OIL SANDS REGIONAL AQUATICS MONITORING PROGRAM (RAMP) 2001

VOLUME I:

CHEMICAL AND BIOLOGICAL MONITORING

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Submitted to:

RAMP Steering Committee

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EXECUTIVE SUMMARY

Purpose and Scope

The Oil Sands Regional Monitoring Program (RAMP) began in 1997. It is an industry funded, long-term, multi-stakeholder initiative that assesses the aquatic environment in the Oil Sands Region of northeastern Alberta, centred around Fort McMurray. The program has been designed to identify and address potential impacts of oil sands developments and is frequently adjusted to reflect monitoring results, technological advances and community concerns. RAMP is currently funded by Albian Sands Energy Inc., Canadian Natural Resources Limited, ExxonMobil Canada Ltd., Northstar Energy Dover, OPTI Canada Inc., Petro-Canada Oil and Gas, Shell Canada Limited, Suncor Energy Inc., Oil Sands, Syncrude Canada Ltd. and TrueNorth Energy L.P.

The RAMP Steering Committee, formed in 1998 as the decision making body of RAMP, held four meetings in Fort McMurray in 2001. Highlights of 2001 include the following:

- establishing the scope of the 2002 monitoring program;
- initiating a fish tag and transmitter return network;
- communicating the fish abnormality program to the community and equipping the local environmental liaison worker with sampling equipment;
- representing RAMP at a community meeting in Fort McKay;
- issuing two RAMP newsletters;
- presenting posters and scientific papers on RAMP at the annual Aquatic Toxicity Workshop; and
- completing planned monitoring activities.

Over the last five years, RAMP has adapted to results from previous monitoring activities and on-going developments in the Oil Sands Region. It is designed as a long-term monitoring program with sampling frequencies ranging from continuous or seasonal to once every few years. RAMP has been in place since 1997; hence, five years of the program have been completed.

Climate and hydrology are reported in Volume II. The 2001 monitoring program included in this volume consists of the following main components:

- water and sediment quality in the Athabasca River, the Athabasca River Delta and some tributaries to the Athabasca River;
- water quality in four wetlands;
- continuous temperature monitoring in some tributaries to the Athabasca River;
- benthic invertebrate communities in five tributaries to the Athabasca River and two wetlands;
- fish populations, including radiotelemetry in the Athabasca and Muskeg rivers, fish inventory survey on the Muskeg River and Jackpine Creek, fish tissue collections in the Muskeg and Athabasca rivers, fish fence in the Muskeg River, sentinel species monitoring at three reference locations (Steepbank, Horse and Dunkirk rivers) and two exposure sites (Muskeg and Steepbank rivers);
- water quality in acid sensitive lakes; and
- a quality assurance/quality control program.

The RAMP regional study area covers a large portion of northeastern Alberta and includes the Regional Municipality of Wood Buffalo. The focus study area within the regional study boundaries includes watersheds where oil sands development is occurring or planned. In 2001, RAMP focused on these main aquatic systems:

- the Athabasca River and Peace Athabasca Delta;
- the tributaries to the Athabasca River including the Steepbank, Muskeg, Clearwater and MacKay rivers and McLean, Poplar, Jackpine, Stanley and Fort creeks;
- wetlands occuring in the vicinity of current and proposed oil sands developments; and
- acid-sensitive lakes in northeastern Alberta.

Water and Sediment Quality

Athabasca River Mainstem

Concentrations of the majority of water quality parameters in the fall 2001 samples from the Athabasca River and the river delta were within the historical range and were considered to be consistent with past water quality conditions. In 2001, the water quality, including metals concentrations, was generally similar in west-bank and east-bank locations on the mainstem of the Athabasca River upstream of Donald Creek, the Steepbank River and Fort Creek.

Total copper, selenium and zinc concentrations in the Athabasca River were noted specifically. Total copper levels in the mainstem above the Steepbank River were higher in 2001 than historical concentrations and exceeded the relevant chronic aquatic life guideline. Total selenium in one sample above the Muskeg River exceeded the chronic life guideline. There appears to be a trend of increasing levels of total zinc in the Athabasca River, upstream of Embarras prior to 2001. However, due to poor data quality for total zinc in 2001, this trend could not be confirmed.

Major ion concentrations appear to be increasing over time, based on fall data, in the Athabasca River upstream of the Steepbank River. Increases in other measures of major ions such as specific conductance, total dissolved solids and hardness were also reported at other sites along the mainstem.

Sediments collected from the Athabasca River in 2001 consisted principally of sand, with varying amounts of silts and clays. Parameter concentrations in sediments collected from all of the mainstem sites were, with few exceptions, consistent with or lower than those observed in sediment from previous sampling events. Total metal and polycyclic aromatic hydrocarbon (PAH) levels were lower than Canadian freshwater sediment guidelines except upstream of the Steepbank River where total arsenic and C1 substituted naphthalene concentrations were above guidelines. The arsenic concentration in the Fletcher Channel (Athabasca River delta) sample was also above the guideline. Overall, there is an increasing trend in total metal and PAH concentrations with distance downstream in 2001 sediment samples from upstream of Donald Creek to the river delta.

Sediment toxicity, as assessed by screening level designs, is quite variable from year to year and site to site. In 2001, reduced growth of *Chironomus tentans* was observed in sediment collected from the Athabasca River upstream of the Embarras River. Reduced growth and survival of *Lumbriculus variegatus* was observed in sediment from various locations on the Athabasca River in 2001, as well as Fletcher Channel in the Delta. Reduced growth of *L. variegatus*, which have been reported in previous years, may be due to the sensitivity of *L. variegatus* to the physical characteristics of the sediment, as opposed to the chemical content.

Athabasca River Tributaries

The Clearwater River, located south of Fort McMurray, was sampled upstream and downstream of the Christina River several times throughout 2001 to help characterize seasonal variability and the influence of the Christina River on water quality. Both TDS and hardness were lower in winter relative to historical records for the site below the Christina River. The Clearwater River is a moderately productive ecosystem. Total phosphorus concentrations have often exceeded the chronic aquatic life guideline in all seasons with the exception of winter, although total phosphorus concentrations were generally slightly lower at the upstream site. Concentrations of nine metals were higher than water quality guidelines, although similar exceedances have been reported in previous years. Total recoverable hydrocarbons and PAHs were not detected in 2001. Total phenolics were usually detected in all seasons and this is consistent with historical data. Comparison of Clearwater River data upstream and downstream of the Christina River suggested that the Christina River frequently had higher concentrations of major ions, TDS and some total metals. The Christina River was a seasonal source of total phosphorus, nitrogen and phenolics.

Water quality was sampled in five tributaries located north of Fort McMurray: McClean Creek, Poplar Creek, Fort Creek, the Steepbank River and the MacKay River. The 2001 data were generally similar to historical data, although there are variations above and below historical values. Major ions and related parameters at the mouth of McLean Creek, Poplar Creek and the Steepbank River were generally higher than historical median levels. Chloride concentrations in Poplar Creek and total phenolics in the Steepbank River and Fort Creek were higher than chronic aquatic guidelines. Aluminum concentrations were higher than historical levels in the MacKay River.

Sediment quality in McLean Creek was generally consistent with that observed in previous sampling events, although there are variations both above and below the historical range. Sediments collected from the mouth of the MacKay River were substantially different from sediments collected previously. The sample contained only 15% sand, whereas previous samples were composed mainly of sand. Exposed oil sands were likely present at the mouth of this river and included in the sample. Total metals and PAH concentrations in 2001 were higher than levels reported previously; however, all concentrations were below the probable effects levels for freshwater sediments.

Water quality in the Muskeg River watershed was generally consistent with historical data, although there are variations above and below the historical range. Water in the Muskeg River upstream of Muskeg Creek was more coloured and had higher dissolved phosphorus concentrations than in previous years. Total iron concentrations exceeded the chronic aquatic life guideline and the human health guideline as it had in previous years.

The water quality in the Muskeg River downstream of Jackpine Creek and upstream of Muskeg Creek was monitored once per season in 2000 and 2001. Seasonal trends in water quality in the Muskeg River upstream of Muskeg Creek were not consistent in 2000 and 2001.

Sediment concentrations of all parameters measured in 2001 at the mouth of the Muskeg River were below Canadian freshwater sediment quality guidelines, although total extractable hydrocarbon and total inorganic carbon levels were higher in 2001 than in previous sampling events. A trend of increasing chromium and manganese that had been observed since 1997 was reversed in 2001.

Wetlands

Water samples were collected from Kearl, Isadores’s, Shipyard and McClelland lakes. Water quality was generally consistent across the two seasons and within the range of historical data, although the data set is quite limited. Total phosphorus concentrations appear to be lower in Kearl Lake in the past several years, while total phosphorus concentrations were above water quality guidelines for the first time in Isadore’s Lake. Some major ion concentrations appear to be increasing slightly over time in Shipyard Lake. Total copper concentrations were higher than aquatic guidelines in both Isadore’s and Shipyard lakes in the summer and fall of 2001. With few exceptions, sediment characteristics in Isadore’s lake were similar to those observed in Shipyard Lake in terms of organic content, PAH levels and metal concentrations. Sediments from Kearl Lake tended to have lower metal concentrations than the other three wetlands.

Benthic Invertebrate Community

The benthic invertebrate component of RAMP included the second year of monitoring using a consistent sampling design for Shipyard Lake and three tributaries, the MacKay, Muskeg and Steepbank rivers, as well as the first year of monitoring in the Clearwater River, Fort Creek and Kearl Lake. Tributaries and wetlands were sampled in September and October, 2001; the mainstem of the Athabasca River was not sampled in 2001. The objective of the 2001 program was to further characterize natural variation before intensive oil sands development occurs within the drainage basins.

The Clearwater and Muskeg rivers were sampled at two locations each while the other tributaries were sampled only near their mouths. The Clearwater River was sampled upstream and downstream of the Christina River. Although the community composition, based on common taxa, and the total abundance were similar between the two locations, total taxonomic richness was substantially higher in the upstream reach. In 2001, the Muskeg River continued to support the most diverse fauna compared to the other tributaries with over 70 taxa in each habitat and a total of 105 taxa when both the erosional and depositional habitats were combined. The total abundance was greater in the depositional habitat of the Muskeg River.

The total abundance and taxonomic richness were similar for the MacKay and Steepbank rivers. The benthic communities were significantly correlated with habitat variables in these rivers although only erosional habitats were sampled in both rivers. The Fort Creek community had a lower richness compared to the MacKay and Steepbank rivers due to the difference in habitat (depositional versus erosional).

Kearl Lake communites were characterized by low total abundance and low mean richness, although the total richness was similar to Shipyard Lake. When Shipyard Lake data were compared to the previous year's data, both abundance and richness of the benthic community declined considerably in Shipyard Lake in 2001. The decline may be related to low dissolved oxygen concentrations resulting from the decay of large aquatic plants.

Fish Populations

Generally, the 2001 program to monitor fish populations consisted of the following:

- completion of the radiotelemetry study initiated during the RAMP 2000 program focussing on longnose sucker and northern pike;
- collection of tissue samples from fish in the Athabasca and Muskeg rivers for analysis of contaminants;
- tributary sentinel species monitoring to assess the health of slimy sculpin populations in the Muskeg and Steepbank rivers;
- a fish fence study to evaluate species composition and abundance for populations utilizing the Muskeg River Basin; and
- a general fish inventory for the Muskeg River and Jackpine Creek.

The radiotelemetry study was initiated to: 1) evaluate the mobility of longnose sucker utilizing the Athabasca and Muskeg rivers and its suitability as a sentinel species for the Oil Sands Region; 2) evaluate the mobility of northern pike within the lower Muskeg River and Athabasca River; and 3) identify overwintering locations for both species. The 2001 portion of the radiotelemetry study included monitoring fish movements from December to June to provide a full year of movement data (in combination with monitoring from 2000).

Twenty-five longnose sucker were radio-tagged and released near Mountain Rapids in the Athabasca River during May 2000. Three were later confirmed dead. The Athabasca River spawning sub-population of longnose sucker appears to use the mainstem river in the Oil Sands Region primarily as a spring migration route to and from the spawning site at Mountain Rapids located upstream of Fort McMurray. The majority (16 out of 22) of the radio-tagged fish were only recorded in the survey area during spring spawning. Five of these fish returned to the rapids area the following spawning season in 2001. A smaller proportion (6 out of 22) remained in the Athabasca River basin for a prolonged time, particularly in the fall and winter.

Twenty-five longnose sucker and 25 northern pike were radio-tagged in the Muskeg River in May 2000. Eight longnose sucker and eight northern pike were confirmed dead. Fish of both species that spawned in the Muskeg River exhibited greater use of the Athabasca River Basin. Eleven of the 17 radio-tagged longnose sucker and 12 of the 17 northern pike are known or believed to use the Athabasca River or its tributaries during much of the year.

Muscle tissue samples were collected from lake whitefish and walleye from the Athabasca River and northern pike from the Muskeg River and analyzed for concentrations of organic and inorganic contaminants. PAHs were not detected in the composite flesh samples of northern pike, lake whitefish or walleye in the fall of 2001. Metal concentrations in muscle tissue for northern pike, lake whitefish and walleye were found to be below those reported to be linked with effects on growth and survival of fish. However, the available experimental data for copper are inconclusive making it difficult to assess the potential effects of the measured concentrations of copper.

A comparison of the fish tissue concentrations with fish consumption guidelines indicated no exceedences of the Health Canada guideline for occasional consumption (0.5 mg/kg). However, the concentration of mercury was close to the occasional consumption guideline in one female walleye sample and above the guideline for subsistence (frequent) consumption in both walleye samples. These results likely indicate the natural variability in mercury concentrations in fish inhabiting this region.

The tributary sentinel species component involved monitoring population and health parameters for a small-bodied fish species exposed to Oil Sands Region activities, in comparison to reference populations outside the development area, as an indicator of ecosystem health. Populations of slimy sculpin in the lower Muskeg River and lower Steepbank River were evaluated in comparison to other tributary populations.

Gonad size in male fish at exposure sites on the Steepbank and Muskeg rivers was significantly lower than gonad size at reference sites. The reason for the smaller gonad size is unknown; it may be due to differences in habitat characteristics between exposure and reference sites. Gonad size in both sexes also appears to decrease over time at both exposure sites. The smaller gonad size in females combined with an apparent increase in fecundity indicates a decrease in egg size, which may reduce embryo survival and hatchability. The fecundity measurement method was changed during this interval; therefore, decreasing egg size must be confirmed using the new method.

The fish fence study utilized a two-way counting fence in the lower Muskeg River to monitor the species composition and abundance of fish migrating into the river basin in the early spring. The fish species targeted were the adult size-classes of key Athabasca River fish species known to ascend the Muskeg River in the spring. In total, 128 fish consisting of white sucker (79 fish), northern pike (35), longnose sucker (12), lake chub (1) and brook stickleback (1) were captured. Although targeted for the study, Arctic grayling were not observed in either the upstream or downstream trap. The total number of fish captured at the fish fence between April 28 and May 26, 2001 was limited due to difficulties in maintaining both the integrity of the fence and complete blockage of the river due to poor substrate characteristics and high flows. The two-way counting fence was fully operational for only 16 of the 29 days of the study. Due to losses in fence integrity, the 2001 fish fence study did not meet the objectives of determining the size of the spring spawning run and the relative abundance of fish species utilizing the Muskeg River basin.

The purpose of the general fish inventory was to monitor species presence, relative abundance and community structure. As part of the 2001 RAMP survey, inventories were conducted in the Muskeg River basin, including the lower Muskeg River and lower Jackpine Creek. The rationale document (Golder 2000a) called for a population estimate study for these two watercourses in 2001, with the study specifically targeting young-of-the-year and juvenile Arctic grayling. However, the Muskeg River spring fish fence study and a short summer angling program both suggested that a spawning run of Arctic grayling did not occur in 2001. Because no Arctic grayling were captured, it was decided to conduct a general fish inventory program during the summer of 2001 rather than the Arctic grayling population estimate study originally planned. Ten fish species were identified in the Muskeg River including sport fish (15% of total), sucker species (36% of total) and small-bodied species (49%). The most abundant species were longnose sucker, trout-perch, emerald shiner and white sucker with catch-per-unit–effort values (CPUE) between 1.18 and 0.76 fish/100 seconds. The CPUE increased in 2001 compared the CPUE in 1997 for all species except Arctic grayling and white suckers.

Backpack electrofishing and minnow trapping were equally effective for sampling Jackpine Creek. Seven fish species were recorded in Jackpine Creek during the summer inventory, including one sport species (one northern pike), one sucker species (11 longnose sucker) and five small-bodied species (93.8% of fish recorded). Lake chub were the most abundant species (85.4%).

Wetlands

The first three years of data collection on Shipyard Lake, Isadore’s Lake and Kearl Lake provide a good baseline for future comparison. Given the need to transition this survey into one that describes quantitative as well as descriptive parameters, these data also help describe community composition at the start of the monitoring program. Further, 2001 sampling showed that water chemistry between the lakes is very similar despite the fact that the wetlands communities are different between the lakes. These similarities and differences may provide insight with respect to changes between the lakes in the future.

Shipyard Lake is a very homogenous lake, given that a large number of plots were very similar in both the Jaccard’s Index and the Bray-Curtis Index. It has a large coverage of a single species of vegetation. In comparison to the other two lakes, it appears to be the most productive of the three lakes but that productivity is due to few species. The lake wetlands are classified as predominately marshes and this classification indicates a fairly nutrient-rich substrate.

Isadore’s Lake has a large number of species and there is a great deal of diversity in the vegetation cover classes. The lake is surrounded by varying wetlands types but is primarily swamp and fen (peatland). Despite being surrounded by peatland wetlands types, the water quality is not significantly different from non-peatland. There is a moderate degree of similarity between plots within the lake.

Kearl Lake has peatland surrounding the lake but there is less diversity both in species number and wetlands types. Kearl Lake is surrounded by upland, unlike the other two lakes that are along the Athabasca River. It is surrounded by shrubby and graminoid fens with a cover of healthy graminoids and shrubs.

Although moss vigour was assessed as poor, this assessment may be due to poor coverage rather than vigour problems. Kearl Lake had the lowest percent cover by group and by species of plants but had a moderate total number of species. Kearl Lake had the lowest similarity between plots within the lake in both the Jaccard's Index and the Bray-Curtis Index.

Acid Sensitive Lakes

Water samples were collected from 32 acid sensitive lakes in northeastern Alberta, as part of the third year of monitoring under RAMP. Acidity-related variables (pH, alkalinity, bicarbonate/divalent cations ratio) showed no indication of changes related to acidification in 2001 compared to previous data. At this time, the available data are insufficient to evaluate trends over time.

Quality Assurance/Quality Control

The results of the RAMP QA/QC assessment indicate that the water and sediment quality, benthic invertebrate communities and fish populations data are valid, with the exception of water quality data for total zinc. Results of each component of the assessment are presented in Section 4.

ACKNOWLEDGEMENTS

This report documents the results of the fifth year of the Oil Sands Regional Aquatics Monitoring Program (RAMP). Funding was provided by Albian Sands Energy Inc. (Albian), Canadian Natural Resources Limited (CNRL), ExxonMobil Canada Ltd. (ExxonMobil), Northstar Energy Dover (Northstar), OPTI Canada Inc. (OPTI), Petro-Canada Oil and Gas (Petro-Canada), Shell Canada Limited (Shell), Suncor Energy Inc. (Suncor), Syncrude Canada Ltd. (Syncrude) and TrueNorth Energy L.P (TrueNorth). In kind support was provided by Syncrude, OPTI and Alberta Environment (AENV). Syncrude provided a boat, along with personnel for the fish tissue collection in the fall on the Athabasca River. OPTI employees collected water quality samples from Birch, Canoe, Caribou, Frog, Kiskatinaw, Long, Poison, Pushup, Rat, Sucker and Unnamed lakes 1, 2 and 3. AENV collected samples for the Acid Sensitive Lake project. Sediment Quality Assurance/Quality Control (QA/QC) data for several monitoring stations was also provided by AENV.

Terry Van Meer was the RAMP Chairperson and Ken Shipley was the Vice-Chairperson. John Gulley was the Secretary and the Project Director. The Golder Associates Ltd. (Golder) Project Manager was Marie Lagimodiere until May 2001. Kym Fawcett took over as Project Manager in June 2001.

RAMP is a multi-stakeholder program composed of representatives from industry, provincial and federal governments, local aboriginal groups and environmental organizations. RAMP benefits from the active participation of its member organizations. Several positive collaborations were achieved in 2001 and are reviewed below:

Winter fish habitat surveys were performed on the Athabasca and Gregoire rivers by Ken Allen (Golder), Tony Calverley (Golder), Laura Mucklow (Golder), Pat Marlowe (Golder) and Richard Cardinal (Fort McMurray). The radio telemetry tracking program for northern pike and longnose suckers that had began in 2000 was completed in the Spring of 2001 by Chris Bjornson (Golder), Melanie Ezekiel (Syncrude), Cory Stiffers (RL&L) and Larry Rude (Fisheries and Wildlife). A spring fish fence inventory program was conducted on the Muskeg River by Ken Allen (Golder), Kris Driscoll (Golder), Melanie Ezekiel (Golder), Chris Davis (Golder), Gary Cooper (Fort McKay) and David Boucier (Fort McKay). Ken Allen (Golder), Charity Beres (Golder) and Gary Cooper (Fort McKay) conducted a fish population estimate and community inventory on Jackpine Creek and Muskeg River during the summer. The fall fisheries program was performed by Lynda Gummer (Golder), Tony Calverley (Golder), Erin James (Golder), Rick Baldwin (Golder) and Melanie Ezekiel (Golder) with help from Terry Van Meer (Syncrude), Joanne Hogg (Syncrude), Neil Rutley (Syncrude), Larry Rhude (ASRD) and Janice Linehan (ASRD). Fish ageing

samples were analyzed by ageing specialist Jon Tost of North Shore Environmental Services, Ontario.

Winter water quality samples were taken by Ken Allen (Golder), Richard Cardinal (Fort McMurray), Pat Marlowe (Golder) and Jane Elser (Golder). Ken Allen (Golder) and Melanie Ezekiel (Golder) conducted the spring water quality collection. Summer water quality collections were made by Ken Allen (Golder), Charity Beres (Golder), Veronica Chisholm (Golder), Tony Calverley (Golder), and Kris Driscoll (Golder). Veronica Chisholm (Golder), Tony Calverley (Golder) and Kelly Gurski (Golder) surveyed vegetation in the wetlands. The fall water, sediment and benthic invertebrate sampling was conducted by Lynda Gummer (Golder), Tony Calverley (Golder), Erin James (Golder), Rick Baldwin (Golder), Melanie Ezekiel (Golder), Ken Allen (Golder) and Jane Elser (Golder). Kym Fawcett (Golder) and J.P. Bechtold (Golder) collected fall water and sediment samples from the Athabasca Delta with assistance from Joe Adams (Athabasca Chipewyan First Nation) and Fred (Jumbo) Fraser (Fort Chipewyan). Benthic invertebrate samples were analyzed for abundance and taxonomic composition by J. Zloty, Ph.D., Calgary, Alberta.

Fall sampling in the Athabasca Delta channels was done by Kym Fawcett (Golder) and J.P. Bechtold (Golder), with assistance from Joe Adam (Athabasca Chipewyan First Nation). Water and sediment sampling of the lower Athabasca River at Embarras was done by Jumbo (Fred) Fraser, J.P. Bechtold (Golder) and Kym Fawcett (Golder).

The RAMP acid sensitive lake monitoring program was undertaken by Alberta Environment (AENV) with David Trew (AENV) and Scott Flett (AENV) conducting the field survey.

The following Golder team members prepared sections of this report:

Executive Summary	Pat Tones Kym Fawcett
Introduction	Kym Fawcett John Gulley (technical review)
Climate and Hydrology Summary	Nathan Schmidt Dejiang Long (technical review)
Quality Assurance/Quality Control	Tanis Dirks J.P. Bechtold (technical review) Kym Fawcett (technical review) Zsolt Kovats (technical review)

Water and Sediment Quality	J.P Bechtold (task manager) Tania Baxter Abe House Sarah Crabbe Mark Digel (technical review)
Fisheries	Chris Bjornson (task manager) Lynda Gummer Gord Walder Charity Beres Jack Patalas (technical review)
Benthic Invertebrates	Zsolt Kovats (task manager) Mark Dunnigan (technical review) Pat Tones (technical review)
Firebag Baseline Sampling	J.P. Bechtold (task manager) Abe House Mark Digel (technical review)
OPTI Lakes Water Quality	J.P. Bechtold (task manager) Tania Baxter Mark Digel (technical review)
Acid Sensitive Lakes	Zsolt Kovats (task manager) Mark Digel (technical review)
Summary and Conclusions	Pat Tones Kym Fawcett (technical review)

Jack Patalas, Jim O'Neil, Pat Tones and John Gulley provided senior editorial review and Janelle Woods, Rene Daub and Carole Collins formatted the report.

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1 INTRODUCTION

Since the mid-1990's, tremendous growth has occurred in northeastern Alberta, resulting from oil sands development and other developments. Such growth highlights the need to integrate environmental monitoring activities so that potential cumulative effects can be identified and addressed. This coordination of data collection results in the development of a more complete, cost-effective database that may be used by oil sands operators for their environmental management programs and by project proponents and reviewers for assessments of proposed oil sands developments.

The existing, approved and planned oil sands developments as of December 31, 2001 are shown on Figure 1.1. Table 1.1 highlights the production capacity, development area and the type of operation of the existing, approved and planned oil sands developments in the region.

Monitoring data pertaining to the aquatic environment are collected through the Oil Sands Regional Aquatics Monitoring Program (RAMP). RAMP is a multi-stakeholder initiative, currently funded by Albian Sands Energy Inc. (Albian), Canadian Natural Resources Limited (CNRL), ExxonMobil Canada Ltd. (Exxon), Northstar Energy Dover (Northstar), OPTI Canada Inc. (OPTI), PetroCanada Oil and Gas (Petro-Canada), Shell Canada Limited (Shell), Suncor Energy Inc., Oil Sands (Suncor), Syncrude Canada Ltd. (Syncrude), and TrueNorth Energy L.P. (TrueNorth). Figure 1.2 shows the RAMP organizational structure.

The mandate of RAMP, as defined by its multi-stakeholder Steering Committee, is to monitor, evaluate, compare, review and communicate the state of the aquatic environment in the Athabasca Oil Sands Region. RAMP incorporates both traditional knowledge and scientific methods. RAMP is designed as a long-term monitoring program with sampling frequencies that range from continuous or seasonal to once every few years.

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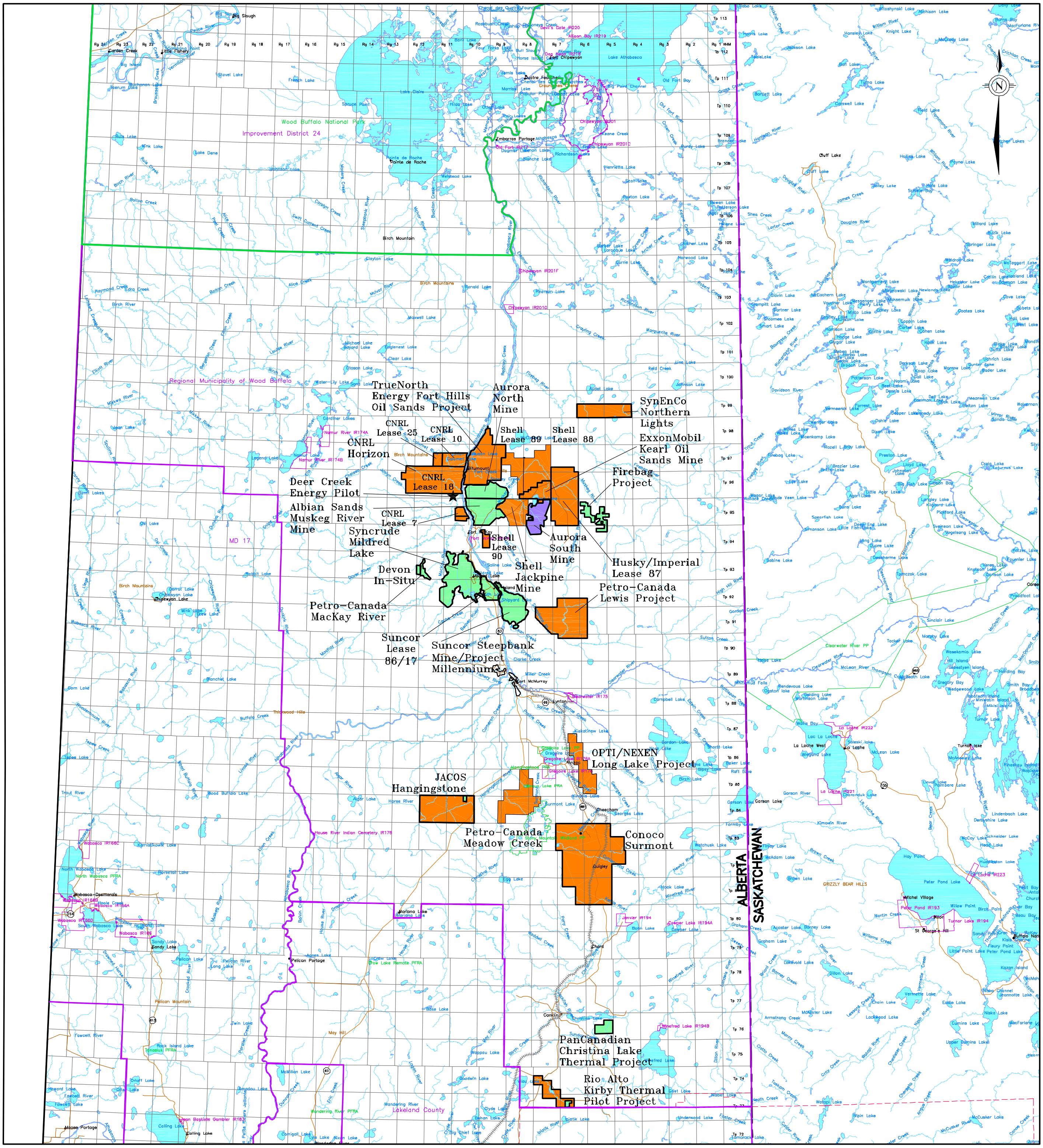

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SCALE KILOMETRES

LEGEND

EXISTING and APPROVED DEVELOPMENTS

PLANNED DEVELOPMENTS

EUB APPROVED DEVELOPMENT

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUGUST 2001. NAD 83 ZONE 12. SHEETS 74D, E AND 74L IN NAD 27 ZONE 12.
SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG. 2001. NAD 83 ZONE 13.
ALL DATA CONVERTED TO NAD 83 UTM ZONE 12.
OIL & GAS AND ENVIRONMENTAL DATA PROVIDED BY VERITAS GeoSERVICES LTD., CURRENT AS OF MAY 2001.

PROJECT

RAMP 2001

TITLE

EXISTING, APPROVED, AND PLANNED DEVELOPMENTS IN THE OIL SANDS REGION

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	Existing-Planned
DESIGN			SCALE AS SHOWN	REV. 1
CADD	RFM	17/05/02		
CHECK	KF	17/05/02	FIGURE: 1.1	
REVIEW				

Table 1.1 Athabasca Oil Sands Production for Existing, Approved and Planned Developments

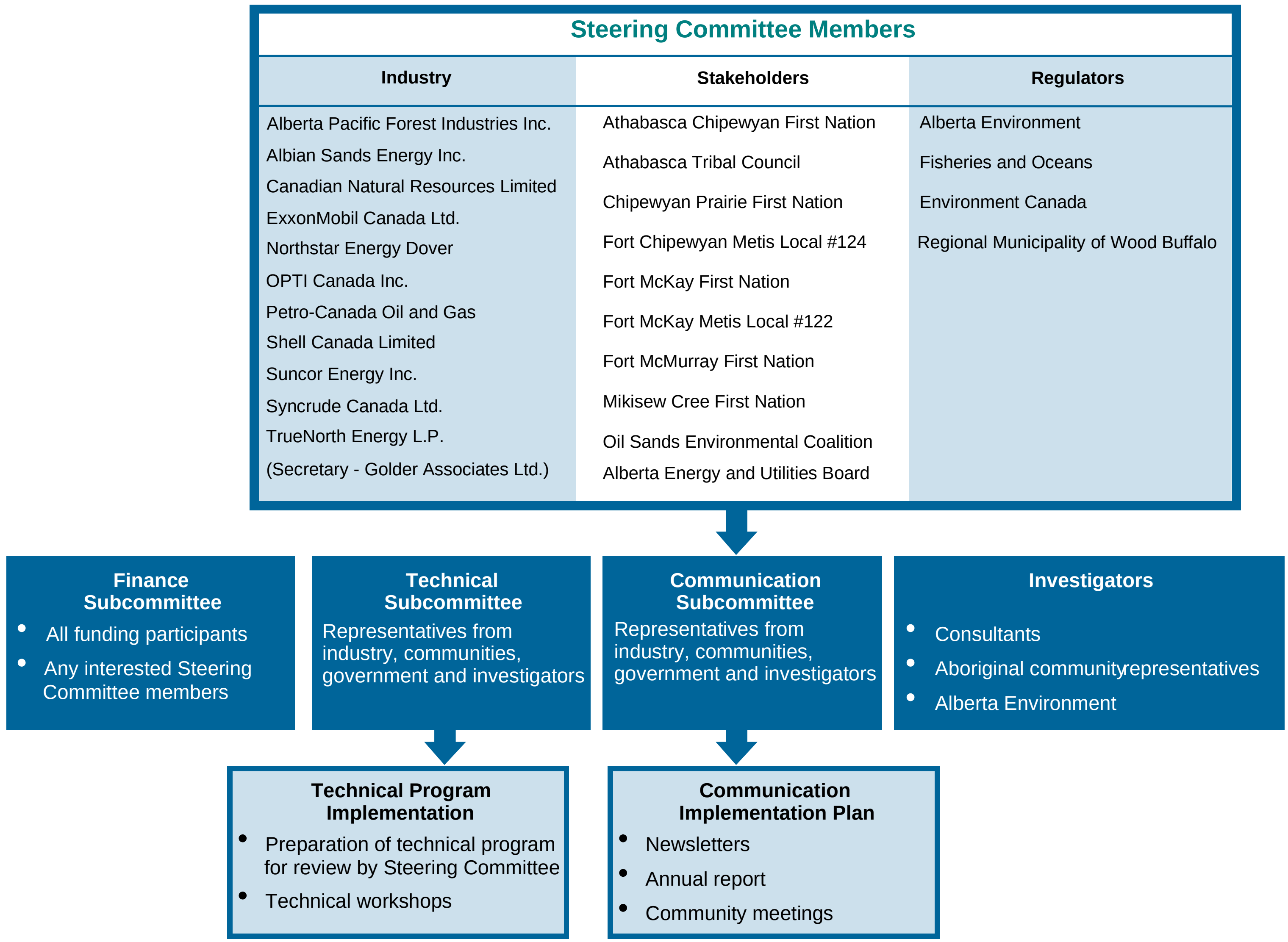
Oil Sands Development	Location	Capacity (bpd)[a]	Development Area (ha)[b]	Type of Operation	Status
Suncor Energy Inc.					
Upgrader Complex	30 km north of Fort McMurray	450,000 S	14,899	processing	approved
Lease 86/17, Steepbank and Millennium Mines	30 km north of Fort McMurray	N/A	3,399	open pit	approved
Firebag Project	40 km northeast of oil plant	140,000 B	1,105	in-situ	planned
Firebag Pilot Project	40 km northeast of oil plant	1,200 B	369	in-situ	approved
Voyageur	25 km north of Fort McMurray	550,000 B	NYD	processing	planned
Syncrude Canada Ltd.					
Mildred Lake Upgrader	45 km north of Fort McMurray	480,000 S	21,000	processing	approved
North Mine	60 km north of Fort McMurray	160,000 B	100	open pit	approved
Aurora North	east side of Athabasca River	200,000 B	7,700	open pit	approved
Aurora South	east side of Athabasca River	200,000 B	NYD	open pit	EUB approved
Albian Sands Energy Inc.					
Muskeg River Mine	75 km north of Fort McMurray	155,000 B	4,343	open pit	approved
Shell Canada Limited					
Jackpine Mine (Phase 1)	east portion of lease 13	200,000 B	8,474	open pit	planned
Lease 88 & 89 (Phase 2)	north of Jackpine Mine	100,000 B	7,105	open pit	planned
Conoco (formerly Gulf)					
Surmont	60 km SE of Fort McMurray (Wood Buffalo Municipality)	100,000 B	567	in-situ	approved pilot planned commercial
Northstar Energy Dover					
Old UTF	90 km north of Fort McMurray	2,000 B	22	in-situ	approved
PanCanadian Petroleum					
Christina Lake	170 km south of Fort McMurray	85,000 B	527	in-situ	approved
JACOS					
Hangingstone	25 km west of Anzac, 50 km southwest Fort McMurray	10,000 B	631	in-situ	approved pilot planned commercial
Petro-Canada Oil and Gas					
MacKay River	60 km northwest of Fort McMurray	30,000 B	170	in-situ	approved
Meadow Creek	45 km south of Fort McMurray	80,000 B	1,181	in-situ	planned
Lewis Project	30 km northeast of Fort McMurray in Steepbank area	50,000 B	1,000	in-situ	planned

Table 1.1 Athabasca Oil Sands Production for Existing, Approved and Planned Developments (continued)

Oil Sands Development	Location	Capacity (bpd)[a]	Development Area (ha)[b]	Type of Operation	Status
OPTI Canada Inc.					
Long Lake Pilot Project	40 km southeast of Fort McMurray	3,800 B	10	in-situ	planned
Long Lake Project	40 km southeast of Fort McMurray	140,000 S 70,000 B	884	in-situ	planned
ExxonMobil Canada Ltd.					
Kearl Mine	70 km north of Fort McMurray	165,000 S	5,336	in-situ	planned
Upgrader	70 km north of Fort McMurray	185,000 B	NYD	processing	planned
TrueNorth Energy L.P.					
Fort Hills	90 km north of Fort McMurray	190,000 B	12,000	open pit	planned
Canadian Natural Resources Limited (CNRL Horizon) [c]					
In-Situ Extraction	west side of lease 18	100,000 B	15,000 [c]	in-situ	planned
Open Pit Mining	80 km north of Fort McMurray	270,000 B	26,881	open pit	planned
Rio Alto Exploration					
Kirby Project	85 km northeast of Lac la Biche	30,000 B	190	in-situ	planned
Kirby Pilot	85 km northeast of Lac la Biche	1,600 B	3	in-situ	approved
SynEnCo [c]					
Northern Lights Project	100 km northeast of Fort McMurray on Firebag River	85,000 S	7,138 [c]	in-situ	planned

(a) Barrels per day (bpd) of B = Bitumen; S = Synthetic Crude or pipelineable crude; bpd values are rounded off.
(b) Development areas are those that will result from the existing approved and planned operations. Areas represent the maximum disturbance footprint for terrestrial resources.
(c) Numbers based on preliminary estimates.
n/a = not applicable.
NYD = not yet determined.

Figure 1.2 RAMP Organizational Chart



The objectives of RAMP are:

- to monitor aquatic environments in the oil sands area to detect and assess cumulative effects and regional trends;
- to collect scientifically defensible baseline and historical data to characterize variability in the oil sands area;
- to collect data against which predictions contained in environmental impact assessments (EIAs) can be verified;
- to collect data that may be used to satisfy the monitoring required by regulatory approvals of developments in the oil sands area;
- to recognize and incorporate traditional knowledge (including Traditional Ecological Knowledge and Traditional Land Use Studies) into the monitoring and assessment activities;
- to communicate monitoring and assessment activities, results and recommendations to communities in the Regional Municipality of Wood Buffalo, regulatory agencies, environmental committees/organizations and other interested parties;
- to design and conduct various RAMP activities such that they have the flexibility to be adjusted, on review, to reflect monitoring results, technological advances and community concerns; and
- to seek cooperation with other relevant research and monitoring programs where practical, and generate interpretable results which can build on their findings and on those of historical programs.

RAMP began monitoring in 1997; hence, five years of sampling have been completed. The RAMP regional study area covers a large portion of northeastern Alberta and includes the Regional Municipality of Wood Buffalo. The focus study area within the regional study boundaries includes watersheds where oil sands development is occurring or planned. In 2001, RAMP focused on these main aquatic systems:

- the Athabasca River and Peace Athabasca Delta;
- the tributaries to the Athabasca River including the Steepbank, Muskeg, Clearwater and MacKay rivers and McLean, Poplar, Jackpine, Stanley and Fort creeks;
- wetlands occurring in the vicinity of current and proposed oil sands developments; and
- acid-sensitive lakes in northeastern Alberta.

Sampling conducted to date includes surveys of water quality, sediment quality, benthic invertebrates, fish, wetlands vegetation, climate and hydrology. Climate and hydrology results are summarized in Section 2.4 of this volume and are reported in detail in Volume II of this report.

This report describes the results of the 2001 field program for water and sediment quality, benthic invertebrates, wetlands vegetation and fish. The results include data collected for RAMP but do not generally include data from other sampling programs in the region. Exceptions include information from Albian and Syncrude's joint monitoring program for the Muskeg River, continuous monitoring data from Alberta Environment (AENV) for the Muskeg River and AENV's water quality data for selected sites; these results are included.

The RAMP program design and rationale is described in the following document: "Oil Sands Regional Aquatic Monitoring Program (RAMP) Program Design and Rationale" (Golder 2000a). This document was developed by the RAMP Technical Subcommittee.

The following publications were also produced by RAMP in the past year:

- RAMP Summary 2000 (Golder 2002a); and
- Oil Sands Regional Aquatic Monitoring Program (RAMP) Newsletters: February 2001 (Volume 3, Issue 1) and October 2001 (Volume 3, Issue 2).

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2 2001 MONITORING APPROACH

2.1 APPROACH

The impacts of human activities on aquatic systems have been traditionally evaluated by monitoring water quality and comparing the measured chemical concentrations with guidelines. Although water quality monitoring is a key component of aquatic monitoring programs, it may not yield a complete understanding of potential effects because it cannot detect effects on aquatic life caused by unmeasured chemicals, mixtures of chemicals or by physical habitat alteration. Therefore, it is also important to monitor biological communities that integrate the effects of these complex and varied stressors on a variety of receptors (e.g., fish, benthic invertebrates, wetlands vegetation).

RAMP is a receptor-oriented monitoring program, which stresses the collection of biological data relevant to the assessment of effects on the aquatic ecosystem. Sensitive biological indicators were chosen in addition to traditional, chemistry-based monitoring to allow early detection of potential effects related to oil sands developments. The collection and analysis of data on these effects will allow the implementation of appropriate mitigation if effects that negatively impact aquatic ecosystems are detected.

The 2001 monitoring program was a continuation of long-term monitoring that began in 1997. It consisted of four main components:

- Water and sediment quality in rivers and some wetlands, which serve as indicators of habitat quality and potential chemical exposure of fish and invertebrates. Water and sediment quality are assessed by chemical analyses and toxicity bioassays.
- Benthic invertebrate communities in tributaries and wetlands, which are bioindicators of cumulative effects.
- Fish populations in rivers, which serve as bioindicators of ecosystem integrity. The emphasis is on regional fish resources and sentinel species.
- Water quality in acid sensitive lakes, which is used as an early-warning indicator of potential effects from acid deposition.

To effectively evaluate aquatic ecosystems within the Oil Sands Region, RAMP has focused on four main aquatic systems that may be affected by development activities: 1) Athabasca River; 2) tributaries of the Athabasca River; 3) lakes and wetlands adjacent to developments; and 4) acid sensitive lakes.

The following sections discuss the approach followed by each monitoring component. Details on study design, sampling locations and methods are described in Section 3.

2.1.1 Water and Sediment Quality

Analysis of water and sediment chemistry provides a direct measure of the suitability of a waterbody to support aquatic life. Changes in water and sediment quality may indicate chemical inputs from point and non-point sources. Measured concentrations of chemicals are compared with water and sediment quality guidelines designed to protect aquatic life. Monitoring of sediment quality enables the assessment of the rate of chemical accumulation over time and identification of potential pathways by which aquatic biota may be exposed to hydrophobic chemicals (e.g., polycyclic aromatic hydrocarbons [PAHs]). Therefore, water and sediment quality surveys also provide valuable supporting data to interpret the results of biological surveys.

In order to determine if and how a development may be affecting water and sediment quality, an upstream site is selected to act as a reference for comparison with downstream results. In the Athabasca River and its tributaries and wetlands in the lower Athabasca River Watershed, water and sediment sampling sites were selected to provide upstream reference water quality information or assess the direct or cumulative effects of oil sands developments.

Existing RAMP water quality sites are monitored annually in the fall and periodically in winter, because water levels and the assimilative capacity of the receiving waterbodies are generally at their lowest in fall and winter. One year of seasonal sampling is conducted at new locations in waterbodies already monitored by RAMP and three years of seasonal baseline information is collected at new sites in new waterbodies added to RAMP.

Existing RAMP sediment quality sites in the Athabasca River are monitored annually in the fall. In this river, bottom sediments are almost completely removed during the spring freshet, with accumulation of fine sediment occurring from late spring to late fall. In most other waterbodies, sampling is conducted every three years in the fall. These waterbodies are sampled less frequently because they are generally exposed to less cumulative development and sedimentation rates are likely lower than in the Athabasca River. New sediment quality sites added to RAMP are monitored every fall for the first three years, with toxicity testing being conducted for the first two years to compile adequate baseline data.

2.1.2 Benthic Invertebrate Community

Benthic invertebrate (benthos) monitoring complements water and sediment quality monitoring by providing an indication of the biological effects of disturbances. Benthic invertebrates are ubiquitous in freshwaters and form communities that reflect the physical and chemical characteristics of their habitat (Rosenberg and Resh 1993). They are sedentary, which render them useful for monitoring at the local or regional scale. Because of their relatively long life cycles, they reflect environmental quality over a period representing the length of their aquatic life stage (months to years), rather than serving as snapshot-type indicators. Benthic invertebrates also represent a food source for many fish species, making them an important feature of fish habitat.

The benthic invertebrate component of RAMP consists of annual baseline sampling of selected tributaries and lakes over a five-year period, followed by continued monitoring at a frequency that will be adjusted to the development schedules of nearby oil sands operations. The fall 2001 field program included sampling of the Clearwater, MacKay, Muskeg and Steepbank rivers, Fort Creek, and Kearl and Shipyard lakes. The fall 2001 program represented the second year of monitoring utilizing a consistent sampling design in the MacKay, Muskeg and Steepbank rivers and Shipyard Lake, as well as the first year of monitoring in the Clearwater River, Fort Creek and Kearl Lake. The approach to be adopted for monitoring the Athabasca River will be developed during 2002 and will depend on the results of the fall 2001 survey of the reach adjacent to the Suncor facilities (Section 11.2).

The tributary monitoring approach adopted by RAMP has focused on the lower reach of each river to allow detection of the cumulative effects of all developments within each basin (MacKay, Muskeg and Steepbank rivers and Fort Creek), or followed the control-impact (upstream-downstream) approach (Clearwater River upstream and downstream of the Christina River). In 2002 and subsequent years, tributary monitoring will be expanded by also sampling the upper river reaches where feasible, to increase the amount of reference site data in the RAMP database. To monitor lakes, sampling effort is distributed over the entire open-water area of a lake, but is restricted by depth to reduce variation in the data. Both river and lake sampling includes the collection of a full suite of supporting data to allow separation of the effects of natural variation on benthic community structure from the effects of oil sands developments.

The objective of the 2001 benthic program was to further characterize natural variation in the rivers and lakes monitored, before the commencement of intensive oil sands development within their drainage basins. Some new development has already occurred in the Muskeg River and Shipyard Lake basins, including forest clearing, muskeg dewatering and construction of roads and camps. However, because the likely impacts of these activities on benthic invertebrate habitat are very low at this time, the 2001 monitoring results are tentatively considered part of the baseline data. Therefore, the 2001 data were not compared statistically with the previous years' data. Trends over time in benthic community structure and potential changes related to oil sands development in the waterbodies monitored by RAMP to date will be examined in the forthcoming five-year summary report, based on data collected by RAMP and previous monitoring.

2.1.3 Fish Populations

Monitoring fish populations is a key component of RAMP for a variety of reasons. Fish integrate the effects of natural and anthropogenic factors and are, therefore, an important ecological indicator. Probably the most pertinent reason for evaluating fish populations is that fish are a highly valued component of the aquatic ecosystem. Hence, there is a public and regulatory expectation that fish will be monitored.

Within the Oil Sands Region there are two distinct yet related issues that need to be addressed by the fisheries component of RAMP. Firstly, it is necessary to ensure that fish populations are not adversely affected by increased oil sands development. The continued use of available fisheries resources for human consumption is of specific interest. Secondly, it is important to maintain the ecological integrity of aquatic ecosystems. With regards to fish, it is important to ensure that there are no adverse effects on ecological attributes such as growth, reproduction and survival. Early warning indicators are used to achieve this objective.

The scope and rationale of the fisheries component for the 2001 monitoring program have been outlined in detail in the Program Design and Rationale document (Golder 2000a). Generally, the 2001 program consisted of the following:

- completion of the radiotelemetry study initiated during the RAMP 2000 program focussing on longnose sucker and northern pike;
- collection of tissue samples from fish in the Athabasca and Muskeg rivers for analysis of contaminants;
- tributary sentinel species monitoring to assess the health of slimy sculpin populations in the Muskeg and Steepbank rivers;
- a fish fence study to evaluate species composition and abundance for populations utilizing the Muskeg River Basin; and
- a general fish inventory for the Muskeg River and Jackpine Creek.

The radiotelemetry study was initiated to: 1) evaluate the mobility of longnose sucker utilizing the Athabasca and Muskeg rivers and its suitability as a sentinel species for the Oil Sands Area; 2) evaluate the mobility of northern pike within the lower Muskeg River and Athabasca River; and 3) identify overwintering locations for both species. The 2001 portion of the radiotelemetry study included monitoring fish movements from December to June to provide a full year of movement data (in combination with monitoring from 2000).

Muscle tissue samples were collected from lake whitefish and walleye from the Athabasca River and northern pike from the Muskeg River and analyzed for concentrations of organic and inorganic contaminants. This assessment was conducted to monitor the suitability of the fish resource for human consumption and potential direct or indirect toxicity affects on fish.

The tributary sentinel species component involved monitoring population and health parameters for a small-bodied fish species exposed to Oil Sands activities, as an indicator of ecosystem health. The sentinel fish species is used to assess potential effects of stressors (e.g., industrial development) on fish populations. The performance (e.g., growth, condition, reproductive parameters) of the sentinel species inhabiting a particular site of interest (e.g., Oil Sands Region) is characterized relative to reference and/or historical performance data. Populations of slimy sculpin in the lower Muskeg River and lower Steepbank River were evaluated in comparison to previous RAMP data and to other tributary populations.

The fish fence study involved using a two-way counting fence in the lower Muskeg River to monitor the species composition and abundance of fish migrating into the river basin in the early spring. While the specific purpose of the fish fence was to monitor the timing and size of the spring 2001 spawning run, the study was also to help in the overall understanding of how mainstem fish utilize the Muskeg River. The fish species targeted were the adult size-classes of key Athabasca River fish species known to ascend the Muskeg River in the spring. These species include northern pike, Arctic grayling, longnose sucker, and white sucker.

The purpose of the general fish inventory was to monitor species presence, relative abundance and community structure. As part of the 2001 RAMP survey, inventories were conducted in the Muskeg River basin, including the lower Muskeg River and lower Jackpine Creek. Fisheries inventories have been conducted previously for RAMP in the lower Muskeg River (Golder 1998), but not in Jackpine Creek. Both watercourses will be included in future inventory studies. The rationale document (Golder 2000a) called for a population estimate study for these two watercourses in 2001, with the study specifically targeting young-of-the-year and juvenile Arctic grayling. However, recent fisheries information suggested that the number of Arctic grayling utilizing the Muskeg River basin had declined from previously recorded levels. The Muskeg River spring fish fence study suggested that a spawning run of Arctic grayling did not occur in 2001; however, the study was inconclusive. A short angling program was conducted in the summer by volunteers from Alberta Sustainable Resource Development (ASRD), Fisheries and Oceans Canada (DFO) and Syncrude to check for the presence of Arctic grayling in the basin. Because no Arctic grayling were captured, it was decided to conduct a general fish inventory program rather than the Arctic grayling population estimate study originally planned.

2.1.4 Acid Sensitive Lakes

The RAMP long-term acidification monitoring network was established in 1999. The objective of this component is to monitor the water chemistry of acid sensitive lakes as an early-warning indicator of effects caused by acidic deposition. Acid sensitive lake monitoring is a partnership between RAMP and Alberta Environment (AENV). This RAMP component routinely interacts with the NO_x and SO_x Management Working Group (NSMWG) to ensure that acid sensitive lake monitoring reflects the latest scientific developments and to ensure consistency with analytical techniques (both chemistry and data analyses) employed in the Oil Sands Region.

The monitoring network consists of 32 moderately to highly acid sensitive lakes in northeastern Alberta, including 22 lakes in the Oil Sands Region, five lakes in the Caribou Mountains and five lakes on the Canadian Shield. The lakes in the Caribou Mountains and the Canadian Shield are distant from sources of acidifying emissions, and are located in different geological settings than the lakes in the Oil Sands Region. The 32 lakes are monitored annually for field parameters, acidity-related parameters, carbon parameters, major ions, nutrients and productivity indicators.

The lakes forming the network were selected to represent a cross-section of lake characteristics in northeastern Alberta. Primary criteria during lake selection included the following:

- moderate to high sensitivity to acidification, defined as total alkalinity <20 mg/L as $CaCO_3$;
- range in organic content, from clear to brown water lakes;
- location along a gradient of acidic deposition radiating from the Oil Sands Region, as predicted in recent EIAs, or location away from the oil

sands area (in the case of the lakes in the Caribou Mountains and the Canadian Shield); and

- access by float plane to ensure a cost-effective program.

The 2001 program represented the third year of monitoring under this component. The lakes monitored, and sampling and analytical methods were similar to those established in 1999. Differences relative to the 1999 and 2000 programs included adding two new lakes (A300 and A301) to replace lakes that have been difficult to access during the field surveys (A47 and R2, respectively). In total, 32 lakes were monitored in 2001.

Due to the scarcity of acid sensitive lakes close to oil sands developments, only a handful of the RAMP lakes are close to the area of highest acid deposition (i.e., in the Muskeg and Steepbank River basins). This deficiency is being addressed in 2002, by selecting a number of acid sensitive ponds close to the area of heaviest oil sands development, in addition to continued monitoring of the 32 lakes sampled in 2001. This will result in approximately 50 lakes and ponds being sampled in 2002.

2.1.5 Wetlands Vegetation

Aquatic vegetation communities in Isadore's, Kearl and Shipyard lakes are monitored on a regular basis as part of the RAMP core sampling program. The current RAMP sampling program includes airphoto interpretation and field sampling every three years. Field sampling was done in 1997, 1998 and again in 2001. In years when field sampling is not scheduled, aerial photographs are assessed and compared to the previous years' photos if they are available.

In 1997, the objective of the RAMP wetlands vegetation survey as stated in the Approach (Golder 1998) was to document baseline conditions as a reference point for future monitoring.

In 1998, the scope of the wetlands vegetation surveys was:

- to further describe the vegetation communities in Isadore's, Kearl and Shipyard Lakes; and
- to identify and evaluate reference wetlands.

The objective of the 2001 aquatic vegetation program was to collect field data to continue the task of characterizing the natural variability in the wetlands types representative of the three study lakes. To date, no suitable reference wetlands have been found for the three lakes originally identified for sampling.

During the first three years of data collection and reporting for the RAMP wetlands vegetation program, the baseline conditions were assessed using a combination of qualitative description and analysis. At the 2002 RAMP technical component subgroup meeting for vegetation, there was a desire to move the study into a more quantitative and analytic focus in future years. This report represents the transition in that direction. This report is designed to compare the parameters across the three lakes as well as to document the conditions in each lake.

2.2 RAMP STUDY AREA

The study area for RAMP includes the Regional Municipality of Wood Buffalo (Figure 2.1). The RAMP study area is consistent with the Cumulative Environmental Management Association, Water Working Group (CEMA WWG) study area.

A focus study area is located within the RAMP study area (Figure 2.1). The focus area includes watersheds where oil sands development is occurring or planned. As well, areas downstream of the proposed developments, such as the lower Athabasca River and the Athabasca River Delta are also included. The Clearwater River and the Athabasca River upstream of Fort McMurray are included as reference areas. The focus study area includes rivers and lakes located south of Fort McMurray that have not previously been included in the RAMP sampling program.

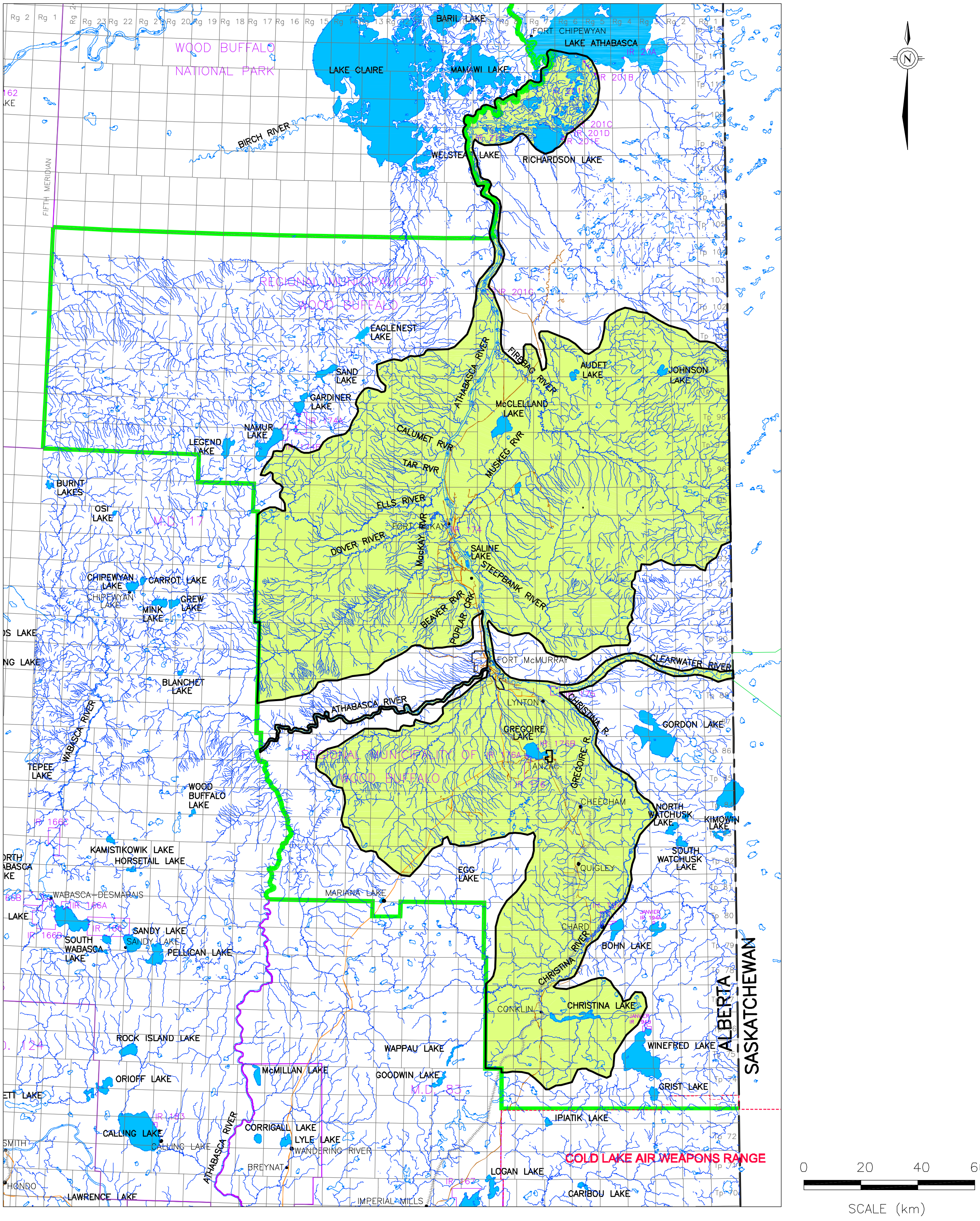
2.3 NON-CORE PROGRAMS

Non-core programs are not identified in RAMP's long-term monitoring plan. These programs tend to be short-term and often include industry commitments. In the past, non-core monitoring has included:

- chronic toxicity testing at the mouth of McLean Creek, the mouth of Fort Creek and the upper Muskeg River in the fall of 2000;
- seasonal sampling at the mouth of Fort Creek in 2000; and
- spring and summer sampling at the mouth of an unnamed creek north of Fort Creek in 2000.

Non-core monitoring undertaken in 2001 included:

- spring and fall sampling of 13 lakes in and around the OPTI Canada Long Lake Project; and
- water quality baseline sampling at Suncor Firebag.



LEGEND

RAMP REGIONAL STUDY AREA

RAMP FOCUS STUDY AREA

REFERENCE

ORIGINAL BASE MAP OF ALBERTA WAS PRODUCED IN 10TM FORMAT. THE MAP WAS CONVERTED FROM DGN FORMAT TO DWG FORMAT IN NAD 83 ZONE 12 UTM PROJECTION.

PROJECT

RAMP 2001

TITLE

RAMP STUDY AREA AND FOCUS AREA

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	STUDY AREA
DESIGN			SCALE AS SHOWN	REV. 0
CADD	RFM	21/05/02		
CHECK	KF	21/05/02	**FIGURE: 2.1**	
REVIEW				

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: STUDY AREA.dwg Jul 10, 2002 - 9:38am

2.4 CLIMATIC AND HYDROLOGIC CONDITIONS

The core components of the 2001 chemical and biological monitoring program (water and sediment quality, benthic invertebrate communities and fish populations) are all influenced by climatic and hydrologic conditions. In particular, changes that alter the quantity of water in the Athabasca River, the tributaries of the Athabasca River, wetlands and lakes will influence these core components.

Monitoring of climatic and hydrologic conditions in the Oil Sands Region is accomplished via the RAMP Climatic and Hydrologic Monitoring Program. This program, which is currently supported by Syncrude, Albian Sands, ExxonMobil, True North, Petro-Canada, Canadian Natural Resources and Suncor, has been in place since 1995. An annual report on the program is issued as Volume II of the 2001 RAMP report. Summaries of historical information, as well as data collected during 2001, are included in Volume II. Since changes in flows and water levels may affect both the success and the results of RAMP sampling throughout the study area, a summary of the 2001 conditions is provided as background information in this section.

Field observations indicate that 2001 was a relatively average year in the Muskeg River and adjacent basins, with lower snowpack and precipitation depth than recorded in 2000. Light snowfall during November and December, 2000 was followed by moderate precipitation in early 2001. The resulting light snowpack (Figure 2.2) produced relatively low stream discharges during snowmelt in 2001. A moderately dry spring was followed by typical summer rainfall, as shown in Figure 2.3. A summary of precipitation measured at the Aurora Climate Station for the hydrologic year November 2000 to October 2001 is provided in Table 2.1. The snow water equivalent snowfall of 45.4 mm measured at the Aurora Climate Station was 12% of the total measured precipitation. However, snow water equivalent depths or the order of 60 mm were recorded for most terrain types during the Muskeg River Basin snow survey. This indicates that the Aurora data is subject to undercatch due to wind effects and trace events, as is typical for these types of stations.

During the late June rainfall event, a four-year flood event was measured on Jackpine Creek. Peak flows for other regional streams with long-term flow records had return periods of less than two years. The total rainfall measured at the Aurora Climate Station in 2001 was 323 mm. This is similar to that measured in 1997 and 1999 (382 mm and 303 mm, respectively) and noticeably less than that measured in 1996 and 2000 (472 mm and 457 mm, respectively) as shown in Figure 2.3.

Figure 2.2 Snow Accumulation in the Muskeg River Basin, 1997 - 2001

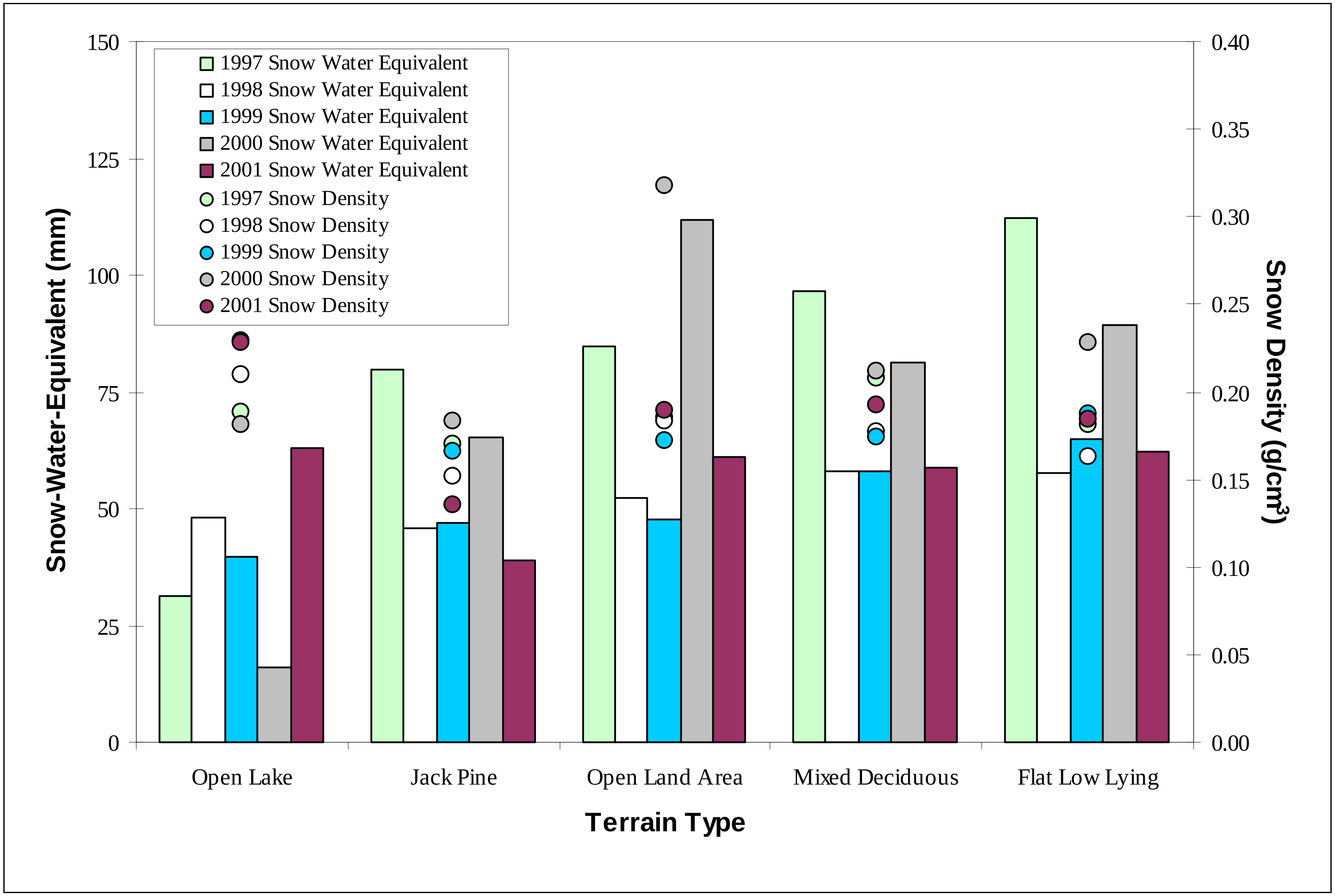


Figure 2.3 Cumulative Annual Rainfall at Aurora Climate Station, 1996 – 2001

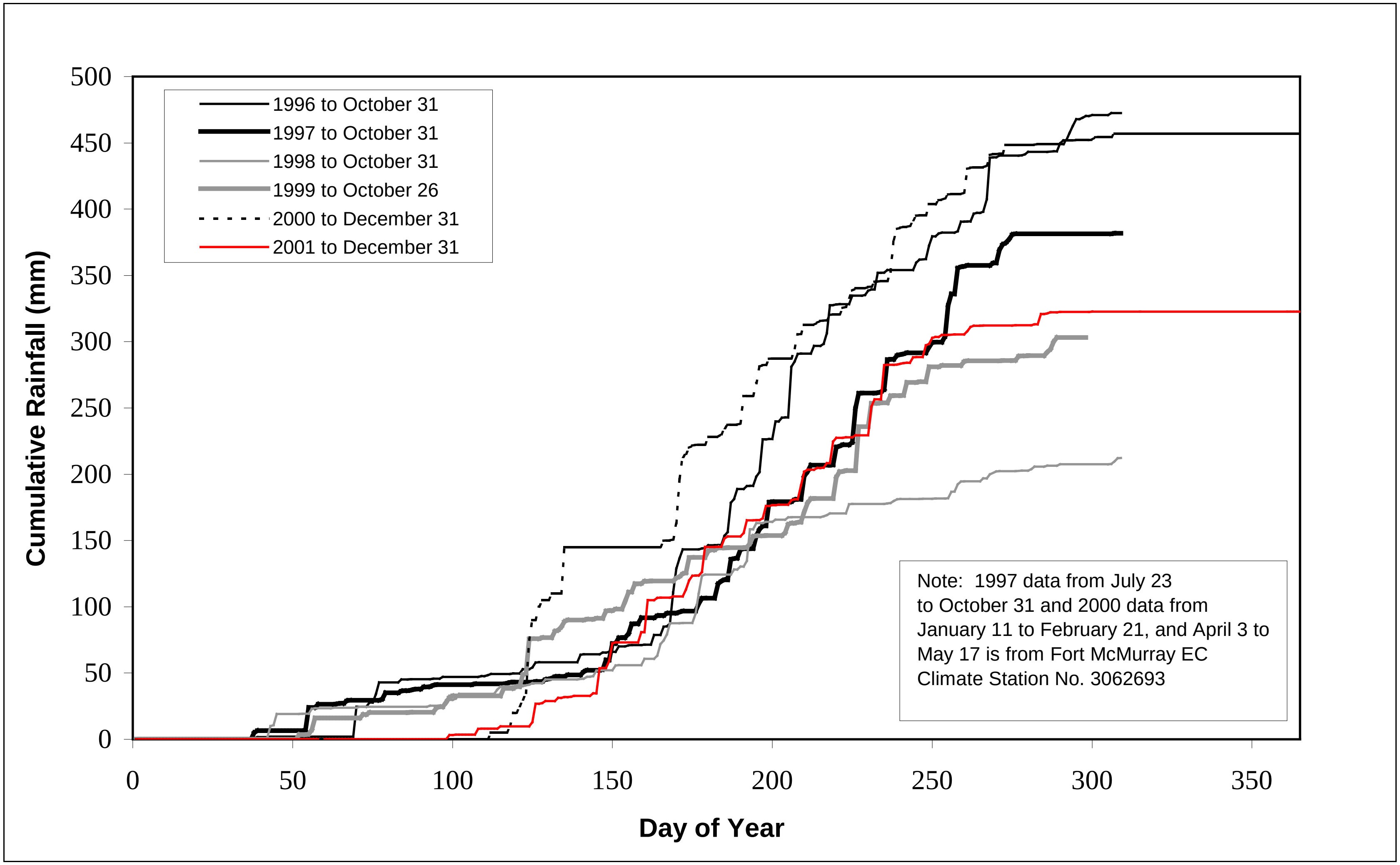


Table 2.1 Precipitation at Aurora Climate Station, Hydrologic Year November 2000 to October 2001

Month	Rainfall (mm water)	Snowfall[a] (mm snow water equivalent)	Precipitation (mm water)
November 2000	2.6	0.0	2.6
December 2000	0.0	0.0	0.0
January 2001	0.0	5.7	5.7
February 2001	0.0	13.2	13.2
March 2001	0.0	22.9	22.9
April 2001	9.8	3.6	13.4
May 2001	63.2	0.0	63.2
June 2001	72.0	0.0	72.0
July 2001	58.4	0.0	58.4
August 2001	80.6	0.0	80.6
September 2001	25.2	0.0	28.2
October 2001	10.4	0.0	13.4
total	325.2	45.4	370.6

[a] No undercatch adjustment has been applied.

The analysis of available data indicates that maximum daily stream discharges in 2001 were slightly higher than the long-term mean of annual maximum daily values for the Athabasca River and Jackpine Creek and slightly lower than the mean for the Steepbank, Muskeg, MacKay, and Firebag rivers (Table 2.2). Minimum daily discharges were close to the mean for most stations. No extreme flood or drought events were observed in the region in 2001.

The cumulative flow volumes for the period from March to September 2001 (i.e., spring melt to late summer) were in general slightly less than the long term average (Table 2.3), with drought return periods in the range of 3 to 4 years. The exception is Jackpine Creek, which had higher than average streamflow volumes in 2001. Annual mean daily flow hydrographs for the Athabasca River, Steepbank River, Muskeg River, Jackpine Creek, MacKay River and Firebag rivers are shown in Figures 2.4 – 2.9, respectively.

Table 2.2 Maximum and Minimum Mean Daily Discharges, RAMP Study Area

Stream Station ID Period of Record	Athabasca R. 07DA001 44 Years	Steepbank R. 07DA006 28 Years	Muskeg R. 07DA008 28 Years	Jackpine Cr. S2 25 Years	MacKay R. 07DB001 28 Years	Firebag R. 07DC001 26 Years
Maximum Mean Daily Discharge						
2001 value (m^3/s)	2930	20.7	14.5	10.3	52.3	84.5
average recorded (m^3/s)	2585	35.6	26.5	8.4	121	104
maximum recorded (m^3/s)	4700	81.0	66.1	17.2	339	236
flood return period (yr)	3 Year	< 2 Year	< 2 Year	4 Year	< 2 Year	< 2 Year
Minimum Mean Daily Discharge						
2001 value (m^3/s)	102	0.290[(a)]	0.292	0.000	0.269[(a)]	7.8[(a)]
average recorded (m^3/s)	134	0.294	0.275	0.007	0.351	7.97
minimum recorded (m^3/s)	89	0.022	0.095	0.000	0.023	4.24
drought return period (yr)	< 2 Year	2 Year	< 2 Year	> 2 Year	3 Year	2 Year

(a) Assumes low flow occurred at end of recession in March. No data available for Jan-Feb or Nov-Dec.
Source: Environment Canada, Water Survey Branch; Golder (2002).

Table 2.3 Cumulative Streamflow Volumes, RAMP Study Area, March to September

Stream Station ID Period of Record	Athabasca R. 07DA001 41 Years	Steepbank R. 07DA006 28 Years	Muskeg R. 07DA008 28 Years	Jackpine Cr. S2 25 Years	MacKay R. 07DB001 29 Years	Firebag R. 07DC001 26 Years
2001 value (dam^3)	(a)	110,304	94,682	34,643	225,200	517,700
maximum recorded (dam^3)	25,279,862	273,634	187,146	59,051	904,734	903,836
average recorded (dam^3)	16,696,207	133,296	105,148	27,640	420,299	602,329
minimum recorded (dam^3)	11,785,000	36,670	17,995	1,000	26,372	344,469
drought return period (yr)	n/a	3 Year	3 Year	< 2 Year	3 Year	4 Year

(a) 9,349,171 dam^3 for period excluding March 9 to June 7, 2001 (no data available from Environment Canada).
Source: Environment Canada, Water Survey Branch; Golder (2002).

Figure 2.4 Annual Mean Daily Flow Hydrograph for the Athabasca River, 2001

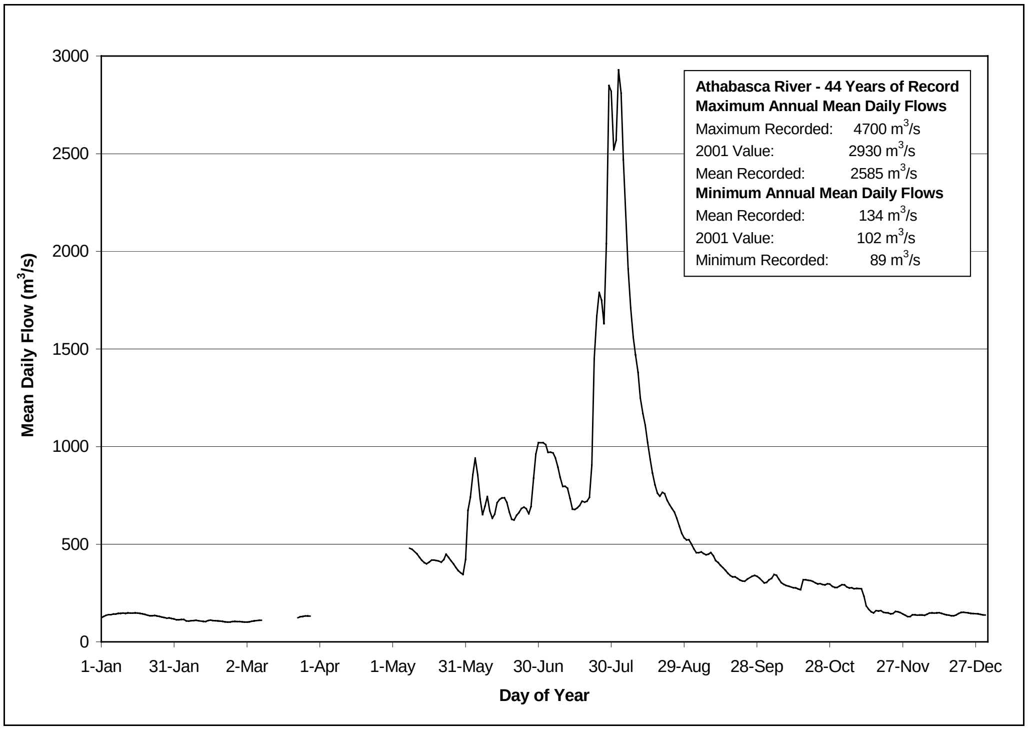


Figure 2.5 Annual Mean Daily Flow Hydrograph for the Steepbank River, 2001

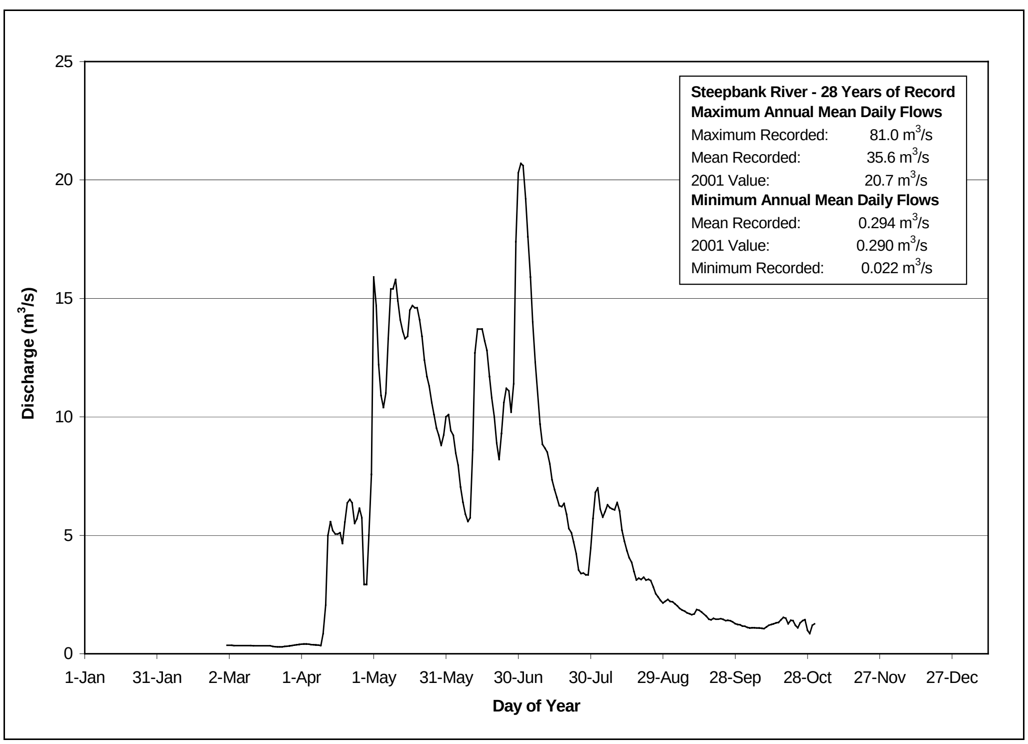


Figure 2.6 Annual Mean Daily Flow Hydrograph for the Muskeg River, 2001

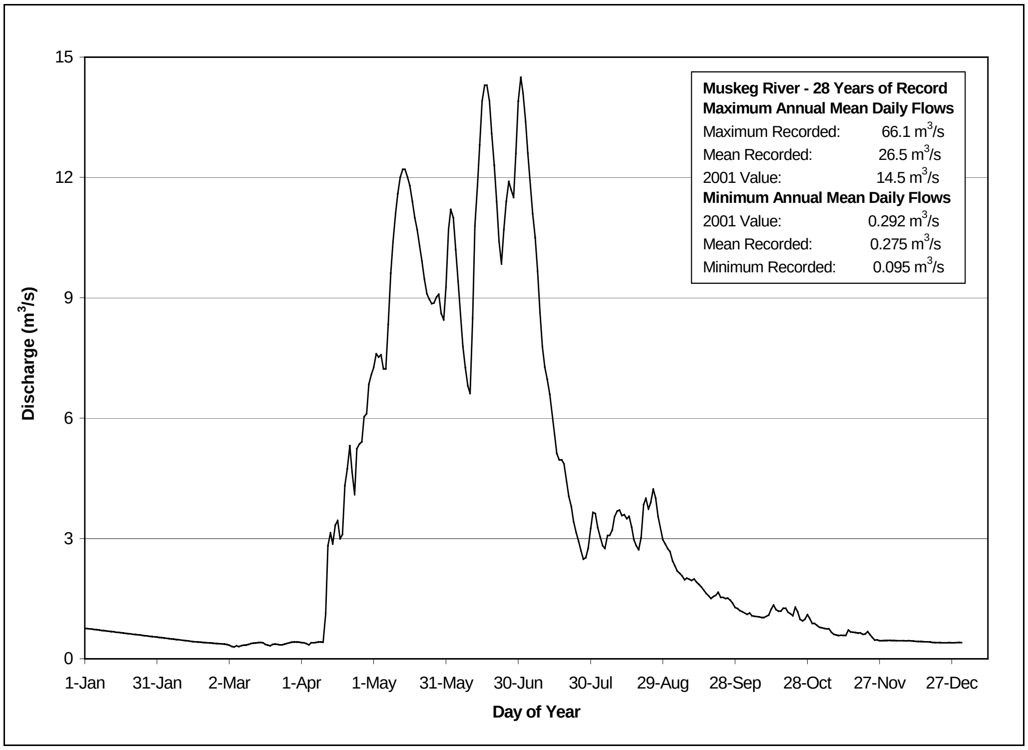


Figure 2.7 Annual Mean Daily Flow Hydrograph for Jackpine Creek, 2001

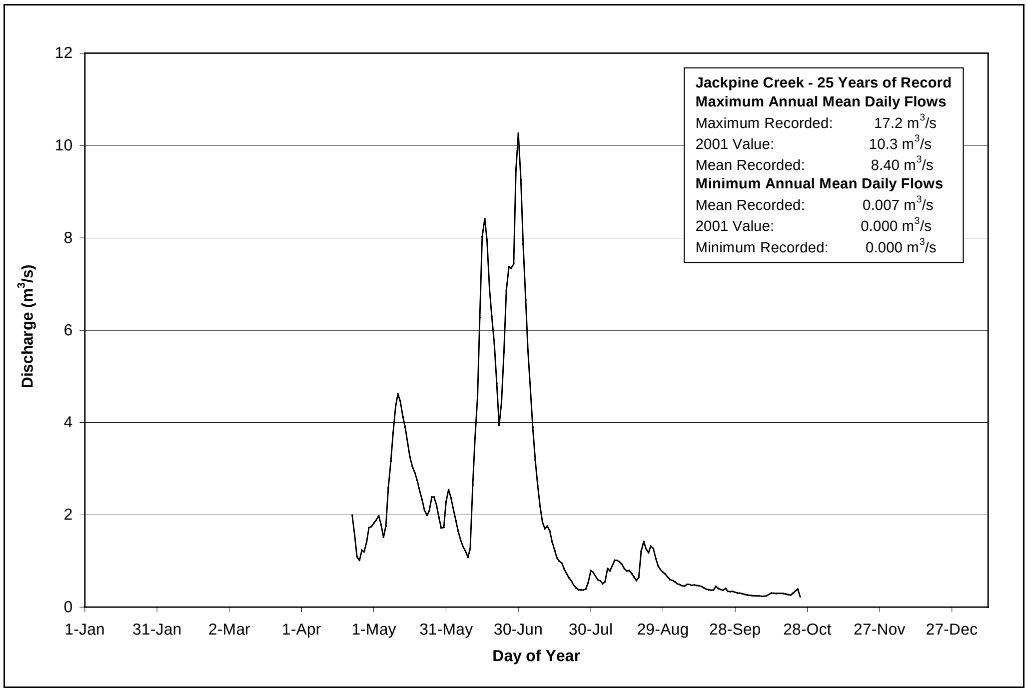


Figure 2.8 Annual Mean Daily Flow Hydrograph for the MacKay River, 2001

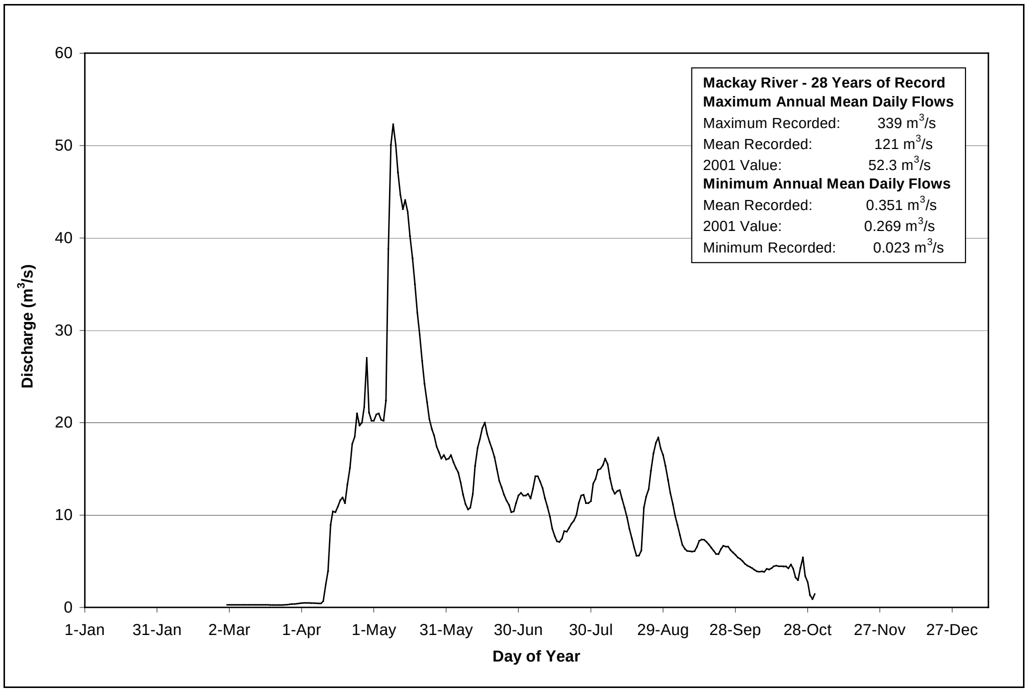
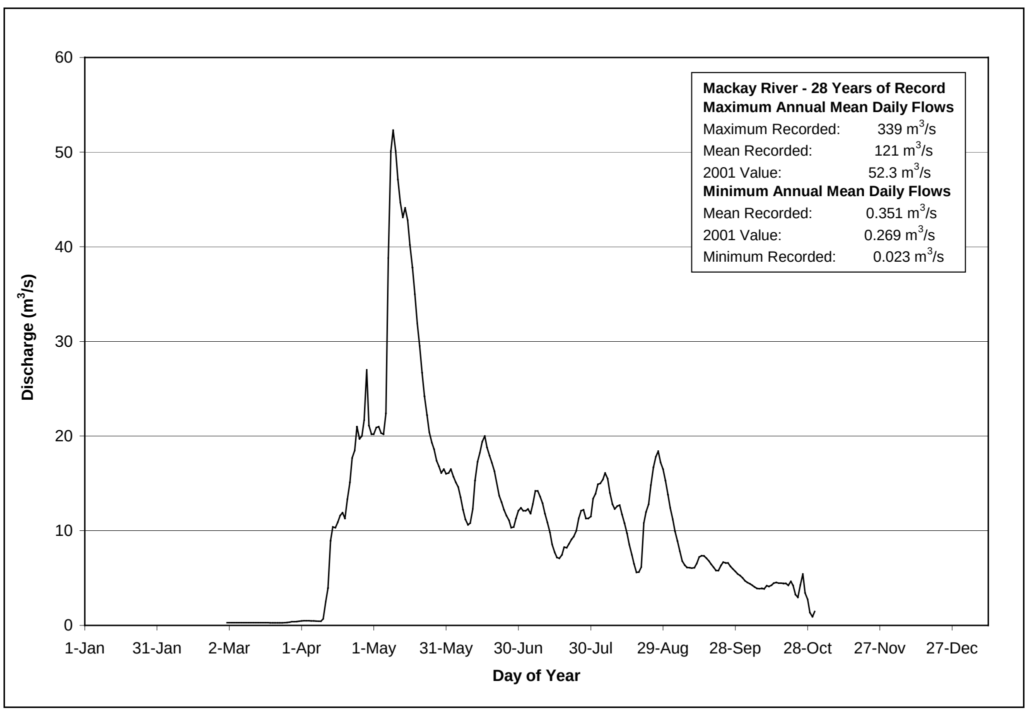


Figure 2.9 Annual Mean Daily Flow Hydrograph for Firebag River, 2001



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3 METHODS

3.1 WATER QUALITY

In 2001, water quality data were collected from the lower Athabasca River Watershed by RAMP, AENV, Albian and Syncrude. The scope of the 2001 water quality survey was to:

- continue to monitor the same set of water quality parameters analyzed in 2000;
- resample the mouths of Jackpine, Muskeg, McLean, Poplar, Fort and Stanley creeks, and the MacKay and Steepbank rivers;
- resample Muskeg River at six locations (i.e., the mouth at the Water Survey of Canada (Environment Canada) gauge station downstream of the Canterra Road, upstream of the Canterra Road crossing and upstream of Jackpine, Muskeg and Wapasu creeks);
- resample Kearl, Isadore's, Shipyard and McClelland lakes;
- resample Big Point Channel in the Athabasca Delta;
- resample the Athabasca River upstream of the Embarras River, and the east and west banks from locations upstream of Donald Creek, the Steepbank River, Muskeg River and Fort Creek;
- continue to monitor seasonal water temperatures in the Muskeg River, McLean Creek and Fort Creek;
- expand sampling and seasonal temperature monitoring to include the Clearwater River at locations upstream of Fort McMurray and the Christina River;
- expand sampling to include selected lakes in and around the OPTI Long Lake project area; and
- expand sampling to include baseline data collection in the headwaters of the Firebag River.

This work included discrete water sampling at the following locations:

- the Athabasca River (RAMP and AENV), including the Delta (RAMP);
- the Clearwater River (RAMP);
- tributaries north of Fort McMurray, including McLean Creek (RAMP), Poplar Creek (RAMP), the Steepbank River (RAMP), the MacKay River (RAMP) and Fort Creek (RAMP);

- the Muskeg River Watershed, including the Muskeg River (RAMP, Albian and Syncrude), Jackpine Creek (RAMP); Muskeg Creek (RAMP) and Stanley Creek (RAMP); and
- Kearl, Shipyard, Isadore's and McClelland lakes (RAMP).

As well, water temperature, pH, dissolved oxygen (DO) and/or conductivity levels were monitored continuously at the following locations:

- the Clearwater River (RAMP);
- McLean Creek (RAMP);
- Fort Creek (RAMP);
- the Muskeg River (RAMP and AENV); and
- the Alsands Drain (RAMP).

Sample locations are shown in Figures 3.1 to 3.4, and the specific methods used to collect this information are discussed in Sections 3.1.1 and 3.1.2.

3.1.1 Discrete Sample Collection and Analysis

3.1.1.1 General Methodology Specific to RAMP

All discrete water quality samples collected by RAMP were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.3-1 (Golder 1999a). Sample locations were determined by Global Positioning System, and all samples were collected from a depth of approximately 30 cm, using clean sample equipment. Field measurements, including pH, conductivity, temperature and DO levels, were recorded at each sample site, except where noted below.

Following sample collection, all samples were split. One portion was shipped to Enviro-Test Laboratories (ETL) in Edmonton, Alberta, for analysis of the standard RAMP water quality parameter list (Table 3.1), which includes conventional parameters, major ions, nutrients, recoverable hydrocarbons, naphthenic acids, and total and dissolved metals. Another portion was sent to the Alberta Research Council (ARC-Vegreville) in Vegreville, Alberta, for ultra-low level analysis of total mercury and total silver. Descriptions of the analytical methods used by each laboratory are provided in Appendix I.

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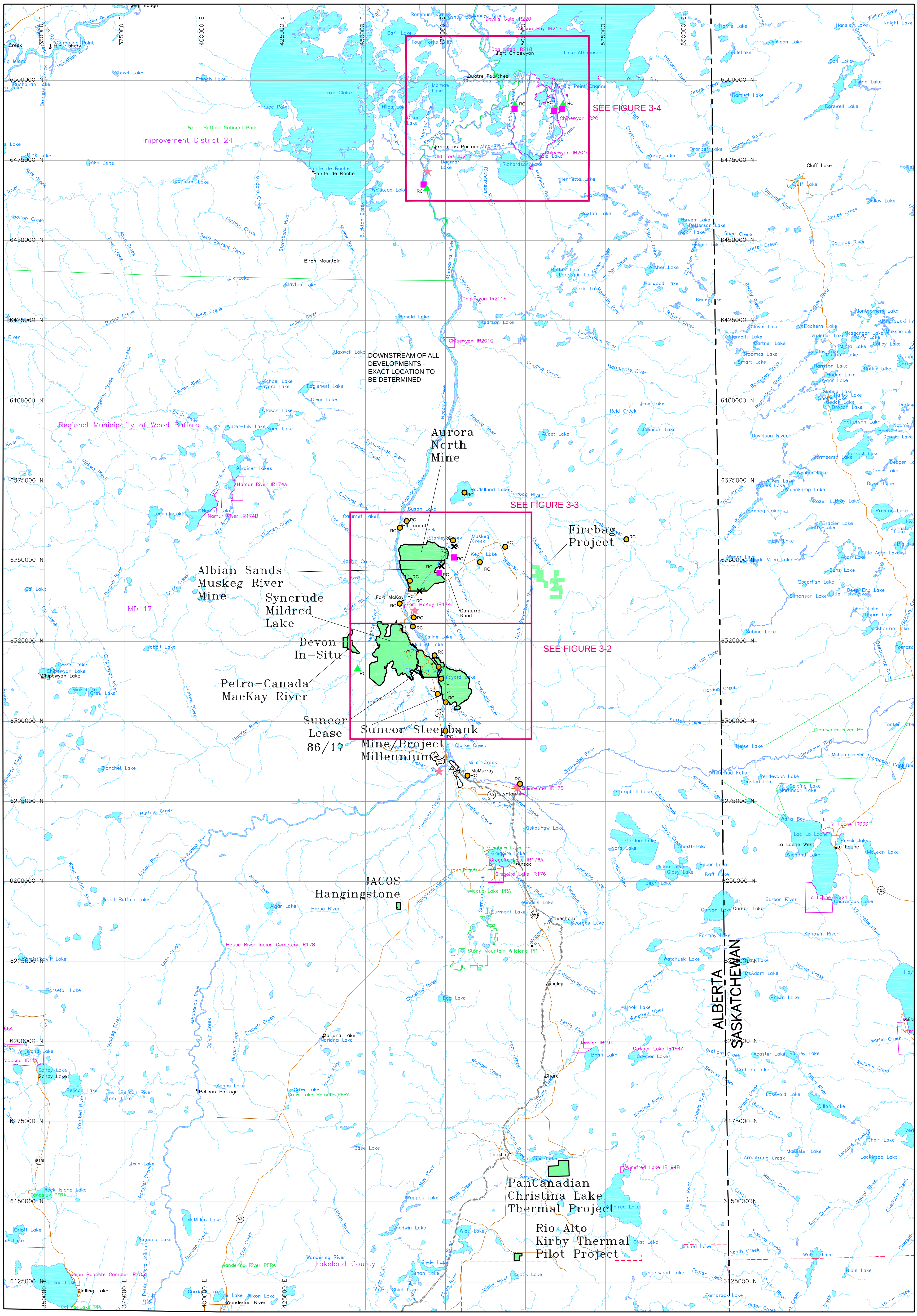

LEGEND

MINOR ROADWAYS	WATER QUALITY SAMPLE SITE	RC	RAMP CORE
MAJOR ROADWAYS	SEDIMENT SAMPLE SITE	A	APPROVAL
RIVERS AND STREAMS	WATER QUALITY AND SEDIMENT SAMPLE SITE	IC	INDUSTRY COMMITMENT
EXISTING DEVELOPMENTS	AENV SAMPLE SITE	X	INDUSTRY SAMPLE SITE

25 0 25
SCALE KILOMETRES

NOTE

FUTURE SITES HAVE BEEN INCLUDED ON MAP. THE FIRST YEAR OF SAMPLING HAS BEEN INCLUDED IN BRACKETS.

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUGUST 2001. NAD 83 ZONE 12. SHEETS 74D, E AND 74L IN NAD 27 ZONE 12. SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG. 2001. NAD 83 ZONE 13. ALL DATA CONVERTED TO NAD 83 UTM ZONE 12.
OIL & GAS AND ENVIRONMENTAL DATA PROVIDED BY VERITAS GeoSERVICES LTD., CURRENT AS OF MAY 2001.

PROJECT

RAMP 2001

TITLE

WATER AND SEDIMENT SAMPLE SITES, 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	WQ-BASE MAP
DESIGN			SCALE AS SHOWN	REV. 2
CADD	RFM	21/05/02		
CHECK	KF	21/05/02		
REVIEW				

FIGURE: 3.1

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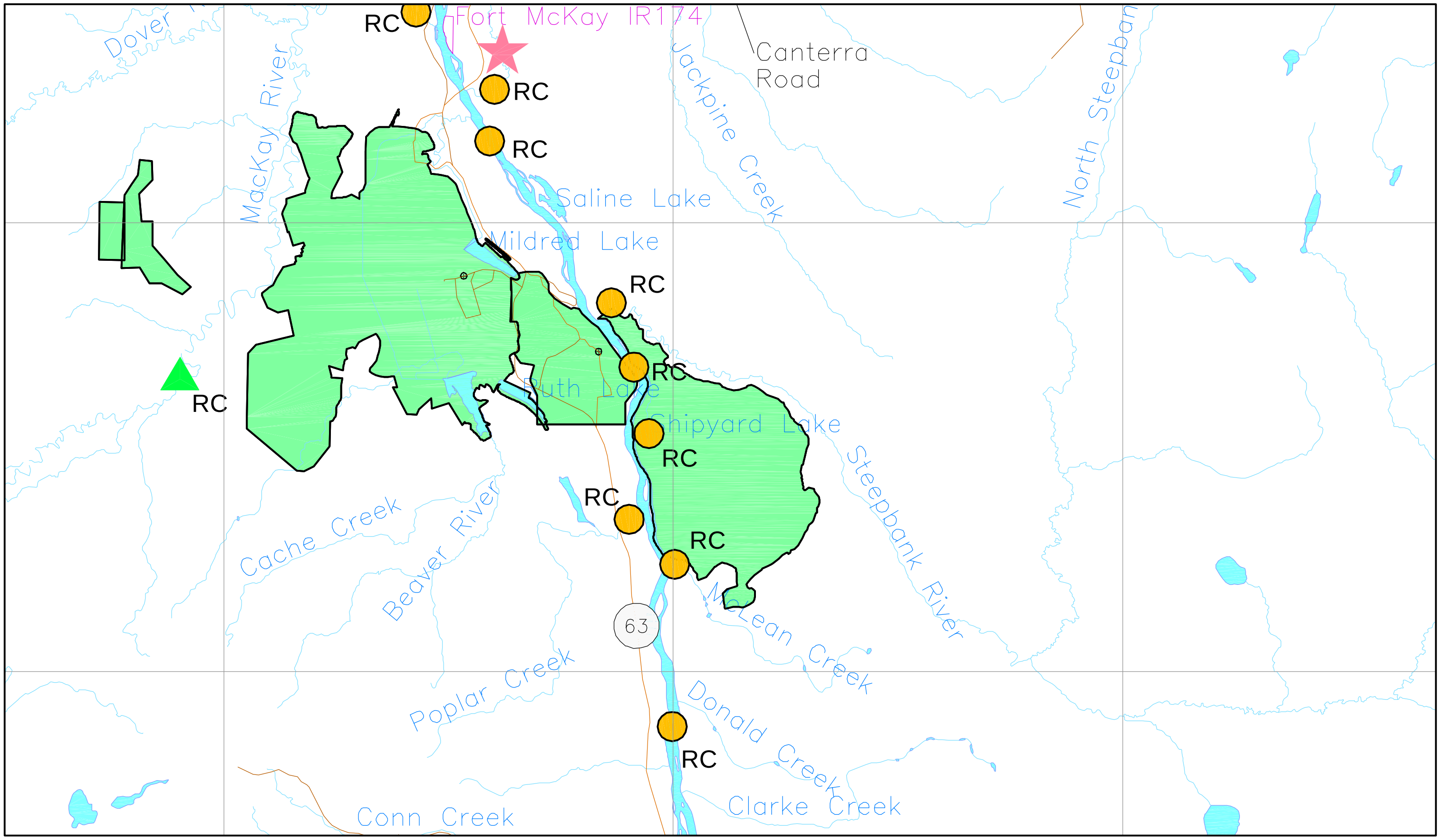

N

10	0	10
SCALE		KILOMETRES

LEGEND

- MAJOR ROADWAYS
- RIVERS AND STREAMS
- EXISTING DEVELOPMENTS
- SEDIMENT QUALITY SAMPLE SITE
- WATER QUALITY AND SEDIMENT SAMPLE SITE
- RC RAMP CORE

NOTE

FUTURE SITES HAVE BEEN INCLUDED ON MAP. THE FIRST YEAR OF SAMPLING HAS BEEN INCLUDED IN BRACKETS.

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUGUST 2001. NAD 83 ZONE 12. SHEETS 74D, E AND 74L IN NAD 27 ZONE 12. SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG. 2001. NAD 83 ZONE 13. ALL DATA CONVERTED TO NAD 83 UTM ZONE 12.

PROJECT

RAMP 2001

TITLE

WATER AND SEDIMENT SAMPLE SITES BETWEEN FORT McMURRAY AND THE MUSKEG RIVER, 2001

Golder Associates
Calgary, Alberta

PROJECT No.	012-2302		FILE No.	WQ-BASE MAP
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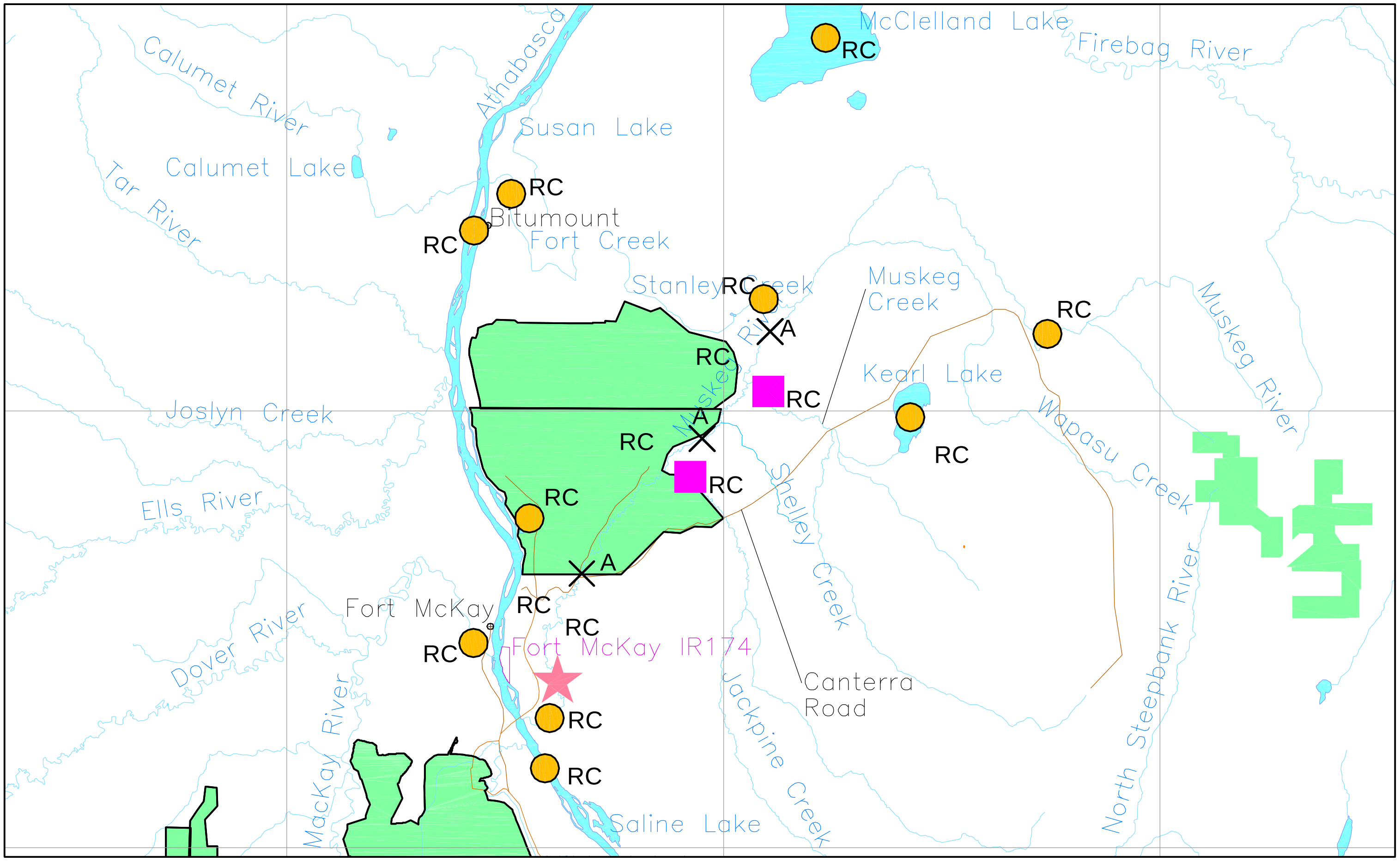
CHECK	KF	17/05/02		
REVIEW				

FIGURE: 3.2



LEGEND

- MAJOR ROADWAYS
- RIVERS AND STREAMS
- EXISTING DEVELOPMENTS
- WATER QUALITY SAMPLE SITE
- WATER QUALITY AND SEDIMENT SAMPLE SITE
- RC RAMP CORE
- A APPROVAL
- ALBIAN AND/OR SYNCRUDE SAMPLE SITE
- AENV SAMPLE SITE

10 0 10
SCALE KILOMETRES

NOTE

FUTURE SITES HAVE BEEN INCLUDED ON MAP. THE FIRST YEAR OF SAMPLING HAS BEEN INCLUDED IN BRACKETS.

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUGUST 2001. NAD 83 ZONE 12. SHEETS 74D, E AND 74L IN NAD 27 ZONE 12. SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG. 2001. NAD 83 ZONE 13. ALL DATA CONVERTED TO NAD 83 UTM ZONE 12.

PROJECT

RAMP 2001

TITLE

WATER AND SEDIMENT SAMPLE SITES BETWEEN THE MUSKEG RIVER AND McCLELLAND LAKE, 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	WQ-BASE MAP	
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CHECK	KF	17/05/02			
REVIEW					

FIGURE: 3.3

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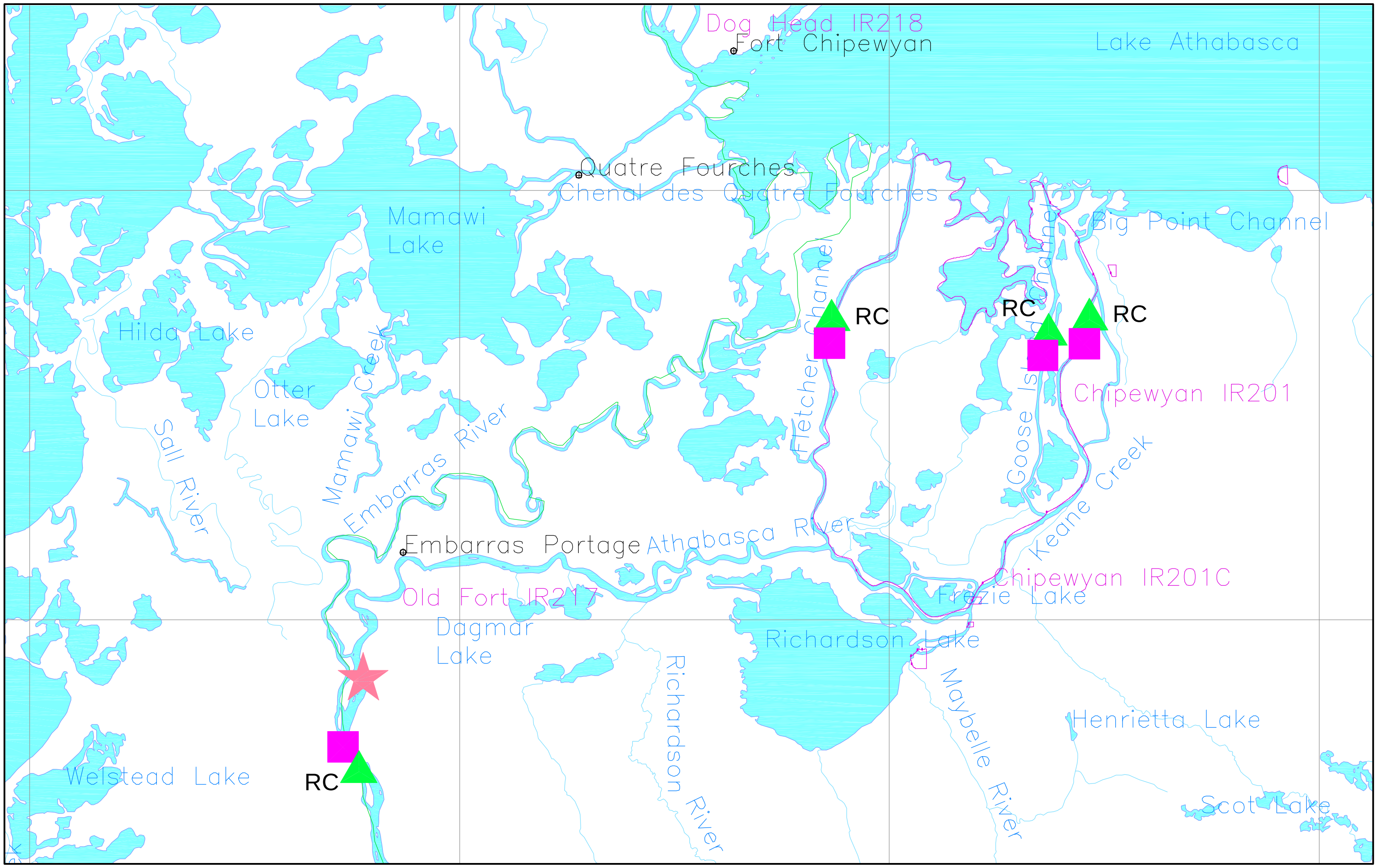


LEGEND

- RIVERS AND STREAMS
- WATER QUALITY SAMPLE SITE
- SEDIMENT SAMPLE SITE
- AENV SAMPLE SITE
- RC RAMP CORE

SCALE 10 0 10 KILOMETRES

NOTE

FUTURE SITES HAVE BEEN INCLUDED ON MAP. THE FIRST YEAR OF SAMPLING HAS BEEN INCLUDED IN BRACKETS.

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUGUST 2001. NAD 83 ZONE 12. SHEETS 74D, E AND 74L IN NAD 27 ZONE 12. SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG. 2001. NAD 83 ZONE 13. ALL DATA CONVERTED TO NAD 83 UTM ZONE 12.

PROJECT

RAMP 2001

TITLE

WATER AND SEDIMENT SAMPLE SITES IN THE ATHABASCA DELTA, 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	WQ-BASE MAP	
DESIGN			SCALE	AS SHOWN	REV. 1
CADD	RFM	21/05/02			
CHECK	KF	21/05/02	**FIGURE: 3.4**		
REVIEW					

Table 3.1 Standard RAMP Water Quality Parameter List

Group Name	Individual Parameters
conventional parameters	colour
	dissolved organic carbon
	pH
	specific conductance
	total alkalinity
	total dissolved solids
	total hardness
	total organic carbon
	total suspended solids
major ions	bicarbonate
	calcium
	carbonate
	chloride
	magnesium
	potassium
	sodium
	sulphate
	sulphide
nutrients	nitrate + nitrite
	nitrogen - ammonia
	nitrogen - kjeldahl
	phosphorus - dissolved
	phosphorus - total
	chlorophyll *a*
biological oxygen demand	biological oxygen demand
organics	naphthenic acids
	total phenolics
	total recoverable hydrocarbons
metals (total and dissolved)	aluminum (Al)
	antimony (Sb)
	arsenic (As)
	barium (Ba)
	beryllium (Be)
	boron (B)
	cadmium (Cd)
	chromium (Cr)
	cobalt (Co)
	copper (Cu)
	iron (Fe)
	lead (Pb)
	lithium (Li)
	manganese (Mn)
	mercury (Hg)
	molybdenum (Mo)
	nickel (Ni)
	selenium (Se)
	silver (Ag)
	strontium (Sr)
	thallium (Tl)
	titanium (Ti)
	uranium (U)
	vanadium (V)
	zinc (Zn)

3.1.1.2 Athabasca River Mainstem and Delta

Conducted by RAMP

In the fall of 2001, east and west bank composite water samples were collected from the Athabasca River approximately 100 m upstream of each of the following tributaries: Donald Creek, the Steepbank River, the Muskeg River and Fort Creek. The sampling schedule is outlined in Table 3.2. Each 15 L composite sample was created by combining three 1 L grab samples collected from five, approximately equally-spaced, locations positioned between the respective river bank and 25% of the river width.

A cross-channel composite water sample was collected from the Athabasca River approximately 100 m upstream of the Embarras River by combining three 1 L grab samples taken from five locations equally-spaced across the entire width of the river. A 15 L composite water sample was also prepared for the Athabasca Delta by combining 5 L grab samples collected from the centre of Big Point Channel, Fletcher Channel and Goose Island Channel. All grab samples were collected using a clean, triple-rinsed 1 L sample bottle and mixed together in clean, triple-rinsed 20 L pails.

In addition to the analyses outlined in Section 3.1.1.1, composite water samples collected from the Athabasca River upstream of Donald Creek and Fort Creek were also analyzed for PAHs. The individual PAH compounds included in this analysis are summarized in Table 3.3.

Table 3.2 Water Sampling Schedule for the Athabasca River Mainstem and Delta, 2001

Sample Location		Short Title	Sample Date
Sampling Site	**Sampling Point**		
upstream of Donald Creek	west bank composite	ATR-DC-W	November 2 (fall)
	east bank composite	ATR-DC-E	
upstream of the Steepbank River	west bank composite	ATR-SR-W	November 1 (fall)
	east bank composite	ATR-SR-E	
upstream of the Muskeg River	west bank composite	ATR-MR-W	November 1 (fall)
	east bank composite	ATR-MR-E	
upstream of Fort Creek	west bank composite	ATR-FC-W	October 14 (fall)
	east bank composite	ATR-FC-E	
upstream of the Embarras River	cross channel composite	ATR-ER	October 18 (fall)
Delta	Big Point Channel Fletcher Channel Goose Island Channel	ATD	October 17 (fall)

Table 3.3 Individual Polycyclic Aromatic Hydrocarbon (PAH) and Alkylated PAH Compounds Included in the RAMP 2001 Water Sampling Program

Group Name	Individual Parameters
target PAHs	acenaphthene
	acenaphthylene
	anthracene
	benzo(a)anthracene/chrysene
	benzo(a)pyrene
	benzo(b&k)fluoranthene
	benzo(g,h,i)perylene
	biphenyl
	dibenzo(a,h)anthracene
	dibenzothiophene
	fluoranthene
	fluorene
	indeno(c,d-123)pyrene
	naphthalene
	phenanthrene
	pyrene
alkylated PAHs	C1 substituted acenaphthene
	C1 substituted benzo(a)anthracene/chrysene
	C2 substituted benzo(a)anthracene/chrysene
	C1 substituted biphenyl
	C2 substituted biphenyl
	C1 substituted benzo(b or k)fluoranthene/methyl benzo(a)pyrene
	C2 substituted benzo(b or k)fluoranthene/benzo(a)pyrene
	C1 substituted dibenzothiophene
	C2 substituted dibenzothiophene
	C3 substituted dibenzothiophene
	C4 substituted dibenzothiophene
	C1 substituted fluoranthene/pyrene
	C1 substituted fluorene
	C2 substituted fluorene
	C1 substituted naphthalenes
	C2 substituted naphthalenes
	C3 substituted naphthalenes
	C4 substituted naphthalenes
	C1 substituted phenanthrene/anthracene
	C2 substituted phenanthrene/anthracene
	C3 substituted phenanthrene/anthracene
	C4 substituted phenanthrene/anthracene
	1-methyl-7-isopropyl-phenanthrene (retene)

Conducted by AENV

In 2001, AENV collected water samples from the Athabasca River upstream of Fort McMurray and at Old Fort. Results from this work were not available at the time this report was prepared.

3.1.1.3 Tributaries South of Fort McMurray

Water samples were collected for the first time from two sites on the Clearwater River in 2001. Sample sites were located approximately 20 km downstream and 2 km upstream of the Christina River (Figure 3.1), and samples were collected in the winter, spring, summer and fall, in accordance to the sampling schedule outlined in Table 3.4. As a result of problems with field instrumentation, field measurements, including pH, conductivity, temperature and DO, were not recorded during each sampling event.

Each grab sample was taken from the middle of the river. In winter, ice and other debris were removed from the water surface prior to sample collection. Composite water samples collected from both sample sites on the Clearwater River were analyzed for PAHs (Table 3.3), in addition to the parameters outlined in Section 3.1.1.1.

Table 3.4 Water Sampling Schedule for Tributaries South of Fort McMurray, 2001

Waterbody	Sample Location	Short Title	Sample Date [(a)]	Available Field Measurements [(b)]
Clearwater River	20 km downstream of the Christina River	CLR-1	March 22 (winter)	pH only
			May 9 & 28 (spring)	none
			August 19 (summer)	none
			September 17 (fall)	all
	2 km upstream of the Christina River	CLR-2	March 22 (winter)	pH only
			May 9 & 28 (spring)	none
			August 15 (summer)	all
			September 17 (fall)	all

(a) Ultra-low level mercury and silver sampling had to be repeated in the spring, as a result of shipping problems (i.e., samples failed to reach ARC-Vegreville within specified holding times).
(b) all = DO, temperature, conductivity and pH.

3.1.1.4 Tributaries North of Fort McMurray

Water samples were collected from McLean, Poplar and Fort creeks, the MacKay River and the Steepbank River in October 2001 (Table 3.5). Each grab sample was collected near the creek or river mouth approximately 100 m upstream of the confluence with the Athabasca River (Figures 3.1 to 3.3). In addition to the analyses outlined in Section 3.1.1.1, portions of the grab samples collected from McLean Creek and the MacKay River were sent to HydroQual Laboratories (HydroQual) in Calgary, Alberta, for chronic toxicity testing using algae (*Selenastrum capricornutum*), the water flea *Ceriodaphnia dubia* and fathead minnow (*Pimephales promelas*).

Table 3.5 Water Sampling Schedule for Tributaries North of Fort McMurray, 2001

Waterbody	Sample Location	Short Title	Sample Date
McLean Creek	mouth	MCC-1	October 15 (fall)
Poplar Creek	mouth	POC-1	October 15 (fall)
MacKay River	mouth	MAR-1	October 14 (fall)
Steepbank River	mouth	STR-1	October 14 (fall)
Fort Creek	mouth	FOC-1	October 11 (fall)

3.1.1.5 Muskeg River Watershed

Conducted by RAMP

In September 2001, grab samples were collected from two locations in the Muskeg River: near the river mouth 100 m upstream of the confluence with the Athabasca River and upstream of Wapasu Creek near the Canterra Road (Figure 3.3). Water samples were also collected from the mouths of Jackpine, Muskeg and Stanley creeks, approximately 100 m upstream of the confluence with the Muskeg River (Table 3.6). In addition to the analyses outlined in Section 3.1.1.1, part of the grab sample taken from the Muskeg River upstream of Wapasu Creek was sent to HydroQual for chronic toxicity testing similar to that discussed in Section 3.1.1.4.

Table 3.6 Water Sampling Schedule for the Muskeg River Watershed, 2001

Waterbody	Sample Location	Short Title	Sample Date
Muskeg River	mouth	MUR-1	September 13 (fall)
	upstream of Wapasu Creek	MUR-6	September 11 (fall)
Jackpine Creek	mouth	JAC-1	September 12 (fall)
Muskeg Creek	mouth	MUC-1	September 24 (fall)
Stanley Creek	mouth	STC-1	September 24 (fall)

Conducted by Albian and Syncrude

In accordance to their respective *Environmental Protection and Enhancement Act* (EPEA) approvals, Albian and Syncrude continued to monitor water quality in the Muskeg River upstream of Aurora North, between Aurora North and the Muskeg River Mine and downstream of the Muskeg River Mine (see Figure 3.3). The information collected by each operator in 2001 is summarized in Tables 3.7 and 3.8. A copy of this data was provided to RAMP and is discussed herein.

Table 3.7 Water Quality Data Collected from the Muskeg River by Albian, 2001

Sampling Location	Parameter		Frequency
upstream of the Muskeg River Mine	total suspended solids		three samples per week
	dissolved oxygen		three samples per week (Oct. 1 to March 31 only)
	5 day biochemical oxygen demand		one sample per week
	nitrogen – ammonia		
	dissolved organic carbon		one sample per month
	dissolved iron		
	dissolved manganese		
upstream and downstream of the Muskeg River Mine	chronic toxicity using *Ceriodaphnia dubia* and fathead minnows		one sample per quarter
	temperature	total hardness	
	dissolved oxygen	pH	
	colour	total alkalinity	
	conductivity	total dissolved solids	
	dissolved organic carbon	total suspended solids	
	biochemical oxygen demand	nitrate and nitrite	
	bicarbonate	potassium	
	calcium	sodium	
	carbonate	sulphate	
	chloride	sulphide	
	magnesium	total phosphorus	
	aluminum (Al)	mercury (Hg)	
	antimony (Sb)	molybdenum (Mo)	
	arsenic (As)	nickel (Ni)	
	barium (Ba)	potassium (K)	
	beryllium (Be)	selenium (Se)	
	boron (B)	silicon (Si)	
	cadmium (Cd)	silver (Ag)	
	calcium (Ca)	sodium (Na)	
	chromium (Cr)	strontium (Sr)	
	cobalt (Co)	sulphur (S)	
	copper (Cu)	thallium (Tl)	
	iron (Fe)	titanium (Ti)	
	lead (Pb)	uranium (U)	
	lithium (Li)	vanadium (V)	
	magnesium (Mg)	zinc (Zn)	
	manganese (Mn)	phenols	
	naphthenic acids	m & p-xylene	
	oil & grease	o-xylene	
	benzene	toluene	
	ethylbenzene	dibenzo(a,h)pyrene	
	acenaphthene	dibenzo(a,i)pyrene	
	acenaphthylene	dibenzo(a,j)pyrene	
	acridine	dimethylbenz(a)anthracene (7,12)	
	anthracene		
	benzo(a)anthracene	fluoranthene	
	benzo(a)pyrene	fluorene	
	benzo(b&j)fluoranthene	indeno(1,2,3-cd)pyrene	
	benzo(c)phenanthrene	3-methylcholanthrene	
	benzo(g,h,i) perylene	naphthalene	
	benzo(k)fluoranthene	phenanthrene	
	chrysene	pyrene	
	dibenz(a,h)anthracene	quinoline	

Table 3.8 Water Quality Data Collected from the Muskeg River by Syncrude, 2001

Sampling Location	Parameter		Frequency
upstream of Aurora North	total suspended solids		three samples per week
	dissolved oxygen		three samples per week (Oct. 1 to March 31 only)
	5 day biochemical oxygen demand		one sample per week
	nitrogen - ammonia		
	chronic toxicity using *Ceriodaphnia dubia* and fathead minnows		one sample per quarter
	temperature	pH	
	dissolved oxygen	total dissolved solids	
	colour	sulphide	
	chloride	sulphate	
	nitrate and nitrite	total phosphorus	
	aluminum (Al)	lead (Pb)	
	antimony (Sb)	mercury (Hg)	
	arsenic (As)	nickel (Ni)	
	beryllium (Be)	selenium (Se)	
	cadmium (Cd)	silver (Ag)	
	chromium (Cr)	thallium (Tl)	
	copper (Cu)	zinc (Zn)	
	iron (Fe)	phenols	
	naphthenic acids	m & p-xylene	
	oil & grease	o-xylene	
	benzene	toluene	
	ethylbenzene	dibenzo(a,h)pyrene	
	acenaphthene	dibenzo(a,i)pyrene	
	acenaphthylene	dibenzo(a,j)pyrene	
	anthracene	dimethylbenz(a)anthracene (7,12)	
	benzo(a)anthracene		
	benzo(a)pyrene	fluoranthene	
	benzo(b&j)fluoranthene	fluorene	
	benzo(c)phenanthrene	indeno(1,2,3-cd)pyrene	
	benzo(g,h,i)perylene	3-methylcholanthrene	
	benzo(k)fluoranthene	naphthalene	
	chrysene	phenanthrene	
	dibenz(a,h)anthracene	pyrene	

3.1.1.6 Wetlands

Composite water samples were collected from Kearl, Isadore's, McClelland and Shipyard lakes in the summer and fall of 2001 (Table 3.9). Sample locations are shown in Figures 3.2 and 3.3. During each sampling event, two or three 1 L grab samples were collected from six to ten randomly selected stations located within the open water areas in each lake, and all grab samples collected from a given wetlands were combined to create one composite sample for that lake.

Table 3.9 Wetlands Water Sampling Schedule, 2001

Wetlands	Short Title	Sample Date
Kearl Lake	KEL-1	August 16, 2001 (summer)
		September 13, 2001 (fall)
Isadore's Lake	ISL-1	August 15, 2001 (summer)
		September 20,2001 (fall)
Shipyard Lake	SHL-1	August 13, 2001 (summer)
		September 25, 2001 (fall)
McClelland Lake	MCL-1	August 14,2001 (summer)
		September 18, 2001 (fall)

3.1.2 Continuous Monitoring

3.1.2.1 General Methodology Specific to RAMP

Continuous monitoring by RAMP in 2001 was limited to recording water temperature in the Clearwater River, McLean Creek, Fort Creek, the Muskeg River and the Alsands Drain. Two types of probes were used: thermographs and thermostrings. Thermographs are stand-alone circular probes approximately 3 cm in diameter that must be programmed prior to deployment and store data internally until downloaded. Thermostrings are flexible, long, string-like probes that connect directly to the data loggers contained within RAMP's hydrometric stations. Data collected by the thermostrings are stored in the data logger and can be remotely downloaded over the Internet.

Both types of units were programmed to record water temperature every 30 minutes. When deployed, they were placed in deep pools or areas that would likely contain water year round. Initially, only thermographs were installed. However, as discussed below, the majority of the thermographs installed in May 2001 could not be located in August and were presumed lost. Five of these thermographs were replaced with thermostrings to determine if these instruments were more reliable than the thermographs.

3.1.2.2 Tributaries North and South of Fort McMurray

In May 2001, thermographs were installed at the mouths of McLean Creek, Fort Creek and in the Clearwater River upstream and downstream of the Christina River (Table 3.10). In August, thermographs installed in Fort Creek and McLean Creek could not be found and were presumed lost. The Fort Creek thermograph was replaced with a thermostring. The thermographs installed in the Clearwater River and the thermostring installed in Fort Creek were retrieved in the fall. However, the data collected from the Clearwater River were not successfully downloaded. As a result, only the temperature data collected from Fort Creek from August to October are included in this report.

Table 3.10 Thermographs and Thermostrings Installed in Tributaries North and South of Fort McMurray, 2001

Waterbody	Site	Short Title	Instrument	Installation Date	Retrieval Date
Clearwater River	upstream of the Christina River	CLR-1	thermograph	May 19	September 18 [a]
	downstream of the Christina River	CLR-2	thermograph	May 19	September 17 [a]
McLean Creek	mouth	MCC-1	thermograph	May 8	- [b]
Fort Creek	mouth	FOC-1	thermograph	May 7	- [b]
			thermostring	August 7	October 28

[a] although thermograph was retrieved, data were corrupted during download.
[b] thermograph could not be found and was presumed to be lost.

3.1.2.3 Muskeg River Watershed

Conducted by RAMP

Three thermographs were installed within the Muskeg River Watershed in May 2001: two in the Muskeg River and one in the Alsands Drain (Table 3.11). At the same time, two previously installed thermographs located in the Muskeg River were downloaded and reinstalled. Thermostrings were installed in August 2001 at two of the sites in the Muskeg River and at the mouth of the Alsands Drain (Table 3.11), because the thermographs previously installed at these locations could not be found.

Table 3.11 Thermographs or Thermostrings Located Within the Muskeg River Watershed, 2001

Waterbody	Site	Short Title	Instrument	Installation Date	Retrieval Date
Muskeg River	upstream of Canterra Road	MUR-2	thermograph	n/a [a]	- [b]
	upstream of Jackpine Creek	MUR-4	thermograph	May 8	- [b]
	upstream of Muskeg Creek	MUR-5	thermograph	n/a [a]	- [b]
			thermostring	August 7	remained in place
	upstream of Wapasu Creek	MUR-6	thermograph	May 8	- [b]
			thermostring	August 6	October 27
Alsands Drain	mouth	ALD-1	thermograph	May 8	- [b]
			thermostring	August 6	remained in place

[a] thermograph was installed in the fall of 2000 and left in place over winter.
[b] thermograph could not be found and was presumed to be lost.

In October 2001, the remaining two thermographs previously installed in the Muskeg River Watershed could not be located and were presumed to be lost. One of the three thermostrings was retrieved. The remaining two thermostrings were left in the field to measure winter water temperatures and to examine the capability of this equipment to withstand cold temperatures.

Conducted by AENV

RAMP purchased a HydroLab DataSonde 4™ continuous monitoring unit in 2000 that AENV services and maintains. Every spring for the past three years, AENV has installed this unit or another one like it in the Muskeg River downstream of the Canterra Road crossing near the Environment Canada gauge station and has retrieved it every fall before freeze-up. The unit was programmed to record in-stream pH, temperature, DO and conductivity levels every hour while deployed in the field. A copy of these data record was supplied to RAMP and is discussed herein.

3.1.3 Data Analysis

3.1.3.1 General Methodology

Water quality data collected in 2001 were compared to available historical information and relevant water quality guidelines for the protection of aquatic life and human health (AENV 1999; U.S. EPA 1999a, 1999b). Published water quality guidelines for the protection of human health were altered to reflect increased fish consumption by local stakeholders, consistent with the TrueNorth EIA (TrueNorth 2001). The adjustments were completed following the methods described in U.S. EPA (1991) using a fish consumption rate of 45 g/d (Richardson 1997). The water quality guidelines used in this assessment are summarized in Table 3.12.

Table 3.12 Water Quality Guidelines for the Protection of Aquatic Life and Human Health

Parameter	Units	Guidelines for the Protection of [a]		
		Aquatic Life [b]		Human Health [c]
		Acute	Chronic	
Conventional Parameters				
pH	-	6.5 - 8.5	6.5 - 8.5	5 - 9
dissolved oxygen	mg/L	5 (1-day minimum)	6.5 (7-day mean)	-
Major Ions				
chloride	mg/L	860	230	-
sulphide [d]	mg/L	-	0.014	-
Nutrients				
ammonia [e]	mg/L	5.6	2.43	-
nitrate	mg/L	-	-	1.4
nitrite	mg/L	-	0.06	-
total nitrogen	mg/L	-	1	-
total phosphorus	mg/L	-	0.05	-
Total Metals				
aluminum	mg/L	0.75	0.1	-
antimony	mg/L	-	-	0.002

Table 3.12 Water Quality Guidelines for the Protection of Aquatic Life and Human Health (continued)

Parameter	Units	Guidelines for the Protection of [a]		
		Aquatic Life [b]		Human Health [c]
		Acute	Chronic	
arsenic	mg/L	0.340	0.005	-
barium	mg/L	-	-	0.144
cadmium [f]	mg/L	0.0038	0.00041	-
chromium [g]	mg/L	0.016	0.001	-
copper [f]	mg/L	0.024	0.003	0.188
iron	mg/L	-	0.3	0.043
lead [f]	mg/L	0.166	0.004	-
manganese	mg/L	-	-	0.007
mercury [h]	mg/L	0.0016	0.0001	0.000007
molybdenum	mg/L	-	0.073	-
nickel [f]	mg/L	0.753	0.084	0.088
selenium	mg/L	-	0.001	0.025
silver [f]	mg/L	0.0106	0.0001	-
thallium	mg/L	-	0.0008	0.002
zinc [f]	mg/L	0.193	0.030	1.31
Organics				
phenolics	µg/L	-	5	-
acenaphthene	µg/L	-	5.8	173
anthracene	µg/L	-	0.012	1,387
benzo(a)anthracene	µg/L	-	0.018	0.0006
benzo(a)pyrene	µg/L	-	0.015	0.0006
benzo(b&k)fluoranthene	µg/L	-	-	0.0006
dibenzo(a,h)anthracene	µg/L	-	-	0.0006
fluoranthene	µg/L	-	0.04	43
fluorene	µg/L	-	3	188
indeno(c,d-123)pyrene	µg/L	-	-	0.0006
naphthalene	µg/L	-	1.1	-
phenanthrene	µg/L	-	0.4	-
pyrene	µg/L	-	0.025	139

(a) - = No guideline available.
(b) AENV (1999).
(c) U.S. EPA (1999a).
(d) Total sulphide concentration equivalent to 0.002 mg/L undissociated H_2S based on a pH value of 8; this value was re-calculated for each site based on local pH conditions to remain consistent with the guideline of 0.002 mg/L undissociated H_2S.
(e) Guidelines are pH (acute and chronic) and temperature (chronic) dependent; values shown here correspond to a pH and temperature of 8 and 10°C, respectively; these guidelines were altered based on site-specific conditions using the methods described in AENV (1999) and U.S. EPA (1999b).
(f) Guidelines are hardness dependent; values shown here are based on a hardness of 175 mg/L; these guidelines were altered based on site-specific hardness levels using the methods described in AENV (1999), U.S. EPA (1999a, 2001a).
(g) Using the guideline for chromium VI.
(h) U.S. EPA (1999a) acute and CCME (1999) chronic guidelines are shown, because Alberta mercury guidelines are still draft.

Protection of aquatic life guidelines listed in Table 3.12 were generally selected according to the recommended protocol outlined in AENV (1999), which stipulates that:

- the most stringent guideline should be used when multiple guidelines are available for a given substance; and
- guidelines developed by AENV after 1996 should be given preference over CCME and U.S. EPA guidelines.

Exceptions to this selection protocol are noted below:

- cadmium
  - using the U.S. EPA (2001a) chronic cadmium guideline in place of the lower CCME (1999) chronic guideline, because, as noted by CCME (1999), most ambient water contain cadmium levels in excess of the recommended CCME chronic cadmium guideline;
- copper
  - using U.S. EPA (1999a) acute and CCME (1999b) chronic copper guidelines, since the Alberta copper guidelines apply to acid extractable values (as opposed to total values); and
- mercury
  - using U.S. EPA (1999a) acute and CCME (1999) chronic guidelines, because Alberta mercury guidelines are still draft.

Historical median, minimum and maximum parameter concentrations were calculated and are summarized, along with all 2001 sample results, in the summary tables contained in Sections 5 through 9.

When fewer than two historical data points were available, no data analysis was performed other than comparing available information to water quality guidelines and identifying any unusual observations that differed substantially from water quality conditions observed elsewhere in the lower Athabasca River watershed.

If two to four historical data points were available, 2001 sample results were compared to historical minimums and maximums. Sample results falling outside of this minimum to maximum historical range were identified and are discussed herein.

When more than four historical data points were available, 2001 sample results were compared to the historical 25th and 75th percentiles. Time series plots were then created for every parameter where observed 2001 concentrations were below the 25th percentile or above the 75th percentile to identify results that might indicate increasing or decreasing trends. Statistical analysis was not completed for this report, although it will be included as part of the five-year trend report that will be published later in 2002.

3.1.3.2 Athabasca River

For the Athabasca River, 2001 east and west bank composite sample results were compared to previous individual east and west bank composite samples collected by RAMP in 1998 and 2000 (Golder 1999b, 2001a) to determine if differences in water quality could be observed between the two sides of the river. Sample results from 2001 were also compared to available historical information that included water quality data collected from either bank or elsewhere in the relevant section of the river prior to 1998. A qualitative analysis was also completed using the 2001 data to look at downstream trends in the Athabasca River.

3.1.3.3 Muskeg River

For the Muskeg River, the data analysis procedure outlined above was completed at the two RAMP sample sites (i.e., Muskeg River mouth and upstream of Wapasu Creek) using data collected prior to 1998 to define historical minimums, maximums, 25th percentiles and 75th percentiles, although the summary tables contained herein present summary statistics for the entire period of record. The year 1998 was chosen based on Aurora North's EPEA Approval being issued on April 7, 1998. Since Aurora North was the first oil sands project to be approved in the Muskeg River watershed, water quality information collected prior to 1998 should represent background conditions prior to development.

As available data for tributaries of the Muskeg River are limited, 2001 sample results were compared to summary statistics developed from the entire available dataset, instead of using summary statistics calculated from water quality information collected prior to 1999. The monitoring data provided by Albian and Syncrude are simply presented as delivered with a comparison to relevant water quality guidelines.

3.1.3.4 Clearwater River

RAMP is currently collecting samples from the Clearwater River to establish baseline conditions in this river. As a result, analysis of the 2001 monitoring results was limited to calculating historical median, minimum and maximum values from the available dataset, comparing the 2001 results to the historical range to determine if conditions in 2001 were generally consistent with those observed in previous sampling events and providing a general discussion of water quality in this river.

3.2 SEDIMENT QUALITY

The scope of the 2001 sediment quality survey was to:

- continue to monitor the same set of sediment quality parameters analyzed in 2000;
- resample the mouths of the Muskeg River, and McLean and Fort creeks;
- resample the Athabasca River, including east and west bank samples from upstream of Donald Creek, the Steepbank River, Muskeg River and Fort Creek, as well as a cross-channel composite upstream of the Embarras River;
- expand sampling to include the Big Point, Goose Island and Fletcher channels;
- expand sampling to include the Clearwater River at locations upstream of Fort McMurray and the Christina River;
- expand sampling to include two locations on the MacKay River; and
- expand sampling to include Kearl, Isadore's and Shipyard lakes.

In 2001, composite sediment samples were collected by RAMP from:

- the Athabasca River, including the Delta;
- the Clearwater River;
- tributaries north of Fort McMurray, including McLean Creek and the MacKay River;
- the Muskeg River; and
- Kearl, Shipyard and Isadore's lakes;

Sample locations are shown in Figures 3.1 to 3.4, and the specific methods used to collect this information are discussed in Section 3.2.1.

3.2.1 Sample Collection and Analysis

3.2.1.1 General Methodology

All composite sediment samples were created by combining four to six grab samples collected from depositional areas located within each sample site. Grab samples were collected using an Ekman sediment sampler, and sample depths were approximately 3 to 5 cm. All samples were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.2-2 (Golder 1999a).

Following sample collection, all sediment samples were split. One portion was shipped to ETL for analysis of carbon content, particle size, total recoverable hydrocarbons, total volatile hydrocarbons, total extractable hydrocarbons and total metals (Table 3.13). Another part was sent to AXYS Analytical Services Ltd. (AXYS) in Sidney, B.C., and analyzed for the target and alkylated PAH compounds listed in Table 3.13. Descriptions of the analytical methods used by each laboratory are provided in Appendix I.

Table 3.13 Standard RAMP Sediment Quality Parameter List

Group Name	Individual Parameters
particle size	percent sand
	percent silt
	percent clay
	moisture content
carbon content	total inorganic carbon
	total organic carbon
	total carbon
organics	total recoverable hydrocarbons
	total volatile hydrocarbons (C5-C10)
	total extractable hydrocarbons (C11-C30)
total metals	aluminum (Al)
	arsenic (As)
	barium (Ba)
	beryllium (Be)
	boron (B)
	cadmium (Cd)
	calcium (Ca)
	chromium (Cr)
	cobalt (Co)
	copper (Cu)
	iron (Fe)
	lead (Pb)
	magnesium (Mg)
	manganese (Mn)
	mercury (Hg)
	molybdenum (Mo)
	nickel (Ni)
	potassium (K)
	selenium (Se)

Table 3.13 Standard RAMP Sediment Quality Parameter List (continued)

Group Name	Individual Parameters
	silver (Ag)
	sodium (Na)
	strontium (Sr)
	thallium (Tl)
	uranium (U)
	vanadium (V)
	zinc (Zn)
target PAHs	acenaphthene
	acenaphthylene
	anthracene
	benzo(a)anthracene/chrysene
	benzo(a)pyrene
	benzofluoranthenes
	benzo(g,h,i)perylene
	biphenyl
	dibenzo(a,h)anthracene
	dibenzothiophene
	fluoranthene
	fluorene
	indeno(c,d-123)pyrene
	naphthalene
	phenanthrene
	pyrene
alkylated PAHs	C1 substituted acenaphthene
	C1 substituted benzo(a)anthracene/chrysene
	C2 substituted benzo(a)anthracene/chrysene
	C1 substituted biphenyl
	C2 substituted biphenyl
	C1 substituted benzofluoranthene/benzo(a)pyrene
	C2 substituted benzofluoranthene/benzo(a)pyrene
	C1 substituted dibenzothiophene
	C2 substituted dibenzothiophene
	C3 substituted dibenzothiophene
	C4 substituted dibenzothiophene
	C1 substituted fluoranthene/pyrene
	C2 substituted fluoranthene/pyrene
	C3 substituted fluoranthene/pyrene
	C1 substituted fluorene
	C2 substituted fluorene
	C3 substituted fluorene
	C1 substituted naphthalenes
	C2 substituted naphthalenes
	C3 substituted naphthalenes
	C4 substituted naphthalenes
	C1 substituted phenanthrene/anthracene
	C2 substituted phenanthrene/anthracene
	C3 substituted phenanthrene/anthracene
	C4 substituted phenanthrene/anthracene
	1-methyl-7-isopropyl-phenanthrene (retene)

3.2.1.2 Athabasca River Mainstem and Delta

In the fall of 2001, east and west bank composite sediment samples were collected from the Athabasca River approximately 100 m upstream of each of the following tributaries: Donald Creek, the Steepbank River, the Muskeg River and Fort Creek. The sediment sampling schedule is outlined in Table 3.14. Each composite sample was created by combining grab samples collected between the respective river bank and 25% of the river width.

Cross-channel composite sediment samples were collected from the Athabasca River approximately 100 m upstream of the Embarras River and from three locations within the Athabasca Delta (i.e., Goose Point Channel, Big Point Channel and Fletcher Channel; Table 3.14) by combining grab samples collected across the entire river/channel width. In addition to the analyses outlined in Section 3.2.1.1, part of all of the composite samples taken from the Athabasca River, including the Delta, were sent to HydroQual for toxicity testing using midge larvae (*Chironomus tentans)*, amphipods (*Hyalella azteca*) and oligochaete worms (*Lumbriculus variegatus*).

Table 3.14 Sediment Sampling Schedule for the Athabasca River, 2001

Sample Location		Short Title	Sample Date
Sampling Site	Sampling Point		
upstream of Donald Creek	west bank	ATR-DC-W	November 2 (fall)
	east bank	ATR-DC-E	
upstream of the Steepbank River	west bank	ATR-SR-W	November 1 (fall)
	east bank	ATR-SR-E	
upstream of the Muskeg River	west bank	ATR-MR-W	November 1 (fall)
	east bank	ATR-MR-E	
upstream of Fort Creek	west bank	ATR-FC-W	October 14 (fall)
	east bank	ATR-FC-E	
upstream of the Embarras River	cross channel	ATR-ER	October 18 (fall)
Athabasca Delta	Big Point Channel	ATD-BPC	October 17 (fall)
	Goose Island Channel	ATD-GIC	October 17 (fall)
	Fletcher Channel	ATD-FLC	October 17 (fall)

3.2.1.3 Other Waterbodies

Composite sediment samples were collected in the fall of 2001 from the Clearwater River upstream and downstream of the Christina River, McLean Creek, the MacKay River, the Muskeg River, Kearl Lake, Isadore's Lake and Shipyard Lake (Table 3.15). Each composite sediment sample was created by combining grab samples collected across the stream width or over the open-water area.

Table 3.15 Water and Sediment Sampling Schedule for Athabasca River Tributaries, 2001

Area	Waterbody	Sample Location	Short Title	Sample Date
tributaries south of Fort McMurray	Clearwater River	downstream of the Christina River	CLR-1	September 17 (fall)
		upstream of the Christina River	CLR-2	September 17 (fall)
tributaries north of Fort McMurray	McLean Creek	mouth	MCC-1	October 15 (fall)
	MacKay River	mouth	MAR-1	October 14 (fall)
		upstream of Highway 63	MAR-2	November 8 (fall)
Muskeg River watershed	Muskeg River	mouth	MUR-1	September 13 (fall)
wetlands	Kearl Lake	-	KEL-1	September 13 (fall)
	Isadore's Lake	-	ISL-1	September 20 (fall)
	Shipyard Lake	-	SHL-1	September 25 (fall)

3.2.2 Data Analysis

3.2.2.1 General Methodology

Sediment quality data collected in 2001 were compared to available historical information and Canadian Sediment Quality Guidelines (Table 3.16). Historical median, minimum and maximum parameter concentrations were developed and are summarized, along with all 2001 sample results, in the summary tables contained in Sections 5 through 9.

When fewer than two historical data points were available, no data analysis was performed other than comparing available information to sediment quality guidelines and identifying any unusual observations that differed substantially from sediment quality conditions observed elsewhere in the lower Athabasca River watershed.

If two to four historical data points were available, 2001 sample results were compared to historical minimums and maximums. Sample results falling outside of this minimum to maximum historical range were identified and are discussed herein.

When more than four historical data points were available, 2001 sample results were compared to the historical 25th and 75th percentiles. Time series plots were then created for every parameter where observed 2001 concentrations were below the 25th percentile or above the 75th percentile to identify results that might indicate increasing or decreasing trends. Statistical analysis was not completed for this report, although it will be included as part of the five year trend report that will be published later in 2002.

Table 3.16 Freshwater Sediment Quality Guidelines for the Protection of Aquatic Life

Parameter	Units	ISQG[(a)]	PEL[(b)]
Total Metals			
arsenic	µg/g	5.9	17
cadmium	µg/g	0.6	3.5
chromium	µg/g	37.3	90
copper	µg/g	35.7	197
lead	µg/g	35	91.3
mercury	µg/g	0.17	0.486
zinc	µg/g	123	315
Polycyclic Aromatic Hydrocarbons			
acenaphthene	ng/g	6.71	88.9
acenaphthylene	ng/g	5.87	128
anthracene	ng/g	46.9	245
benzo(a)anthracene	ng/g	31.7	385
benzo(a)pyrene	ng/g	31.9	782
dibenzo(a,h)anthracene	ng/g	6.22	135
fluoranthene	ng/g	111	2355
fluorene	ng/g	21.2	144
naphthalene	ng/g	34.6	391
C1 substituted naphthalenes	ng/g	20.2	201
phenanthrene	ng/g	41.9	515
pyrene	ng/g	53	875

(a) ISQG= interim sediment quality guideline (CCME 1999).
(b) PEL = probable effects level as defined by CCME (1999).

3.2.2.2 Athabasca River

For the Athabasca River, 2001 east and west bank composite sample results were compared to previous individual east and west bank composite samples collected by RAMP in 1998 and 2000 (Golder 1999, 2001a) to determine if differences in sediment quality could be observed between the two side of the river. Sample results from 2001 were also compared to available historical information that included sediment quality data collected from either bank or elsewhere in the relevant section of the river prior to 1998. A qualitative analysis was also completed using the 2001 data to look at downstream trends in the Athabasca River.

3.3 BENTHIC INVERTEBRATE COMMUNITY

3.3.1 Overview of the 2001 Benthic Invertebrate Program

The fall 2001 benthic invertebrate sampling program consisted of sampling four major tributaries of the Athabasca River, one small stream and two lakes. Sampling site locations, habitat sampled and sampling dates are provided in Table 3.17.

Table 3.17 Summary of the Fall 2001 Benthic Invertebrate Sampling Program

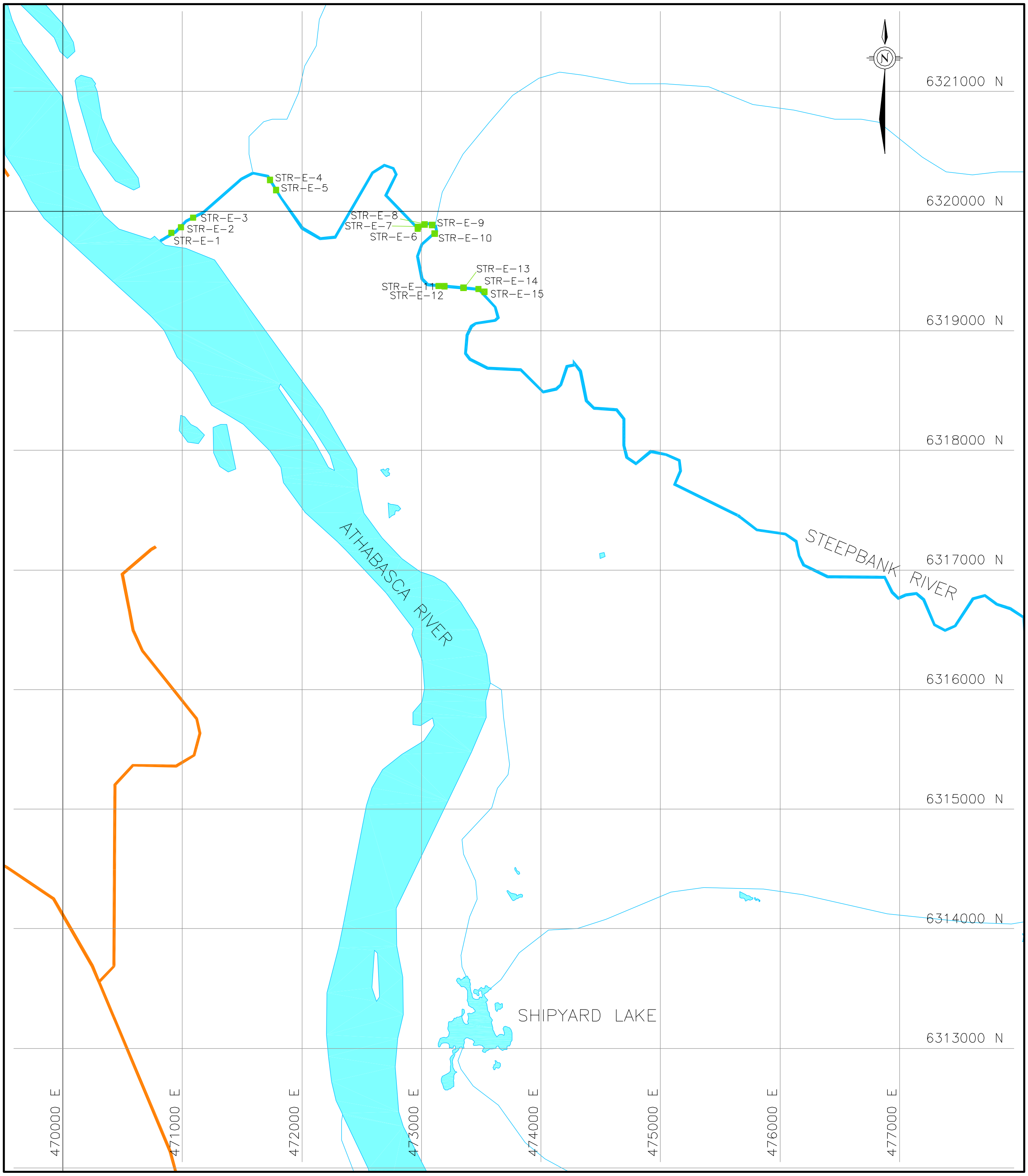
Waterbody	Location Sampled	Sample Identifiers	Habitat	Sample Date
Clearwater River	upstream of Christina River	CLR-D-16 to CLR-D-30	depositional	September 19
	downstream of Christina River	CLR-D-1 to CLR-D-15	depositional	September 17 to 18
Fort Creek	at mouth	FOC-D-1 to FOC-D-5	depositional	October 11
MacKay River	lower reach	MAR-E-1 to MAR-E-15	erosional	September 28
Muskeg River	lower reach	MUR-E-1 to MUR-E-15	erosional	September 12 and 14
	lower to mid-reach	MUR-D-16 to MUR-D-30	depositional	September 20 to 21
Steepbank River	lower reach	STR-E-1 to STR-E-15	erosional	September 17
Kearl Lake	10 sites distributed throughout lake	KEL-1 to KEL-9	lake	September 19
Shipyard Lake	10 sites distributed throughout lake	SHL-1 to SHL-10	lake	September 25

3.3.2 Sampling Site Locations

The dominant habitat types were sampled in each river reach monitored. Benthic invertebrate habitat is typically described as either erosional (i.e., riffles or runs with coarse substrates and moderate to fast currents) or depositional (i.e., runs or backwaters with fine sediments and slow currents). The MacKay and Steepbank rivers are largely erosional throughout their length, whereas the Muskeg River is mostly depositional with the exception of its lowest reach from its mouth to about 10 km upstream. The lower Clearwater River and the lower reach of Fort Creek are predominantly depositional. The sampling reaches in the Muskeg River and Fort Creek contained a number of beaver dams and ponds, which complicated site selection due to poor access.

The sampling design for the MacKay, Muskeg and Steepbank rivers consisted of collecting 15 samples within an approximately 5 km erosional reach upstream from the mouth (Figures 3.5 and 3.6, Table 3.18). In addition, 15 depositional samples were collected in the Muskeg River farther upstream, within a 5 km reach beginning about 10 km upstream from the mouth (Figure 3.6, Table 3.18), above an abrupt change in gradient. One MacKay River sample (MAR-E-5) was spilled during transport, resulting in data available for 14 samples from this river.

Two depositional reaches were sampled in the Clearwater River (Figure 3.7, Table 3.18), including one reach upstream and one downstream of the mouth of the Christina River. Fifteen samples were collected within an approximately 5 km reach in each of these areas. The Christina River receives drainage from a number of in-situ oil sands developments and is scheduled for initial sampling in 2002.



LEGEND

ROADWAYS

RIVERS AND STREAMS

EROSIONAL BENTHIC INVERTEBRATE SAMPLING SITE

1 0 1

SCALE KILOMETRES

PROJECT

RAMP 2001

TITLE

BENTHIC INVERTEBRATE SAMPLING SITES IN THE STEEPBANK RIVER, FALL 2001

Golder Associates
Calgary, Alberta

PROJECT No.	012-2302	FILE No.	Fall 2001 Data.dwg	
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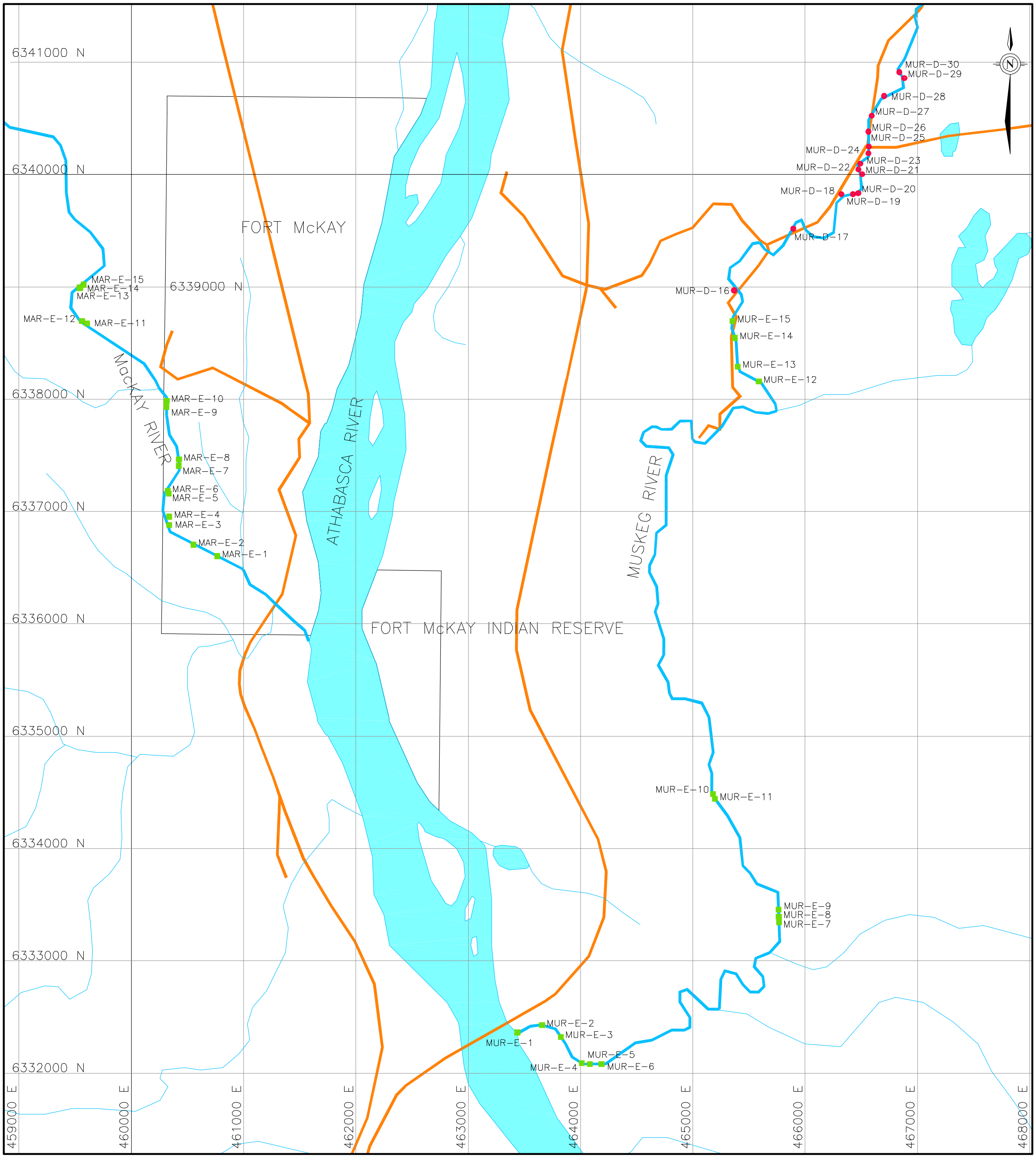
CADD	RFM	17/05/02		
CHECK	KF	17/05/02	**FIGURE: 3.5**	
REVIEW				

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: River-Sample Pts-Fall 2001 Data.dwg Jul 10, 2002 - 10:39am



LEGEND

ROADWAYS

RIVERS AND STREAMS

DEPOSITIONAL BENTHIC INVERTEBRATE SAMPLING SITE

EROSIONAL BENTHIC INVERTEBRATE SAMPLING SITE

1 0 1

SCALE KILOMETRES

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

PROJECT

RAMP 2001

TITLE

BENTHIC INVERTEBRATE SAMPLING SITES IN THE MACKAY AND MUSKEG RIVERS, FALL 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	Fall 2001 Data.dwg
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CADD	RFM	17/05/02	FIGURE: 3.6	
CHECK	KF	17/05/02		
REVIEW				

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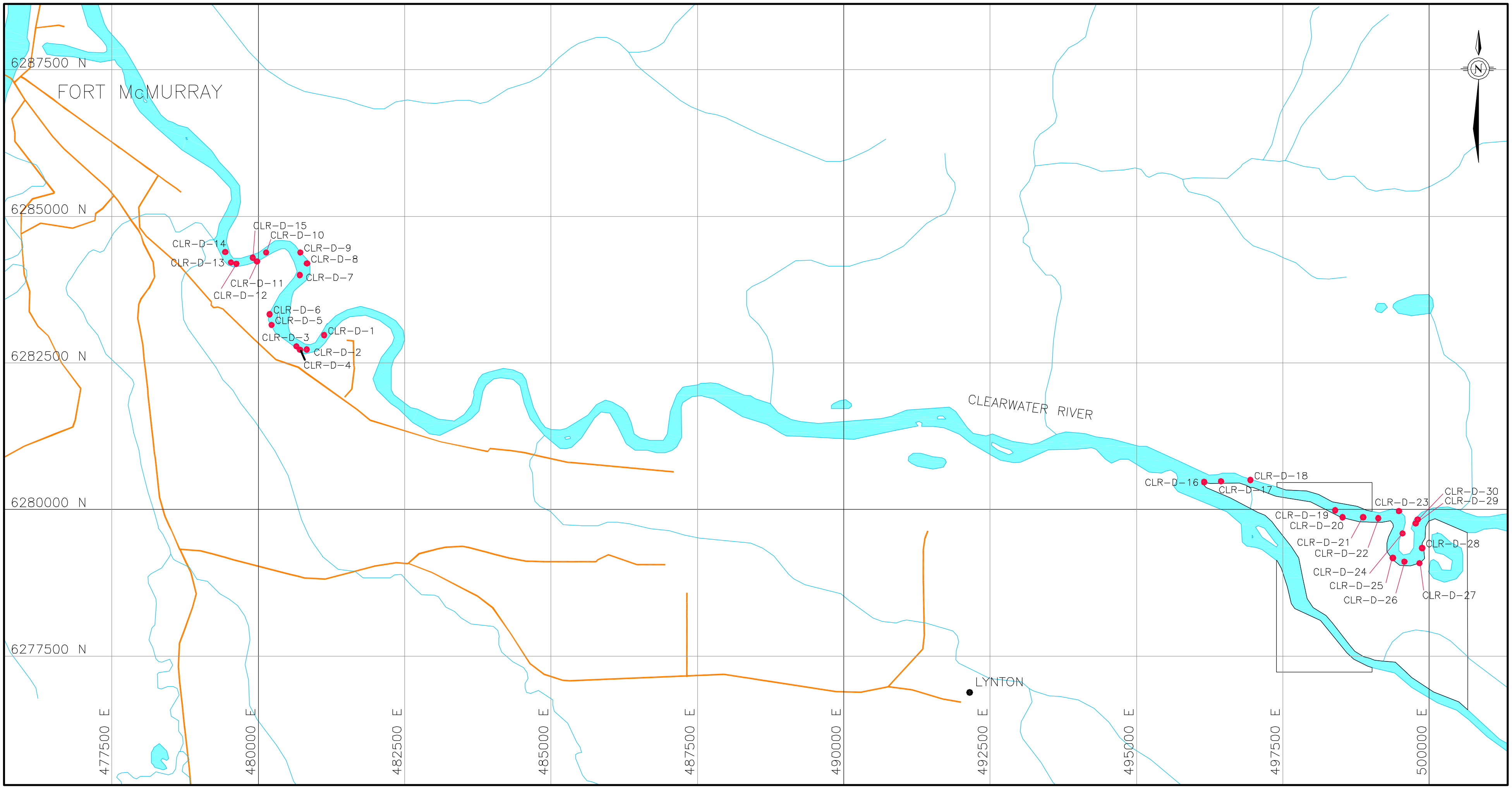


LEGEND

ROADWAYS

RIVERS AND STREAMS

DEPOSITIONAL BENTHIC INVERTEBRATE SAMPLING SITE

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

PROJECT

RAMP 2001

TITLE

BENTHIC INVERTEBRATE SAMPLING SITES IN THE CLEARWATER RIVER, FALL 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302
DESIGN	LG	21/03/02
CADD	RFM	17/05/02
CHECK	KF	17/05/02
REVIEW		

FILE No.	Fall 2001 Data.dwg
SCALE AS SHOWN	REV. 1

FIGURE: 3.7

Table 3.18 Sampling Dates and Locations of River/Stream Benthic Invertebrate Sampling Sites, Fall 2001

River/ Stream	Sample	Sample Date	UTM E	UTM N
MacKay (lower reach)	MAR-E-1	28-Sep-01	460765	6336603
	MAR-E-2	28-Sep-01	460554	6336704
	MAR-E-3	28-Sep-01	460338	6336881
	MAR-E-4	28-Sep-01	460338	6336955
	MAR-E-6	28-Sep-01	460324	6337184
	MAR-E-7	28-Sep-01	460423	6337407
	MAR-E-8	28-Sep-01	460424	6337463
	MAR-E-9	28-Sep-01	460312	6337932
	MAR-E-10	28-Sep-01	460315	6337986
	MAR-E-11	28-Sep-01	459607	6338675
	MAR-E-12	28-Sep-01	459562	6338696
	MAR-E-13	28-Sep-01	459539	6338991
	MAR-E-14	28-Sep-01	459544	6338995
	MAR-E-15	28-Sep-01	459576	6339020
Steepbank (lower reach)	STR-E-1	17-Sep-01	470908	6319817
	STR-E-2	17-Sep-01	471008	6319843
	STR-E-3	17-Sep-01	471035	6319972
	STR-E-4	17-Sep-01	471555	6320300
	STR-E-5	17-Sep-01	471791	6320168
	STR-E-6	17-Sep-01	472970	6319858
	STR-E-7	17-Sep-01	472971	6319869
	STR-E-8	17-Sep-01	473028	6319884
	STR-E-9	17-Sep-01	473092	6319894
	STR-E-10	17-Sep-01	473112	6319812
	STR-E-11	17-Sep-01	473143	6319377
	STR-E-12	17-Sep-01	473192	6319373
	STR-E-13	17-Sep-01	473351	6319360
	STR-E-14	17-Sep-01	473476	6319348
	STR-E-15	17-Sep-01	473528	6319325
Muskeg (lower reach)	MUR-E-1	14-Sep-01	463438	6332362
	MUR-E-2	14-Sep-01	463658	6332427
	MUR-E-3	14-Sep-01	463824	6332323
	MUR-E-4	14-Sep-01	464010	6332090
	MUR-E-5	14-Sep-01	464084	6332081
	MUR-E-6	14-Sep-01	464187	6332081
	MUR-E-7	12-Sep-01	465766	6333341
	MUR-E-8	12-Sep-01	465765	6333393
	MUR-E-9	12-Sep-01	465763	6333457
	MUR-E-10	12-Sep-01	465178	6334483
	MUR-E-11	12-Sep-01	465196	6334442
	MUR-E-12	14-Sep-01	465587	6338157

Table 3.18 Sampling Dates and Locations of River/Stream Benthic Invertebrate Sampling Sites, Fall 2001 (continued)

River/ Stream	Sample	Sample Date	UTM E	UTM N
Muskeg (lower reach) (continued)	MUR-E-13	14-Sep-01	465400	6338291
	MUR-E-14	14-Sep-01	465374	6338546
	MUR-E-15	12-Sep-01	465352	6338696
Muskeg (lower to mid-reach)	MUR-D-16	21-Sep-01	465367	6338970
	MUR-D-17	21-Sep-01	465925	6339503
	MUR-D-18	21-Sep-01	466321	6339827
	MUR-D-19	21-Sep-01	466521	6339792
	MUR-D-20	21-Sep-01	466516	6339833
	MUR-D-21	20-Sep-01	466507	6340004
	MUR-D-22	20-Sep-01	466394	6340038
	MUR-D-23	20-Sep-01	466490	6340098
	MUR-D-24	20-Sep-01	466563	6340190
	MUR-D-25	20-Sep-01	466568	6340249
	MUR-D-26	20-Sep-01	466563	6340384
	MUR-D-27	20-Sep-01	466593	6340524
	MUR-D-28	20-Sep-01	466703	6340701
	MUR-D-29	20-Sep-01	466883	6340860
	MUR-D-30	20-Sep-01	466771	6340865
Clearwater (downstream Christina River)	CLR-D-1	17-Sep-01	481125	6282973
	CLR-D-2	18-Sep-01	480827	6282729
	CLR-D-3	18-Sep-01	480651	6282784
	CLR-D-4	18-Sep-01	480714	6282722
	CLR-D-5	18-Sep-01	480225	6283149
	CLR-D-6	18-Sep-01	480195	6283329
	CLR-D-7	18-Sep-01	480710	6283997
	CLR-D-8	18-Sep-01	480833	6284195
	CLR-D-9	18-Sep-01	480718	6284385
	CLR-D-10	18-Sep-01	480133	6284383
	CLR-D-11	18-Sep-01	479977	6284232
	CLR-D-12	18-Sep-01	479625	6284191
	CLR-D-13	18-Sep-01	479533	6284212
	CLR-D-14	18-Sep-01	479437	6284391
	CLR-D-15	18-Sep-01	479907	6284294
Clearwater (upstream Christina River)	CLR-D-16	19-Sep-01	496156	6280470
	CLR-D-17	19-Sep-01	496444	6280481
	CLR-D-18	19-Sep-01	496946	6280502
	CLR-D-19	19-Sep-01	498396	6279986
	CLR-D-20	19-Sep-01	498520	6279867
	CLR-D-21	19-Sep-01	498873	6279867
	CLR-D-22	19-Sep-01	499130	6279851
	CLR-D-23	19-Sep-01	499483	6279972

Table 3.18 Sampling Dates and Locations of River/Stream Benthic Invertebrate Sampling Sites, Fall 2001 (continued)

River/ Stream	Sample	Sample Date	UTM E	UTM N
Clearwater (upstream Christina River) (continued)	CLR-D-24	19-Sep-01	499544	6279592
	CLR-D-25	19-Sep-01	499379	6279173
	CLR-D-26	19-Sep-01	499576	6279112
	CLR-D-27	19-Sep-01	499834	6279084
	CLR-D-28	19-Sep-01	499880	6279343
	CLR-D-29	19-Sep-01	499770	6279764
	CLR-D-30	19-Sep-01	499804	6279830
Fort Creek (at mouth)	FOC-D-1	11-Oct-01	461537	6363092
	FOC-D-2	11-Oct-01	-	-
	FOC-D-3	11-Oct-01	-	-
	FOC-D-4	11-Oct-01	-	-
	FOC-D-5	11-Oct-01	461566	6363095

Note: - = no data.

