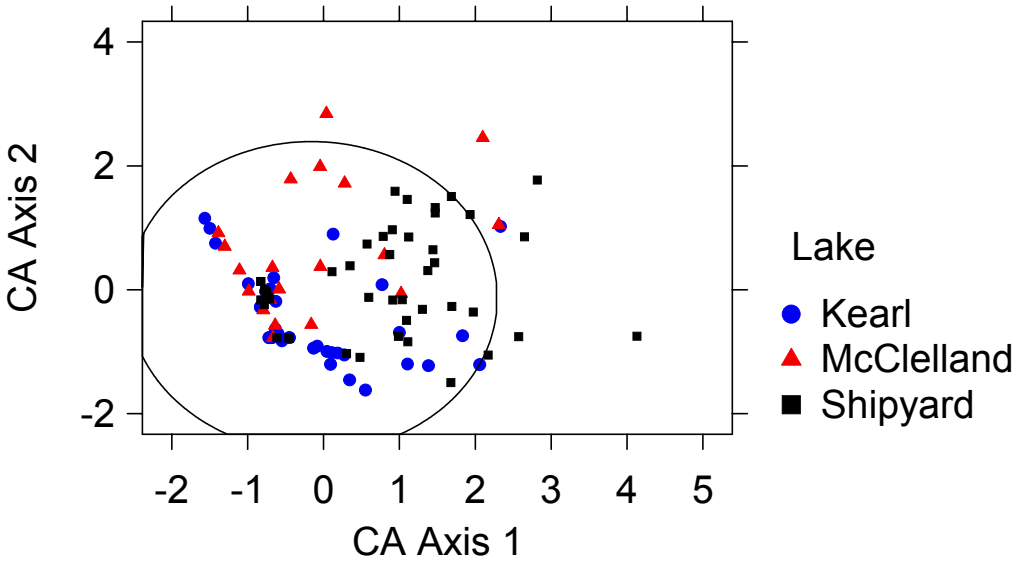
Table 5.7-9 Average habitat characteristics of benthic invertebrate sampling locations in Kearl and Shipyard Lakes, fall 2004.

Variable	Units	Kearl Lake	Shipyard Lake
Sample date	-	Sept 15, 2004	Sept 16, 2004
Habitat	-	Depositional	Depositional
Water depth	M	1.6	2.0
Macrophyte cover	%	39	30
Field Water Quality			
Dissolved oxygen	Mg/L	9.6	7.6
Conductivity	µS/cm	120	281
pH	-	7.9	7.6
Water temperature	°C	10.6	11.4
Sediment Composition			
Sand	%	17.1	13.5
Silt	%	34.2	42.5
Clay	%	48.5	44.1
Total Organic Carbon	%	39.4	7.9

Table 5.7-10 Summary of major taxon abundances and key indices of composition among stations in Kearl, McClelland, and Shipyard Lakes, Fall 2004.

Taxon	Kearl Lake			Shipyard Lake		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Hydra	151	0	1.4	0	0	0
Nematoda	0	0	0	92	129	1.6
Glossiphoniidae	345	0	3.1	0	0	0
Naididae	2,030	5,259	18.3	1,024	2,526	17.6
Tubificidae	0	0	0	156	367	2.7
Hydracarina	0	0	0	199	432	3.4
Ostracoda	34	35	0.3	744	1,349	12.8
Copepoda	52	305	0.5	16	0	0.3
Chydoridae	172	0	1.6	0	0	0
Daphniidae	17	0	0.2	65	0	1.1
Amphipoda	2,797	2,345	25.3	0	0	0
Gastropoda	0	0	0	679	590	11.6
Trichoptera	517	1,219	4.7	11	0	0.2
Zygoptera	0	0	0	86	0	1.5
Coleoptera	353	499	3.2	11	0	0.2
Chaoboridae	0	0	0	948	1,549	16.3
Chironomidae	4,595	2,225	41.5	1,800	769	30.9
Total Abundance	11,065	8,765		5,830	5,180	
Richness	7.1	2.2		9.0	3.2	
Simpson's Diversity	0.623	0.196		0.723	0.115	
Evenness	0.729	0.212		0.824	0.105	

Figure 5.7-10 Biplot of benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for Kearl, Shipyard and McClelland Lakes



Ellipse is for reference data (i.e., McClelland Lake to 2003; Kearl Lake to 2004).

Figure 5.7-11 Variations in indices of benthic invertebrate community composition in Kearl, McClelland and Shipyard Lakes.

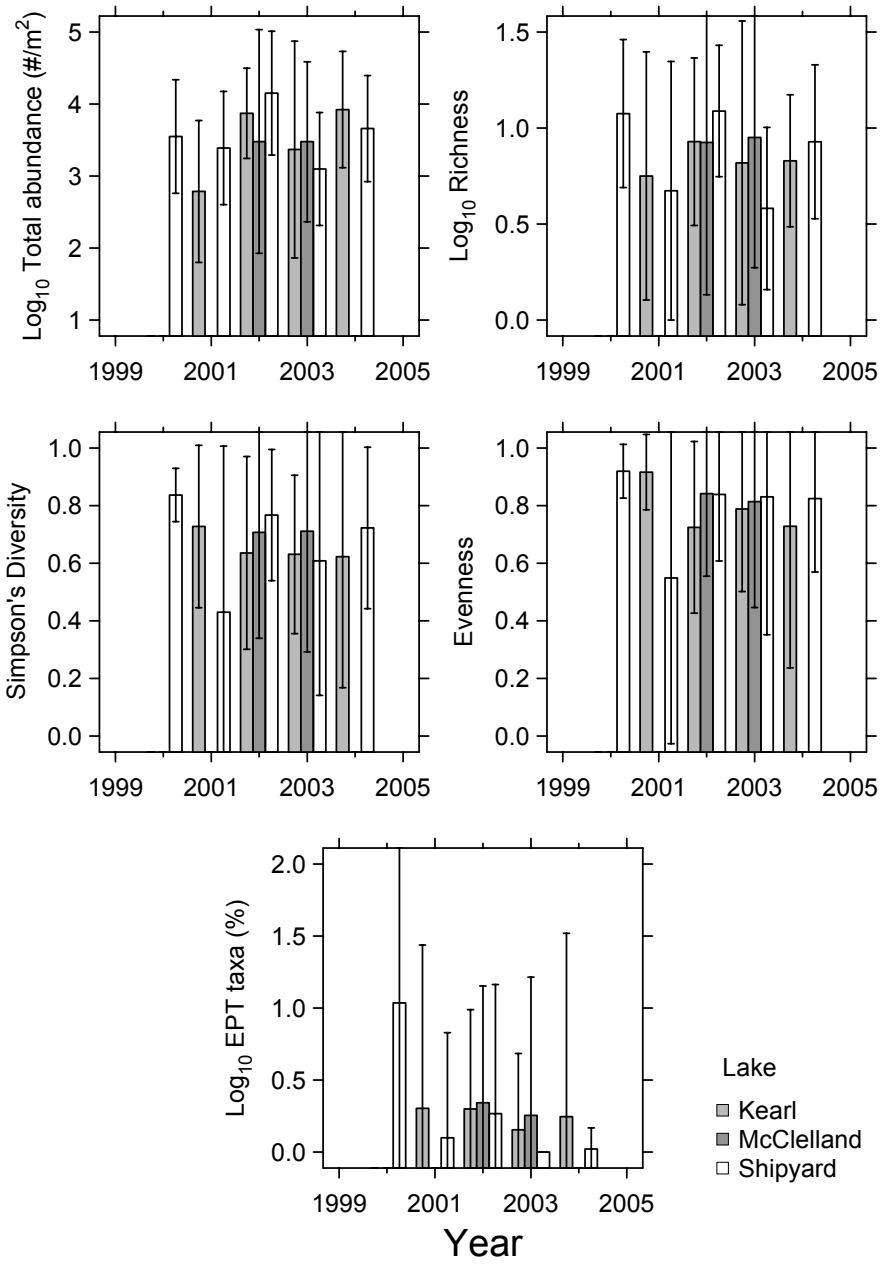


Table 5.7-11 Results of analysis of variance on the lake data; time contrasts are for Kearl versus Shipyard lakes, 2001 to 2004.

Source	SS	df	F	P
Log_{10} Abundance				
Reach-Year	14.07	10	7.495	<0.001
Time (2001-2004)	1.642	1	8.750	0.004
Lake	0.146	1	0.778	0.380
Time × Lake	2.302	1	12.26	0.001
Lake (2004)	0.310	1	1.654	0.202
Error	18.02	96		
Log_{10} Richness				
Reach-Year	2.448	10	4.245	<0.001
Time (2002-2004)	0.035	1	0.600	0.441
Lake	0.004	1	0.066	0.797
Time × Lake	0.004	1	0.068	0.795
Lake (2004)	0.043	1	0.747	0.390
Error	5.537	96		
Simpson's Diversity				
Reach	1.119	10	4.460	<0.001
Time (2002-2004)	0.037	1	1.458	0.230
Lake	0.009	1	0.376	0.541
Time × Lake	0.249	1	9.936	0.002
Lake (2004)	0.044	1	1.770	0.187
Error	2.408	96		
Evenness				
Reach	1.051	10	4.592	<0.001
Time (2002-2004)	0.023	1	1.026	0.314
Lake	0.016	1	0.693	0.407
Time × Lake	0.401	1	17.53	<0.001
Lake (2004)	0.041	1	1.777	0.186
Error	2.197	96		
Log_{10} EPT %				
Reach	7.593	10	5.127	<0.001
Time (2002-2004)	*0.155*	*1*	*1.048*	*0.309*
Lake	*0.453*	*1*	*3.060*	*0.083*
Time × Lake	*0.008*	*1*	*0.053*	*0.819*
Lake (2004)	*0.224*	*1*	*1.514*	*0.221*
Error	14.22	96		

5.8 FIREBAG RIVER SYSTEM

Summary of Results

Climate and Hydrology

	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge Mean winter discharge Annual maximum daily discharge Minimum open-water season discharge	The Firebag River watershed was designated as a reference watershed for 2004.				Total runoff was very close to normal in 2004. Flows were above average for most of June but below average for most of the summer and fall. Winter flows were generally below normal.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=2)	
Physical variables (3 endpoints)	No water quality sampling stations were designated as exposed in 2004.	0	Fall 2004 concentrations of water quality variables were lower than those observed in previous years. All water quality measurement endpoints but one were below guidelines for the protection of aquatic life. Fall 2004 concentrations of selected measurement endpoints were all within the range observed in regional baseline watercourses. There has been little change in overall water quality conditions in the watershed since the beginning of RAMP sampling.
Nutrients (5 endpoints)		1	
Ions (5 endpoints)		0	
Organic compounds (1 endpoint)		0	
Selected metals (5 endpoints)		0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 2 stations X 7 endpoints)
Above 95th	No water quality sampling stations were designated as exposed in 2004.	0
Between 75th and 95th		2
Between median and 75th		1
Between 25th and median		7
Between 5th and 25th		3
Less than 5th		1

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=2)	
Physical variables (4 endpoints)	No sediment quality sampling stations were designated as exposed in 2004.	0	Concentrations of sediment quality variables in fall 2004 were within the range of observations of previous years and within the range observed in regional baseline watercourses. All sediment quality measurement endpoints at both stations in fall 2004 were below CCME ISQG and other guidelines.
Total Hydrocarbons (8 endpoints)		0	
PAHs (7 endpoints)		0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 2 stations X 3 endpoints)
Above 95th	No sediment quality sampling stations were designated as exposed in 2004.	0
Between 75th and 95th		0
Between median and 75th		3
Between 25th and median		2
Between 5th and 25th		0
Less than 5th		1

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline						
	2004 Exposed Stations (n=0)			2004 Reference Stations (n= 1)			
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD	
Abundance	No benthic invertebrate community sampling stations were designated as exposed in 2004.				2		Benthic invertebrate community indices were within the expected regional reference values for erosional and depositional habitats in the lower and upper reaches of the Firebag River, respectively.
Richness					2		
Diversity					2		
Evenness					2		
% EPT					2		

Fish Populations

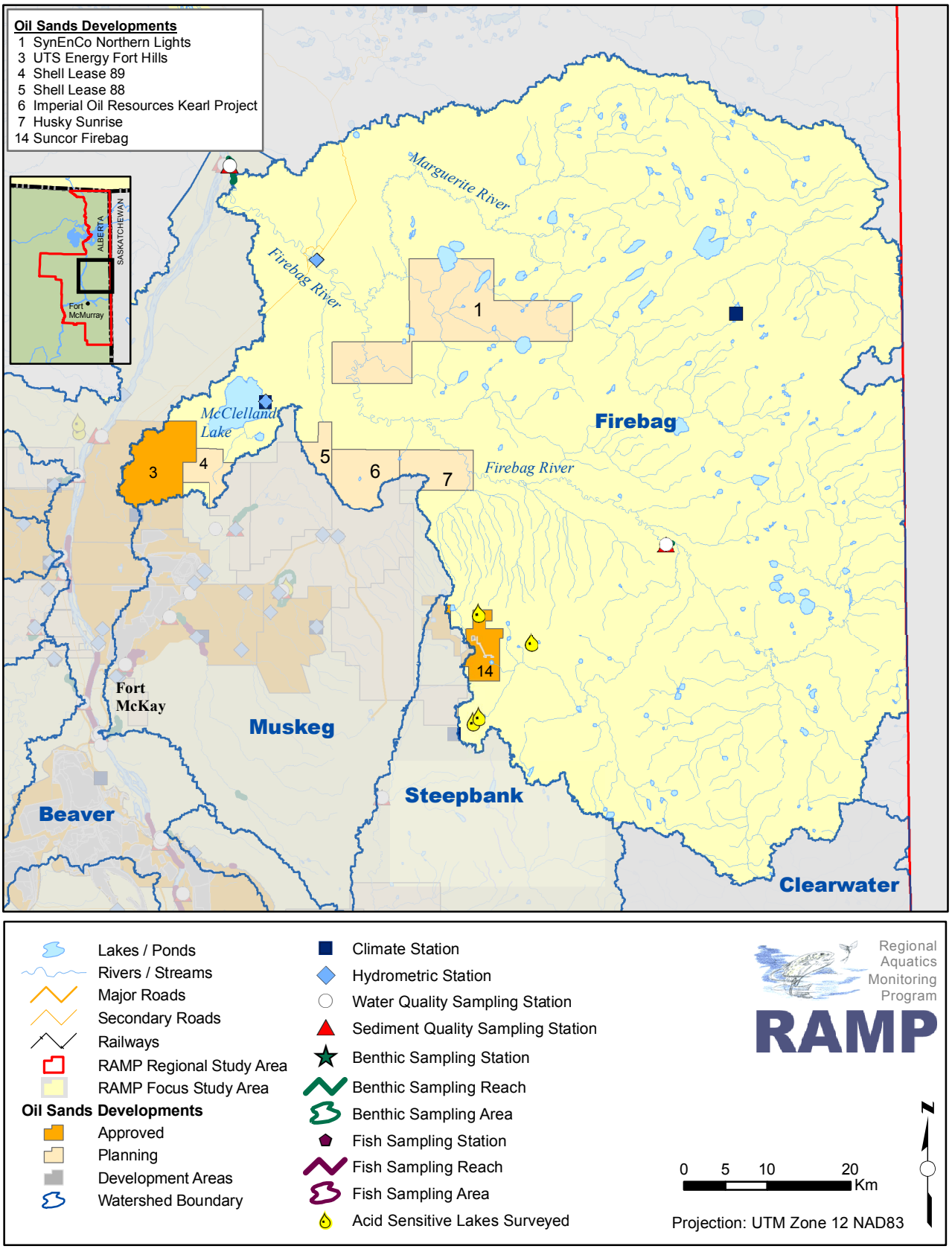
Fish Inventory	No fish inventory studies were conducted in the Firebag River in 2004.	
Sentinel Studies	Sentinel fish studies were not conducted in 2004.	
Fish Tissue	Level of Risk	
Human Health: Subsistence Human Health: Recreational Fishers Human Health: General Consumers Human Health: Tainting Fish and Wildlife: Mercury Fish and Wildlife: Other Chemicals	Fish tissue program was not conducted in the Firebag River in 2004.	

[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 Firebag River watershed.



5.8.1 Hydrologic Conditions

Total runoff in the Firebag River system was very close to normal in 2004, with a total runoff of 117 mm compared to the long-term average of 114 mm. Flows were above average for most of June, but below average for most of the summer and fall, as shown in Figure 5.8-2. Winter flows were below normal from January to February and from November to December. The June maximum daily discharge of 150 m^3/s was 40% higher than the mean annual flood. The minimum open-water discharge was 14.3 m^3/s on August 19, very close to the mean annual minimum of 15.2 m^3/s.

5.8.2 Water Quality

In 2004, water quality samples were collected from the mouth of the Firebag River (station FIR-1) and upstream of the Suncor Firebag project (station FIR-2) in September. Both Station FIR-1 and FIR-2 were designated as reference stations up to and including 2004, as the Suncor Firebag Project was assessed to be sufficiently limited in magnitude and extent that RAMP aquatic resources would not be affected by oil sands development activities. Results of 2004 sampling for selected water quality measurement endpoints identified in Section 3.2.7 are shown in Table 5.8-1 and Table 5.8-2; results for selected measurement endpoints (1997 to 2004) relative to regional baseline conditions are shown in Figure 5.8-3.

In general, fall 2004 concentrations of water quality variables were lower than those observed in previous years. At station FIR-1, all water quality measurement endpoints were below guidelines for the protection of aquatic life, while only total phosphorous exceeded guidelines at station FIR-2. At both stations, fall 2004 concentrations of selected measurement endpoints were within the range observed in regional baseline watercourses (Figure 5.8-3) and, in most cases, were below levels observed previous to 2004.

Figure 5.8-4 indicates that ionic characteristics of the water sampled at both stations (FIR-1 and FIR-2) have been consistent over the period of sampling, suggesting there has been little change in overall water quality conditions in the watershed since the beginning of RAMP sampling. The results contained in Figure 5.8-4 also suggest that station FIR-2 will be a suitable reference station for station FIR-1 should station FIR-1 be designated as exposed in the future.

Table 5.8-3 contains a list of all exceedances of CCME guidelines for protection of aquatic life observed in the Firebag River in 2004.

5.8.3 Sediment Quality

In 2004, sediment quality samples were collected from the mouth of the Firebag River (station FIR-1) and upstream of the Suncor Firebag project (station FIR-2) in September. Both Station FIR-1 and FIR-2 were designated as reference stations up to and including 2004 for the same reasons as the corresponding water quality stations. Results of 2004 sampling for selected sediment quality measurement endpoints identified in Section 3.3.7 are shown in Table 5.8-4 and Table 5.8-5; results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.8-5.

Concentrations of sediment quality variables in the upper and lower Firebag River in 2004 were well within the range of observations of previous years and within the range observed in regional baseline watercourses (Figure 5.8-5). All sediment quality measurement endpoints at both stations in fall 2004 were below CCME ISQG and other guidelines. Carbon-normalized concentrations of TRH, total PAHs and naphthalene have not exhibited any consistent trends over time at either station (Figure 5.8-5) and the two stations were similar in 2004 with respect to concentrations of sediment quality variables.

5.8.4 Benthic Invertebrate Communities

In 2004, benthic invertebrate community samples were collected from a reach near the mouth of the Firebag River (reach FBR-E 1-15, erosional) and upstream of the Suncor Firebag Project (reach FBR-D 1-15, depositional). Both reaches were designated as reference reaches up to and including 2004 for the same reasons as the water and sediment quality stations.

The upper reach of the Firebag River is depositional, with moderate depths, no current velocity, and no macrophytes or benthic algae present (Table 5.8-6). In contrast, the lower reach of the Firebag River is erosional, with shallow depths, moderate current velocity, good macrophyte cover and moderate levels of benthic algae present. Water quality at the two reaches was generally similar, although conductivity in the upper reach was approximately double that of the lower reach of the Firebag River. Sediments of the upper reach were dominated by sand with very little total organic carbon. Substrates in the lower reach were heterogeneous, and ranged from small amounts of sand/silt/clay to boulders. Small cobbles were most abundant at the lower reach.

The benthic invertebrate community at the lower reach of the Firebag River was typical of erosional habitats, dominated by chironomid and EPT taxa (Table 5.8-7). Tubificids were also abundant in the lower reach. Chironomids and tubificids were dominant at the upper reach, while tipulids, heteropterans, and the ceratopogonids were also abundant.

The lower and upper reaches of the Firebag River have been sampled only since 2003; thus, it is difficult to evaluate temporal trends in benthic invertebrate community indices at either reach (Figure 5.8-6, Figure 5.8-7). However, benthic invertebrate community indices were well within the expected regional reference values for erosional habitats in the lower reach of the Firebag River (FBR-E 1-15). Similarly, benthic invertebrate community indices were within expected regional reference ranges for depositional habitats at the upper reach of the Firebag River (FBR-D 1-15).

5.8.5 Fish Populations

The 2004 RAMP fish program did not include any activities in the Firebag River system.

5.8.6 Summary of Conditions

RAMP aquatic resources of the Firebag River system, designated as a reference watershed, were similar in 2004 relative to previous years. Only one measurement endpoint sampled in 2004 exceeded existing environmental guidelines, some measurement endpoints exhibited declines from previous years (particularly water quality variables), and all measurement endpoints were within the range of expected reference conditions for similar river systems and habitats in the RAMP FSA.

Figure 5.8-2 Firebag River: 2004 hydrograph and historical context.

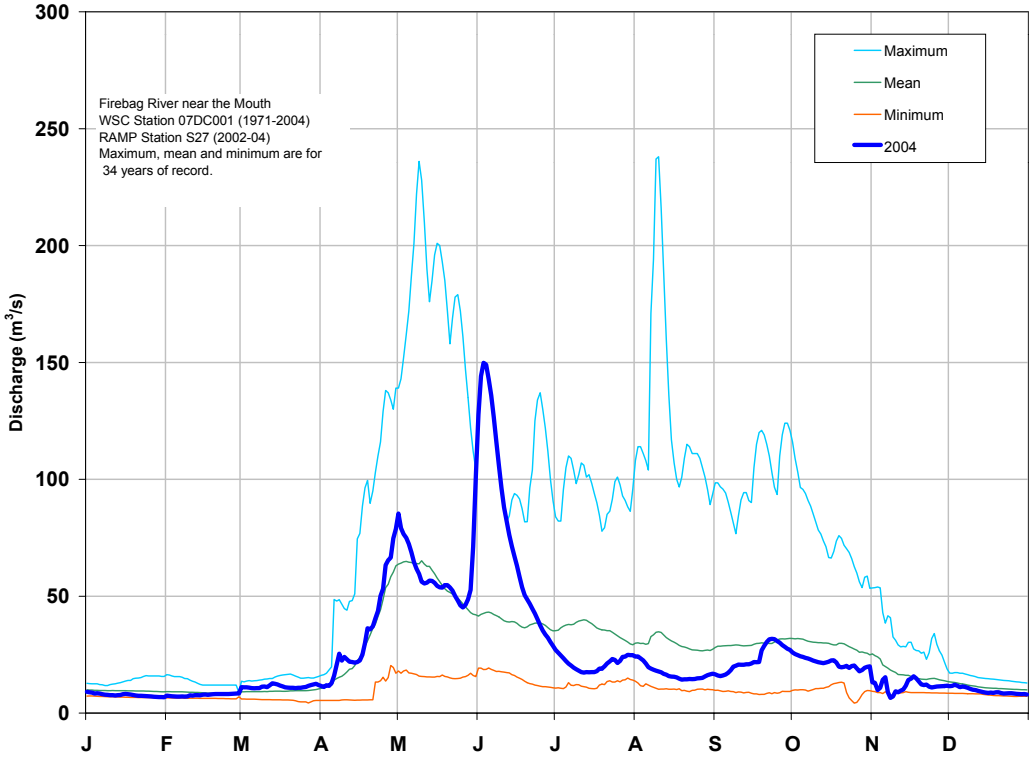


Table 5.8-1 Concentrations of water quality measurement endpoints, mouth of Firebag River (FIR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	7.9	-	8.2
Total suspended solids	mg/L	-	5	2	12	-	17
Conductivity	mg/L	-	190	2	178	-	227
Nutrients							
Total phosphorous	mg/L	0.05	0.03	2	0.05	-	0.07
Dissolved phosporous	mg/L	0.05[1]	0.02	2	0.03	-	0.04
Total nitrogen*	mg/L	1.0	0.5	2	0.4	-	**1.7**
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	8	2	8	-	13
Ions							
Sodium	mg/L	-	4	2	3	-	4
Chloride	mg/L	230, 860[2]	3	2	2	-	2
Sulphate	mg/L	100[3]	2.8	2	3.2	-	4.1
Total dissolved solids	mg/L	-	60	2	130	-	170
Total alkalinity	mg/L	-	112	2	87	-	110
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	1	-	1
Selected metals							
Total aluminum	mg/L	0.1	0.033	2	**0.26**	-	**0.29**
Dissolved aluminum	mg/L	0.1[1]	0.003	2	0.005	-	0.009
Total boron	mg/L	1.2[3]	0.014	2	0.014	-	0.019
Total molybdenum	mg/L	0.073	-	2	0.0001	-	0.0002
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.007**	2	<0.001	-	<0.001
Total iron	mg/L	0.3	**0.4**	2	**0.7**	-	**1.0**

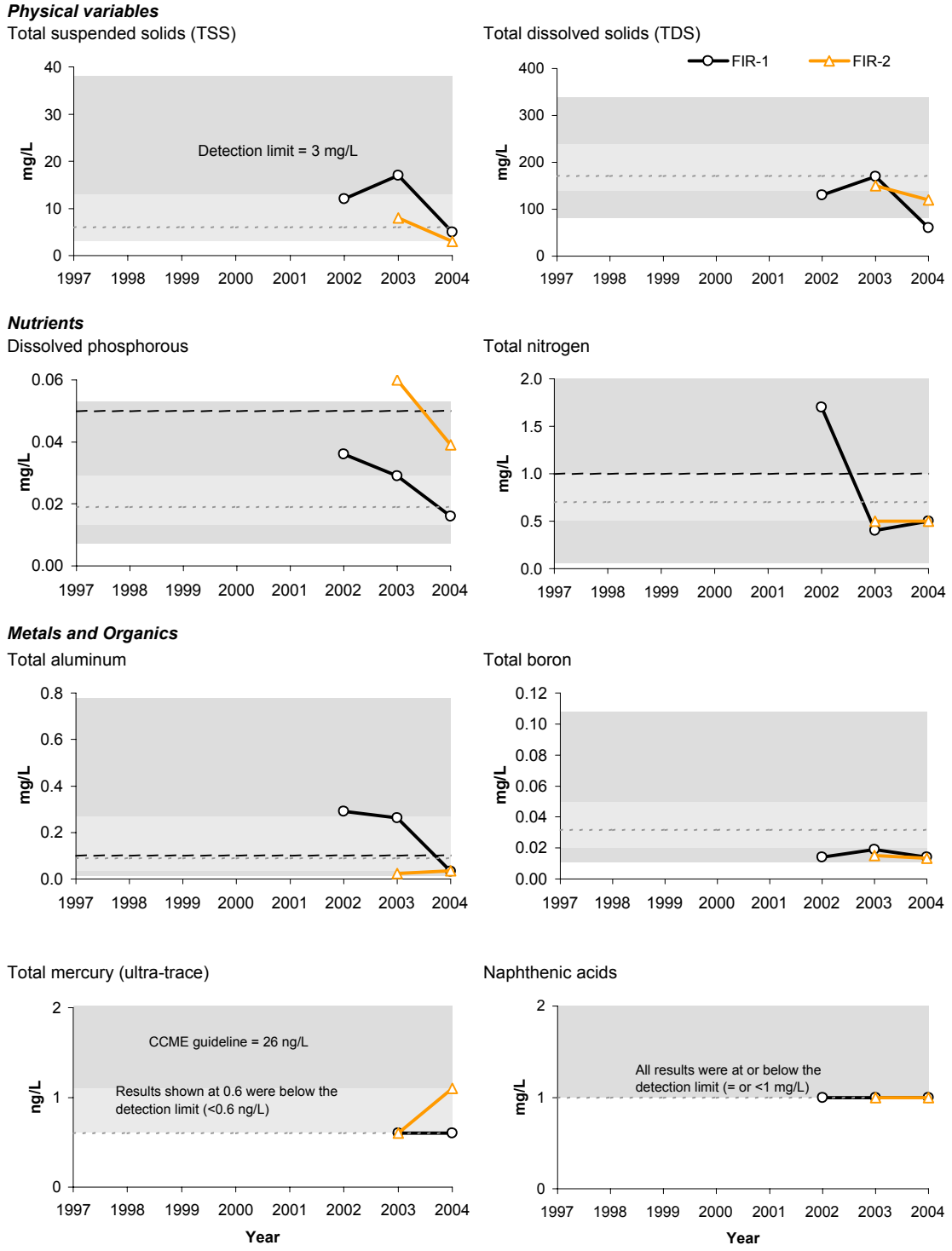
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate-nitrite + total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.8-2 Concentrations of water quality measurement endpoints, Firebag River above Suncor Firebag project (FIR-2), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	1	-	-	8.1
Total suspended solids	mg/L	-	<3	1	-	-	8
Conductivity	mg/L	-	160	1	-	-	174
Nutrients							
Total phosphorous	mg/L	0.05	**0.07**	1	-	-	**0.09**
Dissolved phosporous	mg/L	0.05[1]	0.04	1	-	-	**0.06**
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	-	8	1	-	-	12
Ions							
Sodium	mg/L	-	4	1	-	-	4
Chloride	mg/L	230, 860[2]	2	1	-	-	<1
Sulphate	mg/L	100[3]	1.9	1	-	-	2.9
Total dissolved solids	mg/L	-	120	1	-	-	150
Total alkalinity	mg/L	-	93	1	-	-	91
Organic compounds							
Naphthenic acids	mg/L	-	<1	1	-	-	<1
Selected metals							
Total aluminum	mg/L	0.1	0.036	1	-	-	0.023
Dissolved aluminum	mg/L	0.1[1]	0.003	1	-	-	0.006
Total boron	mg/L	1.2[3]	0.01	1	-	-	0.02
Total molybdenum	mg/L	0.073	0.0002	1	-	-	0.0002
Total mercury (ultra-trace)	ng/L	26	1.1	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total iron	mg/L	0.3	**0.5**	1	-	-	**0.7**

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate-nitrite + total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.8-3 Concentrations of selected water quality measurement endpoints, mouth of Firebag River (FIR-1) and Firebag River above Suncor Firebag Project (FIR-2), relative to regional baseline concentrations.



[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 E for these regional baseline ranges.

Figure 5.8-4 Piper diagram of fall ion concentrations in Firebag River system.

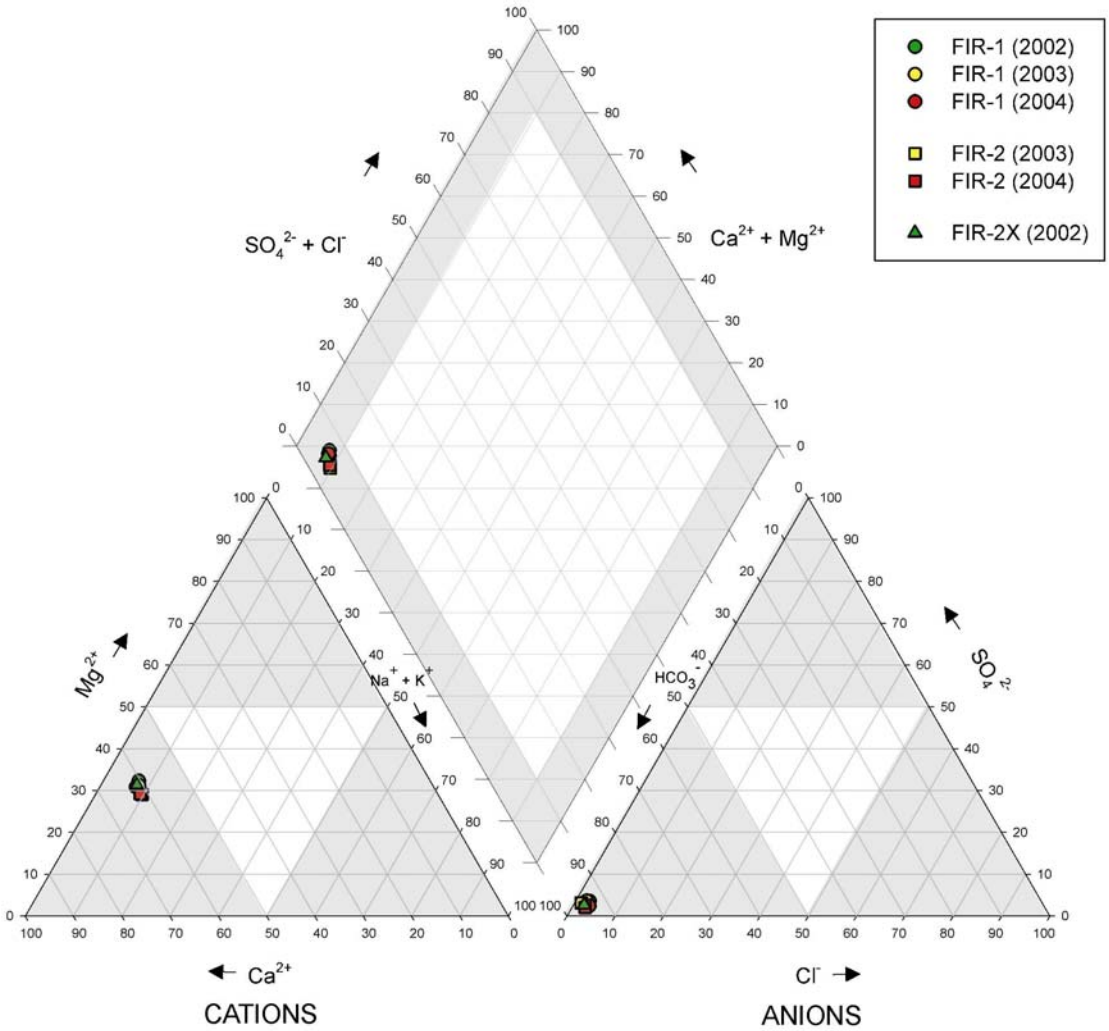


Table 5.8-3 List of all 2004 water quality guideline exceedances, Firebag River.

Parameter	Units	Guideline	FIR-1	FIR-2
Winter				
Total phosphorus	mg/L	0.05	-	**0.099**
Total iron	mg/L	0.300	**0.461**	**0.771**
Spring				
Total aluminum	mg/L	0.100	**0.271**	**0.107**
Total iron	mg/L	0.300	**0.907**	**0.702**
Total phosphorus	mg/L	0.05	**0.06**	**0.08**
Summer				
Total aluminum	mg/L	0.100	**0.102**	-
Total iron	mg/L	0.300	**0.471**	**0.499**
Fall				
Total phenols	mg/L	0.004	**0.007**	-
Total iron	mg/L	0.300	**0.394**	**0.525**
Total phosphorus	mg/L	0.05	-	**0.068**

Guidelines are CCME/AENV guidelines for the protection of aquatic life.

Table 5.8-4 Concentrations of sediment quality measurement endpoints, mouth of Firebag River (FIR-1), fall 2004.

	Units	Guideline	September 2004		1997-2003 (Fall data only)		
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1	2	1	-	6
Silt	%	-	9	2	1	-	21
Sand	%	-	91	2	74	-	100
Total organic carbon	%	-	0.8	2	0.1	-	2.2
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]	32	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	330	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	280	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	2	0.5	-	12
TEH (C11-C30)	mg/kg	-	81	2	62	-	1100
TRH	mg/kg	-	1100	2	300	-	2500
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.002	2	0.001	-	0.01
Retene	mg/kg	-	0.03	2	0.002	-	0.13
Total dibenzothiophenes	mg/kg	-	0.4	2	0.02	-	0.7
Total PAHs	mg/kg	-	1.5	2	0.17	-	3.36
Total HMW PAHs	mg/kg	-	0.57	2	0.10	-	1.52
Total LMW PAHs	mg/kg	-	0.89	2	0.07	-	1.84
Predicted PAH toxicity[1]	H.I.	-	0.61	2	0.26	-	0.64
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	-	1	-	-	7
Chironomus growth	mg/organism	-	-	1	-	-	1.9
Hyallela survival	# surviving	-	-	1	-	-	9
Hyallela growth	mg/organism	-	-	1	-	-	0.1

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV 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 5.8-5 Concentrations of sediment quality measurement endpoints, Firebag River above Suncor Firebag project (FIR-2), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1	1	-	-	13
Silt	%	-	3	1	-	-	10
Sand	%	-	97	1	-	-	77
Total organic carbon	%	-	0.3	1	-	-	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]	6	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	35	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	30	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	0.5	1	-	-	12
TEH (C11-C30)	mg/kg	-	<5	1	-	-	120
TRH	mg/kg	-	<100	1	-	-	400
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.001	1	-	-	0.009
Retene	mg/kg	-	0.006	1	-	-	0.006
Total dibenzothiophenes	mg/kg	-	0.008	1	-	-	0.008
Total PAHs	mg/kg	-	0.06	1	-	-	0.06
Total HMW PAHs	mg/kg	-	0.02	1	-	-	0.02
Total LMW PAHs	mg/kg	-	0.03	1	-	-	0.04
Predicted PAH toxicity[1]	H.I.	-	0.28	1	-	-	0.15
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	8	1	-	-	4
Chironomus growth	mg/organism	-	2.9	1	-	-	2
Hyallela survival	# surviving	-	7	1	-	-	8
Hyallela growth	mg/organism	-	0.16	1	-	-	0.1

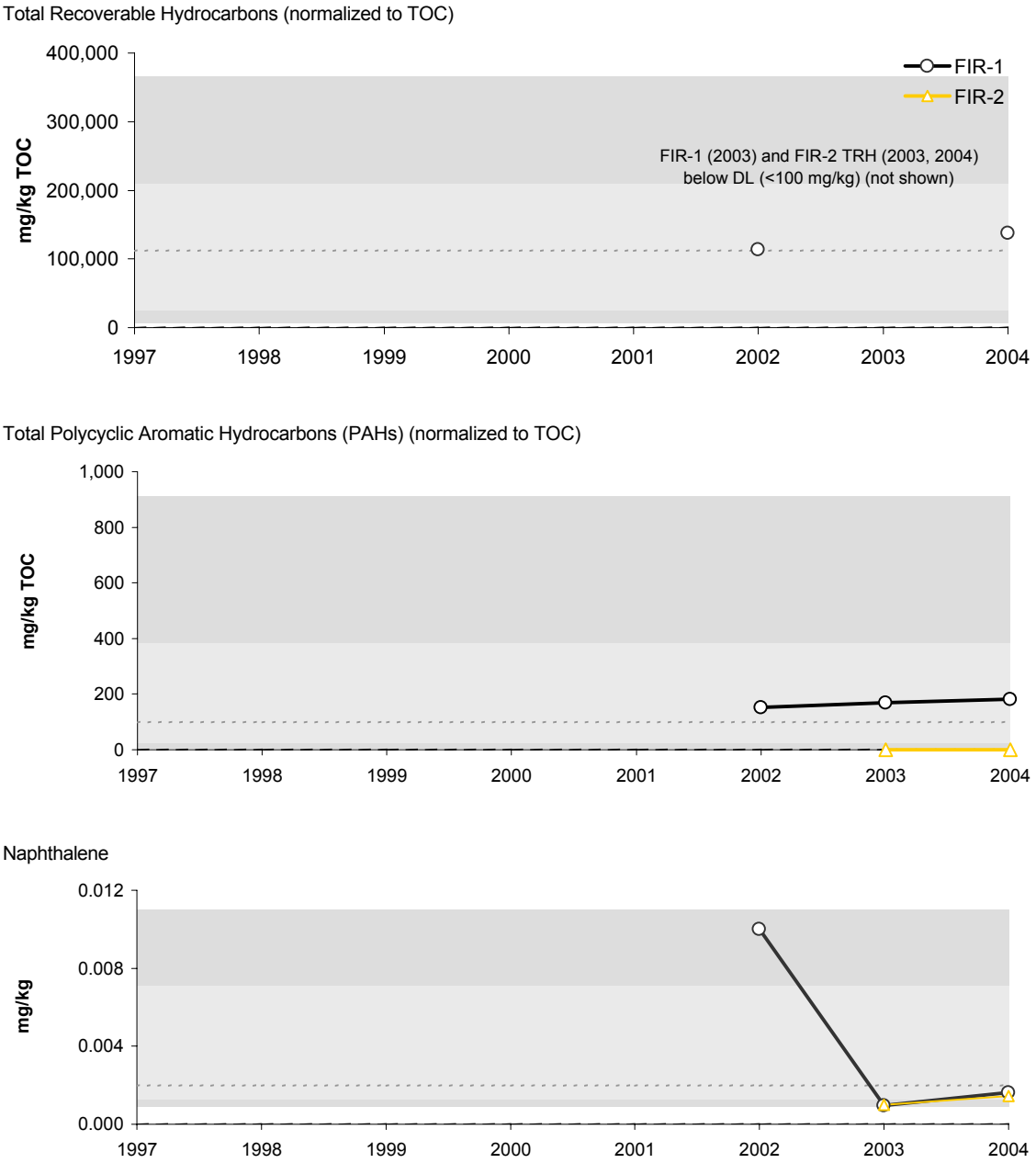
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

[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 5.8-5 Concentrations of selected sediment quality measurement endpoints, mouth of Firebag River (FIR-1) and Firebag River above Suncor Firebag project (FIR-2), 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 F for these regional baseline ranges.

Table 5.8-6 Average habitat characteristics of benthic invertebrate sampling stations in the Firebag River, fall 2004.