Fort Creek was sampled near its mouth, in depositional habitat (Table 3.18). The accessible lower reach of this stream (i.e., below beaver dams) was limited to about 100 m. Therefore, sampling effort was limited to five samples within this reach.

Kearl and Shipyard lakes were sampled at ten locations per lake (Table 3.19). Sample points were located outside of emergent vegetation, in 1 to 3 m deep water. One sample was lost during transport of samples by helicopter from Kearl Lake (KEL-10), resulting in data for a total of nine samples available from this lake.

The objective of site selection in the field was to find locations representing "representative" erosional, depositional or lake habitats, rather than to standardize the habitat sampled to within a narrow range. Although this approach may result in more variable data, it provides a better indication of the range of benthic communities inhabiting the areas sampled. Spacing of the individual samples in rivers was dependent upon access (i.e., helicopter landing sites), availability of suitable habitat and time constraints. In areas where it was necessary to group samples within shorter reaches, spacing was about 50 to 100 m between samples to maximize spatial coverage.

Table 3.19 Sampling Dates and Locations of Wetlands Benthic Invertebrate Sampling Sites, Fall 2001

Wetlands	Sample	Sample Date	UTM E	UTM N
Kearl Lake	KEL-1	19-Sep-01	485099	6350483
	KEL-2	19-Sep-01	485229	6350252
	KEL-3	19-Sep-01	485297	6349844
	KEL-4	19-Sep-01	485461	6349516
	KEL-5	19-Sep-01	485467	6349207
	KEL-6	19-Sep-01	485205	6348643
	KEL-7	19-Sep-01	485408	6348168
	KEL-8	19-Sep-01	485235	6347831
	KEL-9	19-Sep-01	485150	6347598
Shipyard Lake	SHL-1	25-Sep-01	473455	6313831
	SHL-2	25-Sep-01	473419	6313335
	SHL-3	25-Sep-01	473404	6313011
	SHL-4	25-Sep-01	473291	6312863
	SHL-5	25-Sep-01	473575	6312867
	SHL-6	25-Sep-01	473778	6312928
	SHL-7	25-Sep-01	473519	6312828
	SHL-8	25-Sep-01	473306	6312970
	SHL-9	25-Sep-01	473465	6313180
	SHL-10	25-Sep-01	473356	6313369

3.3.3 Field Methods

Benthic invertebrate samples were collected according to Golder Technical Procedure 8.6-1 (Golder 1999a). These procedures meet or exceed government guidelines for monitoring benthos in freshwaters (AENV 1990, Environment Canada 1993). A Neill cylinder of 0.093 m^2 bottom area with a 210 µm mesh collecting net was used to sample benthic invertebrates in erosional habitat. A pole-mounted Ekman grab of 0.0232 m^2 bottom area was used in depositional habitat and in lakes/wetlands. In rivers and streams, one sample was collected at each of the 15 locations selected within the sampling reach. In wetlands, ten grab samples were collected at randomly chosen locations in the wetland, within a depth range of 1 to 3 m. Ekman grab samples were sieved in the field prior to preserving, using a 250 µm mesh sieve. Benthic samples were preserved in 10% buffered formalin.

In depositional reaches and in wetlands, one additional Ekman grab was collected at each sampling location and was analyzed for particle size distribution (sand, silt and clay as dry weight percentages) and total organic carbon (TOC as a dry weight percentage) to aid in the interpretation of the benthic invertebrate data.

Physical characteristics of the sampling sites were recorded to allow an analysis of the influence of such variation on the invertebrate community. Supporting measurements are listed below and were measured at each sampling location using the following instruments:

- wetted and bankfull channel widths – visual estimate (rivers/streams only);
- field water quality: DO, conductivity, pH, water temperature – Multiline™ or Hydrolab™ water quality meter;
- current velocity – Marsh-McBirney™ current velocity meter (rivers/streams only);
- water depth – wading rod of current velocity meter or graduated pole on Ekman grab;
- amount of benthic algae at erosional sites – a quantitative benthic algae sample at each sampling location (2 × 2 cm scrapes from three cobbles, combined into one composite sample), analyzed for chlorophyll *a*;
- substrate particle size distribution at erosional sites – visual estimates of areal coverage by particles in standard size categories using the modified Wentworth classification system (Cummins 1962), expressed as percentages;
- exact position – Garmin™ Global Positioning System (GPS) unit;
- Secchi depth – 20 cm diameter Secchi disk (wetlands only); and
- general site appearance – photograph (rivers/streams only).

Benthic algal scrapes for chlorophyll *a* analysis were stored and transported frozen. Sediment samples for determination of particle size and TOC were stored on ice or in a refrigerator and were transported on ice. Both were submitted for analysis at ETL.

3.3.4 Laboratory Methods

The sample material was first passed through a 250 µm mesh sieve to remove the preservative and any remaining fine sediments. The material retained by this sieve was elutriated using a floatation technique to separate organic material from sand and gravel. Inorganic material was scanned under a magnifying lens and any remaining invertebrates were removed before discarding. The remaining organic material was separated into coarse and fine size fractions using a 1 mm sieve. The fine size fraction of large samples was subsampled using a method based on that described by Wrona et al. (1982). Invertebrates were removed from the detritus under a dissecting microscope. All sorted material was preserved for random checks of removal efficiency.

Invertebrates were identified using recognized taxonomic keys to the lowest practical level, typically genus with the exception of the Oligochaeta, which were identified to family. Small, early-instar or damaged specimens were identified to the lowest level possible, generally to family.

Quality assurance and quality control (QA/QC) procedures related to benthic invertebrate sample processing are discussed in Section 4.2.2. Ten per cent of the total number of samples collected during the field program were re-sorted to evaluate sorting efficiency.

3.3.5 Data Analysis

The 2001 benthic survey results were summarized to describe benthic community characteristics in each waterbody sampled. Non-benthic and terrestrial taxa were deleted from the data set before analysis. Community variables such as total abundance (number/m^2), taxonomic richness (total taxa/sampling reach and the mean number of taxa/sample) and community composition by major invertebrate groups were examined as bar graphs of mean numbers per reach or lake and corresponding standard errors (SE; except for total taxa/reach). Mean abundances of common taxa, defined as those constituting ≥1% of total abundance in a reach or lake, were tabulated to illustrate relative abundances, dominance and variability within sampling reaches or lakes.

The benthic invertebrate abundance data were also examined for relationships between key habitat variables and benthic community structure (summarized as total abundance, richness and abundances of common invertebrates). For this analysis, common taxa were further reduced to those present in at least four samples from a waterbody. Spearman correlation coefficients were calculated to identify potential relationships, separately for each river and lake. Significant correlations were examined visually as scatter-plots. Habitat variables were included in this analysis if they varied over a sufficient range to account for some variation in community structure. Substrate composition in erosional reaches was expressed as the Weighted Average Index (WAI; Fernet and Walder 1986). The WAI summarizes particle size as a single variable, which is useful to represent average particle size, provided that the size distribution is continuous.

3.4 FISH POPULATIONS

Table 3.20 presents the specific components of the 2001 program, the watercourses where sampling activities were conducted and the target fish species, where appropriate. In addition to the sites in Table 3.20, the sentinel species monitoring study also included sampling of the Horse and Dunkirk rivers to provide reference sites for evaluating slimy sculpin populations in the Muskeg and Steepbank rivers.

Appendix II presents the common and scientific names of all fish species mentioned in this report. It also provides the four-letter abbreviation code for each species. The species abbreviations are used in the tables in the main body of the report and in the appendices.

Table 3.20 Tasks, Sampling Sites and Target Species of the 2001 Fisheries Program

Task	Study Period	Watercourse			
		Athabasca River	Muskeg River	Jackpine Creek	Steepbank River
radiotelemetry	May 2000-June 2001	LNSC	NRPK, LNSC	-	-
fish tissue	fall 2001	WALL, LKWH	NRPK	-	-
tributary sentinel species	fall 2001	-	SLSC	-	SLSC
fish fence study	spring 2001	-	general	-	-
fish inventory	summer 2001	-	general	general	-

Note: LNSC = longnose sucker; WALL = walleye; LKWH = lake whitefish: NRPK = northern pike; SLSC = slimy sculpin.
- = not included in task.

3.4.1 Radiotelemetry Study

3.4.1.1 Program Initiation

The 2001 component of the radiotelemetry study involved continuing radio-tracking activities initiated in spring 2000 through to spring 2001 to provide a complete year of telemetry data.

In the spring of 2000, 25 northern pike and 50 longnose sucker were radio-tagged (i.e., fitted with surgically implanted radio transmitters) for the telemetry study (Golder 2001a). The northern pike were radio-tagged during the spawning run in the Muskeg River. The radio-tagged longnose sucker included representatives of two separate spawning sub-populations; mainstem river spawners and tributary spawners. This included 25 fish that spawned at the Mountain Rapids area of the Athabasca River and 25 fish that spawned in the Muskeg River. The two sub-populations were included to evaluate potential differences in movements and residence time in the Oil Sands Region.

3.4.1.2 Radiotelemetry Surveys

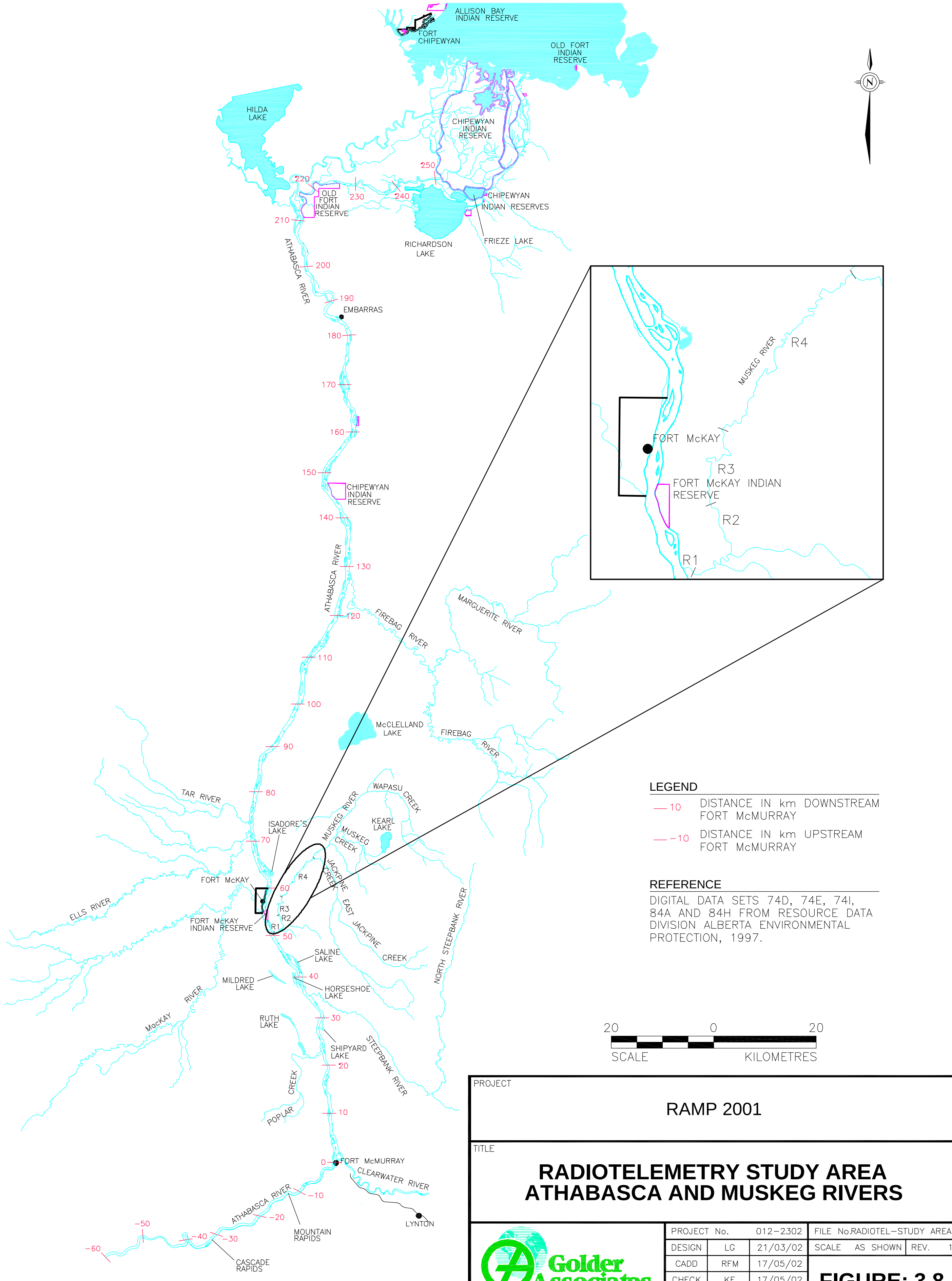
Movements of radio-tagged fish were monitored by radio-tracking flights using a radio receiver mounted in a fixed-wing aircraft. The telemetry survey area included the 300 km section of the mainstem Athabasca River from Cascade Rapids downstream to Lake Athabasca (but not including Lake Athabasca), and the Muskeg River from the mouth upstream to the Jackpine Creek confluence (Figure 3.8). Fish capture procedures, fish measurement data, radio-tagging methods and radio-tracking procedures were presented in the 2000 RAMP report (Golder 2001a).

In 2001, 14 telemetry flights were conducted from January 12 to June 14, at a frequency of two flights per month during the winter and three flights per month during the spring. During the flights, positions of radio-tagged fish were recorded on 1:50,000 scale maps of the telemetry study area and later referenced to the telemetry base map (Figure 3.8). On the base map, the Athabasca River is divided into kilometre posts (KP), which represent the distance from Fort McMurray, and the Muskeg River is divided into reaches (i.e., Reach 1 to 4).

Additional telemetry data were collected in February and March, 2001 during three ground-based surveys conducted as part of a separate overwintering habitat study, an initiative of the Cumulative Environmental Management Association (CEMA). The ground surveys were centred on known fish locations, covering only a limited portion of the telemetry survey area (RL&L 2002).

3.4.2 Fish Tissue Collection

Fish sampling for tissue collection was conducted on the Athabasca and Muskeg rivers in the fall of 2001. Flesh samples (fillets) were collected for analysis of organic contaminants and trace metals.



LEGEND

— 10 DISTANCE IN km DOWNSTREAM FORT McMURRAY

— −10 DISTANCE IN km UPSTREAM FORT McMURRAY

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

PROJECT

RAMP 2001

TITLE

RADIOTELEMETRY STUDY AREA
ATHABASCA AND MUSKEG RIVERS

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No. RADIOTEL-STUDY AREA
DESIGN	LG	21/03/02	SCALE AS SHOWN REV. 1
CADD	RFM	17/05/02	
CHECK	KF	17/05/02	
REVIEW			

FIGURE: 3.8

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3.4.2.1 Fish Capture and Handling

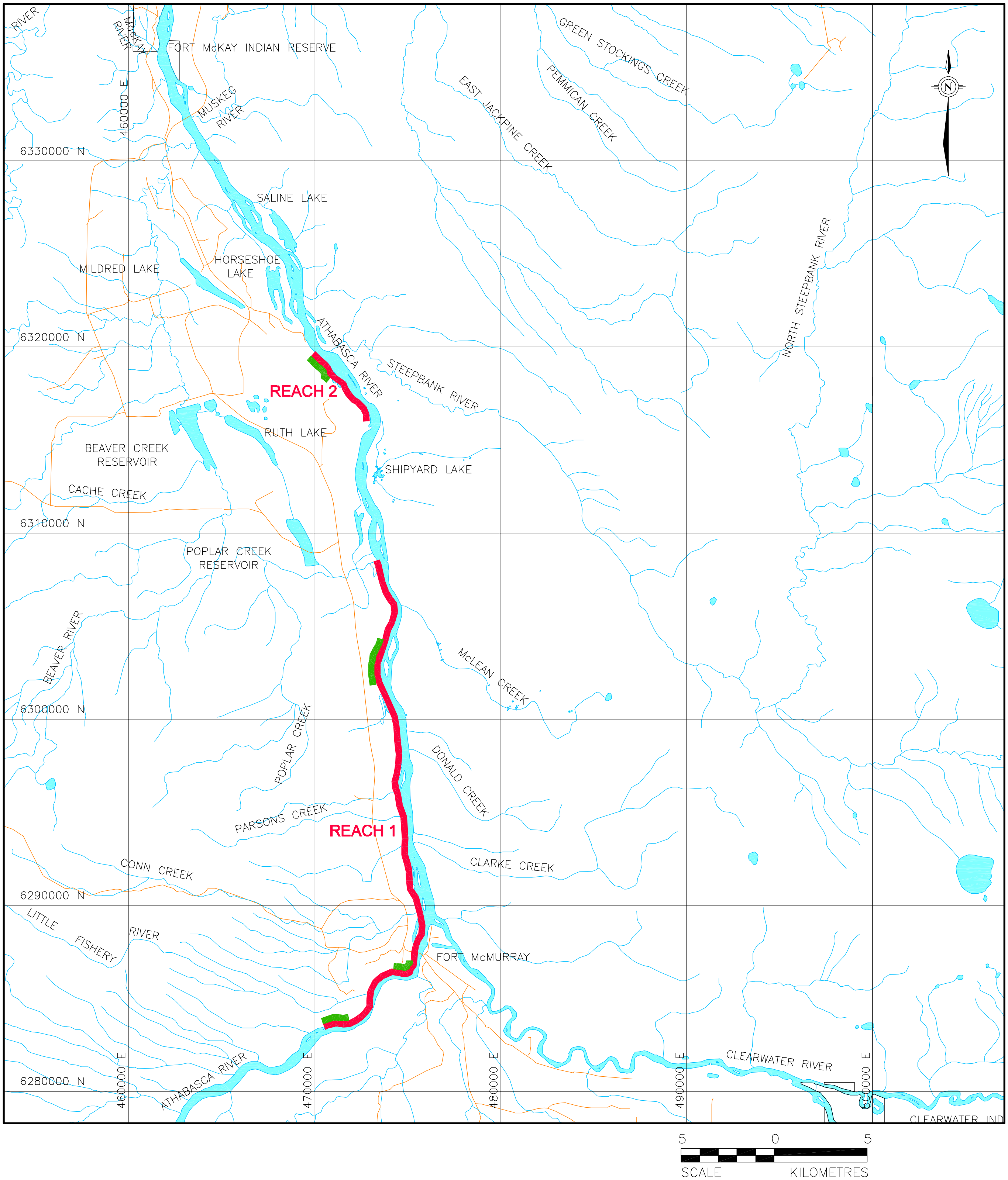
Fish sampling on the Athabasca River was conducted from September 25 to 27 in several sections of the river (Figure 3.9) and tissue samples were collected from walleye and lake whitefish. For the Muskeg River, sampling was conducted in a 2 km section of the river (Figure 3.10) during the period September 7 to 8 and tissue samples were collected from northern pike. The general location and Universal Transverse Mercator (UTM) coordinates of each sampling site on the Athabasca and Muskeg rivers are provided in Table 3.21. The target number of fish for tissue collection was five adult females and five adult males of each species.

Table 3.21 Sampling Locations on the Athabasca and Muskeg Rivers for Fish Tissue Collections, Fall 2001

Site	General Location	UTM Coordinates (NAD 27)	
		Start of Reach	End of Reach
Athabasca River	mountain rapids to Poplar Creek	470525 E / 6283461 N	473860 E / 6301240 N
	vicinity of the Steepbank River mouth	471314 E / 6348285 N	469693 E / 6320292 N
Muskeg River	from 16 to 18 km upstream of the river mouth	465115 E / 6338939 N	465983 E / 6339526 N

Fish collection activities were conducted according to Golder Technical Procedure 8.1-3: 'Fish Inventory Methods' (Golder 1999a). Fish capture on the Athabasca River was conducted jointly by ASRD, AENV and Syncrude, in association with non-RAMP field activities. Golder conducted the fish processing and tissue collections for the sampling on the Athabasca River. For the Muskeg River, Golder conducted the fish capture, processing and tissue collection activities.

Fish were captured by boat electrofishing, using a Smith-Root model 5.0 GPP electrofishing unit powered by a 5,000-watt generator. For the Athabasca River, a Smith-Root model SR-18 electrofishing boat was used and was configured with two anode boom arrays with multiple dropper-cables and utilized the boat hull as the cathode. For the Muskeg River, the electrofisher was mounted in a 3.8 m inflatable boat (Zodiac MK2C) and was configured with two anode booms and two cathode booms with multiple dropper-cables.



LEGEND

- TISSUE COLLECTION (LAKE WHITEFISH)
- TISSUE COLLECTION (WALLEYE)

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

PROJECT

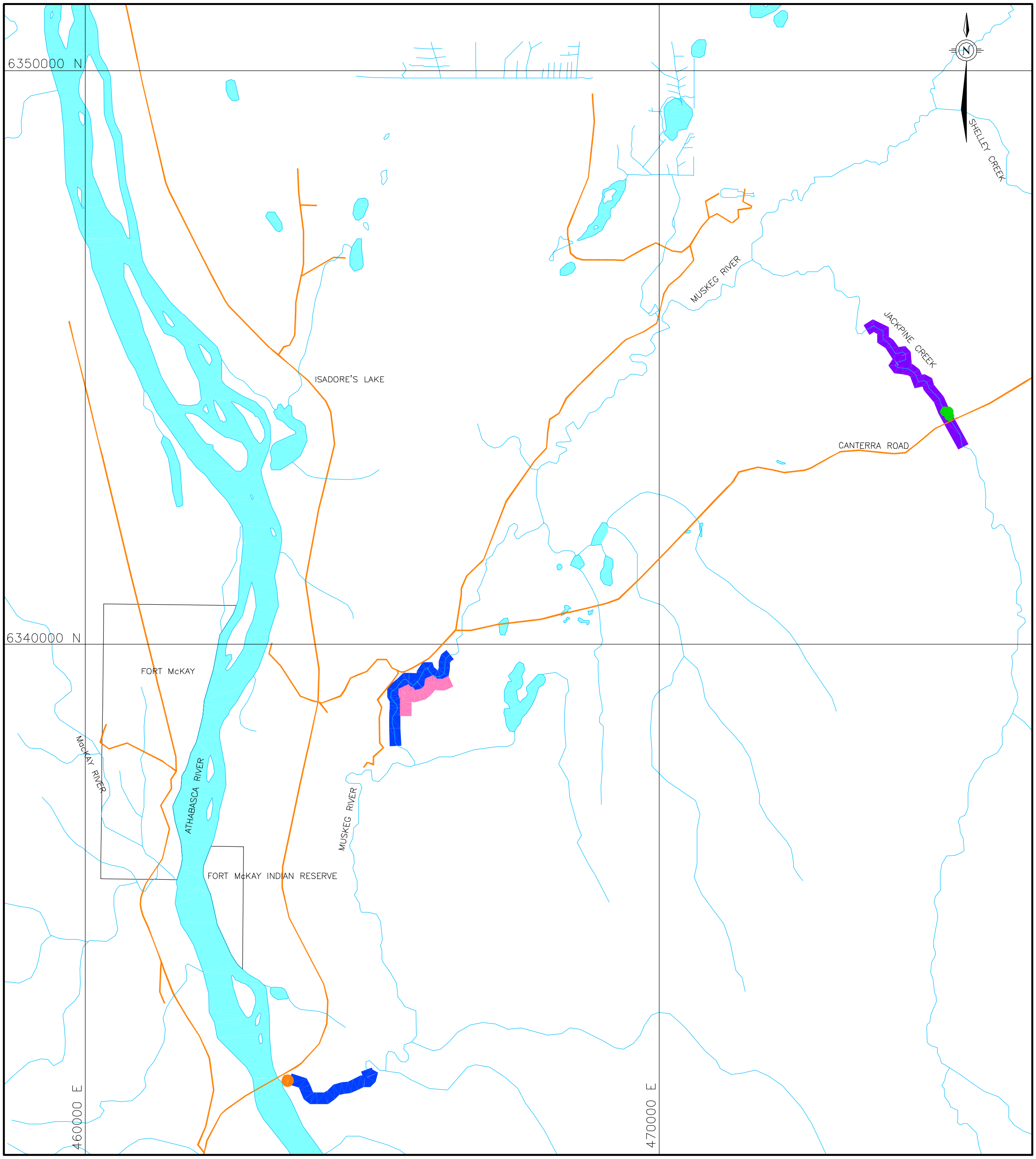
RAMP 2001

TITLE

TISSUE COLLECTION SAMPLING SITES ON THE ATHABASCA RIVER, FALL 2001

Golder Associates
Calgary, Alberta

PROJECT No.	012-2302		FILE No.	Atha-Tissue
DESIGN			SCALE AS SHOWN	REV. 2
CADD	RFM	17/05/02		
CHECK	KF	17/05/02	**FIGURE: 3.9**	
REVIEW				



LEGEND

- BOAT ELECTROFISHING (MUSKEG RIVER)
- BAITED MINNOW TRAPS (JACKPINE CREEK)
- BACKPACK ELECTROFISHING (JACKPINE CREEK)
- FISH FENCE 2001
- MUSKEG RIVER TISSUE COLLECTION

2 0 2
SCALE KILOMETRES

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I, 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION 1997. DATUM: NAD83. PROJECTION: UTM ZONE 12.

PROJECT

RAMP 2001

TITLE

SAMPLING SITES IN THE MUSKEG RIVER WATERSHED FOR SPRING FISH FENCE AND SUMMER INVENTORY, 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	Fish Fence-2
DESIGN	LG	20/02/02	SCALE AS SHOWN	REV. 1
CADD	RFM	17/05/02		
CHECK	KF	17/05/02	**FIGURE: 3.10**	
REVIEW				

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Fish of non-target species that were observed or captured while sampling were enumerated and recorded by species and life stage. Individuals of the target species that were captured and not used for tissue collection were enumerated by species, measured for fork length and weight, examined externally for signs of sex and maturity, and released. Larger fish of the target species were transported to a shore station consisting of a fish holding pen and sampling tent. The tent was used during sample processing to protect the tissue samples and reduce potential contamination.

Environmental parameters recorded at the time of sampling included measurements of pH, water temperature, conductivity, and dissolved oxygen. Water quality parameters were measured using a Horiba model U-10 water quality meter. Secchi depth was measured as an indication of water clarity. Prevalent weather conditions were also recorded.

3.4.2.2 Tissue Collection and Analysis

Tissue collection, storage and shipping procedures were conducted following Golder Technical Procedures 8.15-0 “Fish Health Assessment - Organics” and 8.16-0 “Fish Health Assessment - Metals” (Golder 1999a).

Five male and five female fish of each target species were used for tissue collections, with tissues from each fish used for both metal and organic contaminant analysis. Individuals of the target species were selected for tissue collection and detailed health assessment on the basis of size and/or secondary sex characteristics that identified them as mature adults. Selected fish were removed from the holding pen and sacrificed. These fish were measured for fork length and total body weight and a pathology examination was conducted to check for signs of abnormalities, disease and parasites. The specific variables included in the external and internal pathological examination are described in Appendix III. Results of the examination were used to provide a pathology index (PI) for each fish.

Specific tissue collections were conducted following the external examination and prior to the internal examination to reduce the potential for sample contamination. Tissue collection for organics and metals required two samples from each fish for separate lab analysis, while avoiding cross contamination of the samples. For each fish, a boneless and skinless flesh sample (fillet) was collected from one side using the organics protocol and from the other side using the metals protocol. For each species and sex, the tissue samples for organics and metals analysis were kept separate and were shipped to the laboratory frozen on dry ice.

Following tissue sampling, the fish health assessment was completed by conducting an internal examination. The whole gonad and liver were removed and weighed to the nearest 0.1g. All internal organs were removed and the weight of the remaining carcass was recorded to the nearest 1.0 g. The gonad-somatic index (GSI) and liver-somatic index (LSI) were later calculated as the ratio of organ weight to carcass weight. Appropriate ageing structures (as per MacKay et al. 1990) for individual fish were removed, dried and placed in labelled envelopes. Ageing structures included sagittal otoliths (lake whitefish), pelvic fin rays (walleye) and operculum (northern pike). Dorsal scales were also collected as secondary ageing structures. Ageing samples were analyzed by ageing specialist Jon Tost of North Shore Environmental Services, Ontario.

Tissue analysis was conducted by ETL, Edmonton. At the laboratory, the tissue samples were composited by species and sex, with separate composites for organics and metals analysis. This resulted in a total of four samples for each of the target species. The four samples included two from the five combined females (one each metals and organics) and two from the five combined males (one each for metals and organics). The composite tissue samples were analyzed for target PAHs, alkylated PAHs, mercury and other trace metals. Chemical analyses were conducted according to methods presented in Table 3.22. A full list of the individual chemical parameters included in the analysis, along with the associated detection limits, are provided in Table 3.23 for organic chemicals and Table 3.24 for metals. Tissue concentrations were reported on the basis of wet weight.

Table 3.22 Analytical Methods for Measuring PAHs and Trace Metals in Fish Tissue

Parameter	Method[(a)]
PAHs and alkylated PAHs	GC/MS analysis, U.S. EPA method 354-C (extraction), U.S. EPA method 8270-C (analyses)
metals	ICPMS analysis, U.S. EPA method 200.3 (digestion), U.S. EPA method 200.8 (analysis)
tissue digestion for ICPMS	digestion, U.S. EPA method 200.3 – HNO_3 + H_2O_2

(a) U.S. EPA 2000a, 2000b; Long and Martin 1991; McDaniel 1991.

Table 3.23 Detection Limits (DL) of PAHs and Alkylated PAHs for Fish Tissue Analysis

Target PAHs	DL (mg/kg)	Alkylated PAHs	DL (mg/kg)	Alkylated PAHs	DL (mg/kg)
acenaphthene	0.02	methyl acenaphthene	0.04	C3 substituted phenanthrene/anthracene	0.04
acenaphthylene	0.02	methyl benzo(a)anthracene/chrysene	0.04	C4 substituted phenanthrene/anthracene	0.04
anthracene	0.02	C2 substituted benzo(a)anthracene/chrysene	0.04	1-methyl-7-isopropyl-phenanthrene (retene)	
benzo(a)anthracene/ chrysene	0.02	biphenyl	0.04	methyl naphthalene	0.02
dibenzo(a,h)anthracene	0.02	methyl biphenyl	0.04	C2 substituted naphthalene	0.04
chrysene	0.02	C2 substituted biphenyl	0.04	C3 substituted naphthalene	0.04
dibenzothiophene	0.02	Methyl dibenzothiophene	0.04	C4 substituted naphthalene	0.04
fluorene	0.02	C2 substituted dibenzothiophene	0.04		
fluoranthene	0.02	C3 substituted dibenzothiophene	0.04		
benzo(b)fluoranthene	0.02	C4 substituted dibenzothiophene	0.04		
benzo(k)fluoranthene	0.02	methyl fluorene	0.04		
naphthalene	0.02	C2 substituted fluorene	0.04		
phenanthrene	0.02	methyl fluoranthene/pyrene	0.04		
benzo(g,h,i)perylene	0.02	methyl benzo(b or k) fluoranthene/methyl benzo(a)pyrene	0.04		
pyrene	0.02	methyl enzo(b&k)fluoranthene/benzo(a)pyrene	0.04		
benzo(a)pyrene	0.02	methyl phenanthrene/anthracene	0.04		
indeno(c,d-123)pyrene	0.02	C2 substituted phenanthrene/anthracene	0.04		

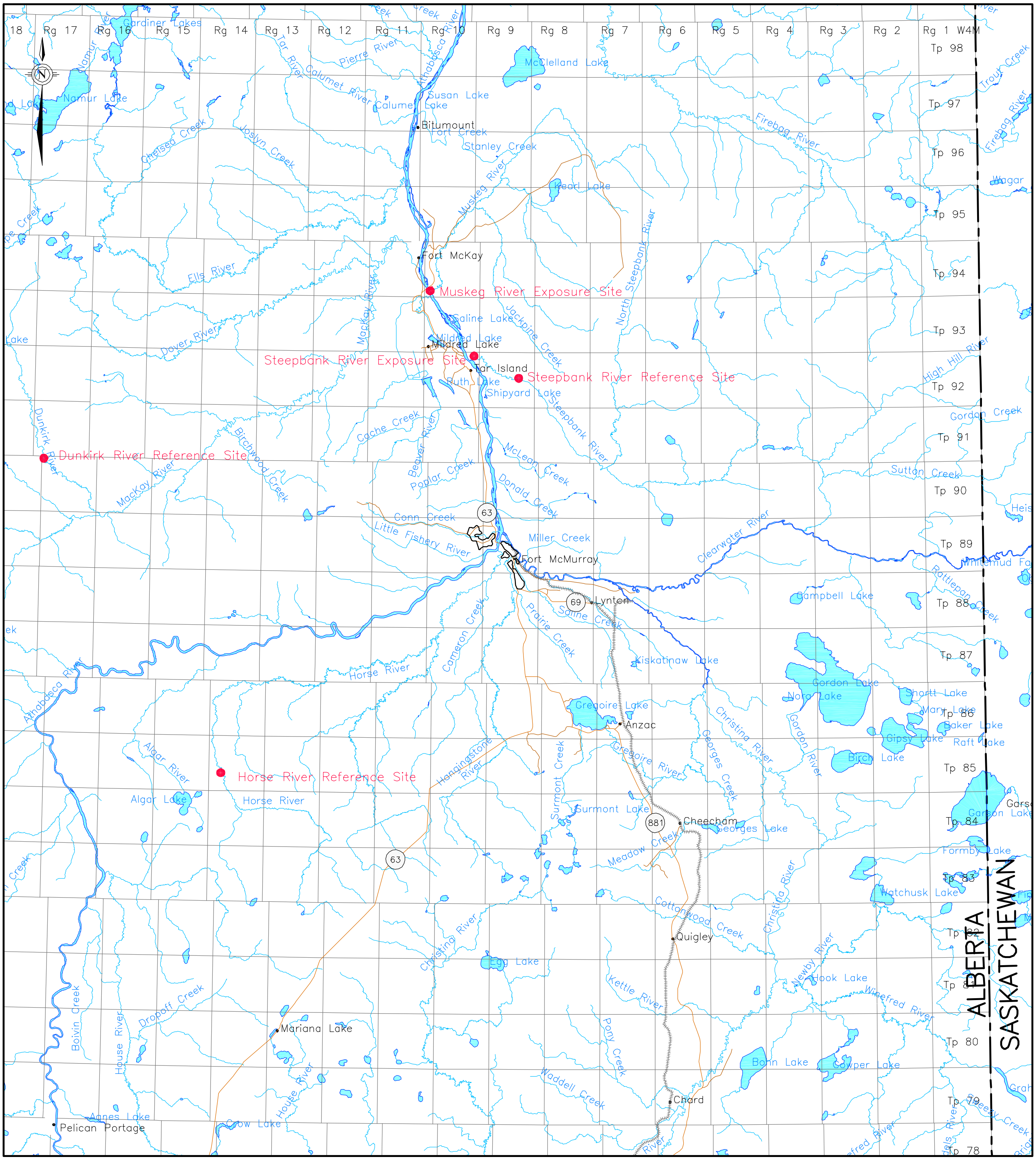
Table 3.24 Detection Limits (DL) of Metals for Fish Tissue Analysis

Total Metals	DL (mg/kg)	Total Metals	DL (mg/kg)	Total Metals	DL (mg/kg)
aluminum (Al)	4	lead (Pb)	0.04	sodium (Na)	2
antimony (Sb)	0.04	lithium (Li)	0.5	silver (Ag)	0.08
arsenic (As)	0.2	magnesium (Mg)	2	strontium (Sr)	0.04
barium (Ba)	0.08	manganese (Mn)	2	tin (Sn)	0.08
beryllium (Be)	0.2	mercury (Hg)	0.01	titanium (Ti)	0.05
cadmium (Cd)	0.08	molybdenum (Mo)	0.04	thallium (Tl)	0.04
chromium (Cr)	0.2	nickel (Ni)	0.08	vanadium (V)	0.08
cobalt (Co)	0.08	phosphorus (P)	2	zinc (Zn)	0.2
copper (Cu)	0.08	potassium (K)	2		
iron (Fe)	2	selenium (Se)	0.2		

3.4.3 Sentinel Species Monitoring

Sentinel species monitoring program in 2001 was conducted in tributaries to the Athabasca River. The tributary sentinel fish species identified under RAMP is slimy sculpin. Sentinel species monitoring focused on sampling exposure and reference sites. Exposure sites are defined as occurring in the vicinity of, or downstream of, current or future Oil Sands developments. These sites are not necessarily exposed to specific Oil Sands outputs (e.g., industrial discharges) but have the potential to be impacted by Oil Sands operations due to their location. Reference sites occur either in the same watercourses, but upstream of Oil Sands development, or in other drainages outside the Oil Sands development area. The exposure sites for monitoring in the Oil Sands Region included the lower Muskeg River (Site MR-E) and the lower Steepbank River (Site SR-E). The reference sites included the upper Steepbank River (Site SR-R), the Horse River (Site HR-R), and the Dunkirk River (Site DR-R) (Figure 3.11). The general location and UTM coordinates of the exposure and reference sites are presented in Table 3.25.

The response of slimy sculpin at the two exposure sites to Oil Sands development is defined relative to changes in the exposure populations over time and relative to sculpin collected at reference sites. Despite efforts to select reference and exposure sites that were as similar as possible, differences in the physical habitat characteristics were evident, particularly for sites located on different river systems. Detailed evaluation of the similarity of exposure and reference sites are presented in previous RAMP reports (Golder 2000b, 2001a). Differences in slimy sculpin abundance and habitat conditions between sites can make



20 0 20

SCALE KILOMETRES

LEGEND

ROADWAYS

RIVERS AND STREAMS

LOCATION OF SLIMY SCULPIN SAMPLING SITE

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUG. 2001. NAD 83 ZONE 12. SHEETS 74D, E AND L IN NAD 27, ZONE 12. SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG, 2001. NAD 83 ZONE 13. ALL DATA CONVERTED TO NAD 83, UTM ZONE 12.

PROJECT

RAMP 2001

TITLE

TRIBUTARY SENTINEL SPECIES SAMPLING SITES, 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	Fall-Slimy-Sculpin	
DESIGN			SCALE	AS SHOWN	REV. 2
CADD	RFM	17/05/02	**FIGURE: 3.11**		
CHECK	KF	17/05/02			
REVIEW					

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: Fall-Slimy-Sculpin.dwg Jul 10, 2002 - 10:47am interpretation of differences in whole-organism characteristics less clear. Differences in physical habitat parameters (e.g., flow, water velocity, habitat type, substrate size, water chemistry, background levels of organic compounds), productivity, species composition and population density can all affect growth, health and other population parameters for the sentinel species. Due to differences in habitat characteristics, any observed differences in whole-organism characteristics may be a function of habitat and/or anthropogenic influences. The assumption of the study design is that sculpin from the reference sites represent the natural condition and range of variability for the slimy sculpin populations within the region. The multiple reference sites are used to ensure that the full range of natural variability in fish characteristics is more accurately defined for the region, with respect to overall range and year-to-year changes, and to increase the understanding of the ecology of slimy sculpin in Athabasca River tributaries.

The two exposure sites and three reference sites were sampled for slimy sculpin during September 5 to 23, 2001. Slimy sculpin populations from each site were examined for length and age distribution, growth and fish health parameters.

Table 3.25 Sampling Locations for the Tributary Sentinel Fish Species Monitoring Program, Fall 2001

Site	General Location	UTM Coordinates[(a)]
Muskeg River		
MR-E	**exposure site** approximately 0.2 to 0.6 km upstream of the confluence with the Athabasca River	S:463693 E / 6332507 N F: 463982 E / 6331862 N
Steepbank River		
SR-E	**exposure site** in the vicinity of the Steepbank Mine, approximately 0.3 to 1 km upstream of the confluence with the Athabasca River	S: 471049 E / 6319993 N F: 471721 E / 6320375 N
SR-R	**reference site** approximately 16 km upstream of the confluence with the Athabasca River	S: 479342 E / 6316444 N F: 479593 E / 6316461 N
Horse River		
HR-R	**reference site** approximately 140 km upstream of the confluence with the Athabasca River	S: 427070 E / 6246983 N F: 427129 E / 6247010 N
Dunkirk River		
DR-R	**reference site** approximately 25 km upstream of the confluence with the MacKay River	S: 395890 E / 6302384 N F: 395852 E / 6302398 N

(a) UTM coordinates (NAD 27) taken at the start (S) and finish (F) boundary of each sampling reach.

3.4.3.1 Fish Capture and Handling

The target number of slimy sculpin to be collected and examined at each of the five tributary sites was 60 fish, consisting of 30 mature female and 30 mature male. Standardized field sampling and fish processing methods were employed for all aspects of the sentinel species survey. The standard protocols are detailed in Golder Technical Procedures TP-8.1-3 "Fish Inventory Methods" and TP-8.15-0 "Fish Health Assessment - Organics" (Golder 1999a).

Fish sampling was conducted only in habitats that were considered suitable for slimy sculpin (i.e., swift-flowing areas of gravel/cobble substrate). Sampling was conducted using a Smith-Root Type 12-B backpack electrofisher, powered by a 24 volt battery and configured with a 27.9 cm diameter anode ring and a rattail cathode. During sampling, a pole-mounted seine net was deployed downstream of the area being electrofished to collect stunned fish and increase sampling efficiency.

All fish captured and observed during sampling activities were enumerated by species and life stage. Non-target species were released and the captured slimy sculpin were retained for processing. Juvenile slimy sculpin and adult fish over the required number to be sacrificed for the fish health assessment were measured for total length and weight prior to release. The length data was used to establish a length frequency distribution for each population.

Larger slimy sculpin considered to be adults were transported in a carrying container filled with site water to the fish processing location. To conduct the health assessment, the fish were sacrificed by a lethal dose of MS-222 (tricaine methane sulfonate) anaesthetic. Processing included measurement of total length, whole weight, total gonad weight, total liver weight and carcass weight. External and internal pathology examinations were also conducted to check for signs of abnormalities, disease and parasites. Ageing structures (otoliths) were collected for age analysis. For females, both whole ovaries were collected and preserved for fecundity analysis.

During sampling activities, water quality measurements and weather conditions were recorded daily. The water quality measurements were conducted using a YSI 556 multi-meter to record temperature, DO, pH and conductivity.

3.4.3.2 Data Analysis

To monitor the health of the slimy sculpin populations, the following analyses were conducted for the physiological parameters that were examined:

- Growth (size and age);
- Fulton's Condition Factor;
- Gonad Somatic Index (GSI);
- Liver Somatic Index (LSI);
- Fecundity Index; and
- Pathology Index (PI) – based on external and internal examination for abnormalities.

The fish indices that describe relationships between body metrics were calculated using whole body weight for condition factor and carcass weight for GSI, LSI and fecundity index. Carcass weight is the body weight after the viscera has been removed. Carcass weight was used instead of whole body weight in calculating organ indices. Whole body weight may include altered organ weight, which would affect the interpretation of the organ index (i.e., variable being examined relative to the body weight).

Growth (Size and Age)

Age data were used to produce an age-frequency distribution for each population. Age data were related to fish size to examine fish growth for the different slimy sculpin populations. Size-at-age analysis was attempted using a regression of mean total length versus age. However, as was the case during previous slimy sculpin monitoring for RAMP (Golder 2000b), the correlation between length and age was very poor and this analysis could not be used.

Fulton's Condition Factor

The Fulton's Condition Factor (k) is a measure of the weight of a fish relative to the cube of its length and is defined as follows:

$$k = 10^5 \text{ x (body weight (g)/ length (mm)}^3)$$

The condition factor reflects the nutritional state or well-being of an individual fish. The k value will be 1.0 for fish whose weight is equal to the cube of its length. Fish which have a higher k value are more plump and are thought to be in a better nutritional state-of-health, whereas fish with a lower k value are considered to be less robust (MacKay et al. 1990).

Gonad Somatic Index (GSI)

The GSI is a measure of the size of the gonad relative to body size and is defined as follows:

GSI = (gonad weight (g) / carcass weight (g)) x 100.

The GSI is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth. It is an important sign of reproductive health, that can often be reduced by chemical stressors in the environment. A population with a comparatively low GSI is considered to have insufficient energy available for proper gonad growth.

Liver Somatic Index (LSI)

The LSI is a measure of liver size relative to body size and is defined as follows:

LSI = (liver weight (g) / carcass weight (g)) x 100

The LSI is used as an indicator of fish health. Energy stored in the liver in the form of glycogen and the relative size of the liver are believed to correlate with nutritional state. Liver size may also be related to the level of detoxification required due to chemical stressors in the environment.

Fecundity Index

Fecundity is a measure of the total number of eggs in both ovaries of a female fish. For each female slimy sculpin, the preserved ovaries were examined and the total number of eggs counted. Since fecundity normally increases with the size of the fish, direct comparison of total fecundity between fish and between populations is not appropriate. Comparisons were made using the size-related fecundity index, which was calculated as follows:

Fecundity Index = total number of eggs / carcass weight (g).

Pathology Index (PI)

A PI was used to obtain quantitative results from the pathological examination. PI is based on the Health Assessment Index (HAI) developed by Adams et al. (1993). Fish exposed to environmental contaminants or stresses frequently show visible external and/or internal signs of disease as abnormal conditions in tissues or organs. Since the incidence of pathological conditions is often related to degradation of the aquatic environment, a pathological examination was conducted for the sentinel species. The slimy sculpin were examined for parasitism, injuries and non-specific abnormalities such as growths, lesions and deformities.

Appendix III presents the 14 parameters included in the pathology examination. Each parameter was assigned a numerical index value based on the condition or appearance of the tissue/organ involved. Normal conditions have an index value of zero and abnormal conditions have a higher value, to a maximum index of 30 per parameter. PI was calculated for each fish by summing the index values for each of the 14 parameters. Therefore, the higher the index value for a fish, the higher the number and/or severity of abnormalities. A mean PI was then calculated for the slimy sculpin populations (sexes separate) from each of the five survey sites.

Also recorded during the pathology examination was the level of mesenteric fat. This parameter was not assigned an index value and was not used in the calculation of the PI, because there are no specific levels of fat that are considered abnormal. Mesenteric fat was recorded in support of the internal examination, as it provides evidence regarding the nutritional state of the fish. Mesenteric fat was addressed only when further evaluation of an individual or a population was required.

Statistical Analysis

Potential responses (i.e., differences between exposure and reference populations) of slimy sculpin at sites MR-E and SR-E were evaluated by statistical analysis for two types of comparisons, including:

- exposure sites in 2001 relative to reference sites in 2001; and
- exposure sites and reference site SR-R in 2001 relative to 1999 results for the same sites (note: sites HR-R and DR-R were not evaluated in 1999).

Variables evaluated for potential responses of slimy sculpin at the exposure sites relative to the reference sites in 2001 included total length, body weight, condition factor, age, fecundity, LSI, GSI and PI. Two types of statistical comparisons were made for each of the two exposure sites. The first approach used analysis of variance (ANOVA) of four treatment groups (i.e., one exposure site and three reference sites) with a specified contrast to test for a significant difference between the mean value at the exposure site and the mean value for all reference sites combined. For the second type of comparison, Dunnet's procedure (Zar 1984) for determining if the mean of one group differs significantly from each of the means of the other groups was used to test for significant differences between the exposure site and each of the reference sites individually.

To more closely approximate the assumptions of normality and homoscedasticity (i.e., homogeneity of variances) that are inherent in the parametric test procedures used, transformations of certain variables were employed prior to conducting statistical analyses. A logarithmic transformation ($\log_{10}$) was used for fish length, body weight, and age. For the LSI and GSI values (calculated as a percentage of carcass weight), an arcsine transformation was used ($\arcsin\sqrt{p}$, where p is a proportion of carcass weight). For PI values, a square root transformation ($\sqrt{\mathrm{PI} + 0.5}$) was used. No transformations were used for condition factor or fecundity values.

For statistical comparisons of body weights, the analyses were conducted using analysis of covariance (ANCOVA) with fish length as the covariate. Tests of hypotheses regarding body weights are therefore based on adjusted least squares mean weights (i.e., adjusted for the effect of length on body weight).

Variables evaluated for potential responses of slimy sculpin at the exposure sites and reference site SR-R in 2001 relative to 1999 included total length, body weight, condition factor, age, fecundity, LSI and GSI. ANOVA was applied to data from sites MR-E, SR-E and SR-R to test for significant differences between the mean values from 1999 and 2001 at each site.

3.4.4 Muskeg River Fish Fence

A two-way fish counting fence was installed and monitored on the Muskeg River during the spring of 2001 to monitor the timing and size of the spawning run. The fish counting fence was included as part of the RAMP core monitoring activities.

3.4.4.1 Field Activities

The fish fence was installed in the lower reach of the Muskeg River, approximately 0.3 km upstream of the river mouth (Figure 3.10). The fish fence was deployed as early as possible in the spring in an attempt to capture the full spawning run, in particular the Arctic grayling run, which typically occurs immediately following ice-out in the spring. Personnel stationed in Fort McMurray examined the lower Muskeg River every few days in the spring to monitor break-up and to determine the earliest possible date for fence installation. The fence was installed on April 28, once the river was relatively free of frazil ice and ice jams. The fish fence study was conducted over a 29 day period extending from April 28 to May 26, 2001.

The fence was composed of several aluminum panels and two trap boxes. Each panel consisted of a frame holding aluminum dowels that were spaced close together so medium and large sized fish could not swim through the fence. The panels formed upstream and downstream 'wings' to lead the fish into the two trap boxes. One trap box was orientated with the mouth facing downstream to capture fish moving upstream and was designated as the upstream trap. The mouth of the second box faced upstream to capture fish moving downstream and was designated as the downstream trap. The trap boxes were covered with fine mesh on three sides, while the fourth side had a funnel net attached to form the mouth of the trap.

Due to poor substrate conditions, periods of high discharge and floating debris, the fence was not operational for the entire 29 days of the study period, and only partial blockage of the river was possible for a portion of the study. At initial installation, the fence and trap boxes extended the entire width of the river. However, the condition of the riverbed substrate proved to be poor due to high bitumen content. The substrate was easily eroded at the base of the fence by the scouring action of the flowing water. As a result, both trap boxes were washed out on April 29. The entire fence was moved about 20 m upstream and reinstalled that day at a site that appeared to have better substrate conditions. The fence was in full operation for only a few days before increasing discharge levels in the Muskeg River resulted in high water levels and strong currents causing problems. On May 2, one side panel was washed away by the higher velocities. The fence was immediately mended, reinstalled and reinforced that day. On May 8, a larger portion of the fence was damaged by large debris that was being washed down river by the increasing water levels. The bottom of the river was deeply scoured at the location of the impact and as a result the fence had to be moved again. On May 8 it was reinstalled further downstream in shallow water close to the mouth of the Muskeg River, approximately 100 m from the previous site.

On May 10, a portion of the fence was again washed out by continually increasing discharge levels and velocities. The fence was then moved to the gravel bar at the mouth of the Muskeg River but could only be set up as a partial installation due to excessive velocities along one side of the river. For the period May 11 to 20 the fence was installed extending from the right-downstream (north) bank part way across the river. The configuration included an upstream trap box only and fence wings extending as far as possible across the river channel. Approximately 75% of the channel was covered by the fence; however, the main portion of the flow along the left-downstream bank was not blocked, allowing fish passage past the site. On May 20, declining discharge levels allowed the fence to be completed, blocking the entire river and adding the downstream trap box. The fish fence remained complete until its final removal on May 26.

In total, the two-way counting fence was fully operational for 16 days of the 29 day study period. Trapping was interrupted on four days due to wash-outs, when the fence was either repaired or moved. For an additional nine days, the fence consisted of only an upstream trap box and partial coverage of the flowing channel width. This provided 13 days when fish could migrate upstream without necessarily passing through the trap box.

Water quality field parameters (conductivity, dissolved oxygen and pH) and the maximum and minimum air and water temperatures were recorded daily during fence operations. Water quality was measured using a Multi-Line model P4 meter. Temperatures were monitored using maximum-minimum recording thermometers.

Each day, the trap boxes were checked for fish every two hours during daylight hours. All fish captured in the traps were identified by species. When discernible from external examination, life stage (juvenile or adult), sex and state-of-maturity (pre-spawning, ripe or post-spawning) were also recorded. The fish were enumerated by date, time and direction (upstream or downstream). For sport fish and longnose suckers, non-lethal ageing structures were taken (according to MacKay et al. 1990) and fish >300 mm fork length were tagged using RAMP Floy tags. Fish were also examined for any external abnormalities or pathological conditions to provide an external Pathological Index (PI) (as per Appendix III). Fish were then released to continue migrating past the fish fence site in the direction they were moving when captured.

3.4.4.2 Data Analysis

For large-bodied fish species, mean and standard error were calculated for fork length, weight, age, condition factor and PI. Condition factor was calculated using Fulton's Condition Factor (k), where:

$$k = (\text{body weight [g]} / \text{fork length [mm]}^3) \times 10^5.$$

For large-bodied species with an adequate sample size (i.e., $n \geq 30$), the following analyses were also conducted:

- size (fork length) frequency distribution;
- age frequency distribution;
- fork length versus weight regression; and
- size-at-age (fork length versus age) regression.

3.4.5 Fish Inventory

General fish inventories to monitor species presence and relative abundance were conducted in the Muskeg River basin, including the lower Muskeg River and lower Jackpine Creek.

3.4.5.1 Fish Sampling and Handling

Fish inventories were conducted during the period August 8-10 (Jackpine Creek) and August 11-12 (Muskeg River). The field procedures for the fish inventory followed Golder TP 8.1-3 "Fish Inventory Methods" (Golder 1999a). The portions of each watercourse sampled during the inventory are presented on Figure 3.10, by sampling technique. The general locations and UTM coordinates for the inventoried sites on the Muskeg River and Jackpine Creek are presented in Table 3.26.

Table 3.26 Location of Sampling Sites for the Jackpine Creek and Muskeg River Fish Inventories, Summer 2001

Site	Sampling Method	General Location	UTM Coordinates [a] (NAD 27)
Jackpine Creek	backpack electrofishing	from 1 km upstream to 3 km downstream of Canterra Road Crossing	S: 475283 E / 6343185 N F: 473758 E / 6345200 N
	minnow trap	set 60 m downstream from Canterra Road crossing (backwater)	475106 E / 6343846 N
		set under the Canterra Road bridge (deep run with riprap and boulders)	475046 E / 6343846 N
		set 100 m downstream of the Canterra Road crossing (by a breached beaver dam)	475120 E/ 6343765 N
Muskeg River	boat electrofishing	3 km section from 15 to 18 km upstream of the river mouth	S: 465453 E / 6337971 N F: 466434 E / 6339570 N
		3 km section immediately upstream of the river mouth (canyon area).	S: 465011 E / 6332390 N F: 463645 E / 6332241 N

[a] UTM taken at the start (S) and finish (F) boundary of each sampling reach.

As Jackpine Creek is a shallow stream, the primary fish capture technique for this watercourse was backpack electrofishing (Smith-Root Type 15-D electrofishing unit). The unit was powered by a 350-watt generator and configured with an anode pole with a 27.9-cm diameter ring and a rattail cathode. The secondary sampling technique employed was baited minnow traps, used to sample for small-bodied fish species and young-of-the-year and juvenile life stages of large-bodied species. An attempt was also made to sample using a beach seine; however, bottom uniformity was poor and this technique was abandoned due to sampling inefficiency.

The Muskeg River was sampled by boat electrofishing utilizing a Smith-Root model 5.0 GPP electrofishing unit mounted in an inflatable boat, as described previously in Section 3.4.2.1.

Sampling effort was recorded for all fish inventory activities. All electrofishing units were equipped with timers that recorded the number of seconds of active electrofishing (i.e., the number of seconds that electrical current was applied to the water). The total set duration in hours was recorded for each minnow trap set.

All fish captured or observed during sampling were enumerated by species and life stage. Fork length and weight were measured for all large-bodied fish and a representative number of individuals for each small-bodied fish species. An external pathology examination was conducted for each fish prior to release to provide an external pathology index (PI) (as per Appendix III). Sport fish and longnose suckers of sufficient size were tagged with RAMP Floy tags.

3.4.5.2 Data Analysis

Catch-per-unit-effort (CPUE) was calculated for each sampling technique to determine relative abundance for different fish species. CPUE was calculated for electrofishing as number of fish per 100 seconds of effort, and for minnow trapping as the number of fish captured per hour of trap set. For electrofishing, CPUE was calculated both for captured fish and for total fish (i.e., captured plus observed). CPUE for captured fish was calculated for comparison to previous inventory studies.

Calculations of mean and standard error were conducted for fork length, weight, Fulton's Condition Factor (k) and external PI. For large-bodied species with suitable sample size (i.e., $n \geq 30$ individuals), length frequency analyses were also conducted.

3.5 ACID SENSITIVE LAKES

3.5.1 Lakes Sampled

Thirty-two lakes were sampled in 2001, including 22 lakes in the Oil Sands Region, five lakes in the Caribou Mountains and five lakes on the Canadian Shield (Table 3.27, Figure 3.12). In the Oil Sands Region, three of the original set of lakes (L1, L30, L47) were not sampled because of difficulties with access via float plane (i.e., the lakes were too small to land on). To keep the number of lakes in this region at 22, Lake L29 (Clayton Lake) was added to the 2001 program to replace the nearby Lake L30 (West Clayton Lake) and Lake A300 was added to replace Lake A47. In addition, Lake R2 was not sampled in 2000 and 2001 because it could not be located using the coordinates available to the field crew. One additional shield lake (A301) was added to the field program to replace this lake.

3.5.2 Field Methods

Acid sensitive lakes were sampled during 10 September to 5 October, 2001, by AENV personnel. AENV also provided sampling equipment and logistical support. A float plane was used to access the study lakes.

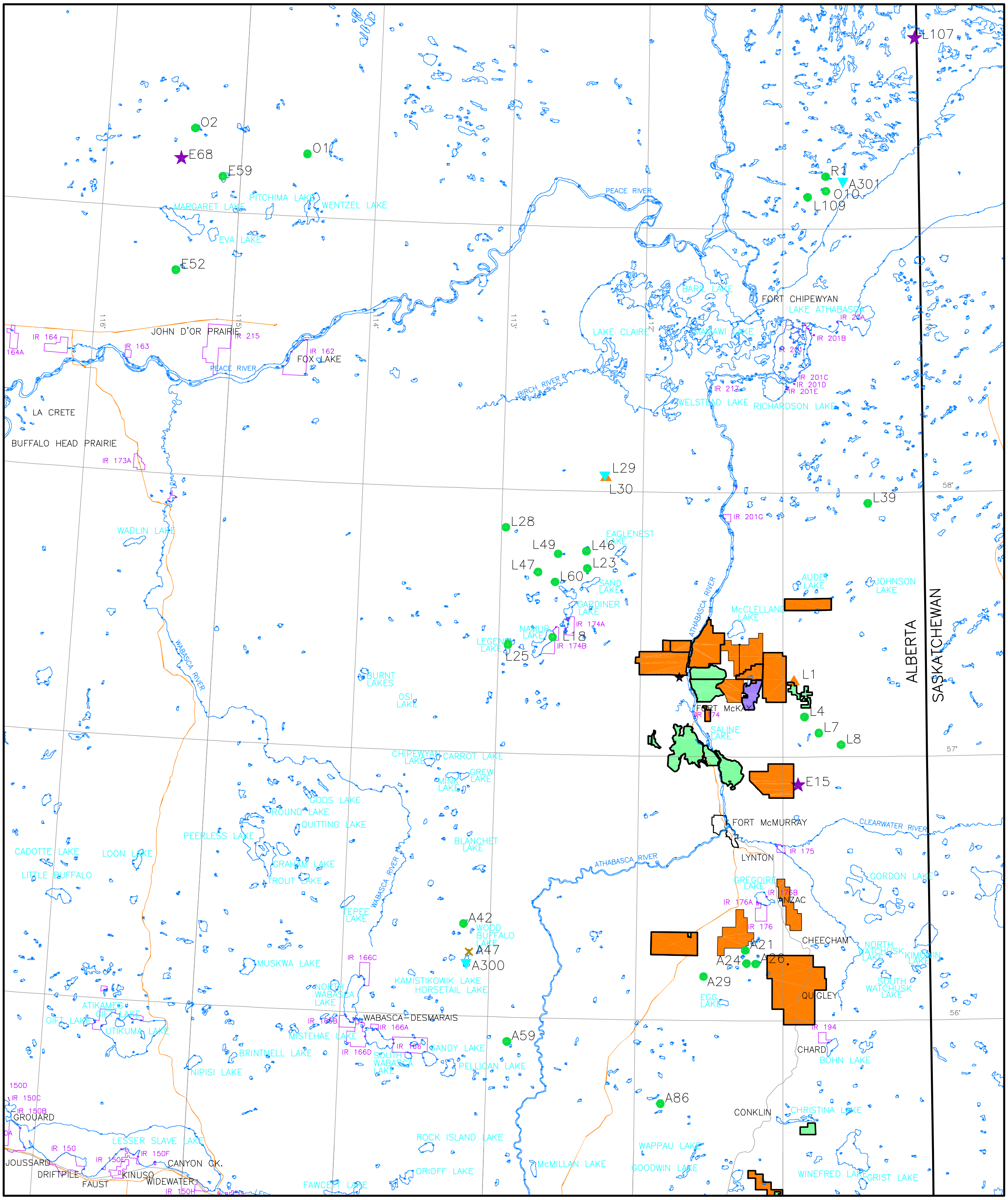
In lakes with depths of 2 m or less, a composite water sample was created by combining discrete samples collected with a drop-sleeve bottle at half metre intervals (surface, 0.5 m, 1 m and 1.5 m). In deeper lakes, vertically integrated euphotic zone samples were collected from up to five sites per lake using weighted Tygon tubing. These samples were then combined to form a single composite sample from each lake for chemical analysis.

Table 3.27 Characteristics of the Lakes Selected for Long-term Acidification Monitoring

Lake	Year Sampled			Latitude	Longitude	Altitude	Max. Depth	Alkalinity[a] (mg/L as
	1999	2000	2001			(m)	(m)	$CaCO_3$)
Oil Sands Region								
A21	Y	Y	Y	56.2667	111.2583	719	1.2	0.8 - 2.0
A24	Y	Y	Y	56.2167	111.2500	710	1.6	0 - 1.3
A26	Y	Y	Y	56.2153	111.1869	712	1.5	1.7 - 9.3
A29	Y	Y	Y	56.1667	111.5417	714	1.4	2.3 - 3.2
A42	Y	Y	Y	56.3500	113.1833	643	1.3	9.2 - 11.3
A47[d]	Y	Y	N	56.2440	113.1410	643	1.7	2.0 - 8.4
A59	Y	Y	Y	55.9083	112.8667	555	2.0	2.1 - 3.5
A86	Y	Y	Y	55.6833	111.8250	712	2.7	5.6 - 7.8
A300	N	N	Y (new)	56.1964	113.1577	-	1.7	15.3 (*n*=1)
E15 (L15b)	N	Y (new)	Y	56.8939	110.8980	457	1.7	20.0 - 21.9
L1[d]	Y	N	N	57.2853	110.9239	-[b]	0.9	4.3 - 6.7
L4 (A-170)	Y	Y	Y	57.1519	110.8514	549	2.1	4.7 - 10.4
L7	Y	Y	Y	57.0903	110.7519	594	1.7	8.7 - 13.1
L8	Y	Y	Y	57.0458	110.5975	610	2.0	14.2 - 21.7
L18 (Namur)	Y	Y	Y	57.4444	112.6211	722	24.0	18.9 - 20.9
L23 (Otasan)	Y	Y	Y	57.7072	112.3875	732	7.6	6.4 - 8.7
L25 (Legend)	Y	Y	Y	57.4122	112.9336	789	10.2	9.0 - 10.5

Table 3.27 Characteristics of the Lakes Selected for Long-term Acidification Monitoring (continued)

Lake	Year Sampled			Latitude	Longitude	Altitude	Max. Depth	Alkalinity[a] (mg/L as
	1999	2000	2001			(m)	(m)	$CaCO_3$)
L28	Y	Y	Y	57.8556	112.9717	716	1.9	0 - 3.0
L29 (Clayton)	N	N	Y (new)	58.0572	112.2761	-	1.1	0 (*n*=1)
L30 (W. Clayton)[e]	Y	N	N	58.0514	112.2669	-	0.9	0 (*n*=1)
L39 (A-150)	Y	Y	Y	57.9600	110.3969	427	1.5	9.9 - 12.2
L46 (Bayard)	Y	Y	Y	57.7725	112.3964	640	1.8	6.9 - 24.2
L47	Y	Y	Y	57.6894	112.7361	643	1.3	7.9 - 16.0
L49	Y	Y	Y	57.7600	112.5967	671	1.4	6.6 - 10.1
L60	Y	Y	Y	57.6533	112.6142	671	2.7	9.6 - 16.1
Caribou Mountains								
E52 (Fleming)	Y	Y	Y	58.7708	115.4342	853	8.5	13.0 - 18.8
E59 (Rocky Island)	Y	Y	Y	59.1350	115.1336	914	>6	9.0 - 15.0
E68 (Whitesand)	N	Y (new)	Y	59.1905	115.4490	911	1.5	13.3 - 14.8
O1 (Unnamed #6) (E55)	Y	Y	Y	59.2378	114.5200	823	1.8	3.9 - 4.5
O2 (Unnamed #9) (E67)	Y	Y	Y	59.3108	115.3589	890	11.5	8.0 - 10.3
O3[c]	Y	N	N	59.0489	116.2556	-	-	10.0 - 35.5
Canadian Shield								
A301	N	N	Y (new)	59.1760	110.5600	-	8.2	22.5 (*n*=1)
L107 (Weekes)	N	Y (new)	Y	59.7219	110.0158	320	7.8	23.2 - 25.5
L109 (Fletcher)	Y	Y	Y	59.1206	110.8197	268	13.7	18.2 - 23.0
O10	Y	Y	Y	59.1436	110.6847	308	1.8	8.0 - 13.1
R1	Y	Y	Y	59.1985	110.6868	305	13.1	13.5 - 15.8
R2[e]	Y	N	N	-	-	-	-	11.0 (*n*=1)
R3[c]	Y	N	N	59.1268	110.9315	-	-	48.3 (*n*=1)



LEGEND

- ▲ LAKES SAMPLED IN 1999
- × LAKES SAMPLED IN 1999 AND 2000
- ★ LAKES SAMPLED IN 2000 AND 2001
- ▼ LAKES SAMPLED IN 2001
- ● LAKES SAMPLED IN ALL YEARS

- EXISTING OR APPROVED PROJECTS
- PLANNED PROJECTS
- EUB APPROVED DEVELOPMENT

REFERENCE

ORIGINAL BASE MAP OF ALBERTA WAS PRODUCED IN 10TM FORMAT. THE MAP WAS CONVERTED FROM DGN FORMAT TO DWG FORMAT IN NAD 83 ZONE 12 UTM PROJECTION.

PROJECT

RAMP 2001

TITLE

LOCATIONS OF ACID SENSITIVE LAKES SURVEYED

Golder Associates
Calgary, Alberta

PROJECT No. 012-2302.6200			FILE No. Acid-Sensitive-Lakes	
DESIGN	ZK	13/05/02	SCALE AS SHOWN	REV. 0
CADD	RFM	16/05/02	**FIGURE: 3.12**	
CHECK	KF	17/05/02		
REVIEW				

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: Acid-Sensitive-Lakes.dwg Jul 10, 2002 - 10:48am

The euphotic zone was defined as the depth of 1% of surface penetrating light, using a light meter. Vertical profiles of dissolved oxygen, temperature, conductivity and pH were measured at the deepest location using a Hydrolab water quality meter, calibrated daily before the start of sampling. Secchi depth was also recorded. Samples for chemical analysis were stored on ice and were shipped to the Limnology Laboratory, University of Alberta, Edmonton, within 48 hours of collection.

Subsamples of 150 mL volume were taken from the euphotic zone composite samples for phytoplankton taxonomy. These samples were preserved using Lugol’s solution. One or two replicate zooplankton samples were also collected in each lake as horizontal tows, using a 63 µm mesh, conical plankton net. Zooplankton samples were preserved in approximately 5% formalin after anaesthetizing in club soda. Plankton samples are being stored at AENV.

The water quality samples were analyzed for the following parameters:

- pH
- turbidity
- colour
- total suspended solids (TSS)
- total dissolved solids (TDS)
- dissolved organic carbon (DOC)
- dissolved inorganic carbon (DIC)
- conductivity
- total alkalinity (fixed point titration to pH 4.5)
- Gran alkalinity
- bicarbonate
- Gran bicarbonate
- chloride
- sulphate
- calcium
- potassium
- sodium
- magnesium
- iron
- silicon
- total dissolved nitrogen (TDN)
- ammonia
- nitrite + nitrate
- total Kjeldahl nitrogen (TKN)
- total nitrogen (TN)
- total phosphorus (TP)
- total dissolved phosphorus (TDP)
- chlorophyll *a*

All samples were also analyzed for a suite of 29 metals and trace elements. This analysis was requested and funded by AENV. As part of the QA/QC program, one field blank was collected using deionized water from the Limnology Laboratory, University of Alberta, and a split sample and a duplicate water sample were collected at Lake A42. Quality control samples were analyzed for all parameters listed above.

3.6 WETLANDS VEGETATION

Locations examined in the RAMP 2001 wetlands vegetation surveys include: Kearl, Isadore's and Shipyard lakes.

3.6.1 Field Methods

Prior to field investigations, wetlands types were prestratified (classified) according to the Alberta Wetland Inventory (AWI) on 1:10,000 and 1:20,000 black-and-white aerial photographs. The boundaries of the wetlands types were transferred to a field-ready copy of the airphoto to allow verification of polygon types and boundaries. This classification system and the wetlands type for each lake is documented in Appendix IV.

Wetlands vegetation was examined during a field survey on August 13, 14 and 16, 2001. Wetlands vegetation was documented by the following procedures:

- observing mapped wetlands classes on aerial photographs and comparing to field conditions;
- conducting a vegetation survey along fixed transects and compiling a list of species and relative percent cover within permanent sampling plots;
- recording vegetation vigour and health characteristics;
- photographing representative vegetation types from fixed points; and
- collecting field water quality parameters that are specified in the wetlands water quality section of this report.

3.6.1.1 Vegetation Survey

Wetlands vegetation transects started from open water and extended back to shore through marsh and fen wetlands. Transects were flagged and marked with rebar and spikes (water depth permitting). Where water depth exceeded the length of the rebar, plots were marked with flagging tape. All sampling locations (transects) were marked on aerial photographs and UTM coordinates were recorded using GPS.

All sampling was conducted using a boat with a two-person field crew. Attempts were made to visit all benchmark plots that were established as part of the 1997 field program. All vegetation communities were measured at representative plots along transects within each distinct community type observed. A representative transect was positioned to traverse perpendicularly from the open water towards the shoreline. Where vegetation species or covers were distinctly variable, two to three replicate transects were positioned within 50 m to measure this variability.

One to seven sampling points were established along the length of the transect, with a point chosen for each distinct community type encountered. Where variability existed within a community, two replicate plots were measured 2 m apart.

At each plot, a 1 by 1 m floating quadrat was used to obtain an estimate of cover for each plant species from the bottom of the lake to the surface. Plant covers were also estimated for species groups including emergent species (forbs, grasses, sedges and shrubs), submergent species and algal species. The percent cover of open water was also estimated. When plants were too deep to see, but still within the 2 m depth range, plants were collected with a rake outside the plot boundary to determine the species. Cover was estimated.

3.6.1.2 Species Determination

Species encountered during the sampling program were collected in plastic, zip-lock bags and labelled with location, date and collector's name. When possible, stems, leaves and fruiting bodies or flowers were collected for unknown species. Species were identified while still fresh using field guides and botanical keys. Species that could not be identified in the field were pressed and dried for later comparisons with herbarium samples. Botanical keys and field guides included "An Identification Guide to Alberta Aquatic Plants" (Burland 1994), "Plants of the Western Boreal Forest and Aspen Parkland" (Johnson et al. 1995), "Flora of Alberta" (Moss 1983) and "Carex of Saskatchewan" (Hudson 1977).

3.6.1.3 Plant Vigour

Plant vigour is a measure of the relative health of a plant Alberta Environmental Protection (AEP) 1994. Plant vigour was estimated for each cover class using the guidelines detailed in the Ecological Land Survey Site Description Manual" (AEP 1994). Plant vigour represents a visual index of health and can be a non-quantitative measure of change over time.

Four vigour classes were used and they are defined as follows: '4' indicates excellent, '3' good, '2' fair (average) and '1' poor, respectively. A '0' is used to show dead vegetation. A dash indicates that there was no vegetation in the cover class.

3.6.1.4 Water Quality

In the 2001 field season, water quality parameters were measured in the RAMP wetlands, where possible, using a Hydrolab™. Parameters measured included pH, water temperature (°C), dissolved oxygen (mg/L), salinity (ppt) and conductivity (µS/cm).

Water depth was measured in each aquatic plot using a tape measure or metre stick.

3.6.2 Data Analysis

A Microsoft Access database was developed for field data entry and analysis. The database includes tables with information on location and site characteristics of transects, site characteristics of the plots including species composition, species cover classes, percent cover and water quality data.

3.6.2.1 Species Richness

Measures of species richness are commonly used to describe biodiversity. Species richness is defined as the total number of species present in a given area (e.g., plot) (Barbour et al. 1987). Species richness was calculated for tree, tall shrub, low shrub, forb, graminoid and bryophyte layer. Total richness of all species was also calculated for each plot surveyed.

3.6.2.2 Species Diversity

Species diversity calculations were based on the Shannon–Wiener Index. There are two community attributes that determine diversity: species richness and evenness. Species richness is independent of species percent cover. Species evenness is the distribution of individuals among the species, or species equitability. The value of evenness is largest when all the species present have the same cover value. Species diversity is an index calculated from species richness and weighted by evenness. Minimal values occur when one or a few species have a disproportionate dominance, whereas maximum values occur when many species share equally in the dominance of the community. Many formulae have been developed, which provide an index of diversity (Washington 1984). The Shannon–Wiener diversity index is used here (Barbour et al. 1987) and is expressed as:

$$H' = -\sum_{i=1}^{s} (p_i)(\ln p_i)$$

where H' is the diversity index number, s is the total number of species in the plot or vegetation layer and p_i is the proportion that each species contributes to the overall percent cover. For example, if the sum of the percent cover values for all species was 60% and the cover value of species A was 6%, then the p_i value for species A would be 0.10.

3.6.2.3 Similarity Indices

Species composition between lakes was compared to assess similarities and differences. In addition, comparisons within lakes and between lakes were made to monitor changes over time. This comparison between lakes was done using similarity indices.

Similarity indices, also referred to as coefficients of community, are measurements of the degree to which two plant communities resemble each other. Similarity indices are based upon the species composition of each community. Washington (1984) recommended the use of both the Jaccard's Index and Bray-Curtis Index to compare species overlap.

3.6.2.4 Jaccard's Index

Jaccard's index is an index of similarity that is calculated by dividing the number of species in common within two communities (*nc*) by the total number of species in each community (*nt*), minus the number of species in common (*nc*). The notation is as follows:

$$JI = nc \ / \ nt - nc$$

As a measure of community structure, the Jaccard index only takes into account species number and not abundance (e.g., percent cover) (Washington 1984). The Jaccard index was therefore used to assess the similarity in relative species composition (i.e., species presence/absence) between plots within lakes and between lakes. The statistical software Systat (SPSS Inc. 1999) was used to calculate Jaccard's indices.

3.6.2.5 Bray-Curtis Index

The Bray-Curtis dissimilarity (or distance) index is a measure of species overlap that also considers species abundance (i.e., percent cover). The index notation is as follows (SPSS 1999):

$$\textit{Bray-Curtis} = \frac{\sum_k | x_{ik} - x_{jk} |}{\sum_k x_{ik} + x_{ik}}$$

where

x_{ik} = percent cover of species *k* in plot *i*

x_{jk} = percent cover of species k in plot j

The Bray-Curtis dissimilarity index was used to assess the dissimilarity in species composition that includes abundance between plots within a lake. The statistical software Systat (SPSS 1999) was used to calculate the Bray-Curtis dissimilarity indices.

The coefficients were then converted to a positive index to make the Bray-Curtis dissimilarity index comparable to Jaccard's.

3.6.2.6 Kruskal-Wallis Non-Parametric Test

The Kruskal-Wallis test is used instead of Analysis of Variance when samples do not come from normal populations, are heterogeneous or do not have equal numbers of data in each group (Zar 1999). The Kruskal-Wallis test was the appropriate test to use for RAMP since different lakes were sampled using varying numbers of transects and plots. The test was applied to identify significant differences between the lakes for vegetation groups, species, and water chemistry.

3.7 NON-CORE PROGRAMS

3.7.1 OPTI Lakes

3.7.1.1 Sample Collection and Analysis

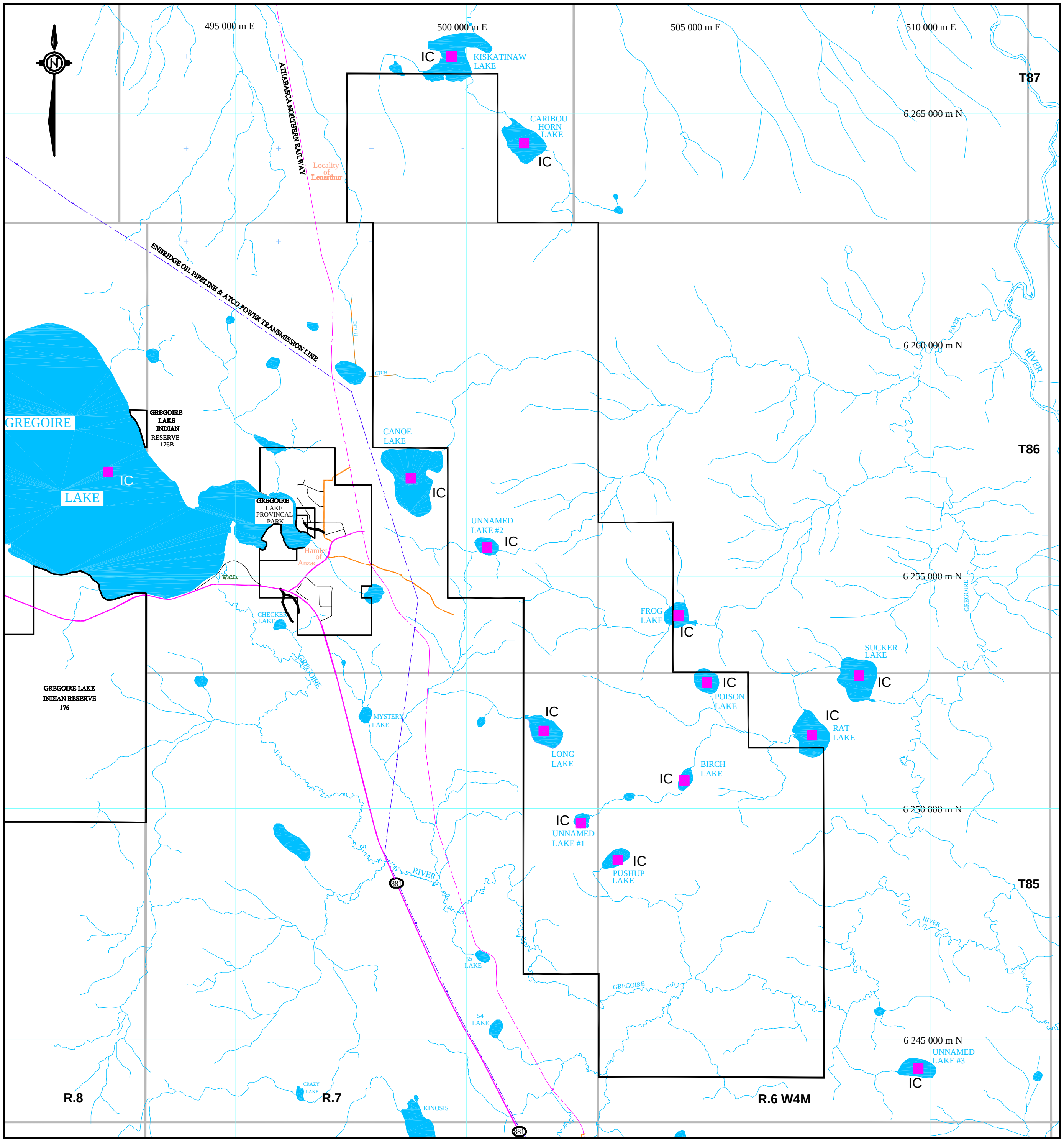
Water quality samples were collected from Gregoire Lake on May 29, 2001 and from 13 lakes, including Birch, Canoe, Caribou Horn, Frog, Kiskatinaw, Long, Poison, Pushup, Rat and Sucker lakes and Unnamed lakes 1, 2 and 3, during May 19 to 20, 2001 and September 18, 2001 (Figure 3.12).

All water quality samples were collected, preserved, stored and shipped in accordance with Golder Technical Procedure 8.3-1: Surface Water Sampling Methods (Golder 1999a). Sample locations were determined by GPS. All samples were collected from a depth of approximately 30 cm, using clean sample equipment. Standard field measurements were recorded at each sample site, including pH, conductivity, temperature and DO levels.

A single grab sample was collected in all lakes except Gregoire Lake. In Gregoire Lake, one 4 L sample was collected at mid-column, using a Kemmerer sampler, from three randomly selected sampling stations in open-water across the lake, and all samples were combined to create one composite sample.

Following sample collection, samples were shipped to ETL in Edmonton, Alberta, for chemical analysis. Samples, except the water sample from Gregoire Lake, were analyzed for conventional parameters, nutrients, major ions and total metals. Samples from Gregoire Lake were analyzed for conventional parameters, major ions and total arsenic.

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: 2002Wtr-Qual_OPTI.dwg Jul 10, 2002 - 10:49am



LEGEND

(black line)	OPTI PROJECT BOUNDARY
(magenta line)	ROAD, HARD SURFACE, ALL WEATHER, 2 OR MORE LANES
(orange line)	ROAD, LOOSE OR STABILIZED SURFACE, ALL WEATHER
(dash-dot magenta line)	RAILWAY
(dash-dot blue line)	PIPELINE
■	WATER QUALITY SAMPLE SITE
IC	INDUSTRY COMMITMENT

2.5 0 2.5

SCALE KILOMETRES

NOTES

TOPOGRAPHY/CULTURE SUPPLIED UNDER LICENSE FROM AltaLIS LTD.
KEY MOOSE/CARIBOU ZONES FROM WATERWAYS FOREST AREA – NEB1 November 1998
CULTURE UPDATED FROM AERIAL PHOTOGRAPHY FLOWN IN 1992
DATA FROM OPTI CANADA INC. (CH11x17A.DWG) NAD83

PROJECT

RAMP 2001

TITLE

OPTI LAKES WATER QUALITY SAMPLE SITES, 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	2002Wtr-Qual_OPTI
DESIGN	LG	21/03/02	SCALE AS SHOWN	REV. 0
CADD	RFM	17/05/02		
CHECK	KF	17/05/02	FIGURE: 3.13	
REVIEW				

3.7.1.2 Data Analysis

Water quality data collected in 2001 were compared to available historical information and relevant water quality guidelines for the protection of aquatic life and human health, as detailed in Section 3.1.3.1.

When more than two historical data points were available, historical median, minimum and maximum parameter concentrations were calculated and were summarized and compared to relevant water quality guidelines, along with 2001 sample results.

The formula used to calculate critical loads (i.e., acid sensitivity) for lakes in the local study area was adopted from Syncrude (1998) with two modifications. The critical load calculations are described in detail by OPTI (2000), Volume 2, Section F4.3.1.4.

3.7.2 Baseline Sampling at Suncor Firebag

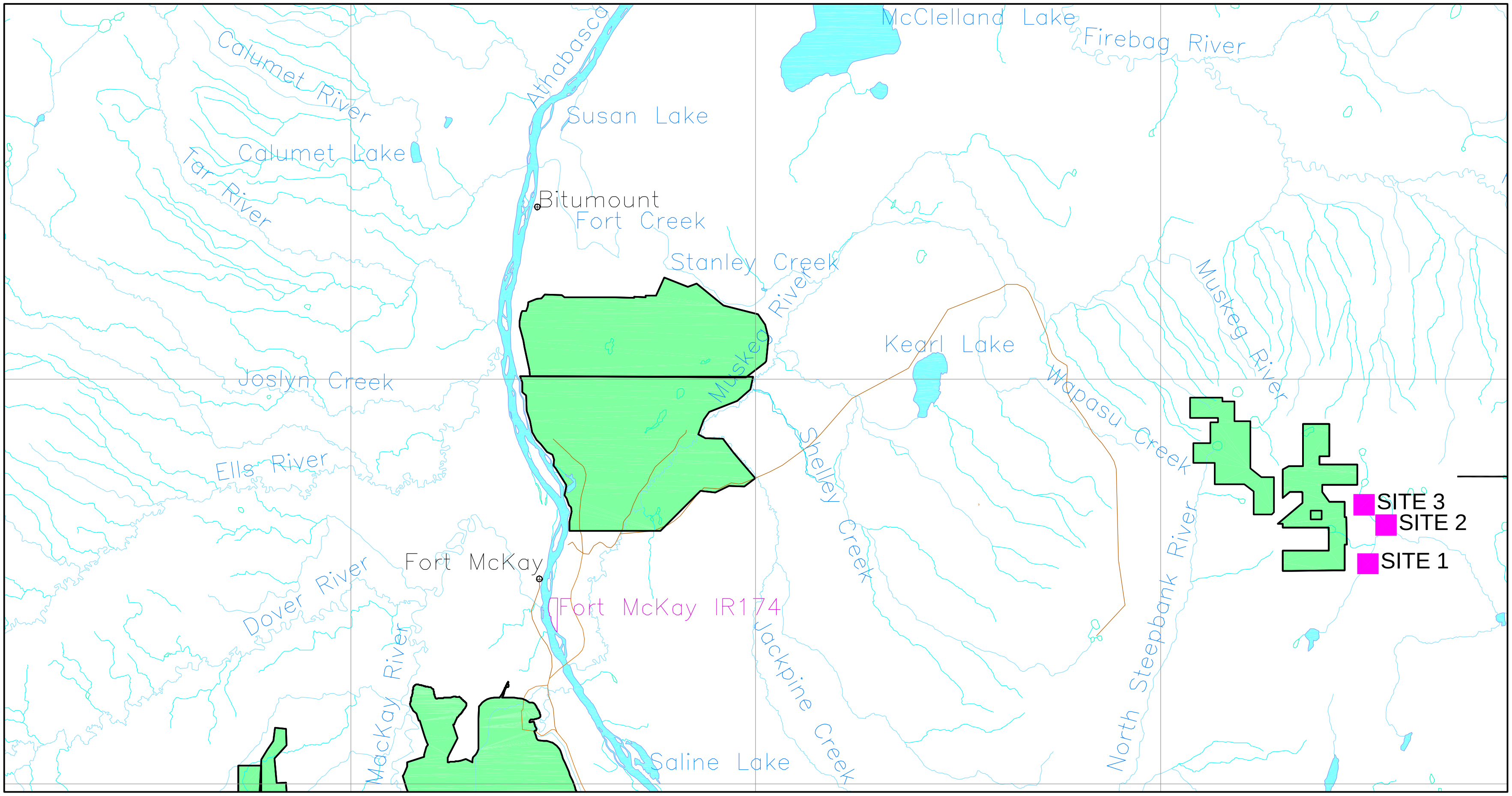
3.7.2.1 Sample Collection and Analysis

Three water samples were collected on November 1, 2001, from the headwaters of the Firebag River near the Suncor Firebag Project (Figure 3.13) to provide baseline information prior to the release of treated effluent from Suncor's domestic wastewater treatment system. Each grab sample was collected and analyzed using the general methodology outlined in Section 3.1.1.1, with the exception that these samples were analyzed for total and fecal coliforms instead of organics.

3.7.2.2 Data Analysis

Data analysis was limited to a comparison of the 2001 sample results to relevant water quality guidelines (Table 3.12) and identifying any unusual observations that differed substantially from water quality conditions observed elsewhere in the lower Athabasca River watershed.

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: Firebag-Water-Sample.dwg Jul 10, 2002 - 10:51am



LEGEND

MAJOR ROADWAYS
RIVERS AND STREAMS
EXISTING DEVELOPMENTS
WATER QUALITY SAMPLE SITE

10 0 10
SCALE KILOMETRES

REFERENCE

ALBERTA NTDB DATA SUPPLIED BY GEOMATICS CANADA, AUGUST 2001. NAD 83 ZONE 12. SHEETS 74D, E AND 74L IN NAD 27 ZONE 12. SASKATCHEWAN NTDB DATA SUPPLIED BY ISC, AUG. 2001. NAD 83 ZONE 13. ALL DATA CONVERTED TO NAD 83 UTM ZONE 12.

PROJECT

RAMP 2001

TITLE

WATER SAMPLE SITES NEAR THE SUNCOR FIREBAG PROJECT, 2001

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	WATER SAMPLE
DESIGN	LG	21/03/02	SCALE AS SHOWN	REV. 1
CADD	RFM	17/05/02		
CHECK	KF	17/05/02	**FIGURE: 3.14**	
REVIEW				

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4 QUALITY ASSURANCE AND QUALITY CONTROL

4.1 QUALITY ASSURANCE PROCEDURES

Quality assurance (QA) refers to plans or programs that encompass a wide range of internal and external management and technical practices designed to ensure the collection of data of known quality matches the intended use of the data (Environment Canada 1998). Golder has developed QA principles that, if diligently followed, will produce data of known and defensible quality. Golder's QA procedures for RAMP 2001 cover three areas of internal and external management and are outlined in more detail below.

Field Staff Training and Operations

To ensure that field data collected are of known, acceptable and defensible quality, Golder field staff are trained to be proficient in standardized field sampling procedures, data recording and equipment operations applicable to RAMP, and all field work is completed according to specified instructions and established technical procedures. For example,

- All water and sediment samples were collected in accordance with Golder Associates Technical Procedures 8.3-1 and 8.2-2, respectively (Golder 1999a). These procedures outline standard sample collection, preservation, storage and shipping protocols. They also provide specific guidelines for field record keeping and sample tracking.
- All field crews use RAMP specific work instructions (SWIs). SWIs are standardized forms that detail specific sampling instructions, equipment needs, required technical procedures, sample labelling and shipping protocols, laboratory contacts and estimated time required to complete the specified field work.

Laboratory

To ensure that high quality data are generated, laboratories used for RAMP water and sediment sample analysis are accredited by the Canadian Association for Environmental Analytical Laboratories (CAEAL). Under CAEAL's accreditation program, performance evaluation assessments are conducted annually for laboratory's procedures, methods and internal quality control.

Office Operations

A data management system is in place to ensure an organized, consistent system of data control, data analysis and filing was used for the project.

In 2001, deficiencies in the present RAMP QA system were identified, including late collection of water samples on the Athabasca River, loss of samples due to shipping problems and incorrect information on analytical chain-of-custody forms. Golder is committed to improve QA procedures for future programs. In 2002, Golder is planning to develop a formal Quality Assurance Plan (QAP) specific to the RAMP project. The QAP will establish the following requirements:

- pre-field meetings to discuss SWIs and review relevant technical procedures with field crew(s);
- post-field meetings to discuss the field program and identify areas of concern or improvement;
- field crews to check-in with task managers every 24 to 48 hours with an update on work completed over that period of time;
- designation of one Golder field crew member who will be responsible for managing the sample shipping process to ensure that:
  - all required samples are collected;
  - chain-of-custody and analytical request forms are completed and correct;
  - proper labelling and documentation procedures are followed;
  - samples are delivered to shipping agents in a timely manner; and
  - samples have arrived at the designated laboratory(ies) within two days of being shipped;
- internal check of chain-of-custody forms by the Task Manager when crews return from the field (the appropriate laboratory would be alerted immediately if analysis request errors are found);
- internal check of laboratory data once it is received to ensure data quality; and
- documentation of all samples collected for RAMP on a sample tracking sheet. Table 4.1 contains an example of how RAMP samples will be tracked as part of the 2002 QA process.

Table 4.1 Example of RAMP Sample Tracking Sheet

Season	Crew	Waterbody	Sample Site	Sample Media	Samples Collected	Date Collected	Lab	Sample Arrival	COC Correct	Results Received	Results Checked	Invoice
fall	KA,LG	McLean Creek	MCC-1	water	groups 1-7	Sept. 15/02	ETL	Sept. 16	yes	digital-Sept. 25	yes-Sept. 30	Oct. 15

4.2 QUALITY CONTROL PROCEDURES

Quality Control (QC) is a specific aspect of QA that refers to the internal techniques used to measure and assess data quality (APHA 1989). QC procedures implemented in 2001 for the water quality, sediment quality, benthic invertebrate and fisheries components are described in the following sections.

4.2.1 Water and Sediment Quality

Water and sediment quality QC procedures for RAMP 2001 consisted of field and laboratory components, which are detailed in Sections 4.2.1.3 and 4.2.1.4, respectively. Standard QC samples used in one or both components of the water and sediment quality QC program are defined in Section 4.2.1.1, and the assessment criteria used to determine if QC sample results were indicative of sample contamination or analytical bias are described in Section 4.2.1.2

4.2.1.1 QC Sample Definitions

Field Blank

A separate sample prepared in the field during a sampling event using laboratory-provided deionized water to fill a set of sample bottles that are submitted to the laboratory for the same analysis as the field samples. Field blanks are used to detect potential sample contamination during collection, shipping and analysis.

Trip Blank

A set of sealed bottles provided by the analytical laboratory that are pre-filled with deionized water and accompany sample bottles to and from the field site. The unopened trip blanks undergo the same analysis as the field samples and are used to determine if sample contamination may have occurred during transport and analysis.

Split Sample

A single sample collected from a given location that is then split into two or more sample containers. Split samples are labelled, preserved individually and submitted separately to the analytical laboratory for identical analyses. These samples are used to assess intra-laboratory precision.

Duplicate Sample

Two samples are collected from one location using identical sampling procedures. They are labelled, preserved individually and submitted separately to the analytical laboratory for identical analyses. Duplicate samples are used to check intra-site variation and precision of field sampling methodology.

Method Blank

Similar to a field blank, a method blank is prepared in the laboratory by filling one or more sample containers with deionized water. It is analyzed along with the field samples and are used to detect possible sample contamination as a result of laboratory procedures.

Matrix Spike

A known amount of one or more target compounds are added to a portion of a given field sample. The percent recovery is measured and compared to specified guidance limits defined by each laboratory. Matrix spikes are used to determine if the sample matrix is interfering with the analysis (i.e., experiencing method bias).

Laboratory Control Sample or Reference Standard

A laboratory control sample (LCS) or reference standard can be purchased directly from a supplier or created in the laboratory by adding a known amount of one or more target compounds to deionized water or another suitable certified reference material. The resulting LCS or reference standard is then analyzed along with the field samples to assess analytical accuracy and precision.

4.2.1.2 Assessment Criteria

The assessment criteria used to determine if QC sample results may be indicative of sample contamination or analytical bias are described below.

Field, Trip and Method Blanks

Although parameters should not be detected in the field, trip or method blanks, parameter concentrations were considered significant if they were greater than five times the corresponding method detection limit (MDL). This threshold is based on the Practical Quantitation Limit defined by the U.S. EPA (1985), which takes into account the potential for data accuracy error when parameter concentrations approach or are below MDLs.

Significant results observed in a field, trip or method blank were evaluated relative to parameter concentrations observed in field samples and other blank samples collected during the corresponding sampling trip to determine if sample contamination was limited to that particular QC sample or apparent in other samples collected at that time. If, based on this comparison, sample contamination did not appear to have been an isolated error, field data were flagged and interpreted with this limitation in mind.

There has been some suggestion by members of the RAMP Steering Committee that this threshold (i.e., five times the corresponding method detection limit) could be improved for major ions and several other parameters. This issue will be discussed by the RAMP Technical Subcommittee in 2002, and the criteria for assessing the significance of reported concentrations in blank samples will be adjusted accordingly.

Split and Duplicate Samples

Differences between parameter concentrations in split or duplicate samples were considered significant if:

- they were greater than 20% (ETL samples); or
- parameter concentrations were greater than or less than the average concentration reported for the split or duplicate samples +/- 30% (AXYS samples); and
- parameter concentrations were greater than five times the reported MDL.

These criteria are consistent with those used by ETL and AXYS for their internal QC procedures and take into account the potential for data accuracy error as parameter concentrations approach MDLs.

Analytical precision was then rated as:

- high if less than 10% of the parameters included in the split sample analysis were significantly different from one another;
- moderate if 10 to 30% of the parameters included in the split sample analysis were significantly different from one another; or
- low if more than 30% of the parameters included in the split sample analysis were significantly different from one another.

Similarly, intra-site variability and field sampling precision was rated as:

- low and high, respectively, if less than 10% of the parameters included in the duplicate sample analysis were significantly different from one another;
- moderate if 10 to 30% of the parameters included in the duplicate sample analysis were significantly different from one another; or
- high and low, respectively, if more than 30% of the parameters included in the duplicate sample analysis were significantly different from one another.

Matrix Spikes and LCS

Because assessment criteria for matrix spikes and LCS are parameter and laboratory specific, percent recoveries and parameter concentrations reported for matrix spikes and LCS, respectively, were evaluated in consultation with the appropriate laboratory(ies) to determine if significant results had been observed and how these findings may affect the interpretation of the 2001 sample results.

4.2.1.3 Field Sampling QC

As detailed in Table 4.2, the water and sediment QC sampling program for the RAMP 2001 field season included the following:

- field blanks;
- trip blanks;
- split water and sediment samples; and
- duplicate sediment samples.

Table 4.2 QC Samples Collected During the RAMP 2001 Field Season

Season	Sample Site	QC Sample
summer	Clearwater River	field blank
	McClelland Lake	trip blank
	Kearl Lake	split water sample
fall	McClelland Lake	trip blank
	Muskeg River, mouth	split water sample split sediment sample (inter-lab comparison)
	Shipyard Lake	duplicate sediment sample
	Kearl Lake	split sediment sample (intra-lab comparison)
	Athabasca River, upstream of Fort Creek	field blank

Field blanks, trip blanks and split water samples were sent to ETL and ARC-Vegreville for the same type of analysis outlined in Section 3.1.1.1, which included ultra-low level mercury and silver (ARC-Vegreville), conventional parameters, major ions, nutrients, organics and total and dissolved metals (ETL). PAHs were not included in the QC analysis for water, because these compounds are not typically present in ambient water, as reflected by the non-detectable results observed in previous RAMP water quality testing (e.g., Golder 2001). The split sediment sample collected from Kearl Lake and the duplicate sediment sample taken from Shipyard Lake were sent to ETL and AXYS for the same type of analysis outlined in Section 3.2.1.1, including carbon content, organics and total metal analysis (ETL) and PAHs (AXYS). The split sediment sample collected at the mouth of the Muskeg River was split into three components, which were subsequently sent to AXYS, ARC-Vegreville and Environment Canada for PAH analysis. Results from Environment Canada were not available at the time this report was prepared. All of the QC sample data discussed herein are reported in Appendix V.

Field and Trip Blanks

Parameters present in the 2001 field or trip blanks at concentrations greater than five times the corresponding MDL are summarized in Tables 4.3 and 4.4. Based on a comparison with relevant seasonal sampling results, possible sample contamination may have occurred in the fall, affecting total Kjeldahl nitrogen, total zinc and dissolved zinc levels.

Table 4.3 Summary of Water Quality Parameters in RAMP 2001 Field Blanks That Exceeded Five Times the Method Detection Limit

Parameter	Units	Detection Limit	Season [a]		Comments [b]
			Summer	Fall	
Nutrients					
nitrogen – Kjeldahl	mg/L	0.2	-	1.3	A
Total Metals					
barium (Ba)	µg/L	0.2	1.3	-	B
strontium (Sr)	µg/L	0.2	7	-	B
zinc (Zn)	µg/L	4	35	103	C,A
Dissolved Metals					
copper (Cu)	µg/L	0.6	7.7	-	C
silver (Ag)	µg/L	0.2	1.2	-	C
strontium (Sr)	µg/L	0.1	0.6	-	B

[a] field blanks were not included in the winter or spring sampling program.
[b] A = Number of instances where sample concentrations from relevant season were outside the historical range and greater than levels in the field blank; results are indicative of potential sample contamination during sampling, transport and/or analysis.
B = Sample concentrations from the relevant season generally contained levels consistent with historic data; therefore, this finding was assumed to be an isolated error (i.e., sample contamination is limited to the field blank).
C = Concentration in the field blank was higher than levels observed in the majority of the water samples collected in the same season; therefore, this finding was assumed to be an isolated error (i.e., sample contamination is limited to the field blank).
Note: - = parameter did not exceed five times the method detection limit.

Table 4.4 Summary of Water Quality Parameters in RAMP 2001 Trip Blanks That Exceeded Five Times the Method Detection Limit

Parameter	Units	Detection Limit	Season[a]		Comments[b]
			Summer	Fall	
Organics					
total recoverable hydrocarbons	mg/L	0.5	-	2.8	A
Total Metals					
copper (Cu)	µg/L	1	17	-	A
iron (Fe)	µg/L	5	33	-	A
strontium (Sr)	µg/L	0.2	1.1	-	B
Dissolved Metals					
boron (B)	µg/L	2	36	-	A
chromium (Cr)	µg/L	0.4	5	-	A
strontium (Sr)	µg/L	0.1	-	0.7	A
vanadium (V)	µg/L	0.1	0.7	-	A
zinc (Zn)	µg/L	2	-	17	C

(a) trip blanks were not included in the winter and spring sampling programs.

(b) A = Concentration in trip blank was higher than concentrations observed in the field blank, and water samples contained levels consistent with historical data; therefore, this finding was assumed to be an isolated error (i.e., sample contamination is limited to the trip blank).

B = Concentration in the trip blank was lower than concentrations observed than either the field blank or water samples collected that season; therefore, this finding was assumed to be an isolated error (i.e., sample contamination is limited to the trip blank).

C = Number of instances where sample concentrations were outside the historical range and/or greater than the corresponding total zinc result; therefore, results are indicative of possible sample contamination during transport and/or analysis.

Note: - = parameter did not exceed five times the method detection limit.

Although the presence of total barium and dissolved strontium in the summer and/or fall field blanks was deemed to be an isolated error (Table 4.3), these two substances, along with total zinc, were also detected in several field blanks included in the RAMP 2000 water sampling program (Golder 2001a). In 2002, Golder will review laboratory and field sampling procedures to determine why these parameters tend to be present in RAMP QC samples.

Split Water Samples

The variation among split water samples was generally acceptable in 2001, although differences of greater than 20% were observed with total zinc in the summer and fall, total iron, dissolved copper and dissolved zinc in the summer and chloride, total aluminum and total boron in the fall (Table 4.5). For all of these parameters, with the exception of zinc, differences between reported split sample concentrations were small scale, isolated incidents that did not affect the interpretation of the 2001 monitoring results. Overall, less than 5% of parameters analyzed exceeded the acceptable limit of difference between split samples, indicative of high analytical precision.

Although sulphide levels were comparable between split water samples (Appendix V, Table V-2), there has been some suggestion by members of the RAMP Steering Committee that the accuracy of these measurements may be questionable. In 2002, the RAMP water QC program will include inter-lab comparisons using split sulphide samples to assess this issue.

Table 4.5 Summary of Water Quality Parameters in RAMP 2001 Split Samples That Exceeded Assessment Criteria

Parameter	Units	Detection Limit	Summer (Kearl Lake) [a]			Percent Difference	Fall (Muskeg River)		Percent Difference
Major Ions									
chloride	mg/L	1	-	-	-	-	5	7	29
Total Metals									
aluminum (Al)	µg/L	20	-	-	-	-	110	50	55
boron (B)	µg/L	2	-	-	-	-	74	46	38
iron (Fe)	µg/L	5	37	60	61	39	-	-	-
zinc (Zn)	µg/L	4	12	33	13	64	159	< 4	98
Dissolved Metals									
copper (Cu)	µg/L	0.6	3.4	4.6	2.3	50	-	-	-
zinc (Zn)	µg/L	2	2	< 2	28	93	-	-	-

[a] Percent difference was calculated using the highest and lowest concentrations observed among the three split samples.
Note: = the assessment criteria was not exceeded.

Split Sediment Samples

Intra-Lab Comparisons

Variations in the concentrations of a number of parameters, including total inorganic carbon, total extractable hydrocarbons, total aluminum, copper, lead, titanium, zinc, dibenzo(a,h)anthracene, benzo(a)anthracene/chrysene, C2 substituted benzo(b&k)fluoranthene/benzo(a)pyrene, benzofluoranthenes, dibenzothiophene, C4 dibenzothiophene and indeno(1,2,3,cd)pyrene, were observed between two split sediment samples collected from Kearl Lake in the fall of 2001 (Table 4.6). Based on these results, ETL's and AXYS' analytical precision for sediment sample analysis was ranked as moderate, because less than 25% of the parameters analyzed exceeded the acceptable limits of difference.

Table 4.6 Summary of Sediment Quality Parameters in RAMP 2001 Split Sediment Samples That Exceeded Assessment Criteria

Parameter	Units	Detection Limit	Fall		Percent Difference	Acceptable Range
Carbon Content						
total inorganic carbon	% by wt	0.01	0.02	0.06	67	-
Organics						
total extractable hydrocarbons	mg/kg	5	270	78	71	-
Total Metals						
aluminum (Al)	µg/g	1	7020	5330	24	-
copper (Cu)	µg/g	0.1	29	10	65	-
lead (Pb)	µg/g	0.1	5.8	4.0	31	-
titanium (Ti)	µg/g	0.05	74	108	32	-
zinc (Zn)	µg/g	0.2	103	78	24	-
Target PAHs and Alkylated PAHs						
dibenzo(a,h)anthracene	ng/g	2.7	28[(b)]	11[(b)]	-	14 - 25
benzo(a)anthracene/chrysene	ng/g	0.7	44	20	-	22 - 41
C2 substituted benzo(b&k)f/b(a)pyrene [(a)]	ng/g	4.1	9.2	27	-	13 - 24
benzofluoranthenes	ng/g	2.2	79	33	-	39 - 73
dibenzothiophene	ng/g	0.6	2.5[(b)]	1.7[(b)]	-	1.5 - 2.7
indeno(1,2,3,cd)pyrene	ng/g	1.9	33[(b)]	17[(b)]	-	18 - 33

(a) benzo(b&k)f / b(a)pyrene = benzo(b&k)fluoranthene/benzo(a)pyrene.
(b) PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
Note: - = not applicable.

Inter-Lab Comparisons

Reported PAH concentrations in the split sample collected from the mouth of the Muskeg River were comparable for ten of the 13 parameters analyzed by both ARC-Vegreville and AXYS (Table 4.7). Based on these results, AXYS' analytical precision for sediment sample analysis was ranked as moderate, because less than 25% of the parameters analyzed exceeded the acceptable limits of difference.

Table 4.7 Comparison of Reported PAH Concentrations in a Split Sediment Sample Taken from the Mouth of the Muskeg River

Parameter	Units	ARC-Vegreville[a]	AXYS[a]	Percent Difference[b]
naphthalene	ng/g	*< 1	*0.85	-
acenaphthene	ng/g	< 1	< 0.13	-
phenanthrene	ng/g	4	1.1	73
pyrene	ng/g	< 1	1.3	-
benzo(a)pyrene	ng/g	< 1	< 3.7	-
indeno(1,2,3,cd)pyrene	ng/g	6	< 1.7	72
acenaphthylene	ng/g	< 1	< 0.13	-
fluorene	ng/g	< 1	< 0.27	-
anthracene	ng/g	< 1	< 0.49	-
fluoranthene	ng/g	< 1	< 0.4	-
1-methyl-7-isopropyl-phenanthrene	ng/g	< 1	3	-
benzo(a)anthracene / chrysene	ng/g	9	5.2	42
dibenzo(a,h)anthracene	ng/g	< 1	< 2.2	-

(a) PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
(b) - = the assessment criteria was not exceeded.

Duplicate Sediment Samples

Variations in concentrations of total extractable hydrocarbons, total titanium and dibenzo(a,h)anthracene between the two duplicate samples were slightly above defined assessment criteria (Table 4.8). With less than 5% of parameters analyzed exceeding the acceptable limit of difference between duplicate samples, intra-site variation in Shipyard Lake was rated as low and field sampling precision was rated as high.

Table 4.8 Summary of Sediment Quality Parameters in RAMP 2001 Duplicate Sediment Samples That Exceeded Assessment Criteria

Parameter	Units	Detection Limit	Fall		Percent Difference	Acceptable Range
Organics						
total extractable hydrocarbons	mg/kg	5	36	48	25	-
Total Metals						
titanium (Ti)	µg/g	0.05	20	16	22	-
Target PAHs and Alkylated PAHs						
dibenzo(a,h)anthracene	ng/g	1.6	11[a]	5.3	-	5.7 - 10.6

(a) PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
Note: - = not applicable.

Results from the duplicate sediment sampling analysis also indicate that the moderate degree of analytical variability observed with the split sediment samples was not consistent over time. If it were, a higher degree of variation would have been observed between the two duplicate samples. These results suggest that the split sediment samples collected at Shipyard Lake may not have been prepared properly and that the variations noted above may result from heterogeneity between the split samples.

4.2.1.4 Laboratory Analysis QC

As part of the laboratory QC program, RAMP requested ETL, AXYS and ARC to provide a detailed description of the laboratory's internal QC procedures or provide the results of internal QC checks on their analytical equipment and sampling procedures. This information is summarized in the following sections.

Laboratory QC programs have included:

- using method blanks to detect contamination from analytical equipment;
- using spiked samples (i.e., matrix spike) to check for interference from the sample matrix by adding a specified amount of a chemical to the sample and measuring the percent recoveries;
- using laboratory control samples to verify that the precision and bias of the analytical process are within control limits; and
- re-analyzing random samples (i.e., lab duplicate) to check precision of laboratory sampling procedures and stability of equipment.

ETL

ETL provided a QC report for every RAMP water or sediment chemical analysis completed in 2001. For every batch of samples processed, the QC report documented the QC procedure used for each corresponding parameter analysis. In general, each QC result must meet acceptance guidelines specified for that particular method. A column in the QC report detailed the kind of corrective action taken if the result fell outside the acceptable limit. After 15% of the samples had been processed, the corresponding QC procedure was duplicated to check precision. Based on the QC reports submitted to RAMP and follow-up communications with the laboratory, ETL's laboratory QC program was successful at ensuring a high level of analytical accuracy and precision. With the noted exception that total zinc, dissolved zinc and total Kjeldahl nitrogen samples from the fall appear to have been contaminated either in the field or during sample analysis.

AXYS

RAMP sediment samples were analyzed in two batches in December 2001 and January 2002. Although a number of parameters were detected in the blank samples (Table 4.9), reported concentrations in the blank samples were generally less than 10% of the PAH levels observed in the RAMP samples. Therefore, the interpretation of, and conclusions drawn from, the 2001 sediment monitoring data should not be affected by these results.

AXYS also analyzed matrix spikes along with each sample batch to check for interference from the laboratory sample matrix. Recovery rates for all parameters, summarized in Table 4.10, were within AXYS specified recovery guidelines, indicating that the analysis was free of bias.

Table 4.9 Summary of Sediment Quality Parameters in AXYS Method Blanks that Exceeded Five Times the Standard Detection Limit

Parameter	Units	December 2001		January 2002	
		Detection Limit	Method Blank	Detection Limit	Method Blank
naphthalene	ng/g	-	-	0.13	1.9
C1 substituted naphthalenes	ng/g	0.110	0.71	0.30	1.9
C2 substituted naphthalenes	ng/g	0.089	0.62	0.39	3.8
C4 substituted naphthalenes	ng/g	0.056	0.48	-	-
anthracene	ng/g	0.053	0.34	-	-
benzo(a)anthracene	ng/g	0.035	0.21[a]	-	-
chrysene	ng/g	0.035	0.23	0.12	0.77
benzofluoranthenes	ng/g	0.036	0.32[a]	-	-
biphenyl	ng/g	0.074	0.58	-	-
dibenzothiophene	ng/g	0.022	0.35	-	-
fluoranthene	ng/g	0.023	0.55	-	-
fluorene	ng/g	0.045	0.29	-	-
C2 substituted fluorene	ng/g	0.030	0.37	-	-
phenanthrene	ng/g	0.041	0.87	0.18	1.6
C1 substituted phenanthrene/anthracene	ng/g	0.095	0.51	-	-
C2 substituted phenanthrene/anthracene	ng/g	0.042	0.34	-	-
pyrene	ng/g	0.024	0.49	0.13	0.77[a]

(a) PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

Note: - = Parameter did not exceed five times the method detection limit.

Table 4.10 Percent Recovery of Selected Sediment Quality Parameters in Spiked Samples Prepared and Analyzed by AXYS

Parameter	Percent Recovery (%)	
	December 2001	January 2002
naphthalene	100	100
acenaphthylene	93	98
acenaphthene	84	95
fluorene	88	97
phenanthrene	110	110
anthracene	120	140
fluoranthene	98	100
pyrene	100	110
benzo(a)anthracene	110	110
chrysene	110	110
benzofluoranthenes	110	120
benzo(a)pyrene	100	100
dibenzo(ah)anthracene	90	87
indeno(1,2,3,cd)pyrene	92	96
benzo(ghi)perylene	90	92
dibenzothiophene	79	77
retene	110	100
C1 substituted phenanthrene/anthracene	150	160
C2 substituted phenanthrene/anthracene	100	110

ARC-Vegreville

ARC-Vegreville's QC program included reference standards, matrix spikes and laboratory duplicates with every batch of RAMP water samples analyzed for ultra low level total mercury and silver. Results of the laboratory QC program indicate that ARC-Vegreville was successful at ensuring a high level of analytical accuracy and precision (Angela Wharmby, ARC-Vegreville, pers. comm.).

4.2.1.5 Data Entry

Water quality and sediment data were entered into the project database from the electronic files and paper reports received from the analytical laboratories. All new data were verified against each laboratory's final reports to ensure data accuracy. Less than 5% of the values were found to be entered incorrectly. All data entry errors were corrected.

4.2.2 Benthic Invertebrates

Procedures used for handling, sorting, subsampling, preserving, identifying, and storing samples met or exceeded guidelines established by federal and provincial agencies (AENV 1990; Environment Canada 1993). Field and laboratory procedures employed by Golder and its subconsultants were developed using guidance from regulatory agencies.

Laboratory analysis of benthic invertebrate samples incorporated an evaluation of invertebrate removal efficiency in 10% of the samples (12 samples) collected during the 2001 program. Sorted portions of 12 sampled were randomly selected and were re-sorted by S. Kovats (independent consultant, Calgary, Alberta). In light of the large number of depositional samples which contained a large amount of organic material but relatively few invertebrates (e.g., substantially fewer than 100 in many cases), minimum removal efficiency of 90% was considered acceptable. Quality control results indicate that the data quality objective of removal of at least 90% of the total number of invertebrates from the sorted fractions of samples was achieved for all samples selected for re-sorting (Table 4.11). Therefore, data quality was acceptable.

The benthic invertebrate abundance data were received in electronic format from the taxonomist. Before releasing the data, data entry was checked by the taxonomist by verifying each number entered. During data manipulation and analysis, backup files were generated before each major operation, and appropriate logic checks were performed to ensure the accuracy of calculations. Benthic invertebrate data and results of analyses are stored in printed and electronic format with appropriate documentation and backups to ensure that analyses may be reproduced if necessary.

Benthic invertebrates removed from the samples will be retained at Golder for an indefinite period, to allow potential re-identification of invertebrates or additional sample analysis.

4.2.3 Fish Populations

4.2.3.1 Field Sampling

Fish collections for sentinel monitoring and inventory work were conducted in accordance to Golder Technical Procedure 8.1.3 “Fish Inventory Methods” (Golder 1999a). Fish collected for tissue analyses were processed according to procedures outlined in the Technical Procedure 8.15-0 “Fish Health Assessment – Organics” and 8.16-0 “Fish Health Assessment – Metals” (Golder 1999a). Detailed field notes were maintained in a perfect-bound notebook and fisheries data were recording using appropriate data sheets.

Table 4.11 Quality Control Data for Re-sorted Benthic Invertebrate Samples

Taxon	CLR-D-2 C+F	CLR-D-22 C+F	FOC-D-5 C	FOC-D-5 F (1/2)	MAR-E-1 C	MAR-E-1 F (1/4)	MAR-E-8 C	MAR-E-8 F (1/4)	MUR-D-19 C	MUR-D-19 F (1/10)
Hydra	0	0	0	0	0	0	0	0	0	1
Nematoda	0	2	0	0	1	0	0	1	0	0
Naididae	1	0	0	0	0	0	0	0	0	0
Ostracoda	0	1	0	0	0	0	0	0	0	0
Hydracarina	0	0	0	0	0	0	0	5	0	0
Baetis	0	0	0	0	1	0	0	1	0	0
Heptageniidae	0	0	0	0	0	0	1	0	0	0
Diptera (adult)	0	0	0	1	0	0	0	0	0	0
Bezzia	1	0	0	0	0	0	0	0	0	0
Chironomidae (i/d)	0	0	1	0	0	0	0	0	0	0
Chironomini	1	5	0	0	0	0	0	0	4	3
Orthocladiinae	0	1	0	0	0	0	0	0	0	3
Tanytarsini	0	3	0	1	0	1	0	0	0	0
total missed	**3**	**12**	**1**	**2**	**2**	**1**	**1**	**7**	**4**	**6**
total in sample	**37**	**229**	**64**		**341**		**401**		**2348**	
percentage missed (%)	**8.1**	**5.2**	**7.8**		**1.8**		**7.2**		**2.7**	
sorting efficiency (%)	**91.9**	**94.8**	**92.2**		**98.2**		**92.8**		**97.3**	

Notes: Numbers of organisms were multiplied by the subsampling factor to calculate the percentage missed and the sorting efficiency.
C = coarse (>1 mm) fraction.
F = fine (0.25 to 1 mm) fraction.
In the event that a sample fraction was subsampled, the amount sorted is indicated in parentheses.

Table 4.11 Quality Control Data for Re-sorted Benthic Invertebrate Samples (continued)

Taxon	MUR-E-11 C	MUR-E-11 F	MUR-D-22 C	MUR-D-22 F (1/2)	STR-E-5 C	STR-E-5 F (1/2)	STR-E-14 C	STR-E-14 F (1/4)	KEL-5 C+F	SHL-2 C	SHL-2 F
Nematoda	0	0	0	0	0	0	0	0	0	0	1
Enchytraeidae	0	0	0	0	0	0	0	1	0	0	0
Naididae	0	0	0	0	0	0	0	1	0	0	1
Ostracoda	0	0	0	0	0	0	0	1	0	0	1
Hydracarina	0	0	0	0	1	1	1	1	0	0	0
Baetis	0	0	0	0	1	3	5	2	0	0	0
Ephemerella	0	0	0	0	0	1	3	6	0	0	0
Tricorythodes	0	0	0	0	0	0	1	0	0	0	0
Chironomidae (i/d)	0	1	0	1	0	0	0	0	0	0	0
Chironomini	0	1	2	2	0	0	0	1	0	0	0
Orthocladiinae	0	0	0	1	0	1	0	1	0	0	0
Tanytarsini	0	0	0	1	0	2	0	0	0	0	0
Hemerodromia	0	0	2	0	0	0	0	0	0	0	0
total missed	**0**	**2**	**4**	**5**	**2**	**8**	**10**	**14**	**0**	**0**	**3**
total in sample	**155**		**272**		**192**		**664**		**9**	**39**	
percentage missed (%)	**1.3**		**5.1**		**9.4**		**9.9**		**0.0**	**7.7**	
sorting efficiency (%)	**98.7**		**94.9**		**90.6**		**90.1**		**100.0**	**92.3**	

Notes: Numbers of organisms were multiplied by the subsampling factor to calculate the percentage missed and the sorting efficiency.
C = coarse (>1 mm) fraction.
F = fine (0.25 to 1 mm) fraction.
In the event that a sample fraction was subsampled, the amount sorted is indicated in parentheses.

Routine water quality data (pH, conductivity, temperature, dissolved oxygen) were collected at each site. Water quality instruments were calibrated as needed. The start and finish of each fisheries sampling reach was recorded using a GPS unit. A photograph of each fish collection site was taken and photograph details were recorded on a Photo Log Form.

Chain-of-custody forms were completed when shipping all samples to the appropriate laboratory for analysis.

4.2.3.2 Laboratory Analysis

Fish ageing was conducted by Northshore Environmental Services, Thunder Bay, Ontario. Jon Tost (proprietor) is recognized as an expert in ageing fish. Ageing structures were read independently at least three times and a numerical confidence level was assigned to each age estimate. Confidence level for northern pike and walleye ageing was relatively low due to difficulty assessing inner annuli. Slimy sculpin (sentinel species) were assessed with moderately high confidence. A Golder Associates technician experienced in ageing fish re-analyzed a random 10% subsample of all ageing structures for each species within each sampling program. Of 33 ageing samples re-analyzed, 97% (32 samples) were identical to the original ageing results. The one sample that differed from the original analysis, showed a difference in age of one year.

A single Golder Associates' Technician conducted all fecundity analyses. At least 10% of all fecundity samples were re-counted by a second independent reader. However, precision of estimates was difficult to evaluate because re-counts were strongly influenced by eggs breaking due to additional handling. In general, the variability in fecundity estimates was less than 10%.

ETL QC Program

ETL provided a QC report for every RAMP fish tissue analysis report. For every sample processed, the QC report documented the QC procedure used for each corresponding parameter analysis. In general, each QC result must meet acceptance guidelines specified for that particular method. A column in the QC report details the type of corrective action taken if the result fell outside the acceptable limit. QC procedures included method blanks, laboratory duplicates, spiked samples, use of certified reference materials, calibration control and internal standard.

4.2.3.3 Data Entry

Fisheries data were entered into the project database from field and laboratory data sheets. All entries were independently checked for errors by a second person. All data were again screened graphically and using summary statistics for possible data entry errors and/or "suspicious" data points prior to data analyses. All entry errors were corrected. All raw sentinel species data have been provided in Appendix VI.

4.2.4 Acid Sensitive Lakes

The QC program for the 2001 acid sensitive lakes component consisted of a field and a laboratory component. QC samples were collected in Lake A42 during the field program and were submitted to the University of Alberta Limnology Laboratory for analysis. A description of the field and laboratory QC procedures and results of the QC sample analyses are provided below.

Field Quality Control Procedures

Water quality sampling in the field incorporated general QC procedures to minimize sample contamination and ensure proper functioning of field instruments, as described in Golder Technical Procedures 8.3-1 and 8.23-0 (Golder 1999a). Briefly, these included:

- proper cleaning of sampling equipment between sites;
- collecting samples upstream of the boat or float plane;
- rinsing sample containers three times before filling them;
- filling the sample bottles completely so that there is no head space;
- storing samples in appropriate containers and keeping them cool (4°C) and in the dark;
- delivering samples to the analytical laboratory within 48 h of collection; and
- proper calibration of field water quality meters.

The water quality field QC program included collection of the following samples:

- field blank, using deionized water provided by the analytical laboratory;
- one split sample at Lake A42; and
- one duplicate sample at Lake A42.

Laboratory Quality Control Procedures

The Limnology Laboratory of the University of Alberta has an internal QA/QC program, which includes the use of standard reference samples, inter-laboratory comparisons and corrective actions if QC objectives are not met. Standard QC samples are prepared for each batch of analysis from analytical grade chemicals or certified standards. Inter-laboratory comparisons are performed twice a year against 10 samples supplied by National Water Research Institute (NWRI) and once a year against 2 samples provided by the Norwegian Institute for Water Research (NIWA).

Standards are run with each set of analyses to establish a standard curve, followed by QC samples, analyzed in duplicate. If the QC results are unacceptable at this point, corrective action is taken. If the analysis is deemed consistent over the length of the run, these are the only QC samples analyzed. For analyses where instrument drift may occasionally occur (e.g., DOC), QC samples are run as every tenth sample. Sulphate, chloride and alkalinity analyses also include analyzing QC samples at the end of a batch of samples. When a new QC sample is prepared, it is run with the previous QC sample to develop a new control chart.

Quality Control Results

Definitions for the QC samples listed above are found in Section 4.2.1.1. The assessment criteria used to determine whether QC sample results may be indicative of sample contamination or analytical bias are described in Section 4.2.1.2.

A number of parameters were present in the field blank at concentrations greater than five times the corresponding detection limits and therefore did not meet the acceptance criteria (identified by shading in Table 4.12). These results are of concern regarding data quality, but do not significantly affect the interpretation of 2001 monitoring results for the following reasons:

- Acidity-related parameters (pH, alkalinity) met the acceptance criteria.
- Most of the exceedances of the acceptance criteria were by parameters present at very low concentrations and in part reflect the unusually low detection limits reported by the Limnology Laboratory. Comparing the field blank data with the more commonly reported ETL detection limits revealed that only conductivity was reported at a level five times above the ETL detection limit (this comparison could not be made for total nitrogen and total dissolved nitrogen, because ETL detection limits are not available for these parameters).
- The reported concentrations in the field blank were in most cases substantially lower than the concentrations measured in the lake water samples.

The variation in parameter concentrations between the Lake A42 sample and the split sample met the acceptable limit defined in Section 4.2.1.2 (i.e., percent differences greater than 20% were not observed for parameters measured at concentrations more than five times the detection limit) (Table 4.12). Therefore, the QC results are indicative of high analytical precision for the parameters with available data.

The analytical laboratory did not report concentrations for several parameters in the original Lake A42 sample and/or the split sample (TSS, potassium, silica, sodium, TN, TDN, nitrate+nitrite, ammonia and TKN), because of suspected equipment contamination, and possible sampling and analytical errors. These were assumed to be isolated events and were not considered to affect the interpretation of the 2001 monitoring results for the remainder of the samples. Nevertheless, the lack of QA data for these parameters is of concern regarding data quality.

Table 4.12 Split Sample Water Chemistry Results for Lake A42 and Results for the Field Blank

Parameter	Units	Detection Limit	Lake A42	Lake A42 Split Sample	Percent Difference	Field Blank
Conventional Parameters						
colour	TCU	1	92	91	1	2
conductivity	µS/cm	0.3	34.8	35.1	1	2.0
dissolved inorganic carbon	mg/L	0.1	1.8	1.9	5	0.4
dissolved organic carbon	mg/L	0.1	49.8	47.5	5	1.1
pH (lab)	--	-[(a)]	6.66	6.64	0.3	5.24
total alkalinity	mg/L as $CaCO_3$	-	11.25	11.23	0.2	1.04
gran alkalinity	mg/L as $CaCO_3$	0.25	10.63	10.81	2	<0.25
total dissolved solids	mg/L	5	108	114	5	<5
total suspended solids	mg/L	0.02	-	-	-	-
turbidity	NTU	0.04	26	26	0	0.14
Major Ions						
bicarbonate	mg/L	-	13.72	13.69	0.2	1.26
gran bicarbonate	mg/L	-	12.95	13.18	2	0
calcium	mg/L	0.003	5.510	5.170	6	0.070
chloride	mg/L	0.3	<0.3	<0.3	0	<0.3
magnesium	mg/L	0.0005	1.3400	1.2800	4	0.0100
potassium	mg/L	0.005	0.440	-	-	0.020

Table 4.12 Split Sample Water Chemistry Results for Lake A42 and Results for the Field Blank (continued)

Parameter	Units	Detection Limit	Lake A42	Lake A42 Split Sample	Percent Difference	Field Blank
silica	mg/L	0.3	-	-	-	-
sodium	mg/L	0.002	1.890	-	-	0.110
sulphate	mg/L	0.5	0.7	0.7	0	<0.5
Nutrients and Chlorophyll a						
total nitrogen	mg/L	0.005	-	7.913	-	0.042
total dissolved nitrogen	mg/L	0.005	-	2.184	-	0.031
nitrate + nitrite	mg/L	0.001	-	0.010	-	0.008
ammonia	mg/L	0.001	-	0.103	-	0.010
total Kjeldahl nitrogen	mg/L	0.006	-	7.903	-	0.034
total phosphorus	mg/L	0.001	0.256	0.244	5	<0.001
dissolved phosphorus	mg/L	0.0005	0.0174	0.0168	3	0.0010
chlorophyll *a*	mg/L	0.002	0.285	0.268	6	<0.002
Total Metals						
iron	mg/L	0.02	0.03	0.06	50	<0.02

Note: Results that did not meet acceptable criteria are shaded.

[a] - = detection limit not available or no data.

The results of the QC sample analysis for duplicate samples are presented in Table 4.13. Because data were not available for a number of parameters in the original Lake A42 sample, the Lake A42 split sample (plus two parameters from the original Lake A42 sample) was used for comparison with the duplicate sample.

Greater than 20% differences were observed between the duplicate samples in the concentrations of potassium, TDN, nitrate+nitrite and ammonia (Table 4.13). Since TKN was calculated by subtracting nitrate+nitrite from TN, the potential exists for incorrect TKN results. Data quality could not be evaluated for TSS and silica due to lack of QC data. Percent differences for 15% of the parameters with available data exceeded the acceptable limit of difference between duplicate samples, which is indicative of only moderate field sampling and analytical precision.

Table 4.13 Duplicate Sample Water Chemistry Results for Lake A42

Parameter	Units	Detection Limit	Lake A42 Split Sample	Lake A42 Duplicate Sample	Percent Difference
Conventional Parameters					
colour	TCU	1	91	99	8
conductivity	µS/cm	0.3	35.1	34.3	2
dissolved inorganic carbon	mg/L	0.1	1.9	1.7	11
dissolved organic carbon	mg/L	0.1	47.5	46.9	1
pH (lab)	--	-[(a)]	6.64	6.65	0.2
total alkalinity	mg/L as $CaCO_3$	-	11.23	11.16	1
gran alkalinity	mg/L as $CaCO_3$	0.25	10.81	10.81	0
total dissolved solids	mg/L	5	114	106	7
total suspended solids	mg/L	0.02	-	-	-
turbidity	NTU	0.04	26	27	4
Major Ions					
bicarbonate	mg/L	-	13.69	13.61	1
gran bicarbonate	mg/L	-	13.18	13.18	0
calcium	mg/L	0.003	5.170	5.400	4
chloride	mg/L	0.3	<0.3	<0.3	0
magnesium	mg/L	0.0005	1.2800	1.3000	2
potassium	mg/L	0.005	0.440[(b)]	0.630	30
silica	mg/L	0.3	-	-	-

Table 4.13 Duplicate Sample Water Chemistry Results for Lake A42 (continued)

Parameter	Units	Detection Limit	Lake A42 Split Sample	Lake A42 Duplicate Sample	Percent Difference
sodium	mg/L	0.002	1.890[b]	1.760	7
sulphate	mg/L	0.5	0.74	0.68	8
Nutrients and Chlorophyll *a*					
total nitrogen	mg/L	0.005	7.913	9.076	13
total dissolved nitrogen	mg/L	0.005	2.184	4.137	47
nitrate + nitrite	mg/L	0.001	0.010	0.007	30
ammonia	mg/L	0.001	0.103	0.337	69
total Kjeldahl nitrogen	mg/L	0.006	7.903	9.070	13
total phosphorus	mg/L	0.001	0.244	0.256	5
dissolved phosphorus	mg/L	0.0005	0.0168	0.0172	2
chlorophyll *a*	mg/L	0.002	0.268	0.277	3
Total Metals					
iron	mg/L	0.02	0.06	0.05	17

Note: Results that did not meet acceptable criteria are shaded.
[a] - = detection limit not available or no data.
[b] Data shown are from the original Lake A42 sample because no data were reported for the split sample.

In summary, QC results for the field blank revealed that acceptance criteria were exceeded for ten parameters. Split sample results were indicative of acceptable analytical precision, but precision could not be evaluated for nine parameters. Based on the duplicate sample results, the variation in concentrations due to field sampling and laboratory analysis was greater than the acceptable limit for three nitrogen parameters. The lack of QC data for a number of parameters is of concern regarding data quality. Data quality for nitrogen parameters is questionable, because either it could not be assessed (split samples), or the acceptance criteria were exceeded for these parameters (field blank and duplicate samples).

The data quality issues highlighted in this section should be examined during future RAMP cycles. They are of limited concern regarding the interpretation of the 2001 monitoring results, because data quality was acceptable for the key parameters used as indicators of acidification.

4.2.5 Wetlands Vegetation

The QA/QC program for the wetlands vegetation component included field protocols for data recording and data entry.

Field Protocol

During the field survey, each crew member recorded and verified the accuracy of pre-stratified map polygons by verifying polygons and comparing with standard vegetation mapping criteria. Following the wetlands vegetation field surveys, the field crew members reviewed the datasheets for completeness, accuracy and to ensure that the entries were legible. Where entries were crossed out, they were checked for a replacement value and an initial to determine who made the change. In addition, the field logbook was reviewed to ensure that signatures and dates were evident and that the recorded information corresponded to the plot numbers on the datasheets. Photologs were also checked to ensure that entries were correctly labelled.

Data Entry

Prior to data entry, the datasheets were checked for inconsistencies in species naming. Ten percent of the datasheets were randomly selected for review and verification.

Once data entry was completed, databases were checked by randomly selecting transect and plot data and comparing the data to the original field data sheets. All quantitative analysis was verified by randomly selecting analytical data and repeating the analysis.

4.3 SUMMARY

Golder's QA procedures for RAMP 2001 covered three areas of internal and external management, including field staff and training, laboratory analysis and office operations. Golder is committed to improve QA procedures for future programs, and Golder is planning to develop a formal QAP in 2002 that outlines detailed protocols specific to RAMP project.

The results of the RAMP water and sediment quality QC assessment indicate that water and sediment quality data collected by Golder and analyzed by ETL, ARC-Vegreville and AXYS are valid.

A summary of the QC assessment is provided below:

- Only nine water quality parameters were detected at five times the corresponding method detection limit in field and trip blanks, and sample contamination appears to have been limited to the corresponding field or trip blank, with the possible exception of total Kjeldahl nitrogen, total zinc and dissolved zinc.
- Less than 5% of parameter levels in split water samples exceeded the assessment criteria, indicative of high analytical precision. Duplicate sediment sample results from Shipyard Lake were also indicative of low intra-site variation and high field sampling precision.
- Less than 25% of the parameters in split sediment samples exceeded the acceptable limit of difference, indicative of moderate analytical precision.
- ETL QC reports submitted with corresponding RAMP sample analysis reports indicated that QC procedures performed on sample batches met acceptable corresponding guidance criteria.
- Analysis of method blanks and spiked samples from AXYS indicate that the laboratory sampling procedures were satisfactory.
- Less than 5% of the values from the laboratory reports were entered into the RAMP water and sediment quality database incorrectly. All data entry errors were corrected.
- Invertebrate removal efficiency was evaluated in 10% of the benthic invertebrate samples analyzed during the 2001 program (12 samples). The results indicate that data quality was acceptable.
- Fish ageing structures were read independently a minimum of three times and a numerical confidence level was assigned to each age estimate. 10% of all ageing samples were re-analyzed by a second independent reader and 97% of the second readings were identical to the original age analysis.
- At least 10% of all fecundity samples were re-counted by a second independent reader. In general, the variability in fecundity estimates was less than 10%.

Fisheries data were independently checked for errors by a second person. All data screened graphically and using summary statistics for possible data entry errors and/or “suspicious” data points prior to data analyses. All entry errors were corrected.

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5 ATHABASCA RIVER MAINSTEM AND DELTA

5.1 WATER QUALITY

5.1.1 Site-Specific Observations

During the fall of 2001, concentrations of the majority of water quality parameters in the Athabasca River and Delta were within the historical range and were considered to be consistent with past water quality conditions. Those water quality parameters with concentrations measured in 2001 that fell outside of historical ranges or were very different than values measured in 2000 are described in the remainder of this section.

5.1.1.1 Upstream of Donald Creek

Total phosphorus, chlorophyll *a* and total aluminum, iron, manganese and zinc levels were lower in 2001 than in previous sampling events in the Athabasca River upstream of Donald Creek (Table 5.1). The decreased total Al, Fe and Mn concentrations may be related to the low TSS levels observed in 2001, because as discussed in the 1999 RAMP report (Golder 2000b), the metals tend to be associated with suspended sediment. The concentrations of several parameters were higher in 2001 than in previous years, including sulphate, alkalinity, hardness and conductance. In contrast to 2000, when the concentrations of several metals were higher in samples from the east-bank, in 2001 the water quality, including metals concentrations, was similar in west-bank and east-bank sampling locations.

5.1.1.2 Upstream of Steepbank River

Levels of total phosphorus and several metals, including total aluminum, arsenic, barium, chromium, manganese, nickel, vanadium and zinc, were lower than in 2000, but were similar to or less than historical median concentrations, in the Athabasca River upstream of the Steepbank River (Table 5.2). As in the Athabasca River upstream of Donald Creek, the decreased total aluminum, iron and manganese levels observed in 2001 may be related to lower TSS concentration in 2001. Total copper levels in 2001 were higher than historical concentrations and exceeded the relevant chronic aquatic life guideline (Table 5.2). Major ion concentrations appear to be increasing over time in the Athabasca River upstream of the Steepbank River, as illustrated in Figure 5.1, which shows magnesium levels over time.

Table 5.1 Water Quality in the Athabasca River Upstream of Donald Creek, Fall

Parameter	Units	Fall 2001		Fall Historical [a]					
				West	East	Other (1976)			
		West	East	2000	2000	median	min	max	n
Field Measured									
pH		8.2	8.4	7.9	8.2	-	-	-	-
specific conductance	uS/cm	367	364	225	271	-	-	-	-
temperature	°C	0.04	0.3	4.3	4.7	-	-	-	-
dissolved oxygen	mg/L	15.2	15.6	12.9	13.2	-	-	-	-
colour	T.C.U.	25	30	30	60	-	-	-	-
conductance	uS/cm	366	364	302	254	-	140	210	2
dissolved organic carbon	mg/L	6	6	6	6	14	-	-	1
hardness	mg/L	156	160	138	78	-	60	108	2
pH		8.1	8.1	7.9	7.7	-	7.3	7.9	2
total alkalinity	mg/L	145	145	117	73	-	62	96	2
total dissolved solids	mg/L	240	240	180	160	-	88	130	2
total organic carbon	mg/L	7	7	7	7	-	15	61	2
total suspended solids	mg/L	< 3	< 3	6	10	-	27	237	2
Major Ions									
bicarbonate	mg/L	177	177	143	88	-	-	-	-
calcium	mg/L	43	44	38	21	-	16	30	2
carbonate	mg/L	< 5	< 5	< 5	< 5	-	-	-	-
chloride	mg/L	6	6	3	25	-	2	12	2
magnesium	mg/L	12	12	11	6	-	5	8	2
potassium	mg/L	1	1	1	1	-	1	1	2
sodium	mg/L	16	17	10	21	-	7	11	2
sulphate	mg/L	49	50	34	12	19	-	-	1
sulphide	mg/L	0.004	< 0.003	< 0.003	0.003	-	-	-	-
Nutrients and Chlorophyll *a*									
nitrogen – ammonia	mg/L	0.12	< 0.05	< 0.1	< 0.1	-	-	-	-
nitrogen, total [b]	mg/L	0.7	0.4	0.69	0.4	-	0.74	2.7	2
phosphorus, total	mg/L	0.026	0.018	0.034	0.384	-	0.05	0.35	2
phosphorus, dissolved	mg/L	0.012	0.013	0.023	0.029	-	-	-	-
chlorophyll *a*	ug/L	2	1	5	5	-	< 1	< 1	2
Biological Oxygen Demand									
biochemical oxygen demand	mg/L	< 2	< 2	< 2	< 2	-	-	-	-
General Organics									
naphthenic acids	mg/L	< 1	< 1	1	< 1	-	-	-	-

Table 5.1 Water Quality in the Athabasca River Upstream of Donald Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical [a]					
				West	East	Other (1976)			
		West	East	2000	2000	median	min	max	n
total phenolics	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	-	< 0.001	0.01	2
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 0.5	-	0.5	7	2
Metals (Total)									
aluminum (Al)	mg/L	0.14	0.13	0.54	0.68	-	-	-	-
antimony (Sb)	mg/L	< 0.005	< 0.005	< 0.005	< 0.005	-	-	-	-
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	-	-	-	-
barium (Ba)	mg/L	0.07	0.069	0.057	0.028	-	-	-	-
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	-	-	-	-
boron (B)	mg/L	0.03	0.03	0.02	0.03	-	-	-	-
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-	-	-	-
chromium (Cr)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	-	-	-	-
cobalt (Co)	mg/L	< 0.0002	< 0.0002	0.0003	0.0003	-	-	-	-
copper (Cu)	mg/L	< 0.001	< 0.001	0.001	0.021	-	-	-	-
iron (Fe)	mg/L	0.26	0.26	0.54	1.17	-	-	-	-
lead (Pb)	mg/L	< 0.0001	< 0.0001	0.0003	0.0006	-	-	-	-
lithium (Li)	mg/L	0.007	0.007	< 0.006	0.007	-	-	-	-
manganese (Mn)	mg/L	0.012	0.01	0.027	0.042	-	-	-	-
mercury (Hg)	mg/L	0.00000002	0.0000042	< 0.0002	< 0.0002	-	< 0.0002	< 0.0002	2
molybdenum (Mo)	mg/L	0.0008	0.0009	0.0007	0.0004	-	-	-	-
nickel (Ni)	mg/L	0.0007	0.0007	0.0008	0.0018	-	-	-	-
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	-	-	-	-
silver (Ag)	mg/L	< 0.000005	< 0.000005	< 0.0004	< 0.0004	-	-	-	-
strontium (Sr)	mg/L	0.29	0.29	0.25	0.12	-	-	-	-
thallium (Tl)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-	-	-
titanium (Ti)	mg/L	0.0046	0.0035	0.0113	0.0142	-	-	-	-
uranium (U)	mg/L	0.0006	0.0006	0.0004	0.0001	-	-	-	-
vanadium (V)	mg/L	0.0006	0.0006	0.0013	0.0017	-	-	-	-
zinc (Zn) [b]	mg/L	0.013	0.006	0.015	0.041	-	-	-	-
Metals (Dissolved) [c]									
aluminum (Al)	mg/L	1.1	0.05	0.01	0.13	-	-	-	-
antimony (Sb)	mg/L	0.0024	< 0.0008	< 0.0008	< 0.0008	-	-	-	-
arsenic (As)	mg/L	0.0005	0.0031	0.0124	0.0106	-	< 0.001	< 0.005	2
barium (Ba)	mg/L	1.13	0.075	0.051	0.052	-	-	-	-
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	-	-	-	-
boron (B)	mg/L	0.02	0.02	0.03	0.02	-	0.2	0.32	2

Table 5.1 Water Quality in the Athabasca River Upstream of Donald Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical [a]					
				West	East	Other (1976)			
		West	East	2000	2000	median	min	max	n
cadmium (Cd)	mg/L	0.0144	0.0197	< 0.0001	< 0.0001	-	-	-	-
chromium (Cr)	mg/L	0.018	0.0058	< 0.0004	< 0.0004	-	-	-	-
cobalt (Co)	mg/L	0.0093	0.0001	0.0001	0.0002	-	-	-	-
copper (Cu)	mg/L	0.0073	0.0051	0.0026	0.0008	-	-	-	-
iron (Fe)	mg/L	0.19	0.2	< 0.01	0.26	-	-	-	-
lead (Pb)	mg/L	0.0961	0.0229	0.0004	0.0002	-	-	-	-
lithium (Li)	mg/L	0.002	0.006	0.006	0.006	-	-	-	-
manganese (Mn)	mg/L	0.009	0.009	0.014	0.019	-	-	-	-
mercury (Hg)	mg/L	0.0002	< 0.0001	< 0.0001	< 0.0001	-	-	-	-
molybdenum (Mo)	mg/L	0.0061	0.0009	0.0008	0.0007	-	-	-	-
nickel (Ni)	mg/L	0.0067	0.0012	0.0007	0.0007	-	-	-	-
selenium (Se)	mg/L	0.0005	0.0005	< 0.0004	< 0.0004	-	0.0005	0.0008	2
silver (Ag)	mg/L	0.0043	0.0015	0.0004	0.0002	-	-	-	-
strontium (Sr)	mg/L	0.07	0.3	0.26	0.25	-	-	-	-
thallium (Tl)	mg/L	0.0143	< 0.00005	< 0.00005	< 0.00005	-	-	-	-
titanium (Ti)	mg/L	0.0074	0.0018	< 0.0003	0.0032	-	-	-	-
uranium (U)	mg/L	0.0006	0.0007	0.0004	0.0004	-	-	-	-
vanadium (V)	mg/L	0.0027	0.0167	0.0001	0.0004	-	-	-	-
zinc (Zn) [b]	mg/L	0.226	0.048	0.009	0.006	-	-	-	-
Target PAHs and Alkylated PAHs									
naphthalene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C1 subst'd naphthalenes	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C2 subst'd naphthalenes	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C3 subst'd naphthalenes	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C4 subst'd naphthalenes	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
acenaphthene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C1 subst'd acenaphthene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
acenaphthylene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
anthracene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
dibenzo(a,h)anthracene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
benzo(a)anthracene/chrysene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C1 subst'd benzo(a)anthracene/chrysene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C2 subst'd benzo(a)anthracene/chrysene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
benzo(a)pyrene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-

Table 5.1 Water Quality in the Athabasca River Upstream of Donald Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical [a]					
				West	East	Other (1976)			
		West	East	2000	2000	median	min	max	n
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
benzo(b&k)fluoranthene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
benzo(g,h,i)perylene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
biphenyl	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C1 subst'd biphenyl	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C2 subst'd biphenyl	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
dibenzothiophene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C1 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C2 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C3 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C4 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
fluoranthene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C1 subst'd fluoranthene/pyrene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
fluorene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C1 subst'd fluorene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C2 subst'd fluorene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
indeno(c,d-123)pyrene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
phenanthrene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-
C1 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C2 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C3 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
C4 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-
1-methyl-7-isopropyl-phenanthrene (retene)	ug/L	-	-	-	-	-	-	-	-
pyrene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-

(a) Information in 2000 from Golder (2001a), other data based on information from WDS stations AB07DA0060\0050\0040\0030.
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.
(c) The accuracy of reported dissolved metal concentrations is uncertain in 2001, because the majority of the dissolved metal data exceeded the concentrations reported for the corresponding total metals by >20% (indicative of possible sample contamination).
Note: - = no data.

Table 5.2 Water Quality in the Athabasca River Upstream of the Steepbank River, Fall

Parameter	Units	Fall 2001		Fall Historical [(a)]							
				West		East		Other (1976-1997)			
		West	East	2000	1998	2000	1998	median	min	max	n
Field Measured											
pH		8.1	7.9	8	-	8	-	8.1	6.5	8.4	12
specific conductance	uS/cm	345	356	253	320	244	340	220	129	280	20
temperature	^{o}C	5.9	6.1	4.3	11.7	4.4	11	7	2	15	23
dissolved oxygen	mg/L	12.5	13.3	12.7	10.5	12.8	11	11.7	9.5	15.7	23
colour	T.C.U.	30	35	40	15	55	15	27	< 5	80	10
conductance	uS/cm	357	346	305	310	272	308	261	150	364	25
dissolved organic carbon	mg/L	6	6	6	4	8	4	9	5	19	11
hardness	mg/L	142	129	121	122	101	122	99	73	140	11
pH		8	8	7.9	8.1	7.8	8.1	7.9	7.4	8.4	24
total alkalinity	mg/L	133	121	104	106	94	107	98	70	135	26
total dissolved solids	mg/L	250	230	190	214	170	198	146	110	221	25
total organic carbon	mg/L	7	8	8	4	10	5	9	3	22	21
total suspended solids	mg/L	3	6	54	20	69	22	21	4	314	26
Major Ions											
bicarbonate	mg/L	162	148	127	130	115	130	111	108	134	6
calcium	mg/L	39	35	32	34	27	34	28	20	42	25
carbonate	mg/L	< 5	< 5	< 5	< 5	< 5	< 5	< 1	0	< 5	6
chloride	mg/L	13	20	8	7	11	7	6	2	26	28
magnesium	mg/L	11	10	10	9	8	9	8	6	12	25
potassium	mg/L	1	1	1	1	1	1	1	0.1	1	26
sodium	mg/L	20	23	13	14	14	15	10	0.4	23	28
sulphate	mg/L	39	32	32	31	22	31	21	8	55	24
sulphide	mg/L	0.01	0.006	0.009	< 0.002	< 0.003	< 0.002	< 0.002	-	-	1
Nutrients and Chlorophyll *a*											
nitrogen – ammonia	mg/L	< 0.05	< 0.05	< 0.1	< 0.05	< 0.1	< 0.05	< 0.01	< 0.01	< 0.05	5

Table 5.2 Water Quality in the Athabasca River Upstream of the Steepbank River, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical [a]							
				West		East		Other (1976-1997)			
		West	East	2000	1998	2000	1998	median	min	max	n
nitrogen, total [b]	mg/L	0.4	0.5	0.2	0.5	0.3	0.3	0.4	0.18	**1.3**[C]	11
phosphorus, total	mg/L	0.022	0.023	**0.054**[C]	0.014	**0.07**[C]	0.016	0.039	0	**0.41**[C]	26
phosphorus, dissolved	mg/L	0.011	0.01	0.018	0.007	0.022	0.007	0.016	0.005	0.092	5
chlorophyll *a*	ug/L	1	2	0.005	0.001	0.004	0.002	2.75	< 1	8	10
Biological Oxygen Demand											
biochemical oxygen demand	mg/L	< 2	< 2	< 2	2	< 2	3	2	< 0.1	8	5
General Organics		-	-	-	-	-	-	-	-	-	-
naphthenic acids	mg/L	< 1	< 1	1	20	1	< 1	-	< 1	< 1	2
total phenolics	mg/L	< 0.001	< 0.001	< 0.001	0.002	< 0.001	< 0.001	0.001	0	**0.011**[C]	25
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6	< 0.1	2	23
Metals (Total)											
aluminum (Al)	mg/L	**0.21**[C]	**0.27**[C]	**2.43**[A,C]	**0.22**[C]	**2.77**[A,C]	**0.19**[C]	**0.66**[C]	**0.11**[C]	**2.23**[A,C]	3
antimony (Sb)	mg/L	< 0.005	< 0.005	< 0.005	< 0.0008	< 0.005	< 0.0008	-	< 0.0002	0.0012	2
arsenic (As)	mg/L	< 0.001	< 0.001	0.003	< 0.001	< 0.001	< 0.001	0.0009	0.0005	**0.01**[C]	7
barium (Ba)	mg/L	0.061	0.052	0.076	0.054	0.076	0.053	0.062	0.04	0.067	4
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	3
boron (B)	mg/L	0.03	0.04	0.02	0.04	0.02	0.05	0.03	0.03	0.09	3
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	**< 0.001**[D>C]	< 0.0002	**< 0.003**[D>A,C]	6
chromium (Cr)	mg/L	**0.0026**[C]	**0.0029**[C]	**0.0054**[C]	< 0.0008	**0.0076**[C]	< 0.0008	**0.0028**[C]	**< 0.002**[D>C]	**0.006**[C]	6
cobalt (Co)	mg/L	< 0.0002	0.0002	0.0013	0.0008	0.0007	0.0004	0.0012	0.0009	0.003	6
copper (Cu)	mg/L	**0.01**[C]	**0.008**[C]	0.003	0.002	**0.003**[C]	0.002	**0.0032**[C]	< 0.001	**0.006**[C]	5
iron (Fe)	mg/L	**0.44**[C,H]	**0.57**[C,H]	**2.49**[C,H]	**0.4**[C,H]	**3.04**[C,H]	**0.5**[C,H]	**2.19**[C,H]	**0.91**[C,H]	**2.22**[C,H]	3
lead (Pb)	mg/L	0.0024	0.0019	0.0013	0.0006	0.001	0.0005	0.0013	0.0013	**< 0.02**[D>C]	3
lithium (Li)	mg/L	0.006	0.007	0.007	< 0.006	< 0.006	< 0.006	0.007	0.006	0.008	3
manganese (Mn)	mg/L	0.022	0.026	**0.085**[H]	0.023	**0.119**[H]	0.03	0.046	0.032	**0.081**[H]	6
mercury (Hg)	mg/L	0.0000021	0.0000014	**< 0.0002**[D>C,H]	**< 0.0002**[D>C,H]	**< 0.0002**[D>C,H]	**< 0.0002**[D>C,H]	**< 0.0001**[D>H]	< 0.00005	**< 0.05**[D>A,C,H]	23
molybdenum (Mo)	mg/L	0.0011	0.0006	0.0053	0.001	0.0004	0.0011	< 0.001	0.0008	< 0.003	6

Table 5.2 Water Quality in the Athabasca River Upstream of the Steepbank River, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical [a]							
				West		East		Other (1976-1997)			
		West	East	2000	1998	2000	1998	median	min	max	n
nickel (Ni)	mg/L	0.0015	0.002	0.0082	0.0098	0.0028	0.0051	0.004	< 0.001	0.0134	6
selenium (Se)	mg/L	**0.0011** [(C)]	< 0.0008	< 0.0008	< 0.0008	**0.0011** [(C)]	< 0.0008	< 0.0002	< 0.0002	0.0007	6
silver (Ag)	mg/L	0.000014	0.000011	**< 0.0004** [(D>C)]	**< 0.0004** [(D>C)]	**< 0.0004** [(D>C)]	**< 0.0004** [(D>C)]	< 0.0001	< 0.0001	**< 0.002** [(D>C)]	3
strontium (Sr)	mg/L	0.26	0.23	0.24	0.26	0.21	0.26	0.17	0.16	0.2	3
thallium (Tl)	mg/L	< 0.0001	< 0.0001	< 0.0001	-	< 0.0001	-	-	-	-	-
titanium (Ti)	mg/L	0.0052	0.0073	0.0378	0.0039	0.0529	0.0028	-	0.007	0.0254	2
uranium (U)	mg/L	0.0006	0.0005	0.0005	0.0004	0.0001	0.0004	0.0004	-	-	1
vanadium (V)	mg/L	0.0019	0.0024	0.0142	0.0007	0.0076	0.0007	< 0.001	< 0.001	0.006	21
zinc (Zn) [(b)]	mg/L	0.014	0.018	**0.033** [(C)]	0.028	0.025	0.017	0.013	0.004	**0.058** [(C)]	5
Metals (Dissolved)											
aluminum (Al)	mg/L	0.01	< 0.01	0.01	0.12	0.05	0.04	0.0443	-	-	1
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	0.0006	-	-	1
arsenic (As)	mg/L	< 0.0004	< 0.0004	*0.0072*	< 0.0004	< 0.0004	< 0.0004	0.0006	0.0003	0.01	16
barium (Ba)	mg/L	0.062	0.049	0.046	0.05	0.04	0.051	0.042	-	-	1
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	-	< 0.001	< 0.001	2
boron (B)	mg/L	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.24	7
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0003	< 0.0001	0.0001	-	-	1
chromium (Cr)	mg/L	*0.0045*	0.0039	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	-	-	1
cobalt (Co)	mg/L	< 0.0001	< 0.0001	0.0002	0.0008	0.0001	0.0001	0.0003	-	-	1
copper (Cu)	mg/L	< 0.0006	< 0.0006	0.0008	0.0015	0.0019	0.0013	0.0022	-	-	1
iron (Fe)	mg/L	0.07	0.09	0.03	0.1	0.11	0.1	0.14	-	-	1
lead (Pb)	mg/L	< 0.0001	< 0.0001	0.0002	0.0001	*0.0059*	0.0002	0.0005	-	-	1
lithium (Li)	mg/L	0.007	0.006	0.006	-	0.006	-	0.006	-	-	1
manganese (Mn)	mg/L	0.013	0.016	0.025	0.005	0.051	0.005	0.011	-	-	1
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0002	-	-	1
molybdenum (Mo)	mg/L	0.0008	0.0006	0.005	0.001	0.0017	0.001	0.0006	-	-	1
nickel (Ni)	mg/L	0.001	0.0006	0.0018	0.0026	*0.0059*	0.0027	0.0016	-	-	1

Table 5.2 Water Quality in the Athabasca River Upstream of the Steepbank River, Fall (continued)

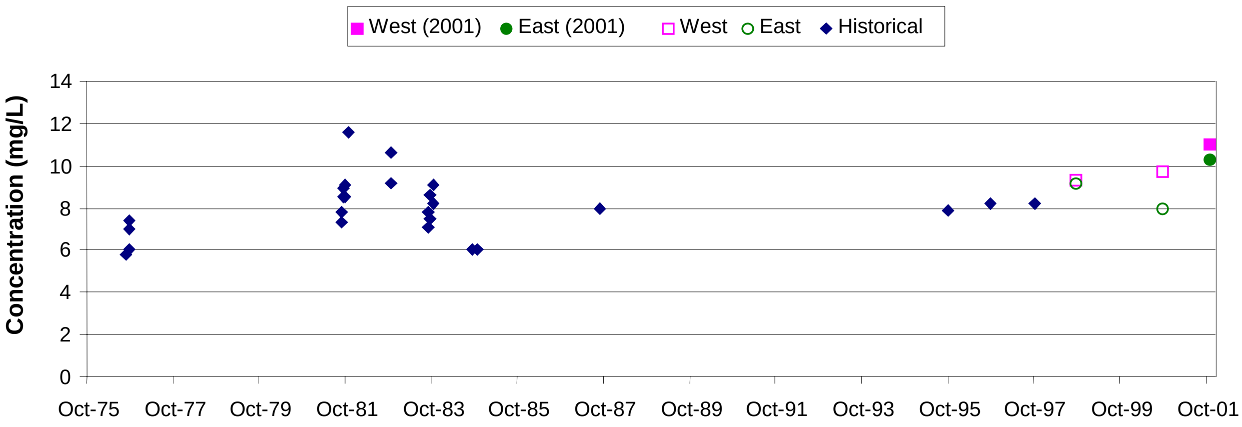
Parameter	Units	Fall 2001		Fall Historical [a]							
				West		East		Other (1976-1997)			
		West	East	2000	1998	2000	1998	median	min	max	n
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0005	< 0.0002	< 0.0005	6
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-	-	1
strontium (Sr)	mg/L	0.26	0.23	0.24	0.24	0.2	0.24	0.18	-	-	1
thallium (Tl)	mg/L	< 0.00005	< 0.00005	< 0.00005	-	< 0.00005	-	-	-	-	-
titanium (Ti)	mg/L	0.0007	0.0007	< 0.0003	0.0005	0.0008	0.0005	0.0009	-	-	1
uranium (U)	mg/L	0.0006	0.0005	0.0004	0.0004	*0.0003*	0.0004	0.0003	-	-	1
vanadium (V)	mg/L	0.0005	0.0004	0.0067	< 0.0001	0.0003	< 0.0001	< 0.0001	-	-	1
zinc (Zn) [b]	mg/L	0.009	0.012	0.007	0.005	*0.267*	0.004	0.014	-	-	1

(a) Information in 1998 and 2000 from Golder (1999b, 2001a); other data based on information from Golder (1996a, 1998) and WDS stations AB07DA0090\0100\0140\0150\0155\0170\0180\0190\1500.

(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the concentration reported for the corresponding total metal by >20% (indicative of possible contamination).
Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D > = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

Figure 5.1 Magnesium Concentrations in the Athabasca River Upstream of the Steepbank River, Fall (1976 to 2001)



In 1998, 2000 and 2001, east-bank and west-bank water quality conditions in the Athabasca River, upstream of the Steepbank River were similar for all parameters, except for total selenium. In contrast to observations in 2000, where the total selenium concentration was greatest on the eastern side of the river, total selenium concentrations were greater on the western side of the river in 2001 (Table 5.2).

5.1.1.3 Upstream of Muskeg River

In 2001, a field-measured pH of 6.9 was recorded on the eastern side of the river; pH levels in this part of the Athabasca River usually range from 7.7 to 8.6 (Table 5.3). The cause of the low pH in 2001 is unknown. The concentration of total selenium in the east sample was higher in 2001 than in previous years and exceeded the chronic aquatic life guideline. The concentrations of specific conductance, TDS and sulphate were higher in 2001 than in previous years. The concentrations of total iron and manganese were lower in 2001 than in previous years, for which there is limited historical data (Table 5.3).

5.1.1.4 Upstream of Fort Creek

Total manganese and iron concentrations were lower on the eastern side of the river in 2001 than in previous years, possibly as a result of decreased TSS levels (Table 5.4). Differences between east and west samples were not consistent between years. For example, there was little variation between the water quality of east and west sampling locations in 1998; metal concentrations tended to be higher on the eastern side of the river in 2000, and there were no consistent patterns in metal concentrations on eastern and western sides in 2001.

Table 5.3 Water Quality in the Athabasca River Upstream of the Muskeg River, Fall

Parameter	Units	Fall 2001		Fall Historical [a]					
				West	East	Other (1976-1997)			
		West	East	2000	2000	median	min	max	n
Field Measured									
pH		7.5	6.9	-	-	8.1	7.7	8.6	15
specific conductance	uS/cm	353	352	256	248	200	145	390	35
temperature	^{o}C	5.4	5	3.2	2.9	10.3	0	90	36
dissolved oxygen	mg/L	12.1	13.1	-	-	10.2	9.1	15.2	36
colour	T.C.U.	30	35	35	40	42	< 5	70	14
conductance	uS/cm	354	356	285	283	258	188	390	38
dissolved organic carbon	mg/L	6	7	7	8	12	4	20	15
hardness	mg/L	136	134	110	106	115	84	200	8
pH		8	8	7.8	7.8	7.7	7.4	8.3	35
total alkalinity	mg/L	128	126	103	100	99	75	194	38
total dissolved solids	mg/L	250	240	190	190	148	120	216	38
total organic carbon	mg/L	8	8	9	10	10	3	22	35
total suspended solids	mg/L	< 3	3	16	15	16	4	68	37
Major Ions									
bicarbonate	mg/L	156	154	125	122	131	91	139	4
calcium	mg/L	37	36	30	29	29	23	54	38
carbonate	mg/L	< 5	< 5	< 5	< 5	< 1	-	-	1
chloride	mg/L	17	18	9	11	8	0.3	16	40
magnesium	mg/L	11	11	9	8	8	6	16	38
potassium	mg/L	1	1	1	1	1	0.1	1	38
sodium	mg/L	22	22	11	12	10	3	18	40
sulphate	mg/L	36	35	26	24	19	1	32	35
sulphide	mg/L	0.003	**0.008** [c]	< 0.003	< 0.003	-	-	-	-
Nutrients and Chlorophyll *a*									
nitrogen - ammonia	mg/L	< 0.05	< 0.05	< 0.1	< 0.1	0.01	0.01	0.17	3
nitrogen, total [b]	mg/L	0.9	0.6	0.2	0.2	0.51	0.288	**2.45** [c]	16
phosphorus, total	mg/L	0.021	0.024	0.032	0.031	0.04	0.018	**0.32** [c]	39
phosphorus, dissolved	mg/L	0.019	0.011	0.017	0.02	0.007	0.006	0.018	5
chlorophyll *a*	ug/L	1	2	3	2	3.6	< 1	7	13
Biological Oxygen Demand									
biochemical oxygen demand	mg/L	< 2	< 2	< 2	< 2	2	-	-	1
General Organics									
naphthenic acids	mg/L	< 1	< 1	2	1	< 1	-	-	1
total phenolics	mg/L	< 0.001	< 0.001	0.002	0.002	0.003	< 0.001	**0.026** [c]	39
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 0.5	0.4	< 0.1	2.1	35

Table 5.3 Water Quality in the Athabasca River Upstream of the Muskeg River, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical [a]					
				West	East	Other (1976-1997)			
		West	East	2000	2000	median	min	max	n
Metals (Total)									
aluminum (Al)	mg/L	**0.19** [C]	**0.27** [C]	**0.24** [C]	**0.14** [C]	-	**0.63** [C]	**3.89** [A,C]	2
antimony (Sb)	mg/L	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	0.0005	-	-	1
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	0.0009	< 0.0005	0.004	8
barium (Ba)	mg/L	0.058	0.058	0.05	0.047	0.065	0.05	0.076	5
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	-	< 0.001	0.001	2
boron (B)	mg/L	0.03	0.03	0.02	0.02	-	0.03	0.03	2
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	**< 0.001** [D>C]	< 0.0002	**< 0.001** [D>C]	5
chromium (Cr)	mg/L	**0.0021** [C]	**0.0021** [C]	**0.0018** [C]	**0.0017** [C]	**0.003** [C]	**< 0.002** [D>C]	**0.0043** [C]	5
cobalt (Co)	mg/L	< 0.0002	< 0.0002	0.0004	0.0004	< 0.001	< 0.001	0.0021	5
copper (Cu)	mg/L	**0.008** [C]	**0.006** [C]	0.001	0.001	< 0.001	< 0.001	**0.0078** [C]	5
iron (Fe)	mg/L	**0.44** [C,H]	**0.56** [C,H]	**0.86** [C,H]	**0.84** [C,H]	-	**2.22** [C,H]	**2.98** [C,H]	2
lead (Pb)	mg/L	0.002	0.0011	0.0004	0.0005	-	0.0016	0.0017	2
lithium (Li)	mg/L	0.006	0.007	0.006	0.007	-	0.004	0.011	2
manganese (Mn)	mg/L	**0.019** [H]	**0.025** [H]	**0.026** [H]	**0.027** [H]	**0.041** [H]	**0.035** [H]	**0.084** [H]	5
mercury (Hg)	mg/L	0.0000024	0.0000036	**< 0.0002** [D>C,H]	**< 0.0002** [D>C,H]	**< 0.0001** [D>H]	**< 0.00005** [D>H]	**0.0036** [A,C,H]	36
molybdenum (Mo)	mg/L	0.0007	0.0008	0.0016	0.0006	< 0.001	0.0009	< 0.003	5
nickel (Ni)	mg/L	0.0016	0.0019	0.0023	0.0022	0.005	0.0034	0.0071	5
selenium (Se)	mg/L	< 0.0008	**0.0011** [C]	< 0.0008	< 0.0008	< 0.0002	< 0.0002	< 0.0004	5
silver (Ag)	mg/L	0.000011	0.000016	**< 0.0004** [D>C]	**< 0.0004** [D>C]	-	< 0.0001	< 0.0001	2
strontium (Sr)	mg/L	0.25	0.24	0.21	0.2	-	0.15	0.19	2
thallium (Tl)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-	-	-
titanium (Ti)	mg/L	0.0064	0.007	0.0114	0.0117	0.0386	-	-	1
uranium (U)	mg/L	0.0005	0.0005	0.0003	0.0003	0.0004	-	-	1
vanadium (V)	mg/L	0.0023	0.0026	0.0036	0.0018	< 0.001	< 0.001	0.0097	35
zinc (Zn) [b]	mg/L	0.012	0.024	0.019	0.027	0.006	0.005	**0.034** [C]	4
Metals (Dissolved)									
aluminum (Al)	mg/L	0.01	< 0.01	0.01	0.01	0.0729	-	-	1
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	0.0006	-	-	1
arsenic (As)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	0.0006	0.0004	0.008	29
barium (Ba)	mg/L	0.056	0.055	0.046	0.042	0.04	-	-	1
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	4
boron (B)	mg/L	0.03	0.03	0.02	0.01	0.09	0.03	0.24	11
cadmium (Cd)	mg/L	0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	-	-	1
chromium (Cr)	mg/L	*0.0038*	*0.0036*	< 0.0004	< 0.0004	< 0.0004	-	-	1
cobalt (Co)	mg/L	< 0.0001	< 0.0001	0.0002	0.0001	0.0003	-	-	1

Table 5.3 Water Quality in the Athabasca River Upstream of the Muskeg River, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical [a]					
				West	East	Other (1976-1997)			
		West	East	2000	2000	median	min	max	n
copper (Cu)	mg/L	< 0.0006	< 0.0006	0.0006	0.0006	0.0042	-	-	1
iron (Fe)	mg/L	0.08	0.09	0.12	0.14	< 0.01	-	-	1
lead (Pb)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0015	-	-	1
lithium (Li)	mg/L	0.007	0.007	0.004	0.004	0.007	-	-	1
manganese (Mn)	mg/L	0.011	0.012	0.007	0.007	0.01	-	-	1
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0002	-	-	1
molybdenum (Mo)	mg/L	0.0007	0.0006	0.0015	0.0006	0.0008	-	-	1
nickel (Ni)	mg/L	0.0007	0.0008	0.0015	0.0012	0.0023	-	-	1
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0002	< 0.0002	< 0.0005	10
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-	-	1
strontium (Sr)	mg/L	0.25	0.24	0.2	0.18	0.18	-	-	1
thallium (Tl)	mg/L	< 0.00005	< 0.00005	< 0.00005	< 0.00005	-	-	-	-
titanium (Ti)	mg/L	0.0005	0.0007	< 0.0003	0.0003	0.0004	-	-	1
uranium (U)	mg/L	0.0005	0.0005	0.0003	0.0003	0.0003	-	-	1
vanadium (V)	mg/L	0.0004	0.0003	0.0016	0.0003	0.0002	-	-	1
zinc (Zn) [b]	mg/L	*0.031*	0.009	0.007	0.007	0.023	-	-	1

[a] Information in 2000 from Golder (2001a); other data based on information from Golder (1997) and WDS stations AB07DA0270\0280\0320\0390\0400\0410\1520.

[b] The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the concentration reported for the corresponding total metal by >20% (indicative of possible contamination).
Bolded concentrations are higher than water quality guidelines.
[A] = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
[C] = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
[H] = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

Table 5.4 Water Quality in the Athabasca River Upstream of Fort Creek, Fall

Parameter	Units	Fall 2001		Fall Historical[a]							
				West		East		Other (1972-1983)			
		West	East	2000	1998	2000	1998	median	min	max	n
Field Measured											
pH		8.2	7.9	8	-	8	-	8.2	8	8.8	15
specific conductance	uS/cm	321	321	252	310	251	320	215	47	300	32
temperature	°C	6.7	6.8	4.3	12	4.2	12.1	11.3	1.5	16	28
dissolved oxygen	mg/L	8.7	8.3	13	9.8	12.8	10	10.9	8	14	32
colour	T.C.U.	33	20	50	20	40	18	20	< 5	240	16
conductance	uS/cm	331	326	288	299	280	303	266	160	364	35
dissolved organic carbon	mg/L	7	7	8	4	8	5	12	4	22	13
hardness	mg/L	114	119	113	124	113	122	98	87	120	4
pH		8	7.9	7.9	8.2	7.9	8.2	7.8	7.4	8.2	31
total alkalinity	mg/L	109	108	100	106	100	104	100	76	135	35
total dissolved solids	mg/L	230	220	90	164	190	958	154	105	224	34
total organic carbon	mg/L	8	8	11	4	10	5	10	3	25	34
total suspended solids	mg/L	8	< 3	14	15	29	13	22	< 1	317	35
Major Ions											
bicarbonate	mg/L	133	132	122	129	122	127	-	-	-	-
calcium	mg/L	31	33	31	34	31	34	30	20	44	35
carbonate	mg/L	< 5	< 5	< 5	< 5	< 5	< 5	-	-	-	-
chloride	mg/L	19	17	11	7	11	11	8	3	18	35
magnesium	mg/L	9	9	9	9	9	9	8	6	12	35
potassium	mg/L	1	1	1	1	1	1	1	0.1	1	35
sodium	mg/L	19	18	12	12	13	15	11	7	20	35
sulphate	mg/L	27	30	26	33	26	32	22	11	32	31
sulphide	mg/L	0.008	0.005	0.005	< 0.002	0.006	< 0.002	-	-	-	-
Nutrients and Chlorophyll *a*											
nitrogen - ammonia	mg/L	< 0.05	< 0.05	< 0.1	< 0.05	< 0.1	< 0.05	-	-	-	-
nitrogen, total [b]	mg/L	0.8	**1.2** [c]	0.4	< 0.2	0.3	< 0.2	0.535	0.26	**2** [c]	14
phosphorus, total	mg/L	0.03	0.028	0.032	0.013	0.039	0.014	0.038	0.015	**0.29** [c]	35
phosphorus, dissolved	mg/L	9	9	0.02	0.007	0.018	0.009	-	-	-	-
chlorophyll *a*	ug/L	2	2	5	1	4	2	2.5	< 1	8	8

Table 5.4 Water Quality in the Athabasca River Upstream of Fort Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical[a]							
				West		East		Other (1972-1983)			
		West	East	2000	1998	2000	1998	median	min	max	n
Biological Oxygen Demand											
biochemical oxygen demand	mg/L	< 2	< 2	< 2	< 2	< 2	< 2	-	-	-	-
General Organics											
naphthenic acids	mg/L	< 1	< 1	1	5	2	3	-	-	-	-
total phenolics	mg/L	0.002	< 0.001	0.002	< 0.001	0.002	< 0.001	0.002	< 0.001	**0.024** (C)	33
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.5	< 0.1	1.4	31
Metals (Total)											
aluminum (Al)	mg/L	**0.16** (C)	**0.17** (C)	**0.59** (C)	**0.41** (C)	**0.93** (A,C)	**0.31** (C)	-	-	-	-
antimony (Sb)	mg/L	< 0.005	< 0.005	< 0.005	< 0.0008	< 0.005	< 0.0008	-	-	-	-
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.005	< 0.001	**0.009** (C)	3
barium (Ba)	mg/L	0.049	0.047	0.047	0.055	0.054	0.052	-	-	-	-
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	-	-	-	-
boron (B)	mg/L	0.03	0.03	0.02	0.02	0.02	0.03	-	-	-	-
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	**0.004** (A,C)	-	-	1
chromium (Cr)	mg/L	< 0.0008	< 0.0008	0.0008	< 0.0008	**0.0029** (C)	< 0.0008	**0.003** (C)	-	-	1
cobalt (Co)	mg/L	0.0002	< 0.0002	0.0003	0.0004	0.0005	0.0004	0.004	-	-	1
copper (Cu)	mg/L	**0.003** (C)	**0.003** (C)	0.001	**0.005** (C)	**0.003** (C)	**0.005** (C)	**0.004** (C)	-	-	1
iron (Fe)	mg/L	**0.42** (C,H)	0.07	**0.81** (C,H)	**0.42** (C,H)	**1.34** (C,H)	**0.42** (C,H)	0.1	-	-	1
lead (Pb)	mg/L	< 0.0001	0.0003	0.0004	0.0003	0.0006	0.0003	**0.016** (C)	-	-	1
lithium (Li)	mg/L	0.008	0.007	0.006	< 0.006	0.006	< 0.006	-	-	-	-
manganese (Mn)	mg/L	0.023	0.008	0.028	0.021	0.042	0.022	0.025	-	-	1
mercury (Hg)	mg/L	< 0.0000006	< 0.0000006	**< 0.0002** (D>C,H)	**< 0.0002** (D>C,H)	**< 0.0002** (D>C,H)	**< 0.0002** (D>C,H)	**< 0.0001** (D>H)	**< 0.0001** (D>H)	**< 0.0005** (D>C,H)	30
molybdenum (Mo)	mg/L	0.0006	0.0007	0.0009	0.0012	0.001	0.0009	-	-	-	-
nickel (Ni)	mg/L	0.0007	0.0008	0.0028	0.0155	0.0039	0.0154	0.004	-	-	1
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	-	-	-	-
silver (Ag)	mg/L	0.000007	0.000015	**< 0.0004** (D>C)	**< 0.0004** (D>C)	**< 0.0004** (D>C)	**< 0.0004** (D>C)	-	-	-	-
strontium (Sr)	mg/L	0.23	0.23	0.19	0.24	0.21	0.23	-	-	-	-
sulphur (S)	mg/L	-	-	-	-	-	-	-	-	-	-
thallium (Tl)	mg/L	< 0.0001	< 0.0001	< 0.0001	-	< 0.0001	-	-	-	-	-
titanium (Ti)	mg/L	0.0028	0.0009	0.0107	0.0055	0.018	0.0054	< 0.03	< 0.01	< 0.05	4

Table 5.4 Water Quality in the Athabasca River Upstream of Fort Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical[a]							
				West		East		Other (1972-1983)			
		West	East	2000	1998	2000	1998	median	min	max	n
uranium (U)	mg/L	0.0004	0.0004	0.0003	0.0004	0.0003	0.0003	-	-	-	-
vanadium (V)	mg/L	< 0.0002	< 0.0002	0.0023	0.0015	0.003	0.0009	< 0.001	< 0.001	0.003	31
zinc (Zn) [b]	mg/L	0.016	**0.128** [c]	0.009	0.011	**0.042** [c]	0.012	0.008	-	-	1
Metals (Dissolved) [c]											
aluminum (Al)	mg/L	0.01	0.02	0.01	0.03	0.01	0.06	-	-	-	-
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	-	-	-	-
arsenic (As)	mg/L	0.0005	*0.0024*	0.0005	< 0.0004	< 0.0004	< 0.0004	0.0006	< 0.0002	0.005	27
barium (Ba)	mg/L	0.045	0.048	0.044	0.052	0.044	0.05	-	-	-	-
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	-	-	-	-
boron (B)	mg/L	0.03	0.04	0.02	0.02	0.02	0.02	0.08	0.02	0.16	12
cadmium (Cd)	mg/L	0.0002	*0.0188*	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-	-	-
chromium (Cr)	mg/L	*0.0035*	*0.0259*	< 0.0004	< 0.0004	< 0.0004	< 0.0004	-	-	-	-
cobalt (Co)	mg/L	0.0001	*0.0009*	0.0001	0.0004	0.0001	0.0012	-	-	-	-
copper (Cu)	mg/L	*0.0012*	*0.0172*	0.0011	0.0014	0.0017	0.0014	-	-	-	-
iron (Fe)	mg/L	0.32	*0.32*	0.15	0.1	0.17	0.15	-	-	-	-
lead (Pb)	mg/L	*0.0002*	*0.0005*	0.0006	0.0002	0.0006	0.0002	-	-	-	-
lithium (Li)	mg/L	0.007	*0.009*	0.005	0.004	0.004	0.004	-	-	-	-
manganese (Mn)	mg/L	0.023	*0.024*	0.013	0.003	0.014	0.01	-	-	-	-
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-	-	-
molybdenum (Mo)	mg/L	0.0006	*0.0016*	0.0022	0.0013	0.0015	0.0009	-	-	-	-
nickel (Ni)	mg/L	*0.0009*	*0.0103*	0.0014	0.0028	0.0014	0.0028	-	-	-	-
selenium (Se)	mg/L	< 0.0004	*0.0022*	0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0002	< 0.0002	0.0003	12
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-	-	-	-
strontium (Sr)	mg/L	0.22	0.25	0.18	0.25	0.19	0.24	-	-	-	-
thallium (Tl)	mg/L	< 0.00005	< 0.00005	< 0.00005	-	< 0.00005	-	-	-	-	-
titanium (Ti)	mg/L	0.0005	*0.0282*	0.0004	0.0005	0.0005	0.0011	-	-	-	-
uranium (U)	mg/L	0.0004	*0.0097*	0.0003	0.0004	0.0003	0.0004	-	-	-	-
vanadium (V)	mg/L	*0.0007*	*0.0331*	0.0008	0.0001	0.0006	< 0.0001	-	-	-	-
zinc (Zn) [b]	mg/L	0.013	0.086	0.007	0.005	0.008	0.005	-	-	-	-

Table 5.4 Water Quality in the Athabasca River Upstream of Fort Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical[a]							
				West		East		Other (1972-1983)			
		West	East	2000	1998	2000	1998	median	min	max	n
Target PAHs and Alkylated PAHs											
naphthalene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-
C1 subst'd naphthalenes	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-
C2 subst'd naphthalenes	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C3 subst'd naphthalenes	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C4 subst'd naphthalenes	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
acenaphthene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-
C1 subst'd acenaphthene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
acenaphthylene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-
anthracene	ug/L	**< 0.02** (D>C)	**< 0.02** (D>C)	-	-	-	-	-	-	-	-
dibenzo(a,h)anthracene	ug/L	**< 0.02** (D>H)	**< 0.02** (D>H)	-	-	-	-	-	-	-	-
benzo(a)anthracene/chrysene	ug/L	**< 0.02** (D>C,H)	**< 0.02** (D>C,H)	-	-	-	-	-	-	-	-
C1 subst'd benzo(a)anthracene/chrysene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C2 subst'd benzo(a)anthracene/chrysene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
benzo(a)pyrene	ug/L	**< 0.02** (D>C,H)	**< 0.02** (D>C,H)	-	-	-	-	-	-	-	-
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
benzo(b&k)fluoranthene	ug/L	**< 0.02** (D>H)	**< 0.02** (D>H)	-	-	-	-	-	-	-	-
benzo(g,h,i)perylene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-
biphenyl	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C1 subst'd biphenyl	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C2 subst'd biphenyl	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
dibenzothiophene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-
C1 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C2 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C3 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C4 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
fluoranthene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-

Table 5.4 Water Quality in the Athabasca River Upstream of Fort Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical[a]							
				West		East		Other (1972-1983)			
		West	East	2000	1998	2000	1998	median	min	max	n
C1 subst'd fluoranthene/pyrene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
fluorene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-
C1 subst'd fluorene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C2 subst'd fluorene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
indeno(c,d-123)pyrene	ug/L	**< 0.02** (D>H)	**< 0.02** (D>H)	-	-	-	-	-	-	-	-
phenanthrene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-
C1 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C2 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C3 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
C4 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	-	-	-	-	-	-	-	-
1-methyl-7-isopropyl-phenanthrene (Retene)	ug/L	-	-	-	-	-	-	-	-	-	-
pyrene	ug/L	< 0.02	< 0.02	-	-	-	-	-	-	-	-

(a) Information in 1998 and 2000 from Golder (1999b, 2001a); other data based on information from Golder (1996) and WDS stations AD07DA0640\0680\0820\1540\1550.
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.
(c) The accuracy of the reported dissolved metal concentrations is uncertain at the eastern bank sampling location in 2001 because the majority of the dissolved metal data exceeded the concentrations reported for the corresponding total metals by >20% (indicative of possible sample contamination).

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain in 2001 because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data / no guideline.

5.1.1.5 Upstream of Embarras River

In a cross-channel composite sample taken from the Athabasca River upstream of the Embarras River in 2001, total chromium and zinc levels were higher than historical median concentrations (Table 5.5). However, results from the quality control program indicate potential contamination of total zinc samples in 2001 (Section 4.2.1.3). Total aluminum, copper, iron and manganese concentrations in 2001 were less than historical median levels, possibly in relation to the lower TSS concentrations observed in 2001 (Table 5.5). However, several dissolved metals concentrations, including dissolved aluminum, iron and manganese, were higher in 2001 than historical median levels. Despite a potential error in the 2001 data, there appears to be a trend of increasing levels of total zinc in the Athabasca River upstream of the Embarras River (Figure 5.2).

Table 5.5 Water Quality in the Athabasca River Upstream of the Embarras River, Fall

Parameter	Units	Fall 2001	Fall Historical (1977-2000) [a]			
			median	min	max	n
Field Measured						
pH		7.9	8	7.7	**8.7** [A,C]	12
specific conductance	uS/cm	-	311	220	1700	17
temperature	°C	4	8.7	0.1	14.5	33
dissolved oxygen	mg/L	8.5	10.4	9.2	13.6	23
colour	T.C.U.	30	30	< 1	110	38
conductance	uS/cm	364	288	2	392	43
dissolved organic carbon	mg/L	6	10	0.3	17	40
hardness	mg/L	122	118	7	140	33
Conventional Parameters						
pH		8.1	7.8	**5.9** [A,C]	8.4	43
total alkalinity	mg/L	113	103	2	140	43
total dissolved solids	mg/L	240	170	16	245	42
total organic carbon	mg/L	8	10	4	18	36
total suspended solids	mg/L	4	25	< 1	189	44
Major Ions						
bicarbonate	mg/L	138	128	3	171	31
calcium	mg/L	34	31	< 1	39	43
carbonate	mg/L	< 5	< 1	0	< 5	29
chloride	mg/L	25	12	< 1	27	43
magnesium	mg/L	9	9	< 1	11	42
potassium	mg/L	1	1	< 0.1	1	43
sodium	mg/L	22	15	< 1	24	43
sulphate	mg/L	28	21	< 3	37	43
sulphide	mg/L	0.007	< 0.003	-	-	1
Nutrients and Chlorophyll *a*						
nitrogen - ammonia	mg/L	< 0.05	0.01	< 0.01	< 0.1	26
nitrogen, total [b]	mg/L	0.4	0.4	< 0.01	**1.94** [C]	39
phosphorus, total	mg/L	0.028	0.044	0.004	**0.158** [C]	42

Table 5.5 Water Quality in the Athabasca River Upstream of the Embarras River, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1977-2000) [a]			
			median	min	max	n
phosphorus, dissolved	mg/L	0.013	0.008	0.002	0.023	29
chlorophyll *a*	ug/L	2	5.8	1.6	10.4	30
Biological Oxygen Demand						
biochemical oxygen demand	mg/L	-	< 2	-	-	1
General Organics						
naphthenic acids	mg/L	< 1	< 1	-	-	1
total phenolics	mg/L	< 0.001	< 0.001	< 0.001	**0.008** (C)	36
total recoverable hydrocarbons	mg/L	< 0.5	0.7	0.1	126	14
Metals (Total)						
aluminum (Al)	mg/L	**0.33** (C)	**0.37** (C)	0.014	**1.67** (A,C)	9
antimony (Sb)	mg/L	< 0.005	< 0.0002	< 0.0002	< 0.005	3
arsenic (As)	mg/L	< 0.001	0.0006	< 0.0001	0.001	11
barium (Ba)	mg/L	0.053	0.058	< 0.001	0.269	9
beryllium (Be)	mg/L	< 0.001	< 0.0003	< 0.0002	< 0.001	6
boron (B)	mg/L	0.02	0.03	< 0.01	0.14	5
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	**< 0.0002** (D>A,C)	**0.002** (C)	9
chromium (Cr)	mg/L	**0.0017** (C)	0.001	< 0.001	**0.0075** (C)	14
cobalt (Co)	mg/L	< 0.0002	0.001	< 0.0003	0.0013	10
copper (Cu)	mg/L	0.001	**0.0021** (C)	< 0.001	**0.009** (C)	14
iron (Fe)	mg/L	**0.55** (C,H)	**1.02** (C,H)	< 0.001	**3.69** (C,H)	11
lead (Pb)	mg/L	< 0.0001	0.0012	< 0.0003	**0.0053** (C)	9
lithium (Li)	mg/L	0.008	0.007	0.007	0.008	3
manganese (Mn)	mg/L	0.034	0.044	< 0.001	**0.102** (H)	14
mercury (Hg)	mg/L	**< 0.0002** (D>C,H)	**< 0.0001** (D>H)	< 0.00005	**0.0004** (C,H)	37
molybdenum (Mo)	mg/L	0.0005	0.001	0.0009	0.0054	9
nickel (Ni)	mg/L	< 0.0002	0.0015	< 0.0005	0.0053	10
selenium (Se)	mg/L	< 0.0008	< 0.0002	< 0.0001	< 0.0008	11
silver (Ag)	mg/L	**< 0.0004** (D>C)	< 0.0001	**< 0.0001** (D>A)	**< 0.0004** (D>C)	5
strontium (Sr)	mg/L	0.21	0.22	0.21	0.23	3
thallium (Tl)	mg/L	< 0.0001	< 0.0002	< 0.0001	0.0002	3
titanium (Ti)	mg/L	0.0068	< 0.01	0.001	< 0.05	8
uranium (U)	mg/L	< 0.0001	< 0.0004	< 0.0004	0.0005	6
vanadium (V)	mg/L	0.0007	< 0.001	< 0.001	0.005	22
zinc (Zn) [b]	mg/L	0.021	0.007	0.001	**0.033** (C)	11
Metals (Dissolved)						
aluminum (Al)	mg/L	0.03	0.01	0.007	0.28	18
antimony (Sb)	mg/L	< 0.0008	< 0.0002	< 0.0002	< 0.0008	3
arsenic (As)	mg/L	0.0007	0.0004	< 0.0002	0.005	26
barium (Ba)	mg/L	0.048	0.049	0.048	0.268	3
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.0002	< 0.001	5
boron (B)	mg/L	0.03	0.03	< 0.01	0.1	26
cadmium (Cd)	mg/L	< 0.0001	< 0.0002	< 0.0001	0.0005	3
chromium (Cr)	mg/L	*0.0052*	< 0.001	< 0.001	0.0016	3
cobalt (Co)	mg/L	0.0001	0.0005	0.0002	0.0008	3
copper (Cu)	mg/L	0.001	0.0016	0.0015	0.0016	3
iron (Fe)	mg/L	0.19	0.13	< 0.01	0.43	20

Table 5.5 Water Quality in the Athabasca River Upstream of the Embarras River, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1977-2000) [a]			
			median	min	max	n
lead (Pb)	mg/L	< 0.0001	< 0.0003	< 0.0003	0.0003	3
lithium (Li)	mg/L	0.008	0.007	0.006	0.008	3
manganese (Mn)	mg/L	0.009	0.005	< 0.001	0.043	20
mercury (Hg)	mg/L	< 0.0001	< 0.0001	-	-	1
molybdenum (Mo)	mg/L	*0.0007*	0.0008	< 0.0002	0.001	3
nickel (Ni)	mg/L	*0.0009*	0.0024	< 0.0005	0.0041	3
selenium (Se)	mg/L	< 0.0004	< 0.0002	< 0.0002	< 0.0004	22
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0001	< 0.001	5
strontium (Sr)	mg/L	0.24	0.21	-	-	1
thallium (Tl)	mg/L	0.00006	< 0.0002	< 0.00005	0.0002	3
titanium (Ti)	mg/L	0.0017	0.003	< 0.001	0.0112	3
uranium (U)	mg/L	*0.0004*	< 0.0004	0.0003	< 0.0004	3
vanadium (V)	mg/L	*0.0011*	0.001	< 0.001	0.0011	3
zinc (Zn) [b]	mg/L	0.002	0.002	0.001	0.008	3
Target PAHs and Alkylated PAHs						
naphthalene	ug/L	< 0.02	< 1	< 0.1	< 1	5
C1 subst'd naphthalenes	ug/L	< 0.02	-	-	-	-
C2 subst'd naphthalenes	ug/L	< 0.04	-	-	-	-
C3 subst'd naphthalenes	ug/L	< 0.04	-	-	-	-
C4 subst'd naphthalenes	ug/L	< 0.04	-	-	-	-
acenaphthene	ug/L	< 0.02	< 1	< 0.1	< 1	5
C1 subst'd acenaphthene	ug/L	< 0.04	-	-	-	-
acenaphthylene	ug/L	< 0.02	< 1	< 0.1	< 1	5
anthracene	ug/L	**< 0.02** (D>C)	**< 1** (D>C)	**< 0.1** (D>C)	**< 1** (D>C)	5
dibenzo(a,h)anthracene	ug/L	**< 0.02** (D>H)	**< 5** (D>H)	**< 0.5** (D>H)	**< 5** (D>H)	5
benzo(a)anthracene/chrysene	ug/L	**< 0.02** (D>C,H)	**< 1** (D>C,H)	**< 0.1** (D>C,H)	**< 1** (D>C,H)	5
C1 subst'd benzo(a)anthracene/chrysene	ug/L	< 0.04	-	-	-	-
C2 subst'd benzo(a)anthracene/chrysene	ug/L	< 0.04	-	-	-	-
benzo(a)pyrene	ug/L	**< 0.02** (D>C,H)	**< 1** (D>C,H)	**< 0.1** (D>C,H)	**< 1** (D>C,H)	5
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	-	-	-	-
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	-	-	-	-
benzo(b&k)fluoranthene	ug/L	**< 0.02** (D>H)	-	-	-	-
benzo(g,h,i)perylene	ug/L	< 0.02	< 2	< 0.2	< 2	5
biphenyl	ug/L	< 0.04	-	-	-	-
C1 subst'd biphenyl	ug/L	< 0.04	-	-	-	-
C2 subst'd biphenyl	ug/L	< 0.04	-	-	-	-
dibenzothiophene	ug/L	< 0.02	-	-	-	-
C1 subst'd dibenzothiophene	ug/L	< 0.04	-	-	-	-
C2 subst'd dibenzothiophene	ug/L	< 0.04	-	-	-	-
C3 subst'd dibenzothiophene	ug/L	< 0.04	-	-	-	-
C4 subst'd dibenzothiophene	ug/L	< 0.04	-	-	-	-
fluoranthene	ug/L	< 0.02	**< 1** (D>C)	**< 0.1** (D>C)	**< 1** (D>C)	5
C1 subst'd fluoranthene/pyrene	ug/L	< 0.04	-	-	-	-

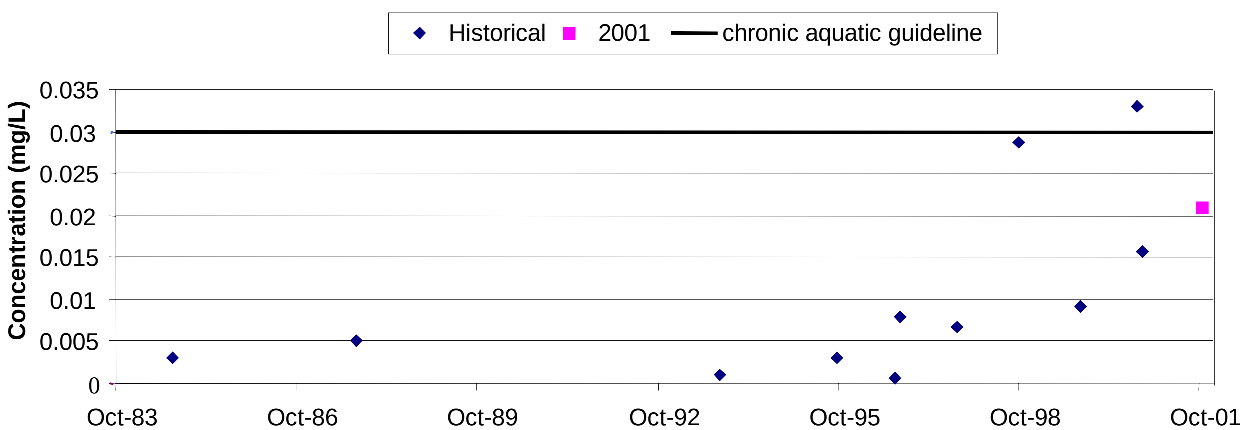
Table 5.5 Water Quality in the Athabasca River Upstream of the Embarras River, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1977-2000) [a]			
			median	min	max	n
fluorene	ug/L	< 0.02	< 1	< 0.1	< 1	5
C1 subst'd fluorene	ug/L	< 0.04	-	-	-	-
C2 subst'd fluorene	ug/L	< 0.04	-	-	-	-
indeno(c,d-123)pyrene	ug/L	**< 0.02** (D>H)	**< 1** (D>H)	**< 0.1** (D>H)	**< 1** (D>H)	5
phenanthrene	ug/L	< 0.02	**< 1** (D>C)	< 0.1	**< 1** (D>C)	5
C1 subst'd phenanthrene/anthracene	ug/L	< 0.04	-	-	-	-
C2 subst'd phenanthrene/anthracene	ug/L	< 0.04	-	-	-	-
C3 subst'd phenanthrene/anthracene	ug/L	< 0.04	-	-	-	-
C4 subst'd phenanthrene/anthracene	ug/L	< 0.04	-	-	-	-
1-methyl-7-isopropyl-phenanthrene (Retene)	ug/L	-	-	-	-	-
pyrene	ug/L	< 0.02	**< 1** (D>C)	**< 0.1** (D>C)	**< 1** (D>C)	5

(a) Information taken from Golder (2000b, 2001a) and WDS stations AB07DD0010\0040\0060\0080.
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain in 2001 because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

Figure 5.2 Total Zinc Concentrations in the Athabasca River Upstream of the Embarras River, Fall (1983 to 2001)



5.1.1.6 Delta

In a cross-channel composite sample taken from the Athabasca Delta, pH and concentrations of several metals, including total aluminum, cobalt, iron, lead, nickel and titanium, were lower and TSS, TDS and total selenium levels were higher in 2001 than previously recorded (Table 5.6).

Table 5.6 Water Quality in the Athabasca Delta, Fall

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [a]			
			median	min	max	n
Field Measured						
pH		7.3	7.9	7.5	8.6	17
specific conductance	uS/cm	-	300	196	2000	24
temperature	^{o}C	5.4	10	1.8	14.7	32
dissolved oxygen	mg/L	9.5	9.7	6	14	22
colour	T.C.U.	25	24	10	100	23
conductance	uS/cm	353	266	180	368	33
dissolved organic carbon	mg/L	6	6	4	20	25
hardness	mg/L	119	117	12	140	24
Conventional Parameters						
pH		8.1	8	7.5	8.4	33
total alkalinity	mg/L	114	104	77	129	33
total dissolved solids	mg/L	230	164	118	198	28
total organic carbon	mg/L	8	13	4	21	17
total suspended solids	mg/L	107	19	6	61	34
Major Ions						
bicarbonate	mg/L	139	130	122	152	17
calcium	mg/L	33	33	24	38	33
carbonate	mg/L	< 5	< 5	< 5	< 5	10
chloride	mg/L	22	11	5	26	33
magnesium	mg/L	9	8	6	11	32
potassium	mg/L	1	1	0.1	1	33
sodium	mg/L	20	12	8	22	33
sulphate	mg/L	28	19	3	28	33
sulphide	mg/L	0.007	< 0.003	-	-	1
Nutrients and Chlorophyll *a*						
nitrogen - ammonia	mg/L	< 0.05	< 0.1	-	-	1
nitrogen, total [b]	mg/L	0.3	0.3	0.227	1.04	31
phosphorus, total	mg/L	0.027	0.04	0.017	0.22	39
phosphorus, dissolved	mg/L	0.014	0.008	0.006	0.024	23
chlorophyll *a*	ug/L	2	5	0.004	6.7	18
Biological Oxygen Demand						
biochemical oxygen demand	mg/L	-	< 2	-	-	1
General Organics						
naphthenic acids	mg/L	< 1	< 1	-	-	1

Table 5.6 Water Quality in the Athabasca Delta, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [a]			
			median	min	max	n
total phenolics	mg/L	< 0.001	0.004	< 0.001	0.032	26
total recoverable hydrocarbons	mg/L	< 0.5	0.3	< 0.2	1.4	26
Metals (Total)						
aluminum (Al)	mg/L	0.24	2.57	-	-	1
antimony (Sb)	mg/L	< 0.005	< 0.005	-	-	1
arsenic (As)	mg/L	< 0.001	0.0007	0.0005	0.001	17
barium (Ba)	mg/L	0.056	0.057	0.005	0.069	17
beryllium (Be)	mg/L	< 0.001	< 0.001	-	-	1
boron (B)	mg/L	0.03	0.02	-	-	1
cadmium (Cd)	mg/L	< 0.0002	< 0.001	< 2E-04	< 0.001	17
chromium (Cr)	mg/L	0.0052	0.003	< 0.001	0.009	17
cobalt (Co)	mg/L	< 0.0002	< 0.001	0.0008	< 0.001	17
copper (Cu)	mg/L	0.003	< 0.001	< 0.001	0.005	17
iron (Fe)	mg/L	0.46	1.99	-	-	1
lead (Pb)	mg/L	< 0.0001	0.0017	-	-	1
lithium (Li)	mg/L	0.008	0.007	-	-	1
manganese (Mn)	mg/L	0.032	0.031	0.025	0.061	17
mercury (Hg)	mg/L	< 0.0002	< 0.0001	< 1E-04	0.0009	28
molybdenum (Mo)	mg/L	0.0007	< 0.001	0.0009	0.004	17
nickel (Ni)	mg/L	0.0004	0.003	< 0.001	0.008	17
selenium (Se)	mg/L	0.0036	< 0.0002	< 2E-04	< 8E-04	17
silver (Ag)	mg/L	< 0.0004	< 0.0004	-	-	1
strontium (Sr)	mg/L	0.23	0.21	-	-	1
thallium (Tl)	mg/L	< 0.0001	< 0.0001	-	-	1
titanium (Ti)	mg/L	0.0063	0.0508	-	-	1
uranium (U)	mg/L	< 0.0001	0.0005	-	-	1
vanadium (V)	mg/L	0.0036	< 0.002	< 0.001	0.0053	28
zinc (Zn)	mg/L	0.022	0.004	0.002	0.058	17
Metals (Dissolved)						
aluminum (Al)	mg/L	0.01	0.31	-	-	1
antimony (Sb)	mg/L	< 0.0008	< 0.0008	-	-	1
arsenic (As)	mg/L	0.0006	0.0006	0.0003	0.0026	17
barium (Ba)	mg/L	0.047	0.049	-	-	1
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	17
boron (B)	mg/L	0.03	0.04	0.02	0.1	8
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	-	-	1
chromium (Cr)	mg/L	0.0051	0.0015	-	-	1
cobalt (Co)	mg/L	< 0.0001	0.0002	-	-	1
copper (Cu)	mg/L	0.0008	0.0017	-	-	1
iron (Fe)	mg/L	0.14	0.47	-	-	1
lead (Pb)	mg/L	< 0.0001	0.0003	-	-	1
lithium (Li)	mg/L	0.007	0.006	-	-	1
manganese (Mn)	mg/L	0.007	0.011	-	-	1

Table 5.6 Water Quality in the Athabasca Delta, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [(a)]			
			median	min	max	n
mercury (Hg)	mg/L	< 0.0001	< 0.0001	-	-	1
molybdenum (Mo)	mg/L	0.0007	0.0009	-	-	1
nickel (Ni)	mg/L	*0.0007*	0.0024	-	-	1
selenium (Se)	mg/L	< 0.0004	< 0.0003	< 2E-04	0.0005	14
silver (Ag)	mg/L	< 0.0002	< 0.0002	-	-	1
strontium (Sr)	mg/L	0.25	0.2	-	-	1
thallium (Tl)	mg/L	< 0.00005	< 0.00005	-	-	1
titanium (Ti)	mg/L	0.0016	0.0131	-	-	1
uranium (U)	mg/L	*0.0004*	0.0003	-	-	1
vanadium (V)	mg/L	0.001	0.0013	-	-	1
zinc (Zn)	mg/L	< 0.002	< 0.002	-	-	1

(a) Based on information from Golder (2001a) and WDS stations AB07DD0090\0105\0130\0180\0150\0160\0170\0200\0220\0230\0360.

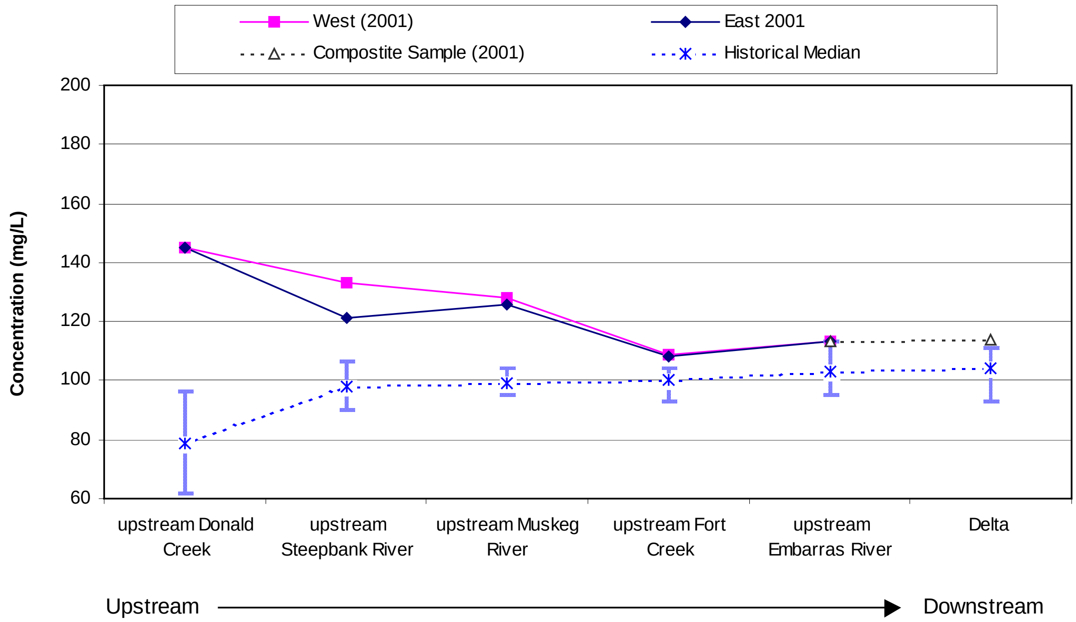
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain in 2001 because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
[A] = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
[C] = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
[H] = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

5.1.2 Spatial Trends

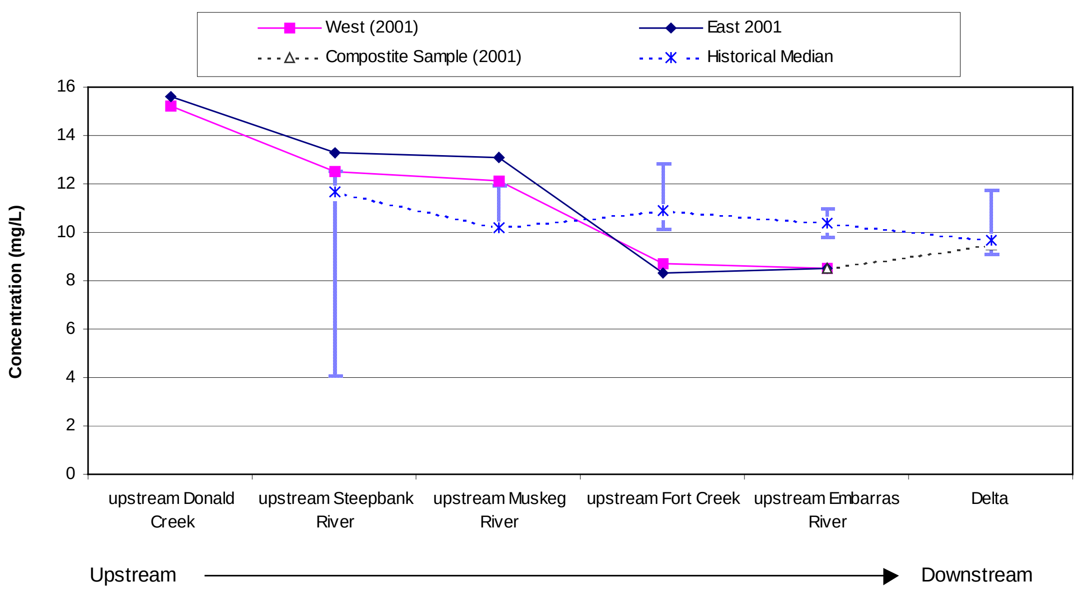
In 2001, concentrations of DO, hardness, bicarbonate, alkalinity and sulphate declined, while total phosphorus increased with distance downstream on the eastern side of the Athabasca River from upstream of Donald Creek to upstream of the Embarras River. Concentrations of DO, hardness, bicarbonate, alkalinity and sulphate also declined with distance downstream on the western side of the river in 2001, along with calcium, magnesium and total barium. The downstream trends of alkalinity and DO levels in 2001 and previous years in the Athabasca River are illustrated in Figure 5.3 and Figure 5.4 respectively. Historically, pH, alkalinity, TDS and chlorophyll *a* concentrations have tended to increase with distance downstream, while DO and total barium have tended to decrease with distance downstream in the Athabasca River.

Figure 5.3 Concentrations of Total Alkalinity in the Athabasca River, 2001 and Historical Median Concentrations



Error bars indicate 25th and 75th percentile values for historical data except for data from upstream of Donald Creek, where error bars indicate minimum and maximum values (n=2).

Figure 5.4 Concentrations of Dissolved Oxygen in the Athabasca River, 2001 and Historical Median Concentrations



Error bars indicate 25th and 75th percentile values for historical data.

5.2 SEDIMENT QUALITY

5.2.1 Mainstem Sediment Chemistry

Sediments collected from the Athabasca River in 2001 consisted principally of sand, with varying amounts of silt and clay (Tables 5.7 to 5.11). Total metal and PAH concentrations tended to be higher in the west bank composite sediment samples in comparison to the east-bank samples collected from upstream of Donald Creek to just upstream of Fort Creek. This has not been a consistent trend over time; total metal and/or PAH concentrations in east-bank samples can be higher than those measured in the west bank samples, as has been observed in previous sampling events upstream of Donald Creek, the Muskeg River and Fort Creek (Tables 5.7, 5.9 and 5.10).

Parameter concentrations in sediments collected from all of the mainstem sample sites, including those taken upstream of the Embarras River, were, with few exceptions, consistent with or lower than those observed in sediment from previous sampling events (Tables 5.7 to 5.11). As in the past, total metal and PAH levels were lower than Canadian freshwater sediment guidelines, except upstream of the Steepbank River where total arsenic and C1 substituted naphthalene levels in the west bank composite sample were above relevant interim guidelines (Table 5.8).

Table 5.7 Sediment Quality in the Athabasca River Upstream of Donald Creek, Fall

Parameter	Units	Fall 2001		Fall Historical							
				West		East		Other (1975 - 1997)(c)			
		West	East	2000(a)	1998(b)	2000(a)	1998(b)	median	min	max	n
Particle Size											
percent sand	%	91	97	97	83	85	70	56	-	-	1
percent silt	%	4	1	1	10	9	20	24	-	-	1
percent clay	%	5	2	2	7	7	10	20	-	-	1
moisture content	%	19	18	23	-	21	-	-	-	-	-
Carbon Content											
total inorganic carbon	% by wt	0.4	0.2	0.2	0.6	0.9	0.6	0.3	-	-	1
total organic carbon	% by wt	< 0.1	< 0.1	0.1	0.4	2.5	0.9	-	0.2	0.7	2
General Organics											
total recoverable hydrocarbons	mg/kg	< 100	< 100	300	214	14,600	653	423	-	-	1
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	< 0.5	-	< 0.5	-	-	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	54	6	35	-	1500	-	-	-	-	-
Total Metals											
aluminum (Al)	ug/g	2,600	1,300	2,500	5,990	3,920	8,080	-	10,700	27,800	2
arsenic (As)	ug/g	3.1	2.9	3.6	**7.7** (l)	3.9	4.2	3.5	2.7	5.6	3
barium (Ba)	ug/g	63	30	67.3	132	109	106	-	168	470	2
beryllium (Be)	ug/g	< 1	< 1	0.2	< 1	0.4	< 1	-	< 1	1	2

Table 5.7 Sediment Quality in the Athabasca River Upstream of Donald Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical							
				West		East		Other (1975 - 1997)[c]			
		West	East	2000[a]	1998[b]	2000[a]	1998[b]	median	min	max	n
boron (B)	ug/g	-	-	5	-	6	-	-	-	-	-
cadmium (Cd)	ug/g	< 0.5	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	-	0.1	< 0.5	2
calcium (Ca)	ug/g	7,200	3,300	7,600	15,400	17,900	14,200	-	12,000	17,500	2
chromium (Cr)	ug/g	6.5	2.4	7.3	13.6	34.5	16.2	33	19	**75 [I]**	3
cobalt (Co)	ug/g	4	2	4.4	6	4.9	5	-	4	7	2
copper (Cu)	ug/g	4	< 2	6	9	6.9	10	12	1.9	15	3
iron (Fe)	ug/g	8,500	7,100	8,960	11,400	18,700	12,500	12,400	10,900	15,000	3
lead (Pb)	ug/g	< 5	< 5	3.2	8	4.2	8	3.8	< 1	9	3
magnesium (Mg)	ug/g	2,400	1,200	1,975	5,100	4,700	5,390	-	3,200	5,680	2
manganese (Mn)	ug/g	240	310	261	251	315	283	248	232	381	3
mercury (Hg)	ug/g	< 0.1	< 0.1	< 0.04	0.03	0.1	0.04	0.02	0.01	0.1	3
molybdenum (Mo)	ug/g	< 1	< 1	0.4	< 1	1.2	< 1	< 1	-	-	1
nickel (Ni)	ug/g	8	5	9.1	14	23.9	13	16	6.8	33.9	3
potassium (K)	ug/g	440	140	645	1,060	1,280	1,640	1,990	-	-	1
selenium (Se)	ug/g	< 0.2	< 0.2	< 0.2	< 0.1	0.5	0.3	-	0.2	0.8	2
silver (Ag)	ug/g	< 1	< 1	< 0.1	< 1	< 0.1	< 1	< 1	-	-	1
sodium (Na)	ug/g	< 100	< 100	100	112	100	215	-	244	7400	2
strontium (Sr)	ug/g	26	15	27	44	45	40	-	52	155	2
thallium (Tl)	ug/g	< 1	< 1	< 0.1	-	0.1	-	-	-	-	-
titanium (Ti)	ug/g	42	24	-	40	-	54	-	54	1100	2
uranium (U)	ug/g	< 40	< 40	0.4	-	0.6	-	-	-	-	-
vanadium (V)	ug/g	10	5	11.1	18	17.6	22	32	28	39	3
zinc (Zn)	ug/g	10	< 10	26.2	48	26.6	46.2	32.1	16	53	3
Target PAHs and Alkylated PAHs											
naphthalene	ng/g	0.91	0.63	15	25	13	12	< 10	-	-	1
C1 subst'd naphthalenes	ng/g	2.2	0.61	11	15	19	18	< 20	-	-	1
C2 subst'd naphthalenes	ng/g	3.3	0.74	< 1	26	< 7	25	20	-	-	1
C3 subst'd naphthalenes	ng/g	3	0.42	< 4	21	< 10	49	30	-	-	1
C4 subst'd naphthalenes	ng/g	1.9	0.077	< 2	< 2	< 9	57	< 20	-	-	1
acenaphthene	ng/g	0.13	*1	1	< 2	< 5	< 3	**< 10 [D>I]**	-	-	1
C1 subst'd acenaphthene	ng/g	0.18	< 0.077	1	< 1	< 4	< 0.2	< 20	-	-	1
acenaphthylene	ng/g	< 0.091	*0.081	< 1	< 1	< 5	< 1	**< 10 [D>I]**	-	-	1
anthracene	ng/g	< 0.097	< 0.045	< 1	< 2	< 12	< 4	< 10	-	-	1
dibenzo(a,h)anthracene	ng/g	< 0.4	< 0.21	< 6	< 4	**< 10 [D>I]**	< 6	**< 10 [D>I]**	-	-	1
benzo(a)anthracene/chrysene	ng/g	3.11	0.43	3	8	***321 [I]**	21	20	-	-	1
C1 subst'd benzo(a)anthracene/chrysene	ng/g	28	< 0.74	< 5	< 1	3,500	< 1	30	-	-	1
C2 subst'd benzo(a)anthracene/chrysene	ng/g	6.6	< 0.12	< 1	< 1	1,600	< 1	50	-	-	1
Benzo(a)pyrene	ng/g	*0.70	< 0.14	< 2	< 6	*24	*11	< 10	-	-	1
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	2.9	< 0.24	< 2	< 5	< 23	< 12	30	-	-	1
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	1.2	< 0.18	< 2	< 3	< 29	< 6	30	-	-	1
benzofluoranthenes	ng/g	3	0.48	< 2	*6	88	*19	10	-	-	1
benzo(g,h,i)perylene	ng/g	*1.0	< 0.18	4	*5	46	13	< 10	-	-	1

Table 5.7 Sediment Quality in the Athabasca River Upstream of Donald Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical							
				West		East		Other (1975 - 1997)[c]			
		West	East	2000[a]	1998[b]	2000[a]	1998[b]	median	min	max	n
biphenyl	ng/g	0.61	0.31	2	< 0.4	< 3	< 1	< 20	-	-	1
C1 subst'd biphenyl	ng/g	< 0.036	< 0.045	< 3	< 0.5	< 4	< 0.5	< 20	-	-	1
C2 subst'd biphenyl	ng/g	< 0.02	< 0.053	< 1	< 0.5	< 6	< 0.3	< 20	-	-	1
dibenzothiophene	ng/g	*0.19	< 0.089	< 1	1	< 4	< 3	< 10	-	-	1
C1 subst'd dibenzothiophene	ng/g	< 0.21	< 0.13	< 1	7	< 12	23	< 20	-	-	1
C2 subst'd dibenzothiophene	ng/g	0.96	< 0.15	< 3	< 3	1,600	110	20	-	-	1
C3 subst'd dibenzothiophene	ng/g	6.3	< 0.19	< 2	< 2	4,400	< 3	40	-	-	1
C4 subst'd dibenzothiophene	ng/g	4.9	1.1	< 2	-	< 9	-	50	-	-	1
fluoranthene	ng/g	0.85	0.22	2	3	27	7	< 10	-	-	1
C1 subst'd fluoranthene/pyrene	ng/g	0.79	0.45	< 1	13	480	36	30	-	-	1
C2 subst'd fluoranthene/pyrene	ng/g	7.1	0.56	4	-	1,200	-	-	-	-	-
C3 subst'd fluoranthene/pyrene	ng/g	5.4	0.39	< 1	-	1,400	-	-	-	-	-
fluorene	ng/g	*0.33	*0.14	1	< 2	< 6	4	< 10	-	-	1
C1 subst'd fluorene	ng/g	0.52	< 0.096	< 1	< 1	< 4	< 1	< 20	-	-	1
C2 subst'd fluorene	ng/g	1.3	< 0.066	< 1	< 2	< 12	< 2	< 20	-	-	1
C3 subst'd fluorene	ng/g	3.3	< 0.18	< 2	-	< 14	-	-	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	*0.90	< 0.23	< 4	< 9	34	*7	< 10	-	-	1
phenanthrene	ng/g	1.9	0.41	4	10	10	20	10	-	-	1
C1 subst'd phenanthrene/anthracene	ng/g	4.5	0.5	2	20	20	60	< 20	-	-	1
C2 subst'd phenanthrene/anthracene	ng/g	5	0.51	1	20	400	90	30	-	-	1
C3 subst'd phenanthrene/anthracene	ng/g	3.4	0.19	< 2	< 3	1,000	140	40	-	-	1
C4 subst'd phenanthrene/anthracene	ng/g	4.4	< 0.11	10	30	700	710	40	-	-	1
1-Methyl-7-isopropyl-phenanthrene (Retene)	ng/g	6.9	0.52	10	-	180	-	-	-	-	-
pyrene	ng/g	1.5	0.33	2	6	110 [I]	16	< 10	-	-	1

[a] Based on information from Golder (2001a).
[b] Based on information from Golder (1999b).
[c] Based on information from Allen and Jackson (1978), Lutz and Hendzel (1977).

Note: Bolded concentrations are higher than the relevant sediment quality guideline.
[I] = concentration higher than the interim sediment quality guideline (CCME 1999).
[P] = concentration higher than the probable effects level defined by CCME (1999).
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
\- = no data / no guideline.
*PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
nt = not toxic.

Table 5.8 Sediment Quality in the Athabasca River Upstream of the Steepbank River, Fall

Parameter	Units	Fall 2001		Fall Historical					
				2000[(a)]		Other (1975 - 1995)[(b)]			
		West	East	West	East	median	min	max	n
Particle Size									
percent sand	%	63	79	71	89	66	37.1	94.4	8
percent silt	%	25	14	21	6	25.8	2	41	8
percent clay	%	12	7	8	5	7.9	0.3	21.9	8
moisture content	%	38	17	29	25	-	-	-	-
Carbon Content									
total inorganic carbon	% by wt	0.9	0.5	0.7	0.3	0.8	-	-	1
total organic carbon	% by wt	0.6	0.2	2.1	0.5	0.9	0.2	6.6	22
General Organics									
total recoverable hydrocarbons	mg/kg	300	300	800	500	-	-	-	-
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	-	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	210	190	150	62	-	-	-	-
Total Metals									
aluminum (Al)	ug/g	18,600	7,500	5,160	2,600	33,000	4,250	87,600	13
arsenic (As)	ug/g	**6.5 (I)**	3.5	3.5	2.5	3	1.3	**8.4 (I)**	17
barium (Ba)	ug/g	193	79	180	63.8	411	88	780	13
beryllium (Be)	ug/g	< 1	< 1	0.4	< 0.2	0.5	0.2	2.4	13
boron (B)	ug/g	-	-	13	< 5	16	14	18	5
cadmium (Cd)	ug/g	< 0.5	< 0.5	0.1	< 0.1	< 0.5	0.1	**7.4 (P)**	23
calcium (Ca)	ug/g	18,400	9,600	21,400	10,100	28,500	59,00	71,000	13
chromium (Cr)	ug/g	30.9	11.5	33.4	12.1	31.7	10.3	**587 (P)**	24
cobalt (Co)	ug/g	8	5	5.4	3.7	13.7	5	25.2	22
copper (Cu)	ug/g	13	6	8.5	3.7	13.2	2.5	27.7	24
iron (Fe)	ug/g	19,500	10,800	12,700	79,80	17,300	10,200	27,800	14
lead (Pb)	ug/g	7	< 5	5.4	3	7.2	< 1	**121 (P)**	24
magnesium (Mg)	ug/g	7,800	4,100	5,840	2,980	6,544	1,512	13,650	22
manganese (Mn)	ug/g	360	250	276	188	335	213	425	14
mercury (Hg)	ug/g	< 0.1	< 0.1	0.1	< 0.04	0.02	0.01	0.1	14
molybdenum (Mo)	ug/g	< 1	< 1	0.7	0.3	< 1	0.9	1.4	12
nickel (Ni)	ug/g	22	11	20.2	8.8	21.4	7.7	44.6	24
potassium (K)	ug/g	3,240	790	1,970	570	7,750	580	11,300	12
selenium (Se)	ug/g	0.5	0.3	< 0.2	< 0.2	< 1	0.2	3	15
silver (Ag)	ug/g	< 1	< 1	0.1	< 0.1	< 0.5	< 0.2	< 0.5	12
sodium (Na)	ug/g	400	< 100	200	< 100	5,500	40	11,500	13
strontium (Sr)	ug/g	73	37	55	25	100	30.7	205	13
thallium (Tl)	ug/g	< 1	< 1	0.1	< 0.1	-	-	-	-
titanium (Ti)	ug/g	195	52	-	-	640	89.7	3300	13
uranium (U)	ug/g	< 40	< 40	0.8	0.4	< 50	< 50	< 50	5
vanadium (V)	ug/g	48	17	30.4	11.4	46.5	14	118	23
zinc (Zn)	ug/g	40	20	30.6	22	48.6	13.9	110	24
Target PAHs and Alkylated PAHs									
naphthalene	ng/g	7.4	2	18	7	-	-	-	-
C1 subst'd naphthalenes	ng/g	**24 (I)**	5.6	29 (I)	11	-	-	-	-
C2 subst'd naphthalenes	ng/g	29	7.5	46	19	-	-	-	-
C3 subst'd naphthalenes	ng/g	39	8.7	42	11	-	-	-	-
C4 subst'd naphthalenes	ng/g	30	6.8	< 9	< 3	-	-	-	-
acenaphthene	ng/g	0.83	0.2	**< 7 (D>I)**	< 3	-	-	-	-
C1 subst'd acenaphthene	ng/g	1.9	0.49	< 4	1	-	-	-	-
acenaphthylene	ng/g	< 0.18	< 0.099	**< 6 (D>I)**	< 1	-	-	-	-

Table 5.8 Sediment Quality in the Athabasca River Upstream of the Steepbank River, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical					
				2000(a)		Other (1975 - 1995)(b)			
		West	East	West	East	median	min	max	n
anthracene	ng/g	0.95	< 0.15	< 4	< 2	-	-	-	-
dibenzo(a,h)anthracene	ng/g	< 1.7	< 0.93	< 4	< 4	-	-	-	-
benzo(a)anthracene/chrysene	ng/g	28.9	9.9	***43 (I)**	11	-	-	-	-
C1 subst'd benzo(a)anthracene/chrysene	ng/g	260	100	290	< 19	-	-	-	-
C2 subst'd benzo(a)anthracene/chrysene	ng/g	61	26	< 120	35	-	-	-	-
benzo(a)pyrene	ng/g	*8.4	*2.3	< 11	*4	-	-	-	-
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	38	10	< 13	< 5	-	-	-	-
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	21	9.2	< 6	< 5	-	-	-	-
benzofluoranthenes	ng/g	*19	7.2	28	17	-	-	-	-
benzo(g,h,i)perylene	ng/g	8.7	3.6	< 33	5	-	-	-	-
biphenyl	ng/g	3.2	1.1	< 4	2	-	-	-	-
C1 subst'd biphenyl	ng/g	< 0.1	< 0.081	< 4	< 2	-	-	-	-
C2 subst'd biphenyl	ng/g	0.087	< 0.047	< 3	< 1	-	-	-	-
dibenzothiophene	ng/g	*3.3	0.67	< 12	< 2	-	-	-	-
C1 subst'd dibenzothiophene	ng/g	3.9	2.5	20	< 2	-	-	-	-
C2 subst'd dibenzothiophene	ng/g	54	14	55	< 2	-	-	-	-
C3 subst'd dibenzothiophene	ng/g	99	39	79	< 6	-	-	-	-
C4 subst'd dibenzothiophene	ng/g	42	24	< 6	< 3	-	-	-	-
fluoranthene	ng/g	5.2	1.7	9	3	-	-	-	-
C1 subst'd fluoranthene/pyrene	ng/g	29	10	58	20	-	-	-	-
C2 subst'd fluoranthene/pyrene	ng/g	60	17	140	40	-	-	-	-
C3 subst'd fluoranthene/pyrene	ng/g	34	14	170	45	-	-	-	-
fluorene	ng/g	*2.1	0.65	< 4	< 2	-	-	-	-
C1 subst'd fluorene	ng/g	9.2	2.7	< 5	< 3	-	-	-	-
C2 subst'd fluorene	ng/g	100	10	< 8	< 4	-	-	-	-
C3 subst'd fluorene	ng/g	33	7.5	< 6	< 3	-	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	5.8	*2.8	12	5	-	-	-	-
phenanthrene	ng/g	17	4.1	20	10	-	-	-	-
C1 subst'd phenanthrene/anthracene	ng/g	44	12	70	10	-	-	-	-
C2 subst'd phenanthrene/anthracene	ng/g	59	17	40	20	-	-	-	-
C3 subst'd phenanthrene/anthracene	ng/g	64	21	40	10	-	-	-	-
C4 subst'd phenanthrene/anthracene	ng/g	48	16	50	20	-	-	-	-
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	54	19	150	40	-	-	-	-
pyrene	ng/g	12	4.3	31	6	-	-	-	-

(a) Based on information from Golder (2001a).
(b) Based on information from Allen and Jackson (1978), Lutz and Hendzel (1977).
Note: Bolded concentrations are higher than the relevant sediment quality guideline.
I = concentration higher than the interim sediment quality guideline (CCME 1999).
P = concentration higher than the probable effects level defined by CCME (1999).
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data / no guideline.
*PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
nt = not toxic.

Table 5.9 Sediment Quality in the Athabasca River Upstream of the Muskeg River, Fall

Parameter	Units	Fall 2001		Fall Historical							
				West		East		Other (1975 - 1997)[c]			
		West	East	2000[a]	1998[b]	2000[a]	1998[b]	median	min	max	n
Particle Size											
percent sand	%	97	95	76	71	48	60	-	64.2	94.2	2
percent silt	%	1	3	14	17	36	22	-	3.1	29.6	2
percent clay	%	2	2	11	12	16	18	-	0.8	6.2	2
moisture content	%	19	15	28	-	34	-	-	-	-	-
Carbon Content											
total inorganic carbon	% by wt	0.4	0.2	0.6	1	0.7	0.7	0.2	-	-	1
total organic carbon	% by wt	< 0.1	< 0.1	0.7	0.7	0.8	1.6	-	0.2	0.4	2
General Organics											
total recoverable hydrocarbons	mg/kg	< 100	200	500	406	700	555	-	-	-	-
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	< 0.5	-	< 0.5	-	-	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	91	28	140	-	32	-	-	-	-	-
Total Metals											
aluminum (Al)	ug/g	2,800	1,200	4,440	9,560	4,680	10,900	45,300	22,200	78,600	3
arsenic (As)	ug/g	3.2	2.9	3.8	4.8	**6.4** [I]	5.5	-	1.6	1.9	2
barium (Ba)	ug/g	44	20	105	172	159	188	537	443	540	3
beryllium (Be)	ug/g	< 1	< 1	0.4	< 1	0.6	< 1	0.3	0.3	1.1	3
boron (B)	ug/g	-	-	< 2	-	18	-	-	-	-	-
cadmium (Cd)	ug/g	< 0.5	< 0.5	0.1	< 0.5	0.2	< 0.5	< 0.5	< 0.5	**1.8** [I]	3
calcium (Ca)	ug/g	3,900	1,900	15,300	24,700	19,200	17,600	15,600	8,900	34,000	3
chromium (Cr)	ug/g	5.2	2.4	12.9	18.1	20.7	21.2	31.3	11.3	36	4
cobalt (Co)	ug/g	4	2	5.6	7	8.1	8	12.5	2	18.5	4
copper (Cu)	ug/g	4	< 2	7.4	12	17.1	15	8.1	2.6	26.5	4
iron (Fe)	ug/g	7,400	5,200	12,200	14,500	19,700	16,200	13,600	10,900	25,400	3
lead (Pb)	ug/g	< 5	< 5	5.5	9	9.3	10	3.5	< 1	7.8	4
magnesium (Mg)	ug/g	1,700	900	4,690	7,400	6,530	6,700	4,677.5	2,700	13,100	4
manganese (Mn)	ug/g	210	140	233	329	496	386	224	189	353	3
mercury (Hg)	ug/g	< 0.1	< 0.1	< 0.04	0.04	0.1	0.04	0.03	0.01	0.03	3
molybdenum (Mo)	ug/g	< 1	< 1	0.3	< 1	0.4	< 1	-	< 1	< 1	2
nickel (Ni)	ug/g	7	4	12.6	17	19.4	19	13.9	7.1	22.2	4
potassium (K)	ug/g	330	150	1,250	1,840	1,910	2,040	-	9,000	12,700	2
selenium (Se)	ug/g	< 0.2	< 0.2	0.7	0.4	1	< 0.1	< 1	-	-	1
silver (Ag)	ug/g	< 1	< 1	< 0.1	< 1	< 0.1	< 1	-	< 0.5	< 0.5	2
sodium (Na)	ug/g	< 100	< 100	121	186	169	216	7,600	5,200	9,200	3
strontium (Sr)	ug/g	20	12	41	65	58	57	128	126	155	3
thallium (Tl)	ug/g	< 1	< 1	0.1	-	0.2	-	-	-	-	-
titanium (Ti)	ug/g	42	25	44.4	41	35.6	47	1200	900	2,140	3
uranium (U)	ug/g	< 40	< 40	0.7	-	1.1	-	-	-	-	-
vanadium (V)	ug/g	9	4	19.1	24	28.8	28	34.9	24.9	65.7	4
zinc (Zn)	ug/g	< 10	< 10	35.7	59.6	71.4	70.5	33.6	16.8	48.5	4
Target PAHs and Alkylated PAHs											
naphthalene	ng/g	0.93	0.64	10	17	8	34	-	-	-	-
C1 subst'd naphthalenes	ng/g	1.6	0.56	**34** [I]	20	**21** [I]	**27** [I]	-	-	-	-
C2 subst'd naphthalenes	ng/g	3.3	1.1	62	30	35	32	-	-	-	-
C3 subst'd naphthalenes	ng/g	6.1	0.65	54	31	35	44	-	-	-	-
C4 subst'd naphthalenes	ng/g	6.6	0.5	34	< 2	33	< 5	-	-	-	-
acenaphthene	ng/g	0.094	< 0.13	< 3	< 2	< 2	4	-	-	-	-
C1 subst'd acenaphthene	ng/g	0.21	< 0.07	2	< 0.4	1	< 0.4	-	-	-	-
acenaphthylene	ng/g	< 0.11	< 0.077	< 1	< 1	< 1	< 1	-	-	-	-

Table 5.9 Sediment Quality in the Athabasca River Upstream of the Muskeg River, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical							
				West		East		Other (1975 - 1997)[c]			
		West	East	2000[a]	1998[b]	2000[a]	1998[b]	median	min	max	n
anthracene	ng/g	*0.13	*0.081	< 1	< 1	< 4	< 4	-	-	-	-
dibenzo(a,h)anthracene	ng/g	< 0.38	< 0.29	< 3	< 2	< 3	< 5	-	-	-	-
benzo(a)anthracene/chrysene	ng/g	4.8	1.6	*23	13	31	23	-	-	-	-
C1 subst'd benzo(a)anthracene/chrysene	ng/g	37	5.6	190	< 1	410	< 1	-	-	-	-
C2 subst'd benzo(a)anthracene/chrysene	ng/g	11	3	64	< 1	150	< 1	-	-	-	-
benzo(a)pyrene	ng/g	*1.1	< 0.37	8	5	8	*10	-	-	-	-
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	3.9	< 0.23	< 4	< 4	< 9	< 6	-	-	-	-
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	2.1	< 0.39	< 5	< 2	< 9	< 3	-	-	-	-
benzofluoranthenes	ng/g	4.5	1.5	32	*11	28	18	-	-	-	-
benzo(g,h,i)perylene	ng/g	1.4	*0.48	9	6	15	*10	-	-	-	-
biphenyl	ng/g	0.41	0.32	4	< 1	3	< 1	-	-	-	-
C1 subst'd biphenyl	ng/g	< 0.052	< 0.036	< 2	< 1	< 3	< 1	-	-	-	-
C2 subst'd biphenyl	ng/g	< 0.031	< 0.035	< 1	< 0.4	< 3	< 1	-	-	-	-
dibenzothiophene	ng/g	*0.16	< 0.082	< 1	1	*3	< 2	-	-	-	-
C1 subst'd dibenzothiophene	ng/g	0.38	< 0.085	5	9	27	15	-	-	-	-
C2 subst'd dibenzothiophene	ng/g	2.1	0.32	33	< 3	190	< 7	-	-	-	-
C3 subst'd dibenzothiophene	ng/g	7.8	1.5	42	< 1	300	< 3	-	-	-	-
C4 subst'd dibenzothiophene	ng/g	3	1.2	< 4	-	< 3	-	-	-	-	-
fluoranthene	ng/g	1.4	0.39	7	4	5	*6	-	-	-	-
C1 subst'd fluoranthene/pyrene	ng/g	6.6	1.9	49	16	89	31	-	-	-	-
C2 subst'd fluoranthene/pyrene	ng/g	13	3	82	-	150	-	-	-	-	-
C3 subst'd fluoranthene/pyrene	ng/g	7.8	3.5	78	-	160	-	-	-	-	-
fluorene	ng/g	*0.19	*0.16	*2	3	< 1	*2	-	-	-	-
C1 subst'd fluorene	ng/g	0.35	< 0.098	< 2	< 1	< 3	< 1	-	-	-	-
C2 subst'd fluorene	ng/g	1.9	< 0.12	< 2	< 1	41	< 1	-	-	-	-
C3 subst'd fluorene	ng/g	2.7	< 0.13	< 4	-	< 7	-	-	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	*1.2	*0.48	11	< 7	13	< 7	-	-	-	-
phenanthrene	ng/g	1.6	0.38	20	10	10	10	-	-	-	-
C1 subst'd phenanthrene/anthracene	ng/g	5.9	0.74	50	30	70	60	-	-	-	-
C2 subst'd phenanthrene/anthracene	ng/g	6	0.82	50	30	120	60	-	-	-	-
C3 subst'd phenanthrene/anthracene	ng/g	6.5	< 0.2	30	40	170	80	-	-	-	-
C4 subst'd phenanthrene/anthracene	ng/g	7.9	< 0.1	40	30	140	90	-	-	-	-
1-methyl-7-isopropyl-phenanthrene (Retene)	ng/g	19	1.8	90	-	60	-	-	-	-	-
pyrene	ng/g	3.3	0.64	15	7	11	13	-	-	-	-

[a] Based on information from Golder (2001a).
[b] Based on information from Golder (1999b).
[c] Based on information from Allen and Jackson (1978), Lutz and Hendzel (1977).

Note: Bolded concentrations are higher than the relevant sediment quality guideline.
[I] = concentration higher than the interim sediment quality guideline (CCME 1999).
[P] = concentration higher than the probable effects level defined by CCME (1999).
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data / no guideline.
*PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
nt = not toxic.

Table 5.10 Sediment Quality in the Athabasca River Upstream of Fort Creek, Fall

Parameter	Units	Fall 2001		Fall Historical							
				West		East		Other (1975 - 1997)[c]			
		West	East	2000[a]	1998[b]	2000[a]	1998[b]	median	min	max	n
Particle Size											
percent sand	%	67	74	98	43	69	74	-	30.5	66	2
percent silt	%	18	16	< 1	36	23	15	-	14.3	36.8	2
percent clay	%	15	10	2	21	8	11	-	19.7	32.7	2
moisture content	%	24	24	21	-	23	-	1.2	-	-	1
Carbon Content											
total inorganic carbon	% by wt	0.7	0.3	0.1	1	0.4	0.8	0.8	0.5	2.1	4
total organic carbon	% by wt	0.6	0.8	2.7	2	4	0.7	1.1	0.3	1.7	5
General Organics											
total recoverable hydrocarbons	mg/kg	400	400	200	900	7,700	581	1,190	-	-	1
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	0.6	-	0.8	-	-	-	-	-
total extractable hydrocarbons (C11-C30)	mg/kg	170	290	7	-	1600	-	-	-	-	-
Total Metals											
aluminum (Al)	ug/g	10,600	7,200	1,850	9,440	3,440	7,630	31,900	7,790	49,800	3
arsenic (As)	ug/g	4.6	3.5	2.3	5.6	1.7	4.1	3.5	2.6	5.1	4
barium (Ba)	ug/g	147	118	43.1	178	94.5	138	560	144.5	680	3
beryllium (Be)	ug/g	< 1	< 1	< 0.2	< 1	0.4	< 1	1.3	< 1	1.9	3
boron (B)	ug/g	-	-	5	-	8	-	-	-	-	-
cadmium (Cd)	ug/g	< 0.5	< 0.5	< 0.1	< 0.5	0.1	< 0.5	-	0.04	< 0.5	2
calcium (Ca)	ug/g	15,400	13,500	8,070	24,400	16,500	19,400	18,550	17,200	20,400	3
chromium (Cr)	ug/g	22.5	20.3	5.8	17.2	11.1	15.7	**46 (l)**	20.2	**72 (l)**	4
cobalt (Co)	ug/g	7	5	4	8	5.4	6	12	7	13	3
copper (Cu)	ug/g	9	8	4.3	16	7.9	10	8.9	3.5	15	4
iron (Fe)	ug/g	15,400	12,800	8,030	16,100	12,100	12,800	14,700	10,700	20,800	4
lead (Pb)	ug/g	6	5	3.7	9	5	8	4	2.5	8	4
magnesium (Mg)	ug/g	6,400	5,700	2,410	7,530	5,020	6,500	6,365	6,300	8,300	3
manganese (Mn)	ug/g	340	280	184	419	261	293	259.5	101	382	4
mercury (Hg)	ug/g	< 0.1	< 0.1	< 0.04	0.1	< 0.04	0.03	0.05	0.01	< 0.1	6
molybdenum (Mo)	ug/g	< 1	< 1	0.2	< 1	0.3	< 1	< 1	-	-	1
nickel (Ni)	ug/g	17	14	7.9	20	12.9	14	16	8.1	23.5	4
potassium (K)	ug/g	1,780	1,210	355	1,690	948	1,420	1,395	-	-	1
selenium (Se)	ug/g	0.4	0.3	0.4	0.6	< 0.2	0.3	-	0.1	0.5	2
silver (Ag)	ug/g	< 1	< 1	< 0.1	< 1	< 0.1	< 1	< 1	-	-	1
sodium (Na)	ug/g	100	< 100	61	146	105	384	6,700	137	8,100	3
strontium (Sr)	ug/g	53	43	21	73	46	52	153	53	190	3
thallium (Tl)	ug/g	< 1	< 1	< 0.1	-	0.1	-	-	-	-	-
titanium (Ti)	ug/g	70	87	47.7	22	31.3	36	2,200	18	2,700	3
uranium (U)	ug/g	< 40	< 40	0.3	-	0.6	-	-	-	-	-
vanadium (V)	ug/g	28	23	8.9	22	15.9	20	38	18.5	95	4
zinc (Zn)	ug/g	30	30	58.8	71.1	41.9	52.7	34.3	22.9	57.4	4
Target PAHs and Alkylated PAHs											
naphthalene	ng/g	2.9	2.5	4	28	24	23	10	6	21	3
C1 subst'd naphthalenes	ng/g	12	9	5	**45 (l)**	**71 (l)**	**21 (l)**	**26 (l)**	15	**27 (l)**	3
C2 subst'd naphthalenes	ng/g	14	11	13	72	65	28	35	23	35	3
C3 subst'd naphthalenes	ng/g	19	14	5	92	180	58	43	26	55	3
C4 subst'd naphthalenes	ng/g	17	14	< 2	< 4	760	< 5	39	14	55	3
acenaphthene	ng/g	*0.74	*0.48	< 2	4	**< 22 (D>l)**	*4	1	1	< 3	3
C1 subst'd acenaphthene	ng/g	1.1	0.82	< 1	< 1	< 5	< 0.4	< 20	-	-	1
acenaphthylene	ng/g	*0.33	*0.28	< 2	< 1	**<13 (D>l)**	< 1	1	0.3	< 3	3
anthracene	ng/g	*0.75	< 0.86	< 2	< 2	< 24	< 3	1	1	< 3	3
dibenzo(a,h)anthracene	ng/g	*1.1	< 1.3	< 2	< 6	**<72 (D>l)**	< 4	3	2	< 3	3

Table 5.10 Sediment Quality in the Athabasca River Upstream of Fort Creek, Fall (continued)

Parameter	Units	Fall 2001		Fall Historical							
				West		East		Other (1975 - 1997)[c]			
		West	East	2000[a]	1998[b]	2000[a]	1998[b]	median	min	max	n
benzo(a)anthracene/chrysene	ng/g	17.2	15.7	5	**46 (I)**	**410 (P)**	27	25	20	31	3
C1 subst'd benzo(a)anthracene/chrysene	ng/g	160	160	39	< 2	4300	< 1	35	-	-	1
C2 subst'd benzo(a)anthracene/chrysene	ng/g	49	40	14	< 2	1800	< 1	85	-	-	1
benzo(a)pyrene	ng/g	*5.7	*3.8	< 3	*16	**< 62 (D>I)**	< 10	6	6	9	3
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	22	21	< 4	< 3	< 83	< 8	35	-	-	1
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	10	11	< 3	< 4	< 53	< 3	35	-	-	1
benzofluoranthenes	ng/g	*15	*11	5	31	130	14	17	17	18	3
benzo(g,h,i)perylene	ng/g	6.7	5.9	< 2	14	< 67	*9	12	7	12	3
biphenyl	ng/g	2.3	1.9	< 1	< 2	< 10	< 1	< 20	-	-	1
C1 subst'd biphenyl	ng/g	< 0.1	< 0.084	< 3	< 1	< 9	< 1	< 20	-	-	1
C2 subst'd biphenyl	ng/g	0.34	0.29	< 1	< 1	< 8	< 1	< 20	-	-	1
dibenzothiophene	ng/g	1.4	1.6	< 2	5	< 13	4	3	2	97	3
C1 subst'd dibenzothiophene	ng/g	8	8.3	< 2	50	210	53	8	7	25	3
C2 subst'd dibenzothiophene	ng/g	28	28	< 3	250	2,000	320	24	22	95	3
C3 subst'd dibenzothiophene	ng/g	64	59	< 4	< 3	5,300	< 2	200	-	-	1
C4 subst'd dibenzothiophene	ng/g	110	100	< 2	-	< 31	-	< 20	-	-	1
fluoranthene	ng/g	4.2	2.7	< 2	11	*11	5	6	6	8	3
C1 subst'd fluoranthene/pyrene	ng/g	32	25	10	50	570	33	45	-	-	1
C2 subst'd fluoranthene/pyrene	ng/g	45	48	8	-	890	-	-	-	-	-
C3 subst'd fluoranthene/pyrene	ng/g	54	45	14	-	1,100	-	-	-	-	-
fluorene	ng/g	1.2	1.3	< 2	*7	< 19	< 3	4	3	4	3
C1 subst'd fluorene	ng/g	< 0.7	0.38	< 2	< 3	< 9	< 2	< 20	-	-	1
C2 subst'd fluorene	ng/g	30	35	< 2	< 3	< 25	< 2	45	-	-	1
C3 subst'd fluorene	ng/g	17	18	< 3	-	< 49	-	-	-	-	-
indeno(1,2,3,cd)pyrene	ng/g	*5.3	*3.7	< 3	< 11	< 35	< 12	8	6	11	3
phenanthrene	ng/g	9.6	7.7	2	30	< 23	20	20	10	20	3
C1 subst'd phenanthrene/anthracene	ng/g	31	26	< 2	110	190	100	50	30	60	3
C2 subst'd phenanthrene/anthracene	ng/g	36	32	8	140	1,200	150	100	90	120	3
C3 subst'd phenanthrene/anthracene	ng/g	31	33	6	230	2,800	210	160	140	160	3
C4 subst'd phenanthrene/anthracene	ng/g	25	23	9	720	2,300	60	230	70	300	3
1-methyl-7-isopropyl-phenanthrene (Retene)	ng/g	37	28	13	-	280	-	-	-	-	-
pyrene	ng/g	8.4	6.3	3	22	**130 (I)**	12	12	10	12	3

(a) Based on information from Golder (2001a).
(b) Based on information from Golder (1999b).
(c) Based on information from Allan and Jackson (1978), Crosley (1996), Lutz and Hendzel (1977).

Note: Bolded concentrations are higher than the relevant sediment quality guideline.
I = concentration higher than the interim sediment quality guideline (CCME 1999).
P = concentration higher than the probable effects level defined by CCME (1999).
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data / no guideline.
*PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
nt = not toxic.

Table 5.11 Sediment Quality in the Athabasca River Upstream of the Embarras River and in the Athabasca Delta, Fall

Parameter	Units	Embarras River					Delta						
		Fall 2001	Fall Historical (1976-2000)[a]				Fall 2001			Fall Historical (1975-2000)[b]			
			median	min	max	n	Big Point	Goose Island	Fletcher	median	min	max	n
Particle Size													
percent sand	%	50	-	31	99.4	2	64	22	70	-	10	14	2
percent silt	%	34	-	0.01	46.5	2	26	58	18	-	58	64	2
percent clay	%	16	-	0.5	22.5	2	10	20	12	-	22	32	2
moisture content	%	30	30	-	-	1	30	34	28	-	-	-	-
Carbon Content													
total inorganic carbon	% by wt	0.7	0.7	0.4	0.8	3	0.6	0.8	0.6	0.9	0.1	1.3	10
total organic carbon	% by wt	1	0.8	0.2	1.5	4	1.2	1.2	0.6	1.7	0.03	2	10
General Organics													
total recoverable hydrocarbons	mg/kg	500	725	-	-	1	600	700	1,400	-	700	800	2
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	0.5	-	-	1	7	10	5.3	< 0.5	-	-	1
total extractable hydrocarbons (C11-C30)	mg/kg	210	110	-	-	1	200	250	500	81	-	-	1
Total Metals													
aluminum (Al)	ug/g	9,390	33,900	12,300	51,100	3	4,390	4,890	11,000	46,600	8,850	67,700	10
arsenic (As)	ug/g	4.6	4.9	2.1	5.2	4	4.7	4.8	**6.2** [I]	4.4	1.9	**6.2** [I]	11
barium (Ba)	ug/g	140	890	168.3	1250	3	142	169	140	680	166	1130	10
beryllium (Be)	ug/g	0.5	1.3	0.7	2	3	0.5	0.7	0.6	1.9	0.5	3	10
boron (B)	ug/g	12	20.8	-	-	1	10	14	16	-	13	27	2
cadmium (Cd)	ug/g	0.2	-	0.2	**< 1** [D>I]	2	0.3	0.2	0.2	0.3	0.2	< 0.5	3
calcium (Ca)	ug/g	19,200	21,575	14,900	23,000	3	19,700	22,400	14,800	25,650	3,300	38,800	10
chromium (Cr)	ug/g	16.7	**54.6** [I]	3	**85** [I]	4	16.1	19.5	18.2	**92** [P]	24	**120** [P]	11
cobalt (Co)	ug/g	6.8	12	7.5	21	3	7.8	7.9	8	15.5	6	29	10
copper (Cu)	ug/g	10.4	7.7	1.8	15.5	4	11.3	12.6	9	14.8	0.3	33.6	11
iron (Fe)	ug/g	14,200	18,600	13,900	23,600	3	16,100	17,500	15,000	20,600	5,800	32,700	11
lead (Pb)	ug/g	6.2	4.5	1.3	8.2	4	6.7	7.1	6.4	7.5	< 1	10.2	11
magnesium (Mg)	ug/g	6,570	7,927.5	5,700	10,300	3	7,340	8,260	5,540	9,365	1,800	14,500	10

Table 5.11 Sediment Quality in the Athabasca River Upstream of the Embarras River and in the Athabasca Delta, Fall (continued)

Parameter	Units	Embarras River					Delta						
		Fall 2001	Fall Historical (1976-2000)[a]				Fall 2001			Fall Historical (1975-2000)[b]			
			median	min	max	n	Big Point	Goose Island	Fletcher	median	min	max	n
manganese (Mn)	ug/g	337	346	179	366.3	3	367	410	245	413	71	722	11
mercury (Hg)	ug/g	0.1	0.04	0.01	0.1	3	0.1	0.1	0.1	0.05	0.01	0.1	11
molybdenum (Mo)	ug/g	0.5	1.5	-	-	1	0.3	0.3	0.3	-	< 1	1.8	2
nickel (Ni)	ug/g	17.9	11.9	6	32.8	4	19.2	20.5	18.8	20.8	4.2	49.7	11
potassium (K)	ug/g	1,530	2,352.5	-	-	1	1,360	1,740	1,810	-	1,400	3,630	2
selenium (Se)	ug/g	1.2	0.7	-	-	1	1.2	1.1	1	0.6	0.3	0.8	3
silver (Ag)	ug/g	< 0.1	0.2	-	-	1	< 0.1	< 0.1	< 0.1	-	0.1	< 1	2
sodium (Na)	ug/g	157	8,900	251.5	9,600	3	164	196	204	7,400	100	8,900	10
strontium (Sr)	ug/g	52	182	63.3	189	3	56	64	50	175.5	69	197	10
thallium (Tl)	ug/g	0.2	0.2	-	-	1	0.2	0.2	0.2	0.3	-	-	1
titanium (Ti)	ug/g	38.4	2,700	54	2,900	3	24.6	33.3	67	2,800	26	3,900	10
uranium (U)	ug/g	0.8	1.1	-	-	1	0.8	0.9	0.8	-	1.3	< 40	2
vanadium (V)	ug/g	23	38	34.7	112	3	20.5	25.4	28.9	88.5	18	156	11
zinc (Zn)	ug/g	50	35.3	11	55.9	4	58.3	63.2	50	57.2	9.6	71	11
Target PAHs and Alkylated PAHs													
naphthalene	ng/g	4.6	20	-	-	1	5	5.1	4.7	-	19	24	2
C1 subst'd naphthalenes	ng/g	17	**30** [I]	-	-	1	18	18	14	-	**35** [I]	**40** [I]	2
C2 subst'd naphthalenes	ng/g	24	37	-	-	1	24	23	19	-	43	49	2
C3 subst'd naphthalenes	ng/g	29	44	-	-	1	26	28	26	-	48	54	2
C4 subst'd naphthalenes	ng/g	30	27	-	-	1	22	25	21	-	< 4	32	2
acenaphthene	ng/g	0.32	**< 7.7** [D>I]	-	-	1	< 0.24	0.64	0.46	-	< 1	**< 10** [D>I]	2
C1 subst'd acenaphthene	ng/g	1.3	2.6	-	-	1	1.4	1.6	1.3	-	3	4	2
acenaphthylene	ng/g	< 0.47	**< 13** [D>I]	-	-	1	< 0.39	< 0.2	< 0.28	-	< 4	**< 8** [D>I]	2
anthracene	ng/g	< 0.75	< 5.5	-	-	1	< 0.61	< 0.63	< 1.1	-	< 3	< 4	2
dibenzo(a,h)anthracene	ng/g	1.4	< 5.5	-	-	1	2	< 2.3	< 2	-	< 5	< 6	2

Table 5.11 Sediment Quality in the Athabasca River Upstream of the Embarras River and in the Athabasca Delta, Fall (continued)

Parameter	Units	Embarras River					Delta						
		Fall 2001	Fall Historical (1976-2000)(a)				Fall 2001			Fall Historical (1975-2000)(b)			
			median	min	max	n	Big Point	Goose Island	Fletcher	median	min	max	n
benzo(a)anthracene/chrysene	ng/g	16.8	22	-	-	1	20	24.8	13	-	26	31	2
C1 subst'd benzo(a)anthracene/chrysene	ng/g	150	188	-	-	1	180	220	220	-	36	250	2
C2 subst'd benzo(a)anthracene/chrysene	ng/g	50	68	-	-	1	60	100	76	-	15	63	2
benzo(a)pyrene	ng/g	4.3	7	-	-	1	4.1	5.7	4.1	-	6	13	2
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	32	< 8.7	-	-	1	36	26	17	-	< 11	< 15	2
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	19	< 6	-	-	1	26	8.3	7.6	-	< 4	< 13	2
benzofluoranthenes	ng/g	17	24	-	-	1	19	22	19	-	26	30	2
benzo(g,h,i)perylene	ng/g	8.8	19	-	-	1	11	9.2	8.3	-	17	20	2
biphenyl	ng/g	2.8	3.6	-	-	1	2.6	2.4	1.5	-	5	8	2
C1 subst'd biphenyl	ng/g	< 0.094	< 3.8	-	-	1	< 0.1	< 0.076	< 0.12	-	< 2	< 5	2
C2 subst'd biphenyl	ng/g	< 0.22	< 3.5	-	-	1	< 0.18	< 0.11	< 0.092	-	< 2	< 2	2
dibenzothiophene	ng/g	1.3	4.2	-	-	1	1.6	1.8	*1.1	-	3	< 3	2
C1 subst'd dibenzothiophene	ng/g	7.5	21	-	-	1	8.5	11	6.3	-	17	18	2
C2 subst'd dibenzothiophene	ng/g	33	110	-	-	1	37	46	32	-	70	75	2
C3 subst'd dibenzothiophene	ng/g	86	209	-	-	1	95	110	78	-	110	140	2
C4 subst'd dibenzothiophene	ng/g	42	< 6.8	-	-	1	64	91	68	< 5	-	-	1
fluoranthene	ng/g	2.9	5.1	-	-	1	3.2	4.4	3.5	-	7	8	2
C1 subst'd fluoranthene/pyrene	ng/g	24	57	-	-	1	31	37	35	-	43	59	2
C2 subst'd fluoranthene/pyrene	ng/g	51	105	-	-	1	64	79	77	110	-	-	1
C3 subst'd fluoranthene/pyrene	ng/g	59	99	-	-	1	70	86	80	100	-	-	1
fluorene	ng/g	*1.7	3	-	-	1	*2.0	*1.9	1.1	-	3	4	2
C1 subst'd fluorene	ng/g	3.9	< 4.6	-	-	1	5	5.7	3.4	-	< 3	< 4	2
C2 subst'd fluorene	ng/g	22	< 7.9	-	-	1	30	25	11	-	< 3	< 8	2
C3 subst'd fluorene	ng/g	23	< 7.4	-	-	1	19	22	17	< 8	-	-	1

Table 5.11 Sediment Quality in the Athabasca River Upstream of the Embarras River and in the Athabasca Delta, Fall (continued)

Parameter	Units	Embarras River					Delta						
		Fall 2001	Fall Historical (1976-2000)[a]				Fall 2001			Fall Historical (1975-2000)[b]			
			median	min	max	n	Big Point	Goose Island	Fletcher	median	min	max	n
indeno(1,2,3,cd)pyrene	ng/g	6	14	-	-	1	8.5	6.3	6.7	-	11	15	2
phenanthrene	ng/g	13	19	-	-	1	13	13	9	-	30	30	2
C1 subst'd phenanthrene/anthracene	ng/g	36	75	-	-	1	33	37	27	-	70	80	2
C2 subst'd phenanthrene/anthracene	ng/g	37	89	-	-	1	38	44	33	-	60	90	2
C3 subst'd phenanthrene/anthracene	ng/g	35	96	-	-	1	32	42	32	-	70	70	2
C4 subst'd phenanthrene/anthracene	ng/g	22	75	-	-	1	23	38	29	-	90	350	2
1-methyl-7-isopropyl-phenanthrene (Retene)	ng/g	81	50	-	-	1	41	54	48	70	-	-	1
pyrene	ng/g	7.1	15	-	-	1	9	12	11	-	15	19	2

(a) Based on information from Allan and Jackson (1976),Dobson et al. (1996), Golder (2001a).
(b) Based on information from Allan and Jackson (1976) Golder (1999b and 2001a), Lutz and Hendzel (1977).

Note: Bolded concentrations are higher than the relevant sediment quality guideline.
[I] = concentration higher than the interim sediment quality guideline (CCME 1999).
[P] = concentration higher than the probable effects level defined by CCME (1999).
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data / no guideline.
*PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
nt = not toxic.

5.2.2 Delta Sediment Chemistry

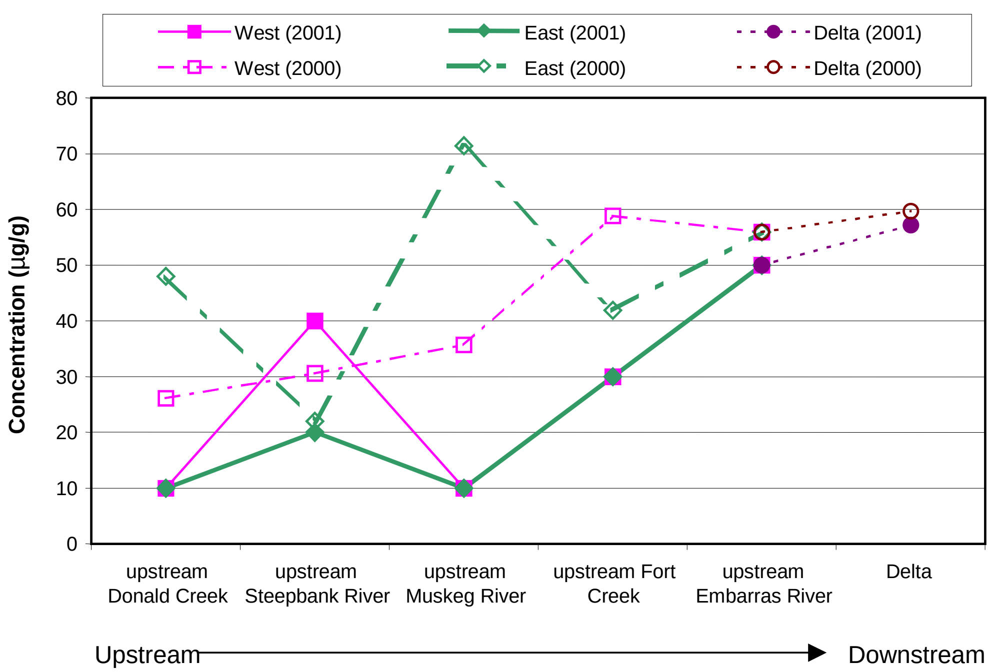
Sediment collected from Big Point Channel and Fletcher Channel consisted predominantly of sand, followed by silt and then clay (Table 5.11). Sediment from Goose Island Channel contained more silt, with similar proportions of sand and clay. The two previous sediment samples collected from the delta and analyzed for particle size consisted mainly of silt.

With the exception of arsenic levels in Fletcher channel, total metal and PAH concentrations in all three delta sediment samples were below Canadian freshwater sediment quality guidelines and generally consistent with, or lower than, parameters levels previously observed in the delta (Table 5.11).

5.2.3 Spatial Trends

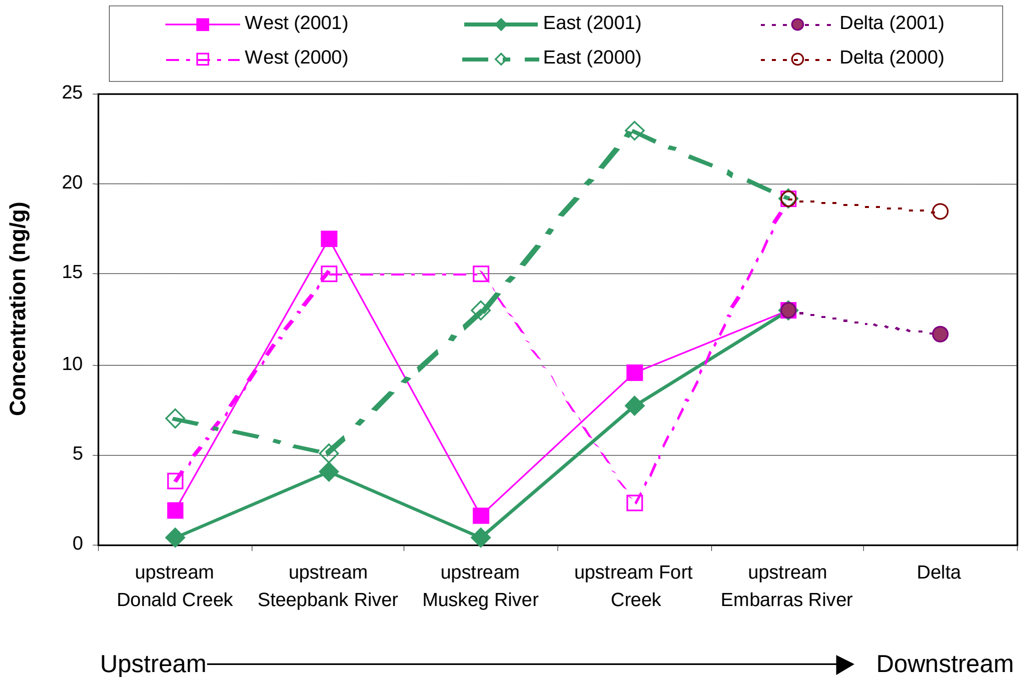
There was an increasing trend in downstream total metal and PAH concentrations in 2001 from upstream of Donald Creek to the river delta. This trend, illustrated in Figures 5.5 and 5.6 for zinc and phenanthrene, respectively, was also observed in the concentrations of most metals and PAHs. Similar trends were observed in 2000, although not as consistently as in 2001, as illustrated by phenanthrene concentrations in the west-bank samples (Figure 5.5). These types of relationships will be examined more fully as part of the five-year trend report scheduled for release in the fourth quarter of 2002.

Figure 5.5 Total Zinc Concentrations in the Athabasca River, 2000 and 2001



Concentrations below the analytical detection limit (n=2) are plotted as the detection limit.

Figure 5.6 Phenanthrene Concentrations in the Athabasca River, 2000 and 2001



Concentrations below the analytical detection limit (n=1) are plotted as the detection limit.

5.2.4 Presence of Sediment Toxicity

There is natural variability in the growth and survival of the test organisms used to detect toxic effects. In general, more than 25% of the test population must be affected before toxicity effects can be distinguished from natural variability (Dr. Stephen Goudey, HydroQual Laboratories, pers. comm.). Based on this criterion, reduced growth of *Chironomus tentans* was observed in 2001 with sediment collected from the Athabasca River upstream of the Embarras River (Table 5.12). Similarly, reduced growth and survival of *Lumbriculus variegatus* was observed in 2001 with Athabasca River sediment collected from upstream of Donald Creek (east-bank), the Steepbank River (east-bank), the Muskeg River (west bank) and the Embarras River, as well as in sediment collected from Fletcher Channel.

Historically, sediment samples collected from the Athabasca Delta in 1999 substantially affected the growth and/or survival of *L. variegatus* and *C. tentans*, and substantial reductions in the growth of *L. variegatus* were observed in 2000 with sediments from the delta and the Athabasca River upstream of the Embarras River (Table 5.12).

All of the sediment toxicity results collected to date suggest that:

- sediment toxicity, as assessed using screening level study designs, is quite variable from year to year and site to site; and
- *L. variegatus* is the most sensitive test species.

Table 5.12 Summary of Sediment Toxicity Testing Results Conducted by RAMP in the Athabasca River

Location	Site	Year	Test Species [(a)]					
			C. tentans		*H. azteca*		*L. variegatus*	
			Survival (%)	Growth (%)	Survival (%)	Growth (%)	Survival (%)	Growth (%)
upstream of Donald Creek	west bank	2001	> 100	95	94	> 100	> 100	> 100
		1998	> 100	> 100	> 100	> 100	> 100	> 100
	east-bank	2001	97	93	80	> 100	**17**	**53**
		1998	> 100	> 100	> 100	> 100	> 100	> 100
	cross-channel	1997	> 100	> 100	> 100	> 100	> 100	> 100
upstream of the Steepbank River	west bank	2001	> 100	89	94	> 100	77	> 100
	east-bank	2001	> 100	85	98	> 100	**29**	> 100
upstream of the Muskeg River	west bank	2001	> 100	83	98	> 100	**0**	**0**
		1998	> 100	> 100	> 100	> 100	> 100	> 100
	east-bank	2001	> 100	90	94	> 100	> 100	> 100
		1998	> 100	> 100	> 100	> 100	> 100	> 100
upstream of Fort Creek	west bank	2001	> 100	90	98	> 100	**60**	> 100
		2000	> 100	> 100	> 100	> 100	> 100	> 100
	east-bank	2001	79	88	98	> 100	> 100	> 100
		2000	> 100	> 100	> 100	> 100	> 100	> 100
upstream of the Embarras River	cross-channel	2001	> 100	**72**	> 100	> 100	**71**	> 100
		2000	84	96	> 100	83	> 100	**68**
Athabasca Delta	Big Point Channel	2001	82	83	> 100	77	> 100	> 100
	Goose Island Channel	2001	> 100	86	> 100	94	> 100	> 100
	Fletcher Channel	2001	> 100	91	> 100	98	**29**	> 100
	composite	2000	86	77	> 100	> 100	> 100	**53**
		1999	**42**	> 100	**72**	> 100	> 100	**62**
	Flour Bay	2000	89	86	> 100	> 100	> 100	**58**

[(a)] Based on information from Golder (1999b, 2000b and 2001a) and that derived by RAMP in 2001 based on screening level testing with inert control sediment.

Note: Bold values indicate results <75%.

L. variegatus typically tunnel in the upper zone of bed sediment (American Society of Testing and Materials 1995). For respiratory exchange, *L. variegatus* undulate their posterior portion in the water with its anterior portion buried in the sediment. Substrate composition must be suitable for maintaining tunnel structure in order for *L. variegatus* to survive. Therefore, the survival and growth of *L. variegatus* can be significantly affected by the physical characteristics of sediment, as opposed to its chemical content.

In the fall of 2000, two species of freshwater mussels, *Lampsilis radiata* and *Pyganodon grandis*, were collected from several locations within the Athabasca Delta and Lake Athabasca to examine the overall health of the organisms and their suitability for human consumption (Golder 2001c). As filter-feeders, mussels are capable of accumulating metals, PAHs and other organics (e.g., dioxins and furans) (Muir et al. 1997; Stewart and Malley 1997; Watson et al. 2000). However, Golder (2001c) found that the mussels collected from the delta and the lake did not contain high metal or PAH concentrations and concluded that they were suitable for human consumption.

Based on these study results, the sensitivity of *L. variegatus* to the physical sediment characteristics and the variability observed in the screening levels tests, it would appear that the sediment toxicity results observed by RAMP, both this year and in previous sampling events, should not be cause for concern.

5.3 FISH POPULATIONS

5.3.1 Radiotelemetry Study

This section provides the results of the radiotelemetry program for the two different sub-populations of longnose sucker. The results for the northern pike radiotelemetry are presented in the Muskeg River section (8.4.1).

A preliminary analysis of longnose sucker movements (until December 2000) was presented in the 2000 RAMP report (Golder 2001a), based on fish movements known at that time. As such, the original analysis is outdated and is replaced by the following information, including the discovery that a number of mortalities occurred for radio-tagged fish. The following analysis includes the results of the entire telemetry program from 2000 through 2001 and supercedes any previous results and conclusions.

The results of the radio-tracking surveys are presented in Appendix VII. Fish locations in the mainstem Athabasca River are presented by KP, which indicates the distance in river kilometres upstream or downstream of Fort McMurray. The Highway 63 bridge was designated as KP 0.0 with areas upstream as negative kilometres and downstream as positive kilometres (Figure 3.8). Fish locations in the Muskeg River are presented by river reach (i.e., Reach 1 to 4, see Figure 3.8). The telemetry results are also summarized in Figures 5.7 through 5.10 which provide a graphic representation of fish movements. Individual fish are identified by their transmitter frequency and code number (e.g., *ƒ*620-01).

Figure 5.7 Movements of Radio-Tagged Longnose Suckers, Athabasca River Spawners

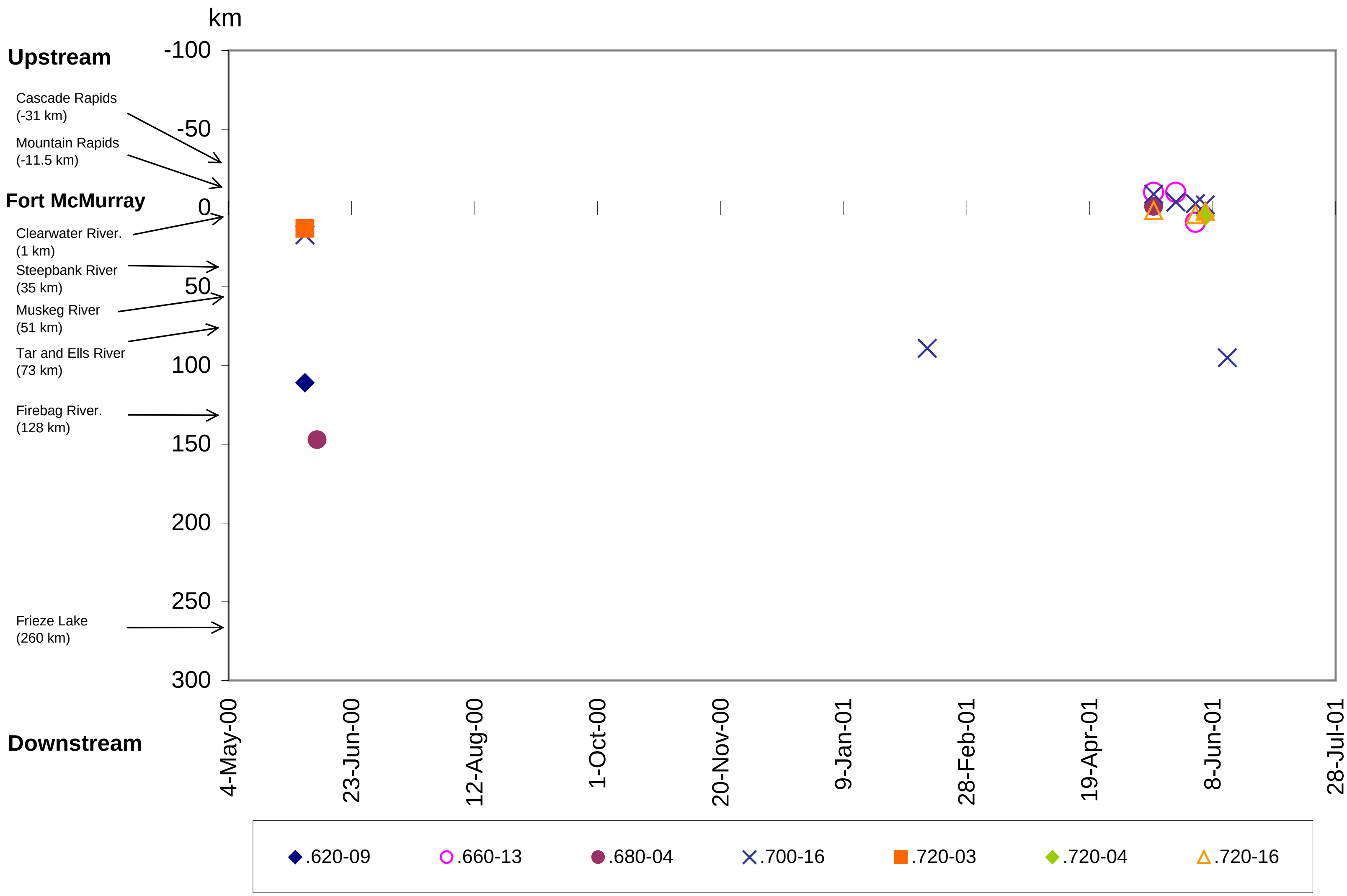


Figure 5.8 Movements of Radio-Tagged Longnose Suckers, Athabasca River Spawners

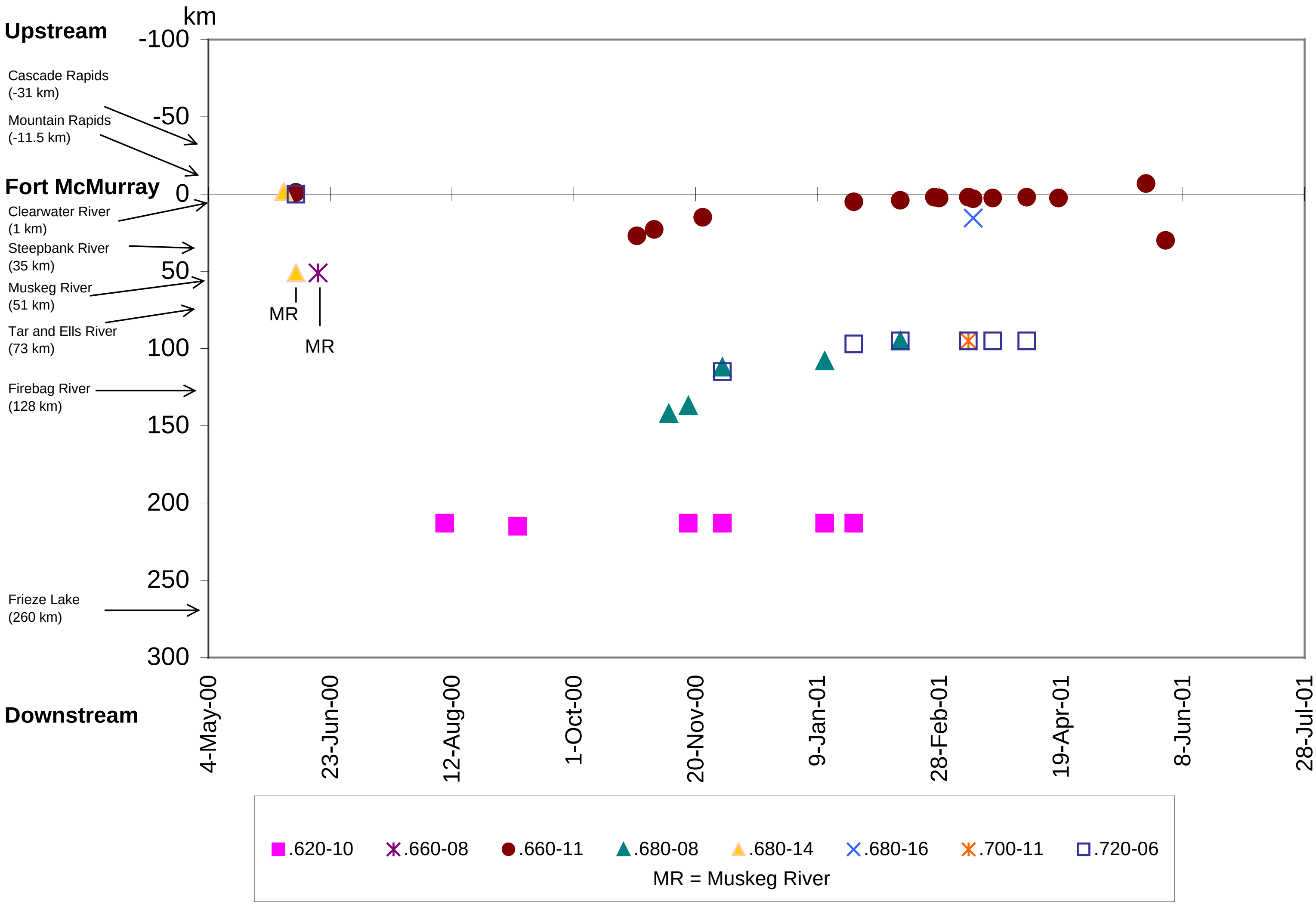


Figure 5.9 Movements of Radio-Tagged Longnose Sucker, Muskeg River Spawners

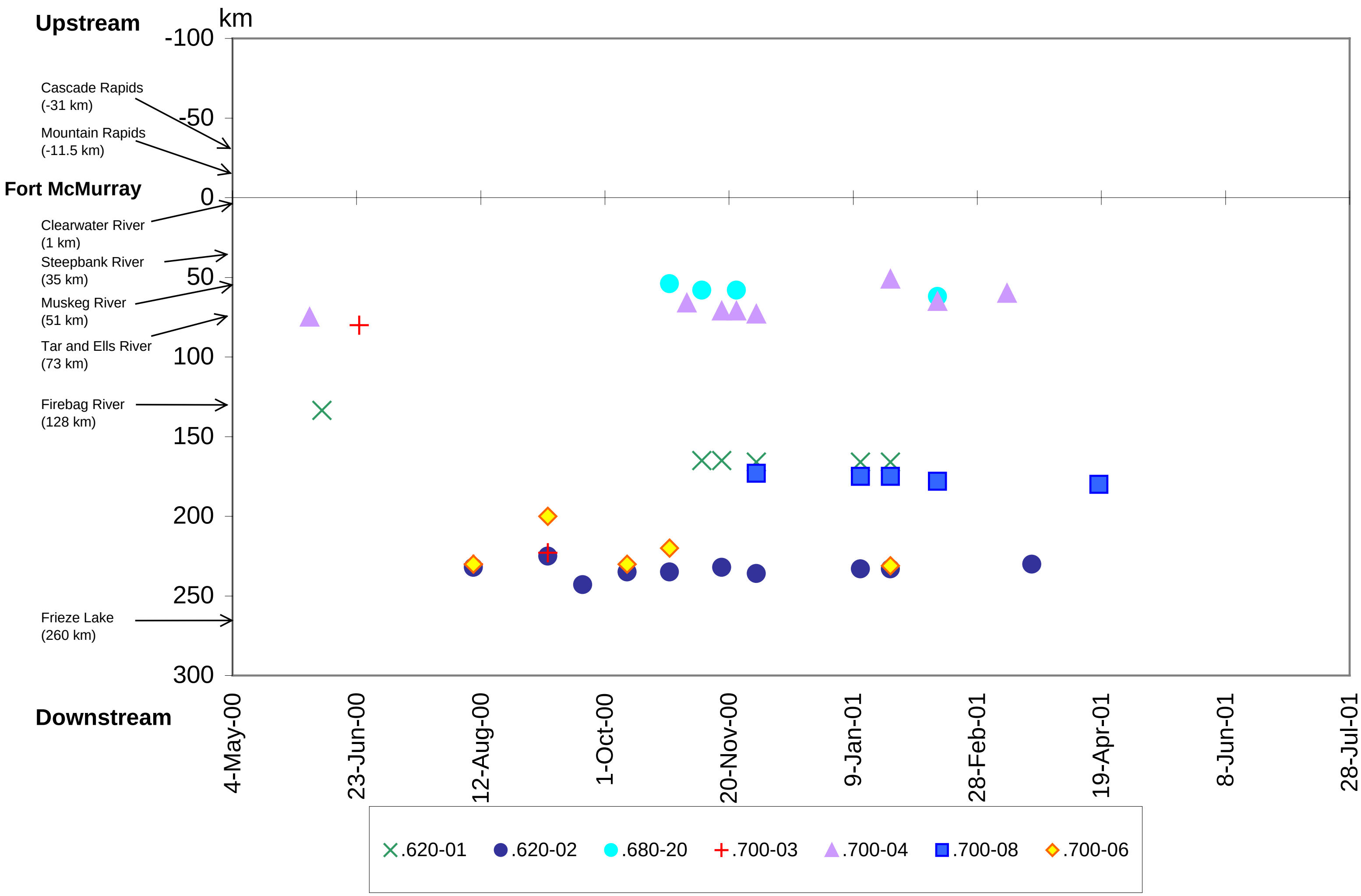
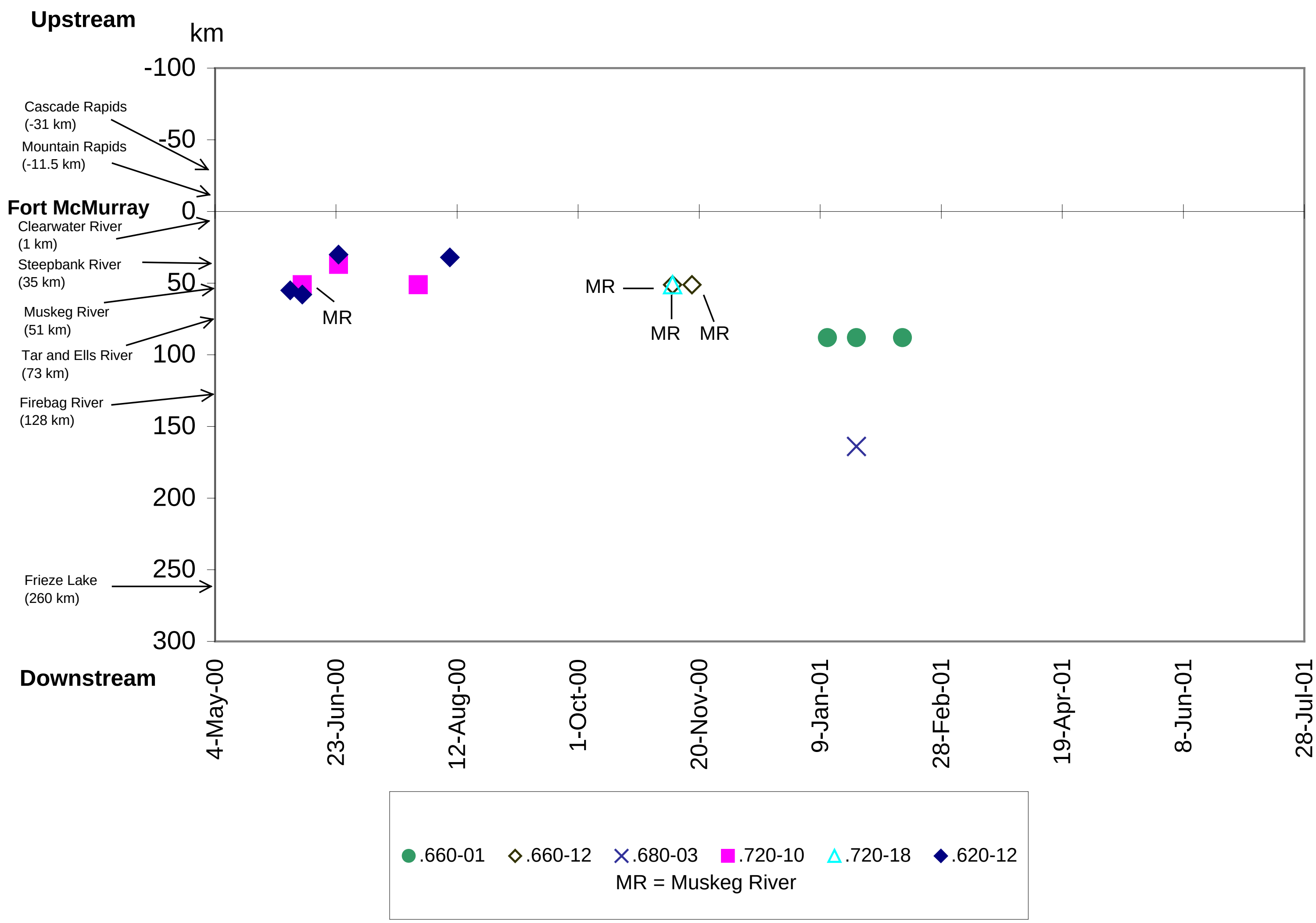


Figure 5.10 Movements of Radio-Tagged Longnose Suckers, Muskeg River Spawners



During the telemetry flights, signals were not recorded for all individual radio transmitters on every survey. For any given survey, a missing signal would have been due to either the receiver not picking up the transmitter's signal or the fish being outside the telemetry survey area.

It is recognized that radio signals may not have been recorded, despite the transmitter being present in the study area, for a variety of reasons, including blockage of signal by underwater obstructions, signal attenuation due to depth, battery failure or transmitter frequency shifts. Another reason for missing transmitter signals for fish present in the study area was the use of coded transmitters that utilize the same frequency. When a number of coded transmitters occur in the same vicinity, the receiver typically decodes and identifies a limited number of individual transmitters. Close proximity of transmitters created problems with identifying individual fish in the Muskeg River.

Transmitter signals would not have been recorded if the transmitter was not present in the survey area. Fish may have left the telemetry study area by moving up the Athabasca River past Cascade Rapids, into tributary watercourses other than the Muskeg River or downstream to Lake Athabasca. Fish may also have been removed from the study area by anglers or predators.

During the ground-based telemetry surveys in February and March of 2001, it was determined that 11 of the 50 radio-tagged longnose sucker were dead, including 8 tagged in the Muskeg River and 3 tagged in the Athabasca River. The cause of death was not known, but one possible reason for the mortalities would have been stress due to capture, holding and surgery combined with stress from spawning activities. Longnose sucker from the Athabasca River were tagged following spawning activities, whereas Muskeg River fish were tagged prior to or during spawning activities, resulting in higher mortality rates for the Muskeg River fish. As it is not known when mortalities occurred for these fish, they were removed from the analysis.

5.3.1.1 Athabasca River Spawners

In total, 25 longnose sucker were radio-tagged in the Athabasca River. Three of these fish were confirmed dead during the winter ground surveys, therefore 22 fish were used for the analysis. All 22 fish were post-spawning adults that were radio-tagged and released near Mountain Rapids (KP8) during May 16 to 18, 2000.

Of the 22 radio-tagged fish, 7 fish were not located following their release. It is possible that they moved to Lake Athabasca soon after spawning, sometime in the 19 day period between radio tagging and the first tracking flight. It is less likely that they moved upstream of the rapids or into tributary streams since the fish were not recorded in the survey area at any time during the summer, fall or winter, indicating that they did not return from further upstream or from tributary streams. However, these fish were not recorded in the Athabasca River telemetry area during the following spring spawning season and their movements remain unknown.

Telemetry locations are available for the remaining 15 radio-tagged longnose sucker and are presented by general movement pattern on Figures 5.7 to 5.10.

There were seven fish which were seldom recorded during summer, fall and winter, but some of them returned to the Athabasca River spawning area again in the spring of 2001 (Figure 5.7). These fish appeared to utilize the Athabasca River in the telemetry survey area only during the spawning period and were absent from the survey area outside of the spring period. Three of these seven fish (*ƒ*660-13, *ƒ*720-04 and *ƒ*720-16) were not recorded for almost a full year following radio-tagging in the spring of 2000. All three fish were then recorded in the spring of 2001 in the vicinity of Fort McMurray or Mountain Rapids. All three of these fish again left the survey area shortly after the 2001 spawning season. Two of these three fish were still in the Fort McMurray area June 5; however, the other fish began moving downstream by June 1, and all three fish were absent from the survey area by mid-June.

Another two of the seven fish in this group (*ƒ*620-09 and *ƒ*720-03) were only recorded on the first survey following radio-tagging in the spring of 2000 and were determined to be moving downstream. One fish was located at KP 13 and the other much further downstream at KP 111 before disappearing from the survey area. The last two fish in this group of seven (*ƒ*680-04 and *ƒ*700-16) were also recorded moving downstream immediately after spawning in the spring of 2000 before disappearing from the survey area. These fish were recorded again in the spring of 2001 upstream of Fort McMurray. Fish *ƒ*680-04 left the survey area immediately after the spawning season in 2001 while fish *ƒ*700-16 remained until June 5. Fish *ƒ*700-16 was again recorded moving downstream after the 2001 spawning season (KP 95) and was absent from the survey area by mid-June. For fish *ƒ*700-16 there is an anomaly in the form of a single location in the Athabasca River at KP 89 from February 12, 2001 which remains unexplained.

There were two radio-tagged longnose sucker that were also only in the telemetry survey area for a limited amount of time, but showed some use of the Muskeg River (Figure 5.7). Fish *ƒ*660-08 and *ƒ*680-14 both moved downstream from the rapids following spawning in 2000, then left the mainstem river and were located in the Muskeg River for a short period of time in early June. These individuals then disappeared from the study area and may have moved to Lake Athabasca, moved further up the Muskeg River or explored other tributaries. However, it is expected that if these fish were utilizing tributary areas, they would return to the telemetry survey area prior to the winter period, but this was not observed.

There was a group of six radio-tagged fish that used the Athabasca River in the Oil Sands Region other than just as a spawning area or migration route (Figure 5.7). One fish (ƒ620-10) was recorded in the vicinity of KP 213-215 at various times in the summer, fall and winter, but disappeared from the survey area in the late winter. Another three fish (ƒ660-11, ƒ680-08 and ƒ720-06) left the survey area soon after the 2000 spawning season, but returned to the Athabasca River in the fall or early winter. It is possible that these fish had moved upstream of the rapids or into tributaries other than the Muskeg River and returned to the mainstem river for overwintering. Based on where these fish were found in the fall, it is possible that they represent a portion of the longnose sucker population that, following spawning activity in the mainstem river, utilize tributary streams in the Oil Sands Region for the remainder of the spring and summer before returning to the Athabasca River. Two of these three fish spent the entire winter period in the Athabasca River while the third left the survey area in mid-February.

The final two fish in this group of six (ƒ680-16 and ƒ700-11) were only recorded once during the telemetry surveys. Fish ƒ680-16 was found at KP 15.5 during the winter ground survey on March 13. Although likely present, this fish was not recorded on the previous days telemetry flight, suggesting problems with the transmitter and its effective range. The only record for fish ƒ700-11 was the March 12 flight where it was found at KP 95. Although nothing else is known about the movements of these two fish following spawning, they were found to be overwintering, at least in part, in the mainstem river.

Although a few different movement patterns were evident from the telemetry results, the Athabasca River spawning sub-population of longnose sucker appears to use the mainstem river in the Oil Sands Region primarily as a spring migration route to and from spawning sites at rapids located upstream of Fort McMurray. The majority (16 out of 22) of radio-tagged fish were only recorded in the telemetry survey area during spring spawning, although two of these fish also visited the Muskeg River before leaving the survey area. All 16 fish were radio tagged following spawning upstream of Fort McMurray in 2000 and five of these fish returned to the rapids area during the spawning season in 2001, after which they again left the survey area. Although a few fish were recorded moving downstream after spawning in 2000 and in 2001, the frequency of telemetry flights was not high enough to record whether the fish moved to Lake Athabasca. Although it is not known exactly where fish outside the telemetry survey area went, the results do show that the majority of radio-tagged longnose sucker were present in the survey area and utilized the mainstem Athabasca River in the Oil Sands Region only during the spawning period in the spring.

A smaller proportion (6 out of 22) of the radio-tagged longnose sucker remained in the Athabasca River basin for a prolonged period of time, particularly in the fall and winter. These fish either utilized specific locations in the mainstem river from summer to winter, or are speculated to have used tributary streams other than the Muskeg River during the open water period, returning to the Athabasca River for the winter. Some fish remained in the mainstem river for the winter while others left the survey area later in the winter, possibly moving to Lake Athabasca.

5.3.1.2 Muskeg River Spawners

In total, 25 longnose sucker were radio-tagged in the Muskeg River. Eight of these fish were confirmed dead during the winter ground surveys, therefore 17 fish were used for the analysis. The 17 fish were a mix of pre-spawning and post-spawning adults that were radio-tagged and released in the lower Muskeg River during the period May 26 to June 1, 2000.

Of the 17 radio-tagged longnose sucker, four fish were never recorded on any of the radio-tracking surveys (ƒ620-18, ƒ660-17, ƒ660-20 and ƒ680-12). These fish left the telemetry survey area soon after tagging and presumably moved downstream to Lake Athabasca, upstream past Cascade Rapids or into tributary streams other than the Muskeg River. It is possible that they returned to the lake soon after spawning, sometime in the 19-day period between radio tagging and the first tracking flight. It is less likely that they moved further up the Muskeg River, to the Athabasca River above the rapids or into other tributary streams. The fish were not recorded in the survey area at any time during the summer, fall or winter, indicating that they did not return from further upstream or from tributary streams. However, these fish were not recorded during the following spring spawning season and their movements remain unknown.

Telemetry locations are available for the remaining 13 radio-tagged longnose sucker and are presented by general movement pattern on Figures 5.9 and 5.10.

Two of the 13 radio-tagged fish (ƒ660-12 and ƒ720-18) were present in the Muskeg River in early November (Figure 5.8). These fish were not recorded before or after November. It is possible that they were in the Muskeg River through the open water period, but their signals were masked by the large number of transmitters present in this area. It is not possible to confirm the movements for these fish but they may represent a portion of the longnose sucker population that utilizes the Muskeg River for spring spawning and summer feeding habitat.

Another two of the 13 radio-tagged fish were recorded to leave the Muskeg River in the spring (Figure 5.8). Fish ƒ620-12 was present in the Athabasca River near the Muskeg River mouth in early June, while fish ƒ720-10 remained in the Muskeg River in early June but was present in the Athabasca River by late June. Both of these fish moved upstream a short distance (KP 30-37) before disappearing from the survey area in August. It is not known if these fish continued up the Athabasca River, entered other tributaries or moved downstream to Lake Athabasca.

The remaining nine radio-tagged longnose sucker exhibited more extensive use of the Athabasca River and are believed to have utilized the Athabasca River basin for much of the year (Figures 5.9 and 5.10). All of these fish were either not recorded or were recorded on only a few of the surveys during the open-water period, but returned to the Athabasca River in the survey area during the winter. Their full movements during the summer are not known but it is speculated that they may have utilized tributaries in the basin other than the Muskeg River and returned to the Athabasca River for the winter.

Two of the nine fish (ƒ620-01 and ƒ700-04) remained in the Muskeg River for a short time after spawning but were present in the Athabasca River in June. Fish ƒ620-01 was recorded moving down the Athabasca River (KP 133) soon after the spring spawning season, after which it left the survey area until returning to the mainstem river at KP 165 in November. It remained in the river in the vicinity of KP 165 for the early winter before again disappearing from the study area. This fish may have utilized a tributary in the lower Athabasca River during the summer and fall. Fish ƒ700-04 left the Muskeg River for the Athabasca River immediately after spawning. It was recorded at KP 75 in early June but was not recorded again until early November at KP 66. This fish may have utilized a tributary in the Oil Sands Region during the summer and fall.

Another three longnose sucker (ƒ620-02, ƒ700-03 and ƒ700-06) in this group of nine were not recorded for the first few surveys following the spring spawning season until they were found in the Athabasca River in late July or early August. During the spring, these fish were either present, but not identified, in the Muskeg River or were outside the survey area. They utilized the lower Athabasca River (KP 200-243) in the summer and fall. Fish ƒ700-03 left the survey area in early September, while fish ƒ620-02 and ƒ700-06 remained to overwinter in the Athabasca River.

The final four longnose sucker in this group of nine fish were not recorded for an extended period following spawning and were absent from the survey area through the spring, summer and fall. All four fish were found in the mainstem Athabasca River in the winter. Fish ƒ660-01 spent the early winter in the vicinity of KP 88 before leaving the survey area in February. Fish ƒ680-03 was recorded only once in January at KP 164. Fish ƒ680-20 overwintered in the Oil Sands Region (KP 54-62) until leaving the survey area in February. Fish ƒ700-08 overwintered in the lower Athabasca River at KP 173-180.

Compared to longnose sucker that spawned in the mainstem Athabasca River, Muskeg River spawners exhibited greater use of the Athabasca River basin. In total, 11 of the 17 radio-tagged fish are known or believed to have utilized the Athabasca River and/or its tributaries during much of the year. A small number of the fish radio-tagged in the Muskeg River (2 of 17 fish) may have used the Muskeg River for summer feeding in addition to spring spawning. Another nine fish were speculated to use the Athabasca River basin outside the telemetry survey area and were known to return to the mainstem river in the survey area in the fall or early winter. These fish spent all or part of the winter in the river, with some leaving the survey area in the late winter.

The remaining six of the 17 radio-tagged longnose sucker left the telemetry survey area soon after spawning. Four fish left immediately, while two fish moved from the Muskeg River to the Athabasca River in the spring and then left the survey area for the remainder of the study. It is possible that these fish only utilized the river basin for spawning activity.

5.3.1.3 Recommendations

The telemetry flights determined the periods when fish were outside the survey area but did not always show exactly where they went, particularly with respect to fish moving to Lake Athabasca. In order to improve results for future RAMP radiotelemetry work, it is recommended that the frequency of flights be increased and/or telemetry shore stations be used. More frequent flights would help in following large-scale fish movements that may occur over short periods. Strategically placed shore stations would also help track movements and could be used to monitor movements into major tributaries, if identifying specific tributaries was a goal of the study. Radio-tagging fish during spawning activities should be avoided, whenever possible, to reduce mortalities. Transmitters with mortality sensors to identify dead fish are also recommended. Although coded radio transmitters are necessary for projects involving large numbers of radio-tagged fish, the number of frequencies used should be increased to reduce transmitter masking when clumping of radio-tagged fish occurs. Transmitters should be tested in the Athabasca River to determine the depth at which signal attenuation occurs.

5.3.2 Fish Tissue Collection

Results of the fish measurements for and examinations of the 10 walleye and 10 lake whitefish used in the tissue collection study for the Athabasca River are presented in Appendix VIII. Tissue concentrations were compared between 2001 and previous sampling in 1998. Female lake whitefish and walleye collected in 1998 for tissue analysis were slightly smaller relative to those collected in 2001, while male lake whitefish and walleye from 1998 were within the same size range as those collected in 2001 (Table 5.13). All fish used for tissue analysis in 2001 were adults.

Table 5.13 Range of Size and Age of Walleye and Lake Whitefish Used for Tissue Collection from the Athabasca River, 1998 and 2001

Species	Sex	*n*	Fork Length (mm)		Age (years)	
			Min	Max	Min	Max
2001 – Oil Sands Region						
LKWH	female	5	422	482	10	19
	male	5	421	493	8	25
WALL	female	5	504	611	7	17
	male	5	396	482	6	12
1998 – Oil Sands Region						
LKWH	female	4	390	466	N/A	N/A
	male	3	425	462	N/A	N/A
WALL [(a)]	female	4	423	508	7	12
	male	6	403	498	6	12
WALL [(b)]	female	3	442	647	7	15
	male	4	415	475	8	14
1998 – Reference Area						
WALL	female[(c)]	2	324	448	6	6
	male	4	374	506	5	10

(a) Samples collected in spring 1998.
(b) Samples collected in fall 1998.
(c) Fish sampled were juvenile (life stage).

Note: LKWH = Lake whitefish.
WALL = Walleye.
N/A = Not aged.

Complete results by species and sex for the tissue analyses of the composite samples are presented in Appendix VIII. Table 5.14 presents the results for the analyses that showed concentrations above the parameter detection limits. Results are provided on the basis of wet tissue weight. In the discussion that follows, results from the 2001 survey are compared to results from previous sampling efforts (i.e., 1998).

Table 5.14 Tissue Concentrations of Metals Detected in Walleye and Lake Whitefish from the Athabasca River, Fall 2001

Parameter	Units	Detection Limit	Lake Whitefish		Walleye		Fish Consumption Guideline[(a)]
			Female (n=5)	Male (n=5)	Female (n=5)	Male (n=5)	
aluminum (Al)	mg/kg	4	7	<	<	<	1,400
antimony (Sb)	mg/kg	0.04	<	<	0.05	<	0.54
barium (Ba)	mg/kg	0.08	0.14	<	0.15	0.09	95
cadmium (Cd)	mg/kg	0.08	0.08	0.09	<	0.11	1.4
calcium (Ca)	mg/kg	10	100	120	100	160	-
chromium (Cr)	mg/kg	0.2	0.5	0.5	<	0.5	4.1
copper (Cu)	mg/kg	0.08	0.32	0.45	0.36	0.32	54
iron (Fe)	mg/kg	2	10	16	15	11	410
lead (Pb)	mg/kg	0.04	0.04	0.08	<	0.15	-
magnesium (Mg)	mg/kg	2	243	299	261	289	-
manganese (Mn)	mg/kg	0.04	0.21	0.22	0.12	0.24	190
mercury (Hg)	mg/kg	0.01	0.11	0.11	0.46	0.36	0.2[(b)], 0.5[(c)]
nickel (Ni)	mg/kg	0.08	0.65	1.22	0.26	0.56	27
phosphorus (P)	mg/kg	2	2,210	2,250	1,210	2,460	-
potassium (K)	mg/kg	2	3,000	3,580	3,550	3,520	-
selenium (Se)	mg/kg	0.2	0.5	0.5	0.4	0.6	6.8
sodium (Na)	mg/kg	2	305	327	215	227	-
strontium (Sr)	mg/kg	0.04	0.12	0.12	0.1	0.11	810
tin (Sn)	mg/kg	0.08	<	<	0.12	<	810
titanium (Ti)	mg/kg	0.05	0.83	0.48	0.11	0.49	5,400
thallium (Tl)	mg/kg	0.04	<	<	0.04	<	0.095
vanadium (V)	mg/kg	0.08	0.12	0.17	<	0.14	9.5
zinc (Zn)	mg/kg	0.2	4.8	3.3	7.4	4.3	410

(a) U.S. EPA Risk Based Criteria Table, Dated May 2001 (unless otherwise indicated).
(b) Health and Welfare Canada 1999 value (subsistence consumption) (Wheatley 1999).
(c) Health Canada 1981 value (occasional consumption).
Note: < = below the detection limit.
- = no guideline provided.

PAHs were not detected in the composite flesh samples of lake whitefish or walleye captured from the Athabasca River in the fall of 2001. The results indicate that these fish populations have not accumulated PAHs in their muscle tissue. Previous assessments in the Athabasca River in the fall of 1998 found naphthalene and methyl naphthalene at concentration of 0.01 mg/kg in male and female longnose sucker and naphthalene at a concentration of 0.01 mg/kg in female walleye (Golder 1999b). All other PAHs were below detection limits in the 1998 assessment. Given that the detection limit for PAHs in the 1998 fall study was lower (0.01 mg/kg) than in 2001 (0.02 mg/kg), and that there are currently only two years of walleye data available for comparison, the fish tissue results to date are insufficient to indicate a trend in PAH concentrations over time. However, the results do indicate that PAHs are not found at high concentrations in the muscle tissue of fish captured in the Athabasca River.

A summary of the concentrations of detectable inorganic compounds in walleye and lake whitefish tissues is shown in Table 5.14. Where possible, these concentrations were compared to fish consumption guidelines (Health Canada 1981; U.S. EPA 2001) and data regarding deleterious effects levels for fish (Jarvinen and Ankley 1999). With the exception of mercury, all of the metals were below guideline levels, and several (arsenic, beryllium, cobalt, lithium, molybdenum and silver) were below the limit of detection.

Health Canada and other organizations (e.g., World Health Organization) have calculated acceptable guidelines for mercury in fish for human consumption; these guidelines are based on the level of mercury that does not cause detectable health effects in humans (this level is called the tolerable daily intake, or TDI). The guidelines of 0.5 milligram mercury per kilogram of fish for occasional consumption, and 0.2 milligram of mercury per kilogram of fish for subsistence consumption, were derived using a TDI level of 0.48 microgram per kilogram body weight, and an estimate of the quantity of food ingested for each type of consumption pattern (WHO 1990, Wheatley 1999). A person eating an average of 402 g (0.89 lbs) or approximately 4 servings of fish per week over their lifetime is considered an occasional level consumer, while a person eating about 1005 g (2.22 lbs) or approximately 10 servings of fish per week is a subsistence level consumer (John Salminen, Health Canada, pers comm.).

None of the samples collected to date by RAMP have had mercury concentrations above the Health Canada (1981) guideline value of 0.5 mg/kg for occasional consumption, though the concentration of mercury in the female walleye sample collected in 2001 (0.46 mg/kg) was close. The concentrations of mercury in all of the walleye samples collected in 1998 and 2001 were at or above the guideline value of 0.2 mg/kg for subsistence consumption (Figure 5.11). Mercury concentrations in walleye samples collected in 2001 (0.36 to 0.46 mg/kg) were slightly higher than those collected from the same area in 1998 (0.2 to 0.29 mg/kg). However, walleye from the reference area sampled in 1998 were found to contain mercury at concentrations ranging from 0.33 to 0.37 mg/kg. Therefore, the 2001 results do not likely represent an increasing trend from oil sands exposure. Rather, the results are likely indicative of the natural variability in mercury concentrations in fish inhabiting this region.

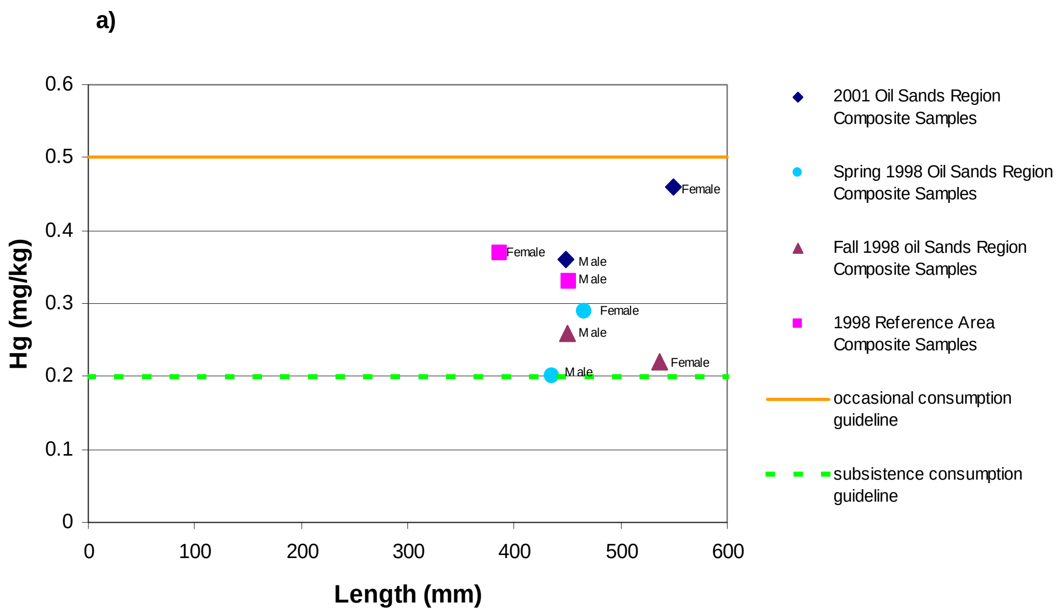
Mercury concentrations in fish will typically increase with both age and size (Donald et al. 1996). This relationship is a function of the uptake of mercury in fish, which occurs through the gills and by ingestion of contaminated food. Uptake is more rapid than elimination, which can take from months to years.

Consequently, mercury concentrations increase with age (Jackson 1991). Though a relationship between mercury concentrations and either size or age was not found in this study (Fig 5.11), the sample composed of fish with the highest mean age and mean length had the highest concentration of mercury.

Mercury may accumulate in fish as a result of exposure to natural sources in soils and sediments rather than anthropogenic activities (Eisler 1987). The levels of mercury found in walleye tissue in the Oil Sands area are within the range of mercury concentrations found in previous studies conducted in the Oil Sands Region (including reference areas), as well as other areas of Alberta (Dillon 2001; Donald et al. 1996; Golder 1999b; AEC 1983).

Tissue concentrations from the Athabasca River were also compared to deleterious effects levels, where these data were available for fish (Table 5.15). In the first instance, literature data from adult fish muscle were used for comparison. Where these were not available, data from juvenile fish muscle, or adult whole body residues. Fish data were not available for calcium, iron, magnesium, phosphorus, potassium and sodium, as these are inorganic compounds essential for normal cell function in all vertebrate animals. The concentrations of all of these compounds were essentially similar between the male and female samples, and also between the lake whitefish and walleye samples. Deleterious effect data were also not available for barium, manganese, selenium, strontium, titanium, thallium and vanadium.

Figure 5.11 Fish Tissue Mercury Concentrations as a Function of a) Mean Length and b) Mean Age for Walleye Collected in 1998 and 2001



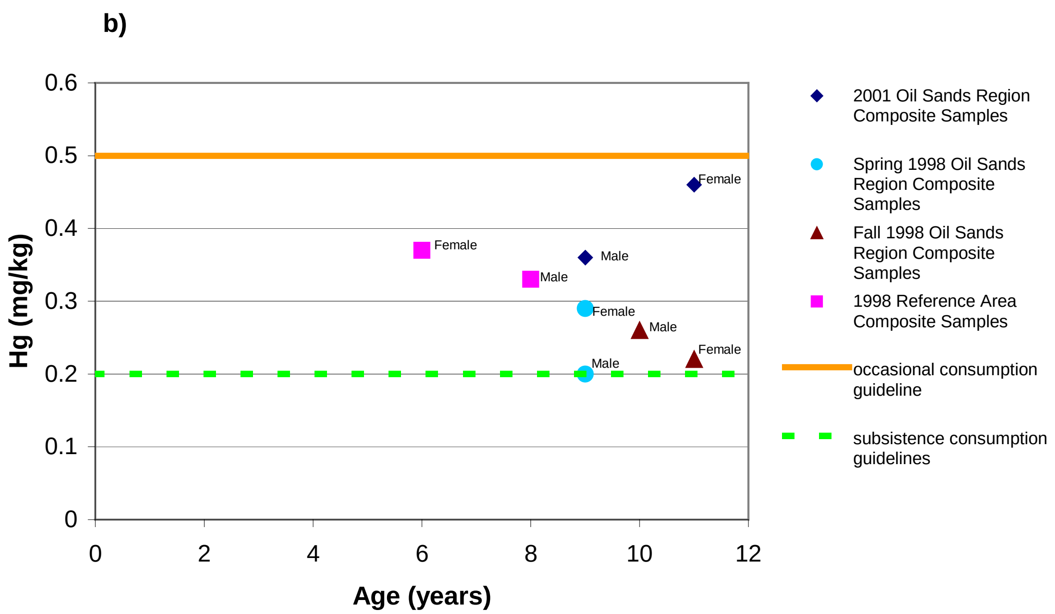


Table 5.15 Toxicity and Tissue Residue Data

Parameter	Tissue Concentration[a] (mg/kg)	Species	Life Stage	Tissue Analyzed	Endpoint	Direction of Effect
aluminum (Al)	8.53	rainbow trout	subadult	whole body less gut	survival	no effect
antimony (Sb)	5	rainbow trout	fingerling	whole body	survival	no effect
	9					reduced, 50%
cadmium (Cd)	0.08	rainbow trout	subadult	muscle	survival	no effect
	0.6	rainbow trout	adult	muscle	reproduction	reduced
chromium (Cr)	0.58	rainbow trout	adult	muscle	survival	no effect
copper (Cu)	0.5	rainbow trout	subadult	muscle	survival	reduced, 63%
	0.5		subadult			no effect
	0.4	tilapia	adult	muscle	survival, growth	no effect
lead (Pb)	4	rainbow trout	underyearlings	carcass	survival	no effect
mercury (Hg)	0.7	rainbow trout	subadult	muscle	survival	reduced
	2.4-2.9		fingerling	edible flesh	survival	reduced, 10%
	0.5	chum salmon	fry-juvenile	muscle	growth	no effect
	5.8				survival	no effect
	9.2	brook trout	yearling-adult	muscle	reproduction	no effect
nickel (Ni)	0.82	rainbow trout	subadult	muscle	survival	no effect
tin (Sn)	1.05	carp	20 to 28 g	muscle	survival	no effect
	1.21	sheepshead minnow	juvenile	muscle	survival, growth, reproduction	no effect
zinc (Zn)	13.6	dogfish	adult	muscle	survival	reduced
	60	Atlantic salmon	juvenile	whole body	survival, growth	no effect

[a] All data from Jarvinen and Ankley (1999).

Aluminum was detected in the female lake whitefish sample at a concentration of 7 mg/kg. Similar concentrations in whole body analyses of adult rainbow trout (*Oncorhynchus mykiss*) have shown no effects on fish survival (Jarvinen and Ankley 1999).

Antimony was detected in the female lake whitefish sample at a concentration of 0.05 mg/kg. This concentration is well below the whole body concentrations that have been found in fingerling rainbow trout showing reduced survival in laboratory experiments (Jarvinen and Ankley 1999).

Cadmium was detected in the male and female lake whitefish and the male walleye samples at concentrations ranging from 0.08 to 0.11 mg/kg. Similar muscle concentrations of cadmium have not been found to affect survival of adult rainbow trout, and are below the concentration that has been shown to reduce reproductive success in rainbow trout (Jarvinen and Ankley 1999).

Chromium was detected in the male and female lake whitefish samples and in the male walleye at a concentration of 0.5 mg/kg. Available deleterious effects data on chromium were limited to potassium dichromate residues in adult rainbow trout muscle, where a concentration of 0.58 mg/kg was shown to have no effects on fish survival (Jarvinen and Ankley 1999).

Copper was detected in all lake whitefish and walleye samples, at concentrations ranging from 0.32 to 0.45 mg/kg. Muscle copper concentration in fish does not appear to be well correlated with effects on survival, with experiments showing both reduced survival and no effects on survival of adult rainbow trout at a muscle concentration of 0.5 mg/kg (Jarvinen and Ankley 1999). An experiment on tilapia (*Oreochromis mossambicus*) indicated no effects on survival at a muscle copper concentration of 0.4 mg/kg.

Lead was detected in the female and male lake whitefish samples and in the male walleye sample at concentrations ranging from 0.04 to 0.15 mg/kg. The limited data available indicate that these concentrations are below those that would have an impact on survival of fish (Jarvinen and Ankley 1999).

Mercury was detected in all walleye and lake whitefish samples at concentrations ranging from 0.11 to 0.46 mg/kg. These concentrations are below those that have been linked with reduced survival of subadult and fingerling rainbow trout and reduced growth and survival of juvenile chum salmon (*Oncorhynchus keta*) (Jarvinen and Ankley 1999). They are also below concentrations shown to reduce reproduction in yearling-adult brook trout (*Salvelinus fontinalis*) (Jarvinen and Ankley 1999).

Nickel was detected in all fish samples at concentration ranging from 0.26 to 1.22 mg/kg. A muscle concentration of 0.82 mg/kg has not been shown to affect survival of adult rainbow trout (Jarvinen and Ankley 1999).

Tin was detected in the female walleye sample only at a concentration of 0.12 mg/kg. Tissue residue data for tin were mainly limited to di- and tributyl tins and antifouling paints, where effects on survival in fish are seen at whole body and muscle residue concentrations in excess of 2 mg/kg (Jarvinen and Ankley 1999).

Zinc was detected in all fish samples, at concentrations ranging from 3.3 to 7.4 mg/kg. These muscle concentrations were below those that have been linked with reduced survival in adult dogfish (*Scyliorhinus canicula*). Similarly, no effects on survival and growth in juvenile Atlantic salmon (*Salmo salar*) have been shown at whole body zinc concentrations up to 60 mg/kg (Jarvinen and Ankley 1999).

In summary, the fall 2001 muscle concentrations from the Athabasca River were found to be below those reported to be linked with effects on growth and survival of fish. However, the experimental data for copper was inconclusive with respect to assessing the potential effects of the measured concentrations for this parameter.

There are no consistent trends over time in the inorganic parameters measured in walleye and whitefish. For example, cadmium, chromium and vanadium were detected in 2001 fish, but not in 1998 fish, whereas strontium appears to have decreased in concentration in both species over the 1998 to 2001 period. It is difficult to assess whether the Oil Sands Region is affecting the concentrations of inorganics in fish tissue. There are currently only two years of data available for comparison. Also, apparent increases or decreases in individual contaminants over time are not always consistent between fish species and sexes.

5.3.2.1 Recommendations

To increase the utility of among-year comparisons of tissue analyses, it is recommended that the size range of adult fish used for tissue collection be restricted to increase the probability of using fish of similar size and age. Existing fork length and age data from the Athabasca River inventory study should be used to provide the recommended size range for fish tissue collections.

It is also recommended that tissue samples from each individual fish sample be archived for a short period, pending analysis of composite samples, in case analysis of individual tissues is warranted.

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6.1 WATER QUALITY

As discussed in Section 3.1.3.4, RAMP is currently collecting samples from the Clearwater River to establish baseline conditions in this river. As a result, the following discussion presents an overall description of water quality in the Clearwater River, as opposed to a strict comparison of the 2001 sample results to historical data.

6.1.1 Clearwater River, Downstream of the Christina River

The Clearwater River, downstream of the Christina River, was sampled several times throughout 2001 to define baseline conditions and characterize seasonal variability. Monitoring results showed that the Clearwater River waters tend to be slightly alkaline, with median pH values ranging from 7.3 to 8 (Table 6.1). DO concentrations tend to be lowest in summer (i.e., median of 8.7 mg/L) and highest in winter (i.e., median of 12.5 mg/L). Historically, DO levels in the Clearwater River have been recorded below chronic aquatic guidelines. Water temperatures in the Clearwater River have a median range of 0.1 to 17.5°C. Although there was a paucity of field measured data in 2001, results are generally consistent with historical data.

In 2001, TDS concentrations were lower, relative to historical records during winter (Table 6.1) with a concentration (i.e., 120 mg/L) below the minimum historical range (Figure 6.1). Historically, TDS concentrations tend to be lowest in fall and highest in winter. In 2001, TDS levels peaked in fall, reaching a concentration of 150 mg/L (Figure 6.1).

Historically, hardness levels are also lowest in the spring and highest in winter (Table 6.1). However, hardness levels in 2001 were low in winter and spring, below historical minimum ranges (Figure 6.2). Hardness ranged from 39 to 68 mg/L in 2001, peaking in fall.

In general, colour, TOC and dissolved organic carbon (DOC) concentrations in the Clearwater River were characteristic of streams with light brown colour. These parameters were typically lowest during winter and increased through spring, summer and fall. Historically, median colour levels range from 22 to 53 Total Colour Units (TCU). In previous years, median TOC and DOC concentration ranged from 6 to 17 mg/L. In 2001, Clearwater River colour, TOC and DOC levels were consistent with historical data. Sulphide was detected in summer of 2001 and was higher than chronic aquatic life guidelines.