Variable	Units	Upper Reach of the Firebag River	Lower Reach of the Firebag River
Sample date	-	Sept. 17, 2004	Sept. 17, 2004
Habitat	-	Depositional	Erosional
Water depth	m	0.7	0.3
Current velocity	m/s	0	0.5
Macrophyte cover	%	0	17.7
Benthic algae	mg/m^2	n/a	56.7
Field Water Quality			
Dissolved oxygen	mg/L	10.5	10.5
Conductivity	µS/cm	242	122
pH	pH units	8.4	8.9
Water temperature	°C	8.7	8.6
Sediment Composition			
Sand	%	86.6	n/a
Silt	%	8.8	n/a
Clay	%	4.3	n/a
Total Organic Carbon	%	1.0	n/a
Sand/Silt/Clay	%	n/a	3.2
Small gravel	%	n/a	10.0
Large gravel	%	n/a	20.9
Small cobble	%	n/a	35.5
Large cobble	%	n/a	23.2
Boulder	%	n/a	6.8
Bedrock	%	n/a	0

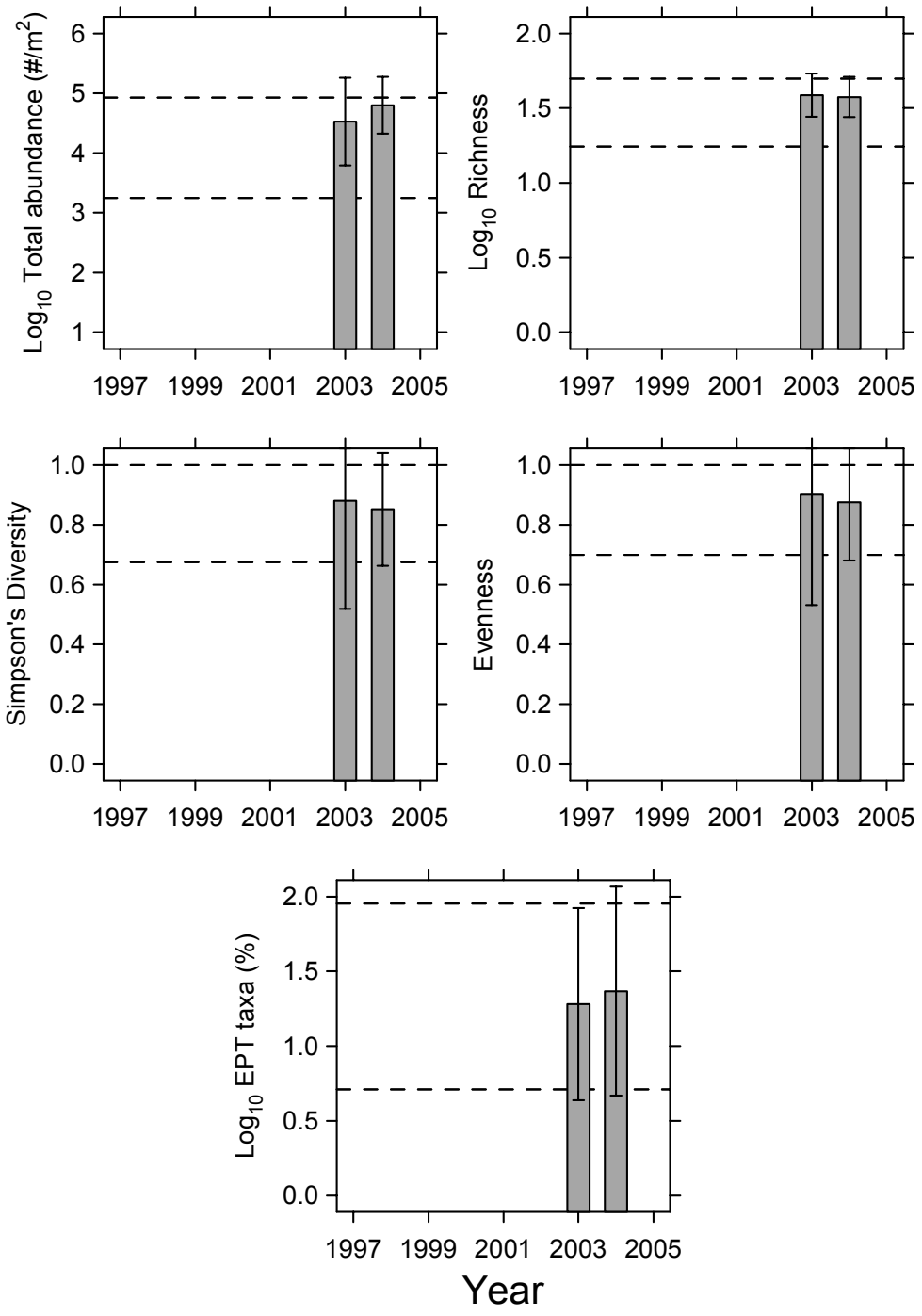
Table 5.8-7 Summary of major taxon abundances and key indices of composition among benthic invertebrate sampling stations in the Firebag River, fall 2004.

Taxon	Lower Reach of the Firebag River			Upper Reach of the Firebag River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Hydra	63	61	0.1	0	0	0
Nematoda	305	481	0.4	24	74	1.2
Glossiphoniidae	316	897	0.4	0	0	0
Erpobdellidae	23	0	0.0	0	0	0
Enchytraeidae	638	710	0.9	0	0	0
Naididae	1520	2269	2.2	30	274	1.5
Tubificidae	10207	19523	14.5	523	858	25.6
Lumbriculidae	0	0	0	22	0	1.1
Hydracarina	282	349	0.4	38	0	1.9
Ostracoda	293	693	0.4	20	63	1.0
Copepoda	1325	4519	1.9	0	0	0
Chydoridae	448	2560	0.6	0	0	0
Daphniidae	0	0	0	47	464	2.3
Amphipoda	632	4267	0.9	0	0	0
Collembola	9	0	0.0	0	0	0
Gastropoda	540	614	0.8	0	0	0
Ephemeroptera	4704	2462	6.7	21	11	1.0
Plecoptera	2902	4915	4.1	0	0	0
Trichoptera	13144	6069	18.6	0	0	0
Anisoptera	2233	2728	3.2	0	0	0
Coleoptera	2466	1739	3.5	1	0	0.0
Heteroptera	658	1629	0.9	201	1977	9.8
Tipulidae	126	759	0.2	371	772	18.2
Athericidae	86	305	0.1	0	0	0
Dolichopodidae	0	0	0	1	0	0.1
Tabanidae	83	220	0.1	0	0	0
Empididae	2920	1695	4.1	69	157	3.4
Ephydridae	0	0	0	9	0	0.4
Ceratopogonidae	397	1072	0.6	160	382	7.8
Chironomidae	23914	3707	33.9	505	298	24.7

Table 5.8-7 (cont'd.)

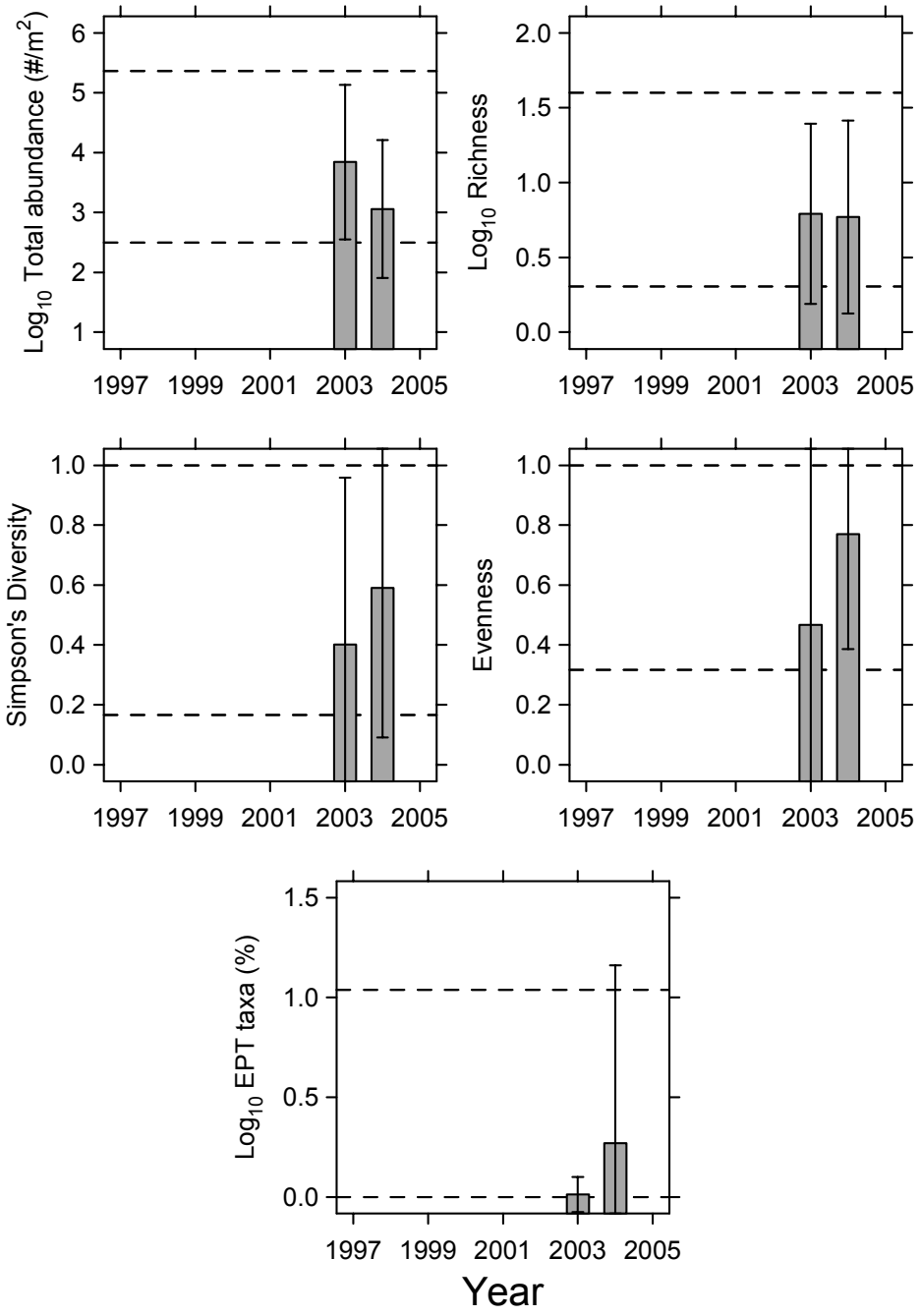
Taxon	Lower Reach of the Firebag River			Upper Reach of the Firebag River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Simuliidae	69	0	0.1	0	0	0
Megaloptera	201	0	0.3	0	0	0
Total Abundance	70503	33827	-	2041	2082	-
Richness	37.9	5.3	-	7.0	3.7	-
Simpson's Diversity	0.852	0.086	-	0.591	0.228	-
Evenness	0.875	0.088	-	0.770	0.175	-

Figure 5.8-6 Variations in indices of benthic invertebrate community composition in the lower Firebag River, fall 2004.



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

Figure 5.8-7 Variations in indices of benthic invertebrate community composition in the upper Firebag River, fall 2004.



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

5.9 CALUMET RIVER SYSTEM

Summary of Results

Climate and Hydrology

	Assessment of Change			
	Negligible	Low	Moderate	High
Mean open-water season discharge	The Calumet River watershed was designated as a reference watershed for 2004.			
Mean winter discharge				
Annual maximum daily discharge				
Minimum open-water season discharge				

Total runoff volume in the Calumet River basin in 2004 was the lowest recorded in four years of record. A peak flow occurred in early June in response to rainfall, but for the rest of the year, river discharges were well below normal.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=1)
Physical variables (3 endpoints)	No water quality sampling stations were designated as exposed in 2004.	0
Nutrients (5 endpoints)		2
Ions (5 endpoints)		0
Organic compounds (1 endpoint)		0
Selected metals (5 endpoints)		1

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 1 station X 7 endpoints)
Above 95th	No water quality stations were designated as exposed in 2004.	1
Between 75th and 95th		1
Between median and 75th		3
Between 25th and median		1
Between 5th and 25th		1
Less than 5th		0

While guidelines for total aluminum, total phosphorus, and total nitrogen were exceeded in fall 2004, concentrations of these and other metal and nutrient measurement endpoints in fall 2004 were similar to those observed in previous years. The concentration of TDS in fall 2004 was greater than the level of TDS corresponding to the 95th percentile of levels in regional baseline watercourses. High concentrations of magnesium, calcium, bicarbonate, and potassium ions are characteristic of most western Athabasca River tributaries, and ion balance has been relatively constant at CAR-1 over the three years of RAMP sampling.

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=1)
Physical variables (4 endpoints)	No sediment quality stations were designated as exposed in 2004.	0
Total Hydrocarbons (8 endpoints)		2
PAHs (7 endpoints)		0

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 1 station X 3 endpoints)
Above 95th	No sediment quality stations were designated as exposed in 2004.	0
Between 75th and 95th		2
Between median and 75th		1
Between 25th and median		0
Between 5th and 25th		0
Less than 5th		0

Sediments sampled in 2004 were comprised primarily of sand and silt, and exhibited much higher levels of organic carbon than previously observed. Relatively high total hydrocarbon and PAH concentrations were also observed. Both F3 (C16-C34) and F4 (C35-C50) CCME total hydrocarbon fractions exceeded CCME ISQG guidelines. Although total PAH concentrations in 2004 were very high relative to the previous measurement, predicted PAH toxicity was lower.

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline					
	2004 Exposed Stations (n=0)			2004 Reference Stations (n= 1)		
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD
Abundance	No benthic invertebrate community sampling stations were designated as exposed in 2004.				2	
Richness					2	
Diversity					2	
Evenness					2	
% EPT					2	

No obvious trends in benthic invertebrate community indices or differences between the two reaches of the Calumet River were observed. All measurement endpoints in 2004 were within expected ranges for regional reference conditions for depositional habitats.

Fish Populations

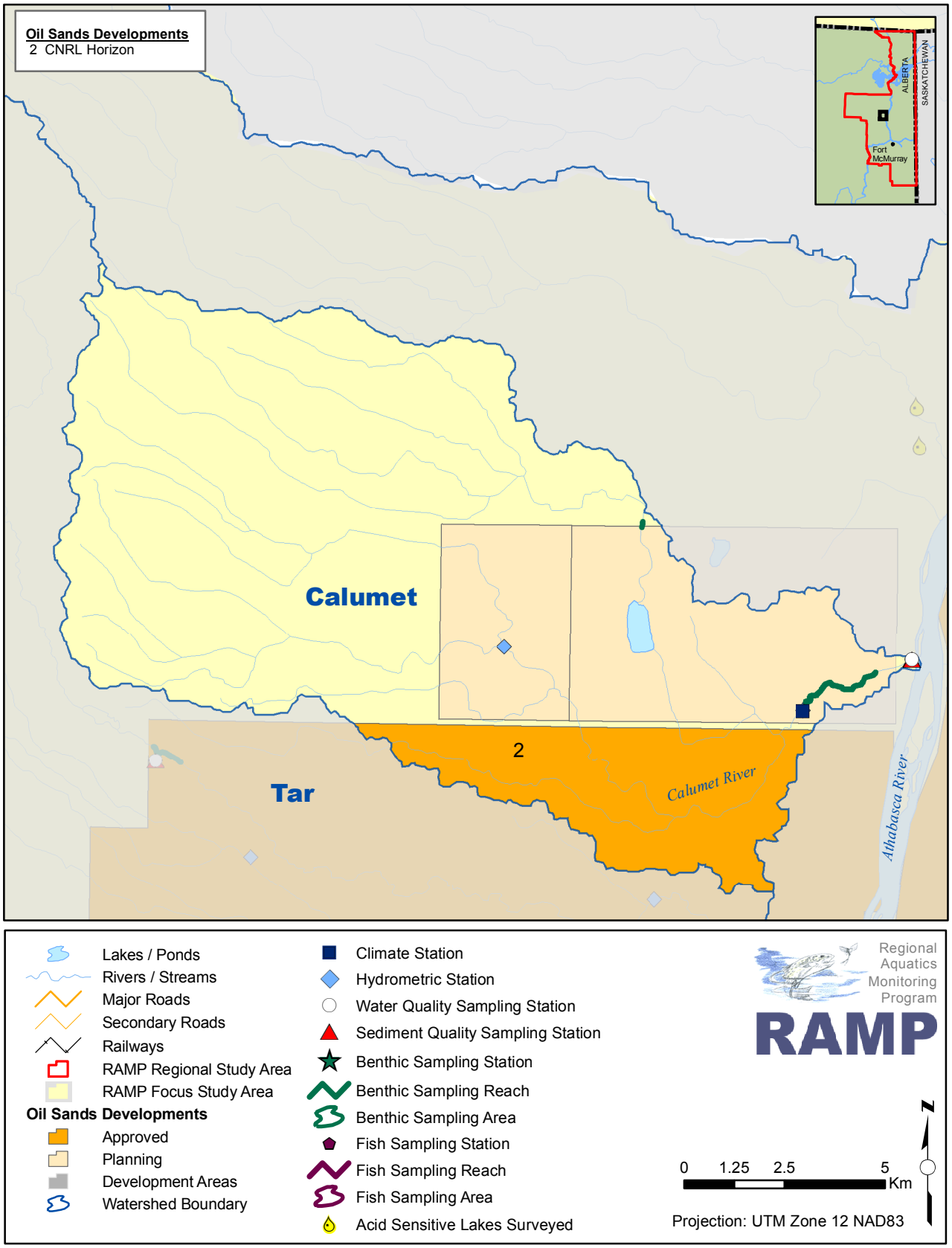
Fish Inventory	No fish inventory studies were conducted in the Calumet River in 2004.
Sentinel Studies	Sentinel fish studies were not conducted in 2004.
Fish Tissue	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in the Calumet River in 2004.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	
Fish and Wildlife: Mercury	
Fish and Wildlife: Other Chemicals	

[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 Calumet River watershed.



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5.9.1 Hydrologic Conditions

Total runoff volume in the Calumet River basin in 2004, as measured at the RAMP Station S16 near the mouth of the Calumet River, was the lowest recorded in four years of record, as shown in Figure 5.9-2. A peak flow occurred in early June in response to rainfall, but river discharges were well below normal during the rest of the year. The June maximum daily discharge was 0.40 m^3/s, the smallest annual maximum measured in four years of monitoring and less than 40% of the mean annual flood of 1.11 m^3/s. The minimum open-water discharge measured on the Calumet River in 2004 was 0.002 m^3/s, compared to the four-year mean annual minimum open-water discharge of 0.023 m^3/s.

5.9.2 Water Quality

Water quality samples were collected from the mouth of the Calumet River (station CAR-1) in spring, summer, and fall 2004. While a portion of the Calumet River drainage is within the CNRL Horizon project lease (Figure 5.9-1), station CAR-1 was classified as a reference station up to and including 2004 due to an absence of CNRL Horizon Project activities potentially affecting the Calumet River watershed. Results of fall 2004 sampling for water quality measurement endpoints are shown in Table 5.9-1; results of RAMP sampling at CAR-1 relative to regional baseline conditions are shown in Figure 5.9-3.

While CCME/AENV guidelines for total aluminum, total phosphorous, and total nitrogen were exceeded in fall 2004, concentrations of these and other metal and nutrient measurement endpoints in fall 2004 were similar to those observed at CAR-1 in previous years. Conductivity and concentrations of sodium, chloride, and total dissolved solids were higher in fall 2004 than in previous years; the concentration of total dissolved solids in fall 2004 was greater than the 95th percentile of total dissolved solids concentrations in regional baseline watercourses (Figure 5.9-3). High concentrations of magnesium, calcium, bicarbonate, and potassium ions were found to be characteristic of most western Athabasca River tributaries (Appendix E), and ion balance has been relatively constant at CAR-1 over the three years of RAMP sampling (Figure 5.9-4).

Table 5.9-2 contains a list of all exceedances of CCME/AENV guidelines for the protection of aquatic life observed in the Calumet River in 2004.

5.9.3 Sediment Quality

In 2004, sediment quality samples were collected from the mouth of the Calumet River (station CAR-1) in September. Station CAR-1 was designated as a reference station up to and including 2004 for the same reasons as the corresponding water quality station. Results of 2004 sampling for sediment quality measurement endpoints identified in Section 3.3.7 are shown in Table 5.9-3; results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.9-5.

Sediments sampled from the lower Calumet River in 2004 were comprised primarily of sand and silt, and exhibited much higher levels of organic carbon than in 2002 (i.e., 4.1% versus 0.6%). Relatively high total hydrocarbon and PAH concentrations were also observed (Table 5.9-3). Both F3 (C16-C34) and F4 (C35-C50) CCME total hydrocarbon fractions exceeded CCME guidelines. Although total PAH concentrations were very high relative to the previous measurement, predicted PAH toxicity in 2004 was lower.

5.9.4 Benthic Invertebrate Communities

In 2004, benthic invertebrate community samples were collected from a reach near the mouth of the Calumet River (reach CAL-D 16-30, depositional) and from a reach in the upstream area of the river (reach CAL-D 1-15, depositional). Both reaches were designated as reference reaches up to and including 2004 for the same reasons as the water and sediment quality stations.

The lower reach (CAL-D 16-30) was shallow with some macrophytes present when the site was visited in September 2004 (Table 5.9-4). The upper reach (CAL-D 1-15) was deeper while macrophytes were absent. No measurable current was evident at either reach. Dissolved oxygen in the upper reach was low (2.5 mg/L) and below the CCME guideline for the protection of aquatic life. Conductivity was high at both reaches. pH was slightly higher at the lower reach than at the upper reach. Sediments at the lower reach were heavily dominated by sand, whereas sand, silt and clay were more evenly distributed at the upper reach; total organic carbon was also higher at the upper reach.

The benthic invertebrate community was dominated by chironomids and ostracods at the lower reach of the Calumet River (CAL-D 1-15) and by chironomids and nematodes at the upper reach (Table 5.9-5). Chaoborus, a genus restricted almost entirely to lakes and ponds, were present in small numbers at the upper reach of the Calumet River, reflecting proximity to a lentic pond or lake environment. Both upper and lower reaches contained sensitive groups including members of EPT taxa, beetles, a variety of fly larvae (tabanids, stratiomyids), amphipods, and snails.

The lower reach of the Calumet River has been sampled since 2002, whereas the upper reach has been sampled since 2003. There are no obvious trends in benthic invertebrate community indices or between the two reaches of the Calumet River, and all measurement endpoints were within expected ranges for regional reference conditions for depositional habitats (Figure 5.9-6).

5.9.5 Fish Populations

The 2004 RAMP fish program did not include any activities in the Calumet River system.

5.9.6 Summary of Conditions

The RAMP aquatic resources of the Calumet River system were similar in 2004 to previous years. Relatively few measurement endpoints sampled in 2004 exceeded existing environmental guidelines, and all but one measurement endpoint were within the range of expected reference conditions for similar river systems and habitats in the RAMP FSA.

Figure 5.9-2 Calumet River 2004 hydrograph and historical context.

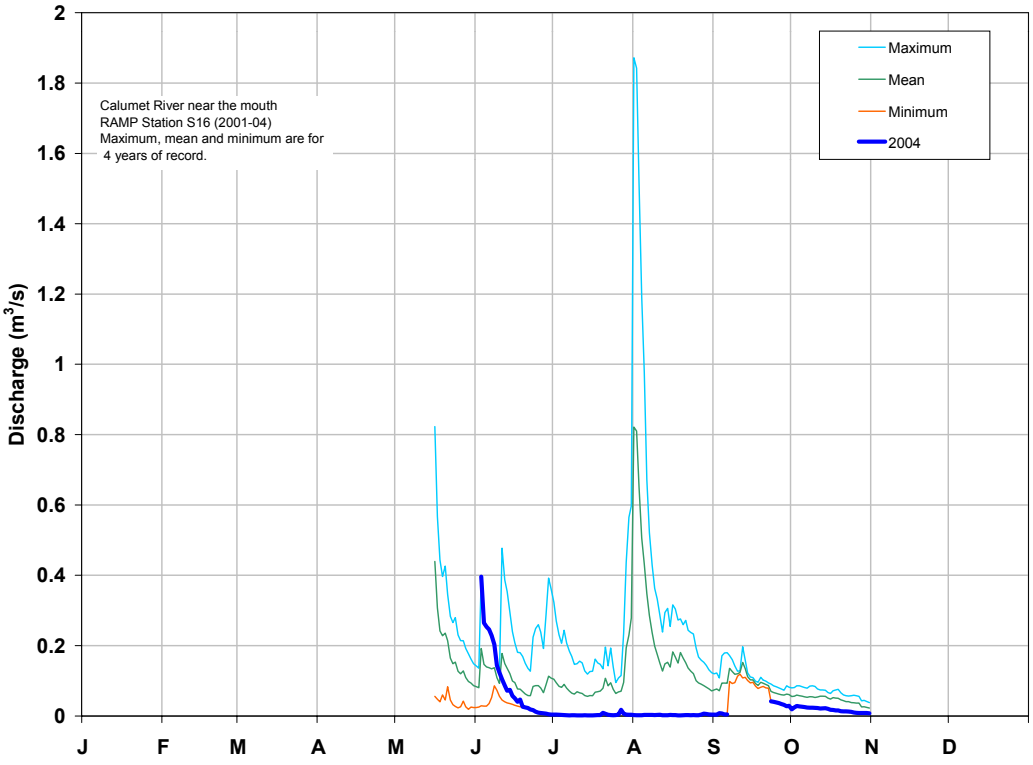
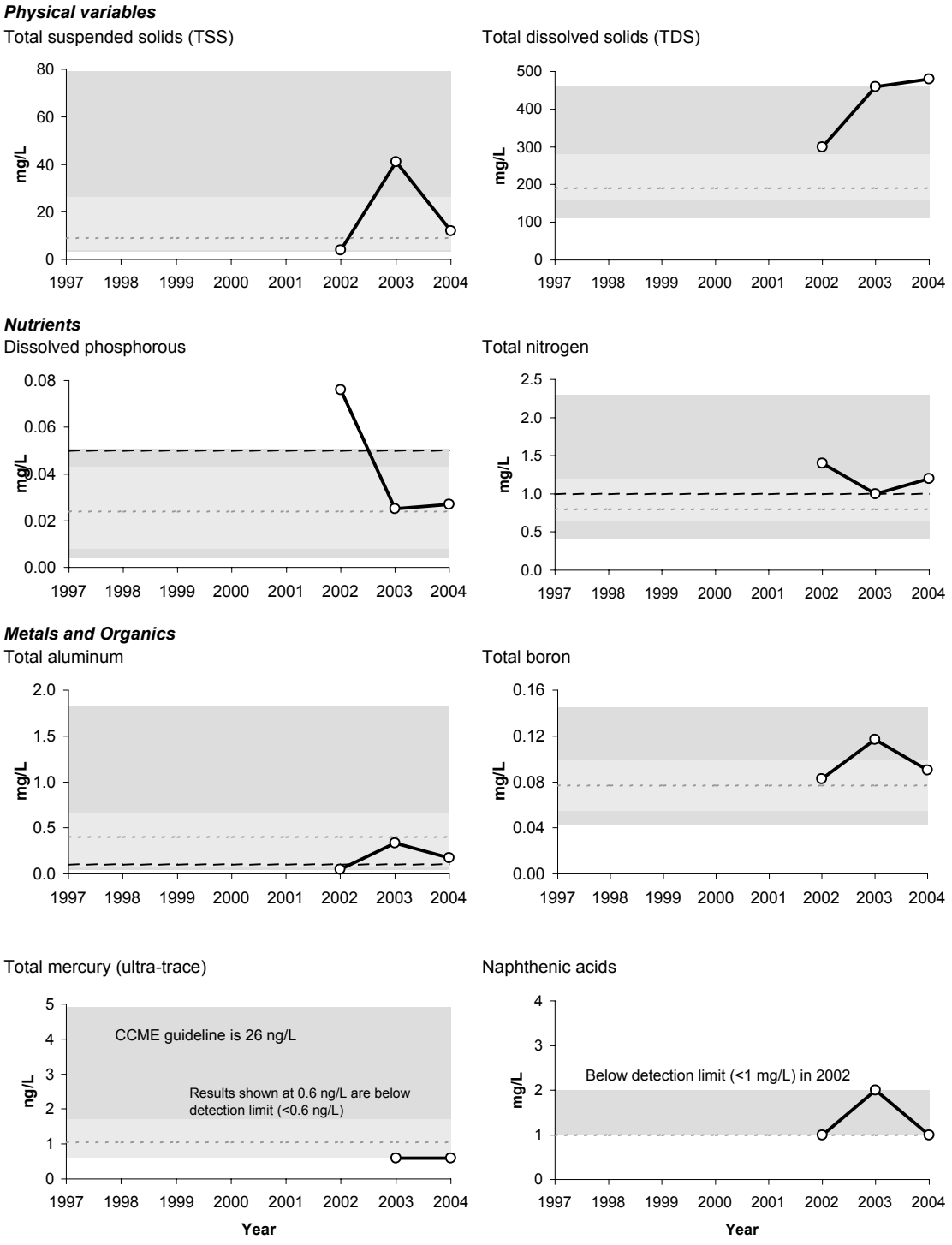


Table 5.9-1 Concentrations of water quality measurement endpoints, mouth of Calumet River (CAR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	2	8.1	-	8.2
Total suspended solids	mg/L	-	12	2	4	-	41
Conductivity	mg/L	-	631	2	463	-	702
Nutrients							
Total phosphorous	mg/L	0.05	**0.08**	2	**0.09**	-	**0.10**
Dissolved phosporous	mg/L	0.05[1]	0.03	2	0.03	-	**0.08**
Total nitrogen*	mg/L	1.0	**1.2**	2	1.0	-	**1.4**
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	29	2	30	-	34
Ions							
Sodium	mg/L	-	71	2	47	-	67
Chloride	mg/L	230, 860[2]	34	2	14	-	30
Sulphate	mg/L	100[3]	12	2	11	-	14
Total dissolved solids	mg/L	-	480	2	300	-	460
Total alkalinity	mg/L	-	316	2	216	-	337
Organic compounds							
Naphthenic acids	mg/L	-	1	2	<1	-	2
Selected metals							
Total aluminum	mg/L	0.1	**0.18**	2	0.05	-	**0.34**
Dissolved aluminum	mg/L	0.1[1]	0.005	2	0.003	-	0.006
Total boron	mg/L	1.2[3]	0.09	2	0.08	-	0.12
Total molybdenum	mg/L	0.073	0.0002	2	0.0002	-	0.0003
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
	mg/L	0.004	**0.01**	2	<0.001	-	0.002
Total iron	mg/L	0.3	**1.5**	2	**0.6**	-	**3.1**

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines for the protection of aquatic life.
* Total nitrogen = Nitrate-nitrite + total Kjeldahl nitrogen (TKN).
[1] Guideline is for total analyte (no guideline for dissolved species).
[2] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.9-3 Concentrations of selected water quality measurement endpoints, mouth of Calumet River (CAR-1), relative to regional baseline concentrations.



[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 E for these regional baseline ranges.

Figure 5.9-4 Piper diagram of fall ion concentrations in Calumet River system.

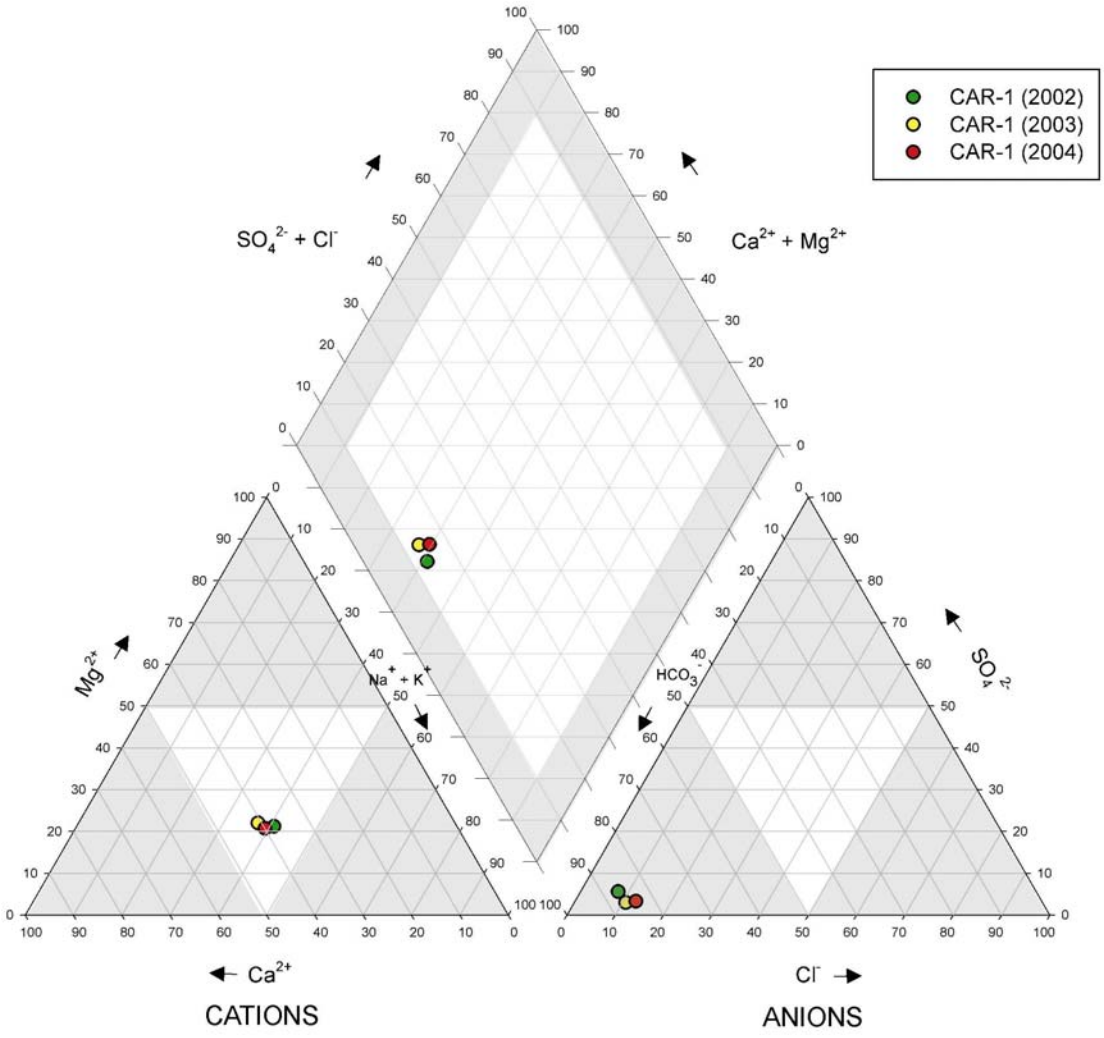


Table 5.9-2 List of all 2004 water quality guideline exceedances, Calumet River.

Parameter	Units	Guideline	CAR-1
Spring [1]			
Total phosphorus	mg/L	0.05	**0.079**
Total Kjeldahl nitrogen	mg/L	1.0[3]	**1.3**
Total iron	mg/L	0.300	**0.968**
Dissolved iron	mg/L	0.300[2]	**0.571**
Summer			
Total aluminum	mg/L	0.100	**0.647**
Total iron	mg/L	0.300	**1.52**
Dissolved iron	mg/L	0.300[2]	**0.522**
Total phosphorus	mg/L	0.05	**0.068**
Fall			
Total phenols	mg/L	0.004	**0.01**
Total aluminum	mg/L	0.100	**0.175**
Total iron	mg/L	0.300	**1.48**
Dissolved iron	mg/L	0.300[2]	**0.339**
Total phosphorus	mg/L	0.05	**0.081**
Total Kjeldahl nitrogen	mg/L	1.0[3]	**1.1**

Guidelines are CCME/AENV guidelines for the protection of aquatic life.
[1]: CAR-1 not sampled in winter.
[2]: Guideline is for total analyte (no guideline for dissolved species).
[3]: Guideline is for total nitrogen.

Table 5.9-3 Concentrations of sediment quality measurement endpoints, mouth of Calumet River (CAR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	10	1	-	-	18
Silt	%	-	23	1	-	-	30
Sand	%	-	67	1	-	-	52
Total organic carbon	%	-	4.1	1	-	-	0.6
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]	200	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**3400**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	**3000**	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	1	-	-	1.8
TEH (C11-C30)	mg/kg	-	3200	1	-	-	500
TRH	mg/kg	-	14600	1	-	-	500
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.0036	1	-	-	0.011
Retene	mg/kg	-	0.181	1	-	-	0.05
Total dibenzothiophenes	mg/kg	-	5.4	1	-	-	0.31
Total PAHs	mg/kg	-	17.5	1	-	-	1.54
Total HMW PAHs	mg/kg	-	5.8	1	-	-	0.54
Total LMW PAHs	mg/kg	-	11.7	1	-	-	1.00
Predicted PAH toxicity[1]	H.I.	-	0.61	1	-	-	1.55
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	9	1	-	-	9
Chironomus growth	mg/organism	-	2.0	1	-	-	1.8
Hyallela survival	# surviving	-	9	1	-	-	9
Hyallela growth	mg/organism	-	0.2	1	-	-	0.1

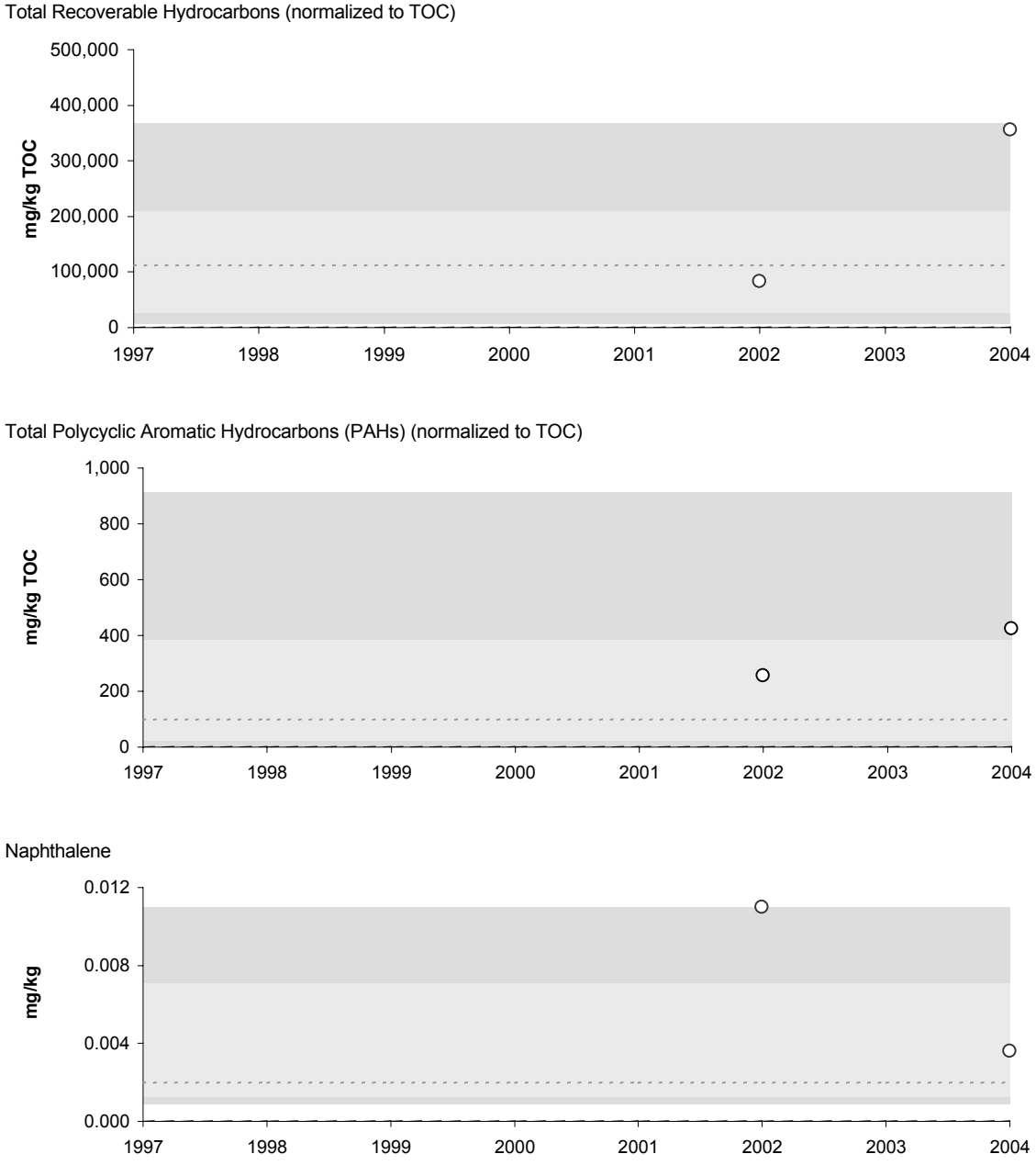
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

[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 5.9-5 Concentrations of selected sediment quality measurement endpoints, mouth of Calumet River (CAR-1), 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 F for these regional baseline ranges.

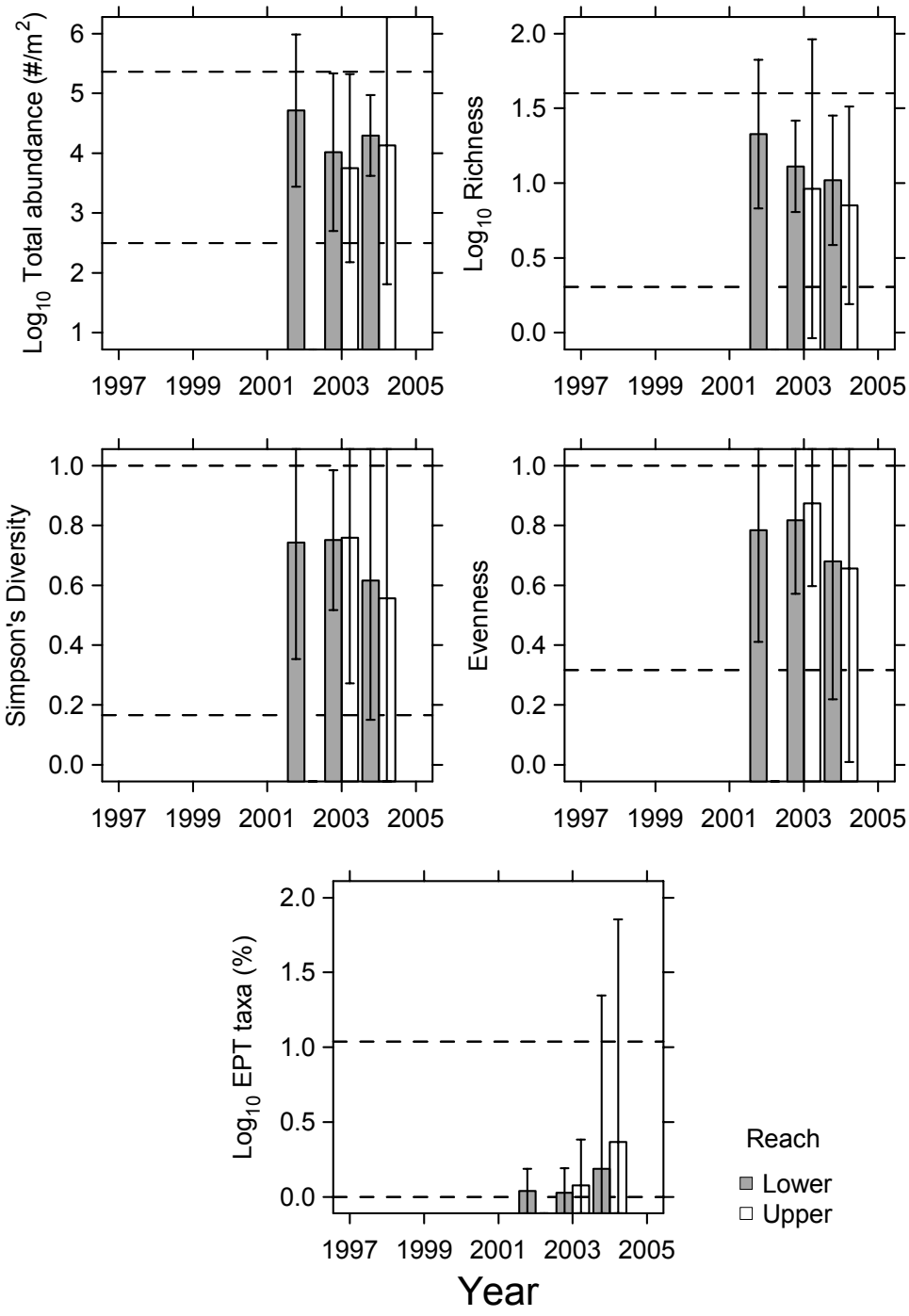
Table 5.9-4 Average habitat characteristics of benthic invertebrate sampling stations in the Calumet River, fall 2004.