Table 6.1 Water Quality in the Clearwater River, Downstream of the Christina River

Parameter	Units	Winter					Spring					Summer					Fall				
		2001	Historical (1973-2000) [(a)]				2001	Historical (1976-2000) [(a)]				2001	Historical (1976-2000) [(a)]				2001	Historical (1976-2000) [(a)]			
			median	min	max	n		median	min	max	n		median	min	max	n		median	min	max	n
Field Measured																					
pH		7.8	7.3	6.6	8.1	19	-	7.8	6.9	8.2	5	-	7.9	7.1	8.5	18	8.1	8	7.5	8.45	9
specific conductance	uS/cm	-	316	180	408	18	-	203	14	360	7	-	183	81	360	20	269	190	54	326	11
temperature	^{o}C	-	0.1	0	0.1	21	-	11.6	1	14	8	-	17.5	12.5	25.5	21	14	8.65	1	14	12
dissolved oxygen	mg/L	-	12.5	11.4	13.4	23	-	10.9	9.9	11.5	4	-	8.7	**6.3** (C)	13.5	20	9.9	10.4	6.9	13.9	11
Conventional Parameters																					
colour	T.C.U.	30	22	9	45	19	60	46	19	80	4	50	50	24	115	11	30	53	24	120	8
conductance	uS/cm	199	309	200	425	29	155	198	150	340	9	233	200	129	354	25	272	191	130	331	15
dissolved organic carbon	mg/L	3	6	1	15	28	8	10	7	12	9	11	11	7	28	23	8	12	6	20	14
hardness	mg/L	47	67	52	90	20	39	54	44	109	4	62	60	42	99	15	68	60.5	49.3	75	9
pH		7.2	7.5	7	8.2	30	7.6	7.8	7.3	8	9	7.8	7.6	6.3	9.6	25	7.9	7.46	7.18	8.1	15
total alkalinity	mg/L	47	70	52	86	30	40	57	50	95	9	60	64	45	89	25	71	57	48	82	15
total dissolved solids	mg/L	120	180	132	251	28	120	132	78	220	9	140	135	77	223	25	150	116	89	200	15
total organic carbon	mg/L	4	7	1	16	19	10	11	7	14	7	11	13	8	29	19	9	17	8	83	11
total suspended solids	mg/L	3	5	< 0.3	23	29	34	25	5	322	9	66	40	5	1751	25	8	21	7	204	15
Major Ions																					
bicarbonate	mg/L	57	89	82	105	13	49	-	61	76	2	73	75	69	90	8	87	85	65	100	5
calcium	mg/L	12	18	13	25	30	10	14	11	30	9	16	16	12	24	25	18	16	12	20	15
chloride	mg/L	27	47	28	72	30	18	25	10	54	9	28	23	13	55	25	36	24	8	51	15
magnesium	mg/L	4	6	5	8	30	3	5	4	9	9	5	5	3	9	25	6	5	4	6	15
potassium	mg/L	1	1	1	1	30	1	1	1	2	9	1	1	1	2	25	1	1	0.5	1	15
sodium	mg/L	19	36	20	50	30	14	19	10	36	9	22	19	10	41	25	25	18	10	38	15
sulphate	mg/L	6	8	< 3	13	30	4	7	< 5	19	9	7	8	0.1	19	25	8	7	2	27	15
sulphide	mg/L	< 0.003	-	-	-	-	< 0.003	-	-	-	-	**0.012** (C)	-	-	-	-	< 0.003	-	-	-	-
Nutrients and Chlorophyll *a*																					
nitrogen - ammonia	mg/L	0.07	0.065	< 0.01	0.11	12	< 0.05	-	-	-	-	< 0.05	-	0.02	0.02	2	< 0.05	< 0.01	-	-	1
nitrogen, total [(b)]	mg/L	0.4	0.4	0.3	**1.1** (C)	26	0.7	0.6	0.3	**2.5** (C)	7	0.6	0.6	0.3	**2.6** (C)	24	< 0.2	0.6	0.3	**1.2** (C)	15
phosphorus, total	mg/L	0.048	0.046	0.028	**< 0.1** (D>C)	30	**0.077** (C)	**0.075** (C)	0.037	**0.33** (C)	9	0.03	**0.063** (C)	0.022	**0.215** (C)	25	0.035	**0.065** (C)	0.036	**0.32** (C)	15
phosphorus, dissolved	mg/L	0.041	0.025	0.016	0.034	13	0.06	-	0.02	0.024	2	0.03	0.025	0.008	0.052	8	0.022	0.02	0.01	0.068	5
chlorophyll *a*	ug/L	< 1	0.6	0.3	< 1	5	16	-	8.2	8.4	2	3	4.4	< 1	7.1	9	6	4	< 1	7.9	7
Biological Oxygen Demand																					
biochemical oxygen demand	mg/L	< 2	0.4	0.2	1	19	3	< 1	-	-	1	< 2	-	1	2	2	< 2	< 0.1	-	-	1
General Organics																					
naphthenic acids	mg/L	< 1	-	-	-	-	-	-	-	-	-	< 1	-	-	-	-	< 1	-	-	-	-
total phenolics	mg/L	0.001	0.003	< 0.001	**0.012** (C)	27	**.015** (C)	0.004	< 0.001	**0.008** (C)	8	0.003	0.003	< 0.001	**0.011** (C)	24	0.002	0.004	< 0.001	**0.009** (C)	13
total recoverable hydrocarbons	mg/L	< 0.5	0.2	> 0.1	2	17	< 0.5	0.6	0.3	1.1	7	-	0.4	> 0.1	2.6	22	< 0.5	0.7	> 0.2	3	14
Metals (Total)																					
aluminum (Al)	mg/L	**0.15** (C)	-	0.03	0.04	2	**0.88** (A,C)	-	-	-	-	**1.04** (A,C)	-	**0.36** (C)	**0.43** (C)	2	**0.14** (C)	**0.38** (C)	-	-	1
antimony (Sb)	mg/L	**< 0.005** (D>H)	-	-	-	-	**< 0.005** (D>H)	-	-	-	-	**< 0.005** (D>H)	-	-	-	-	**< 0.005** (D>H)	-	-	-	-
arsenic (As)	mg/L	< 0.001	0.0002	< 0.0002	0.0007	12	< 0.001	-	0.0006	0.0006	2	< 0.001	0.0009	0.0003	< 0.005	9	< 0.001	0.0007	0.0004	0.004	6
barium (Ba)	mg/L	0.016	0.02	0.019	0.025	12	0.023	0.021	-	-	1	0.026	0.018	0.00003	0.03	6	0.019	0.02	0.017	0.02	3
beryllium (Be)	mg/L	< 0.001	-	< 0.001	< 0.001	2	< 0.001	-	-	-	-	< 0.001	-	0.001	0.002	2	< 0.001	< 0.001	-	-	1
boron (B)	mg/L	0.02	0.06	-	-	1	0.04	-	-	-	-	0.04	-	0.05	30	2	0.05	0.03	-	-	1
cadmium (Cd)	mg/L	< 0.0002	**< 0.001** (D>C)	< 0.0002	**0.002** (A,C)	13	< 0.0002	-	**< 0.001** (D>C)	**0.002** (A,C)	2	< 0.0002	**< 0.001** (D>C)	**< 0.0002** (D>C)	**0.003** (A,C)	8	< 0.0002	**< 0.001** (D>C)	**< 0.0002** (D>C)	**< 0.001** (D>C)	5
chromium (Cr)	mg/L	**0.002** (C)	**0.002** (C)	< 0.001	**0.007** (C)	12	**0.002** (C)	-	< 0.001	**0.003** (C)	2	< 0.0008	**0.0025** (C)	< 0.001	**0.009** (C)	8	0.0008	**0.004** (C)	< 0.001	**0.013** (C)	5
cobalt (Co)	mg/L	< 0.0002	< 0.001	< 0.001	0.005	11	0.0006	-	< 0.001	< 0.001	2	0.0008	0.001	0.0009	0.014	8	0.0011	< 0.001	0.0007	< 0.001	5
copper (Cu)	mg/L	0.001	< 0.001	< 0.001	**0.004** (C)	12	0.002	-	< 0.001	< 0.001	2	0.002	0.002	< 0.001	**0.026** (A,C)	8	< 0.001	< 0.001	< 0.001	**0.003** (C)	5
iron (Fe)	mg/L	**0.85** (C,H)	**0.9** (C,H)	**0.74** (C,H)	**1.05** (C,H)	11	**2.35** (C,H)	-	-	-	-	**1.93** (C,H)	-	**1.88** (C,H)	**2.04** (C,H)	2	**0.66** (C,H)	**1.83** (C,H)	-	-	1

Table 6.1 Water Quality in the Clearwater River, Downstream of the Christina River (continued)

Parameter	Units	Winter					Spring					Summer					Fall				
		2001	Historical (1973-2000) (a)				2001	Historical (1976-2000) (a)				2001	Historical (1976-2000) (a)				2001	Historical (1976-2000) (a)			
			median	min	max	n		median	min	max	n		median	min	max	n		median	min	max	n
lead (Pb)	mg/L	0.0001	-	0.0003	**0.0021 (C)**	2	0.0005	-	-	-	-	0.0011	-	0.001	**0.0014 (C)**	2	0.0002	0.0008	-	-	1
lithium (Li)	mg/L	< 0.006	0.006	-	-	1	< 0.006	-	-	-	-	0.006	-	0.004	0.006	2	0.006	0.004	-	-	1
manganese (Mn)	mg/L	**0.032 (H)**	**0.034 (H)**	**0.022 (H)**	**0.206 (H)**	13	**0.079 (H)**	-	**0.039 (H)**	**0.077 (H)**	2	**0.106 (H)**	**0.077 (H)**	**0.031 (H)**	**0.142 (H)**	8	**0.039 (H)**	**0.047 (H)**	**0.039 (H)**	**0.092 (H)**	5
mercury (Hg)	mg/L	0.000007	**< 0.0001 (D>H)**	**< 0.00004 (D>H)**	**0.0014 (C,H)**	28	< 0.0000006	**< 0.0001 (D>H)**	**< 0.0001 (D>H)**	**0.0003 (C,H)**	7	0.0000013	**< 0.0001 (D>H)**	**< 0.00005 (D>H)**	**0.0003 (C,H)**	24	0.0000007	**< 0.0001 (D>H)**	**< 0.00005 (D>H)**	**0.0008 (C,H)**	15
molybdenum (Mo)	mg/L	0.0003	0.002	< 0.001	0.007	13	0.0002	-	< 0.001	< 0.001	2	0.0003	< 0.003	< 0.001	0.007	8	0.0002	< 0.001	< 0.001	< 0.003	5
nickel (Ni)	mg/L	0.0024	0.002	< 0.001	0.0097	13	0.002	-	< 0.001	< 0.001	2	0.0024	0.004	< 0.0005	0.028	8	0.0009	0.0045	< 0.001	0.017	5
selenium (Se)	mg/L	< 0.0008	< 0.0001	< 0.0001	< 0.0002	12	< 0.0008	-	< 0.0002	< 0.0002	2	< 0.0008	< 0.0002	< 0.0002	< 0.0002	6	< 0.0008	< 0.0002	< 0.0002	< 0.0002	5
silver (Ag)	mg/L	< 0.000005	< 0.0001	-	-	1	0.000009	-	-	-	-	< 0.000005	-	< 0.0001	**0.0006 (C)**	2	< 0.000005	< 0.0001	-	-	1
strontium (Sr)	mg/L	0.08	0.11	-	-	1	0.07	-	-	-	-	0.09	-	0.08	71	2	0.11	0.06	-	-	1
thallium (Tl)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	-	-	-	< 0.0001	-	-	-	-	< 0.0001	-	-	-	-
titanium (Ti)	mg/L	0.0046	-	< 0.05	< 0.05	2	0.0037	-	-	-	-	0.0206	< 0.01	-	-	1	0.0053	-	< 0.05	< 0.05	2
uranium (U)	mg/L	< 0.0001	-	-	-	-	0.0001	-	-	-	-	0.0001	-	-	-	-	< 0.0001	-	-	-	-
vanadium (V)	mg/L	0.0008	< 0.001	< 0.001	0.008	27	0.0029	< 0.0015	< 0.001	0.006	6	0.0015	< 0.002	< 0.001	0.01	19	0.0007	< 0.002	< 0.001	0.01	13
zinc (Zn) (b)	mg/L	0.016	0.003	< 0.001	**0.033 (C)**	12	0.006	-	< 0.001	0.004	2	**0.043 (C)**	0.006	0.002	**0.096 (A,C)**	6	0.008	0.004	0.002	0.01	4
Metals (Dissolved)																					
aluminum (Al)	mg/L	< 0.01	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-	< 0.01	-	-	-	-
antimony (Sb)	mg/L	< 0.0008	-	-	-	-	< 0.0008	-	-	-	-	-	-	-	-	-	< 0.0008	-	-	-	-
arsenic (As)	mg/L	< 0.0004	0.0005	< 0.0002	0.0014	12	< 0.0004	0.0005	< 0.0005	0.0021	4	-	0.0004	< 0.0002	0.0021	6	< 0.0004	0.0007	< 0.0002	0.0018	4
barium (Ba)	mg/L	0.012	-	-	-	-	0.013	-	-	-	-	-	-	-	-	-	0.016	-	-	-	-
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.005	12	< 0.001	< 0.001	< 0.001	< 0.005	3	-	< 0.001	< 0.001	< 0.005	5	< 0.001	-	< 0.001	< 0.001	2
boron (B)	mg/L	0.02	0.06	< 0.01	0.13	6	0.03	0.09	0.03	0.11	3	-	0.1	0.02	0.21	5	0.04	0.08	0.02	0.38	5
cadmium (Cd)	mg/L	< 0.0001	0.002	-	-	1	< 0.0001	-	0.001	0.002	2	-	< 0.001	-	-	1	< 0.0001	-	-	-	-
chromium (Cr)	mg/L	0.0006	-	-	-	-	0.0008	-	-	-	-	-	-	-	-	-	< 0.0004	-	-	-	-
cobalt (Co)	mg/L	< 0.0001	0.002	-	-	1	< 0.0001	-	< 0.002	< 0.002	2	-	< 0.002	-	-	1	< 0.0001	-	-	-	-
copper (Cu)	mg/L	< 0.0006	< 0.001	-	-	1	0.0007	-	0.001	0.005	2	-	0.003	-	-	1	< 0.0006	-	-	-	-
iron (Fe)	mg/L	0.79	0.49	-	-	1	0.68	-	0.15	0.18	2	-	0.17	-	-	1	0.16	-	-	-	-
lead (Pb)	mg/L	< 0.0001	0.004	-	-	1	0.0004	-	< 0.004	< 0.004	2	-	< 0.004	-	-	1	< 0.0001	-	-	-	-
lithium (Li)	mg/L	0.004	-	-	-	-	0.005	-	-	-	-	-	-	-	-	-	0.007	-	-	-	-
manganese (Mn)	mg/L	0.033	-	-	-	-	0.022	0.007	-	-	1	-	< 0.01	-	-	1	0.011	-	-	-	-
mercury (Hg)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	-	-	-	-	-	-	-	-	< 0.0001	-	-	-	-
molybdenum (Mo)	mg/L	< 0.0001	-	-	-	-	0.0014	-	-	-	-	-	-	-	-	-	0.0002	-	-	-	-
nickel (Ni)	mg/L	0.0004	0.004	-	-	1	0.0007	-	0.006	0.007	2	-	0.002	-	-	1	< 0.0001	-	-	-	-
selenium (Se)	mg/L	< 0.0004	< 0.0003	< 0.0002	< 0.0005	11	< 0.0004	< 0.0004	< 0.0002	< 0.0005	4	-	< 0.0002	< 0.0002	< 0.0005	6	< 0.0004	< 0.0002	< 0.0002	< 0.0002	4
silver (Ag)	mg/L	< 0.0002	-	-	-	-	< 0.0002	-	-	-	-	-	-	-	-	-	< 0.0002	-	-	-	-
strontium (Sr)	mg/L	0.08	-	-	-	-	0.06	-	-	-	-	-	-	-	-	-	0.11	-	-	-	-
thallium (Tl)	mg/L	< 0.00005	-	-	-	-	< 0.00005	-	-	-	-	-	-	-	-	-	0.0001	-	-	-	-
titanium (Ti)	mg/L	0.0015	-	-	-	-	0.0011	-	-	-	-	-	-	-	-	-	0.0003	-	-	-	-
uranium (U)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	-	-	-	-	-	-	-	-	< 0.0001	-	-	-	-
vanadium (V)	mg/L	0.0005	< 0.001	-	-	1	0.0005	-	< 0.001	0.001	2	-	0.001	-	-	1	0.0005	-	-	-	-
zinc (Zn) (b)	mg/L	0.002	< 0.001	-	-	1	0.004	-	< 0.001	< 0.001	2	-	0.001	-	-	1	0.003	-	-	-	-
Target PAHs and Alkylated PAHs																					
naphthalene	ug/L	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	**< 1 (D>H)**	**< 1 (D>H)**	2	**< 0.02 (D>H)**	-	-	-	-
C1 subst'd naphthalenes	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	-	-	-
C2 subst'd naphthalenes	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C3 subst'd naphthalenes	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C4 subst'd naphthalenes	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
acenaphthene	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	< 1	< 1	2	< 0.02	-	-	-	-
C1 subst'd acenaphthene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-

Table 6.1 Water Quality in the Clearwater River, Downstream of the Christina River (continued)

Parameter	Units	Winter					Spring					Summer					Fall				
		2001	Historical (1973-2000) (a)				2001	Historical (1976-2000) (a)				2001	Historical (1976-2000) (a)				2001	Historical (1976-2000) (a)			
			median	min	max	n		median	min	max	n		median	min	max	n		median	min	max	n
acenaphthylene	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	< 1	< 1	2	< 0.02	-	-	-	-
anthracene	ug/L	**< 0.02 (D>C)**	-	-	-	-	**< 0.02 (D>C)**	-	-	-	-	**< 0.02 (D>C)**	-	**< 1 (D>C)**	**< 1 (D>C)**	2	**< 0.02 (D>C)**	-	-	-	-
dibenzo(a,h)anthracene	ug/L	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	**< 5 (D>H)**	**< 5 (D>H)**	2	**< 0.02 (D>H)**	-	-	-	-
benzo(a) anthracene/chrysene	ug/L	**< 0.02 (D>C,H)**	-	-	-	-	**< 0.02 (D>C,H)**	-	-	-	-	**< 0.02 (D>C,H)**	-	**< 1 (D>C,H)**	**< 1 (D>C,H)**	2	**< 0.02 (D>C,H)**	-	-	-	-
C1 subst'd benzo(a) anthracene/chrysene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C2 subst'd benzo(a) anthracene/chrysene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
benzo(a)pyrene	ug/L	**< 0.02 (D>C,H)**	-	-	-	-	**< 0.02 (D>C,H)**	-	-	-	-	**< 0.02 (D>C,H)**	-	**< 1 (D>C,H)**	**< 1 (D>C,H)**	2	**< 0.02 (D>C,H)**	-	-	-	-
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C2 subst'd benzo(b& k) fluoranthene/benzo(a) pyrene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
benzo(b&k)fluoranthene	ug/L	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	-	-	-
benzo(g,h,i)perylene	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	< 2	< 2	2	< 0.02	-	-	-	-
biphenyl	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C1 subst'd biphenyl	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C2 subst'd biphenyl	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
dibenzothiophene	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	-	-	-
C1 subst'd dibenzothiophene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C2 subst'd dibenzothiophene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C3 subst'd dibenzothiophene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C4 subst'd dibenzothiophene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
fluoranthene	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	**< 1 (D>C)**	**< 1 (D>C)**	2	< 0.02	-	-	-	-
C1 subst'd fluoranthene/pyrene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
fluorene	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	< 1	< 1	2	< 0.02	-	-	-	-
C1 subst'd fluorene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C2 subst'd fluorene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
indeno(c,d-123)pyrene	ug/L	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	-	-	-	**< 0.02 (D>H)**	-	**< 1 (D>H)**	**< 1 (D>H)**	2	**< 0.02 (D>H)**	-	-	-	-
phenanthrene	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	**< 1 (D>C)**	**< 1 (D>C)**	2	< 0.02	-	-	-	-
C1 subst'd phenanthrene/anthracene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C2 subst'd phenanthrene/anthracene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C3 subst'd phenanthrene/anthracene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
C4 subst'd phenanthrene/anthracene	ug/L	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-	< 0.04	-	-	-	-
pyrene	ug/L	< 0.02	-	-	-	-	< 0.02	-	-	-	-	< 0.02	-	**< 1 (D>C)**	**< 1 (D>C)**	2	< 0.02	-	-	-	-

(a) Based on information from WDS stations AB07CD0100 and AB07CD0210.
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Bolded concentrations are higher than water quality guidelines.

- A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
- C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
- H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
- D> = analytical detection limit was higher than the relevant water quality guideline(s.
- \- = no data / no guideline.

Figure 6.1 Seasonal TDS Concentration in the Clearwater River

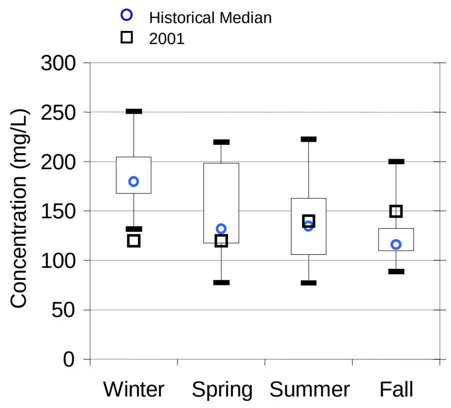
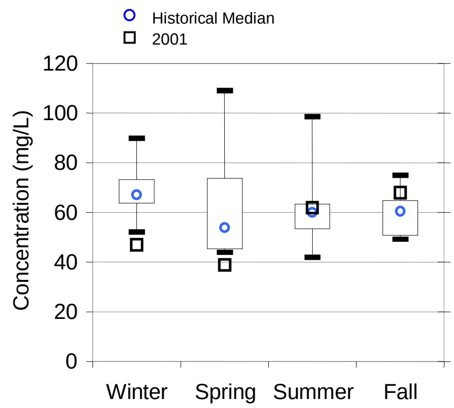


Figure 6.2 Seasonal Hardness Concentration in the Clearwater River



Note: Box indicates 25th and 75th percentiles and whiskers show minimum and maximum range of historical data.

Total phosphorus concentrations in the Clearwater River have often exceeded the chronic aquatic life guideline of 0.05 mg/L in all seasons, with the exception of winter (Table 6.1). Historically, total nitrogen levels tend to be slightly lower in winter and relatively static (i.e., ~0.6 mg/L) through the remainder of the year. Water quality in 2001 was similar, although total nitrogen was below the detection limit in fall samples. Based on total phosphorus concentrations and the definitions put forward by Wetzel (1983), the Clearwater River would be considered a moderate to productive ecosystem.

Total recoverable hydrocarbon concentrations have often been detected in historical sampling events, with a median range of 0.2 to 0.7 mg/L, close to or slightly above method detection limits. In 2001, total recoverable hydrocarbons were not detected. Typically, total phenolics have been detected in all seasons, occasionally at concentrations exceeding the chronic aquatic life guideline of 0.005 mg/L. In 2001, total phenolics were detected in all seasons, and concentrations were higher than aquatic guidelines in spring.

Historically, concentrations of total aluminum, cadmium, chromium, iron, lead, manganese, mercury, silver and vanadium are higher than water quality guidelines for the protection of aquatic life and/or human health, with the greatest frequency of exceedance generally occurring in the summer (Table 6.1). In 2001, winter and summer concentrations of total aluminum were higher than in previous years.

PAHs were not detected in 2001 samples (Table 6.1). However, detection limits for the following PAHs were greater than human health and/or chronic aquatic water quality guidelines: naphthalene, anthracene, dibenzo(a,h)anthracene, benzo(a)anthracene/chrysene, benzo(a)pyrene, benzo(b&k)fluoranthene and indeno(c,d-123)pyrene.

6.1.2 Clearwater River, Upstream of the Christina River

The Clearwater River, upstream of the Christina River was also monitored seasonally in 2001. In the winter of 2001, the Clearwater River, upstream of the Christina River had similar concentrations of major ions, hardness and TDS compared to the downstream location (Tables 6.1 and 6.2). However, in spring, summer and fall, the levels of these parameters were sometimes lower in the upstream sample. In the Clearwater River upstream of the Christina River, colour, TOC and DOC levels were highest in spring and summer and lowest in fall and winter. Concentrations of TOC and DOC were slightly lower in the upstream samples compared to downstream in spring, summer and fall. Summer colour levels were marginally higher at the upstream site.

Total nitrogen concentrations were somewhat higher in upstream samples during winter and fall, relative to the downstream site (Tables 6.1 and 6.2), although results from the quality control program indicate potential contamination of total nitrogen samples in 2001 (Section 4.2.1.3). At both locations, total phosphorus levels were highest in spring and lowest in summer and fall, although concentrations were generally slightly lower at the upstream site. Total phosphorus levels exceeded the chronic aquatic life guideline of 0.05 mg/L in spring at both upstream and downstream sites.

Total phenolics concentrations exceeded aquatic guidelines in spring and summer. Total aluminum and iron concentrations were higher than the chronic aquatic life guidelines, and total iron and manganese concentrations were higher than the relevant human health guidelines in all seasons in 2001. Spring total aluminum concentrations were higher than acute aquatic life guideline in 2001. In winter and spring, total chromium concentrations were higher than chronic aquatic life guidelines. Lead concentrations also exceeded chronic aquatic guidelines in summer.

Table 6.2 Water Quality in the Clearwater River, Upstream of the Christina River

Parameter	Units	2001				Historical [(a)]	
		Winter	Spring	Summer	Fall	1973	1993
Field Measured							
pH		8.1	-	7.9	8.1	-	-
specific conductance	uS/cm	-	-	190	198	-	-
temperature	^oC	-	-	20.9	13.8	-	-
dissolved oxygen	mg/L	-	-	10.7	10.3	-	-
Conventional Parameters							
colour	T.C.U.	30	60	60	25	-	-
conductance	uS/cm	201	136	201	205	190	-
dissolved organic carbon	mg/L	3	7	8	6	-	-
hardness	mg/L	47	38	51	48	-	-
pH		7.2	7.5	7.6	7.6	7.3	-
total alkalinity	mg/L	47	35	46	48	52	-
total dissolved solids	mg/L	130	110	140	110	131	-
total organic carbon	mg/L	4	9	9	7	-	-
total suspended solids	mg/L	< 3	26	6	7	-	-
Major Ions							
bicarbonate	mg/L	57	42	56	58	-	-
calcium	mg/L	12	10	13	12	23	-
chloride	mg/L	27	16	28	28	40	-
magnesium	mg/L	4	3	5	4	6	-
potassium	mg/L	1	1	1	1	1	-
sodium	mg/L	18	13	20	18	26	-
sulphate	mg/L	6	6	7	6	< 10	-
sulphide	mg/L	< 0.003	< 0.003	0.006	0.005	-	-
Nutrients and Chlorophyll *a*							
nitrogen - ammonia	mg/L	0.06	< 0.05	< 0.05	< 0.05	-	-
nitrogen, total [(b)]	mg/L	0.5	0.5	0.4	0.3		
phosphorus, total	mg/L	0.044	**0.065** [(C)]	0.03	0.032	< 0.1	-
phosphorus, dissolved	mg/L	0.041	0.057	0.023	0.02	-	-
chlorophyll *a*	ug/L	< 1	15	4	5	-	-
Biological Oxygen Demand							
biochemical oxygen demand	mg/L	< 2	2	< 2	< 2	-	1.3
General Organics							
naphthenic acids	mg/L	< 1	-	< 1	< 1	-	-

Table 6.2 Water Quality in the Clearwater River, Upstream of the Christina River (continued)

Parameter	Units	2001				Historical [a]	
		Winter	Spring	Summer	Fall	1973	1993
total phenolics	mg/L	< 0.001	**0.022** [(C)]	**0.006** [(C)]	0.002	-	-
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	-	< 0.5	-	-
Metals (Total)							
aluminum (Al)	mg/L	**0.14** [(C)]	**0.78** [(A,C)]	**0.22** [(C)]	**0.13** [(C)]	-	-
antimony (Sb)	mg/L	**< 0.005** [(D>H)]	**< 0.005** [(D>H)]	**< 0.005** [(D>H)]	**< 0.005** [(D>H)]	-	-
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	-	-
barium (Ba)	mg/L	0.015	0.017	0.018	0.013	-	-
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	-	-
boron (B)	mg/L	0.02	0.03	0.04	0.03	-	-
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	**< 0.0002** [(D>C)]	**< 0.0002** [(D>C)]	-	-
chromium (Cr)	mg/L	**0.0023** [(C)]	**0.002** [(C)]	< 0.0008	< 0.0008	-	-
cobalt (Co)	mg/L	< 0.0002	0.0004	0.0002	0.0009	-	-
copper (Cu)	mg/L	0.001	0.001	0.001	0.002	-	-
iron (Fe)	mg/L	**0.85** [(C,H)]	**2.04** [(C,H)]	**0.72** [(C,H)]	**0.62** [(C,H)]	**0.5** [(A,C,H)]	-
lead (Pb)	mg/L	0.0002	0.0004	**0.0016** [(C)]	0.0002	-	-
lithium (Li)	mg/L	< 0.006	0.006	< 0.006	< 0.006	-	-
manganese (Mn)	mg/L	**0.034** [(H)]	**2.94** [(H)]	**0.04** [(H)]	**0.038** [(H)]	-	-
mercury (Hg)	mg/L	< 0.0000006	< 0.0000006	< 0.0000006	< 0.0000006	-	-
molybdenum (Mo)	mg/L	0.0003	0.0002	0.0002	0.0002	-	-
nickel (Ni)	mg/L	0.0057	0.0011	0.0007	0.0004	-	-
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	-	-
silver (Ag)	mg/L	0.000006	0.000005	< 0.000005	< 0.000005	-	-
strontium (Sr)	mg/L	0.08	0.05	0.08	0.08	-	-
thallium (Tl)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-
titanium (Ti)	mg/L	0.0216	0.0138	0.0038	0.0033	-	-
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-
vanadium (V)	mg/L	0.0007	0.0026	< 0.0002	0.0006	-	-
zinc (Zn) [(b)]	mg/L	0.015	0.008	0.008	0.011	-	-
Metals (Dissolved)							
aluminum (Al)	mg/L	< 0.01	0.03	0.01	0.04	-	-
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	-	-
arsenic (As)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	-	-
barium (Ba)	mg/L	0.012	0.012	0.013	0.011	-	-
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	-	-

Table 6.2 Water Quality in the Clearwater River, Upstream of the Christina River (continued)

Parameter	Units	2001				Historical [(a)]	
		Winter	Spring	Summer	Fall	1973	1993
boron (B)	mg/L	0.02	0.03	0.03	*0.06*	-	-
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-
chromium (Cr)	mg/L	0.0007	0.0005	< 0.0004	< 0.0004	-	-
cobalt (Co)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-
copper (Cu)	mg/L	0.0008	0.0007	*0.0084*	< 0.0006	-	-
iron (Fe)	mg/L	0.19	0.82	0.26	0.16	-	-
lead (Pb)	mg/L	< 0.0001	*0.0008*	< 0.0001	< 0.0001	-	-
lithium (Li)	mg/L	0.004	0.007	0.005	0.005	-	-
manganese (Mn)	mg/L	0.015	0.019	0.009	0.013	-	-
mercury (Hg)	mg/L	< 0.0001	*0.0001*	< 0.0001	< 0.0001	-	-
molybdenum (Mo)	mg/L	< 0.0001	*0.004*	*0.0004*	0.0001	-	-
nickel (Ni)	mg/L	0.0003	0.0009	0.0003	< 0.0001	-	-
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	-	-
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-	-
strontium (Sr)	mg/L	0.08	0.05	0.08	0.08	-	-
thallium (Tl)	mg/L	< 0.00005	< 0.00005	*0.00027*	< 0.00005	-	-
titanium (Ti)	mg/L	0.0013	0.0015	0.0004	0.0007	-	-
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	-
vanadium (V)	mg/L	0.0004	0.0006	< 0.0001	0.0007	-	-
zinc (Zn) [(b)]	mg/L	< 0.002	0.007	*0.028*	0.004	-	-
Target PAHs and Alkylated PAHs							
naphthalene	ug/L	**< 0.02** [(D>H)]	**< 0.02** [(D>H)]	**< 0.02** [(D>H)]	**< 0.02** [(D>H)]	-	-
C1 subst'd naphthalenes	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-
C2 subst'd naphthalenes	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C3 subst'd naphthalenes	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C4 subst'd naphthalenes	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
acenaphthene	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-
C1 subst'd acenaphthene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
acenaphthylene	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-
anthracene	ug/L	**< 0.02** [(D>C)]	**< 0.02** [(D>C)]	**< 0.02** [(D>C)]	**< 0.02** [(D>C)]	-	-
dibenzo(a,h)anthracene	ug/L	**< 0.02** [(D>H)]	**< 0.02** [(D>H)]	**< 0.02** [(D>H)]	**< 0.02** [(D>H)]	-	-
benzo(a)anthracene/chrysene	ug/L	**< 0.02** [(D>C,H)]	**< 0.02** [(D>C,H)]	**< 0.02** [(D>C,H)]	**< 0.02** [(D>C,H)]	-	-
C1 subst'd benzo(a)anthracene/chrysene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C2 subst'd benzo(a)anthracene/chrysene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-

Table 6.2 Water Quality in the Clearwater River, Upstream of the Christina River (continued)

Parameter	Units	2001				Historical [a]	
		Winter	Spring	Summer	Fall	1973	1993
benzo(a)pyrene	ug/L	**< 0.02** (D>C,H)	**< 0.02** (D>C,H)	**< 0.02** (D>C,H)	**< 0.02** (D>C,H)	-	-
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
benzo(b&k)fluoranthene	ug/L	**< 0.02** (D>H)	**< 0.02** (D>H)	**< 0.02** (D>H)	**< 0.02** (D>H)	-	-
benzo(g,h,i)perylene	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-
biphenyl	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C1 subst'd biphenyl	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C2 subst'd biphenyl	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
dibenzothiophene	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-
C1 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C2 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C3 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C4 subst'd dibenzothiophene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
fluoranthene	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-
C1 subst'd fluoranthene/pyrene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
fluorine	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-
C1 subst'd fluorine	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C2 subst'd fluorine	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
indeno(c,d-123)pyrene	ug/L	**< 0.02** (D>H)	**< 0.02** (D>H)	**< 0.02** (D>H)	**< 0.02** (D>H)	-	-
phenanthrene	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-
C1 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C2 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C3 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
C4 subst'd phenanthrene/anthracene	ug/L	< 0.04	< 0.04	< 0.04	< 0.04	-	-
Pyrene	ug/L	< 0.02	< 0.02	< 0.02	< 0.02	-	-

(a) Based on information from WDS stations AB07CD0100 and AB07CD0210.
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D> = analytical detection limit was higher than the relevant water quality guideline(s).
\- = no data / no guideline.

Differences in the water quality results between Clearwater River sites located upstream and downstream of the Christina River (Tables 6.1 and 6.2) can be used to evaluate the influence of the Christina River on Clearwater River water quality. With the exception of winter, comparison of upstream and downstream data for the Clearwater River suggested that the Christina River contained consistently higher major ions, TDS, total aluminum, barium, strontium and vanadium levels than the Clearwater River upstream of the Christina River in 2001. Similarly, the increased concentrations of total cobalt, copper, iron, lead, manganese, molybdenum, nickel, silver, titanium and zinc, as well as higher levels of total phosphorus and nitrogen occasionally observed at the downstream site suggest that the Christina River may contain higher metal and nutrient levels than the Clearwater River upstream of the Christina River.

6.2 SEDIMENT QUALITY

Sand was the major component of both composite sediment samples taken from the Clearwater River (Table 6.3); however, the upstream sample was almost entirely composed of sand and generally contained lower hydrocarbon and metal concentrations than the downstream sample collected just upstream of the town of Fort McMurray. All parameter concentrations in both samples were below Canadian Freshwater Sediment Quality Guidelines (CCME 1999).

Table 6.3 Sediment Quality in the Clearwater River, Fall 2001

Parameter	Units	Upstream Fort McMurray	Upstream Christina River
Particle Size			
percent sand	%	84	98
percent silt	%	12	< 1
percent clay	%	4	2
moisture content	%	22	20
Carbon Content			
total inorganic carbon	% by wt	0.16	0.04
total organic carbon	% by wt	0.3	< 0.1
Organics			
total recoverable hydrocarbons	mg/kg	400	< 100
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5
total extractable hydrocarbons (C11-C30)	mg/kg	56	< 5
Total Metals			
aluminum (Al)	ug/g	5,450	590
arsenic (As)	ug/g	2.2	0.7
barium (Ba)	ug/g	43.9	16.1
beryllium (Be)	ug/g	0.2	< 0.2
boron (B)	ug/g	12	3
cadmium (Cd)	ug/g	< 0.1	< 0.1
calcium (Ca)	ug/g	3,820	330
chromium (Cr)	ug/g	9.9	1.1

Table 6.3 Sediment Quality in the Clearwater River, Fall 2001 (continued)

Parameter	Units	Upstream Fort McMurray	Upstream Christina River
cobalt (Co)	ug/g	3.4	0.9
copper (Cu)	ug/g	8.9	6.1
iron (Fe)	ug/g	8,730	2310
lead (Pb)	ug/g	4.4	1.5
magnesium (Mg)	ug/g	2,480	200
manganese (Mn)	ug/g	225	179
mercury (Hg)	ug/g	< 0.04	< 0.04
molybdenum (Mo)	ug/g	0.1	< 0.1
nickel (Ni)	ug/g	5.4	0.3
potassium (K)	ug/g	1,020	106
selenium (Se)	ug/g	< 0.2	< 0.2
silver (Ag)	ug/g	< 0.1	< 0.1
sodium (Na)	ug/g	82	21
strontium (Sr)	ug/g	21	12
thallium (Tl)	ug/g	0.06	< 0.05
titanium (Ti)	ug/g	65.5	15.2
uranium (U)	ug/g	0.4	0.1
vanadium (V)	ug/g	14	1.7
zinc (Zn)	ug/g	20.4	6.9
Target PAHs and Alkylated PAHs			
naphthalene	ng/g	0.86	1.2
C1 subst'd naphthalenes	ng/g	1.3	1.7
C2 subst'd naphthalenes	ng/g	1	0.74
C3 subst'd naphthalenes	ng/g	1.4	1
C4 subst'd naphthalenes	ng/g	3.3	0.44
acenaphthene	ng/g	0.19	*0.41
C1 subst'd acenaphthene	ng/g	< 0.044	< 0.057
acenaphthylene	ng/g	*0.25	*0.36
anthracene	ng/g	< 0.53	0.39
dibenzo(a,h)anthracene	ng/g	*0.51	*0.17
benzo(a)anthracene/chrysene	ng/g	5.52	0.6
C1 subst'd benzo(a)anthracene/chrysene	ng/g	84	0.97
C2 subst'd benzo(a)anthracene/chrysene	ng/g	50	< 0.092
benzo(a)pyrene	ng/g	*3.0	*0.27
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	12	< 0.24
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	6.4	< 0.084
benzofluoranthenes	ng/g	*6.8	1.2
benzo(g,h,i)perylene	ng/g	*3.9	*0.21
biphenyl	ng/g	0.54	0.84
C1 subst'd biphenyl	ng/g	< 0.078	< 0.062
C2 subst'd biphenyl	ng/g	0.17	2.7
dibenzothiophene	ng/g	< 3.6	0.32
C1 subst'd dibenzothiophene	ng/g	1.6	0.11
C2 subst'd dibenzothiophene	ng/g	4.4	0.084
C3 subst'd dibenzothiophene	ng/g	31	0.49
C4 subst'd dibenzothiophene	ng/g	67	0.67
fluoranthene	ng/g	0.92	0.63

Table 6.3 Sediment Quality in the Clearwater River, Fall 2001 (continued)

Parameter	Units	Upstream Fort McMurray	Upstream Christina River
C1 subst'd fluoranthene/pyrene	ng/g	12	0.46
C2 subst'd fluoranthene/pyrene	ng/g	25	0.25
C3 subst'd fluoranthene/pyrene	ng/g	29	< 0.085
fluorene	ng/g	*0.34	*0.30
C1 subst'd fluorene	ng/g	< 0.24	< 0.094
C2 subst'd fluorene	ng/g	10	12
C3 subst'd fluorene	ng/g	10	1.9
indeno(1,2,3,cd)pyrene	ng/g	3.6	0.47
phenanthrene	ng/g	1.1	0.94
C1 subst'd phenanthrene/anthracene	ng/g	3.6	0.9
C2 subst'd phenanthrene/anthracene	ng/g	9.6	0.58
C3 subst'd phenanthrene/anthracene	ng/g	20	0.4
C4 subst'd phenanthrene/anthracene	ng/g	17	< 0.043
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	*10	3.2
pyrene	ng/g	1.8	0.63

Note: - = no data / no guideline.

*PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

6.3 BENTHIC INVERTEBRATE COMMUNITY

6.3.1 Clearwater River

6.3.1.1 Benthic Habitat

The lower Clearwater River is a large river with a wetted width of approximately 150 to 200 m in the reaches sampled for benthic invertebrates (Figure 3.7; detailed support data in Appendix IX). In terms of habitat characteristics, it is similar to the Athabasca River. Depositional areas are common and bottom substrates are dominated by shifting sands.

The reaches sampled in 2001 were very similar in terms of the measured habitat variables (Table 6.4). On average, sampling locations were about 0.5 m deep, with no measurable currents to slow currents. Field water quality measurements were typical of Alberta rivers. The bottom sediments were dominated by sand, and had a mean TOC of 1% indicating low organic content. Aquatic macrophyte cover was low (means of 10 to 15%) with the exception of one location (CLR-D-16), where it was 70%.

Table 6.4 Habitat Characteristics of the Benthic Invertebrate Sampling Reaches in the Clearwater River, Fall 2001

Variable	Units	Upstream Christina River (depositional) Mean (range)	Downstream Christina River (depositional) Mean (range)
sample date	-	September 19, 2001	September 17-18, 2001
habitat	-	run/backwater/snye	run/backwater
water depth	m	0.50 (0.21 - 0.77)	0.50 (0.19 - 0.75)
current velocity	m/s	0.09 (0 - 0.25)	0.11 (0 - 0.69)
macrophyte cover	%	15 (0 - 70)	10 (0 - 50)
Field Water Quality			
dissolved oxygen	mg/L	-	9.7 (9.5 - 10.4)
conductivity	µS/cm	-	264 (256 - 274)
pH	-	-	-
water temperature	^{o}C	-	13.6 (12.8 - 14.7)
Substrate			
sand	%	67 (36 - 97)	65 (23 - 95)
silt	%	19 (0 - 43)	22 (1 - 51)
clay	%	13 (3 - 31)	13 (3 - 26)
total organic carbon	%	1.1 (0.01 - 2.9)	0.9 (0.02 - 2.6)

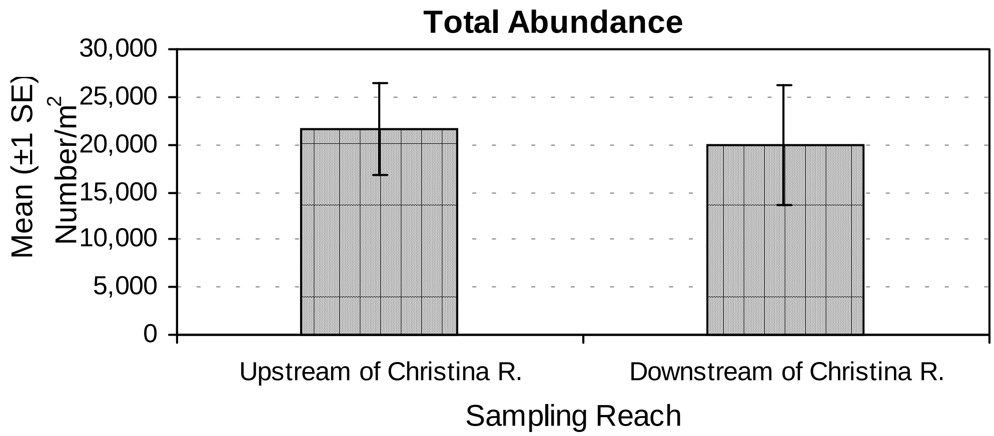
Note: - = Not applicable or no data.

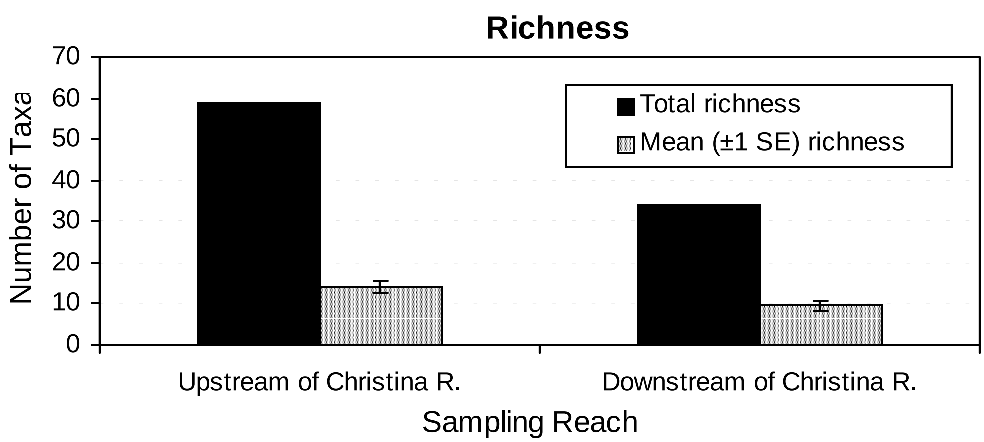
6.3.1.2 Benthic Community

Total benthic invertebrate abundance was moderate in the Clearwater River, with site means close to 20,000 organisms/m^2 (Figure 6.3; raw data in Appendix IX). There was no apparent difference in total abundance between the two reaches sampled in 2001. Taxonomic richness expressed as the total richness (= total taxa in 15 samples from a reach combined) was close to 60 in the upstream reach but was substantially lower downstream of the Christina River. Mean richness (= mean number of taxa based on 15 samples) was only slightly lower in the downstream reach.

Community composition at the level of major taxon was generally similar in the reaches sampled (Figure 6.3). Chironomid midges (Chironomidae), oligochaete worms (Oligochaeta) and fingernail clams (Pelecypoda) accounted for about 90% of total abundance. The percentage of fingernail clams was higher in the downstream reach, with a corresponding reduction in the percentage of oligochaete worms. At a finer taxonomic resolution, the benthic fauna of the Clearwater River was numerically dominated by oligochaete worms of the families Tubificidae and Naididae, fingernail clams (Sphaeriidae), a number of chironomid genera and ostracods (*Candona*) (Table 6.5). The two sampling reaches shared most of the common taxa listed in Table 6.5.

Figure 6.3 Total Invertebrate Abundance, Richness and Community Composition in the Clearwater River, Fall 2001





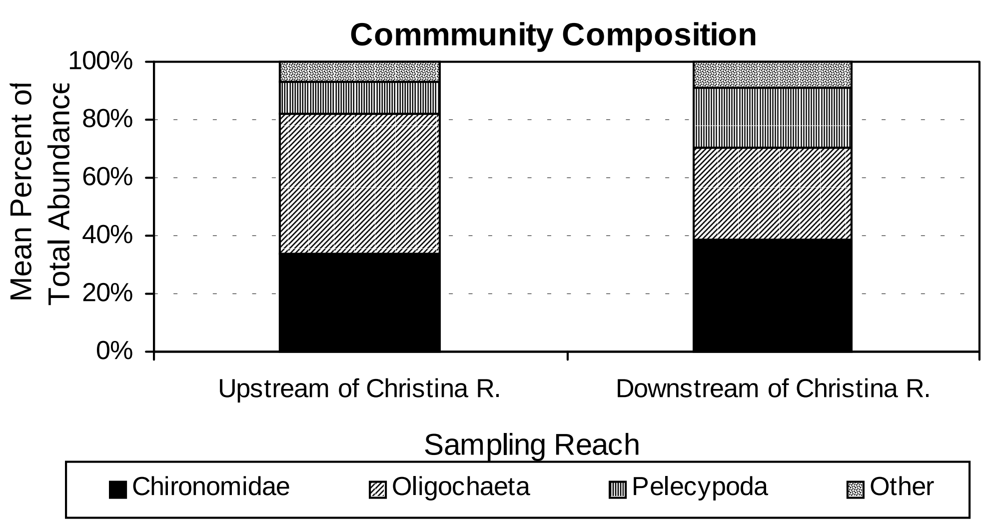


Table 6.5 Abundances of Common Invertebrates in the Clearwater River, Fall 2001

Taxon	Major Group	Mean (no./m^2)	Standard Error	% of Total Abundance
Clearwater River Upstream of Christina River				
Tubificidae	Oligochaeta	5,685	2,198	26.3
Naididae	Oligochaeta	4,667	4,016	21.6
Pisidium/Sphaerium	Pelecypoda	2,374	1,220	11.0
Polypedilum	Chironomidae	1,677	725	7.7
Micropsectra	Chironomidae	1,055	395	4.9
Paralauterborniella	Chironomidae	906	563	4.2
Procladius	Chironomidae	894	336	4.1
Paracladopelma	Chironomidae	837	657	3.9
Candona	Ostracoda	754	234	3.5
Tribelos	Chironomidae	579	424	2.7
Chironomus	Chironomidae	453	290	2.1
Kloosia [(a)]	Chironomidae	358	255	1.7
total % for common taxa				(93.5%)
total abundance		21,646	4,874	-
richness		13.9	1.4	-
total richness		59	-	-
Clearwater River Downstream of Christina River				
Tubificidae	Oligochaeta	5,610	2,423	28.2
Pisidium/Sphaerium	Pelecypoda	4,122	2,226	20.7
Polypedilum	Chironomidae	3,021	1,635	15.2
Paralauterborniella	Chironomidae	2,703	1,467	13.6
Candona	Ostracoda	1,324	768	6.7
Micropsectra	Chironomidae	1,118	703	5.6
Naididae	Oligochaeta	694	555	3.5
Procladius	Chironomidae	281	101	1.4
Paracladopelma	Chironomidae	244	145	1.2
total % for common taxa				(96.2%)
total abundance		19,880	6,347	-
richness		9.5	1.2	-
total richness		34	-	-

(a) tentative identification.

There were a number of significant correlations between invertebrate abundances and habitat variables (Table 6.6). The strongest correlations were with sediment variables, which were also strongly intercorrelated. Examination of scatter-plots revealed that the correlations with depth and macrophyte cover were generally weak. The positive correlations with sediment variables were consistent with the habitat associations of the taxa involved. Richness was positively correlated with macrophyte cover, possibly because macrophytes provide additional habitat for invertebrates in depositional habitat.

The data collected from the Clearwater River in 2001 suggests that the two sampling reaches are appropriate for future monitoring. Both habitat and community characteristics were similar in these reaches, with the exception of the lower total richness in the downstream reach. However, sensitive tests of effects on richness can be applied during data analysis by including habitat factors that may influence richness (e.g., by using macrophyte cover as a covariate) or incorporating existing differences in richness into the analysis (e.g., by using a Before-After Control-Impact [BACI] approach).

Table 6.6 Correlations Between Benthic Community Variables and Habitat Variables in the Clearwater River, Fall 2001

Benthic Community Variable	Depth	% Silt + Clay	TOC[(a)]	Macrophyte Cover	Comment (based on scatter-plot)
total abundance	-	0.61***	0.61***	-	-
richness	-	-	-	0.47**	-
Oligochaeta abundance	-0.39*	0.73***	0.72***	0.45**	weak relationship with depth and macrophyte cover
Tubificidae abundance	-0.42*	0.75***	0.73***	-	weak relationship with depth
Naididae abundance	-	-	-	0.42*	very weak relationship
Sphaeriidae abundance	-	0.72***	0.66***	0.44**	weak relationships
Procladius abundance	-	0.73***	0.76***	-	weak relationship with % silt + clay

(a) TOC = total organic carbon content of bottom sediments.
Notes: Spearman rank correlation coefficients (r_S) shown; n=29-30.
- = no significant correlation; P>0.05;
* = significant correlation; P<0.05;
** = significant correlation; P<0.01;
*** = significant correlation; P<0.001.

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7 TRIBUTARIES NORTH OF FORT MCMURRAY

7.1 WATER QUALITY

During the fall of 2001, water quality in sampled tributaries located north of Fort McMurray (i.e., McLean Creek, Poplar Creek, Fort Creek, the Steepbank River and the MacKay River) were generally consistent with historical data. Those water quality parameters observed to be notably different in 2001 than in previous sampling events are discussed below.

7.1.1 McLean Creek

Major ion concentrations at the mouth of McLean Creek in the fall of 2001 were generally higher than historical median levels (Table 7.1). Consequently, conductivity, TDS, hardness and total alkalinity measurements were also higher in 2001. These results may be reflective of the dry climatic conditions experienced in 2001. However, calcium and sulphate levels in McLean Creek may be increasing over time, although data are limited to five sample points (Figures 7.1 and 7.2).

Although natural, background chronic toxicity has been observed in the Muskeg River Watershed (Golder 2000b, 2001a), sample waters taken from the mouth of McLean Creek were non-toxic in 2000 and 2001.

Total titanium, copper and chromium levels and dissolved arsenic and manganese concentrations were higher in 2001 than in previous years (Table 7.1). Total phosphorus, nickel, iron and aluminum concentrations were lower in 2001 compared to previous sampling events in McLean Creek, which may be related to lower TSS concentrations in 2001.

7.1.2 Poplar Creek

Major ion concentrations, especially hardness, alkalinity, chloride and sodium levels, were higher at the mouth of Poplar Creek in the fall of 2001 than in previous sampling events, as illustrated in Figure 7.3 using TDS. Chloride levels (i.e., 321 mg/L) were higher than the aquatic guideline of 230 mg/L (Figure 7.4). As there is currently no oil-sands development in the Poplar Creek watershed, high major ions concentrations (e.g., sodium, chloride) observed in 2001 cannot be attributed to anthropogenic influences, but may reflect dry climatic conditions experienced in 2001. Other variations included higher levels of hardness and total chromium and selenium in 2001.

Table 7.1 Water Quality in McLean Creek, Poplar Creek and the Steepbank River, Fall

Parameter	Units	McLean Creek					Poplar Creek					Steepbank River				
		Fall 2001	Fall Historical (1995-2000) (a)				Fall 2001	Fall Historical (1976-2000) (b)				Fall 2001	Fall Historical (1972-2000) (c)			
			median	min	max	n		median	min	max	n		median	min	max	n
Field Measured																
pH		**8.6** (A,C)	8.2	7.1	8.3	3	8	8	7.9	8.3	12	8.5	8.2	6.9	**8.7** (A,C)	7
specific conductance	uS/cm	684	650	287	658	3	576	300	110	960	20	361	180	78	630	9
temperature	^{o}C	3.4	4	3.6	10.8	3	5.2	9.9	3.3	15	20	5.1	6	0.76	12	9
dissolved oxygen	mg/L	8.4	13.4	8.5	13.6	3	8.4	10.5	**5.8** (C)	18.3	22	8.6	10.2	**4.6** (A,C)	12.8	6
Conventional Parameters																
colour	T.C.U.	35	70	50	80	3	60	100	25	140	20	75	123	50	180	6
conductance	uS/cm	787	495	307	1,000	4	1,590	375	237	1,290	31	372	178	100	516	12
dissolved organic carbon	mg/L	15	18	13	21	4	21	26	24	30	21	16	22	11	28	12
hardness	mg/L	286	177	142	219	4	301	120	104	140	9	149	102	59	192	9
pH		8.3	8	8	8.3	4	8.2	7.9	7.28	8.3	31	8.3	7.7	7.2	8.4	13
total alkalinity	mg/L	239	171	133	251	4	304	156	117	259	31	189	89	54	263	13
total dissolved solids	mg/L	490	330	167	620	4	890	244	156	709	31	260	120	74	320	12
total organic carbon	mg/L	18	16	15	27	3	26	27	22	31	28	22	25	14	31	11
total suspended solids	mg/L	< 3	9	1	49	4	12	8	2	117	31	3	9	1	60	12
Major Ions																
bicarbonate	mg/L	292	208	162	305	4	371	202	160	219	5	229	105	65	306	5
calcium	mg/L	82	49	39	60	4	72	31	24	48	31	40	23	16	50	13
chloride	mg/L	76	42	8	165	4	**321** (C)	22	4	**232** (C)	31	5	2	1	8	13
magnesium	mg/L	20	13	11	17	4	29	10	9	20	31	12	7	5	16	13
potassium	mg/L	2	1	1	2	4	4	1	0.1	3	31	1	0.4	0.2	2	13
sodium	mg/L	74	41	13	140	4	238	40	23	190	31	20	8	4	38	13
sulphate	mg/L	76	25	11	56	4	44	13	4	24	31	9	5	2	12	13
sulphide	mg/L	0.005	0.004	< 0.002	0.015	3	< 0.003	0.009	-	-	1	0.004	0.006	< 0.003	**0.041** (C)	3
Nutrients and Chlorophyll *a*																
nitrogen - ammonia	mg/L	< 0.05	< 0.075	< 0.01	0.16	4	0.08	0.1	0.02	0.18	3	< 0.05	< 0.05	< 0.01	< 0.1	5
nitrogen, total (d)	mg/L	**1.5** (C)	0.7	0.4	1	3	**1.9** (C)	1	0.5	**2** (C)	20	**2.4** (C)	**1.1** (C)	< 0.2	**2.3** (C)	11
phosphorus, total	mg/L	0.008	0.029	0.012	**0.053** (C)	4	0.04	0.047	0.023	**0.129** (C)	31	0.034	0.047	0.008	**0.3** (C)	13
phosphorus, dissolved	mg/L	0.008	0.006	0.005	0.029	3	0.017	0.031	0.021	0.043	4	0.021	0.018	0.006	0.032	4
chlorophyll *a*	ug/L	2	-	0.002	0.005	2	2	1	< 1	7	10	1	0.551	0.002	7	4
Biological Oxygen Demand																
biochemical oxygen demand	mg/L	< 2	< 2	< 2	4	3	< 2	-	0.3	< 2	2	< 2	2	0.3	7	4
General Organics																
naphthenic acids	mg/L	2	1.8	< 1	2	4	2	-	< 1	2	2	2	< 1	< 1	1	4
total phenolics	mg/L	<0.001	0.002	< 0.001	0.002	4	0.002	0.004	< 0.001	**0.015** (C)	29	**0.006** (C)	< 0.001	< 0.001	**0.007** (C)	13
total recoverable hydrocarbons	mg/L	1.2	< 0.5	< 0.5	< 1	4	< 0.5	0.6	< 0.1	2.1	30	1.6	0.9	< 0.1	26.7	12
Toxicity																
algal growth inhibition test (72 h) - IC25	%	> 100	> 100	-	-	1	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d mortality test - LC25	%	> 100	> 100	-	-	1	-	-	-	-	-	-	-	-	-	-
Ceriodaphnia 7 d reproduction test - IC25	%	> 100	> 100	-	-	1	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d growth - IC25	%	> 100	> 100	-	-	1	-	-	-	-	-	-	-	-	-	-
fathead minnow 7d mortality test - LC25	%	> 100	> 100	-	-	1	-	-	-	-	-	-	-	-	-	-
Metals (Total)																
aluminum (Al)	mg/L	0.07	**0.445** (C)	0.06	**1.16** (A,C)	4	**0.32** (C)	**0.31** (C)	< 0.01	**0.48** (C)	3	0.04	**0.43** (C)	0.05	**2.73** (A,C)	5
antimony (Sb)	mg/L	< 0.005	< 0.0008	< 0.0002	< 0.005	4	< 0.005	-	< 0.0002	< 0.005	2	< 0.005	< 0.0008	< 0.0002	< 0.005	4
arsenic (As)	mg/L	< 0.001	< 0.001	0.0008	< 0.001	4	0.002	0.0008	0.0005	**0.007** (C)	7	< 0.001	0.001	< 0.0002	**0.012** (C)	7
barium (Ba)	mg/L	0.041	0.036	0.02	0.055	4	0.088	0.035	0.01	0.04	3	0.039	0.03	0.02	0.052	5
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	4	< 0.001	< 0.001	< 0.001	0.001	3	< 0.001	< 0.001	< 0.001	0.002	5
boron (B)	mg/L	0.09	0.08	0.02	0.2	4	0.18	0.12	0.1	0.14	3	0.13	0.04	0.02	0.2	5
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	**0.003** (C)	4	0.0004	**< 0.001** (D>C)	< 0.0002	**0.003** (A,C)	5	< 0.0002	< 0.0002	< 0.0002	**0.004** (A,C)	6
chromium (Cr)	mg/L	**0.0022** (C)	**0.0014** (C)	0.0009	**< 0.002** (D>C)	4	**0.0035** (C)	**< 0.002** (D>C)	< 0.0008	**0.003** (C)	5	0.0009	**0.0045** (C)	< 0.0004	**0.011** (C)	6
cobalt (Co)	mg/L	0.0003	0.0006	0.0004	< 0.003	4	0.0004	< 0.001	0.0004	< 0.003	5	< 0.0002	0.0007	< 0.0002	0.004	6
copper (Cu)	mg/L	**0.013** (C)	0.002	0.0015	**0.004** (C)	3	0.004	**0.0024** (C)	< 0.001	**0.004** (C)	4	0.002	**0.0025** (C)	0.001	**0.004** (C)	5
iron (Fe)	mg/L	**0.36** (C,H)	**0.79** (C,H)	**0.41** (C,H)	**1.41** (C,H)	4	**3.63** (C,H)	**1.12** (C,H)	**1.1** (C,H)	**1.21** (C,H)	3	**0.77** (C,H)	**1** (C,H)	**0.47** (C,H)	**2.28** (C,H)	6
lead (Pb)	mg/L	0.0007	0.0009	0.0002	**< 0.02** (D>C)	4	0.001	0.0004	0.0004	**< 0.02** (D>C)	3	< 0.0001	0.0011	0.0007	**< 0.02** (D>C)	6

Table 7.1 Water Quality in McLean Creek, Poplar Creek and the Steepbank River, Fall (continued)

Parameter	Units	McLean Creek					Poplar Creek					Steepbank River				
		Fall 2001	Fall Historical (1995-2000) [(a)]				Fall 2001	Fall Historical (1976-2000) [(b)]				Fall 2001	Fall Historical (1972-2000) [(c)]			
			median	min	max	n		median	min	max	n		median	min	max	n
lithium (Li)	mg/L	0.018	0.015	0.007	0.032	4	0.05	0.02	0.008	0.021	3	0.014	0.006	0.003	0.026	5
manganese (Mn)	mg/L	**0.077** (H)	**0.066** (H)	0.02	**0.096** (H)	4	**0.12** (H)	**0.101** (H)	0.046	**0.18** (H)	5	0.012	0.05	0.015	**0.075** (H)	6
mercury (Hg)	mg/L	< 0.0000006	**< 0.0002** (D>C,H)	< 0.00005	**< 0.0002** (D>C,H)	4	< 0.0000006	**< 0.0001** (D>H)	< 0.00005	**0.0013** (C,H)	29	< 0.0000006	**< 0.0001** (D>H)	< 0.00005	**< 0.05** (D>A,C,H)	13
molybdenum (Mo)	mg/L	0.0003	0.0004	0.0002	0.004	4	0.0005	< 0.001	0.0003	< 0.003	5	0.0003	0.0005	0.0002	< 0.003	5
nickel (Ni)	mg/L	0.0004	0.0035	0.0014	< 0.005	4	0.0015	0.001	0.0004	0.014	5	< 0.0002	0.0031	< 0.0005	0.007	6
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0002	< 0.0008	4	**0.0014** (C)	< 0.0002	< 0.0002	< 0.0008	5	< 0.0008	< 0.0007	< 0.0002	0.0008	5
silver (Ag)	mg/L	0.000012	**< 0.0004** (D>C)	**< 0.0004** (D>C)	**< 0.002** (D>C)	4	0.000025	**< 0.0004** (D>C)	< 0.0001	**< 0.002** (D>C)	3	0.000009	**< 0.0004** (D>C)	< 0.0001	**< 0.002** (D>C)	5
strontium (Sr)	mg/L	0.22	0.15	0.1	0.27	4	0.51	0.17	0.15	0.19	3	0.17	0.09	0.06	0.25	5
thallium (Tl)	mg/L	< 0.0001	< 0.0001	-	-	1	< 0.0001	< 0.0001	-	-	1	< 0.0001	< 0.0001	-	-	1
titanium (Ti)	mg/L	0.0021	0.008	0.007	0.0177	4	0.0113	0.0315	0.0083	< 0.05	4	0.0031	0.0319	0.0015	0.0579	6
uranium (U)	mg/L	0.0003	0.0002	0.0001	0.0004	3	0.0003	0.0001	-	-	1	0.0001	< 0.0001	< 0.0001	0.0002	3
vanadium (V)	mg/L	0.0005	0.0017	0.0009	0.0031	4	0.0026	0.001	< 0.001	0.004	27	< 0.0002	0.0017	0.0004	0.0068	11
zinc (Zn) [(d)]	mg/L	0.014	0.021	0.007	0.026	4	0.018	**0.041** (C)	< 0.001	**0.046** (C)	4	0.01	0.016	0.01	0.029	5
Metals (Dissolved)																
aluminum (Al)	mg/L	< 0.01	0.01	0.01	0.045	3	< 0.01	< 0.01	-	-	1	< 0.01	0.0591	0.03	0.07	3
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	0.0008	3	< 0.0008	< 0.0008	-	-	1	< 0.0008	0.0008	0.0007	0.0008	3
arsenic (As)	mg/L	0.0022	0.0004	0.0004	0.001	3	*0.0066*	0.0007	0.0002	0.0012	25	0.0005	0.0004	< 0.0002	0.0021	7
barium (Ba)	mg/L	0.037	0.036	0.023	0.044	3	*0.068*	0.029	-	-	1	0.036	0.02	0.016	0.052	3
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	3	< 0.001	< 0.001	-	-	1	< 0.001	< 0.001	< 0.001	< 0.001	3
boron (B)	mg/L	0.09	0.08	0.03	0.15	3	*0.18*	0.17	0.08	0.23	17	0.13	0.11	0.02	0.24	7
cadmium (Cd)	mg/L	0.0002	< 0.0001	< 0.0001	< 0.0001	3	0.0006	< 0.0001	-	-	1	< 0.0001	< 0.0001	< 0.0001	0.0001	3
chromium (Cr)	mg/L	*0.007*	< 0.0004	< 0.0004	0.0012	3	*0.0087*	< 0.0004	-	-	1	*0.005*	< 0.0004	< 0.0004	< 0.0004	3
cobalt (Co)	mg/L	0.0002	0.0003	0.0001	0.0004	3	0.0003	0.0001	-	-	1	0.0001	0.0002	0.0001	0.0002	3
copper (Cu)	mg/L	0.0016	0.0011	< 0.0006	0.003	3	0.0015	0.0008	-	-	1	< 0.0006	0.0017	0.0009	0.0028	3
iron (Fe)	mg/L	0.17	0.25	0.04	0.46	3	0.15	0.41	-	-	1	0.19	0.27	0.22	0.29	3
lead (Pb)	mg/L	0.0001	0.0002	< 0.0001	0.0003	3	0.0003	0.0001	-	-	1	< 0.0001	0.0006	0.0002	0.0011	3
lithium (Li)	mg/L	0.02	-	0.009	0.034	2	0.05	0.022	-	-	1	0.015	0.007	0.005	0.022	3
manganese (Mn)	mg/L	0.085	0.039	0.022	0.064	3	0.121	0.029	-	-	1	0.007	0.014	0.002	0.018	3
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3	< 0.0001	< 0.0001	-	-	1	< 0.0001	< 0.0001	< 0.0001	< 0.0002	3
molybdenum (Mo)	mg/L	0.0003	0.0002	0.0002	0.0004	3	0.0005	0.0003	-	-	1	0.0003	0.0002	0.0002	0.0005	3
nickel (Ni)	mg/L	< 0.0001	0.0027	0.0004	0.0036	3	0.0009	< 0.0001	-	-	1	0.0003	0.0008	0.0005	0.0038	3
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	3	< 0.0004	< 0.0002	< 0.0002	< 0.0004	15	< 0.0004	< 0.0002	< 0.0002	< 0.0004	7
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	3	< 0.0002	< 0.0002	-	-	1	< 0.0002	< 0.0002	< 0.0002	< 0.0002	3
strontium (Sr)	mg/L	0.23	0.18	0.11	0.26	3	0.54	0.2	-	-	1	0.16	0.08	0.06	0.23	3
thallium (Tl)	mg/L	< 0.00005	< 0.00005	-	-	1	*0.00027*	< 0.00005	-	-	1	< 0.00005	< 0.00005	-	-	1
titanium (Ti)	mg/L	0.0016	0.0009	0.0003	0.0018	3	0.0025	< 0.0003	-	-	1	0.001	0.0007	0.0003	0.0007	3
uranium (U)	mg/L	0.0003	0.0002	< 0.0001	0.0003	3	0.0003	< 0.0001	-	-	1	0.0001	< 0.0001	< 0.0001	0.0002	3
vanadium (V)	mg/L	*0.006*	0.0003	< 0.0001	0.0009	3	*0.0159*	0.0004	-	-	1	0.0002	< 0.0001	< 0.0001	0.0003	3
zinc (Zn) [(d)]	mg/L	*0.104*	0.003	0.003	0.006	3	*0.106*	0.005	-	-	1	0.005	0.013	0.005	0.015	3

(a) Based on information from Golder (1996a, 2000b, 2001a) and unpublished data from Suncor Energy Inc.
(b) Based on information from Golder (1996a, 2001a) and WDS stations AB07DA0110 and AB07DA1040.
(c) Based on information from Golder (1996a, 1998, 1999b, 2000b, 2001a) and WDS stations AB07DA0260, AB07DA1000 and AB07DA2710.
(d) The accuracy of reported total nitrogen, total zinc and dissolved zinc is uncertain because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain in 2001 because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data / no guideline.

Figure 7.1 Sulphate Concentrations in McLean Creek, Fall (1995-2001)

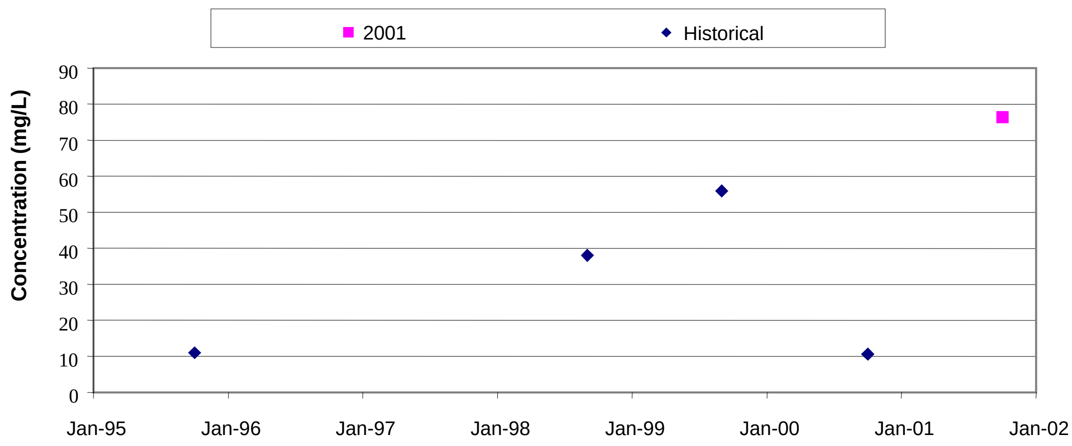


Figure 7.2 Calcium Concentrations in McLean Creek, Fall (1995-2001)

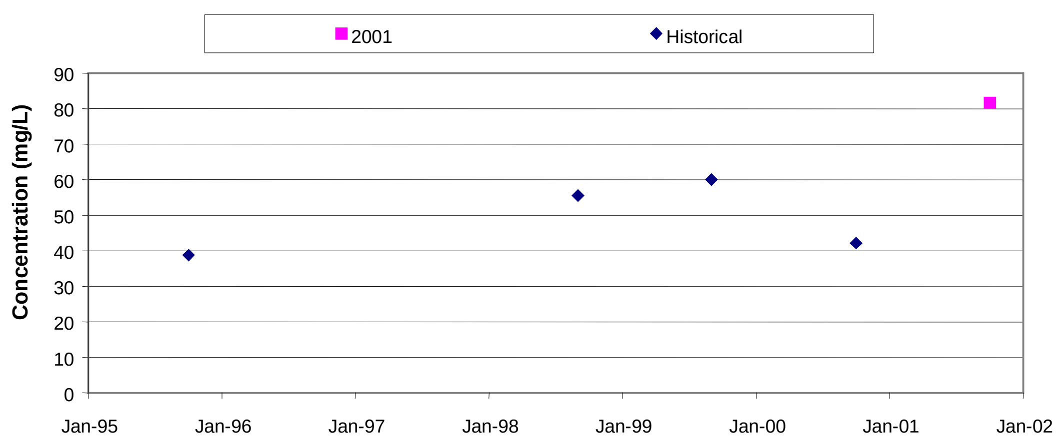


Figure 7.3 TDS Concentrations in Poplar Creek, Fall (1976-2001)

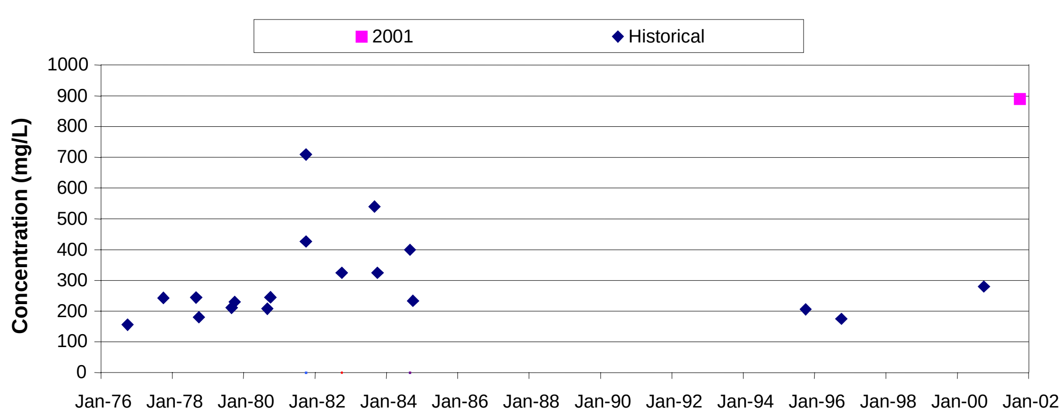
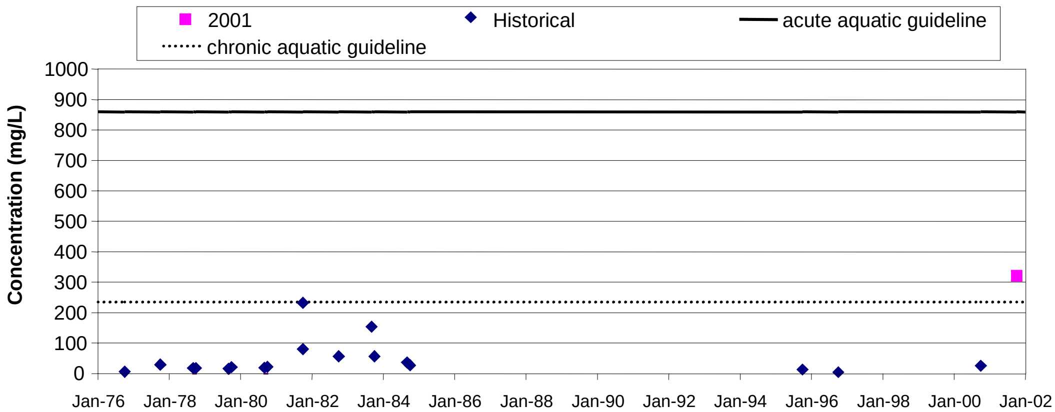


Figure 7.4 Chloride Levels in Poplar Creek, Fall (1976-2001)

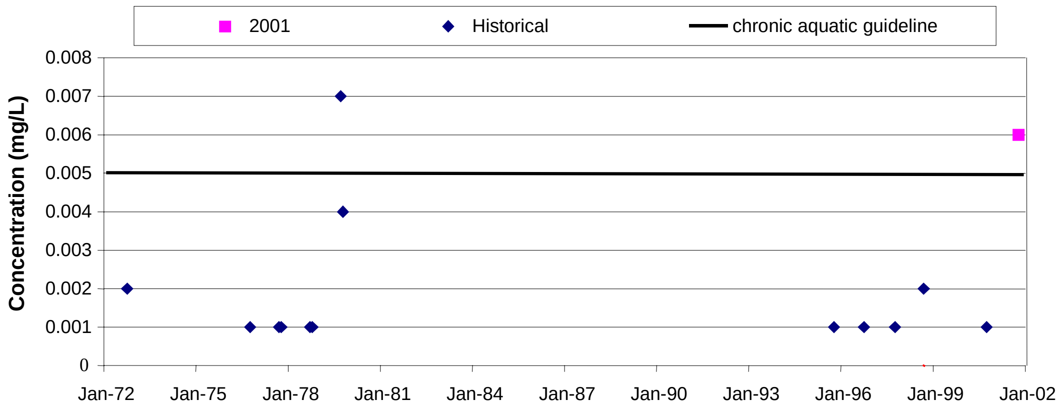


Aquatic guidelines for some metals are dependent on the total hardness of the water. Because of the high hardness level in Poplar Creek in 2001, the concentration of copper (0.004 mg/L) was below the aquatic guideline. In previous years, when the hardness was lower, copper concentrations of 0.004 mg/L were above the aquatic guideline.

7.1.3 Steepbank River

In 2001, major ion concentrations were higher than historical median levels (Table 7.1). The concentration of total phenolics was higher in 2001 than historical median levels and, unlike most recent sampling events, was higher than the chronic aquatic guideline (Figure 7.5). Compared to previous years, there were relatively low levels of total cobalt, lead, manganese, nickel and vanadium in the 2001 sample.

Figure 7.5 Total Phenolics Concentration in the Steepbank River, Fall (1972-2001)



Concentrations below the analytical detection limit are plotted as the detection limit.

7.1.4 MacKay River

Total aluminum concentrations were higher in 2001 than in previous years, although historical data are limited (n=2) (Table 7.2); elevated total aluminum levels in 2001 may be related to higher TSS concentrations than previously recorded. Colour levels were also higher in 2001 compared to previous sampling events.

7.1.5 Fort Creek

The water quality in Fort Creek in 2001 was similar to previous sampling events, although historical data are limited (n≤ 4) (Table 7.2). The dissolved oxygen concentration was lower in 2001 than in previous years. The level of total phenolics was higher in 2001 than previously recorded and exceeded the chronic aquatic guideline (Table 7.2).

Water temperature was monitored continuously through late summer and fall on Fort Creek (Figure 7.6). The temperature pattern was typical for small tributaries in this region.

Figure 7.6 Water Temperature in Fort Creek, Fall 2001

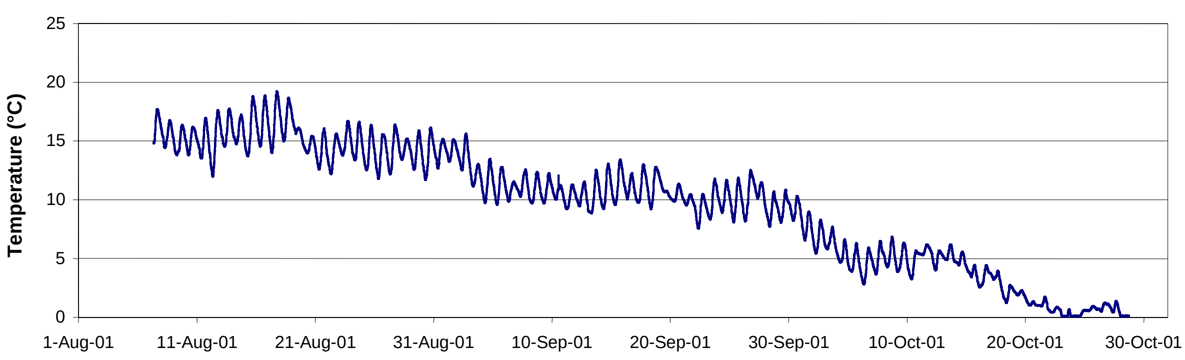


Table 7.2 Water Quality in Fort Creek and the MacKay River, Fall

Parameter	Units	MacKay River					Fort Creek				
		Fall 2001	Fall Historical (1972-2000) [(a)]				Fall 2001	Fall Historical (1996-2000) [(b)]			
			median	min	max	n		median	min	max	n
Field Measured											
pH		8.3	**8.6** [(A,C)]	-	-	1	8.3	8.2	8.1	8.2	3
specific conductance	uS/cm	268	203	-	-	1	263	417	368	458	3
temperature	^oC	5.5	-	0.4	10	2	5.6	3	1.5	11.9	3
dissolved oxygen	mg/L	8.5	8.2	-	-	1	8.5	13	11.6	13.4	3
Conventional Parameters											
colour	T.C.U.	200	-	70	150	2	18	33	20	40	4
conductance	uS/cm	278	375	233	576	4	520	469	386	533	4
dissolved organic carbon	mg/L	28	-	20	24	2	11	13	10	15	4
hardness	mg/L	100	154	96	177	4	268	242	215	267	4
pH		8	8.1	7.6	8.3	4	8.2	8.2	8.1	8.3	4
total alkalinity	mg/L	116	191	100	202	3	283	248	221	284	4
total dissolved solids	mg/L	240	-	170	342	2	330	295	264	380	4
total organic carbon	mg/L	36	-	26	34	2	13	16	12	17	4
total suspended solids	mg/L	26	-	< 2	7	2	14	16	< 0.4	61	4
Major Ions											
bicarbonate	mg/L	142	-	122	245	2	346	301	269	347	4
calcium	mg/L	26	44	25	51	4	78	72	64	78	4
chloride	mg/L	6	6	2	41	4	4	2	1	3	4
magnesium	mg/L	9	10	3	16	4	18	15	13	18	4
potassium	mg/L	1	2	1	2	4	1	1	1	2	4
sodium	mg/L	20	32	17	60	4	10	9	8	11	4
sulphate	mg/L	18	42	18	70	4	11	8	2	9	4
sulphide	mg/L	0.017	-	0.003	0.009	2	0.004	0.003	< 0.003	0.004	3
Nutrients and Chlorophyll *a*											
nitrogen - ammonia	mg/L	< 0.05	-	< 0.05	< 0.1	2	< 0.05	< 0.075	0.02	< 0.1	4
nitrogen, total [(c)]	mg/L	**3.2** [(C)]	-	1	**1.3** [(C)]	2	1	0.4	0.4	0.6	4
phosphorus, total	mg/L	**0.054** [(C)]	**0.126** [(C)]	0.011	**0.5** [(C)]	4	0.027	0.024	0.018	0.033	4
phosphorus, dissolved	mg/L	0.04	-	0.004	0.047	2	0.019	0.017	0.004	0.02	4
chlorophyll *a*	ug/L	0.001	< 0.001	-	-	1	-	0.003	< 0.001	0.7	4
Biological Oxygen Demand											
biochemical oxygen demand	mg/L	< 2	-	< 2	< 2	2	-	< 2	< 0.1	2	4
General Organics											
naphthenic acids	mg/L	< 1	-	< 1	1	2	1	1	< 1	2	3
total phenolics	mg/L	0.001	0.004	< 0.001	0.004	3	**.027** [(C)]	0.002	< 0.001	0.004	4

Table 7.2 Water Quality in Fort Creek and the MacKay River, Fall (continued)

Parameter	Units	MacKay River					Fort Creek				
		Fall 2001	Fall Historical (1972-2000) [a]				Fall 2001	Fall Historical (1996-2000) [b]			
			median	min	max	n		median	min	max	n
total recoverable hydrocarbons	mg/L	< 0.5	2.7	0.8	5.4	3	< 0.5	> 0.5	> 0.5	> 0.5	3
Metals (Total)											
aluminum (Al)	mg/L	**0.5** [C]	-	0.05	**0.2** [C]	2	0.04	0.05	0.05	**0.43** [C]	4
antimony (Sb)	mg/L	< 0.005	-	< 0.0008	< 0.005	2	< 0.005	**< 0.005** [D>H]	< 0.0008	**< 0.005** [D>H]	3
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	3	< 0.001	< 0.001	< 0.0002	< 0.001	4
barium (Ba)	mg/L	0.03	-	0.021	0.049	2	0.091	0.083	0.06	0.105	4
beryllium (Be)	mg/L	< 0.001	-	< 0.001	< 0.001	2	< 0.001	< 0.001	< 0.001	0.003	4
boron (B)	mg/L	0.08	-	0.11	0.14	2	0.05	0.03	0.02	0.05	4
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	**0.004** [A,C]	3	< 0.0002	< 0.0002	< 0.0002	< 0.0002	4
chromium (Cr)	mg/L	**0.0013** [C]	**0.0018** [C]	< 0.0008	**0.006** [C]	3	< 0.0008	< 0.0008	< 0.0008	**0.01** [C]	4
cobalt (Co)	mg/L	0.0006	0.0026	0.0003	0.004	3	< 0.0002	0.0003	< 0.0002	0.0011	4
copper (Cu)	mg/L	**0.003** [C]	**0.004** [C]	0.001	**0.012** [C]	3	0.002	< 0.001	< 0.001	0.001	4
iron (Fe)	mg/L	**1.9** [C,H]	**0.75** [C,H]	**0.31** [C,H]	**23.3** [C,H]	4	0.07	**0.66** [C,H]	**0.56** [C,H]	**1.2** [C,H]	4
lead (Pb)	mg/L	0.0004	0.0005	0.0002	**0.016** [C]	3	< 0.0001	0.0004	< 0.0001	0.0006	4
lithium (Li)	mg/L	0.019	-	0.015	0.032	2	0.018	0.013	0.009	0.084	4
manganese (Mn)	mg/L	**0.051** [H]	0.03	0.024	**0.442** [H]	3	**0.108** [H]	**0.098** [H]	**0.062** [H]	**0.106** [H]	4
mercury (Hg)	mg/L	< 0.0000006	**< 0.0002** [D>C,H]	**< 0.0002** [D>C,H]	**< 0.0005** [D>C,H]	3	< 0.0000006	**< 0.0002** [D>C,H]	**< 0.00005** [D>H]	**< 0.0002** [D>C,H]	4
molybdenum (Mo)	mg/L	0.0004	-	0.0006	0.0006	2	0.0001	< 0.0001	< 0.0001	< 0.003	4
nickel (Ni)	mg/L	0.0019	0.0207	0.0027	0.035	3	< 0.0002	0.0012	< 0.0005	0.0023	4
selenium (Se)	mg/L	< 0.0008	-	< 0.0008	< 0.0008	2	< 0.0008	< 0.0008	< 0.0002	< 0.0008	4
silver (Ag)	mg/L	0.000009	-	**< 0.0004** [D>C]	**< 0.0004** [D>C]	2	0.000043	**< 0.0004** [D>C]	< 0.0001	**< 0.0004** [D>C]	4
strontium (Sr)	mg/L	0.16	-	0.13	0.29	2	0.18	0.16	0.12	0.19	4
thallium (Tl)	mg/L	< 0.0001	< 0.0001	-	-	1	< 0.0001	-	< 0.0001	< 0.0001	2
titanium (Ti)	mg/L	0.0128	-	0.0011	0.0046	2	0.0026	0.0019	0.0014	0.009	3
uranium (U)	mg/L	0.0002	-	0.0001	0.0004	2	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3
vanadium (V)	mg/L	0.0005	-	< 0.0002	0.0006	2	< 0.0002	0.0008	< 0.0002	< 0.002	4
zinc (Zn) [c]	mg/L	0.017	0.008	0.004	**0.067** [C]	3	0.012	0.014	0.005	0.019	3
Metals (Dissolved)											
aluminum (Al)	mg/L	0.03	-	0.01	0.02	2	0.05	< 0.01	< 0.01	0.09	3
antimony (Sb)	mg/L	< 0.0008	-	< 0.0008	< 0.0008	2	< 0.0008	< 0.0008	< 0.0008	0.001	3
arsenic (As)	mg/L	0.0008	-	< 0.0004	0.0004	2	< 0.0004	< 0.0004	< 0.0004	< 0.0004	3
barium (Ba)	mg/L	0.019	-	0.015	0.047	2	0.094	0.094	0.074	0.095	3
beryllium (Be)	mg/L	< 0.001	-	< 0.001	< 0.001	2	< 0.001	< 0.001	< 0.001	< 0.001	3
boron (B)	mg/L	0.08	-	0.07	0.18	2	0.05	0.02	0.02	0.05	3
cadmium (Cd)	mg/L	< 0.0001	-	< 0.0001	< 0.0001	2	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3

Table 7.2 Water Quality in Fort Creek and the MacKay River, Fall (continued)

Parameter	Units	MacKay River					Fort Creek				
		Fall 2001	Fall Historical (1972-2000) [(a)]				Fall 2001	Fall Historical (1996-2000) [(b)]			
			median	min	max	n		median	min	max	n
chromium (Cr)	mg/L	0.0031	-	< 0.0004	0.0005	2	*0.0095*	< 0.0004	< 0.0004	0.0008	3
cobalt (Co)	mg/L	0.0001	-	0.0001	0.0001	2	0.0001	0.0001	< 0.0001	0.0001	3
copper (Cu)	mg/L	0.001	-	0.0009	0.0019	2	< 0.0006	0.001	< 0.0006	0.0012	3
iron (Fe)	mg/L	0.48	-	0.23	0.6	2	*0.83*	0.17	0.13	0.24	3
lead (Pb)	mg/L	0.0002	-	0.0001	0.0002	2	0.0001	0.0003	< 0.0001	0.0005	3
lithium (Li)	mg/L	0.019	-	0.016	0.032	2	0.018	0.013	0.011	0.026	3
manganese (Mn)	mg/L	0.009	-	0.011	0.013	2	0.129	0.071	0.05	0.08	3
mercury (Hg)	mg/L	< 0.0001	-	< 0.0001	< 0.0001	2	< 0.0001	< 0.0001	< 0.00002	< 0.0001	3
molybdenum (Mo)	mg/L	0.0003	-	0.0003	0.0005	2	< 0.0001	< 0.0001	< 0.0001	0.0012	3
nickel (Ni)	mg/L	0.0009	-	0.0012	0.0023	2	< 0.0001	0.001	0.0009	0.0014	3
selenium (Se)	mg/L	< 0.0004	-	< 0.0004	< 0.0004	2	< 0.0004	< 0.0004	< 0.0004	< 0.0004	3
silver (Ag)	mg/L	< 0.0002	-	< 0.0002	< 0.0002	2	< 0.0002	< 0.0002	< 0.0002	< 0.0002	3
strontium (Sr)	mg/L	0.16	-	0.13	0.28	2	0.18	0.17	0.14	0.2	3
thallium (Tl)	mg/L	< 0.00005	< 0.00005	-	-	1	< 0.00005	-	< 0.00005	< 0.00005	2
titanium (Ti)	mg/L	0.0009	-	< 0.0003	0.0008	2	0.0032	0.0007	0.0006	0.0012	3
uranium (U)	mg/L	0.0002	-	0.0001	0.0003	2	0.0001	< 0.0001	< 0.0001	< 0.0001	3
vanadium (V)	mg/L	0.0005	-	0.0002	0.0004	2	0.0001	< 0.0001	< 0.0001	0.0002	3
zinc (Zn) [(c)]	mg/L	*0.03*	-	< 0.002	0.005	2	0.002	0.003	< 0.002	0.008	3

(a) Based on information from Golder (1999b, 2001a) and WDS stations AB07DB0030\0070.
(b) Based on information from Golder (2001a), True North (2001) and WDS station AB07DA2760.
(c) The accuracy of reported total nitrogen, total zinc and dissolved zinc is uncertain because of irregularities in QC sample result which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain in 2001 because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
^{A} = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
^{C} = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
^{H} = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
$^{D>}$ = analytical detection limit was higher than the relevant water quality guideline(s).
\- = no data / no guideline.

7.2 SEDIMENT QUALITY

7.2.1 McLean Creek

Sediment collected from the mouth of McLean Creek in 2001 consisted primarily of sand, with some silt and clay. Total metal concentrations were below freshwater sediment quality guidelines (Table 7.3). Concentrations of two PAH compounds, benzo(a)anthracene/chrysene and pyrene, were above guideline levels. In general, sediment quality in 2001 was consistent with that observed in previous sampling events, with parameter concentrations observed in 2001 falling within the historical range. Exceptions included:

- lower calcium, zinc, naphthalene, C1 substituted naphthalene and phenanthrene concentrations in 2001; and
- higher C1 and C2 substituted benzo(b&k)fluoranthene/benzo(a)pyrene, C2 substituted fluorene and C1 substituted phenanthrene/anthracene concentrations in 2001 compared to those observed in earlier sampling events.

7.2.2 MacKay River

Sediments collected from the mouth of the MacKay River in 2001 were substantially different from sediments previously collected from this site, as well as those collected in 2001 from upstream of Highway 63 (Table 7.3). The 2001 sample taken from the river mouth contained only 15% sand, whereas the upstream sample and those collected from the mouth in previous years were composed predominately of sand. Similarly, total metal and PAH concentrations at the river mouth in 2001 were higher than levels observed at the upstream site and were generally beyond the range previously observed at this sample site. However, all parameter concentrations were below the probable effects level defined by CCME (1999) for freshwater sediments (Table 7.3).

Based on the PAH classification system defined by Thorsen et al. (2001), the increased PAH concentrations observed at the mouth of the MacKay River in 2001 were generally associated with those of petrogenic origin (i.e., originate from oil sands or other petroleum-based media) (Table 7.4). The composition of this sample, in terms of its bulk characteristics (i.e., mainly silt and clay) and chemical content, (i.e., PAH composition and increased metal content) would therefore suggest that exposed oil sands are present at the mouth of this river and that the 2001 sample was collected from these exposed areas. Conversely, exposed oil sands were not encountered at the upstream sample site or at the river mouth in previous years.

Table 7.3 Sediment Quality in McLean Creek and the MacKay River, Fall

Parameter	Units	McLean Creek					MacKay River					
							Mouth					Upstream (2001)
		Fall 2001	Fall Historical (1998-2000)[a]				Fall 2001	Fall Historical (1997-1998)[b]				
			median	min	max	n		median	min	max	n	
Particle Size												
percent sand	%	69	78.5	10	84	3	15	-	74	89	2	90
percent silt	%	17	12	12	60	3	48	-	6	10.3	2	6
percent clay	%	14	9.5	4	30	3	37	-	5	15.7	2	4
moisture content	%	21	19	-	-	1	45	-	-	-	-	38
Carbon Content												
total inorganic carbon	% by wt	0.2	0.3	< 0.1	1.1	3	0.9	0.2			1	0.25
total organic carbon	% by wt	2.5	2.3	2.3	5.6	3	2.7	-	1.4	1.6	2	0.4
Organics												
total recoverable hydrocarbons	mg/kg	17,100	10,240	900	43,900	3	7,800	-	4,180	11,300	2	100
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	< 0.5	-	-	1	< 0.5	-	-	-	-	1.2
total extractable hydrocarbons (C11-C30)	mg/kg	4,800	5,800	-	-	1	6,600	-	-	-	-	64
Total Metals												
aluminum (Al)	ug/g	7,900	5,565	3,500	15,500	3	28,700	-	2,550	5,650	2	2,340
arsenic (As)	ug/g	3.3	3.4	2.7	**6.4** [l]	3	**8.9** [l]	-	1.8	4.5	2	3.6
barium (Ba)	ug/g	60	59.2	49.7	205	3	288	-	27.2	70	2	52
beryllium (Be)	ug/g	< 1	< 1	0.2	< 1	3	< 1	-	< 1	< 1	2	< 0.2
boron (B)	ug/g	-	-	< 5	15	2	-	-	-	-	-	11
cadmium (Cd)	ug/g	< 0.5	< 0.5	< 0.1	< 0.5	3	< 0.5	-	< 0.5	< 0.5	2	< 0.1
calcium (Ca)	ug/g	1,900	8,090	3,200	39,600	3	22,300	-	2,690	7,690	2	2,900
chromium (Cr)	ug/g	13.8	29.4	11.1	31.8	3	**40.9** [l]	-	4.5	12.9	2	5.3
cobalt (Co)	ug/g	6	5	4.4	12	3	12	-	2	5	2	2.8
copper (Cu)	ug/g	8	10.5	9	24	3	22	-	4	11	2	6
iron (Fe)	ug/g	10,700	10,425	10,100	24,600	3	30,800	-	6,730	14,400	2	11,400
lead (Pb)	ug/g	5	7	4.4	12	3	13	-	5	6	2	3.2
magnesium (Mg)	ug/g	1,900	3,200	1,580	9,440	3	10,300	-	1,420	4,270	2	1,950
manganese (Mn)	ug/g	350	252	188	682	3	1,110	-	134	302	2	189
mercury (Hg)	ug/g	< 0.1	< 0.04	< 0.01	0.04	3	< 0.1	-	0.02	0.1	2	< 0.05
molybdenum (Mo)	ug/g	< 1	< 1	< 1	1.5	3	< 1	-	< 1	< 1	2	0.2
nickel (Ni)	ug/g	14	23.2	10.5	33	3	29	-	4	12	2	4.9

Table 7.3 Sediment Quality in McLean Creek and the MacKay River, Fall (continued)

Parameter	Units	McLean Creek					MacKay River					
							Mouth					Upstream (2001)
		Fall 2001	Fall Historical (1998-2000)[a]				Fall 2001	Fall Historical (1997-1998)[b]				
			median	min	max	n		median	min	max	n	
potassium (K)	ug/g	1,310	1,285	1,120	3,050	3	5,260	-	600	1,380	2	670
selenium (Se)	ug/g	< 0.2	0.2	0.1	0.4	3	1.2	-	< 0.1	0.3	2	< 0.2
silver (Ag)	ug/g	< 1	< 1	< 0.1	< 1	3	< 1	-	< 1	< 1	2	< 0.1
sodium (Na)	ug/g	100	152	< 100	500	3	300	-	< 100	119	2	110
strontium (Sr)	ug/g	28	27.5	16	95	3	91	-	15	34	2	21
thallium (Tl)	ug/g	< 1	0.1	-	-	1	< 1	-	-	-	-	< 0.05
titanium (Ti)	ug/g	28	-	6	55	2	98	-	15	24	2	19.8
uranium (U)	ug/g	< 40	-	0.5	< 40	2	< 40	-	-	-	-	0.3
vanadium (V)	ug/g	22	19.4	15.5	38	3	63	-	9	16	2	10.1
zinc (Zn)	ug/g	10	33.9	24.7	81.1	3	70	-	37.9	44.3	2	25
Target PAHs and Alkylated PAHs												
naphthalene	ng/g	*4.2	16	14	27	3	*10	-	8	< 20	2	0.65
C1 subst'd naphthalenes	ng/g	3.7	**24 (I)**	**< 23 (D>I)**	**64 (I)**	3	**71 (I)**	-	6	**< 27 (D>I)**	2	0.8
C2 subst'd naphthalenes	ng/g	14	81	< 26	100	3	160	-	< 22	60	2	1.1
C3 subst'd naphthalenes	ng/g	110	92	< 20	310	3	340	-	< 30	420	2	0.88
C4 subst'd naphthalenes	ng/g	540	< 32	< 30	51	3	1,200	-	< 58	750	2	0.58
acenaphthene	ng/g	4	**< 17 (D>I)**	< 3	**< 30 (D>I)**	3	**11 (I)**	-	**16 (I)**	**< 35 (D>I)**	2	< 0.14
C1 subst'd acenaphthene	ng/g	< 0.99	< 8	< 4	< 12	3	*3.1	-	< 10	40	2	0.15
acenaphthylene	ng/g	*3.4	**< 7 (D>I)**	< 4	**< 20 (D>I)**	3	**< 5.8 (D>I)**	-	4	**< 15 (D>I)**	2	< 0.085
anthracene	ng/g	*7.8	**< 58 (D>I)**	< 3	**< 92 (D>I)**	3	*7.5	-	< 3	< 30	2	< 0.059
dibenzo(a,h)anthracene	ng/g	**< 23 (D>I)**	**< 54 (D>I)**	**< 10 (D>I)**	**< 100 (D>I)**	3	**< 21 (D>I)**	-	< 3	**< 50 (D>I)**	2	*0.43
benzo(a)anthracene/chrysene	ng/g	**399 (P)**	**445 (P)**	61 (I)	**1200 (P)**	3	**322 (I)**	-	**110 (I)**	**220 (I)**	2	1.86
C1 subst'd benzo(a)anthracene/chrysene	ng/g	4,700	56	< 25	14,000	3	4,200	-	< 21	250	2	39
C2 subst'd benzo(a)anthracene/chrysene	ng/g	1,500	20	10	6,200	3	1,400	-	< 15	400	2	9
benzo(a)pyrene	ng/g	**< 54 (D>I)**	**< 45 (D>I)**	< 14	**156 (I)**	3	***35 (I)**	-	23	**< 92 (D>I)**	2	2
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	390	< 31	< 5	< 78	3	320	-	< 93	150	2	9.5
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	220	< 18	< 14	< 52	3	240	-	< 39	110	2	2.8
benzofluoranthenes	ng/g	*110	140	38	410	3	*100	-	< 38	53	2	6.1
benzo(g,h,i)perylene	ng/g	*69	98	24	210	3	*43	-	17	< 54	2	*3.2
biphenyl	ng/g	6	11	7	11	3	15	-	< 17	< 20	2	0.1
C1 subst'd biphenyl	ng/g	< 2	< 4	< 3	< 10	3	< 1.4	-	< 7	< 20	2	< 0.05

Table 7.3 Sediment Quality in McLean Creek and the MacKay River, Fall (continued)

Parameter	Units	McLean Creek					MacKay River					
							Mouth					Upstream (2001)
		Fall 2001	Fall Historical (1998-2000)[a]				Fall 2001	Fall Historical (1997-1998)[b]				
			median	min	max	n		median	min	max	n	
C2 subst'd biphenyl	ng/g	5	< 5	< 3	< 14	3	5	-	< 13	< 20	2	< 0.078
dibenzothiophene	ng/g	*6.1	< 26	4	< 26	3	< 190	-	22	< 28	2	*0.10
C1 subst'd dibenzothiophene	ng/g	290	205	23	740	3	350	-	170	310	2	0.51
C2 subst'd dibenzothiophene	ng/g	1,500	76	< 60	4,000	3	1,900	-	1,000	1,200	2	2.3
C3 subst'd dibenzothiophene	ng/g	4,300	130	< 51	20,000	3	4,600	-	< 26	1,400	2	2.8
C4 subst'd dibenzothiophene	ng/g	6,300	< 47	-	-	1	5,900	1,800			1	4.5
fluoranthene	ng/g	*21	35	10	60	3	20	-	< 21	22	2	0.91
C1 subst'd fluoranthene/pyrene	ng/g	630	525	65	2,400	3	620	-	200	250	2	3.9
C2 subst'd fluoranthene/pyrene	ng/g	1,100	5,300	-	-	1	1,100	-	-	-	-	9.1
C3 subst'd fluoranthene/pyrene	ng/g	1,300	7,400	-	-	1	1,300	-	-	-	-	3.8
fluorene	ng/g	6	14	6	**< 50 (D>I)**	3	15	-	11	**< 44 (D>I)**	2	*0.14
C1 subst'd fluorene	ng/g	17	< 11	< 4	< 31	3	15	-	< 31	80	2	0.66
C2 subst'd fluorene	ng/g	380	< 8	< 3	< 33	3	560	-	< 30	430	2	2.7
C3 subst'd fluorene	ng/g	600	< 17	-	-	1	920	-	-	-	-	2.6
indeno(1,2,3,cd)pyrene	ng/g	*40	72	14	160	3	22	-	10	< 61	2	*3.1
phenanthrene	ng/g	*34	**60 (I)**	**50 (I)**	**90 (I)**	3	**62 (I)**	-	30	**80 (I)**	2	0.74
C1 subst'd phenanthrene/anthracene	ng/g	210	< 50	< 30	120	3	400	-	220	280	2	2.3
C2 subst'd phenanthrene/anthracene	ng/g	740	510	100	2,100	3	1,100	-	540	1,300	2	2.8
C3 subst'd phenanthrene/anthracene	ng/g	1,700	2,450	120	7,800	3	1,700	-	1200	1,200	2	2
C4 subst'd phenanthrene/anthracene	ng/g	1,200	4,500	420	7,100	3	2,000	-	820	2,600	2	1.5
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	330	1,100	-	-	1	420	-	-	-	-	20
pyrene	ng/g	**97 (I)**	**170 (I)**	26	**490 (I)**	3	**100 (I)**	-	47	**73 (I)**	2	0.59

[a] Based on information from Golder (1999b 2000b, 2001a).
[b] Based on information from Golder (1998, 1999b).

Note: *PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).
Bolded concentrations are higher than the relevant sediment quality guideline.
I = concentration higher than the interim sediment quality guideline (CCME 1999).
P = concentration higher than the probable effects level defined by CCME (1999).
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data / no guideline.
nt = not toxic.

Table 7.4 Classification of PAHs as Either of Petrogenic and Pyrogenic Origin

Class	PAH Compound
Petrogenic	naphthalene
	C1 substituted naphthalenes
	C2 substituted naphthalenes
	C3 substituted naphthalenes
	C4 substituted naphthalenes
	fluorene
	C1 substituted fluorenes
	C2 substituted fluorenes
	C3 substituted fluorenes
	dibenzothiophene
	C1 substituted dibenzothiophenes
	C2 substituted dibenzothiophenes
	C3 substituted dibenzothiophenes
	C1 substituted phenanthrenes/anthracenes
	C2 substituted phenanthrenes/anthracenes
	C3 substituted phenanthrenes/anthracenes
	C4 substituted phenanthrenes/anthracenes
	C1 substituted fluoranthenes/pyrenes
	C1 substituted chrysenes
	C2 substituted chrysenes
	C3 substituted chrysenes
	C4 substituted chrysenes
Pyrogenic	acenaphthene
	anthracene
	fluoranthene
	pyrene
	benzo(a)anthracene/chrysene
	benzo(b,k)fluoranthene
	benzo(a)pyrene
	indeno(1,2,3-c,d)pyrene
	dibenzo(a,h)anthracene
	benzo(g,h,i)perylene
other [a]	phenanthrene

[a] Phenanthrene can be classified as either petrogenic or pyrogenic.
Note: Adapted from Thorsen et al. (2001).

7.3 BENTHIC INVERTEBRATE COMMUNITY

7.3.1 MacKay River, Steepbank River and Fort Creek

7.3.1.1 Benthic Habitat

The MacKay and Steepbank rivers (Figures 3.6 and 3.5, respectively) are of medium size, with wetted channel widths generally between 15 and 30 m during the fall low-flow period (Table 7.5; detailed supporting data in Appendix IX). Fort Creek is a small stream, with a wetted width of about 3 m near its mouth.

Erosional reaches were characterized by similar ranges in current velocity (0.3 to 1 m/s, with one higher value measured in the MacKay River) and depth (0.2 to 0.5 m). The variation in depth was low largely due to the narrow depth range that can be sampled by the Neill cylinder (0.2 to 0.6 m). The depositional reach sampled in Fort Creek was shallower and had a lower current velocity.

Table 7.5 Habitat Characteristics of the Benthic Invertebrate Sampling Reaches in the MacKay and Steepbank Rivers and Fort Creek, Fall 2001

Variable	Units	MacKay River (erosional) Mean (range)	Steepbank River (erosional) Mean (range)	Fort Creek (depositional) Mean (range)
sample date	-	September 28, 2001	September 17, 2001	October 11, 2001
habitat	-	run/riffle	run/riffle	run
wetted channel width	m	29 (21 - 36)	17 (10 - 26)	6
bankfull channel width	m	36 (24 - 45)	24 (16 - 33)	3
water depth	m	0.4 (0.3 - 0.5)	0.3 (0.2 - 0.5)	0.26 (0.20 – 0.32)
current velocity	m/s	0.64 (0.30 - 1.35)	0.51 (0.17 - 1.02)	0.08 (0 - 0.18)
macrophyte cover	%	0	0	0
Field Water Quality				
dissolved oxygen	mg/L	9.9	11.4 (10.3 - 12.1)	8.5
conductivity	µS/cm	217 (216 - 218)	308 (306 - 313)	268
pH	-	8.1	8.5 (8.0 - 8.7)	8.3
water temperature	^{o}C	10.7 (9.7 - 11.4)	11.7 (10.0 - 12.4)	5.5
Benthic Algae				
benthic algal chlorophyll *a* (15 samples/river)	mg/m^2	31 (14 - 48)	44 (3 - 80)	-
Substrate (erosional habitat)				
sand/silt/clay	%	9 (0 - 15)	5 (0 - 35)	99
small gravel	%	26 (10 - 55)	8 (0 - 20)	1
large gravel	%	33 (15 - 45)	16 (0 - 40)	-
small cobble	%	21 (5 - 30)	23 (10 - 45)	-
large cobble	%	8 (0 - 30)	29 (0 - 60)	-
boulder	%	3 (0 - 20)	19 (0 - 50)	-
weighted average index	-	4.7 (3.7 - 6.2)	6.0 (4.3 - 6.9)	-

Note: - = not applicable or no data.

The substratum was dominated by gravel and small cobbles in the MacKay River and by larger particles in the Steepbank River that has a higher gradient in the reach sampled (Table 7.5). The mean benthic algal biomass on cobble surfaces was slightly lower in the MacKay River. Fort Creek sediments consisted mostly of sand, silt and clay. Aquatic macrophytes were not present at the sampling locations in these watercourses. Field water quality measurements were typical of rivers and streams in the region. The lower water temperature in Fort Creek likely reflects the later sampling date in this stream relative to the other two watercourses.

The habitat data indicate that both the MacKay and Steepbank rivers represent high quality erosional habitat for benthic invertebrates, whereas the depositional habitat sampled in Fort Creek is of relatively low quality.

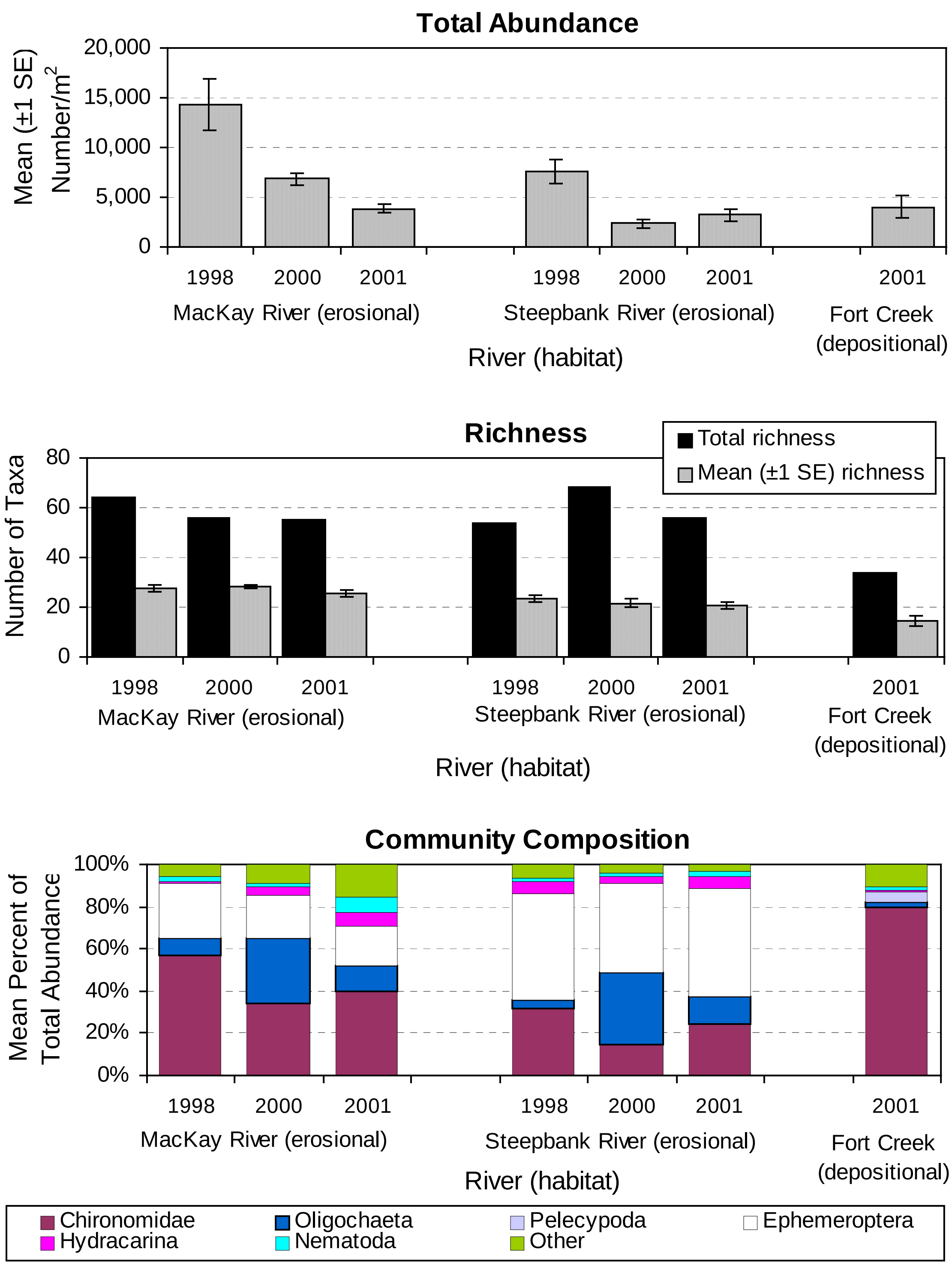
7.3.1.2 Benthic Community

Total benthic invertebrate abundance was generally low in 2001 (means of ≤5,000 organisms/m^2) in the MacKay and Steepbank rivers, and Fort Creek (Figure 7.7; raw data in Appendix IX). Total abundance was similar in the Muskeg and Steepbank rivers in 2000 and 2001, but was about 50% lower than the abundance reported by the first RAMP benthic survey in 1998 (Golder 1999b). However, the sampling design was different in 1998 (three distinct sites were sampled rather than a longer reach), which suggests that direct comparisons of the 1998 data with the 2000 and 2001 data may not be appropriate.

Taxonomic richness was less variable among years in the MacKay and Steepbank rivers (Figure 7.7). The benthic community in Fort Creek had a lower richness, reflecting the difference in habitat from the other two watercourses.

Taxonomic composition at the level of major taxon showed some consistent differences among rivers (Figure 7.7). Chironomid midges, mayflies (Ephemeroptera) and oligochaete worms dominated in the MacKay and Steepbank rivers, usually accounting for 80 to 90% of total abundance. However, chironomids were the dominant group in the MacKay River and mayflies dominated the Steepbank River. The depositional fauna of Fort Creek consisted mostly of chironomids. These differences among rivers are consistent with the variation in habitat characteristics. The coarse substrates and fast currents in the Steepbank River favour mayflies, which frequently dominate erosional rivers. The MacKay River is wider, with smaller sized substrates and somewhat slower currents, which is reflected in a reversal in the importance of chironomids and mayflies. Fort Creek is depositional near its mouth, which accounts for the chironomid-dominated depositional community sampled in this stream.

Figure 7.7 Total Invertebrate Abundance, Richness and Community Composition in the MacKay and Steepbank Rivers and Fort Creek, Fall 1998 to 2001



At the level of individual taxa, the dominant organisms (operationally defined as those accounting for ≥5% of total abundance) in the MacKay River were the mayfly *Baetis*, a number of chironomid genera, the oligochaete worm family Enchytraeidae, roundworms (Nematoda) and aquatic mites (Hydracarina) (Table 7.6). Three of these taxa (*Baetis*, Enchytraeidae, Hydracarina) were also dominant in the Steepbank River, where the chironomid genus *Rheotanytarsus* and the mayfly family Ephemerellidae were also dominant (Table 7.7). The reach sampled at the mouth of Fort Creek was dominated by taxa that favour depositional habitat, including chironomid midges, the crane fly *Hexatoma* and fingernail clams (*Pisidium* and *Sphaerium*) (Table 7.8).

There were a number of significant correlations between habitat variables and benthic community variables in the MacKay and Steepbank rivers (Table 7.9). Habitat variation was too low in Fort Creek to warrant an analysis. Total abundance and richness were weakly negatively correlated with current velocity in the MacKay River. Abundances of a number of taxa were also negatively correlated with current velocity in this river, whereas abundance of the stonefly (Plecoptera) family Chloroperlidae was negatively correlated with substrate particle size (represented by the weighted average index [WAI]). In the Steepbank River, abundances of a number of common taxa were positively correlated with substrate particle size. The combined abundance of the morphologically similar chironomid genera *Cricotopus* and *Orthocladius* were negatively correlated with the WAI. Correlations with the WAI were usually stronger than those with current velocity.

The directions of the significant correlations were not necessarily consistent with the habitat associations of the taxa involved. For example, taxa common in depositional habitat (e.g., chironomids) were in some cases positively correlated with substrate particle size (Table 7.9). These results suggest that the variation in habitat features among sites is not consistently reflected in the biological data. This may be a consequence of sampling a relatively small number of sites, which does not allow a sensitive analysis, or the large natural variation in benthic community characteristics (i.e., patchiness), which may obscure true habitat associations. Additionally, if significant changes in flows occurred in the weeks preceding the field program, instantaneous habitat measurements may not yield an accurate reflection of the physical conditions that shaped the benthic communities.

Table 7.6 Abundances of Common Invertebrates in the MacKay River, Fall 2001

Taxon	Major Group	Mean (no./m^2)	Standard Error	% of Total Abundance
Baetis	Ephemeroptera	517	104	13.5
Tanytarsus	Chironomidae	416	74	10.9
Polypedilum	Chironomidae	410	108	10.7
Enchytraeidae	Oligochaeta	397	46	10.4
Nematoda	-	304	67	7.9
Hydracarina	-	241	67	6.3
Thienemannimyia complex	Chironomidae	180	35	4.7
Hemerodromia	Empididae	154	33	4.0
Rhithrogena	Ephemeroptera	87	35	2.3
Lopescladius	Chironomidae	83	26	2.2
Hydropsyche	Trichoptera	79	24	2.1
Stempellinella	Chironomidae	79	26	2.1
Tvetenia	Chironomidae	74	25	1.9
Rheotanytarsus	Chironomidae	71	28	1.8
Naididae	Oligochaeta	67	17	1.7
Taeniopteryx	Plecoptera	64	15	1.7
Saetheria	Chironomidae	64	36	1.7
Ophiogomphus	Odonata	62	24	1.6
Chloroperlidae	Plecoptera	49	28	1.3
Candona	Ostracoda	46	14	1.2
total % for common taxa				(90.0%)
total abundance		3,825	461	-
richness		25.6	1.3	-
total richness		55	-	-

Table 7.7 Abundances of Common Invertebrates in the Steepbank River, Fall 2001

Taxon	Major Group	Mean (no./m^2)	Standard Error	% of Total Abundance
Baetis	Ephemeroptera	1,255	290	39.1
Rheotanytarsus	Chironomidae	348	77	10.8
Enchytraeidae	Oligochaeta	320	94	10.0
Ephemerellidae	Ephemeroptera	319	80	9.9
Hydracarina	-	183	45	5.7
Naididae	Oligochaeta	73	15	2.3
Nematoda	-	69	19	2.1
Eukiefferiella	Chironomidae	65	28	2.0
Tvetenia	Chironomidae	62	15	1.9
Polypedilum	Chironomidae	56	20	1.7
Hemerodromia	Empididae	47	9	1.5
Micropsectra	Chironomidae	39	19	1.2
Orthocladiinae	Chironomidae	36	13	1.1
Cricotopus/Orthocladius	Chironomidae	36	12	1.1
Thienemannimyia complex	Chironomidae	32	11	1.0
Saetheria	Chironomidae	32	12	1.0
total % for common taxa				(92.6%)
total abundance		3,209	544	-
richness		20.6	1.3	-
total richness		56	-	-

Table 7.8 Abundances of Common Invertebrates in Fort Creek, Fall 2001

Taxon	Major Group	Mean (no./m^2)	Standard Error	% of Total Abundance
Micropsectra	Chironomidae	1,118	452	27.6
Heterotrissocladius	Chironomidae	765	530	18.9
Polypedilum	Chironomidae	335	100	8.3
Pseudodiamesa	Chironomidae	275	117	6.8
Hexatoma	Tipulidae	267	120	6.6
Psectrocladius	Chironomidae	241	79	5.9
Pisidium/Sphaerium	Pelecypoda	198	156	4.9
Nematoda	-	86	45	2.1
Paracladopelma	Chironomidae	86	47	2.1
Enchytraeidae	Oligochaeta	60	37	1.5
Candona	Ostracoda	52	25	1.3
Chaetocladius	Chironomidae	52	34	1.3
Dicranota	Tipulidae	52	52	1.3
Thienemannimyia complex	Chironomidae	43	27	1.1
Orthocladiinae	Chironomidae	43	33	1.1
total % for common taxa				(90.7%)
total abundance		4,051	1,175	-
richness		14.6	2.1	-
total richness		34	-	-

Table 7.9 Correlations Between Benthic Community Variables and Habitat Variables in the MacKay and Steepbank Rivers, Fall 2001

Benthic Community Variable	Current Velocity	WAI[a]	Comment (based on scatter-plot)
MacKay River (n=14)			
total abundance	-0.59*	-	weak relationship
richness	-0.53*	-	weak relationship
Chironomidae abundance	-0.60*	-	-
Polypedilum abundance	-0.65*	-	-
Hemerodromia abundance	-0.68**	-	-
Lopescladius abundance	-0.65*	-	-
Ophiogomphus abundance	-0.72**	-	-
Chloroperlidae abundance	-	-0.59*	-
Steepbank River (n=12 to 15)			-
Rheotanytarsus abundance	-	0.67**	-
Ephemerellidae abundance	-	0.67**	-
Hydracarina abundance	-	0.87***	-
Cricotopus/Orthocladius abundance	-	-0.60*	-
Thienemannimyia complex abundance	-	0.54*	-

[a] WAI = weighted average index of substrate particle size.
Note: Spearman rank correlation coefficients (r_S) shown.
- = no significant correlation; P>0.05;
* = significant correlation; P<0.05;
** = significant correlation; P<0.01;
*** = significant correlation; P<0.001.

7.4 FISH POPULATIONS

7.4.1 Sentinel Species Monitoring

Monitoring of slimy sculpin populations was conducted at exposure sites on the Muskeg River (Site MR-E) and Steepbank River (SR-E) as well as reference sites on the Steepbank (SR-R), Horse (HR-R) and Dunkirk rivers (DR-R). Monitoring results for the Steepbank River are presented in Section 7.4.1.1, whereas the results for the Muskeg River are presented in Section 8.4.1.1

7.4.1.1 Steepbank River Exposure Site

Slimy sculpin results for the 2001 monitoring of the Steepbank River in the vicinity of the Steepbank Mine (Site SR-E) include fish community data, slimy sculpin population/health data and statistical comparisons. These results are compared to reference populations of slimy sculpin from sites on the Horse, Steepbank and Dunkirk rivers. Additionally, the 2001 results for sites SR-E and SR-R are compared to the 1999 results from the same sites.

Fish Community Data

Thirteen species of fish were captured or observed during the collection of slimy sculpin at the exposure and reference sites combined (Table 7.10). The sampling technique was biased towards collecting slimy sculpin. As such, the majority of fish recorded were sculpin or other small-bodied fish species, although some juvenile sucker species and juvenile sport fish were also recorded. Slimy sculpin, longnose dace and spoonhead sculpin were the most abundant and widely distributed small-bodied species. The total number of species present was higher at the two exposure sites (10 to 11 species) than at the reference sites (4 to 8 species).

Table 7.10 Total Number of Fish Recorded at the Exposure and Reference Sites, Muskeg, Steepbank, Horse and Dunkirk Rivers, Fall 2001

Fish Species	Total Number of Fish[a]				
	Exposure Sites		Reference Sites		
	MR-E	SR-E	HR-R	SR-R	DR-R
slimy sculpin	276	173	144	230	226
spoonhead sculpin	6	16	0	41	0
longnose sucker	29	35	3	13	2
white sucker	1	0	0	0	0
trout perch	6	14	0	1	0
lake chub	2	3	0	0	0
pearl dace	7	11	4	1	7
longnose dace	8	7	2	80	4
burbot	4	2	0	2	0
walleye	2	1	0	0	0
northern pike	2	0	0	0	0
mountain whitefish	0	0	0	1	0
Arctic grayling	0	1	0	0	0
total	**343**	**263**	**153**	**369**	**239**

[a] Includes captured plus observed fish.

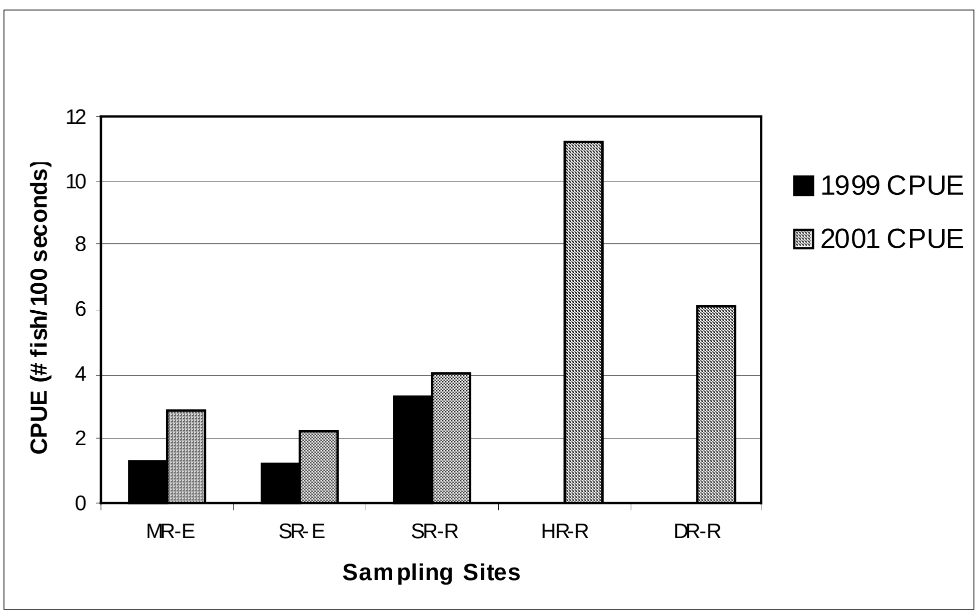
The relative abundance for each fish species at all sites was calculated as CPUE (Table 7.11). CPUE values for slimy sculpin and for all species combined at the two exposure sites were similar to one another, but were considerably lower than the CPUE values at the reference sites. A similar pattern was recorded during the sentinel species monitoring program in 1999, when the slimy sculpin CPUE value at the reference site was more than two times higher than the CPUE values at the two exposure sites (Figure 7.8). At each comparable site, the CPUE values for slimy sculpin were higher in 2001 than in 1999.

Table 7.11 Catch-Per-Unit-Effort for Fish Recorded at Exposure Sites on the Muskeg and Steepbank Rivers and Reference Sites on the Horse and Dunkirk Rivers, Fall 2001

Fish Species	CPUE (No. fish/100 s)[a]				
	Exposure Sites		Reference Sites		
	MR-E	SR-E	HR-R	SR-R	DR-R
slimy sculpin	2.92	2.25	11.19	4.18	6.13
spoonhead sculpin	0.06	0.21	0.00	0.75	0.00
longnose sucker	0.31	0.45	0.23	0.24	0.05
white sucker	0.01	0.00	0.00	0.00	0.00
trout perch	0.06	0.18	0.00	0.02	0.00
lake chub	0.02	0.04	0.00	0.00	0.00
pearl dace	0.07	0.14	0.31	0.02	0.19
longnose dace	0.09	0.09	0.16	1.45	0.11
burbot	0.04	0.03	0.00	0.04	0.00
walleye	0.02	0.01	0.00	0.00	0.00
northern pike	0.02	0.00	0.00	0.00	0.00
mountain whitefish	0.00	0.00	0.00	0.02	0.00
Arctic grayling	0.00	0.01	0.00	0.00	0.00
total	**3.65**	**3.42**	**11.89**	**6.71**	**6.48**
sampling effort (seconds)	**9,449**	**7,697**	**1,287**	**5,503**	**3,690**

[a] CPUE calculated from captured plus observed fish.

Figure 7.8 Catch-Per-Unit-Effort of Slimy Sculpin at Exposure Sites on the Muskeg and Steepbank Rivers as well as Reference Sites on the Horse, Steepbank and Dunkirk Rivers, 1999 and 2001



Differences in fish community structure (i.e., species diversity and abundance) were apparent between the five sampling sites, with more species present and lower fish abundance at the exposure sites than at the reference sites. These differences were likely due to differences in habitat characteristics between these sites. The differences in abundance need to be taken into consideration when examining population parameters that may be affected by fish density (e.g., growth rates and fish size).

The number of female, male and immature slimy sculpin collected for processing at each site is presented in Table 7.12. Approximately 30 or more fish of each sex were collected at each of the sites, with the exception of sites SR-E and DR-R, where the number of males collected was 22 and 11, respectively.

Table 7.12 Total Number of Female, Male and Immature Slimy Sculpin Captured for Processing at Sentinel Species Monitoring Sites, Fall 2001

Sex	Exposure Sites		Reference Sites		
	MR-E	SR-E	HR-R	SR-R	DR-R
female	31	37	31	38	40
male	29	22	30	30	11
immature[(a)]	1	0	0	0	2
total	**61**	**59**	**61**	**68**	**53**

(a) Not included in sentinel species analyses.

Water quality parameters measured in the field at each site indicated similarities between the two exposure sites with the exception of a higher pH at site SR-E (Table 7.13). Every parameter measured at the Steepbank River reference site was higher than the corresponding parameters in the Horse and Dunkirk rivers. Water temperature and conductivity at all reference sites were lower than at the exposure sites.

Table 7.13 Mean Values ± SD of Water Quality Parameters Measured at Sentinel Species Monitoring Sites, Fall 2001

Parameter	Exposure Sites[(a)]		Reference Sites[(b)]		
	MR-E (*n*=3)	SR-E (*n*=2)	HR-R (*n*=1)	SR-R (*n*=2)	DR-R (*n=1)*
water temperature (°C)	11.49 ± 0.02	11.12 ± 0.25	8.93	10.54 ± 0.71	8.82
dissolved oxygen (mg/L)	9.00 ± 0.56	9.44 ± 0.10	9.66	10.73 ± 0.40	9.68
conductivity (µS/cm)	343 ± 25.4	309 ± 2.83	111	298 ± 0.71	182
pH	7.83 ± 0.01	8.45 ± 0.09	7.42	8.15 ± 0.02	7.76

(a) Muskeg River n=3; Steepbank River n=2.
(b) Steepbank River n=2; Horse River n=1; Dunkirk River n=1, where n = number of times measurements were taken.
Note: Means were calculated from measurements taken each time a site was sampled for slimy sculpin.

Slimy Sculpin Population Data

Mean length, weight, condition factor, age, fecundity, LSI, GSI and PI for slimy sculpin from the Muskeg and Steepbank rivers exposure sites and the three reference sites are presented in Table 7.14.

Table 7.14 Mean ± SE (*n*) of Body Size, Age, Fecundity, Liver Size, Gonad Size and PI of Slimy Sculpin, Sentinel Species Monitoring Sites, Fall 2001

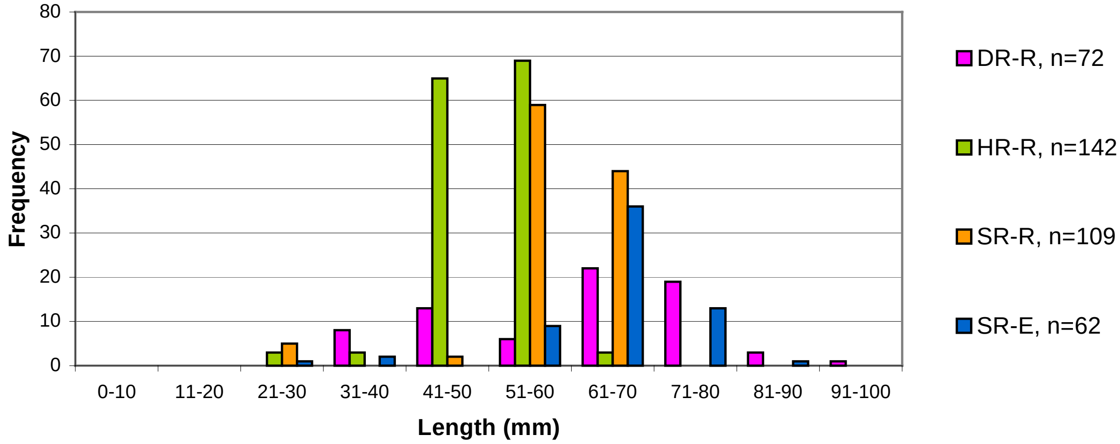
Sex	Parameter	Exposure Sites		Reference Sites		
		MR-E	SR-E	HR-R	SR-R	DR-R
female	total length (mm)	76.74± 1.23 (31)	71.81 ± 0.75 (37)	59.03 ± 0.97 (31)	67.00 ± 0.59 (38)	78.58 ± 1.28 (40)
	body weight (g)	5.05 ± 0.30 (31)	4.09 ± 0.13 (37)	2.01 ± 0.09 (31)	3.50 ± 0.10 (38)	5.18 ± 0.22 (40)
	condition factor [(a)]	1.09 ± 0.03 (31)	1.09 ± 0.01 (37)	0.97 ± 0.02 (31)	1.15 ± 0.01 (38)	1.05 ± 0.02 (40)
	age (y)	1.58 ± 0.17 (31)	2.46 ± 0.16 (37)	2.45 ± 0.12 (31)	2.18 ± 0.07 (38)	2.65 ± 0.22 (40)
	fecundity (#eggs/g)[(b)]	87.89 ± 4.32 (31)	99.27 ± 4.56 (36)	101.05 ± 2.48 (29)	98.26 ± 2.6 (38)	86.01 ± 2.15 (40)
	LSI[(c)]	2.68 ± 0.10 (30)	2.89 ± 0.09 (37)	2.32 ± 0.10 (31)	3.39 ± 0.11 (38)	2.62 ± 0.08 (40)
	GSI[(d)]	1.40 ± 0.07 (31)	1.33 ± 0.04 (37)	2.43 ± 0.10 (30)	2.04 ± 0.07 (38)	2.64 ± 0.08 (40)
	PI[(e)]	18.06 ± 2.72 (31)	9.19 ± 2.37 (37)	3.87 ± 1.72 (31)	22.63 ± 4.34 (38)	16.50 ± 2.25 (40)
male	total length (mm)	82.76 ± 1.39 (29)	80.0 ± 1.14 (22)	63.33 ± 0.60 (30)	72.77 ± 0.50 (30)	82.27 ± 2.07 (11)
	body weight (g)	6.69 ± 0.38 (29)	5.60 ± 0.26 (22)	2.51 ± 0.07 (30)	4.37 ± 0.13 (30)	6.64 ± 0.67 (11)
	condition factor [(a)]	1.15 ± 0.02 (29)	1.08 ± 0.02 (22)	0.98 ± 0.01 (30)	1.13 ± 0.02 (30)	1.16 ± 0.07 (11)
	age (y)	1.55 ± 0.18 (29)	2.77 ± 0.25 (22)	2.30 ± 0.11 (30)	2.10 ± 0.06 (30)	1.73 ± 0.19 (11)
	LSI[(c)]	1.72 ± 0.08 (28)	1.79 ± 0.11 (21)	1.13 ± 0.06 (30)	1.58 ± 0.07 (30)	1.35 ± 0.05 (11)
	GSI[(d)]	1.86 ± 0.10 (28)	1.67 ± 0.05 (21)	2.39 ± 0.07 (30)	2.29 ± 0.08 (30)	2.28 ± 0.07 (11)
	PI[(e)]	18.97 ± 3.30 (29)	11.36 ± 2.96 (22)	2.0 ± 1.11 (30)	19.67 ± 3.37 (30)	9.09 ± 6.25 (11)

(a) Condition Factor = (body weight)/(length^3) * 10^5.
(b) Fecundity Index (# eggs / carcass weight).
(c) LSI = Liver Somatic Index.
(d) GSI = Gonad Somatic Index.
(e) PI = Pathology Index (the higher the index value, the higher the number and/or severity of abnormalities).

Size and Age Distributions, – 2001 Results

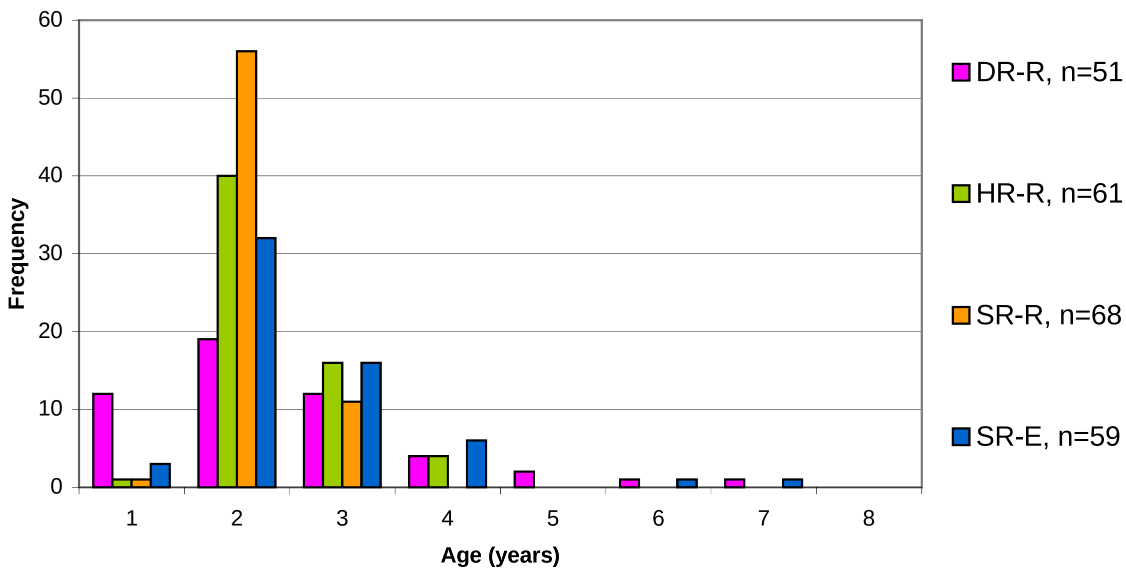
Length-frequency distributions of slimy sculpin at the Steepbank River exposure site and the three reference sites are presented in Figure 7.9. This figure presents the size distribution for all fish captured, including sacrificed fish and juvenile and adult fish that were released. The Steepbank River exposure site exhibited a peak mode at 70-79 mm and a maximum size in the 90-99 mm range. Both the peak mode and maximum size of slimy sculpin were higher at the exposure site than at the reference sites SR-R and HR-R, but were similar to site DR-R. This is reflected in the size of the fish sacrificed for the analysis; the mean length and weight of fish from the exposure site were higher than those at sites SR-R and HR-R, but slightly lower than at site DR-R (Table 7.14).

Figure 7.9 Length-Frequency Distributions for Slimy Sculpin, Steepbank River Exposure Site and Reference Sites on the Horse, Steepbank and Dunkirk Rivers, Fall 2001



Age distributions of sacrificed adult slimy sculpin (Figure 7.10) indicated that exposure and reference fish used in the health analysis consisted primarily of 2 and 3 year old fish, with some 1 and 4 year old fish. The Steepbank River exposure site and the Dunkirk River reference site also included a few fish of up to 7 years of age, whereas the maximum age at the reference sites SR-R and HR-R was 4 years.

Figure 7.10 Age-Frequency Distributions for Adult Slimy Sculpin, Steepbank River Exposure Site and Reference Sites on the Horse, Steepbank and Dunkirk Rivers, Fall 2001



Size and Age Distributions – Comparisons of 1999 and 2001

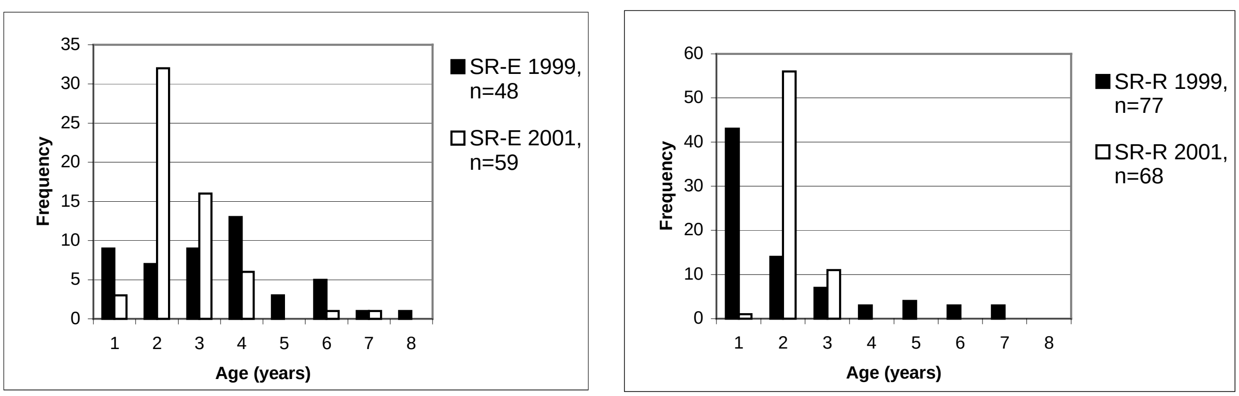
Length frequency distributions are not comparable between the 1999 and 2001 results, as only adults were selected for measurement during fish collection in 1999 and do not represent the whole population. In 2001, measurements were taken for all fish captured to provide a more complete representation of population structure.

A comparison of age distributions for adult slimy sculpin from the exposure and reference sites on the Steepbank River in 1999 and 2001 are shown in Figure 7.11. Generally, the majority of sculpin collected in 1999 at SR-E ranged between one and four years of age, whereas mainly two and three year old fish were collected in 2001. Almost half of the fish collected at site SR-R in 1999 were yearlings, whereas most of the fish collected in 2001 were two years old.

Pathology

Comparison of the mean PI for the Steepbank River exposure site to the reference sites showed variable results (Table 7.14). The index of abnormal pathology (PI) at SR-E was higher than at HR-R, lower than at SR-R, lower than DR-R (for females) and similar to DR-R (for males).

Figure 7.11 Age-Frequency Distributions for Adult Slimy Sculpin at Exposure and Reference Sites on the Steepbank River, 1999 and 2001



The percentages of slimy sculpin with specific pathological abnormalities are presented in Table 7.15 for the exposure and reference sites. Most external abnormalities occurred in low frequency (i.e., <10% of the population), with the exception of fin erosion at site DR-R (53%). The most frequent external pathology observed at the Steepbank River exposure site were gill abnormalities (clubbed and frayed gills). A similar frequency of gill abnormalities was recorded at the reference site SR-R and smaller percentages were recorded at the other two reference sites.

Table 7.15 Percentage of Slimy Sculpin with Specific Pathological Abnormalities at Exposure and Reference Sites, Muskeg, Steepbank, Horse and Dunkirk Rivers, Fall 2001

Pathology Parameter	Exposure Sites		Reference Sites		
	MR-E (n=60)	SR-E (n=59)	SR-R (n=68)	HR-R (n=61)	DR-R (n=51)
External Abnormalities					
eyes	5	2	0	0	0
gills	15	7	9	2	4
skin	7 (low)[a]	2 (low)	1 (low)	2 (low)	2 (low)
fins	0	2 (low)	9 (low)	3 (low)	53 (low)
body deformities	0	3	0	0	4
Pseudobranchs	0	2	0	2	0
thymus	0	0	0	0	0
opercle	2 (low)	0	1 (low)	0	0
Internal Abnormalities					
hindgut	0	0	4 (low)	5 (low)	4 (low)
liver	20	5	19	2	14
spleen	7	10	9	2	0
gall bladder	0	0	0	0	0
kidney	2	0	9	0	0
External and Internal Combined					
parasites	32 (low)	10 (low)	49 (low)	0	8 (low)

(a) Severity of abnormality is indicated in parentheses where appropriate.

A small percentage (2%) of slimy sculpin at the Steepbank River exposure site showed pathology of the eyes (Table 7.15). Although the percentage was low, the type of abnormality was also recorded among fish from the exposure site on the lower Muskeg River. A thick mucus membrane covering the eyes of fish was observed at both sites SR-E and MR-E and was not seen in the reference populations.

One of the most frequent pathologies observed at the Steepbank River exposure site was parasitism. The incidence of parasites in slimy sculpin at the exposure site was considerably lower than at site SR-R, higher than at site HR-R and similar to site DR-R. Observed parasitism included external and internal cysts and each occurred at the same frequency. Internal cysts were observed in the body cavity and embedded in the organs. External parasites were observed in the gill chambers, as well as on the skin and fins.

The most frequent internal pathology observed in fish from the Steepbank River exposure site was abnormal spleen size (extremely small). Similar spleen abnormalities were also recorded at reference site SR-R. Another internal pathology observed at site SR-E was abnormal discolouration of the liver. The incidence of similar liver abnormality was higher at all reference sites, except for site HR-R. Other internal abnormalities recorded at the reference sites but not at the exposure site were hindgut inflammation and kidney abnormalities. External and internal pathology data are presented for all fish examined in Appendix VI.

Statistical Comparisons

Comparisons were made for parameters for which statistical analyses were possible. Growth comparisons were attempted using size-at-age analysis (length-at-age regression). However, the correlation between length and age for slimy sculpin were found to be very poor, and this analysis could not be used. Table 7.16 presents the coefficient of determination (r^2) values for the five sentinel sites.

Table 7.16 Coefficient of Determination (r^2) Values for Slimy Sculpin Size-at-Age Analysis, Sentinel Monitoring Sites, 1999 and 2001

Site	1999		2001	
	Male	Female	Male	Female
MR-E	0.28	0.10	0.26	0.17
SR-E	0.16	0.56	0.38	0.04
SR-R	0.25	0.60	<0.01	0.06
HR-R	-	-	0.11	0.39
DR-R	-	-	0.64	0.63

2001 Results

A summary of the responses (i.e., differences) between slimy sculpin from the Steepbank River exposure site and the three reference sites is presented in Table 7.17. The results are presented as ‘0’ (no statistical difference), ‘-’ (exposure site is statistically lower) or ‘+’ (exposure site is statistically higher). Comparisons are presented between the exposure site and each individual reference site, as well as for the reference sites combined.

Mean lengths of both male and female fish were greater at the exposure site than the average for all reference sites combined (Table 7.17). Lengths of males and females at the exposure site were greater than at the Horse River and Steepbank River reference sites. Compared to the Dunkirk River, lengths of exposure site females were less, while males were not significantly different.

Table 7.17 Summary of the Responses of Slimy Sculpin from the Steepbank River Exposure Site Relative to the Reference Sites, Fall 2001

Sex	Parameter	Dunkirk River Reference		Horse River Reference		Steepbank River Reference		Mean of All Reference Sites	
		Response[(a)]	% Difference[(b)]	Response	% Difference	Response	% Difference	Response	% Difference
female	total length (mm)	-	-8.61	+	21.65	+	7.18	+	4.10
	body weight (g)[(c)]	0	ns	+	23.19	0	ns	+	5.89
	condition factor[(d)]	0	ns	+	12.93	-	-5.31	0	ns
	age (y)	0	ns	0	ns	0	ns	0	ns
	fecundity[(e)]	+	15.42	0	ns	0	ns	0	ns
	LSI[(f)]	0	ns	+	24.62	-	-14.59	0	ns
	GSI[(g)]	-	-49.59	-	-45.24	-	-34.69	-	-43.84
	PI[(h)]	-	-44.31	0	ns	-	-59.40	0	ns
male	total length (mm)	0	ns	+	26.32	+	9.94	+	13.87
	body weight (g)[(c)]	0	ns	0	ns	0	ns	0	ns
	condition factor[(d)]	0	ns	+	10.26	0	ns	0	ns
	age (y)	+	60.53	0	ns	+	32.03	+	30.37
	LSI[(f)]	+	33.18	+	58.66	0	ns	+	32.67
	GSI[(g)]	-	-26.87	-	-30.29	-	-27.09	-	-28.44
	PI[(h)]	0	ns	+	468.18	0	ns	0	ns

(a) Response relative to reference site: 0 indicates no difference.
(b) Percent difference of exposed site relative to reference site; ns = not significantly different.
(c) Adjusted least squares mean weight from analysis of covariance with length as the covariate.
(d) Condition Factor = (weight)/(length^3) * 10^5.
(e) Fecundity (# eggs/carcass weight).
(f) LSI = Liver Somatic Index ([liver weight/carcass weight] x 100).
(g) GSI = Gonad Somatic Index ([gonad weight/carcass weight] x 100).
(h) PI = Pathology Index (index increases as number and severity of abnormalities increases).
Note: + indicates reference site is significantly higher (P<0.05).
- indicates reference site is significantly lower (P<0.05).

Adjusted mean body weight (adjusted for the effect of fish length in analysis of covariance) was greater at the exposure site than the average of all reference sites for female fish, but was not significantly different for male fish. The body weight of females at the exposure site was greater than at the Horse River reference site, but there were no significant differences between the exposure site and either the Dunkirk River or Steepbank River reference sites. Mean weight of male fish at the exposure site was not significantly different from male fish at any of the reference sites.

There were few significant differences in condition factor. The condition factor for males at the exposure site was greater than for males at the Horse River reference site, but was not significantly different than the condition factor for males at either of the other two reference sites. Condition factor was also not significantly different than the average for all reference sites. For females, the condition factor was also greater at the exposure site than at the Horse River reference site, but was less than at the Steepbank River reference site and was not significantly different than the average for all reference sites.

The mean age of male slimy sculpin at the exposure site was greater than the average for all reference sites and was greater than the mean age of males at both the Dunkirk River and Steepbank River reference sites. Mean age of females at the exposure site was not significantly different than the mean age of females at any of the reference sites. Reasons for the inconsistency in response of males and females, with respect to mean age, are not apparent. An increase in mean age can result from an increase in juvenile or early life stage mortality or from a decrease in recruitment (Gibbons and Munkittrick 1994). However, these factors would be expected to affect both males and females equally.

Fecundity at the exposure site was not significantly different than the average fecundity for all reference sites. It was also not significantly different than at either the Horse River or Steepbank River reference sites; however, fecundity was greater at the exposure site than at the Dunkirk River reference site. These results indicate that fecundity of slimy sculpin at the exposure site has not likely been affected, relative to the range of fecundity values observed among the reference sites.

For female slimy sculpin, the LSI response was not consistent relative to all of the reference sites. LSI for females at the exposure site was less than at the Steepbank River reference site, greater than at the Horse River reference site, and not significantly different from the Dunkirk River reference site. There was also no significant difference between the exposure site and the average for all reference sites. The LSI for males was greater at the exposure site than at either the Dunkirk River or Horse River reference sites. It was also greater than the average for all reference sites, but was not significantly different from the LSI for males at the Steepbank River reference site. Reasons for the observed inconsistencies in LSI response, relative to different reference sites and between male and female fish are not apparent. Changes in liver size may reflect changes in food availability and have also been associated with exposure to various chemicals (Sloof et al. 1983; Hodson et al. 1992; McMaster et al. 1991). However, responses would be expected to be similar for both males and females.

The GSI response of slimy sculpin at the exposure site was consistent relative to all reference sites and the direction of the response was the same for both males and females. The GSI for both sexes was less at the exposure site than at any of the reference sites, but the magnitude of the differences was greater for female fish. Therefore, relative gonad size was smaller at the exposure site than the range of variation represented by the reference sites.

Some differences in the PI were noted, but these differences were not consistent relative to all references sites. For both males and females, the PI at the exposure site was not significantly different than the average PI for all reference sites. However, there were some significant differences between the exposure site and specific reference sites. For females, the PI was less at the exposure site than at either of the Dunkirk River and Steepbank River reference sites. For males, the PI at the exposure site was not significantly different than at the Dunkirk River and Steepbank River reference sites, but was significantly greater than at the Horse River reference site.

Comparisons of 1999 and 2001

Comparisons of the responses of slimy sculpin between 1999 and 2001 at the Steepbank River reference site and the Steepbank River exposure site are presented in Table 7.18. There were significant differences between years for most parameters at both sites. Except for the GSI parameter, the pattern of changes from 1999 to 2001 was similar at both the exposure site and the reference site.

Fish lengths decreased from 1999 to 2001 for both males and females at both sites, but the magnitude of the change was relatively small. Adjusted mean body weights, the condition factor and LSI all increased from 1999 to 2001 for both males and females at both sites (except the change in LSI for males at the reference site was not significant), suggesting a general increase in energy storage in slimy sculpin at both sites.

There was no change in mean age of females at either site from 1999 to 2001, and there was also no change in mean age of males at the exposure site. The mean age of males at the reference site increased slightly from 1999 to 2001. These results for fish ages, together with the results for fish lengths, may indicate a change in growth rate; a decrease in mean lengths would be expected to be associated with a decrease in mean age if growth rate remained the same. Except for males at the reference site, mean ages did, in fact, decrease from 1999 to 2001 but the differences were not statistically significant. However, for males at the reference site, mean age increased significantly, and mean length decreased significantly, from 1999 to 2001. This could be accounted for by a change in growth rate over time at the reference site for male fish.

Table 7.18 Comparisons of the Responses of Slimy Sculpin in 1999 and 2001 at the Steepbank River Reference Site and the Steepbank River Exposure Site

Sex	Parameter	Steepbank River Exposure Site							Steepbank River Reference Site						
		1999			2001			%	1999			2001			%
		Mean	SE	N	Mean	SE	N	Change	Mean	SE	N	Mean	SE	N	Change[a]
female	total length (mm)	81.853	1.425	34	71.811	0.752	37	-12.27	75.302	1.496	43	67.000	0.588	38	-11.03
	body weight (g)[b]	4.197	-	34	4.807	-	37	14.53	3.500	-	43	4.150	-	38	18.57
	condition factor[c]	0.950	0.018	34	1.093	0.014	37	15.13	0.989	0.010	43	1.155	0.011	38	16.73
	age (y)	3.294	0.315	34	2.459	0.158	37	ns	2.310	0.288	42	2.184	0.074	38	ns
	fecundity[d]	57.230	4.316	30	99.274	4.495	37	73.47	62.817	2.872	29	98.256	2.604	38	56.42
	LSI[e]	2.298	0.133	34	2.895	0.087	37	25.94	2.479	0.097	41	3.389	0.112	38	36.73
	GSI[f]	1.820	0.057	34	1.330	0.040	37	-26.92	1.840	0.048	42	2.036	0.066	38	10.66
male	total length (mm)	86.333	2.216	15	80.000	1.136	22	-7.34	79.427	1.750	37	72.767	0.504	30	-8.39
	body weight (g)[b]	5.319	-	15	5.990	-	22	12.62	4.395	-	37	4.703	-	30	7.01
	condition factor[c]	0.955	0.014	15	1.081	0.020	22	13.25	0.970	0.018	37	1.130	0.025	30	16.59
	age (y)	3.571	0.441	14	2.773	0.254	22	ns	1.886	0.249	35	2.100	0.056	30	11.36
	LSI[e]	1.261	0.058	15	1.794	0.106	21	42.24	1.430	0.058	37	1.576	0.074	30	ns
	GSI[f]	2.120	0.103	15	1.669	0.047	21	-21.30	2.100	0.066	37	2.289	0.081	30	ns

(a) Percent change from 1999 to 2001 where the change was significant (P<0.05); ns = not significantly different.
(b) Adjusted least squares mean weight from analysis of covariance with length as the covariate.
(c) Condition Factor = (weight)/(length^3) * 10^5.
(d) Fecundity (# eggs/carcass weight).
(e) LSI = Liver Somatic Index ([liver weight/carcass weight] x 100).
(f) GSI = Gonad Somatic Index ([gonad weight/carcass weight] x 100).

Fecundity increased at both sites from 1999 to 2001, by 56% at the reference site and by 73% at the exposure site. The GSI for females at the reference site also increased from 1999 to 2001 and this is consistent with the observed increase in fecundity. However, GSI for females at the exposure site decreased (by 27%) while fecundity increased, implying that the number of eggs increased and their size decreased. For male fish, the GSI did not change at the reference site from 1999 to 2001, but decreased by 21% over the same period at the exposure site.

Summary

Differences in slimy sculpin populations between the Steepbank River exposure site and the three reference sites were found to be variable between sites and among parameters. Following the 2000 survey to select reference areas for the tributary sentinel species monitoring program, it was recommended that the multiple reference sites be combined to provide average conditions that represent the range of natural variation in slimy sculpin populations in the region (Golder 2001a). Therefore, the following summary is based on statistical comparisons between the exposure site and the combined reference sites. Support for assessing changes in the exposure population over time is obtained from between year comparisons of fish at the exposure site. Where changes appear to be occurring, between year comparisons at the reference site are used to determine if the changes reflect natural variation or occur only at the exposure site.

Female slimy sculpin were not significantly different from the combined reference sites, with the exception of greater average length and weight, and lower gonad size (i.e., GSI). Male fish showed greater average length, age and liver size (LSI) and lower gonad size.

While there was some tendency for fish to be larger at the exposure site, the results of analyses of body weight and condition factor did not provide conclusive evidence that the condition of fish at the exposure site was different from to the condition of fish at the reference sites. It was determined that fish abundance was lower at the exposure site than any of the reference sites, but whether this would affect fish size would depend on differences in productivity between the sites. Nevertheless, the results show some potential interactions between abundance and size; the Horse River site had the highest fish abundance, but the lowest average length, weight and condition factor.

The higher LSI for males at the exposure site was not considered a response to either greater food availability (i.e., glycogen storage) or chemical exposure (i.e., increased need for detoxification), because the response was not consistent for both sexes.

The one parameter for which the difference between the exposure site and the range of variability represented by the combined reference sites may be meaningful is relative gonad size. GSI values were significantly lower at the exposure site for both male (-28.44%) and female (-43.84%) slimy sculpin. This response appears to be consistent, as the comparison of 1999 data to 2001 results for the Steepbank River exposure site shows a decrease in relative gonad size for both sexes. Over the same period, relative gonad size at the Steepbank River reference site increased slightly for females and remained unchanged for males.

In addition, there was a corresponding increase in fecundity from 1999 to 2001 at the exposure site, suggesting that egg size had decreased for females at the exposure site.

One factor that may account for the smaller GSI in the Steepbank River exposure population would be the differences in age structure among populations. There was a shift towards younger dominant age classes at the exposure site in 2001 compared to 1999. The dominant age class for captured fish went from four years (1999) to two years (2001) at the exposure site. In contrast, the dominant age for captured fish shifted from age one to age two for the Steepbank River reference population over the same period. Smaller relative gonad size for the exposure population would be expected, especially since first-time spawners (i.e., younger fish) generally produce smaller gonads.

Another factor that may account for the smaller GSI values in exposure fish relative to reference fish is the bigger size of the exposure fish. Fish from the exposure population appeared to be directing more energy towards somatic growth, rather than gonad growth, compared to reference fish. Though this could help explain the smaller GSI in exposure fish, this factor, in combination with the very young age of exposure fish, likely explains the lower GSI in that population.

An interesting observation that should be noted is that the actual gonad size (i.e., not corrected for carcass weight) in male fish from the exposure population was larger than in reference populations. The actual amount of gonadal development in the male fish from the exposure population (including the younger fish) was higher than in reference fish. Actual gonad size for female fish from the exposure site was similar to reference fish, but was still somewhat smaller.

This data indicates that, despite the lower GSI values for fish from the Steepbank River exposure site, the reproductive potential for the population is similar to reference populations and has not changed much since 1999. Rather, the increase in fish size at the exposure site observed between 1999 and 2001 has not been reflected in a corresponding increase in gonad size. Since fish size at the exposure site is as large, or larger, than most of the reference sites, it appears that the exposure population distributes relatively more energy to somatic growth than gonad growth. Emphasis on somatic growth over gonad development is typical for younger fish.

Due to differences in habitat characteristics between exposure and reference sites, it may be that within-site comparisons are more appropriate than between-site comparisons for defining impacts. Within-site trends over time may be the best monitoring tool. Based on this, the decrease in relative gonad size from

1999 to 2001 at the exposure site suggests that this parameter should be closely monitored.

The high fecundity level combined with smaller gonad size for the exposure population indicates a smaller egg size, which may reduce embryo survival and hatchability. Differences in fecundity between 1999 and 2001 may be due, in part, to different measurement methods. In 1999, fecundity was estimated from an ovarian sub-sample, while in 2001, true fecundity was determined by a direct count of all eggs. The direct egg count technique will be used for future tributary sentinel species monitoring.

Significance of Effects

The concern remains whether the observed changes in GSI for slimy sculpin at the Steepbank River exposure site represent an effect of oil sands development or are related to natural variability. In many studies, a statistically significant difference in biological measures has been used as evidence that an effect has occurred. Indeed, several industry-wide monitoring programs have adopted this approach (Environment Canada 1998, 1999). Unfortunately, extrapolation from statistical significance to ecological significance is flawed because statistical significance can be guaranteed if enough samples are collected, irrespective of the size of the impact. It was concluded that an effect on relative gonad size had occurred based on the consistent pattern observed in both males and females in the exposure population when compared to reference populations; however, it is important to know whether these differences are of ecological relevance.

The approach proposed by Kilgour et al. (1998) was used to determine the ecological significance of the observed effects. They define ecologically relevant differences as observations from impact locations that fall outside the normal range of variation based on reference-location data. They also define the normal range as the region enclosing 95% of reference-location observations. The 95% region can then be expressed generically as standard deviations in univariate responses. For example, in single responses that are normally distributed, the region defined by $\mu \pm 1\,\sigma$ incorporates about 67% of the population, and $\mu \pm 1.96\,\sigma$ incorporates about 95% of the population. All of the mean values of exposure population parameters fell within the normal range based on the three reference populations; however, GSI in female fish was very close to the lower boundary of the normal range.

Considering the number of possible explanations, as described above, that could account for the low GSI observations, it is believed that the low relative gonad sizes encountered are not abnormal. The above explanation of effects also highlighted inconsistencies in a number of observed responses, both between populations and between years. More consistent differences would be expected if, indeed, observed responses were related to a particular stressor. Annual variations in the various parameters measured must be understood before an effect of concern can be identified. Results of the benthos monitoring provided additional evidence of the nature of annual variability these systems undergo. The magnitude of differences observed over three years of benthos monitoring provides evidence of the scope of natural variability that can be observed in natural systems.

Sample Size Considerations

To evaluate the suitability of sample sizes used for statistical analyses of the slimy sculpin response parameters, a power analysis was conducted using the SYSTAT 10 statistical software. This analysis determined the number of fish required from each site to detect parameter differences of various magnitudes between an exposure site and the three reference sites using ANOVA. The magnitudes of parameter differences used for this analysis were 10, 20, 30 and 50% of the mean value of each parameter for all reference sites.

Two sets of power analyses were conducted; one for the Steepbank River exposure site with the three reference sites, and one for the Muskeg River exposure site with the three reference sites. The results of these analyses are summarized in Table 7.19. With the exception of age, fecundity and PI sample sizes of female and male slimy sculpin were sufficient, at most sites, to detect a 10% difference between sites. For two sites (Dunkirk River reference site and Steepbank River exposure site), the number of males collected was less than at other sites and these sample sizes were not sufficient for detection of a 10% difference in most parameters. However, the sample sizes for males at these sites were sufficient to detect a 20% difference in all parameters except age and pathology index.

Due to greater variability in ages of slimy sculpin, relative to the variability of most other parameters, a 20% difference in age was the smallest detectable with the sample sizes used. In addition, the number of males collected from the Dunkirk River reference site was less than required to detect a 20% difference in age. While sample sizes were not sufficient for detection of a 10% difference in fecundity, they were sufficient for detection of a 20% difference in fecundity.

The variability of the pathology index was very high, and sample sizes were not sufficient for detection of differences as great as 50%. To be able to detect a 50% difference in PI, 46 females and 59 males would be required for comparisons involving the Steepbank River exposure site and 46 females and 62 males would be required for comparisons involving the Muskeg River exposure site. For detection of a 20% difference in PI, the sample sizes required are 279 females and 364 males for Steepbank River comparisons and 281 females and 377 males for Muskeg River comparisons.

Table 7.19 Sample Sizes Required to Detect Parameter Differences Between the Steepbank River Exposure Site or the Muskeg River and the Three Reference Sites Using Analysis of Variance (ANOVA) [a]

Sex	Parameter	Steepbank River Exposure Site				Muskeg River Exposure Site			
		10% Difference	20% Difference	30% Difference	50% Difference	10% Difference	20% Difference	30% Difference	50% Difference
female	total length (mm)	2	2	2	2	2	2	2	2
	body weight (g)[b]	11	4	2	2	18	6	3	2
	condition factor[c]	17	6	3	2	23	7	4	3
	age (y)	91	24	11	5	101	26	13	6
	fecundity[d]	77	20	10	5	65	17	9	4
	LSI[e]	22	7	4	3	23	7	4	3
	GSI[f]	19	6	4	2	21	7	4	3
	PI[g]	1,120	279	125	46	1,120	281	126	46
male	total length (mm)	2	2	2	2	2	2	2	2
	body weight (g)[b]	17	5	3	2	16	5	3	2
	condition factor[c]	26	8	4	3	26	8	4	3
	age (y)	59	16	8	4	74	20	10	5
	LSI[e]	38	11	6	3	42	12	6	3
	GSI[f]	16	5	3	2	23	7	4	3
	PI[g]	1,460	364	163	59	1,510	377	168	62

(a) Magnitudes of the detectable differences are 10, 20, 30 and 50% of the mean value for all reference sites.
(b) Adjusted least squares mean weight from analysis of covariance with length as the covariate.
(c) Condition Factor = (weight)/(length^3) * 10^5.
(d) Fecundity (# eggs/carcass weight).
(e) LSI = Liver Somatic Index ([liver weight/carcass weight] x 100).
(f) GSI = Gonad Somatic Index ([gonad weight/carcass weight] x 100).
(g) PI = Pathology Index (index increases as number and severity of abnormalities increases).

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8.1 WATER QUALITY

Water quality in the Muskeg River watershed was generally consistent with historical data. Those water quality parameters observed to be notably different in 2001 than in previous sampling events are discussed below.

8.1.1 Jackpine Creek

In Jackpine Creek, downstream of the Canterra Road, dissolved phosphorus and thallium levels were higher in 2001 than in previous years and total metals concentrations were generally lower in 2001 than historical median levels (Table 8.1).

Table 8.1 Water Quality Data for Jackpine Creek, Fall

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [(a)]			
			median	min	max	n
Field Measured						
pH		**8.6** [(A,C)]	7.8	7.1	**8.6** [(A,C)]	11
specific conductance	µS/cm	242	223	46	451	14
temperature	°C	11.2	6.5	0	11.4	15
dissolved oxygen	mg/L	10.1	9.8	**6.3** [(C)]	12.6	16
Conventional Parameters						
colour	T.C.U.	100	100	35	150	14
conductance	µS/cm	244	204	120	460	22
dissolved organic carbon	mg/L	24	24	13	36	17
hardness	mg/L	119	102	77	222	14
pH		8	7.6	7.3	7.9	21
total alkalinity	mg/L	127	112	80	243	22
total dissolved solids	mg/L	230	126	94	467	22
total organic carbon	mg/L	31	26	18	40	19
total suspended solids	mg/L	< 3	6	< 0.4	52	22
Major Ions						
bicarbonate	mg/L	155	141	102	297	7
calcium	mg/L	33	26	19	62	21
carbonate	mg/L	< 5	< 3	< 1	< 5	4
chloride	mg/L	2	2	1	13	22
magnesium	mg/L	9	8	6	16	22
potassium	mg/L	1	1	0.2	1	22
sodium	mg/L	12	13	9	21	22
sulphate	mg/L	4	4	0.1	10	22

Table 8.1 Water Quality Data for Jackpine Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [(a)]			
			median	min	max	n
sulphide	mg/L	0.009	0.006	0.006	**0.103** [(C)]	3
Nutrients and Chlorophyll *a*						
nitrogen - ammonia	mg/L	< 0.05	< 0.05	0.01	< 0.1	5
nitrogen - total [(b)]	mg/L	**1.4** [(C)]	0.8	0.3	**3.4** [(C)]	19
phosphorus, total	mg/L	0.023	0.035	0.01	**0.08** [(C)]	22
phosphorus, dissolved	mg/L	0.026	0.014	0.006	0.017	5
chlorophyll *a*	mg/L	0.001	< 0.001	< 0.001	0.024	10
Biological Oxygen Demand						
biochemical Oxygen Demand	mg/L	< 2	2	1	3	8
General Organics						
naphthenic acids	mg/L	1	1	< 1	1	4
total phenolics	mg/L	0.005	0.004	< 0.001	**0.011** [(C)]	15
total recoverable hydrocarbons	mg/L	< 0.5	0.6	< 0.1	2.9	16
Toxicity						
Ceriodaphnia 7 d mortality test - LC25	%	> 100	-	-	-	-
Ceriodaphnia 7 d reproduction test - IC25	%	> 100	-	-	-	-
fathead minnow 7d growth - IC25	%	> 100	-	-	-	-
fathead minnow 7d mortality test - LC25	%	> 100	-	-	-	-
Metals (Total)						
aluminum (Al)	mg/L	0.04	0.07	< 0.01	**0.91** [(A,C)]	8
antimony (Sb)	mg/L	**< 0.005** [(D>H)]	0.0002	0.00002	**< 0.005** [(D>H)]	7
arsenic (As)	mg/L	< 0.001	0.0008	0.0002	**0.02** [(C)]	12
barium (Ba)	mg/L	0.022	0.049	0.013	0.056	7
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.00004	0.001	7
boron (B)	mg/L	0.04	0.05	0.03	0.07	8
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.00002	**0.004** [(A,C)]	8
chromium (Cr)	mg/L	< 0.0008	0.0008	0.0003	**0.012** [(C)]	8
cobalt (Co)	mg/L	< 0.0002	0.0002	0.0001	0.009	7
copper (Cu)	mg/L	< 0.001	0.001	0.0003	**0.0046** [(C)]	8
iron (Fe)	mg/L	**0.73** [(C,H)]	**1.08** [(C,H)]	**0.38** [(C,H)]	**1.57** [(C,H)]	8
lead (Pb)	mg/L	0.0002	0.0002	0.00004	**< 0.02** [(D>C)]	8
lithium (Li)	mg/L	0.008	0.013	0.009	0.079	7
manganese (Mn)	mg/L	**0.018** [(H)]	**0.053** [(H)]	**0.016** [(H)]	**0.077** [(H)]	8
mercury (Hg)	mg/L	< 0.0000006	**< 0.0001** [(D>H)]	**< 0.00005** [(D>H)]	**0.0045** [(A,C,H)]	18
molybdenum (Mo)	mg/L	0.0001	0.0001	0.0001	0.003	7
nickel (Ni)	mg/L	< 0.0002	0.0013	< 0.0001	< 0.005	8
selenium (Se)	mg/L	< 0.0008	< 0.0005	< 0.0002	< 0.0008	8
silver (Ag)	mg/L	< 0.000005	< 0.0001	< 0.000005	**0.005** [(A,C)]	7
strontium (Sr)	mg/L	0.11	0.17	0.09	0.19	7
thallium (Tl)	mg/L	< 0.0001	0.00008	< 0.000003	0.00017	4

Table 8.1 Water Quality Data for Jackpine Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [a]			
			median	min	max	n
titanium (Ti)	mg/L	0.002	0.0036	0.0016	< 0.05	8
uranium (U)	mg/L	< 0.0001	0.0001	0.0001	< 0.5	7
vanadium (V)	mg/L	< 0.0002	< 0.001	0.0004	0.002	19
zinc (Zn)[b]	mg/L	< 0.004	0.005	0.0005	**0.186** [A,C]	8
Metals (Dissolved)						
aluminum (Al)	mg/L	*0.17*	0.01	0.0033	0.0489	5
antimony (Sb)	mg/L	< 0.0008	0.0007	0.00001	< 0.0008	5
arsenic (As)	mg/L	0.0004	0.0004	< 0.0002	0.0011	15
barium (Ba)	mg/L	*3.31*	0.044	0.012	0.051	5
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.00004	< 0.001	5
boron (B)	mg/L	*0.86*	0.07	0.03	0.48	18
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 0.00001	< 0.0001	5
chromium (Cr)	mg/L	*0.0006*	0.0004	0.0002	0.0009	5
cobalt (Co)	mg/L	*0.0003*	0.0001	0.0001	0.0002	5
copper (Cu)	mg/L	*0.0011*	0.0006	0.0003	0.0039	5
iron (Fe)	mg/L	0.7	0.31	0.17	0.39	6
lead (Pb)	mg/L	*0.0012*	0.0001	0.00002	0.0008	5
lithium (Li)	mg/L	0.009	0.013	0.007	0.023	5
manganese (Mn)	mg/L	0.016	0.037	0.012	0.049	6
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.00001	< 0.0002	3
molybdenum (Mo)	mg/L	0.0002	0.0001	0.0001	0.0001	5
nickel (Ni)	mg/L	< 0.0001	0.0009	0.0005	0.0012	5
selenium (Se)	mg/L	< 0.0004	< 0.0002	< 0.0001	< 0.0005	13
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.000005	< 0.0002	5
strontium (Sr)	mg/L	*0.15*	0.17	0.08	0.18	5
thallium (Tl)	mg/L	0.00015	< 0.00005	< 0.000003	0.00009	3
titanium (Ti)	mg/L	0.0021	0.0005	< 0.0003	0.0014	5
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	5
vanadium (V)	mg/L	*0.0005*	0.0003	< 0.0001	0.0004	5
zinc (Zn) [b]	mg/L	*1.78*	0.002	< 0.0002	0.014	5

[a] Based on information from Golder (1996a, 1997, 2000b, 2001a), RL&L (1989) and WDS stations AB07DA0600 and AB07DA1090.