Variable	Units	Lower Reach	Upper Reach
Sample date	-	Sept. 12, 2004	Sept. 12, 2004
Habitat	-	Depositional	Depositional
Water depth	m	0.1	0.7
Current velocity	m/s	0	0
Macrophyte cover	%	10	n/a
Field Water Quality			
Dissolved oxygen	mg/L	9.9	2.5
Conductivity	µS/cm	435	491
pH	pH units	8.1	7.6
Water temperature	°C	6.7	6.5
Sediment Composition			
Sand	%	83.5	29.6
Silt	%	11.5	41.8
Clay	%	5.1	28.0
Total Organic Carbon	%	3.5	9.9

Table 5.9-5 Summary of major taxon abundances and key indices of composition among benthic invertebrate sampling stations in the Calumet River, fall 2004.

Taxon	Lower Reach of the Calumet River			Upper Reach of the Calumet River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Nematoda	1313	7635	5.3	12940	35116	44.2
Erpobdellidae	144	0	0.6	86	0	0.3
Enchytraeidae	92	432	0.4	0	0	0
Naididae	129	323	0.5	259	0	0.9
Tubificidae	704	1316	2.8	26	0	0.1
Lumbriculidae	6	0	0.0	0	0	0
Hydracarina	23	0	0.1	0	0	0
Ostracoda	6917	23650	27.7	371	958	1.3
Copepoda	3	0	0.0	60	152	0.2
Daphniidae	46	0	0.2	0	0	0
Macrothricidae	29	0	0.1	0	0	0
Amphipoda	302	0	1.2	733	1067	2.5
Gastropoda	1121	1815	4.5	414	975	1.4
Ephemeroptera	917	0	3.7	276	0	0.9
Plecoptera	172	0	0.7	0	0	0
Trichoptera	0	0	0	190	0	0.6
Anisoptera	1184	10178	4.7	17	0	0.1
Coleoptera	112	241	0.4	207	172	0.7
Heteroptera	23	0	0.1	0	0	0
Dolichopodidae	20	100	0.1	0	0	0
Tabanidae	236	467	0.9	0	0	0
Stratiomyidae	575	0	2.3	0	0	0
Chaoboridae	0	0	0	836	2895	2.9
Ceratopogonidae	1557	2269	6.2	0	0	0
Chironomidae	9362	2960	37.5	12862	6044	43.9
Total Abundance	24986	19026	-	29276	27794	-
Richness	11.3	4.2	-	7.8	3.2	-
Simpson's Diversity	0.616	0.212	-	0.556	0.221	-
Evenness	0.680	0.210	-	0.656	0.226	-

Figure 5.9-6 Variations in indices of benthic invertebrate community composition in the Calumet River, lower and upper reaches.



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

5.10 ELLS RIVER SYSTEM

Summary of Results

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 2004.			
Mean winter discharge				
Annual maximum daily discharge				
Minimum open-water season discharge				

Runoff volume in the Ells River basin was 24% below normal in 2004, with a June – October total runoff of 34 mm compared to the long-term average of 45 mm. The only significant flow in the year occurred during the May-June rainfall event.

Water Quality

Guideline Exceedances

	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=2)
Physical variables (3 endpoints)	No water quality sampling stations were designated as exposed in 2004.	0
Nutrients (5 endpoints)		0
Ions (5 endpoints)		0
Organic compounds (1 endpoint)		0
Selected metals (5 endpoints)		1

Comparison to Regional Baselines

Percentile of Regional Baseline Values	Endpoints in 2004 Compared to Regional Baseline[2]	
	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 2 stations X 7 endpoints)
Above 95th	No water quality stations were designated as exposed in 2004.	0
Between 75th and 95th		0
Between median and 75th		4
Between 25th and median		5
Between 5th and 25th		4
Less than 5th		1

At station ELR-1, concentrations of all water quality measurement endpoints except total aluminum were below guidelines for the protection of aquatic life in fall 2004. Concentrations of all water quality variables measured at station ELR-1 in fall 2004 were similar to previous years, with the exceptions of ions which exceeded the previously measured maxima. The concentrations of selected water quality measurement endpoints in 2004 were within the range of natural variation for regional baseline conditions, tending towards the lower percentile ranges.

Sediment Quality

Guideline Exceedances

	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=2)
Physical variables (4 endpoints)	No sediment quality stations were designated as exposed in 2004.	0
Total Hydrocarbons (8 endpoints)		2
PAHs (7 endpoints)		0

Comparison to Regional Baselines

Percentile of Regional Baseline Values	Endpoints in 2004 Compared to Regional Baseline[3]	
	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 2 stations X 3 endpoints)
Above 95th	No sediment quality stations were designated as exposed in 2004.	0
Between 75th and 95th		1
Between median and 75th		4
Between 25th and median		1
Between 5th and 25th		0
Less than 5th		0

Concentrations of Fraction 3 hydrocarbons (C16-C34) exceeded CCME guidelines at both stations in fall 2004. Total arsenic concentrations at ELR-1 also exceeded CCME guidelines.

Benthic Invertebrate Communities

Comparison to Regional Baselines

	Endpoints in 2004 Compared to Regional Baseline					
	2004 Exposed Stations (n= 0)			2004 Reference Stations (n= 2)		
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD
Abundance	No benthic invertebrate community sampling stations were designated as exposed in 2004.				2	
Richness					2	
Diversity					2	
Evenness					2	
% EPT					2	

The lower and upper reaches of the Ells River have been monitored for two years. The benthic community measurement endpoints for each reach in 2004 were similar to those in 2003, and well within expected ranges for regional reference conditions for depositional and erosional habitats.

Fish Populations

Fish Inventory

A fish inventory program was not conducted on the Ells River system in 2004.

Sentinel Studies

Based on studies in 2004, it appears that a sentinel species monitoring program using longnose dace could be established in this watershed.

Fish Tissue

	Level of Risk
Human Health: Subsistence	Fish tissue program was not conducted in the Ells River in 2004.
Human Health: Recreational Fishers	
Human Health: General Consumers	
Human Health: Tainting	
Fish and Wildlife: Mercury	
Fish and Wildlife: Other Chemicals	

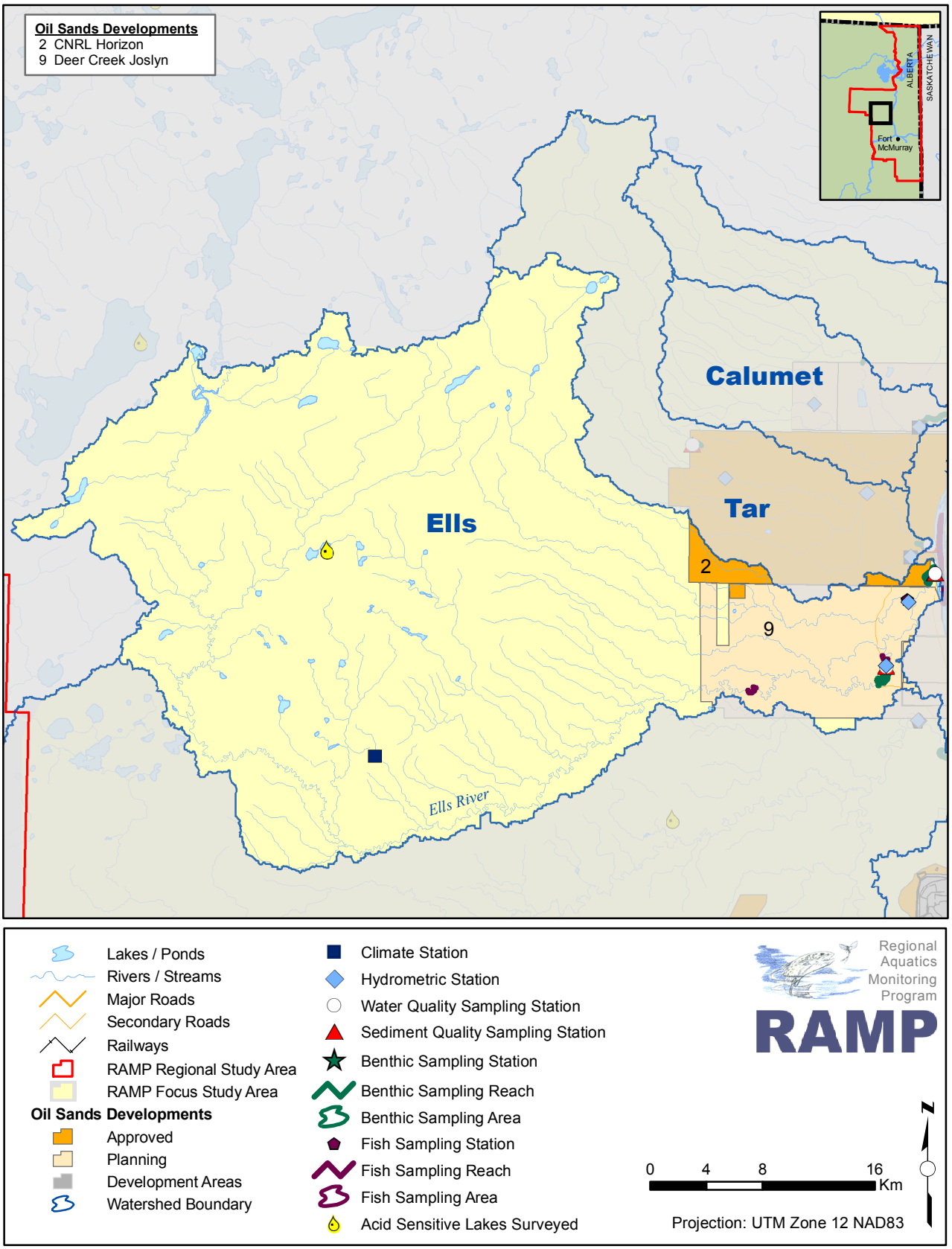
Based on results of fish fence reconnaissance studies in 2004, the Ells River appears to meet basic criteria for the establishment of a fish fence. However, any fish fence design and deployment will need to consider discharge, particularly in the early spring period, as well as erosion and scouring issues.

[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 Hydrologic Conditions

Runoff volume in the Ells River basin, as measured at WSC Station 07DA017 and RAMP Station S14, was 24% below normal in 2004, with a June to October total runoff of 34 mm compared to the long-term average of 45 mm. The only significant flow occurred during the May-June rainfall event as shown in Figure 5.10-2; from July through October the flow was well below normal. In October, however, the flow did not recede as much as usual, so that the discharge at the end of October was approximately equal to the average value for that time of year. The June maximum daily discharge of 46 m^3/s was 13% below the mean annual flood of 53 m^3/s. The minimum open-water discharge of 1.96 m^3/s on August 18 was significantly lower than the mean annual minimum of 2.96 m^3/s.

5.10.2 Water Quality

In 2004, water quality samples were collected from the mouth of the Ells River (station ELR-1) and upstream of CNRL Lease 7 (ELR-2) in September. Both Station ELR-1 and ELR-2 were designated as reference stations up to and including 2004 for the following reasons:

- the extent of the Deer Creek Energy Joslyn Phase 1 Project in 2004 was assessed to be sufficiently limited in magnitude; and
- activities related to the CNRL Horizon Project in 2004 were focused in the Tar River basin rather than in the Ells River basin.

Results of 2004 sampling for water quality measurement endpoints identified in Section 3.2.7 are shown in Table 5.10-1; results for selected measurement endpoints (1997 to 2004) relative to regional baseline conditions are shown in Figure 5.10-3.

At station ELR-1, fall 2004 concentrations of all water quality measurement endpoints except total aluminum were below guidelines for the protection of aquatic life and were, in general, similar to concentrations observed in previous years (Table 5.10-1). Concentrations of sodium, chloride, and sulphate at station ELR-1, however, exceeded the highest concentrations of these ions previously measured at this station; ion concentrations at station ELR-2 (fall 2004) exceeded the historical median concentrations at ELR-1. Concentrations of selected water quality measurement endpoints in 2004 were within the lower range of regional baseline values (Figure 5.10-3). Ion balance at station ELR-1 has been relatively constant over the three years of RAMP sampling (Figure 5.10-3).

Table 5.10-2 contains a list of all exceedances of CCME/AENV guidelines for the protection of aquatic life observed in the Ells River in 2004.

5.10.3 Sediment Quality

In 2004, sediment quality samples were collected from the mouth of the Ells River (station ELR-1) and upstream of CNRL Lease 7 (ELR-2). Both stations ELR-1 and ELR-2 were designated as reference stations up to and including 2004 for the same reasons as the corresponding water quality stations. Results of 2004 sampling for sediment quality measurement endpoints identified in Section 3.3.7 are shown in Table 5.10-3; results for

selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.10-5.

Sediments at station ELR-2 are almost exclusively comprised of sand, while station ELR-1 has a more even composition of sand, silt, and clay (Table 5.10-3). Concentrations of Fraction 3 hydrocarbons (C16-C34) exceeded CCME guidelines at both stations in fall 2004 (Table 5.10-3), and the CCME interim sediment quality guideline for arsenic was exceeded at station ELR-1. Concentrations of selected sediment quality measurement endpoints in fall 2004 were within the range of regional baseline conditions (Figure 5.10-5). At station ELR-1, concentrations of both total recoverable hydrocarbons and PAHs (normalized to the concentration of total organic carbon) were lower in 2004 than in previous years in which the regional baseline 95th percentile concentration had been exceeded (Figure 5.10-5).

5.10.4 Benthic Invertebrate Communities

In 2004, benthic invertebrate community samples were collected from a reach near the mouth of the Ells River (reach ELR-D 1-15, depositional) and from an upper reach of the river (reach ELR-E 1-15, erosional). Both reaches were designated as reference reaches up to and including 2004 for the same reasons as the water and sediment quality stations.

The lower reach of the Ells River was typical of depositional habitats in the region: water depths were moderate, current velocity was zero, and there were virtually no macrophytes present in the reach (Table 5.10-4). In contrast, the upper reach of the Ells River was typical of erosional habitats: water depth was shallow, moderate current velocity was observed, macrophytes were more abundant, and benthic algal biomass was moderate. Water chemistry was similar at the two reaches, with very little difference in dissolved oxygen concentrations, pH, and water temperature. Conductivity was higher in the lower reach of the Ells River but was within normal ranges for the region. Sediments in the lower reach were composed primarily of sand and silt, whereas gravel and cobble dominated the substrate in the upper reach.

Chironomids were the most abundant organism in the lower reach of the Ells River, followed by coleopterans, ceratopogonids, trichopterans, and tubificids. In contrast, the upper reach was dominated by chironomids and EPT taxa (Table 5.10-5).

The lower and upper reaches of the Ells River have been monitored for two years (2003 and 2004). Benthic community measurement endpoints for each reach were similar in 2003 and 2004, and were within ranges for regional reference conditions for depositional and erosional habitats (Figure 5.10-6, Figure 5.10-7).

5.10.5 Fish Populations

5.10.5.1 Fish Fence Reconnaissance

The suitability of fish fence deployment on the Ells River (upstream of the Joslyn Creek confluence) was assessed in spring 2004. This site was selected for assessment based on an examination of topographic maps and air photos of the watershed; proximity to an existing RAMP hydrometric monitoring station (RAMP S14) was also a consideration due to the availability of historical discharge information for the assessment. Figure 5.10-8

provides a downstream view of the Ells River reconnaissance site. This photo was taken in May of 2004, approximately one month after the actual reconnaissance survey. Access to this site is by helicopter only.

The site assessment focused on the rightward bend (looking downstream) of the Ells River, just upstream from the Joslyn Creek confluence. Most of the river channel was ice-covered at the time of the field assessment. As a result, channel morphology measurements were based primarily on visual observations and observations made during previous field visits.

Average water depth in the Ells River during April ranges from 1.2 to 1.5 m, with a maximum depth of approximately 1.5 to 1.7 m. At the time of the survey, the left bank was incised while the right bank exhibited a shallow 3:1 slope. Substrate was comprised of cobble and sand, creating the potential for erosion/scour problems during fence deployment.

During the 2003 ice-out, an ice jam downstream of the Ells River hydrology station caused water levels to rise by 2 to 3 m, resulting in extensive damage to the hydrometric monitoring equipment. Flows during spring 2004 were also very high, as shown in Figure 5.10-9. Conditions observed at this site, particularly stream velocity, indicate that maintenance of a wadeable fish fence on this section of the Ells River during spring freshet would be difficult.

Based on reconnaissance results, the potential fish fence site assessed on the Ells River appears to generally meet basic evaluation criteria. The cobble/sand substrate is characteristic of many streams in the oil sands area, and is susceptible to scour and erosive forces on both the channel bottom and banks. However, substrate issues can be largely addressed if stream flow velocities are appropriate and the fence is properly deployed. Of greater concern is the potentially high discharge and velocity in the Ells River during April-May. Discharge information from the hydrograph in Figure 5.10-9 is incomplete for this period, but available data indicate that discharge may exceed the maximum allowable discharge specified in the 2003 Muskeg River fish fence protocols (9 m^3/s, Appendix H). While the 2003 protocols were developed specifically for the Muskeg River and may not be widely applicable, they do provide some level of guidance for evaluating potential fish fence sites in other watersheds.

5.10.5.2 Sentinel Species Reconnaissance

A total of 364 fish of eight different species were caught in the two areas sampled for the Ells River sentinel species reconnaissance. Longnose dace were the most abundant (205 individuals), followed by pearl dace (72 individuals) and white sucker (41 individuals).

Early sampling efforts indicated that the majority of all fish species within the Ells River utilized rocks and grasses for cover, therefore subsequent sampling effort was concentrated in these areas. Longnose and pearl dace preferred riffles while trout-perch and northern pike preferred weedy beds along river banks.

Electrofishing Effort 1 (located in the proposed upstream reference area, approximately 9.5 km west of the CNRL Ells River bridge crossing) caught 185 fish; four of the eight species found during the survey were represented in this catch. Effort 2 and Effort 3

(located in the downstream potential exposed area) captured 69 and 59 fish representing five and seven species, respectively. Catch-per-unit-effort (CPUE) for the two sampling areas was 4.59 (Effort 1) and 2.47 (Efforts 2, 3, 4, and 5) (Table 5.10-6).

132 longnose dace were caught during electrofishing Effort 1. The other four effort locations, all within the potential exposed area, had a lower abundance of longnose dace; Efforts 2, 3, and 5 caught 38, 19, and 16 longnose dace, respectively, while Effort 4 did not capture any longnose dace. Table 5.10-7 shows the final results for the Ells River sentinel reconnaissance program.

5.10.5.3 Discussion

The success of a non-lethal sentinel species monitoring program depends greatly on the selection of appropriate fish species. Important criteria for species selection include: relative abundance and ease of capture; limited mobility and home range to allow for optimum exposure to potentially harmful substances in the aquatic environment; availability of non-lethal aging structures; and a single annual spawning event as opposed to multiple spawning events. Based on these criteria the slimy sculpin has been selected as the most appropriate species for use in the current RAMP sentinel monitoring program.

Although both slimy and spoonhead sculpin have been reported in the Ells River (Sekerak and Walder 1980), neither of these species were captured during the 2004 sentinel reconnaissance. Basic reconnaissance-level sampling was also conducted by Golder Associates and Environment Canada in the Ells River during the fall of 1999 (Golder 2000); while four sites in the watershed were sampled using electrofishing methods, no sculpin were found. Regardless of whether sculpin are present in the watershed, it is expected that their abundance would be too low to serve as an appropriate sentinel species. Therefore, given the basic criteria for species selection, results from the reconnaissance indicated that the longnose dace would be the best candidate for a future sentinel species monitoring program in the Ells River.

Longnose dace are widely distributed from coast to coast in north-central North America and are generally found in clean, swift flowing, gravel or bouldery streams, at times inhabiting very turbulent waters as well as inshore waters of lakes over boulder or gravel bottoms (Scott and Crossman 1973). Although less benthic than slimy or spoonhead sculpin, longnose dace are primarily bottom-dwelling fish, particularly when inhabiting fast-flowing stream reaches. Similar to sculpin, the longnose dace has a limited home range. Longnose dace usually spawn between May and early August, with females laying 200-1200 transparent, adhesive eggs (McPhail and Lindsey 1970). This species does not appear to be a multiple spawner.

Longnose dace abundance in both reconnaissance sampling areas appeared to be adequate to support a non-lethal sentinel monitoring program (i.e., 100 fish or more per sample). A full-scale sentinel program using longnose dace will be conducted in 2005.

5.10.6 Summary of Conditions

In 2004, the condition of RAMP aquatic resources in the Ells River system were similar to conditions in previous years. Relatively few measurement endpoints sampled in 2004

exceeded existing environmental guidelines, and all water quality, sediment quality, and benthic invertebrate measurement endpoints were within the range of expected reference conditions for similar river systems and habitats in the RAMP FSA. The river appears to meet basic criteria for the establishment of a fish fence, although any fish fence design and deployment will need to consider discharge, particularly in the early spring period, as well as erosion and scouring issues. Finally, it appears that a sentinel species monitoring program using longnose dace could be established in this watershed.

Figure 5.10-2 Ells River 2004 hydrograph and historical context.

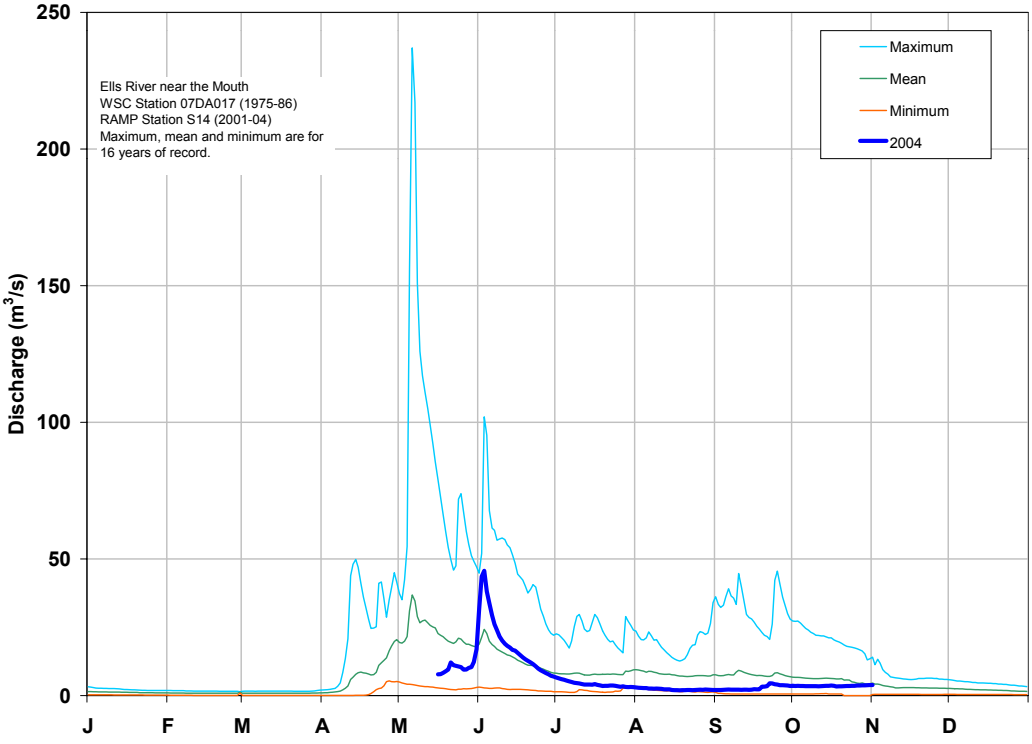
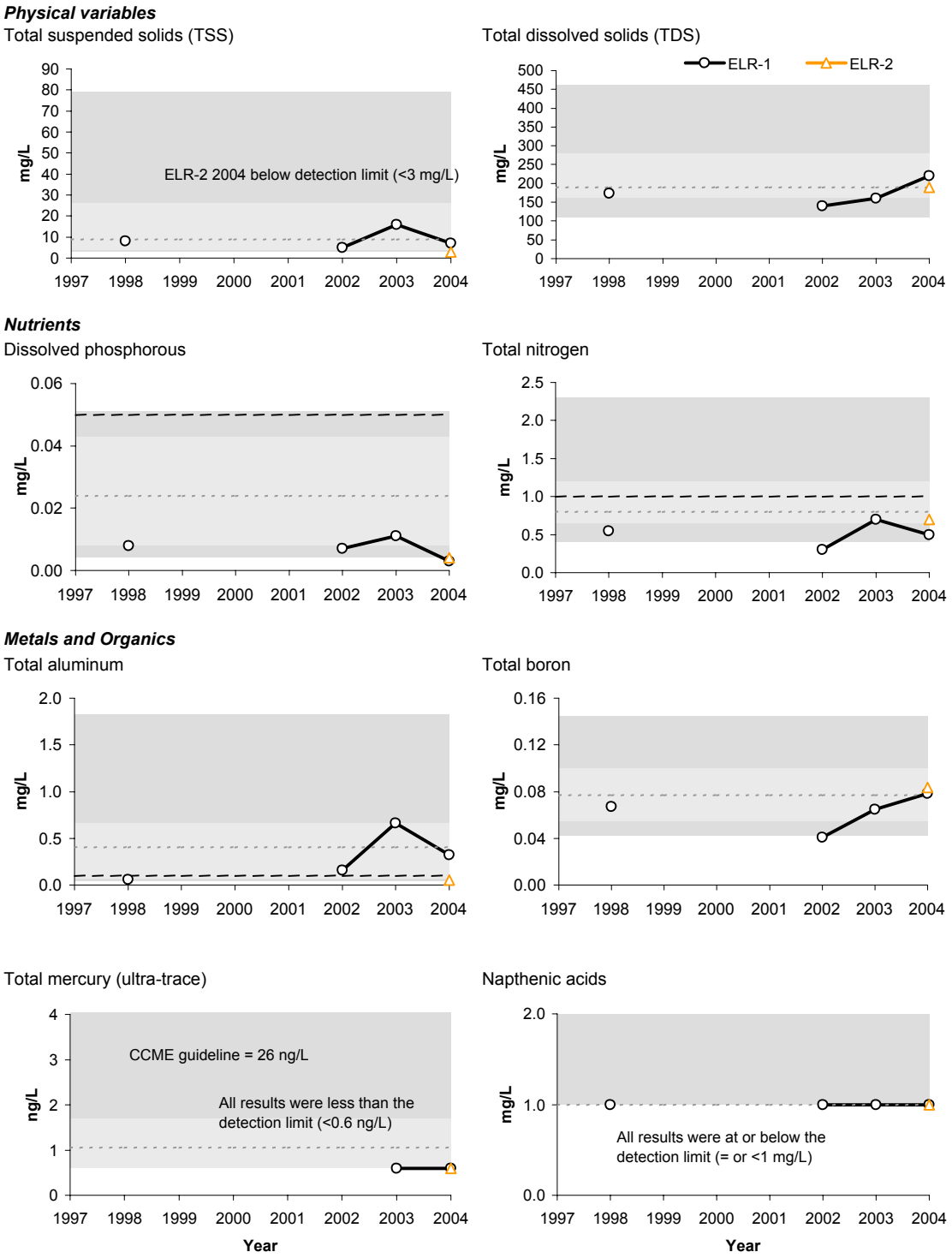


Table 5.10-1 Concentrations of water quality measurement endpoints, mouth of Ells River (ELR-1) and Ells River upstream (ELR-2), fall 2004.

	Units	Guideline	September 2004		1997-2003 (ELR-1, fall data only)			
			ELR-1	ELR-2[2]	n	Min	Median	Max
Physical variables								
pH	pH units	6.5-9.0	8.2	7.8	3	7.9	8.2	8.4
Total suspended solids	mg/L	-	7	<3	3	5	8	16
Conductivity	mg/L	-	258	195	3	186	236	249
Nutrients								
Total phosphorus	mg/L	0.05	0.014	0.01	3	0.011	0.014	0.043
Dissolved phosphorus	mg/L	0.05[1]	0.003	0.004	3	0.007	0.008	0.011
Total nitrogen*	mg/L	1.0	0.5	0.7	3	0.3	0.6	0.7
Nitrate+nitrite	mg/L	-	<0.1	<0.1	3	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	11	10	3	11	12	12
Ions								
Sodium	mg/L	-	18	13	3	8	12	15
Chloride	mg/L	230, 860[3]	4	3	3	1	1	2
Sulphate	mg/L	100[4]	27.9	18.9	3	15.4	17.7	22.5
Total dissolved solids	mg/L	-	220	190	3	140	160	174
Total alkalinity	mg/L	-	111	110	3	78	97	101
Organic compounds								
Naphthenic acids	mg/L	-	<1	<1	3	<1	<1	<1
Selected metals								
Total aluminum	mg/L	0.1	**0.32**	0.052	3	0.060	**0.16**	**0.66**
Dissolved aluminum	mg/L	0.1[1]	0.008	<0.0002	3	0.009	0.05	0.08
Total boron	mg/L	1.2[4]	0.078	0.084	3	0.04	0.06	0.07
Total molybdenum	mg/L	0.073	0.0008	0.0008	3	0.0006	0.0007	0.0008
Total mercury (ultra-trace)	ng/L	26	<0.6	<0.6	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004								
Total iron	mg/L	0.3	**0.7**	-	3	**0.5**	**0.5**	**0.8**

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] New station in 2004. No previous data are available.
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[4] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.10-3 Concentrations of selected water quality measurement endpoints, mouth of Ells River (ELR-1) and Ells River upstream (ELR-2), relative to regional baseline concentrations.



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 E for these regional baseline ranges.

Figure 5.10-4 Piper diagram of fall ion concentrations in Ells River system.

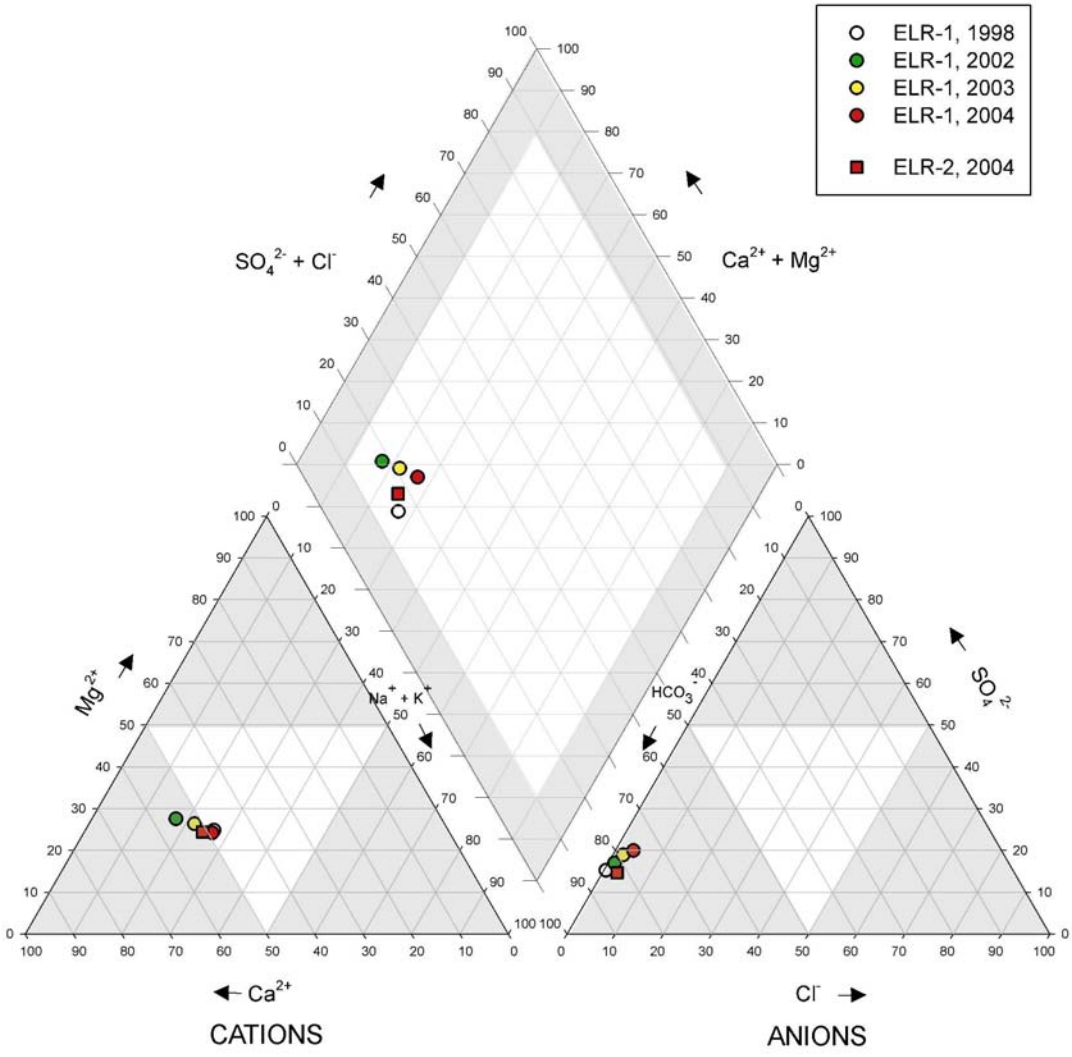


Table 5.10-2 List of all 2004 water quality guideline exceedances, Ells River.

Parameter	Units	Guideline	ELR-1	ELR-2	ELR-1b
Winter [1]					
Total iron	mg/L	0.300	**0.383**	ns	**0.377**
Spring					
Total copper	mg/L	0.002-0.004[3]	**0.0021**	**0.0023**	ns
Total aluminum	mg/L	0.100	**0.898**	**0.953**	ns
Total iron	mg/L	0.300	**1.58**	**1.38**	ns
Dissolved iron	mg/L	0.300[2]	**0.388**	-	ns
Total phosphorus	mg/L	0.05	**0.061**	**0.054**	ns
Summer					
none	-	-	-	-	ns
Fall					
Total aluminum	mg/L	0.100	**0.501**	-	ns
Total iron	mg/L	0.300	**1.0**	-	ns
Dissolved iron	mg/L	0.300[2]	**0.306**	-	ns

Guidelines are CCME/AENV guidelines for the protection of aquatic life.
[1]: ELR-1b sampled in winter instead of ELR-2.
[2]: Guideline is for total analyte (no guideline for dissolved species).
[3]: Guideline is hardness dependent.
ns: not sampled.

Table 5.10-3 Concentrations of sediment quality measurement endpoints, mouth of Ells River (ELR-1) and Ells River upstream (ELR-2), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	10	1	-	-	18
Silt	%	-	23	1	-	-	30
Sand	%	-	67	1	-	-	52
Total organic carbon	%	-	4.1	1	-	-	0.6
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]	200	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**3400**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	**3000**	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	1	-	-	1.8
TEH (C11-C30)	mg/kg	-	3200	1	-	-	500
TRH	mg/kg	-	14600	1	-	-	500
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.0036	1	-	-	0.011
Retene	mg/kg	-	0.181	1	-	-	0.05
Total dibenzothiophenes	mg/kg	-	5.4	1	-	-	0.31
Total PAHs	mg/kg	-	17.5	1	-	-	1.54
Total HMW PAHs	mg/kg	-	5.8	1	-	-	0.54
Total LMW PAHs	mg/kg	-	11.7	1	-	-	1.00
Predicted PAH toxicity[1]	H.I.	-	0.61	1	-	-	1.55
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	9	1	-	-	9
Chironomus growth	mg/organism	-	2.0	1	-	-	1.8
Hyallela survival	# surviving	-	9	1	-	-	9
Hyallela growth	mg/organism	-	0.2	1	-	-	0.1

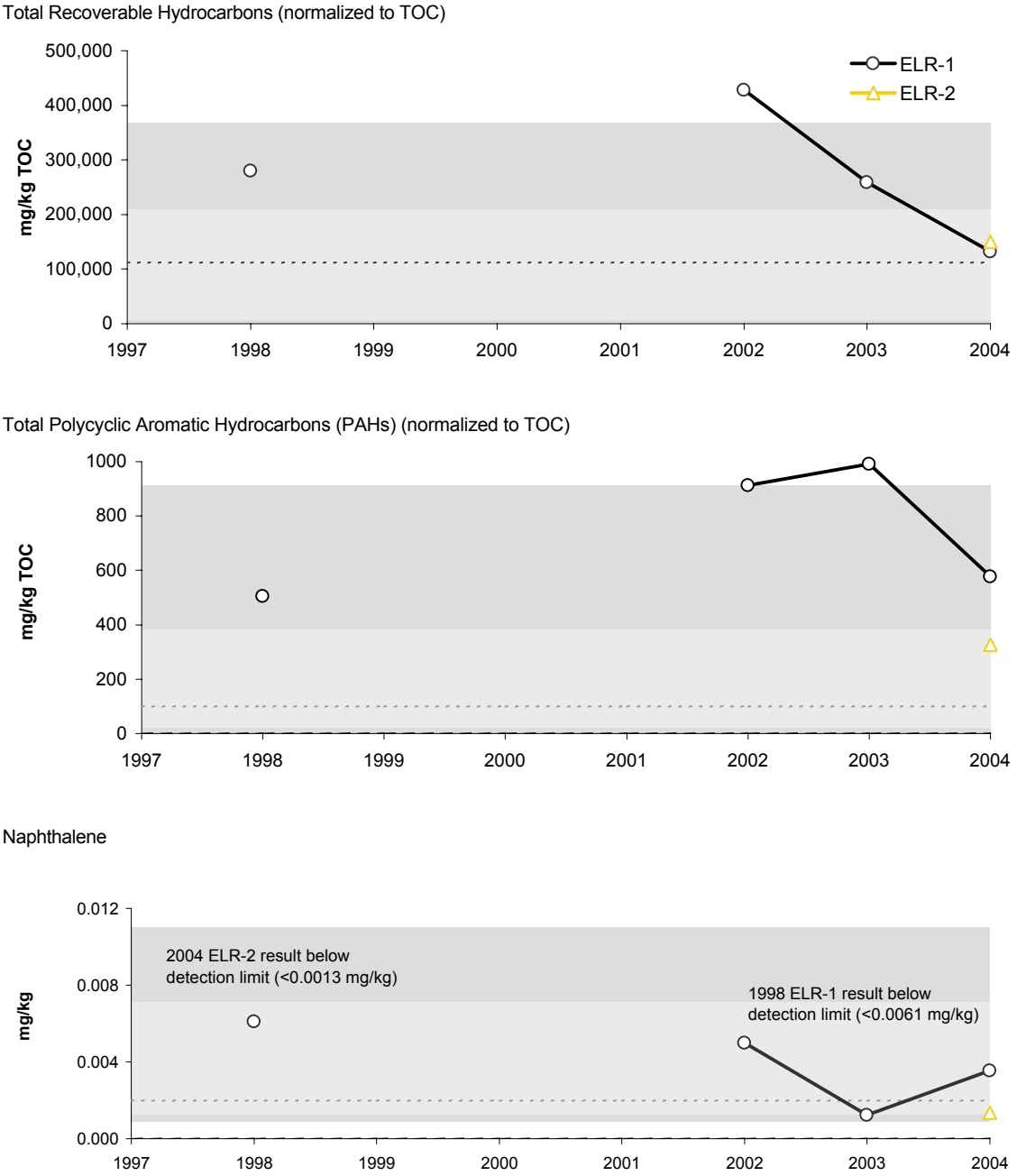
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

[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, mouth of Ells River (ELR-1) and Ells River upstream (ELR-2), 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 F for these regional baseline ranges.

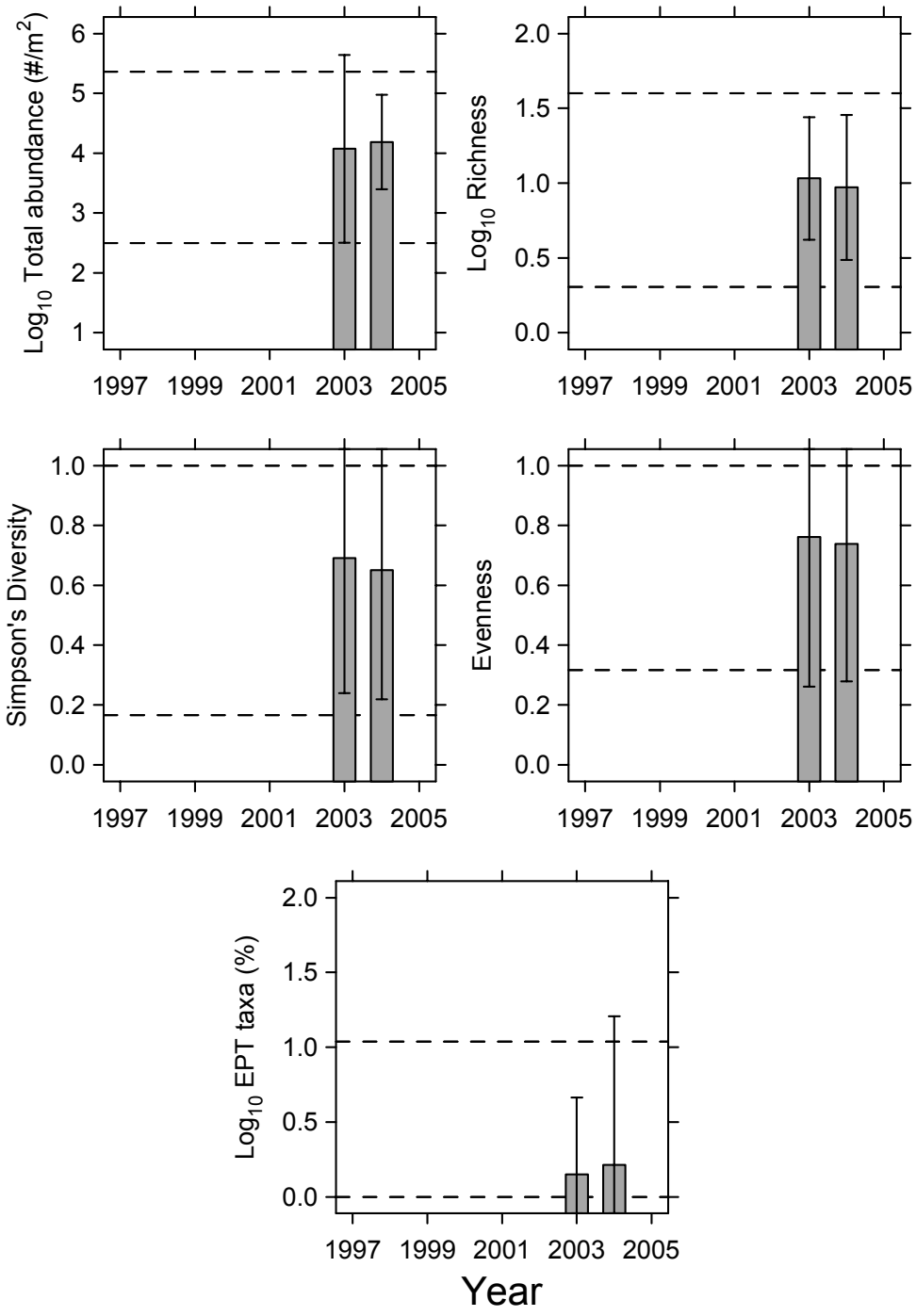
Table 5.10-4 Average habitat characteristics of benthic invertebrate sampling stations in the Ells River, fall 2004.