[b] The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
[A] = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
[C] = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
[H] = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
\- = no data.

8.1.2 Muskeg Creek

Sulphide and total selenium concentrations were higher than in previous years (Table 8.2) and despite a potential error in the 2001 total nitrogen result (Section 4.2.1.3), there appears to be a recent trend of increasing total nitrogen concentrations (Figure 8.1). In 2001, the water from the mouth of Muskeg Creek was toxic to fathead minnows, as shown by fathead minnow 7d mortality tests (Table 8.2). Natural background toxicity has been observed in other parts of the Muskeg River watershed (Golder 2000b). These findings have previously been attributed to humic materials or other similar organics released from decaying vegetation, as they are often accompanied by high colour and DOC readings (Dr. Mike MacKinnon, Syncrude Canada Ltd., pers. comm.). In this instance, it is not clear what the contributing factor(s) may be, considering that colour and DOC concentrations observed at this site are similar in magnitude to those observed at the mouth of Jackpine Creek in the fall of 2001 when no toxicity was present (Table 8.2). Further research into the source of natural, background chronic toxicity in the Muskeg River watershed will be proceeding in 2002.

Table 8.2 Water Quality in Muskeg Creek, Fall

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [(a)]			
			median	min	max	n
Field Measured						
pH		7.3	7.6	7.1	8.2	9
specific conductance	µS/cm	292	240	80	585	9
temperature	^{o}C	9.9	2.8	2	13	9
dissolved oxygen	mg/L	6.8	8.6	**4.4** [(A,C)]	14.5	9
Conventional Parameters						
colour	T.C.U.	110	120	59	200	9
conductance	µS/cm	297	438	192	671	8
dissolved organic carbon	mg/L	26	22	20	28	8
hardness	mg/L	129	114	76	244	12
pH		7.7	7.7	7.4	8.1	8
total alkalinity	mg/L	153	127	98	313	12
total dissolved solids	mg/L	230	149	106	417	12
total organic carbon	mg/L	31	27	21	31	9
total suspended solids	mg/L	< 3	3	1	9	12
Major Ions						
bicarbonate	mg/L	186	170	119	382	10
calcium	mg/L	34	30	19	71	11
carbonate	mg/L	< 5	< 1	< 1	< 5	5
chloride	mg/L	3	2	0.3	36	12
magnesium	mg/L	10	9	7	17	12
potassium	mg/L	1	1	1	2	12
sodium	mg/L	17	16	6	64	12
sulphate	mg/L	6	4	1	8	12

Table 8.2 Water Quality in Muskeg Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [a]			
			median	min	max	n
sulphide	mg/L	**0.008** [(C)]	0.004	< 0.002	0.005	3
Nutrients and Chlorophyll *a*						
nitrogen - ammonia	mg/L	< 0.05	0.05	0.03	0.28	7
nitrogen-total [(b)]	mg/L	1	0.9	0.5	**1.3** [(C)]	10
phosphorus, total	mg/L	0.028	0.034	0.016	**0.066** [(C)]	11
phosphorus, dissolved	mg/L	0.026	0.023	0.014	0.03	4
chlorophyll *a*	mg/L	< 0.001	0.001	0	0.007	3
Biological Oxygen Demand						
biochemical oxygen demand	mg/L	< 2	2	0.2	8	9
General Organics						
naphthenic acids	mg/L	< 1	1	< 1	2	4
total phenolics	mg/L	0.005	0.002	< 0.001	0.005	5
total recoverable hydrocarbons	mg/L	< 0.5	0.8	< 0.1	3.5	10
Toxicity						
Ceriodaphnia 7 d mortality test - LC25	%	>100	>100	-	-	1
Ceriodaphnia 7 d reproduction test - IC25	%	>100	15	-	-	1
fathead minnow 7d growth - IC25	%	>100	>100	-	-	1
fathead minnow 7d mortality test - LC25	%	15	-	-	-	-
Metals (Total)						
aluminum (Al)	mg/L	0.04	0.03	< 0.01	**0.129** [(C)]	10
antimony (Sb)	mg/L	**< 0.005** [(D>H)]	< 0.0008	0.00003	**< 0.005** [(D>H)]	5
arsenic (As)	mg/L	< 0.001	0.0004	0.0002	0.002	10
barium (Ba)	mg/L	0.024	0.052	0.022	0.067	6
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.00004	< 0.001	6
boron (B)	mg/L	0.06	0.08	< 0.01	0.15	10
cadmium (Cd)	mg/L	< 0.0002	**< 0.0006** [(D>C)]	< 0.00002	**< 0.003** [(D>A,C)]	10
chromium (Cr)	mg/L	< 0.0008	0.001	0.0006	**0.0762** [(A,C)]	10
cobalt (Co)	mg/L	0.0002	0.0004	0.0002	0.006	6
copper (Cu)	mg/L	< 0.001	< 0.001	0.0003	**0.011** [(C)]	10
iron (Fe)	mg/L	**0.63** [(C,H)]	**1.27** [(C,H)]	**0.25** [(H)]	**1.81** [(C,H)]	10
lead (Pb)	mg/L	< 0.0001	0.0012	0.0001	**0.02** [(C)]	10
lithium (Li)	mg/L	0.01	0.023	0.007	0.095	6
manganese (Mn)	mg/L	**0.058** [(H)]	**0.092** [(H)]	**0.013** [(H)]	**0.534** [(H)]	10
mercury (Hg)	mg/L	< 6E-07	**< 0.0001** [(D>H)]	**< 0.00005** [(D>H)]	**< 0.0002** [(D>C,H)]	9
molybdenum (Mo)	mg/L	0.0001	0.0001	0.0001	0.0064	6
nickel (Ni)	mg/L	0.0003	0.0013	< 0.0001	0.0363	10
selenium (Se)	mg/L	**0.0012** [(C)]	< 0.0007	< 0.0002	0.0008	9
silver (Ag)	mg/L	0.000016	**0.0004** [(C)]	0.000005	**0.003** [(C)]	6

Table 8.2 Water Quality in Muskeg Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [a]			
			median	min	max	n
strontium (Sr)	mg/L	0.11	0.24	0.08	0.3	6
thallium (Tl)	mg/L	< 0.0001	0.0001	0.00004	0.00016	3
titanium (Ti)	mg/L	0.0016	0.0027	0.0015	< 0.05	7
uranium (U)	mg/L	< 0.0001	0.0002	< 0.0001	< 0.5	6
vanadium (V)	mg/L	0.0006	< 0.001	< 0.0002	< 0.002	11
zinc (Zn) [b]	mg/L	0.01	0.004	0.001	**0.032** [C]	10
Metals (Dissolved)						
aluminum (Al)	mg/L	0.01	< 0.01	< 0.01	0.03	3
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	3
arsenic (As)	mg/L	< 0.0004	< 0.0004	< 0.0002	0.0005	4
barium (Ba)	mg/L	0.025	0.048	0.019	0.063	3
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	3
boron (B)	mg/L	0.06	0.11	0.03	0.17	5
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3
chromium (Cr)	mg/L	< 0.0004	0.0005	< 0.0004	0.0008	3
cobalt (Co)	mg/L	0.0002	0.0003	< 0.0001	0.0007	3
copper (Cu)	mg/L	0.0007	< 0.0006	< 0.0006	0.0007	3
iron (Fe)	mg/L	0.44	0.35	0.21	1.02	5
lead (Pb)	mg/L	0.0001	0.0001	< 0.0001	0.0001	3
lithium (Li)	mg/L	0.01	0.026	0.008	0.033	3
manganese (Mn)	mg/L	0.056	0.271	0.01	0.522	5
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.00001	< 0.0001	3
molybdenum (Mo)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3
nickel (Ni)	mg/L	0.0002	0.0011	0.0006	0.0035	3
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0002	< 0.0004	4
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	3
strontium (Sr)	mg/L	0.13	0.25	0.07	0.27	3
thallium (Tl)	mg/L	< 0.00005	< 0.00005	-	-	1
titanium (Ti)	mg/L	0.0006	0.0005	0.0004	0.0007	3
uranium (U)	mg/L	< 0.0001	0.0002	< 0.0001	0.0002	3
vanadium (V)	mg/L	0.0005	< 0.0001	< 0.0001	0.0004	3
zinc (Zn) [b]	mg/L	0.009	0.004	0.002	0.007	3

[a] Based on information from Golder (1996a, 1997, 1999b, 2000b, 2001a), RL&L (1989), and WDS stations AB07DA0530 and AB07DA2755.

[b] The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Bolded concentrations are higher than water quality guidelines.

[A] = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.

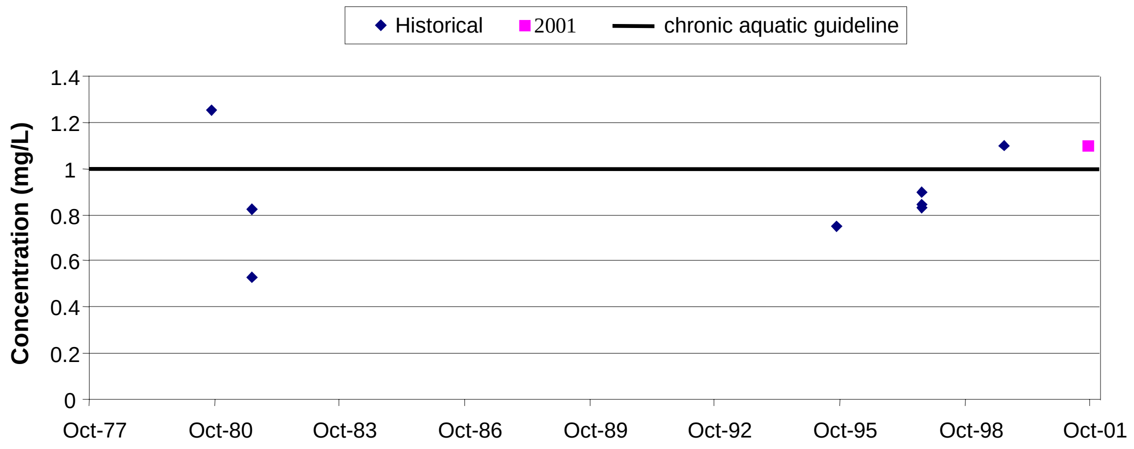
[C] = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

[H] = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.

[D>] = analytical detection limit was higher than the relevant water quality guideline(s).

- = no data.

Figure 8.1 Total Nitrogen Concentrations in Muskeg Creek, Fall



8.1.3 Stanley Creek

Concentrations of total aluminum, iron and manganese were lower in 2001 than in previous years, which may be related to low TSS levels observed in 2001, while the concentrations of total barium, chromium and vanadium were higher in 2001 than in previous years (Table 8.3).

Table 8.3 Water Quality Data for Stanley Creek, Fall

Parameter	Units	Fall 2001	Fall Historical (1976 to 2000)[(a)]			
			median	min	max	n
Field Measured						
pH		7.21	-	6.93	**9.21** [(A,C)]	2
specific conductance	uS/cm	304	-	255	310	2
temperature	^{o}C	9.5	2.2	2.1	10	3
dissolved oxygen	mg/L	2.94	-	7.9	9.3	2
Conventional Parameters						
colour	T.C.U.	15	45	-	-	1
conductance	uS/cm	307	310	266	320	3
dissolved organic carbon	mg/L	6	-	8	14	2
hardness	mg/L	165	142	139	164	3
pH		7.7	7.6	7.4	7.8	3
total alkalinity	mg/L	170	145	142	170	3
total dissolved solids	mg/L	200	184	150	201	3
total organic carbon	mg/L	7	14	9	16	3
total suspended solids	mg/L	< 3	13	12	58	3
Major Ions						
bicarbonate	mg/L	207	176	-	-	1
calcium	mg/L	47.4	41	40	49	3
carbonate	mg/L	< 5	-	-	-	-

Table 8.3 Water Quality for Stanley Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976 to 2000)[a]			
			median	min	max	n
chloride	mg/L	< 1	1	0.2	1	3
magnesium	mg/L	11.3	10	10	10	3
sodium	mg/L	2	2	2	2	3
sulphate	mg/L	5.1	1	1	< 3	3
sulphide	mg/L	0.004	0.003	-	-	1
Nutrients and Chlorophyll *a*						
nitrogen - ammonia	mg/L	0.09	< 0.05	-	-	1
nitrogen-total [b]	mg/L	0.9	0.73	0.49	**2.45** [C]	4
phosphorus, total	mg/L	0.017	**0.125** [C]	0.026	**0.32** [C]	4
phosphorus, dissolved	mg/L	0.017	-	0.012	0.017	2
chlorophyll *a*	mg/L	< 1	-	0.004	0.004	2
Biological Oxygen Demand						
biochemical oxygen demand	mg/L	< 2	-	0.4	< 2	2
General Organics						
naphthenic acids	mg/L	1	< 1	-	-	1
total phenolics	mg/L	< 0.001	< 0.001	< 0.001	0.002	3
total recoverable hydrocarbons	mg/L	< 0.5	0.6	0.2	0.8	3
Metals (Total)						
aluminum (Al)	mg/L	< 0.02	-	0.02	0.0369	2
antimony (Sb)	mg/L	< 0.005	-	0.00001	< 0.0008	2
arsenic (As)	mg/L	< 0.001	< 0.001	0.0001	< 0.005	4
barium (Ba)	mg/L	0.0621	-	0.037	0.041	2
beryllium (Be)	mg/L	< 0.001	-	< 0.00004	< 0.001	2
boron (B)	mg/L	0.025	-	0.02	0.02	2
cadmium (Cd)	mg/L	< 0.0002	-	< 0.00002	< 0.0002	2
chromium (Cr)	mg/L	0.0024	-	0.0002	< 0.0008	2
cobalt (Co)	mg/L	< 0.0002	-	< 0.00002	< 0.0002	2
copper (Cu)	mg/L	< 0.001	-	0.0002	< 0.001	2
iron (Fe)	mg/L	0.086	-	**0.29** [H]	**0.66** [C,H]	2
lead (Pb)	mg/L	< 0.0001	-	0.0001	< 0.0001	2
lithium (Li)	mg/L	0.007	-	0.007	0.078	2
manganese (Mn)	mg/L	0.012	-	**0.023** [H]	**0.083** [H]	2
mercury (Hg)	mg/L	< 6E-07	**< 0.0002** [D>C,H]	**< 0.0002** [D>C,H]	**0.0036** [A,C,H]	3
molybdenum (Mo)	mg/L	0.0002	-	0.00004	< 0.0001	2
nickel (Ni)	mg/L	< 0.0002	-	< 0.0001	0.0004	2
selenium (Se)	mg/L	< 0.0008	-	< 0.0005	< 0.0008	2
silver (Ag)	mg/L	0.000034	-	0.000006	< 0.0004 [D>C]	2
strontium (Sr)	mg/L	0.0856	-	0.08	0.08	2
thallium (Tl)	mg/L	< 0.0001	0.00001	-	-	1
titanium (Ti)	mg/L	0.0015	-	< 0.0006	0.0031	2
uranium (U)	mg/L	0.0002	-	0.00001	< 0.0001	2
vanadium (V)	mg/L	0.0003	-	< 0.0002	0.0002	2
zinc (Zn) [b]	mg/L	0.008	-	0.001	0.004	2

Table 8.3 Water Quality for Stanley Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976 to 2000)[(a)]			
			median	min	max	n
Metals (Dissolved)						
aluminum (Al)	mg/L	< 0.01	0.02	-	-	1
antimony (Sb)	mg/L	< 0.0008	< 0.0008	-	-	1
arsenic (As)	mg/L	< 0.0004	< 0.0004	-	-	1
barium (Ba)	mg/L	0.0675	0.039	-	-	1
beryllium (Be)	mg/L	< 0.0005	< 0.001	-	-	1
boron (B)	mg/L	0.027	0.04	0.02	0.09	3
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	-	-	1
chromium (Cr)	mg/L	< 0.0004	< 0.0004	-	-	1
cobalt (Co)	mg/L	< 0.0001	< 0.0001	-	-	1
copper (Cu)	mg/L	0.0008	0.0012	-	-	1
iron (Fe)	mg/L	0.035	-	0.19	0.24	2
lead (Pb)	mg/L	*0.0002*	< 0.0001	-	-	1
lithium (Li)	mg/L	0.0069	0.015	-	-	1
manganese (Mn)	mg/L	0.013	-	0.022	0.023	2
mercury (Hg)	mg/L	< 0.0001	< 0.00001	-	-	1
molybdenum (Mo)	mg/L	< 0.0001	0.0002	-	-	1
nickel (Ni)	mg/L	< 0.0001	0.0002	-	-	1
selenium (Se)	mg/L	< 0.0004	< 0.0004	-	-	1
silver (Ag)	mg/L	< 0.0002	< 0.0002	-	-	1
strontium (Sr)	mg/L	0.0981	0.08	-	-	1
thallium (Tl)	mg/L	< 0.00005	-	-	-	-
titanium (Ti)	mg/L	0.0007	0.0023	-	-	1
uranium (U)	mg/L	< 0.0001	< 0.0001	-	-	1
vanadium (V)	mg/L	0.0002	0.0003	-	-	1
zinc (Zn) [(b)]	mg/L	0.005	0.003	-	-	1

(a) Based on information from Golder (1996a, 2000b) and WDS station AB07DA0490.
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

8.1.4 Muskeg River

The water quality results of samples collected on a continuous, weekly, monthly and quarterly basis in the Muskeg River are discussed below. In order to assess whether differences in water quality, compared to previous sampling events, can be attributed to natural variations or to anthropogenic activities, water quality data from polishing ponds discharge waters should be made available to RAMP in future years.

8.1.4.1 Site-Specific Observations

Upstream of Wapasu Creek

In the Muskeg River, upstream of Wapasu Creek, chloride and chlorophyll *a* concentrations were higher, and total barium and dissolved nickel levels were lower than in previous years (Table 8.4). Although historical data are limited (i.e., n=5), there appears to be a trend of decreasing concentrations of total barium in the Muskeg River upstream of Wapasu Creek (Figure 8.2).

Water temperature, measured between from August to October, in the Muskeg River upstream of Wapasu Creek was highest in August (18.4°C) and steadily declined to 1°C in late October (Figure 8.3). In 2001, water from Muskeg River upstream of Wapasu was somewhat toxic to *Ceriodaphnia* as indicated by reduced reproduction in the IC25 *Ceriodaphnia* reproduction test.

Table 8.4 Water Quality in the Muskeg River Upstream of Wapasu Creek, Fall

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [a]			
			median	min	max	n
Field Measured						
pH		7.8	7.6	7	8.1	7
specific conductance	uS/cm	326	371	150	493	10
temperature	^{o}C	11.3	3.4	0.4	10.5	10
dissolved oxygen	mg/L	10.2	7.6	**3.4** [(A,C)]	10.2	9
Conventional Parameters						
colour	T.C.U.	50	65	38	140	8
conductance	uS/cm	337	390	233	506	11
dissolved organic carbon	mg/L	19	20	17	25	9
hardness	mg/L	180	200	128	272	12
pH		8.1	7.6	7.2	8	11
total alkalinity	mg/L	184	194	120	281	13
total dissolved solids	mg/L	260	210	158	359	13
total organic carbon	mg/L	23	22	14	30	11
total suspended solids	mg/L	< 3	4	0.4	25	12
Major Ions						
bicarbonate	mg/L	225	261	147	343	7

Table 8.4 Water Quality in the Muskeg River Upstream of Wapasu Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [(a)]			
			median	min	max	n
calcium	mg/L	45	49	31	77	12
carbonate	mg/L	< 5	< 5	< 1	< 5	4
chloride	mg/L	3	1	0.3	2	13
magnesium	mg/L	16	16	12	19	13
potassium	mg/L	0.3	1	0.3	2	13
sodium	mg/L	7	6	3	7	13
sulphate	mg/L	5	3	0.1	6	13
sulphide	mg/L	< 0.003	**0.011** [(C)]	< 0.002	**0.014** [(C)]	3
Nutrients and Chlorophyll *a*						
nitrogen - ammonia	mg/L	< 0.05	0.08	< 0.05	0.27	5
nitrogen-total [(b)]	mg/L	0.2	**1.17** [(C)]	0.39	**5.5** [(C)]	12
phosphorus, total	mg/L	0.02	0.04	0.014	**0.32** [(C)]	12
phosphorus, dissolved	mg/L	0.021	0.018	0.006	0.029	4
chlorophyll *a*	mg/L	1	< 0.001	< 0.001	0.014	6
Biological Oxygen Demand						
biochemical oxygen demand	mg/L	< 2	2	1	6	7
General Organics						
naphthenic acids	mg/L	< 1	< 1	< 1	12	3
total phenolics	mg/L	0.002	0.005	< 0.001	**0.013** [(C)]	9
total recoverable hydrocarbons	mg/L	< 0.5	0.5	> 0.1	1.3	10
Toxicity						
Ceriodaphnia 7 d mortality test - LC25	%	> 100	> 100	> 100	> 100	3
Ceriodaphnia 7 d reproduction test - IC25	%	85	> 100	35	> 100	3
fathead minnow 7d growth - IC25	%	> 100	> 100	12	> 100	3
fathead minnow 7d mortality test - LC25	%	> 100	28	6.4	49	3
Metals (Total)						
aluminum (Al)	mg/L	< 0.02		0.0099	**0.11** [(C)]	7
antimony (Sb)	mg/L	**< 0.005** [(D>H)]	< 0.0008	0.00001	**< 0.005** [(D>H)]	5
arsenic (As)	mg/L	< 0.001	0.0009	0.0002	**0.009** [(C)]	11
barium (Ba)	mg/L	0.025	0.081	0.034	0.088	5
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.00004	< 0.001	5
boron (B)	mg/L	0.01	0.02	0.01	< 0.05	7
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.00002	**< 0.001** [(D>C)]	7
chromium (Cr)	mg/L	< 0.0008	0.001	< 0.0008	**0.006** [(C)]	7

Table 8.4 Water Quality in the Muskeg River Upstream of Wapasu Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [(a)]			
			median	min	max	n
cobalt (Co)	mg/L	< 0.0002	0.0002	0.0001	0.0004	5
copper (Cu)	mg/L	< 0.001	< 0.001	0.0002	0.0029	7
iron (Fe)	mg/L	**0.26** [(H)]	**2.31** [(C,H)]	**0.19** [(H)]	**13.9** [(C,H)]	7
lead (Pb)	mg/L	< 0.0001	0.0005	0.00002	0.002	7
lithium (Li)	mg/L	< 0.006	0.009	< 0.006	0.011	5
manganese (Mn)	mg/L	**0.021** [(H)]	**0.296** [(H)]	**0.014** [(H)]	**0.786** [(H)]	7
mercury (Hg)	mg/L	< 6E-07	**< 0.0002** [(D>C,H)]	**< 0.00005** [(D>H)]	**0.0043** [(A,C,H)]	11
molybdenum (Mo)	mg/L	< 0.0001	0.0001	0.00004	0.0003	5
nickel (Ni)	mg/L	0.0003	0.0016	< 0.0001	0.0136	7
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0002	0.0009	7
silver (Ag)	mg/L	0.000009	**< 0.0004** [(D>C)]	**< 0.000005**	**< 0.0004** [(D>C)]	5
strontium (Sr)	mg/L	0.09	0.16	0.06	0.17	5
thallium (Tl)	mg/L	< 0.0001	< 0.00008	< 0.000003	< 0.0001	3
titanium (Ti)	mg/L	0.0008	0.0024	0.0009	< 0.05	6
uranium (U)	mg/L	< 0.0001	< 0.0001	0.00003	< 0.0001	5
vanadium (V)	mg/L	< 0.0002	< 0.0009	< 0.0002	< 0.001	9
zinc (Zn) [(b)]	mg/L	0.012	0.017	0.001	**0.075** [(C)]	7
Metals (Dissolved)						
aluminum (Al)	mg/L	< 0.01	< 0.01	< 0.01	0.01	3
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	3
arsenic (As)	mg/L	< 0.0004	< 0.0004	< 0.0002	< 0.0004	5
barium (Ba)	mg/L	0.025	0.032	0.017	0.042	3
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	3
boron (B)	mg/L	0.01	0.04	0.003	0.24	9
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3
chromium (Cr)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	3
cobalt (Co)	mg/L	< 0.0001	0.0002	< 0.0001	0.0002	3
copper (Cu)	mg/L	*0.0021*	< 0.0006	< 0.0006	0.001	3
iron (Fe)	mg/L	0.16	0.24	0.04	0.89	5
lead (Pb)	mg/L	*0.0007*	< 0.0001	< 0.0001	0.0002	3
lithium (Li)	mg/L	0.005	0.007	0.004	0.008	3
manganese (Mn)	mg/L	0.019	0.292	0.008	0.626	5
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.00001	< 0.0001	3
molybdenum (Mo)	mg/L	< 0.0001	0.0001	< 0.0001	0.0001	3
nickel (Ni)	mg/L	0.0001	0.0009	0.0004	0.0033	3

Table 8.4 Water Quality in the Muskeg River Upstream of Wapasu Creek, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1976-2000) [a]			
			median	min	max	n
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0002	< 0.0004	5
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	3
strontium (Sr)	mg/L	0.09	0.12	0.06	0.15	3
thallium (Tl)	mg/L	< 0.00005	< 0.00005	-	-	1
titanium (Ti)	mg/L	0.0005	0.0003	< 0.0003	0.0007	3
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3
vanadium (V)	mg/L	0.0001	< 0.0001	< 0.0001	< 0.0001	3
zinc (Zn) [b]	mg/L	0.01	0.01	0.002	0.01	3

(a) Data based on information from Golder (1999b, 2000b, 2001a), RL&L (1989), and WDS stations AB07DA1125, ABO7DA0420 and AB07DA0440.
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain because of irregularities in QC sample results which may be indicative of sample contamination.
Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination). Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

Figure 8.2 Total Barium Concentrations in the Upper Muskeg River, Fall

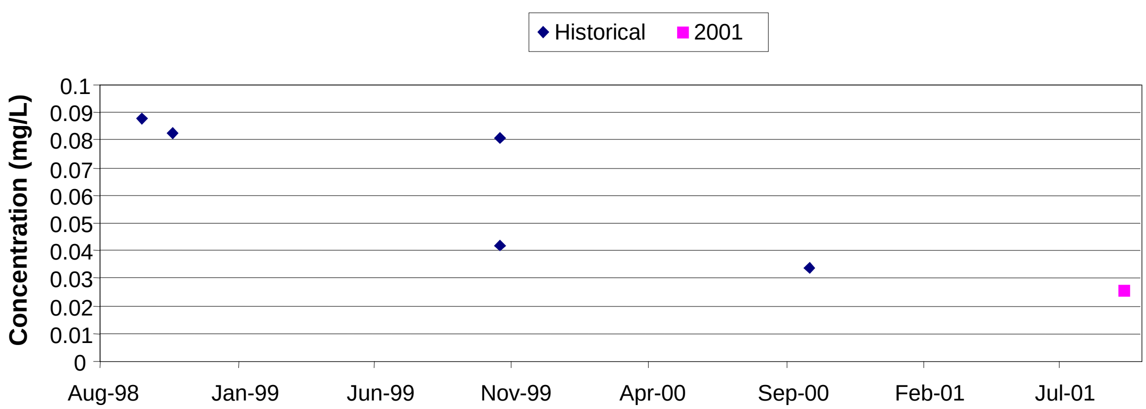
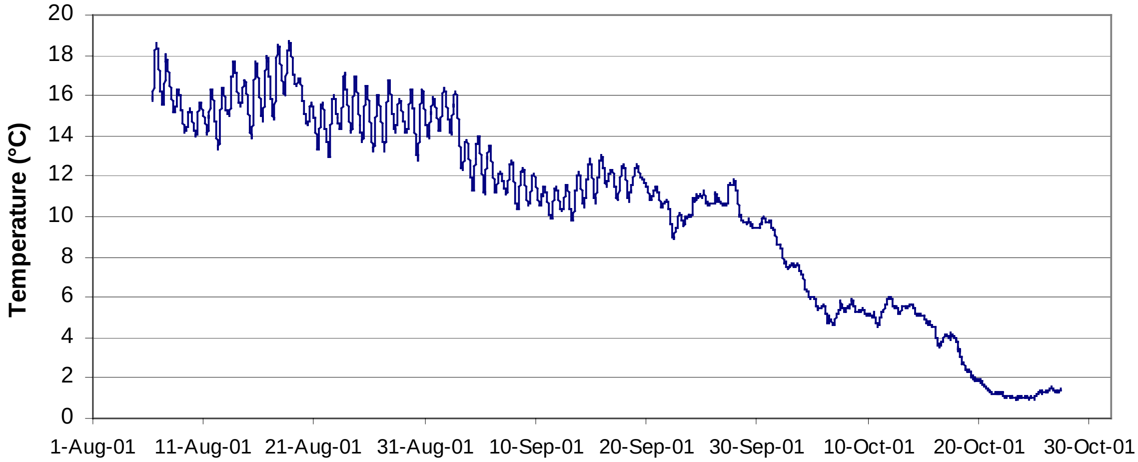


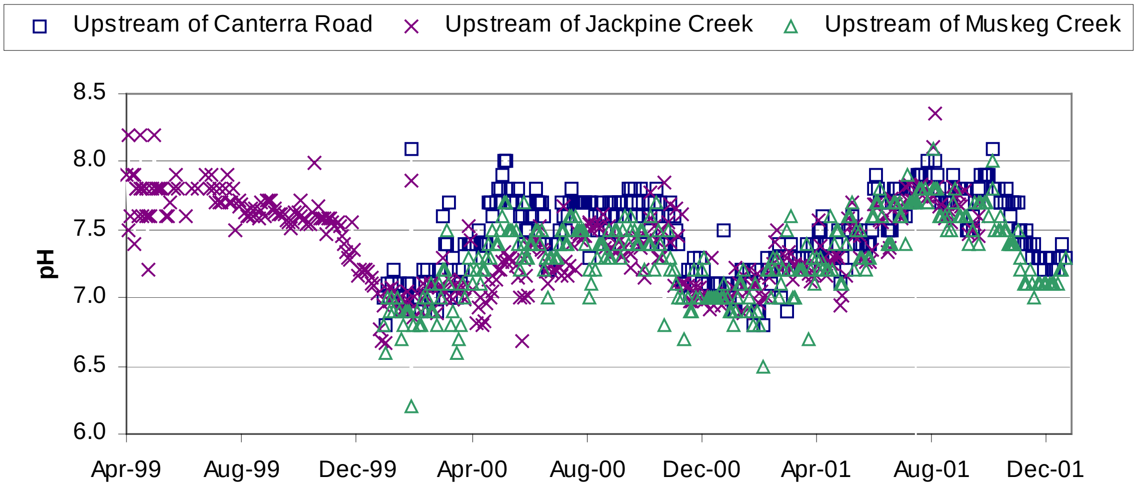
Figure 8.3 Water Temperatures in the Muskeg River Upstream of Wapasu Creek, Fall 2001



Stanley Creek to the Mouth

Figures 8.4 to 8.8 present the weekly monitoring results for pH, DO, total suspended solids (TSS), ammonia and biological oxygen demand (BOD) in samples collected by Albian and Syncrude from three stations between the mouth of Muskeg River and Stanley Creek. During 1999 to 2001, recorded pH levels typically ranged from 6.7 to 8.0, with minimum values in winter (December-March) and highest recorded values occurring during summer and fall (June-October) (Figure 8.4). Levels of TSS ranged from <1 to 64 mg/L, although concentrations were generally less than 15 mg/L, with higher levels occurring in winter and spring (Figure 8.5). DO concentrations generally ranged from 0.5 to 13.5 mg/L, with DO levels reaching a minimum in December and January and a maximum during the fall (October) and briefly in the spring, following ice break-up (Figure 8.6). Ammonia concentrations ranged from <0.01 to 1.04 mg/L, with elevated levels recorded during winter and declining during spring to reach minimum levels in summer and fall (Figure 8.7). BOD levels reach 6.6 mg/L although they were generally less than 4 mg/L (Figure 8.8).

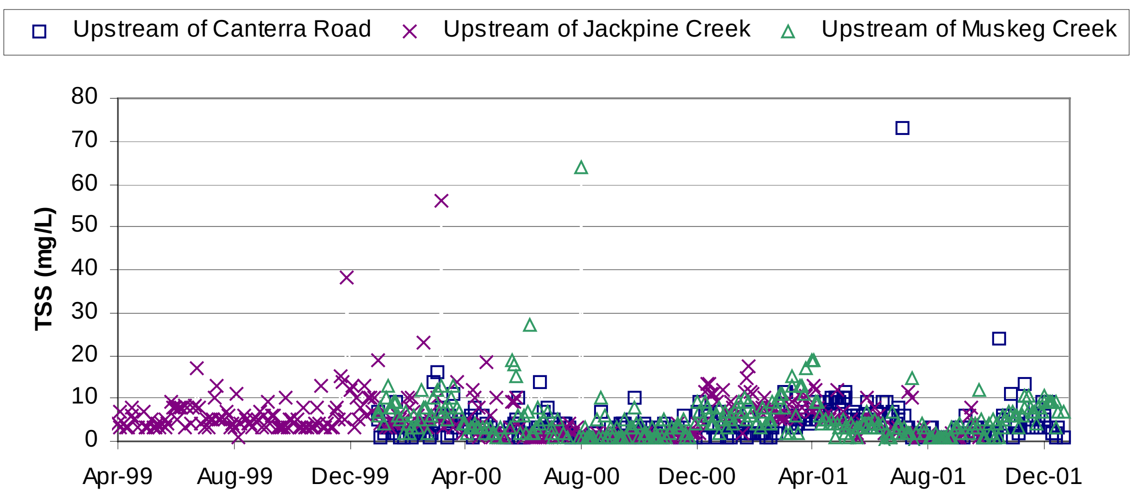
Figure 8.4 pH Levels in the Muskeg River between Stanley Creek and the River Mouth, 1999 to 2001



Concentrations below the analytical detection limit are plotted as the detection limit

Note: In the RAMP 2000 (Golder 2001) report, symbols for data from upstream of Canterra Road and Upstream of Muskeg Creek were mislabelled.

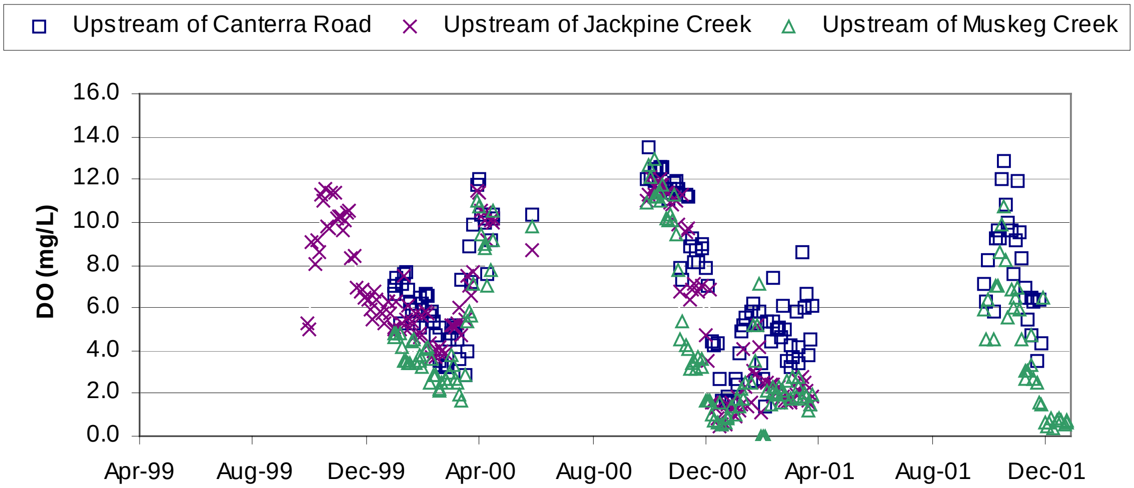
Figure 8.5 Total Suspended Solid Concentrations in the Muskeg River between Stanley Creek and the River Mouth, 1999 to 2001



Concentrations below the analytical detection limit are plotted as the detection limit

Note: In the RAMP 2000 (Golder 2001) report, symbols for data from upstream of Canterra Road and Upstream of Muskeg Creek were mislabelled.

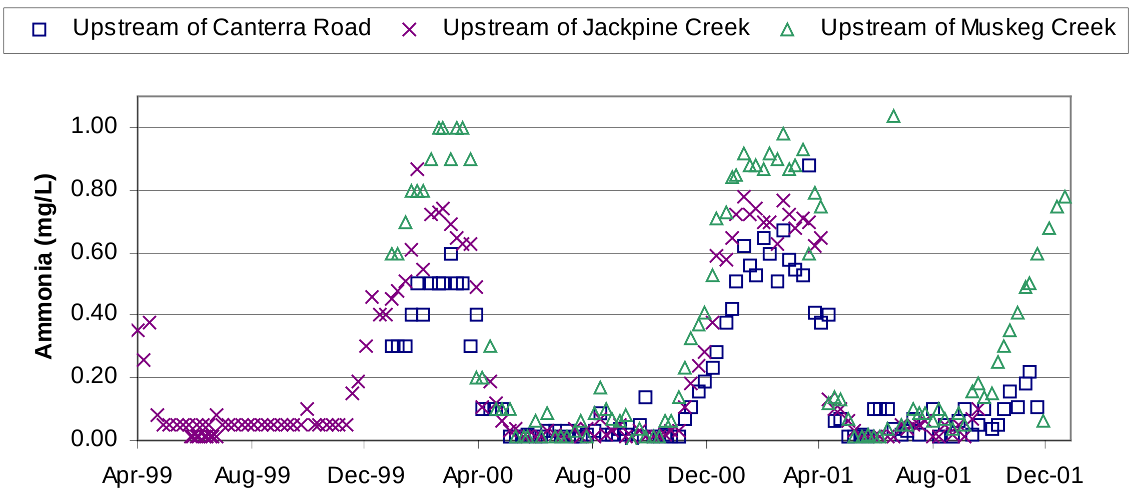
Figure 8.6 Dissolved Oxygen Concentrations in the Muskeg River between Stanley Creek and the River Mouth, 1999 to 2001



Concentrations below the analytical detection limit are plotted as the detection limit

Note: In the RAMP 2000 (Golder 2001) report, symbols for data from upstream of Canterra Road and Upstream of Muskeg Creek were mislabelled.

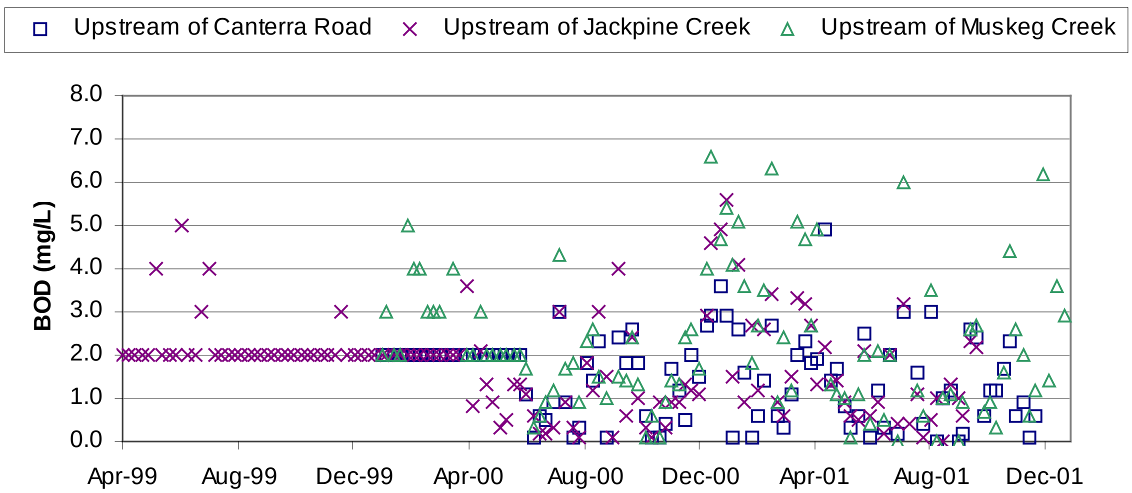
Figure 8.7 Ammonia Concentrations in the Muskeg River between Stanley Creek and the River Mouth, 1999 to 2001



Concentrations below the analytical detection limit are plotted as the detection limit

Note: In the RAMP 2000 (Golder 2001) report, symbols for data from upstream of Canterra Road and Upstream of Muskeg Creek were mislabelled.

Figure 8.8 Biological Oxygen Demand Concentrations in the Muskeg River between Stanley Creek and the River Mouth, 1999 to 2001



Concentrations below the analytical detection limit are plotted as the detection limit

Note: In the RAMP 2000 (Golder 2001) report, symbols for data from upstream of Canterra Road and Upstream of Muskeg Creek were mislabelled.

Upstream of Muskeg Creek

Seasonal trends in water quality were not consistent in 2000 and 2001, with the exception of total chromium and iron levels, which reached annual maximum concentrations in February of both years (Table 8.5). Total aluminum and chromium concentrations were lower in summer and fall of 2001 than in 2000 (Table 8.5). Winter and summer levels of cadmium and copper concentrations were lower in 2001, spring concentrations of total aluminum and iron were higher in 2001, summer concentrations of iron were lower in 2001 and fall levels of copper and zinc were lower in 2001 than in 2000. Phenols were higher in winter and fall 2001 but lower in spring and summer 2001 than in 2000. Concentrations of anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b+j)fluoranthene, chrysene, fluoranthene, phenanthrene and pyrene were detected in February 2001.

Water temperatures, measured between August and December 2001, were similar to those observed in the upstream thermograph (Muskeg River upstream of Wapasu Creek), although minimum temperatures were lower (0°C) in late October in the Muskeg River upstream of Muskeg Creek (Figure 8.9).

Table 8.5 Water Quality in the Muskeg River Upstream of Muskeg Creek, 2000 to 2001

Parameter	Units	2000				2001			
		Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
Conventional Parameters									
temperature	^{o}C	0.1	12.6	14.6	4.7	0.1	0.2	0.1	6.5
dissolved oxygen	mg/L	2.7 (A,C)	7.3	5.6 (C)	11	**2.1 (A,C)**	**3.6 (A,C)**	2.1 (A,C)	5.6 (C)
colour	PtCo units	10	50	120	80	30	NA	70	60
conductance	uS/cm	-	-	-	-	-	-	-	-
dissolved organic carbon	mg/L	-	-	-	-	-	-	-	-
hardness	mg/L								
pH		7.2	7.5	7.8	7.1	7.3	7.3	7.7	8
total alkalinity	mg/L	-	-	-	-	-	-	-	-
total dissolved solids	mg/L	304	171	218	150	310	289	144	244
total suspended solids	mg/L	5	-	< 1	1	8	10	2	4
Biological Oxygen Demand									
biochemical oxygen demand	mg/L	3	< 2	2	1	6	5	NA	1
Major Ions									
bicarbonate	mg/L	-	-	-	-	-	-	-	-
calcium	mg/L	-	-	-	-	-	-	-	-
carbonate	mg/L	-	-	-	-	-	-	-	-
chloride	mg/L	3	1	1	2	3	3	1	< 0.01
magnesium	mg/L	-	-	-	-	-	-	-	-
potassium	mg/L	-	-	-	-	-	-	-	-
sodium	mg/L	-	-	-	-	-	-	-	-
sulphate	mg/L	0.4	1	0.3	1	1	1	1	1
sulphide	mg/L	< 0.01 (D>C)	< 0.01 (D>C)	0.01 (C)	< 0.01 (D>C)	0.01 (C)	< 0.01 (D>C)	0.01 (C)	< 0.01
Nutrients and Chlorophyll a									
nitrate + nitrite	mg/L	< 0.003	< 0.003	0.1	0.02	0.01	0.1	0.02	0.1
nitrogen - ammonia	mg/L	1	< 0.1	0.16	< 0.1	0.89	0.79	0.05	0.15
phosphorus, total	mg/L	< 0.1 (D>C)	0.4 (C)	0.3 (C)	**0.3 (C)**	0.2 (C)	0.2 (C)	0.3 (C)	< 0.1 (D>C)
Toxicity									
Ceriodaphnia 7 d mortality test - LC25	%	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100
Ceriodaphnia 7 d mortality test - LC50	%	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100
fathead minnow 7d growth - LC25	%	> 100	> 100	> 100	> 100	> 100	> 100	30	12.1
fathead minnow 7d Growth - LC50	%	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100

Table 8.5 Water Quality in the Muskeg River Upstream of Muskeg Creek, 2000 to 2001 (continued)

Parameter	Units	2000				2001			
		Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
Metals (Total)									
aluminum (Al)	mg/L	0.019	0.008	0.032	0.017	0.167 (C)	0.109 (C)	0.015	0.014
antimony (Sb)	mg/L	0.0221 (H)	< 0.0002	< 0.0002	0.0017	< 0.0002	0.0006	< 0.0002	NA
arsenic (As)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0002
barium (Ba)	mg/L	-	-	-	-	-	-	-	-
beryllium (Be)	mg/L	0.001	< 0.001	< 0.0004	0.001	< 0.0004	< 0.0001	< 0.0001	NA
boron (B)	mg/L	-	-	-	-	-	-	-	-
cadmium (Cd)	mg/L	0.0032 (C)	< 0.0002	0.0005 (C)	< 0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0002
chromium (Cr)	mg/L	0.007 (C)	0.001	0.003 (C)	0.003 (C)	0.003 (C)	< 0.002 (D>C)	< 0.001	< 0.001
cobalt (Co)	mg/L	-	-	-	-	-	-	-	-
copper (Cu)	mg/L	0.0029	0.0018	0.0017	0.0024	0.0004	< 0.004 (D>C)	0.0009	0.0008
iron (Fe)	mg/L	3.69 (C,H)	1.42 (C,H)	2.08 (C,H)	1.09 (C,H)	3.48 (C,H)	3.33 (C,H)	0.93 (C,H)	3.48 (C,H)
lead (Pb)	mg/L	0.0048 (C)	< 0.0004	< 0.0004	< 0.0003	< 0.0004	< 0.0004	< 0.0001	< 0.0003
lithium (Li)	mg/L	-	-	-	-	-	-	-	-
manganese (Mn)	mg/L	-	-	-	-	-	-	-	-
mercury (Hg)	mg/L	**< 0.00005** (D>H)	**< 0.00005** (D>H)	**< 0.00005** (D>H)	**< 0.00005** (D>H)	**< 0.0005** (D>C,H)	**< 0.0001** (D>H)	**< 0.0005** (D>C,H)	**< 0.00005** (D>H)
molybdenum (Mo)	mg/L	-	-	-	-	-	-	-	-
nickel (Ni)	mg/L	< 0.0005	0.0025	0.0039	0.0049	0.0111	0.0087	0.0017	0.0032
selenium (Se)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.001	< 0.001	< 0.001	< 0.0001
silicon (Si)	mg/L	-	-	-	-	-	-	-	-
silver (Ag)	mg/L	**0.0004** (C)	< 0.0001	**0.0002** (C)	< 0.0001	**< 0.001** (D>C)	**< 0.001** (D>C)	**< 0.001** (D>C)	< 0.0001
strontium (Sr)	mg/L	-	-	-	-	-	-	-	-
thallium (Tl)	mg/L	0.0018 (C,H)	< 0.0002	< 0.0002	< 0.0002	NA	**< 0.001** (D>C,H)	NA	< 0.0002
titanium (Ti)	mg/L	-	-	-	-	-	-	-	-
uranium (U)	mg/L	-	-	-	-	-	-	-	-
vanadium (V)	mg/L	-	-	-	-	-	-	-	-
zinc (Zn)	mg/L	0.021	0.016	0.003	**0.036** (C)	0.026	0.01	0.015	0.01
General Organics									
naphthenic acids	mg/L	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
total recoverable hydrocarbons	mg/L	< 2	< 0.2	< 2	< 0.02	NA	< 2	5	2
total phenolics	ug/L	0.004	0.005	**0.008** (C)	0.005	0.007 **(C)**	< 0.001	< 0.001	**0.006 (C)**
Target PAHs and Alkylated PAHs									
acenaphthene	ug/L	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
acenaphthylene	ug/L	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
acridine	ug/L	-	-	-	-	-	-	-	-
anthracene	ug/L	< 0.01	< 0.005	< 0.005	< 0.005	**0.06** (C)	< 0.01	< 0.005	< 0.005

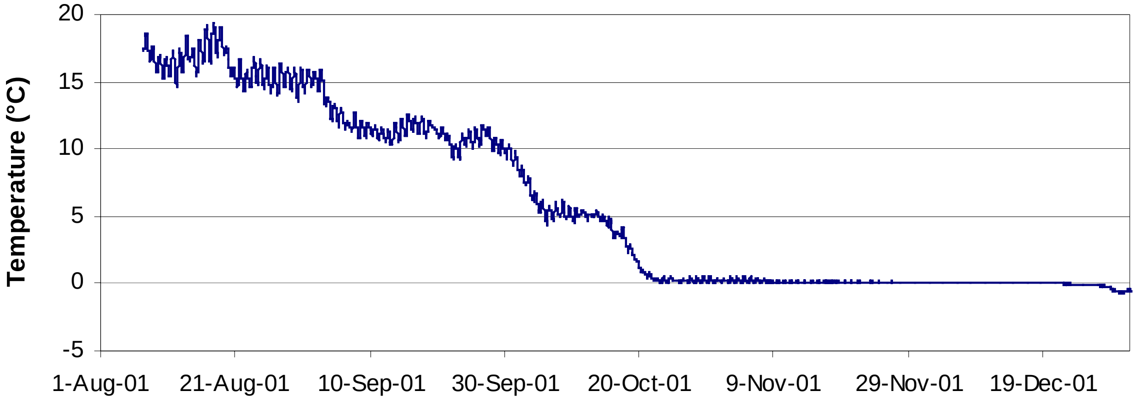
Table 8.5 Water Quality in the Muskeg River Upstream of Muskeg Creek, 2000 to 2001 (continued)

Parameter	Units	2000				2001			
		Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
benzo(a)anthracene / chrysene	ug/L	**< 0.05** (D>C,H)	**0.03** (C,H)	**< 0.03** (D>C,H)	**< 0.03** (D>C,H)	**0.27** (C,H)	**< 0.03** (D>C,H)	**< 0.03** (D>C,H)	**< 0.03** (D>C,H)
benzo(a)pyrene	ug/L	**< 0.01** (D>H)	**< 0.005** (D>H)	**< 0.005** (D>H)	**< 0.009** (D>H)	**0.07** (C,H)	**< 0.005** (D>H)	**< 0.009** (D>H)	**< 0.009** (D>H)
benzo(b&j)fluoranthene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1
benzo(c)phenanthrene	ug/L	< 0.05	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
benzo(g,h,i) perylene	ug/L	< 0.1	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
benzo(k)fluoranthene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
dibenzo(a,h)anthracene	ug/L	**< 0.05** (D>H)	**< 0.03** (D>H)	**< 0.03** (D>H)	**< 0.05** (D>H)	**< 0.03** (D>H)	**< 0.03** (D>H)	**< 0.03** (D>H)	**< 0.05** (D>H)
dibenzo(a,h)pyrene	ug/L	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
dibenzo(a,i)pyrene	ug/L	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
dibenzo(a,j)pyrene	ug/L	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
dimethylbenz(a)anthracene (7,12)	ug/L	< 0.5	< 0.05	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
fluoranthene	ug/L	< 0.04	< 0.03	< 0.02	< 0.02	**0.18** (C)	< 0.02	< 0.02	< 0.02
fluorene	ug/L	< 0.05	< 0.005	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
indeno(c,d-123) pyrene	ug/L	**< 0.1** (D>H)	**< 0.03** (D>H)	**< 0.05** (D>H)	**< 0.05** (D>H)	**< 0.05** (D>H)	**< 0.05** (D>H)	**< 0.05** (D>H)	**< 0.05** (D>H)
3-methylcholanthrene	ug/L	< 0.05	< 0.05	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
naphthalene	ug/L	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
phenanthrene	ug/L	< 0.05	< 0.02	< 0.03	< 0.15	0.17	< 0.03	< 0.15	< 0.15
pyrene	ug/L	< 0.02	< 0.005	< 0.01	< 0.01	**0.13** (C)	< 0.01	< 0.01	< 0.01
quinoline	ug/L	-	-	-	-	-	-	-	-
Volatile Organics									
benzene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
ethylbenzene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
m & p-xylene	ug/L	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
o-xylene	ug/L	-	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
toluene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4

Source: Based on unpublished information from Syncrude (2001).

Note: NA indicates zero values that were not confirmed by the laboratory at the time of publication
Bolded concentrations are higher than water quality guidelines
[A] = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
[C] = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
[H] = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

Figure 8.9 Water Temperature in the Muskeg River Upstream of Muskeg Creek, Fall 2001



Upstream of Jackpine Creek

In 2000 and 2001, levels of TDS, alkalinity and total aluminum, barium, chromium, manganese and titanium were greater in winter than other seasons in the Muskeg River upstream of Jackpine Creek (Table 8.6). In 2001, total aluminum, iron and phosphorus concentrations were generally higher than in the previous two years. In 2001, spring and fall concentrations of total barium and manganese were higher than in previous years, as were titanium and zinc in winter and total cadmium, copper and zinc concentrations in the fall. In February 2001, total chromium levels were greater than in previous years and concentrations of anthracene, benzo(a)anthracene, benzo(a)pyrene and pyrene were detected (Table 8.6).

Figures 8.10 to 8.12 present the results of dissolved iron, dissolved manganese and total dissolved organic carbon (TDOC) concentrations in samples collected once a month by Albian from the Muskeg River upstream of Jackpine Creek (MUR-4) in 2000 and 2001. Maximum levels of dissolved iron and manganese occurred in September and March 2001, respectively (Figures 8.10 and 8.11). However, concentrations of dissolved iron and manganese varied less between seasons in 2001 than in 2000, when there were elevated levels of both parameters in January, February, April and July (Figures 8.10 and 8.11). TDOC levels were similar in 2000 and 2001, with maximum concentrations occurring in June and July respectively (Figure 8.12).

Table 8.6 Water Quality in the Muskeg River Upstream of Jackpine Creek, 1999 to 2001

Parameter	Units	1999			2000				2001			
		May	July	Oct	Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
Conventional Parameters												
temperature	°C	10	8.7	8.7	0.1	-	16	5	0.1	0.3	18.1	4.7
dissolved oxygen	mg/L	8.7	10	12.1	**4.5** [A,C]	10.4	8.4	12.1	**1.9** [A,C]	7.4	7.8	7.6
colour	T.C.U	80	60	40	20	40	120	80	50	40	60	70
conductivity	uS/cm	302	302	503	546	300	334	243	484	443	251	392
dissolved organic carbon	mg/L	-	-	-	-	-	-	-	20	9	28	22
total hardness	mg/L	140	140	270	270	170	170	110	270	220	130	220
pH		7.8	7.8	7.9	7.1	7.9	7.8	7.7	7.1	7.6	7.8	8
total alkalinity	mg/L	153	199	279	317	174	186	133	271	225	132	225
total dissolved solids	mg/L	156	156	291	307	175	188	134	277	232	135	232
total suspended solids	mg/L	-	-	-	-	-	-	-	1	12	2	4
Biological Oxygen Demand												
biochemical oxygen demand	mg/L	-	-	-	-	-	-	-	1	1	3	< 1
Major Ions												
bicarbonate (HCO3)	mg/L	187	243	340	387	212	226	163	330	274	161	274
calcium	mg/L	38.0	48.0	77.0	78	46	47	29	75	62	35	61
carbonate (CO3)	mg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
chloride	mg/L	3.0	2.0	7.0	4	3	2	2	4	3	2	4
magnesium	mg/L	10.0	12.0	19.0	19	12	13	9	20	17	10	16
potassium	mg/L	1.0	0.4	3.0	1	2	1	1	2	2	< 0.3	1
sodium	mg/L	7.0	6.0	17.0	12	7	13	11	12	10	9	13
sulphate	mg/L	5.0	1.0	1.0	1	2	1	1	2	2	1	1
sulphide	mg/L	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**0.01** [C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]
Nutrients												
nitrate and nitrite	mg/L	< 0.003	0.03	< 0.003	0.01	< 0.003	0.1	0.02	0.1	0.1	0.02	0.1
ammonia- n	mg/L	-	-	-	-	-	-	-	-	-	-	-
total phosphorus	mg/L	**< 0.1** [D>C]	**< 0.1** [D>C]	**0.3** [C]	< 0.01	**0.3** [C]	**0.2** [C]	**0.1** [C]	**0.3** [C]	**0.4** [C]	**0.4** [C]	**< 0.1** [D>C]
Chronic toxicity testing												
fathead minnow 7d mortality - LC25	%	-	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100
fathead minnow 7d mortality - LC50	%	-	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100
Ceriodaphnia dubia 7d mortality - LC25	%	-	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100
Ceriodaphnia dubia 7d mortality - LC50	%	-	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100	> 100
Total Metals												
aluminum (Al)	mg/L	0.031	0.058	0.025	0.018	0.008	0.012	0.018	**0.645** [C]	0.046	0.02	0.084
antimony (Sb)	mg/L	< 0.0002	< 0.0002	< 0.0003	0.0004	< 0.0002	< 0.0002	0.0017	< 0.0002	< 0.0002	< 0.0002	< 0.0002
arsenic (As)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0002	< 0.0002	0.0002	< 0.0002	0.0003	0.0002

Table 8.6 Water Quality in the Muskeg River Upstream of Jackpine Creek, 1999 to 2001 (continued)

Parameter	Units	1999			2000				2001			
		May	July	Oct	Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
barium (Ba)	mg/L	0.041	0.055	0.051	0.079	< 0.005	0.04	0.027	0.079	0.066	0.039	0.072
beryllium (Be)	mg/L	< 0.0002	0.002	< 0.0002	< 0.0002	0.037	< 0.0002	0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
boron (B)	mg/L	0.14	< 0.01	0.04	0.04	0.0002	0.04	0.01	0.09	0.1	0.05	0.05
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0004	< 0.0002	< 0.0002	< 0.0002	< 0.0002	**0.0017** (C)
chromium (Cr)	mg/L	**0.002** (C)	< 0.001	**0.004** (C)	**0.003** (C)	< 0.001	**0.003** (C)	**0.003** (C)	**0.005** (C)	**0.002** (C)	< 0.001	**0.002** (C)
cobalt (Co)	mg/L	< 0.0003	< 0.0003	0.0041	0.0005	0.0003	0.0014	0.0006	0.0011	0.0004	< 0.0003	0.0004
copper (Cu)	mg/L	0.002	0.0011	0.0019	0.0004	0.0006	0.0011	0.0019	0.0018	0.0011	0.0005	**0.0041** (C)
iron (Fe)	mg/L	**1.27** (C,H)	**0.98** (C,H)	**0.69** (C,H)	0.3	**1.1** (C,H)	**1** (C,H)	**0.78** (C,H)	**2.73** (C,H)	**2.55** (C,H)	**1.28** (C,H)	**2.49** (C,H)
lead (Pb)	mg/L	< 0.0004	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003
lithium (Li)	mg/L	0.006	0.012	0.014	0.014	< 0.004	0.008	0.009	0.012	0.01	0.007	0.012
manganese (Mn)	mg/L	0.032	0.044	**0.106** (H)	**1.22** (H)	0.035	0.05	0.044	**0.493** (H)	**0.364** (H)	0.042	**0.171** (H)
mercury (Hg)	mg/L	**< 0.05** (D>A,C,H)	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
molybdenum (Mo)	mg/L	< 0.0002	< 0.0002	< 0.0002	0.0003	< 0.0002	< 0.0002	< 0.0002	0.0002	< 0.0002	< 0.0002	0.0005
nickel (Ni)	mg/L	0.0034	0.0022	0.0181	< 0.0005	0.0026	0.0029	0.0031	0.0034	0.003	0.0028	0.002
selenium (Se)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
silicon (Si)	mg/L	2.3	3.7	4.9	7.7	2.4	5.3	2.9	7.2	5.8	2.4	5.9
silver (Ag)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
strontium (Sr)	mg/L	0.09	0.12	0.15	0.2	0.09	0.13	0.08	0.19	0.15	0.09	0.04
sulphur (S)	mg/L	1.5	0.6	1.3	0.6	0.8	0.4	1.1	1.6	0.9	0.9	1.6
thallium (Tl)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
titanium (Ti)	mg/L	< 0.001	0.004	0.003	0.003	0.002	< 0.001	0.002	0.075	0.003	0.002	0.002
uranium (U)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004
vanadium (V)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
zinc (Zn)	mg/L	0.026	0.011	0.006	0.007	0.015	< 0.001	0.01	0.013	0.008	0.01	**0.162** (C)
General Organics												
naphthenic acids	mg/L	< 1	< 1	< 1	1	< 1	8	< 1	< 1	< 1	2	2
oil & grease	mg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	3	< 2	3	3
total phenolics	mg/L	< 0.003	**0.009** (C)	< 0.002	< 0.004	**0.006** (C)	**0.012** (C)	**0.008** (C)	0.005	0.004	**0.009** (C)	0.005
Polycyclic Aromatic Hydrocarbons												
acenaphthene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	0.1	< 0.1	< 0.1	< 0.09	< 0.1
acenaphthylene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
acridine	ug/L	< 0.5	< 0.5	< 0.5	< 0.5	< 0.3	< 0.3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
anthracene	ug/L	**< 0.05** (D>C)	**< 0.05** (D>C)	**< 0.05** (D>C)	< 0.01	< 0.005	< 0.005	< 0.01	**0.02** (C)	< 0.01	< 0.009	< 0.01
benzo(a)anthracene	ug/L	< 0.1	< 0.1	< 0.1	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01
benzo(a)pyrene	ug/L	**< 0.05** (D>C,H)	**< 0.05** (D>C,H)	**< 0.05** (D>C,H)	**< 0.01** (D>H)	**< 0.005** (D>H)	**< 0.005** (D>H)	**< 0.01** (D>H)	**0.01** (H)	**< 0.01** (D>H)	**< 0.009** (D>H)	**< 0.01** (D>H)

Table 8.6 Water Quality in the Muskeg River Upstream of Jackpine Creek, 1999 to 2001 (continued)

Parameter	Units	1999			2000				2001			
		May	July	Oct	Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
benzo(b&j)fluoranthene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
benzo(c)phenanthrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
benzo(g,h,I) perylene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
benzo(k)fluoranthene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
chrysene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
dibenz(a,h)anthracene	ug/L	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.03 (D>H)**	**< 0.03 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**
dibenzo(a,h)pyrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
dibenzo(a,i)pyrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
dibenzo(a,j)pyrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
dimethylbenz(a)anthracene (7,12)	ug/L	< 1	< 1	< 1	< 1	< 0.3	< 0.3	< 1	< 1	< 1	< 1	< 1
Fluoranthene	ug/L	**< 0.05 (D>C)**	**< 0.05 (D>C)**	< 0.04	< 0.04	< 0.02	< 0.02	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
fluorene	ug/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
indeno(1,2,3-cd)pyrene	ug/L	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.1 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.1 (D>H)**	**< 0.1 (D>H)**	**< 0.1 (D>H)**	**< 0.09 (D>H)**	**< 0.1 (D>H)**
3-methylcholanthrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
naphthalene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
phenanthrene	ug/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
pyrene	ug/L	**< 0.05 (D>C)**	**< 0.05 (D>C)**	< 0.02	< 0.02	< 0.01	< 0.01	< 0.02	0.02	< 0.02	< 0.02	< 0.02
quinoline	ug/L	< 3	< 3	< 3	< 3	< 3	< 0.3	< 3	< 3	< 3	< 3	< 3
Volatile Organics												
benzene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.2	< 0.4	< 0.4
ethylbenzene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.2	< 0.4	< 0.4
m & p-xylene	ug/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 0.3	< 1	< 1
o-xylene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.2	< 0.4	< 0.4
toluene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.2	< 0.4	< 0.4

(a) Based on unpublished information from Albian (2001).

Note: Bolded concentrations are higher than water quality guidelines.

A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.

C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.

D> = analytical detection limit was higher than the relevant water quality guideline(s).

- = no data.

Figure 8.10 Dissolved Iron Concentrations in Samples Collected Once a Month From the Muskeg River Upstream of Jackpine Creek, 2000 and 2001

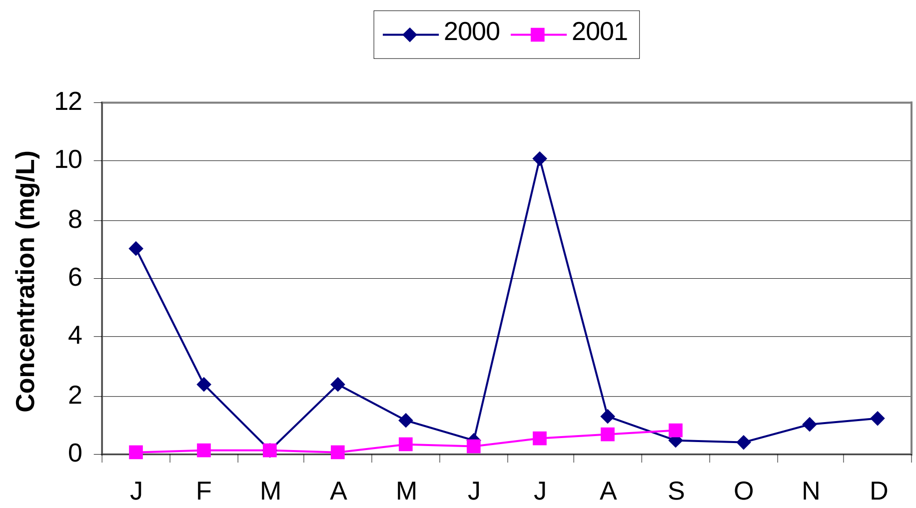


Figure 8.11 Dissolved Manganese Concentrations in Samples Collected Once a Month From the Muskeg River Upstream of Jackpine Creek, 2000 and 2001

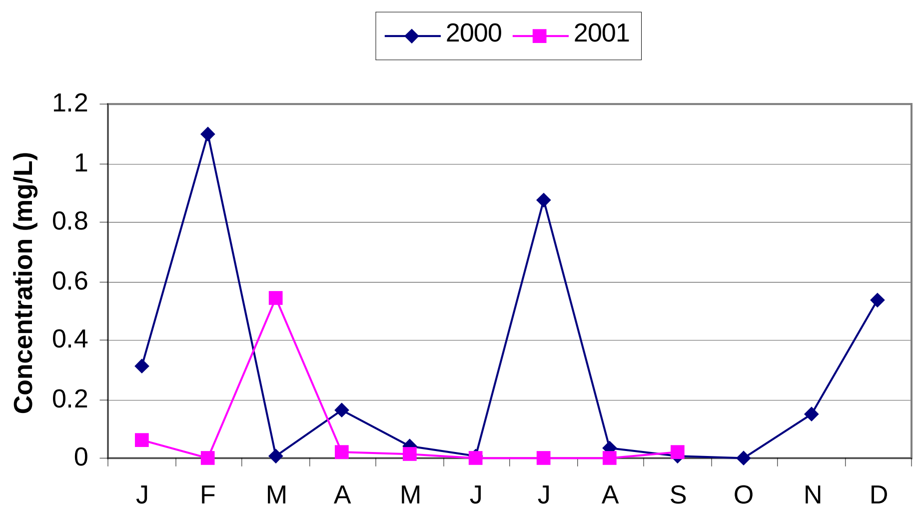
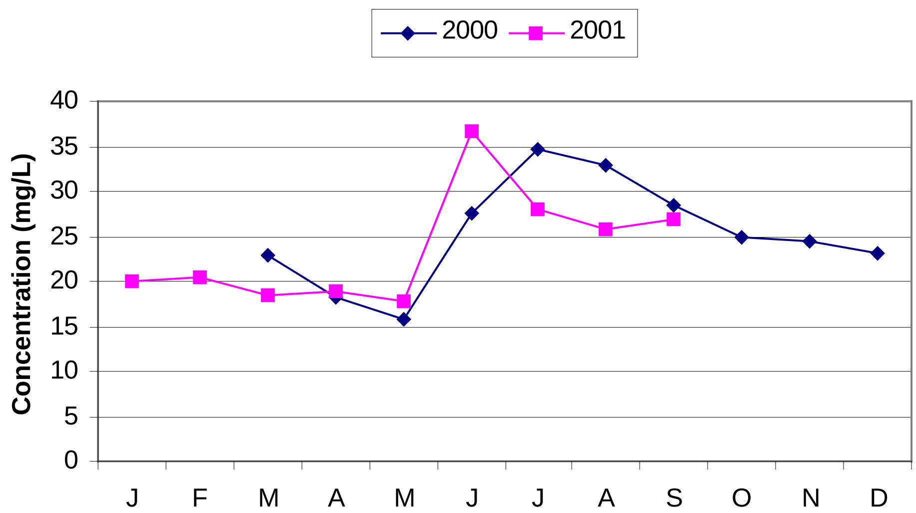


Figure 8.12 Total Dissolved Organic Carbon Concentrations in Samples Collected Once a Month From the Muskeg River Upstream of Jackpine Creek, 2000 and 2001



Downstream of Jackpine Creek

Table 8.7 presents the water quality results of samples taken from the Muskeg River downstream of Jackpine Creek once per season in 1999 to 2001 (winter sample not done in 1999).

Seasonal trends in water quality varied between years in the Muskeg River downstream of Jackpine Creek. For example, maximum annual TDS levels were recorded during spring in 2001, winter in 2000 and fall in 1999 (Table 8.7). Generally, water quality in February was similar in 2000 and 2001. However, winter levels of DO, pH and total aluminum, cobalt, iron, nickel, titanium and zinc were higher in 2001. Spring levels of TDS, nitrate + nitrite and metals, except total iron, were generally higher in 2001, and summer concentrations of TDS and metals, except total copper, were similar to or lower in 2001 than in previous years. Fall levels of total iron and manganese were higher in 2001 than previous years and fall concentrations of most metals and TDS were highest in 1999.

During continuous monitoring in the Muskeg River downstream of Jackpine Creek, pH levels typically ranged from 6.7 to 8.3 between 1998 and 2001, with maximum levels occurring in summer (Figure 8.13). Dissolved oxygen concentrations ranged from 0.6 to 13.1 mg/L, increasing in spring and fall, declining over summer and dropping to minimum levels over winter (Figure 8.14). Conductivity levels ranged from 70 to 950 µS/cm, increasing in spring and summer and reaching maximum concentrations in fall and winter (Figure 8.15). Temperature ranged from –0.2 to 23.6°C (Figure 8.16).

Table 8.7 Water Quality in the Muskeg River Downstream of Jackpine Creek, 1999 to 2001

Parameter	Units	1999			2000				2001			
		May	July	Oct	Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
Conventional Parameters												
temperature	°C	10.0	8.7	8.7	0.1	-	15.3	4.7	0.1	1.5	14.8	5.5
dissolved oxygen	mg/L	8.7	10.0	11.3	**3.6** [A,C]	9.9	8.2	12.6	**6.1** [C]	6.7	8.7	8.5
colour	T.C.U	80	40	40	10	50	100	80	50	40	20	100
conductivity	µS/c	325	325	638	596	295	367	242	535	645	181	399
dissolved organic carbon	mg/L	-	-	-	-	-	-	-	20	18	27	25
total hardness	mg/L	150	150	350	300	160	180	110	280	350	110	200
pH		7.9	7.9	8.0	7.2	8	7.9	7.7	7.4	7.4	7.8	8.2
total alkalinity	mg/L	151	194	291	320	169	186	132	281	277	108	204
total dissolved solids	mg/L	173	173	393	343	175	210	136	292	409	119	219
total suspended solids	mg/L	-	-	-	< 1	-	< 1	< 0.01	5	6	4	2
Biological Oxygen Demand												
biochemical oxygen demand	mg/L	-	-	-	< 2	2	2.3	< 0.1	5	3	0.2	1
Major Ions												
bicarbonate (HCO3)	mg/L	184	237	355	390	206	226	161	343	338	132	249
calcium	mg/L	42.0	49.0	107.0	87	45	54	30	78	105	31	58
carbonate (CO3)	mg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
chloride	mg/L	3.0	2.0	6.0	5	3	2	2	6	7	1	6
magnesium	mg/L	10.0	12.0	21.0	19	11	12	8	20	21	8	14
potassium	mg/L	1.0	0.4	3.0	1	2	1	1	2	2	< 0.3	1
sodium	mg/L	9.0	7.0	16.0	13	9	13	11	16	18	10	15
sulphate	mg/L	17.0	2.0	65.0	25	4	17	4	2	90	4	1
sulphide	mg/L	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**< 0.01** [D>C]	**0.01** [C]	**< 0.01** [D>C]	**0.01** [C]	**< 0.01** [D>C]	**0.02** [C]	**< 0.01** [D>C]
Nutrients												
nitrate and nitrite	mg/L	< 0.003	0.01	0.02	0.1	< 0.003	0.02	< 0.003	0.1	0.1	0.01	0.1
ammonia- n	mg/L	-	-	-	0.5	< 0.1	0.16	< 0.1	-	-	-	-
total phosphorus	mg/L	**< 0.1** [D>C]	**< 0.1** [D>C]	**0.4** [C]	**< 0.1** [D>C]	**0.3** [C]	**0.2** [C]	**0.3** [C]	**0.2** [C]	**< 0.1** [D>C]	**0.3** [C]	**< 0.1** [D>C]
Toxicity testing												
96h rainbow trout bioassay survival (100 % concentration)	%	-	-	-	-	-	-	-	-	> 100	-	-
48h *Daphnia Magna* bioassay survival (100% concentration)	%	-	-	-	-	-	-	-	-	> 100	-	-
fathead minnow 7d mortality -LC50	%	-	-	-	100	100	100	100	> 100	> 100	> 100	100
fathead minnow 7d mortality - LC25	%	-	-	-	100	100	100	100	> 100	> 100	> 100	100
Ceriodaphnia dubia 7d mortality - LC50	%	-	-	-	100	100	100	100	> 100	> 100	> 100	100
Ceriodaphnia dubia 7d mortality - LC25	%	-	-	-	100	100	100	100	> 100	> 100	> 100	100

Table 8.7 Water Quality in the Muskeg River Downstream of Jackpine Creek, 1999 to 2001 (continued)

Parameter	Units	1999			2000				2001			
		May	July	Oct	Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
Total Metals												
aluminum (Al)	mg/L	**0.104** (C)	0.097	0.038	0.018	0.01	0.022	0.035	**0.104** (C)	**0.379** (C)	0.069	0.018
antimony (Sb)	mg/L	< 0.0002	0.0003	< 0.0002	0.0012	< 0.0002	< 0.0002	0.0017	0.0002	0.0003	< 0.0002	< 0.0002
arsenic (As)	mg/L	< 0.0002	0.0003	< 0.0002	< 0.0002	< 0.0002	0.0002	0.0003	0.0002	**0.041** (C)	0.0002	< 0.0002
barium (Ba)	mg/L	0.049	0.053	0.074	0.075	0.035	0.051	0.028	0.074	0.921	0.028	0.039
beryllium (Be)	mg/L	< 0.0002	0.009	< 0.0002	< 0.0002	0.0004	< 0.0002	0.001	< 0.0002	< 0.0002	< 0.0002	< 0.0002
boron (B)	mg/L	0.04	0.05	0.05	0.04	0.03	0.05	0.02	0.07	1.21	0.05	0.04
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0004	< 0.0002	< 0.0002	**0.0008** (C)	< 0.0002	< 0.0002
calcium (Ca)	mg/L	45	51	109	91	49	55	34	79	105	32	70
chromium (Cr)	mg/L	**0.003** (C)	0.001	**0.003** (C)	**0.003** (C)	< 0.001	**0.004** (C)	**0.003** (C)	0.001	**0.006** (C)	0.001	< 0.001
cobalt (Co)	mg/L	< 0.0004	< 0.0003	0.0041	0.0003	< 0.0003	0.0019	0.0006	0.0007	0.0053	< 0.0003	< 0.0003
copper (Cu)	mg/L	0.0025	0.0013	0.0022	< 0.0002	0.001	0.0012	0.0018	< 0.0002	< 0.0002	0.0017	0.0002
iron (Fe)	mg/L	**1.25** (C,H)	**0.58** (C,H)	**0.5** (C,H)	**0.93** (C,H)	**0.94** (C,H)	**0.82** (C,H)	**0.72** (C,H)	**1.6** (C,H)	**1.07** (C,H)	**0.5** (C,H)	**1.91** (C,H)
lead (Pb)	mg/L	< 0.0003	0.0013	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	0.0013	0.0003	< 0.0003
lithium (Li)	mg/L	0.007	0.004	0.015	0.013	0.01	0.01	0.01	0.013	0.014	0.007	< 0.004
magnesium (Mg)	mg/L	10	13	21	20	15	13	9	20	22	8	17
manganese (Mn)	mg/L	0.044	0.034	0.029	**0.703** (H)	0.047	**0.068** (H)	0.043	**0.454** (H)	**0.407** (H)	0.029	**0.074** (H)
mercury (Hg)	mg/L	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
molybdenum (Mo)	mg/L	< 0.0002	< 0.0002	< 0.0002	0.0007	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0036	< 0.0002	0.0002
nickel (Ni)	mg/L	0.0031	0.0019	**0.196** (C)	< 0.0005	0.0022	0.0044	0.0046	0.0091	0.116	0.002	0.0025
potassium (K)	mg/L	1	1	3	2	2	1	1	2	2	< 0.3	2
selenium (Se)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
silicon (Si)	mg/L	2.7	3.1	4.6	7.3	2.1	4.4	3	5.8	6	1.6	4.5
silver (Ag)	mg/L	< 0.0001	**0.0014** (C)	< 0.0001	< 0.0001	< 0.0001	**0.0002** (C)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
sodium (Na)	mg/L	9	8	17	13	13	14	12	17	18	10	20
strontium (Sr)	mg/L	0.1	0.12	0.17	0.21	0.09	0.16	0.09	0.18	2.28	0.08	0.1
sulphur (S)	mg/L	5.8	2.1	21.1	7.7	1.9	5.6	1.6	1.3	29.1	2.3	< 0.2
thallium (Tl)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
titanium (Ti)	mg/L	0.002	0.001	0.003	0.003	< 0.001	< 0.001	0.005	0.008	< 0.001	0.002	0.002
uranium (U)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	< 0.0004	0.0038	< 0.0004	< 0.0004
vanadium (V)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	0.018	< 0.001	< 0.001
zinc (Zn)	mg/L	0.016	**0.05** (C)	0.011	0.007	0.003	< 0.001	0.007	**0.043** (C)	**0.075** (C)	**0.038** (C)	0.005
General Organics												
naphthenic acids	mg/L	< 1	< 1	< 1	1	< 1	8	< 1	< 1	0.1	< 1	< 1
oil & grease	mg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	3	2	5	3
total phenolics	mg/L	< 0.003	**0.007** (C)	< 0.002	0.004	**0.006** (C)	**0.009** (C)	**0.006** (C)	0.004	0.005	< 0.002	**0.007** (C)

Table 8.7 Water Quality in the Muskeg River Downstream of Jackpine Creek, 1999 to 2001 (continued)

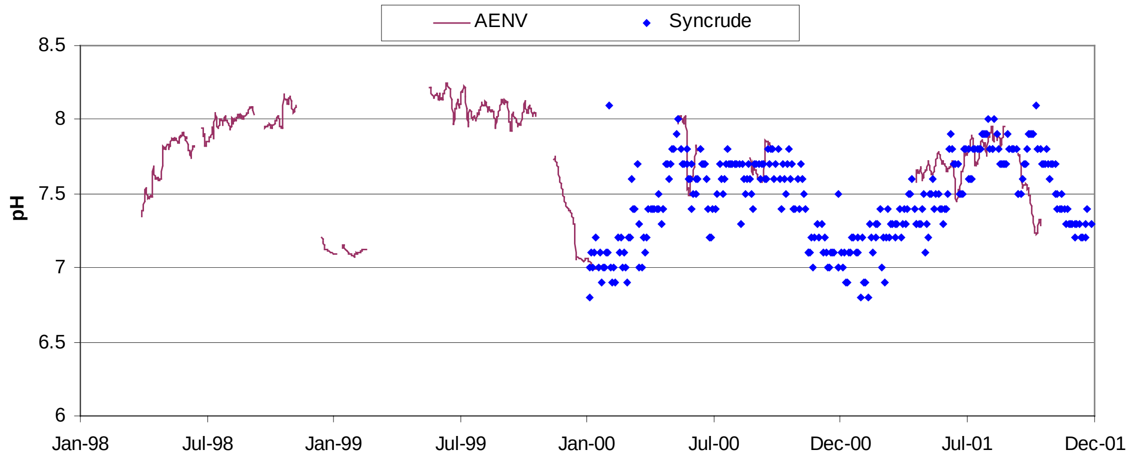
Parameter	Units	1999			2000				2001			
		May	July	Oct	Feb	May	Aug	Oct	Feb	Apr	Jul	Oct
Polycyclic aromatic hydrocarbons												
acenaphthene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
acenaphthylene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
acridine	ug/L	< 0.05	< 0.05	< 0.05	< 0.5	< 0.3	< 0.3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
anthracene	ug/L	**< 0.05 (D>C)**	**< 0.05 (D>C)**	< 0.01	< 0.01	< 0.005	< 0.005	**0.03 (C)**	0.01	< 0.01	< 0.009	< 0.01
benzo(a)anthracene	ug/L	< 0.1	< 0.1	< 0.01	< 0.01	< 0.01	< 0.01	0.1	0.01	< 0.01	< 0.01	< 0.01
benzo(a)pyrene	ug/L	**< 0.05 (D>C,H)**	**< 0.05 (D>C,H)**	**< 0.05 (D>C,H)**	**< 0.01 (D>H)**	**< 0.005 (D>H)**	**< 0.005 (D>H)**	**< 0.01 (D>H)**	**0.02 (C,H)**	**< 0.01 (D>H)**	**< 0.009 (D>H)**	**< 0.01 (D>H)**
benzo(b&j)fluoranthene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
benzo(c)phenanthrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
benzo(g,h,il) perylene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
benzo(k)fluoranthene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
chrysene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.03	< 0.03	0.1	< 0.1	< 0.1	< 0.1	< 0.1
dibenz(a,h)anthracene	ug/L	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.03 (D>H)**	**< 0.03 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**
dibenzo(a,j)pyrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	< 0.09	< 0.1
dibenzo(a,h)pyrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
dibenzo(a,i)pyrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
dimethylbenz(a)anthracene (7,12)	ug/L	< 1	< 1	< 1	< 1	< 0.3	< 0.3	< 1	< 1	< 1	< 1	< 1
fluoranthene	ug/L	**< 0.05 (D>C)**	**< 0.05 (D>C)**	< 0.04	< 0.04	< 0.02	< 0.02	**< 0.09 (D>C)**	< 0.04	< 0.04	< 0.04	< 0.04
fluorene	ug/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.03	< 0.03	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
indeno(1,2,3-cd)pyrene	ug/L	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.1 (D>H)**	**< 0.05 (D>H)**	**< 0.05 (D>H)**	**< 0.1 (D>H)**	**< 0.1 (D>H)**	**< 0.1 (D>H)**	**< 0.09 (D>H)**	**< 0.1 (D>H)**
3-methylcholanthrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	< 0.03	< 0.03	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
naphthalene	ug/L	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.1	< 0.1	< 0.1	0.17	< 0.1
phenanthrene	ug/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.03	< 0.03	0.15	< 0.05	< 0.05	< 0.05	< 0.05
pyrene	ug/L	**< 0.05 (D>C)**	**< 0.05 (D>C)**	< 0.02	< 0.02	< 0.01	< 0.01	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
quinoline	ug/L	< 3	< 3	< 3	< 3	< 3	< 0.3	< 3	< 3	< 3	< 3	< 3
Volatile Organics												
benzene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
ethylbenzene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
m & p-xylene	ug/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
o-xylene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
toluene	ug/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4

(a) Based on unpublished information from Albian Sands (2001) and Syncrude (2001).

Note: Bolded concentrations are higher than water quality guidelines.

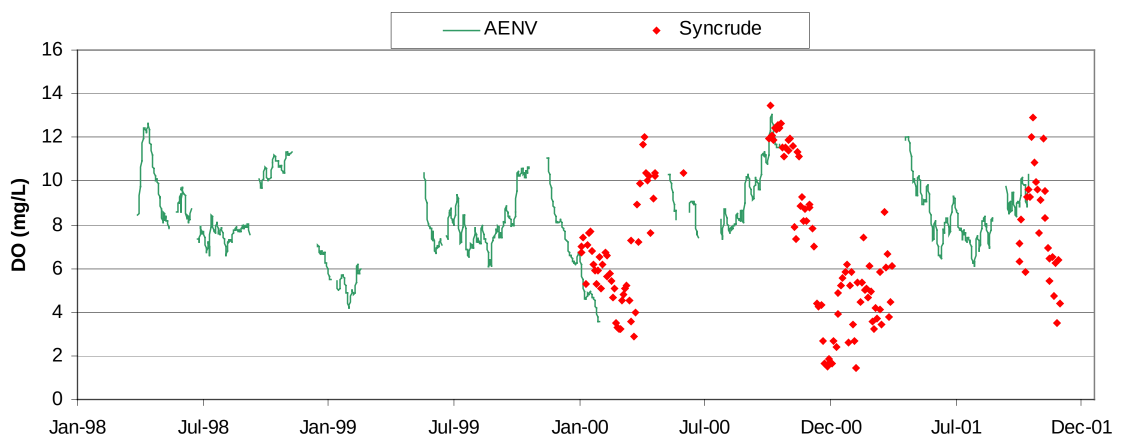
- A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
- C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
- H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
- D> = analytical detection limit was higher than the relevant water quality guideline(s).
- \- = no data.

Figure 8.13 pH Levels in the Muskeg River Downstream of Jackpine Creek, 1998 to 2001



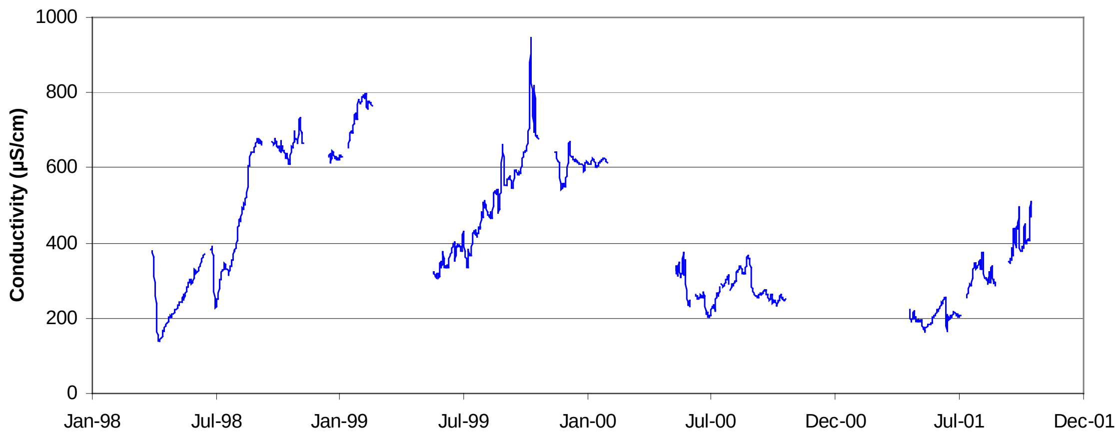
Based on continuous monitoring data collected by AENV using a HydroLab DataSonde positioned at the Environment Canada gauge station and weekly monitoring data collected by Syncrude (2001) upstream of the Canterra Road Crossing.

Figure 8.14 Dissolved Oxygen Levels in the Muskeg River Downstream of Jackpine Creek, 1998 to 2001



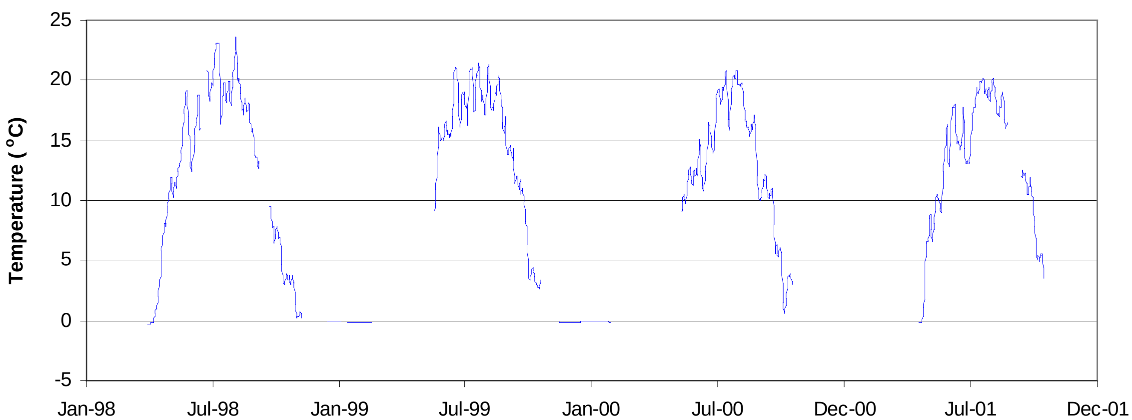
Based on continuous monitoring data collected by AENV using a HydroLab DataSonde positioned at the Environment Canada gauge station and weekly monitoring data collected by Syncrude (2001) upstream of the Canterra Road Crossing.

Figure 8.15 Conductivity Levels in the Muskeg River Downstream of Jackpine Creek, 1998 to 2001



Based on continuous monitoring data collected by AENV using a HydroLab DataSonde positioned at the Environment Canada gauge station.

Figure 8.16 Water Temperatures in the Muskeg River Downstream of Jackpine Creek, 1998 to 2001



Based on continuous monitoring data collected by AENV using a HydroLab DataSonde positioned at the Environment Canada gauge station.

Muskeg River Mouth

The water was more coloured and dissolved phosphorus levels were higher in 2001 than in previous years at the mouth of the Muskeg River (Table 8.8). In 2001, the total zinc concentration was also greater than in previous years and exceeded the chronic aquatic life guideline (Table 8.8); however, results from the quality control program indicate potential contamination of total zinc samples in 2001 (Section 4.2.1.3). In 2001, the level of total iron was greater than historical median levels and the chronic aquatic life and human health guidelines were exceeded, as has been observed in previous sampling events.

In 1998 and 1999, subsequent to the onset of development in the Muskeg River Watershed, magnesium, sulphate, conductance, hardness, alkalinity, TDS, bicarbonate and calcium levels increased at the mouth of the Muskeg River. However, in 2000 and 2001 concentrations returned to pre-1998 levels, as illustrated by TDS levels in Figure 8.17. Although there are little data prior to 1998, total cobalt, manganese and vanadium levels declined in the mouth of the Muskeg River following development in the watershed.

Table 8.8 Water Quality at the Mouth of the Muskeg River, Fall

Parameter	Units	Fall 2001	Fall Historical (1972-2000) [(a)]			
			median	min	max	n
Field Measured						
pH		**8.6** [(A,C)]	8.1	7.8	9.2	
specific conductance	uS/cm	364	607	177	655	8
temperature	^oC	10.9	4.7	1.51	12	8
dissolved oxygen	mg/L	10.3	11.7	9.5	12.6	8
Conventional Parameters						
colour	T.C.U.	100	35	29	120	9
conductance	uS/cm	368	340	193	666	15
dissolved organic carbon	mg/L	21	18	11	27	13
hardness	mg/L	176	182	96	353	15
pH		8.2	8	7.6	8.4	15
total alkalinity	mg/L	180	199	101	282	15
total dissolved solids	mg/L	280	254	120	482	14
total organic carbon	mg/L	26	24	12	29	7
total suspended solids	mg/L	< 3	3	1	70	14
Major Ions						
bicarbonate	mg/L	220	293	123	341	12
calcium	mg/L	51	42	26	111	13
carbonate	mg/L	< 5	< 3	0	7	9
chloride	mg/L	5	4	1	18	15
magnesium	mg/L	12	11	7	19	15
potassium	mg/L	1	1	1	2	15
sodium	mg/L	12	11	8	27	15
sulphate	mg/L	15	10	1	95	15
sulphide	mg/L	0.007	< 0.003	< 0.002	0.003	4
Nutrients and Chlorophyll *a*						
nitrogen - ammonia	mg/L	< 0.05	0.055	0.04	< 0.1	6
nitrogen-total [(b)]	mg/L	0.8	0.63	0.4	0.9	10
phosphorus, total	mg/L	0.023	0.021	0.007	**0.6** [(C)]	13
phosphorus, dissolved	mg/L	0.023	0.008	0.002	0.017	8
chlorophyll *a*	mg/L	1	< 0.001	0	< 1	7

Table 8.8 Water Quality at the Mouth of the Muskeg River, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1972-2000) [a]			
			median	min	max	n
Biological Oxygen Demand						
biochemical oxygen demand	mg/L	< 2	1	< 0.1	4	10
General Organics						
naphthenic acids	mg/L	1	< 1	< 1	1	6
total phenolics	mg/L	0.002	0.001	< 0.001	**0.019** (C)	9
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	0.1	1.5	9
Metals (Total)						
aluminum (Al)	mg/L	**0.11** (C)	0.09	0.0107	**1.2** (A,C)	11
antimony (Sb)	mg/L	< 0.005	0.0002	0.00002	< 0.005	9
arsenic (As)	mg/L	< 0.001	0.0006	0.0002	**0.014** (C)	12
barium (Ba)	mg/L	0.036	0.079	0.02	0.094	11
beryllium (Be)	mg/L	< 0.001	< 0.001	< 4E-05	0.003	11
boron (B)	mg/L	0.07	0.04	0.03	0.16	11
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 2E-05	**0.004** (A,C)	12
chromium (Cr)	mg/L	< 0.0008	0.0008	0.0002	**0.008** (C)	12
cobalt (Co)	mg/L	< 0.0002	0.0002	0.00002	0.006	12
copper (Cu)	mg/L	< 0.001	0.001	0.0005	0.004	12
iron (Fe)	mg/L	**1.06** (C,H)	**0.5** (C,H)	0.1	**1.81** (C,H)	12
lead (Pb)	mg/L	< 0.0001	0.0004	0.00001	**< 0.02** (D>C)	12
lithium (Li)	mg/L	0.009	0.009	0.006	0.012	11
manganese (Mn)	mg/L	0.034	0.031	0.016	**0.115** (H)	12
mercury (Hg)	mg/L	< 6E-07	**< 0.0002** (D>C,H)	< 5E-05	**< 0.05** (D>A,C,H)	9
molybdenum (Mo)	mg/L	0.0001	0.0002	< 0.0001	0.005	11
nickel (Ni)	mg/L	< 0.0002	0.0015	< 0.0001	0.015	12
selenium (Se)	mg/L	< 0.0008	< 0.0005	< 0.0002	< 0.0008	10
silver (Ag)	mg/L	< 0.000005	< 0.0001	< 2E-06	**0.003** (C)	11
strontium (Sr)	mg/L	0.13	0.19	0.07	0.23	11
thallium (Tl)	mg/L	< 0.0001	0.00003	< 3E-06	0.00016	5
titanium (Ti)	mg/L	0.0034	0.0027	0.0015	0.0167	10
uranium (U)	mg/L	< 0.0001	0.0003	< 0.0001	< 0.5	10
vanadium (V)	mg/L	0.0003	0.0004	< 0.0002	0.0029	12
zinc (Zn) [b]	mg/L	**0.159** (C)	0.013	< 0.0002	**0.033** (C)	11
Metals (Dissolved)						
aluminum (Al)	mg/L	< 0.01	0.01	0.0018	0.09	6
antimony (Sb)	mg/L	< 0.0008	< 0.0008	0.00001	< 0.0008	5
arsenic (As)	mg/L	< 0.0004	< 0.0004	0.0002	< 0.001	7
barium (Ba)	mg/L	0.033	0.077	0.024	0.093	6
beryllium (Be)	mg/L	< 0.001	< 0.001	< 4E-05	< 0.001	6
boron (B)	mg/L	0.05	0.04	0.01	0.16	8
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 1E-05	< 0.0001	6
chromium (Cr)	mg/L	< 0.0004	< 0.0004	0.0001	0.0005	6
cobalt (Co)	mg/L	< 0.0001	0.0002	< 2E-05	0.0002	6
copper (Cu)	mg/L	0.0016	0.0009	0.0004	0.0016	6
iron (Fe)	mg/L	0.47	0.17	0.02	0.44	8

Table 8.8 Water Quality at the Mouth of the Muskeg River, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1972-2000) [(a)]			
			median	min	max	n
lead (Pb)	mg/L	0.0001	0.0002	< 1E-05	0.0009	6
Lithium (Li)	mg/L	0.009	0.01	0.007	0.012	6
manganese (Mn)	mg/L	0.019	0.015	0.008	0.035	8
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 1E-05	0.0002	4
molybdenum (Mo)	mg/L	0.0001	0.0001	0.0001	0.0002	6
nickel (Ni)	mg/L	0.0002	0.0005	0.0001	0.0044	6
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0005	7
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 5E-06	< 0.0002	6
strontium (Sr)	mg/L	0.13	0.2	0.07	0.23	6
thallium (Tl)	mg/L	0.00008	< 0.00005	< 3E-06	0.00009	3
titanium (Ti)	mg/L	0.0009	0.0013	0.0006	0.0022	6
uranium (U)	mg/L	< 0.0001	0.0002	< 0.0001	0.0005	5
vanadium (V)	mg/L	0.0001	0.0002	< 0.0001	0.0003	5
zinc (Zn) [(b)]	mg/L	0.003	0.002	< 0.0002	0.013	5

(a) Based on information from Golder (1996a, 1998, 1999b, 2000b, 2001a), Alsands (1974), RL&L (1981) and WDS station AB07DA0620.

(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Bolded concentrations are higher than water quality guidelines.

^{A} = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.

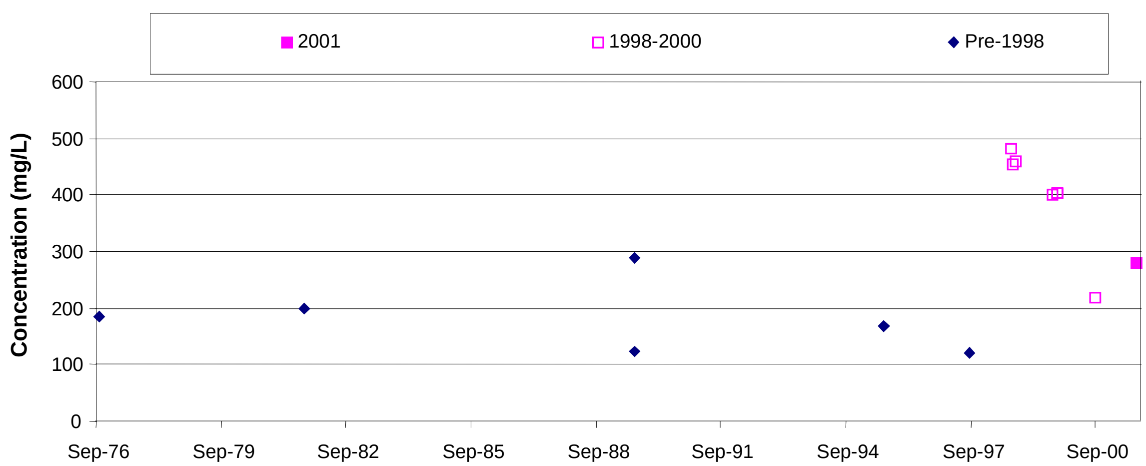
^{C} = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

^{H} = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.

$^{D>}$ = analytical detection limit was higher than the relevant water quality guideline(s).

\- = no data / no guideline.

Figure 8.17 Total Dissolved Solids Concentrations in the Mouth of the Muskeg River, Fall



8.2 SEDIMENT QUALITY

All parameter concentrations measured in 2001 at the mouth of the Muskeg River were below Canadian freshwater sediment quality guidelines (Table 8.9), although total extractable hydrocarbon and total inorganic carbon levels were higher in 2001 than in previous sampling events. Total metal levels, with the exception of titanium, were generally lower in 2001 compared to historical results, reversing an increasing trend that had been observed with both chromium and manganese since 1997 (Figures 8.18 and 8.19).

PAH concentrations were also generally lower in 2001 than in previous sampling events (Table 8.9). Exceptions included C1 and C2 substituted benzo(a)anthracene/chrysene and C1 substituted benzo(b&k) fluoranthene /benzo(a)pyrene, which were present at higher concentrations in 2001 compared to historical median values. However, for all three parameters, measured concentrations fell within the historical range. Although the relative abundance of different PAHs at the mouth of the Muskeg River tends to be variable (e.g. Figure 8.20), naphthalene and benzo(a)pyrene levels appear to be decreasing over time (Figures 8.21 and 8.22)

Table 8.9 Sediment Quality at the Mouth in the Muskeg River, Fall

Parameter	Units	Fall 2001	Fall Historical (1975 - 2000)[a]			
			median	min	max	n
Particle Size						
percent sand	%	-	79.5	68	90	4
percent silt	%	-	13.2	4	20	4
percent clay	%	-	8	4.7	12	4
moisture content	%	17	24	-	-	1
Carbon Content						
total inorganic carbon	% by wt	2.65	1.2	0.9	1.4	3
total organic carbon	% by wt	0.5	1.3	0.5	3	4
Organics						
total recoverable hydrocarbons	mg/kg	800	1970	800	3440	4
total volatile hydrocarbons (C5-C10)	mg/kg	0.5	< 0.5	-	-	1
total extractable hydrocarbons (C11-C30)	mg/kg	190	72	-	-	1
Total Metals						
aluminum (Al)	ug/g	2600	5830	2970	9030	4
arsenic (As)	ug/g	1.1	2.5	1	3.5	5
barium (Ba)	ug/g	26.9	114.5	40.1	120	4
beryllium (Be)	ug/g	< 0.2	< 1	0.3	< 1	4
boron (B)	ug/g	4	-	14	20	2
cadmium (Cd)	ug/g	< 0.1	< 0.5	< 0.1	< 0.5	5
calcium (Ca)	ug/g	33600	49000	39400	64800	4

Table 8.9 Sediment Quality at the Mouth in the Muskeg River, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1975 - 2000)[a]			
			median	min	max	n
chromium (Cr)	ug/g	4.3	25.2	6.9	**59** (I)	5
cobalt (Co)	ug/g	1.5	4.7	3	6	4
copper (Cu)	ug/g	4.5	9	7	26.2	5
iron (Fe)	ug/g	8640	16300	11200	22400	5
lead (Pb)	ug/g	2.5	7	< 5	9.9	5
magnesium (Mg)	ug/g	2040	4935	3240	6140	4
manganese (Mn)	ug/g	275	576	327	756	5
mercury (Hg)	ug/g	< 0.04	0.04	0.03	0.1	5
molybdenum (Mo)	ug/g	< 0.1	< 1	< 1	1.3	4
nickel (Ni)	ug/g	3	18	6	26.9	5
potassium (K)	ug/g	588	1230	741	1840	4
selenium (Se)	ug/g	< 0.2	0.2	< 0.1	0.7	5
silver (Ag)	ug/g	< 0.1	< 1	< 0.1	< 1	4
sodium (Na)	ug/g	73	142.5	< 100	200	4
strontium (Sr)	ug/g	50	71	62	99	4
thallium (Tl)	ug/g	< 0.05	0.1	-	-	1
titanium (Ti)	ug/g	56.4	30.8	17	52	4
uranium (U)	ug/g	0.4	-	0.4	< 40	2
vanadium (V)	ug/g	6	20	4.8	86	5
zinc (Zn)	ug/g	14.2	38.9	26.4	57.2	5
Target PAHs and Alkylated PAHs						
naphthalene	ng/g	*0.85	13	< 3	18	5
C1 subst'd naphthalenes	ng/g	1.1	10	< 3	20	5
C2 subst'd naphthalenes	ng/g	1.7	< 18	< 4	22	5
C3 subst'd naphthalenes	ng/g	2	16	< 6	40	5
C4 subst'd naphthalenes	ng/g	2	< 5	< 2	60	5
acenaphthene	ng/g	< 0.13	< 3	< 2	< 6	5
C1 subst'd acenaphthene	ng/g	0.15	< 3	< 1	< 20	5
acenaphthylene	ng/g	< 0.13	< 4	< 1	**< 6** (D>I)	5
anthracene	ng/g	< 0.49	< 2	< 1	< 3	5
dibenzo(a,h)anthracene	ng/g	< 2.2	< 4	< 3	**< 21** (D>I)	5
benzo(a)anthracene/chrysene	ng/g	5.2	17	8	**35** (I)	5
C1 subst'd benzo(a)anthracene/chrysene	ng/g	44	17	< 3	120	5
C2 subst'd benzo(a)anthracene/chrysene	ng/g	39	9	< 2	130	5
benzo(a)pyrene	ng/g	< 3.7	< 7	< 4	13	5
C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene	ng/g	21	< 9	< 5	90	5
C2 subst'd benzo(b& k) fluoranthene/benzo(a)pyrene	ng/g	8.5	< 6	< 6	100	5
benzofluoranthenes	ng/g	*3.1	11	< 6	14	5
benzo(g,h,i)perylene	ng/g	2.6	12	7	14	5
biphenyl	ng/g	0.19	< 4	< 1	< 20	5

Table 8.9 Sediment Quality at the Mouth in the Muskeg River, Fall (continued)

Parameter	Units	Fall 2001	Fall Historical (1975 - 2000)[a]			
			median	min	max	n
C1 subst'd biphenyl	ng/g	< 0.059	< 2	< 1	< 20	5
C2 subst'd biphenyl	ng/g	< 0.097	< 2	< 1	< 20	5
dibenzothiophene	ng/g	*0.26	< 2	< 1	< 3	5
C1 subst'd dibenzothiophene	ng/g	1.7	< 11	< 2	< 20	5
C2 subst'd dibenzothiophene	ng/g	8.8	42	< 4	110	5
C3 subst'd dibenzothiophene	ng/g	16	72	< 4	210	5
C4 subst'd dibenzothiophene	ng/g	21	-	44	240	2
fluoranthene	ng/g	< 0.4	3	< 1	3	5
C1 subst'd fluoranthene/pyrene	ng/g	6.3	17	8	70	5
C2 subst'd fluoranthene/pyrene	ng/g	20	64	-	-	1
C3 subst'd fluoranthene/pyrene	ng/g	21	78	-	-	1
fluorine	ng/g	< 0.27	< 3	< 2	< 3	5
C1 subst'd fluorine	ng/g	0.37	< 3	< 2	< 20	5
C2 subst'd fluorine	ng/g	7.1	< 3	< 2	60	5
C3 subst'd fluorine	ng/g	1.7	< 7	-	-	1
indeno(1,2,3,cd)pyrene	ng/g	< 1.7	6	4	< 13	5
phenanthrene	ng/g	1.1	10	10	20	5
C1 subst'd phenanthrene/anthracene	ng/g	5.6	30	20	40	5
C2 subst'd phenanthrene/anthracene	ng/g	5.2	40	30	100	5
C3 subst'd phenanthrene/anthracene	ng/g	6.8	40	30	180	5
C4 subst'd phenanthrene/anthracene	ng/g	6.1	90	40	150	5
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	3	10	-	-	1
pyrene	ng/g	1.3	6	3	12	5

(a) Based on information from Golder (1997, 1999, 2000, 2001a), Lutz and Hendzel (1997).

Note: * PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra)

Bolded concentrations are higher than the relevant sediment quality guideline.

I = concentration higher than the interim sediment quality guideline (CCME 1999).

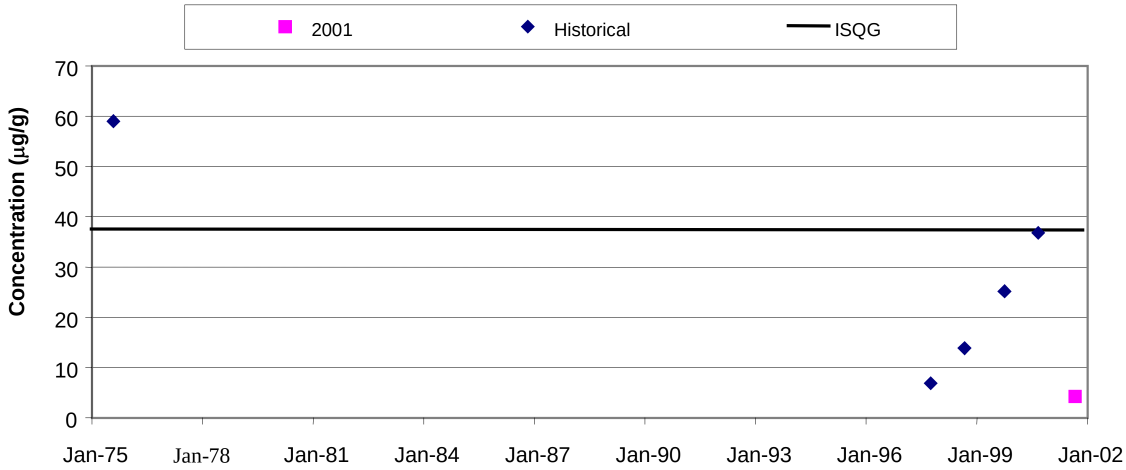
P = concentration higher than the probable effects level defined by CCME (1999).

D> = analytical detection limit was higher than the relevant water quality guideline(s).

- = no data.

nt = not toxic.

Figure 8.18 Chromium Concentrations in Sediment Collected From the Mouth of the Muskeg River



ISQG = interim sediment quality guideline.

Figure 8.19 Manganese Concentrations in Sediment Collected From the Mouth of the Muskeg River

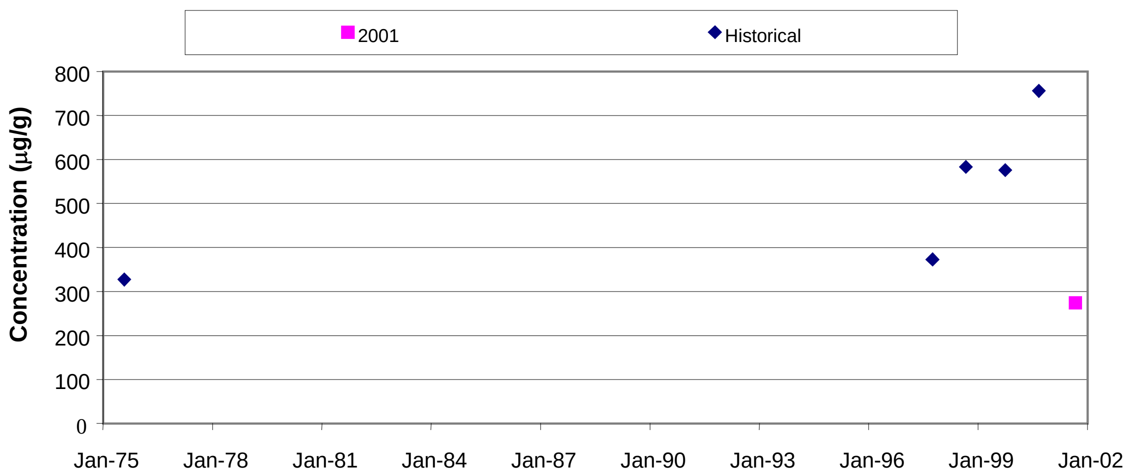


Figure 8.20 Benzo(g,h,i)perylene Concentrations in Sediment Collected From the Mouth of the Muskeg River

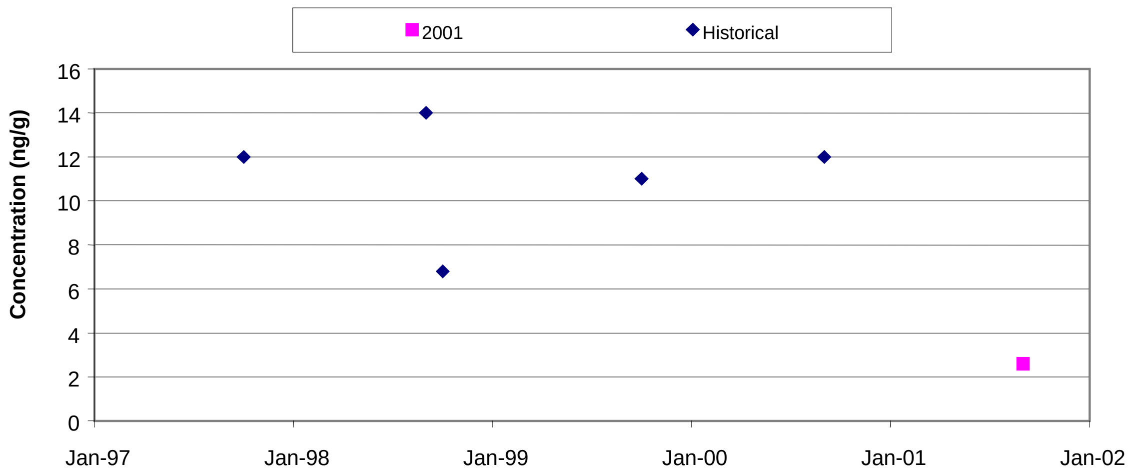
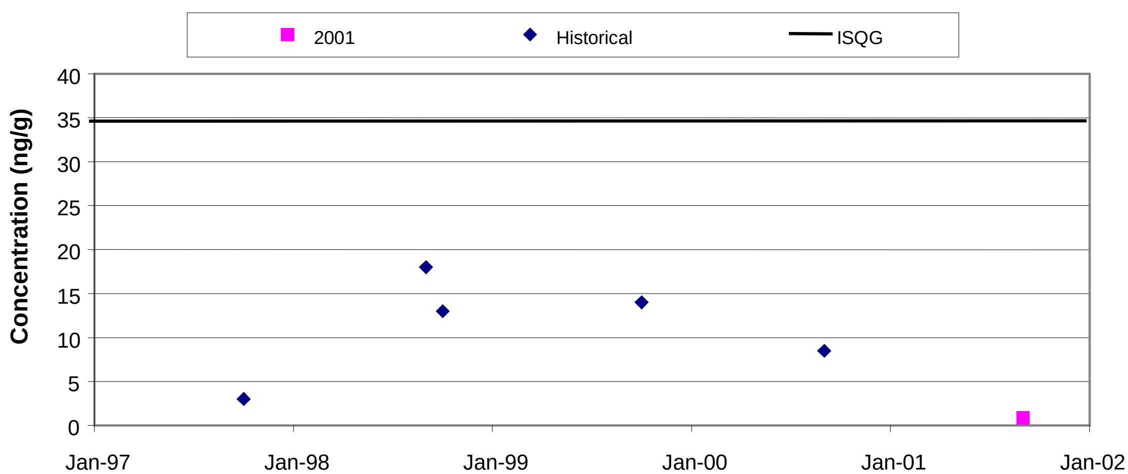
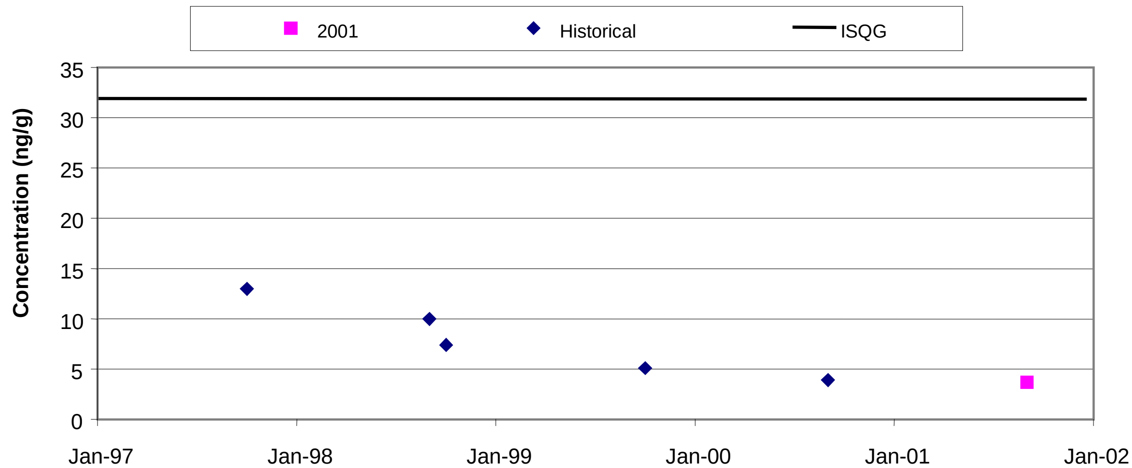


Figure 8.21 Naphthalene Concentrations in Sediment Collected From the Mouth of the Muskeg River



ISQG = interim sediment quality guideline.
Concentrations below analytical detection limits are plotted as the detection limit.

Figure 8.22 Benzo(a)pyrene Concentrations in Sediment Collected From the Mouth of the Muskeg River



ISQG = interim sediment quality guideline.
Concentrations below analytical detection limits are plotted as the detection limit.

8.3 BENTHIC INVERTEBRATE COMMUNITY

8.3.1 Muskeg River

8.3.1.1 Benthic Habitat

The Muskeg River (Figure 3.6) is of medium size, with a wetted channel width between 5 and 25 m during the fall low-flow period (Table 8.10; detailed supporting data in Appendix IX). The depositional reach was deeper and had a narrower channel compared to the lower erosional reach, which was similar to the Steepbank River in terms of habitat features. Mean current velocity was in the moderate range in the erosional reach and was non-measurable to very low in the depositional reach. The variation in water depth in the depositional reach was considerably greater (0.3 to 1.5 m) than in the erosional reach (0.3 to 0.6 m).

The substratum was dominated by gravel and cobbles in the erosional reach and by sand in the depositional reach (Table 8.10). The mean benthic algal biomass on cobble surfaces was slightly lower than in the MacKay and Steepbank rivers. Sediment TOC was low (mean of 1.9%), considering the abundant aquatic plant flora observed in this river. Aquatic macrophytes were absent from the erosional sampling locations and macrophyte cover was highly variable among depositional sampling locations, ranging from 0 to 60%. Field water quality measurements were typical of rivers and streams in the region. Conductivity was lower in the downstream erosional reach, possibly reflecting day-to-day variation in salinity or the input of less saline water from tributaries between the reaches sampled.

Table 8.10 Habitat Characteristics of the Benthic Invertebrate Sampling Reaches in the Muskeg River, Fall 2001

Variable	Units	Lower Reach (erosional) Mean (range)	Lower to Mid Reach (depositional) Mean (range)
sample date	-	September 12-14, 2001	September 20-21, 2001
habitat	-	run/riffle	run/backwater/pool
wetted channel width	m	15 (11 - 23)	9 (6 - 14)
bankfull channel width	m	21 (12 - 50)	11 (6 - 16)
water depth	m	0.4 (0.3 - 0.6)	0.7 (0.3 - 1.5)
current velocity	m/s	0.70 (0.19 - 1.13)	0.004 (0 - 0.04)
macrophyte cover	%	1 (0 - 10)	18 (0 - 60)
Field Water Quality			
dissolved oxygen	mg/L	10.3 (9.2 - 10.7)	8.3 (7.4 - 8.7)
conductivity	µS/cm	353 (331 - 378)	438 (412 - 460)
pH	-	8 (7.7 - 8.2)	7.8 (7.6 - 7.9)
water temperature	^{o}C	12.1 (10.5 - 13.3)	10.2 (9.0 - 11.54)
Benthic Algae			
benthic algal chlorophyll *a* (15 samples/river)	mg/m^2	25 (1 - 72)	-
Substrate (erosional habitat)			
sand/silt/clay	%	5 (0 - 10)	-
small gravel	%	7 (0 - 20)	-
large gravel	%	38 (0 - 80)	-
small cobble	%	27 (10 - 60)	-
large cobble	%	17 (0 - 45)	-
boulder	%	5 (0 - 30)	-
bedrock	%	1 (0 - 10)	-
weighted average index	-	5.5 (4.8 - 7.0)	-
Substrate (depositional habitat)			
sand	%	-	87 (67 - 98)
silt	%	-	6 (2 - 18)
clay	%	-	7 (2 - 15)
total organic carbon	%	-	1.9 (0.2 - 8.5)

Note: - = not applicable or no data.

8.3.1.2 Benthic Community

Total benthic invertebrate abundance was low (mean of ≤10,000 organisms/m^2) in the erosional reach sampled in the Muskeg River (Figure 8.23; raw data in Appendix IX). The depositional reach supported larger numbers of invertebrates, in the moderate to high range in absolute terms. As in the Steepbank and MacKay rivers, abundance declined gradually from 1998 to 2001 in the erosional reach, but did not change appreciably in the depositional reach.

Taxonomic richness was less variable among years and was slightly lower in the depositional reach than in the erosional reach (Figure 8.23). As in 1998 and 2000, the Muskeg River supported the most diverse benthic fauna of the three tributaries, with over 70 taxa in each habitat and a total of 105 taxa in all samples combined. Mean richness also declined slightly over time in the erosional reach during the years sampled. As noted above, the sampling design was different in 1998 from the design in 2000 and 2001; therefore direct comparisons with the 1998 data are not appropriate.

Taxonomic composition at the level of major taxon was variable among years in the erosional reach (Figure 8.23). The 1998 and 2001 data are indicative of diverse and balanced communities, dominated by chironomids (1998) or chironomids and mayflies (2001). In 2000, the benthic community was strongly dominated by chironomids and mayflies. The higher proportion of mayflies in 2000 may reflect the higher stream flows (and hence more erosional conditions) in 2000 relative to the other two years with data, which were “low flow” years in the Oil Sands Region. The depositional benthic community was dominated by chironomid midges in both 2000 and 2001 (Figure 8.23). There was no substantial variation in community composition in this reach at the level of major group.

At the lowest level of taxonomy, the erosional benthic fauna of the Muskeg River was dominated by the mayfly genus *Baetis*, aquatic mites, the chironomid midge *Lopescladius*, the oligochaete worm family Naididae and net-spinning caddisflies (*Hydropsyche*) (Table 8.11). In contrast, all dominant taxa in the depositional reach were chironomid midges.

Significant correlations between habitat variables and benthic community variables were few, and generally weak in both habitats sampled in the Muskeg River (Table 8.12). The one exception was the positive correlation between oligochaete worm abundance and macrophyte cover, which is consistent with the frequently observed association between these invertebrates and sediments rich in organic-rich material in areas of high plant cover.

Figure 8.23 Total Invertebrate Abundance, Richness and Community Composition in the Muskeg River, Fall 2001

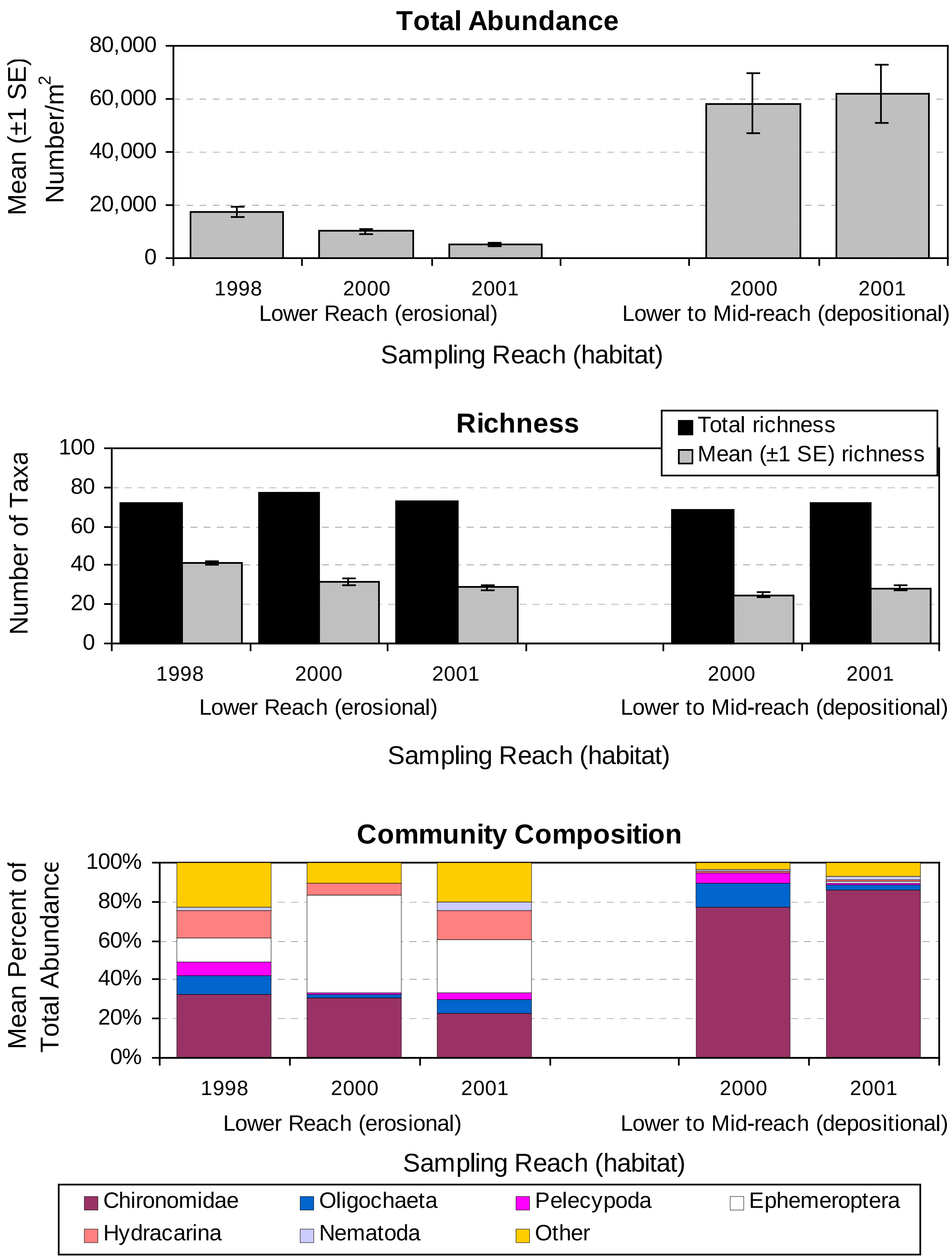


Table 8.11 Abundances of Common Invertebrates in the Muskeg River, Fall 2001

Taxon	Major Group	Mean (no./m^2)	Standard Error	% of Total Abundance
Lower Muskeg River (erosional)				
Baetis	Ephemeroptera	1,143	386	22.7
Hydracarina	-	749	168	14.9
Lopescladius	Chironomidae	341	144	6.8
Naididae	Oligochaeta	282	135	5.6
Hydropsyche	Trichoptera	250	60	5.0
Tvetenia	Chironomidae	217	58	4.3
Nematoda	-	197	89	3.9
Pisidium/Sphaerium	Pelecypoda	144	66	2.9
Tanytarsus	Chironomidae	122	88	2.4
Heptagenia	Ephemeroptera	114	32	2.3
Chloroperlidae	Plecoptera	107	25	2.1
Optioservus	Coleoptera	98	18	2.0
Ophiogomphus	Odonata	95	24	1.9
Rheotanytarsus	Chironomidae	91	20	1.8
Stempellinella	Chironomidae	81	41	1.6
Ephemerellidae	Ephemeroptera	77	46	1.5
Hemerodromia	Empididae	76	20	1.5
Cricotopus/Orthocladius	Chironomidae	65	22	1.3
Isoperla	Plecoptera	63	24	1.3
Taeniopteryx	Plecoptera	56	20	1.1
Glossosoma	Trichoptera	56	18	1.1
Enchytraeidae	Oligochaeta	55	23	1.1
Stempellina	Chironomidae	50	14	1.0
total % for common taxa				(90.2%)
total abundance		5,026	796	-
richness		28.5	1.6	-
total richness		73	-	-
Lower to Middle Reach of Muskeg River (depositional)				
Micropsectra	Chironomidae	19,708	4,711	31.7
Tanytarsus	Chironomidae	5,616	1,641	9.0
Polypedilum	Chironomidae	4,380	1,177	7.1
Stempellinella	Chironomidae	4,220	1,609	6.8
Parakiefferiella	Chironomidae	3,446	1,684	5.5
Pagastiella	Chironomidae	3,334	906	5.4
Tanypodinae	Chironomidae	2,769	875	4.5
Paralauterborniella	Chironomidae	2,044	758	3.3
Planorbidae	Gastropoda	1,511	691	2.4

Table 8.11 Abundances of Common Invertebrates in the Muskeg River, Fall 2001 (continued)

Taxon	Major Group	Mean (no./m^2)	Standard Error	% of Total Abundance
Procladius	Chironomidae	1,456	443	2.3
Ablabesmyia	Chironomidae	1,453	431	2.3
Candona	Ostracoda	1,261	548	2.0
Tanytarsini	Chironomidae	1,175	640	1.9
Paratanytarsus	Chironomidae	940	518	1.5
Nematoda	-	820	196	1.3
Pisidium/Sphaerium	Pelecypoda	768	271	1.2
Ceratopogoninae	Ceratopogonidae	731	245	1.2
Hydracarina	-	645	135	1.0
total % for common taxa				(90.6%)
total abundance		62,098	11,009	-
richness		28.3	1.5	-
total richness		72	-	-

Table 8.12 Correlations Between Benthic Community Variables and Habitat Variables in the Muskeg River, Fall 2001

Benthic Community Variable	Current Velocity	Chloro-phyll *a*	Depth	% Silt + Clay	TOC[a]	Macrophyte Cover	Comment (based on scatter-plot)
Lower Reach (erosional) (n=15)							
Baetis abundance	-	0.56*	NT[b]	NT	NT	NT	weak relationship
Lopescladius abundance	0.58*	-	NT	NT	NT	NT	-
Lower to Mid-reach (depositional) (n=12 to 15)							
Ablabesmyia abundance	NT	NT	0.56*	-	-	-	weak relationship
Planorbidae abundance	NT	NT	0.74**	0.65*	0.65*	-	weak relationships
Sphaeriidae abundance	NT	NT	0.60*	-	-	-	weak relationship
Oligochaeta abundance	NT	NT	-	-	-	0.77**	-

[a] TOC = total organic carbon content of bottom sediments.

[b] NT = not tested in the habitat type shown.

Note: Spearman rank correlation coefficients (r_S) shown.

- = no significant correlation; P>0.05

* = significant correlation; P<0.05

** = significant correlation; P<0.01

8.4 FISH POPULATIONS

8.4.1 Radiotelemetry Study

The following analysis of fish movements for radio-tagged northern pike includes the results of the entire telemetry program from 2000 through 2001 and supercedes any previous results and conclusions.

The results of the radio-tracking surveys are presented in Appendix VII. Fish locations in the mainstem Athabasca River are presented by kilometre post (KP) and locations in the Muskeg River are presented by river reach (i.e., Reach 1 to 4, see Figure 3.8). The telemetry results are also summarized in Figures 8.24 through 8.26, which provide a graphic representation of fish movements. Individual fish are identified by their transmitter frequency and code number (e.g., ƒ620-01).

During the telemetry flights, signals were not recorded for all individual radio transmitters on every survey. For any given survey, a missing signal could be due to either the receiver not picking up the transmitter's signal, or the fish being outside the telemetry survey area, as described in Section 5.3.1.

In total, 25 northern pike were radio-tagged in the Muskeg River. However, two of the 25 fish were removed at the start of the study by anglers and six were confirmed dead during the ground-based telemetry surveys in February and March of 2001. This provided 17 fish for the analysis of movements for this species. The 17 fish included two juveniles and 15 pre-spawning or post-spawning adults that were tagged and released in the lower Muskeg River during the period May 26 to June 1, 2000.

Of the 17 radio-tagged northern pike, three fish (ƒ700-07, ƒ700-09 and ƒ720-12) were never recorded on any of the telemetry surveys. These fish likely left the telemetry survey area immediately after the spring spawning season. These fish may have moved further up the Muskeg River. It is possible that they moved to Lake Athabasca soon after spawning, sometime in the 19-day period between radio-tagging and the first tracking flight. It is less likely that they moved upstream of the rapids or into tributary streams since the fish were not recorded in the survey area at any time during the summer, fall or winter, indicating that they did not return from further upstream or from tributary streams. However, these fish were not recorded in the Athabasca River telemetry area during the following spring spawning season and their movements remain unknown.

Figure 8.24 Movements of Radio-Tagged Northern Pike, Muskeg River Spawners

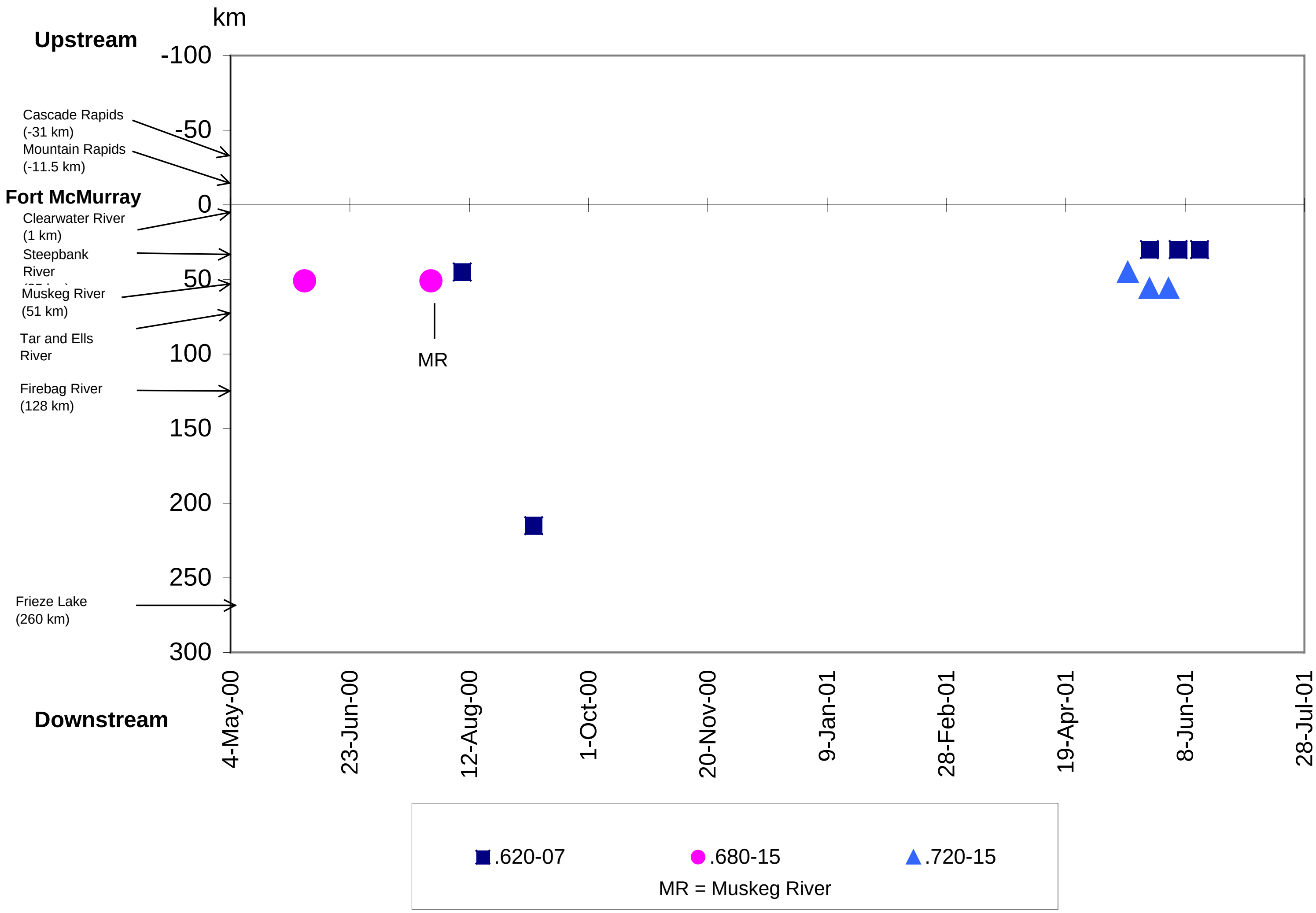


Figure 8.25 Movements of Radio-Tagged Northern Pike, Muskeg River Spawners

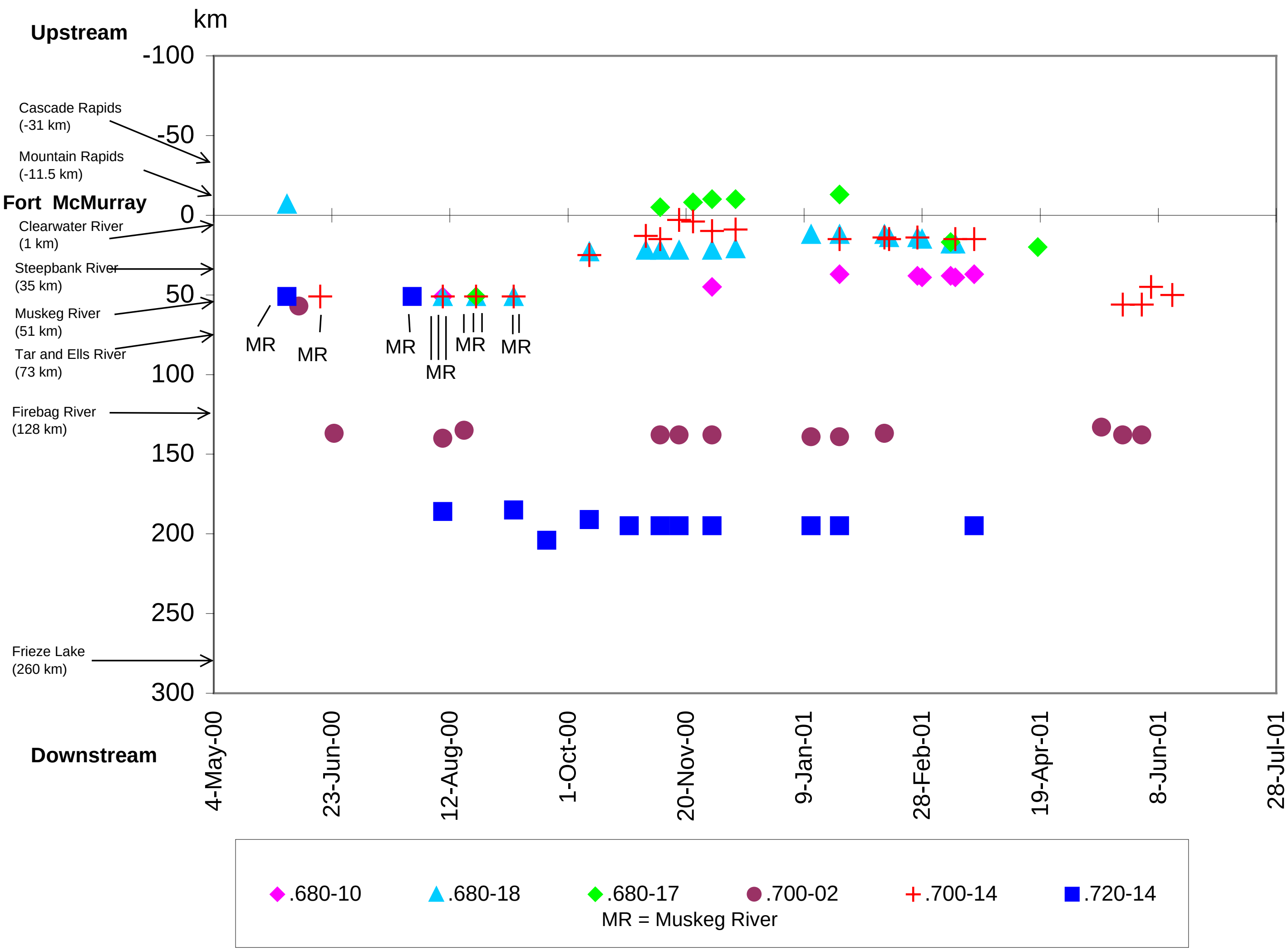
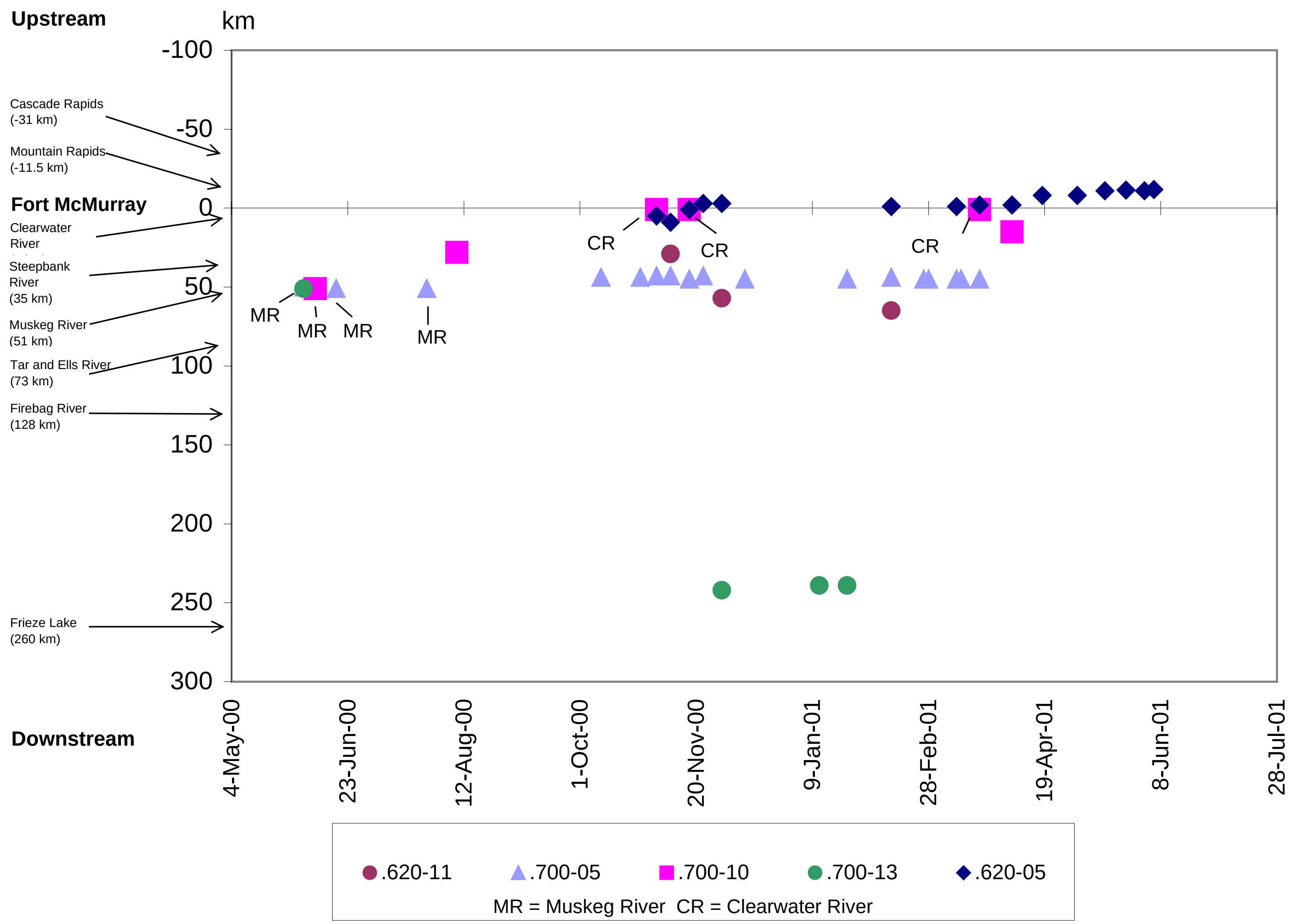


Figure 8.26 Movements of Radio-Tagged Northern Pike, Muskeg River Spawners



Telemetry locations are available for the remaining 14 radio-tagged northern pike and are presented by general movement pattern on Figures 8.24, 8.25 and 8.26.

Two of the 14 radio-tagged fish showed limited use of the Athabasca River basin within the telemetry survey area (Figure 8.24). Fish ƒ720-15 was absent from the survey area for most of the study period, but was recorded in the Athabasca River at the Muskeg River mouth in the spring of 2001. Fish ƒ680-15 remained in the Muskeg River or the Athabasca River at the Muskeg River mouth until late June 2000, after which it left the survey area. These fish may represent a portion of the population that utilizes the Athabasca River in the survey area only during the spring spawning period.

One radio-tagged fish (ƒ620-07) appears to have utilized the Athabasca River basin until the summer. This fish was not recorded between tagging and the early August survey, when it was present in the Athabasca River near the Muskeg River mouth. It is suspected that this fish was using the Muskeg River in the spring and early summer but the signal was masked by the large number of transmitters present in the same area. This fish was recorded moving down the Athabasca River (KP 215) later in August and then disappeared from the survey area and is believed to have moved to Lake Athabasca.

The remaining 11 radio-tagged northern pike showed extensive use of the Athabasca River basin. Six of these fish (ƒ680-10, ƒ680-17, ƒ680-18, ƒ700-02, ƒ700-14 and ƒ720-14) utilized the Muskeg River and/or the Athabasca River during the spring, summer and fall (Figure 8.25). In addition, overwintering use was recorded for all of these fish in the mainstem Athabasca River. Overwintering sites included various locations upstream of the Oil Sands Region (KP 3 to 25), in the Oil Sands Region (KP 37 to 45) and the lower river (KP 135 to 204). Fish ƒ700-02 was not recorded in the survey area after February while the other five fish remained in the Athabasca River through the winter. One of these fish was recorded back at the mouth of the Muskeg River during the spring of 2001.

The remaining five fish in this group of 11 (ƒ620-05, ƒ620-11, ƒ700-05, ƒ700-10 and ƒ700-13) were not recorded for a time in the spring and/or summer but returned to the Athabasca River survey area in the fall or winter (Figure 8.26). Some of these fish were located in the Muskeg or Athabasca rivers in June but others left the survey area immediately after spawning. When out of the survey area, all five of these fish are suspected to have utilized tributaries of the Athabasca River other than the Muskeg River, or the Muskeg River upstream of the survey area. Fish ƒ700-05 returned to the Athabasca River in September and overwintered at KP 43-45. Fish ƒ620-05 returned to the Athabasca River at KP 5 in November and overwintered near Fort McMurray. Fish ƒ620-11 returned to the Athabasca River in November and overwintered at

KP 57-65 until February. Fish ƒ700-13 returned to the Athabasca River in December to spend part of the winter at KP 239-242. Fish ƒ620-11 and ƒ700-13 left the survey area later in the winter, possibly to move to Lake Athabasca. The final fish in this group demonstrated that northern pike that spawn in the Muskeg River do use alternate tributaries at other periods of the year. Fish ƒ700-10 left the Muskeg River and, in August, was recorded at KP 28 moving up the Athabasca River. This fish was then recorded incidentally in the Clearwater River in November and was suspected to have been using this tributary for a while. The Clearwater River was not included in the survey area, but is located in close proximity to the Fort McMurray airport, resulting in partial coverage of this watercourse during the telemetry flights.

Northern pike that spawn in the Muskeg River generally showed extensive use of the Athabasca River basin. Most (12 of 17) radio-tagged fish were known or suspected to have used the Athabasca River basin for the spring and summer. All but one fish were also present in the river in the fall and all or part of the winter period. One of the 12 fish remained in the study area only until August, after which it was recorded well downstream before leaving the survey area. Six of the 12 fish utilized either the Muskeg River or the Athabasca River mainstem during the open-water period, and utilized the Athabasca River during the winter. The remaining five fish were suspected to have used the upper Muskeg River or other Athabasca River tributaries during the open-water period, but returned to the Athabasca River for the winter. Although other tributaries were not surveyed, use of tributaries other than the Muskeg River was demonstrated for one fish that was located in the Clearwater River.

A small number (5 of 17) of radio-tagged northern pike from the Muskeg River spent a limited amount of time in the survey area. It was speculated that these fish moved to Lake Athabasca following the spawning season or later in the summer. However, movement down the Athabasca River was demonstrated for only one of these fish.

8.4.2 Sentinel Species Monitoring

Monitoring of slimy sculpin populations was conducted at exposure sites on the Muskeg River (Site MR-E) and Steepbank River (Site SR-E) and reference sites on the Steepbank (Site SR-R), Horse (Site HR-R) and Dunkirk rivers (Site DR-R). Most of the results are presented in Section 7.4.1.1. This section addresses the sentinel species analysis for the Muskeg River.

8.4.2.1 Muskeg River Exposure Site

Slimy sculpin results for the 2001 monitoring of the Muskeg River downstream of current mining developments (Site MR-E) include fish community data, slimy sculpin population/health data and statistical comparisons. These results are compared to reference populations of slimy sculpin from the Horse, Steepbank and Dunkirk rivers. Additionally, the 2001 results for sites MR-E and SR-R are compared to the 1999 results from the same sites.

Fish Community Data

The total number of each fish species captured at each monitoring site is presented in Table 8.13. The Muskeg River exposure site had the highest number of fish species, higher than any of the three reference sites. Slimy sculpin was the most numerous species recorded; however, the sampling technique was biased towards the collection of this species. Other small-bodied species were present in low numbers, as were juvenile suckers and juvenile sport species.

The relative abundance of fish species (i.e., CPUE) was lower at the Muskeg River exposure site than any of the three reference sites, both for slimy sculpin and for all species combined (Table 7.10). This was comparable to sampling from 1999 when the slimy sculpin CPUE value from the single reference site was more than twice the CPUE value from the Muskeg River exposure site. However, the catch rate of slimy sculpin at the exposure site was higher in 2001 (2.92 fish/100 s) than in 1999 (1.28 fish/100 s) (Figure 7.8).

Differences in fish community structure (i.e., species diversity and abundance) were apparent between the five sampling sites (Table 7.11), with higher species diversity and lower fish abundance at the exposure sites than at the reference sites. These differences were likely due to differences in habitat characteristics between these sites. The differences in abundance need to be taken into consideration when examining population parameters that may be affected by fish density (e.g., growth rates and fish size).

The number of female, male and immature slimy sculpin collected for processing at each monitoring site is presented in Table 7.11. The target number of 30 adult fish of each sex was achieved for most sites, with the exception of the Dunkirk River reference site (11 adult males captured) and the Muskeg River exposure site (29 males captured).

Field water quality parameters measured at exposure site MR-E varied from reference site SR-R for each parameter measured (Table 7.13). Relative to the reference sites on the Horse and Dunkirk rivers, dissolved oxygen and pH at MR-E were similar while temperature and conductivity were considerably higher.

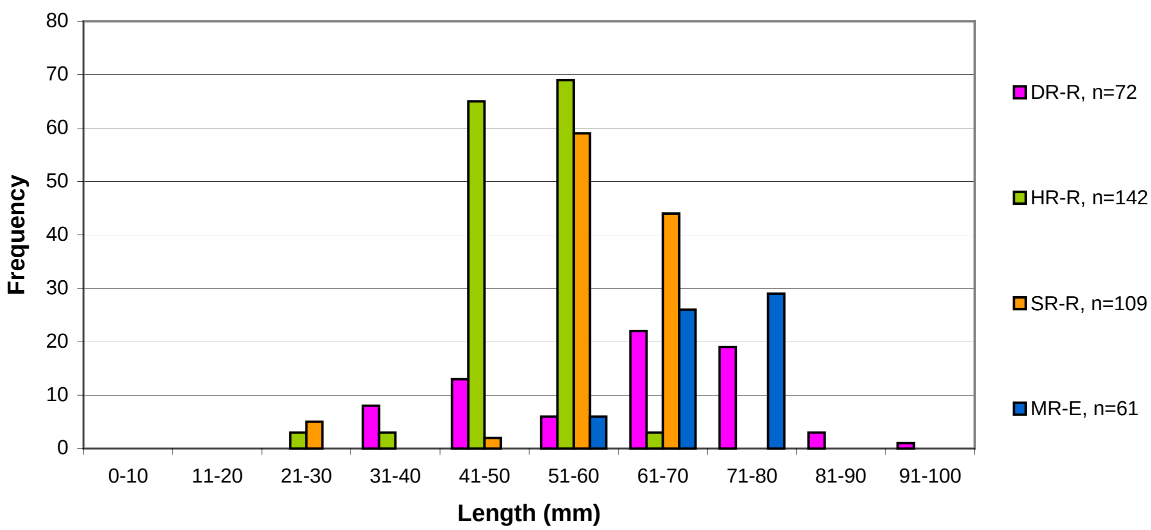
Slimy Sculpin Population Data

Mean length, body weight, condition factor, age, fecundity, LSI, GSI and PI for slimy sculpin from the Muskeg River exposure site and the three reference sites are presented in Table 7.14.

Size and Age Distributions – 2001 Results

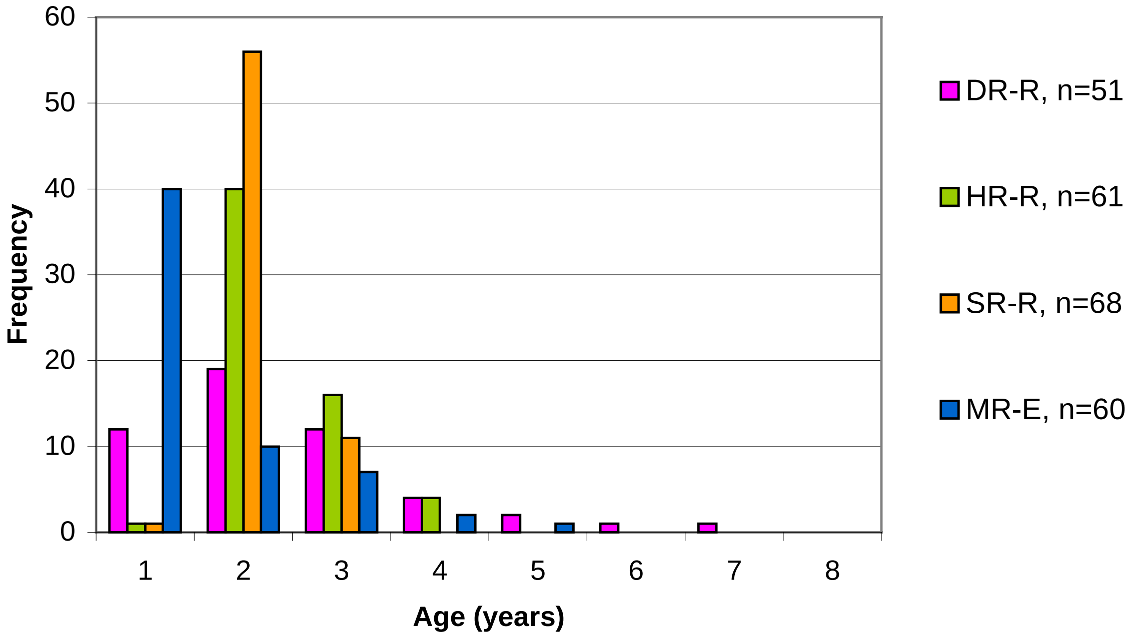
Length-frequency distributions of slimy sculpin at the Muskeg River exposure site and the three reference sites are presented in Figure 8.27. This figure presents the size distribution for all fish captured, including sacrificed fish and juvenile and adult fish that were released. Most slimy sculpin from the Muskeg River exposure site were 70 to 89 mm in length and the maximum size range was 80 to 89 mm. Both the peak size and maximum sizes were higher at the exposure site than at the Horse River and Steepbank River reference sites. The size distribution was similar to the Dunkirk River reference site, except that the Dunkirk River sample included a much larger size range (i.e., included both smaller and larger fish). This was reflected in the differences in the size of the fish that were sacrificed for analysis; the mean length and weight for fish from the exposure site were higher than fish from the Horse and Steepbank rivers, but lower than the Dunkirk River site (Table 7.14).

Figure 8.27 Length-Frequency Distributions for Slimy Sculpin, Muskeg River Exposure Site and Reference Sites on the Steepbank, Horse and Dunkirk Rivers, Fall 2001



Age distributions of adult (i.e., sacrificed) slimy sculpin indicated that fish used in the health analysis from the Muskeg River exposure site were primarily yearlings, with a smaller number of 2 to 5 year old fish (Figure 8.28). In contrast, fish from the three reference sites were primarily 2 and 3 years of age, although a number of 1 year old fish were included at the Dunkirk River. The maximum ages at the reference sites were age 4 at the Horse and Steepbank rivers, and age 7 at the Dunkirk River.

Figure 8.28 Age-Frequency Distributions for Adult Slimy Sculpin, Muskeg River Exposure Site and Reference Sites on the Steepbank, Horse and Dunkirk Rivers, Fall 2001

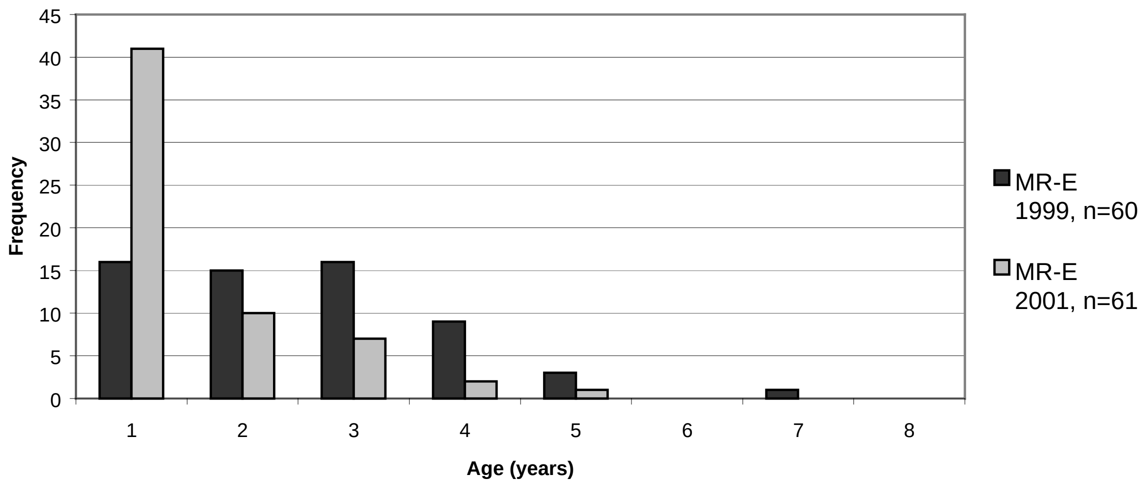


Size and Age Distributions – Comparisons of 1999 and 2001

Length-frequency distributions cannot be compared between the 1999 and 2001 studies as only adults were included during fish collections in 1999 and do not represent the whole population.

Age-frequency distribution of slimy sculpin from the Muskeg River exposure site varied between 1999 and 2001 (Figure 8.29). The majority (67%) of slimy sculpin collected in 2001 were yearlings, whereas most sculpin collected in 1999 were distributed evenly between the 1, 2 and 3 year old age-classes, but with a larger number of 4 and 5 year old fish recorded in 1999 relative to 2001.

Figure 8.29 Age-Frequency Distributions for Adult Slimy Sculpin at the Muskeg River Exposure Site, 1999 and 2001



Pathology

Comparisons of the mean PI for the Muskeg River exposure site and the three reference sites showed variable results (Table 7.14). The index of pathology (PI) for abnormal fish at site MR-E was higher than at HR-R, similar to site SR-R, similar to site DR-R for females and higher than at site DR-R for males.

The percentages of slimy sculpin with specific abnormalities are presented in Table 7.15. Most abnormalities that were observed occurred in low frequency (i.e., < 10%) at the Muskeg River exposure site, with the exception of gill and liver abnormalities and parasites.

The most frequent pathology observed in slimy sculpin from the exposure site was the presence of parasites. Of the 32% of the sculpin examined with parasites, most (27%) had external parasites observed in the gill chambers, on the skin or fins. Internal parasites occurred in a few fish and were observed in the hindgut, on the outer stomach wall or embedded in the kidney. The incidence of parasites at site MR-E was much higher than at sites DR-R (8%) and HR-R (0%), however it was still lower than the incidence of parasites at site SR-R (49%).

Clubbed and frayed gills were observed in 15% of the slimy sculpin from MR-E, while gill abnormalities occurred less frequently in fish from the reference sites. Although the percentage of sculpin exhibiting pathology of the eyes at site MR-E was relatively low (5%), the type of pathology was similar to that seen among fish from the other exposure site on the Steepbank River. A thick cloudy membrane covering the eyes of fish was observed at both sites MR-E and SR-E, but not seen in the reference populations.

The most frequent internal pathology observed in the exposure population from the Muskeg River was liver anomalies (20%) in the form of liver discolouration. Similar liver discolouration was observed at reference site DR-R, but at a lower frequency (14%). Liver abnormalities occurred at reference site SR-R in a similar frequency as the exposure site (19%). However, the liver anomalies observed at site SR-R were different in nature and included abnormal shape and texture or the presence of nodules.

Statistical Comparisons

2001 Results

The responses of slimy sculpin from the Muskeg River exposure site, relative to slimy sculpin from the three reference sites are summarized in Table 8.13. The results are presented as ‘0’ (no statistical difference), ‘-‘ (exposure site is statistically lower) or ‘+’ (exposure site is statistically higher). Comparisons are presented between the exposure site and each individual reference site, as well as for the reference sites combined.

Mean lengths of both male and female fish were greater at the exposure site than the average for all reference sites combined (Table 8.13). In individual comparisons, the mean lengths for both sexes from the exposure site were higher than at the Horse River and Steepbank River reference sites, but were not significantly different from fish lengths at the Dunkirk River reference site.

For female slimy sculpin, the adjusted mean body weight (i.e., adjusted for the effect of fish length in analysis of covariance) at the exposure site was greater than the average for all reference sites and was also greater than at the Horse River reference site. There was no difference in mean weight of females between the exposure site and either of the other two reference sites. The only difference in mean body weight of males was between the Horse River reference site and the exposure site, with the weight being greater at the exposure site.

The condition factor was greater at the exposure site than the average for all reference sites for males, but was not significantly different for females. The condition factor for both males and females was greater at the exposure site than at the Horse River reference site, but there were no differences in condition factor between the exposure site and either of the other two reference sites.

Mean ages for slimy sculpin from the Muskeg River exposure site were generally different from all other sites and were significantly lower than the average of the three reference sites. Female slimy sculpin mean ages were lower at the exposure site than at any of the reference sites. For males, the mean ages at the exposure site were less than the mean ages at both the Horse River and Steepbank River reference sites. There was no significant difference in the mean ages of males between the exposure site and the Dunkirk River reference site. Since only adult fish were included in the analysis, the generally lower mean ages at the exposure site could represent a reduction in the average age-at-maturity, increased recruitment or increased mortality of older fish. An increase in recruitment would not be consistent with observations for fecundity (which was less at the exposure site than at two of the reference sites) and GSI (which was consistently lower at the exposure site, relative to all reference sites).

Table 8.13 Summary of the Responses of Slimy Sculpin from the Muskeg River Exposure Site Relative to the Reference Sites, Fall 2001

Sex	Parameter	Dunkirk River Reference		Horse River Reference		Steepbank River Reference		Mean of All Reference Sites	
		Response[a]	% Difference[b]	Response	% Difference	Response	% Difference	Response	% Difference
female	total length (mm)	0	ns	+	30.00	+	14.54	+	11.25
	body weight (g)[c]	0	ns	+	24.77	0	ns	+	7.47
	condition factor[d]	0	ns	+	12.68	0	ns	0	ns
	age (y)	-	-40.35	-	-35.53	-	-27.63	-	-34.98
	fecundity[e]	0	ns	-	-13.02	-	-10.55	-	-6.93
	LSI[f]	0	ns	+	15.24	-	-21.02	0	ns
	GSI[g]	-	-46.99	-	-42.41	-	-31.32	-	-40.94
	PI[h]	0	ns	+	366.67	0	ns	0	ns
male	total length (mm)	0	ns	+	30.67	+	13.73	+	17.80
	body weight (g)[c]	0	ns	+	16.91	0	ns	0	ns
	condition factor[d]	0	ns	+	17.48	0	ns	+	7.53
	age (y)	0	ns	-	-32.53	-	-26.11	-	-27.04
	LSI[f]	0	ns	+	52.20	0	ns	+	27.27
	GSI[g]	-	-18.40	-	-22.21	-	-18.65	-	-20.15
	PI[h]	0	ns	+	848.28	0	ns	+	79.54

(a) Response relative to reference site: 0 indicates no difference.
(b) Percent difference of exposed site relative to reference site; ns = not significantly different.
(c) Adjusted least squares mean weight from analysis of covariance with length as the covariate.
(d) Condition Factor = (weight)/(length^3) * 10^5.
(e) Fecundity (# eggs/carcass weight).
(f) LSI = Liver Somatic Index ([liver weight/carcass weight] x 100).
(g) GSI = Gonad Somatic Index ([gonad weight/carcass weight] x 100).
(h) PI = Pathology Index (index increases as number and severity of abnormalities increases).

Note: + indicates reference site is significantly higher (P<0.05).
- indicates reference site is significantly lower (P<0.05).

Fecundity at the exposure site was not significantly different than fecundity at the Dunkirk River reference site, but was significantly less than fecundity at the other two reference sites. It was also less than the average fecundity for all reference sites. However, the magnitude of these differences is not particularly large.

The LSI for female fish at the exposure site was greater than at one reference site (Horse River) and less than one other reference site (Steepbank River). There were no significant differences in LSI for females between the exposure site and the Dunkirk River reference site, or between the exposure site and the average LSI for all reference sites. The LSI for male fish at the exposure site was greater than the LSI at the Horse River reference site, but was not significantly different from the LSI for males at the other two reference sites. The LSI for males at the exposure site was also greater than the average for all reference sites. Results of the LSI analyses should be considered inconclusive. The direction of the response of female fish at the exposure site was different relative to two of the reference sites, and there was no significant difference relative to the average of all reference sites. For males, LSI at the exposure site was different from only one of the reference sites.