Variable	Units	Lower Reach of the Ells River	Upper Reach of the Ells River
Sample date	-	Sept 14, 2004	Sept 14, 2004
Habitat	-	Depositional	Erosional
Water depth	m	0.7	0.2
Current velocity	m/s	0	0.4
Macrophyte cover	%	1	7.6
Benthic algae	mg/m^2	n/a	73
Field Water Quality			
Dissolved oxygen	mg/L	12.0	11.2
Conductivity	µS/cm	254	176
pH	pH units	8.5	8.1
Water temperature	°C	8.1	9.8
Sediment Composition			
Sand	%	77.9	n/a
Silt	%	15.6	n/a
Clay	%	6.6	n/a
Total Organic Carbon	%	1.6	n/a
Sand/Silt/Clay	%	n/a	2.5
Small gravel	%	n/a	9.5
Large gravel	%	n/a	24.3
Small cobble	%	n/a	42.7
Large cobble	%	n/a	17.9
Boulder	%	n/a	3.7
Bedrock	%	n/a	0

Table 5.10-5 Summary of major taxon abundances and key indices of composition among stations in the Ells River, fall 2004.

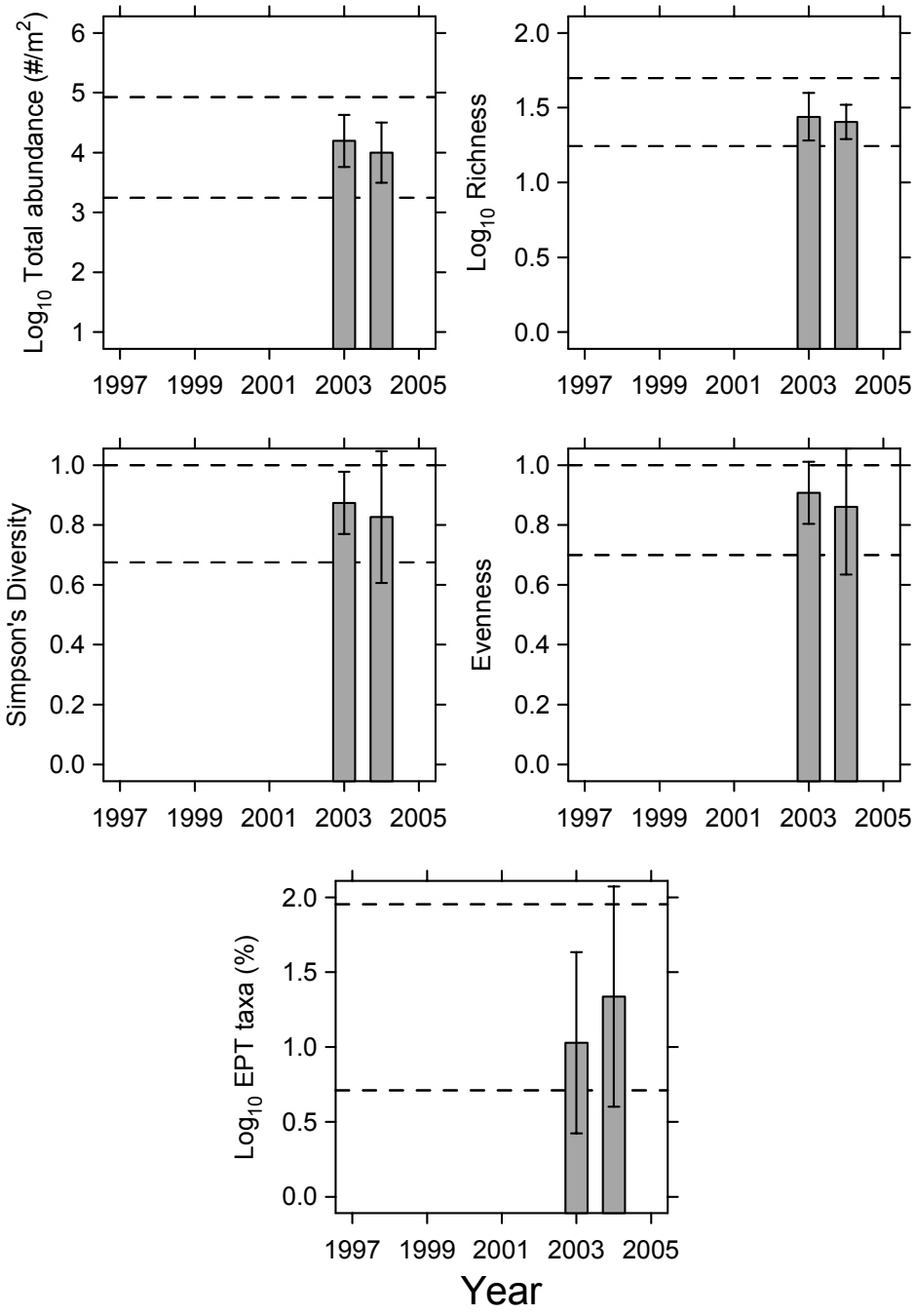
Taxon	Lower Reach of the Ells River			Upper Reach of the Ells River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Nematoda	532	998	2.5	677	1023	6.0
Enchytraeidae	57	0	0.3	131	178	1.2
Naididae	89	194	0.4	153	147	1.4
Tubificidae	1092	1505	5.1	67	284	0.6
Hydracarina	23	0	0.1	566	1156	5.0
Ostracoda	69	488	0.3	58	601	0.5
Copepoda	0	0	0	551	0	4.9
Chydoridae	3	0	0.0	1	0	0.0
Collembola	0	0	0	24	0	0.2
Gastropoda	385	969	1.8	7	0	0.1
Ephemeroptera	80	149	0.4	1345	728	11.9
Plecoptera	0	0	0	1085	1467	9.6
Trichoptera	1842	19476	8.7	877	875	7.8
Anisoptera	57	0	0.3	494	657	4.4
Zygoptera	9	0	0.0	0	0	0
Coleoptera	3164	20863	14.9	68	155	0.6
Tipulidae	954	4064	4.5	0	0	0
Athericidae	0	0	0	186	396	1.7
Dolichopodidae	112	896	0.5	0	0	0
Tabanidae	69	157	0.3	0	0	0
Empididae	158	466	0.7	411	783	3.7
Ceratopogonidae	2405	5062	11.3	467	635	4.2
Chironomidae	10161	4565	47.8	4032	868	35.8
Simuliidae	0	0	0	57	236	0.5
Total Abundance	21261	18663	-	11257	5626	-
Richness	10.5	4.9	-	25.6	3.1	-
Simpson's Diversity	0.650	0.196	-	0.826	0.100	-
Evenness	0.739	0.209	-	0.860	0.103	-

Figure 5.10-6 Variations in indices of benthic invertebrate community composition in the Ells River, lower reach.



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

Figure 5.10-7 Variations in indices of benthic invertebrate community composition in the Ells River, upper reach.



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

Figure 5.10-8 Downstream view of Ells River fish fence reconnaissance site, April 2004.

Figure 5.10-9 Hydrograph of Ells River measured upstream of Joslyn Creek.

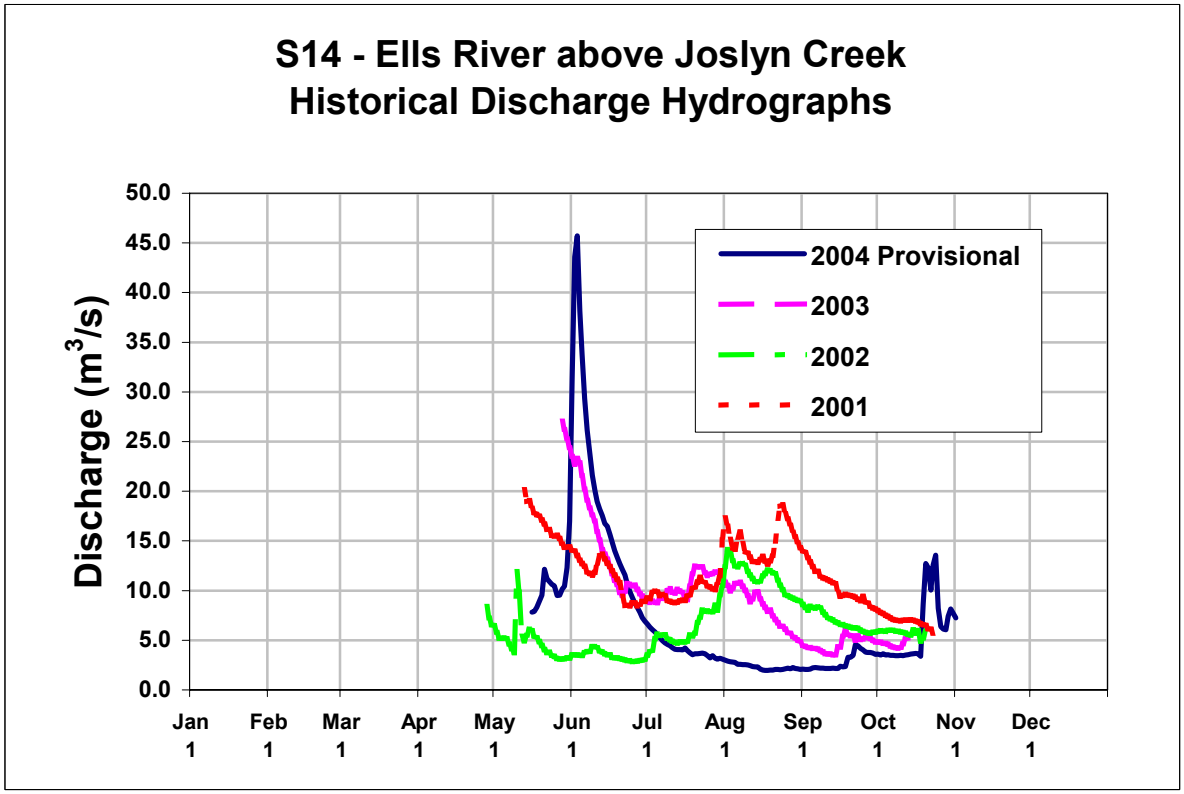


Table 5.10-6 Average CPUE for the five electrofishing efforts on the Ells River sentinel reconnaissance, September 2004.

Effort	Date	Effort (seconds)	Total Fish Caught	CPUE (#fish/100s)
1	Sep-10	4028	185	4.59
2,3,5	Sep-8, 9	7236	179	2.47

Table 5.10-7 Results of the Ells River sentinel reconnaissance fish sampling program, September 2004.

		Effort						
		Area A		Area B			B Total	Grand Total
Species	Parameter	Effort 1	Effort 2	Effort 3	Effort 4	Effort 5		
LKCH	n		8				8	8
	mean fork length (mm)		55				55	55
	mean weight (g)		3.2				3.2	3.2
LNDC	n	132	38	19		16	73	205
	mean fork length (mm)	59	61	50		62	59	59
	mean weight (g)	2.6	2.8	1.9		3.0	2.6	2.6
NRPK	n			1		1	2	2
	mean fork length (mm)			395		460	428	428
	mean weight (g)			362.0			362.0	362.0
PRDC	n	31	1	13	16	11	41	72
	mean fork length (mm)	58	56	54	29	34	39	47
	mean weight (g)	2.6	1.9	2.5	0.3	0.8	1.2	1.8
SPSH	n			1			1	1
	mean fork length (mm)			44			44	44
	mean weight (g)			0.9			0.9	0.9
TRPR	n	13	7	13		1	21	34
	mean fork length (mm)	47	46	50		40	48	48
	mean weight (g)	1.5	1.5	1.5		1.4	1.5	1.5
WHSC	n	9	15	11		6	32	41
	mean fork length (mm)	134	87	66		82	79	91
	mean weight (g)	76.5	14.3	6.2		6.5	10.1	24.6
YLPR	n			1			1	1
	mean fork length (mm)			104			104	104
	mean weight (g)			13.2			13.2	13.2
Total		185	69	59	16	35	179	364

LKCH= Lake chub, LNDC= Longnose Dace, NRPK= Northern Pike, PRDC= Pearl Dace, SPSH= Spottail Shiner, TRPR= Trout Perch, WHSC= White Sucker, YLPR= Yellow Perch

5.11 CLEARWATER-CHRISTINA RIVER SYSTEM

Summary of Results

Climate and Hydrology

	Assessment of Change			
	Negligible	Low	Moderate	High
Mean open-water season discharge	The Clearwater-Christina River watersheds were designated as reference watersheds for 2004.			
Mean winter discharge				
Annual maximum daily discharge				
Minimum open-water season discharge				

Runoff volume in the Clearwater River basin was 5% above normal in 2004. In the Christina River basin, the 2004 March-October runoff of 96 mm was 22% above average.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=4)
Physical variables (3 endpoints)	No water quality sampling stations were designated as exposed in 2004.	0
Nutrients (5 endpoints)		4
Ions (5 endpoints)		0
Organic compounds (1 endpoint)		0
Selected metals (5 endpoints)		3

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 4 stations X 7 endpoints)
Above 95th	No water quality stations were designated as exposed in 2004.	1
Between 75th and 95th		9
Between median and 75th		5
Between 25th and median		7
Between 5th and 25th		4
Less than 5th		0

Concentrations of water quality endpoints on the Clearwater River were generally consistent between upstream and downstream stations. With one exception (CHR-2), TSS concentrations were relatively high at all stations and approximately 3- to 9-fold higher than historical fall values. Other water quality variables typically associated with TSS, including aluminum, total iron and total phosphorous, exceeded relevant guidelines at some stations. In all instances, concentrations of selected measurement endpoints in fall 2004 were within the range of regional baseline conditions.

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]	
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=2)
Physical variables (4 endpoints)	No sediment quality stations were designated as exposed in 2004.	0
Total Hydrocarbons (8 endpoints)		1
PAHs (7 endpoints)		0

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 2 stations X 3 endpoints)
Above 95th	No sediment quality stations were designated as exposed in 2004.	0
Between 75th and 95th		1
Between median and 75th		2
Between 25th and median		2
Between 5th and 25th		1
Less than 5th		0

Concentrations of sediment quality variables in the lower Christina River in 2004 were within the range of previous observations and within the range observed in regional reference watercourses. However, concentrations of sediment quality variables measured at the upstream station were generally lower than the range recorded in previous years and below the 25th or 5th percentile of the regional reference range for total PAHs, TRH, and naphthalene.

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline					
	2004 Exposed Stations (n=0)			2004 Reference Stations (n= 4)		
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD
Abundance	No benthic invertebrate community sampling stations were designated as exposed in 2004.				4	
Richness					4	
Diversity					4	
Evenness					4	
% EPT					4	

Total abundance and richness have consistently been higher in upstream reaches than in downstream reach, but all benthic community indices have consistently fallen within expected values for regional reference conditions. There have been no obvious trends in indices over the last four years of monitoring.

Fish Populations

Fish Inventory	The 2004 fall sampling effort was incomplete due to low water and technical difficulties.
Sentinel Studies	Sentinel fish studies were not conducted in 2004.

Fish Tissue	Level of Risk	
	Clearwater River	*Winefred Lake*
Human Health: Subsistence	High	High
Human Health: Recreational Fishers	High	High
Human Health: General Consumers	Moderate	Moderate
Human Health: Tainting	Low	Low
Fish and Wildlife: Mercury	High	High
Fish and Wildlife: Other Chemicals	Low	Low

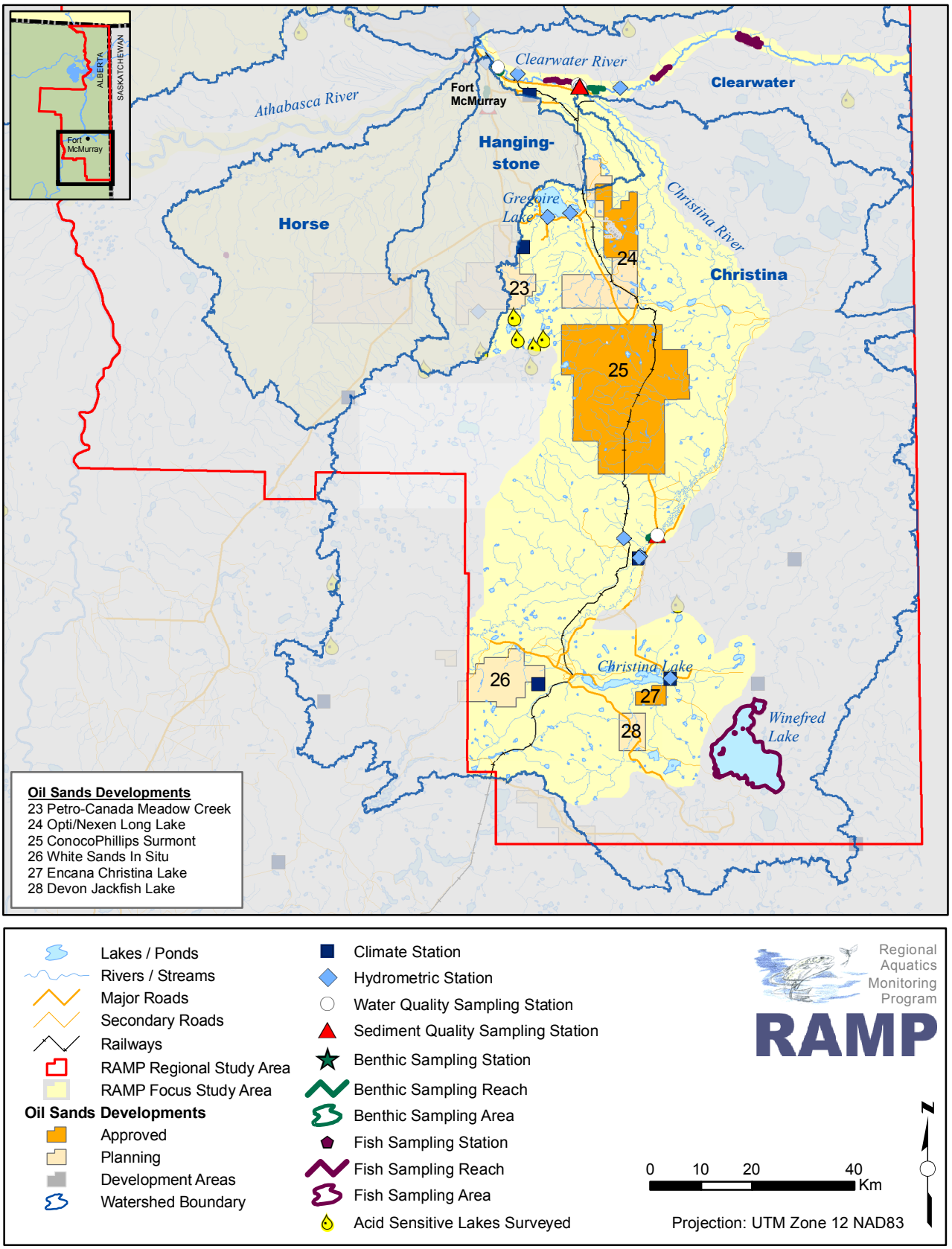
The Christina River reconnaissance inventory field program was hindered by high water levels and flow conditions which significantly reduced the efficacy of fish sampling efforts. It may be appropriate to conduct a second reconnaissance sampling program. Additional information on the overall feasibility of a regular Christina River fish inventory is needed.

[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 Hydrologic Conditions

In contrast to the river basins north of Fort McMurray, runoff volume in the Clearwater River basin, as measured at WSC Station 07CD005, was 5% above normal in 2004. The March to October total runoff was 109 mm compared to the long-term average of 104 mm. The runoff hydrograph contains two significant peaks, one at the end of April in response to snowmelt, and a second higher peak at the beginning of June in response to rainfall (Figure 5.11-2). July to October discharges were below normal, but not extremely low. The June maximum daily discharge of 239 m^3/s on the Clearwater River was 18% higher than the mean annual flood. That discharge has been exceeded only five times since 1966, with the most recent higher flow occurring in 1985. The minimum open-water discharge on the Clearwater River was 54.3 m^3/s on October 28, slightly below the mean annual minimum discharge of 60.9 m^3/s.

In the Christina River basin, the 2004 March to October runoff of 96 mm was 22% above average. The Christina River responded to the same rainstorm that affected the area north of Fort McMurray early in June, producing discharges well above average for the entire month of June (Figure 5.11-3). The June maximum daily discharge of 81.8 m^3/s was 8% greater than the mean annual flood.

5.11.2 Water Quality

In 2004, water quality samples were collected from the Clearwater River upstream of Fort McMurray (CLR-1) and upstream of the Christina River confluence (CLR-2). In addition, water samples were collected from the mouth of the Christina River (CHR-1) and upstream of Janvier (CHR-2). Although a number of *in situ* oil sands projects are planned or undergoing initial development within the Christina River watershed, stations on the Christina River and lower Clearwater River were designated as reference until operations intensify. In addition, *in situ* projects require a low amount of site disturbance and generally have little direct influence on surface water resources. Station CLR-2 is considered a long-term reference station. Results of 2004 sampling for selected water quality variables 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 (2001 to 2004) relative to regional baseline conditions are shown in Figure 5.11-4.

Concentrations of water quality endpoints measured on the Clearwater River were generally consistent between upstream and downstream stations. With the exception of CHR-2 near Janvier, total suspended solids (TSS) concentrations were relatively high at all stations on the Clearwater and Christina rivers and approximately 3- to 9-fold higher than historical fall values. Other water quality variables typically associated with TSS, including aluminum, total iron and total phosphorous were also higher, often exceeding CCME/AENV water quality guidelines for the protection of aquatic life. In all instances, concentrations of selected measurement endpoints in fall 2004 were within the range of regional baseline conditions.

Ion 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). Upper Christina River station CHR-2 exhibits dissimilar relative ion concentrations than 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.

In 2004, water quality observed at Station CLR-2 (e.g., concentrations of ions, TSS, TDS, total nitrogen) was distinct from water quality at the lower Christina River (and Clearwater stations). Greater consistency between stations was observed in 2003; however, marked differences were also recorded in 2002 (Figure 5.11-4). Accordingly, the suitability of CHR-2 as a reference station for the Christina River basin should be re-evaluated. A new station location could be considered or, perhaps, a survey could be conducted to determine where along the river water quality changes. The latter approach may lead to greater understanding of potential influences on water quality of the Christina River.

Table 5.11-5 contains a list of all exceedances of CCME/AENV guidelines for the protection of aquatic life observed in the Clearwater and Christina Rivers in 2004.

5.11.3 Sediment Quality

In 2004, sediment quality samples were collected from the mouth of the Christina River (CHR-1) and upstream of Janvier (CHR-2). As with water quality, both stations were designated as reference stations. Results of the 2004 survey of selected sediment quality variables are presented in Table 5.11-6 and Table 5.11-7; results for selected measurement endpoints relative to regional baseline conditions are shown in Figure 5.11-6.

Concentrations of sediment quality variables in the lower Christina River in 2004 were within the range of observations of previous years and within the range observed in regional reference watercourses. However, concentrations of sediment quality variables measured at the upstream station were generally lower than the range recorded in previous years and in the lower end of the regional reference range for total PAHs, TRH, and naphthalene (Figure 5.11-6). At the lower station, the influence of natural hydrocarbon sources was observed visually in the field; this is reflected in higher hydrocarbon concentrations relative to the upper station. As concluded for water quality, the sediment quality results suggest that the upper station on the Christina River may not be a suitable reference station for the station located at the mouth.

5.11.4 Benthic Invertebrate Communities

In 2004, benthic invertebrate community samples were collected from reaches on the Clearwater River located upstream (CLR-D-16-30) and downstream (CLR-D-1-15) of the Christina River confluence, and from reaches on the Christina River located near the mouth (CHR-D-1-15) and upstream of Janvier (CHR-D-16-30). All reaches were designated as reference reaches. Habitats at these reaches were depositional. The upper reach of the Christina River was moderately deep with no measurable current velocity or macrophytes (Table 5.11-8). In contrast, the lower reach of the Christina River was shallow with low current velocity and some macrophyte cover. Water quality was generally similar at the upper and lower reaches of the Christina River, although conductivity in the lower reach was more than double that of the upper reach. Sediments in both the upper and lower reaches were similar and were dominated by sand and silt.

Water depth in the Clearwater River upstream and downstream of the Christina River confluence was moderate (Table 5.11-9). There was no measurable current in the upstream reach, whereas current velocity was moderate in the downstream reach of the Clearwater River. Macrophytes were absent from the upstream reach and rare in the downstream reach. Water quality (i.e., dissolved oxygen, conductivity, pH and water temperature) was similar at the upstream and downstream reaches of the Clearwater River. Sediments in the downstream reach were heavily dominated by sand, whereas silt and clay were abundant in the upstream reach of the Clearwater River.

Chironomids and ostracods dominated the benthic invertebrate communities of the upper and lower reaches of the Christina River (Table 5.11-10). The Ceratopogonidae, Ephemeroptera, and Tubificidae were also abundant in the lower reach of the Christina River, whereas the Ephydridae, Tubificidae, Tipulidae, and nematodes were abundant in the upper reach of the Christina River.

The benthic invertebrate community in the Clearwater River, downstream of the Christina River, was also dominated by chironomids, followed by coleopterans and the Ceratopogonidae (Table 5.11-11). Upstream of the Christina River, the benthic community of the Clearwater River was dominated by chironomids, EPT taxa, the Ceratopogonidae, and tubificids.

The lower and upper reaches of the Christina River have been monitored by the RAMP program since 2002 and both reaches are considered to be unaffected by oil sands development to date. Benthic invertebrate community indices were similar between the two reaches and fell within expected values for regional reference conditions for depositional habitats (Figure 5.11-7). Abundance and richness at both reaches appear to have declined slightly over the last three years of sampling.

The Clearwater River reaches, both upstream and downstream of the Christina River, have been sampled as part of the RAMP program since 2001. Total abundance and richness have consistently been higher in the upstream reach than in the downstream reach, but all benthic community indices have consistently fallen within expected values for regional reference conditions for depositional habitats (Figure 5.11-8). There have been no obvious trends in the benthic invertebrate community indices in either reach over the last four years of monitoring.

5.11.5 Fish Populations

Fish population monitoring in the Clearwater River/Christina River watersheds included a fish inventory and fish tissue analyses on the Clearwater River, and a reconnaissance fish inventory on the Christina River near Janvier.

Additionally, fish from Winefred Lake, located within the Christina watershed but outside the RAMP FSA, were sampling in 2004 is part of the regional lakes fish tissue sampling program.

5.11.5.1 Clearwater Fish Inventory

Fourteen species of fish (total of 867 fish) were captured or observed during the Clearwater River fish inventory in 2004. Boat electrofishing resulted in the capture/observation of 844 fish (spring: 618 fish; fall: 226 fish) (Table 5.11-12 and Table 5.11-13), while beach seining (spring only) resulted in the capture of an additional 23

fish (Table 5.11-14). Percent species composition and catch-per-unit-effort for fish caught during boat electrofishing are provided in Table 5.11-12 and Table 5.11-13.

Overall, fish catch during the 2004 Clearwater River fish inventory was down substantially from 2003 due primarily to low, turbid water conditions and technical difficulties that occurred during the fall sampling period. Fish catches in the spring were dominated by two large-bodied species, white sucker and northern pike, and one small-bodied species, trout-perch. In the fall, the dominant large-bodied species were white sucker and northern pike, while the dominant small-bodied species was spottail shiner.

Length-frequency analysis

Length-frequency distributions for key fish indicators captured during the 2004 Clearwater River inventory are shown in Figure 5.11-9 to 5.11-13. Data were pooled to include fish captured in the spring and fall, and were compared to 2003 results.

For walleye, the dominant length class in 2004 was 401-450 mm. An additional group of fish was found in the 201-250 mm class (Figure 5.11-9). With the exception of the outlying group, the dominant mode was similar to historical lengths for walleye observed (1997-2004) in the Athabasca River (Figure 5.1-21).

The dominant length class for goldeye in 2004 was 351-375 mm (Figure 5.11-10), which is identical to results from the 2003 Clearwater River fish inventory, and similar to Athabasca River goldeye sampled in 2003 (*cf.* Figure 5.1-23), although this comparison is weak given the small numbers of goldeye captured in 2003 (n=18) and 2004 (n=43).

Longnose sucker captured in the 2004 Clearwater River inventory were primarily small to mid-size individuals (dominant mode 201-250 mm; Figure 5.11-11). In 2003, the dominant size class was even smaller (101-150 mm). This contrasts with historical results (1997-1999) for the Athabasca River where the dominant length class was typically 350-450 mm (Figure 5.1-24).

Northern pike sampled in 2004 were predominantly in the 501-550 mm and 551-600 mm length classes, with a smaller peak in the 351-240 mm length class (Figure 5.11-12). These results were similar to 2003 and 2004 inventory results for the Athabasca River (Figure 5.1-25).

The dominant length class for white sucker captured during the 2004 Clearwater River fish inventory was 51-100 mm (Figure 5.11-13). This is in contrast to 2003 when the dominant size class was 401-450 mm. Despite this difference the overall distribution of size ranges was similar between years.

Condition factor

Mean condition factors for key fish indicators captured in the spring 2004 Clearwater River inventory are shown in Figure 5.11-14 relative to 2003 values. Lake whitefish (none captured in 2004) and trout-perch (body weight not measured) are not included.

Mean condition factor for goldeye, northern pike, walleye and white sucker sampled on the Clearwater River in the spring of 2004 were similar to results obtained during the 2003 fish inventory. The 2004 mean condition factor for longnose sucker is significantly

higher than the 2003 value. Results from 2003-2004 are generally comparable across species with those obtained from the Athabasca River (1997-2004) (Figure 5.1-27 to 5.1-31). Longnose sucker from the Clearwater River had a lower mean condition factor in 2003 relative to historical inventory results from the Athabasca River.

Discussion

The 2004 Clearwater River fish inventory was the second successive year that this program has been carried out under RAMP. The fish community in the Clearwater River appears to be similar to that found in the Athabasca River mainstem. Although only 14 species of fish were identified during the 2004 RAMP inventory, other studies have reported a total of 22 species including eight sport species, two sucker species and twelve small-bodied forage species (Golder 2004). The degree of mixing between individuals from these two rivers and the likelihood of fish being from the same population is not known. The 2004 results were similar to those obtained in 2003 in that mean size of goldeye was larger than in the Athabasca River samples, while northern pike and walleye were on average slightly smaller than those captured in the Athabasca River. White sucker populations in the Clearwater River appear to be dominated by smaller individuals, possible juveniles, while northern pike size classes were distributed across a wide range.

No lake whitefish were captured during the fall sampling effort on the Clearwater River. Although sampling effort was low during the fall field program, the lack of lake whitefish during this period strongly suggests that the river is not used by this species for annual spawning migration, as is the case in the Athabasca River mainstem. This finding is consistent with 2003 results. Jones et al. (1978) examined the Clearwater River in the fall to investigate spawning activity by lake whitefish. No lake whitefish spawning was observed and no fish in spawning condition were captured in this watershed.

Length-weight relationships for walleye and northern pike captured in the Clearwater River in 2004 were similar to 2003 values. Longnose sucker had a significantly higher mean condition factor in 2004 when compared to 2003. The relatively low condition factor in 2003 was likely influenced by the presence of immature individuals in the sample. Condition factors for all other species in 2004 were generally consistent with those calculated in 2003, and with Athabasca River fish.

Impact Analysis

Only two years of Clearwater River fish inventory data have been collected to date. Sampling in 2003 was generally successful during both the spring and fall field programs, but the 2004 fall sampling effort was incomplete due to low water and technical difficulties. This two-year data set is not adequate for meaningful analysis of the designated inventory measurement endpoints (e.g., relative abundance and condition factor). It is generally accepted that seven years of data are required for an effective trend analysis. In this regard, at least five more years of inventory data collection will be needed to provide an adequate data set for statistical or trend analysis of any designated measurement endpoints.

All three sampling sites on the Clearwater River have been classified as reference sites. Clearwater Site 3 (CR3), located downstream of the confluence with the Christina River,

may eventually be designated as an exposure site depending on the progress of future oil sands developments in the watershed.

5.11.5.2 Fish Tissue Analyses

Clearwater River Tissue

Whole-Organism Metrics

Whole-organism metrics for Clearwater River northern pike and walleye are summarized in Table 5.11-15. Results from the external and internal fish health assessment for the Clearwater River fish are provided in Table 5.11-17.

Thirteen northern pike, 9 females and 4 males, were caught in the Clearwater River. The mean size of female northern pike was approximately 20% greater than the mean size of males; however, the mean age of males was slightly higher relative to females. Relative gonad size (i.e., GSI) of female northern pike was almost identical to values calculated for males. This is to be expected given these fish are spring spawners. Mean liver somatic index (LSI) was considerably smaller for males compared to females.

Results from the external and internal fish health assessment for northern pike and walleye are summarized in Table 5.11-17. However, these data should be interpreted with caution because of the small sample sizes and the lack of regional reference data characterizing the natural variability in the frequency of abnormalities.

External abnormalities, such as fin erosion and skin abrasions, and internal abnormalities, including enlarged or granular spleens, discoloration of the liver, and presence of parasites, were observed at low frequencies in both species. Full yellow gall bladders and other observations, such as percent mesenteric fat and fatty livers, which are reflective of food availability and storage, occurred at a similar frequency in both species.

To provide an overall picture of fish health, the percent of fish affected by abnormalities was calculated; this estimation included all abnormalities with the exception of those related to food availability and storage, such as levels of mesenteric fat, gall bladder/bile colour and fatty livers. The occurrence of abnormalities was in excess of 75% for both species and sexes. The most prevalent conditions were scars on the surface of the skin. Serious abnormalities, such as parasitic infections, were observed at very low rates.

Mercury

Mercury concentrations in muscle of individual northern pike and walleye from the Clearwater River are presented in Table 5.11-15. Mean mercury concentration was highest in walleye at 0.402 mg/kg. The highest individual concentration of mercury (0.824 mg/kg) occurred in the largest female northern pike (837 mm and 4750 g). Mean mercury concentrations in northern pike were higher in females (0.340 mg/kg) than in males (0.281 mg/kg).

Scatterplots of fork length, total weight, GSI, LSI and age against mercury concentrations in muscle of individual northern pike from Clearwater River are

presented in Figure 5.11-15. Although samples sizes are low there appears to be a weak positive relationship between fish age and size and mercury concentrations.

Rank correlations were used to further evaluate the relationship between mercury concentrations in muscle and whole-organism metrics (fork length, total weight, GSI, LSI, and age) for female and combined sexes for northern pike (Table 5.11-18). The sample size for male northern pike was not large enough to conduct the ranking analysis. For female northern pike, mercury concentrations were most strongly correlated with total weight (r_s = 0.795). A moderate, positive correlation (r_s = 0.601) with fork length was also observed. Mercury concentrations in the combined male-female sample were strongly positively correlated with fork length and total weight, and moderately positively correlated with age. Correlations with other whole-organism parameters were statistically insignificant.

Other Chemicals

Concentrations of other chemicals in composite muscle samples of walleye and northern pike from the Clearwater River are presented in Table 5.11-16. Concentrations of 12 of 25 metals and five of the nine tainting compounds were below analytical detection limits. Concentrations of the remaining metals, including barium, copper, iron, manganese, selenium, strontium, titanium and zinc were low, and varied little between sexes and species. Arsenic was the only metal that occurred at concentrations in excess of the Region III USEPA risk-based criterion.

Discussion

5.11.5.3 Effect on Human Health

Mercury

Sample sizes for the 2004 Clearwater River fish tissue analysis were small, which limits meaningful statistical analysis and comparison with other data sets (e.g., historical Athabasca River fish tissue results). 2004 was the first year of tissue testing on the Clearwater River, so comparisons to historical data for this watershed were not possible. However, in general there were only slight significant differences between mean mercury concentrations in tissue from the two fish species tested (northern pike and walleye), and no marked differences between male and female northern pike (only male walleye were tested due to the limited size range available in the total sample). Substantial differences in muscle mercury concentrations of northern pike and walleye are generally not expected given that diets of these two species are similar, particularly with respect to the proportion of fish consumed by adults (Scott and Crossman 1973).

For northern pike, positive correlations between fish size (i.e., length and weight) and muscle mercury concentrations were observed. Because of the tendency of mercury to bioaccumulate up the food chain, larger upper trophic level consumers, such as piscivorous fish, can accumulate higher concentrations of mercury in their tissues than smaller fish of the same species (Eisler 1987b), assuming fish of different sizes have similar diets. The relationship between fish age and mercury burden was more variable. This weak correlation may be an artifact of the sample sizes collected during the 2004 Clearwater River tissue program. Because the fish tissue program targets larger fish, it might be expected that the relationship between mercury concentration and body size would be weaker compared to age because the growth rate in older fish

continues to decrease with age. At this latter stage in the growth curve, age may be a more accurate predictor of compounds that bioaccumulate over time. However, this trend was not observed in fish collected in 2004.

Mercury concentrations in individual fish from the Clearwater River were compared to a number of criteria to assess potential risks to human health (Table 5.11-19). Concentrations of mercury in all individual samples were higher than the Health Canada and USEPA screening values for subsistence fishers. The highest individual concentration was greater than 16 times higher than the USEPA screening criteria for subsistence fishers. Two northern pike females slightly exceeded the USEPA screening value for recreational fishers, and two other pike exceeded the Health Canada screening value for general consumers, one by 1.6 times. One of the two male walleye samples from the Clearwater River slightly exceeded the Health Canada screening value for general consumers.

Based on the above information, there are potential health risks for humans consuming northern pike and walleye from the Clearwater River. The risk to individuals, especially subsistence fishers, will vary with the consumption rates and dietary preferences of the community in question, community characteristics, extent of exposure to other contaminants, and exposure to contaminants through other routes (USEPA 2000). In general, results from Clearwater River samples are consistent with data on mercury concentrations in fish tissue from the Athabasca River and other waterbodies in the oil sands area (e.g., regional lakes). It is apparent that the range of mercury concentrations found in fish from the Clearwater system fall within the range observed for the region, and it is likely that the exceedances observed represent normal background concentrations.

As 2004 was the first year of the RAMP Clearwater River fish tissue program, comparisons to historical data for the system are not possible. However, general comparisons can be made to data from the Athabasca River, where tissue sampling has been carried out for a number of years under RAMP. Historically, mercury concentrations in fish have ranged from 0.33 to 0.79 mg/kg from the Athabasca River upstream of the oil sands region and 0.15 to 0.79 mg/kg within or downstream of the oil sands region (Golder 2003a). Fish tissue data collected from the Clearwater River in 2004 fall within this range, indicating that mercury concentrations are not elevated above regional background levels.

Other Chemicals

Metals and tainting compounds in fish from the Clearwater River were screened against several criteria to assess potential risks to human health (Table 5.11-16). Only one exceedance was observed. Arsenic concentrations were higher than the USEPA screening values (0.00327 and 0.026 mg/kg) and Region III risk-based criteria (0.002 mg/kg). Overall, these results indicate that metals and tainting compounds do not pose a risk to human health; however, arsenic is seen as a potential health risk to subsistence fishers in the oil sands area, depending on individual consumption habits. Concentrations of metals and tainting compounds in fish from the Clearwater River are similar to those found in fish from the Athabasca River. Results from the Athabasca River indicate that fish tissue quality has remained constant or improved since 2002.

5.11.5.4 Effects on Fish and Wildlife

Mercury

Mercury concentrations in individual northern pike and walleye samples were compared to criteria and thresholds for effects in fish and wildlife (Table 5.11-20). All mercury concentrations exceeded the CCME criteria for the protection of piscivorous wildlife (0.033 mg/kg) by up to 24 times, indicating potential risks to wildlife that consume fish. Mercury concentrations did not exceed any of the effects (or no effects) thresholds for fish.

Other Chemicals

Concentrations of other contaminants in northern pike and walleye composite tissue samples from the Clearwater River were screened against the lowest thresholds for effects (and absence of effects) in fish (Table 5.11-21). Three metals, aluminum, copper, and silver, exceeded the no effects thresholds for fish. Silver was below analytical detection limits for the male composite; 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 for silver 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 presence of an undesirable odor or flavor. All tainting compounds with associated tainting criteria in Clearwater River fish tissue were below threshold values (Table 5.11-22).

Impact Analysis

Measurement endpoints used in the impact assessment for the Clearwater River fish tissue program are the range of metals and tainting compounds included in the tissue analysis for both individual and composite samples. The assessment of potential effects related to fish tissue measurement endpoints from the Clearwater River is provided in Table 5.11-23. Potential effects on human health were predicted from the fish tissue analyses. Results indicate that due to the presence of elevated concentrations of mercury, there is potential risk to humans consuming target fish species (northern pike and walleye) from the Clearwater River. There are potential human health risks from consuming both northern pike and walleye for the subsistence and recreational fishers, sensitive subpopulations (i.e., children, pregnant women), and to a lesser extent, general fish consumers. 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 analytes, and should be employed in future sampling programs.

Although mercury concentrations were elevated in fish tissues from the Clearwater River, comparison with historical data from the Athabasca River shows that mercury concentrations observed in the current study fall within the naturally elevated range of concentrations observed in this region. Water and sediment concentrations of mercury

presented in this document further support the assertion that there is a baseline level of mercury in the oil sands region unrelated to increasing oil sands development.

Effects on fish health were not predicted from the screening against literature-based thresholds for effects. The fish health assessment also indicated that chemical-related effects were not evident in fish collected from the Clearwater River. However, based on comparisons with CCME criterion for wildlife, there are potential risks to wildlife that consume fish from the Clearwater River.

Effects on fish palatability were not predicted, given that concentrations of the tainting compounds measured were below detection limits and screening values.