The GSI response of slimy sculpin at the exposure site was consistent relative to all reference sites and this pattern was similar for both males and females. The GSI for both males and females was less at the exposure site than at any of the reference sites, but the percentage difference was greater for female fish. The consistently lower GSI values for fish from the Muskeg River exposure site may indicate a reduced reproductive potential for slimy sculpin at that site. This could conceivably result from reduced food availability, reduced habitat suitability, or exposure to less suitable water quality conditions.

The PI for both male and female fish at the exposure site was greater than at the Horse River reference site, but was not significantly different from the PI at either of the other two reference sites. For male fish only, the PI at the exposure site was also significantly greater than the average PI for all references sites.

Comparisons of 1999 and 2001

Changes in the responses of slimy sculpin between 1999 and 2001 are summarized in Table 8.14 for the Muskeg River exposure site and the Steepbank River reference site. There were several statistically significant changes at each of the two sites over time, with the pattern of changes for most parameters similar at the exposure and reference sites, with the exception of mean length, mean age and gonad size.

At the reference site, mean lengths of both males and females decreased slightly from 1999 to 2001. Over the same period, the mean age of females did not change significantly at the reference site and the mean age of males increased slightly. At the exposure site, the mean ages of both females and males decreased significantly (by 36 and 41%, respectively) from 1999 to 2001, while the mean lengths increased for both sexes. This implies an increase in growth rates of slimy sculpin at the exposure site over that period of time.

The adjusted mean body weight and condition factor for both males and females increased significantly from 1999 to 2001 at the reference site and the exposure site. The LSI for females also increased at both sites and LSI for males did not change significantly at either site. These results suggest a general increase in energy storage in slimy sculpin at both sites from 1999 to 2001.

Fecundity increased significantly at both the reference site and the exposure site (by 56 and 59%, respectively) from 1999 to 2001. The GSI for females at the reference site also increased from 1999 to 2001 and this is consistent with the observed increase in fecundity. However, GSI for females at the exposure site decreased (by 13%) while fecundity increased, implying that the number of eggs increased and their size decreased. For male fish, the GSI did not change significantly at either the reference site or the exposure site from 1999 to 2001.

Table 8.14 Comparisons of the Responses of Slimy Sculpin in 1999 and 2001 at the Muskeg River Exposure Site and the Steepbank River Reference Site

Sex	Parameter	Muskeg River Exposure Site							Steepbank River Reference Site						
		1999			2001			% Change	1999			2001			% Change[(a)]
		Mean	SE	N	Mean	SE	N		Mean	SE	N	Mean	SE	N	
female	total length (mm)	73.268	1.031	41	76.742	1.233	31	4.74	75.302	1.496	43	67.000	0.588	38	-11.03
	body weight (g)[(b)]	3.598	-	41	4.453	-	31	23.76	3.500	-	43	4.150	-	38	18.57
	condition factor[(c)]	0.878	0.015	41	1.091	0.027	31	24.30	0.989	0.010	43	1.155	0.011	38	16.73
	age (y)	2.488	0.216	41	1.581	0.166	31	-36.46	2.310	0.288	42	2.184	0.074	38	ns
	fecundity[(d)]	55.127	3.140	30	87.890	4.315	31	59.43	62.817	2.872	29	98.256	2.604	38	56.42
	LSI[(e)]	2.099	0.097	41	2.677	0.100	30	27.53	2.479	0.097	41	3.389	0.112	38	36.73
	GSI[(f)]	1.612	0.038	41	1.398	0.069	31	-13.25	1.840	0.048	42	2.036	0.066	38	10.66
male	total length (mm)	77.684	1.427	19	82.759	1.391	29	6.53	79.427	1.750	37	72.767	0.504	30	-8.39
	body weight (g)[(b)]	4.574	-	19	5.973	-	29	30.59	4.395	-	37	4.703	-	30	7.01
	condition factor[(c)]	0.883	0.018	19	1.152	0.019	29	30.43	0.970	0.018	37	1.130	0.025	30	16.59
	age (y)	2.632	0.278	19	1.552	0.183	29	-41.03	1.886	0.249	35	2.100	0.056	30	11.36
	LSI[(e)]	1.541	0.074	19	1.721	0.085	28	ns	1.430	0.058	37	1.576	0.074	30	ns
	GSI[(f)]	2.086	0.111	19	1.862	0.101	28	ns	2.100	0.066	37	2.289	0.081	30	ns

(a) Percent change from 1999 to 2001 where the change was significant (P<0.05); ns = not significantly different.
(b) Adjusted least squares mean weight from analysis of covariance with length as the covariate.
(c) Condition Factor = (weight)/($length^3$) * 10^5.
(d) Fecundity (# eggs/carcass weight).
(e) LSI = Liver Somatic Index ([liver weight/carcass weight] x 100).
(f) GSI = Gonad Somatic Index ([gonad weight/carcass weight] x 100).

Summary

Differences in the slimy sculpin populations between the Muskeg River exposure site and the three reference sites were found to be variable between sites and among parameters. The following summary is based on statistical comparisons between the exposure site and the combined reference sites, which represent the range of natural variation in regional slimy sculpin populations. Between year comparisons of populations at the exposure and reference sites were also used to evaluate changes over time and to see if the changes occur only at the exposure site.

Female slimy sculpin from the Muskeg River exposure site were different from the average of the reference sites for several parameters. Exposure site females were longer and heavier but had lower age, fecundity and GSI. Exposure males were longer with better condition factor and higher LSI, but had lower age and GSI. The PI for males was also higher than the reference site average.

There appears to be some tendency for slimy sculpin to be larger at the exposure site than at the reference sites. However, the results of analyses of length, body weight and condition factor indicate that, although the exposure fish are generally longer than reference fish, the weight and condition of slimy sculpin at the exposure site is higher than only one of the reference sites (Horse River). Average length of fish at the exposure site increased between 1999 and 2001, while decreasing at the Steepbank River reference site over the same period. Average age for adult fish is lower at the exposure site and has decreased at this site over time. This is due to a significant occurrence of one year old fish at the exposure site. Although all sites have had mature fish at age 1, the number has been minor at all sites except the Muskeg and Dunkirk rivers (Figure 8.28). The exposure site has shown a combination of longer, younger fish (relative to reference sites) and increased average length and decreased average age over time. This suggests an increased growth rate at this site and more fish becoming mature at age 1.

Slimy sculpin at the Muskeg River exposure site have smaller relative gonad size and slightly lower fecundity than the average of the three reference sites. Male and female GSI values at the Muskeg River exposure site were smaller than at all reference sites, putting it outside the natural range of variability as represented by the reference sites. Over time, the GSI has decreased at the exposure site for female fish, while increasing at the one reference site examined in more than one year. Over the same period, fecundity has increased at both sites, suggesting that egg size may have decreased at the exposure site.

One factor that may account for the smaller GSI in the Muskeg River exposure population would be the differences in age structure among populations. The mean age of both male and female fish captured at the exposure site was significantly younger than in reference populations, with 1 year old fish being the dominant age class at the exposure site. In contrast, 2 year old fish were the dominant age class in all three reference populations. Smaller relative gonad size for the exposure population would be expected, especially since first-time spawners (i.e., younger fish) generally produce smaller gonads.

Another factor that may account for the smaller GSI values in exposure fish relative to reference fish is the bigger size of the exposure fish. Fish from the exposure population appeared to be directing more energy towards somatic growth, rather than gonad growth, compared to reference fish. Though this could help explain the smaller GSI in exposure fish, this factor, in combination with the very young age of exposure fish, likely explains the lower GSI in that population.

An interesting observation that should be noted is that the actual gonad size (i.e., not corrected for carcass weight) in male fish from the exposure population was larger than in reference populations. The actual amount of gonadal development in the male fish from the exposure population (including the younger fish) was higher than in reference fish. Actual gonad size for female fish from the exposure site was similar to reference fish, but was still somewhat smaller. However, the younger females from the Muskeg River exposure population produced more eggs than reference population females.

This data indicates that, despite the lower GSI values for fish from the Muskeg River exposure site, the reproductive potential for the population is similar to reference populations and has not changed much since 1999. Rather, the increase in fish size at the exposure site observed between 1999 and 2001 has not been reflected in a corresponding increase in gonad size. Since fish size at the exposure site is as large, or larger, than most of the reference sites, it appears that the exposure population distributes relatively more energy to somatic growth than gonad growth. Emphasis on somatic growth over gonad development is typical for younger fish. However, changes in relative gonad size from 1999 to 2001 for female fish at the exposure site suggests that this parameter should be closely monitored, particularly as the same pattern was recorded for the Steepbank River exposure site.

The increase in fecundity level combined with smaller gonad size for the exposure population indicates a decrease in egg size, which may reduce embryo survival and hatchability. Differences in fecundity between 1999 and 2001 may be due, in part, to different measurement methods. In 1999, fecundity was estimated from an ovarian sub-sample, while in 2001, true fecundity was determined by a direct count of all eggs.

The higher PI at the exposure site relative to the average for the three reference sites is not considered to reflect poor fish health at this site. Examination of the data shows that the higher PI is for male fish only, and only in comparison to the Horse river reference site.

Significance of Effects

The concern remains whether the observed changes in GSI for slimy sculpin at the Muskeg River exposure site represent an effect of oil sands development or are related to natural variability. In many studies, a statistically significant difference in biological measures has been used as evidence that an effect has occurred. The approach proposed by Kilgour *et al.* (1998) was used to determine the ecological significance of the observed effects. They define ecologically relevant differences as observations from impact locations that fall outside the normal range of variation based on reference-location data. They also define the normal range as the region enclosing 95% of reference-location observations. The 95% region can then be expressed generically as standard deviations in univariate responses. For example, in single responses that are normally distributed, the region defined by $\mu \pm 1\,\sigma$ incorporates about 67% of the population, and $\mu \pm 1.96\,\sigma$ incorporates about 95% of the population. All of the mean values of exposure population parameters fell within the normal range based on the three reference populations; however, GSI in female fish was very close to the lower boundary of the normal range.

Considering the number of possible explanations, as described above, that could account for the low GSI observations, it is believed that the low relative gonad sizes encountered are not abnormal. The above explanation of effects also highlighted inconsistencies in a number of observed responses, both between populations and between years. More consistent differences would be expected if observed responses were related to a particular stressor. Annual variations in the various parameters measured must be understood before an effect of concern can be identified.

Sample Size Considerations

The results of the power analysis to evaluate the sample sizes required to determine responses between the Muskeg River exposure site and the reference sites is presented with the Steepbank River analysis in section 7.4.1.1.

8.4.3 Fish Fence

The total number of fish captured at the fish fence between April 28 and May 26 was limited due to difficulties in maintaining both the integrity of the fence and complete blockage of the river. The two-way counting fence was fully operational for only 16 of the 29 days of the fish fence study.

In total, 128 fish consisting of five species were captured at the fish fence site. In order of abundance, the species included white sucker (79 fish), northern pike (35), longnose sucker (12), lake chub (1) and brook stickleback (1). Table 8.15 presents the numbers of fish captured for large-bodied species during each day of trap operation, by direction of travel. Although targeted by the study, Arctic grayling were not observed in either the upstream or downstream trap.

Table 8.15 Fish Captured in the Muskeg River Counting Fence, Spring 2001

Date		Upstream Trap				Downstream Trap			
		ARGR	NRPK	LNSC	WHSC	ARGR	NRPK	LNSC	WHSC
April	28	-	1	-	-	-	-	-	-
	29 [a]	-	-	-	-	-	-	-	-
	30	-	-	-	-	-	-	-	-
May	1	-	1	-	1	-	-	-	-
	2 [a]	-	5	-	1	-	-	-	1
	3	-	7	1	-	-	1	-	-
	4	-	3	1	2	-	-	-	-
	5	-	3	-	-	-	-	-	-
	6	-	-	-	-	-	1	1	-
	7	-	3	-	-	-	1	-	1
	8 [a]	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-
	10 [a]	-	-	-	-	-	-	-	-
	11 [b]	-	1	-	1	-	-	-	-
	12 [b]	-	2	-	6	-	-	-	-
	13 [b]	-	2	-	6	-	-	-	-
	14 [b]	-	-	-	1	-	-	-	-
	15 [b]	-	1	-	-	-	-	-	-
	16 [b]	-	-	-	8	-	-	-	-
	17 [b]	-	-	-	-	-	-	-	-
	18 [b]	-	1	-	22	-	-	-	-
	19 [b]	-	1	1	2	-	-	-	-
	20	-	-	2	-	-	-	-	-
	21	-	-	2	6	-	-	-	2
	22	-	-	-	2	-	-	-	-
	23	-	-	2	2	-	-	-	2
	24	-	1	2	11	-	-	-	1
	25	-	-	-	-	-	-	-	1
	26	-	-	-	-	-	-	-	-
total		0	32	11	71	0	3	1	8
		114				**12**			

[a] Fence washed out.
[b] Partial blockage of river with upstream trap only.
Note: - = No captures.
ARGR = Arctic grayling; NRPK = northern pike; LNSC = longnose sucker; WHSC = white sucker.

As expected, most of the captured fish were migrating upstream during the spring sampling period. The upstream trap captured a total of 114 large-bodied fish, while the downstream trap captured 12 fish (Table 8.15). Upstream migrants included 71 white sucker, 32 northern pike and 11 longnose sucker.

Size, age and health data for fish captured at the fish fence are presented in detail in Appendix X and are summarized in Table 8.16. Fish captured during the spring migration were primarily adults, although a small number of juvenile fish were also captured (Appendix X). Fish were generally in good condition and had a low incidence of external abnormalities (PI). The average condition factor was much greater than 1.0 for the sucker species, likely due to the inclusion of heavy, gravid fish. The average condition factor was only 0.68 for northern pike, which also included gravid fish. The low value for northern pike is likely due to the elongated body form typical for this species.

Table 8.16 Mean ± SE Length, Weight, Condition Factor and External Pathology Index of Northern Pike, White Sucker and Longnose Sucker Captured in the Muskeg River Fish Fence, Spring 2001

Species	Analysis	Fork Length (mm)	Weight (g)	Condition (k)	Age	External Pathology Index
WHSC	range	163-565	50-2915	0.97-190	3-21	0-30
	mean	433.8 ± 11.6 (79)	1,455.3 86.7 (77)	1.48 ± 0.02 (77)	11.1 ± 0.6 (74)	2.7 ± 0.9 (79)
NRPK	range	356-900	290-5225	0.48-0.82	2-9	0-30
	mean	571.3 ± 17.5 (35)	1,433.9 ± 167.0 (35)	0.69 ± 0.02 (35)	4.6 ± 0.3 (35)	2.6 ± 1.4 (35)
LNSC	range	162-543	50-2720	0.94-1.70	2-17	0-30
	mean	349.4 ± 34.7 (12)	736.7 ± 207.9 (12)	1.29 ± 0.06 (12)	8.1 ± 1.4 (10)	2.5 ± 2.5 (12)

Note: WHSC = white sucker; NRPK = northern pike; LNSC = longnose sucker (sample size).

Environmental conditions over the period of the fish fence study are presented in Table 8.17. This table includes the measurements conducted during the field program and Muskeg River discharge data supplied by Environment Canada for the flow monitoring station located approximately 15 km upstream of the river mouth. Maximum air temperatures ranged from 14 to 28°C, but were generally in the range of 19 to 23°C. Air temperatures remained at or below 23°C for most of the study, with increased temperatures occurring towards the end of the study (May 23-26). On the initial day of the study, water temperatures were quite low, with a minimum and maximum of 0 and 1°C, respectively. Daily water temperatures generally increased throughout the study, with maximum temperatures exceeding 11°C from May 13 to 26.

Table 8.17 Environmental Measurements for the Fish Fence Sampling Period, Spring 2001

Date		Daily Air Temp. Range (°C)		Daily Water Temp. Range (°C)		Dissolved Oxygen (mg/l)	pH (pH units)	Conductivity (mS/cm)	Discharge (m^3/s)
		Min.	Max.	Min.	Max.				
April	28	2	22	0	1	9.6	8.36	207	6.11
	29	4	22	2	6	9.6	8.34	206	6.85[(a)]
	30	4	22	4	6	9.8	8.32	207	7.10
May	1	1	20	4	7	9.6	8.34	206	7.26
	2	3	19	6	9	9.8	8.36	208	7.60[(a)]
	3	3	20	6	10	9.6	8.34	206	7.52
	4	6	23	8	11	9.0	8.51	206	7.58
	5	3	23	9	9	9.5	8.34	206	7.23
	6	0	22	7	7	9.9	8.34	207	7.23
	7	3	15	8	9	9.6	8.52	209	8.34
	8	3	14	9	9	9.8	8.34	207	9.61[(a)]
	9	2	19	8	9	8.8	8.54	208	10.40
May	10	n/a	n/a	8	9	n/a	n/a	n/a	11.14[(a)]
	11	4	21	7	11	10.0	8.37	175	11.59[(b)]
	12	3	23	7	11	9.4	8.37	173	11.97[(b)]
	13	6	19	8	12	9.2	8.31	179	12.20[(b)]
	14	3	20	9	13	9.8	8.21	181	12.21[(b)]
	15	1	19	9	13	9.5	8.30	180	12.02[(b)]
	16	2	21	9	13	10.8	8.10	201	11.80[(b)]
	17	2	23	9	12	11.8	n/a	161	11.43[(b)]
	18	3	17	9	12	12.2	n/a	194	11.01[(b)]
	19	3	18	9	12	12.2	n/a	192	10.73[(b)]
	20	2	17	9	12	11.2	n/a	194	10.31
	21	3	17	11	12	11.2	n/a	197	9.91
	22	1	23	9	12	11.4	n/a	201	9.47
	23	7	24	10	12	10.4	n/a	200	9.10
	24	8	25	12	13	10.4	n/a	201	8.97
	25	9	28	12	15	10.4	n/a	201	8.85
	26	9	27	12	15	10.2	n/a	201	8.87

(a) Fence washed out.

(b) Partial blockage of river with upstream trap only.

The dissolved oxygen concentration generally increased throughout the month, with readings of 9.6 mg/L in April to 10.4 mg/L at the end of May. The pH stayed relatively constant with an average of 8.3. The conductivity of the water stayed fairly stable for the first half of the sampling period, averaging 207 µS/cm. Conductivity decreased to 175 µS/cm on May 11 as the river discharge increased, then slowly rose back up to 201 µS/cm on May 22 and remained constant as discharge declined.

The river discharge at the time of fence installation was 6.11 m^3/s. The discharge increased continually through the first half of the study period, reaching a peak of 12.21 m^3/s on May 14 (Table 8.17). The period when only partial blockage of the river was possible was associated with discharge levels above 10.0 m^3/s.

Population parameters were analyzed for the two species for which a sufficient number of fish were captured; length-frequency analyses, length-weight regressions, age-frequency distributions and size (length)-at-age regressions were conducted for northern pike and white sucker. Due to the relatively small numbers of fish involved, the regression analyses were conducted for the sexes combined.

The length-frequency analysis for northern pike shows that, as expected, the fish in the spring run consisted primarily of adult fish (Figure 8.30). Most fish were in the 501 to 700 mm size range, with two fish larger than 850 mm. The length-weight regression line (Figure 8.31) has a moderately high coefficient of determination ($r^2 = 0.96$), indicating a fairly good relationship between length and weight. The slope of the regression line (3.06) indicates a fair state-of-well-being for the population, based on how weight increases as length increases. However, the slope of the regression line would be influenced, in part, by using only adult fish in the analysis and the likelihood that most of the fish would be gravid and would have seasonably high weights. The age-frequency distribution (Figure 8.32) shows a range of ages from 2 to 9 years, with a peak in distribution at age 4. As only a few juvenile fish were recorded, most northern pike appear to be adult by three years of age. The size-at-age relationship (Figure 8.33) shows a very poor correlation ($r^2 = 0.27$) between length and age and is not suitable for comparisons in growth rates between years. Table 8.18 presents the fork lengths and weights for northern pike by age class for future comparisons.

Figure 8.30 Northern Pike Length-Frequency Distribution, Muskeg River, Spring 2001

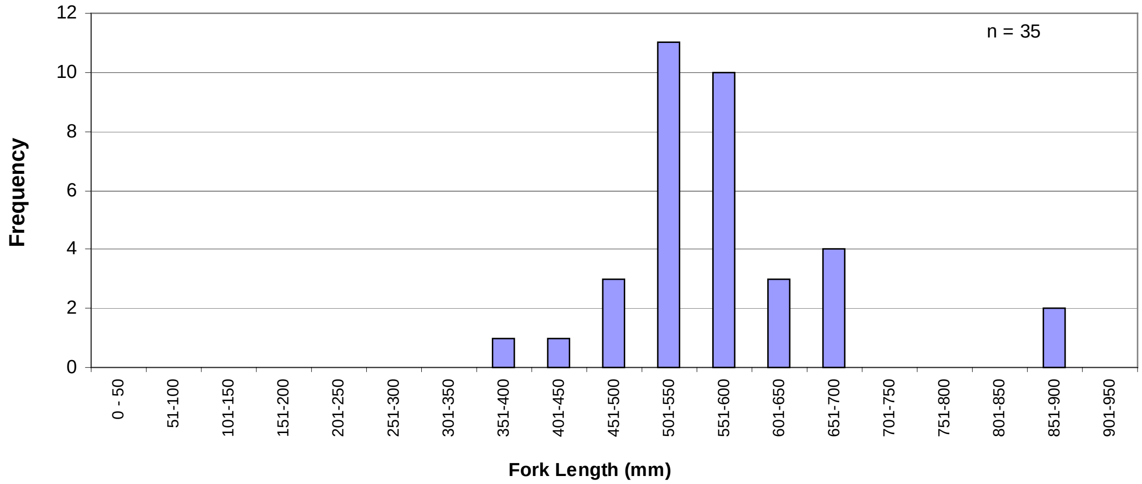


Figure 8.31 Northern Pike Length – Weight Regression Analysis, Muskeg River, Spring 2001

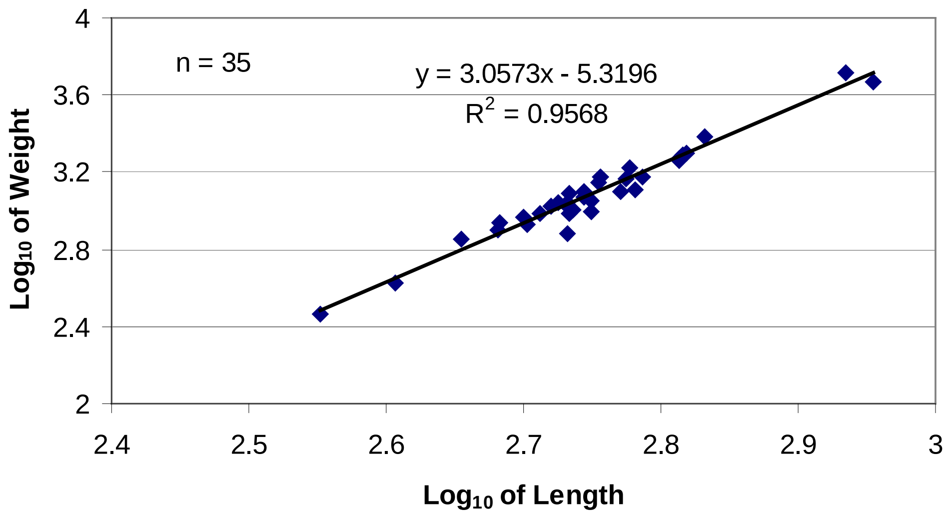


Figure 8.32 Northern Pike Age-Frequency Distribution, Muskeg River, Spring 2001

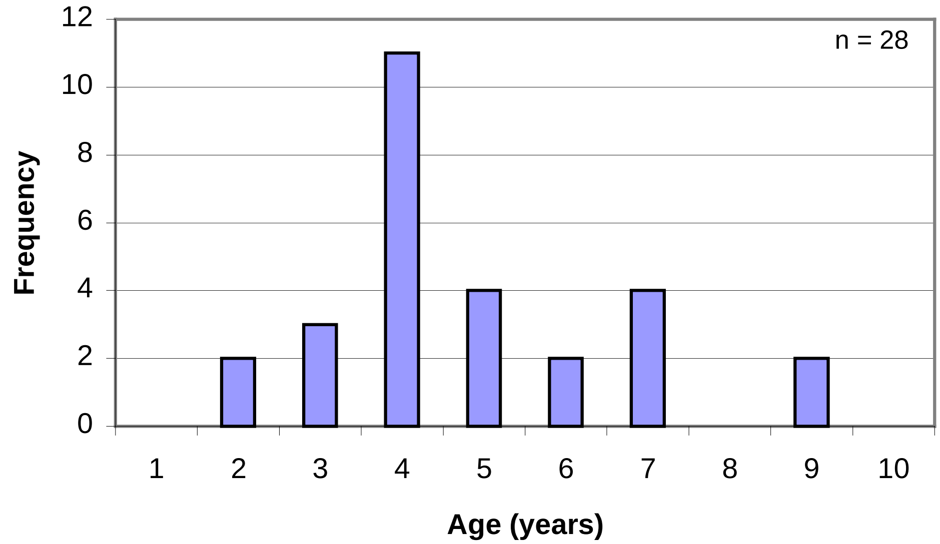


Figure 8.33 Northern Pike Size-at-Age Relationship, Muskeg River, Spring 2001

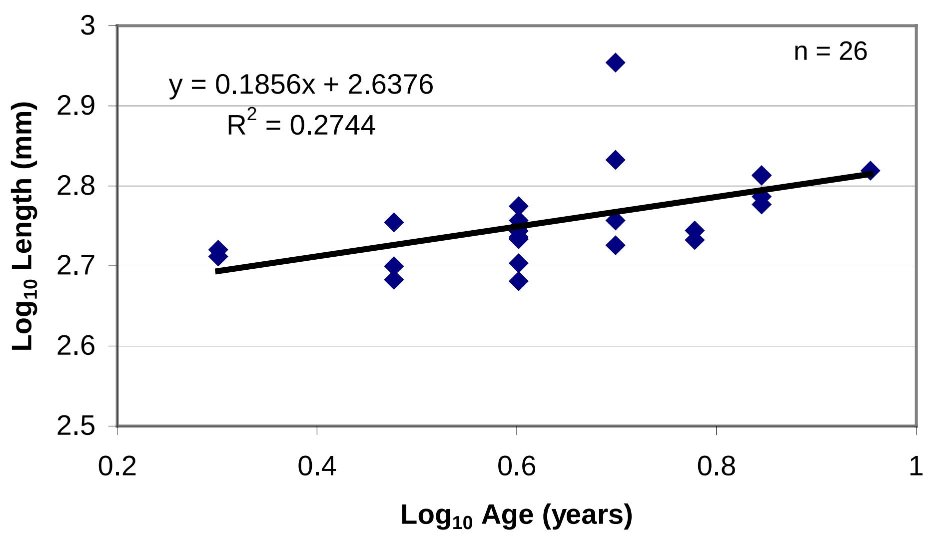


Table 8.18 Ranges, Means and Standard Error of Fork Length and Weight by Age for Northern Pike and White Sucker, Muskeg River, Spring 2001

Species	Age (y)	n	Fork Length (mm)				Weight (g)			
			min	max	mean	± SE	Min	max	mean	± SE
NRPK	2	2	356	404	380.0	24.0	290	425	357.5	67.5
	3	3	515	545	528.3	9.0	960	1,050	1,005.0	26.0
	4	12	505	659	584.2	15.0	850	1,975	1,405.4	100.3
	5	4	452	554	505.0	23.0	710	1,190	965.0	109.9
	6	2	541	598	569.5	29.0	960	1,675	1,317.5	357.5
	7	4	561	680	592.5	29.0	995	2,400	1,485.0	316.9
	9	1	-	-	571	-	-	-	1,490	-
WHSC	3	4	240	301	263.5	14.7	165	375	270	60.6
	4	5	208	301	249.0	16.6	170	350	240.0	43.6
	5	4	390	428	408.0	7.9	640	1,230	966.3	132.4
	6	2	422	425	423.5	1.5	1,105	1,200	1,152.5	47.5
	7	7	390	485	434.3	13.1	860	1,780	1,250.7	130.4
	8	4	371	425	403.3	11.7	725	1,190	995.0	97.6
	9	4	359	486	420.5	33.4	630	1,790	1,223.8	279.3
	10	5	378	496	430.0	20.8	700	2,205	1,301.0	264.9
	11	3	370	495	412.0	41.5	750	1,650	1,066.7	292.0
	12	2	475	536	505.5	30.5	1,590	2,220	1,905.0	315.0
	13	6	459	532	496.2	11.3	1,450	2,350	1,866.7	144.9
	14	2	472	529	500.5	28.5	1,550	2,300	1,925.0	375.0
	15	7	458	565	515.3	15.6	1,650	2,505	2,162.1	120.7
	16	6	463	556	508.3	17.3	1,360	2,785	2,027.5	210.5
	17	6	480	563	517.5	13.2	1,450	2,915	2,219.2	202.3
	18	4	505	550	523.3	9.9	1,875	2,609	2,236.0	151.0
	21	2	525	560	542.5	17.5	1,435	2,360	1,897.5	462.5

Note: NRPK = northern pike; WHSC = white sucker.

The white sucker length-frequency analysis (Figure 8.34) shows that the fish captured in the spring migration were primarily adults, but that the run also included some juvenile fish. There is a minor peak in the distribution at 251 to 300 mm (juvenile), with most fish grouped in the range 401 to 600 mm (adult). The length-weight regression for white sucker (Figure 8.35) shows there is a high correlation between length and weight ($r^2 = 0.99$) for this species. The slope of the regression line is fairly high, indicating a good state-of-well-being for these fish, which is likely influenced by the inclusion of gravid fish in the analysis. The age distribution (Figure 8.36) is broad, with ages ranging from three to 21 years. The size-at-age analysis shows a moderate correlation between length and age ($r^2 = 0.72$) and may allow comparisons of growth rates between years (Figure 8.37). However, previous RAMP fish fence data are insufficient for comparisons. The fork lengths and weights for white sucker by age class are presented in Table 8.18 for future comparisons.

Figure 8.34 White Sucker Length-Frequency Distribution, Muskeg River, Spring 2001

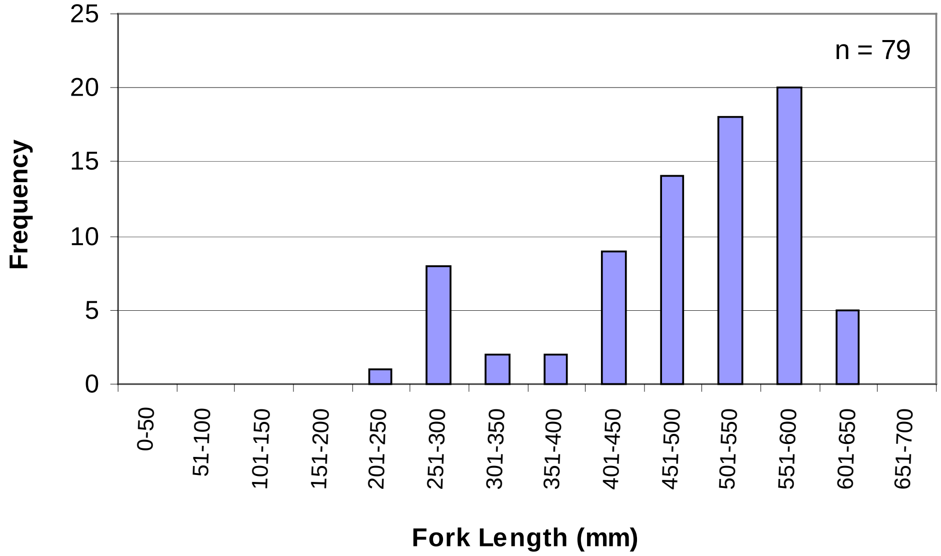


Figure 8.35 White Sucker Length-Weight Regression Analysis, Muskeg River, Spring 2001

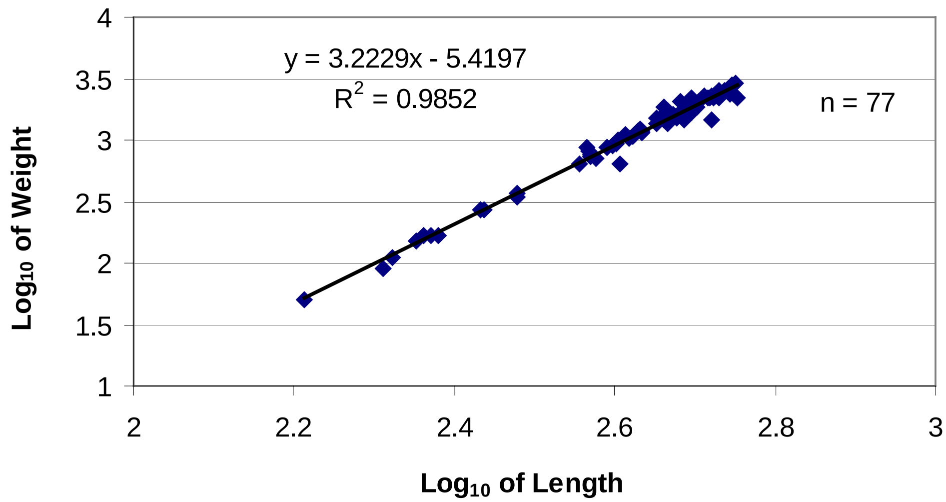


Figure 8.36 White Sucker Age-Frequency Distribution, Muskeg River, Spring 2001

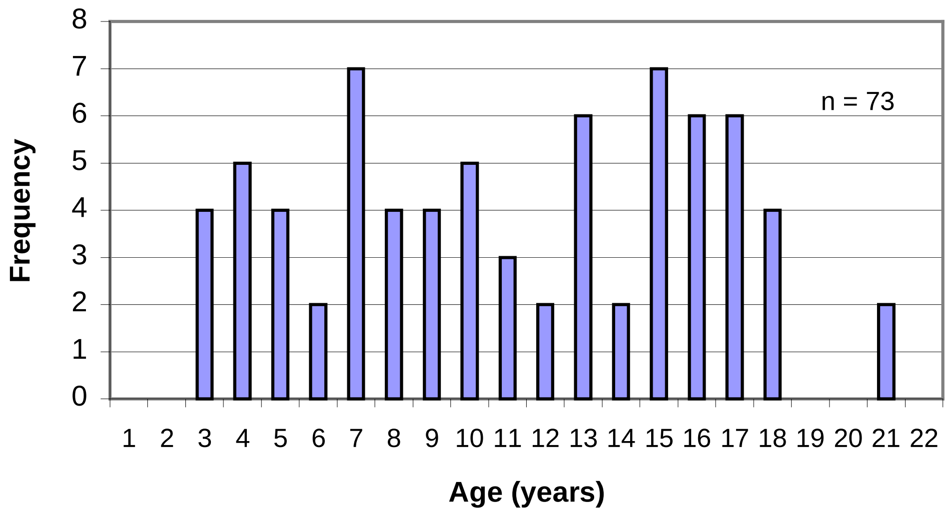
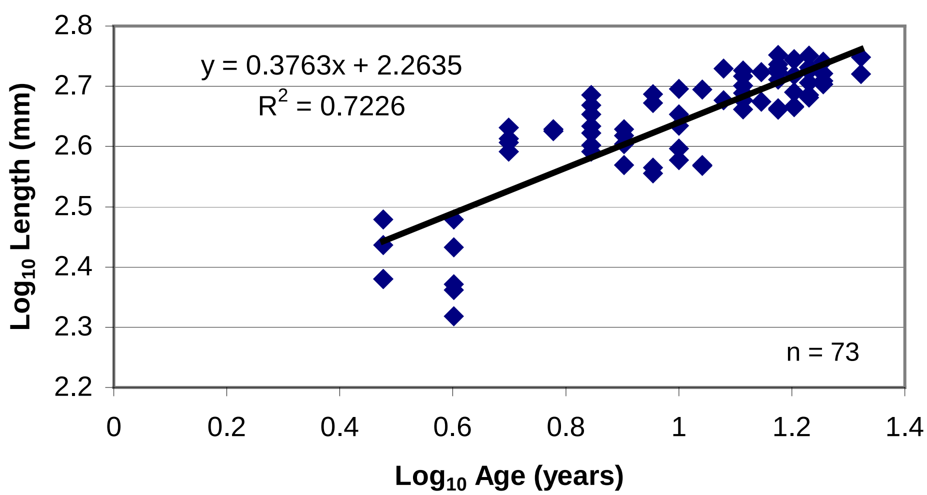
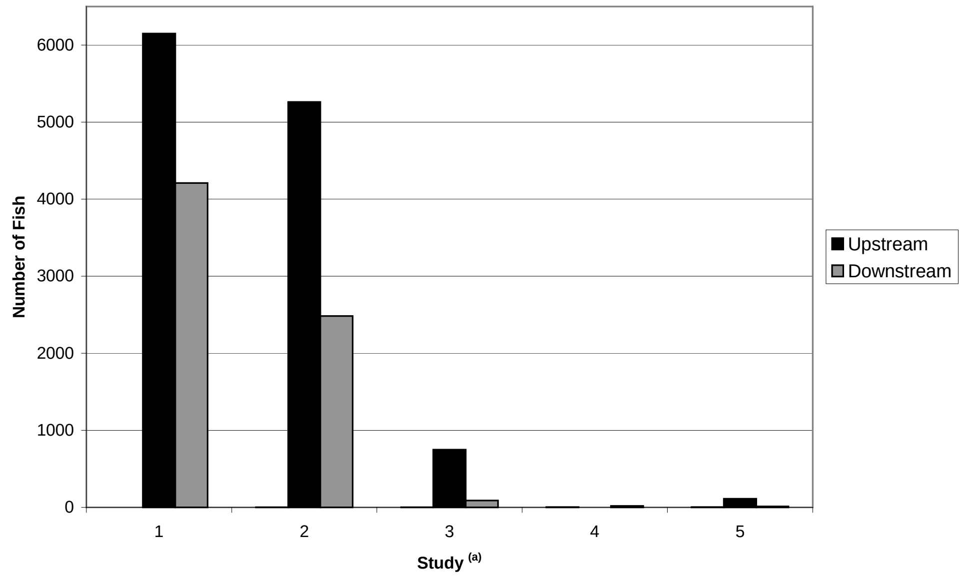


Figure 8.37 White Sucker Size-at-Age Relationship, Muskeg River, Spring 2001



Due to losses in fence integrity during the period of the study, the 2001 fish fence study did not meet the objectives of determining the size of the spring spawning run and the relative abundance of fish species utilizing the Muskeg River basin. Figure 8.38 presents a comparison of total numbers of fish captured in the Muskeg River fish fence in 2001 to fish fence studies conducted in previous years. The timing and locations of the different fences has varied between the studies and was found to have a significant effect on capture results. Fence results from 1976 and 1977 showed much higher numbers of fish than subsequent studies. However, more recent fish fences were either started later in the spring or were located 16 km upstream of the river mouth. The later start would mean missing a portion of the spring run and locating the fence 16 km upstream would mean missing the portion of the run for fish that spawn in the lower river.

Figure 8.38 Comparison of Total Numbers of Fish Captured for All Known Muskeg River Fish Fence Operations



(a) Study 1 = Bond and Machniak (1977); fish fence within 1 km of river mouth April 28 to July 30, 1976.

Study 2 = Bond and Machniak (1979); fish fence within 1 km of river mouth April 28 to June 15, 1977.

Study 3 = Golder (1996a); fish fence 16 km upstream of mouth May 6 to 31, 1995.

Study 4 = RAMP (Golder 1999b); fish fence 16 km upstream of river mouth May 8 to 14, 1998.

Study 5 = RAMP 2001; partial installation at river mouth April 28 to May 26.

The 2001 fish fence attempted to repeat the original fence studies and provide data directly comparable to the historical information. However the range of flows experienced in 2001 (6.1 to 12.2 m^3/s) was higher than in the previous studies (0.5 to 6.5 m^3/s) and fence integrity could not be maintained.

8.4.3.1 Recommendations

Monitoring of ice conditions to determine the earliest time for fence installation should be repeated and the fence must be installed as close as possible to the river mouth (i.e., within 1 km of the mouth) to capture the largest portion of the spring migration. Advanced reconnaissance is required to select an appropriate site for the fence, based on channel and substrate characteristics, and fence design should be reviewed to provide a configuration suitable for withstanding higher discharges. The flow record should be examined to determine the range of flows typically experienced during the fence period, and a hydrological risk analysis should be conducted prior to fence installation to assess the likelihood of excessive spring discharges occurring that would reduce the possibility of success.

8.4.4 Fish Inventory

8.4.4.1 Muskeg River

The total number of each fish species captured in the Muskeg River and the catch-per-unit-effort (CPUE) is shown in Table 8.19. Ten fish species were recorded in the Muskeg River in 2001, including three sport species, two sucker species and five small-bodied species. Sport fish were not abundant and the combined species comprised 15% of the total, compared to 36% for sucker species and 49% for small-bodied fish. The most abundant species (captured plus observed) were longnose sucker, trout-perch, emerald shiner and white sucker with CPUE values between 1.18 and 0.76 fish/100 seconds.

In addition to the summer inventory sampling, additional inventory data were collected incidentally during sampling for the fish tissue program (Section 3.4.2.1). Sampling results are not directly comparable between the two seasons since the fall sampling was directed towards the capture of northern pike only. However, an additional small-bodied species was captured during the fall sampling; a small number of pearl dace (2) were captured in the fall with a CPUE of 0.04 fish/100 seconds.

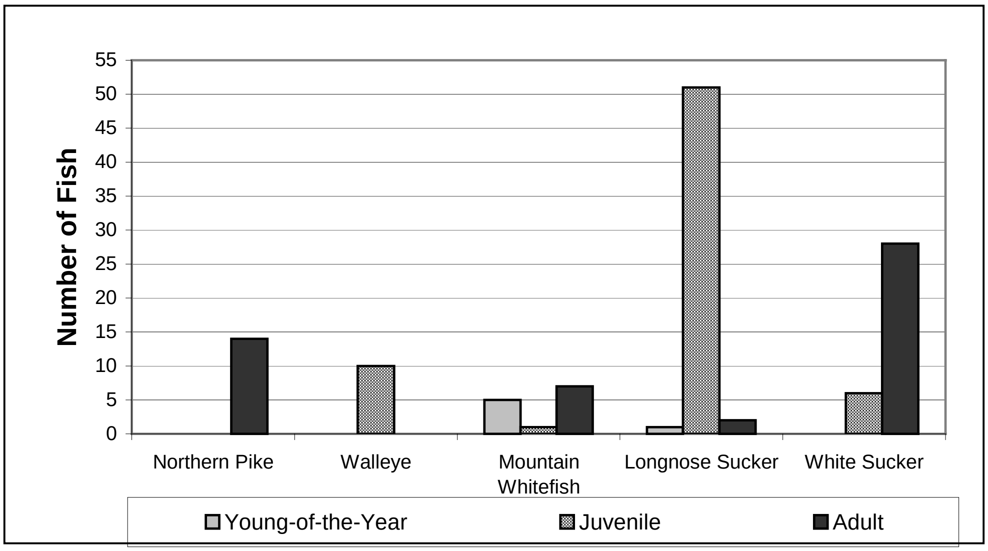
Table 8.19 Boat Electrofishing Results and Catch-Per-Unit Effort (CPUE) for the Muskeg River Fish Inventory, Summer 2001

Species	Number		Percent of Total		CPUE (fish/100 sec)	
	C	C & O	C	C & O	C	C & O
northern pike	4	14	3.3	5.8	0.09	0.31
walleye	10	10	8.1	4.1	0.22	0.22
mountain whitefish	7	13	5.7	5.3	0.16	0.29
longnose sucker	38	53	30.9	21.7	0.85	1.18
white sucker	25	34	20.3	13.9	0.56	0.76
trout-perch	6	50	4.9	20.5	0.13	1.12
lake chub	16	16	13.0	6.6	0.36	0.36
emerald shiner	11	41	8.9	16.8	0.25	0.92
longnose dace	1	1	0.8	0.4	0.02	0.02
spoonhead sculpin	5	12	4.1	4.9	0.11	0.27
total	**123**	**244**	**100**	**100**	**2.75**	**5.45**

Note: Total electrofishing effort was 4,475 seconds.
C = captured.
C & O = captured plus observed.

Figure 8.39 shows the number of fish recorded by life stage for the large-bodied species. Northern pike and white sucker were primarily represented by adult fish, indicating that the Muskeg River provides summer feeding habitat for these species; rearing activity by juvenile white suckers was also recorded. Walleye use the river for summer rearing. Longnose sucker use the river in the summer mainly for juvenile rearing, but young-of-the-year and adult life stages were also present. All life stages of mountain whitefish were present, and the capture of young-of-the-year suggests that spawning activity may occur in the Muskeg River for this species.

Figure 8.39 Numbers of Large-Bodied Fish by Life Stage, Muskeg River Inventory, Summer 2001



Measurement data for captured fish are presented in detail in Appendix X. Means and standard errors of the various fish measurements are shown in Table 8.20 for each of the species for which more than one individual was captured. The external pathology index numbers were low for all fish species.

The species composition for the Muskeg River was different from that observed during the 1997 RAMP inventory (Golder 1998) when only six species were recorded. Differences in 2001 included the presence of northern pike, walleye, longnose dace, emerald shiner and trout-perch, and the absence of Arctic grayling. The abundance of Arctic grayling in the Muskeg River in 1997 was low to moderate (CPUE of 0.18). Comparison of relative abundance of fish species between 1997 and 2001 (Table 8.21) shows that the CPUE increased in 2001 for all species except Arctic grayling and white suckers.

Table 8.20 Mean ± SE for Length, Weight, Condition Factor and External Pathology Index for Fish Captured in the Muskeg River, Summer 2001

Species	Fork Length (mm)	Weight (g)	Condition Factor	External Pathology Index
northern pike	546.8 ± 20.5 (4)	1,163.8 ± 87.7 (4)	0.71 ± 0.03 (4)	7.5 ± 7.5 (4)
walleye	85.7 ± 3.3 (10)	6.2 ± 0.7 (10)	0.96 ± 0.05 (10)	0 (10)
mountain whitefish	138.4 ± 45.3 (7)	141.3 ± 132.4 (7)	0.68 ± 0.15 (7)	0 (7)
longnose sucker	134.7 ± 9.9 (38)	56.1 ± 19.1 (37)	1.33 ± 0.1 (37)	0.8 ± 0.8 (38)
white sucker	315.2 ± 24.5 (25)	539.4 ± 68.3 (25)	1.23 ± 0.06 (25)	2.7 ± 1.4 (25)
trout-perch	66.5 ± 4.8 (6)	4.2 ± 0.9 (6)	1.42 ± 0.32 (6)	0 (6)
lake chub	73.6 ± 3.8 (15)	5.8 ± 1.2 (11)	1.09 ± 0.09 (11)	0 (11)
emerald shiner	81.3 ± 1.1 (11)	4.2 ± 0.1 (11)	0.78 ± 0.02 (11)	0 (11)
spoonhead sculpin	66.8 ± 7.3 (5)	5.5 ± 1.1 (5)	1.31 ± 0.1 (5)	0 (5)

Note: Values in parenthesis = sample size.

Table 8.21 Comparison of Fish Abundances Between 1997 and 2001 Muskeg River Summer Inventories

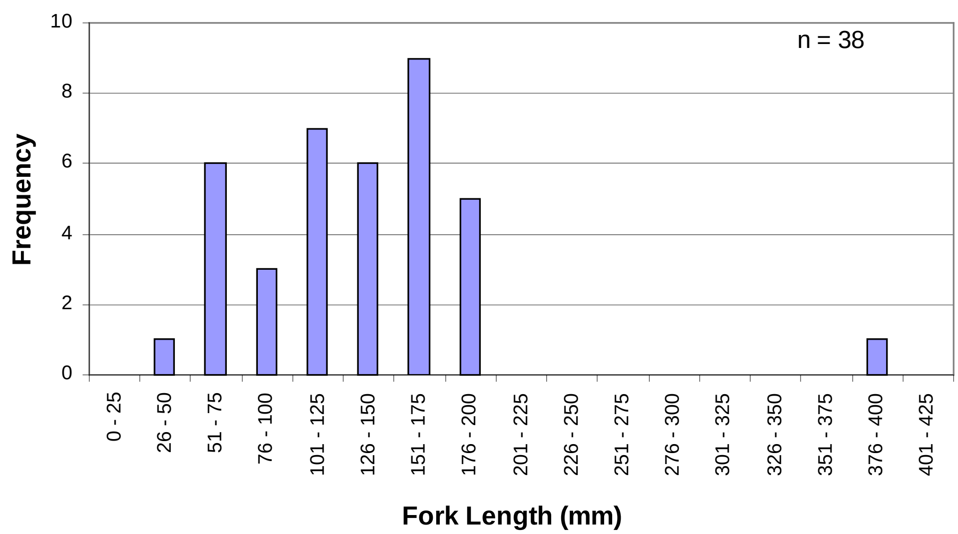
Species	n[a]		Percent of Catch		CPUE (fish/100 sec)	
	1997	2001	1997	2001	1997	2001
Arctic grayling	6	0	6.7	0.0	0.18	0.00
northern pike	0	4	0.0	3.3	0.00	0.09
walleye	0	10	0.0	8.1	0.00	0.22
mountain whitefish	3	7	3.3	5.7	0.09	0.16
longnose sucker	15	38	16.7	30.9	0.46	0.85
white sucker	56	25	62.2	20.3	1.71	0.56
trout-perch	0	6	0.0	4.9	0.00	0.13
lake chub	8	16	8.9	13.0	0.24	0.36
emerald shiner	0	11	0.0	8.9	0.00	0.25
longnose dace	0	1	0.0	0.8	0.00	0.02
spoonhead sculpin	2	5	2.2	4.1	0.06	0.11

[a] Numbers are captured fish only.

Additional inventory information for 2001 is available from a local resident (Gary Cooper) who was a member of the field staff contracted during the Muskeg River fish fence study. Mr. Cooper spent four hours angling in October at a location approximately 6 km upstream of the mouth of the Muskeg River and reported capturing three Arctic grayling (per. comm. Gary Cooper). This information shows that Arctic grayling were present in the river in 2001. This species may have been missed during inventory sampling if it was present in very low abundance.

Only longnose suckers were collected in sufficient numbers to conduct analysis for population parameters. The size (fork length) distribution for longnose sucker is presented in Figure 8.40. A number of young-of-the-year (< 100 mm) were present in the summer, as would be expected since the Muskeg River is a known spawning area for this species. It is difficult to assess the number of young-of-the-year that may be present as the capture technique (boat electrofishing) is known to be biased toward capture of larger fish. The summer longnose sucker population consisted primarily of juvenile fish from 101 to 200 mm. These fish were smaller juveniles, suggesting that larger juveniles may exit the river to complete rearing activities. A few adult fish (376 to 400 mm) were also present, showing a small amount of summer feeding activity in the Muskeg River.

Figure 8.40 Longnose Sucker Length-Frequency Distribution, Muskeg River, Summer 2001



The results for the water quality parameters that were measured at the time of sampling are shown in Table 8.22 and were typical of this watercourse during summer.

Table 8.22 Mean Values (± SD) of Water Quality Parameters, Muskeg River, Summer 2001

Field Parameter	Muskeg River (*n*=2)
water temperature (°C)	15.5 ± 0.71
dissolved oxygen (mg/L)	10.3 ± 0.0
conductivity (µS/cm)	296 ± 0.0
pH	8.29 ± 0.0

8.4.4.2 Recommendations

It is recommended that the sampling areas and catch for the summer inventory of the Muskeg River be divided between the different reaches of the river, as defined in Sekerak and Walder (1980). The reaches have distinct habitat characteristics that likely affect fish abundance and distribution. The different reaches are currently included in the inventory program but the fish catch has not been recorded by reach. Comparisons of distribution and abundance to previous years in the RAMP monitoring program will still be possible.

8.4.4.3 Jackpine Creek

In total, seven fish species were recorded in Jackpine Creek during the summer inventory, including one sport species, one sucker species and five small-bodied species. Table 8.23 presents the total number of fish captured and observed and the percent of total for both electrofishing and minnow trapping; catch-per-unit-effort (CPUE) for each fish species is presented separately by capture method. Both capture techniques were effective for sampling in Jackpine Creek. In total, 52% of the fish were recorded during backpack electrofishing, compared to 48% captured in minnow traps.

The fish fauna recorded in Jackpine Creek during the summer consisted mainly of small-bodied species (93.8% of fish recorded); lake chub were the most abundant species (85.4%). The remaining 6.2% of fish recorded included 11 longnose sucker and one northern pike. The single northern pike was a small juvenile (201 mm fork length) and the longnose sucker were young-of-the-year or juvenile fish (<108 mm). No Arctic grayling were recorded during the inventory, although they were reported from this watercourse in the past. The lack of young-of-the-year and juvenile Arctic grayling suggested that spawning by this species was limited or did not occur in Jackpine Creek in 2001.

Means and standard errors are given in Table 8.24 for various measurements of fish for the four species where more than one individual was captured. The condition factor was > 1.0 for all species. The external pathology index data shows a low incidence of external abnormalities.

The results for the water quality parameters that were measured during sampling activities are shown in Table 8.25.

Table 8.23 Inventory Results and Catch-Per-Unit Effort (CPUE) for the Jackpine Creek Inventory, Summer 2001

Species	Number		Percent of Total		Electrofishing CPUE (fish/100 sec)		Minnow Trap CPUE (fish/hr)
	C	C & O	C	C & O	C	C & O	C
northern pike	1	1	0.6	0.4	0.01	0.01	-
longnose sucker	11	11	5.6	4.9	0.02	0.02	0.48
lake chub	165	192	83.0	85.4	0.63	0.72	5.39
brook stickleback	8	8	4.0	3.6	0.07	0.08	0.05
longnose dace	1	1	0.6	0.4	0.01	0.01	-
spoonhead sculpin	11	11	5.6	4.9	0.11	0.12	-
slimy sculpin	1	1	0.6	0.4	0.01	0.01	-
total	**198**	**225**	**100**	**100**	**0.85**	**0.98**	**5.92**

Note: Total effort was 10,177 seconds electrofishing and 18.75 hours minnow trap set.
C = captured.
C & O = captured plus observed.

Table 8.24 Mean ± SE for Length, Weight, Condition Factor and External Pathology for Fish Caught, Jackpine Creek, Fall 2001

Species	Fork Length (mm)	Weight (g)	Condition	External Pathology Index
longnose sucker	83.6 ± 3.4 (11)	10.5 ± 2.5 (2)	1.10 ± 0.07 (2)	0 (11)
lake chub	62.9 ± 1.3 (161)	3.2 ± 0.5 (29)	1.11 ± 0.69 (29)	0.36 ± 0.26 (165)
brook stickleback	55.4 ± 1.3 (7)	2.0 ± 0 (4)	1.28 ± 0.08 (4)	0 (8)
spoonhead sculpin	62.6 ± 3.5 (12)	3.6 ± 0.4 (7)	1.16 ± 0.04 (7)	0 (11)

Table 8.25 Mean Values (± SD) of Water Quality Parameters, Jackpine Creek, Summer 2001

Parameter	Jackpine Creek (n = 2)
water temperature (°C)	16.5 ± 0.39
dissolved oxygen (mg/L)	10.5 ± 0.11
conductivity (µS/cm)	219 ± 0.52
pH	7.9 ± 0.01

8.4.4.4 Recommendations

It is recommended that gill nets or portable boat electrofishing be used in addition to the current inventory techniques to sample some of the deep-water areas associated with beaver impoundments in Jackpine Creek to check for large-bodied fish species.

8.4.5 Fish Tissue Collection

The results of the field measurements and examinations for the 10 northern pike used in the tissue collection study for the Muskeg River are presented in Appendix VIII. Table 8.26 shows the range in size (as represented by fork length) and age of the fish used for tissue collection. All fish used for tissue analysis were adults.

Table 8.26 Range of Size and Age of Northern Pike Used for Tissue Collection From the Muskeg River, Fall 2001

Sex	n	Fork Length (mm)		Age (years)	
		min	max	min	max
female	5	561	723	4	6
male	5	538	631	4	6

Complete results of the analysis of the composite tissue samples is presented in Appendix VII by sex. Table 8.27 presents the results for the parameters that showed concentrations above the detection limits. Results are provided on the basis of wet tissue weight.

PAHs were not detected in the composite tissue samples of northern pike from the Muskeg River in the fall of 2001. The results indicate that the northern pike population has not accumulated PAHs in muscle tissue.

With respect to metals analysis, antimony, arsenic, beryllium, cadmium, chromium, cobalt, lithium, molybdenum, selenium, silver, tin, thallium and vanadium were also not detected in any of the fish tissue samples from the Muskeg River. A summary of the concentrations of inorganic compounds detected in the northern pike flesh samples is shown in Table 8.27. Where possible, these concentrations were compared to consumption guidelines (Health Canada 1981; U.S. EPA 2001) and data regarding deleterious effects levels for fish (Jarvinen and Ankley 1999).

Table 8.27 Tissue Concentrations of Metals Detected in Northern Pike From the Muskeg River, Fall 2001

Parameter	Units	Detection Limit	Northern Pike		Fish consumption guideline[(a)]
			Female (n=5)	Male (n=5)	
aluminum (Al)	mg/kg	4	<	4	1400
barium (Ba)	mg/kg	0.08	0.09	<	95
calcium (Ca)	mg/kg	10	550	310	-
copper (Cu)	mg/kg	0.08	0.29	1.18	54
iron (Fe)	mg/kg	2	4	6	410
lead (Pb)	mg/kg	0.04	<	0.04	-
magnesium (Mg)	mg/kg	2	313	324	-
manganese (Mn)	mg/kg	0.04	0.42	0.30	190
mercury (Hg)	mg/kg	0.01	0.14	0.12	0.5[(b)]
nickel (Ni)	mg/kg	0.08	0.09	0.47	27
phosphorus (P)	mg/kg	2	2,240	2,120	-
potassium (K)	mg/kg	2	3,770	4,020	-
sodium (Na)	mg/kg	2	266	297	-
strontium (Sr)	mg/kg	0.04	0.37	0.2	810
titanium (Ti)	mg/kg	0.05	0.24	0.74	5,400
zinc (Zn)	mg/kg	0.2	6.4	7.2	410

(a) U.S. EPA Risk Based Criteria Table, Dated May 2001 (unless otherwise indicated).
(b) Health Canada 1981 value.
Note: < = below the detection limit.
- = no guideline provided.

Comparison of the fish tissue chemical concentrations with Health Canada (1981) and U.S. EPA (2001) fish consumption guidelines indicates no exceedences of the guidelines. With the exception of mercury, the tissue concentrations were at least one order of magnitude below the consumption guidelines. Mercury concentrations were also well below the guidelines.

Tissue residue concentrations from the Muskeg River were compared to deleterious effects levels, where these data were available for fish (Table 5.15). The same procedure was followed as used for the fish from the Athabasca River (Section 5.3.2). Deleterious effects-based fish data were not available for calcium, iron, magnesium, phosphorus, potassium and sodium, as these are inorganic compounds essential for normal cell function in all vertebrate animals. Data were also not available for barium, manganese, selenium, strontium, titanium and thallium.

Aluminum was detected in male northern pike at a concentration of 4 mg/kg. Higher concentrations in whole body analyses of adult rainbow trout have shown no effects on fish survival (Jarvinen and Ankley 1999).

Copper was detected in both the female and male samples at concentrations ranging from 0.29 to 1.18 mg/kg. Muscle copper concentration in fish does not appear to be well correlated with effects on survival, with experiments showing both reduced survival and no effects on survival of adult rainbow trout at a muscle concentration of 0.5 mg/kg (Jarvinen and Ankley 1999). Other data show no effects on stone loach (*Noemacheilus barbatulus*) survival at copper muscle concentrations of 1.0 to 2.0 mg/kg.

Lead was detected in the male northern pike sample at a concentration of 0.04 mg/kg, the detection limit for that analytical method. The limited data available indicate that this concentration is below those that would impact survival of fish (Jarvinen and Ankley 1999).

Mercury was detected in both the female and male northern pike samples at concentrations ranging from 0.12 to 0.14 mg/kg. These concentrations are below those that have been linked with reduced survival of subadult and fingerling rainbow trout, and reduced growth and survival of juvenile chum salmon (Jarvinen and Ankley 1999). They are also below concentrations shown to reduce reproduction in yearling-adult brook trout (Jarvinen and Ankley 1999).

Nickel was detected in both the female and male northern pike samples, at concentrations ranging from 0.09 to 0.47 mg/kg. These concentrations are well below those that affect survival of fish (Jarvinen and Ankley 1999).

Zinc was detected in both the male and female northern pike samples, at concentrations ranging from 6.4 to 7.2 mg/kg. These muscle concentrations are below those that have been linked with reduced survival in adult dogfish (*Scyliorhinus canicula*).

In summary, the fall 2001 muscle concentrations for northern pike from the Muskeg River were found to be below those reported to be linked with effects on growth and survival of fish. However, the experimental data for copper is inconclusive with respect to assessing the potential effects of the measured concentrations for this parameter.

8.4.5.1 Recommendations

To increase the utility of among year comparisons of tissue analyses, it is recommended that the size range of adult fish used for tissue collection be restricted to increase the probability of using fish of similar size and age. Existing fork length and age data for the Muskeg River should be used to provide the recommended size range for fish tissue collections.

It is also recommended that tissue samples from each individual fish sample be archived for a short period, pending analysis of composite samples, in case analysis of individual tissues is warranted.

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9.1 WATER QUALITY

9.1.1 Kearl Lake

Water samples were collected from Kearl Lake in summer and fall of 2001. Water quality was generally consistent across the two seasons and within the range of historical data (Table 9.1), although the data set is quite limited (n ≤ 6).

Water quality variations, compared to previous years, included lower colour, nickel, total iron and total manganese levels in the summer of 2001. In addition, total phosphorus levels measured during the fall appear to have increased over time (Figure 9.1).

Table 9.1 Water Quality in Kearl Lake, Summer and Fall

Parameter	Units	Summer					Fall				
		2001	Historical (1988-1998) [a]				2001	Historical (1983-2000) [a]			
			median	min	max	n		median	min	max	n
Field Measured											
pH		8.4	-	-	-	-	-	-	7.4	8.1	2
specific conductance	uS/cm	160	-	-	-	-	179	-	159	170	2
temperature	°C	23.3	-	-	-	-	16	12.6	2	19	4
dissolved oxygen	mg/L	**5.5** [(c)]	-	-	-	-	9.6	10	8.9	13.7	4
Conventional Parameters											
colour	T.C.U.	30	76	40	100	3	35	75	30	100	4
conductance	uS/cm	186	169	166	171	3	183	181	169	201	4
dissolved organic carbon	mg/L	18	21	15	25	3	19	17	15	23	3
hardness	mg/L	81	71	71	71	4	77	74	67	83	6
pH		8	7.9	7.8	8.2	3	7.9	8	7.6	8.4	4
total alkalinity	mg/L	91	85	82	87	4	93	87	82	100	6
total dissolved solids	mg/L	160	94	90	192	4	160	96	90	220	6
total organic carbon	mg/L	21	-	19	26	2	23	23	18	27	4
total suspended solids	mg/L	< 3	3	1	7	3	4	3	1	4	5
Major Ions											
bicarbonate	mg/L	111	103	100	106	4	114	106	100	118	6
calcium	mg/L	20	17	14	20	4	20	19	17	22	6
carbonate	mg/L	< 5	< 1	< 1	< 5	3	< 5	< 5	< 1	< 5	5
chloride	mg/L	< 1	1	1	1	3	< 1	< 1	< 1	1	5
magnesium	mg/L	7	7	6	7	4	7	7	6	7	6
potassium	mg/L	1	1	1	1	3	1	1	1	1	5
sodium	mg/L	10	11	9	12	4	9	10	8	13	6
sulphate	mg/L	6	4	3	8	4	5	5	3	6	6
sulphide	mg/L	< 0.003	< 0.002	-	-	1	< 0.003	-	< 0.002	0.007	2
Nutrients and Chlorophyll *a*											
nitrogen, ammonia	mg/L	< 0.05	-	0.04	0.07	2	< 0.05	0.09	0.04	0.2	4
nitrogen, total [(b)]	mg/L	0.9	0.9	< 0.03	**1.1** [(c)]	4	0.7	1	0.4	**1.6** [(c)]	4
phosphorus, total	mg/L	0.01	0.017	0.012	0.023	4	0.013	0.027	0.011	0.04	6
phosphorus, dissolved	mg/L	0.006	-	0.01	0.017	2	0.013	-	0.009	0.012	2
chlorophyll *a*	ug/L	3	-	10	5.2	2	4	-	2	3	2

Table 9.1 Water Quality in Kearl Lake, Summer and Fall (continued)

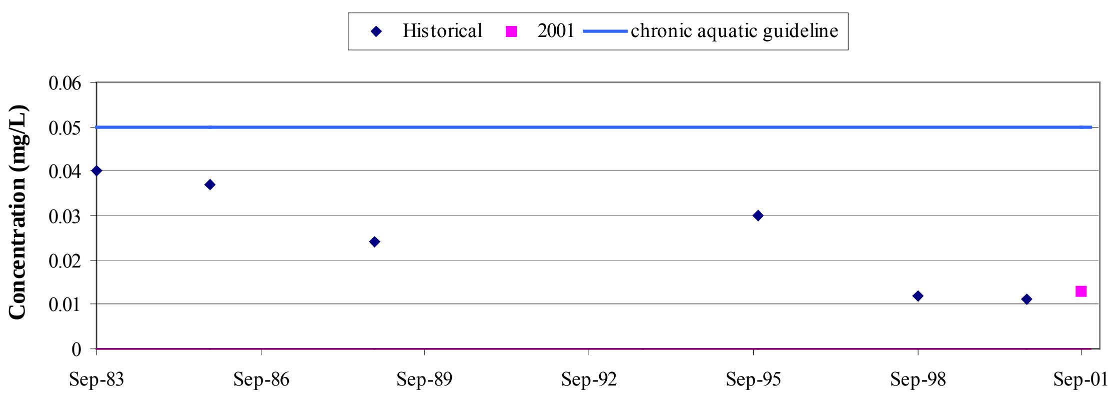
Parameter	Units	Summer					Fall				
		2001	Historical (1988-1998) [a]				2001	Historical (1983-2000) [a]			
			median	min	max	n		median	min	max	n
Biological Oxygen Demand											
biochemical oxygen demand	mg/L	< 2	-	2	< 2	2	< 2	2	2	3	4
General Organics											
naphthenic acids	mg/L	< 1	-	< 1	< 1	2	< 1	< 1	< 1	< 1	3
total phenolics	mg/L	0.004	-	0.005	**0.014 [C]**	2	< 0.001	-	< 0.001	0.005	2
total recoverable hydrocarbons	mg/L	-	< 0.5	< 0.1	< 1	3	< 0.5	< 0.5	< 0.1	< 1	5
Metals (Total)											
aluminum (Al)	mg/L	0.03	0.02	< 0.01	0.03	3	0.03	< 0.01	< 0.01	**0.13 [C]**	5
antimony (Sb)	mg/L	**< 0.005 [D>H]**	< 0.0008	-	-	1	**< 0.005 [D>H]**	-	**0.0023 [H]**	**< 0.005 [D>H]**	2
arsenic (As)	mg/L	< 0.001	< 0.0002	< 0.0002	< 0.001	3	< 0.001	< 0.0007	< 0.0002	< 0.001	4
barium (Ba)	mg/L	0.015	0.011	0.01	0.016	3	0.017	0.02	0.02	0.115	3
beryllium (Be)	mg/L	< 0.001	-	< 0.001	< 0.001	2	< 0.001	< 0.001	< 0.001	< 0.001	3
boron (B)	mg/L	0.05	0.05	0.04	0.06	3	0.05	0.06	0.01	0.07	5
cadmium (Cd)	mg/L	< 0.0002	**< 0.001 [D>C]**	< 0.0002	**< 0.003 [D>C]**	4	< 0.0002	**< 0.001 [D>C]**	< 0.0002	**< 0.003 [D>A,C]**	5
chromium (Cr)	mg/L	< 0.0008	< 0.001	< 0.0008	**< 0.002 [D>C]**	4	< 0.0008	< 0.001	< 0.0008	**0.348 [A,C]**	5
cobalt (Co)	mg/L	< 0.0002	< 0.001	< 0.0002	< 0.003	3	< 0.0002	< 0.003	< 0.0002	0.016	3
copper (Cu)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	3	< 0.001	< 0.001	< 0.001	0.002	5
iron (Fe)	mg/L	0.04	**0.08 [H]**	**0.08 [H]**	**0.1 [H]**	4	**0.05 [H]**	**0.07 [H]**	**0.05 [H]**	**0.19 [H]**	5
lead (Pb)	mg/L	< 0.0001	< 0.002	0.0002	**< 0.02 [D>C]**	3	0.0001	< 0.002	0.0003	**< 0.02 [D>C]**	5
lithium (Li)	mg/L	0.006	-	0.002	< 0.006	2	< 0.006	< 0.006	< 0.006	0.006	3
manganese (Mn)	mg/L	**0.014 [H]**	**0.033 [H]**	**0.017 [H]**	**0.04 [H]**	4	**0.021 [H]**	**0.011 [H]**	0.007	**0.05 [H]**	5
mercury (Hg)	mg/L	0.0000009	**< 0.0001 [D>H]**	**< 0.0001 [D>H]**	**< 0.0002 [D>C,H]**	3	< 0.0000006	**< 0.00015 [D>C,H]**	**< 0.00005 [D>H]**	**0.0003 [C,H]**	4
molybdenum (Mo)	mg/L	< 0.0001	< 0.001	< 0.0001	< 0.003	3	< 0.0001	0.0009	0.0002	0.003	3
nickel (Ni)	mg/L	0.0002	0.0015	0.0009	< 0.005	4	< 0.0002	0.001	0.0008	0.0057	5
selenium (Se)	mg/L	< 0.0008	< 0.0002	< 0.0002	< 0.0008	3	< 0.0008	< 0.0008	< 0.0002	< 0.0008	4
silver (Ag)	mg/L	< 0.000005	-	**< 0.0004 [D>C]**	**< 0.002 [D>C]**	2	< 0.000005	**< 0.0004 [D>C]**	**< 0.0004 [D>C]**	**0.003 [A,C]**	3
strontium (Sr)	mg/L	0.06	-	0.05	0.06	2	0.06	0.07	0.06	0.22	3
thallium (Tl)	mg/L	< 0.0001	-	-	-	-	< 0.0001	< 0.0001	-	-	1
titanium (Ti)	mg/L	< 0.0006	-	< 0.0006	< 0.003	2	0.0007	0.001	0.0006	0.004	3
uranium (U)	mg/L	< 0.0001	< 0.0001	-	-	1	< 0.0001	< 0.0003	< 0.0001	< 0.0005	3
vanadium (V)	mg/L	< 0.0002	< 0.002	< 0.0002	0.002	4	0.0002	< 0.001	< 0.0002	0.002	5
zinc (Zn) [b]	mg/L	0.012	0.012	< 0.001	0.028	4	0.008	0.011	0.003	0.024	5
Metals (Dissolved)											
aluminum (Al)	mg/L	< 0.01	0.01	-	-	1	< 0.01	-	< 0.01	0.03	2
antimony (Sb)	mg/L	< 0.0008	< 0.0008	-	-	1	< 0.0008	-	< 0.0008	< 0.0008	2
arsenic (As)	mg/L	< 0.0004	0.0006	-	-	1	< 0.0004	-	< 0.0004	< 0.0004	2
barium (Ba)	mg/L	0.015	0.015	-	-	1	0.016	-	0.017	0.018	2
beryllium (Be)	mg/L	< 0.001	-	< 0.001	< 0.001	2	< 0.001	-	< 0.001	< 0.001	2
boron (B)	mg/L	0.05	0.04	-	-	1	0.05	-	0.05	0.05	2
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	-	-	1	< 0.0001	-	< 0.0001	< 0.0001	2
chromium (Cr)	mg/L	< 0.0004	< 0.0004	-	-	1	< 0.0004	-	< 0.0004	< 0.0004	2
cobalt (Co)	mg/L	< 0.0001	0.0003	-	-	1	< 0.0001	-	0.0001	0.0012	2
copper (Cu)	mg/L	*0.0034*	0.0006	-	-	1	*0.0031*	-	< 0.0006	0.0014	2
iron (Fe)	mg/L	0.02	0.1	-	-	1	0.02	-	< 0.01	0.09	2
lead (Pb)	mg/L	0.0001	0.0001	-	-	1	*0.0004*	-	< 0.0001	0.0003	2
lithium (Li)	mg/L	0.006	0.004	-	-	1	0.006	-	0.006	0.007	2
manganese (Mn)	mg/L	0.001	0.008	-	-	1	0.004	-	0.004	0.004	2
mercury (Hg)	mg/L	< 0.0001	< 0.0001	-	-	1	< 0.0001	-	< 0.0001	< 0.0001	2
molybdenum (Mo)	mg/L	*0.0002*	< 0.0001	-	-	1	< 0.0001	-	< 0.0001	0.0002	2
nickel (Ni)	mg/L	< 0.0001	0.001	-	-	1	< 0.0001	-	0.0002	0.0016	2
selenium (Se)	mg/L	< 0.0004	< 0.0004	-	-	1	< 0.0004	-	< 0.0004	< 0.0004	2
silver (Ag)	mg/L	< 0.0002	< 0.0002	-	-	1	< 0.0002	-	< 0.0002	< 0.0002	-

Table 9.1 Water Quality in Kearl Lake, Summer and Fall (continued)

Parameter	Units	Summer					Fall				
		2001	Historical (1988-1998) [a]				2001	Historical (1983-2000) [a]			
			median	min	max	n		median	min	max	n
strontium (Sr)	mg/L	0.06	0.06	-	-	1	0.07	-	0.07	0.07	2
thallium (Tl)	mg/L	< 0.00005	-	-	-	-	< 0.00005	< 0.00005	-	-	1
titanium (Ti)	mg/L	< 0.0003	0.0004	-	-	1	< 0.0003	-	< 0.0003	0.0005	2
uranium (U)	mg/L	< 0.0001	< 0.0001	-	-	1	< 0.0001	-	< 0.0001	< 0.0001	2
vanadium (V)	mg/L	< 0.0001	< 0.0001	-	-	1	< 0.0001	-	< 0.0001	0.0001	2
zinc (Zn)	mg/L	0.002	0.011	-	-	1	0.007	-	0.005	0.011	2

[a] Based on information from R.L&L. (1989), Golder (1996a, 1999, 2001b) and WDS Stations AB07DS2210 and AB07DA2220.
[b] The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.
Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
[A] = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
[C] = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
[H] = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

Figure 9.1 Total Phosphorus Concentrations in Kearl Lake, Fall (1983 to 2001)



9.1.2 Isadore's Lake

Water quality in Isadore's Lake was generally consistent with historical data in the summer and fall of 2001 (Table 9.2), although the historical data set is quite limited (n ≤ 2). Water quality variations in the 2001 data, compared to previous years, included:

- higher calcium, bicarbonate, sulphate, TDS, hardness and total alkalinity concentrations in both the summer and fall of 2001;
- higher sulphide concentrations and total concentrations of nitrogen, phosphorus, barium, copper and manganese in the summer of 2001, which, except for barium, are also higher than aquatic guidelines;
- lower total concentrations of iron, mercury and titanium, as well as lower dissolved concentrations of iron, manganese and nickel in the summer of 2001; and
- higher chlorophyll *a* and total concentrations of recoverable hydrocarbons, phosphorus, phenols, barium, manganese and titanium, as well as higher dissolved concentrations of barium in the fall of 2001.

Sulphide, total phosphorus and total copper concentrations were also above water quality guidelines for the protection of aquatic life for the first time in the summer of 2001.

Table 9.2 Water Quality in Isadore's Lake, Summer and Fall

Parameter	Units	Summer			Fall		
		2001	Historical [a]		2001	Historical [a]	
			1997	1998		1997	2000
Field Measured							
pH		8.2	-	-	8	-	8.1
specific conductance	uS/cm	498	-	-	552	-	525
temperature	^{o}C	23.7	-	-	14.5	-	11.5
dissolved oxygen	mg/L	**6** [(c)]	-	-	8.7	-	7.2
Conventional Parameters							
colour	T.C.U.	30	20	15	25	20	20
conductance	uS/cm	515	319	454	551	349	462
dissolved organic carbon	mg/L	12	11	9	11	9	9
hardness	mg/L	259	154	226	299	164	227
pH		7.8	8.4	8	8.1	8	7.7
total alkalinity	mg/L	203	129	146	227	136	173
total dissolved solids	mg/L	330	236	322	340	220	250
total organic carbon	mg/L	12	12	9	15	12	11
total suspended solids	mg/L	5	2	< 2	10	6	5
Major Ions							
bicarbonate	mg/L	248	154	178	277	166	211
calcium	mg/L	60	0.1	47	72	38	49
carbonate	mg/L	< 5	< 5	< 5	< 5	< 5	< 5
chloride	mg/L	3	3	3	4	2	4

Table 9.2 Water Quality in Isadore's Lake, Summer and Fall (continued)

Parameter	Units	Summer			Fall		
		2001	Historical [a]		2001	Historical [a]	
			1997	1998		1997	2000
magnesium	mg/L	27	15	26	29	17	26
potassium	mg/L	2	2	2	2	2	2
sodium	mg/L	7	7	7	6	6	6
sulphate	mg/L	79	37	78	83	38	64
sulphide	mg/L	**0.024** [C]	0.009	0.004	0.003	0.002	0.011
Nutrients and Chlorophyll *a*							
nitrogen, ammonia	mg/L	0.06	< 0.05	< 0.05	< 0.05	0.11	< 0.1
nitrogen, total[b]	mg/L	**1.7**[C]	0.4	0.6	0.2	0.5	**1.2**[C]
phosphorus, total	mg/L	**0.096** [C]	0.016	0.029	**0.098** [C]	0.012	**0.075** [C]
phosphorus, dissolved	mg/L	0.055	0.008	0.028	0.038	0.012	0.067
chlorophyll *a*	ug/L	6	-	5	45	< 1	10
Biological Oxygen Demand							
biochemical oxygen demand	mg/L	6	< 2	2	5	2	6
General Organics							
naphthenic acids	mg/L	< 1	< 1	2	< 1	1	< 1
total phenolics	mg/L	0.004	< 0.001	0.001	**0.007** [C]	< 0.001	< 0.001
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	1.8	< 0.5	< 0.5
Metals (Total)							
aluminum (Al)	mg/L	0.04	0.018	**0.18** [C]	0.04	0.062	< 0.02
antimony (Sb)	mg/L	**< 0.005** [D>H]	< 0.0004	< 0.0008	**< 0.005** [D>H]	0.0007	**< 0.005** [D>H]
arsenic (As)	mg/L	< 0.001	< 0.0004	0.002	< 0.001	0.0018	< 0.001
barium (Ba)	mg/L	0.118	0.0003	0.074	0.138	0.055	0.082
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.04	0.01	0.05	0.04	0.04	0.04
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0003	< 0.0002
chromium (Cr)	mg/L	< 0.0008	**0.0014** [C]	< 0.0008	< 0.0008	< 0.0004	**0.0028** [C]
cobalt (Co)	mg/L	< 0.0002	< 0.0005	< 0.0002	< 0.0002	< 0.0005	< 0.0002
copper (Cu)	mg/L	**0.012** [C]	0.0009	0.003	< 0.001	**0.0066** [C]	< 0.001
iron (Fe)	mg/L	**0.07** [H]	**0.21** [H]	**0.27** [H]	**0.12** [H]	< 0.01	**0.13** [H]
lead (Pb)	mg/L	< 0.0001	**0.0087** [C]	0.001	< 0.0001	0.0009	< 0.0001
lithium (Li)	mg/L	0.006	0.007	0.008	0.008	0.009	< 0.006
manganese (Mn)	mg/L	**0.141** [H]	0.001	**0.053** [H]	**0.165** [H]	**0.043** [H]	**0.013** [H]
mercury (Hg)	mg/L	0.0000015	**0.0001** [H]	**< 0.0002** [D>C,H]	0.000006	**< 0.0001** [D>H]	**< 0.0002** [D>C,H]
molybdenum (Mo)	mg/L	< 0.0001	< 0.0001	0.0001	0.0001	0.0008	< 0.0001
nickel (Ni)	mg/L	0.0014	0.001	0.0026	< 0.0002	0.0012	< 0.0002
selenium (Se)	mg/L	< 0.0008	< 0.0004	< 0.0008	< 0.0008	< 0.0004	**0.0011** [C]
silver (Ag)	mg/L	0.000006	< 0.0001	**< 0.0004** [D>C]	0.000001	< 0.0001	**< 0.0004** [D>C]
strontium (Sr)	mg/L	0.24	0.0002	0.21	0.24	0.22	0.21
thallium (Tl)	mg/L	< 0.0001	-	-	< 0.0001	-	< 0.0001
titanium (Ti)	mg/L	< 0.0006	0.0012	0.0025	0.0022	0.0009	0.0007
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0002	< 0.0001
vanadium (V)	mg/L	< 0.0002	0.0004	< 0.0002	< 0.0002	< 0.0002	< 0.0002
zinc (Zn) [b]	mg/L	0.006	0.013	0.011	**0.035** [C]	0.012	**0.032** [C]
Metals (Dissolved)							
aluminum (Al)	mg/L	< 0.01	-	0.06	0.02	0.0346	< 0.01
antimony (Sb)	mg/L	< 0.0008	-	< 0.0008	< 0.0008	0.0005	< 0.0008
arsenic (As)	mg/L	< 0.0004	-	0.0022	0.0008	0.0016	< 0.0004
barium (Ba)	mg/L	0.119	-	0.076	0.132	0.054	0.08
beryllium (Be)	mg/L	< 0.001	-	< 0.001	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.04	-	0.04	0.04	0.04	0.03
cadmium (Cd)	mg/L	< 0.0001	-	< 0.0001	< 0.0001	0.0003	< 0.0001
chromium (Cr)	mg/L	< 0.0004	-	< 0.0004	< 0.0004	< 0.0004	< 0.0004
cobalt (Co)	mg/L	< 0.0001	-	< 0.0001	< 0.0001	0.0002	< 0.0001
copper (Cu)	mg/L	0.0064	-	0.0037	*0.0037*	0.0015	< 0.0006

Table 9.2 Water Quality in Isadore's Lake, Summer and Fall (continued)

Parameter	Units	Summer			Fall		
		2001	Historical (a)		2001	Historical (a)	
			1997	1998		1997	2000
iron (Fe)	mg/L	0.03	-	0.2	0.02	*0.02*	< 0.01
lead (Pb)	mg/L	0.0001	-	0.0012	*0.0002*	0.0003	0.0001
lithium (Li)	mg/L	*0.009*	-	0.008	0.01	0.009	*0.01*
manganese (Mn)	mg/L	0.009	-	0.051	0.011	0.034	0.015
mercury (Hg)	mg/L	< 0.0001	-	< 0.0001	< 0.0001	< 0.0002	< 0.0001
molybdenum (Mo)	mg/L	*0.0002*	-	< 0.0001	< 0.0001	0.0007	< 0.0001
nickel (Ni)	mg/L	< 0.0001	-	0.0025	< 0.0001	0.0008	0.0002
selenium (Se)	mg/L	< 0.0004	-	< 0.0004	< 0.0004	< 0.0004	< 0.0004
silver (Ag)	mg/L	< 0.0002	-	< 0.0002	< 0.0002	< 0.0002	< 0.0002
strontium (Sr)	mg/L	0.22	-	0.22	0.24	0.2	0.21
thallium (Tl)	mg/L	*< 0.0003*	-	-	< 0.00005	-	< 0.00005
titanium (Ti)	mg/L	< 0.0001	-	< 0.0003	0.0006	< 0.0003	0.0005
uranium (U)	mg/L	< 0.0001	-	< 0.0001	< 0.0001	0.0001	< 0.0001
vanadium (V)	mg/L	0.005	-	< 0.0001	< 0.0001	0.0001	< 0.0001
zinc (Zn) (b)	mg/L	0.005	-	0.003	0.037	*0.017*	0.011

(a) Based on information from Golder (1997, 1999, 2001b).
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D> = analytical detection limit was higher than the relevant water quality guideline(s).
\- = no data.

9.1.3 Shipyard Lake

Water quality in Shipyard Lake in 2001 was generally consistent with historical data (Table 9.3), although the data set was quite small ($n \leq 4$). Dissolved oxygen levels were below the chronic aquatic guideline of 6.5 mg/L in the summer and fall of 2001. Some major ion concentrations (i.e., chloride, magnesium, potassium, sodium and sulphate) appear to be increasing slightly over time. An example is shown for sodium in Figure 9.2. Colour, total phenolics, total copper and dissolved iron levels were also higher in the summer of 2001 than in previous years. Total phenolics, total iron and total copper concentrations were also higher than aquatic guidelines.

Colour and major ion levels, which were high in the summer of 2001, were still relatively high when the fall sample was collected on September 25, 2001 (Table 9.3). Total chromium levels were lower in the fall of 2001 compared to previous samples and concentrations of total phosphorus, total and dissolved barium, total iron, total and dissolved manganese were higher in the fall of 2001.

Table 9.3 Water Quality in Shipyard Lake, Summer and Fall

Parameter	Units	Summer					Fall		
		2001	Historical (1995-2000) [a]				2001	Historical [a]	
			median	min	max	n		2000	1999
Field Measured									
pH		8.4	**8.9** [A,C]	-	-	1	7.4	7.7	**8.7** [A,C]
specific conductance	uS/cm	109	264	-	-	1	374	346	333
temperature	^{o}C	21	22.8	-	-	1	15.6	7.3	2.2
dissolved oxygen	mg/L	**5.9** [C]	14	-	-	1	**5.5** [C]	9	8.2
Conventional Parameters									
colour	T.C.U.	120	60	40	80	3	60	10	30
conductance	uS/cm	389	297	274	329	4	394	378	358
dissolved organic carbon	mg/L	22	16	16	17	3	22	18	17
hardness	mg/L	187	132	120	149	4	176	150	152
pH		8.1	7.7	7.4	8.9	4	7.8	7.8	8.1
total alkalinity	mg/L	185	139	134	161	4	189	159	165
total dissolved solids	mg/L	300	220	147	386	4	280	200	240
total organic carbon	mg/L	26	21	18	24	4	26	21	19
total suspended solids	mg/L	3	9	4	180	4	< 3	15	5
Major Ions									
bicarbonate	mg/L	226	169	131	196	4	230	194	201
calcium	mg/L	54	38	32	44	4	52	42	42
carbonate	mg/L	< 5	< 5	< 5	16	4	< 5	< 5	< 5
chloride	mg/L	13	8	5	13	4	16	18	11
magnesium	mg/L	13	10	8	10	4	12	11	11
potassium	mg/L	2	1	1	1	4	2	2	1
sodium	mg/L	19	13	9	14	4	17	18	16
sulphate	mg/L	7	3	2	5	4	8	11	6
sulphide	mg/L	0.013	< 0.003	< 0.002	< 0.005	4	**0.009** [C]	0.008	0.005
Nutrients and Chlorophyll *a*									
nitrogen, ammonia	mg/L	< 0.05	0.077	< 0.05	< 0.1	4	0.13	< 0.1	< 0.05
nitrogen, total [b]	mg/L	0.6	1	0.6	**1.1** [C]	4	**1.3** [C]	**1.2** [C]	0.8
phosphorus, total	mg/L	0.029	0.025	0.012	0.034	4	0.031	0.016	0.017
phosphorus, dissolved	mg/L	0.026	0.015	0.004	0.024	4	0.026	0.013	0.007
chlorophyll *a*	ug/L	4	3	2	6	3	1	-	-
Biological Oxygen Demand									
biochemical oxygen demand	mg/L	< 2	2	< 2	3	3	< 2	-	< 2
General Organics									
naphthenic acids	mg/L	< 1	< 1	< 1	< 1	4	1	2	< 1
total phenolics	mg/L	**0.012** [C]	0.002	< 0.001	0.003	3	< 0.001	< 0.001	**0.006** [C]
total recoverable hydrocarbons	mg/L	0.7	< 0.5	< 0.5	< 1	4	< 0.5	< 0.5	< 0.5
Metals (Total)									
aluminum (Al)	mg/L	0.09	0.06	0.03	**0.16** [C]	4	0.03	**0.14** [C]	0.03
antimony (Sb)	mg/L	**< 0.005** [D>H]	< 0.0008	0.0002	**< 0.005** [D>H]	4	**< 0.005** [D>H]	**< 0.005** [D>H]	< 0.0008
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	4	0.001	< 0.001	< 0.001
barium (Ba)	mg/L	0.042	0.032	0.022	0.042	4	0.045	0.032	0.027
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	4	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.05	0.04	0.03	0.05	4	0.04	0.03	0.03
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	**< 0.003** [D>C]	4	< 0.0002	< 0.0002	< 0.0002
chromium (Cr)	mg/L	< 0.0008	< 0.0008	< 0.0008	**0.009** [C]	4	< 0.0008	**0.0042** [C]	**0.0015** [C]
cobalt (Co)	mg/L	0.0002	< 0.0002	< 0.0002	< 0.003	4	< 0.0002	< 0.0002	< 0.0002
copper (Cu)	mg/L	**0.021** [C]	< 0.001	< 0.001	0.001	3	< 0.001	**0.004** [C]	< 0.001
iron (Fe)	mg/L	**2.32** [C,H]	**2.37** [C,H]	**0.22** [H]	**4.66** [C,H]	4	**1.48** [C,H]	**0.42** [C,H]	**0.27** [H]
lead (Pb)	mg/L	0.0003	0.0008	0.0001	**< 0.02** [D>C]	4	< 0.0001	< 0.0001	< 0.0001
lithium (Li)	mg/L	0.013	0.01	0.007	0.011	4	0.01	< 0.006	0.011
manganese (Mn)	mg/L	**0.071** [H]	**0.113** [H]	**0.079** [H]	**0.18** [H]	4	**0.104** [H]	0.006	**0.015** [H]
mercury (Hg)	mg/L	< 0.0000006	**< 0.0002** [D>C,H]	**< 0.0002** [D>C,H]	**< 0.05** [D>A,C,H]	4	< 0.0000006	**< 0.0002** [D>C,H]	**< 0.0002** [D>C,H]
molybdenum (Mo)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.003	4	< 0.0001	< 0.0001	0.0002

Table 9.3 Water Quality in Shipyard Lake, Summer and Fall (continued)

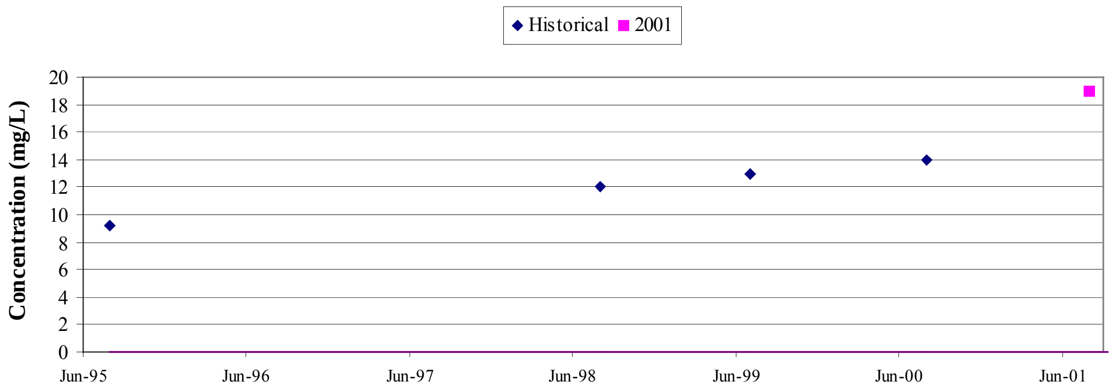
Parameter	Units	Summer					Fall		
		2001	Historical (1995-2000) [(a)]				2001	Historical [(a)]	
			median	min	max	n		2000	1999
nickel (Ni)	mg/L	0.0014	0.0012	0.0006	0.01	4	< 0.0002	< 0.0002	0.0016
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.001	4	< 0.0008	< 0.0008	< 0.0008
silver (Ag)	mg/L	< 0.000005	**< 0.0004 [(D>C)]**	**< 0.0004 [(D>C)]**	**< 0.002 [(D>C)]**	4	0.000006	**< 0.0004 [(D>C)]**	**< 0.0004 [(D>C)]**
strontium (Sr)	mg/L	0.16	0.12	0.11	0.13	4	0.16	0.13	0.13
thallium (Tl)	mg/L	< 0.0001	< 0.0001	-	-	1	< 0.0001	< 0.0001	-
titanium (Ti)	mg/L	0.002	0.0015	< 0.0006	0.02	4	< 0.0006	0.0037	0.0009
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3	< 0.0001	< 0.0001	< 0.0001
vanadium (V)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.002	4	0.0006	< 0.0002	0.0002
zinc (Zn) [(b)]	mg/L	0.007	0.012	< 0.004	0.013	4	0.006	**0.031 [(C)]**	< 0.004
Metals (Dissolved)									
aluminum (Al)	mg/L	< 0.01	0.06	0.01	0.11	3	< 0.01	< 0.01	< 0.01
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	0.001	3	< 0.0008	< 0.0008	< 0.0008
arsenic (As)	mg/L	< 0.0004	0.0006	0.0005	0.0013	3	0.0005	0.0004	< 0.0004
barium (Ba)	mg/L	0.039	0.028	0.017	0.033	3	0.045	0.027	0.028
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	3	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.05	0.04	0.03	0.04	3	0.05	*0.07*	0.03
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 0.0001	0.0001	3	< 0.0001	< 0.0001	< 0.0001
chromium (Cr)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	3	*0.0011*	0.0005	0.0008
cobalt (Co)	mg/L	< 0.0001	< 0.0001	< 0.0001	0.0001	3	0.0001	< 0.0001	0.0001
copper (Cu)	mg/L	< 0.0006	0.0006	< 0.0006	0.0016	3	< 0.0006	0.0015	0.0009
iron (Fe)	mg/L	1.98	0.28	0.13	1.48	3	0.14	< 0.01	0.22
lead (Pb)	mg/L	< 0.0001	0.0002	0.0001	0.0009	3	0.0001	0.0001	< 0.0001
lithium (Li)	mg/L	0.009	0.01	0.007	0.012	3	0.011	*0.014*	0.011
manganese (Mn)	mg/L	0.016	0.033	0.001	0.102	3	0.097	0.003	0.003
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.0001	0.0002	3	< 0.0001	< 0.0001	0.00003
molybdenum (Mo)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0009	3	< 0.0001	*0.0002*	0.0002
nickel (Ni)	mg/L	0.0006	0.0005	0.0003	0.0016	3	< 0.0001	*0.0004*	0.0018
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	3	< 0.0004	< 0.0004	< 0.0004
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	3	< 0.0002	< 0.0002	< 0.0002
strontium (Sr)	mg/L	0.15	0.12	0.11	0.13	3	0.17	0.13	0.14
thallium (Tl)	mg/L	0.00005	< 0.00005	-	-	1	< 0.00005	< 0.00005	-
titanium (Ti)	mg/L	0.0004	< 0.0003	< 0.0003	0.0005	3	*0.0011*	< 0.0003	0.0004
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	3	< 0.0001	< 0.0001	0.0003
vanadium (V)	mg/L	< 0.0001	< 0.0001	< 0.0001	0.0002	3	0.0002	*0.0003*	0.0001
zinc (Zn) [(b)]	mg/L	< 0.002	< 0.002	< 0.002	0.015	3	*0.035*	0.006	0.003

(a) Based on information from Golder (1996a, 1999, 2000b, 2001a) and Suncor (1998).

(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
[A] = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
[C] = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
[H] = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
[D>] = analytical detection limit was higher than the relevant water quality guideline(s).
\- = no data.

Figure 9.2 Sodium Concentrations in Shipyard Lake, Summer (1995 to 2001)



9.1.4 McClelland Lake

Water quality in McClelland Lake was generally consistent with historical data in the summer and fall of 2001 (Table 9.4), although the historical data set is quite limited ($n \leq 4$). Total mercury levels were lower in summer, and total nickel and dissolved phosphorus concentrations were lower in fall 2001 than in previous years.

Table 9.4 Water Quality in McClelland Lake, Summer and Fall

Parameter	Units	Summer					Fall				
		2001	Historical (1973-1988) [a]				2001	Historical (1972-2000) [a]			
			median	min	max	n		median	min	max	n
Field Measured											
pH		**8.6** [A,C]	-	8.4	8.5	2	**9** [A,C]	-	**8.6** [A,C]	**9** [A,C]	2
specific conductance	uS/cm	221	-	267	267	2	218	-	220	234	2
temperature	^oC	18.7	19.8	16	19.8	3	14.9	-	7.2	13	2
dissolved oxygen	mg/L	10.3	-	8.9	9.1	2	9.1	-	10.7	11.5	2
Conventional Parameters											
colour	T.C.U.	15	4	-	-	1	5	-	5	10	2
conductance	uS/cm	253	230	195	275	4	224	241	230	253	3
dissolved organic carbon	mg/L	12	12	-	-	1	13	-	12	17	2
hardness	mg/L	122	124	105	135	3	114	115	106	119	3
pH		8.5	8.4	7.8	8.9	4	8.5	8.1	7.4	8.4	3
total alkalinity	mg/L	125	106	54	147	4	122	128	117	129	3
total dissolved solids	mg/L	140	143	-	-	1	150	-	140	165	2
total organic carbon	mg/L	13	-	-	-	-	13	-	14	20	2
total suspended solids	mg/L	5	-	-	-	-	3	5	< 3	8	3
Major Ions											
bicarbonate	mg/L	147	-	153	162	2	141	-	152	158	2
calcium	mg/L	21	23	6	25	3	19	22	22	24	3
carbonate	mg/L	< 5	8	-	-	1	< 5	-	< 5	< 5	2
chloride	mg/L	< 1	1	< 1	6	4	< 1	< 1	< 1	< 1	3
magnesium	mg/L	17	15	14	19	4	16	15	11	15	3
potassium	mg/L	3	3	2	3	4	3	3	3	3	3
sodium	mg/L	5	4	3	5	4	4	4	4	5	3
sulphate	mg/L	6	9	< 5	37	4	4	2	2	10	3
sulphide	mg/L	0.03	-	-	-	-	< 0.003	-	< 0.003	< 0.003	2
Nutrients and Chlorophyll *a*											
nitrogen, ammonia	mg/L	< 0.05	-	-	-	-	< 0.05	-	< 0.1	< 0.1	2
nitrogen, total [b]	mg/L	**1.2** [C]	0.9	-	-	1	**1.9** [C]	-	0.5	0.8	2
phosphorus, total	mg/L	0.018	**0.1** [C]	0.017	**0.45** [C]	3	0.012	0.015	0.014	**0.2** [C]	3
phosphorus, dissolved	mg/L	0.012	0.007	-	-	1	0.004	-	0.013	0.015	2
chlorophyll *a*	ug/L	-	7	2	3.3	4	1	-	1	3	2
Biological Oxygen Demand											
biochemical oxygen demand	mg/L	3	-	-	-	-	< 2	-	< 2	2	2
General Organics											
naphthenic acids	mg/L	< 1	-	-	-	-	< 1	-	-	-	-

Table 9.4 Water Quality in McClelland Lake, Summer and Fall (continued)

Parameter	Units	Summer					Fall				
		2001	Historical (1973-1988) [(a)]				2001	Historical (1972-2000) [(a)]			
			median	min	max	n		median	min	max	n
total phenolics	mg/L	< 0.001	**0.006** [(C)]	< 0.001	**0.01** [(C)]	4	< 0.001	> 0.001	-	-	1
total recoverable hydrocarbons	mg/L	0.6	< 1	< 1	1.1	3	2.1	0.9	-	-	1
Metals (Total)											
aluminum (Al)	mg/L	0.08	-	-	-	-	< 0.02	-	< 0.02	0.06	2
antimony (Sb)	mg/L	**< 0.005** [(D>H)]	-	-	-	-	**< 0.005** [(D>H)]	-	**< 0.005** [(D>H)]	**< 0.005** [(D>H)]	2
arsenic (As)	mg/L	< 0.001	< 0.0002	-	-	1	< 0.001	< 0.001	< 0.001	< 0.001	3
barium (Ba)	mg/L	0.027	0.039	-	-	1	0.031	-	0.031	0.032	2
beryllium (Be)	mg/L	< 0.001	-	-	-	-	< 0.001	-	< 0.001	< 0.001	2
boron (B)	mg/L	0.06	-	-	-	-	0.07	-	0.06	0.07	2
cadmium (Cd)	mg/L	< 0.0002	**< 0.001** [(D>C)]	**< 0.001** [(D>C)]	**0.006** [(A,C)]	3	< 0.0002	< 0.0002	< 0.0002	**0.004** [(A,C)]	3
chromium (Cr)	mg/L	**0.0015** [(C)]	**0.002** [(C)]	< 0.001	**0.015** [(C)]	3	< 0.0008	0.0009	< 0.0008	**0.003** [(C)]	3
cobalt (Co)	mg/L	< 0.0002	< 0.001	< 0.001	< 0.001	3	< 0.0002	< 0.0002	< 0.0002	0.004	3
copper (Cu)	mg/L	**0.018** [(A,C)]	**0.062** [(A,C)]	< 0.001	**0.07** [(A,C)]	3	< 0.001	0.001	< 0.001	**0.006** [(C)]	3
iron (Fe)	mg/L	**0.14** [(H)]	**0.1** [(H)]	**0.06** [(H)]	**0.2** [(H)]	3	**0.06** [(H)]	< 0.02	< 0.02	**0.1** [(H)]	3
lead (Pb)	mg/L	0.0003	-	< 0.001	**0.006** [(C)]	2	0.0003	0.0011	0.0003	**0.014** [(C)]	3
lithium (Li)	mg/L	0.018	-	-	-	-	0.018	-	0.02	0.023	2
manganese (Mn)	mg/L	**0.018** [(H)]	0.004	0.003	**0.019** [(H)]	3	**0.016** [(H)]	**0.008** [(H)]	0.007	**0.042** [(H)]	3
mercury (Hg)	mg/L	0.0000012	**0.0003** [(C,H)]	**< 0.0001** [(D>H)]	**0.0009** [(C,H)]	4	**< 0.0002** [(D>C,H)]	**< 0.0002** [(D>C,H)]	**< 0.0002** [(D>C,H)]	**< 0.0005** [(D>C,H)]	3
molybdenum (Mo)	mg/L	< 0.0001	< 0.001	-	-	1	< 0.0001	-	< 0.0001	0.0001	2
nickel (Ni)	mg/L	0.0012	0.003	0.003	0.004	3	0.0006	0.002	0.001	0.004	3
selenium (Se)	mg/L	< 0.0008	< 0.0002	-	-	1	< 0.0008	-	< 0.0008	< 0.0008	2
silver (Ag)	mg/L	0.000011	-	-	-	-	**< 0.0004** [(D>C)]	-	**< 0.0004** [(D>C)]	**< 0.0004** [(D>C)]	2
strontium (Sr)	mg/L	0.13	-	-	-	-	0.12	-	0.13	0.14	2
thallium (Tl)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	< 0.0001	< 0.0001	2
titanium (Ti)	mg/L	0.0061	-	-	-	-	0.0018	-	0.0009	0.0013	2
uranium (U)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	< 0.0001	< 0.0001	2
vanadium (V)	mg/L	< 0.0002	< 0.002	-	-	1	< 0.0002	-	< 0.0002	0.0003	2
zinc (Zn) [(b)]	mg/L	0.007	< 0.01	< 0.001	0.01	3	0.026	0.008	0.005	**0.046** [(C)]	3
Metals (Dissolved)											
aluminum (Al)	mg/L	< 0.01	-	-	-	-	0.01	-	< 0.01	0.06	2
antimony (Sb)	mg/L	< 0.0008	-	-	-	-	< 0.0008	-	< 0.0008	< 0.0008	2
arsenic (As)	mg/L	< 0.0004	-	-	-	-	< 0.0004	-	< 0.0004	< 0.0004	2
barium (Ba)	mg/L	0.025	-	-	-	-	0.033	-	0.03	0.031	2

Table 9.4 Water Quality in McClelland Lake, Summer and Fall (continued)

Parameter	Units	Summer					Fall				
		2001	Historical (1973-1988) [a]				2001	Historical (1972-2000) [a]			
			median	min	max	n		median	min	max	n
beryllium (Be)	mg/L	< 0.001	< 0.001	-	-	1	< 0.001	-	< 0.001	< 0.001	2
boron (B)	mg/L	0.05	-	-	-	-	0.07	-	0.06	0.06	2
cadmium (Cd)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	< 0.0001	< 0.0001	2
chromium (Cr)	mg/L	0.0007	-	-	-	-	< 0.0004	-	< 0.0004	0.0009	2
cobalt (Co)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	< 0.0001	< 0.0001	2
copper (Cu)	mg/L	0.0008	-	-	-	-	0.0012	-	0.0009	0.003	2
iron (Fe)	mg/L	0.08	-	-	-	-	0.01	-	< 0.01	0.01	2
lead (Pb)	mg/L	< 0.0001	-	-	-	-	0.0001	-	0.0002	0.0011	2
lithium (Li)	mg/L	0.018	-	-	-	-	0.021	-	0.022	0.023	2
manganese (Mn)	mg/L	0.017	-	-	-	-	< 0.001	-	0.0009	0.00215	2
mercury (Hg)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	< 0.00002	< 0.0001	2
molybdenum (Mo)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	0.0002	0.0002	2
nickel (Ni)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	< 0.0001	0.0016	2
selenium (Se)	mg/L	< 0.0004	-	-	-	-	< 0.0004	-	< 0.0004	< 0.0004	2
silver (Ag)	mg/L	< 0.0002	-	-	-	-	< 0.0002	-	< 0.0002	< 0.0002	2
strontium (Sr)	mg/L	0.12	-	-	-	-	0.13	-	0.13	0.14	2
thallium (Tl)	mg/L	< 0.00005	-	-	-	-	< 0.00005	-	< 0.00005	< 0.00005	2
titanium (Ti)	mg/L	< 0.0003	-	-	-	-	0.0007	-	0.0005	0.0007	2
uranium (U)	mg/L	< 0.0001	-	-	-	-	< 0.0001	-	< 0.0001	< 0.0001	2
vanadium (V)	mg/L	< 0.0001	-	-	-	-	0.0001	-	< 0.0001	< 0.0001	2
zinc (Zn) [b]	mg/L	< 0.002	-	-	-	-	*0.033*	-	0.013	0.043	2

(a) Based on information from True North (2001) and WDS stations AB07DA2290\2300\2310\2320\2770.
(b) The accuracy of reported total nitrogen, total zinc and dissolved zinc levels in 2001 are uncertain, because of irregularities in QC sample results which may be indicative of sample contamination.

Note: Italicized font indicates that the accuracy of the reported dissolved metal concentration is uncertain because it exceeds the corresponding total metal concentration by >20% (indicative of possible sample contamination).
Bolded concentrations are higher than water quality guidelines.
A = concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
C = concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
H = concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
D> = analytical detection limit was higher than the relevant water quality guideline(s).
- = no data.

9.2 SEDIMENT QUALITY

Composite sediment samples were collected from Kearl, Isadore's and Shipyard lakes in the fall of 2001. With few exceptions (e.g., sand content and total extractable hydrocarbon levels), sediment characteristics in Isadore's Lake were similar to those observed in Shipyard Lake, in terms of organic content, PAH levels and metal concentrations (Table 9.5). Sediments from Kearl Lake tended to have lower metal levels than those observed in the other two wetlands, while PAH concentrations tended to be comparable among the three waterbodies. Concentrations of PAHs in Kearl Lake in 2001 were also generally consistent with those observed in 1998.

Table 9.5 Sediment Quality in Kearl, Isadore's and Shipyard Lakes

Parameter	Units	Kearl Lake		Isadore's Lake	Shipyard Lake
		2001	1998[a]	2001	2001
Particle Size					
percent sand	%	9	-	20	2
percent silt	%	33		54	40
percent clay	%	58	-	26	59
specific conductance	%	92	-	63	79
Carbon Content					
total inorganic carbon	% by wt	0.02		2.9	0.9
total organic carbon	% by wt	34.4	-	1.3	5.5
total carbon	% by wt	34.4	-	4.2	6.3
Organics					
total recoverable hydrocarbons	mg/kg	1600		1500	2300
total volatile hydrocarbons (C5-C10)	mg/kg	< 0.5	-	1.1	7.9
total extractable hydrocarbons (C11-C30)	mg/kg	270	-	280	36
Metals (total)					
aluminum (Al)	ug/g	7020		13800	19900
arsenic (As)	ug/g	4.7	-	**7.4** [l]	**7.8** [l]
barium (Ba)	ug/g	78.9	-	283	210
beryllium (Be)	ug/g	0.3	-	0.9	1
boron (B)	ug/g	30	-	27	23
cadmium (Cd)	ug/g	0.4	-	0.3	0.3
calcium (Ca)	ug/g	12100	-	54300	22000
chromium (Cr)	ug/g	11.6	-	32.8	31.8
cobalt (Co)	ug/g	4.3	-	10	13.5
copper (Cu)	ug/g	28.6	-	28	33
iron (Fe)	ug/g	7450	-	24400	29100
lead (Pb)	ug/g	5.8	-	10.9	14.6
magnesium (Mg)	ug/g	2190	-	8500	8900
manganese (Mn)	ug/g	123	-	461	361
mercury (Hg)	ug/g	0.1	-	0.1	0.1
molybdenum (Mo)	ug/g	1.1	-	0.8	0.8
nickel (Ni)	ug/g	15.1	-	26.2	36
potassium (K)	ug/g	1120	-	3690	3200
selenium (Se)	ug/g	1	-	1.3	1.1
silver (Ag)	ug/g	< 0.1	-	< 0.1	< 0.1
sodium (Na)	ug/g	356	-	310	371
strontium (Sr)	ug/g	47	-	112	75
thallium (Tl)	ug/g	0.1	-	0.3	0.3

Table 9.5 Sediment Quality in Kearl, Isadore's and Shipyard Lakes (continued)

Parameter	Units	Kearl Lake		Isadore's Lake	Shipyard Lake
		2001	1998 (a)	2001	2001
titanium (Ti)	ug/g	73.9	-	66	20.3
uranium (U)	ug/g	0.7	-	1.3	1.5
vanadium (V)	ug/g	14.7	-	51.4	54.1
zinc (Zn)	ug/g	103	-	77	86.5
Target PAHs and Alkylated PAHs					
naphthalene	ng/g	12	25.79	6	11
C1 subst'd naphthalenes	ng/g	15	**57.09** (I)	19	**35** (I)
C2 subst'd naphthalenes	ng/g	24	108	25	49
C3 subst'd naphthalenes	ng/g	19	17	31	50
C4 subst'd naphthalenes	ng/g	7	18.5	11	20
acenaphthylene	ng/g	5.7	3.14	2	2.7
C1 subst'd acenaphthene	ng/g	14	-	1.6	3.4
acenaphthylene	ng/g	0.93	1.58	< 0.29	< 0.91
anthracene	ng/g	4.2	5.21	1.4	2.8
dibenzo(a,h)anthracene	ng/g	**28** (I)	**10.4** (I)	**7.9** (I)	**11** (I)
benzo(a)pyrene	ng/g	**44** (I)	20.8	31.4	**50** (I)
C1 subst'd benzo(a)anthracene/chrysene	ng/g	110	15	270	450
C2 subst'd benzo(a)anthracene/chrysene	ng/g	33	39.5	66	270
benzo(a)pyrene	ng/g	7.9	13.38	10	14
C1 subst'd benzo(b&k)fluoranthene/benzo(a)pyrene	ng/g	< 6.2	-	51	82
C2 subst'd benzo(b&k)fluoranthene/benzo(a)pyrene	ng/g	9.2	-	19	26
benzoflouronthene	ng/g	79	31.65	36	44
benzo(g,h,I)perylene	ng/g	36	31.19	20	29
biphenyl	ng/g	4.2	-	2.5	5.3
C1 subst'd biphenyl	ng/g	< 0.7	-	< 0.14	< 0.23
C2 subst'd biphenyl	ng/g	1.6	-	0.31	0.84
dibenzothiophene	ng/g	2.5	4.28	2.1	5.5
C1 subst'd dibenzothiophene	ng/g	7.1	164.5	13	27
C2 subst'd dibenzothiophene	ng/g	6.5	86.5	34	60
C3 subst'd dibenzothiophene	ng/g	4.6	9.5	55	120
C4 subst'd dibenzothiophene	ng/g	8.2	-	49	52
flouranthene	ng/g	24	14.42	7.8	10
C1 subst'd flouranthene/pyrene	ng/g	15	26.5	50	66
C2 subst'd flouranthene/pyrene	ng/g	17	-	87	110
C3 subst'd flouranthene/pyrene	ng/g	4.3	-	57	91
flourene	ng/g	15	19.34	3.1	7.9
C1 subst'd flourene	ng/g	20	69	7.8	15
C2 subst'd flourene	ng/g	230	171	47	91
C3 subst'd flourene	ng/g	16	-	20	38
indeno(1,2,3,cd)pyrene	ng/g	33	42.87	14	19
phenanthrene	ng/g	30	37.56	13	28
C1 subst'd phenanthrene/anthracene	ng/g	72	204.5	51	110
C2 subst'd phenanthrene/anthracene	ng/g	39	195.5	56	89
C3 subst'd phenanthrene/anthracene	ng/g	14	132	55	93
C4 subst'd phenanthrene/anthracene	ng/g	9.3	0	37	66
1-methyl-7-isopropyl-phenanthrene (retene)	ng/g	65	54.1	71	94
pyrene	ng/g	21	8.97	14	20

(a) From Golder (1999b).

Note: Bolded concentrations are higher than water quality guidelines.

I = concentration higher than the interim sediment quality guidline (CCME 1999).

P = concentration higher than the probable effects level defined by CCME (1999).

D> = analytical detection limit was higher than the relevant water quality guidline(s).

- = no data/no guidline.

9.3 BENTHIC INVERTEBRATE COMMUNITY

Kearl and Shipyard Lakes

The sampling locations in Kearl and Shipyard lakes were 1.5 to 3 m deep (Table 9.6; detailed supporting data in Appendix IX). Secchi depth was close to 1.5 m in both lakes. Conductivity was about two times higher in Shipyard Lake than in Kearl Lake, which may reflect the periodic influence of Athabasca River water in Shipyard Lake or differences between the lakes in groundwater-surface water interaction. The pH values measured in these lakes were somewhat lower than typical values in nearby streams, but were not unusual for the region. Dissolved oxygen was close to saturation in Kearl Lake (8.3 mg/L), but was low (<4 mg/L) in Shipyard Lake, where bottom sediments were anoxic at all sampling locations. Water temperature was within the expected range for the fall season. Bottom sediments consisted mostly of silt and clay, and contained moderate to high amounts of organic material (Table 9.6). In particular, TOC was very high (≥30%) in Kearl Lake. Although these lakes support abundant submergent macrophyte growth, bottom cover by macrophytes was zero, possibly because benthic samples were collected after the seasonal senescence and decay of submergent plants.

Table 9.6 Benthic Habitat Characteristics in Kearl and Shipyard Lakes, Fall 2001

Variable	Units	Kearl Lake Mean (range)	Shipyard Lake Mean (range)
sample date	-	September 19, 2001	September 25, 2001
water depth	m	2.1 (1.8 - 2.4)	1.9 (1.3 - 2.8)
Secchi depth	m	1.5	1.6 (1.3 - 1.8)
Field Water Quality			
dissolved oxygen	mg/L	8.3	3.1 (2.3 - 3.7)[a]
conductivity	µS/cm	176	374 (350 - 380)
pH	-	7.7	7.2 (6.8 - 7.3)
water temperature	^{o}C	14.4	13.0 (11.7 - 13.8)
Bottom Sediments and Macrophyte Cover			
sand	%	9 (4 - 21)	2 (1 - 4)
silt	%	33 (26 - 39)	40 (34 - 49)
clay	%	58 (47 - 69)	59 (50 - 64)
total organic carbon	%	33.6 (29.4 - 38.7)	9.8 (4.5 - 15.4)
macrophyte cover	%	2 (0 - 20)	1 (0 - 5)

[a] Bottom sediments were anaerobic at all sampling locations in the lake.
Note: - = Not applicable.

The benthic communities were characterized by low total abundance (<5,000 oranisms/m^2), especially in Kearl Lake (Figure 9.3; raw data in Appendix IX), where the mean total abundance was less than 1,000 oranisms/m^2. Total richness per lake was 22 (Kearl Lake) and 27 (Shipyard Lake), but the mean richness was only about five taxa per site in both lakes. Both total abundance and richness were highly variable within Shipyard Lake in 2001, where one of the ten samples (SHL-9) contained more benthic organisms and more taxa than the other nine samples combined. The habitat characteristics of the location where sample SHL-9 was collected were not unusual relative to the other nine locations; thus, it is not known why this sample contained unusually high numbers of invertebrates and taxa.

The samples collected in 2001 from Kearl and Shipyard lakes were dominated by chironomid midges (Figure 9.3, Table 9.7). Amphipods and ostracods were also numerous in Kearl Lake, each accounting for about 10% or more of total abundance. Chironomid dominance was more pronounced in Shipyard Lake, where nearly 80% of total abundance consisted of midges in 2001. Other than chironomids, only ostracods were present at more than 5% of total abundance in these lakes (Table 9.7).

Compared to the previous year's data, both abundance and richness of the benthic community were lower in Shipyard Lake in 2001 (Figure 9.3). Community composition was also different between these two years: the lake supported a diverse and balanced benthic community in 2000, but a chironomid-dominated community was found in 2001. The possible reasons for these findings include sampling in areas with lower macrophyte cover in 2001 compared to 2000, or the lower DO measured in 2001, which may have been caused by early decay of macrophytes.

In both years with data for Shipyard Lake, sampling was conducted in late September. DO was near saturation during the fall 2000 sampling program, with a range of 7.4 to 10.3 mg/L at the ten sampling locations (Golder 2001a). Aquatic macrophyte cover was 100% on the lake bottom at the sampling locations, suggesting sampling was completed before the seasonal senescence and decay of macrophytes. In contrast, macrophyte cover was near zero at the sampling locations in 2001 and the lake was close to anaerobic throughout. This may indicate that the 2001 sampling locations were outside of macrophyte beds, in areas with anaerobic sediments, or that macrophytes have already decayed by the time of sampling, thereby lowering DO concentration. Because the sampling depths were generally greater in 2001 (1.3 to 2.8 m) than in 2000 (1.2 to 1.9 m), and because late September is rather early for complete macrophyte decay, the first explanation appears more likely.

Figure 9.3 Total Invertebrate Abundance, Richness and Community Composition in Kearl and Shipyard Lakes, Fall 2001

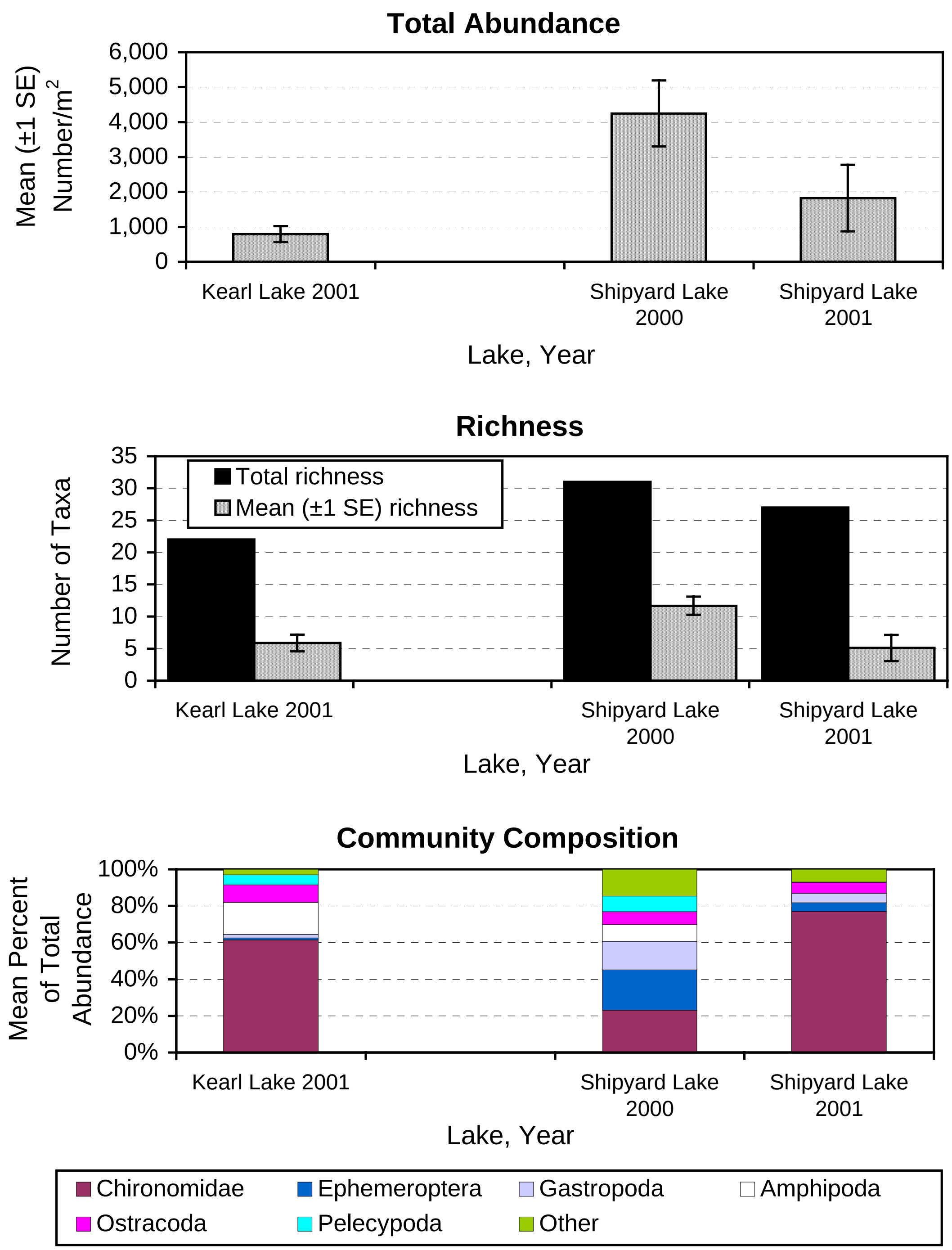


Table 9.7 Abundances of Common Invertebrates in Kearl and Shipyard Lakes, Fall 2001

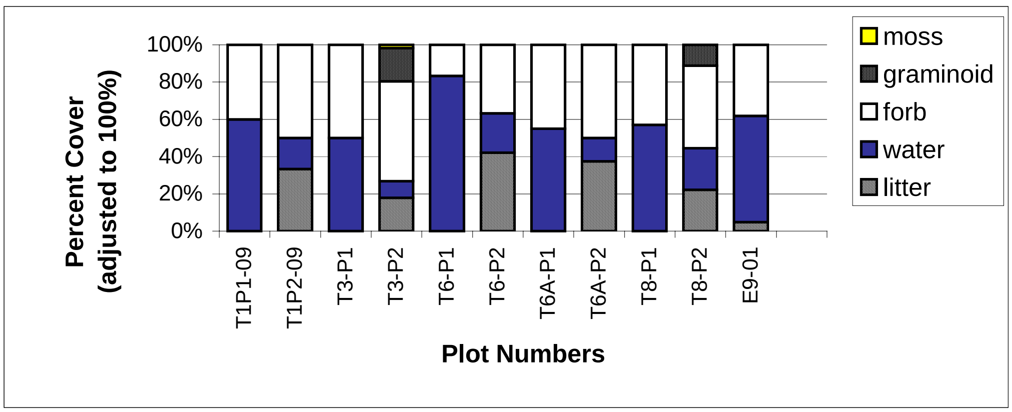
Taxon	Major Group	Mean (no./m^2)	Standard Error	% of Total Abundance
Kearl Lake				
Procladius	Chironomidae	148	37	18.7
Einfeldia	Chironomidae	148	77	18.7
Hyalella azteca	Amphipoda	139	61	17.5
Ostracoda	Ostracoda	76	37	9.6
Cladopelma	Chironomidae	72	37	9.0
Sphaeriidae	Pelecypoda	43	38	5.4
Thienemannimyia complex	Chironomidae	29	29	3.6
Microtendipes	Chironomidae	24	15	3.0
Glyptotendipes	Chironomidae	19	15	2.4
Cryptochironomus	Chironomidae	14	7	1.8
Polypedilum	Chironomidae	14	10	1.8
Planorbidae	Gastropoda	10	10	1.2
Polycentropus	Trichoptera	10	10	1.2
Chironomus	Chironomidae	10	6	1.2
total % for common taxa				(95.2%)
total abundance		793	225	-
richness		5.9	1.3	-
total richness		22	-	-
Shipyard Lake				
Chironomus	Chironomidae	761	218	41.7
Ablabesmyia	Chironomidae	116	111	6.4
Thienemannimyia complex	Chironomidae	116	116	6.4
Ostracoda	Ostracoda	108	52	5.9
Caenis	Ephemeroptera	86	86	4.7
Tanytarsus	Chironomidae	82	57	4.5
Microtendipes	Chironomidae	77	77	4.2
Dicrotendipes	Chironomidae	73	73	4.0
Tanypus	Chironomidae	65	26	3.5
Procladius	Chironomidae	60	46	3.3
Leucorrhinia	Odonata	39	39	2.1
Dero	Oligochaeta	34	34	1.9
Armiger crista	Gastropoda	34	34	1.9
Gyraulus	Gastropoda	34	34	1.9
Parachironomus	Chironomidae	22	17	1.2
total % for common taxa				(93.6%)
total abundance		1,823	951	-
richness		5.1	2.0	-
total richness		27	-	-

In light of the potentially large year-to-year variation in benthic community characteristics in these lakes, sampling within a limited depth range (e.g., 1 to 2 m) and earlier in the season (i.e., early September) are recommended for future sampling programs.

9.4 AQUATIC VEGETATION

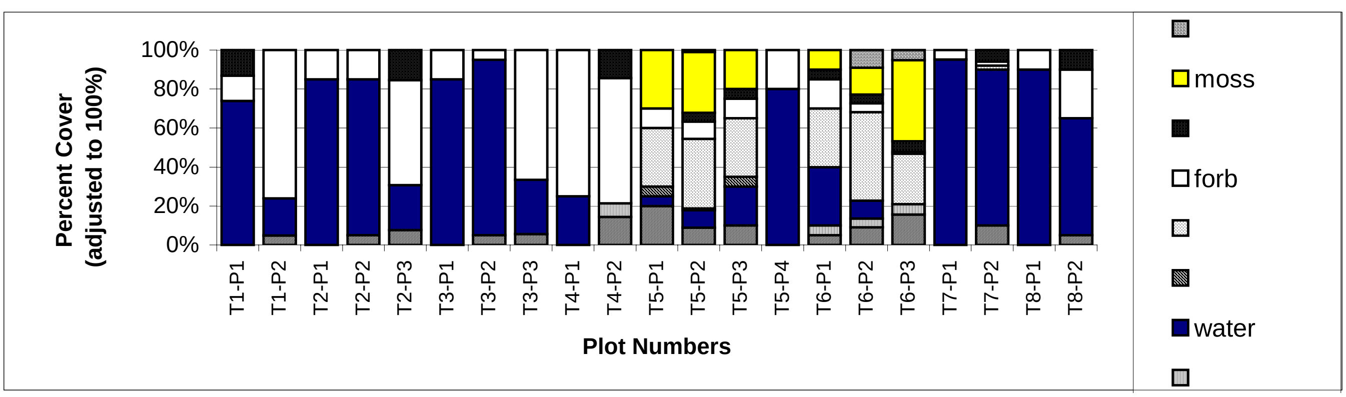
This section describes the wetlands types, species compositions, percent cover, diversity, richness and vigour of the vegetation of Shipyard, Isadore's and Kearl lakes. In addition, the results of comparative analysis of the three lakes compare the water quality data, similarity indices and depth of the three lakes. In plant communities, the calculation of total percent cover by cover type is greater than 100% in some cases due to the layering of plant cover. All values in the illustration of percent cover for Figures 9.4 to 9.5 were scaled to total 100% for ease of presentation. Total values below 5% are not illustrated on these figures.

Figure 9.4 Cover types of Shipyard Lake, Summer 2001



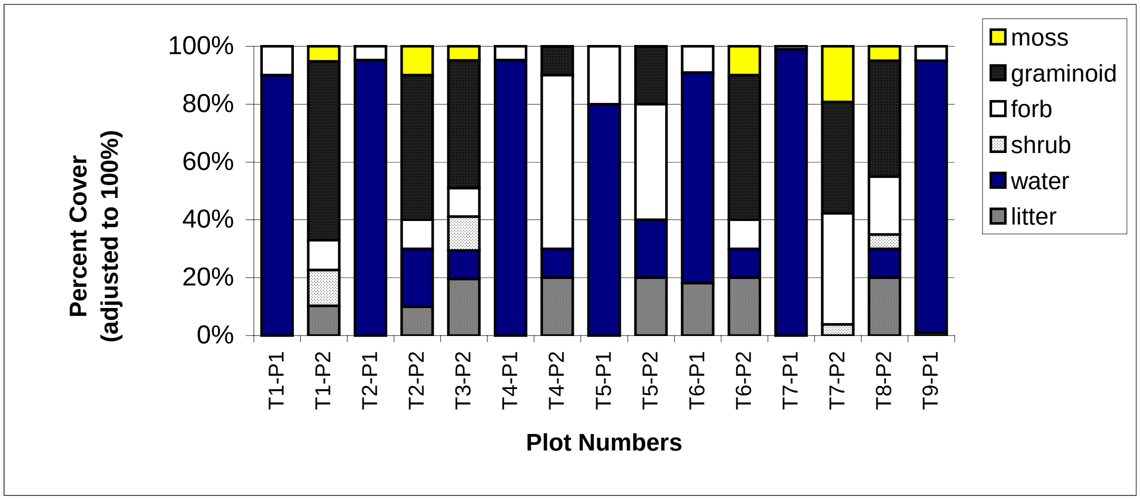
Layers scaled to 100% to allow visual comparison between plots.

Figure 9.5 Vegetation Layers, Water and Litter at Isadore's Lake, Summer 2001



Layers were scaled to 100% to allow visual comparison between plots.

Figure 9.6 Vegetation Layers, Water and Litter of Kearl Lake, Summer, 2001



Layers were scaled to 100% to allow visual comparison between plots.

Table 9.8 shows that Shipyard Lake has the lowest number of species followed by Kearl Lake. Isadore's Lake has a large number of cover classes as well as the largest number of species.

Table 9.8 Comparison of Species for Each Cover Class at Shipyard, Isadore's and Kearl Lakes, Summer 2001

Cover class	Shipyard Lake	Isadore's Lake	Kearl Lake
shrub	0	13	2
forb	18	23	24
graminoid	3	7	9
moss	1	6	5
lichen	0	5	0
total number of species	**22**	**54**	**40**

9.4.1 Shipyard Lake

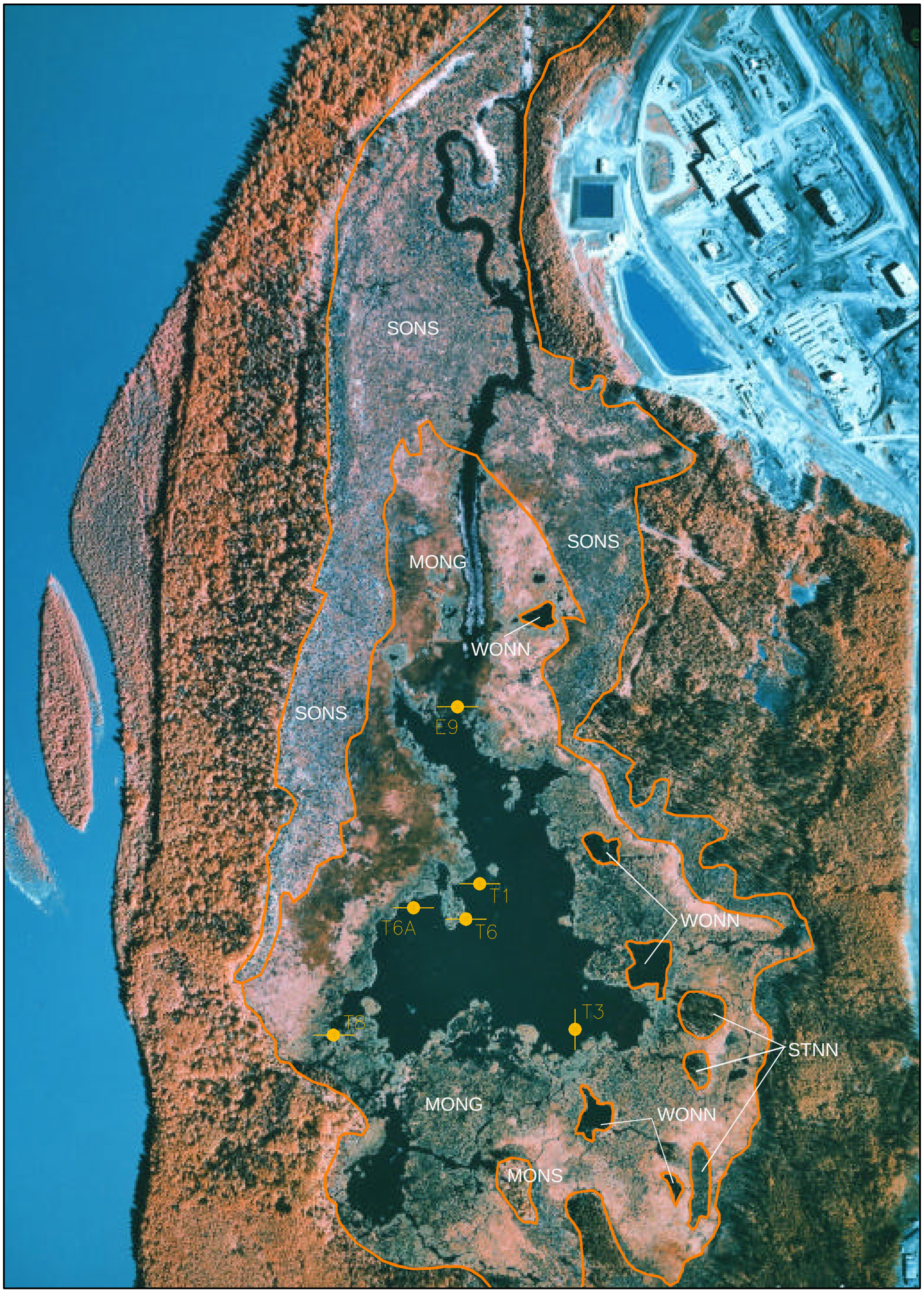
Shipyard Lake is a riparian wetlands complex located within the Athabasca River floodplain, adjacent to Suncor's Steepbank/Millennium Mine. It is 159.6 ha in area and is predominantly a shallow, open-water/marsh wetlands complex (Figure 9.7). Hence, all of Shipyard Lake is classified as wetlands and not as lake basin under the AWI. The main watercourses within the Shipyard Lake drainage system include Unnamed Creek, which enters the wetlands from the northeast, and several small channels and creeks that enter the wetlands from the southeast. Shipyard Creek, a narrow channel to the north, provides the outlet to the Athabasca River.

Analysis of peat depth in Shipyard Lake indicated that it has been isolated from the Athabasca River for several hundred years (Golder 1996b). Five transects and 11 plots were surveyed in the wetlands complexes of Shipyard Lake during the 2001 field season.

The AWI classes reported for Shipyard Lake in Golder (1998) are as follows: 130.3 ha of marsh, consisting of MONS (open, non-patterned shrubby marsh) and MONG (open, non-patterned graminoid marsh); 11.3 ha of open treed swamp (STNN); and 26.9 ha of shallow open water (WONN).

The graminoid marshes that surround Shipyard Lake are described as "floating vegetated mats". This cattail emergent community ringing the lake in combination with the shallow depth make plots around Shipyard Lake more homogeneous than plots around Isadore's or Kearl lake (Figures 9.4, 9.5 and 9.6). Shipyard lake had 22 species with the forb cover class having 18 of these species (Table 9.8). In 2001, there were no shrubs or trees in the plots surveyed around Shipyard Lake. A detailed species list with percent covers for the plots surveyed on Shipyard Lake is provided in Appendix XI.

Forb was the dominant vegetation class in each Shipyard Lake plot, but when compared to total cover type, water and litter were dominant in every plot (Figure 9.4). The plots T3-P2 and T8-P2 had some graminoid coverage but this was less than the coverage of cattails in those plots.



N

250 0 250
SCALE METRES

LEGEND

TRANSECT LOCATION

REFERENCE

PHOTO IMAGES SUPPLIED BY AMEC, PHOTO FFC01045 L-9A PHOTO 284, FLOWN 1:10,000 01/08/01

PROJECT

RAMP 2001

TITLE

SHIPYARD LAKE

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No. SHIPYARD WETLANDS	
DESIGN			SCALE AS SHOWN	REV. 1
CADD	RFM	17/05/02	**FIGURE: 9.7**	
CHECK	KF	17/05/02		
REVIEW				

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: Shipyard Wetlands.dwg Jul 10, 2002 - 10:53am Image:shipyard_ir.jpg

Plant Vigour

The overall plant vigour for Shipyard Lake (Table 9.9) was good for all plots except for plots on transects T1P1-02 and T6AP1 which were assessed as fair.

Table 9.9 Plant Vigour for Shipyard Lake Vegetation Cover Classes, Summer 2001

Plots	Shrub	Forb	Grass	Moss
E9-01	-	3	-	-
T1P1-09	-	2	-	-
T1P2-09	-	3	-	-
T3-P1	-	3	-	-
T3-P2	-	3	3	3
T6A-P1	-	2	-	-
T6A-P2	-	3	3	3
T6-P1	-	3	-	-
T6-P2	-	3	-	-
T8-P1	-	3	-	-
T8-P2	-	3	3	-

Note: 0 = dead.
1= poor.
2 = fair.
3 = good.
4 = excellent.
- = no vegetation in the cover class.

9.4.2 Isadore's Lake

Isadore's Lake is a riparian wetlands situated in the Athabasca River floodplain adjacent to Shell's Muskeg River Mine Project. It is an open water fen complex dominated by cattails and sedges, with low shrub and treed fens along the outer perimeter (Figure 9.8). A channel situated north of the lake provides an outlet to the Athabasca River.

Isadore's Lake wetlands complex is 149.6 ha in area, whereas the lake basin is 38.3 ha (Golder 1998). In 2001, eight transects and 21 plots were surveyed in the wetlands complex of Isadore's Lake.

The AWI classes reported at Isadore's Lake in Golder (1998) were as follows: 82.3 ha of fen consisting of open, non-patterned, shrubby fen (FONS); open, non-patterned, graminoid fen (FONG); and wooded fen with no internal lawns (FTNN). There was 14.2 ha of open, shrubby swamp (SONS) and 14.8 ha of shallow open water (WONN).

LEGEND

TRANSECT LOCATION

REFERENCE

PHOTO IMAGES SUPPLIED BY AMEC, PHOTOS FFC01046 L-28 PHOTOS 362 AND 399, FLOWN 1:10,000 02/08/01

PROJECT

RAMP 2001

TITLE

ISADORE'S LAKE

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	ISADORE WETLANDS
DESIGN			SCALE AS SHOWN	REV. 0
CADD	RFM	17/05/02	FIGURE: 9.8	
CHECK	KF	17/05/02		
REVIEW				

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: Isadore Wetlands.dwg Jul 10, 2002 - 10:54am Image:isadore_new.jpg

Isadore's Lake, with 54 vegetation species, had the largest number of species of the three lakes surveyed (Table 9.8). The vegetation cover class forb had 23 species, while cattails had the largest percent coverage in this class. There were 13 species of shrubs recorded. The coverage shows that T5 and T6 had more shrub-dense plots than other transects. This is partly due to location; the coverage of FONS surrounding the lake was uneven (Figure 9.5). The increased shrub component may also play a part in the increase in mosses. Transect 5 also had some tree component, although this is very small in terms of total plot coverage. Isadore's Lake had more diversity of cover classes than the other wetlands surveyed.

Plant Vigour

The cover classes in Isadore's Lake had plants with a large amount of dieback. In the shrub class, most plots had shrubs that were in good health, except T8P2, which was scored as poor (Table 9.10). In the forb cover class, T6P3 showed poor health and T8P1 was fair (Table 9.10). Moss and lichen cover classes had the poorest health; this may be due to poor coverage rather than poor health (Table 9.10). It is difficult to determine the health of these two cover classes due to their growth form.

Table 9.10 Plant Vigour for Isadore's Lake Vegetation Cover Classes, Summer 2001

Plots	Shrub	Forb	Grass	Moss	Lichens
T1-P1	-	3	-	-	-
T1-P2	-	3	-	-	-
T2-P1	-	1	-	-	-
T2-P2	-	3	-	-	-
T2-P3	-	3	-	-	-
T3-P1	-	2	-	-	-
T3-P2	-	3	-	-	-
T3-P3	-	3	-	-	-
T4-P1	-	3	-	-	-
T4-P2	3	3	3	-	-
T5-P1	3	3	3	3	3
T5-P2	3	3	3	3	3
T5-P3	3	3	3	-	-
T5-P4	-	3	3	-	-
T5-P5	-	3	-	-	-
T6-P1	3	3	2	1	1
T6-P2	3	3	2	1	1
T6-P3	3	1	3	2	1

Table 9.10 Plant Vigour for Isadore's Lake Vegetation Cover Classes, Summer 2001 (continued)

Plots	Shrub	Forb	Grass	Moss	Lichens
T7-P1	-	-	3	-	-
T7-P2	4	3	4	-	-
T8-P1	-	2	-	-	-
T8-P2	1	3	4	-	-

Note: 0 = dead.
1= poor.
2 = fair.
3 = good.
4 = excellent.
- = no vegetation in the cover class.

9.4.1 Kearl Lake

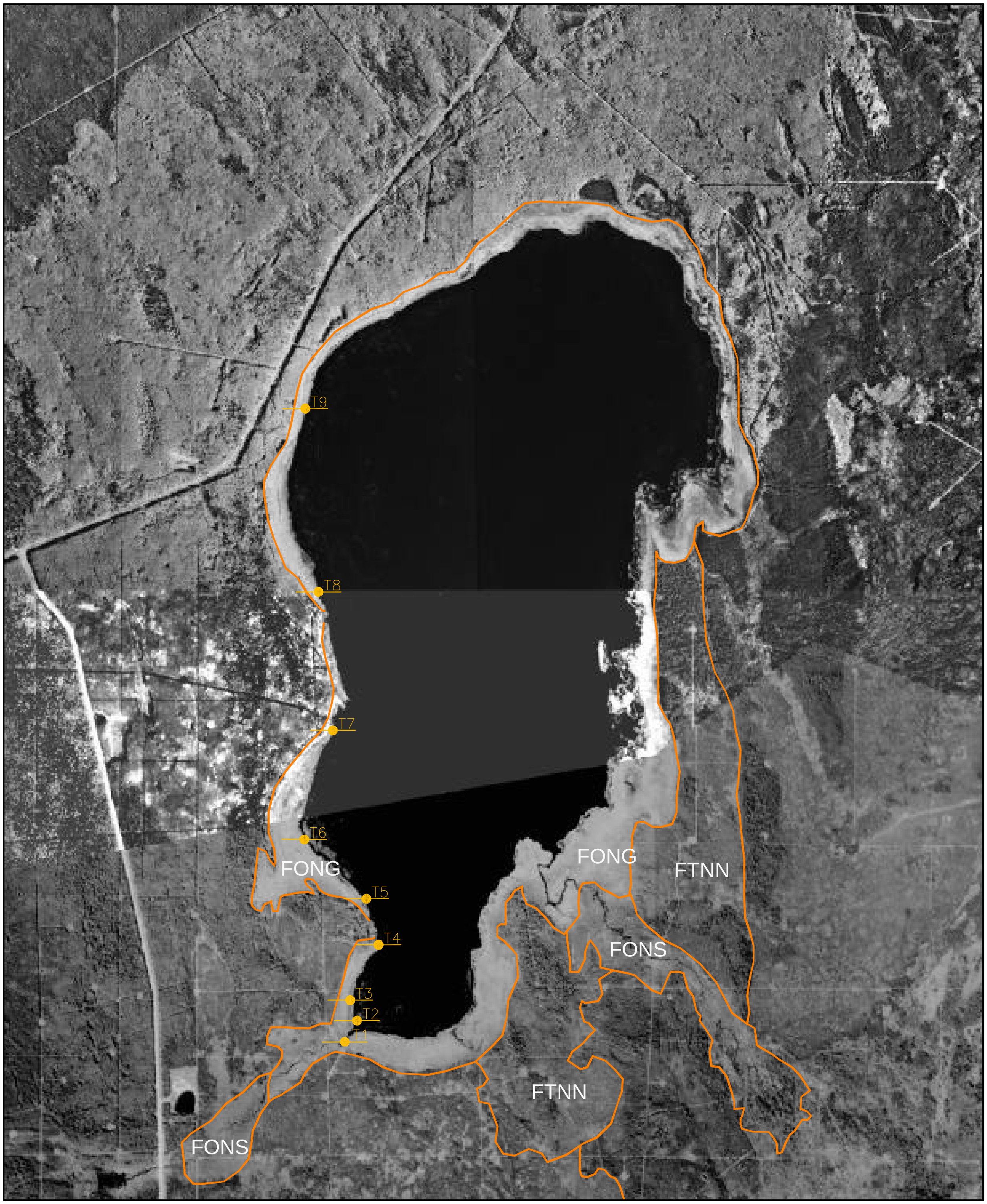
Kearl Lake is a large lake-wetlands complex located approximately 12 km east of the Athabasca River along the Muskeg River Drainage System. The entire complex is approximately 955 ha in area, while the lake basin is approximately 547 ha (Golder 1998). The lake is bordered by 407.4 ha of graminoid and shrubby fens (Figure 9.9). Kearl Lake is not a riparian wetlands, but rather a large upland lake with a wetlands border. Eight transects and 15 plots were surveyed in the wetlands complexes of Kearl Lake.

The AWI classes reported in Golder (1998) for Kearl Lake include: 162.9 ha of FONG, 137.7 ha of FONS, and 106.8 ha of FTNN. A detailed description of the AWI classes is provided in Appendix XI.

Water cover class in Kearl Lake had the greatest percent of cover (Figure 9.6). Seven plots had over 70% water as cover. This could result from plots being placed further out into the lake due to the shallow nature of the lake. The wetlands complexes that ring shallow lakes tend to move out into the water. Most of the vegetation species were classified as graminoids but also include some forbs. Due to the high percentage of water, the moss layer was either not existent or had a very low cover value.

Plant Vigour

The edge of Kearl Lake was made up primarily of open graminoid fens and the graminoids which appeared to be healthy (Table 9.11). Forbs and shrubs were fair to good in vigour (Table 9.11). The moss cover class was assessed as fair to poor; however, it is very difficult to determine the difference between healthy and unhealthy mosses and lichens due to their growth form (Table 9.11).



N

5 0 5

SCALE KILOMETRES

LEGEND

TRANSECT LOCATION

REFERENCE

ORTHOPHOTO IMAGE BOTTOM PORTION KEARL LAKE FROM ALBERTA PACIFIC LTD. FLOWN JUNE 2001

ORTHOPHOTO IMAGE UPPER PORTION KEARL LAKE FROM ORTHOSHOP, FLOWN 1998

PROJECT

RAMP 2001

TITLE

KEARL LAKE

Golder Associates
Calgary, Alberta

PROJECT No.		012-2302	FILE No.	KEARL WETLANDS	
DESIGN			SCALE	AS SHOWN	REV. 0
CADD	RFM	17/05/02			
CHECK	KF	17/05/02	**FIGURE: 9.9**		
REVIEW					

R:\CAD\2300\012-2302\2001 Annual Report\ Drawing file: Kearl Wetlands.dwg Jul 10, 2002 - 10:54am Image:kearl.tif

Table 9.11 Plant Vigour for Kearl Lake Vegetation Cover Classes, Summer 2001

Plot	Shrubs	Forbs	Grasses	Mosses	Lichens
T1-P1	-	2	-	-	-
T1-P2	3	3	4	1	-
T2-P1	-	2	-	-	-
T2-P2	3	3	4	1	-
T3-P1	-	2	-	-	-
T3-P2	3	3	4	1	-
T4-P1	-	2	-	-	-
T4-P2	-	3	4	-	-
T5-P1	-	2	-	-	-
T5-P2	-	3	4	1	-
T6-P1	N/A				
T6-P2	N/A				
T7-P1	-	2	-	-	-
T7-P2	3	3	4	2	-
T8-P1	-	2	-	-	-
T8-P2	3	3	4	2	-
T9-P1	-	3	-	-	-
T9-P2	2	3	4	2	-

Note: 0 = dead
1= poor
2 = fair
3 = good
4 = excellent.
N/A = not available.
- = no vegetation in the cover class.

Species Diversity and Species Richness

The Shannon-Wiener Index (species diversity), the total percent cover by an individual species and species richness (expressed as number of species), were calculated for each lake and compared between the lakes (Table 9.12). Shipyard Lake had the lowest diversity and richness but the highest cover (total numbers), Kearl and Isadore's lakes had the highest diversity and richness, while Kearl Lake had the lowest percent cover (Table 9.12).

Table 9.12 Plot Richness, Cover and Diversity by Species for Shipyard, Isadore's and Kearl Lakes, 2001

Lake	Plots	Shannon-Wiener (diversity)			Percent Cover			Richness (number of species)		
		Mean	+/- SD	min./ max.	Mean	+/- SD	min./ max.	Mean	+/- SD	min./ max.
Shipyard	11	0.352	0.339	0.018 / 0.950	36.15	13.36	17.60 / 62.80	4.73	3.23	2.00 / 11.00
Isadore's	21	1.145	0.634	0.000 / 2.098	32.82	20.92	3.00 / 70.10	7.48	6.35	1.00 / 19.00
Kearl	15	1.151	0.763	1.600 / 70.50	25.47	24.63	1.60 / 70.50	7.67	5.23	1.00 / 16.00

Isadore's Lake contained the most species per plot (19), although the highest mean richness was determined for Kearl Lake (7.67). Shipyard Lake had the lowest mean species richness (4.73) and the lowest number of species (11).

Overall, 82 species were recorded in the three wetlands. A species list and species distribution according to plot is provided in Appendix XI.

The Shannon-Wiener Index total number and richness were averaged by lake based on vegetation group rather than species. Isadore's and Kearl lakes had the highest diversity and richness while Shipyard Lake had the highest percent cover value but the lowest richness (Table 9.13).

Table 9.13 Plot Richness, Cover and Diversity by Plant Group for Shipyard, Isadore's and Kearl Lakes, Summer 2001

Lake	Number of plots	Shannon-Wiener (diversity)			Percent Cover			Richness (number of species groups)		
		Mean	+/- SD	min./ max.	Mean	+/- SD	min./ max.	Mean	+/- SD	min./ max.
Shipyard	10	0.116	0.248	0.000 / 0.663	46.20	18.35	20.00 / 82.00	1.30	0.68	1.00 / 3.00
Isadore's	15	0.480	0.540	0.000 / 1.376	44.23	29.51	5.00 / 92.00	2.32	1.70	1.00 / 6.00
Kearl	22	0.454	0.474	0.000 / 1.177	36.47	0.93	1.00 / 85.00	2.20	1.32	1.00 / 4.00

Note: species groups are trees, shrubs, forbs, graminoids, mosses, lichens.

However, Kruskal-Wallis test statistics of the above parameters (Shannon-Wiener Index [p=0.135], percent cover [p=0.453] and species richness [p= 0.163]) showed no significant difference [p<.05] between the lakes by vegetation group. The Kruskal-Wallis test detected a difference between lakes in the Shannon-Weiner Index by individual species (0.006).

Jaccard's Index of Similarity within Lakes

Jaccard's index was used to assess similarity in relative species composition (i.e., species presence/absence) between plots within lakes and between lakes.

If a cut-off value of 0.50 is selected as a measure of moderate similarity, 15 paired plots (i.e., paired plots are two plots for which a similarity index $\geq$ 0.50 is given) are similar within Isadore's Lake (Table 9.14), while only two paired plots are similar within Kearl Lake (Table 9.14). Shipyard Lake has 19 paired plots that are similar (Table 9.14). Thus, Shipyard Lake appears to have the most homogeneous wetlands communities (mean of 0.325 +/- standard deviation of 0.240) while Kearl Lake appears to have the most dissimilar wetlands communities (mean of 0.157 +/- standard deviation of 0.192). The mean is 0.134 +/- standard deviation of 0.191 for Isadore's Lake.

Table 9.14 Jaccard's Index of Similarity for Shipyard, Isadore's and Kearl Lakes, Summer 2001

Plots	Jaccard's Index
Shipyard Lake	
SLT3P1 x SLE901	0.50
SLT6P1 x SLE901	0.50
SLT6P2 x SLT3P1	0.50
SLT8P1 x SLT3P1	0.50
SLTIP109 x SLE901	0.60
SLT1P109 x SLT3P1	0.50
SLT1P109 x SLT6P1	0.50
SLT1P109 x SLT6P2	0.60
SLT1P209 x SLE901	0.50
SLT1P209 x SLT3P1	1.00
SLT1P209 x SLT6P2	0.50
SLT1P209 x SLT8P1	0.50
SLT1P209 x SLT1P109	0.50
SLT6AP1 x SLE901	0.50
SLT6AP1 x SLT3P1	1.00
SLT6AP1 x SLT6P2	0.50
SLT6AP1 x SLT8P1	0.50
SLT6AP1 x SLT1P109	0.50

Table 9.14 Jaccard's Index of Similarity for Shipyard, Isadore's and Kearl Lakes, Summer 2001 (continued)

Plots	Jaccard's Index
SLT6AP1 x SLT1P209	1.00
Isadore's Lake	
ILT2P3 x ILT2P2	0.75
ILT3P1 x ILT1P1	0.667
ILT3P1 x ILT2P2	0.667
ILT3P3 x ILT2P2	0.75
ILT3P3 x ILT2P3	0.60
ILT5P3 x ILT5P2	0.50
ILT6P1 x ILT5P3	0.632
ILT6P2 x ILT5P3	0.545
ILT6P2 x ILT6P1	0.522
ILT7P1 x ILT1P1	0.50
ILT7P1 x ILT2P1	0.50
ILT8P1 x ILTIP1	0.667
ILT8P1 x ILT2P1	0.667
ILT8P1 x ILT2P2	0.50
ILT8P1 x ILT3P1	0.50
Kearl Lake	
KLT7P1 x KLT1P1	0.667
KLT7P1 x KLT2P2	0.50

Note: Similarity $\geq$ 0.50

Bray-Curtis Index

The Bray-Curtis is a dissimilarity index that measures species overlap and also considers species abundance (e.g., percent cover). However, for this analysis, the coefficients were converted to a positive index so that the Bray-Curtis index measured "similarity" instead of "dissimilarity". This change made the index comparable to Jaccard's index. For the Bray-Curtis index, a value of 0 is dissimilar, while a value of 1 is similar.

Using a cut-off value of 0.50, 11 paired plots (i.e., paired plots are two plots for which a similarity index $\geq$ 0.5 is given) were similar within Isadore's Lake, while only four paired plots were similar within Kearl Lake (Table 9.15). Shipyard Lake had 16 paired plots that were similar (Table 9.15).

As in Jaccard's Index, the Bray-Curtis index showed that Shipyard Lake had the least variation (mean of 0.339 +/- standard deviation of 0.316) and Kearl Lake had the most variation (mean of 0.104 +/- standard deviation of 0.165). Isadore's Lake had a mean of 0.100 +/- standard deviation of 0.171 (Table 9.15).

Table 9.15 Bray-Curtis Index of Similarity for Shipyard, Isadore's and Kearl Lakes, Summer 2001

Plots	Bray-Curtis Index
Shipyard Lake	
SLT6P1 x SLE901	0.667
SLT6P1 x SLT3P1	0.632
SLT6P2 x SLT3P2	0.856
SLT6AP2 x SLT3P2	0.921
SLT6AP2 x SLT6P2	0.858
SLT8P1 x SLT3P1	0.749
SLT8P2 x SLT3P2	0.565
SLT8P2 x SLT6AP2P2	0.567
SLT1P109 x SLT6P1	0.626
SLT1P209 x SLE901	0.667
SLT1P209 x SLT3P1	0.638
SLT1P209 x SLT6P1	0.994
SLT1P209 x SLT1P109	0.626
SLT6AP1 x SLT6P1	0.634
SLT6AP1 x SLT8P1	0.749
SLT6AP1 x SLT1P209	0.638
Isadore's Lake	
ILT2P2 x ILT2P1	0.769
ILT5P2 x ILT5P1	0.543
ILT5P5 x ILT2P3	0.737
ILT6P1 x ILT5P3	0.584
ILT6P2 x ILT6P1	0.634
ILT6P3 x ILT5P1	0.633
ILT8P1 x ILT2P1	0.837
ILT8P1 x ILT2P2	0.783
ILT8P1 x ILT3P1	0.519
ILT8P2 x ILT2P3	0.556
ILT8P2 x ILT2P3	0.627
Kearl Lake	
KLT3P2 x KLT2P2	0.59
KLT5P1 x KLT4P1	0.513
KLT8P2 x KLT7P2	0.522
KLT9P1 x KLT5P1	0.574

Note: Similarity $\geq$ 0.50

Wet (P1) Plots Results

All plots at the beginning of the transects (i.e., away from the land, labeled as P1) were pooled for comparison within wetlands and between wetlands. These plots represent the most important plots for RAMP because they are the wettest plots (water depth: mean = 95.7 cm +/- 22.60 cm; range 48.00 - 120 cm) and may indicate change over time. During the field survey, transects were always started in the wettest community and continued toward dryer plots.

Water Depth

Shipyard Lake plots are not only the deepest (water depth of 120 cm), but also have no water depth variation (SD = 0.00 cm) (Table 9.16). Isadore's Lake plots have the shallowest mean (73.17 cm) and the widest range (48 to 104 cm), while Kearl Lake plots have an average of 97.22 cm and a range of 77 to 113 cm (Table 9.16).

Table 9.16 Water Depth for all P1 Plots in Isadore's, Kearl and Shipyard Lakes, Summer 2001

Wetlands	Water Depth (cm)			
	Number of samples	Mean	Standard Deviation	Minimum / Maximum
Shipyard Lake	5	120.00	0.00	120.00 / 120.00
Isadore's Lake	6	73.17	23.70	48.00 / 104.00
Kearl Lake	9	97.22	10.48	77.00 / 113.00

Mean water depth of the sampled P1 plots was more homogeneous within Shipyard Lake (120 +/- 0) as compared to either Isadore's Lake (73.17 +/- 23.70), or Kearl Lake (97.22 +/- 10.48) (Table 9.14).

Bray-Curtis For Wet (P1) Plots

P1 plots were compared within each wetlands using the Bray-Curtis Index of Similarity (P=0.95) and converted to a positive value to make the index comparable to Jaccard's Index. Hence, a value of 1 is similar, while a value of 0 is dissimilar.

Selecting a cut-off of 0.5, only two paired plots (i.e., paired plots are two plots for which a similarity index >0.5 is given) within Isadore's Lake (Table 9.17) and only two paired plots within Kearl Lake were similar (Table 9.18), while six paired plots within Shipyard Lake were similar (Table 9.19). Similarity is based on species overlap and abundance (percent cover), hence the plots represent similar communities.

Table 9.17 Bray-Curtis Index of Similarity (p < .05) for P1 Plots in Isadore's Lake, Summer 2001

	IL-T1P1	IL-T2P1	IL-T3P1	IL-T4P1	IL-T5P1	IL-T6P1	IL-T7P1	IL-T8P1
IL-T1P1	1							
IL-T2P1	0.2	1						
IL-T3P1	0.252	0.426	1					
IL-T4P1	0.073	0.234	0.101	1				
IL-T5P1	0	0	0	0	1			
IL-T6P1	0	0	0	0.002	0.295	1		
IL-T7P1	0.202	0.341	0.433	0.047	0	0	1	
IL-T8P1	0.262	0.837	0.519	0.222	0	0.048	0.474	1

Note: Bray-Curtis has been converted to a positive index to make it comparable to Jaccards's Index.
1=similar
0=dissimilar.

Table 9.18 Bray-Curtis Index of Similarity (p < .05) in P1 Plots for Kearl Lake, Summer 2001

	KL-T1P1	KL-T2P1	KL-T4P1	KL-T5P1	KL-T6P1	KL-T7P1	KL-T9P1
KL-T1P1	1						
KL-T2P1	0	1					
KL-T4P1	0	0	1				
KL-T5P1	0.032	0.017	0.513	1			
KL-T6P1	0.005	0.003	0.083	0.136	1		
KL-T7P1	0.075	0	0	0.039	0.045	1	
KL-T9P1	0.028	0	0	0.574	0.003	0.039	1

Note: Bray-Curtis has been converted to a positive index to make it comparable to Jaccards's Index.
1=similar
0=dissimilar.

Table 9.19 Bray-Curtis Index of Similarity (p < .05) in P1 Plots in Shipyard Lake, Summer 2001

	SL-E901	SL-T3P 1	SL-T6P1	SL-T8P1	SL-T1P109	SL-T6AP1
SL-E901	1					
SL-T3P1	0.484	1				
SL-T6P1	0.667	0.634	1			
SL-T8P1	0.359	0.749	0.435	1		
SL-T6AP1	0.484	1	0.634	0.749	0.462	1

Note: Bray-Curtis has been converted to a positive index to make it comparable to Jaccards's Index.
1=similar
0=dissimilar.

The Bray-Curtis Index of similarity shows that plots within Shipyard Lake were more similar to each other compared to plots within either Isadore's or Kearl lakes (Table 9.20). The results could have been skewed by the small sample size. Therefore, future sampling should focus on sampling more wet plots to increase the sample number.

Table 9.20 Bray-Curtis Index of Similarity ($p < .05$) for Percent Species Cover Values for P1 Plots in Isadore's, Kearl and Shipyard Lakes, Summer 2001

Wetlands	Bray-Curtis Index[a] for P1 Plots Only			
	Number of samples[b]	Mean	Standard Deviation	Minimum/ Maximum
Shipyard Lakes	13; 5	0.513	0.282	0.003 / 1
Isadore's Lakes	28; 8	0.177	0.213	0 / 0.837
Kearl Lakes	21; 7	0.076	0.160	0 / 0.574

(a) Bray-Curtis has been converted to a positive index to make it comparable to Jaccards's Index.
1=similar
0=dissimilar.
(b) Number of comparisons within lake, followed by the number of actual wet plots within wetlands.

Water Chemistry

Water chemistry measurements included pH, temperature, dissolved oxygen, salinity and conductivity. Water chemistry samples were collected when possible. Average values for all plots are given for each lake in Table 9.21 and average values for all P1 plots for each wetlands are given in Table 9.22. Kruskal-Wallis test results ($p < .05$) showed no significant difference between lakes for either pooled or P1 plots results.

Isadore's Lake had the highest pH when water chemistry values for all plots were pooled, while Kearl Lake had the highest pH when only the wet plots were pooled. Shipyard Lake had the lowest pH for either comparison.

Isadore's Lake had the highest conductivity and salinity, while Kearl Lake had the lowest values for both parameters. Further, Kearl Lake had the highest value for dissolved oxygen, for both pooled plots and wet (P1) plots (Tables 9.21 and 9.22)

Table 9.21 Average Water Chemistry Values for All Plots of Isadore's, Kearl and Shipyard Lakes, 2001

Wetlands	pH		Temperature (ºC)		Dissolved Oxygen (mg/L)		Salinity (mg/L)		Conductivity (µS/cm)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Isadore's Lake (n = 9)[a]	7.78	0.27	21.58	0.93	3.93	2.62	0.26	0.03	516.00	58.98
Kearl Lake (n = 17)[a]	7.66	0.27	20.12	0.74	5.07	0.46	0.06	0.01	138.65	22.97
Shipyard Lake (n = 12)[a]	7.22	0.12	21.12	0.90	3.62	1.08	0.17	0.04	344.42	74.10

[a] n = the number of samples

Table 9.22 Average Water Chemistry Values for P1 Plots in Isadore's, Kearl and Shipyard Lakes, 2001

Wetlands	pH		Temperature (ºC)		Dissolved Oxygen (mg/L)		Salinity (mg/L)		Conductivity (µS/cm)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Isadore's Lake (n = 9)[a]	7.74	0.32	21.58	1.07	4.50	2.35	0.26	0.04	523.00	70.71
Kearl Lake (n = 17)[a]	7.79	0.22	20.46	0.63	5.23	0.36	0.06	0.02	142.67	25.45
Shipyard Lake (n = 12)[a]	7.22	0.12	21.28	0.66	3.61	1.13	0.18	0.004	365.00	7.21

[a] n = the number of samples

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10 ACID SENSITIVE LAKES

10.1 BACKGROUND INFORMATION

Acid deposition rates were modelled in the Oil Sands Region as part of a number of recent Environmental Impact Assessments (EIAs) for oil sands developments (Shell 1997, Suncor 1998, Syncrude 1998, Suncor 2000, OPTI 2000, Petro-Canada 2001). The most useful variable in assessing the effects of acid deposition in standing waters is the modelled Potential Acid Input (PAI, in units of keq/ha/yr). PAI includes wet and dry deposition by sulphur and nitrogen compounds from sources within the area being evaluated and from background sources, and accounts for the mitigating effect of base cations.