Fish tissue chemistry has only been monitored within the Clearwater River watershed for one year (2004) under RAMP. Furthermore, sample sizes of target fish species in 2004 were small, and samples were collected from only one of the three fish sampling sites in the Clearwater River watershed. All Clearwater River fish sampling sites have been designated as reference sites, reflecting the current lack of oil sands development activity in the watershed. Fish tissue monitoring in the Clearwater River watershed is conducted in conjunction with the fish inventory. In this regard, the overall monitoring framework for fish tissue is adequate given the current status of the watershed (i.e., minimal oil sands development).

Further tissue monitoring activities in the Clearwater system should ensure that the desired number of fish from the two target species is collected to allow for a more in-depth analysis of the chemistry data. At least five more years of fish tissue data are needed to provide a meaningful assessment of natural variability in measurement endpoints (i.e., metals and tainting compounds) and to conduct a trend analysis.

Non-Lethal Biopsy Pilot

The non-lethal fish tissue biopsy pilot assessment carried out on Clearwater River fish in 2004 involved a comparison of mercury concentrations in samples acquired using a conventional lethal approach against those collected using a non-lethal biopsy needle technique. Due to the small sample sizes acquired using the needle, 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. An inter-laboratory comparison is provided in addition to the comparison of sampling techniques. Clearwater River tissue samples were acquired from seven female and three male northern pike.

Reports from the field indicate that there were only minor problems encountered when using the biopsy needle, and that adequate sample volumes were obtained from all fish included in the assessment. 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 be successfully completed.

With the exception of one fish, mercury concentrations in fish fillets measured by ETL were higher than those determined by Flett Research. Mercury concentrations in plug samples were generally lower than fillet samples tested by both laboratories (Figure 5.11-16). A Wilcoxon paired-sample test (Zar 1984) determined that mercury

concentrations measured in fillets were significantly different ($p<0.05$) between analytical laboratories, with an average difference of 0.11 mg/kg and a maximum difference of 0.351 mg/kg.

The same statistical analysis also determined a significant difference between mercury concentrations measured in samples collected using different sampling methods (i.e., fillet versus biopsy plug) as measured by Flett Research ($p<0.05$). However, the mean difference between plug and fillet (0.045 mg/kg) was over 50% lower than the difference between laboratories (Table 5.11-24). QA/QC duplicate samples indicate that further refinement to the plug methodology and additional comparison to corresponding fillet concentrations is required.

Indications are that the non-lethal biopsy approach to acquiring fish tissue samples for mercury analysis can be incorporated into the RAMP fish tissue monitoring program. However, lethal sampling will remain necessary for the analysis of metals and tainting compounds since sample weights acquired by the biopsy needle are too small for the testing of all required parameters. Given the above-noted variance between the duplicate fillet and biopsy plug samples analyzed at Flett Research, it is recommended that an additional year of testing be carried out before final consideration is given to adopting the non-lethal approach.

5.11.5.5 Christina River Reconnaissance Fish Inventory

The Christina River reconnaissance inventory field program was carried out over a two-day period, September 21-22, 2004. High water levels and flow conditions significantly reduced the efficacy of the fish sampling efforts. As can be seen from the photograph in Figure 5.11-17, the water level at the time of the field program was in excess of bankfull depth. High flow velocity and turbidity also negatively affected the fish sampling efforts, particularly fish observation and recovery during boat electrofishing.

Both minnow trapping and boat electrofishing methods were used during the inventory. Eight minnow traps were set overnight for an average soaking time of 18.5 hours, while the boat electrofishing effort totaled 4,995 seconds. The combined trapping and electrofishing effort resulted in the capture of only 17 fish, one from the minnow traps and 16 from electrofishing (Table 5.11-25). Four species were represented in the catch: trout-perch, longnose dace, longnose sucker and white sucker. Several northern pike were observed during the electrofishing effort. White sucker represented 75% of the total inventory catch.

Discussion

The 2004 Christina River reconnaissance fish inventory was hampered by exceptionally high flow that occurred during the later half of September and early October. The Christina River discharge during the inventory field program was approximately twice as high as the long-term mean and apparently uncharacteristic for that time period (Figure 5.11-18).

Depending on the perceived importance of this system as a future RAMP fish inventory monitoring site, it may be appropriate for a second reconnaissance sampling program to be carried out. Additional information is needed on the overall feasibility of a regular fish inventory on the Christina River. Access to the sampling site used for the 2004 reconnaissance is excellent and there are several other possible access points for

fish sampling on the system. Timing for a second reconnaissance inventory on the Christina River should again be late September or early October, since water levels should be low at that time based on historical discharge data. Depending on water level and habitat characteristics, inventory methods should include boat and backpack electrofishing, as well as minnow trapping. These methods are consistent with other RAMP fish inventory programs.

5.11.5.6 Mercury Concentrations in Winefred Lake Fish Tissues

In 2004, mercury testing was carried out on individual tissue samples from 18 lake whitefish, 10 northern pike and 24 walleye collected from Winefred Lake. Lengths and weights for individual fish included in the samples are presented in Table 5.11-26. With the exception of northern pike, the majority of size classes were well represented in the sample.

Mercury concentrations in muscle of individual lake whitefish, northern pike and walleye from Winefred are presented in Table 5.11-27. The highest concentrations of mercury were observed in walleye; concentrations ranged from 0.05 mg/kg in a 359 mm old male fish to 0.26 mg/kg in a 277 mm male. Mean mercury concentrations in walleye were similar in females (0.15 mg/kg), males (0.13 mg/kg) and immature fish (0.10 mg/kg).

Average northern pike mercury concentrations were marginally higher in females (0.1 mg/kg) compared with males (0.09 mg/kg). Only one immature northern pike was captured, which exhibited a mercury concentration of 0.10 mg/kg.

Mercury concentrations in lake whitefish ranged from 0.03 to 0.18 mg/kg; mean mercury concentrations were similar in males (0.08 mg/kg) and females (0.09 mg/kg). No immature lake whitefish were captured during this study.

Scatterplots of fork length and total weight against mercury concentrations in muscle of individual fish are presented in Figure 5.11-19 and Figure 5.11-20, respectively. There appears to be a weak positive correlation between mercury concentration and size, particularly for walleye.

Rank correlations were used to further evaluate the relationship between mercury concentrations in muscle and organism metrics for individual fish of the three species tested from Winefred Lake (Table 5.11-28). In general, weak correlations were found between mercury concentrations and length/weight in female fish, particularly walleye.

Effect on Human Health

In Table 5.11-29, mercury concentrations in individual lake whitefish, northern pike and walleye muscle samples are screened against criteria for fish consumption for the protection of human health. Most fish from Winefred Lake had muscle mercury concentrations that exceeded the USEPA screening value for subsistence fisheries (0.049 mg/kg). However, six lake whitefish (four female and two male) and two walleye (both male) had levels below this screening value. Four fish (all walleye) exceeded the Health Canada screen value for subsistence fishers.

In general, the mercury levels in fish from Winefred Lake are lower than values recorded for fish collected from the Athabasca and Muskeg River tissue sampling in 2004. However, results indicate that there are potential health risks for humans consuming lake whitefish, northern pike and walleye from Winefred Lake. Potential human health risks relate primarily to subsistence fisheries and will depend on specific consumption patterns.

Effects on Fish and Wildlife

In Table 5.11-30, mercury concentrations in individual lake whitefish, northern pike and walleye samples from Winefred Lake are screened against criteria and thresholds for effects in fish and wildlife. All mercury concentrations with the exception of one female lake whitefish exceeded the CCME criteria for the protection of piscivorous wildlife (0.033 mg/kg) by up to 8-fold, indicating that there are potential risks to wildlife that consume fish. Mercury concentrations in the Winefred Lake samples did not exceed any of the effects (or no effects) thresholds for fish.

Discussion

Although mercury concentrations are elevated in fish tissues from the Winefred Lake, comparison with historical data from other waterbodies in the oil sands area, including other regional lakes, shows that mercury concentrations observed in the current study fall within the naturally elevated range of concentrations observed in this region. The range of mercury concentrations measured in individual fish from Winefred Lake in 2004 was similar to that found in Lake Claire, Christina Lake and Gregoire Lake fish during the 2003 and 2002 RAMP tissue programs (Table 5.11-31). In fact, ranges were generally lower in Winefred Lake samples than for all three species in the other two regional lakes sampled.

Potential effects on human health were predicted from Winefred fish tissue analysis. Mercury concentrations in the majority of fish evaluated pose a potential health risk to subsistence fishers and sensitive populations. Effects on fish health were not predicted from the screening against literature-based thresholds for effects. However, based on comparisons with CCME criterion for wildlife, there are potential risks to wildlife that consume fish from Winefred Lake.

As previously stated, all findings to date strongly indicate that mercury concentrations in fish tissue are naturally high in the oil sand region and are not related to current oil sands development activities.

5.11.6 Summary of Conditions

Monitoring activities in the Clearwater River and Christina River basins in 2004 focused on collecting baseline data for hydrology, water and sediment quality, benthic invertebrate communities and fish populations.

In contrast to the river basins north of Fort McMurray, runoff volume in both the Clearwater River and Christina River basins were above normal in 2004. Water and sediment quality measurement endpoints were generally within historical ranges and within the range for regional reference stations. However, concentrations of water and sediment quality endpoints on the upper Christina River were often dissimilar from concentrations observed at the lower station near the mouth. As well, benthic

invertebrate abundance and richness have consistently been higher in the upper Christina reach relative to the mouth, although still within the range for regional reference conditions. As a result, the suitability of the upper Christina River station as a future reference station is uncertain.

A second year of fish inventory work on the Clearwater River was conducted to expand the baseline dataset for this river. Fish community composition was similar to what was recorded in 2003, and what has been found in the Athabasca River (with the exception of lake whitefish in the Athabasca River). Elevated concentrations of mercury were found in the muscle tissue of northern pike and walleye, which could pose a risk to human consumers. 2004 results were consistent with naturally elevated mercury levels in fish from the Athabasca River and other waterbodies in the oil sands region. Tissue concentrations of metals and tainting compounds were not sufficient to pose a risk to human health; however, arsenic was seen as a potential risk to subsistence fishers. Concurrent work evaluating the suitability of a non-lethal biopsy needle for fish tissue sampling was successful, but refinement of the approach is necessary to minimize sample variability.

A reconnaissance fish inventory on the upper Christina River was hampered by exceptionally high flows and water levels during the latter half of September and early October. Depending on the importance of this system as a future RAMP fish inventory monitoring site, a second reconnaissance inventory program may be required.

Finally, with respect to regional lakes fish tissue sampling in Winefred Lake, mercury concentrations in the majority of fish evaluated pose a potential health risk to subsistence fishers and sensitive populations; there are also potential risks to wildlife that consume fish from Winefred Lake. However, it must be emphasized that all findings to date strongly indicate that mercury concentrations in fish tissue are naturally high in the oil sands region and are not related to current oil sands development activities.

Figure 5.11-2 Clearwater River 2004 hydrograph and historical context.

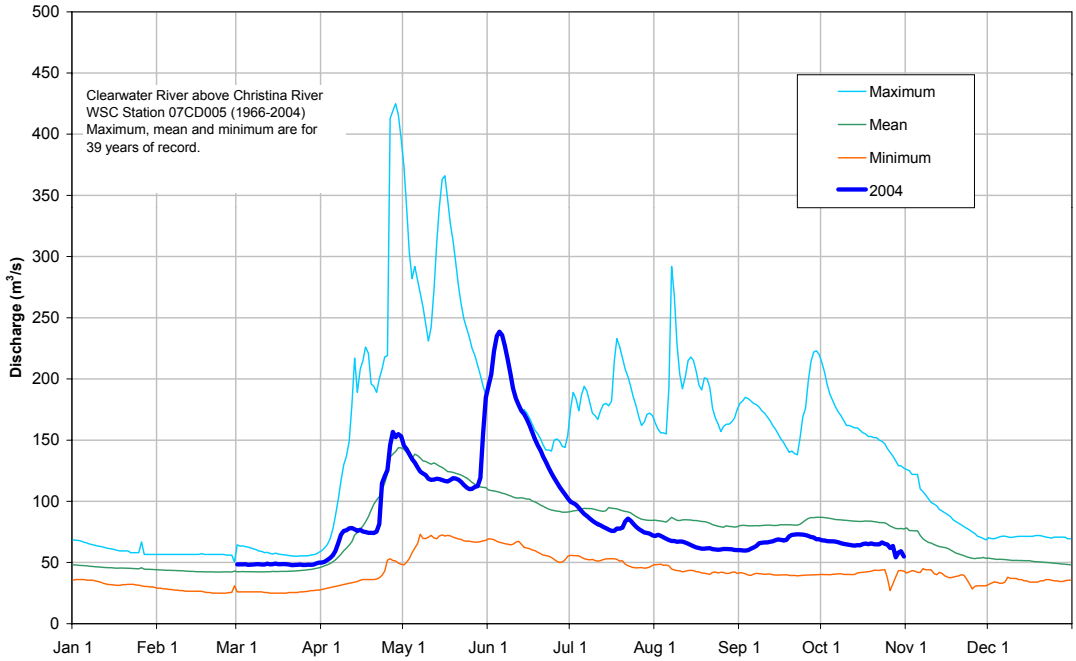


Figure 5.11-3 Christina River 2004 hydrograph and historical context.

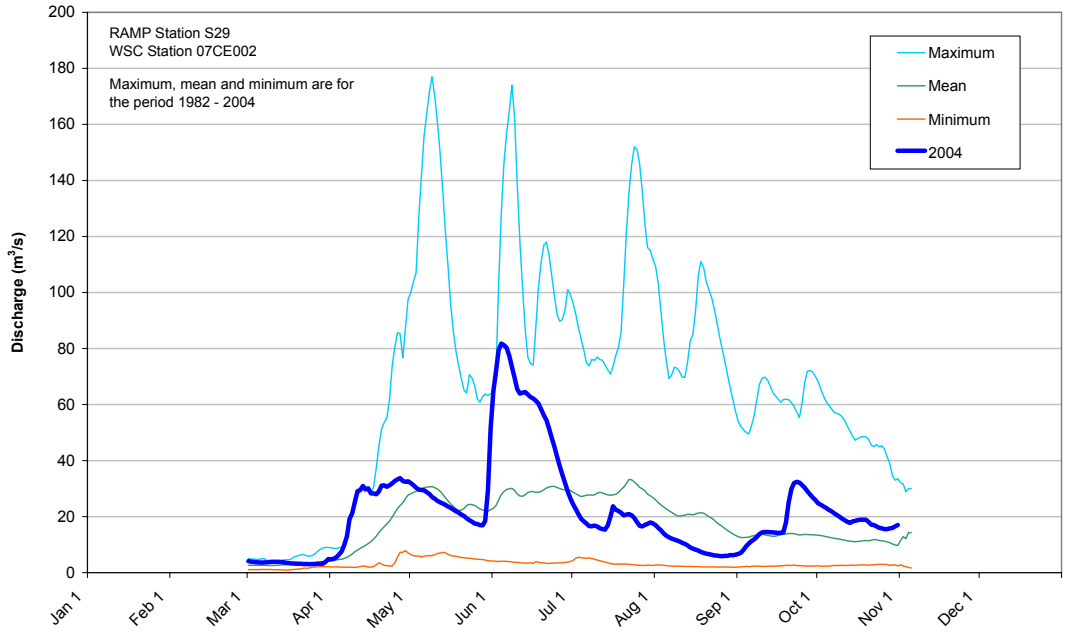


Table 5.11-1 Concentrations of water quality measurement endpoints, mouth of Christina River (CHR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.3	2	8.1	-	8.4
Total suspended solids	mg/L	-	26	2	<3	-	10
Conductivity	mg/L	-	291	2	295	-	375
Nutrients							
Total phosphorus	mg/L	0.05	**0.06**	2	0.05	-	**0.06**
Dissolved phosphorus	mg/L	0.05[1]	0.02	2	0.02	-	0.03
Total nitrogen*	mg/L	1.0	0.6	2	0.7	-	**1.6**
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	14	2	16	-	16
Ions							
Sodium	mg/L	-	27	2	25	-	34
Chloride	mg/L	230, 860[2]	30	2	24	-	41
Sulphate	mg/L	100[3]	6.9	2	7.4	-	7.9
Total dissolved solids	mg/L	-	250	2	140	-	240
Total alkalinity	mg/L	-	115	2	110	-	118
Organic compounds							
Naphthenic acids	mg/L	-	<1	2	<1	-	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.6**	2	**0.2**	-	**0.7**
Dissolved aluminum	mg/L	0.1[1]	0.008	2	0.007	-	0.009
Total boron	mg/L	1.2[3]	0.05	2	0.05	-	0.07
Total molybdenum	mg/L	0.073	0.0004	2	0.0004	-	0.0004
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.006**	2	<0.001	-	<0.001
Total iron	mg/L	0.3	**1.6**	2	**0.8**	-	**1.1**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.11-2 Concentrations of water quality measurement endpoints, upper Christina River (CHR-2), fall 2004.

	Units	Guideline	September 2004	1997-2003 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	2	8.2	-	8.3
Total suspended solids	mg/L	-	9	2	8	-	8
Conductivity	mg/L	-	211	2	226	-	266
Nutrients							
Total phosphorus	mg/L	0.05	**0.07**	2	0.05	-	**0.06**
Dissolved phosphorus	mg/L	0.05[1]	0.04	2	0.03	-	0.03
Total nitrogen*	mg/L	1.0	**1.4**	2	0.6	-	0.8
Nitrate+nitrite	mg/L	-	<0.1	2	<0.1	-	<0.1
Dissolved organic carbon	mg/L	-	18	2	14	-	15
Ions							
Sodium	mg/L	-	7	2	8	-	10
Chloride	mg/L	230, 860[2]	2	2	<1	-	2
Sulphate	mg/L	100[3]	4.4	2	5.8	-	9.6
Total dissolved solids	mg/L	-	140	2	190	-	240
Total alkalinity	mg/L	-	106	2	113	-	138
Organic compounds							
Naphthenic acids	mg/L	-	1	2	<1	-	<1
Selected metals							
Total aluminum	mg/L	0.1	-	2	0.05	-	0.09
Dissolved aluminum	mg/L	0.1[1]	-	2	0.004	-	0.01
Total boron	mg/L	1.2[3]	-	2	0.04	-	0.05
Total molybdenum	mg/L	0.073	-	2	0.0004	-	0.0006
Total mercury (ultra-trace)	ng/L	26	0.9	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.01**	2	0.001	-	**0.019**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.11-3 Concentrations of water quality measurement endpoints, mouth of Clearwater River (CLR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.1	3	7.7	7.9	8.2
Total suspended solids	mg/L	-	38	3	6	8	12
Conductivity	mg/L	-	233	3	177	272	291
Nutrients							
Total phosphorus	mg/L	0.05	**0.05**	3	0.03	0.04	**0.05**
Dissolved phosphorus	mg/L	0.05[1]	0.01	3	0.02	0.02	0.02
Total nitrogen*	mg/L	1.0	0.4	3	0.3	0.4	0.7
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	9	3	8	10	10
Ions							
Sodium	mg/L	-	26	3	16	25	31
Chloride	mg/L	230, 860[2]	34	3	17	36	43
Sulphate	mg/L	100[3]	6.8	3	5.2	7.7	7.7
Total dissolved solids	mg/L	-	180	3	60	150	200
Total alkalinity	mg/L	-	69	3	59	66	71
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.7**	3	**0.1**	**0.1**	**0.5**
Dissolved aluminum	mg/L	0.1[1]	0.006	3	0.006	0.010	0.01
Total boron	mg/L	1.2[3]	0.03	3	0.03	0.04	0.05
Total molybdenum	mg/L	0.073	0.00019	3	0.00016	0.0002	0.0002
Total mercury (ultra-trace)	ng/L	26	<0.6	1	<0.6	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.006**	3	0.001	0.001	0.002
Total iron	mg/L	0.3	**1.6**	3	**0.5**	**0.7**	**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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.11-4 Concentrations of water quality measurement endpoints, upper Clearwater River (CLR-2), fall 2004.

	Units	Guideline	September 2004	1997-2003 (fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	3	7.6	7.6	8.0
Total suspended solids	mg/L	-	25	3	7	7	7
Conductivity	mg/L	-	207	3	138	205	249
Nutrients							
Total phosphorus	mg/L	0.05	0.04	3	0.03	0.03	0.04
Dissolved phosphorus	mg/L	0.05[1]	0.01	3	0.02	0.02	0.02
Total nitrogen*	mg/L	1.0	0.3	3	0.3	0.4	**1.2**
Nitrate+nitrite	mg/L	-	<0.1	3	<0.1	<0.1	<0.1
Dissolved organic carbon	mg/L	-	6	3	6	7	8
Ions							
Sodium	mg/L	-	25	3	13	18	29
Chloride	mg/L	230, 860[2]	34	3	16	28	43
Sulphate	mg/L	100[3]	6.6	3	4.4	6.4	7.6
Total dissolved solids	mg/L	-	160	3	40	110	140
Total alkalinity	mg/L	-	49	3	39	42	48
Organic compounds							
Naphthenic acids	mg/L	-	<1	3	<1	<1	<1
Selected metals							
Total aluminum	mg/L	0.1	**0.5**	3	**0.13**	**0.17**	**0.21**
Dissolved aluminum	mg/L	0.1[1]	0.007	3	0.005	0.011	0.040
Total boron	mg/L	1.2[3]	0.024	3	0.018	0.026	0.030
Total molybdenum	mg/L	0.073	0.00012	3	0.0001	0.00012	0.0002
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.005**	3	<0.001	<0.001	0.002
Total iron	mg/L	0.300	**1.17**	3	**0.56**	**0.62**	**0.79**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Table 5.11-5 List of all 2004 water quality guideline exceedances, Clearwater and Christina Rivers.

Parameter	Units	Guideline	CLR-1	CLR-2	CHR-1	CHR-2
Winter						
Total selenium	mg/L	0.0010	**-**	**-**	**0.00113**	**-**
Total aluminum	mg/L	0.100	**0.192**	**-**	**0.154**	**-**
Total iron	mg/L	0.300	**0.845**	**0.733**	**0.963**	**0.605**
Dissolved iron	mg/L	0.300[1]	**0.356**	**0.364**	**0.325**	**-**
Total phosphorus	mg/L	0.05	**-**	**-**	**0.055**	**-**
Spring						
Total copper	mg/L	0.002-0.004[2]	**0.00356**	**0.00259**	**0.00212**	**-**
Total lead	mg/L	0.001-0.007[2]	**0.00199**	**-**	**-**	**-**
Total aluminum	mg/L	0.100	**1.85**	**0.941**	**1.06**	**0.322**
Total iron	mg/L	0.300	**3.58**	**1.75**	**2.22**	**1.33**
Dissolved iron	mg/L	0.300[1]	**0.396**	**0.412**	**0.384**	**0.562**
Total phosphorus	mg/L	0.05	**0.177**	**0.062**	**0.095**	**0.084**
Summer						
Total phenols	mg/L	0.004	**-**	**-**	**0.006**	**0.01**
Total aluminum	mg/L	0.100	**0.634**	**0.276**	**0.594**	**0.254**
Total iron	mg/L	0.300	**1.55**	**0.764**	**1.46**	**1.83**
Dissolved iron	mg/L	0.300[1]	**-**	**-**	**0.443**	**0.983**
Total phosphorus	mg/L	0.05	**0.07**	**-**	**0.074**	**0.087**
Fall						
Total phenols	mg/L	0.004	**0.006**	**0.005**	**0.006**	**0.01**
Total aluminum	mg/L	0.100	**0.717**	**0.5**	**0.587**	**-**
Total iron	mg/L	0.300	**1.55**	**1.17**	**1.6**	**-**
Dissolved iron	mg/L	0.300[1]	**-**	**-**	**0.493**	**-**
Total phosphorus	mg/L	0.05	**0.051**	**-**	**0.064**	**0.068**
Total Kjeldahl nitrogen	mg/L	1.0[3]	**-**	**-**	**-**	**1.3**

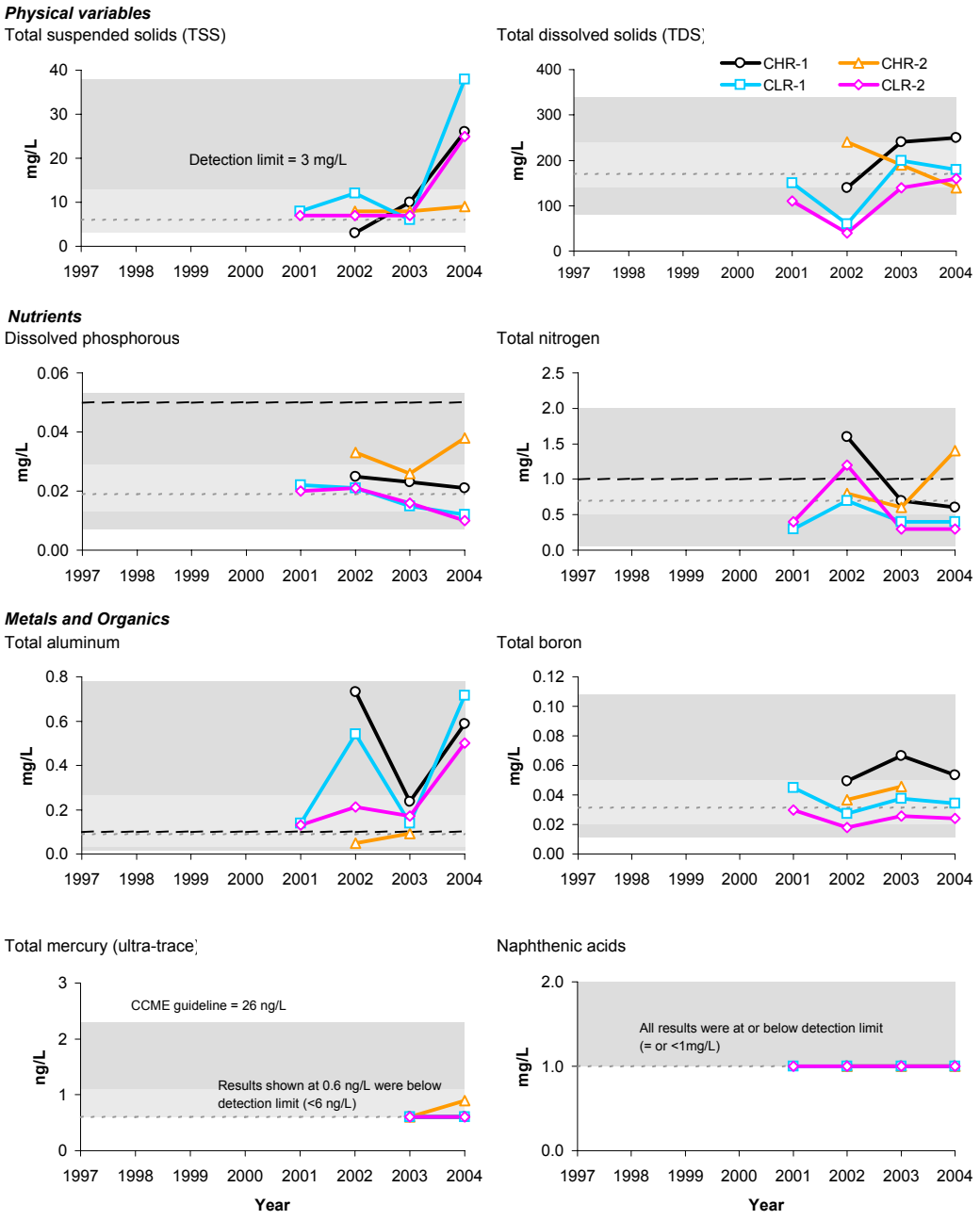
Guidelines are CCME/AENV guidelines for the protection of aquatic life.

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

[2]: Guideline is hardness dependent.

[3]: Guideline is for total nitrogen.

Figure 5.11-4 Concentrations of selected water quality measurement endpoints in the Clearwater-Christina River system, relative to regional baseline concentrations.



[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 E for these regional baseline ranges.

Figure 5.11-5 Piper diagram of fall ion concentrations in Clearwater-Christina River system.

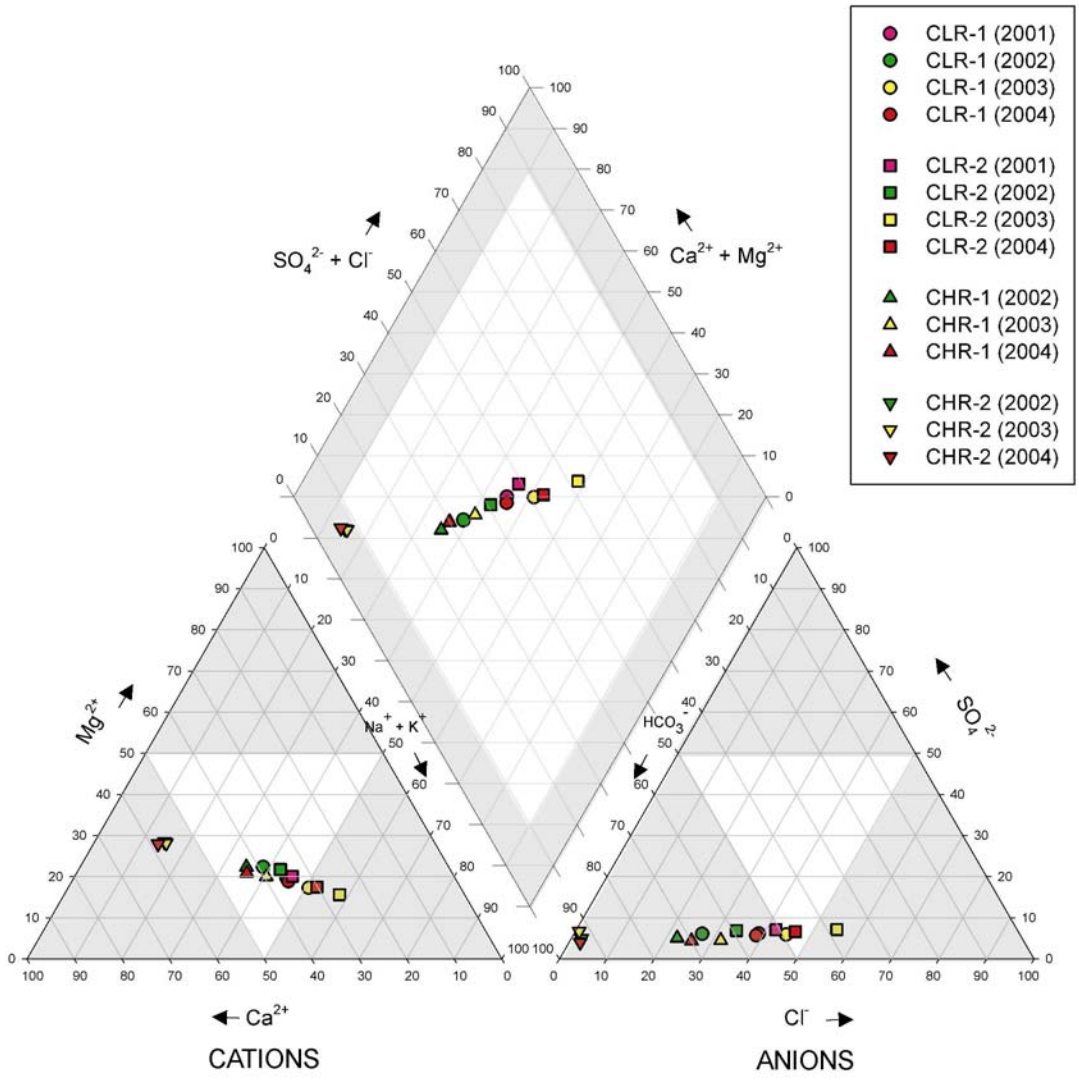


Table 5.11-6 Concentrations of sediment quality measurement endpoints, mouth of Christina River (CHR-1), fall 2004.

	Units	Guideline	September 2004		1997-2003 (Fall data only)		
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	13	2	10	-	17
Silt	%	-	17	2	16	-	25
Sand	%	-	70	2	58	-	74
Total organic carbon	%	-	1.8	2	0.8	-	2
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]	100	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	**970**	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	480	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	2	0.5	-	4.3
TEH (C11-C30)	mg/kg	-	1600	2	5	-	2300
TRH	mg/kg	-	2400	2	1600	-	2800
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.002	2	0.001	-	0.008
Retene	mg/kg	-	0.10	2	0.03	-	0.15
Total dibenzothiophenes	mg/kg	-	1.7	2	0.6	-	3.3
Total PAHs	mg/kg	-	7.5	2	3.1	-	11.7
Total HMW PAHs	mg/kg	-	2.7	2	1.4	-	4.1
Total LMW PAHs	mg/kg	-	4.9	2	1.8	-	7.7
Predicted PAH toxicity[1]	H.I.	-	1.6	2	1.0	-	2.0
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	9	-	-	-	-
Chironomus growth	mg/organism	-	2.1	-	-	-	-
Hyallela survival	# surviving	-	6	-	-	-	-
Hyallela growth	mg/organism	-	0.1	-	-	-	-

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV 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 5.11-7 Concentrations of sediment quality measurement endpoints, upper Christina River (CHR-2), fall 2004.

	Units	Guideline	September 2004		1997-2003 (Fall data only)		
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	4	2	8	-	13
Silt	%	-	17	2	22	-	30
Sand	%	-	79	2	57	-	69
Total organic carbon	%	-	0.6	2	1.1	-	1.6
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]	13	-	-	-	-
Fraction 3 (C16-C34)	mg/kg	400[2]	47	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	32	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	2	0.5	-	8.2
TEH (C11-C30)	mg/kg	-	<5	2	25	-	270
TRH	mg/kg	-	<100	2	300	-	400
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.001	2	0.002	-	0.003
Retene	mg/kg	-	0.01	2	0.08	-	0.09
Total dibenzothiophenes	mg/kg	-	0.01	2	0.02	-	0.02
Total PAHs	mg/kg	-	0.15	2	0.27	-	0.32
Total HMW PAHs	mg/kg	-	0.05	2	0.11	-	0.12
Total LMW PAHs	mg/kg	-	0.10	2	0.16	-	0.20
Predicted PAH toxicity[1]	H.I.	-	0.73	2	0.47	-	0.52
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	9	-	-	-	-
Chironomus growth	mg/organism	-	2.5	-	-	-	-
Hyallela survival	# surviving	-	8	-	-	-	-
Hyallela growth	mg/organism	-	0.2	-	-	-	-

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV 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.

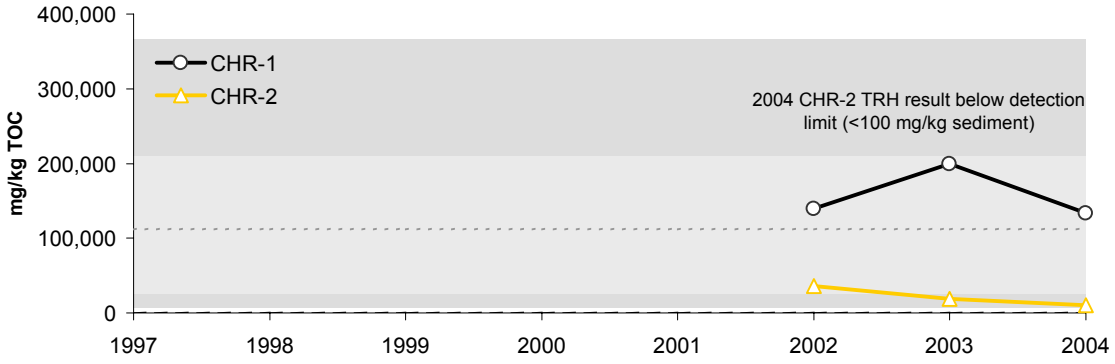
[2] Guideline is for residential/parkland coarse (median grain size > 75 μm) surface soils (CCME 2001).

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

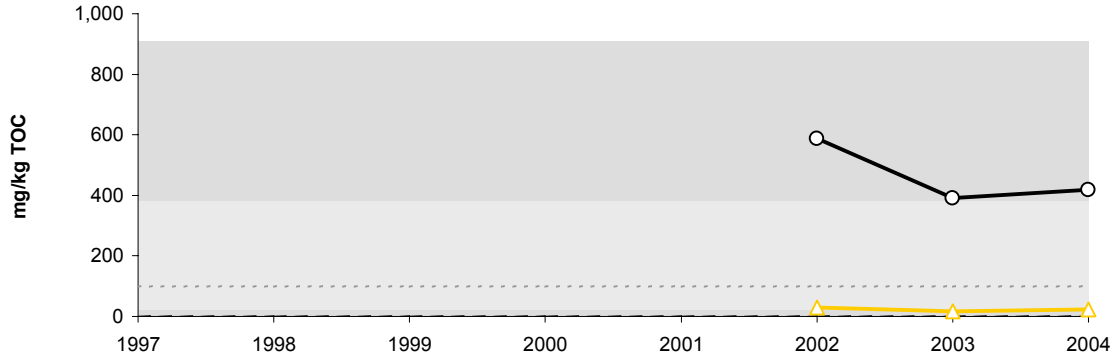
Figure 5.11-6 Concentrations of selected sediment quality measurement endpoints in the Christina River system, relative to regional baseline concentrations.

Note : CLR-1 and CLR-2 not sampled in 2004

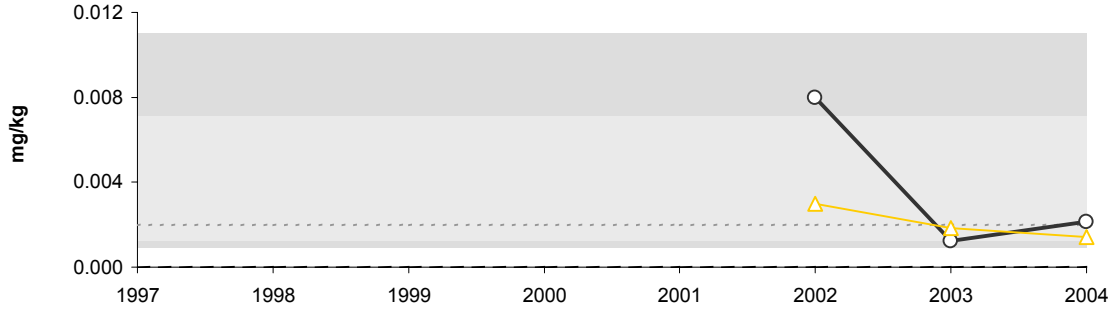
Total Recoverable Hydrocarbons (normalized to TOC)



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 F for these regional baseline ranges.

Table 5.11-8 Average habitat characteristics of benthic invertebrate sampling stations in the Christina River, fall 2004.

Variable	Units	Lower Reach of the Christina River	Upper Reach of the Christina River
Sample date	-	Sept. 10, 2004	Sept. 22, 2004
Habitat	-	Depositional	Depositional
Water depth	m	0.2	0.8
Current velocity	m/s	0.1	0
Macrophyte cover	%	16	0
Field Water Quality			
Dissolved oxygen	mg/L	10.9	10.2
Conductivity	µS/cm	265	122
pH	pH units	8.3	7.8
Water temperature	°C	9.0	8.6
Sediment Composition			
Sand	%	70.4	83.5
Silt	%	20.5	11.0
Clay	%	9.1	5.4
Total Organic Carbon	%	1.0	0.5

Table 5.11-9 Average habitat characteristics of benthic invertebrate sampling stations in the Clearwater River, fall 2004.

Variable	Units	Clearwater River downstream of Christina River	Clearwater River upstream of Christina River
Sample date	-	Sept. 9, 2004	Sept. 18, 2004
Habitat	-	Depositional	Depositional
Water depth	m	0.5	0.6
Current velocity	m/s	0.5	0
Macrophyte cover	%	0.2	0
Field Water Quality			
Dissolved oxygen	mg/L	10.9	9.5
Conductivity	µS/cm	196	222
pH	pH units	8.0	8.3
Water temperature	°C	9.8	9.6
Sediment Composition			
Sand	%	91.0	68.7
Silt	%	5.4	20.5
Clay	%	3.7	10.7
Total Organic Carbon	%	0.3	1.1

Table 5.11-10 Summary of major taxon abundances and key indices of composition among benthic invertebrate sampling stations in the Christina River, fall 2004.

Taxon	Lower Reach of the Christina River			Upper Reach of the Christina River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Nematoda	420	2132	3.4	753	2791	6.5
Erpobdellidae	46	0	0.4	0	0	0
Enchytraeidae	0	0	0	181	655	1.6
Naididae	118	335	0.9	224	725	1.9
Tubificidae	629	620	5.1	989	1228	8.6
Lumbriculidae	3	0	0.0	0	0	0
Ostracoda	3149	10069	25.3	3454	26940	29.9
Copepoda	0	0	0	69	0	0.6
Ephemeroptera	885	2783	7.1	80	366	0.7
Plecoptera	34	0	0.3	0	0	0
Anisoptera	293	1280	2.4	0	0	0
Coleoptera	147	870	1.2	431	1702	3.7
Tipulidae	402	3657	3.2	891	1287	7.7
Dolichopodidae	6	0	0.0	80	246	0.7
Tabanidae	0	0	0	259	1829	2.2
Empididae	417	2781	3.4	0	0	0
Ephydridae	32	274	0.3	1402	4240	12.1
Ceratopogonidae	1207	2023	9.7	287	972	2.5
Chironomidae	4644	3171	37.4	2388	3527	20.7
Psychodidae	0	0	0	57	0	0.5
Total Abundance	12431	13294	-	11546	17460	-
Richness	7.5	4.2	-	6.5	3.6	-
Simpson's Diversity	0.600	0.175	-	0.518	0.247	-
Evenness	0.720	0.175	-	0.771	0.136	-

Table 5.11-11 Summary of major taxon abundances and key indices of composition among benthic invertebrate sampling stations in the Clearwater and Christina Rivers, fall 2004.

Taxon	Clearwater River downstream of the Christina River			Clearwater River upstream of the Christina River		
	Abundance #/m^2	SD	% Abundance	Abundance #/m^2	SD	% Abundance
Nematoda	276	690	3.5	198	588	2.1
Glossiphoniidae	0	0	0	259	0	2.7
Erpobdellidae	0	0	0	57	0	0.6
Enchytraeidae	60	152	0.8	0	0	0
Naididae	322	946	4.1	57	0	0.6
Tubificidae	121	671	1.5	603	1009	6.3
Lumbriculidae	0	0	0	52	488	0.5
Hydracarina	29	0	0.4	0	0	0
Ostracoda	0	0	0	385	2750	4.0
Copepoda	0	0	0	9	0	0.1
Chydoridae	86	0	1.1	0	0	0
Macrothricidae	0	0	0	546	0	5.7
Ephemeroptera	382	1008	4.9	563	1694	5.8
Plecoptera	29	0	0.4	693	0	7.2
Anisoptera	147	335	1.9	356	805	3.7
Zygoptera	0	0	0	23	0	0.2
Coleoptera	563	2307	7.2	287	676	3.0
Tipulidae	0	0	0	158	449	1.6
Dolichopodidae	0	0	0	6	0	0.1
Tabanidae	0	0	0	60	311	0.6
Empididae	129	1067	1.6	693	3427	7.2
Ceratopogonidae	431	2743	5.5	230	236	2.4
Chironomidae	5267	3778	67.2	4414	3144	45.7
Total Abundance	7842	9022	-	9649	8243	-
Richness	5.5	3.6	-	6.1	3.8	-
Simpson's Diversity	0.519	0.273	-	0.521	0.297	-
Evenness	0.753	0.255	-	0.757	0.245	-

Figure 5.11-7 Variations in indices of benthic invertebrate community composition in the Christina River, upper and lower reaches.