The estimated PAI values for acid sensitive lakes monitored by RAMP are shown in Table 10.1, using data from Suncor (2000), OPTI (2000), Petro-Canada (2001) and Rio Alto (2002). PAI values in this table represent combined acid deposition from all existing and approved oil sands developments at the time these EIAs were submitted (i.e., the baseline case) and from existing, approved and planned oil sands developments (i.e., the cumulative effects assessment [CEA] case, from the most recently submitted EIAs). PAI values are not available for lakes outside of the Oil Sands Region at this time. All projects were considered "fully developed" during modelling, suggesting the baseline acid deposition rates to these lakes may be higher than the current rate. Therefore, for the purpose of this document, the baseline PAI values are considered to represent potential "near-future" deposition rates. The CEA case PAI values provide an indication of future acid deposition rates if all approved and planned projects are built.

To allow the evaluation of the likelihood of soil and lake acidification in Alberta, the Target Loading Subgroup of the Clean Air Strategic Alliance (CASA) established guidelines for acid deposition, including the critical load, target load and monitoring load (CASA 1996, 1999). Of these, the critical load is the most useful for aquatic assessments. It is defined as the highest load that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems. The critical load was set at 0.25 keq/ha/yr for highly sensitive soils in Alberta, and was subsequently extended to sensitive aquatic systems based on a review by Schindler (1996). It is applicable at the spatial resolution of 1^{o} latitude by 1^{o} longitude cells and is not intended for evaluating the effects of acid deposition on individual lakes.

Table 10.1 Modelled Acid Deposition Rates and Critical Loads for Acid Sensitive Lakes Monitored by RAMP

Lake	Modelled PAI (Baseline = Existing and Approved Developments)			Modelled PAI (CEA = Existing, Approved and Planned Developments)[c] (keq/ha/yr)	Critical $Load_{PAI}$ (keq/ha/yr)	Critical Load Data Source
	Suncor Firebag EIA[a] (keq/ha/yr)	OPTI Long Lake EIA[b] (keq/ha/yr)	Petro-Canada Meadow Creek EIA[c] (keq/ha/yr)			
A21	(<0.15)[c]	**0.14**	**0.136**	**0.198**	0.117	WRS (2000)
A24	(<0.15)	**0.14**	**0.135**	**0.188**	0.024	WRS (2000)
A26	(<0.15)	**0.15**	**0.137**	**0.196**	0.048	WRS (2000)
A29	(<0.14)	**0.12**	**0.126**	**0.170**	0.064	WRS (2000)
A42	(<0.12)	(<0.12)	(<0.17)	(<0.17)	0.335	WRS (2000)
A47	(<0.12)	(<0.12)	(<0.17)	(<0.17)	0.279	WRS (2000)
A59	(<0.12)	(<0.11)	(<0.17)	(<0.17)	0.172	WRS (2000)
A86	(<0.12)	0.11	0.102[d]	0.120[d]	0.124	WRS (2000)
E15 (L15b)	0.18	0.31	0.224	0.338	0.656	WRS (2000)
L1	0.17	**0.21**	0.135	**0.243**	0.190	P-C (2001)
L4 (A-170)	0.16	0.20	0.130	0.240	0.247	WRS (2000)
L7	0.15	0.18	0.120	0.218	0.403	P-C (2001)
L8	0.15	0.18	0.116	0.202	0.608	P-C (2001)
L18 (Namur)	(<0.17)	(0.13)	0.097	0.129	0.223	P-C (2001)
L23 (Otasan)	**0.14**	**(0.12-0.13)**	**0.072**	**0.112**	0.049	P-C (2001)
L25 (Legend)	(<0.16)	**(0.12-0.13)**	(<0.17)	(<0.17)	0.112	D. Andrews (pers. comm.)
L28	(<0.13)	(<0.12)	(<0.17)	(<0.17)	0.096	D. Andrews (pers. comm.)
L30 (W. Clayton)	(<0.13)	**(0.13-0.15)**	(<0.17)	(<0.17)	0.015	WRS (2000)
L39 (A-150)	(<0.13)	(0.12-0.13)	0.055	0.092	0.271	WRS (2000)
L46 (Bayard)	0.13	(0.12-0.13)	0.067	0.103	0.327	P-C (2001)
L47	(0.13)	(0.12)	(<0.17)	(<0.17)	0.261	D. Andrews (pers. comm.)
L49	(0.13)	(0.12)	(<0.17)	(<0.17)	0.361	D. Andrews (pers. comm.)
L60	(0.14)	(0.12-0.13)	0.081	0.114	0.421	P-C (2001)

Notes: PAI values in parentheses are visual estimates based on positions of PAI contours on deposition maps.
Shaded and bolded PAI values are above the corresponding critical load.
PAI was predicted using the CALPUFF-3D dispersion model. Differences among EIAs in model parameters are provided by Appendix IV of the Petro-Canada Meadow Creek Project EIA (Petro-Canada 2001).
WRS = Western Resource Solutions.
P-C = Petro-Canada.
[a] Data from Firebag In-Situ Oil Sands Project EIA (Suncor 2000).
[b] Data from Long Lake Project EIA (OPTI 2000).
[c] Data from Meadow Creek Project EIA (Petro-Canada 2001); note exception identified by next footnote.
[d] Data from Kirby Project EIA (Rio Alto 2002).

Recent oil sands EIAs adopted the use of the lake-specific critical load, calculated based on the Henriksen steady state model (Henriksen et al. 1992, Rhim 1995). Use of this critical load allows assessment of the potential effects of acid deposition on individual lakes by comparison with the corresponding modelled PAI (e.g., Syncrude 1998, Suncor 2000, OPTI 2000, Petro-Canada 2001, Rio Alto 2002). The critical load takes into account the buffering capacity of the lake being evaluated and inputs of base cations from the drainage basin. It represents the amount of acid deposition below which acid neutralizing capacity (ANC) or pH remain above a specified threshold value. The ANC threshold value is referred to as the ANC_{lim} and has been set at 75 µeq/L (i.e., the value suggested for the Oil Sands Area by the NO_x and SO_x Management Working Group [NSMWG]). This value corresponds to a pH of 6, based on information presented by Western Resource Solutions (2000).

Critical loads of acidity have been calculated for all of the lakes monitored by RAMP and are presented for the lakes within the Oil Sands Region in Table 10.1. Critical loads for the RAMP lakes located in the Caribou Mountains and on the Canadian Shield were calculated by Western Resource Solutions, but will not be available until the final report is released by the NSMWG. The critical loads available for RAMP lakes at this time range from 0.015 to 0.656 keq/ha/yr (Table 10.1) and are subject to updates based on water chemistry data being collected by RAMP. The modelled baseline PAI values exceed the critical loads in four lakes in the Stony Mountains south of Fort McMurray (A21, A24, A26, A29), two lakes in the Birch Mountains (L23, L25), one lake in the headwaters of the Muskeg River (L1) and one lake north of the Birch Mountains (L30). Modelled cumulative acidic deposition rates exceed the critical loads in six of these lakes. Exceedances cannot be evaluated for the remaining two because the exact PAI values are not available. These results suggest that there is already some concern regarding acidification in the Oil Sands Region in the foreseeable future.

10.2 PH, ALKALINITY AND ACID SENSITIVITY

Field pH ranged between 4.3 and 7.6 in 2001, with 13 of the 32 lakes having pH <7 (the entire 2001 data set is presented in Appendix XII). Lab pH measurements were lower than field measurements, with the exception of five lakes near the low end of the pH range. The difference between lab and field pH was <1 pH unit for all lakes. As in previous years, lab pH was used as the primary measure of acidity.

The variation in pH among years has been relatively low (0.5 unit on average based minimum and maximum measurements for each lake) and progressive declines in pH were not observed in any of the lakes monitored (Figure 10.1).

Visual comparison of the combined pH data set for the 26 lakes sampled in all three years of monitoring also showed no decline over time (Figure 10.2). A decline in pH is unlikely at this time because pH usually does not change appreciably until most of the buffering capacity of a lake is lost.

Total alkalinity varied from 0 to 23.2 mg/L as $CaCO_3$ among lakes in 2001 (Figure 10.1). Using the sensitivity categories described by Saffran and Trew (1996), 13 of the 32 lakes were highly sensitive to acidic deposition (alkalinity of 0 to 10 mg/L as $CaCO_3$). Thirteen lakes were moderately sensitive (>10 to 20 mg/L) and six lakes showed only a low sensitivity (>20 mg/L). The maximum alkalinity measurement was below 25 mg/L as $CaCO_3$ in all of the lakes surveyed. Therefore, based on alkalinity, the set of lakes monitored in 2001 is appropriate for the objectives of this monitoring program (i.e., they represent a subset of the most sensitive lakes in northeastern Alberta).

There was a strong, non-linear relationship between alkalinity and pH in the 2001 data set (Figure 10.3). As in previous years, the "steepest" part of the curve was below the alkalinity value of 10 mg/L as $CaCO_3$. The lakes in this category are particularly susceptible to acidification, because even small changes in alkalinity will result in rapid changes in pH.

The magnitude of year-to-year variation in alkalinity was different among lakes. Of the 32 lakes with more than one year's data (including historical data), the difference between the minimum and maximum alkalinity values was <2 mg/L for 10 lakes, between 2 and 5 mg/L for 12 lakes and >5 mg/L for 10 lakes. Two-fold or greater variation in alkalinity among years was observed for 6 lakes (A21, A26, A47, L4, L46 and L47). Differences between consecutive years were considerably lower; only three lakes (A26, A47, L46) had differences >5 mg/L, and only between 1999 and 2000. The variation in alkalinity among years may partly reflect seasonal changes (i.e., samples were not collected at the exact same time each year) and year-to-year differences in hydrology.

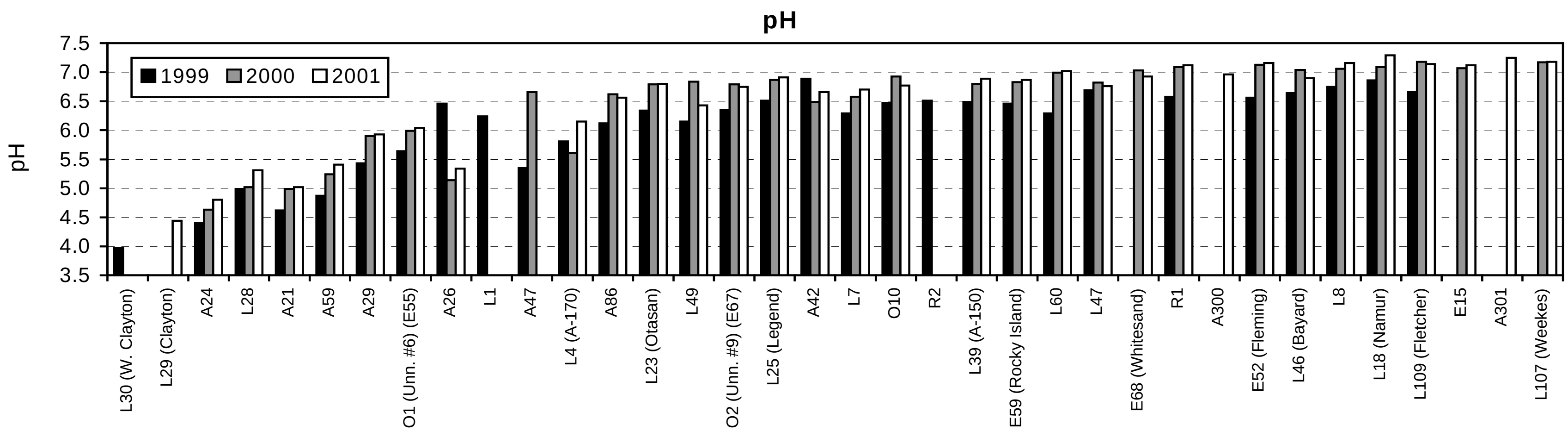
Although the available data are insufficient for a trend analysis, visual examination of the alkalinity data revealed no consistent declines in alkalinity in any of the lakes monitored (Figure 10.1). Additionally, the box and whisker plot of the combined alkalinity data set for the 26 lakes sampled in all three years of monitoring by RAMP showed no appreciable change over time (Figure 10.2).

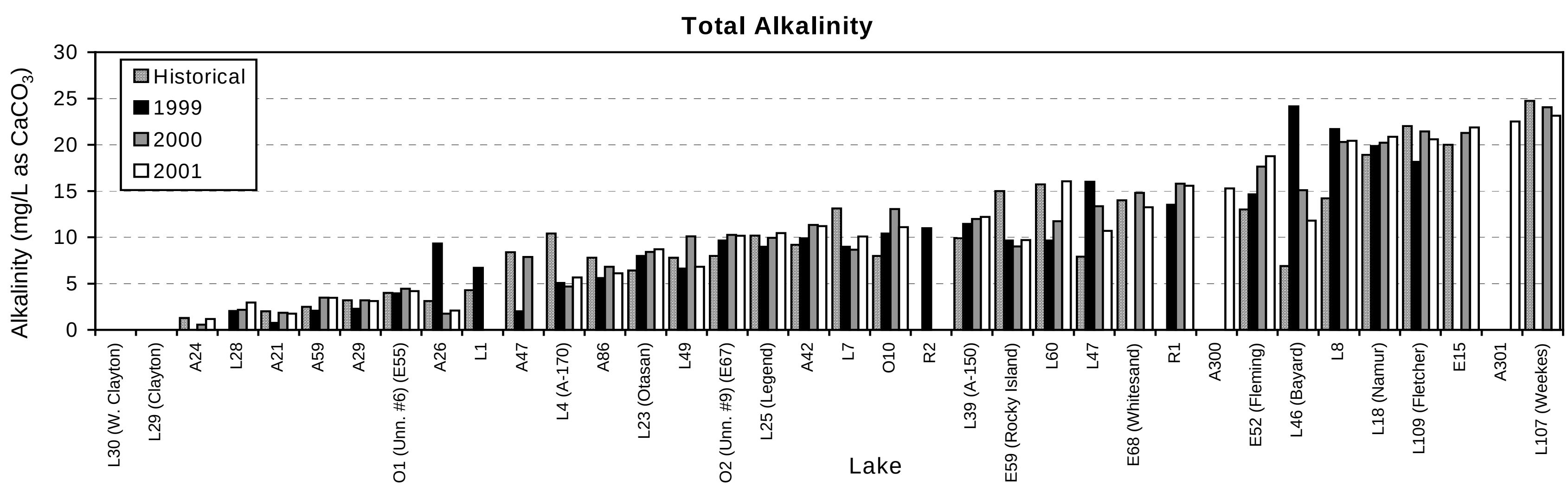
Alkalinity was significantly correlated with the critical load (Pearson correlation, r=0.79, P=0.00001; Figure 10.4 shows the mean of available alkalinity data for each lake). Critical loads suggest a slightly different order of acid sensitivity compared to alkalinity. This difference arises from the fact that critical loads are not entirely based on existing water chemistry, but rather incorporate runoff volume in an attempt to account for the supply of base cations from the drainage basin. For example, if two lakes have similar alkalinity but one has a considerably larger drainage area (and hence receives more runoff annually), the lake with the larger drainage area would have a higher critical load (i.e., it would be less acid sensitive) because it has a greater annual supply of buffering chemicals.

Examining Table 10.2 reveals that some of the lakes have critical loads well above the predicted deposition rates and, despite low alkalinity values, are probably not highly sensitive to acidification at the predicted deposition rates in the Oil Sands Region. The availability of critical loads and modelled deposition rates could thus be used to identify which of the lakes monitored by RAMP are at the greatest risk of acidification. This information can also be used to direct more specific investigations, to intensify monitoring, or target specific research questions.

Since the monitoring data for this component consist of single samples collected during the fall, it is important to ascertain that fall data provide a reliable indication of acid sensitivity and lake water chemistry in general. Seasonal data are available for three lakes (L4, L7 and L25), for four or five years. Comparisons of mean open-water alkalinity with the fall alkalinity values indicate that fall measurements were higher in most years, by up to 3.8 mg/L (L25 in 1989), although in most cases the difference was <2.5 mg/L (Figure 10.5). Since these results suggest that fall data may underestimate acid-sensitivity, a more detailed examination of seasonal fluctuations in water chemistry appears warranted for the lakes monitored by RAMP.

Figure 10.1 Variation in pH and Total Alkalinity Among Years in the Lakes Monitored





Notes: All alkalinity measurements were 0 mg/L in lakes L30 and L29.
Historical alkalinity measurement was 0 mg/L in Lake L28.
1999 alkalinity measurement was 0 mg/L in Lake A24.

Figure 10.2 Box and Whisker Plots of pH and Alkalinity for Lakes Sampled in all Three Years of Acid Sensitive Lake Monitoring

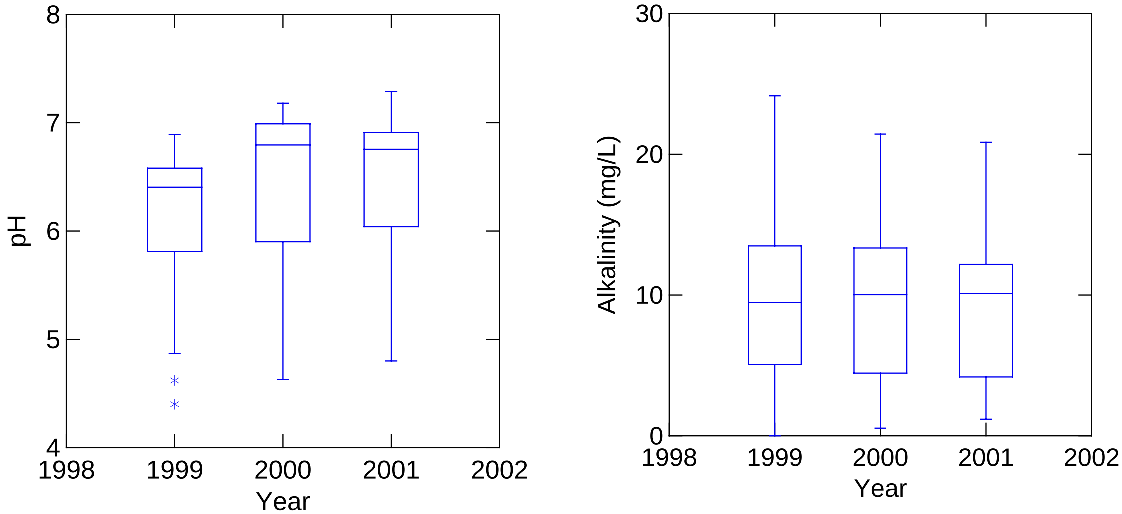


Figure 10.3 The Relationship Between Total Alkalinity and pH in the 2001 Data Set

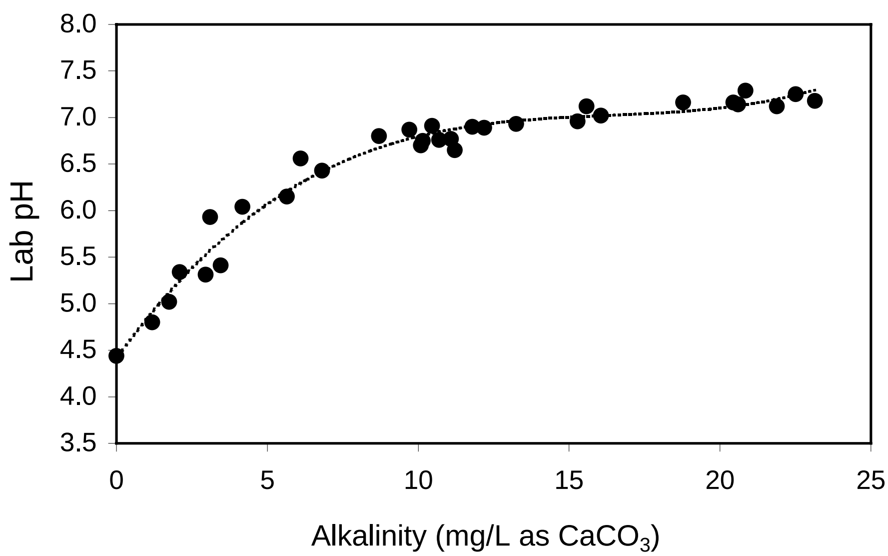


Figure 10.4 Plot of Mean Alkalinity Versus Critical Load for the Lakes Monitored in the Oil Sands Region

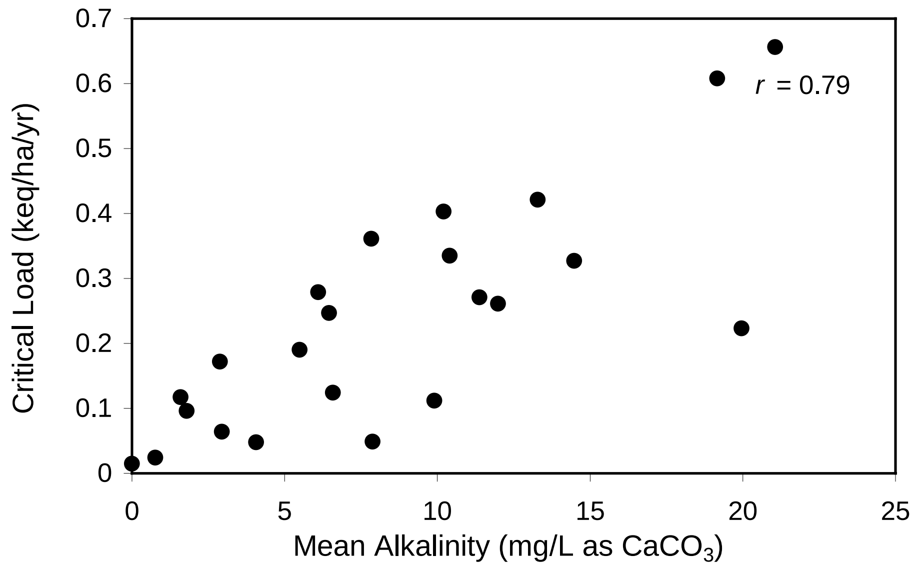
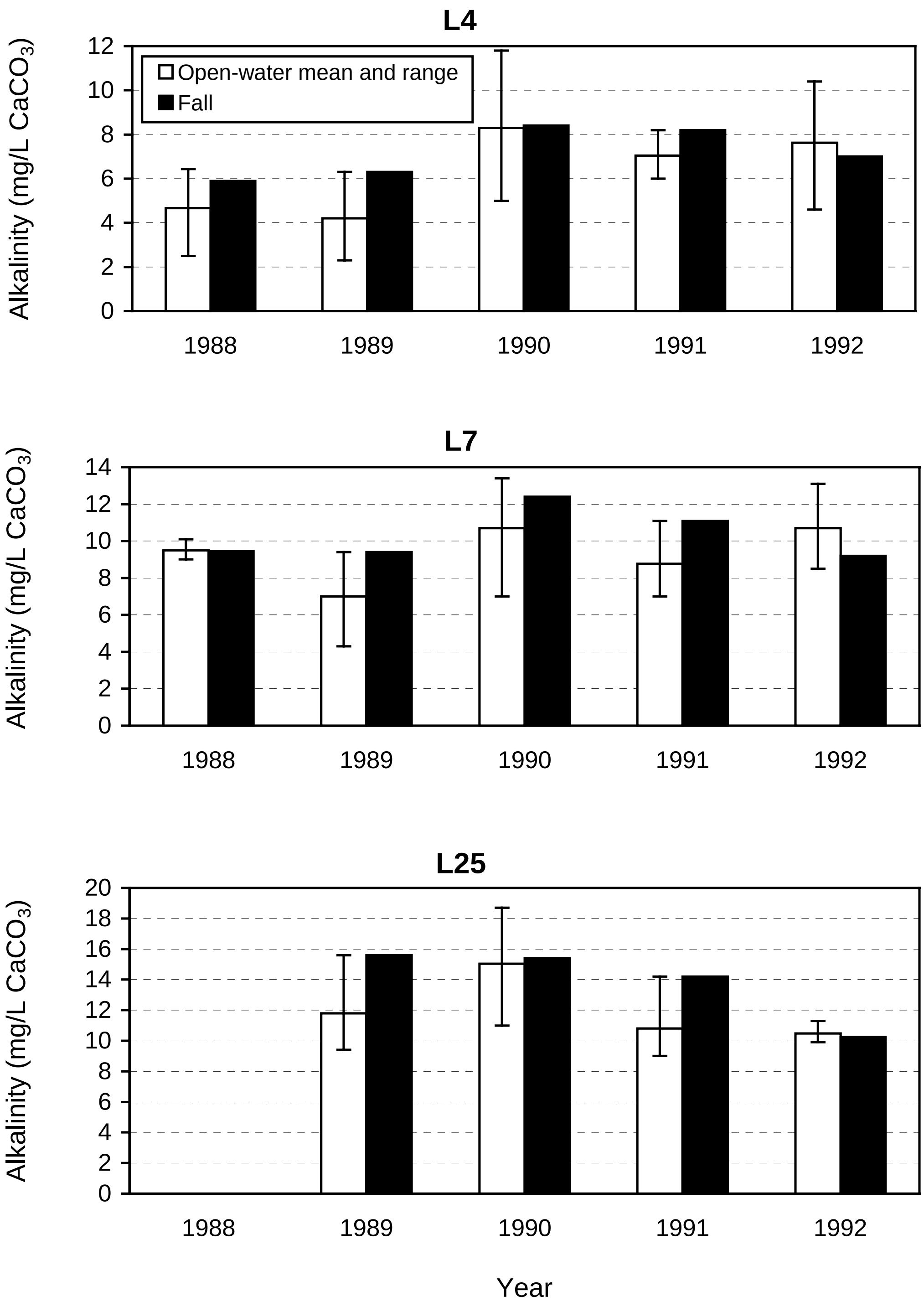


Figure 10.5 Comparison of Mean Open-Water Alkalinity With Alkalinity Measured in the Fall for Lakes With Seasonal Data



10.3 MAJOR IONS, COLOUR AND DOC

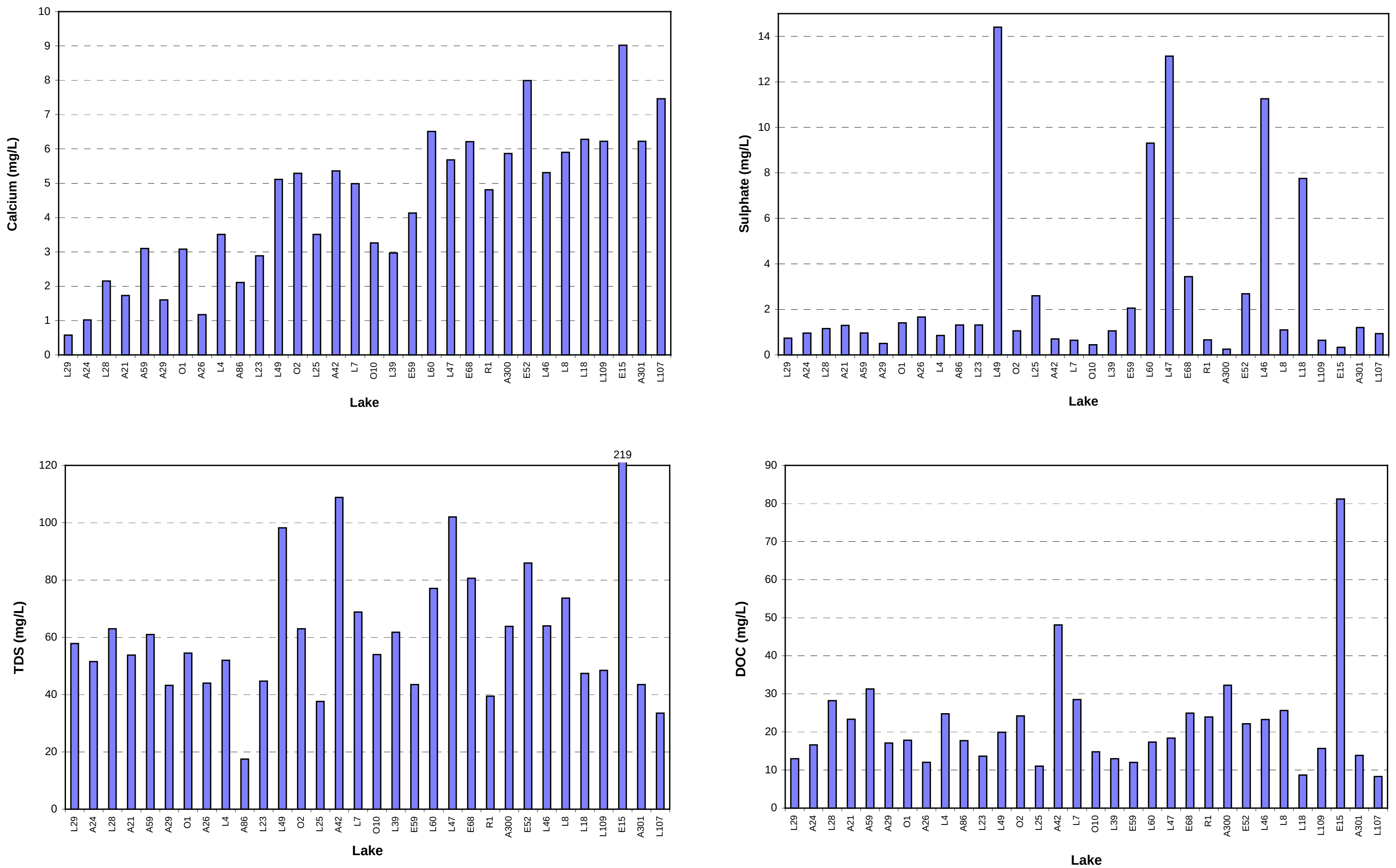
Concentrations of dissolved ions were low to moderate in the lakes monitored in 2001. TDS ranged between 17.5 and 113.5 mg/L, with one outlier (E15; 219.3 mg/L) (Figure 10.6). Conductivity, TDS and concentrations of most ions varied without obvious grouping of lakes at any level (e.g., calcium and TDS in Figure 10.6). As in previous years of monitoring, the variation in sulphate concentration was discontinuous, with elevated levels observed in a cluster of lakes in the Birch Mountains (L18, L46, L47, L49, L60) relative to the other lakes.

Ion balance calculations revealed anion deficits in all lakes, which appeared related to the presence of organic anions. The ratio of (total cations)/(total anions) ranged from 1.08 to 4.42 on an equivalent basis and about half of the lakes had ratios >1.5 (Table XII.1, Appendix XII). The difference between total cations and total anions was significantly related to DOC (linear regression, r^2=0.72, P<0.00001; Figure 10.7). Since DOC is an indicator of organic compounds in surface waters (Sullivan 2000), this relationship suggests that the excess cations were balanced by organic anions.

Colour and DOC spanned wide ranges in the lakes monitored, as intended during the selection of lakes (DOC in Figure 10.6; colour in Table XII.1, Appendix XII). There was no obvious break-point between clear water and brown water lakes in terms of either parameter. Lakes in the Caribou Mountains tended to have higher colour and DOC than those on the Canadian Shield, with a few exceptions. The lakes in the Oil Sands Region spanned the full range of the colour and DOC data. Colour was significantly correlated with DOC, but there were three conspicuous outliers (A42, E15 and A300; the three lakes with the highest DOC in the data set) (Pearson correlation, r=0.75, P<0.00001, outliers removed).

The sum of base cations was significantly related to alkalinity (linear regression, r^2=0.86, P<0.00001, Figure 10.8). In lakes with low DOC content, a 1:1 relationship would be expected between these variables (Sullivan 2000). In the case of the RAMP lakes (characterized by elevated DOC), the deviation from this relationship may be due to the presence of organic acids, which tend to lower ANC relative to base cation concentrations (Sullivan 2000). There was a significant but weak relationship between DOC and the residuals from the regression line shown in Figure 10.8 (linear regression, r^2=0.23, P=0.009), suggesting the variation in alkalinity was at least partly related to the presence of organic acids.

Figure 10.6 Calcium, Sulphate, Total Dissolved Solids (TDS) and Dissolved Organic Carbon (DOC) in the Lakes Sampled in 2001



Note: Lakes are ordered by increasing alkalinity.

The ratio of bicarbonate to divalent cations was also calculated for each lake monitored by RAMP. This ratio is expected to equal one under pristine conditions, unless organic acids are present in elevated concentrations, or the lakes being evaluated are located in unusual geological settings (Schindler 1996). Both of these conditions may apply to the RAMP lakes, since DOC is elevated in most lakes and elevated sodium concentration is common. Acidification causes a decline in bicarbonate and an increase in divalent cations by increased leaching from soils and lake sediments. As a result, the ratio is more sensitive to acidification than either the numerator or the denominator, and a declining ratio over time may indicate progressive acidification.

The ratio of bicarbonate to divalent cations was <1 for all lakes (Table 10.2) based on the 1999 to 2001 RAMP data sets. Considerably more data are available for lakes L4, L7, L18 and L25, as discussed by Schindler (1996). At this time, available data are insufficient to statistically evaluate trends over time using this approach for most RAMP lakes. Of 25 the lakes with three years' data, three (L8, L46, L47) show a decline in this ratio with each consecutive year, seven (A59, L23, L25, L28, L39, E52, O2) show an increase and the remaining 15 show no consistent trend over time. The lakes with declines in the ratio are not subject to predicted exceedances of the critical load (Table 10.1). The absolute changes in the ratios for these lakes are small and within the year-to-year variation documented by Schindler (1996) for Lakes L4, L7, L18 and L25. Visual comparison of the combined data set for the 26 lakes sampled in all three years of monitoring under RAMP also showed no decline in the ratio (Figure 10.9).

Figure 10.7 The Relationship Between Dissolved Organic Carbon (DOC) and (Sum of Cations – Sum of Anions) in the 2001 Data Set

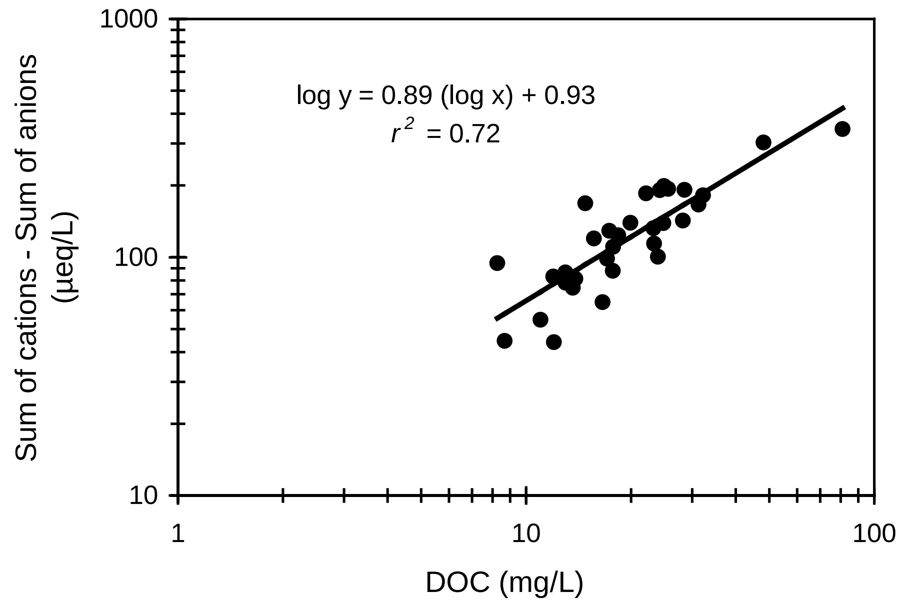


Figure 10.8 The Relationship Between the Sum of Base Cations and Alkalinity in the 2001 Data Set

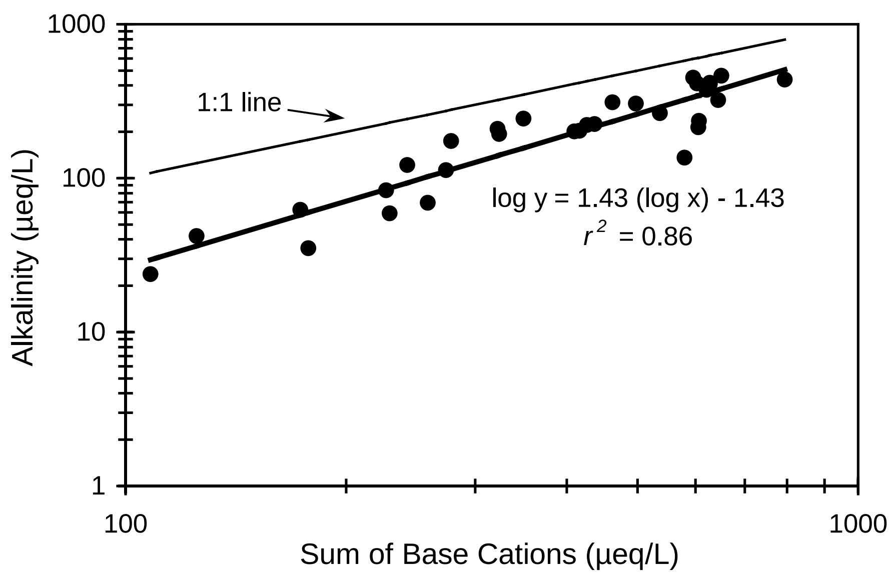
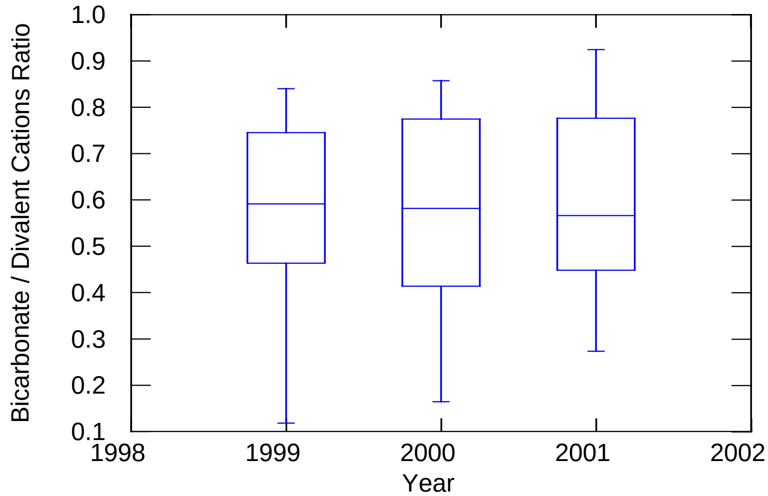


Table 10.2 Bicarbonate/Divalent Cations Ratios for the Acid Sensitive Lakes Monitored by RAMP in 1999, 2000 and 2001

Lake	$HCO_3^- / (Ca^{2+}+Mg^{2+})$ (Equivalents)		
	1999	2000	2001
Oil Sands Region			
A21	0.12	0.30	0.27
A24	-[(a)]	0.16	0.29
A26	0.64	0.40	0.48
A29	0.46	0.63	0.53
A42	0.58	0.60	0.59
A47	0.39	0.57	-
A59	0.20	0.30	0.32
A86	0.67	0.76	0.70
A300	-	-	0.78
E15 (L15b)	-	0.70	0.72
L1	0.55	-	-
L4 (A-170)	0.39	0.34	0.45
L7	0.56	0.45	0.54
L8	0.84	0.80	0.79
L18 (Namur)	0.84	0.83	0.86
L23 (Otasan)	0.67	0.72	0.75
L25 (Legend)	0.75	0.77	0.80
L28	0.25	0.26	0.37
L29 (Clayton)	-	-	0
L30 (W. Clayton)	-	-	-
L39 (A-150)	0.82	0.86	0.92
L46 (Bayard)	0.77	0.57	0.55
L47	0.57	0.56	0.49
L49	0.31	0.42	0.35
L60	0.47	0.46	0.63
Caribou Mountains			
E52 (Fleming)	0.59	0.65	0.68
E59 (Rocky Island)	0.64	0.66	0.66
E68 (Whitesand)	-	0.59	0.57
O1 (Unnamed #6) (E55)	0.35	0.41	0.40
O2 (Unnamed #9) (E67)	0.50	0.51	0.54
O3	1.12	-	-
Canadian Shield			
A301	-	-	0.88
L107 (Weekes)	-	0.93	0.92
L109 (Fletcher)	0.75	0.84	0.83
O10	0.66	0.80	0.78
R1	0.76	0.84	0.82
R2	0.61	-	-
R3	1.00	-	-

[(a)] - = No data.

Figure 10.9 Box and Whisker Plot of the Bicarbonate to Divalent Cations Ratio for Lakes Sampled in all Three Years of Acid Sensitive Lake Monitoring



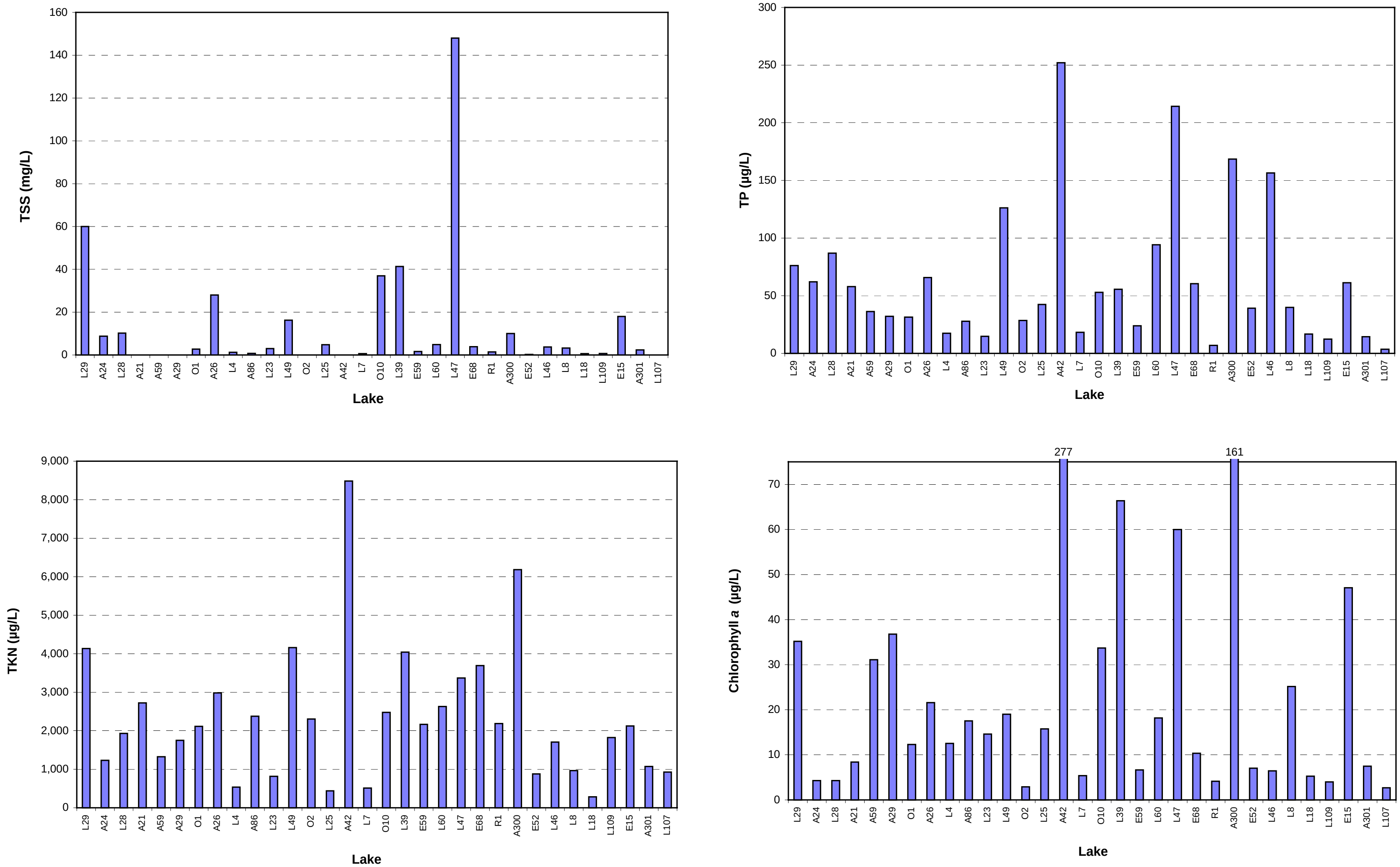
10.4 SUSPENDED SOLIDS, NUTRIENTS AND TROPHIC STATUS

The concentration of TSS was elevated in a number of lakes (Figure 10.10), and appeared linked to lake depth. All TSS measurements above 10 mg/L were in samples from lakes with maximum depths <2 m (Figure 10.11). The most likely reason for this observation is wind-induced mixing, which is common in shallow lakes.

Nutrient and chlorophyll *a* concentrations varied widely among lakes (Figure 10.10) and appeared to reflect suspended sediment concentrations. Based on chlorophyll *a* concentration, 12 lakes were mesotrophic (2.5 to 8 µg/L), 10 lakes were eutrophic (8 to 25 µ/L) and 10 lakes were hyper-eutrophic (>25 µg/L) (trophic categories from Mitchell and Prepas 1990). There were significant correlations between TSS and TN (r=0.40), TKN (r=0.40) and TP (r=0.62) (Pearson correlations, P<0.05 for all tests; scatter-plots in Figure 10.12). Although there was no significant correlation between TSS and chlorophyll *a*, a number of the lakes with elevated TSS (>15 mg/L) were in the hyper-eutrophic category.

As in previous years, there was a weak log-log relationship between TP and chlorophyll *a* (Figure 10.13). Concentrations of phosphorus and nitrogen variables were significantly intercorrelated (Pearson correlations; P<0.005) with the exception of TDP and nitrite+nitrate. Since this RAMP component is focused on acidification, additional analysis and interpretation of the nutrient and chlorophyll *a* data was not warranted.

Figure 10.10 Total Suspended Solids (TSS), Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN) and Chlorophyll *a* in the Lakes Sampled in 2001



Note: Lakes are ordered by increasing alkalinity.

Figure 10.11 Plot of Maximum Lake Depth Versus TSS in the Lakes Sampled in 2001

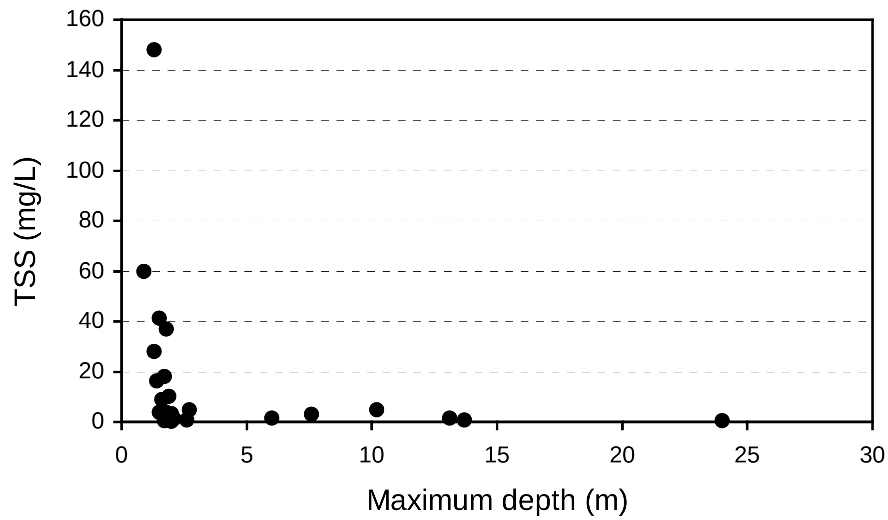


Figure 10.12 Plot of TSS Versus Nutrient Concentrations for the Lakes Sampled in 2001

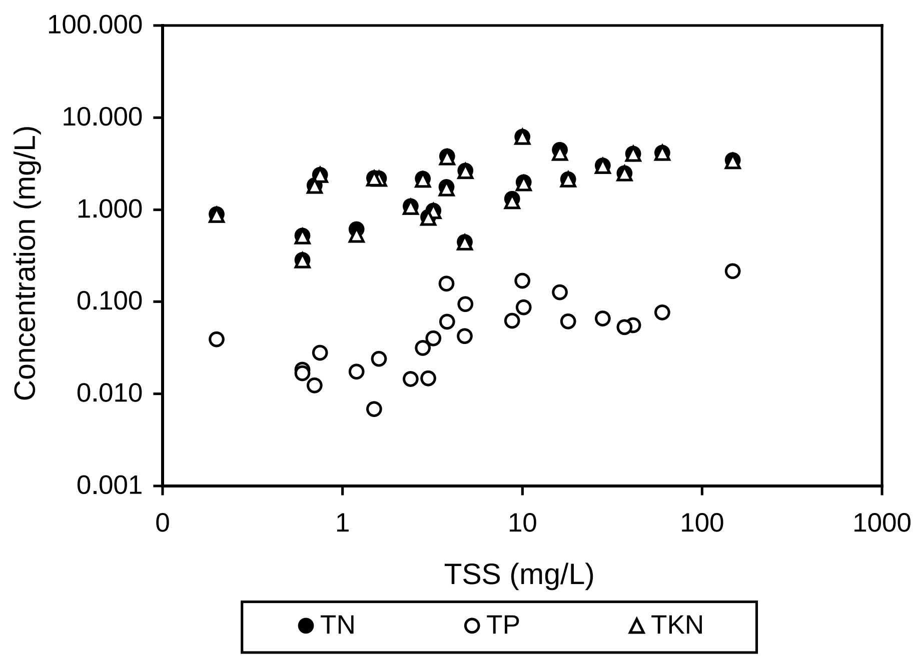
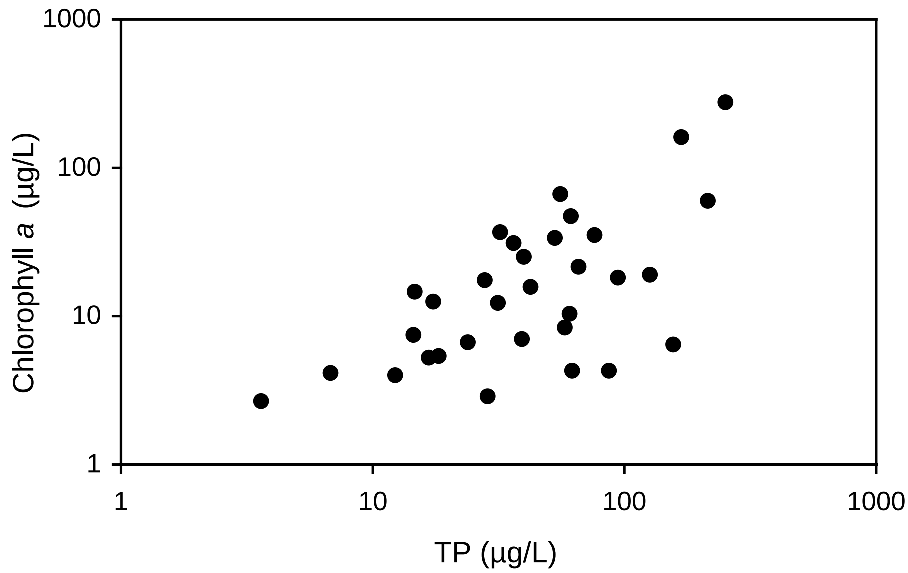


Figure 10.13 Plot of TP Versus Chlorophyll *a* Concentrations for the Lakes Sampled in 2001



10.5 SUMMARY

The RAMP long-term acidification monitoring network was established in 1999. It consists of 32 moderately to highly acid sensitive lakes in north-eastern Alberta, including 22 lakes in the Oil Sands Region, five lakes in the Caribou Mountains and five lakes on the Canadian Shield. Water chemistry is evaluated annually, with special attention to indicators of acidification.

The most recent estimates of acid deposition rates and critical loads were summarized for the lakes in the network to provide an indication of which lakes are at the greatest potential risk of acidification. The five lakes located closest to the area of most intense oil sands development (E15, L1, L4, L7 and L8) have the highest predicted acid deposition rates, but the critical load is predicted to be exceeded for only one of these lakes (L1). Modelled acid deposition rates are above the critical loads for seven additional lakes, including two lakes in the Birch Mountains (L23, L25), one lake north of the Birch Mountains (L30) and four lakes in the Stony Mountains (A21, A24, A26, A29). The use of critical loads to evaluate potential effects of acid deposition is currently being refined by the NSMWG.

Acidity-related variables (pH, alkalinity) showed no indication of changes related to acidification in 2001 compared to previous years' data. Concentrations of dissolved ions were low to moderate. Colour and DOC spanned wide ranges.

Ion balance calculations revealed anion deficits in all lakes, which appeared related to the presence of organic anions.

The bicarbonate to divalent cations ratio was <1 for all lakes, due to elevated concentrations of other negatively charged species, which include sulphate, chloride and organic anions. At this time, the available data are insufficient to evaluate trends over time using this approach for most RAMP lakes. The year-to-year changes in this ratio since 1999 were within the typical year-to-year variation observed for lakes with long-term data sets.

Suspended sediment levels were elevated in a number of lakes and appeared related to lake depth. This suggests that TSS may have been influenced by wind induced mixing in shallow lakes. Concentrations of a number of nutrients were significantly correlated with TSS.

The 32 lakes varied widely in nutrient and chlorophyll *a* concentrations. Based on chlorophyll *a* concentration, 12 lakes were mesotrophic, 10 lakes were eutrophic and 10 lakes were hyper-eutrophic. Trophic status designations for the shallow lakes also may have been affected by the variation in suspended sediments. There was a weak relationship between TP and chlorophyll *a*. Concentrations of phosphorus and nitrogen variables were significantly intercorrelated with the exception of TDP and nitrite+nitrate.

The data collected during the third year of acid sensitive lake monitoring indicate that relative to 1999, 2000 and historical data, changes related to acidification have not occurred. As this component is still in its initial phase of implementation, it is expected to evolve as new information and needs dictate. Potential changes to the program include addition of acid sensitive lakes close to sources of acidifying emissions, directing research towards issues related to temporal changes in lake chemistry and sampling times, and studying groundwater fluxes to lakes that have critical load exceedances or are close to exceedance.

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11 NON-CORE PROGRAMS

11.1 BASELINE WATER QUALITY SOUTH OF FORT MCMURRAY

Water quality results of the fourteen lakes monitored in 2001, along with available historical data are summarized in the following sections.

11.1.1 OPTI Lakes

All of the lakes were neutral to slightly alkaline (pH between 7.0 to 8.6), with alkalinity ranging from 8 to 115 mg/L (Tables 11.1 and 11.2). In Unnamed Lakes 1 and 2 and in Canoe, Long, Birch and Pushup lakes, dissolved salts were low (conductivity ≤93 µS/cm, total dissolved solids ≤90 mg/L). Hardness concentrations were relatively low in all lakes. Total and dissolved organic carbon and colour were in the characteristic ranges for lakes fed by brown water streams. Field data indicated that stratification did not occur within any of the lakes (Table 11.3).

In 2001, nutrient concentrations were moderate in most lakes, although total phosphorus concentrations exceeded the chronic guideline for the protection of aquatic life in Long Lake and Unnamed Lake 3 in spring and in all lakes in fall (Tables 11.1 and 11.2). Metal concentrations were generally low in all lakes, with the exception of aluminum in spring 2001 (Table 11.1). In spring, the total aluminum concentration exceeded the chronic aquatic life guideline in 11 lakes and exceeded the acute aquatic life guideline in Birch, Sucker, Canoe, Caribou Horn and Kiskatinaw lakes. In all lakes, except Poison Lake, the concentration of total iron was higher than the human health guideline in spring and fall. Total iron levels also were higher than the chronic aquatic life guideline in Canoe and Birch lakes in spring and in Birch and Frog lakes, and Unnamed Lake 2 in fall 2001. Total lead concentrations were higher than the chronic aquatic life guidelines in Canoe and Frog lakes in spring. However, the levels of total lead in fall 2001 were generally less than the detection limit and occasionally the detection limit was greater than the hardness-dependent chronic aquatic life guideline (Table 11.2). Total chromium concentrations exceeded chronic aquatic life guidelines in Long, Pushup, Rat, Poison and Frog lakes and in Unnamed lakes 1, 2 and 3 in spring 2001 (Table 11.1).

In 2001, most parameter concentrations, except total aluminum and zinc, were similar to 2000 values. Total aluminum concentrations were similar between years in fall but total aluminum levels were higher in spring 2001 (0.14 to 2.02 mg/L) than in spring 2000 (<0.02 to 0.15 mg/L). Total zinc concentrations were generally lower in fall 2001 than in 2000, when aquatic life guidelines were occasionally exceeded (Table 11.2).

Table 11.1 Water Quality of Selected Lakes in the OPTI Long Lake Project Local Study Area, Spring 2000 and 2001

Parameter	Units	Canoe Lake		Long Lake		Pushup Lake		Birch Lake	Sucker Lake	Rat Lake	Poison Lake	Frog Lake	Caribou Lake	Kiskatinaw Lake	Unnamed Lake 1	Unnamed Lake 2	Unnamed Lake 3
Year Sampled		**2000**	**2001**	**2000**	**2001**	**2000**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**	**2001**
Field Measured																	
pH		8.5	7.9	8.1	7.8	8.1	8.4	7.8	8.5	8.5	**8.6** [A,C]	8	8.1	8.2	7	7	**8.6** [A,C]
specific conductance	uS/cm	-	85	-	65	-	77	87	212	191	128	163	172	184	24	33	197
temperature	°C	-	11.5	-	9.5	-	10.5	9.7	9.6	11.3	9.2	10.4	12.4	12.2	9.2	10.9	9.8
dissolved oxygen	mg/L	-	9.1	-	10	-	10.8	9.9	10.1	9.9	10.1	9.2	8.8	9.2	9.6	9.8	10.8
redox potential	mV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conventional Parameters																	
colour	T.C.U.	50	50	50	70	30	20	100	25	20	25	60	50	50	70	140	50
conductivity	uS/cm	88	92	88	70	86	83	92	226	204	138	176	184	195	27	36	209
dissolved organic carbon	mg/L	18	19	15	18	14	15	23	18	16	15	24	17	17	19	22	27
hardness	mg/L	39	38	33	28	33	33	41	94	91	58	74	84	89	9	16	87
pH		7.2	7.4	7.7	7.1	7.2	7.5	7.3	8	8	7.9	7.7	7.9	8	**6.1** [A,C]	6.5	7.8
total alkalinity	mg/L	40	40	37	26	39	38	41	109	99	67	83	87	96	8	10	102
total dissolved solids	mg/L	120	80	80	90	70	90	120	170	130	110	140	120	150	60	90	190
total organic carbon	mg/L	21	21	18	21	16	16	23	18	16	15	24	19	20	22	28	30
total suspended solids	mg/L	22	7	< 3	9	6	6	4	6	3	< 3	5	< 3	< 3	3	< 3	14
Major Ions																	
bicarbonate	mg/L	48	48	45	32	48	47	50	133	120	81	102	106	117	9	13	124
calcium	mg/L	10	10	9	7	9	9	11	25	25	17	20	22	23	2	4	25
carbonate	mg/L	-	< 5	-	< 5	-	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
chloride	mg/L	1	2	< 1	< 1	< 1	< 1	1	2	1	2	1	1	< 1	1	1	< 1
magnesium	mg/L	3	3	3	2	2	2	3	8	7	4	6	7	7	1	1	6
potassium	mg/L	1	1	1	1	2	3	2	2	1	1	1	1	1	2	1	2
sodium	mg/L	3	4	4	4	2	2	3	10	6	5	8	5	6	< 1	1	10
sulphate	mg/L	2	2	4	6	< 1	1	2	4	3	1	2	3	2	2	3	3
sulphide	mg/L	0.013	< 0.003	**0.022** [C]	< 0.003	**0.02** [C]	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Nutrients and Chlorophyll *a*																	
nitrate + nitrite	mg/L	< 0.1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
nitrogen-ammonia	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	0.57	0.23	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
nitrogen-kjeldahl	mg/L	1.3	1.5	1	1.5	1.5	1.7	1.7	1.7	1.9	2.3	2.2	1.5	1.6	1.5	1.2	2.6
nitrogen, total	mg/L	< 0.1	< 0.1	< 0.1	< 0.1	1.5 [C]	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
phosphorus, total	mg/L	0.048	0.039	0.028	**0.059** [C]	0.036	0.038	0.025	0.032	0.025	0.021	0.037	0.012	0.017	0.025	0.03	**0.068** [C]
phosphorus, dissolved	mg/L	0.015	0.013	0.02	0.022	0.008	0.01	0.011	0.005	0.012	0.003	0.014	0.004	0.009	0.016	0.015	0.024
chlorophyll a	µg/L	12	-	6	-	10	-	-	-	-	-	-	-	-	-	-	-
Biological Oxygen Demand																	
biological oxygen demand		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General Organics																	
naphthenic acids	mg/L	2	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-
total phenolics	mg/L	0.002	-	0.004	-	0.003	-	-	-	-	-	-	-	-	-	-	-
total recoverable hydrocarbons	mg/L	2.7	-	2.6	-	1.9	-	-	-	-	-	-	-	-	-	-	-
Total Metals																	
aluminum (Al)	mg/L	**0.15** [C]	**2.02** [A,C]	0.03	**0.23** [C]	< 0.02	**0.14** [C]	**1.97** [A,C]	**1.97** [A,C]	**0.14** [C]	0.09	**0.17** [C]	**1.95** [A,C]	**2.05** [A,C]	0.1	**0.14** [C]	**0.17** [C]
antimony (Sb)	mg/L	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]	**< 0.005** [D>H]
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table 11.1 Water Quality of Selected Lakes in the OPTI Long Lake Project Local Study Area, Spring 2000 and 2001 (continued)

Parameter	Units	Canoe Lake		Long Lake		Pushup Lake		Birch Lake	Sucker Lake	Rat Lake	Poison Lake	Frog Lake	Caribou Lake	Kiskatinaw Lake	Unnamed Lake 1	Unnamed Lake 2	Unnamed Lake 3
Year Sampled		2000	2001	2000	2001	2000	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001	2001
barium (Ba)	mg/L	0.017	0.015	0.008	0.008	0.01	0.007	0.017	0.027	0.018	0.021	0.022	0.011	0.014	0.005	0.007	0.014
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.02	0.07	0.02	0.02	0.01	0.02	0.03	0.07	0.03	0.06	0.07	0.06	0.06	< 0.002	0.01	0.03
cadmium (Cd)	mg/L	**< 0.0002 (D>C)**	**< 0.0002 (D>C)**	**< 0.0002 (D>C)**	**< 0.0002 (D>C)**	**< 0.0002 (D>C)**	**< 0.0002 (D>C)**	**< 0.0002 (D>C)**	< 0.0002	< 0.0002	**< 0.0002 (D>C)**	< 0.0002	< 0.0002	< 0.0002	**< 0.0002 (D>C)**	**< 0.0002 (D>C)**	< 0.0002
calcium (Ca)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
chromium (Cr)	mg/L	< 0.0008	< 0.0008	< 0.0008	**0.0021 (C)**	< 0.0008	**0.0021 (C)**	< 0.0008	< 0.0008	**0.0016 (C)**	**0.002 (C)**	**0.0019 (C)**	< 0.0008	< 0.0008	**0.0013 (C)**	**0.0016 (C)**	**0.0025 (C)**
cobalt (Co)	mg/L	< 0.0002	0.0003	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0003	0.0003	< 0.0002	< 0.0002	< 0.0002	0.0002	0.0003	< 0.0002	< 0.0002	< 0.0002
copper (Cu)	mg/L	**0.005 (C)**	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	0.001	0.001
iron (Fe)	mg/L	**0.48 (C,H)**	**0.45 (C,H)**	**0.11 (H)**	**0.23 (H)**	**0.27 (H)**	**0.16 (H)**	**0.47 (C,H)**	**0.25 (H)**	**0.06 (H)**	**0.11 (H)**	**0.14 (H)**	**0.17 (H)**	**0.24 (H)**	**0.18 (H)**	**0.19 (H)**	**0.07 (H)**
lead (Pb)	mg/L	**0.0096 (C)**	**0.0016 (C)**	0.0001	0.0002	< 0.0001	0.0003	0.0005	0.0005	0.0004	0.0004	**0.0034 (C)**	0.0007	0.0006	0.0005	0.0008	0.0004
lithium (Li)	mg/L	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	0.009	< 0.006	0.007	0.008	< 0.006	< 0.006	< 0.006	< 0.006	0.007
magnesium (Mg)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
manganese (Mn)	mg/L	**0.042 (H)**	**0.035 (H)**	0.006	**0.018 (H)**	**0.066 (H)**	**0.076 (H)**	**0.044 (H)**	**0.154 (H)**	**0.026 (H)**	**0.027 (H)**	**0.028 (H)**	**0.008 (H)**	**0.027 (H)**	**0.026 (H)**	**0.008 (H)**	**0.051 (H)**
mercury (Hg)	mg/L	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**0.00002 (H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**	**< 0.00002 (D>H)**
molybdenum (Mo)	mg/L	0.0001	0.0014	< 0.0001	0.0002	< 0.0001	0.0003	0.0006	0.0007	0.0003	0.0003	0.0002	0.0006	0.0006	< 0.0001	0.0002	0.0002
nickel (Ni)	mg/L	0.001	0.0101	0.0007	0.0012	0.0003	0.0014	0.0104	0.0105	0.0015	0.0015	0.0017	0.0106	0.0108	0.0009	0.0012	0.0022
potassium (K)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008
silicon (Si)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
silver (Ag)	mg/L	**< 0.0004 (D>C)**	< 0.0001	**< 0.0004 (D>C)**	< 0.0001	**< 0.0004 (D>C)**	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
sodium (Na)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
strontium (Sr)	mg/L	0.03	0.04	0.04	0.04	0.03	0.03	0.04	0.1	0.09	0.08	0.08	0.06	0.06	0.01	0.01	0.08
sulphur (S)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
thallium (Tl)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
titanium (Ti)	mg/L	0.0039	0.0006	< 0.0006	0.0018	< 0.0006	0.0009	< 0.0006	0.0007	0.0009	0.0008	0.0016	0.0006	0.002	< 0.0006	0.001	0.0011
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
vanadium (V)	mg/L	0.0004	0.0007	< 0.0002	0.0006	< 0.0002	< 0.0002	0.0005	0.0004	0.0002	< 0.0002	0.0004	0.0006	0.0006	0.0004	0.0005	0.0003
zinc (Zn)	mg/L	0.018	0.009	< 0.004	0.007	< 0.004	0.02	0.005	0.007	0.026	0.021	0.033 (C)	0.008	0.014	0.009	0.018	0.011

Note: Bolded concentrations are higher than water quality guidelines.
[A] = Concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
[C] = Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
[H] = Concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
[D>] = Analytical detection limit was higher than the relevant water quality guideline(s).
- = No data.

Table 11.2 Water Quality of Selected Lakes in the OPTI Long Lake Project Local Study Area, Fall 2000 and 2001

Parameter	Units	Canoe Lake			Long Lake		Pushup Lake		Birch Lake (BIL)		Sucker Lake (SUL)		Rat Lake	Poison Lake	Frog Lake	Caribou Lake	Kiskatinaw Lake	Unnamed Lake 1		Unnamed Lake 2		Unnamed Lake 3
		2000	2000 (dupl.)	2001	2000	2001	2000	2001	2000[a]	2001	2000[a]	2001	2001	2001	2001	2001	2001	2000	2001	2000	2001	2001
Field Measured																						
pH		8.4	-	7.9	7.3	7.9	7.4	8.3	7.7	7.7	8.1	8.2	**8.6** [A,C]	8.4	7.9	8	8.1	8.1	7.1	8; 6.7[a]	7	**8.6** [A,C]
specific conductance	uS/cm	88	-	86	59	66	60	77	-	87	-	208	189	130	163	169	180	29	24	35	33	200
temperature	°C	5.6	-	11.2	6.7	9.8	6.7	9.9	-	10.4	-	10.1	11.1	9.2	11.3	11.8	12.3	6	9.5	6	11.1	9.9
dissolved oxygen	mg/L	8.9	-	9.1	8.7	9.8	8	9.9	-	9.1	-	10.1	9.9	9.8	9	8.9	9.2	8.6	9.2	8.6	9.8	9.3
redox potential	mV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Conventional Parameters																						
colour	T.C.U.	70	80	60	125	61	30	22	125	61	25	25	25	25	61	60	58	125	61	125 [a]	61	40
conductivity	uS/cm	83	85	84	87	78	85	82	101	91	218	211	208	186	178	176	183	39	23	35[a]	34	196
dissolved organic carbon	mg/L	20	20	22	24	22	16	33	-	23	-	19	18	26	28	18	20	22	22	25	26	45
hardness	mg/L	37	38	36	38	35	35	36	45	44	91	94	99	88	90	89	90	11	9	15 [a]	17	87
pH		6.8	6.5	7.3	7.1	7.1	7.2	**9.2** [A,C,H]	6.8	7.1	7.7	7.9	7.7	7.6	7.5	7.8	7.8	**6.4** [A,C]	**5.6** [A,C]	**6.1** [A,C] [a]	**6.2** [A,C]	7.7
total alkalinity	mg/L	36	37	43	32	39	40	39	46	43	106	115	109	101	95	94	99	15	10	9 [a]	10	103
total dissolved solids (calculated)	mg/L	41	44	47	47	47	43	44	53	49	115	117	113	104	100	97	102	19	14	16 [a]	18	109
total organic carbon	mg/L	26	25	-	32	-	17	-	-	-	-	-	-	-	-	-	-	30	-	34	-	-
total suspended solids	mg/L	19	13	1	9	1	10	3	-	1	-	< 1	< 1	12	5	2	1	5	< 1	-	< 1	17
Major Ions																						
bicarbonate	mg/L	44	45	52	39	48	48	7	56	53	130	141	133	123	116	114	121	18	< 5	11 [a]	12	126
calcium	mg/L	10	10	9	10	10	10	11	13	12	24	25	27	24	24	23	24	3	3	4 [a]	5	24
carbonate	mg/L	-	-	< 6	-	< 6	-	20	-	< 6	-	< 6	< 6	< 6	< 6	< 6	< 6	-	12	-	< 6	< 6
chloride	mg/L	1	1	2	< 1	1	< 1	2	2	1.3	2	0.8	1	1	1	1	1	< 1	1	2 [a]	2	1
magnesium	mg/L	3	3	3	3	3	3	2	3	3.21	7	7.71	8	7	7	8	7	1	1	1.2 [a]	1	7
potassium	mg/L	-	1	< 0.4	1	< 0.4	3	2	2	1	2	1	1	1	1	1	1	1	< 0.4	0.3 [a]	< 0.4	2
sodium	mg/L	3	4	4	5	4	2	2	3	3	10	10	7	8	8	5	6	< 1	1	< 1	1	10
sulphate	mg/L	3	3	2	8	6	1	2	2	2	6	3	5	2	3	3	3	2	3	3 [a]	3	4
sulphide	mg/L	0.017	**0.055** [C]	-	**0.005** [C]	-	**0.007** [C]	-	-	-	-	-	-	-	-	-	-	0.004	-	0.005	-	-
Nutrients and Chlorophyll *a*																						
nitrate + nitrite	mg/L	< 0.1	< 0.1	0.061	< 0.1	< 0.006	< 0.1	< 0.006	< 0.1	< 0.006	< 0.1	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	-	< 0.006	<0.1 [a]	< 0.006	0.006
nitrogen-ammonia	mg/L	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.25	< 0.05	-	< 0.05	-	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	-	< 0.05	-	< 0.05	< 0.05
nitrogen-kjeldahl	mg/L	1.3	1.7	1	2.1	0.8	1.8	1.6	-	0.94	-	0.76	0.8	2.2	1.3	0.6	0.8	-	0.7	-	0.7	2.2
nitrogen, total	mg/L	**1.3** [C]	**1.7** [C]	**1.1** [C]	**2.1** [C]	0.8	**1.8** [C]	**1.6** [C]	-	0.94	-	0.76	0.8	**2.2** [C]	**1.3** [C]	0.6	0.8	-	0.7	-	0.7	**2.2** [C]
phosphorus, total	mg/L	**0.091** [C]	**0.089** [C]	**0.14** [C]	**0.064** [C]	**0.12** [C]	**0.055** [C]	**0.12** [C]	-	**0.13** [C]	-	**0.11** [C]	**0.11** [C]	**0.11** [C]	**0.16** [C]	**0.14** [C]	**0.15** [C]	-	**0.12** [C]	**0.11** [C]	**0.14** [C]	**0.15** [C]
phosphorus, dissolved	mg/L	0.065	0.06	-	0.044	-	0.034	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
chlorophyll a	µg/L	10	11	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General Organics																						
naphthenic acids	mg/L	< 1	< 1	-	< 1	-	< 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
total phenolics	mg/L	< 0.001	0.002	0.004	< 0.001	**0.009** [C]	< 0.001	**0.024** [C]	-	**0.012** [C]	-	**0.008** [C]	**0.007** [C]	**0.012** [C]	**0.01** [C]	**0.007** [C]	**0.007** [C]	-	**0.01** [C]	0.002	**0.01** [C]	**0.012** [C]
total recoverable hydrocarbons	mg/L	< 0.5	-	-	< 0.5	-	< 0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 11.2 Water Quality of Selected Lakes in the OPTI Long Lake Project Local Study Area, Fall 2000 and 2001 (continued)

Parameter	Units	Canoe Lake			Long Lake		Pushup Lake		Birch Lake (BIL)		Sucker Lake (SUL)		Rat Lake	Poison Lake	Frog Lake	Caribou Lake	Kiskatinaw Lake	Unnamed Lake 1		Unnamed Lake 2		Unnamed Lake 3
		2000	2000 (dupl.)	2001	2000	2001	2000	2001	2000[a]	2001	2000[a]	2001	2001	2001	2001	2001	2001	2000	2001	2000	2001	2001
Total Metals																						
aluminum (Al)	mg/L	**0.11 (C)**	0.08	0.072	0.09	0.057	0.07	0.065	-	0.052	-	0.032	0.033	0.049	0.043	0.047	0.047	-	0.081	**0.23 (C)**	**0.146 (C)**	0.042
antimony (Sb)	mg/L	**< 0.005 (D>H)**	**< 0.005 (D>H)**	**< 0.006 (D>H)**	**< 0.005 (D>H)**	**< 0.006 (D>H)**	**< 0.005 (D>H)**	**< 0.006 (D>H)**	-	**< 0.006 (D>H)**	-	**< 0.006 (D>H)**	**< 0.006 (D>H)**	**< 0.006 (D>H)**	**< 0.006 (D>H)**	**< 0.006 (D>H)**	**< 0.006 (D>H)**	-	**< 0.006 (D>H)**	**< 0.005 (D>H)**	**< 0.006 (D>H)**	**< 0.006 (D>H)**
arsenic (As)	mg/L	< 0.001	< 0.001	**< 0.01 (D>C)**	< 0.001	**< 0.01 (D>C)**	< 0.001	**< 0.01 (D>C)**	-	**< 0.01 (D>C)**	-	**< 0.01 (D>C)**	**< 0.01 (D>C)**	**< 0.01 (D>C)**	**< 0.01 (D>C)**	**< 0.01 (D>C)**	**< 0.01 (D>C)**	-	**< 0.01 (D>C)**	< 0.001	**< 0.01 (D>C)**	**< 0.01 (D>C)**
barium (Ba)	mg/L	0.019	0.018	0.017	0.011	0.011	0.016	0.013	-	0.018	-	0.023	0.02	0.047	0.024	0.014	0.015	-	0.004	0.027	0.009	0.023
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	-	< 0.001	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	-	< 0.001	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.02	0.02	0.02	0.02	0.02	0.01	0.003	-	0.01	-	0.05	0.02	0.06	0.05	0.03	0.04	-	< 0.002	0.03	0.02	0.02
cadmium (Cd)	mg/L	**< 0.0002 (D>C)**	< 0.0002	**< 0.0006 (D>C)**	**< 0.0002 (D>C)**	**< 0.0006 (D>C)**	**< 0.0002 (D>C)**	**< 0.0006 (D>C)**	-	**< 0.0006 (D>C)**	-	**< 0.0006 (D>C)**	**< 0.0006 (D>C)**	**< 0.0006 (D>C)**	**< 0.0006 (D>C)**	**< 0.0006 (D>C)**	**< 0.0006 (D>C)**	-	**< 0.0006 (D>A,C)**	**< 0.0002 (D>C)**	**< 0.0006 (D>A,C)**	**< 0.0006 (D>C)**
calcium (Ca)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
chromium (Cr)	mg/L	< 0.0008	< 0.0008	< 0.0009	< 0.0008	< 0.0009	< 0.0008	< 0.0009	-	< 0.0009	-	< 0.0009	< 0.0009	< 0.0009	< 0.0009	< 0.0009	< 0.0009	-	< 0.0009	< 0.0008	< 0.0009	< 0.0009
chromium - hexavalent (Cr6+)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cobalt (Co)	mg/L	< 0.0002	< 0.0002	< 0.0008	< 0.0002	< 0.0008	< 0.0002	< 0.0008	-	< 0.0008	-	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	< 0.0008	-	< 0.0008	0.0002	< 0.0008	< 0.0008
copper (Cu)	mg/L	0.001	0.001	0.001	0.001	< 0.001	0.002	< 0.001	-	< 0.001	-	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	-	< 0.001	**0.003 (A,C)**	< 0.001	< 0.001
iron (Fe)	mg/L	**0.37 (C,H)**	**0.35 (C,H)**	**0.27 (H)**	**0.24 (H)**	**0.19 (H)**	**0.29 (H)**	**0.5 (C,H)**	-	**0.85 (C,H)**	-	**0.11 (H)**	**0.18 (H)**	0.04	**0.32 (C,H)**	**0.11 (H)**	**0.15 (H)**	-	**0.12 (H)**	**0.85 (C,H)**	**0.5 (C,H)**	**0.1 (H)**
lead (Pb)	mg/L	**0.0016 (C)**	0.0009	**< 0.002 (D>C)**	**0.0016 (C)**	**< 0.002 (D>C)**	**0.0026 (C)**	**< 0.002 (D>C)**	-	**< 0.002 (D>C)**	-	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	-	**< 0.002 (D>C)**	**0.0026 (C)**	**< 0.002 (D>C)**	< 0.002
lithium (Li)	mg/L	< 0.006	< 0.006	0.006	< 0.006	0.005	< 0.006	0.003	-	0.005	-	0.012	0.008	0.012	0.009	0.006	0.006	-	< 0.001	0.009	0.003	0.009
magnesium (Mg)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
manganese (Mn)	mg/L	**0.033 (H)**	**0.031 (H)**	0.002	**0.022 (H)**	0.001	**0.089 (H)**	**0.039 (H)**	-	0.004	-	0.001	0.001	0.001	0.002	0.001	0.001	-	**0.008 (H)**	**0.033 (H)**	0.004	0.002
mercury (Hg)	mg/L	**< 0.0002 (D>C,H)**	**< 0.0002 (D>C,H)**	**< 0.0001 (D>H)**	**< 0.0002 (D>C,H)**	**< 0.0001 (D>H)**	**< 0.0002 (D>C,H)**	**< 0.0001 (D>H)**	-	**< 0.0001 (D>H)**	-	**< 0.0001 (D>H)**	**< 0.0001 (D>H)**	**< 0.0001 (D>H)**	**< 0.0001 (D>H)**	**< 0.0001 (D>H)**	**< 0.0001 (D>H)**	-	**< 0.0001 (D>H)**	**< 0.0002 (D>C,H)**	**< 0.0001 (D>H)**	**< 0.0001 (D>H)**
molybdenum (Mo)	mg/L	< 0.0001	0.0001	< 0.001	0.0002	< 0.001	< 0.0001	< 0.001	-	< 0.001	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	-	< 0.001	0.0009	< 0.001	< 0.001
nickel (Ni)	mg/L	0.0019	0.0015	< 0.001	0.0051	< 0.001	0.0034	< 0.001	-	0.001	-	0.002	0.002	0.001	0.002	0.002	0.002	-	< 0.001	0.0074	< 0.001	0.001
potassium (K)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
selenium (Se)	mg/L	< 0.0008	< 0.0008	**0.008 (C)**	< 0.0008	**0.007 (C)**	< 0.0008	**< 0.004 (D>C)**	-	**0.007 (C)**	-	**0.007 (C)**	**0.01 (C)**	**0.005 (C)**	**0.013 (C)**	**0.006 (C)**	**0.009 (C)**	-	**< 0.004 (D>C)**	< 0.0008	**< 0.004 (D>C)**	**0.006 (C)**
silicon (Si)	mg/L	-	-	1.2	-	2.8	-	0.6	-	0.9	-	1.8	1	0.3	2.9	1.9	2.4	-	-	-	-	3.4
silver (Ag)	mg/L	**< 0.0004 (D>C)**	**< 0.0004 (D>C)**	**< 0.001 (D>A,C)**	**< 0.0004 (D>C)**	**< 0.001 (D>A,C)**	**< 0.0004 (D>C)**	**< 0.001 (D>A,C)**	-	**< 0.001 (D>C)**	-	**< 0.001 (D>C)**	**< 0.001 (D>C)**	**< 0.001 (D>C)**	**< 0.001 (D>C)**	**< 0.001 (D>C)**	**< 0.001 (D>C)**	-	**< 0.001 (D>A,C)**	**< 0.0004 (D>A,C)**	**< 0.001 (D>A,C)**	**< 0.001 (D>C)**
sodium (Na)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
strontium (Sr)	mg/L	0.04	0.04	0.04	0.05	0.05	0.03	0.03	-	0.05	-	0.11	0.1	0.12	0.1	0.07	0.07	-	0.01	-	0.02	0.09
sulphur (S)	mg/L	-	-	0.9	-	1.8	-	0.4	-	2.2	-	1.2	1.3	1.2	1.7	1.1	0.9	-	-	-	-	1.6
thallium (Tl)	mg/L	< 0.0001	< 0.0001	**< 0.004 (D>C,H)**	< 0.0001	**< 0.004 (D>C,H)**	< 0.0001	**< 0.004 (D>C,H)**	-	**< 0.004 (D>C,H)**	-	**< 0.004 (D>C,H)**	**< 0.004 (D>C,H)**	**< 0.004 (D>C,H)**	**< 0.004 (D>C,H)**	**< 0.004 (D>C,H)**	**< 0.004 (D>C,H)**	-	**< 0.004 (D>C,H)**	< 0.0001	**< 0.004 (D>C,H)**	**< 0.004 (D>C,H)**
titanium (Ti)	mg/L	0.0021	0.0017	0.0046	0.002	0.0012	0.0017	0.0014	-	0.0004	-	< 0.0004	< 0.0004	0.0023	0.0004	0.0023	< 0.0004	-	< 0.0004	0.0037	< 0.0004	< 0.0004
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.06	< 0.0001	< 0.06	< 0.0001	< 0.06	-	< 0.06	-	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	-	< 0.06	0.0001	< 0.06	< 0.06
vanadium (V)	mg/L	0.0003	0.0003	0.003	0.0004	0.003	0.0002	0.001	-	0.002	-	0.003	0.002	0.003	0.001	0.002	0.002	-	0.001	0.0005	0.004	0.003
zinc (Zn)	mg/L	0.03	**0.045 (C)**	0.002	**0.19 (A,C)**	0.002	**0.119 (A,C)**	0.003	-	0.001	-	0.001	0.001	0.002	0.003	0.002	0.002	-	0.003	**0.16 (A,C)**	0.004	0.002

[a] Data collected during a second fall sampling trip on Nov 1, 2000.

Note: Bolded concentrations are higher than water quality guidelines.

- A = Concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.
- C = Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
- H = Concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.
- D> = Analytical detection limit was higher than the relevant water quality guideline(s).
- \- = No data

Table 11.3 Field Data Collected for Lakes in the OPTI Long Lake Project Local Study Area in Spring and Fall, 2001

Lake	Maximum Depth (m)		Relative Depth	Dissolved Oxygen (mg/L)		Temperature (°C)		Conductivity (µS/cm)		pH	
	Spring	Fall		Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Birch Lake	3.4	3.5	surface	9.87	9.11	9.7	10.4	87	87	7.8	7.7
			mid	9.6	9.2	10.3	10.6	87	87	7.8	7.8
			bottom	7.91	8.24	9.6	9.6	87	87	7.5	7.6
Canoe Lake	2.5	2.1	surface	9.11	9.1	11.5	11.2	85	86	7.9	7.9
			mid	9.13	8.56	11.7	11.7	85	86	7.8	7.9
			bottom	8.67	8.55	11.3	11.6	85	86	7.8	7.7
Caribou Horn Lake	2.25	2.4	surface	8.83	8.9	12.4	11.8	172	169	8.1	8
			mid	8.76	8.89	12.4	11.8	172	169	8.1	8
			bottom	8.87	8.46	12.4	11.6	172	170	8.2	8.3
Frog Lake	1.9	2	surface	9.19	8.95	10.4	11.3	163	163	8	7.9
			mid	9.2	9.2	10.6	11.4	163	164	8	7.8
			bottom	9.07	8.89	10.4	11.3	165	164	7.9	7.9
Kiskatinaw Lake	4.4	4.5	surface	9.24	9.2	12.2	12.3	184	180	8.2	8.1
			mid	9.2	9	12.1	12.1	184	182	8.2	8.2
			bottom	9.11	8.95	12.3	12	184	182	8.3	8.2
Long Lake	1.5	1.5	surface	10	9.8	9.5	9.8	65	66	7.8	7.9
			mid	10.01	9.77	9.2	9.7	66	66	7.9	7.8
			bottom	10.03	10.01	9.4	9.8	66	66	7.9	7.9
Poison Lake	0.8	0.9	surface	10.09	9.78	9.2	9.2	128	130	8.6	8.4
			mid	10.17	10.12	9.2	9.2	128	130	8.6	8.4
			bottom	-	10.03	-	9.2	-	131	-	8.4
Pushup Lake	1.9	1.9	surface	10.76	9.89	10.5	9.9	77	77	8.4	8.3
			mid	10.73	10.56	10.5	10.2	77	76	8.3	8.5
			bottom	10.78	10.78	11.1	10.1	79	75	8.3	8.4
Rat Lake	2.7	2.85	surface	9.93	9.9	11.3	11.1	191	189	8.5	8.6
			mid	9.83	9.98	11.2	11	192	192	8.5	8.6
			bottom	9.82	10.12	11	10.8	192	191	8.5	8.4
Sucker Lake	5.5	5.7	surface	10.1	10.09	9.6	10.1	212	208	8.5	8.2
			mid	10.02	10.01	9.6	9.7	212	208	8.5	8.2
			bottom	9.24	10.03	9.5	9.6	214	210	8.2	8.1
Unnamed Lake 1	1.25	1.2	surface	9.58	9.23	9.2	9.5	24	24	7	7.1
			mid	9.66	9.4	9.5	9.4	24	25	6.5	6.9
			bottom	-	9.43	-	9.1	-	23	-	6.5
Unnamed Lake 2	1.55	1.75	surface	9.75	9.75	10.9	11.1	33	33	7	7
			mid	9.75	9.73	10.9	11.1	33	33	7.2	6.9
			bottom	9.69	9.7	11	10.8	33	33	7.3	7.2
Unnamed Lake 3	0.9	1	surface	10.75	9.26	9.8	9.9	197	200	8.6	8.6
			mid	10.76	9.29	9.8	9.5	197	198	8.5	8.6
			bottom	-	9.35	-	9.6	-	198	-	8.5

Note: - = Lake too shallow, measurements not taken.

11.1.2 Gregoire Lake

In 2001, data were collected from Gregoire Lake in spring, but not fall. In spring 2001, Gregoire Lake was slightly alkaline (pH 8.2) and the alkalinity concentration was 69 mg/L (Table 11.4). Hardness and total dissolved solids were low, with bicarbonate and calcium being the dominant ions. Dissolved and total organic carbon concentrations were elevated (14 and 16 mg/L, respectively) which is consistent with other lakes in this area (Table 11.1). Nutrients were not sampled in 2001 and the only metal that was measured during the 2001 spring sampling period, total arsenic, was below the detection limit of 0.001 mg/L. Finally, stratification did not occur at Gregoire Lake, as indicated by the field data (Table 11.5).

Based on available historical data (1977 to 1997), total dissolved solids and conductivity were relatively low in Gregoire Lake compared to other Alberta lakes. In 2001, these parameters had higher concentrations than historical maximum concentrations. Although not sampled for nutrients in 2001, the most recent nutrient data suggest that the lake is oligo-mesotrophic (unproductive to moderately productive).

Table 11.4 Historical and 2001 Water Quality of Gregoire Lake, Spring

Parameter	Units	2001	Spring (1977-83, 1994, 1996-97)			
			Median	Min	Max	n
Conventional Parameters						
pH (field)	-	8.2	7.5	6.6	8.2	20
pH (lab)	-	7.8	-	-	-	-
conductivity	µS/cm	155	109	15	147	20
total dissolved solids	mg/L	120	76	53	95	18
total suspended solids	mg/L	14	4	<0.4	6	11
hardness	mg/L	72	54	26	71	9
alkalinity	mg/L	69	52	22	66	20
dissolved organic carbon	mg/L	14	12	4	22	12
total organic carbon	mg/L	16	12	4	30	12
colour	TCU	25	-	-	-	-
chlorophyll a	µg/L	-	3	<1	7	12
Nutrients						
nitrate + nitrite	mg/L	-	0.017	<0.003	0.21	13
total Kjeldahl nitrogen	mg/L	-	0.72	0.085	1.02	12
total phosphorus	mg/L	-	0.025	0.018	0.05	15
orthophosphate	mg/L	-	0.01	0.003	0.025	12
Major Ions						
bicarbonate	mg/L	84	59	26	69	5
calcium	mg/L	19.7	15.4	7	21.5	20
chloride	mg/L	2	0.9	0.5	2	20

Table 11.4 Historical and 2001 Water Quality of Gregoire Lake, Spring (continued)

Parameter	Units	2001	Spring (1977-83, 1994, 1996-97)			
			Median	Min	Max	n
magnesium	mg/L	5.5	4.3	2	5.5	20
potassium	mg/L	1.5	0.9	0.2	1.3	20
silica	mg/L	-	2.2	0.4	11	19
sodium	mg/L	4	2.4	1.9	10	20
sulphate	mg/L	5.9	7.3	2.9	29	20
sulphide	mg/L	-	<0.01	<0.01	<0.01	5
Total Metals						
aluminum (Al)	mg/L	-	0.05	0.02	**0.40**(C)	12
arsenic (As)	mg/L	<0.001	-	-	-	-
beryllium (Be)	mg/L	-	<0.001	-	-	1
cadmium (Cd)	mg/L	-	<0.001	<0.001	<0.001	7
chromium – hexavalent (Cr^{6+})	mg/L	-	<0.003	<0.003	<0.003	11
cobalt (Co)	mg/L	-	<0.001	<0.0001	<0.002	7
copper (Cu)	mg/L	-	0.002	<0.001	**0.069**(A,C)	12
iron (Fe)	mg/L	-	0.17	0.06	**0.46**(C,H)	14
lead (Ph)	mg/L	-	<0.002(D>C)	<0.001(D>C)	**0.005**(C)	14
manganese (Mn)	mg/L	-	**0.058**(H)	0.012	**0.276**(H)	12
mercury (Hg)	mg/L	-	<0.0001(D>H)	<0.0001(D>H)	**0.0006**(C,H)	12
nickel (Ni)	mg/L	-	<0.001	<0.0001	<0.002	12
silver (Ag)	mg/L	-	<0.001(D>C)	<0.001(D>C)	**0.004**(A,C)	5
titanium (Ti)	mg/L	-	-	<0.01	<0.01	2
vanadium (V)	mg/L	-	<0.001	<0.001	<0.001	9
zinc (Zn)	mg/L	-	0.006	<0.001	**0.15**(A,C)	12
Dissolved Metals						
arsenic (As)	mg/L	-	0.0011	<0.0002	0.0018	12
selenium (Se)	mg/L	-	<0.0002	<0.0002	**0.0011**(C)	12
boron (B)	mg/L	-	0.03	<0.01	0.08	7
Organics						
oil and grease	mg/L	-	7	4	9	5
phenolics	mg/L	-	0.002	<0.001	0.004	10

Source: AENV WDS.

Note: Bolded concentrations are higher than water quality guidelines.

A = Concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.

C = Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

H = Concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.

D>= Analytical detection limit was higher than the relevant water quality guideline(s).

- = No data.

Table 11.5 Field Data Collected in Gregoire Lake in Spring (May 29, 2001)

Site	Depth (m)	Dissolved Oxygen (mg/L)	Temperature (^{o}C)	Conductivity (µS/cm)	pH
1	Surface	8.93	15.7	143	8.33
	0.5	9.06	15.7	143	8.30
	1.9	9.06	15.5	144	8.29
2	Surface	9.14	15.0	141	8.22
	0.5	9.09	14.8	142	8.20
	0.75	8.89	14.8	142	8.30
3	Surface	8.89	15.7	141	8.16
	0.5	8.74	15.7	141	8.16
	0.9	8.03	15.6	142	8.27

11.1.3 Acid Sensitivity

Acid sensitivity of lakes in the LSA was evaluated based on total alkalinity and lake-specific critical loads (use of critical loads is described in Golder 2001a, Section 8.1). Total alkalinity and conductivity measurements indicate that two lakes (Unnamed lakes 1 and 2) are highly acid sensitive. Alkalinity ≤10 mg/L as $CaCO_3$ is considered highly sensitive according to Saffran and Trew (1996). Moderately to highly acid sensitive lakes (i.e., those with alkalinity ≤20 mg/L as $CaCO_3$) typically have conductivity values ≤60 µS/cm, based on data summarized by Saffran and Trew (1996) for a large number of lakes in northeastern Alberta. Conductivity is typically positively correlated with alkalinity and both variables were below these critical values in Unnamed lakes 1 and 2.

The remaining twelve lakes do not appear to be acid sensitive, based on the alkalinity and conductivity data collected in 2001. In these lakes, alkalinity ranged between 36 to 115 mg/L and conductivity varied from 70 to 226 µS/cm. The lakes with low alkalinity and conductivity also have the lowest critical loads (CLs). The critical load is defined as the highest load of acidity that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems.

The CL guideline was set at 0.25 keq/ha/yr for highly sensitive soils in Alberta, and was subsequently extended to sensitive aquatic systems based on review by Schindler (1996). It is applicable at the spatial resolution of 1^{o} latitude by 1^{o} longitude cells and is not intended for evaluating the effects of acid deposition on individual lakes. The critical loads were calculated in 2000 (Golder 2000b) and are re-calculated in this report to include 2001 sampling results (Table 11.5). The critical loads are provided here for ongoing evaluation of potential impacts due to acid deposition. The critical loads are expected to change slightly in the future, as more data become available.

The CLs estimated for the lakes in the LSA also suggest that only two of the lakes are acid sensitive. Unnamed lakes 1 and 2 had the lowest CLs, 0.18 and 0.28 keq/ha/yr, respectively (Table 11.6). The CL for Pushup Lake was 0.48 keq/ha/yr, and for Canoe Lake was 0.53 keq/ha/yr. However, the remaining lakes had CLs that were at least two times higher than those calculated for Unnamed lakes 1 and 2, suggesting they are much less sensitive to acid deposition.

Table 11.6 Water Chemistry Variables Related to Acid Sensitivity for the Lakes in the Long Lake Project Local Study Area

Lake	Distance (km)[(a)]	Critical Load (keq/ha/yr)	Field Conductivity (µS/cm)[(b)]	Field pH[(b)]	Alkalinity (mg/L as $CaCO_3$)[(b)]
Birch Lake	1.9	0.92	92	7.7	43
Canoe Lake	7.6	0.53	85	7.8	39
Caribou Lake	12.7	1.68	171	8.1	91
Frog Lake	2.4	1.83	163	7.9	89
Gregoire Lake	15.0	1.05	114[(c)]	7.6 [(c)]	51[(c)]
Kiskatinaw Lake	5.9	1.89	183	8.1	98
Long Lake	1.6	0.67	76	7.9	34
Poison Lake	1.9	0.89	129	8.5	84
Pushup Lake	3.3	0.48	81	8.4	39
Rat Lake	4.1	2.02	191	8.5	104
Sucker Lake	5.5	1.74	213	8.3	110
Unnamed Lake #1	2.5	0.18	29	6.8	11
Unnamed Lake #2	2.4	0.28	34	7.1	10
Unnamed Lake #3	10	1.48	198	9.7	103

(a) Distance from Long Lake Project central facility.
(b) Open water average values (2000 and 2001).
(c) Mean value determined from 2001 data and WDS historical data.

11.2 BASELINE SAMPLING AT SUNCOR FIREBAG

Generally, water quality in the headwaters of the Firebag River was typical of other tributaries located in the lower Athabasca River watershed (Table 11.7). Water quality data are considered typical of small, headwater streams, brown in colour, generally with low amounts of dissolved material and containing comparable amounts of organic material relative to other streams in the area. These waters exhibited high manganese and iron levels, often identified in surface water discharges in this region.

The pH samples collected at two of the sample sites (Sites 1 and 2) were slightly acidic and were lower than surface water guidelines of 6.5 pH units. At Site 3, dissolved oxygen was below chronic aquatic guidelines of 6.5 mg/L. Total phosphorus levels at Sites 2 and 3 were greater than surface water guidelines of 0.05 mg/L.

A number of metals were found at relatively high levels at Site 3. In particular, total aluminum, cadmium, copper and lead concentrations were greater than chronic aquatic surface water guidelines. Copper concentrations were higher than acute aquatic surface water guidelines. Like other streams in this region, iron and manganese concentrations were greater than U.S. EPA human health guidelines.

At Sites 2 and 3, copper, iron and lead were higher than chronic aquatic life guidelines. At Site 2, cadmium and antimony concentrations were undetected, but the detection limits were greater than surface water quality guidelines.

Table 11.7 Water Quality in the Headwaters of the Firebag River, November 2001

Parameter	Units	Site 1	Site 2	Site 3
Field Measured				
pH		**5** (A,C)	**6.13** (A,C)	6.55
specific conductance	uS/cm	30	105	162
temperature	^{o}C	0.24	0.58	0.28
dissolved oxygen	mg/L	8	7.7	**5.4** (C)
Conventional Parameters				
colour	T.C.U.	120	120	140
conductance	uS/cm	33	106	168
dissolved organic carbon	mg/L	-	-	-
hardness	mg/L	17	17	17
pH		**6.1** (A,C)	6.8	7
total alkalinity	mg/L	11	51	83
total dissolved solids	mg/L	80	120	150
total organic carbon	mg/L	23	20	15
total suspended solids	mg/L	< 3	< 3	< 3

Table 11.7 Water Quality in the Headwaters of the Firebag River, November 2001 (continued)

Parameter	Units	Site 1	Site 2	Site 3
Major Ions				
bicarbonate	mg/L	13	62	101
calcium	mg/L	5	15	24
chloride	mg/L	2	2	2
magnesium	mg/L	1	4	5
potassium	mg/L	0.3	0.2	0.4
sodium	mg/L	< 1	2	3
sulphate	mg/L	2	3	3
sulphide	mg/L	-	-	-
Nutrients and Chlorophyll *a*				
nitrogen - ammonia	mg/L	< 0.05	0.06	0.13
nitrogen - total	mg/L	0.6	0.6	0.6
phosphorus, total	mg/L	0.027	**0.117** (C)	**0.13** (C)
phosphorus, dissolved	mg/L	0.019	0.062	0.078
chlorophyll *a*	mg/L	-	-	-
Biological Oxygen Demand				
biochemical oxygen demand	mg/L	< 2	< 2	< 2
Total and Fecal Coliform Count				
Fecal Coliforms	CFU/100 ml	2	7	< 1
Total Coliforms	CFU/100 ml	32	49	19
Metals (Total)				
aluminum (Al)	mg/L	**0.11** (C)	0.05	< 0.02
antimony (Sb)	mg/L	**< 0.005** (D>H)	**< 0.005** (D>H)	**< 0.005** (D>H)
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001
barium (Ba)	mg/L	0.008	0.031	0.054
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	< 0.002	0.002	0.01
cadmium (Cd)	mg/L	**0.0002** (C)	**< 0.0002** (D>C)	**< 0.0002** (D>C)
chromium (Cr)	mg/L	< 0.0008	< 0.0008	< 0.0008
cobalt (Co)	mg/L	< 0.0002	0.0004	0.0006
copper (Cu)	mg/L	**0.005** (A,C)	**0.006** (A,C)	**0.007** (A,C)
iron (Fe)	mg/L	**0.66** (C,H)	**2.59** (C,H)	**4.65** (C,H)
lead (Pb)	mg/L	**0.0017** (C)	**0.0018** (C)	**0.0021** (C)
lithium (Li)	mg/L	< 0.006	< 0.006	< 0.006
manganese (Mn)	mg/L	**0.068** (H)	**0.378** (H)	**0.551** (H)
mercury (Hg)	mg/L	< 0.0000006	< 0.0000006	< 0.0000006
molybdenum (Mo)	mg/L	< 0.0001	< 0.0001	< 0.0001
nickel (Ni)	mg/L	0.0004	< 0.0002	0.0014
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0008
silver (Ag)	mg/L	0.000007	0.000026	0.000049
strontium (Sr)	mg/L	0.01	0.04	0.06
thallium (Tl)	mg/L	< 0.0001	< 0.0001	< 0.0001
titanium (Ti)	mg/L	0.002	0.0028	0.0034
uranium (U)	mg/L	0.0001	< 0.0001	< 0.0001
vanadium (V)	mg/L	0.0013	0.001	0.0009
zinc (Zn)	mg/L	0.008	0.013	0.011

Table 11.7 Water Quality in the Headwaters of the Firebag River, November 2001 (continued)

Parameter	Units	Site 1	Site 2	Site 3
Metals (Dissolved)				
aluminum (Al)	mg/L	0.1	0.04	< 0.01
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008
arsenic (As)	mg/L	< 0.0004	< 0.0004	< 0.0004
barium (Ba)	mg/L	0.007	0.03	0.05
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	< 0.002	0.004	0.01
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 0.0001
chromium (Cr)	mg/L	0.0008	0.003	0.0039
cobalt (Co)	mg/L	< 0.0001	0.0004	0.0006
copper (Cu)	mg/L	< 0.0006	< 0.0006	< 0.0006
iron (Fe)	mg/L	0.63	1.71	2.36
lead (Pb)	mg/L	< 0.0001	< 0.0001	< 0.0001
lithium (Li)	mg/L	0.001	0.002	0.003
manganese (Mn)	mg/L	0.064	0.367	0.485
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.0001
molybdenum (Mo)	mg/L	< 0.0001	< 0.0001	0.0023
nickel (Ni)	mg/L	0.0001	< 0.0001	0.0008
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0004
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002
strontium (Sr)	mg/L	0.01	0.04	0.06
thallium (Tl)	mg/L	< 0.00005	< 0.00005	< 0.00005
titanium (Ti)	mg/L	0.0011	0.001	0.0013
uranium (U)	mg/L	0.0001	< 0.0001	< 0.0001
vanadium (V)	mg/L	0.0005	0.0003	0.0001
zinc (Zn)	mg/L	0.005	0.004	0.004

Note: Bolded concentrations are higher than water quality guidelines.

A = Concentration higher than the relevant acute aquatic life guideline or beyond the recommended pH or DO concentration range.

C = Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.

H = Concentration higher than the relevant human health guideline or beyond the recommended pH or DO concentration range.

D> = Analytical detection limit was higher than the relevant water quality guideline(s).

\- = No data.

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12 SUMMARY AND CONCLUSIONS

12.1 SUMMARY

12.1.1 Water and Sediment Quality

12.1.1.1 Athabasca River Mainstem

The fall 2001 water and sediment quality study continued to monitor the same set of water and and sediment quality parameters, including sediment toxicity (i.e, bioassays using benthic invertebrates*: Chironomus tentans, Hyalella azteca and Lumbriculus variegatus*) as were analyzed in 2000. Sampling occurred in the Athabasca River Delta and the Athabasca River upstream of the Embarras River, as well as the east and west banks of the Athabasca River from locations upstream of Donald Creek, the Steepbank River, Muskeg River and Fort Creek. Sediment sampling was expanded to include Big Point, Goose Island and Fletcher Channel. The results of the water quality study are as follows:

- Concentrations of the majority of water quality parameters were within the historial range and were considered to be consistent with past water quality conditions. Although some results were outside this range, the results were just as likely to be below this range as above.
- The results for the east-bank water samples were not consistently different than the results for the west-bank samples.
- Total copper, selenium and zinc concentrations were higher in 2001 than previous concentrations at some locations.
- Major ion concentrations appear to be increasing over time in the Athabasca River upstream of the Steepbank River. Increases in other measures of major ions such as specific conductance, total dissolved solids and hardness were reported at other sites along the mainstem.
- Parameter concentrations in sediments collected from all of the mainstem sample sites were, with few exceptions, consistent with or lower than those observed in sediment from previous sampling events.
- With a few exceptions (total arsenic and chlorine substituted napthalene), total metal and PAH levels were lower than Canadian freshwater sediment guidelines.
- Overall, there is an increasing trend in total metal and PAH concentrations with distance downstream in 2001 sediment samples from upstream of Donald Creek to the river delta.
- Reduced growth of *Chironomus tentans* was observed in sediment collected from the Athabasca River upstream of the Embarras River.

- Reduced growth and survival of *Lumbriculus variegatus* was observed in sediment from various locations on the Athabasca River and the river delta. Growth reductions may be due to the sensitivity of *L. variegatus* to the physical characteristics of the sediment, as opposed to the chemical content.

12.1.1.2 Athabasca River Tributaries

The 2001 water quality study resampled the mouths of Jackpine, Muskeg, McLean, Poplar, Fort and Stanley creeks and the MacKay and Steepbank rivers. The study was expanded to include sampling and seasonal temperature monitoring of the Clearwater River. Temperature monitoring continued at the Muskeg River, McLean Creek and Fort Creek. The Clearwater River was sampled upstream and downstream of the Christina River several times throughout 2001 to help characterize seasonal variability and the influence of the Christina River on water quality. The results are summarized as follows:

- Both TDS and hardness were lower in winter relative to historical records for the Clearwater River site below the Christina River.
- Total phosphorus conentrations in the Clearwater River have often exceeded the chronic aquatic life guideline in all seasons with the exception of winter although total phosphorus concentrations were generally slightly lower at the upstream site.
- Concentrations of nine metals were higher in the Clearwater River than water quality guidelines, although similar exceedances have been reported in previous years.
- Total recoverable hydrocarbons and PAHs were not detected in the Clearwater River in the Clearwater River in 2001. Total phenolics were usually detected in all seasons; this is consistent with historical data.
- Comparison of Clearwater River data upstream and downstream of the Christina River suggested that the Christina River frequently had higher concentrations of major ions, TDS and some total metals concentrations were also higher.
- The 2001 water quality data were generally similar to historical data for the tributaries sampled in 2000, although there were some results both above and below historical values.
- Major ions and related parameters at the mouth of McLean Creek, Poplar Creek, and the Steepbank River were generally higher than historical median levels.
- Chloride levels in Popular Creek and total phenolics in the Steepbank River and Fort Creek were higher than chronic aquatic guidelines.

- Aluminum concentrations were higher than historical levels in the MacKay River, although elevated concentrations may be related to higher TSS levels than previously recorded.
- In general, sediment quality in 2001 in McLean Creek was consistent with that observed in previous sampling events, although there were variations both above and below the historical range.
- Sediments collected from the mouth of the MacKay River had substantially less sand than sediments previously collected from this site. Exposed oil sands were likely present at this location and included in the sample. Total metals and PAH concentrations in 2001 were higher than levels reported previously; however, all concentrations were below the probable effects levels for freshwater sediments.

12.1.1.3 Muskeg River

The 2001 water quality study resampled the Muskeg River at six locations. The results are summarized below:

- Water quality in the Muskeg River watershed was generally consistent with historical data, although there are variations above and below the historical range.
- Water in the Muskeg River upstream of Muskeg Creeek was more coloured, had higher dissolved phosphorus levels and greater total zinc concentrations than in previous years.
- Total zinc and total iron concentrations exceeded the chronic aquatic life guideline and total iron exceeded the human health guideline as it has in previous sampling events.
- The seasonal trends in the water quality of the Muskeg River downstream of Jackpine Creek and upstream of Muskeg Creek, which was monitored once per season in 2000 and 2001, varied noticably between years.
- Sediment concentrations of all parameters measured in 2001 at the mouth of the Muskeg River were below Canadian freshwater sediment quality guidelines, although total extractable hydrocarbon and total inorganic carbon levels were higher in 2001 than in previous sampling events.
- A trend of increasing chromium and manganese concentrations that had been observed in sediments at the mouth of the Muskeg River in sediments since 1997 was reversed in 2001.

12.1.1.4 Wetlands

- The 2001 water quality data were generally similar to horizontal data for wetlands. Although there were parameters with concentrations both above and below historical values, the data were limited (i.e., n≤6).
- In 2001, sediments from Kearl Lake generally had lower levels of metals than those observed in Isadore's and Shipyard lakes, while PAH concentrations were comparable among the three waterbodies. In 2001, the PAH levels in Kearl Lake were similar to those recorded in 1998.

12.1.2 Benthic Invertebrate Community

The benthic invertebrate component of RAMP included the second year of monitoring using a consistent sampling design for Shipyard Lake and three tributaries, the MacKay, Muskeg and Steepbank rivers, as well as the first year of monitoring in the Clearwater River, Fort Creek and Kearl Lake. Tributaries and wetlands were sampled in September and October, 2001. The results of the 2001 surveys can be summarized as follows:

- The Clearwater River was sampled upstream and downstream of the Christina River. Although the community composition, based on common taxa, and the total abundance were similar between the two locations, total taxonomic richness was substantially higher in the upstream reach. These two sampling reaches were deemed approriate for future monitoring.
- The Muskeg River continued to support the most diverse fauna compared to the other tributaries monitored in 2000 and 2001 with over 70 taxa in each of the erosional and depositional habitats and a total of 105 taxa when both habitats are combined. The total abundance was greater in the depositional habitat of the Muskeg River.
- Total abundance and taxonomic richness were similar for the MacKay and Steepbank rivers. Only erosional habitats were sampled in both rivers.
- The benthic communities were significantly correlated with habitat variables including current velocity and substrate particle size in these rivers, although the directions of the significant correlations were not necessarily consistent with the habitat associations of the taxa involved.
- The Fort Creek community had a lower richness compared to communities in the MacKay and Steepbank rivers. The lower richness is likely due to the difference in habitat (depositional versus erosional) between Fort Creek and the two rivers.
- Kearl Lake communites were characterized by low total abundance and low mean richness, although the total richness was similar to Shipyard Lake.

- When Shipyard Lake data were compared to the previous year's data, both abundance and richness of the benthic community declined considerably in Shipyard Lake in 2001 compared to 2000. The decline may be related to low dissolved oxygen concentrations resulting from the decay of large aquatic plants in 2001.
- Impoverished fauna were also documented by a previous (August 1996) survey of Shipyard Lake. Considered together, the 1996, 2000 and 2001 data indicate substantial year-to-year variation.

12.1.3 Fish Populations

The fisheries component of the 2001 RAMP focused on the Muskeg River, although monitoring was also completed on the Athabasca and Steepbank rivers. Generally, the 2001 program to monitor fish populations consisted of the following studies:

- completion of the radiotelemetry study initiated during the RAMP 2000 program focussing on longnose sucker and northern pike;
- collection of tissue samples from fish in the Athabasca and Muskeg rivers for analysis of contaminants;
- tributary sentinel species monitoring to assess the health of slimy sculpin populations in the Muskeg and Steepbank rivers;
- a fish fence study to evaluate species composition and abundance for populations utilizing the Muskeg River Basin; and
- a general fish inventory for the Muskeg River and Jackpine Creek.

The 2001 portion of the radiotelemetry study included monitoring fish movements from December to June 2001 to provide a full year of movement data (in combination with monitoring from 2000). The following results are for the full year of monitoring:

- Twenty-five longnose sucker were radio-tagged and released near Mountain Rapids in the Athabasca River during May 2000. Three of these fish were later confirmed dead.
- The Athabasca River spawning sub-population of longnose sucker appears to use the mainstem river in the Oil Sands Region primarily as a spring migration route to and from the spawning site at Mountain Rapids located upstream of Fort McMurray. The majority (16 out of 22) of the radio-tagged fish were only recorded in the survey area during spring spawning. Five of these fish returned to the rapids area the following spawning season in 2001.

- A smaller proportion of this subpopulation (6 out of 22) remained in the Athabasca River basin for a prolonged time, particularly in the fall and winter.
- Twenty-five longnose sucker and 25 northern pike were radio-tagged in the Muskeg River in May, 2000. Eight longnose sucker and 8 northern pike were confirmed dead.
- Fish of both species that spawned in the Muskeg River exhibited greater use of the Athabaca River basin than the subpopulation of fish that spawn at Mountain Rapids. Eleven of the 17 radio-tagged longnose sucker and 12 of the 17 northern pike are known or believed to use the Athabasca River or its tributaries during much of the year.

Muscle tissue samples were collected from lake whitefish and walleye from the Athabasca River and northern pike from the Muskeg River. Samples were analysed for concentrations of organic and inorganic contaminants. The results of the muscle tissue sampling are as follows:

- PAHs were not detected in the composite flesh samples of northern pike, lake whitefish and walleye in the fall of 2001.
- Metal concentrations in flesh samples of northern pike, lake whitefish and walleye were found to be below those reported to be linked with effects on growth and survival of fish. However, the available experimental data for copper is inconclusive making it difficult to assess the potential effects of the measured concentrations of copper.
- A comparison of the fish tissue concentrations with fish consumption guidelines indicated no exceedences of the 0.5 mg/kg Health Canada guideline for occasional consumption. However, the concentration of mercury was close to the occasional consumption guideline in one Athabasca River female walleye sample (0.46 mg/kg) and above the guideline for subsistence (frequent) consumption (0.2 mg/kg) in both Athabasca River walleye samples. These results likely indicate the natural variability in mercury concentrations in fish inhabiting this region.

The following tributary sentinel species component involved monitoring population and health parameters for a small-bodied fish species exposed to Oil Sands Region activities, in comparison to reference populations outside the development area, as an indicator of ecosystem health:

- Populations of slimy sculpin in the lower Muskeg River and lower Steepbank River were evaluated in comparison to other tributary populations.
- Gonad size in male fish at exposure sites on the Steepbank and Muskeg rivers was significantly lower than gonad size at reference sites.

The following fish fence study utilized a two-way counting fence in the lower Muskeg River to monitor the species composition and abundance of fish migrating into the river basin in the early spring:

- The fish species targeted were the adult size-classes of key Athabasca River fish species known to ascend the Muskeg River in the spring.
- In total, 128 fish consisting of white sucker (79 fish), northern pike (35), longnose sucker (12), lake chub (1) and brook stickleback (1) were captured. Although targeted for the study, Arctic grayling were not observed in either the upstream or downstream trap.
- The total number of fish captured at the fish fence between April 28 and May 26, 2001 was limited due to difficulties in maintaining both the integrity of the fence and complete blockage of the river due to poor substrate characteristics and high flows. The two-way counting fence was fully operational for only 16 of the 29 days of the study.
- Due to losses in fence integrity, the 2001 fish fence study did not meet the objectives of determining the size of the spring spawning run and the relative abundance of fish species utilizing the Muskeg River basin.

The purpose of the general fish inventory was to monitor species presence, relative abundance and community structure.

- As part of the 2001 RAMP survey, inventories were conducted in the Muskeg River basin, including the lower Muskeg River and lower Jackpine Creek. Because no Arctic grayling were captured, it was decided to conduct a general fish inventory program during the summer of 2001 rather than the Arctic grayling population estimate study originally planned.
- Ten fish species were identified including sport fish (15% of total), sucker species (36% of total) and small-bodied species (49%).
- The most abundant species were longnose sucker, trout-perch, emerald shiner and white sucker with catch-per-unit–effort values between 1.18 and 0.76 fish /100 seconds. The CPUE increased in 2001 compared the CPUE in 1997 for all species except Arctic grayling and white suckers.
- Backpack electrofishing and minnow trapping were equally effective in for sampling Jackpine Creek.
- Seven fish species were recorded in Jackpine Creek during the summer inventory, including one sport species (one northern pike), one sucker species (11 longnose sucker) and five small-bodied species (93.8% of fish recorded). Lake chub were the most abundant species (85.4%).

12.1.4 Acid Sensitive Lakes

Water samples were collected from 32 acid sensitive lakes in northeastern Alberta, as part of the third year of acid sensitive lake monitoring under RAMP. Results of the 2001 program indicate the following:

- Comparison of lake-specific critical loads with modelled acid deposition rates revealed that the predicted cumulative acid deposition rates (from existing, approved and planned developments) were above the critical loads for eight lakes monitored by RAMP.
- The variation in acidity-related variables (pH, alkalinity, major ions) during the last three years was not indicative of effects related to acidification. Ion balance calculations revealed anion deficits in all lakes, which appeared related to the presence of organic anions.
- The ratio of bicarbonate to divalent cations was <1 for all lakes. The variation among years in this ratio has been within the typical range of year-to-year variation demonstrated for lakes with long-term data.
- Suspended sediment levels were elevated in a number of lakes, which appeared related to wind-induced mixing in shallow lakes. Based on chlorophyll *a* concentration, 12 lakes were mesotrophic, 10 lakes were eutrophic and 10 lakes were hyper-eutrophic. Concentrations of nutrients (and potentially chlorophyll *a*) were influenced by the variation in suspended sediments. There was a weak relationship between TP and chlorophyll *a*.

No indication of changes related to acidification was found in the lakes monitored in 2001 relative to 1999, 2000 and available historical data. Since this component is still in its initial phase of implementation, it is expected to evolve as new information and needs dictate. Potential changes to the program include addition of acid sensitive lakes close to sources of acidifying emissions, directing research towards issues related to temporal changes in lake chemistry and sampling times, and studying groundwater fluxes to lakes that have critical load exceedances or are close to exceedance.

12.1.5 Wetlands

Water samples were collected from Kearl, Isadores's, Shipyard and McClelland lakes. Total phosphorus concentrations appear to be lower in Kearl Lake in the past several years, while total phosphorus concentrations were above water quality guidelines for the first time in Isadore's lake. Some major ion concentrations appear to be increasing slightly over time in Shipyard Lake. Total copper concentrations were higher than aquatic guidelines in both Isadore's and

Shipyard lakes in the summer and fall of 2001. Water quality was generally consistent across the two seasons and within the range of historical data, although the dataset is quite limited. With few exceptions, sediment characteristics in Isadore's Lake were similar to those observed in Shipyard Lake in terms of organic content, PAH levels and metal concentrations. Sediments from Kearl Lake tended to have lower metal concentrations than the other two wetlands.

The vegetation data collected in 2001 for Shipyard, Isadore's and Kearl lakes represents the third year of monitoring for these lakes. No reference lakes have been located to serve as a comparison for lakes in undeveloped regions. The results of the 2001 survey can be summarized as follows:

- Shipyard Lake has the lowest number of species (22) followed by Kearl Lake (40). Isadore's Lake (54) has the highest number of species.
- Shipyard Lake has the lowest number of cover classes (5) followed by Kearl Lake (6). Isadore's Lake (9) has the most diverse number of cover classes.
- Shipyard Lake is the most productive of the three lakes if percent cover is used as an indicator (i.e., Shipyard Lake wetlands have the highest percent cover values). However, productivity is due to a few species. Shipyard Lake wetlands are classified as predominately marshes and this classification indicates a fairly nutrient-rich substrate.
- Shipyard Lake is the most homogeneous of the lakes. A large number of plots within the lake were very similar when both the Jaccard's Indices and the Bray-Curtis Indices were compared. It has a large coverage of a single species of vegetation.
- Vigour was rated as good for all wetlands in all three lakes. Evaluating vigour in the moss and lichen cover class is very difficult and of doubtful value.
- In all lakes, forbs is the dominant vegetation cover class.
- Wetlands classification showed that Isadore's and Kearl lakes have deeper open water that is classified as lake and not as wetlands, whereas all of Shipyard Lake is classified as a wetlands type.
- Wetlands water chemistry (pH, temperature, dissolved oxygen, salinity and conductivity) did not vary significantly between lakes even though the wetlands communities are different between the lakes.
- Shipyard Lake wetlands are very homogenous within the lake compared to Isadore's Lake and Kearl Lake wetlands. These two wetlands show more variation within the respective lakes.

12.2 CONCLUSION

In 2001, RAMP has continued to experience growth and change. Although the program is now five years old, none of the sections (except water quality) have five years of data for the same parameters, collected in the same way from the same locations. This has been a period of method development, sampling location selection, changes in direction and expansion. There has been notable successes, such as the use of sentinel fish species and notable failures such as the fish fence deployment.

One of the first objectives of RAMP is to collect scientifically defensible baseline and historical data to characterize variability in the oil sands area. As mentioned in the RAMP 2000 report, the key to RAMP's success is to select and verify monitoring methods that will differentiate effects of oil sands developments from natural variability and existing anthropogenic effects (e.g., pulp mill and municipal effluents). The results to date demonstrate substantial variability. For example, the benthic invertebrate results for Shipyard Lake show a decrease in the benthic community from 2000 to 2001, which may be related to dissolved oxygen concentrations. Also, each subsequent year the water quality monitoring results include concentrations that are both above and below the range of existing data. Seasonal variability as well as year-to-year changes are evident.

The aquatic environments are being monitored to detect and assess cumulative and regional trends against this baseline. Before this can be achieved, sufficient comparable baseline data must be available. When the results of the whole program for 2001 are reviewed, it becomes apparent that this is not an easy task in light of the changes that are occurring. In spite of all the effort that has been expended, there are very few years of consistent data for each component of RAMP and each location.

The benthic invertebrate component has undergone a substantive expansion, the number of sites have doubled this year. The first year of data are available for the Clearwater River (two sites), Fort Creek and Kearl Lake. Communities in three tributaries, the MacKay, Muskeg and Steepbank rivers, have been monitored using a consistent method for two years so that data from 2000 and 2001 are comparable. Although there are differences in the benthic communities between years, this variation is expected due to the large areas being covered in the sampling program and the natural variability expected in benthic invertebrate communities. The most recent change in methods likely decreased the precision of the sampling in favour of a better representation of the tributaries. The results appear to represent an expansion of knowledge; no unusual changes were noted for the tributaries.

The direction of the wetlands vegetation component is changing. The approach employed up to and including the 2001 study design was primarily descriptive, providing an understanding of the individual wetlands. The 2001 report has included more analytical methods. However, analysis of annual changes in each wetlands are not possible this year and will require a very precise, consistent field program designed to support the new, more analytical direction. Differences of a metre in sampling sites located in deep water could confound annual differences. Thus, the direction and likely the supporting field methods of the wetlands vegetation component are in transition.

The 2000 RAMP report concluded that one of the major achievements in 1999 and 2000 is that the studies have verified that RAMP now has an assessment tool in the form of small-bodied fish. This sentinel species component has more precision (i.e., it can separate potential mining effects from general oil sands effects) and statistical strength than previous monitoring. For example, gonad sizes in the sentinel fish were smaller in the development areas than in the reference areas. Futher monitoring is needed to determine whether these differences are due to habitat differences (including natural toxicity) between these areas. Within-site trends over time will be watched to see if decreases in gonad size are related to increases in oil sands development.

Fish tissue analysis is underway and proving to be a source of useful data (i.e., data on the accumulation of metals and PAHs that can be directly related to the consumption of fish). The baseline is not yet complete. The first year of data for the Muskeg River is presented in this report, although more data are available for the Athabasca River. Although the parameters to be measured have been increased, the core parameters are being maintained so that three years of data will eventually be available for comparison.

Although the previous two fish programs are building a database of scientifically defensible data, the fish fence study has been unsuccessful in meeting its objectives in 2001 and previous years. However, the 2001 program did, in conjunction with the general fish inventory conducted in the summer, indicate that Arctic grayling were not using the Muskeg River.

Although the radiotelemetry studies are not monitoring per se, the 2000/2001 study results indicated that northern pike and longnose suckers that spawn in the Muskeg River utilize the Athabasca River and its tributaries. Therefore, the radiotelemetry study has shown that many of these fish are potentially exposed to changes caused by the oil sands development over some or all of the year. This information may be useful in interpreting monitoring results.

As a result of refinements such as the sentinel species program and the fish tissue analysis added to the fish program in the last few years, this program has the capacity to detect cumulative effects and regional trends.

The water and sediment quality component of RAMP has also undergone refinement of methods and expansion. This component has the greatest quantity of data; however, changes have been made to the sampling methods to improve resolution and more sediment sampling locations have been added. Apparent trends in increasing concentrations of major ions have been identified by graphs this year. Data analysis scheduled for later this year may provide greater insight.

A long-term acidification monitoring network formed a new component of RAMP in 1999. The objective of this component is to monitor lake water chemistry as an early-warning indicator of excessive acidic deposition. Acidity-related variables (pH, alkalinity, bicarbonate/divalent cations ratio) showed no indication of changes related to acid deposition in 2001 compared to previous data. Since this component is still in its initial phase of implementation, it is expected to evolve over time.

In addition to the changes and expansion of existing programs, new programs have also been added in 2001 such as the non-core programs.

It is important that RAMP change and expand to meet the needs of communities, the changing interests and direction of the Steering Committee, improvements in methods and the expansion of oil sands developments in the region. However, if this change endangers the existing ongoing monitoring, it could reduce RAMP's capacity to meet the fundamental objectives. Consistency, quality control and precision in the repetition of sampling and analysis are essential elements in the development of a scientifically defensible database.

13 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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15 GLOSSARY AND LIST OF ACRONYMS

15.1 GLOSSARY

Acute	Acute refers to a stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
Ageing Structures	Parts of the fish which are taken for ageing analyses. These structures contain bands for each year of growth or maturity which can be counted. Some examples of these structures are scales, fin rays, otoliths and opercula. Most ageing structures can be taken with minimal effect on the fish and vary according to fish species
ANOVA	Analysis of Variance. A statistical test of whether 2 or more sample means could have been obtained from populations with the same parametric (true, absolute) mean.
Baseline	A surveyed condition which serves as a reference point to which later surveys are compared.
Benthic Invertebrates	Invertebrate organisms living on the bottom of lakes, ponds and streams. Examples of benthic invertebrates include the aquatic insects such as caddisfly larvae, which spend at least part of their life on or in bottom sediments. Many benthic invertebrates are major food sources for fish.
Biological Indicator (Bioindicator)	Any biological parameter used to indicate the response of individuals, populations or ecosystems to environmental stress. For example, growth is a biological indicator.
Biomonitoring	The use of living organisms as indicators of the quality and integrity of aquatic or terrestrial systems in which they reside.
Catch-Per-Unit-Effort (CPUE)	A measure which relates to the catch of fish, with a particular type of gear, per unit of time (number of fish/hour). Results can be given for a particular species or the entire catch. The results can reflect both the density and/or the vulnerability of the gear utilized, of a species in a particular system.

Chronic	Defines a stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of the organism. The measurement of a chronic effect can be reduced growth, reduce reproduction, etc., in addition to lethality.
Community	Plant or animal species living in close association in a defined location (e.g., fish community of a lake).
Concentration	Quantifiable amount of a chemical in environmental medium, expressed as mass of a substance per unit volume (e.g., mg/L), or per unit sample mass (e.g., mg/g).
Condition Factor	A measure of the relative "fitness" of an individual or population of fishes by examining the mathematical relationship between length and weight. The values calculated show the relationship between growth in length relative to growth in weight. In populations where increases in length are matched by increases in weight, the growth is said to be isometric. Allometric growth, the most common situation in wild populations, occurs when increases in either length or weight are disproportionate.
Conductivity	A measure of a water's capacity to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water.
Detection Limit (DL)	The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.
Discharge	In a stream or river, the volume of water that flows past a given point in a unit of time (i.e., m^3/s).
Diversity	The variety, distribution and abundance of different plant and animal communities and species within an area.
Ecological Indicator	Any ecological parameter used to indicate the response of individuals, populations or ecosystems to environmental stress.

Environmental Impact Assessment (EIA)	A review of the effects that a proposed development will have on the local and regional environment.
Fauna	A term referring to an association of animals living in a particular place or at a particular time.
Fecundity Index	The most common measure of reproductive potential in fishes. It is the number of eggs in the ovary of a female fish. It is most commonly measured in gravid fish. Fecundity increases with the size of the female.
Gonad Somatic Index (GSI)	The proportion of reproductive tissue in the body of a fish. It is calculated by dividing the total gonad weight by the carcass weight and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth.
GPS	Global Positioning System. This system is based on a constellation of satellites which orbit the earth every 24 hours. GPS provides exact position in standard geographic grid (e.g., UTM).
Lethal	Causing death by direct action.
Liver Somatic Index (LSI)	Ratio of liver versus total body weight. Expressed as a percentage of carcass weight.
m^3/s	Cubic metres per second. The standard measure of water flow in rivers; i.e., the volume of water in cubic metres that passes a given point in one second.
Microtox®	A toxicity test that includes an assay of light production by a strain of luminescent bacteria (*Photobacterium phosphoreum*).
Oil Sands	A sand deposit containing a heavy hydrocarbon (bitumen) in the intergranular pore space of sands and fine grained particles. Typical oil sands comprise approximately 10 wt% bitumen, 85% coarse sand (>44 μm) and a fines (<44 μm) fraction, consisting of silts and clays.

Organics	Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., $CaCo_3$).
Pathological Index (PI)	A quantitative summary of pathology where variables examined are assigned numerical values (either 0, 10, 20 or 30) to indicate normal or abnormal condition. In this system, variables that exhibit an increasing degree of pathology are assigned higher values. The PI is calculated by summing the index values for each variable. The PI value increases as the number and severity of abnormalities increases. Based on the Health Assessment Index (HAI) developed by Adams *et al.* (1993).
Pathology	The science which deals with the cause and nature of disease or diseased tissues.
PAH	Polycyclic Aromatic Hydrocarbon. A chemical by-product of petroleum-related industry and combustion of organic materials. PAHs are composed of at least two fused benzene rings. Toxicity increases with molecular size and degree of alkylation.
PEL	Probable Effect Level. Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.
QA/QC	Quality Assurance and Quality Control refers to a set of practices that ensure the quality of a product or a result. For example, "Good Laboratory Practice" is part of QA/QC in analytical laboratories and involves proper instrument calibration, meticulous glassware cleaning and an accurate sample information system.
Reach	A comparatively short length of river, stream channel or shore. The length of the reach is defined by the purpose of the study.
Receptor	The person or organism subjected to exposure to chemicals or physical agents.
Relative Abundance	The proportional representation of a species in a sample or a community.
Riffle Habitat	Shallow rapids where the water flows swiftly over completely or partially submerged materials to produce surface agitation.

Run Habitat	Areas of swiftly flowing water, without surface waves, that approximates uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.
Sediments	Solid fragments of inorganic or organic material that fall out of suspension in water, wastewater, or other liquid.
Shannon-Weiner Diversity Index	A calculation used to estimate species diversity using both species richness and relative abundance. A basic count of the number of species present in a community represents species richness. The number of individuals of each species occurring in a community is the species relative abundance.
Spawning Habitat	A particular type of area where a fish species chooses to reproduce. Preferred habitat (substrate, water flow, temperature) varies from species to species.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Sport/Game Fish	Large fish that are caught for food or sport (e.g., northern pike, trout).
Stressor	An agent, a condition, or another stimulus that causes stress to an organism.
Transect	A line drawn perpendicular to the flow in a channel along which measurements are taken.
Toxic	A substance, dose, or concentration that is harmful to a living organism.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.

Wetlands	Term for a broad group of wet habitats. Wetlands are transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands include features that are permanently wet, or intermittently water-covered such as swamps, marshes, bogs, muskeg, potholes, swales, glades, slashes and overflow land of river valleys.

15.2 ACRONYMS

AENV	Alberta Environment
AEP	Alberta Environmental Protection
Albian	Albian Sands Energy Inc.
Al-Pac	Alberta–Pacific Forest Industries
ANC	Acid Neutralizing Capacity
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
ARC-Vegreville	Alberta Research Council located in Vegreville
ASRD	Alberta Sustainable Resource Department
AWI	Alberta Wetland Inventory
AXYS	AXYS Analytical Services Ltd.
BACI	Before–After–Control–Impact
benthos	Benthic invertebrate
BOD	Bological Oxygen Demand
CAEAL	Canadian Association for Environmental Analytical Laboratories
CCME	Canadian Council of Ministers of the Environment
CEMA	Cumulative Environmental Management Association
CL	Critical load
CNRL	Canadian Natural Resources Limited
CPUE	Catch-per-unit-effort
DFO	Fisheries and Oceans Canada
DL	Detection limit
DO	Dissolved oxygen
DOC	Dissolved organic carbon

D/S	Downstream
EIA	Environmental Impact Assessment
EPEA	Environment Protection & Enhancement Act
EPI	External pathological index
ETL	Enviro-Test Laboratories
Exxon	ExxonMobil Canada Ltd.
GPS	Global Positioning System
GSI	Gonad Somatic Index
HAI	Health Assessment Index
Hydroqual	Hydroqual Laboratories
ISQG	Interim Freshwater Sediment Quality Guidelines
KIR	Key Indicator Resource
KP	Kilometer Posts
LCS	Laboratory Control Sample
LSI	Liver Somatic Index
MDL	Method Detection Limit
MS-222	Tricaine methane sulfonate
Northstar	Northstar Energy Dover
OPTI	OPTI Canada Inc.
PAH	Polycyclic aromatic hydrocarbon
Petro-Canada	Petro-Canada Oil and Gas
PI	Pathology index
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAP	Quality Assurance Plan
QC	Quality Control
RAMP	Regional Aquatics Monitoring Program
Shell	Shell Canada Limited
SPSS	Statistical software Systat
Suncor	Suncor Energy Inc., Oil Sands
SWI	Specific Work Instructions

Syncrude	Syncrude Canada Ltd
TCU	Total colour units
TDOC	Total dissolved organic carbon
TDS	Total dissolved solids
TOC	Total organic carbon
TP	Technical Procedures
TrueNorth	TrueNorth Energy L.P.
TSS	Total suspended solids
U/S	Upstream
U.S. EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
WAI	Weighted Average Index
WBEA	Wood Buffalo Environmental Association
Yr	Year

APPENDIX I

WATER AND SEDIMENT ANALYTICAL METHODS

Table I.1 Analytical Methods used by EnviroTest Labs when Analyzing RAMP Water Samples

Parameter	Units	Detection Limits	Analytical Methods[a]
Conventional Parameters			
bicarbonate (HCO3)	mg/L	5	APHA 2320B
calcium	mg/L	0.5	APHA 3120 B
carbonate (CO3)	mg/L	5	APHA 2320 B
chloride	mg/L	1	APHA 4500
colour	T.C.U.	3	APHA 2120B
conductance	µS/cm	0.2	APHA 2510 B
dissolved organic carbon	mg/L	1	APHA 5310 B
hardness	mg/L	1	APHA 2340 B
magnesium	mg/L	0.1	APHA 3120 B
pH		0.1	APHA 4500-H
potassium	mg/L	0.1	APHA 3120 B
sodium	mg/L	1	APHA 3120 B
sulphate	mg/L	0.5	APHA 4110 B
sulphide	µg/L	3	AEP
total alkalinity	mg/L	5	APHA 2320 B
total dissolved solids	mg/L	10	APHA 2540 c
total organic carbon	mg/L	1	APHA 5310 B
total suspended solids	mg/L	3	APHA 2540-D
Nutrients			
nitrate + nitrite	mg/L	0.1	APHA 4500NO3H
nitrogen - ammonia	mg/L	0.05	APHA 4500NH3F
nitrogen - kjeldahl	mg/L	0.2	APHA 4500N-C
phosphorus, total	µg/L	2	APHA 4500-PBE
phosphorus, total dissolved	µg/L	2	APHA 4500-PBE
Biochemical Oxygen Demand			
biochemical oxygen demand	mg/L	2	APHA 5210 B
Organics			
naphthenic acids	mg/L	1	FTIR
total phenolics	µg/L	1	EPA 420.2
total recoverable hydrocarbons	mg/L	0.5	APHA 5520 F
Metals (Total)			
aluminum (Al)	µg/L	20	SW6010
antimony (Sb)	µg/L	0.8	SW 3015
arsenic (As)	µg/L	1	ICP-MS
barium (Ba)	µg/L	0.2	SW6010
beryllium (Be)	µg/L	1	SW6010
boron (B)	µg/L	4	SW6010
cadmium (Cd)	µg/L	0.2	SW6010
calcium (Ca)	µg/L	100	APHA 3120 B
chromium (Cr)	µg/L	0.8	SW6010
cobalt (Co)	µg/L	0.2	SW6010
copper (Cu)	µg/L	1	SW6010
iron (Fe)	µg/L	20	SW6010
lead (Pb)	µg/L	0.1	SW6010
lithium (Li)	µg/L	6	SW3015
magnesium (Mg)	µg/L	20	APHA 3120 B
manganese (Mn)	µg/L	0.2	SW6010

Table I.1 Analytical Methods used by EnviroTest Labs when Analyzing RAMP Water Samples (continued)

Parameter	Units	Detection Limits	Analytical Methods[a]
mercury (Hg)	µg/L	0.2	APHA 3112 B
molybdenum (Mo)	µg/L	0.1	SW6010
nickel (Ni)	µg/L	0.2	SW6010
potassium (K)	µg/L	20	APHA 3120 B
selenium (Se)	µg/L	0.8	SW 3015
silver (Ag)	µg/L	0.4	SW6010
sodium (Na)	µg/L	200	APHA 3120 B
strontium (Sr)	µg/L	0.2	SW6010
titanium (Ti)	µg/L	0.6	SW 3015
uranium (U)	µg/L	0.1	SW 3015
vanadium (V)	µg/L	0.2	SW6010
zinc (Zn)	µg/L	4	SW6010
Metals (Dissolved)			
aluminum (Al)	µg/L	10	APHA 3120 B
antimony (Sb)	µg/L	0.8	ICP-MS
arsenic (As)	µg/L	0.4	ICP-MS
barium (Ba)	µg/L	0.1	APHA 3120 B
beryllium (Be)	µg/L	0.5	APHA 3120 B
boron (B)	µg/L	2	APHA 3120 B
cadmium (Cd)	µg/L	0.1	APHA 3120 B
chromium (Cr)	µg/L	0.4	APHA 3120 B
cobalt (Co)	µg/L	0.1	APHA 3120 B
copper (Cu)	µg/L	0.6	APHA 3120 B
iron (Fe)	µg/L	10	APHA 3120 B
lead (Pb)	µg/L	0.1	APHA 3120 B
lithium (Li)	µg/L	3	APHA 3120 B
manganese (Mn)	µg/L	0.1	APHA 3120 B
mercury (Hg)	µg/L	0.01 - 0.1	ICP-MS
molybdenum (Mo)	µg/L	0.1	APHA 3120 B
nickel (Ni)	µg/L	0.1	APHA 3120 B
selenium (Se)	µg/L	0.4 - 0.8	ICP-MS
silver (Ag)	µg/L	0.2	APHA 3120 B
strontium (Sr)	µg/L	0.1	APHA 3120 B
titanium (Ti)	µg/L	0.3	APHA 3120 B
uranium (U)	µg/L	0.1	ICP
vanadium (V)	µg/L	0.1	APHA 3120 B
zinc (Zn)	µg/L	2	APHA 3120 B

[a] APHA = Protocols developed by the American Public Health Association.

EPA and SW = Protocols established by the United States Environmental Protection Agency.

AEP = Protocol developed by Alberta Environment Protection.

ICP = Inductively Coupled Plasma.

MS = Mass spectrometry.

FTIR = Fourier Transform Infrared Spectroscopy.

Table I.2 Analytical Methods used by EnviroTest Labs when Analyzing RAMP Sediment Samples

Parameter	Units	Detection Limits	Analytical Methods[a]
Conventional Parameters			
particle size - % sand	%	1	gravimetric
particle size - % silt	%	1	gravimetric
particle size - % clay	%	1	gravimetric
total inorganic carbon	% by wt	0.01	combustion/acid reaction
total organic carbon	% by wt	0.01	combustion/acid reaction
total carbon	% by wt	0.01	combustion/acid reaction
General Organics			
total recoverable hydrocarbons	µg/g	100	APHA 5520 C
Metals (Total)			
aluminum (Al)	µg/g	10	SW 3051/6010
antimony (Sb)	µg/g	0.02	APHA 3114 C
arsenic (As)	µg/g	0.05	APHA 3114 C
barium (Ba)	µg/g	0.5	SW 3051/6010
beryllium (Be)	µg/g	1	SW 3051/6010
cadmium (Cd)	µg/g	0.5	SW 3051/6010
calcium (Ca)	µg/g	100	SW 3051/6010
chromium (Cr)	µg/g	0.5	SW 3051/6010
cobalt (Co)	µg/g	1	SW 3051/6010
copper (Cu)	µg/g	1	SW 3051/6010
iron (Fe)	µg/g	1	SW 3051/6010
lead (Pb)	µg/g	5	SW 3051/6010
magnesium (Mg)	µg/g	10	SW 3051/6010
manganese (Mn)	µg/g	0.1	SW 3051/6010
mercury (Hg)	µg/g	0.04	APHA 3114 C
molybdenum (Mo)	µg/g	1	SW 3051/6010
nickel (Ni)	µg/g	2	SW 3051/6010
potassium (K)	µg/g	20	SW 3051/6010
selenium (Se)	µg/g	0.1	APHA 3114 C
silver (Ag)	µg/g	1	SW 3051/6010
sodium (Na)	µg/g	100	SW 3051/6010
strontium (Sr)	µg/g	1	SW 3051/6010
sulphur (S)	µg/g	100	SW 3051/6010
titanium (Ti)	µg/g	5	SW 3051/6010
vanadium (V)	µg/g	1	SW 3051/6010
zinc (Zn)	µg/g	0.5	SW 3051/6010

[a] APHA = Protocols developed by the American Public Health Association.
SW = Protocols established by the United States Environmental Protection Agency.

Table I.3 Analytical Methods used by HydroQual Labs when Analyzing RAMP Water and Sediment Samples

Parameter	Analytical Methods
Water	
Microtox®	Toxicity testing using luminescent bacteria (*Vibrio fischeri*). 1992. Environment Canada. EPS 1/RM/24.
chlorophyll *a*	Spectrophotometric determination of chlorophyll. Standard methods for the examination of water and wastewater, 18th ed. 1992. American Public Health Association.
Selenastrum capricornutum	Growth inhibition test using the freshwater alga *Selenastrum capricornutum*. 1992. Environment Canada. EPS 1/RM/25. Amended November 1997.
Ceriodaphnia dubia (growth and survival)	Test of reproduction and survival using the Cladoceran *Ceriodaphnia dubia*. 1992. Environment Canada. EPS 1/RM/21. Amended November 1997.
fathead minnow (growth and survival)	Test of larval growth and survival using fathead minnow. 1992. Environment Canada. EPS 1/RM/22. Amended November 1997.
Sediments	
Chironomus tentans (growth and survival)	Test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus tentans* or *Chironomus riparius*). 1997. Environment Canada. EPS 1/RM/32.
Hyalella azteca (growth and survival)	Test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca*. 1997. Environment Canada. EPS 1/RM/33.
Lumbriculus variegatus (growth and survival)	Standard test methods for measuring the toxicity of sediment-associated contaminant with freshwater invertebrates. 1995. ASTM E 1706-98a.

Table I.4 Analytical Methods used by Alberta Research Council when Analyzing RAMP Water and Sediment Samples

Parameter	Units	Detection Limits	Analytical Methods[a]
Trace Metals			
mercury	ng/L	0.6	EPA Method 6020 CLP-M, Version 7.0
silver	ng/L	5	Envirodat Code system (VMV 101979, method code 2858); based on EPA Method 1631

SUMMARY OF THE ANALYTICAL PROTOCOL USED BY AXYS LABS TO ANALYZE FOR POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) IN RAMP SEDIMENT SAMPLES

Summary

Sediments were analyzed for a suite of polycyclic aromatic hydrocarbons (PAHs), including alkylated PAHs. All samples were spiked with an aliquot of surrogate standard solution containing perdeuterated analogues of acenaphthene, chrysene, naphthalene, 2-methylnaphthalene, perylene, phenanthrene, pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene and benzo(a)pyrene prior to analysis. Sediment samples were extracted by elution through a chromatographic column. Each extract was cleaned up on silica gel prior to analysis of PAHs by high resolution gas chromatography with low resolution (quadrupole) mass spectrometric detection (HRGC/MS).

Extraction Methods

A sub-sample of homogenized sediment was dried overnight at 105°C to determine moisture content.

Homogenized sediment sample was dried by grinding with anhydrous sodium sulphate. The mixture was transferred to a glass chromatographic column containing methanol. An aliquot of surrogate standard solution was added and the column was eluted with dichloromethane. The eluate was backwashed by shaking with potassium hydroxide solution followed by solvent extracted distilled water. The extract was dried over anhydrous sodium sulphate and concentrated. Activated copper was added to the extract to remover sulphur. The extract was ready for chromatographic cleanup procedures.

Chromatographic Cleanup Procedures

The extract was loaded onto a silica gel column (5% deactivated) and eluted with pentane (F1, discarded) followed by dichloromethane (F2, retained). The F2 fraction was concentrated and an aliquot of recovery standard, containing perdeuterated analogues of benzo(b)fluoranthene, fluoranthene and acenaphthylene was added. The extract was transferred to an autosampler vial in preparation for GC/MS analysis.

GC/MS Analysis

Analysis of the extract for PAHs was carried out using a Finnigan INCOS 50 mass spectrometer equipped with a Varian 3400 gas chromatograph with CTC autosampler and a Prolab Envirolink data system for MS control and data acquisition. The mass spectrometer was operated at unit mass resolution, in the

EI mode (70 Ev), using Multiple Ion Detection (MID) to enhance sensitivity. At least two characteristic ions for each target analyte and surrogate standard were monitored. A Restek Rtx-5 capillary chromatography column (30 m, 0.25 mm i.d. x 0.25 mm film thickness), used for chromatographic separation, was coupled to the MS source. A splitless/split injection sequence was used.

Quantitation Procedures

Concentrations of PAHs were calculated using the internal standard (isotope dilution) method of quantitation, comparing the area of the quantitation ion to that of the corresponding deuterated standard and correcting for response factors. Response factors were determined daily using authentic PAHs. Quantification was carried out using HP EnviroQuant and Prolab MS Extend software.

Concentrations of analytes were corrected based on the percent recovery of surrogate standards. Concentrations were reported on a dry weight basis.

APPENDIX II

COMMON AND SCIENTIFIC NAMES OF FISH SPECIES

Table II.1 Fish Species Common Names, Scientific Names and Abbreviations

Common Name	Scientific Name	Abbreviation[a]
northern pike	Esox lucius	NRPK
lake whitefish	*Coregonus clupeaformis*	LKWH
mountain whitefish	*Prosopium williamsoni*	MNWH
walleye	*Stizostedion vitreum*	WALL
Arctic grayling	*Thymallus arcticus*	ARGR
longnose sucker	*Catostomus catostomus*	LNSC
white sucker	*Catostomus commersoni*	WHSC
lake chub	*Couesius plumbeus*	LKCH
slimy sculpin	*Cottus cognatus*	SLSC
spoonhead sculpin	*Cottus ricei*	SPSC
brook stickleback	*Culaea inconstans*	BRST
emerald shiner	*Notropis atherinoides*	EMSH
trout-perch	*Percopsis omiscomaycus*	TRPR
longnose dace	*Rhinichthys cataractae*	LNDC
pearl dace	*Margariscus margarita*	PRDC
rainbow trout	*Oncorhynchus mykiss*	RNTR
tilapia	*Oreochromis mossambicus*	n/a
chub salmon	*Oncorhynchus keta*	n/a
brook trout	*Salvelinus fontinalis*	n/a
dogfish	*Sayliorhinus canicula*	n/a
Atlantic salmon	*Salmo salar*	n/a
stone loach	*Noemacheilus barbatulus*	n/a

[a] According to Mackay et al. (1990).

APPENDIX III

INTERNAL AND EXTERNAL PATHOLOGY DEFINITIONS

Table III.1 Pathology Examination: Variables, Conditions and Index Values

Variable	Variable Condition	Code	Pathology Index Value
eyes	no aberrations; good “clear” eye	N	0
	blind; an opaque eye (one or both)	B	30
	swollen, protruding eye (one or both)	E	30
	hemorrhaging or bleeding in the eye (one or both)	H	30
	missing one or both eyes	M	30
	other; any condition not covered above	OT	30
gills	normal; no apparent aberrations	N	0
	frayed; erosion of tips of gill lamellae resulting in “ragged” gills	F	30
	clubbed; swelling of the tips of the gill lamellae	C	30
	marginate; gills with light, discoloured margin along tips of the lamellae	M	30
	pale; very light in colour	P	30
	other; any condition not covered above	OT	30
pseudobranchs	normal; flat, containing no aberrations	N	0
	swollen; convex in aspect	S	30
	lithic; mineral deposits, white, somewhat amorphous spots	L	30
	inflamed; redness, hemorrhage, or other	I	30
	other; any condition not covered above	OT	30
thymus	no hemorrhage	0	0
	mild hemorrhage	1	10
	moderate hemorrhage	2	20
	Severe hemorrhage	3	30
skin	normal; no aberrations	0	0
	mild skin aberrations	1	10
	moderate skin aberrations	2	20
	severe skin aberrations	3	30
fins	no active erosion	0	0
	light active erosion	1	10
	moderate active erosion with some hemorrhaging	2	20
	severe active erosion with hemorrhaging	3	30
opercle	no shortening	0	0
	mild shortening	1	30
	Severe shortening	2	30
hindgut	normal; no inflammation or reddening	0	0
	slight inflammation or reddening	1	10
	moderate inflammation or reddening	2	20
	severe inflammation or reddening	3	30
body deformities	none	None	0
	any deformity (provide details)	N/A	30

Table III.1 Pathology Examination: Variables, Conditions and Index Values (continued)

Variable	Variable Condition	Code	Pathology Index Value
mesenteric fat	none	0	n/a
	< 50 % coverage of mesentery	1	n/a
	50 % coverage of mesentery	2	n/a
	> 50 % coverage of mesentery	3	n/a
	100 % coverage of mesentery	4	n/a
liver	normal; solid red or light red colour	A	0
	"fatty" liver; "coffee with cream" colour	C	30
	nodules in the liver; cysts or nodules	D	30
	focal discoloration; distinct localized colour changes	E	30
	general discoloration; colour change in whole liver	F	30
	other; any condition not covered above	OT	30
spleen	normal; black, very dark red, or red	B	0
	granular; rough appearance of spleen	G	30
	nodular; containing fistulas or nodules of varying sizes	D	30
	enlarged; noticeable enlarged	E	30
	other; any condition not covered above	OT	30
gall bladder	normal	0	0
	enlarged	1	30
	parasites	2	n/a
kidney	normal; firm dark red colour, lying relatively flat along vertebral column	N	0
	swollen; enlarged or swollen wholly or in part	S	30
	mottled; gray discoloration	M	30
	granular; granular appearance and texture	G	30
	urolithiasis/nephrocalcinosis; white/cream mineral material in tubules	U	30
	other; any condition not covered above	OT	30
parasites	no observed parasites	0	0
	few observed parasites	1	10
	moderate parasite infestation	2	20
	numerous parasites	3	30

APPENDIX IV

CLASSIFICATION SYSTEM AND TYPES OF WETLANDS

IV CLASSIFICATION SYSTEM AND TYPES OF WETLANDS

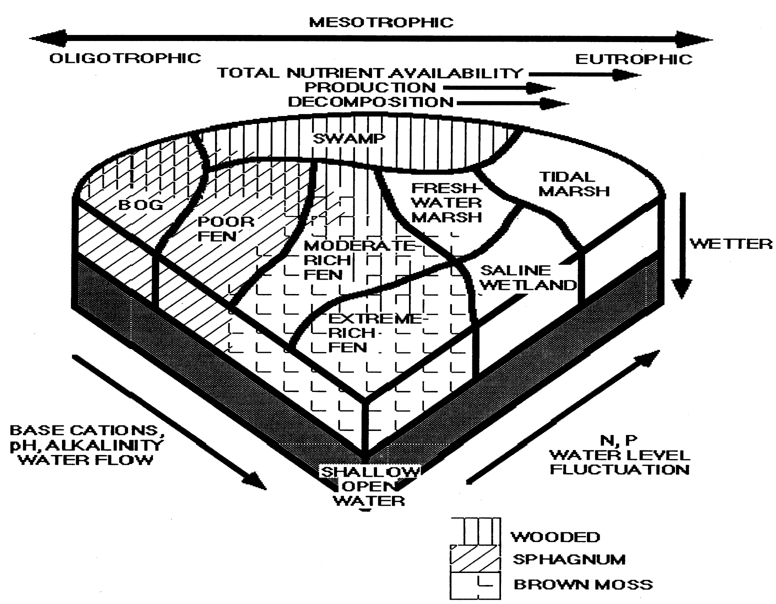
The National Wetlands Working Group (NWWG 1988) defined wetlands as:

"land that is saturated with water long enough to promote wetland or aquatic processes as indicated by hydric soil, hydrophytic vegetation, and various kinds of biological activity which are adapted to the wet environment".

This definition has been adopted in the Alberta Environment Protection Draft Wetland Policy (AEP 1997). In addition, wetlands in the province are classified according to the AWI as detailed by Halsey and Vitt (1996).

According to this classification system, wetlands are divided into 5 general types: bogs, fens, marshes, swamps and shallow open water. These wetlands are further described based on a combinations of factors, which include water level, water chemistry, floristic composition, topographic location, geomorphic basin configuration and other variables. These factors combine to form chemical and biotic gradients, which provides a framework for classifing wetlands as presented in Figure IV.1 and Table IV.1 (Nicholsol and Gignac 1995). Bogs, for example, are oligotrophic, acidic, with no flowing water whereas fens are mesotrophic, neutral to alkaline, with flowing water.

Figure IV.1 Wetlands Classification Based on Chemical and Biotic Gradients



Source: Halsey and Vitt 1996, modified from Vitt 1994

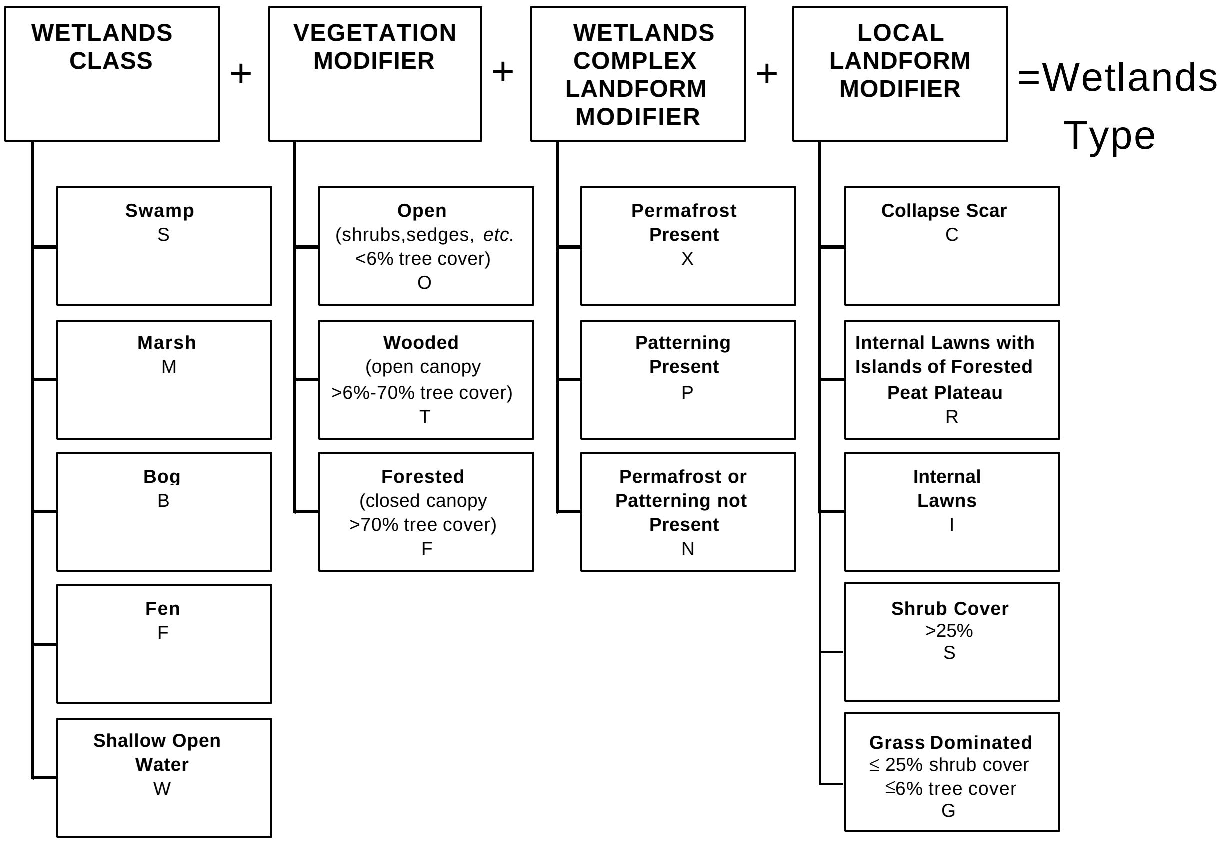
Changes in the chemical or biotic gradients could potentially effect wetlands properties, which may effect how the wetland functions within an ecosystem. Table IV.2 provides a summary of the properties associated with each general wetlands types.

Table IV.1 Summary of General Wetland Types and their Properties

	Bogs	Fens	Marshes	Swamps	Shallow Open Water
peat-forming	yes (*Sphagnum*)	yes (sedges, brown moss)	no	no	no
pH	strongly acidic	acidic to neutral	neutral to slightly alkaline	neutral to moderately acidic	variable
water level	at or near surface	at or near surface	fluctuates seasonally	at or near surface; may be seasonally flooded	intermittent or permanently flooded
flowing water	no	yes	yes	yes	yes
nutrients	low	medium to high	high	high	variable
minerals	low	medium to high	medium	medium	high
dominant vegetation	*Sphagnum*, ericaceous shrubs	sedges, grasses, reeds, brown moss	emergent sedges, grasses, rushes, reeds, submerged and floating aquatics	deciduous or coniferous trees or shrubs, herbs, some mosses	emergent vegetation

All of these wetlands properties are encorporated in the AWI classification. The classification contains four descriptive levels: the wetlands class, the vegetation modifier, the wetlands complex landform modifier and the local landform modifier (Figure IV.2). Approximately 14 of all the possible combinations occur in Alberta. For example, a wetland type denoted as FONG, is characterized as a fen (F), that is open (O), without permafrost (N) with grasses dominant (G).

Figure IV.2 Flow Chart Representation of Wetlands Classification Process



Local Land Modifier without internal lawns = N

Source: Nesby 1997

IV.1 WETLAND TYPE DESCRIPTIONS AFTER HALSEY AND VITT (1996)

Shallow Open Water are non-peat forming wetlands that are characterized by aquatic processes confined to less than 2 m depth at midsummer. These wetlands have submergent to floating vegetation and form a transition to truly aquatic ecosystems.

Marshes are open, non-peat forming wetlands that are dominated by sedges (Cyperaceae), other monocots (Mong), or shrubs (Mons). Marshes are characterized by seasonal water level fluctuations, relatively high amounts of water flow, and are influenced by ground and surface waters. Nutrient concentration of nitrogen and phosphorus is high, thus leading to high production but also high decomposition which limits peat accumulation.

Swamps are forested, wooded or shrubby non-peaty wetlands. Swamps and marshes have a poorly developed bryophyte layer that results from strong seasonal water level fluctuations and high vascular plant production. Peat accumulation is limited in swamps as decomposition rates are high. Vegetatively swamps are quite diverse and in Alberta may be composed of some combination of *Larix laricina*, *Picea mariana*, *Betula*, and *Salix*. Swamps can be treed (Stnn), forested (Sfnn), or open (> 6% trees cover) and shrub-dominated (Sons).

Peatlands, often termed muskeg, differ from non-peat forming wetlands by having a decrease in decomposition relative to plant production, thus allowing for the accumulation of peat. For a wetland to be classified as peatland in Canada, peat accumulation must > / = 40 cm. Peatlands are divided into two peat sequestering system, fens and bogs.

Fens are ecosystems that are affected by mineral soil waters (ground and/or surface) that may be relatively rich in mineral elements. Fens are influenced by flowing surface water or associated lakes and ponds. Fens have water levels at or near the peat surface.

Fens can be open and dominated by *Carex*, *Scirpus*, and *Eriophorum (Fong)*; or shrubby and dominated by *Betula* and *Salix (Fons)*; or wooded to forested with species such as *Picea mariana*, *Larix laricina*, *Betula*, and *Salix (Ftnn or Ffnn)*. Fens can be patterned (have flarks and strings) (Fopn or Ftpn).

Poor fens are low in indicator species, while extreme-rich fens are high in indicator species; moderate-rich fens are intermediate. Poor fens are acid (pH 4.5-5.5) and are ecologically more similar to bogs than to moderate-rich or rich fens. They are dominated by oligotrophic and mesotrophic species of *Sphagnum.* Moderate-rich fens have a slightly acid to neutral pH (5.5-7.0) and have species such as *Drepanocladus and Calliergonella*, and low abundances of mesotrophic species of *Sphagnum.* Extreme-rich fens have a basic pH (above 7.0) and are characterized by species of *Drepanocladus*, *Scorpidium*, and *Campylium.*

Bogs are peatlands that receive water only from precipitation and the water table is generally 40-60 cm below the peat surface. Bogs are acidic ecosystems with pH below 4.5 and are generally poor in available nutrients. Bogs are dominated by oligotrophic species of *Sphagnum* and feather mosses such as *Pleurozium schreberi* and *Hylocomnium splendens*.. They can be open, wooded or forested with only one tree species, *Picea mariana*.

Permafrost can be found in peatlands and the above classification recognizes permafrost features (x = permafrost present, c = collapse scar, r = internal lawns with islands of forested peat plateaus, and I = internal lawns). See Halsey and Vitt (1996) for detailed AWI classification.

APPENDIX V

QUALITY CONTROL SAMPLE DATA

Table V.1 Water Quality of Field Blanks and Trip Blanks, RAMP 2001 Field QC Program

Parameter	Units	Detection Limit	Field Blanks		Trip Blanks	
			Summer	Fall	Summer	Fall
Conventional Parameters						
colour	T.C.U.	3	5	< 3	5	< 3
conductance	µS/cm	0.2	2.1	2.2	2.1	2.0
dissolved organic carbon	mg/L	1	1	1	< 1	< 1
hardness	mg/L	-	< 1	< 1	< 1	< 1
pH	-	0.1	5.7	5.6	5.3	5.6
total alkalinity	mg/L	5	6	6	< 5	6
total dissolved solids	mg/L	10	10	20	10	< 10
total organic carbon	mg/L	1	1	3	< 1	1
total suspended solids	mg/L	3	< 3	< 3	< 3	< 3
Major Ions						
bicarbonate	mg/L	5	7	7	6	7
calcium	mg/L	0.5	< 0.5	< 0.5	< 0.5	< 0.5
carbonate	mg/L	5	< 5	< 5	< 5	< 5
chloride	mg/L	1	< 1	< 1	< 1	< 1
magnesium	mg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
potassium	mg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
sodium	mg/L	1	< 1	< 1	< 1	< 1
sulphate	mg/L	1.5	< 0.5	< 0.5	< 0.5	< 0.5
sulphide	µg/L	3	< 3	< 3	< 3	< 3
Nutrients and Chloropyll *a*						
nitrate + nitrite	mg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
nitrogen - ammonia	mg/L	0.05	< 0.05	< 0.05	< 0.05	< 0.05
nitrogen - Kjeldahl	mg/L	0.2	< 0.2	1.3	< 0.2	0.3
phosphorus, total	µg/L	1	< 1	3	< 1	< 1
phosphorus, dissolved	µg/L	1	< 1	2	3	< 1
chlorophyll *a*	µg/L	1	< 1	< 1	-	-
Biochemical Oxygen Demand						
biochemical oxygen demand	mg/L	2	< 2	< 2	< 2	< 2
Organics						
naphthenic acids	mg/L	1	< 1	< 1	< 1	< 1
total phenolics	µg/L	1	< 1	4	< 1	< 1
total recoverable hydrocarbons	mg/L	0.5	-	< 0.5	0.7	2.8
Total Metals						
aluminum (Al)	µg/L	20	< 20	< 20	30	< 20
antimony (Sb)	µg/L	5	< 5	< 5	< 5	< 5
arsenic (As)	µg/L	1	< 1	< 1	< 1	< 1
barium (Ba)	µg/L	0.2	1.3	< 0.2	0.3	0.3
beryllium (Be)	µg/L	1	< 1	< 1	< 1	< 1
boron (B)	µg/L	2	7	4	< 2	< 2
cadmium (Cd)	µg/L	0.2	< 0.2	< 0.2	< 0.2	< 0.2

Table V.1 Water Quality of Field Blanks and Trip Blanks, RAMP 2001 Field QC Program (continued)

Parameter	Units	Detection Limit	Field Blanks		Trip Blanks	
			Summer	Fall	Summer	Fall
calcium (Ca)	µg/L	500	< 500	< 500	< 500	< 500
chromium (Cr)	µg/L	0.8	< 0.8	< 0.8	< 0.8	< 0.8
cobalt (Co)	µg/L	0.2	< 0.2	< 0.2	< 0.2	< 0.2
copper (Cu)	µg/L	1	2	2	17	< 1
iron (Fe)	µg/L	5	25	11	33	6
lead (Pb)	µg/L	0.1	0.1	< 0.1	0.1	< 0.1
lithium (Li)	µg/L	6	< 6	< 6	< 6	< 6
magnesium (Mg)	µg/L	100	200	< 100	< 100	< 100
manganese (Mn)	µg/L	1	< 1	< 1	< 1	< 1
mercury (Hg)	µg/L	0.0006	0.0012	< 0.0006	<0.2[a]	<0.2[a]
molybdenum (Mo)	µg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
nickel (Ni)	µg/L	0.2	< 0.2	< 0.2	0.5	1.0
potassium (K)	µg/L	100	< 100	< 100	< 100	< 100
selenium (Se)	µg/L	0.8	< 0.8	< 0.8	< 0.8	< 0.8
silver (Ag)	µg/L	0.005	< 0.005	< 0.005	< 0.4	< 0.4
sodium (Na)	µg/L	1000	< 1000	< 1000	< 1000	< 1000
strontium (Sr)	µg/L	0.2	7.0	0.3	1.1	0.9
thallium (Tl)	µg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
titanium (Ti)	µg/L	0.6	< 0.6	< 0.6	<0.6	0.6
uranium (U)	µg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
vanadium (V)	µg/L	0.2	< 0.2	< 0.2	< 0.2	< 0.2
zinc (Zn)	µg/L	4	35	103	8	11
Dissolved Metals						
aluminum (Al)	µg/L	10	< 10	< 10	< 10	< 10
antimony (Sb)	µg/L	0.8	< 0.8	< 0.8	< 0.8	< 0.8
arsenic (As)	µg/L	0.4	< 0.4	< 0.4	0.4	< 0.4
barium (Ba)	µg/L	0.1	0.2	0.2	0.3	0.3
beryllium (Be)	µg/L	0.5	< 0.5	< 0.5	< 0.5	< 0.5
boron (B)	µg/L	2	3	2	36	2
cadmium (Cd)	µg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
chromium (Cr)	µg/L	0.4	< 0.4	< 0.4	5	< 0.4
cobalt (Co)	µg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
copper (Cu)	µg/L	0.6	7.7	1.3	< 0.6	< 0.6
iron (Fe)	µg/L	5	18	11	19	< 5
lead (Pb)	µg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
lithium (Li)	µg/L	0.1	0.2	< 0.1	< 0.1	0.2
manganese (Mn)	µg/L	1	< 1	< 1	< 1	< 1
mercury (Hg)	µg/L	0.1	0.1	< 0.1	< 0.1	< 0.1
molybdenum (Mo)	µg/L	0.1	0.2	< 0.1	0.1	< 0.1
nickel (Ni)	µg/L	0.1	0.2	0.3	0.2	< 0.1
selenium (Se)	µg/L	0.4	< 0.4	< 0.4	1.1	< 0.4

Table V.1 Water Quality of Field Blanks and Trip Blanks, RAMP 2001 Field QC Program (continued)

Parameter	Units	Detection Limit	Field Blanks		Trip Blanks	
			Summer	Fall	Summer	Fall
silver (Ag)	µg/L	0.2	1.2	< 0.2	< 0.2	< 0.2
strontium (Sr)	µg/L	0.1	0.6	0.2	< 0.1	0.7
thallium (Tl)	µg/L	0.05	< 0.05	< 0.05	< 0.05	< 0.05
titanium (Ti)	µg/L	0.3	< 0.3	< 0.3	1.8	< 0.3
uranium (U)	µg/L	0.1	< 0.1	< 0.1	< 0.1	< 0.1
vanadium (V)	µg/L	0.1	< 0.1	0.3	0.7	< 0.1
zinc (Zn)	µg/L	2	2	7	< 2	17

[(a)] Total mercury in summer and fall trip blanks was analyzed by ETL.