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

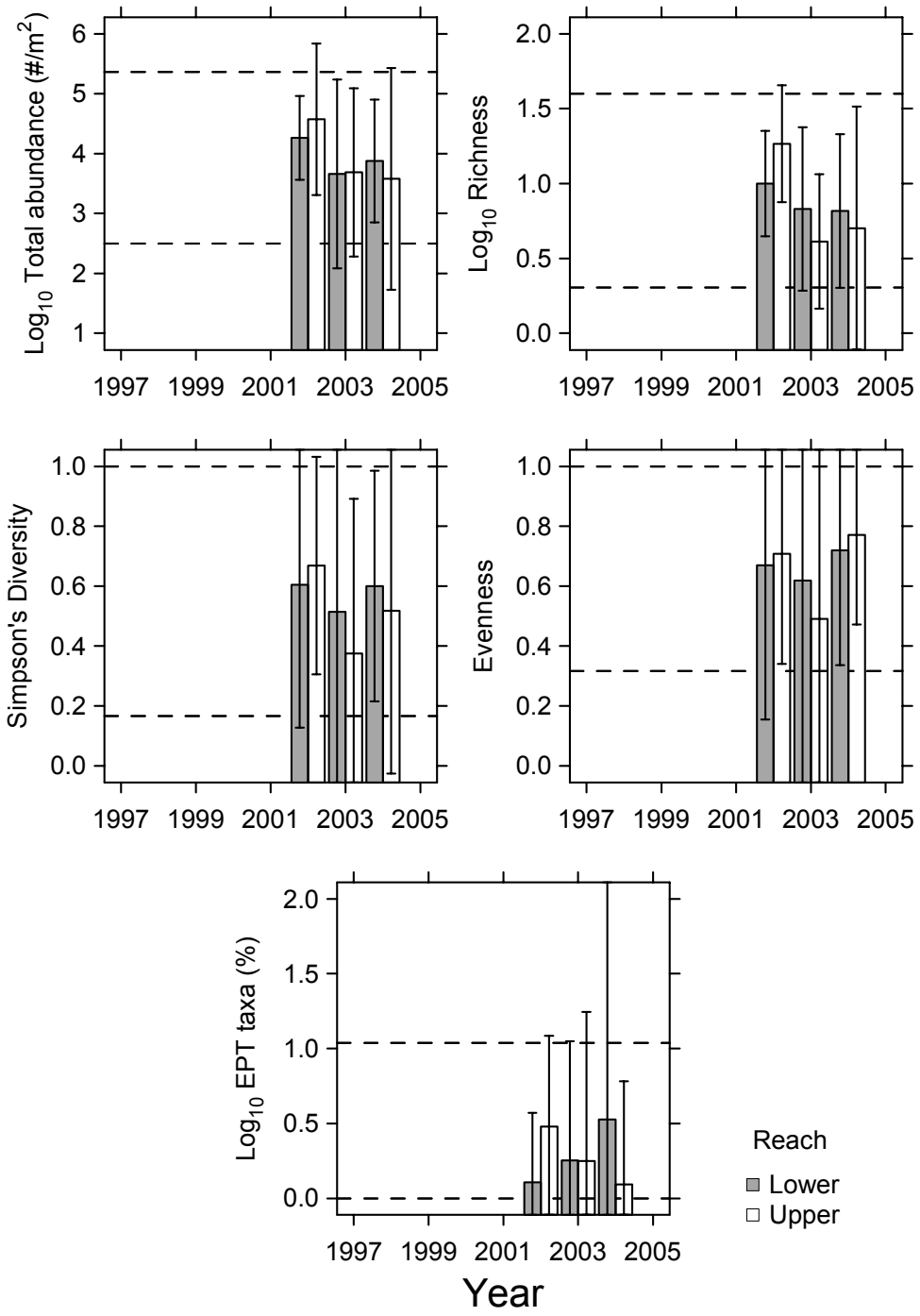


Figure 5.11-8 Variations in indices of benthic invertebrate community composition in the Clearwater River, upstream and downstream of Christina River.

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

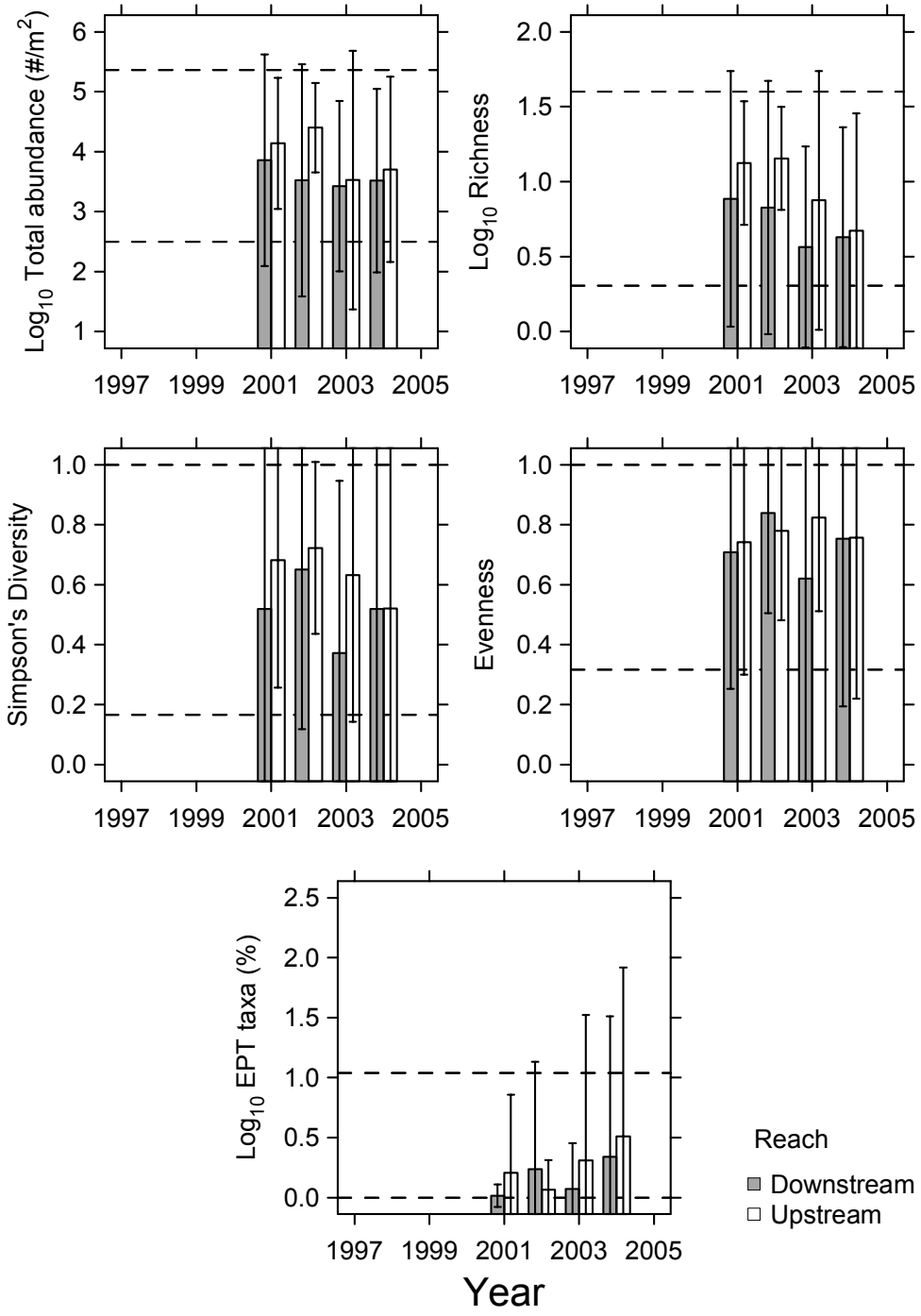


Table 5.11-12 Fish inventory results from electrofishing on the Clearwater River, spring 2004.

Spring Results (total effort = 15,830 s)					
Species	**Number Captured**	**Number Observed**	**Total (Captured+ Observed)**	**Species Composition (% of total)**	**CPUE (#/100 s)**
Arctic grayling	10	0	10	1.62	0.06
Flathead chub	0	1	1	0.16	0.01
Fathead minnow	1	0	1	0.16	0.01
Goldeye	43	14	57	9.22	0.36
Lake chub	4	0	4	0.65	0.03
Lake whitefish	8	0	8	1.29	0.05
Longnose sucker	36	6	42	6.80	0.27
Mountain whitefish	17	19	36	5.83	0.23
Northern pike	79	62	141	22.82	0.89
Slimy sculpin	1	0	1	0.16	0.01
Spottail shiner	13	0	13	2.10	0.08
Trout-perch	8	99	107	17.31	0.68
Walleye	21	10	31	5.02	0.20
White sucker	128	38	166	26.86	1.05
Total	**369**	**249**	**618**	**100**	**-**

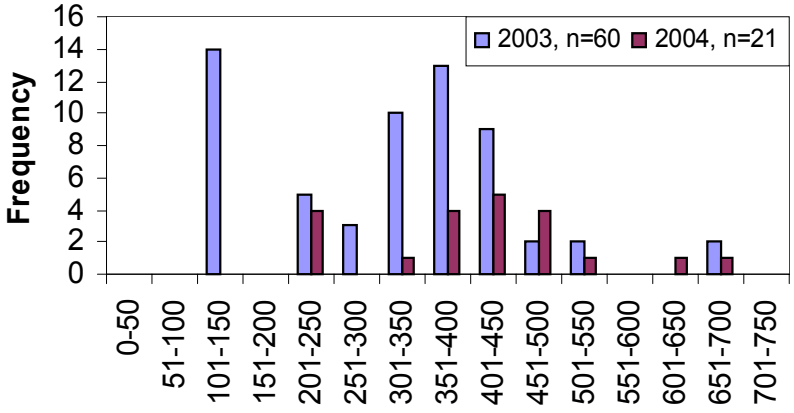
Table 5.11-13 Fish inventory results from electrofishing on the Clearwater River, fall 2004.

Fall Results (total effort = 4,988 s)					
Species	**Number Captured**	**Number Observed**	**Total (Captured+ Observed)**	**Species Composition (% of total)**	**CPUE (#/100 s)**
Arctic grayling	3	0	3	1.33	0.06
Fathead minnow	1	0	1	0.44	0.02
Longnose sucker	3	0	3	1.33	0.06
Mountain whitefish	7	4	11	4.87	0.22
Northern pike	12	13	25	11.06	0.50
Spottail shiner	11	124	135	59.73	2.71
Walleye	0	2	2	0.88	0.04
White sucker	24	22	46	20.35	0.92
Total	**61**	**165**	**226**	**100**	-

Table 5.11-14 Fish inventory from beach seining on the Clearwater River, spring 2004.

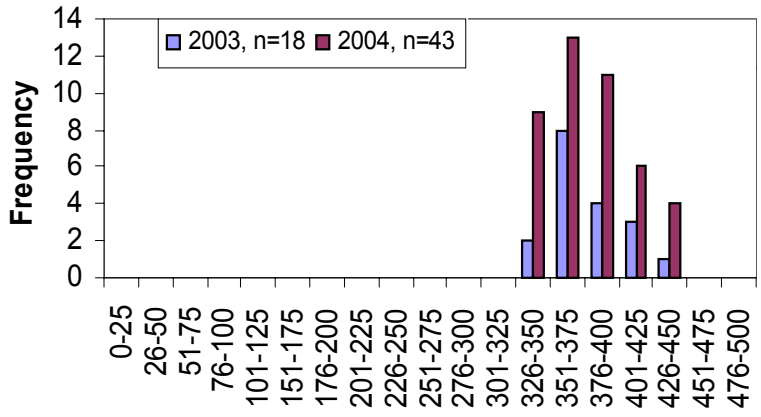
Species	Total	Species Composition (% of total)
Longnose dace	1	4.3
Longnose sucker	3	13.0
Slimy sculpin	2	8.7
Spottail shiner	15	65.2
Trout-perch	1	4.3
White sucker	1	4.3
TOTAL	**23**	**100**

Figure 5.11-9 Length-frequency distribution for walleye captured by electrofishing in the Clearwater River, spring and fall 2003 and 2004.



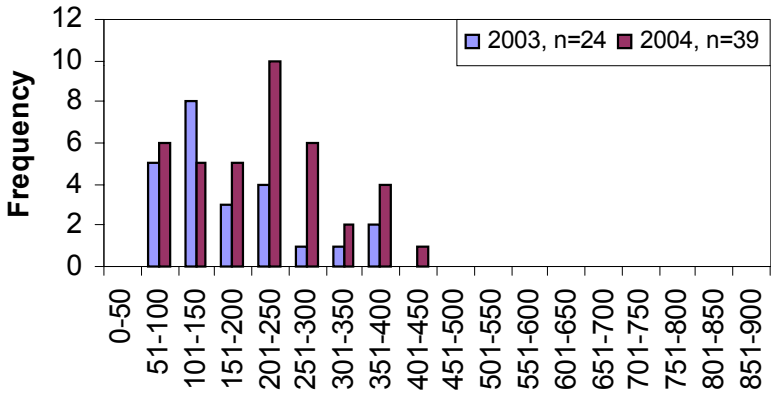
Note: Frequency is the number of fish caught per size class; length size class in millimeters (mm).

Figure 5.11-10 Length-frequency distribution for goldeye captured by electrofishing in the Clearwater River, spring and fall 2003 and 2004.



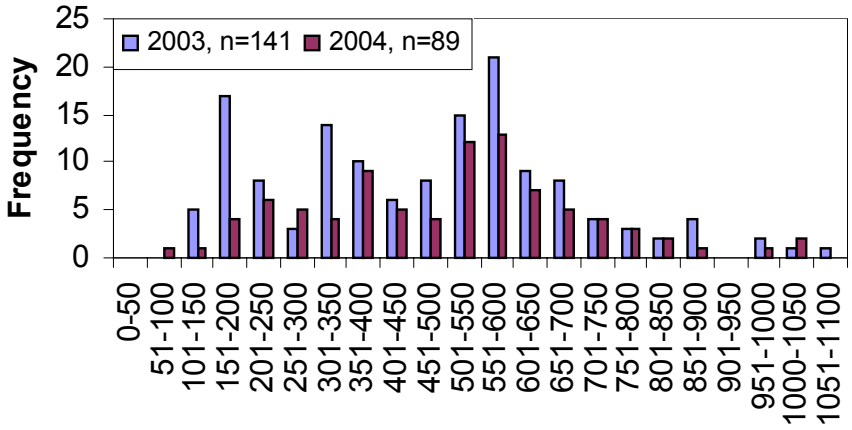
Note: Frequency is the number of fish caught per size class; length size class in millimeters (mm).

Figure 5.11-11 Length-frequency distribution for longnose sucker captured by electrofishing in the Clearwater River, spring and fall 2003 and 2004.



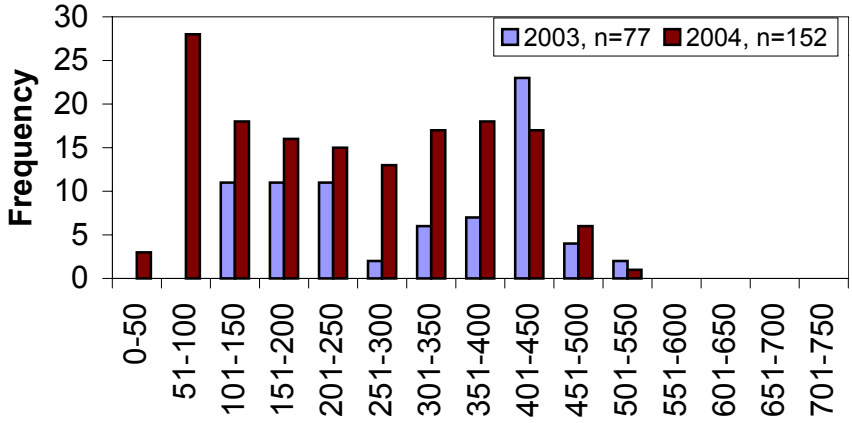
Note: Frequency is the number of fish caught per size class; length size class in millimeters (mm).

Figure 5.11-12 Length-frequency distribution for northern pike captured by electrofishing in the Clearwater River, spring and fall 2003 and 2004.



Note: Frequency is the number of fish caught per size class; length size class in millimeters (mm).

Figure 5.11-13 Length-frequency distributions for white sucker captured in the Clearwater River, spring and fall 2003 and 2004.



Note: Frequency is the number of fish caught per size class; length size class in millimeters (mm).

Figure 5.11-14 Mean condition factor (± SE) and number analyzed for key fish indicator species in the Clearwater River, spring 2003.

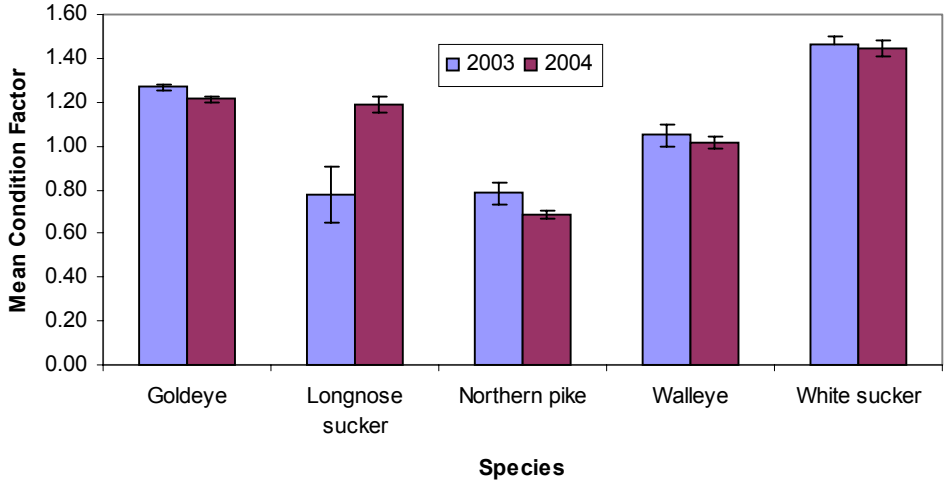


Table 5.11-15 Metrics and mercury concentrations in northern pike and walleye collected from the Clearwater River, September 2004

Species	Sex	Fish ID	Stage	Fork Length (mm)	Total Weight (g)	Carcass Weight (g)	GSI	LSI	Age (years)	Mercury Concentration (mg/kg)
Northern Pike	Female									0.231
		NRPK-2	Maturing	428	515.1	493.3	0.8	0.3	4	
		NRPK-3	Mature	547	1,142.7	1,041.8	1.6	1.9	5	0.423
		NRPK-4	Mature	662	2,111.2	1,705.7	0.9	2.1	4	0.335
		NRPK-6	Immature	369	370.4	347.4	1.4	0.3	2	0.131
		NRPK-7	Mature	570	1,522.5	1,285.7	2.7	2.4	5	0.240
		NRPK-8	Maturing	562	1,137.8	1,067.9	0.8	0.6	7	0.335
		NRPK-10	Mature	837	4,750.0	4,042.7	2.5	1.4	6	0.824
		NRPK-11	Mature	698	2,750.0	2341.6	2.5	1.4	6	0.421
		NRPK-13	Mature	562	1,117.0	1,051.3	1.0	1.2	7	0.119
	Mean			**582**	**1,713.0**	**1,486.4**	**1.6**	**1.3**	**5**	**0.340**
	SD			**140**	**1,357.5**	**1,129.2**	**0.8**	**0.8**	**2**	**0.213**
	Male	NRPK-1	Mature	392	441.3	396.2	1.9	1.5	3	0.170
		NRPK-5	Mature	485	805.7	755.1	1.6	1.1	5	0.246
		NRPK-9	Maturing	761	3,086.0	2609.6	1.7	0.4	12	0.509
		NRPK-12	Immature	493	924.4	792.0	1.2	0.2	4	0.200
	Mean			**533**	**1,314.4**	**1,138.2**	**1.6**	**0.8**	**6**	**0.281**
	SD			**159**	**1,198.9**	**997.0**	**0.3**	**0.6**	**4**	**0.155**
Walleye	*Male*	***WALL-1***	Mature	503	1,340.3	1,168.4	2.5	1.7	13	0.508
		WALL-2	Maturing	378	532.8	494.1	1.1	0.3	5	0.296
	Mean			**441**	**936.6**	**831.3**	**1.8**	**1.0**	**9**	**0.402**
	SD			**88**	**571.0**	**476.8**	**1.0**	**1.0**	**6**	**0.150**

italics = fish used for composite samples

GSI = gonad somatic index LSI = liver somatic index

Table 5.11-16 Screening of metals and tainting compounds in northern pike and walleye composite samples collected from the Clearwater River (September 2004) against risk-based criteria for fish consumption for the protection of human health.

	Walleye	Northern Pike		Health Canada Criteria		National USEPA		Region III USEPA
Analyte	**Composite 1 Male n=2**	**Composite 1 Female n=3**	**Composite 2 Male n=2**	**General Consumer (mg/kg)**	**Subsistence Fisher (mg/kg)**	**Recreational Fishers (mg/kg)**	**Subsistence Fishers (mg/kg)**	**Risk-based Criteria (mg/kg)**
Total Metal								
Aluminum (Al)	4	3	<2	nc	nc	nc	nc	1400
Antimony (Sb)	<0.04	<0.04	<0.04	nc	nc	nc	nc	0.54
Arsenic (As)	***0.020***	***0.022***	***0.019***	nc	nc	0.026	0.00327	0.002
Barium (Ba)	<0.08	0.09	0.12	nc	nc	nc	nc	95
Beryllium (Be)	<0.2	<0.2	<0.2	nc	nc	nc	nc	2.7
Boron (B)	<2	<2	<2	nc	nc	nc	nc	270
Cadmium (Cd)	<0.01	<0.01	<0.01	nc	nc	4	0.491	1.4
Chromium (Cr)	0.07	0.11	0.15	nc	nc	nc	nc	4.1
Cobalt (Co)	<0.08	<0.08	<0.08	nc	nc	nc	nc	27
Copper (Cu)	0.42	0.43	0.57	nc	nc	nc	nc	54
Iron (Fe)	<2	<2	<2	nc	nc	nc	nc	410
Lead (Pb)	<0.02	<0.02	<0.02	nc	nc	nc	nc	nc
Lithium (Li)	<0.5	<0.5	<0.5	nc	nc	nc	nc	27
Manganese (Mn)	0.10	0.55	<0.04	nc	nc	nc	nc	190
Molybdenum (Mo)	<0.04	<0.04	<0.04	nc	nc	nc	nc	6.8

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

Table 5.11-16 (cont'd.)

Analyte	Walleye	Northern Pike		Health Canada Criteria		National USEPA		Region III USEPA
	Composite 1 Male n=2	Composite 1 Female n=3	Composite 2 Male n=2	General Consumer (mg/kg)	Subsistence Fisher (mg/kg)	Recreational Fishers (mg/kg)	Subsistence Fishers (mg/kg)	Risk-based Criteria (mg/kg)
Nickel (Ni)	0.02	0.04	0.04	nc	nc	nc	nc	27
Selenium (Se)	0.20	0.08	0.07	nc	nc	nc	nc	6.8
Silver (Ag)	<0.02	<0.02	<0.02	nc	nc	20	2.457	6.8
Sodium (Na)	224	339	4	nc	nc	nc	nc	nc
Strontium (Sr)	0.13	1.64	1.22	nc	nc	nc	nc	810
Thallium (Tl)	<0.04	<0.04	<0.04	nc	nc	nc	nc	0.09
Tin (Sn)	<0.08	<0.08	<0.08	nc	nc	nc	nc	810
Titanium (Ti)	0.17	0.15	<0.05	nc	nc	nc	nc	5400
Vanadium (V)	0.008	0.010	0.016	nc	nc	nc	nc	0.41
Zinc (Zn)	3.9	5.1	5.9	nc	nc	nc	nc	410
Tainting Compounds (PAHs)								
1,3,5-Trimethylbenzene	<0.01	<0.01	<0.01	nc	nc	nc	nc	68
M+P-Xylenes	<0.01	<0.01	<0.01	nc	nc	nc	nc	270
Naphthalene	<0.02	<0.02	<0.02	nc	nc	nc	nc	27
o-Xylene	<0.01	<0.01	<0.01	nc	nc	nc	nc	270
Thiophene	<0.01	<0.01	<0.01	nc	nc	nc	nc	nc
Toluene	0.16	0.09	0.08	nc	nc	nc	nc	270

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

Table 5.11-17 External and internal observations for northern pike and walleye from the Clearwater River, September 2004.

			Northern Pike		Walleye
			Female	Male	Male
Exam	Observation		n=9	n=4	n=2
External	Fin Erosion	light	1	0	0
		moderate	0	0	0
		severe	0	0	0
	Skin Aberration	mild	0	2	0
		moderate	0	0	0
		severe	0	0	0
	Eye	opaque	0	0	0
		swollen protruding	0	0	0
		bleeding	0	0	0
		missing	0	0	0
		other	0	0	0
	Opercle shortening	mild	0	0	0
Internal		moderate	0	0	0
		severe	0	0	0
	Pseudobranchs	swollen	0	0	0
		lithic	0	0	0
		swollen and lithic	0	0	0
		inflamed	0	0	0
	Gills	frayed	0	0	0
		clubbed	0	0	0
		marginate	0	0	0
		pale	0	0	0
		other (ectoparasite)	1	0	0
	Thymus hemorrhage	mild	0	0	0
		moderate	0	0	0
		severe	0	0	0
	Mesenteric Fat	<50%	2	1	1
		50%	1	0	0
		>50%	1	0	0
		completely covered	0	0	0
	Parasites	few	0	1	0
		moderate	0	0	0
		numerous	0	0	0

Table 5.11-17 (cont'd.)

Exam	Observation		Northern Pike Female n=9	Northern Pike Male n=4	Walleye Male n=2
	Liver	fatty	0	0	0
		cysts or nodules	0	0	0
		focal discolouration	1	1	1
		general discolouration	1	0	0
	Kidney	swollen	0	0	0
		mottled	1	0	0
		granular	0	1	0
		urolithiasis	0	0	0
	Spleen	granular	0	0	0
		nodular	0	0	1
		enlarged	0	0	0
	Hindgut	slightly inflamed	0	0	0
		moderately inflamed	0	0	0
		severely inflamed	0	0	0
	Gall Bladder	yellow full	4	2	1
		light to grass green	0	0	0
		dark green - blue-green	3	0	0
	Other				
# of different types of abnormalities observed[1]			7	5	3
% fish with one or more abnormalities[1]			89%	75%	100%

[1] Level of mesenteric fat, presence of fat on the heart, and occurrence of fatty liver were excluded from the calculation of abnormalities because of these observations relate to food availability and storage. An individual fish may exhibit more than one type of abnormality.

Table 5.11-18 Rank correlations between mercury concentrations in muscle from Clearwater River northern pike versus length, weight, GSI, LSI and age.

	Rank Correlation with Mercury Concentrations (r_s)	
Organism Metric	**Female n = 9**	**Combined Male/Female n = 13**
Fork Length	0.601	0.734
Total Weight	0.795	**0.823**
GSI	0.376	0.333
LSI	0.460	0.278
Age	0.196	0.517

Bolded values represent significant correlation (alpha=0.05)

Figure 5.11-15 Scatterplots of mercury concentration in northern pike muscle versus length, weight, GSI, LSI and age, Clearwater River, 2004.

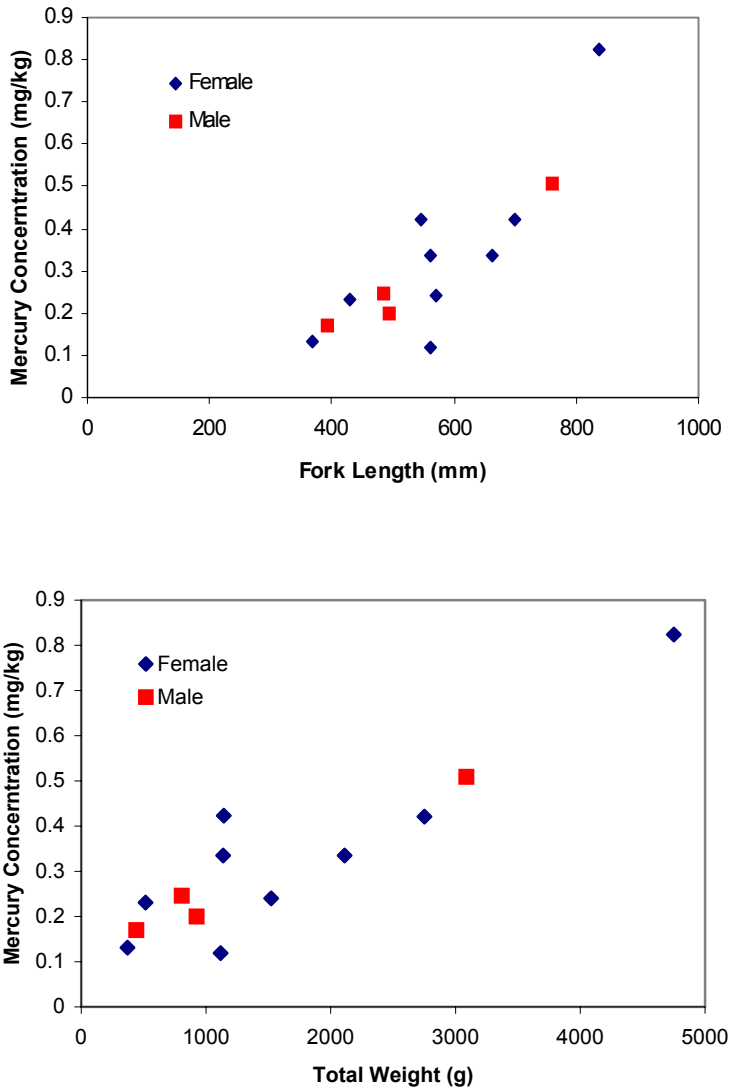
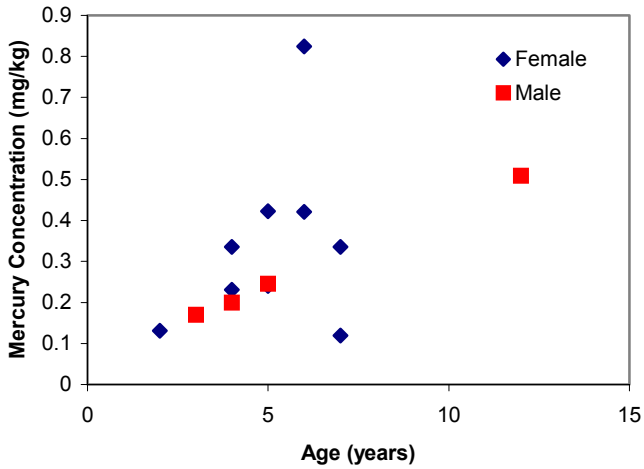
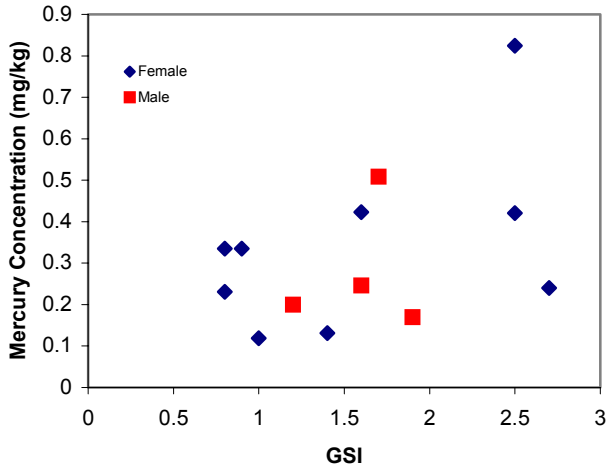


Figure 5.11-15 (cont'd.)





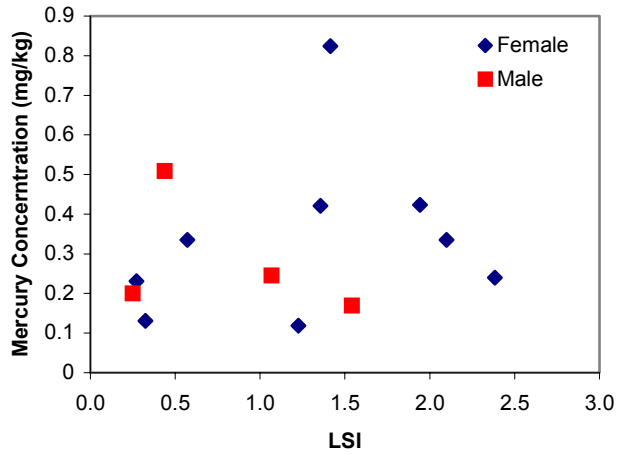


Table 5.11-19 Screening of mercury concentrations in northern pike and walleye from Clearwater River (September, 2004) against criteria for fish consumption for the protection of human health.

Mercury Screening Criteria		Mercury Concentration (mg/kg)
Health Canada Criteria	*General Consumer*	0.50
	Subsistence Fishers	0.20
Region III USEPA Risk-Based Criterion[1]		0.14
National USEPA Screening Values[2]	*Recreational Fishers*	0.40
	Subsistence Fishers	0.049

Mercury Concentrations in Clearwater River Fish Muscle

Species	Sex	Mercury Concentration (mg/kg)
Northern Pike	Female	***0.423***
		0.335
		0.240
		0.824
		0.421
		0.119
	Male	0.170
		0.246
	Maturing / Immature	***0.509***
		0.200
Walleye	Male	***0.508***
	Maturing / Immature	0.296

All values exceed the Health Canada and USEPA screening values for subsistence fishers.

value **=** exceeds USEPA screening value for recreational fishers.

value = exceeds Health Canada criterion for the general consumer.

[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 methylmercury.

[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 70 kg individual consuming 142.4 g of fish per day over a 70-year period; (USEPA 2000).Criterion is for methylmercury.

Table 5.11-20 Screening of mercury concentrations in northern pike and walleye from Clearwater River (September, 2004) against criteria for protection of fish and wildlife.

Mercury Screening Criteria		Mercury Concentration (mg/kg)
CCME criteria for the protection of wildlife[1]		0.033
Effects thresholds for fish[2]	*No effects - lethal*	1.91
	No effects - sublethal	2.28
	Effects - lethal	6.2
	No effects - sub-lethal	8.6

Mercury Concentrations in Clearwater River Fish Muscle

Species	Sex	Mercury Concentration (mg/kg)
Northern Pike	Female	0.423
		0.335
		0.240
		0.824
		0.421
		0.119
	Male	0.170
		0.246
	Maturing / Immature	0.509
		0.200
Walleye	Male	0.508
	Maturing / Immature	0.296

All values exceed CCME criteria for piscivorous wildlife; potential risk to animals consuming fish.

value = exceeds lethal effects thresholds; potential risk to fish.

Thresholds and criteria are for methylated forms of mercury.

[1] Canadian Councils of Ministers of the Environment (CCME) criteria for the protection of wildlife that consume fish (CCME 2001b).

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

Table 5.11-21 Screening of metals and tainting compounds in northern pike and walleye composite samples collected from the Clearwater River (September, 2004) against criteria for the protection of fish.

Analyte	Walleye	Northern Pike		Thresholds for the Protection of Fish[1]			
				Lowest no-effects thresholds		Lowest effects thresholds	
	Composite 1 Male n=2	Composite 1 Female n=3	Composite 2 Male n=2	Lethal (mg/kg)	Sublethal (mg/kg)	Lethal (mg/kg)	Sublethal (mg/kg)
Total Metal							
Aluminum (Al)	*4*	*3*	*<2*	1.0	nd	20	nd
Antimony (Sb)	<0.04	<0.04	<0.04	5	nd	9	nd
Arsenic (As)	0.020	0.022	0.019	2.6	0.9	11.2	3.1
Barium (Ba)	<0.08	0.09	0.12	nd	nd	nd	nd
Beryllium (Be)	<0.2	<0.2	<0.2	nd	nd	nd	nd
Boron (B)	<2	<2	<2	nd	nd	nd	nd
Cadmium (Cd)	<0.01	<0.01	<0.01	0.02	0.09	0.14	0.12
Chromium (Cr)	0.07	0.11	0.15	nd	nd	nd	nd
Cobalt (Co)	<0.08	<0.08	<0.08	nd	nd	nd	nd
Copper (Cu)	*0.42*	*0.43*	***0.57***	0.5	3.4	0.5	nd
Iron (Fe)	<2	<2	<2	nd	nd	nd	nd
Lead (Pb)	<0.02	<0.02	<0.02	4.0	nd	nd	nd
Lithium (Li)	<0.5	<0.5	<0.5	nd	nd	nd	nd
Manganese (Mn)	0.10	0.55	<0.04	nd	nd	nd	nd
Molybdenum (Mo)	<0.04	<0.04	<0.04	nd	nd	nd	nd
Nickel (Ni)	0.02	0.04	0.04	0.82	nd	118.1	nd

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

nd = no data available

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

Table 5.11-21 (cont'd.)

Analyte	Walleye	Northern Pike		Thresholds for the Protection of Fish[1]			
				Lowest no-effects thresholds		Lowest effects thresholds	
	Composite 1 Male n=2	Composite 1 Female n=3	Composite 2 Male n=2	Lethal (mg/kg)	Sublethal (mg/kg)	Lethal (mg/kg)	Sublethal (mg/kg)
Selenium (Se)	0.20	0.08	0.07	0.28	0.08	0.92	0.32
Silver (Ag)	*<0.02*	*<0.02*	*<0.02*	0.003	0.003	nd	nd
Sodium (Na)	224	339	4	nd	nd	nd	nd
Strontium (Sr)	0.13	1.64	1.22	nd	nd	nd	nd
Thallium (Tl)	<0.04	<0.04	<0.04	nd	nd	nd	nd
Tin (Sn)	<0.08	<0.08	<0.08	nc	nc	nc	nc
Titanium (Ti)	0.17	0.15	<0.05	nc	nc	nc	nc
Vanadium (V)	0.008	0.010	0.016	5.33	0.02	nd	0.41
Zinc (Zn)	3.9	5.1	5.9	60	60	nc	nc
Tainting Compounds							
1,3,5-Trimethylbenzene	<0.01	<0.01	<0.01	nc	nc	nc	nc
M+P-Xylenes	<0.01	<0.01	<0.01	nc	nc	nc	nc
Naphthalene	<0.02	<0.02	<0.02	nc	nc	nc	nc
o-Xylene	<0.01	<0.01	<0.01	nc	nc	nc	nc
Thiophene	<0.01	<0.01	<0.01	nc	nc	nc	nc
Toluene	0.16	0.09	0.08	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

nd = no data available

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

Table 5.11-22 Screening of tainting compounds included in the analysis of Clearwater River fish tissue composite samples.

Analyte	Tainting Threshold[1] (mg/kg)	Male Walleye	Female Northern Pike	Male Northern Pike
1,3,5-Trimethylbenzene	no criteria	<0.01	<0.01	<0.01
M+P-Xylenes	9[2]	<0.01	<0.01	<0.01
Naphthalene	0.33	<0.02	<0.02	<0.02
o-Xylene	9[2]	<0.01	<0.01	<0.01
Thiophene	nc	<0.01	<0.01	<0.01
Toluene	nc	0.16	0.09	0.08

[1] Tainting thresholds derived from Jardine and Hrudey (1988) and Golder (2003).

[2] Criteria is for *p*-xylene.

nc = no criteria

Table 5.11-23 Assessment of potential effects related to fish tissue measurement endpoint, Clearwater River 2004.

Parameter	Potential for Effects
Protection of Human Health	High - General
Protection of Fish Health	Negligible – Low[1]
Protection of Wildlife	Moderate - High
Tainting	Negligible - Low

[1] Metals with detection limits above criteria were excluded from this rating.

Figure 5.11-16 Results of inter-laboratory analysis of mercury in Clearwater River fish tissue, September 2004.

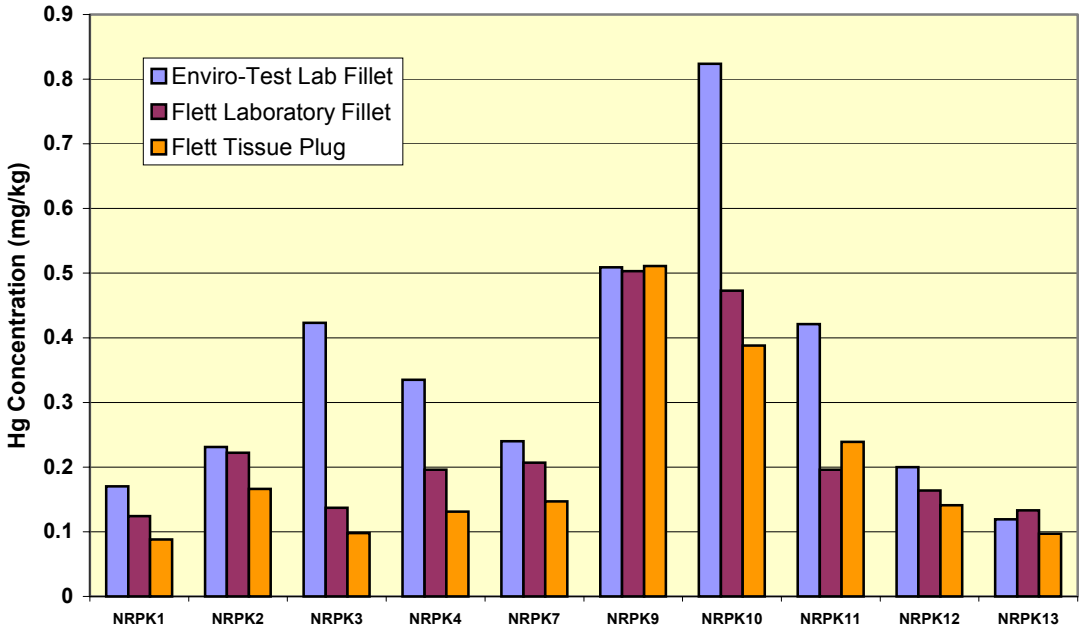


Table 5.11-24 Differences in mercury concentrations in Clearwater River fish fillet and plug tissue samples analyzed at two different laboratories.

Sample ID	ETL Fillet – Flett Fillet Difference (mg/kg wet weight)	Flett Fillet – Flett Plug Difference (mg/kg wet weight)
NRPK1	0.046	0.036
NRPK2	0.009	0.056
NRPK3	0.286	0.039
NRPK4	0.139	0.065
NRPK7	0.033	0.060
NRPK9	0.006	0.008
NRPK10	0.351	0.085
NRPK11	0.225	0.043
NRPK12	0.036	0.023
NRPK13	-0.014	0.036

Figure 5.11-17 Christina River looking downstream at the Hwy. 881 bridge crossing, September 22, 2004.

Table 5.11-25 Reconnaissance fish inventory results from electrofishing on the Christina River, fall 2004.

Fall Results (total effort = 4,995 s)					
Species	**Total**	**Species Composition (% of total)**	**CPUE (#/100 s)**	**Mean Length (mm)**	**Mean Weight (g)**
Longnose sucker	1	6.3	0.020	269	299
White sucker	12	75.0	0.240	302	545.1
Trout-perch	3	18.8	0.060	70	3.1
TOTAL	**16**	**100**	**0.320**	-	-

Note: A single longnose dace was captured in 148.5 minnow trap hours.

Figure 5.11-18 Christina River hydrograph 1985-2004.

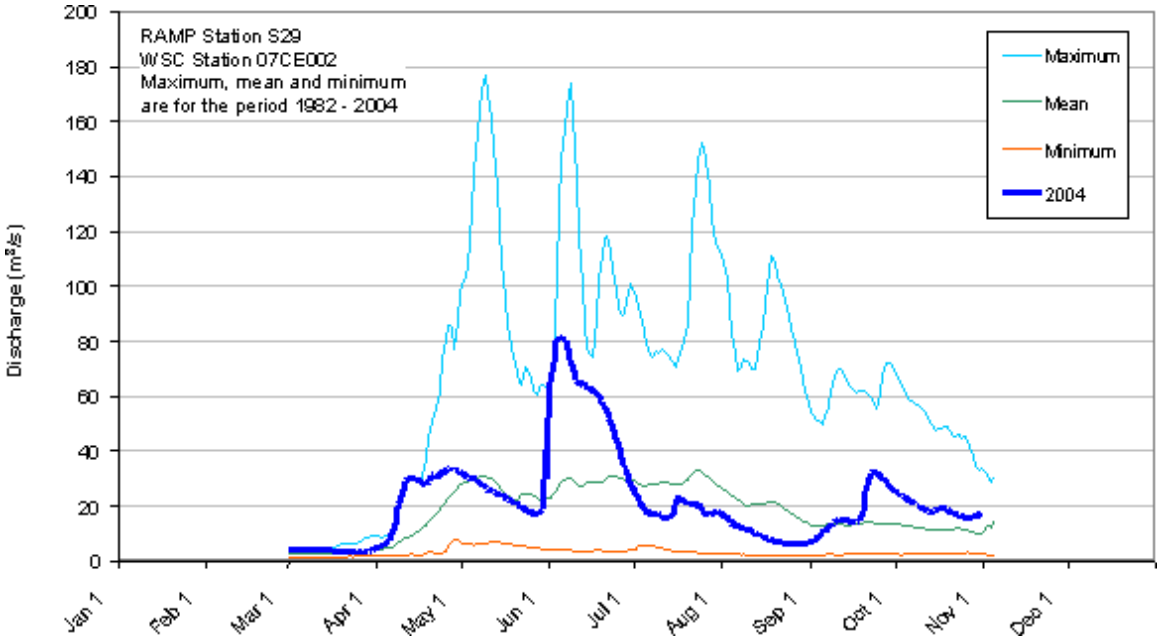


Table 5.11-26 Target size classes and actual numbers of fish collected for mercury testing, Winefred lake, September 2004.

Species	Target Size Classes for Mercury Analysis (mm)				
	1	2	3	4	5
Lake whitefish	350-400	401-450	451-500	501-550	551-600
No. in size class	4	5	4	5	0
Northern Pike	200-300	301-400	401-500	501-600	601-700
No. in size class	0	0	0	4	6
Walleye	200-300	301-400	401-500	501-600	601-700
No. in size class	6	5	5	3	5

Table 5.11-27 Fork length, total weight, sex, maturity and mercury concentrations for lake whitefish, northern pike and walleye collected from Winefred Lake, September 2004.

Species	Fork Length (mm)	Total Weight (g)	Sex	Maturity Code	Mercury Concentration (mg/kg)
Lake Whitefish n=18	387	790	F	M	0.029
	465	1,230	F	M	0.133
	375	715	F	M	0.044
	515	1,510	F	M	0.181
	503	1,950	F	M	0.160
	507	1,820	F	M	0.055
	520	1,660	F	M	0.066
	446	1,240	F	M	0.039
	441	1,090	F	M	0.044
	404	920	F	M	0.114
	430	1,050	M	M	0.061
	373	690	M	M	0.146
	485	1,640	M	M	0.108
	482	1,420	M	M	0.047
	487	1,460	M	M	0.094
	507	1,660	M	M	0.038
	411	950	M	M	0.079
	397	900	M	M	0.057

Table 5.11-27 (cont'd.)

Species	Fork Length (mm)	Total Weight (g)	Sex	Maturity Code	Mercury Concentration (mg/kg)
Northern Pike n=10	613	1,770	M	M	0.071
	691	2,610	M	M	0.121
	678	2,150	F	M	0.078
	602	1,680	M	M	0.094
	627	2,010	M	M	0.059
	828	3,760	F	M	0.141
	547	1,210	F	M	0.036
	543	1,140	F	M	0.085
	542	1,360	F	M	0.136
	595	1,710	F	IMM	0.101
Walleye N=24	466	1,300	F	IMM	0.067
	234	410	F	IMM	0.122
	649	3,720	F	M	0.137
	657	3,640	F	M	0.238
	697	4,240	F	M	0.161
	359	510	M	IMM	0.045
	435	920	M	IMM	0.151
	495	1,660	M	IMM	0.071
	320	380	M	IMM	0.048
	283	240	M	IMM	0.05
	277	220	M	IMM	0.256
	268	210	M	IMM	0.092
	303	290	M	IMM	0.161
	344	410	U	IMM	0.065
	254	190	U	IMM	0.095
	466	1,530	M	M	0.073
	477	1,460	M	M	0.106
	528	1,880	M	M	0.148
	559	2,470	M	M	0.184
	614	3,120	M	M	0.231
	590	2,560	M	M	0.21
	607	2,690	M	M	0.129
	361	540	M	M	0.105
	273	220	U	U	0.227

Figure 5.11-19 Scatterplots of mercury concentration in lake whitefish, northern pike and walleye relative to fork length, Winefred Lake, fall 2004.

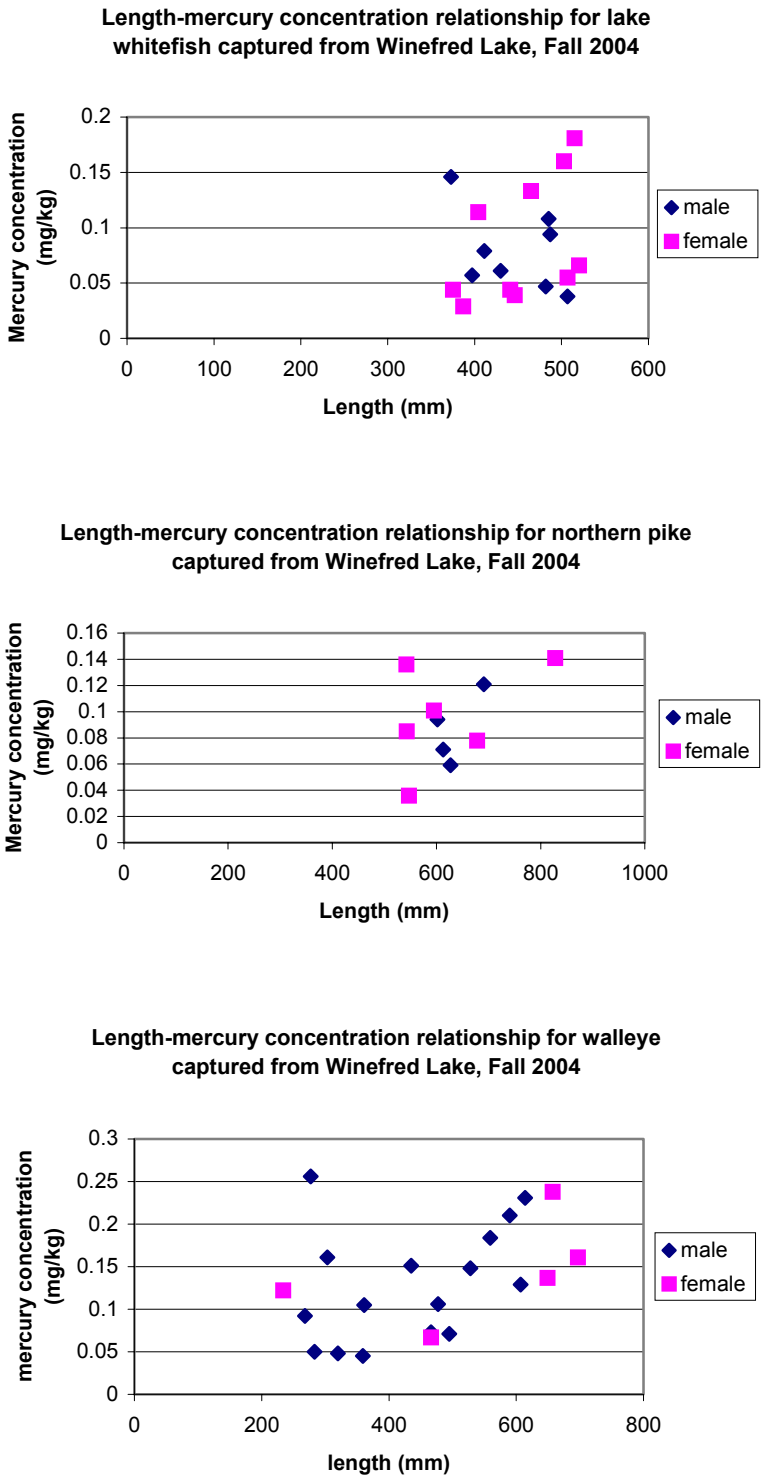
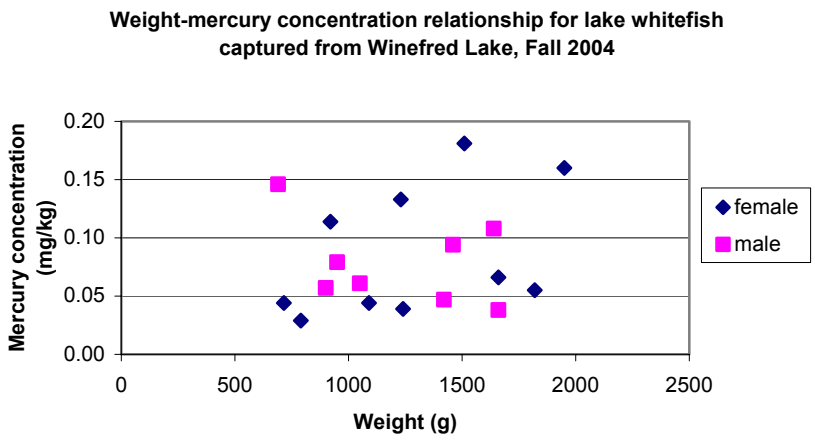
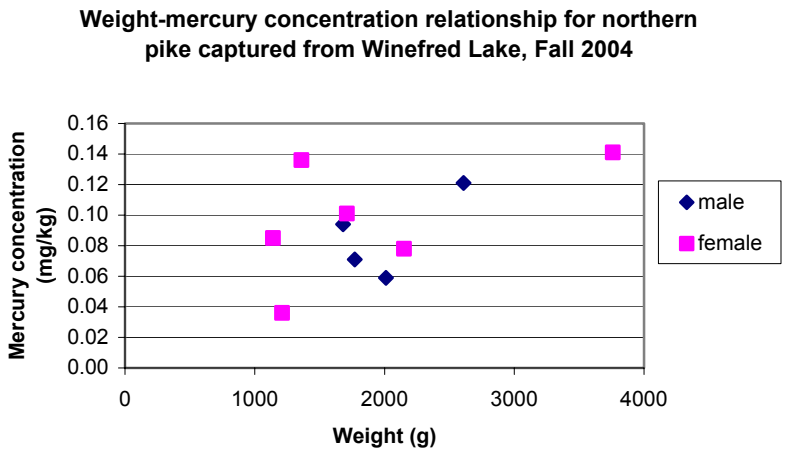


Figure 5.11-20 Scatterplots of mercury concentration in lake whitefish, northern pike and walleye relative to total weight, Winefred Lake, fall 2004.





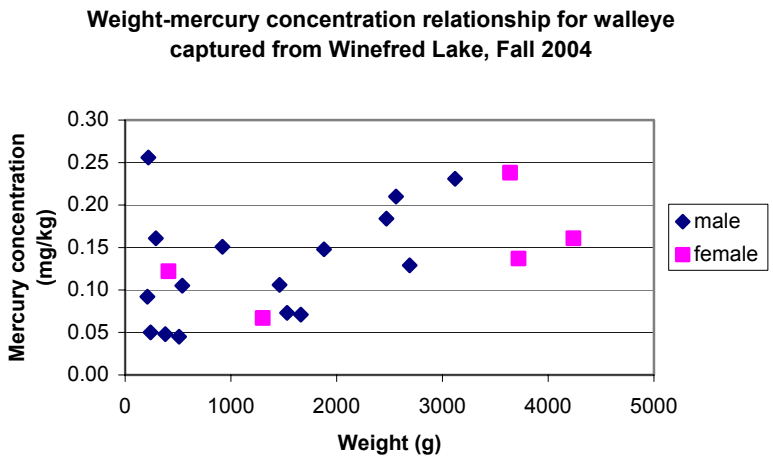


Table 5.11-28 Rank correlations between mercury concentrations in muscle of Winefred Lake fish versus length and weight.

Organism Metric	Rank Correlations with Mercury Concentrations (r_s)								
	Lake whitefish			Walleye			Northern Pike		
	Male n=8	Female n=10	Total n=18	Male n=16	Female n=5	Total n=24	Male n=4	Female n=6	Total n=10
Fork Length	-0.357	0.596	0.184	0.356	0.800	0.341	nc	0.143	0.164
Total Weight	-0.333	0.523	0.150	0.347	0.600	0.332	nc	0.486	0.321

Table 5.11-29 Screening of mercury concentrations in lake whitefish, northern pike and walleye from Winefred Lake, September, 2004, against criteria for fish consumption for the protection of human health.

Mercury Screening Criteria		Mercury Concentration (mg/kg)
Health Canada Criteria	*General Consumer*	0.50
	Subsistence Fishers	0.20
Region III USEPA Risk-Based Criterion[1]		0.14
National USEPA Screening Values[2]	*Recreational Fishers*	0.40
	Subsistence Fishers	0.049

Mercury Concentrations in Winefred Lake Fish Muscle

Species	Sex	Mercury Concentration (mg/kg)
Lake Whitefish	Female	0.029
		0.133
		0.044
		0.181
		0.160
		0.055
		0.066
		0.039
		0.044
		0.114
Lake Whitefish	Male	*0.061*
		0.146
		0.108
		0.047
		0.094
		0.038
		0.079
		0.057

value = exceeds USEPA screening value for subsistence fishers.
value = exceeds USEPA Region III risk based criterion.
value = exceed the Health Canada screening value for subsistence fishers.
value = exceeds USEPA screening value for recreational fishers.
value = exceeds Health Canada criterion for the general consumer.

[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 methylmercury.

[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 70 kg individual consuming 142.4 g of fish per day over a 70-year period; (USEPA 2000).Criterion is for methylmercury.

Table 5.11-29 (cont'd.)

Mercury Concentrations in Winefred Lake Fish Muscle		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Northern Pike	Female	*0.141*
		0.036
		0.085
		0.136
		0.101
		0.078
	Male	*0.071*
		0.121
		0.094
		0.059
Walleye	Female	*0.067*
		0.122
		0.137
		0.238
		0.161
	Male	0.045
		0.151
		0.071
		0.048
		0.050
		0.256
		0.092
		0.161
		0.073
		0.106
		0.148
		0.184
		0.231
		0.210
		0.129
		0.105
	Unknown	*0.065*
		0.095
		0.227

value = exceeds USEPA screening value for subsistence fishers.

value = exceeds USEPA Region III risk based criterion.

value = exceed the Health Canada screening value for subsistence fishers.

value **=** exceeds USEPA screening value for recreational fishers.

value = exceeds Health Canada criterion for the general consumer.

[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 methylmercury.

[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 70 kg individual consuming 142.4 g of fish per day over a 70-year period; (USEPA 2000).Criterion is for methylmercury.

Table 5.11-30 Screening of mercury concentrations in lake whitefish, northern pike and walleye from Winefred Lake, September, 2004, against criteria for protection of fish and wildlife.

Mercury Screening Criteria		Mercury Concentration (mg/kg)
CCME criteria for the protection of wildlife[1]		0.033
Effects thresholds for fish[2]	*No effects - lethal*	1.91
	No effects - sublethal	2.28
	Effects - lethal	6.2
	No effects - sub-lethal	8.6
Mercury Concentrations in Winefred Lake Fish Muscle		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Lake Whitefish	Female	0.029
		0.133
		0.044
		0.181
		0.160
		0.055
		0.066
		0.039
		0.044
		0.114
	Male	*0.061*
		0.146
		0.108
		0.047
		0.094
		0.038
		0.079
		0.057

value = exceeds CCME criteria for piscivorous wildlife; potential risk to animals consuming fish.

value = exceeds lethal effects thresholds; potential risk to fish.

Thresholds and criteria are for methylated forms of mercury.

[1] Canadian Councils of Ministers of the Environment (CCME) criteria for the protection of wildlife that consume fish (CCME 2001b).

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

Table 5.11-30 (cont'd.)

Mercury Concentrations in Winefred Lake Fish Muscle		
Species	**Sex**	**Mercury Concentration (mg/kg)**
Northern Pike	Female	*0.141*
		0.036
		0.085
		0.136
		0.101
		0.078
	Male	*0.071*
		0.121
		0.094
		0.059
Walleye	Female	0.067
		0.122
		0.137
		0.238
		0.161
	Male	*0.045*
		0.151
		0.071
		0.048
		0.050
		0.256
		0.092
		0.161
		0.073
		0.106
		0.148
		0.184
		0.231
		0.210
		0.129
		0.105

value = exceeds CCME criteria for piscivorous wildlife; potential risk to animals consuming fish.

value = exceeds lethal effects thresholds; potential risk to fish.

Thresholds and criteria are for methylated forms of mercury.

[1] Canadian Councils of Ministers of the Environment (CCME) criteria for the protection of wildlife that consume fish (CCME 2001b).

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

Table 5.11-30 (cont'd.)

Mercury Concentrations in Winefred Lake Fish Muscle		
Species	**Sex**	**Mercury Concentration (mg/kg)**
	Unknown	*0.065*
		0.095
		0.227

value = exceeds CCME criteria for piscivorous wildlife; potential risk to animals consuming fish.

value = exceeds lethal effects thresholds; potential risk to fish.

Thresholds and criteria are for methylated forms of mercury.

[1] Canadian Councils of Ministers of the Environment (CCME) criteria for the protection of wildlife that consume fish (CCME 2001b).

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

Table 5.11-31 Comparison of the range of mercury concentrations in individual fish muscle samples from Winefred Lake with those from Christina Lake, Lake Claire and Gregoire Lake.

	Range of Individual Mercury Concentrations (mg/kg) (combined male and female)		
Regional Lake	**Lake Whitefish**	**Northern Pike**	**Walleye**
Winefred Lake (2004)	0.029 – 0.181	0.036 - 0.141	0.045 – 0.256
Christina Lake (2003)	0.06 – 0.20	0.27 – 0.66	0.31 – 0.61
Lake Claire (2003)	0.07 – 0.15	0.14 – 0.63	0.18 – 0.21
Gregoire Lake (2002)	0.02 – 0.08	0.04 – 0.81	0.04 – 0.43

5.12 HANGINGSTONE RIVER SYSTEM

Summary of Results

Climate and Hydrology

	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge Mean winter discharge Annual maximum daily discharge Minimum open-water season discharge	The Hangingstone River watershed was designated as a reference watershed for 2004.				Total runoff volume was 9% below normal. Spring runoff came relatively early, producing record high discharges for early April. A second, higher peak flow occurred in June, but for the rest of the year, discharges were below normal.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=1)	
Physical variables (3 endpoints)	No water quality sampling stations were designated as exposed in 2004.	0	Fall 2004 results for water quality measurement endpoints were within the range of natural variation of regional baseline concentrations. Water quality measurement endpoints, with the exception of total phosphorous and total aluminum, were below guidelines for the protection of aquatic life in fall 2004.
Nutrients (5 endpoints)		1	
Ions (5 endpoints)		0	
Organic compounds (1 endpoint)		0	
Selected metals (5 endpoints)		1	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]		
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 1 station X 7 endpoints)	
Above 95th	No water quality sampling stations were designated as exposed in 2004.	0	
Between 75th and 95th		4	
Between median and 75th		1	
Between 25th and median		1	
Between 5th and 25th		2	
Less than 5th		0	

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=1)	
Physical variables (4 endpoints)	No sediment quality sampling stations were designated as exposed in 2004.	0	Sediments in fall 2004 were sandy, low in organic carbon, and low in concentrations of hydrocarbons, PAHs and metals. No sediment quality measurement endpoints exceeded CCME guidelines. Concentrations of selected sediment quality measurement endpoints were all below the median and in the lower range of regional reference concentrations.
Total Hydrocarbons (8 endpoints)		0	
PAHs (7 endpoints)		0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]		
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 1 station X 3 endpoints)	
Above 95th	No sediment quality sampling stations were designated as exposed in 2004.	0	
Between 75th and 95th		0	
Between median and 75th		0	
Between 25th and median		2	
Between 5th and 25th		0	
Less than 5th		1	

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline						
	2004 Exposed Stations (n=0)			2004 Reference Stations (n= 1)			
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD	
Abundance	No benthic invertebrate community sampling stations were designated as exposed in 2004.				1		All benthic invertebrate community measurement endpoints were within the range of expected conditions based on regional reference data for erosional habitats.
Richness					1		
Diversity					1		
Evenness					1		
% EPT					1		

Fish Populations

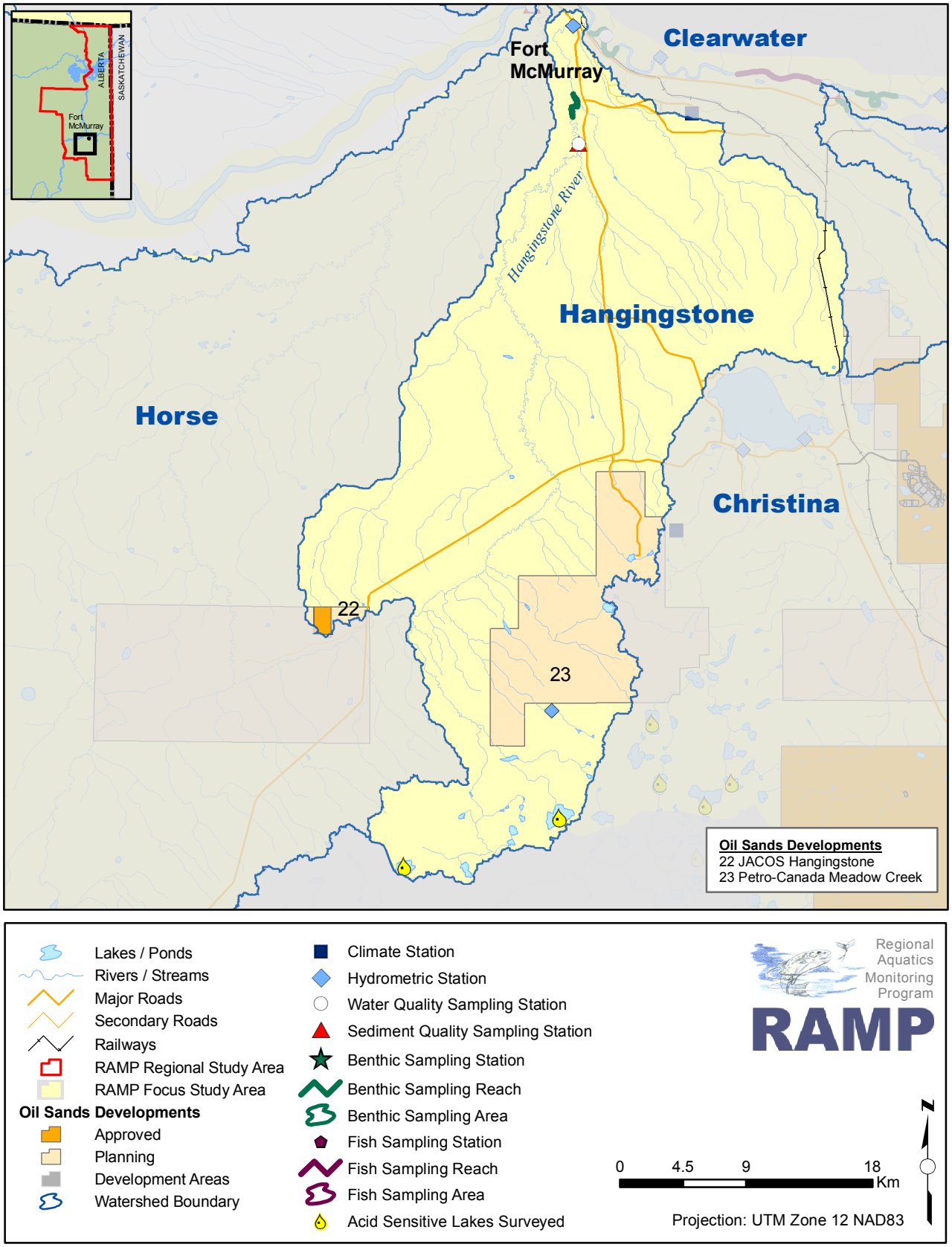
Fish Inventory	No fish inventory studies were conducted in the Hangingstone River in 2004.	
Sentinel Studies	Sentinel fish studies were not conducted in 2004.	
Fish Tissue	Level of Risk	
Human Health: Subsistence Human Health: Recreational Fishers Human Health: General Consumers Human Health: Tainting Fish and Wildlife: Mercury Fish and Wildlife: Other Chemicals	Fish tissue program was not conducted in the Hangingstone River in 2004.	

[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 Hydrologic Conditions

Total runoff volume in the Hangingstone River basin, as measured at WSC Station 07CD004 (Hangingstone River at Fort McMurray), was 9% below normal in 2004 (Figure 5.12-2). The March to October runoff was 103 mm compared to the long-term average of 113 mm. The spring runoff came relatively early, producing record high discharges (for the time of year) in early April. A second higher peak flow occurred in early June in response to rainfall, but river discharges were below normal during the rest of the year (Figure 5.12-2). The June maximum daily discharge of 37.5 m^3/s was 12% less than the mean annual flood. The lowest discharge of the open-water season was 0.72 m^3/s on August 30, lower than the mean annual minimum open-water discharge of 0.98 m^3/s.

5.12.2 Water Quality

Water quality sampling in the Hangingstone River was conducted for the first time in 2004, with water quality samples collected from station HAR-1 (mouth of river) in spring, summer, and fall 2004. Oil sands development in the watershed is limited to the JACOS Hangingstone SAGD Pilot Project in the upper watershed; station HAR-1 is therefore designated as a reference water quality station. Results of 2004 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 reference conditions in Figure 5.12-3. Ionic characteristics of water quality at HAR-1 are shown in Figure 5.12-4.

No historical data for the selected water quality measurement endpoints are available for comparison to 2004 results. In general, fall 2004 results for water quality measurement endpoints were within the natural variation of regional baseline concentrations (Figure 5.12-3). Water quality measurement endpoints in fall 2004 were below CCME/AENV guidelines for the protection of aquatic life with the exception of total phosphorous and total aluminum (Table 5.12-1).

Cluster analysis indicated that water quality at station HAR-1 was similar to that observed in southern tributaries of the Athabasca River (e.g., Clearwater River, Christina River) and other regional watercourses and lakes (Appendix E). In general, this group of stations has to date exhibited low concentrations of most metals and ions.

Table 5.12-2 contains a list of all exceedances of CCME/AENV guidelines for the protection of aquatic life observed at HAR-1 in 2004.

5.12.3 Sediment Quality

As with water quality, sediment quality sampling in the Hangingstone River was conducted for the first time in 2004. Sediment quality samples were collected from station HAR-1 (mouth of river) in fall 2004. As with water quality

station HAR-1, sediment quality station HAR-1 was designated as a reference station.

Sediments at HAR-1 in fall 2004 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 below the median and in the lower range of regional baseline concentrations (Figure 5.12-5).

5.12.4 Benthic Invertebrate Communities

The lower reach of the Hangingstone River was added as part of the 2004 sampling program (Station HAR-E 1-15), and was designated as a reference site due to the limited oil sands development activities upstream of this reach in the Hangingstone River watershed.

The Hangingstone River reach sampled in 2004 was typical of erosional habitats, with shallow depths, moderate current velocity, absence of macrophytes, and low benthic algal biomass (Table 5.12-4). Dissolved oxygen, conductivity, pH and water temperature were within normal values for the region. The river bottom was heterogeneous, with substrates ranging from sand/silt/clay to boulders, but was dominated by small cobble. Benthic invertebrate community composition was also typical of erosional habitat, with chironomids and the EPT taxa most abundant in the samples collected (Table 5.12-5). The benthic community was broadly diverse including worms (naidids, tubificids), snails (gastropods), beetles (Coleoptera) and a variety of fly larvae (tabanids, empidids, ceratopogonids).

All benthic invertebrate community measurement endpoints were within the range of expected conditions based on regional reference data for erosional habitats (Figure 5.12-6).

5.12.5 Fish Populations

The 2004 RAMP fish program did not include any activities in the Hangingstone River system.

5.12.6 Summary of Conditions

2004 was the first year of sampling in the Hangingstone River watershed. Results of 2004 sampling indicate that the Hangingstone River is a typical Athabasca River basin watershed, with RAMP aquatic resources in 2004 within the range of regional reference conditions for similar watersheds and habitat types. It appears that the selected sampling stations are suitable for monitoring possible influences of upstream oil sands development activities.

Figure 5.12-2 Hangingstone River 2004 hydrograph and historical context.

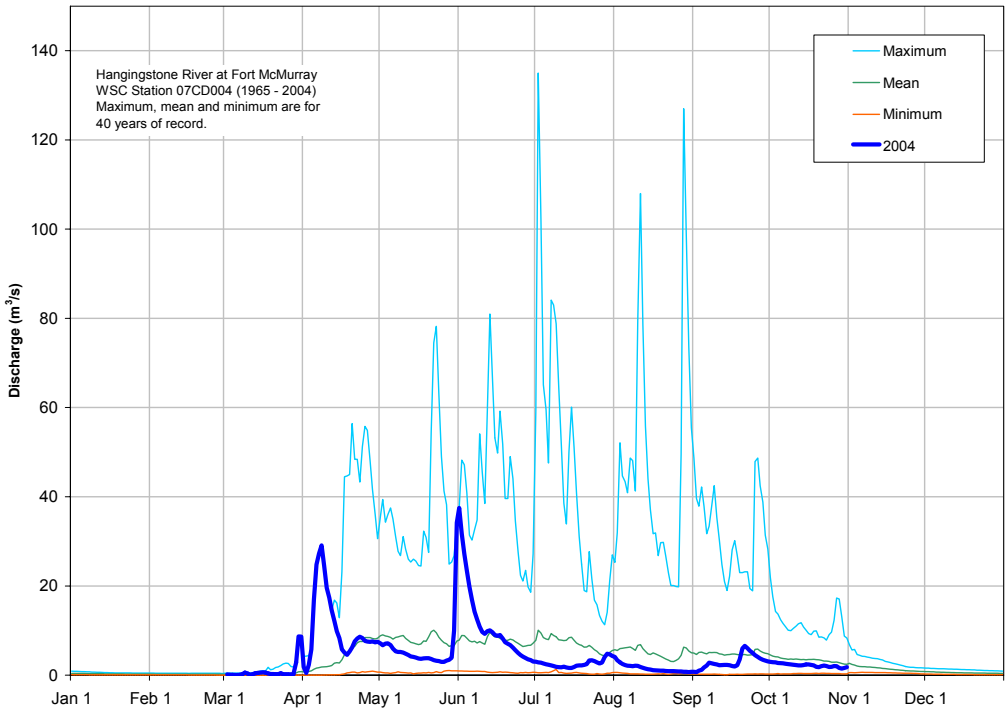
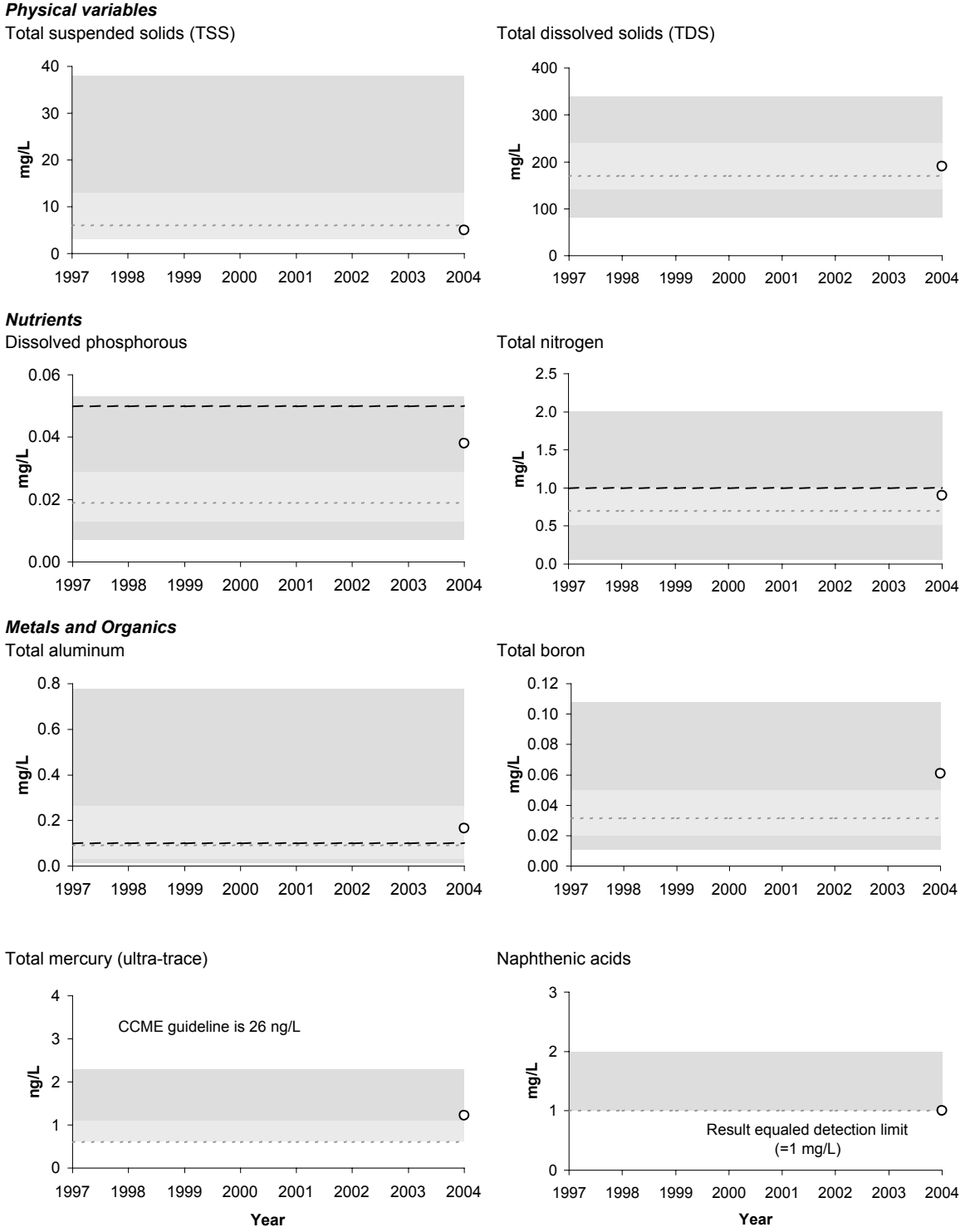


Table 5.12-1 Concentrations of water quality measurement endpoints, mouth of Hangingstone River (HAR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (fall data only)[2]			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.2	-	-	-	-
Total suspended solids	mg/L	-	5	-	-	-	-
Conductivity	mg/L	-	233	-	-	-	-
Nutrients							
Total phosphorus	mg/L	0.05	**0.059**	-	-	-	-
Dissolved phosphorus	mg/L	0.05[1]	0.038	-	-	-	-
Total nitrogen*	mg/L	1.0	0.9	-	-	-	-
Nitrate+nitrite	mg/L	-	<0.1	-	-	-	-
Dissolved organic carbon	mg/L	-	21	-	-	-	-
Ions							
Sodium	mg/L	-	17	-	-	-	-
Chloride	mg/L	230, 860[3]	9	-	-	-	-
Sulphate	mg/L	100[4]	10	-	-	-	-
Total dissolved solids	mg/L	-	190	-	-	-	-
Total alkalinity	mg/L	-	99	-	-	-	-
Organic compounds							
Naphthenic acids	mg/L	-	1	-	-	-	-
Selected metals							
Total aluminum	mg/L	0.1	**0.17**	-	-	-	-
Dissolved aluminum	mg/L	0.1[1]	0.014	-	-	-	-
Total boron	mg/L	1.2[4]	0.06	-	-	-	-
Total molybdenum	mg/L	0.073	0.0010	-	-	-	-
Total mercury (ultra-trace)	ng/L	26	1	-	-	-	-
Other variables that exceeded CCME/AENV guidelines in fall 2004							
Total phenols	mg/L	0.004	**0.01**	-	-	-	-
Total iron	mg/L	0.3	**1.1**	-	-	-	-

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] New station in 2004. No previous data are available.
[3] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[4] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.12-3 Concentrations of selected water quality measurement endpoints, mouth of Hangingstone River (HAR-1), relative to regional reference conditions.



[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 E for these regional baseline ranges.

Figure 5.12-4 Piper diagram of fall ion concentrations in Hangingstone River system.

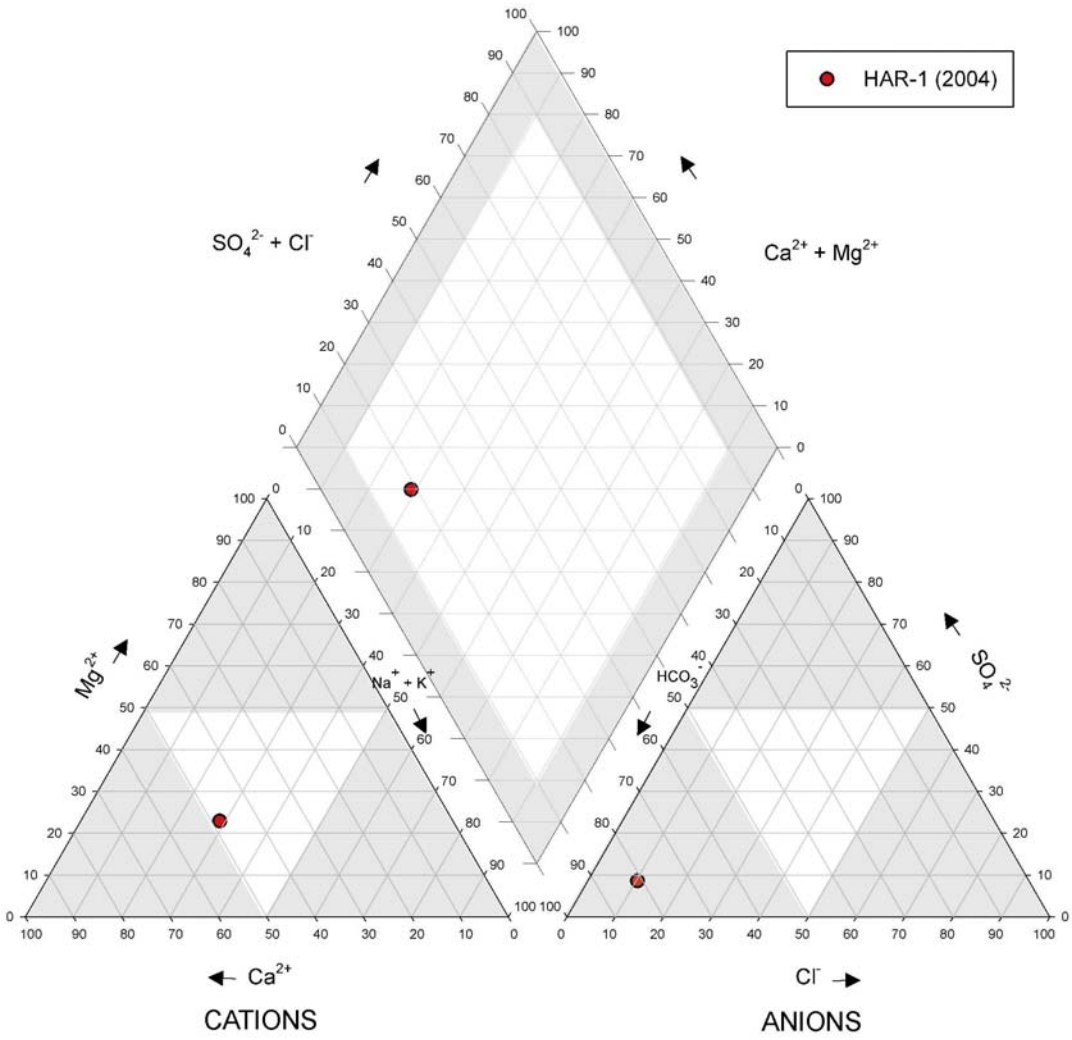


Table 5.12-2 List of all 2004 water quality guideline exceedances, Hangingstone River (HAR-1).

Parameter	Units	Guideline	HAR-1
Spring [1]			
Total copper	mg/L	0.002-0.004[3]	**0.00306**
Total aluminum	mg/L	0.100	**0.384**
Total iron	mg/L	0.300	**1.00**
Dissolved iron	mg/L	0.300[2]	**0.44**
Summer			
Total phenols	mg/L	0.004	**0.01**
Total aluminum	mg/L	0.100	**0.33**
Total iron	mg/L	0.300	**1.69**
Dissolved iron	mg/L	0.300[2]	**0.87**
Total phosphorus	mg/L	0.05	**0.10**
Fall			
Total phenols	mg/L	0.004	**0.011**
Total aluminum	mg/L	0.100	**0.166**
Total iron	mg/L	0.300	**1.13**
Dissolved iron	mg/L	0.300[2]	**0.739**
Total phosphorus	mg/L	0.05	**0.06**

Guidelines are CCME/AENV guidelines for the protection of aquatic life.
[1]: HAR-1 not sampled in winter.
[2]: Guideline is for total analyte (no guideline for dissolved species).
[3]: Guideline is hardness dependent.

Table 5.12-3 Concentrations of sediment quality measurement endpoints, mouth of Hangingstone River (HAR-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	<1	-	-	-	-
Silt	%	-	1	-	-	-	-
Sand	%	-	99	-	-	-	-
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]	12	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	11	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	-	-	-	-
TEH (C11-C30)	mg/kg	-	7	-	-	-	-
TRH	mg/kg	-	<100	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	0.0010	-	-	-	-
Retene	mg/kg	-	0.0019	-	-	-	-
Total dibenzothiophenes	mg/kg	-	0.013	-	-	-	-
Total PAHs	mg/kg	-	0.07	-	-	-	-
Total HMW PAHs	mg/kg	-	0.02	-	-	-	-
Total LMW PAHs	mg/kg	-	0.05	-	-	-	-
Predicted PAH toxicity[1]	H.I.	-	0.31	-	-	-	-
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	9	-	-	-	-
Chironomus growth	mg/organism	-	2.4	-	-	-	-
Hyallela survival	# surviving	-	5	-	-	-	-
Hyallela growth	mg/organism	-	0.3	-	-	-	-

Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV 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).

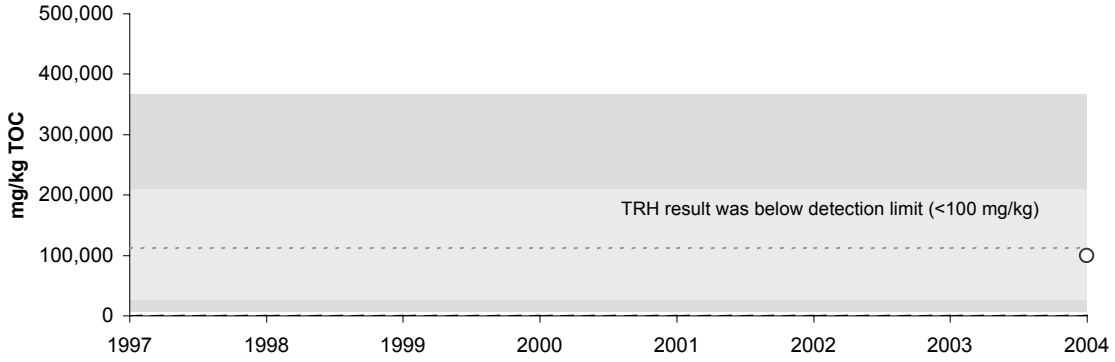
[3] Interim sediment quality guideline (ISQG) (CCME 2003).

[4] New station in 2004. No previous data are available.

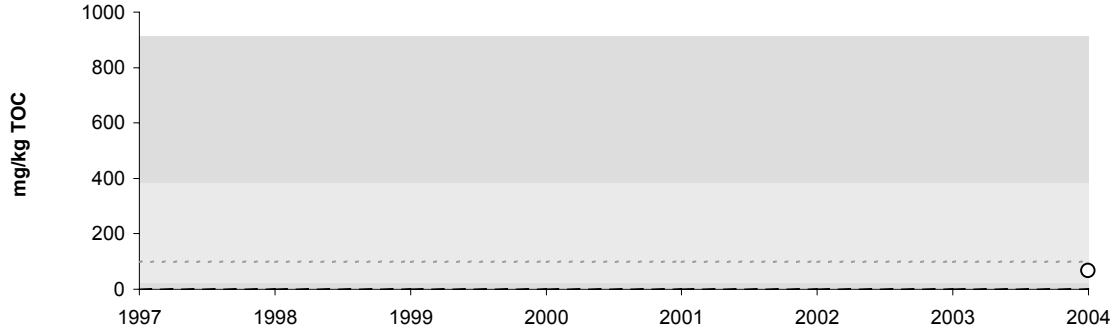
Figure 5.12-5 Concentrations of selected sediment quality measurement endpoints, mouth of Hangingstone River (HAR-1), relative to regional reference conditions.

Note : New station in 2004

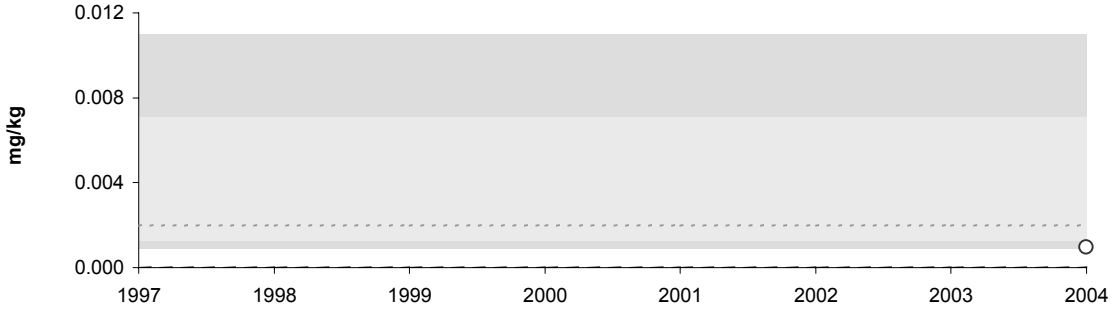
Total Recoverable Hydrocarbons (normalized to TOC)



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 F for these regional baseline ranges.

Table 5.12-4 Average habitat characteristics of benthic invertebrate sampling stations in the Hangingstone River (HAR-E 1-15), fall 2004.

Variable	Units	Hangingstone River
Sample date	-	Sept 11, 2004
Habitat	-	Erosional
Water depth	m	0.2
Current velocity	m/s	0.5
Macrophyte cover	%	0
Benthic algae	mg/m^2	26.2
Field Water Quality		
Dissolved oxygen	mg/L	11.3
Conductivity	µS/cm	157
pH	pH units	8.1
Water temperature	°C	6.5
Sediment Composition		
Sand/Silt/Clay	%	7.3
Small gravel	%	10.7
Large gravel	%	23.3
Small cobble	%	31.3
Large cobble	%	22.0
Boulder	%	5.3
Bedrock	%	0

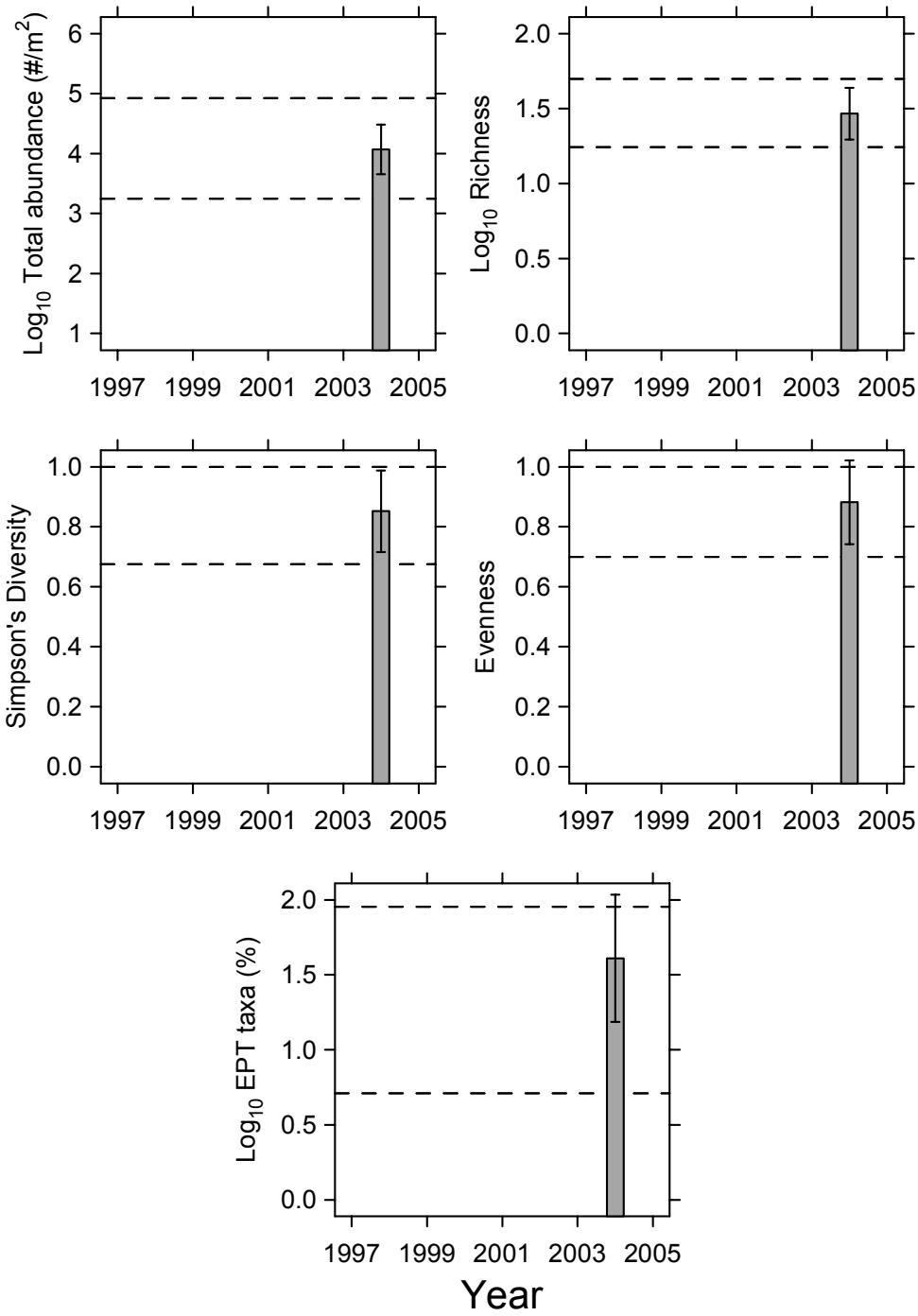
Table 5.12-5 Summary of major taxon abundances and key indices of composition among stations in the Hangingstone River (HAR-E 1-15), fall 2004.

Taxon	Abundance $\#/m^2$	SD	% Abundance
Nematoda	435	979	3.4
Enchytraeidae	97	131	0.8
Naididae	315	616	2.4
Tubificidae	21	88	0.2
Hydracarina	195	378	1.5
Ostracoda	151	324	1.2
Copepoda	468	4889	3.6
Gastropoda	17	50	0.1
Ephemeroptera	2274	701	17.7
Plecoptera	863	611	6.7

Table 5.12-5 (cont'd.)

Taxon	Abundance #/m^2	SD	% Abundance
Trichoptera	2509	1710	19.5
Anisoptera	538	1962	4.2
Coleoptera	97	298	0.8
Athericidae	47	198	0.4
Tabanidae	34	0	0.3
Empididae	430	526	3.3
Ceratopogonidae	14	0	0.1
Chironomidae	4351	750	33.8
Total Abundance	12856	6294	-
Richness	29.7	5.4	-
Simpson's Diversity	0.852	0.062	-
Evenness	0.882	0.064	-

Figure 5.12-6 Variations in benthic invertebrate community measurement endpoints in the Hangingstone River (HAR-E 1-15).



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

5.13 MISCELLANEOUS REFERENCE AQUATIC SYSTEMS

Summary of Results

Climate and Hydrology

	Assessment of Change				
	Negligible	Low	Moderate	High	
Mean open-water season discharge Mean winter discharge Annual maximum daily discharge Minimum open-water season discharge	Kearl Lake and McCLelland Lakes were designated as reference waterbodies for 2004.				In 2004, the range in lake levels at both Kearl and McLelland Lake was less than or approximately 0.3 m, respectively. This compares to a range in lake levels of 0.5 m and 0.6 m, respectively, over the period of record.

Water Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=0)	2004 Reference Stations (n=1)	
Physical variables (3 endpoints)	No water quality sampling stations were designated as exposed in 2004.	0	Concentrations of all water quality measurement endpoints except total nitrogen at Kearl Lake were below guidelines in fall 2004. In addition, concentrations of all water quality variables measured at Kearl Lake in fall 2004 were similar to the range in concentration of these variables in previous years, and were within the range of natural variation for regional baseline conditions. McClelland Lake was not sampled in 2004.
Nutrients (5 endpoints)		1	
Ions (5 endpoints)		0	
Organic compounds (1 endpoint)		0	
Selected metals (5 endpoints)		0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[2]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 1 station X 7 endpoints)
Above 95th	No water quality sampling stations were designated as exposed in 2004.	0
Between 75th and 95th		1
Between median and 75th		2
Between 25th and median		3
Between 5th and 25th		1
Less than 5th		0

Sediment Quality

Guideline Exceedances	Station-Endpoint Combinations Exceeding Guidelines in 2004[1]		
	2004 Exposed Stations (n=1)	2004 Reference Stations (n=1)	
Physical variables (4 endpoints)	No sediment quality sampling stations were designated as exposed in 2004.	0	Particle size analysis on the September 2004 Kearl Lake sediment was not conducted due to the very high levels of organic matter in the sample. None of the measurement endpoints exceeded CCME guidelines in fall 2004, and concentrations of selected sediment quality measurement endpoints for Kearl Lake in 2004 were well within the range of regional baseline conditions. McClelland Lake was not sampled in 2004.
Total Hydrocarbons (8 endpoints)		0	
PAHs (7 endpoints)		0	

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline[3]	
Percentile of Regional Baseline Values	2004 Exposed Stations (n= 0 stations)	2004 Reference Stations (n= 1 station X 3 endpoints)
Above 95th	No sediment quality sampling stations were designated as exposed in 2004.	1
Between 75th and 95th		0
Between median and 75th		0
Between 25th and median		0
Between 5th and 25th		0
Less than 5th		1

Benthic Invertebrate Communities

Comparison to Regional Baselines	Endpoints in 2004 Compared to Regional Baseline						
	2004 Exposed Stations (n=0)			2004 Reference Stations (n= 1)			
	< 2 SD	w/i 2 SD	> 2 SD	< 2 SD	w/i 2 SD	> 2 SD	
Abundance	No benthic invertebrate community sampling stations were designated as exposed in 2004.				1		In general, Kearl Lake is in relatively good condition, with benthic community indices that are within regional baseline ranges.
Richness					1		
Diversity					1		
Evenness					1		
% EPT					1		

Fish Populations

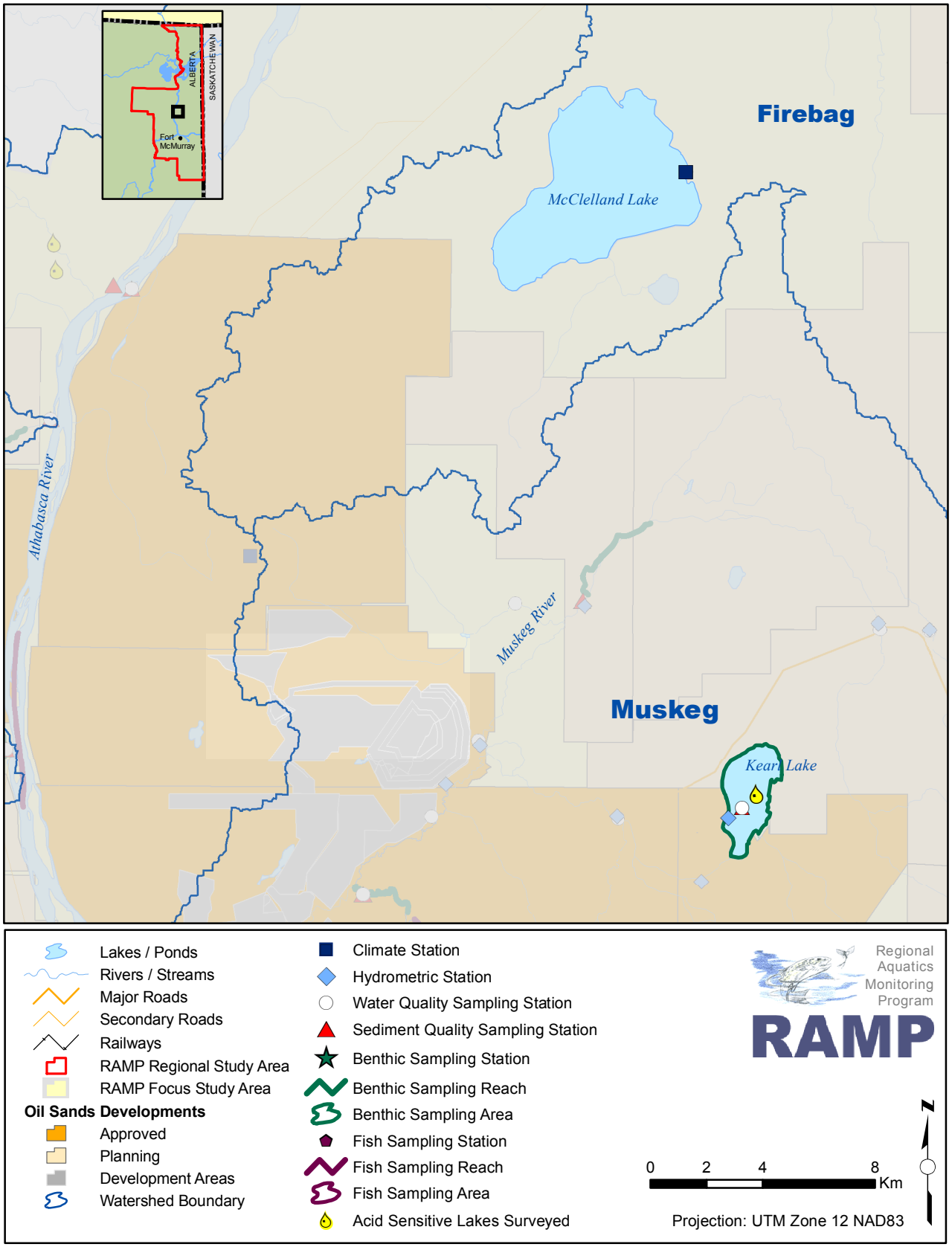
Fish Inventory	No fish inventory studies were conducted in 2004.
Sentinel Studies	Sentinel fish studies were not conducted in 2004.
Fish Tissue	Level of Risk
Human Health: Subsistence Human Health: Recreational Fishers Human Health: General Consumers Human Health: Tainting Fish and Wildlife: Mercury Fish and Wildlife: Other Chemicals	Fish tissue program was not conducted in either McClelland Lake or Kearl Lake in 2004.

[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 not yet exposed to RAMP oil sands developments.



RAMP1110\GIS\2004_MISCYET.MXD

This section includes 2004 results from Kearl Lake and McClelland Lake. Both waterbodies were unexposed to oil sands development activities and were therefore designated as reference waterbodies.

5.13.1 Hydrologic Conditions

Hydrologic conditions were examined on both Kearl Lake and McClelland Lake.

Water levels on Kearl Lake, measured at RAMP Station L2, followed a normal trend for the first half of 2004 (Figure 5.13-2). The water level was below normal and fell slowly during January, February and March, then rose in April and May as snowmelt runoff entered the lake (Figure 5.13-2). The water level rose in June to well above normal after the regional rainfall event, and fell to well below normal levels for the remainder of the year. The total range in lake levels during 2004 was less than 0.3 m, compared to a total range over the period of record of approximately 0.5 m. Estimates of normal and extreme conditions are somewhat uncertain because of the short (six years) and intermittent period of record for the lake.

McClelland Lake water levels, measured at RAMP Station L1, rose very slightly in spring and fell gradually throughout the summer (Figure 5.13-3). In mid-September, the lake rose abruptly in response to rainfall. The range of lake levels observed in 2004 was approximately 0.3 m, compared to a total range of 0.6 m over eight years of monitoring.

5.13.2 Water Quality

In 2004, water quality samples were collected from Kearl Lake (station KEL-1) in September (McClelland Lake, station MCL-1 was not sampled in 2004). Station KEL-1 was designated as a reference station up to and including 2004. Results of 2004 sampling for water quality measurement endpoints identified in Section 3.2.7 are shown in Table 5.13-1; results for selected measurement endpoints relative to regional baseline conditions for both stations KEL-1 and MCL-1 are shown in Figure 5.13-4.

At KEL-1, fall 2004 concentrations of all water quality measurement endpoints except total nitrogen were below CCME/AENV guidelines for the protection of aquatic life (Table 5.13-1). In addition, concentrations of all water quality variables measured at station KEL-1 in fall 2004 were similar to the range in concentration of these variables in previous years.

The concentrations of selected water quality measurement endpoints for station KEL-1 in 2004 were within the lower end of the range of natural variation for regional baseline conditions (Figure 5.13-4). The concentration of total nitrogen in 2004 fell between the 75th and 95th percentile of regional baseline concentrations. Ion balance within the watershed has been relatively constant at both stations KEL-1 and MCL-1 in the past five years of RAMP sampling (Figure 5.13-5).

Table 5.13-2 contains a list of all exceedances of CCME/AENV guidelines for the protection of aquatic life observed in Kearl Lake.

5.13.3 Sediment Quality

In 2004, sediment quality samples were collected from Kearl Lake (station KEL-1) in September (McClelland Lake, station MCL-1 was not sampled in 2004). Station KEL-1 was designated as a reference station up to and including 2004. Results of 2004 sampling for sediment quality measurement endpoints identified in Section 3.3.7 are shown in Table 5.13-3; results for selected measurement endpoints relative to regional baseline conditions for both stations KEL-1 and MCL-1 are shown in Figure 5.13-6.

Particle size analysis could not be conducted on the September 2004 Kearl Lake sediment sample due the very high levels of organic matter in the sample (Table 5.13-3). None of the measurement endpoint concentrations exceeded CCME guidelines in fall 2004 (Table 5.13-3), and fall 2004 concentrations of selected sediment quality measurement endpoints for station KEL-1 were well within the range of regional baseline conditions (Figure 5.13-6).

5.13.4 Benthic Invertebrate Communities

In 2004, benthic invertebrate community samples were collected from Kearl Lake (station KRL-1-10). 2004 results are presented and discussed in the context of Shipyard Lake in Section 5.7, Miscellaneous Aquatic Systems Exposed to RAMP Oil Sands Development Activities (Section 5.7.4, Benthic Invertebrate Communities).

5.13.5 Fish Populations

The 2004 RAMP Fish Population component did not include any elements in Kearl or McClelland Lakes.

5.13.6 Summary of Conditions

The RAMP aquatic resources of Kearl Lake and McClelland Lake in 2004, designated for 2004 as reference aquatic systems, were found to have similar conditions to previous years. Only one water measurement endpoint sampled in 2004 exceeded existing environmental guidelines, and all water and sediment quality measurement endpoints were within the range of expected reference conditions for aquatic systems in the RAMP FSA.

Figure 5.13-2 Kearl Lake 2004 water levels and historical context.

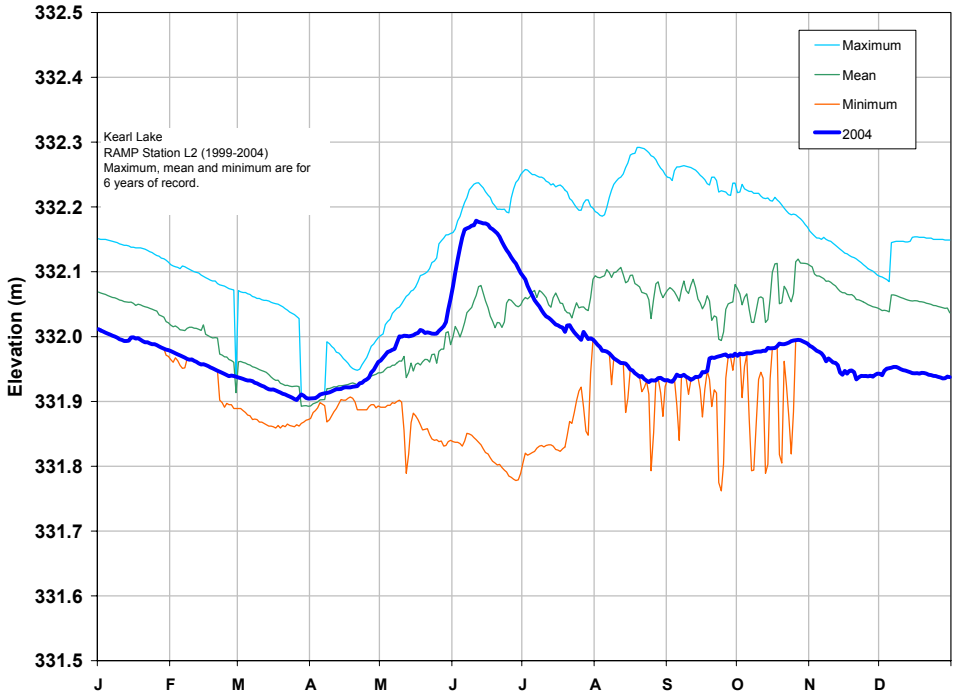


Figure 5.13-3 McClelland Lake 2004 water levels and historical context.

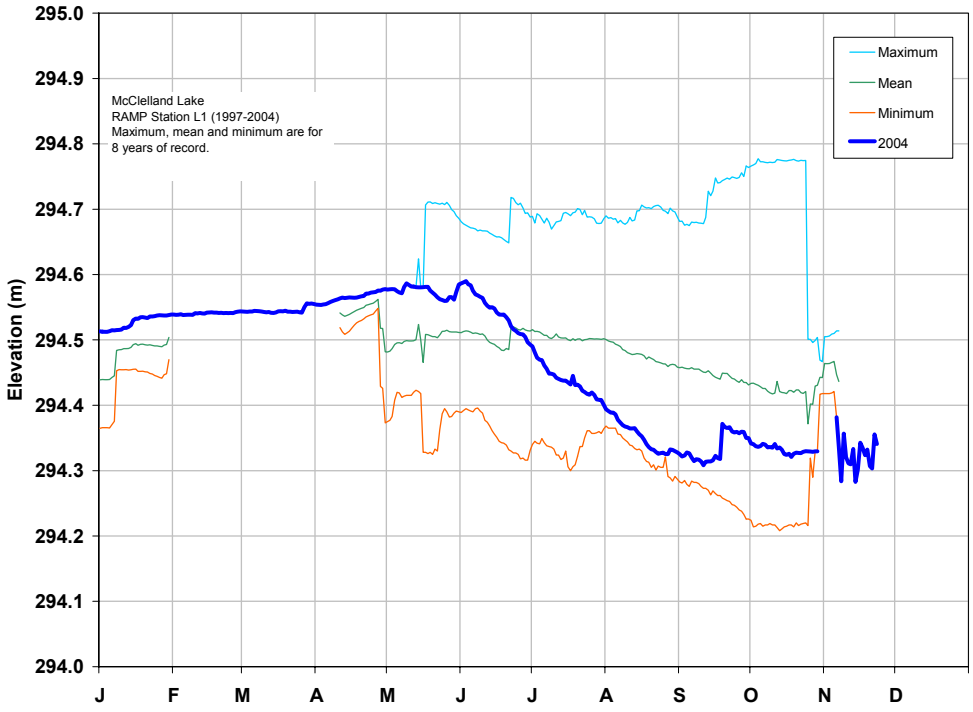
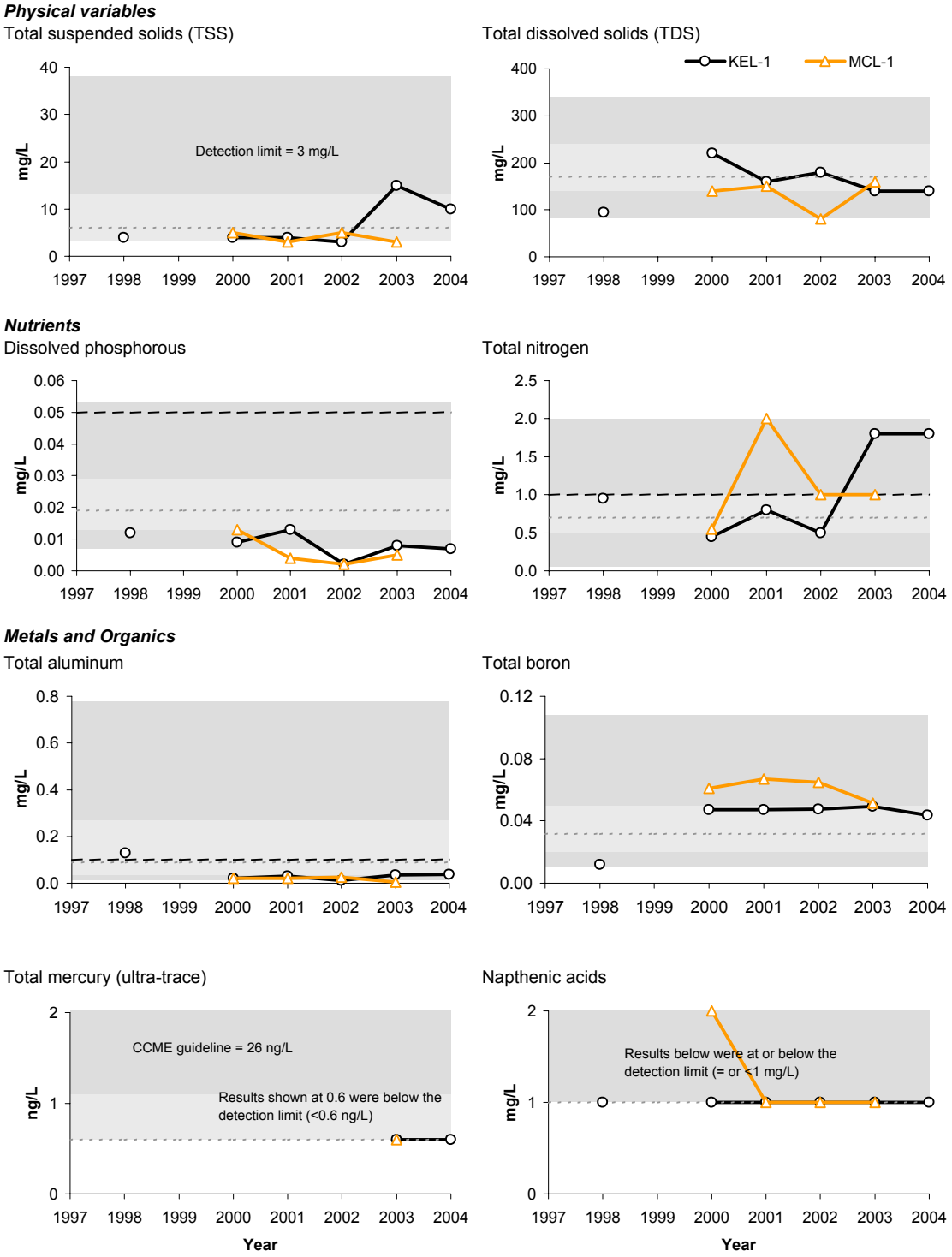


Table 5.13-1 Concentrations of water quality measurement endpoints, Kearl Lake (KEL-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
pH	pH units	6.5-9.0	8.0	5	7.7	8.0	8.1
Total suspended solids	mg/L	-	10	5	3	4	15
Conductivity	mg/L	-	169	5	165	181	183
Nutrients							
Total phosphorus	mg/L	0.05	0.03	5	0.009	0.01	0.02
Dissolved phosphorus	mg/L	0.05[1]	0.007	5	0.002	0.009	0.01
Total nitrogen*	mg/L	1.0	**1.8**	5	0.5	0.8	**1.8**
Nitrate+nitrite	mg/L	-	<0.1	5	<0.05	<0.1	<0.1
Dissolved organic carbon	mg/L	-	24	5	15	19	21
Ions							
Sodium	mg/L	-	10	5	8	10	11
Chloride	mg/L	230, 860[2]	2	5	<0.5	<1	<1
Sulphate	mg/L	100[3]	4.8	5	2.7	4.7	5.7
Total dissolved solids	mg/L	-	140	5	94	160	220
Total alkalinity	mg/L	-	82	5	79	88	93
Organic compounds							
Naphthenic acids	mg/L	-	1	5	<1	<1	1
Selected metals							
Total aluminum	mg/L	0.1	0.04	5	0.01	0.03	**0.13**
Dissolved aluminum	mg/L	0.1[1]	0.001	5	0.003	<0.01	0.03
Total boron	mg/L	1.2[3]	0.04	5	0.01	0.05	0.05
Total molybdenum	mg/L	0.073	0.0001	5	0.0001	0.0001	0.0009
Total mercury (ultra-trace)	ng/L	26	<0.6	1	-	-	<0.6
Other variables that exceeded CCME/AENV guidelines in 2004							
Total phenols	mg/L	0.004	**0.012**	5	<0.001	<0.001	**0.005**

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] U.S. EPA Guideline for Continuous and Maximum Concentration, respectively (U.S. EPA 1999).
[3] B.C. Working Water Quality Guideline (B.C. 2003).

Figure 5.13-4 Concentrations of selected water quality measurement endpoints, Kearl Lake (KEL-1) and McLelland Lake (MCL-1), relative to regional baseline conditions.



[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 E for these regional baseline ranges.

Figure 5.13-5 Piper diagram of fall ion concentrations in Kearl Lake and McLelland Lake.

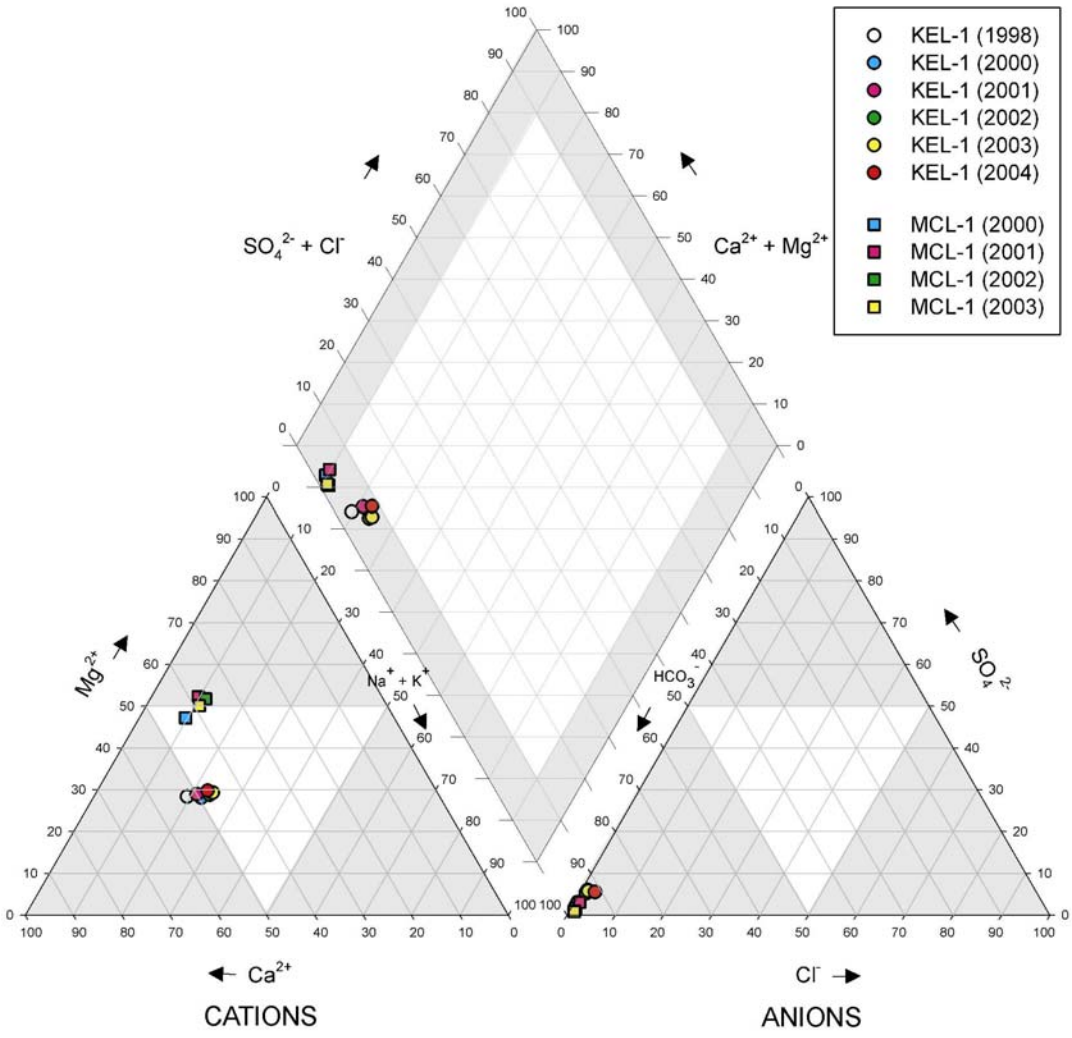


Table 5.13-2 List of all 2004 water quality guideline exceedances in Kearl Lake.

Parameter	Units	Guideline	KEL-1
Summer [1]			
Total phenols	mg/L	0.004	**0.011**
Fall			
Total phenols	mg/L	0.004	**0.012**
Total Kjeldahl nitrogen	mg/L	1.0[2]	**1.7**

Guidelines are CCME/AENV guidelines for the protection of aquatic life.
[1]: KEL-1 not sampled in winter or spring.
[2]: Guideline is for total nitrogen.

Table 5.13-3 Concentrations of sediment quality measurement endpoints, Kearl Lake (KEL-1), fall 2004.

	Units	Guideline	September 2004	1997-2003 (Fall data only)			
			Value	n	Min	Median	Max
Physical variables							
Clay	%	-	-	1	-	-	58
Silt	%	-	-	1	-	-	33
Sand	%	-	-	1	-	-	9
Total organic carbon	%	-	33.5	1	-	-	34.4
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]	230	-	-	-	-
Fraction 4 (C34-C50)	mg/kg	2800[2]	81	-	-	-	-
AEP Tier 1 variables							
TVH (C5-C10)	mg/kg	-	<0.5	1	-	-	0.5
TEH (C11-C30)	mg/kg	-	260	1	-	-	270
TRH	mg/kg	-	-	1	-	-	1600
Polycyclic Aromatic Hydrocarbons (PAH)							
Naphthalene	mg/kg	0.0346[3]	-	1	-	-	0.012
Retene	mg/kg	-	0.037	1	-	-	0.065
Total dibenzothiophenes	mg/kg	-	0.066	1	-	-	0.029
Total PAHs	mg/kg	-	1.10	1	-	-	1.05
Total HMW PAHs	mg/kg	-	0.28	1	-	-	0.47
Total LMW PAHs	mg/kg	-	0.81	1	-	-	0.58
Predicted PAH toxicity[1]	H.I.	-	-	1	-	-	0.35
Metals that exceeded CCME guidelines in fall 2004							
none	mg/kg	-	-	-	-	-	-
Chronic toxicity							
Chironomus survival	# surviving	-	-	-	-	-	-
Chironomus growth	mg/organism	-	-	-	-	-	-
Hyallela survival	# surviving	-	-	-	-	-	-
Hyallela growth	mg/organism	-	-	-	-	-	-

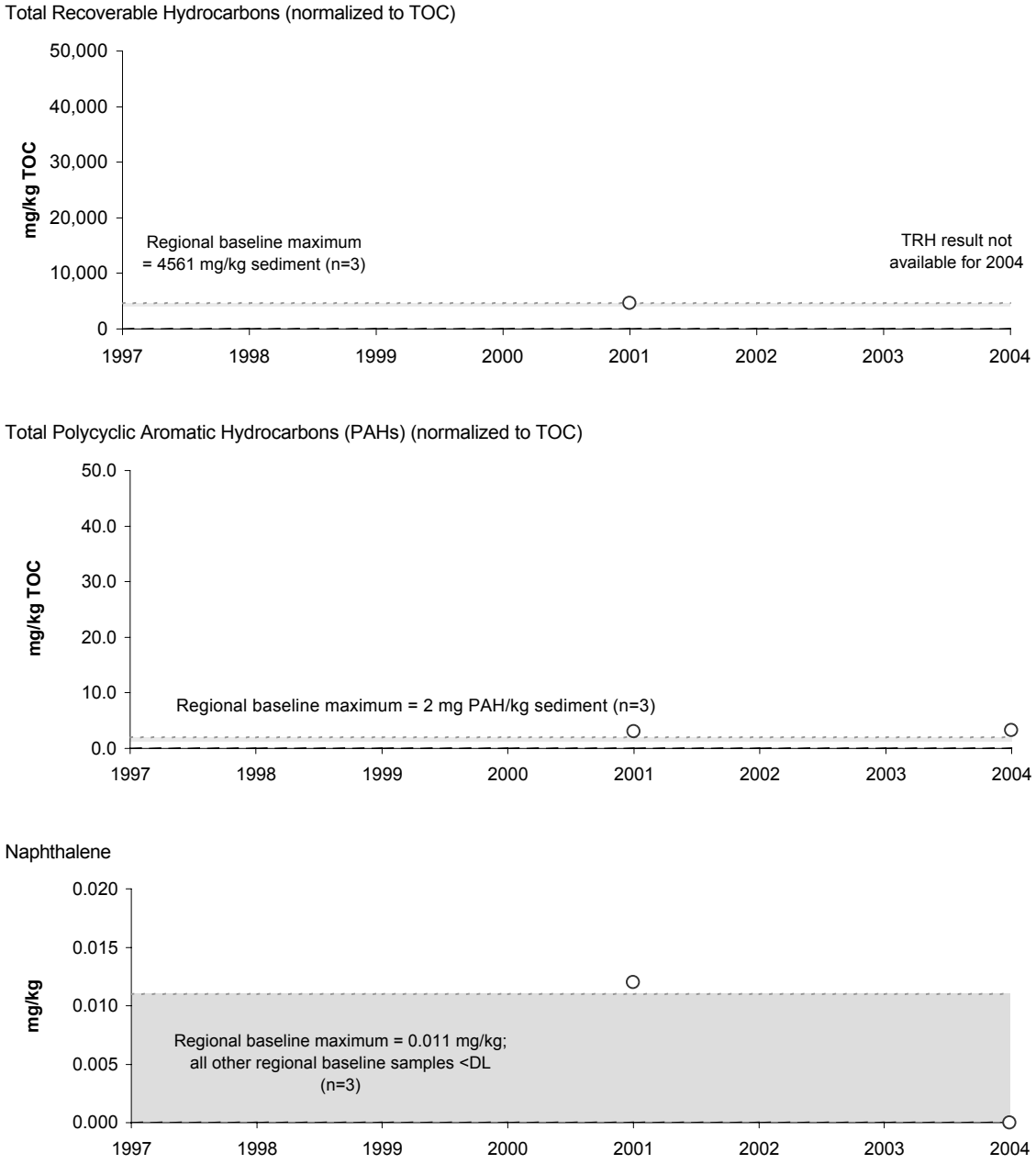
Note: unless otherwise stated, guideline values are CCME/AENV guidelines.
Values in **bold** indicate concentrations exceeding CCME/AENV guidelines.

[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 5.13-6 Concentrations of selected sediment quality measurement endpoints, Kearl Lake (KEL-1), relative to regional baseline conditions.



[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 F for these regional baseline ranges.