Table V.2 Water Quality of Split Samples, RAMP 2001 Field QC Program

Parameter	Units	Detection Limit	Summer Kearl Lake			Percent Difference [(a)]	Fall Muskeg River Mouth		Percent Difference
Conventional Parameters									
colour	T.C.U.	3	30	30	30	0	100	110	9
conductance	µS/cm	0.2	186	190	186	2	368	369	0.3
dissolved organic carbon	mg/L	1	18	18	18	0	21	21	0
hardness	mg/L	-	81	83	81	2	176	176	0
pH	-	-	8.0	8.0	8.0	0	8.2	8.2	0
total alkalinity	mg/L	5	91	91	90	1	180	180	0
total dissolved solids	mg/L	10	160	160	160	0	280	260	7
total organic carbon	mg/L	1	21	21	21	0	26	26	0
total suspended solids	mg/L	3	< 3	< 3	3	0	< 3	< 3	0
Major Ions									
bicarbonate	mg/L	5	111	112	110	2	220	219	0.5
calcium	mg/L	0.5	20.1	20.9	20.7	3	50.6	50.8	0.4
carbonate	mg/L	5	< 5	< 5	< 5	0	< 5	< 5	0
chloride	mg/L	1	< 1	< 1	< 1	0	5	7	29
magnesium	mg/L	0.1	7.4	7.4	7.2	3	12.0	12.0	0
potassium	mg/L	0.1	0.9	0.9	0.9	0	0.8	0.7	13
sodium	mg/L	1	10	10	10	0	12	15	20
sulphate	mg/L	0.5	5.9	5.8	5.8	0	15.2	15.7	3
sulphide	µg/L	3	< 3	3	< 3	0	7	12	42
Nutrients and Chloropyll *a*									
nitrate + nitrite	mg/L	0.1	< 0.1	< 0.1	< 0.1	0	< 0.1	< 0.1	0
nitrogen - ammonia	mg/L	0.05	< 0.05	< 0.05	< 0.05	0	< 0.05	< 0.05	0
nitrogen - Kjeldahl	mg/L	0.7	0.9	0.8	0.8	11	0.8	1.1	27
phosphorus, total	µg/L	1	10	9	9	10	23	24	4
phosphorus, dissolved	µg/L	1	6	7	6	14	23	25	8
chlorophyll *a*	µg/L	1	3	1	2	67	1	1	0
Biochemical Oxygen Demand									
biochemical oxygen demand	mg/L	2	< 2	< 2	2	0	< 2	< 2	0
Organics									
naphthenic acids	mg/L	1	< 1	< 1	< 1	0	1	1	0
total phenolics	µg/L	1	4	5	4	20	2	4	50
total recoverable hydrocarbons	mg/L	0.5	-	-	-	-	< 0.5	< 0.5	0
Total Metals									
aluminum (Al)	µg/L	20	30	< 20	< 20	33	110	50	55
antimony (Sb)	µg/L	5	< 5	< 5	< 5	0	< 5	< 5	0
arsenic (As)	µg/L	1	< 1	< 1	< 1	0	< 1	< 1	0
barium (Ba)	µg/L	0.2	14.8	15.9	14.9	7	35.8	36.1	1
beryllium (Be)	µg/L	1	< 1	< 1	< 1	0	< 1	< 1	0
boron (B)	µg/L	2	49	54	52	9	74	46	38
cadmium (Cd)	µg/L	0.2	< 0.2	< 0.2	< 0.2	0	< 0.2	< 0.2	0

Table V.2 Water Quality of Split Samples, RAMP 2001 Field QC Program (continued)

Parameter	Units	Detection Limit	Summer			Percent Difference [(a)]	Fall		Percent Difference
			Kearl Lake				Muskeg River Mouth		
calcium (Ca)	µg/L	500	18700	18900	18400	3	48700	48100	1
chromium (Cr)	µg/L	0.8	< 0.8	< 0.8	< 0.8	0	< 0.8	< 0.8	0
cobalt (Co)	µg/L	0.2	< 0.2	< 0.2	< 0.2	0	< 0.2	< 0.2	0
copper (Cu)	µg/L	1	< 1	< 1	1	0	< 1	< 1	0
iron (Fe)	µg/L	5	37	60	61	39	1060	1050	1
lead (Pb)	µg/L	0.1	< 0.1	< 0.1	0.2	50	< 0.1	< 0.1	0
lithium (Li)	µg/L	0.1	6	7	6	14	9	9	0
magnesium (Mg)	µg/L	100	6500	6500	6400	2	11200	11100	1
manganese (Mn)	µg/L	1	14	12	12	14	34	33	3
mercury (Hg)	µg/L	0.0006	0.0009	< 0.0006	< 0.0006	33	< 0.0006	< 0.0006	0
molybdenum (Mo)	µg/L	0.1	< 0.1	< 0.1	< 0.1	0	0.1	< 0.1	0
nickel (Ni)	µg/L	0.2	0.2	0.3	0.5	60	< 0.2	< 0.2	0
potassium (K)	µg/L	100	800	800	800	0	700	700	0
selenium (Se)	µg/L	0.8	< 0.8	< 0.8	< 0.8	0	< 0.8	< 0.8	0
silver (Ag)	µg/L	0.005	< 0.005	< 0.005	< 0.005	0	< 0.005	< 0.005	0
sodium (Na)	µg/L	100	9000	10000	9000	10	12000	12000	0
strontium (Sr)	µg/L	0.2	64	68	61	10	131	129	2
thallium (Tl)	µg/L	0.1	< 0.1	< 0.1	< 0.1	0	< 0.1	< 0.1	0
titanium (Ti)	µg/L	0.6	< 0.6	< 0.6	< 0.6	0	3.4	3.0	12
uranium (U)	µg/L	0.1	< 0.1	< 0.1	< 0.1	0	< 0.1	< 0.1	0
vanadium (V)	µg/L	0.2	< 0.2	< 0.2	< 0.2	0	0.3	0.3	0
zinc (Zn)	µg/L	4	12	33	13	64	159	< 4	98
Dissolved Metals									
aluminum (Al)	µg/L	10	< 10	< 10	< 10	0	< 10	< 10	0
antimony (Sb)	µg/L	0.8	< 0.8	< 0.8	< 0.8	0	< 0.8	< 0.8	0
arsenic (As)	µg/L	0.4	< 0.4	< 0.4	< 0.4	0	< 0.4	< 0.4	0
barium (Ba)	µg/L	0.1	15.2	15.4	16.3	7	32.7	33.0	1
beryllium (Be)	µg/L	0.5	< 0.5	< 0.5	< 0.5	0	< 0.5	< 0.5	0
boron (B)	µg/L	2	46	46	46	0	49	49	0
cadmium (Cd)	µg/L	0.1	< 0.1	< 0.1	< 0.1	0	< 0.1	< 0.1	0
chromium (Cr)	µg/L	0.4	< 0.4	< 0.4	< 0.4	0	< 0.4	< 0.4	0
cobalt (Co)	µg/L	0.1	< 0.1	< 0.1	0.1	0	< 0.1	< 0.1	0
copper (Cu)	µg/L	0.6	3.4	4.6	2.3	50	1.6	0.8	50
iron (Fe)	µg/L	5	23	26	24	12	468	490	4
lead (Pb)	µg/L	0.1	0.1	< 0.1	< 0.1	0	0.1	0.1	0
lithium (Li)	µg/L	0.1	6.3	6.4	6.5	3	8.9	8.9	0
manganese (Mn)	µg/L	1	1	1	1	0	19	20	5
mercury (Hg)	µg/L	0.1	< 0.1	< 0.1	< 0.1	0	< 0.1	< 0.1	0
molybdenum (Mo)	µg/L	0.1	0.2	0.2	0.1	50	0.1	< 0.1	0
nickel (Ni)	µg/L	0.1	< 0.1	0.3	0.1	67	0.2	< 0.1	50
selenium (Se)	µg/L	0.4	< 0.4	< 0.4	< 0.4	0	< 0.4	< 0.4	0

Table V.2 Water Quality of Split Samples, RAMP 2001 Field QC Program (continued)

Parameter	Units	Detection Limit	Summer			Percent Difference[(a)]	Fall		Percent Difference
			Kearl Lake				Muskeg River Mouth		
silver (Ag)	µg/L	0.2	< 0.2	< 0.2	< 0.2	0	< 0.2	< 0.2	0
strontium (Sr)	µg/L	0.1	62	63	69	10	131	134	2
thallium (Tl)	µg/L	0.05	< 0.05	< 0.05	< 0.05	0	0.08	< 0.05	38
titanium (Ti)	µg/L	0.3	< 0.3	< 0.3	< 0.3	0	0.9	0.7	22
uranium (U)	µg/L	0.1	< 0.1	< 0.1	< 0.1	0	< 0.1	< 0.1	0
vanadium (V)	µg/L	0.1	< 0.1	< 0.1	< 0.1	0	0.1	0.2	50
zinc (Zn)	µg/L	2	2	< 2	28	93	3	7	57

[(a)] Percent difference was calculated using the highest and lowest concentrations from the three split samples.

Note: water quality parameters that did not meet acceptance criteria are shaded.

Table V.3 Sediment Quality of Fall Duplicate and Split Samples, RAMP 2001 Field QC Program

Parameter	Units	Detection Limit	Duplicate Samples			Split Samples		
			Shipyard Lake		Percent Difference	Kearl Lake		Percent Difference
Particle Size								
moisture content	%	0.1	79	82	4	92	92	0
Carbon Content								
total inorganic carbon	% by wt	0.01	0.85	0.83	2	0.02	0.06	67
total organic carbon	% by wt	0.1	5.5	6.7	18	34.4	33.1	4
total carbon	% by wt	0.1	6.3	7.5	16	34.4	33.1	4
Organics								
total recoverable hydrocarbons	mg/kg	100	2300	2500	8	1600	1400	13
total volatile hydrocarbons	mg/kg	0.5	7.9	7.7	3	< 0.5	< 0.5	0
total extractable hydrocarbons	mg/kg	5	36	48	25	270	78	71
Total Metals								
aluminum (Al)	µg/g	1	19900	22400	11	7020	5330	24
arsenic (As)	µg/g	0.5	7.8	8.5	8	4.7	4.3	9
barium (Ba)	µg/g	0.1	210	216	3	78.9	78.1	1
beryllium (Be)	µg/g	0.2	1.0	1.1	9	0.3	< 0.2	33
boron (B)	µg/g	2	23	26	12	30	30	0
cadmium (Cd)	µg/g	0.1	0.3	0.4	25	0.4	0.4	0
calcium (Ca)	µg/g	10	22000	21900	0	12100	11800	2
chromium (Cr)	µg/g	0.2	31.8	33.6	5	11.6	10.0	14
cobalt (Co)	µg/g	0.1	13.5	12.7	6	4.3	3.7	14
copper (Cu)	µg/g	0.1	33	32.4	2	28.6	10.0	65
iron (Fe)	µg/g	10	29100	29700	2	7450	7020	6
lead (Pb)	µg/g	0.1	14.6	14.2	3	5.8	4.0	31
magnesium (Mg)	µg/g	10	8900	8470	5	2190	2170	1
manganese (Mn)	µg/g	0.1	361	361	0	123	118	4
mercury (Hg)	µg/g	0.04	0.07	0.09	22	0.06	0.06	0
molybdenum (Mo)	µg/g	0.1	0.8	0.8	0	1.1	0.9	18
nickel (Ni)	µg/g	0.1	36.0	36.6	2	15.1	14.5	4
potassium (K)	µg/g	2	3200	3430	7	1120	1300	14
selenium (Se)	µg/g	0.2	1.1	1.1	0	1.0	0.9	10
silver (Ag)	µg/g	0.1	< 0.1	< 0.1	0	< 0.1	< 0.1	0
sodium (Na)	µg/g	2	371	422	12	356	356	0
strontium (Sr)	µg/g	1	75	76	1	47	49	4
thallium (Tl)	µg/g	0.05	0.32	0.29	9	0.09	0.09	0
titanium (Ti)	µg/g	0.05	20.3	15.8	22	74	108	32
uranium (U)	µg/g	0.1	1.5	1.5	0	0.7	0.7	0
vanadium (V)	µg/g	0.1	54.1	60.5	11	14.7	16.3	10
zinc (Zn)	µg/g	0.2	86.5	91.4	5	103	78	24

[a] PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to identify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

Note: sediment quality parameters that are above acceptance criteria are shaded.

Table V.4 Reported PAH Concentrations in Fall Duplicate and Split Samples, RAMP 2001 Field QC Program

Parameter	Units	Duplicate Samples			Split Samples		
		Shipyard Lake		Acceptable Range	Kearl Lake		Acceptable Range
naphthalene	µg/g	11	10	7 - 14	12	10	8 - 14
C1 subst'd naphthalenes	µg/g	35	31	23 - 43	15	14	10 - 19
C2 subst'd naphthalenes	µg/g	49	45	33 - 61	24	19	15 - 28
C3 subst'd naphthalenes	µg/g	50	43	33 - 60	19	16	12 - 23
C4 subst'd naphthalenes	µg/g	20	19	14 - 25	7	4.3	4 - 7
acenaphthene	µg/g	2.7	2.3	1.8 - 3.3	5.7	4.3	3.5 - 6.5
C1 subst'd acenaphthene	µg/g	3.4	3.0	2.2 - 4.2	14	12	9 - 17
acenaphthylene	µg/g	<0.91	0.55[a]	0.51 - 0.95	0.93[a]	0.9[a]	0.64 - 1.2
anthracene	µg/g	2.8[a]	3.1[a]	2.1 - 3.8	4.2	3.5	2.7 - 5.0
dibenzo(a,h)anthracene	µg/g	11.0[a]	5.3	5.7 - 10.6	28[a]	11[a]	14 - 25
benzo(a)anthracene/chrysene	µg/g	50	48	34 - 64	44	19.6	22 - 41
C1 subst'd benzo(a)anthracene/chrysene	µg/g	450	420	305 - 566	110	130	84 - 156
C2 subst'd benzo(a)anthracene/chrysene	µg/g	270	250	182 - 338	33	37	25 - 46
benzo(a)pyrene	µg/g	14	14	10 - 18	7.9[a]	4.2	4.2 - 7.9
C1 subst'd benzo(b&k) f/b(a)pyrene[b]	µg/g	82	83	58 - 107	<6.2	13	6.7 - 12.5
C2 subst'd benzo(b&k) f/b(a)pyrene[b]	µg/g	26	28	19 - 35	9.2	27.0	12.6 - 23.5
benzofluoranthenes	µg/g	44	38	29 - 53	79	33	39 - 73
benzo(g,h,i)perylene	µg/g	29[a]	24	19 - 34	36[a]	19[a]	19 - 36
biphenyl	µg/g	5.3	4.7	3.5 - 6.5	4.2	3.3	2.6 - 4.9
C1 subst'd biphenyl	µg/g	<0.23	<0.27	-	<0.7	<0.63	-
C2 subst'd biphenyl	µg/g	0.84	<0.20	0.36 - 0.68	1.6	1.3	1 - 1.9
dibenzothiophene	µg/g	5.5[a]	5.7[a]	3.9 - 7.3	2.5[a]	1.7[a]	1.5 - 2.7
C1 subst'd dibenzothiophene	µg/g	27	28	19 - 36	7.1	8	5.3 - 9.8
C2 subst'd dibenzothiophene	µg/g	60	68	45 - 83	6.5	4	3.7 - 6.8
C3 subst'd dibenzothiophene	µg/g	120	120	84 - 156	4.6	<1.4	2.1 - 3.9
C4 subst'd dibenzothiophene	µg/g	52	57	38 - 71	8.2	4.2	4.3 - 8.1
fluoranthene	µg/g	10	9.7	6.9 - 12.8	24	19	15 - 28
C1 subst'd fluoranthene/pyrene	µg/g	6.6	57	43 - 80	15	18	12 - 21
C2 subst'd fluoranthene/pyrene	µg/g	110	100	74 - 137	17	11	9.8 - 18
C3 subst'd fluoranthene/pyrene	µg/g	91	91	64 - 118	4.3	7.1	4.0 - 7.4
fluorene	µg/g	7.9	7.5	5.4 - 10	15	14	10 - 19
C1 subst'd fluorene	µg/g	15	15	10 - 20	20	18	13 - 25
C2 subst'd fluorene	µg/g	91	92	64 - 119	230	140	130 - 241
C3 subst'd fluorene	µg/g	38	37	26 - 49	16	10	9 - 17
indeno(1,2,3,cd)pyrene	µg/g	19[a]	16[a]	12 - 23	33[a]	17[a]	18 - 33
phenanthrene	µg/g	28	27	19 - 38	30	27	20 - 37
C1 subst'd phenanthrene/anthracene	µg/g	110	110	77 - 143	72	70	50 - 92
C2 subst'd phenanthren/anthracene	µg/g	89	87	62 - 114	39	39	27 - 51
C3 subst'd phenanthrene/anthracene	µg/g	93	91	64 - 120	14	14	10 - 18
C4 subst'd phenanthrene/anthracene	µg/g	66	58	43 - 81	9.3	13	8 - 14
1-methyl-7-isopropyl-phenanthrene	µg/g	94	88	64 - 118	65	58	43 - 80
pyrene	µg/g	20	17	13 - 24	21	13	12 - 20

[a] PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to indentify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

[b] C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene.

Note: sediment quality parameters that are above acceptance criteria are shaded.
- = Not appliable.

Table V.5 PAH Concentrations in AXYS Method Blanks, RAMP 2001 Laboratory QC Program

Parameter	Units	Dec/01	Jan/02
naphthalene	µg/g	0.46	1.9
C1 subst'd naphthalenes	µg/g	0.71	1.9
C2 subst'd naphthalenes	µg/g	0.62	3.8
C3 subst'd naphthalenes	µg/g	0.41	< 0.47
C4 subst'd naphthalenes	µg/g	0.48	< 0.21
acenaphthene	µg/g	< 0.14	< 0.42
C1 subst'd acenaphthene	µg/g	< 0.042	< 0.18
acenaphthylene	µg/g	0.29[(a)]	< 0.21
anthracene	µg/g	0.34	< 0.23
dibenzo(a,h)anthracene	µg/g	0.17[(a)]	1.1[(a)]
benzo(a)anthracene/chrysene	µg/g	0.44	1.08
C1 subst'd benzo(a)anthracene/chrysene	µg/g	< 0.22	< 0.66
C2 subst'd benzo(a)anthracene/chrysene	µg/g	0.13	< 0.17
benzo(a)pyrene	µg/g	0.2[(a)]	0.23[(a)]
C1 subst'd benzo(b&k) f/b(a)pyrene[(b)]	µg/g	< 0.07	< 0.34
C2 subst'd benzo(b&k) f/b(a)pyrene[(b)]	µg/g	0.17	< 0.26
benzofluoranthenes	µg/g	0.32[(a)]	2.1
benzo(g,h,i)perylene	µg/g	0.11[(a)]	0.95[(a)]
biphenyl	µg/g	0.58	< 0.33
C1 subst'd biphenyl	µg/g	< 0.061	< 0.19
C2 subst'd biphenyl	µg/g	< 0.057	< 0.13
dibenzothiophene	µg/g	0.35	< 0.21
C1 subst'd dibenzothiophene	µg/g	0.096	< 0.41
C2 subst'd dibenzothiophene	µg/g	0.11	< 0.24
C3 subst'd dibenzothiophene	µg/g	0.26	< 0.27
C4 subst'd dibenzothiophene	µg/g	1.2	< 0.32
fluoranthene	µg/g	0.55	0.6
C1 subst'd fluoranthene/pyrene	µg/g	0.13	< 0.26
C2 subst'd fluoranthene/pyrene	µg/g	0.16	< 0.24
C3 subst'd fluoranthene/pyrene	µg/g	< 0.048	< 0.092
fluorene	µg/g	0.29	0.38[(a)]
C1 subst'd fluorene	µg/g	< 0.05	< 0.23
C2 subst'd fluorene	µg/g	0.37	< 0.23
C3 subst'd fluorene	µg/g	< 0.12	< 0.26
indeno(1,2,3,cd)pyrene	µg/g	0.17[(a)]	1.2[(a)]
phenanthrene	µg/g	0.87	1.6
C1 subst'd phenanthrene/anthracene	µg/g	0.51	< 0.75
C2 subst'd phenanthrene/anthracene	µg/g	0.34	< 0.39
C3 subst'd phenanthrene/anthracene	µg/g	0.069	< 0.16
C4 subst'd phenanthrene/anthracene	µg/g	< 0.06	< 0.13
1-methyl-7-isopropyl-phenanthrene	µg/g	0.28	< 0.25
pyrene	µg/g	0.49	0.77[(a)]

(a) PAH concentrations are reported with the limitation that interference from the sample matrix resulted in a GCMS spectrum without clear, easy to indentify peaks (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

(b) C1 subst'd benzo(b&k) fluoranthene/benzo(a)pyrene.

APPENDIX VI

SENTINEL SPECIES DAT A, FALL 2001

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
MR-E	MEM001	SLSC	M	SD	8.9	7.89	1.12	6.606	2					3 small trichopterans & 1 large one	3 white parasitic cysts in gill cavity
MR-E	MEM002	SLSC	M	SD	9.8	12.65	1.34	10.935	2				30	trichopteran	
MR-E	MEF003	SLSC	F	SD	8.3	6.65	1.16	5.792	2				25	1 caddisfly larv.	
MR-E	MEM004	SLSC	M	SD	8.8	8.226	1.21	6.889	1			green	100	Trich. case	
MR-E	MEF005	SLSC	F	SD	8	5.665	1.11	4.787	2				50	caddisflies	
MR-E	MEF006	SLSC	F	MA	7.8	6.16	1.30	5.177	1			green	25	green mush	
MR-E	MEM007	SLSC	M	SD	7.8	5.75	1.21	5.02	1				100	caddisflies, algal balls	left pectoral base=lesion / caudal base=small growth
MR-E	MEF008	SLSC	F	SD	9.4	11.108	1.34	9.135	2				50		
MR-E	MEM009	SLSC	M	SD	8.3	5.76	1.01	4.763	1	1			25	caddisflies	
MR-E	MEM010	SLSC	M	SD	7.3	4.567	1.17	2.747	1				25	caddis cases	large gonads for the size of fish
MR-E	MEM011	SLSC	M	SD	9.4	9.954	1.20	8.888	2	2			40	caddisfly and mush	
MR-E	MEM012	SLSC	M	SD	7.9	6.025	1.22		2			green	100	mayfly parts and beetle larvae	slightly pale liver
MR-E	MEM013	SLSC	M	SD	7.9	5.974	1.21	5.288	1	2			25	trichoptera	small white cysts in gill cavity
MR-E	MEM014	SLSC	M	SD	7.6	4.631	1.05	3.983	1				50	chironomids	slightly pale liver
MR-E	MEF015	SLSC	F	SD	7.4	3.987	0.98	3.46	1				50	coleoptera/ trichoptera	
MR-E	MEF016	SLSC	F	SD	8.7	7.607	1.16	6.206	4				12.5	small chironomids	1 round fluid cyst in hindgut
MR-E	MEM017	SLSC	M	SD	8.5	7.534	1.23	6.592	3				50	trichoptera	cysts on outer stomach wall also throughout the kidney-they were collected
MR-E	MEM018	SLSC	M	SD	8	5.534	1.08	4.603	1			green	75	chironomids and coleoptera	LIVER-slightly pale and small; DORSAL FIN - white cyst
MR-E	MEF019	SLSC	F	SD	7.7	4.867	1.07	4.252	1			green	25	caddisflies	
MR-E	MEM020	SLSC	M	SD	8.2	7.33	1.33	6.19	5				50	caddisflies	thick membranous film over left eye
MR-E	MEM021	SLSC	M	SD	7.8	5.149	1.09	4.537	1			green	40	caddisflies	
MR-E	MEM022	SLSC	M	IM	6.9	2.989	0.91	2.28	1				25	caddisflies/ chironomids	gonads not taken immature fish

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
MR-E	MEF023	SLSC	F	SD	7.4	4.688	1.16	4.255	1			green	0	empty	white nodules on left side below lateral line, posterior to pectoral fin
MR-E	MEF024	SLSC	F	SD	8.2	6.398	1.16	4.035	3				75	caddisflies/ chironomids	
MR-E	MEM025	SLSC	M	SD	8	6.489	1.27	5.745	1				0	empty	
MR-E	MEF026	SLSC	F	SD	7.5	4.747	1.13	4.264	1				25	green mush	cysts on right side of gills, spleen slightly enlarged
MR-E	MEM027	SLSC	M	SD	7.5	4.49	1.06	3.921	1		100		25	mush and mollusks	R pectoral 3rd ray missing (broken)
MR-E	MEM028	SLSC	M	SD	6.8	3.563	1.13	3.171	1				50	trichoptera	membrane/film over eye, L pelvic fin has white cyst
MR-E	MEF029	SLSC	F	SD	7.7	5.105	1.12	4.623	1				30	digested matter	slightly pale liver
MR-E	MEF030	SLSC	F	SD	7.5	4.607	1.09	4.144	1				25	chironomids	
MR-E	MEF031	SLSC	F	SD	7.8	4.834	1.02	4.335	1			green	0	empty	lesion on right side below fin above lateral line and small white cyst on right opercle
MR-E	MEF032	SLSC	F	SD	7.3	3.864	0.99	3.851	1				25	mayflies/chironomids	
MR-E	MEF033	SLSC	F	SD	7.7	3.934	0.86	3.426	1		0		0	empty	slight haemorrhaging posterior right gill cavity
MR-E	MEF034	SLSC	F	SD	8.5	7.498	1.22	6.402	4				100	mush (brownish)	membranous film over left eye
MR-E	MEF035	SLSC	F	SD	6.3	2.705	1.08	2.215	3				25	mush	very pale sculpin-albino!!!
MR-E	MEF036	SLSC	F	SD	7.9	4.622	0.94	3.842	2				25	mush	
MR-E	MEM037	SLSC	M	SD	7.7	5.267	1.15	4.47	1				50	chironomids, mayflies, limpets	small liver, white round cysts on right pelvic fin
MR-E	MEM038	SLSC	M	SD	8.7	7.136	1.08	6.195	1				24	mayflies and mush	round cysts in right gill cavity
MR-E	MEF039	SLSC	F	SD	7.1	3.835	1.07	3.332	1				50	trichoptera	2 cysts below lateral line, 1 cyst on opercle below gill
MR-E	MEM040	SLSC	M	SD	8.8	6.68	0.98	5.904	1	1			10	chironomid	
MR-E	MEM041	SLSC	M	SD	10.1	11.307	1.10	9.7	3				100	plecoptera	R gill frayed
MR-E	MEF042	SLSC	F	SD	8.3	6.392	1.12	5.526	2				30	caddisflies	round white cysts in right gill chamber
MR-E	MEM043	SLSC	M	SD	8.2	6.283	1.14	5.473	1	1			75	mayfly	
MR-E	MEM044	SLSC	M	SD	8	5.089	0.99	4.823	1				30	limpet	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
MR-E	MEM045	SLSC	M	SD	9	8.774	1.20	7.891	3				100	chironomids	cyst on caudal peduncle
MR-E	MEF046	SLSC	F	SD	7.4	5.135	1.27	4.429	2				25	beetle larvae / caddisfly	
MR-E	MEM047	SLSC	M	SD	8.8	6.918	1.02	6.189	3				10	ephemeroptera	
MR-E	MEM048	SLSC	M	SD	8.1	6.029	1.13	5.134	1				25	caddisfly cases	white cyst beside anal fin on right side
MR-E	MEM049	SLSC	M	SD	7.3	5.35	1.38	4.819	1				50	coleoptera/ trichoptera	cyst in right gill cavity
MR-E	MEM050	SLSC	M	SD	8.8	7.695	1.13	6.595	1				75	caddisfly cases	
MR-E	MEM051	SLSC	M	SD	8	5.952	1.16	5.29	1				25	trichoptera	white on one lobe of liver, cyst in left gill cavity
MR-E	MEF052	SLSC	F	SD	7.8	5.628	1.19	4.725	1				50	beetle larvae	very orange liver
MR-E	MEF053	SLSC	F	SD	6.5	3.134	1.14	2.747	1	1			10	trichoptera	small spleen
MR-E	MEF054	SLSC	F	SD	7	3.655	1.07	3.282	1				50	mollusks	
MR-E	MEF055	SLSC	F	SD	6.5	2.976	1.08	2.624	1						
MR-E	MEF056	SLSC	F	SD	8.7	3.274	0.50	2.865	1		100	green	50	stonefly, beetle larvae	
MR-E	MEF057	SLSC	F	SD	6.9	3.842	1.17	3.405	1				0	empty	small otherwise normal colour
MR-E	MEF058	SLSC	F	SD	8	5.646	1.10	5.062	1		0		25	unidentified digested material	saved preserved dorsal fin cyst
MR-E	MEF059	SLSC	F	SD	7.2	4.262	1.14	2.933	1			green	50	beetle larvae	
MR-E	MEF060	SLSC	F	SD	8.1	5.493	1.03	4.899	3				5	chironomids/mayflies	
MR-E	MEF061	SLSC	F	SD	7.3	4.152	1.07	3.741	1				<10	digested matter	white cyst in left gill chamber
SR-E	SEM001	SLSC	M	SD	8.8	6.824	1.00	6.088	4				30	mush	
SR-E	SEF002	SLSC	F	SD	7.5	4.976	1.18	4.333	4				30	mush	
SR-E	SEF003	SLSC	F	SD	7.4	4.026	0.99	3.513	2				10		
SR-E	SEF004	SLSC	F	SD	7.9	5.24	1.06	4.49	2				75	mush	parasitic cysts floating in body cavity and attached to the anterior kidney
SR-E	SEF005	SLSC	F	SD	7.5	4.803	1.14	4.215	3				25	blackfly larvae	
SR-E	SEM006	SLSC	M	SD	7.8	5.207	1.10	4.405	3				0	empty	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[(a)]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
SR-E	SEF007	SLSC	F	SD	7	3.517	1.03	3.075	2				50	partially digested food	dorsal fin split
SR-E	SEM008	SLSC	M	SD	8.1	5.963	1.12	5.256	3				50	limpet	abnormally small
SR-E	SEF009	SLSC	F	SD	7	4.018	1.17	3.434	2						white worm in skin/muscle tissue on ventral surface
SR-E	SEF010	SLSC	F	SD	6.7	3.155	1.05	2.687	3	3			25	beetle larvae	
SR-E	SEM011	SLSC	M	SD	8.1	5.111	0.96	4.5	2				30	mush	
SR-E	SEM012	SLSC	M	SD	8.2	5.448	0.99	5.037	2				0	empty	small white parasitic cysts in body cavity and embedded in kidney; one in head near otolith region
SR-E	SEM013	SLSC	M	SD	8.7	6.875	1.04	6.124	3	3	0	clear	10	green mush	
SR-E	SEM014	SLSC	M	SD	8.1	5.039	0.95		3		0	clear	0	empty	
SR-E	SEF015	SLSC	F	SD	7.1	4.405	1.23	3.874	3				10	mush	
SR-E	SEF016	SLSC	F	SD	7.5	3.781	0.90	3.243	2				0	empty	
SR-E	SEM017	SLSC	M	SD	7.5	4.172	0.99	3.702	2				5	green mush	
SR-E	SEF018	SLSC	F	SD	7.5	4.531	1.07	4	2				50	blackfly larvae/limpets	spleen practically non existent
SR-E	SEF019	SLSC	F	SD	7.2	4.004	1.07	3.101	2		0	clear	25	green mush	
SR-E	SEM020	SLSC	M	SD	8	5.432	1.06	4.626	2				25	mollusks	
SR-E	SEM021	SLSC	M	SD	7.2	3.438	0.92	3.097	3			green	0	empty	
SR-E	SEF022	SLSC	F	SD	7	3.503	1.02	3.137	2	2			20	mush	very small and flattened spleen
SR-E	SEM023	SLSC	M	SD	7.8	5.571	1.17	4.893	2				25	limpet	
SR-E	SEM024	SLSC	M	SD	7.8	5.04	1.06	4.38	2		100	green	25	limpet	
SR-E	SEF025	SLSC	F	SD	7.1	4.207	1.18	3.668	3				50	caddisfly cases/chironomid	
SR-E	SEF026	SLSC	F	SD	7	3.87	1.13	3.332	2				50	mush	
SR-E	SEF027	SLSC	F	SD	6.8	3.572	1.14	3.096	2				50	limpet	
SR-E	SEF028	SLSC	F	SD	6.9	3.568	1.09	3.183	2				10	mush	
SR-E	SEF029	SLSC	F	MA	6.1	2.239	0.99	2.083	1				<5	small caddisfly	very small ovaries
SR-E	SEM030	SLSC	M	SD	7.1	3.874	1.08	3.323	1				25	chironomids	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[(a)]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
SR-E	SEF031	SLSC	F	SD	7.1	3.966	1.11	3.546	2				0	empty	
SR-E	SEF032	SLSC	F	SD	6.9	3.741	1.14	3.216	2				50	chironomids	head short and 'blunt nose', liver is a bit fatty
SR-E	SEF033	SLSC	F	MA	6.4	2.823	1.08	2.505	1				5	green mush	
SR-E	SEF034	SLSC	F	SD	7.4	4.33	1.07	3.673	2				30	limpets	left pelvic fin is short and twisted
SR-E	SEM035	SLSC	M	SD	8.4	5.988	1.01	5.57	2				80	limpet/caddisfly	
SR-E	SEM036	SLSC	M	SD	8.2	6.715	1.22	5.849	3			green	40	green mush	small white lump on L lateral line also a white 'worm-like' cyst under skin under R pelvic fin
SR-E	SEM037	SLSC	M	SD	8	5.366	1.05	4.528	2				80	caddisfly	1 cyst in body cavity beside left swim bladder, cyst under skin on isthmus
SR-E	SEF038	SLSC	F	MA	6.9	3.656	1.11	3.177	3		0		<5	green mush	staging is required for gonads
SR-E	SEF039	SLSC	F	SD	6.8	2.901	0.92	2.456	2				10	mush	
SR-E	SEF040	SLSC	F	SD	8.6	6.157	0.97	5.457	3	3	0		12.5	digested matter	
SR-E	SEF041	SLSC	F	SD	7.6	4.976	1.13	4.964	2				25	mayfly larvae	
SR-E	SEM042	SLSC	M	SD	7.1	4.633	1.29	3.891	2		50		75	limpets	spleen very small
SR-E	SEF043	SLSC	F	SD	7.2	4.259	1.14	3.6	2				90	mush	cysts on ventral surface beside anal fin (collected)
SR-E	SEM044	SLSC	M	SD	7.6	5.017	1.14	4.335	3		0		100	limpet / caddisfly	spleen fairly large
SR-E	SEF045	SLSC	F	SD	7.2	4.383	1.17	3.924	4				50	mush	
SR-E	SEM046	SLSC	M	SD	7.6	5.067	1.15	4.531	3		100	yell/gr	40	limpet/green mush	
SR-E	SEF047	SLSC	F	SD	7.6	4.117	0.94	3.996	3				20		
SR-E	SEF048	SLSC	F	SD	7.7	5.09	1.11	4.477	4		0		100	limpet	spleen very small
SR-E	SEM049	SLSC	M	SD	8.6	7.034	1.11	6.047	3				100	limpet/mush	
SR-E	SEF050	SLSC	F	SD	7.8	5.832	1.23	5.176	2	2		yell/gr	25	caddisfly case	
SR-E	SEF051	SLSC	F	SD	7	4.188	1.22	3.704	2						
SR-E	SEF052	SLSC	F	SD	7.4	4.385	1.08	3.785	2				25	limpet / mayfly	
SR-E	SEF053	SLSC	F	SD	7.1	3.903	1.09	3.443	4				10	mush	
SR-E	SEF054	SLSC	F	SD	7	3.709	1.08	3.243	2		0		100	caddisfly case and mush	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[(a)]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
SR-E	SEF055	SLSC	F	SD	6.4	3.082	1.18	2.652	6		25	green	25	caddisfly case and mush	
SR-E	SEM056	SLSC	M	SD	8.2	6.558	1.19	5.887	4		0		50	mush	
SR-E	SEM057	SLSC	M	SD	9.1	8.814	1.17	7.38	7				100	mush	
SR-E	SEF058	SLSC	F	SD	7.4	4.478	1.11	3.973	2	2	0		40	caddisflies and pebble	
SR-E	SEF059	SLSC	F	SD	7	3.94	1.15	2.487	2				25	caddisfly cases	
SR-R	SRF001	SLSC	F	SD	6.3	2.611	1.04	2.113	2				0	empty	parasite left of anal fin
SR-R	SRF002	SLSC	F	SD	6.1	2.634	1.16	2.268	2				50	mush and unknown benthic	
SR-R	SRM003	SLSC	M	SD	7	4.436	1.29	3.724	2				90	mayfly/caddisfly	
SR-R	SRM004	SLSC	M	SD	7.4	2.427	0.60	3.566	2	2			100	caddisflies/ mush	liver oddly shaped and mushy
SR-R	SRF005	SLSC	F	SD	7.1	4.253	1.19	3.56	3				100	2 mayflies	
SR-R	SRM006	SLSC	M	SD	6.8	3.386	1.08	2.946	2				50	caddisfly and mayfly	abnormally small liver, parasite on ventral surface
SR-R	SRM007	SLSC	M	SD	7.3	4.013	1.03	3.469	2		0		50	full of mayfly, caddisfly, algae	white cyst in gill cavity(RS)
SR-R	SRF008	SLSC	F	SD	6.2	2.875	1.21	2.324	2		100	clear	100	mush	kidney- grey, liver- mushy, cyst on ventral surface near caudal fin
SR-R	SRF009	SLSC	F	SD	6.5	3.305	1.20	2.658	3		0		90	mayfly and mush	nodules on intestine and entire body cavity
SR-R	SRF010	SLSC	F	SD	6.4	3.07	1.17	2.462	2		0		75	mayfly and mush	nodules on intestine and in entire body cavity
SR-R	SRF011	SLSC	F	SD	6.5	3.047	1.11	2.504	2				25	mayflies	nodules on ovaries; white pigmentation on ventral side
SR-R	SRM012	SLSC	M	SD	6.8	3.806	1.21	3.092	3				100	mayfly and caddisfly	parasites on skin, liver is mushy and has nodules
SR-R	SRF013	SLSC	F	SD	6.6	3.014	1.05	2.578	2				40	mayfly and algae	
SR-R	SRF014	SLSC	F	SD	6.2	2.928	1.23	2.45	2				50	mayfly and green mush	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
SR-R	SRF015	SLSC	F	SD	6.9	3.869	1.18	3.233	2				100	mayfly and caddisfly	
SR-R	SRF016	SLSC	F	SD	6.1	2.613	1.15	2.179	2						
SR-R	SRM017	SLSC	M	SD	7.7	5.652	1.24	4.71	2				100	mayflies	white nodules on outer stomach wall, mucus and fat kidney, spleen-small
SR-R	SRM018	SLSC	M	SD	7.4	4.703	1.16	3.858	2	2 or 3	100	yell/gr	50	3 limpets, 1 mayfly	nodule in body cavity, rectangular cyst on L ventral surface
SR-R	SRM019	SLSC	M	SD	7.6	5.378	1.23	4.305	2		0		80	mayflies and limpets	nodules in whole body cavity, floating in body fluid
SR-R	SRM020	SLSC	M	SD	7.2	4.361	1.17	3.574	2			yell/gr	50	mayfly	liver- pale, jelly like (mushy)
SR-R	SRF021	SLSC	F	SD	6.7	3.326	1.11	2.578	3		100	yell/gr	50	algae, mayflies	
SR-R	SRF022	SLSC	F	SD	6.1	2.429	1.07	1.902	2		100	yellow	10	mush, invert parts	
SR-R	SRF023	SLSC	F	SD	6.3	2.842	1.14	2.365	2		0		90	limpets, mush	
SR-R	SRF024	SLSC	F	SD	7.2	4.266	1.14	3.429	3		100	yell/gr	40	limpet, mayflies, mush	
SR-R	SRM025	SLSC	M	SD	7.3	4.322	1.11	3.545	2	2	100	yell/gr	100	mayfly and caddisfly	
SR-R	SRF026	SLSC	F	SD	6.9	4.35	1.32	3.4	2				90	mayflies	
SR-R	SRF027	SLSC	F	SD	6.7	3.052	1.01	2.495	2				80	mayflies and caddisfly cases	
SR-R	SRM028	SLSC	M	SD	7.5	5.95	1.41	4.44	2		0		100	mayfly and algae	
SR-R	SRF029	SLSC	F	SD	7	4.213	1.23	3.347	2		100	yell/gr	60	mayfly and algae	sm. White floating cysts in body cavity
SR-R	SRM030	SLSC	M	SD	7.4	4.996	1.23	3.94	2		100	green	50	caddisfly cases and invert parts	external cysts
SR-R	SRF031	SLSC	F	SD	6.7	3.468	1.15	2.945	2		100	green	40	mayflies	
SR-R	SRF032	SLSC	F	SD	6.8	3.177	1.01	2.43	3		0		80	mayfly and mush	
SR-R	SRF033	SLSC	F	SD	6.5	3.099	1.13	2.637	2				50	mayfly and mush	
SR-R	SRF034	SLSC	F	SD	6.7	3.602	1.20	2.805	2		0		80	mayflies	cyst on ventral side beside anal fin
SR-R	SRF035	SLSC	F	SD	6.5	3.184	1.16	2.596	2		0		40	mayfly and caddisflies	L pectoral missing ray, some regrowth
SR-R	SRF036	SLSC	F	SD	6.7	3.702	1.23	2.775	2		100	yellow	40	mayfly parts	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
SR-R	SRF037	SLSC	F	SD	6.5	3.27	1.19	2.591	2		0		50	mayfly parts	cysts floating in fluid around body cavity
SR-R	SRF038	SLSC	F	SD	6.8	3.788	1.20	3.209	2		0		40	mayfly	inner cavity full of white nodules- floating around near anterior portion
SR-R	SRF039	SLSC	F	SD	7.5	4.98	1.18	4.161	2	2	10	green	100	mayflies and caddisfly cases	cysts- moderate in body cavity, L pec fin frayed
SR-R	SRF040	SLSC	F	SD	6.7	3.838	1.28	3.262	3		100	green	0	empty	skin-white cysts under skin on isthmu and ventral surface.
SR-R	SRF041	SLSC	F	SD	7	3.654	1.07	3.111	1				40	mush	small cysts on swimbladder-small parasite on intestine
SR-R	SRM042	SLSC	M	SD	7.6	4.491	1.02	3.982	2				20	invert parts	
SR-R	SRM043	SLSC	M	SD	7.2	4.146	1.11	3.666	2				0	empty	cyst on ventral side beside anal fin
SR-R	SRM044	SLSC	M	SD	7.4	4.598	1.13	3.965	2	2			0	empty	
SR-R	SRM045	SLSC	M	SD	7.5	5.14	1.22	4.482	3		100	green	0	empty	cyst near swim bladder in front of kidney
SR-R	SRM046	SLSC	M	SD	6.7	3.633	1.21	3.149	2		100	green	0	empty	
SR-R	SRM047	SLSC	M	SD	7.2	3.965	1.06	3.488	2	2	100	green	0	empty	left side of anal fin 2 cyst like formations and one on the swimbladder
SR-R	SRM048	SLSC	M	SD	7.3	4.299	1.11	3.772	2		50	green	0	empty	
SR-R	SRM049	SLSC	M	SD	7.3	4.407	1.13	3.765	2		100		0	empty	
SR-R	SRF050	SLSC	F	SD	6.9	3.948	1.20	3.469	2		100	green	0	empty	spleen-small and have cysts on the external
SR-R	SRF051	SLSC	F	SD	6.8	3.8	1.21	3.389	2				0	empty	enlarged liver
SR-R	SRM052	SLSC	M	SD	7.3	4.246	1.09	3.705	2	2	100	green	0	empty	rectangular white skin cyst like previously seen, liver small
SR-R	SRF053	SLSC	F	SD	7	4.068	1.19	3.56	2				10	mush	shorten gills, liver enlarged, and a cyst on the ventral side
SR-R	SRM054	SLSC	M	SD	7.3	4.557	1.17	3.793	2		100	green	40	mayfly parts	rectangular white skin cyst like previously seen, cyst by anal fin and a growth on the left base of dorsal fin

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
SR-R	SRF055	SLSC	F	SD	6.7	3.273	1.09	2.857	2				0	empty	liver not a defined shape kind of mushy
SR-R	SRF056	SLSC	F	SD	7	3.765	1.10	3.282	3		100	green	0	empty	
SR-R	SRF057	SLSC	F	SD	7.7	5.001	1.10	4.373	3		0		80	mayfly, caddisfly, mush	
SR-R	SRM058	SLSC	M	SD	7.2	4.354	1.17	3.682	2		100	green	100	mayflies	liver very small
SR-R	SRM059	SLSC	M	SD	6.9	3.962	1.21	3.389	2		0		50	mush	spleen slightly enlarged, liver is small
SR-R	SRF060	SLSC	F	SD	6.6	3.322	1.16	2.871	2		100	yell/gr	0	empty	white nodule under skin ventral head
SR-R	SRF061	SLSC	F	SD	7	3.977	1.16	3.412	2		0		80	mush	rectangular nodule ventral between pelvic fins
SR-R	SRF062	SLSC	F	SD	6.7	3.543	1.18	2.903	2		0		80	mayflies	white nodule near urogenital
SR-R	SRM063	SLSC	M	SD	7.7	5.109	1.12	4.551	2		0		90	mayfly and mush	liver small in size
SR-R	SRM064	SLSC	M	SD	7.5	4.538	1.08	3.994	2		100	green	75	mush	liver small in size
SR-R	SRM065	SLSC	M	SD	7	3.905	1.14	3.443	2		100	yell/gr	30	mush	spleen-small, white cyst on opercle left side
SR-R	SRM066	SLSC	M	SD	7.5	4.777	1.13	4.073	3		100	yell/gr	80	mayflies	2 white nodules on kidney; cyst on ventral side
SR-R	SRM067	SLSC	M	SD	7.5	3.794	0.90	3.379	2		100	green	25	mayflies and limpets	liver is small, and mushy, 2 white nodules
SR-R	SRM068	SLSC	M	SD	6.8	3.646	1.16	3.183	2		100	green	25	mayflies	small mushy
HR-R	HRM001	SLSC	M	SD	6.7	3.311	1.10	2.864	2		0		90	mayfly and mush	small liver
HR-R	HRM002	SLSC	M	SD	6.4	2.572	0.98	2.362	4		100		50	mayfly, caddisfly, mush	small liver
HR-R	HRM003	SLSC	M	SD	7.2	3.136	0.84	2.689	3		0	green	0	empty	
HR-R	HRF004	SLSC	F	SD	6.6	2.938	1.02	2.627	3	3	100		70	caddisfly cases and mush	
HR-R	HRM005	SLSC	M	SD	6.4	2.679	1.02	2.254	2				0		
HR-R	HRM006	SLSC	M	SD	6.2	2.337	0.98	2.122	2				0	empty	small liver
HR-R	HRF007	SLSC	F	SD	5.6	1.808	1.03	1.562	2		0		20	unidentified	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
HR-R	HRM008	SLSC	M	SD	6.4	2.379	0.91	2.16	2	2	100		50	caddisfly cases and mush	small liver
HR-R	HRF009	SLSC	F	SD	6.1	2.364	1.04	1.959	2		100	yell/gr	50	mayfly and caddisflies	
HR-R	HRM010	SLSC	M	SD	6.4	2.718	1.04	2.387	2				30	invert parts and mush	small liver
HR-R	HRM011	SLSC	M	SD	6.4	2.506	0.96	2.159	2		100	yell/gr	10	mush	
HR-R	HRM012	SLSC	M	SD	6.2	2.493	1.05	2.109	2	2	0		60		opercle appears more defined
HR-R	HRM013	SLSC	M	SD	6.5	2.382	0.87	2.059	2		100	green	10	mush	small liver
HR-R	HRF014	SLSC	F	SD	6	2.081	0.96	1.82	2		100	green	20		
HR-R	HRM015	SLSC	M	SD	5.8	2.049	1.05	1.748	2		0		25	3 caddisflies	small liver
HR-R	HRM016	SLSC	M	SD	6.1	2.395	1.06	2.055	2		0		10	mush	small liver
HR-R	HRM017	SLSC	M	SD	6	2.168	1.00	1.776	2		0		80	caddisflies	small liver
HR-R	HRM018	SLSC	M	SD	6.2	2.386	1.00	1.983	2		50	yellow	30	bug parts	
HR-R	HRM019	SLSC	M	SD	5.9	1.966	0.96	1.717	2		0		40	mush	small liver
HR-R	HRM020	SLSC	M	SD	6.4	2.637	1.01	2.329	2	2	0	green	80	caddisfly and mush	
HR-R	HRF021	SLSC	F	SD	5.5	1.911	1.15	1.611	2		0		10	unidentified with pebble	
HR-R	HRF022	SLSC	F	SD	5.7	1.94	1.05	1.622	2		100	green	20	invert parts	
HR-R	HRF023	SLSC	F	SD	5.4	1.588	1.01	1.233	1		0		80	mush	hemorrhage on the isthmus
HR-R	HRM024	SLSC	M	SD	6.2	2.52	1.06	2.136	2		50	green	50	caddisfly and mush	
HR-R	HRF025	SLSC	F	SD	6.5	2.261	0.82	1.906	3				100	caddisfly	
HR-R	HRF026	SLSC	F	SD	5.6	1.565	0.89	1.333	2				0	empty	split pectoral fin
HR-R	HRM027	SLSC	M	SD	6.6	2.718	0.95	2.334	2		100	green	75	3 caddisflies	
HR-R	HRM028	SLSC	M	SD	5.8	1.751	0.90	1.475	3		100	green	40	caddisfly cases and mush	small liver
HR-R	HRM029	SLSC	M	SD	5.8	1.74	0.89	1.463	2	2	0		10	unidentified	small liver
HR-R	HRF030	SLSC	F	SD	5.9	1.879	0.91	1.653	3		50	green	50		
HR-R	HRF031	SLSC	F	SD	6	1.858	0.86	1.63	2		100	green	0	empty	
HR-R	HRM032	SLSC	M	SD	6.5	2.83	1.03	2.479	3		100	green	60	invert parts	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[(a)]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
HR-R	HRM033	SLSC	M	SD	6.2	2.209	0.93	1.846	2		100	green	30	unidentified	small liver
HR-R	HRF034	SLSC	F	SD	6.5	3.028	1.10	2.505	4		0		50	caddisfly and mush	
HR-R	HRM035	SLSC	M	SD	6.5	2.887	1.05	2.456	3		100	green	50	caddisfly	small liver
HR-R	HRF036	SLSC	F	SD	7	2.76	0.80	2.376	3		0		30	mush	
HR-R	HRF037	SLSC	F	SD	6	2.012	0.93	1.709	2		100	green	5	mayfly	
HR-R	HRM038	SLSC	M	SD	6.8	3.036	0.97	2.617	2		100	green	50	mush	
HR-R	HRM039	SLSC	M	SD	6.3	2.35	0.94	1.965	3		50	green	80	caddisfly	small liver
HR-R	HRM040	SLSC	M	SD	6.5	2.423	0.88	2.119	2		100	green	10	mush	
HR-R	HRM041	SLSC	M	SD	6.2	2.383	1.00	2.002	2		50	green	20	limpets	
HR-R	HRM042	SLSC	M	SD	6	2.19	1.01	1.908	2		100	green	10	caddisfly	
HR-R	HRF043	SLSC	F	SD	5.9	2.093	1.02	1.736	3		50	yellowish	5	mayfly	
HR-R	HRF044	SLSC	F	SD	5.5	1.757	1.06	1.623	2		50	green	10	mush	
HR-R	HRF045	SLSC	F	SD	5.6	1.888	1.08	1.622	2		50	yellowish	5	mayfly	
HR-R	HRF046	SLSC	F	SD	5.7	1.811	0.98	1.548	2		0		25	invert parts	
HR-R	HRF047	SLSC	F	SD	5.5	1.73	1.04	1.44	2		100	green	50	limpet and caddisfly	
HR-R	HRF048	SLSC	F	SD	5.6	1.7	0.97	1.473	2	2	100	green	0	empty	
HR-R	HRF049	SLSC	F	SD	5.8	1.745	0.89	1.507	3		50	green	10	unidentified	
HR-R	HRF050	SLSC	F	SD	5.6	1.902	1.08	1.625	3		0		70	stonefly	
HR-R	HRF051	SLSC	F	SD	5.5	1.697	1.02	1.46	2		100	yellow	0	empty	
HR-R	HRF052	SLSC	F	SD	5.7	1.668	0.90	1.443	2		100	green	0	empty	
HR-R	HRF053	SLSC	F	SD	5.5	1.415	0.85	1.207	2		100	green	50	mayfly	dorsal fin split
HR-R	HRF054	SLSC	F	SD	5.5	1.66	1.00	1.451	3		0		10	invert parts	
HR-R	HRF055	SLSC	F	SD	6.4	2.034	0.78	1.726	3		50	green	50	limpet and mayfly	
HR-R	HRF056	SLSC	F	SD	5.7	2.057	1.11	1.771	2		50	green	50	2 stoneflies	spleen very pale pink
HR-R	HRM057	SLSC	M	SD	6.5	2.898	1.06	2.46	2		100	green	50	mayflies	
HR-R	HRF058	SLSC	F	SD	7.9	3.668	0.74	3.507	4		100	green	5	mush	
HR-R	HRF059	SLSC	F	SD	5.5	1.586	0.95	1.362	3		50	green	15	mush	
HR-R	HRM060	SLSC	M	SD	6.9	3.113	0.95	2.788	4		100	green	5	mush	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
HR-R	HRF061	SLSC	F	SD	5.7	1.778	0.96	1.489	3		100	green	0	empty	
DR-R	DRF001	SLSC	F	SD	7.7	5.004	1.10	4.102	2		75	green	20	caddisfly cases and snail	liver-small and white; 3 small cysts in body cavity
DR-R	DRF002	SLSC	F	SD	8.2	5.593	1.01	4.784	3		50	yell/gr	70	caddisfly cases	
DR-R	DRF003	SLSC	F	SD	7.3	4.119	1.06	3.659	1		0		50	caddisfly	
DR-R	DRU004	SLSC	U	IM	5.2	1.503	1.07	1.22	0		50	green	20	unidentified	
DR-R	DRF005	SLSC	F	SD	8.6	7.525	1.18	6.357	4		0		85	snail, caddis case, pebble	pelvic fin eroded
DR-R	DRF006	SLSC	F	SD	6.8	3.474	1.10	2.979	1		100	green	0	empty	
DR-R	DRF007	SLSC	F	SD	7.9	5.522	1.12	4.554	3		50		70	stonefly and caddisfly	pelvic fin eroded
DR-R	DRM008	SLSC	M	SD	9.3	8.817	1.10	7.722	2	2	0		50	stonefly	
DR-R	DRF009	SLSC	F	SD	7.6	4.31	0.98	3.671	2		50	green	100	caddisfly cases	
DR-R	DRF010	SLSC	F	SD	7.8	4.356	0.92	3.73	2		100	green	50	caddisflies	
DR-R	DRF011	SLSC	F	SD	6.9	4.158	1.27	3.436	1		0		80	invert parts	
DR-R	DRF012	SLSC	F	SD	6.5	2.932	1.07	2.483	1		50	green	0	empty	
DR-R	DRF013	SLSC	F	SD	8.3	6.315	1.10	5.261	5	5	100	green	100	caddisfly cases, mayfly	pectoral and pelvic fins eroding
DR-R	DRF014	SLSC	F	SD	7.2	3.501	0.94	2.796	2		100	green	75	coleoptera , caddisfly	
DR-R	DRF015	SLSC	F	SD	8.9	7.925	1.12	6.454	3		100		10	caddisfly case	
DR-R	DRM016	SLSC	M	SD	8.6	8.15	1.28	6.937	2		0		100	caddisfly, stonefly, snail	
DR-R	DRF017	SLSC	F	SD	8.9	6.716	0.95	5.577	6		75	green	100		
DR-R	DRF018	SLSC	F	SD	7.5	4.237	1.00	3.29	2	2	50	green	80	caddisfly cases	white cyst floating in body cavity
DR-R	DRM019	SLSC	M	SD	7.8	5.86	1.23	4.97	1		50		90	mush	
DR-R	DRF020	SLSC	F	SD	8.6	4.745	0.75	4.058	3		50	green	100	caddisfly and mush	
DR-R	DRF021	SLSC	F	SD	7.9	5.504	1.12	4.597	3		25	green	75	caddisfly and mayfly	
DR-R	DRM022	SLSC	M	SD	7.6	4.231	0.96	3.627	1		50	green	60	stonefly and caddisfly	
DR-R	DRM023	SLSC	M	SD	9.1	9.231	1.22	7.982	3		0		10	caddisfly and mush	
DR-R	DRF024	SLSC	F	SD	7	3.99	1.16	3.413	1		100	green	20	limpet, mush	

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
DR-R	DRF025	SLSC	F	SD	8	4.771	0.93	4.071	2		25	green	50	caddisfly cases	liver-mottled- red and orange section
DR-R	DRF026	SLSC	F	SD	8.5	6.016	0.98	5.168	2		100	green	20	caddisfly and mayfly	caudal fin eroded
DR-R	DRF027	SLSC	F	SD	8	5.35	1.04	4.556	4		50		10	caddisfly and limpets	
DR-R	DRF028	SLSC	F	SD	8.3	6.573	1.15	5.361	3		50	green	100	stonefly	pelvic and pectoral fins eroded
DR-R	DRF029	SLSC	F	SD	10.2	8.477	0.80	7.01	7		100	green	10		pelvic and pectoral fins eroded
DR-R	DRF030	SLSC	F	SD	8.5	6.641	1.08	5.883	3		50	green	50	caddisfly and cases	pelvic and pectoral fins eroded
DR-R	DRM031	SLSC	M	SD	7.3	4.25	1.09	3.66	1		100		50	caddisfly and mush	
DR-R	DRF032	SLSC	F	SD	8.8	6.899	1.01	5.644	4		100	green	50	caddisflies	pelvic and pectoral fins eroded
DR-R	DRM033	SLSC	M	SD	8.7	9.479	1.44	7.599	2		100		60	caddisfly and mush	
DR-R	DRF034	SLSC	F	SD	8.2	6.543	1.19	5.522	3		0		70	stonefly and caddisfly	pelvic and pectoral fins eroded
DR-R	DRF035	SLSC	F	SD	7.2	4.489	1.20	3.865	3	3	100		50	caddisflies	L.pec finray_ regrowth
DR-R	DRM036	SLSC	M	SD	7.6	6.364	1.45	5.438	1		50		0	empty	
DR-R	DRM037	SLSC	M	SD	8.8	8.001	1.17	7.163	2		100	green	0	empty	pec. Fins eroded
DR-R	DRF038	SLSC	F	MA	6.8	4.318	1.37	3.611	1		50		0	empty	
DR-R	DRF039	SLSC	F	SD	7.9	5.042	1.02	4.335	3		0		0	empty	pelvic and pectoral fins eroded
DR-R	DRF040	SLSC	F	SD	6.2	2.788	1.17	2.707	1		0		0	empty	pelvic fin bent in half; L pectoral eroded
DR-R	DRF041	SLSC	F	SD	7.1	3.77	1.05	3.22	2				0	empty	
DR-R	DRF042	SLSC	F	SD	8.6	6.227	0.98	5.049	2		100	green	50	caddisflies	hemorrhaging on ventral surface
DR-R	DRF043	SLSC	F	SD	8.3	5.839	1.02	5.08	3		0		0	empty	pec fin eroded
DR-R	DRM044	SLSC	M	SD	7.8	3.241	0.68	3.701	2		0		75	caddisfly and beetle	pec fin eroded; bulge on L ventral side; hindgut-bright yellow
DR-R	DRF045	SLSC	F	SD	6.6	2.741	0.95	2.317	2		0		0	empty	
DR-R	DRF046	SLSC	F	SD	7.6	5.132	1.17	4.333	2	2	100	green	20		
DR-R	DRF047	SLSC	F	SD	7.8	4.599	0.97	4.048	1		100	green	0	empty	
DR-R	DRU048	SLSC	U	IM	5	1.344	1.08	1.178	0		100	green			
DR-R	DRF049	SLSC	F	SD	7.5	3.944	0.93	3.573	2		100		0	empty	
DR-R	DRM050	SLSC	M	SD	7.9	5.369	1.09	4.686	2		0		0	empty	pelvic and pectoral fins eroded

Table VI.1 Tributary Sentinel Species (Slimy Sculpin) Data (continued)

Site[a]	ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC (10%)	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents	Description of External Condition
DR-R	DRF051	SLSC	F	SD	8.1	5.483	1.03	4.738	5				5	invert parts	white cyst in gill cavity, pec fin abnormal
DR-R	DRF052	SLSC	F	SD	9	7.01	0.96	5.753	4		100	green	80	stonefly and caddisfly	possible cyst in body cavity by the ovaries; pelvic and pec fins eroded; dorsal fin is split
DR-R	DRF053	SLSC	F	SD	7.5	4.583	1.09	3.859	2		100	green	0	empty	gills appear swollen

[a] MR-E = Muskeg River Exposure; SR-E = Steepbank River Exposure; SR-R = Steepbank River Reference; HR-R = Horse River Reference; DR-R = Dunkirk River Reference

Note: Dates of fish collection in 2001: Sept 5,6 at site MR-E; Sept 9, 10 at site SR-E; Sept 15, 16 at site SR-R; Sept 22 at site HR-R; and Sept 23 at site DR-R.

Table VI.2 Tributary Sentinel Species (Slimy Sculpin) Pathology Data

Site[a]	ID Number	Eyes		Gills		Pseudobranchs		Thymus		Skin		Body Deformities		Fins		Opercles		Hindgut		Mesenteric Fat	Liver		Spleen		Gall Bladder		Kidney		Parasites		Total Score
		Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	
ME	MEM001	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	40
ME	MEM002	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEF003	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	F	30	B	0	0	0	N	0	0	0	30
ME	MEM004	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	F	30	B	0	0	0	N	0	0	0	30
ME	MEF005	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	C	30	B	0	0	0	N	0	0	0	30
ME	MEF006	N	0	F	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
ME	MEM007	N	0	N	0	N	0	0	0	1	10	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
ME	MEF008	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
ME	MEM009	N	0	N	0	N	0	0	0	1	10	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
ME	MEM010	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	F	30	B	0	0	0	N	0	0	0	30
ME	MEM011	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	A	0	B	0	0	0	N	0	0	0	0
ME	MEM012	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	F	30	B	0	0	0	N	0	0	0	30
ME	MEM013	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
ME	MEM014	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	F	30	B	0	0	0	N	0	0	0	30
ME	MEF015	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	A	0	B	0	0	0	N	0	0	0	30
ME	MEF016	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
ME	MEM017	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	OT	30	1	10	40
ME	MEM018	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
ME	MEF019	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
ME	MEM020	OT	30	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
ME	MEM021	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEM022	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
ME	MEF023	N	0	N	0	N	0	0	0	1	10	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	20
ME	MEF024	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	E	30	0	0	N	0	0	0	30
ME	MEM025	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	F	30	B	0	0	0	N	0	0	0	30
ME	MEF026	N	0	N	0	N	0	0	0	0	0	none	0	0	0	1	10	0	0	1	A	0	E	30	0	0	N	0	1	10	50
ME	MEM027	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	F	30	B	0	0	0	N	0	0	0	30
ME	MEM028	OT	30	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	40
ME	MEF029	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	F	30	B	0	0	0	N	0	0	0	30
ME	MEF030	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
ME	MEF031	N	0	N	0	N	0	0	0	1	10	none	0	0	0	0	0	0	0	2	A	0	B	0	0	0	N	0	1	10	20
ME	MEF032	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEF033	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
ME	MEF034	OT	30	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	30
ME	MEF035	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
ME	MEF036	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
ME	MEM037	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	1	10	40
ME	MEM038	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
ME	MEF039	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
ME	MEM040	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEM041	N	0	F	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30

Table VI.2 Tributary Sentinel Species (Slimy Sculpin) Pathology Data (continued)

Site[a]	ID Number	Eyes		Gills		Pseudobranchs		Thymus		Skin		Body Deformities		Fins		Opercles		Hindgut		Mesenteric Fat	Liver		Spleen		Gall Bladder		Kidney		Parasites		Total Score
		Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	
ME	MEF042	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
ME	MEM043	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEM044	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEM045	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
ME	MEF046	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEM047	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
ME	MEM048	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	F	30	B	0	0	0	N	0	1	10	40
ME	MEM049	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
ME	MEM050	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEM051	N	0	F	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	E	30	B	0	0	0	N	0	1	10	70
ME	MEF052	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	F	30	B	0	0	0	N	0	0	0	30
ME	MEF053	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	OT	30	0	0	N	0	0	0	30
ME	MEF054	N	0	F	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	30
ME	MEF055	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
ME	MEF056	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
ME	MEF057	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	OT	30	0	0	N	0	0	0	30
ME	MEF058	N	0	F	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	A	0	B	0	0	0	N	0	1	10	40
ME	MEF059	N	0	F	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
ME	MEF060	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
ME	MEF061	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
SE	SEM001	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF002	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
SE	SEF003	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF004	N	0	F	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	A	0	B	0	0	0	N	0	1	10	40
SE	SEF005	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEM006	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF007	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEM008	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	OT	30	0	0	N	0	0	0	30
SE	SEF009	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SE	SEF010	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	F	30	B	0	0	0	N	0	0	0	30
SE	SEM011	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEM012	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SE	SEM013	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM014	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF015	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	F	30	B	0	0	0	N	0	0	0	30
SE	SEF016	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM017	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF018	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	OT	30	0	0	N	0	0	0	30
SE	SEF019	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM020	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	30

Table VI.2 Tributary Sentinel Species (Slimy Sculpin) Pathology Data (continued)

Site[(a)]	ID Number	Eyes		Gills		Pseudobranchs		Thymus		Skin		Body Deformities		Fins		Opercles		Hindgut		Mesenteric Fat	Liver		Spleen		Gall Bladder		Kidney		Parasites		Total Score
		Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	
SE	SEM021	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF022	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	OT	30	0	0	N	0	0	0	40
SE	SEM023	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM024	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF025	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF026	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF027	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF028	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF029	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM030	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF031	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF032	N	0	N	0	N	0	0	0	0	0	n/a	30	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
SE	SEF033	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	C	30	B	0	0	0	N	0	0	0	30
SE	SEF034	N	0	N	0	N	0	0	0	0	0	n/a	30	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
SE	SEM035	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM036	N	0	N	0	N	0	0	0	1	10	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	20
SE	SEM037	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SE	SEF038	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF039	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF040	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF041	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM042	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	OT	30	0	0	N	0	0	0	30
SE	SEF043	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SE	SEM044	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	OT	30	0	0	N	0	0	0	30
SE	SEF045	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM046	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	OT	30	0	0	N	0	0	0	30
SE	SEF047	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF048	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEM049	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF050	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF051	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF052	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SE	SEF053	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF054	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF055	B1	30	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	30
SE	SEM056	N	0	N	0	S	30	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
SE	SEM057	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	30
SE	SEF058	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SE	SEF059	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRF001	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	20
SR	SRF002	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0

Table VI.2 Tributary Sentinel Species (Slimy Sculpin) Pathology Data (continued)

Site[a]	ID Number	Eyes		Gills		Pseudobranchs		Thymus		Skin		Body Deformities		Fins		Opercles		Hindgut		Mesenteric Fat	Liver		Spleen		Gall Bladder		Kidney		Parasites		Total Score
		Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	
SR	SRM003	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	10
SR	SRM004	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	1	10	40
SR	SRF005	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	D	30	B	0	0	0	N	0	0	0	30
SR	SRM006	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	1	10	40
SR	SRM007	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SR	SRF008	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	OT	30	B	0	0	0	M	30	1	10	70
SR	SRF009	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	D	30	B	0	0	0	OT	30	3	30	90
SR	SRF010	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	D	30	B	0	0	0	N	0	3	30	60
SR	SRF011	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	1	10	1	D	30	B	0	0	0	N	0	1	10	60
SR	SRM012	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	D	30	B	0	0	0	N	0	1	10	40
SR	SRF013	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	M	30	0	0	60
SR	SRF014	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	M	30	0	0	30
SR	SRF015	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
SR	SRF016	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRM017	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	OT	30	0	0	N	0	1	10	40
SR	SRM018	N	0	N	0	N	0	0	0	0	0	none	0	0	0	1	10	0	0	2	A	0	B	0	0	0	N	0	1	10	20
SR	SRM019	N	0	OT	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	3	30	60
SR	SRM020	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	OT	30	B	0	0	0	N	0	0	0	30
SR	SRF021	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SR	SRF022	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SR	SRF023	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SR	SRF024	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SR	SRM025	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRF026	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	A	0	B	0	0	0	N	0	0	0	0
SR	SRF027	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	A	0	B	0	0	0	N	0	0	0	0
SR	SRM028	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SR	SRF029	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
SR	SRM030	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	1	10	40
SR	SRF031	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SR	SRF032	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
SR	SRF033	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRF034	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
SR	SRF035	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
SR	SRF036	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRF037	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	OT	30	0	0	N	0	1	10	40
SR	SRF038	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	OT	30	0	0	OT	30	3	30	90
SR	SRF039	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	2	20	30
SR	SRF040	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
SR	SRF041	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SR	SRM042	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	OT	30	0	0	N	0	0	0	30
SR	SRM043	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10

Table VI.2 Tributary Sentinel Species (Slimy Sculpin) Pathology Data (continued)

Site[a]	ID Number	Eyes		Gills		Pseudobranchs		Thymus		Skin		Body Deformities		Fins		Opercles		Hindgut		Mesenteric Fat	Liver		Spleen		Gall Bladder		Kidney		Parasites		Total Score
		Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	
SR	SRM044	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	10
SR	SRM045	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	1	10	1	A	0	B	0	0	0	N	0	1	10	50
SR	SRM046	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRM047	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	1	10	40
SR	SRM048	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRM049	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRF050	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	OT	30	0	0	N	0	1	10	40
SR	SRF051	N	0	C	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	60
SR	SRM052	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	1	10	40
SR	SRF053	N	0	OT	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	1	10	70
SR	SRM054	N	0	N	0	N	0	0	0	1	10	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	20
SR	SRF055	N	0	OT	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	60
SR	SRF056	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0			1	A	0	B	0	0	0	N	0	0	0	0
SR	SRF057	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRM058	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	30
SR	SRM059	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	OT	30	E	30	0	0	N	0	0	0	60
SR	SRF060	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SR	SRF061	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SR	SRF062	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	10
SR	SRM063	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	1	0	0	OT	30	B	0	0	0	N	0	0	0	30
SR	SRM064	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
SR	SRM065	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	1	10	10
SR	SRM066	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	OT	30	1	10	40
SR	SRM067	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	1	10	40
SR	SRM068	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRM001	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0		0	0		OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRM002	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRM003	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRF004	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM005	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM006	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRF007	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM008	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	1	10	0	OT	30	B	0	0	0	N	0	0	0	40
HR-R	HRF009	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM010	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRM011	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0		1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM012	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM013	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRF014	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
HR-R	HRM015	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRM016	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	30

Table VI.2 Tributary Sentinel Species (Slimy Sculpin) Pathology Data (continued)

Site[a]	ID Number	Eyes		Gills		Pseudobranchs		Thymus		Skin		Body Deformities		Fins		Opercles		Hindgut		Mesenteric Fat	Liver		Spleen		Gall Bladder		Kidney		Parasites		Total Score
		Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	
HR-R	HRM017	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRM018	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0		0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM019	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM020	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF021	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF022	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF023	N	0	N	0	N	0	0	0	1	10	none	0	0	0	0	0	1	10	0	A	0	B	0	0	0	N	0	0	0	20
HR-R	HRM024	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF025	N	0	P	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	30
HR-R	HRF026	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM027	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM028	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	1	10	0	A	0	B	0	0	0	N	0	0	0	10
HR-R	HRM029	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	40
HR-R	HRF030	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF031	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM032	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM033	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRF034	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM035	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRF036	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF037	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM038	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM039	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	OT	30	B	0	0	0	N	0	0	0	30
HR-R	HRM040	N	0	N	0	I	30	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30
HR-R	HRM041	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM042	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF043	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF044	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF045	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF046	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF047	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF048	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF049	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	F	30	B	0	0	0	N	0	0	0	30
HR-R	HRF050	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF051	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF052	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF053	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF054	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF055	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF056	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	OT	30	0	0	N	0	0	0	30
HR-R	HRM057	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0

Table VI.2 Tributary Sentinel Species (Slimy Sculpin) Pathology Data (continued)

Site[a]	ID Number	Eyes		Gills		Pseudobranchs		Thymus		Skin		Body Deformities		Fins		Opercles		Hindgut		Mesenteric Fat	Liver		Spleen		Gall Bladder		Kidney		Parasites		Total Score
		Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	
HR-R	HRF058	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF059	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRM060	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
HR-R	HRF061	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF001	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	D	30	G	30	0	0	N	0	1	10	70
DR-R	DRF002	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF003	N	0	N	0	N	0		0	0	0	none	0	0	0	0	0			0	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRU004	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF005	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF006	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF007	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRM008	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF009	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF010	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF011	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF012	N	0	N	0	N	0	0	0	0	0	none	0	2	20	0	0	1	10	0	A	0	B	0	0	0	N	0	0	0	30
DR-R	DRF013	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	3	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF014	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF015	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRM016	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF017	N	0	N	0	N	0	0	0	0	0	none	0	2	20	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	20
DR-R	DRF018	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	20
DR-R	DRM019	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF020	N	0	N	0	N	0	0	0	0	0	none	0	3	30	0	0	0	0	2	A	0	B	0	0	0	N	0	0	0	30
DR-R	DRF021	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	3	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRM022	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRM023	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF024	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	E	30	B	0	0	0	N	0	0	0	30
DR-R	DRF025	N	0	N	0	N	0	0	0	0		none	0	0	0	0	0	0	0	1	E	30	B	0	0	0	N	0	0	0	30
DR-R	DRF026	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF027	N	0	N	0	N	0	0	0	0	0	none	0	2	20	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	20
DR-R	DRF028	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF029	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF030	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRM031	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF032	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRM033	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF034	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF035	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	C	30	B	0	0	0	N	0	0	0	30
DR-R	DRM036	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRM037	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10

Table VI.2 Tributary Sentinel Species (Slimy Sculpin) Pathology Data (continued)

Site[(a)]	ID Number	Eyes		Gills		Pseudobranchs		Thymus		Skin		Body Deformities		Fins		Opercles		Hindgut		Mesenteric Fat	Liver		Spleen		Gall Bladder		Kidney		Parasites		Total Score
		Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Condition	Score	Condition	Score	Condition	Score	Condition	Score	Condition	Score	
DR-R	DRF038	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	2	C	30	B	0	0	0	N	0	0	0	30
DR-R	DRF039	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF040	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF041	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF042	N	0	N	0	N	0	0	0	1	10	none	0	1	10	0	0	0	0	2	A	0	B	0	0	0	N	0	0	0	20
DR-R	DRF043	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRM044	N	0	C	30	N	0	0	0	0	0	n/a	30	1	10	0	0	0	0	1	OT	30	B	0	0	0	N	0	0	0	100
DR-R	DRF045	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	1	10	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF046	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	E	30	B	0	0	0	N	0	0	0	30
DR-R	DRF047	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRU048	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	0	A	0	B	0	0	0	N	0	0	0	0
DR-R	DRF049	N	0	N	0	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	C	30	B	0	0	0	N	0		0	30
DR-R	DRM050	N	0	N	0	N	0	0	0	0	0	none	0	1	10	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	10
DR-R	DRF051	N	0	N	0	N	0	0	0	0	0	n/a	30	0	0	0	0	0	0		A	0	B	0	0	0	N	0	1	10	40
DR-R	DRF052	N	0	N	0	N	0	0	0	0	0	none	0	2	20	0	0	0	0	1	A	0	B	0	0	0	N	0	1	10	30
DR-R	DRF053	N	0	OT	30	N	0	0	0	0	0	none	0	0	0	0	0	0	0	1	A	0	B	0	0	0	N	0	0	0	30

[(a)] MR-E = Muskeg River Exposure; SR-E = Steepbank River Exposure; SR-R = Steepbank River Reference; HR-R = Horse River Reference; DR-R = Dunkirk River Reference.

Note: Dates of fish collection in 2001: Sept 5, 6 at site MR-E; Sept 9, 10 at site SR-E; Sept 15, 16 at site SR-R; Sept 22 at site HR-R; and Sept 23 at site DR-R.

Table VI.3 Tributary Sentinel Species (Slimy Sculpin) Fish Caught and Inventoried But Not Biomarked

Site[(a)]	ID Number	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Condition Factor
SR-E	SE60	SPSC	60.00	1.8	U	unknown	0.83
SR-E	SE61	SPSC	38.00	0.7	U	immature	1.28
SR-E	SE62	SPSC	40.00	0.6	U	immature	0.94
SR-E	SE63	SLSC	37.00	0.7	U	immature	1.38
SR-E	SE64	SPSC	46.00	0.9	U	immature	0.97
SR-E	SE65	SLSC	45.00	1.1	U	immature	1.21
SR-E	SE66	SLSC	45.00	1.0	U	immature	1.09
SR-E	SE67	SPSC	43.00	0.8	U	immature	0.98
SR-E	SE68	SPSC	41.00	0.8	U	immature	1.16
SR-R	SR69	SLSC	31.00	0.4	U	immature	1.37
SR-R	SR70	SLSC	33.00	0.4	U	immature	1.11
SR-R	SR71	SLSC	35.00	0.6	U	immature	1.40
SR-R	SR72	SLSC	34.00	0.6	U	immature	1.53
SR-R	SR73	SLSC	36.00	0.6	M	immature	1.28
SR-R	SR74	SLSC	67.00	3.4	U	unknown	1.12
SR-R	SR75	SLSC	63.00	3.0	U	unknown	1.20
SR-R	SR76	SLSC	63.00	3.6	U	unknown	1.44
SR-R	SR77	SLSC	67.00	3.4	U	unknown	1.13
SR-R	SR78	SLSC	61.00	3.7	U	unknown	1.63
SR-R	SR79	SLSC	65.00	3.5	U	unknown	1.27
SR-R	SR80	SLSC	70.00	3.8	U	unknown	1.11
SR-R	SR81	SLSC	62.00	3.4	U	unknown	1.41
SR-R	SR82	SLSC	68.00	3.2	U	unknown	1.02
SR-R	SR83	SLSC	73.00	3.6	U	unknown	0.93
SR-R	SR84	SLSC	68.00	3.8	U	unknown	1.21
SR-R	SR85	SLSC	68.00	2.9	U	unknown	0.92
SR-R	SR86	SLSC	70.00	3.5	U	unknown	1.02
SR-R	SR87	SLSC	65.00	3.3	U	unknown	1.19
SR-R	SR88	SLSC	70.00	3.6	U	unknown	1.05
SR-R	SR89	SLSC	70.00	3.3	U	unknown	0.95
SR-R	SR90	SLSC	69.00	3.5	U	unknown	1.07
SR-R	SR91	SLSC	63.00	3.1	U	unknown	1.22
SR-R	SR92	SLSC	63.00	2.8	U	unknown	1.12
SR-R	SR93	SLSC	65.00	3.4	U	unknown	1.23
SR-R	SR94	SLSC	65.00	3.8	U	unknown	1.37
SR-R	SR95	SLSC	68.00	3.3	U	unknown	1.05
SR-R	SR96	SLSC	62.00	2.9	U	unknown	1.22
SR-R	SR97	SLSC	70.00	3.7	U	unknown	1.08
SR-R	SR98	SLSC	60.00	2.3	U	unknown	1.05

Table VI.3 Tributary Sentinel Species (Slimy Sculpin) Fish Caught and Inventoried But Not Biomarked (continued)

Site[(a)]	ID Number	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Condition Factor
SR-R	SR99	SLSC	68.00	3.6	U	unknown	1.14
SR-R	SR100	SLSC	67.00	2.9	U	unknown	0.96
SR-R	SR101	SLSC	70.00	3.2	U	unknown	0.93
SR-R	SR102	SLSC	60.00	2.7	U	unknown	1.25
SR-R	SR103	SLSC	57.00	2.4	U	unknown	1.28
SR-R	SR104	SLSC	65.00	3.4	U	unknown	1.22
SR-R	SR105	SLSC	62.00	2.7	U	unknown	1.13
SR-R	SR106	SLSC	70.00	3.7	U	unknown	1.08
SR-R	SR107	SLSC	70.00	3.8	U	unknown	1.11
SR-R	SR108	SLSC	59.00	2.5	U	unknown	1.20
SR-R	SR109	SLSC	70.00	3.1	U	unknown	0.90
HR-R	HR62	SLSC	53.00	1.6	U	unknown	1.10
HR-R	HR63	SLSC	57.00	1.7	U	unknown	0.92
HR-R	HR64	SLSC	63.00	2.4	U	unknown	0.95
HR-R	HR65	SLSC	54.00	1.7	U	unknown	1.05
HR-R	HR66	SLSC	58.00	1.7	U	unknown	0.87
HR-R	HR67	SLSC	57.00	1.8	U	unknown	0.97
HR-R	HR68	SLSC	65.00	2.7	U	unknown	0.98
HR-R	HR69	SLSC	60.00	2.2	U	unknown	1.01
HR-R	HR70	SLSC	53.00	1.7	U	unknown	1.13
HR-R	HR71	SLSC	60.00	2.3	U	unknown	1.06
HR-R	HR72	SLSC	62.00	2.3	U	unknown	0.97
HR-R	HR73	SLSC	61.00	1.9	U	unknown	0.84
HR-R	HR74	SLSC	62.00	2.5	U	unknown	1.05
HR-R	HR75	SLSC	58.00	2.0	U	unknown	1.01
HR-R	HR76	SLSC	61.00	2.3	U	unknown	1.01
HR-R	HR77	SLSC	63.00	2.1	U	unknown	0.84
HR-R	HR78	SLSC	61.00	2.4	U	unknown	1.06
HR-R	HR79	SLSC	62.00	2.6	U	unknown	1.09
HR-R	HR80	SLSC	58.00	1.9	U	unknown	0.97
HR-R	HR81	SLSC	54.00	1.8	U	unknown	1.14
HR-R	HR82	SLSC	52.00	1.7	U	unknown	1.21
HR-R	HR83	SLSC	68.00	3.1	U	unknown	0.97
HR-R	HR84	SLSC	58.00	2.1	U	unknown	1.06
HR-R	HR85	SLSC	64.00	2.6	U	unknown	0.99
HR-R	HR86	SLSC	61.00	2.2	U	unknown	0.95
HR-R	HR87	SLSC	63.00	2.5	U	unknown	1.00
HR-R	HR88	SLSC	61.00	2.2	U	unknown	0.97
HR-R	HR89	SLSC	63.00	2.4	U	unknown	0.96

Table VI.3 Tributary Sentinel Species (Slimy Sculpin) Fish Caught and Inventoried But Not Biomarked (continued)

Site[(a)]	ID Number	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Condition Factor
HR-R	HR90	SLSC	57.00	1.8	U	unknown	0.97
HR-R	HR91	SLSC	58.00	2.2	U	unknown	1.10
HR-R	HR92	SLSC	54.00	1.5	U	unknown	0.95
HR-R	HR93	SLSC	53.00	1.5	U	unknown	1.01
HR-R	HR94	SLSC	58.00	2.1	U	unknown	1.06
HR-R	HR95	SLSC	54.00	1.7	U	unknown	1.06
HR-R	HR96	SLSC	55.00	1.7	U	unknown	1.02
HR-R	HR97	SLSC	62.00	2.6	U	unknown	1.09
HR-R	HR98	SLSC	61.00	2.3	U	unknown	1.01
HR-R	HR99	SLSC	52.00	1.4	U	unknown	1.00
HR-R	HR100	SLSC	57.00	1.7	U	unknown	0.91
HR-R	HR101	SLSC	61.00	2.4	U	unknown	1.06
HR-R	HR102	SLSC	57.00	1.9	U	unknown	1.03
HR-R	HR103	SLSC	59.00	2.1	U	unknown	1.02
HR-R	HR104	SLSC	59.00	2.2	U	unknown	1.07
HR-R	HR105	SLSC	61.00	2.4	U	unknown	1.04
HR-R	HR106	SLSC	55.00	1.7	U	unknown	1.00
HR-R	HR107	SLSC	62.00	2.4	U	unknown	1.01
HR-R	HR108	SLSC	56.00	1.6	U	unknown	0.91
HR-R	HR109	SLSC	60.00	2.1	U	unknown	0.97
HR-R	HR110	SLSC	62.00	2.7	U	unknown	1.13
HR-R	HR111	SLSC	60.00	2.1	U	unknown	0.96
HR-R	HR112	SLSC	52.00	1.7	U	unknown	1.21
HR-R	HR113	SLSC	64.00	3.1	U	unknown	1.18
HR-R	HR114	SLSC	33.00	0.4	U	immature	1.02
HR-R	HR115	SLSC	65.00	2.9	U	unknown	1.06
HR-R	HR116	SLSC	62.00	2.6	U	unknown	1.09
HR-R	HR117	SLSC	57.00	1.6	U	unknown	0.86
HR-R	HR118	SLSC	58.00	1.9	U	unknown	0.96
HR-R	HR119	SLSC	51.00	1.3	U	unknown	0.98
HR-R	HR120	SLSC	65.00	2.4	U	unknown	0.87
HR-R	HR121	SLSC	40.00	0.6	U	immature	0.86
HR-R	HR122	SLSC	53.00	1.5	U	unknown	0.98
HR-R	HR123	SLSC	61.00	2.3	U	unknown	1.01
HR-R	HR124	SLSC	56.00	2.0	U	unknown	1.14
HR-R	HR125	SLSC	61.00	2.2	U	unknown	0.95
HR-R	HR126	SLSC	58.00	2.1	U	unknown	1.08
HR-R	HR127	SLSC	55.00	1.8	U	unknown	1.08
HR-R	HR128	SLSC	60.00	2.0	U	unknown	0.92
HR-R	HR129	SLSC	53.00	1.6	U	unknown	1.05

Table VI.3 Tributary Sentinel Species (Slimy Sculpin) Fish Caught and Inventoried But Not Biomarked (continued)

Site[a]	ID Number	Species	Fork Length (mm)	Weight (g)	Sex	Maturity	Condition Factor
HR-R	HR130	SLSC	52.00	1.6	U	unknown	1.12
HR-R	HR131	SLSC	62.00	2.6	U	unknown	1.09
HR-R	HR132	SLSC	64.00	2.6	U	unknown	0.99
HR-R	HR133	SLSC	55.00	1.7	U	unknown	1.02
HR-R	HR134	SLSC	62.00	2.3	U	unknown	0.97
HR-R	HR135	SLSC	56.00	1.5	U	unknown	0.85
HR-R	HR136	SLSC	32.00	0.4	U	immature	1.22
HR-R	HR137	SLSC	58.00	2.1	U	unknown	1.07
HR-R	HR138	SLSC	62.00	2.2	U	unknown	0.92
HR-R	HR139	SLSC	48.00	1.0	U	immature	0.90
HR-R	HR140	SLSC	53.00	2.0	U	unknown	1.31
HR-R	HR141	SLSC	31.00	0.4	U	immature	1.26
HR-R	HR142	SLSC	42.00	0.7	U	immature	0.94
DR-R	DR54	SLSC	53.00	1.2	U	immature	0.81
DR-R	DR55	SLSC	54.00	1.4	U	immature	0.89
DR-R	DR56	SLSC	49.00	1.3	U	immature	1.09
DR-R	DR57	SLSC	51.00	1.3	U	immature	0.98
DR-R	DR58	SLSC	52.00	1.4	U	immature	1.00
DR-R	DR59	SLSC	47.00	1.1	U	immature	1.06
DR-R	DR60	SLSC	46.00	1.1	U	immature	1.10
DR-R	DR61	SLSC	49.00	1.2	U	unknown	1.02
DR-R	DR62	SLSC	43.00	1.0	U	unknown	1.26
DR-R	DR63	SLSC	49.00	1.2	U	unknown	0.99
DR-R	DR64	SLSC	51.00	1.2	U	unknown	0.88
DR-R	DR65	SLSC	51.00	1.0	U	unknown	0.75
DR-R	DR66	SLSC	47.00	1.1	U	unknown	1.06
DR-R	DR67	SLSC	58.00	1.6	U	unknown	0.80
DR-R	DR68	SLSC	58.00	1.2	U	unknown	0.62
DR-R	DR69	SLSC	53.00	1.3	U	unknown	0.84
DR-R	DR70	SLSC	49.00	1.2	U	unknown	1.02
DR-R	DR71	SLSC	52.00	1.5	U	unknown	1.07
DR-R	DR72	SLSC	50.00	1.2	U	unknown	0.96

[a] SR-E = Steepbank River Exposure; SR-R = Steepbank River Reference; HR-R = Horse River Reference;
DR-R = Dunkirk River Reference

Note: Dates of fish collection in 2001: Sept 5,6 at site MR-E; Sept 9, 10 at site SR-E; Sept 15, 16 at site SR-R; Sept 22 at site HR-R; and Sept 23 at site DR-R.

APPENDIX VII

RADIOTELEMETRY DATA

Table VII.1 Telemetry Survey Results for the 2000/2001 Longnose Sucker and Northern Pike Radio Tagging Study

Transmitter (149 MHz)		Fish	Release Information		Fish Locations by Telemetry Survey Date (a)																		
					2000																		
Frequ.	Code	Species	Date	Site	Jun 4	Jun 9	Jun 18	Jun 27	Jul 24	Aug 9	Aug 18	Aug 23 [b]	Sep 8	Sep 22	Oct 10	Oct 19	Oct 27	Nov 3	Nov 9	Nov 17	Nov 23	Dec 1	Dec 11
.620	09	LNSC	16-May	KP -8.0	111																		
.620	10	LNSC	15-May	KP -8.0						213			215							213		213	
.620	13	LNSC	15-May	KP -8.0																			
.620	16	LNSC	15-May	KP -8.0																			
.660	08	LNSC	15-May	KP -8.0			MR-R3																
.660	11	LNSC	16-May	KP -8.0		-1											27	23			15		
.660	13	LNSC	16-May	KP -8.0																			
.660	18	LNSC	15-May	KP -8.0																			
.660	19	LNSC	15-May	KP -8.0																			
.680	04	LNSC	16-May	KP -8.0		147																	
.680	08	LNSC	15-May	KP -8.0															142	137		112	
.680	14	LNSC	16-May	KP -8.0	-1.5	MR-R2																	
.680	16	LNSC	15-May	KP -8.0																			
.700	11	LNSC	15-May	KP -8.0																			
.700	12	LNSC	15-May	KP -8.0																			
.700	16	LNSC	16-May	KP -8.0	17																		
.700	18	LNSC	16-May	KP -8.0																			
.720	03	LNSC	15-May	KP -8.0	13																		
.720	04	LNSC	16-May	KP -8.0																			
.720	06	LNSC	16-May	KP -8.0		0																115	
.720	16	LNSC	15-May	KP -8.0																			
.720	19	LNSC	16-May	KP -8.0																			
.620	01	LNSC	30-May	Muskeg R. - reach 3/4 boundary		133.5													165	165		166	
.620	02	LNSC	27-May	Muskeg R. - reach 3/4 boundary						232			225	243	235		235			232		236	
.620	12	LNSC	26-May	Muskeg R. - reach 3/4 boundary	55	58			30	32													
.620	18	LNSC	28-May	Muskeg R. mouth																			
.660	01	LNSC	30-May	Muskeg R. - reach 3/4 boundary																			
.660	12	LNSC	27-May	Muskeg R. - reach 3/4 boundary															MR-R3	MR-R4			
.660	17	LNSC	30-May	Muskeg R. - reach 3/4 boundary																			
.660	20	LNSC	29-May	Muskeg R. @ Jackpine Ck.																			
.680	03	LNSC	31-May	Muskeg R. - reach 2																			
.680	12	LNSC	31-May	Muskeg R. mouth																			
.680	20	LNSC	28-May	Muskeg R. mouth													54		58		58		
.700	03	LNSC	30-May	Muskeg R. - reach 3/4 boundary					80	230			223										
.700	04	LNSC	27-May	Muskeg R. - reach 3/4 boundary	75													66		71	71	73	
.700	08	LNSC	27-May	Muskeg R. - reach 3/4 boundary																		173	
.700	06	LNSC	29-May	Muskeg R. @ Jackpine Ck.						230			200		230		220						
.720	10	LNSC	27-May	Muskeg R. - reach 3/4 boundary		MR-R2		51	37														
.720	18	LNSC	27-May	Muskeg R. - reach 3/4 boundary															MR-R4				
.620	05	NRPK	01-Jun	Muskeg R. - reach 2														5	9	1	-3	-3	
.620	11	NRPK	31-May	Muskeg R. - reach 2															29			57	
.620	07	NRPK	31-May	muskeg r. mouth						45			215										
.680	10	NRPK	31-May	Muskeg R. - reach 2						MR-R4												45	
.680	15	NRPK	31-May	Muskeg R. - reach 2	51			MR-R2															
.680	18	NRPK	27-May	Muskeg R. - reach 3/4 boundary	-7					MR-R3		MR-R3	MR-R3		23			22	22	22		22	21
.680	17	NRPK	28-May	muskeg r. mouth								MR-R3							-5		-8	-10	-10
.700	02	NRPK	01-Jun	Muskeg R. - reach 2		57			137	140	135								138	138		138	
.700	05	NRPK	01-Jun	Muskeg R. - reach 2	50	MR-R1	MR-R1	51							44		44	43	43	45	43		45
.700	09	NRPK	01-Jun	Muskeg R. - reach 2																			
.700	10	NRPK	31-May	Muskeg R. - reach 2		MR-R2				28								CR-25		CR-25			
.700	13	NRPK	01-Jun	Muskeg R. - reach 2	MR-R2																	242	
.700	14	NRPK	01-Jun	Muskeg R. - reach 2			MR-R3			MR-R3		MR-R2	MR-R3		25			13	15	3	4	10	9
.700	07	NRPK	28-May	muskeg r. mouth																			
.720	14	NRPK	01-Jun	Muskeg R. - reach 2	MR - R2			MR-R1		186			185	204	191		195		195	195		195	
.720	12	NRPK	28-May	muskeg r. mouth																			
.720	15	NRPK	28-May	muskeg r. mouth																			
.620	20	LNSC	16-May	KP -8.0		40	mortality																
.680	05	LNSC	15-May	KP -8.0		0			16	mortality													
.700	15	LNSC	16-May	KP -8.0	17	mortality																	
.620	06	LNSC	27-May	Muskeg R. - reach 3/4 boundary	MR-R3	mortality																	
.620	17	LNSC	30-May	Muskeg R. - reach 3/4 boundary	MR-R3	mortality																	
.660	05	LNSC	26-May	Muskeg R. - reach 3/4 boundary	51			30					55				16	mortality					
.680	02	LNSC	26-May	Muskeg R. - reach 3/4 boundary						MR-R4	mortality												
.680	13	LNSC	30-May	Muskeg R. - reach 3/4 boundary	MR-R3	mortality																	
.700	01	LNSC	29-May	Muskeg R. @ Jackpine Ck.	mortality																		
.720	07	LNSC	30-May	Muskeg R. - reach 3/4 boundary	mortality																		
.720	05	LNSC	29-May	Muskeg R. @ Jackpine Ck.			MR-R4	mortality															
.620	03	NRPK	31-May	Muskeg R. mouth	Removed by angler at Muskeg River mouth																		
.620	08	NRPK	31-May	Muskeg R. reach 2	MR - R2	mortality																	
.680	01	NRPK	31-May	Muskeg R. - reach 2	MR-R2	mortality																	
.700	19	NRPK	31-May	Muskeg R. - reach 2		MR-R2	mortality																
.720	20	NRPK	31-May	Muskeg R. - reach 2				MR-R1	mortality														
.720	21	NRPK	01-Jun	Muskeg R. - reach 2	removed by angler																		
.720	02	NRPK	31-May	Muskeg R. - reach 2		MR-R1	mortality																
.720	08	NRPK	01-Jun	Muskeg R. - reach 2			MR-R2	mortality															

Table VII.1 Telemetry Survey Results for the 2000/2001 Longnose Sucker and Northern Pike Radio Tagging Study (continued)

Transmitter (149 MHz)		Fish	Release Information		Fish Locations by Telemetry Survey Date (a) 2001																
Frequ.	Code	Species	Date	Site	Jan 12	Jan 24	Feb 12	Feb 13-15(c)	Feb 26	Feb 27-Mar 1 (c)	Mar 12	Mar 13-15(c)	Mar 22	Apr 5	Apr 18	May 3	May 15	May 24	Jun 1	Jun 5	Jun 14
.620	09	LNSC	16-May	KP -8.0																	
.620	10	LNSC	15-May	KP -8.0	213	213															
.620	13	LNSC	15-May	KP -8.0																	
.620	16	LNSC	15-May	KP -8.0																	
.660	08	LNSC	15-May	KP -8.0																	
.660	11	LNSC	16-May	KP -8.0		5	4		2	2.5	2	3	2.5	2	2.5			-6.8	30		
.660	13	LNSC	16-May	KP -8.0													-10	-10	9		
.660	18	LNSC	15-May	KP -8.0																	
.660	19	LNSC	15-May	KP -8.0																	
.680	04	LNSC	16-May	KP -8.0													-1				
.680	08	LNSC	15-May	KP -8.0	108		95														
.680	14	LNSC	16-May	KP -8.0																	
.680	16	LNSC	15-May	KP -8.0								15.5									
.700	11	LNSC	15-May	KP -8.0							95										
.700	12	LNSC	15-May	KP -8.0																	
.700	16	LNSC	16-May	KP -8.0			89										-8.8	-3.8	-2.8	-2	95
.700	18	LNSC	16-May	KP -8.0																	
.720	03	LNSC	15-May	KP -8.0																	
.720	04	LNSC	16-May	KP -8.0																5	
.720	06	LNSC	16-May	KP -8.0		97	95				95		95	95							
.720	16	LNSC	15-May	KP -8.0													1.5		4	2	
.720	19	LNSC	16-May	KP -8.0																	
.620	01	LNSC	30-May	Muskeg R. - reach 3/4 boundary	166	166															
.620	02	LNSC	27-May	Muskeg R. - reach 3/4 boundary	233	233							230								
.620	12	LNSC	26-May	Muskeg R. - reach 3/4 boundary																	
.620	18	LNSC	28-May	muskeg r. mouth																	
.660	01	LNSC	30-May	Muskeg R. - reach 3/4 boundary	88	88	88														
.660	12	LNSC	27-May	Muskeg R. - reach 3/4 boundary																	
.660	17	LNSC	30-May	Muskeg R. - reach 3/4 boundary																	
.660	20	LNSC	29-May	Muskeg R. @ Jackpine Ck.																	
.680	03	LNSC	31-May	Muskeg R. - reach 2		164															
.680	12	LNSC	31-May	muskeg r. mouth																	
.680	20	LNSC	28-May	muskeg r. mouth			62														
.700	03	LNSC	30-May	Muskeg R. - reach 3/4 boundary																	
.700	04	LNSC	27-May	Muskeg R. - reach 3/4 boundary		51	65				60										
.700	08	LNSC	27-May	Muskeg R. - reach 3/4 boundary	175	175	178								180						
.700	06	LNSC	29-May	Muskeg R. @ Jackpine Ck.		231															
.720	10	LNSC	27-May	Muskeg R. - reach 3/4 boundary																	
.720	18	LNSC	27-May	Muskeg R. - reach 3/4 boundary																	
.620	05	NRPK	01-Jun	Muskeg R. - reach 2			-1				-1		-2	-2	-8	-8	-11	-11.5	-11	-11.7	
.620	11	NRPK	31-May	Muskeg R. - reach 2			65														
.620	07	NRPK	31-May	muskeg r. mouth														30		30	30
.680	10	NRPK	31-May	Muskeg R. - reach 2		37			38	39	38	39	37								
.680	15	NRPK	31-May	Muskeg R. - reach 2																	
.680	18	NRPK	27-May	Muskeg R. - reach 3/4 boundary	12	12	12	14	14	15	18	18									
.680	17	NRPK	28-May	muskeg r. mouth		-13					17				20						
.700	02	NRPK	01-Jun	Muskeg R. - reach 2	139	139	137										133	138	138		
.700	05	NRPK	01-Jun	Muskeg R. - reach 2		45	44		45	45	45	45	45								
.700	09	NRPK	01-Jun	Muskeg R. - reach 2																	
.700	10	NRPK	31-May	Muskeg R. - reach 2									CR-2.5	15							
.700	13	NRPK	01-Jun	Muskeg R. - reach 2	239	239															
.700	14	NRPK	01-Jun	Muskeg R. - reach 2		15	14	15	14			15	15					56	56	45	50
.700	07	NRPK	28-May	muskeg r. mouth																	
.720	14	NRPK	01-Jun	Muskeg R. - reach 2	195	195							195								
.720	12	NRPK	28-May	muskeg r. mouth																	
.720	15	NRPK	28-May	muskeg r. mouth													45	56	56		
.620	20	LNSC	16-May	KP -8.0																	
.680	05	LNSC	15-May	KP -8.0																	
.700	15	LNSC	16-May	KP -8.0																	
.620	06	LNSC	27-May	Muskeg R. - reach 3/4 boundary																	
.620	17	LNSC	30-May	Muskeg R. - reach 3/4 boundary																	
.660	05	LNSC	26-May	Muskeg R. - reach 3/4 boundary																	
.680	02	LNSC	26-May	Muskeg R. - reach 3/4 boundary																	
.680	13	LNSC	30-May	Muskeg R. - reach 3/4 boundary																	
.700	01	LNSC	29-May	Muskeg R. @ Jackpine Ck.																	
.720	07	LNSC	30-May	Muskeg R. - reach 3/4 boundary																	
.720	05	LNSC	29-May	Muskeg R. @ Jackpine Ck.																	
.620	03	NRPK	31-May	muskeg r. mouth																	
.620	08	NRPK	31-May	Muskeg R. reach 2																	
.680	01	NRPK	31-May	Muskeg R. - reach 2																	
.700	19	NRPK	31-May	Muskeg R. - reach 2																	
.720	20	NRPK	31-May	Muskeg R. - reach 2																	
.720	21	NRPK	01-Jun	Muskeg R. - reach 2																	
.720	02	NRPK	31-May	Muskeg R. - reach 2																	
.720	08	NRPK	01-Jun	Muskeg R. - reach 2																	

(a) Key to Fish Locations: Athabasca River - number equals distance from Ft. McMurray (i.e., kilometre post according to Figure _)
Muskeg River MR-R1 = Reach 1 (mouth)
MR-R2 = Reach 2 (canyon)
MR-R3 = Reach 3 (ford to canyon)
MR-R4 = Reach 4 (upstream of ford)
Clearwater River - CR (kilometres from mouth)
(b) Float survey of Muskeg River
(c) Ground survey of selected Athabasca River sites
Note: Shaded cells = mortality or fish remov ed by angler

APPENDIX VIII

FISH TISSUE COLLECTION DATA, FALL 2001

Table VIII.1 Fish Captured for Athabasca River Tissue Study, Fall 2001

Fish ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC	Gonad Weight (g)	GSI	Liver Weight (g)	LSI	Gall Bladder Fullnes (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents
ARF005*	LKWH	F	PR	460	1495	1.54	920	17		237.9	25.86	18.8	2.04	<5	yellow	75	water boatmen beetle
ARF011	LKWH	F	PR	438	1570	1.87	860	10	10	260.1	30.24	13.2	1.53	40	yellow/brown	0	empty
ARF012	LKWH	F	PR	482	1620	1.45	930	19		219	23.55	26.7	2.87	25	yelloworange	<5	invertebrate parts
ARF013	LKWH	F	PR	454	1410	1.51	815	19		248.6	30.50	12.3	1.51	10	yellow	0	empty
ARF020	LKWH	F	PR	422	1190	1.58	520	11		189	36.35	15.1	2.90	30	yellow/green	0	empty
ARF021	LKWH	F	PR	425	1380	1.80	715	12		237.5	33.22	15.2	2.13	10	yellow/green	0	empty
ARM001	LKWH	M	RS	458	1550	1.61	1100	16		7.7	0.70	12	1.09	50	green	0	empty
ARM002	LKWH	M	PR	421	1130	1.51	750	8		13.1	1.75	5.4	0.72	0	empty	0	empty
ARM003	LKWH	M	PR	468	1395	1.36	925	20		17.1	1.85	11.3	1.22	0	empty	25	invertebrate parts
ARM004	LKWH	M	PR	439	1280	1.51	820	22		21	2.56	7.5	0.91	10	green/brown	0	2 water boatmen
ARM022	LKWH	M	PR	493	1550	1.29	1050	25		18.7	1.78	11.1	1.06	20	green	0	empty
ARF007*	WALL	F	IM	387	680	1.17	420	4			0.00	12.1	2.88	5-10%	yellow	25	1 small fish
ARF010	WALL	F	SD	504	1510	1.18	975	8		80.5	8.26	30.6	3.14	25	yellow	0	empty
ARF015*	WALL	F	IM	504	1350	1.05	950	8		5.7	0.60	14.6	1.54	20	yellow	0	empty
ARF017	WALL	F	SD	595	2530	1.20	1580	17	17	133.6	8.46	56.7	3.59	0	yellow	0	empty
ARF018	WALL	F	SD	504	1610	1.26	1050	12		70.8	6.74	27.3	2.60	15	yellow	0	empty
ARF023	WALL	F	SD	611	2650	1.16	1560	14		168	10.77	39	2.50	25	yellow	0	empty
ARF024	WALL	F	SD	534	1735	1.14	910	7		98	10.77	32	3.52	0	empty	0	empty
ARM006	WALL	M	SD	396	680	1.10	415	6		15.4	3.71	6.8	1.64	5	yellow	0	empty
ARM008*	WALL	M	IM	411	780	1.12	500	6			0.00	9.6	1.92	10	yellow	0	empty
ARM009	WALL	M	SD	416	860	1.19	540	8		21.6	4.00	13.2	2.44	10	yellow	0	empty
ARM014	WALL	M	SD	469	1160	1.12	740	11		30.1	4.07	14.3	1.93	10	yellow	0	empty
ARM016	WALL	M	SD	482	1210	1.08	840	12		37	4.40	16.1	1.92	5	yellow	0	empty
ARM019	WALL	M	SD	477	1160	1.07	790	7		23.1	2.92	11.1	1.41	0	yellow	0	empty

Note: M = Male; F =Female
PR = Pre-spawning; RS = Resting; IM = Immature; SD = Seasonal Develpoment
LKWH = Lake Whitefish; WALL = Walleye
* Fish not included in composite sample for analysis

Table VIII.2 Fish Captured for Athabasca River Tissue Study, Fall 2001; Pathology Results

ID Number	Species	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fin	Opercles	Hindgut	Mesenteric Fat	Liver	Spleen	Gall Bladder	Kidney	Parasites	Total Score
		Condition															
ARF005	LKWH	H1	N	N	0	1	none	1	0	0	1	A	B	0	N	3	80
ARF011	LKWH	N	N	N	0	3	none	1	0	1	1	D	B	0	N	3	110
ARF012	LKWH	N	N	N	0	2	none	1	0	0	1	A	E	0	S	2	110
ARF013	LKWH	N	N	N	0	1	none	1	0	1	1	A	B	0	N	2	50
ARF020	LKWH	N	N	N	0	1	none	2	0	0	0	A	B	0	N	1	40
ARF021	LKWH	N	N	N	0	1	none	1	0	0	1	A	B	0	OT	3	80
ARM001	LKWH	H2	N	N	0	1	none	2	0	0	1	D	B	0	N	3	120
ARM002	LKWH	N	N	N	0	1	none	1	0	0	1	F	B	0	N	1	80
ARM003	LKWH	N	OT	N	0	0	none	1	0	1	1	A	B	0	N	0	50
ARM004	LKWH	N	N	N	0	0	none	1	0	0	1	A	G	0	N	3	70
ARM022	LKWH	N	N	N	0	0	none	1	0	0	1	D	B	0	N	3	70
ARF007	WALL	N	N	N	0	0	none	0	0	0	1	F	B	0	N	2	50
ARF010	WALL	N	N	N	0	0	none	1	0	0	4	E	B	0	N	0	40
ARF015	WALL	N	N	N	0	1	none	1	0	0	3	F	B	0	N	3	80
ARF017	WALL	N	N	N	0	0	none	1	0	0	3	A	B	0	N	3	40
ARF018	WALL	N	N	N	0	0	none	0	0	0	3	A	B	0	N	0	0
ARF023	WALL	N	N	N	0	0	none	0	0	0	2	A	B	0	N	0	0
ARF024	WALL	N	N	N	0	0	none	0	0	0	2	A	B	0	N	0	0
ARM006	WALL	N	N	N	0	0	none	0	0	0	3	E	G	0	N	0	60
ARM008	WALL	N	N	N	0	1	none	0	0	0	2	A	B	0	N	3	40
ARM009	WALL	N	N	N	0	0	none	0	0	0	3	E	G	0	N	1	70
ARM014	WALL	N	N	N	0	0	none	0	0	0	3	F	B	0	N	2	50
ARM016	WALL	N	N	N	0	0	none	1	0	0	3	A	B	0	N	2	30
ARM019	WALL	N	N	N	0	0	none	2	0	0	2	F	B	0	N	0	50

Note: LKWH = lake whitefish; WALL = walleye.
See Appendix III for pathology codes.

Table VIII.3 Fish Captured for Muskeg River Tissue Collection, Fall 2001

Fish ID Number	Species	Sex	Maturity	Fork Length (mm)	Body Weight (g)	Condition Factor	Carcass Weight (g)	Age	Age QAQC	Gonad Weight (g)	GSI	Liver Weight (g)	LSI	Gall Bladder Fullness (%)	Bile Colour	Stomach Fullness (%)	Stomach Contents
MRF001	NRPK	F	SD	561	1330	0.75	935	6		33.2	3.55	21.5	2.30	0	empty	0	empty
MRM002	NRPK	M	SD	539	1190	0.76	790	4		20	2.53	11	1.39	100	brown	0	empty
MRF003	NRPK	F	SD	605	1665	0.75	1165	4		48	4.12	30.4	2.61	100	yellow/brown	25	cyhme
MRF004	NRPK	F	SD	580	1660	0.85	1050	5		37.4	3.56	33.1	3.15	0	white	100	white sucker
MRF005	NRPK	F	SD	664	2215	0.76	1650	6		40.6	2.46	28.8	1.75		empty	100	3 birds
MRM006	NRPK	M	SD	613	1640	0.71	1035	6		25.6	2.47	15	1.45		empty	75	juv sucker
MRF007	NRPK	F	SD	723	2830	0.75	2285	6		33.1	1.45	54.7	2.39	100	empty	0	worm on outside?
MRM008	NRPK	M	SD	610	1610	0.71	1210	5	5	24.3	2.01	15	1.24	75	yellow/brown	0	empty
MRM009	NRPK	M	SD	631	1780	0.71	1390	5		31.9	2.29	15.2	1.09	75	yellow/brown	0	empty
MRM010	NRPK	M	SD	538	1280	0.82	840	4		26.2	3.12	20.1	2.39	25	yellow/brown	10	small fish

Note: M = male; F =female.
SD = seasonal development.
NRPK = northern pike.

Table VIII.4 Fish Captured for Muskeg River Tissue Study, Fall 2001; Pathology Results

Fish ID Number	Species	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fin	Opercles	Hindgut	Mesenteric Fat	Liver	Spleen	Gall Bladder	Kidney	Parasites	Total Score
		Condition															
MRF001	NRPK	N	N	N	0	2	none	0	0	0	2	A	B	0	N	0	20
MRM002	NRPK	N	N	N	0	0	n/a	0	0	0	2	A	G	0	N	0	60
MRF003	NRPK	N	F	N	0	1	none	0	0	0	2	A	B	0	N	0	40
MRF004	NRPK	N	N	N	0	0	none	0	0	0	1	A	B	0	N	0	0
MRF005	NRPK	N	N	N	0	0	none	0	0	0	1	A	B	0	G	0	30
MRM006	NRPK	N	N	N	0	1	none	0	0	0	1	OT	B	0	N	0	40
MRF007	NRPK	N	F	N	0	0	none	0	0	0	3	A	B	0	N	0	30
MRM008	NRPK	N	N	N	0	0	none	0	0	0	1	A	B	0	N	0	0
MRM009	NRPK	N	N	N	0	0	none	1	0	0	1	A	B	0	N	0	10
MRM010	NRPK	N	F	N	0	0	none	0	0	0	1	F	G	0	N	0	90

Note: NRPK = northern pike.
See Appendix III for pathology codes.

Table VIII.5 Athabasca River Walleye Tissue Lab Results

Sex	Parameter	Results	Units	Detection Limit	Methods
female	acenaphthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	acenaphthylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(a)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(a)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(b)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(k)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(ghi)perylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	chrysene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	dibenzo(a,h)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	dibenzothiophene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	fluorene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	indeno(c,d-123)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	methyl B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl acenaphthene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl fluoranthene/pyrene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	methyl phenanthrene/anthracene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS

Table VIII.5 Athabasca River Walleye Tissue Lab Results (continued)

Sex	Parameter	Results	Units	Detection Limit	Methods
female	phenanthrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	lithium (Li)	<0.5	mg/kg	0.5	EPA 200.3/200.8-ICPMS
female	mercury (Hg)	0.46	mg/kg	0.01	EPA 200.3/200.8-ICPMS
female	silver (Ag)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	aluminum (Al)	<4	mg/kg	4	EPA 200.3/200.8-ICPMS
female	arsenic (As)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	barium (Ba)	0.15	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	beryllium (Be)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	calcium (Ca)	100	mg/kg	10	EPA 200.3/200.8-ICPMS
female	cadmium (Cd)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	cobalt (Co)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	chromium (Cr)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	copper (Cu)	0.36	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	iron (Fe)	15	mg/kg	2	EPA 200.3/200.8-ICPMS
female	potassium (K)	3550	mg/kg	2	EPA 200.3/200.8-ICPMS
female	magnesium (Mg)	261	mg/kg	2	EPA 200.3/200.8-ICPMS
female	manganese (Mn)	0.12	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	molybdenum (Mo)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	sodium (Na)	215	mg/kg	2	EPA 200.3/200.8-ICPMS
female	nickel (Ni)	0.26	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	phosphorus (P)	1210	mg/kg	2	EPA 200.3/200.8-ICPMS
female	lead (Pb)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	antimony (Sb)	0.05	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	selenium (Se)	0.4	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	tin (Sn)	.12	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	strontium (Sr)	0.10	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	titanium (Ti)	0.11	mg/kg	0.05	EPA 200.3/200.8-ICPMS
female	thallium (Tl)	0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	vanadium (V)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	zinc (Zn)	7.4	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	acenaphthylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(a)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(a)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(b)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(k)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(ghi)perylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS

Table VIII.5 Athabasca River Walleye Tissue Lab Results (continued)

Sex	Parameter	Results	Units	Detection Limit	Methods
male	C2 sub'd B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	chrysene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	dibenzo(a,h)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	dibenzothiophene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	fluorene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	indeno(c,d-123)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	methyl B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl acenaphthene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl fluoranthene/pyrene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	methyl phenanthrene/anthracene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	phenanthrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	lithium (Li)	<0.5	mg/kg	0.5	EPA 200.3/200.8-ICPMS
male	mercury (Hg)	0.36	mg/kg	0.01	EPA 200.3/200.8-ICPMS
male	silver (Ag)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	aluminum (Al)	<4	mg/kg	4	EPA 200.3/200.8-ICPMS
male	arsenic (As)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	barium (Ba)	0.09	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	beryllium (Be)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS

Table VIII.5 Athabasca River Walleye Tissue Lab Results (continued)

Sex	Parameter	Results	Units	Detection Limit	Methods
male	calcium (Ca)	160	mg/kg	10	EPA 200.3/200.8-ICPMS
male	cadmium (Cd)	0.11	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	cobalt (Co)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	chromium (Cr)	0.5	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	copper (Cu)	0.32	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	iron (Fe)	11	mg/kg	2	EPA 200.3/200.8-ICPMS
male	potassium (K)	3520	mg/kg	2	EPA 200.3/200.8-ICPMS
male	magnesium (Mg)	289	mg/kg	2	EPA 200.3/200.8-ICPMS
male	manganese (Mn)	0.24	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	molybdenum (Mo)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	sodium (Na)	227	mg/kg	2	EPA 200.3/200.8-ICPMS
male	nickel (Ni)	0.56	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	phosphorus (P)	2460	mg/kg	2	EPA 200.3/200.8-ICPMS
male	lead (Pb)	0.15	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	antimony (Sb)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	selenium (Se)	0.6	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	tin (Sn)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	strontium (Sr)	0.11	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	titanium (Ti)	0.49	mg/kg	0.05	EPA 200.3/200.8-ICPMS
male	thallium (Tl)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	vanadium (V)	0.14	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	zinc (Zn)	4.3	mg/kg	0.2	EPA 200.3/200.8-ICPMS

Table VIII.6 Athabasca River Lake Whitefish Tissue Lab Results

Sex	Parameter	Results	Units	Detection Limit	Methods
female	acenaphthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	acenaphthylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(a)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(a)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(b)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(k)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(ghi)perylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	chrysene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	dibenzo(a,h)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	dibenzothiophene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	fluorene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	Indeno(c,d-123)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	methyl B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl acenaphthene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl fluoranthene/pyrene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	methyl phenanthrene/anthracene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS

Table VIII.6 Athabasca River Lake Whitefish Tissue Lab Results (continued)

Sex	Parameter	Results	Units	Detection Limit	Methods
female	phenanthrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	lithium (Li)	<0.5	mg/kg	0.5	EPA 200.3/200.8-ICPMS
female	mercury (Hg)	0.11	mg/kg	0.01	EPA 200.3/200.8-ICPMS
female	silver (Ag)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	aluminum (Al)	7	mg/kg	4	EPA 200.3/200.8-ICPMS
female	arsenic (As)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	barium (Ba)	0.14	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	beryllium (Be)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	calcium (Ca)	100	mg/kg	10	EPA 200.3/200.8-ICPMS
female	cadmium (Cd)	0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	cobalt (Co)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	chromium (Cr)	0.5	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	copper (Cu)	0.32	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	iron (Fe)	10	mg/kg	2	EPA 200.3/200.8-ICPMS
female	potassium (K)	3000	mg/kg	2	EPA 200.3/200.8-ICPMS
female	magnesium (Mg)	243	mg/kg	2	EPA 200.3/200.8-ICPMS
female	manganese (Mn)	0.21	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	molybdenum (Mo)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	sodium (Na)	305	mg/kg	2	EPA 200.3/200.8-ICPMS
female	nickel (Ni)	0.65	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	phosphorus (P)	2210	mg/kg	2	EPA 200.3/200.8-ICPMS
female	lead (Pb)	0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	antimony (Sb)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	selenium (Se)	0.5	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	tin (Sn)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	strontium (Sr)	0.12	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	titanium (Ti)	0.83	mg/kg	0.05	EPA 200.3/200.8-ICPMS
female	thallium (Tl)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	vanadium (V)	0.12	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	zinc (Zn)	4.8	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	acenaphthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	acenaphthylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(a)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(a)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(b)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(k)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(ghi)perylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS

Table VIII.6 Athabasca River Lake Whitefish Tissue Lab Results (continued)

Sex	Parameter	Results	Units	Detection Limit	Methods
male	biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	chrysene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	dibenzo(a,h)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	dibenzothiophene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	fluorene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	indeno(c,d-123)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	methyl B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl acenaphthene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl fluoranthene/pyrene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	methyl phenanthrene/anthracene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	phenanthrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	lithium (Li)	<0.5	mg/kg	0.5	EPA 200.3/200.8-ICPMS
male	mercury (Hg)	0.11	mg/kg	0.01	EPA 200.3/200.8-ICPMS
male	silver (Ag)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	aluminum (Al)	<4	mg/kg	4	EPA 200.3/200.8-ICPMS
male	arsenic (As)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	barium (Ba)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	beryllium (Be)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS

Table VIII.6 Athabasca River Lake Whitefish Tissue Lab Results (continued)

Sex	Parameter	Results	Units	Detection Limit	Methods
male	calcium (Ca)	120	mg/kg	10	EPA 200.3/200.8-ICPMS
male	cadmium (Cd)	0.09	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	cobalt (Co)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	chromium (Cr)	0.5	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	copper (Cu)	0.45	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	iron (Fe)	16	mg/kg	2	EPA 200.3/200.8-ICPMS
male	potassium (K)	3580	mg/kg	2	EPA 200.3/200.8-ICPMS
male	magnesium (Mg)	299	mg/kg	2	EPA 200.3/200.8-ICPMS
male	manganese (Mn)	0.22	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	molybdenum (Mo)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	sodium (Na)	327	mg/kg	2	EPA 200.3/200.8-ICPMS
male	nickel (Ni)	1.22	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	phosphorus (P)	2250	mg/kg	2	EPA 200.3/200.8-ICPMS
male	lead (Pb)	0.08	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	antimony (Sb)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	selenium (Se)	0.5	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	tin (Sn)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	strontium (Sr)	0.12	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	titanium (Ti)	0.48	mg/kg	0.05	EPA 200.3/200.8-ICPMS
male	thallium (Tl)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	vanadium (V)	0.17	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	zinc (Zn)	3.3	mg/kg	0.2	EPA 200.3/200.8-ICPMS

Table VIII.7 Muskeg River Northern Pike Fish Tissue Composite Lab Results

Sex	Parameter	Result	Units	Detection Limit	Method
female	acenaphthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	acenaphthylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(a)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(a)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(b)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(k)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	benzo(ghi)perylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C2 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C3 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	C4 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	chrysene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	dibenzo(a,h)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	dibenzothiophene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	fluorene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	Indeno(c,d-123)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	methyl B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl acenaphthene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl fluoranthene/pyrene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	methyl naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	methyl phenanthrene/anthracene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
female	naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS

Table VIII.7 Muskeg River Northern Pike Fish Tissue Composite Lab Results (continued)

Sex	Parameter	Result	Units	Detection Limit	Method
female	phenanthrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
female	lithium (Li)	<0.5	mg/kg	0.5	EPA 200.3/200.8-ICPMS
female	mercury (Hg)	0.14	mg/kg	0.01	EPA 200.3/200.8-ICPMS
female	silver (Ag)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	aluminum (Al)	<4	mg/kg	4	EPA 200.3/200.8-ICPMS
female	arsenic (As)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	barium (Ba)	0.09	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	beryllium (Be)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	calcium (Ca)	550	mg/kg	10	EPA 200.3/200.8-ICPMS
female	cadmium (Cd)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	cobalt (Co)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	chromium (Cr)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	copper (Cu)	0.29	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	iron (Fe)	4	mg/kg	2	EPA 200.3/200.8-ICPMS
female	potassium (K)	3770	mg/kg	2	EPA 200.3/200.8-ICPMS
female	magnesium (Mg)	313	mg/kg	2	EPA 200.3/200.8-ICPMS
female	manganese (Mn)	0.42	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	molybdenum (Mo)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	sodium (Na)	266	mg/kg	2	EPA 200.3/200.8-ICPMS
female	nickel (Ni)	0.09	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	phosphorus (P)	2240	mg/kg	2	EPA 200.3/200.8-ICPMS
female	lead (Pb)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	antimony (Sb)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	selenium (Se)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
female	tin (Sn)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	strontium (Sr)	0.37	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	titanium (Ti)	0.24	mg/kg	0.05	EPA 200.3/200.8-ICPMS
female	thallium (Tl)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
female	vanadium (V)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
female	zinc (Zn)	6.4	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	acenaphthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	acenaphthylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(a)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(a)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(b)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	benzo(k)fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS

Table VIII.7 Muskeg River Northern Pike Fish Tissue Composite Lab Results (continued)

Sex	Parameter	Result	Units	Detection Limit	Method
male	benzo(ghi)perylene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C2 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C3 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd naphthalene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	C4 sub'd phenanthrene/anth.	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	chrysene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	dibenzo(a,h)anthracene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	dibenzothiophene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	fluoranthene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	fluorene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	indeno(c,d-123)pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	methyl B(a)A/chrysene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl B(b&k)F/B(a)P	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl acenaphthene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl biphenyl	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl dibenzothiophene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl fluoranthene/pyrene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl fluorene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	methyl naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	methyl phenanthrene/anthracene	<0.04	mg/kg	0.04	EPA 3540/8270-GC/MS
male	naphthalene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	phenanthrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	pyrene	<0.02	mg/kg	0.02	EPA 3540/8270-GC/MS
male	lithium (Li)	<0.5	mg/kg	0.5	EPA 200.3/200.8-ICPMS
male	mercury (Hg)	0.12	mg/kg	0.01	EPA 200.3/200.8-ICPMS
male	silver (Ag)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	aluminum (Al)	4	mg/kg	4	EPA 200.3/200.8-ICPMS
male	arsenic (As)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS

Table VIII.7 Muskeg River Northern Pike Fish Tissue Composite Lab Results (continued)

Sex	Parameter	Result	Units	Detection Limit	Method
male	barium (Ba)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	beryllium (Be)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	calcium (Ca)	310	mg/kg	10	EPA 200.3/200.8-ICPMS
male	cadmium (Cd)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	cobalt (Co)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	chromium (Cr)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	copper (Cu)	1.18	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	iron (Fe)	6	mg/kg	2	EPA 200.3/200.8-ICPMS
male	potassium (K)	4020	mg/kg	2	EPA 200.3/200.8-ICPMS
male	magnesium (Mg)	324	mg/kg	2	EPA 200.3/200.8-ICPMS
male	manganese (Mn)	0.30	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	molybdenum (Mo)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	sodium (Na)	297	mg/kg	2	EPA 200.3/200.8-ICPMS
male	nickel (Ni)	0.47	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	phosphorus (P)	2120	mg/kg	2	EPA 200.3/200.8-ICPMS
male	lead (Pb)	0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	antimony (Sb)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	selenium (Se)	<0.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS
male	tin (Sn)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	strontium (Sr)	0.20	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	titanium (Ti)	0.74	mg/kg	0.05	EPA 200.3/200.8-ICPMS
male	thallium (Tl)	<0.04	mg/kg	0.04	EPA 200.3/200.8-ICPMS
male	vanadium (V)	<0.08	mg/kg	0.08	EPA 200.3/200.8-ICPMS
male	zinc (Zn)	7.2	mg/kg	0.2	EPA 200.3/200.8-ICPMS

APPENDIX IX

BENTHIC INVERTEBRATE DATA

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Clearwater River Downstream of Christina River (depositional)															Clearwater River Upstream of Christina River (depositional)														
			CLR-D-1	CLR-D-2	CLR-D-3	CLR-D-4	CLR-D-5	CLR-D-6	CLR-D-7	CLR-D-8	CLR-D-9	CLR-D-10	CLR-D-11	CLR-D-12	CLR-D-13	CLR-D-14	CLR-D-15	CLR-D-16	CLR-D-17	CLR-D-18	CLR-D-19	CLR-D-20	CLR-D-21	CLR-D-22	CLR-D-23	CLR-D-24	CLR-D-25	CLR-D-26	CLR-D-27	CLR-D-28	CLR-D-29	CLR-D-30
Hydrozoa	Hydridae	*Hydra*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	-[(a)]	-	0	0	0	1	0	0	0	0	0	0	8	0	1	0	0	2	1	8	0	8	5	15	4	0	1	0	8	0	8	0
Oligochaeta	Enchytraeidae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
	Lumbriculidae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Naididae	-	0	0	0	0	45	0	0	1	2	0	192	1	0	1	0	62	1414	8	0	48	10	1	3	40	1	8	0	25	8	0
	Tubificidae	-	0	4	0	26	535	706	24	186	127	8	291	4	28	10	8	57	80	9	737	299	34	0	8	205	14	1	4	315	81	139
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Helobdella stagnalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
	Erpobdellidae	*Erpobdella punctata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda	Ancylidae	*Ferrissia rivularis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydrobiidae	(i/d)[(b)]	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lymnaeidae	*Stagnicola?*	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	13	0	0	0	0	0	0	2	0	0	0	0	0	0
	Physidae	*Physa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Planorbidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
	Valvatidae	*Valvata sincera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Valvata tricarinata	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	14	0	0	0	0	0	0	0	0	0	0	1	0	0
Pelecypoda	Sphaeriidae	*Pisidium / Sphaerium*	0	23	0	81	29	123	0	782	235	0	5	80	16	0	64	44	49	2	13	158	2	2	6	12	24	0	3	425	49	39
	Unionidae	*Lampsilis radiata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydracarina	-	-	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Cladocera	Chydoridae	-	0	0	0	0	200	0	0	0	16	0	16	2	0	0	0	0	0	8	8	0	0	0	0	0	0	16	0	0	8	0
	Daphnidae	*Daphnia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Macrothricidae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda - Cyclopoida	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	8	0	0	0	0
Copepoda - Harpacticoida	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	Candonidae	*Candona*	0	2	2	1	128	40	0	0	24	0	250	3	4	8	0	40	2	8	80	24	15	13	1	24	0	24	0	8	24	0
Amphipoda	Talitridae	*Hyalella azteca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	12	0	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Ameletidae	*Ameletus subnotatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Baetidae	*Acentrella*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Baetis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
		Procloeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Baetiscidae	*Baetisca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Caenidae	*Caenis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ephemerellidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Drunella grandis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ephemerella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heptageniidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Heptagenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		Rhithrogena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stenonema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leptophlebiidae	*Leptophlebia*	0	0	0	0	4	0	0	0	2	0	0	0	0	0	0	0	26	0	1	0	0	0	1	0	1	0	0	0	0	0
	Tricorythidae	*Tricorythodes*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata - Anisoptera	Aeshnidae	*Aeshna*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Corduliidae	*Epitheca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gomphidae	*Gomphus*	0	1	0	2	9	1	0	6	13	3	7	3	4	0	4	0	1	0	1	3	2	0	0	7	0	0	0	0	1	2
		Ophiogomphus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Odonata - Zygoptera	Calopterygidae	*Calopteryx aequabilis*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coenagrionidae	*Enallagma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plecoptera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Capniidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chloroperlidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
	Nemouridae	*Zapada*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perlidae	*Acroneuria*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Claassenia sabulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perlodidae	*Isogenoides*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Isoperla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Skwala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pteronarcyidae	*Pteronarcys*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Taeniopterygidae	*Taeniopteryx*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemiptera	Corixidae	*Sigara*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Callicorixa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megaloptera	Sialidae	*Sialis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Brachycentridae	*Brachycentrus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Glossosomatidae	*Glossosoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydroptilidae	(pupa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hydroptila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Oxyethira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Clearwater River Downstream of Christina River (depositional)															Clearwater River Upstream of Christina River (depositional)														
			CLR-D-1	CLR-D-2	CLR-D-3	CLR-D-4	CLR-D-5	CLR-D-6	CLR-D-7	CLR-D-8	CLR-D-9	CLR-D-10	CLR-D-11	CLR-D-12	CLR-D-13	CLR-D-14	CLR-D-15	CLR-D-16	CLR-D-17	CLR-D-18	CLR-D-19	CLR-D-20	CLR-D-21	CLR-D-22	CLR-D-23	CLR-D-24	CLR-D-25	CLR-D-26	CLR-D-27	CLR-D-28	CLR-D-29	CLR-D-30
Trichoptera (continued)	Hydropsychidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cheumatopsyche	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropsyche	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Lepidostomatidae	*Lepidostoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Limnephilidae	*Nemotaulius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chimarra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Polycentropodidae	*Neureclipsis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Polycentropus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Psychomyiidae	*Psychomyia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	*Liodessus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Elmidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dubiraphia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Optioservus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haliplidae	*Brychius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Haliplus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera - Brachycera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Athericidae	Atherix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ceratopogonidae (Ceratopogoninae)	(i/d)	0	3	12	8	1	0	0	0	4	0	3	2	5	9	0	5	0	1	0	0	5	1	0	1	1	0	7	8	5	5
	Chironomidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		(pupa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(Tanypodinae)	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ablabesmyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Clinotanypus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
		Larsia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nilotanypus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Procladius	0	0	0	0	20	5	0	19	20	11	22	1	0	0	0	69	40	0	12	6	10	0	0	53	0	0	0	98	13	11
		Thienemannimyia complex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	8	0	0	0	0	0	0	1	0	0	0	0	0
	(Chironomini)	(i/d)	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	73	0	0	0	0	0	0	76	0	0
		Cryptochironomus	0	0	0	0	0	0	0	0	0	0	0	1	4	33	0	5	0	16	0	9	1	1	0	0	0	25	0	1	9	0
		Cryptotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Demicryptochironomus	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	13	0
		Dicrotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Kloosia?	2	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	88	0	0	0	23	3	0	0	0	11	0	0	0
		Microtendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nilothauma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pagastiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parachironomus	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paracladopelma	0	0	5	0	0	0	0	0	0	4	41	0	0	34	1	0	0	0	0	0	15	18	1	0	0	8	18	0	232	0
		Paralauterborniella	0	0	4	1	64	16	0	0	96	65	519	2	64	112	0	1	0	0	0	16	106	8	1	8	0	176	0	0	0	0
		Paratendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Phaenopsectra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Polypedilum	0	0	5	0	60	16	0	8	138	133	569	0	8	114	3	75	0	32	0	16	90	10	3	8	1	240	4	8	98	0
		Robackia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stictochironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Saetheria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
		Tribelos	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	150	10	0	9	2	0	0	0	10	2	0	0	19	0	0
	(Tanytarsini)	(i/d)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cladotanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Micropsectra	0	0	10	0	16	0	0	0	24	4	88	5	1	240	2	12	0	32	0	0	65	113	1	40	1	80	0	0	24	0
		Paratanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rheotanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	1	0	0	0	0	0	0	0	0
		Stempellina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Stempellinella	0	0	0	0	0	0	0	0	0	0	8	1	0	8	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
		Sublettea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tanytarsus	0	0	0	0	8	5	0	0	0	0	24	0	0	0	0	0	0	8	0	0	15	0	0	0	0	0	0	0	0	0
	(Orthocladiinae)	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Brillia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
		Chaetocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Corynoneura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
		Cricotopus/Orthocladius	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Eukiefferiella	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
		Euryhapsis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Heterotrissocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0	0	0	0	8	0

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Clearwater River Downstream of Christina River (depositional)															Clearwater River Upstream of Christina River (depositional)														
			CLR-D-1	CLR-D-2	CLR-D-3	CLR-D-4	CLR-D-5	CLR-D-6	CLR-D-7	CLR-D-8	CLR-D-9	CLR-D-10	CLR-D-11	CLR-D-12	CLR-D-13	CLR-D-14	CLR-D-15	CLR-D-16	CLR-D-17	CLR-D-18	CLR-D-19	CLR-D-20	CLR-D-21	CLR-D-22	CLR-D-23	CLR-D-24	CLR-D-25	CLR-D-26	CLR-D-27	CLR-D-28	CLR-D-29	CLR-D-30
Diptera (continued)	(Orthocladiinae)	*Lopescladius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nanocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parakiefferiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parametriocnemus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Psectrocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	2	0	0	0	0	0	0	0	0
		Pseudosmittia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rheocricotopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rheosmittia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Synorthocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Thienemanniella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Tvetenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(Diamesinae)	*Potthastia (gaedii type)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Potthastia (longimanus type)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
		Pseudodiamesa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dolichopodidae	*Rhaphium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Empididae	*Chelifera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hemerodromia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	2	0	0	0	0	0	0	0	0
		Oreogeton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rhamphomyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae	*Pericoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Simulium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
	Tabanidae	*Chrysops*	0	0	0	0	1	0	0	2	2	1	0	1	1	0	1	1	0	0	1	0	0	0	0	2	0	0	0	0	0	0
		Tabanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	*Dicranota*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hexatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
terrestrial	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
total			**2**	**33**	**51**	**120**	**1130**	**915**	**24**	**1008**	**704**	**229**	**2055**	**108**	**136**	**570**	**84**	**553**	**1704**	**278**	**870**	**591**	**462**	**217**	**39**	**420**	**47**	**586**	**55**	**995**	**589**	**196**

Sample codes: Clearwater River (CLR-D, Ekman grab samples); MacKay River (MAR-E, Neill cylinder samples); Steepbank River (STR-E, Neill cylinder samples) and Muskeg River (MUR-E, Neill cylinder samples; MUR-D, Ekman grab samples); Fort Creek (FOC-D, Ekman grab samples).

[a] - = not identified to this level.

[b] (i/d) = immature or damaged specimen.

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Lower Reach of MacKay River (erosional)														Lower Reach of Steepbank River (erosional)														
			MAR-E-1	MAR-E-2	MAR-E-3	MAR-E-4	MAR-E-6	MAR-E-7	MAR-E-8	MAR-E-9	MAR-E-10	MAR-E-11	MAR-E-12	MAR-E-13	MAR-E-14	MAR-E-15	STR-E-1	STR-E-2	STR-E-3	STR-E-4	STR-E-5	STR-E-6	STR-E-7	STR-E-8	STR-E-9	STR-E-10	STR-E-11	STR-E-12	STR-E-13	STR-E-14	STR-E-15
Hydrozoa	Hydridae	*Hydra*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	-[(a)]	-	24	4	61	9	24	4	0	36	65	39	56	41	24	0	2	3	3	8	12	2	26	12	9	2	2	0	1	8	4
Oligochaeta	Enchytraeidae	-	45	57	20	22	46	15	29	36	58	42	55	38	9	33	11	10	17	131	33	4	39	55	8	2	11	28	4	32	51
	Lumbriculidae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Naididae	-	4	5	12	8	4	4	0	0	4	20	4	5	0	15	2	9	10	20	8	0	8	12	4	1	0	4	6	8	8
	Tubificidae	-	12	0	0	5	1	0	0	1	1	0	5	6	1	0	0	0	1	1	1	0	0	0	8	0	0	0	0	0	2
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Helobdella stagnalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Erpobdellidae	*Erpobdella punctata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda	Ancylidae	*Ferrissia rivularis*	4	3	5	4	0	1	1	5	1	1	1	4	0	0	0	2	1	2	0	0	0	0	0	0	0	4	5	0	0
	Hydrobiidae	(i/d)[(b)]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lymnaeidae	*Stagnicola?*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Physidae	*Physa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Planorbidae	(i/d)	0	0	0	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Valvatidae	*Valvata sincera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Valvata tricarinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pelecypoda	Sphaeriidae	*Pisidium / Sphaerium*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Unionidae	*Lampsilis radiata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydracarina	-	-	4	0	12	8	0	32	44	4	20	44	60	65	4	10	0	0	2	12	6	14	36	33	46	1	9	40	14	28	8
Cladocera	Chydoridae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Daphnidae	*Daphnia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Macrothricidae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda - Cyclopoida	-	-	0	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda - Harpacticoida	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	0	0	0	0
Ostracoda	Candonidae	*Candona*	4	0	0	0	4	16	0	8	4	4	0	0	8	10	0	0	0	0	0	0	0	4	0	1	0	0	0	0	0
Amphipoda	Talitridae	*Hyalella azteca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Ameletidae	*Ameletus subnotatus*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0
	Baetidae	*Acentrella*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
		Baetis	30	40	20	40	5	92	80	31	38	21	130	61	4	66	59	59	40	245	62	238	165	137	195	4	28	95	16	343	26
		Procloeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Baetiscidae	*Baetisca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Caenidae	*Caenis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ephemerellidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	18	8	8	14	76	52	64	2	7	60	27	76	20
		Drunella grandis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	1	0	0	1	0	0	0
		Ephemerella	0	0	0	0	4	4	0	0	6	4	0	0	0	5	0	0	0	1	0	2	9	2	12	0	0	1	1	5	0
	Heptageniidae	(i/d)	0	0	0	0	0	8	16	0	0	0	8	0	0	10	0	0	4	0	0	0	0	0	4	0	4	0	0	0	0
		Heptagenia	1	0	1	1	1	6	7	3	6	3	7	0	0	0	1	1	2	9	2	1	1	1	1	0	1	0	0	4	1
		Rhithrogena	0	0	0	4	4	5	2	1	0	14	25	7	7	42	0	0	0	6	0	3	4	0	3	0	0	0	1	0	0
		Stenonema	0	1	0	0	2	0	3	0	2	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leptophlebiidae	*Leptophlebia*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tricorythidae	*Tricorythodes*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1
Odonata - Anisoptera	Aeshnidae	*Aeshna*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Corduliidae	*Epitheca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gomphidae	*Gomphus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ophiogomphus	11	0	0	0	0	0	24	2	4	4	15	18	0	1	0	0	0	1	0	0	1	2	1	0	0	0	0	0	2
Odonata - Zygoptera	Calopterygidae	*Calopteryx aequabilis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coenagrionidae	*Enallagma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plecoptera	-	(i/d)	0	0	4	0	8	0	0	0	0	4	4	5	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Capniidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chloroperlidae	(i/d)	0	1	0	1	0	37	4	4	5	0	4	6	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Nemouridae	*Zapada*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Perlidae	*Acroneuria*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Claassenia sabulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perlodidae	*Isogenoides*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Isoperla	1	2	8	2	2	7	8	2	4	1	1	2	0	2	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0
		Skwala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
	Pteronarcyidae	*Pteronarcys*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Taeniopterygidae	*Taeniopteryx*	7	13	11	4	6	17	9	2	4	1	3	1	0	4	0	0	2	1	0	0	0	0	0	0	0	1	0	1	0
Hemiptera	Corixidae	*Sigara*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Callicorixa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megaloptera	Sialidae	*Sialis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	-	(i/d)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Brachycentridae	*Brachycentrus*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Glossosomatidae	*Glossosoma*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydroptilidae	(pupa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hydroptila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0
		Oxyethira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Lower Reach of MacKay River (erosional)														Lower Reach of Steepbank River (erosional)														
			MAR-E-1	MAR-E-2	MAR-E-3	MAR-E-4	MAR-E-6	MAR-E-7	MAR-E-8	MAR-E-9	MAR-E-10	MAR-E-11	MAR-E-12	MAR-E-13	MAR-E-14	MAR-E-15	STR-E-1	STR-E-2	STR-E-3	STR-E-4	STR-E-5	STR-E-6	STR-E-7	STR-E-8	STR-E-9	STR-E-10	STR-E-11	STR-E-12	STR-E-13	STR-E-14	STR-E-15
Trichoptera (continued)	Hydropsychidae	(i/d)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cheumatopsyche	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropsyche	0	3	1	1	0	5	8	5	8	2	21	16	5	26	0	0	0	0	0	0	3	1	0	1	0	0	0	1	0
	Leptoceridae	*Oecetis*	0	1	0	0	0	0	0	0	0	1	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lepidostomatidae	*Lepidostoma*	0	0	0	0	1	0	1	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Limnephilidae	*Nemotaulius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	(i/d)	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chimarra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Polycentropodidae	*Neureclipsis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Polycentropus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Psychomyiidae	*Psychomyia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	*Liodessus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Elmidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dubiraphia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Optioservus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haliplidae	*Brychius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Haliplus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera - Brachycera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Athericidae	Atherix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Ceratopogonidae (Ceratopogoninae)	(i/d)	8	4	0	1	1	0	0	1	0	1	1	2	0	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
	Chironomidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	12	8	0	0	0	0	0	0	0
		(pupa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	1	0	2	0	0	0	4	0	0	0	0	0	0
	(Tanypodinae)	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
		Ablabesmyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0
		Clinotanypus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Larsia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nilotanypus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Procladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Thienemannimyia complex	33	28	4	2	21	8	17	10	10	14	26	39	0	17	0	0	1	0	2	2	1	11	9	1	0	9	0	8	0
	(Chironomini)	(i/d)	0	0	4	0	0	0	0	4	0	4	9	5	0	0	0	1	1	4	2	2	0	0	0	0	0	0	0	0	0
		Chironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cryptochironomus	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cryptotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Demicryptochironomus	0	0	0	0	0	0	0	16	0	1	0	15	0	5	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0
		Dicrotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Kloosia?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Microtendipes	0	0	0	0	1	0	1	1	0	0	0	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1
		Nilothauma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pagastiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parachironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paracladopelma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paralauterborniella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paratendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Phaenopsectra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Polypedilum	23	13	8	13	2	8	0	76	51	128	68	65	24	43	18	0	6	20	0	0	0	4	5	0	0	16	2	0	5
		Robackia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stictochironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Saetheria	0	0	0	0	0	0	0	0	0	1	9	10	16	45	0	0	0	12	4	0	12	8	0	0	0	4	0	4	0
		Tribelos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(Tanytarsini)	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cladotanytarsus	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Micropsectra	8	4	0	0	4	0	0	0	0	0	0	0	0	0	2	1	5	4	0	0	12	0	0	0	1	24	0	4	0
		Paratanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
		Rheotanytarsus	0	5	12	0	0	16	22	0	5	1	28	1	0	0	0	11	23	8	13	12	48	88	72	1	19	65	37	36	41
		Stempellina	4	8	0	4	0	0	4	4	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stempellinella	0	4	0	0	4	4	4	16	8	4	32	10	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Sublettea	1	1	1	1	1	1	1	1	1	1	4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tanytarsus	69	80	46	21	24	45	76	8	20	20	56	30	0	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(Orthocladiinae)	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	4	2	0	16	12	0	0	4	1	0	4
		Brillia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
		Corynoneura	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	2	4	0	0	4	0	0	0	0	0	0	0	0
		Cricotopus/Orthocladius	4	0	0	0	0	4	0	0	0	4	0	5	0	0	5	16	6	5	5	2	4	1	0	1	3	0	1	0	0
		Eukiefferiella	0	0	0	0	0	0	0	0	0	0	0	0	4	0	2	6	6	0	0	10	0	12	12	0	3	0	1	0	37
		Euryhapsis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Heterotrissocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Lower Reach of MacKay River (erosional)														Lower Reach of Steepbank River (erosional)														
			MAR-E-1	MAR-E-2	MAR-E-3	MAR-E-4	MAR-E-6	MAR-E-7	MAR-E-8	MAR-E-9	MAR-E-10	MAR-E-11	MAR-E-12	MAR-E-13	MAR-E-14	MAR-E-15	STR-E-1	STR-E-2	STR-E-3	STR-E-4	STR-E-5	STR-E-6	STR-E-7	STR-E-8	STR-E-9	STR-E-10	STR-E-11	STR-E-12	STR-E-13	STR-E-14	STR-E-15
Diptera (continued)	(Orthocladiinae)	*Lopescladius*	4	4	0	2	0	0	0	12	4	24	28	11	4	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nanocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
		Parakiefferiella	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0
		Parametriocnemus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Psectrocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pseudosmittia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rheocricotopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
		Rheosmittia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Synorthocladius	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		Thienemanniella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	2	2	0	0	0	0	0	0	0	0	0
		Tvetenia	0	7	5	3	1	19	5	0	0	8	9	7	0	30	0	1	4	14	1	10	1	12	9	1	5	8	0	5	14
	(Diamesinae)	*Potthastia (gaedii type)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Potthastia (longimanus type)	1	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	1	4	4	1	3	4	1	9	0
		Pseudodiamesa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dolichopodidae	*Rhaphium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Empididae	*Chelifera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	5	0	5	0	0	0	1	9	0
		Hemerodromia	25	11	10	10	4	10	1	13	13	35	38	14	1	11	2	1	1	7	4	2	10	4	7	3	3	0	3	11	6
		Oreogeton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rhamphomyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae	*Pericoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Simulium*	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	3	0	4	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae	*Chrysops*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tabanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	*Dicranota*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hexatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
terrestrial	-	-	0	1	0	0	0	0	0	0	0	0	0	0	0	6	0	1	1	1	0	1	0	2	2	1	0	0	0	0	1
total			**335**	**304**	**249**	**168**	**179**	**373**	**372**	**304**	**344**	**454**	**724**	**504**	**113**	**460**	**107**	**142**	**168**	**538**	**174**	**330**	**481**	**492**	**514**	**29**	**104**	**373**	**126**	**598**	**236**

Sample codes: Clearwater River (CLR-D, Ekman grab samples); MacKay River (MAR-E, Neil

[(a)] - = not identified to this level.

[(b)] (i/d) = immature or damaged specimen.

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Lower Reach of Muskeg River (erosional)															Lower to Mid-reach of Muskeg River (depositional)															Fort Cr. at Mouth (dep.)				
			MUR-E-1	MUR-E-2	MUR-E-3	MUR-E-4	MUR-E-5	MUR-E-6	MUR-E-7	MUR-E-8	MUR-E-9	MUR-E-10	MUR-E-11	MUR-E-12	MUR-E-13	MUR-E-14	MUR-E-15	MUR-D-16	MUR-D-17	MUR-D-18	MUR-D-19	MUR-D-20	MUR-D-21	MUR-D-22	MUR-D-23	MUR-D-24	MUR-D-25	MUR-D-26	MUR-D-27	MUR-D-28	MUR-D-29	MUR-D-30	FOC-D-1	FOC-D-2	FOC-D-3	FOC-D-4	FOC-D-5
Hydrozoa	Hydridae	*Hydra*	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	10	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	-[a]	-	1	123	17	9	24	4	4	3	8	0	3	10	46	11	6	24	4	62	4	24	52	10	20	3	4	17	22	20	0	20	0	1	4	0	5
Oligochaeta	Enchytraeidae	-	0	16	0	0	4	0	0	4	0	0	3	24	19	0	5	0	0	20	0	0	10	10	10	10	46	0	42	0	20	20	0	0	0	4	3
	Lumbriculidae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	3	1	0	0	0	0	0	0
	Naididae	-	2	107	45	0	1	0	0	0	164	2	8	7	32	5	12	0	10	0	37	0	11	2	0	0	28	16	45	0	40	0	0	0	0	0	4
	Tubificidae	-	0	0	0	0	9	0	0	0	9	0	0	0	0	0	0	32	0	18	0	0	3	0	4	0	0	0	4	0	9	0	0	0	0	0	0
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Helobdella stagnalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0
	Erpobdellidae	*Erpobdella punctata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Gastropoda	Ancylidae	*Ferrissia rivularis*	0	2	0	0	0	1	0	0	1	0	0	2	1	6	6	10	0	10	0	2	0	0	0	0	0	12	0	0	1	22	0	0	0	0	0
	Hydrobiidae	(i/d)[b]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lymnaeidae	*Stagnicola?*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Physidae	*Physa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
	Planorbidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	2	104	14	35	1	0	1	0	0	21	0	192	152	4	0	0	0	0	0
	Valvatidae	*Valvata sincera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Valvata tricarinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pelecypoda	Sphaeriidae	*Pisidium / Sphaerium*	0	85	5	1	3	5	16	2	2	5	0	48	3	4	18	71	15	23	3	3	2	3	0	1	4	3	2	33	71	34	0	2	2	19	0
	Unionidae	*Lampsilis radiata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydracarina	-	-	1	24	20	56	80	28	12	96	36	126	32	109	37	185	180	30	26	20	8	20	10	0	20	10	0	1	20	20	0	40	0	2	0	0	0
Cladocera	Chydoridae	-	0	0	0	0	0	0	0	0	0	0	0	2	1	5	8	50	10	10	30	0	0	4	40	11	0	16	10	41	60	20	0	0	0	0	0
	Daphnidae	*Daphnia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Macrothricidae	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda - Cyclopoida	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	20	30	28	0	0	0	2	70	30	0	16	61	40	20	0	1	0	0	0	0
Copepoda - Harpacticoida	-	-	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	Candonidae	*Candona*	0	24	0	0	0	0	0	2	0	0	0	2	1	0	4	180	0	48	0	20	20	4	70	10	0	8	0	0	80	0	3	1	0	2	0
Amphipoda	Talitridae	*Hyalella azteca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Ameletidae	*Ameletus subnotatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Baetidae	*Acentrella*	2	0	9	0	0	0	1	0	4	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Baetis	4	170	65	37	97	68	57	89	384	22	11	24	16	456	58	1	0	0	4	0	0	2	11	10	0	0	12	0	0	0	0	0	0	0	0
		Procloeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Baetiscidae	*Baetisca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Caenidae	*Caenis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	4	5	5	12	1	0	10	0	0	0	0	1	21	0	0	0	0	0
	Ephemerellidae	(i/d)	0	0	4	64	16	8	0	0	4	0	2	2	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Drunella grandis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ephemerella	0	0	1	9	6	3	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heptageniidae	(i/d)	0	0	4	8	8	0	0	0	0	0	0	0	0	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Heptagenia	0	1	7	46	15	12	1	7	6	12	5	12	4	12	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rhithrogena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stenonema	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Leptophlebiidae	*Leptophlebia*	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	12	5	11	1	0	0	0	0	1	0	21	4	15	0	1	0	0	0
	Tricorythidae	*Tricorythodes*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata - Anisoptera	Aeshnidae	*Aeshna*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Corduliidae	*Epitheca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Gomphidae	*Gomphus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ophiogomphus	2	10	3	28	25	5	2	4	8	5	2	13	0	10	12	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Odonata - Zygoptera	Calopterygidae	*Calopteryx aequabilis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coenagrionidae	*Enallagma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plecoptera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	22	0	0	0	0	0	0	0	0
	Capniidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Chloroperlidae	(i/d)	0	0	3	19	24	0	4	6	27	15	10	9	1	13	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nemouridae	*Zapada*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perlidae	*Acroneuria*	0	0	0	0	2	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Claassenia sabulosa	0	0	0	0	0	3	2	1	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perlodidae	*Isogenoides*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Isoperla	0	0	0	5	4	5	4	3	3	2	3	4	1	30	22	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Skwala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pteronarcyidae	*Pteronarcys*	0	0	0	0	4	2	0	1	0	0	0	1	1	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Taeniopterygidae	*Taeniopteryx*	1	0	11	0	9	9	8	0	2	1	2	0	0	26	8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Hemiptera	Corixidae	*Sigara*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Callicorixa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megaloptera	Sialidae	*Sialis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Brachycentridae	*Brachycentrus*	0	0	0	2	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Glossosomatidae	*Glossosoma*	0	0	4	9	11	7	0	4	0	6	1	4	2	25	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydroptilidae	(pupa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hydroptila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Oxyethira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	10	0	0	0	0	0	20	0	0	0	0	0

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Lower Reach of Muskeg River (erosional)															Lower to Mid-reach of Muskeg River (depositional)															Fort Cr. at Mouth (dep.)				
			MUR-E 1	MUR-E 2	MUR-E 3	MUR-E 4	MUR-E 5	MUR-E 6	MUR-E 7	MUR-E 8	MUR-E 9	MUR-E 10	MUR-E 11	MUR-E 12	MUR-E 13	MUR-E 14	MUR-E 15	MUR-D 16	MUR-D 17	MUR-D 18	MUR-D 19	MUR-D 20	MUR-D 21	MUR-D 22	MUR-D 23	MUR-D 24	MUR-D 25	MUR-D 26	MUR-D 27	MUR-D 28	MUR-D 29	MUR-D 30	FOC-D 1	FOC-D 2	FOC-D 3	FOC-D 4	FOC-D 5
Trichoptera (continued)	Hydropsychidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cheumatopsyche	0	0	4	6	21	1	2	8	10	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hydropsyche	0	0	2	44	65	42	46	24	17	13	12	19	4	5	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	0	0	1	2	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lepidostomatidae	*Lepidostoma*	0	0	0	0	4	0	0	0	0	3	0	1	0	2	15	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Limnephilidae	*Nemotaulius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Philopotamidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chimarra	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Polycentropodidae	*Neureclipsis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Polycentropus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	1	0	0	0	0	0
	Psychomyiidae	*Psychomyia*	0	0	0	0	0	0	5	0	4	10	2	9	4	5	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	*Liodessus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Elmidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dubiraphia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Optioservus	0	19	6	11	9	8	4	12	7	12	11	4	1	7	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haliplidae	*Brychius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	4	0	0	0	0	0
		Haliplus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Diptera - Brachycera	-	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Athericidae	Atherix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ceratopogonidae (Ceratopogoninae)	(i/d)	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	7	20	52	12	75	1	2	1	35	2	9	4	0	5	30	0	0	0	1	0
	Chironomidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		(pupa)	1	0	1	0	0	0	0	0	0	1	0	1	2	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(Tanypodinae)	(i/d)	0	3	0	0	0	0	0	0	0	0	0	6	0	0	0	58	37	89	58	311	92	2	50	52	2	9	12	26	22	146	0	0	0	4	0
		Ablabesmyia	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	31	4	37	38	102	0	2	0	20	0	16	10	127	60	60	0	0	0	0	0
		Clinotanypus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Larsia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nilotanypus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Procladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	0	100	11	20	30	0	27	3	0	32	0	46	111	21	0	2	0	0	0
		Thienemannimyia complex	0	10	0	1	1	1	0	0	3	5	1	11	10	10	6	0	0	0	5	0	1	2	10	10	0	0	10	0	2	20	3	0	0	2	0
	(Chironomini)	(i/d)	0	8	0	4	0	0	0	0	0	0	0	0	1	0	8	0	20	0	1	20	0	2	0	30	2	0	70	21	0	0	0	1	0	0	0
		Chironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2	1
		Cryptochironomus	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	10	2	0	21	2	0	0	0	4	20	2	2	0	0	0
		Cryptotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Demicryptochironomus	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dicrotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	145	4	6	6	1	8	0	0	0	0	4	0	2	3	1	0	0	0	0	0
		Kloosia?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Microtendipes	1	10	0	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
		Nilothauma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pagastiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	37	152	254	224	90	2	20	102	0	72	0	0	100	100	0	0	0	0	0
		Parachironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0
		Paracladopelma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	6	2
		Paralauterborniella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	8	136	202	0	8	20	160	0	8	11	0	0	100	2	0	0	0	0
		Paratendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Phaenopsectra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	8	10	41	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Polypedilum	0	8	0	0	4	0	4	4	0	0	6	5	1	5	0	60	16	363	33	158	50	84	78	100	51	8	98	2	108	319	6	16	6	2	9
		Robackia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stictochironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Saetheria	0	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	8	0	0	16	0	24	0	0	0	0	0	0	0	0
		Tribelos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(Tanytarsini)	(i/d)	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	20	0	0	0	0	0	10	220	60	40	0	0	0	0	0
		Cladotanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Micropsectra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1393	160	553	747	567	60	53	352	513	4	24	1265	246	356	582	58	9	6	44	13
		Paratanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53	20	10	0	11	12	0	8	10	183	1	20	0	1	2	0	0
		Rheotanytarsus	2	0	8	4	21	4	16	2	12	20	3	9	0	15	8	0	0	10	0	0	1	2	10	30	0	0	1	1	0	0	0	0	0	0	0
		Stempellina	0	8	8	0	4	0	4	10	4	0	9	0	17	0	4	0	0	10	20	0	0	2	0	10	0	8	0	0	0	20	0	0	0	0	0
		Stempellinella	0	48	0	4	0	0	0	0	0	2	0	2	2	20	32	30	10	20	154	540	40	8	100	40	0	40	30	40	120	300	0	0	0	0	0
		Sublettea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tanytarsus	0	121	8	0	0	0	0	0	0	4	0	19	10	0	4	510	10	211	348	240	40	4	20	163	0	32	140	41	160	40	0	0	0	0	0
	(Orthocladiinae)	(i/d)	1	0	0	0	0	4	0	0	0	2	0	0	2	0	4	0	0	10	0	40	0	0	0	0	2	0	13	0	0	0	4	1	0	0	0
		Brillia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Chaetocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
		Corynoneura	0	24	4	4	0	0	0	0	0	10	0	6	0	5	0	0	0	0	0	0	0	0	0	0	2	0	40	0	0	0	0	0	0	0	0
		Cricotopus/Orthocladius	2	1	14	0	4	0	0	7	16	2	1	16	1	24	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Eukiefferiella	0	0	0	0	0	0	0	0	0	0	0	2	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Euryhapsis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Heterotrissocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	20	0	0	0	20	2	0	11	0	20	20	67	4	4	6	8

Table IX.1 Benthic Invertebrate Abundance Data (numbers/sample) for the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Lower Reach of Muskeg River (erosional)															Lower to Mid-reach of Muskeg River (depositional)															Fort Cr. at Mouth (dep.)				
			MUR-E-1	MUR-E-2	MUR-E-3	MUR-E-4	MUR-E-5	MUR-E-6	MUR-E-7	MUR-E-8	MUR-E-9	MUR-E-10	MUR-E-11	MUR-E-12	MUR-E-13	MUR-E-14	MUR-E-15	MUR-D-16	MUR-D-17	MUR-D-18	MUR-D-19	MUR-D-20	MUR-D-21	MUR-D-22	MUR-D-23	MUR-D-24	MUR-D-25	MUR-D-26	MUR-D-27	MUR-D-28	MUR-D-29	MUR-D-30	FOC-D-1	FOC-D-2	FOC-D-3	FOC-D-4	FOC-D-5
Diptera (continued)	(Orthocladiinae)	*Lopescladius*	0	24	20	116	177	60	0	18	12	18	14	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Nanocladius	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parakiefferiella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	246	542	0	30	1	80	4	16	234	0	40	1	0	0	0	0	0
		Parametriocnemus	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
		Psectrocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	2	12	6
		Pseudosmittia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
		Rheocricotopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Rheosmittia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0	0	0	0	0	0	0
		Synorthocladius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Thienemanniella	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tvetenia	1	0	20	38	60	61	29	4	16	2	3	12	11	5	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(Diamesinae)	*Potthastia (gaedii type)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Potthastia (longimanus type)	0	1	0	1	4	0	0	0	1	0	0	2	0	0	0	1	0	1	1	0	0	0	0	1	0	0	1	0	4	1	0	0	0	0	0
		Pseudodiamesa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	12	2	14	2
	Dolichopodidae	*Rhaphium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Empididae	*Chelifera*	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	21	1	2	0	0	0	0
		Hemerodromia	0	17	2	0	9	4	0	1	16	8	2	16	4	6	19	0	0	8	1	0	10	6	0	0	0	0	18	1	0	43	0	0	0	0	0
		Oreogeton	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
		Rhamphomyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Psychodidae	*Pericoma*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Simuliidae	*Simulium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae	*Chrysops*	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	1	0	0	0	0	2	2	0	0	0	2	2	2	0	0	0	0	0
		Tabanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tipulidae	*Dicranota*	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
		Hexatoma	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	8	5	0	16	2
terrestrial	-	-	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	2	0	0	1	0	0	1	0	0	0	0	0	0
total			**23**	**888**	**301**	**534**	**733**	**351**	**223**	**315**	**783**	**316**	**153**	**433**	**260**	**968**	**631**	**2897**	**446**	**2037**	**2284**	**3330**	**598**	**258**	**952**	**1511**	**181**	**406**	**2255**	**1355**	**1664**	**2114**	**172**	**67**	**28**	**146**	**59**

Sample codes: Clearwater River (CLR-D, Ekman grab samples); MacKay River (MAR-E, Neil

[a] - = not identified to this level.

[b] (i/d) = immature or damaged specimen.

Table IX.2 Benthic Invertebrate Abundance Data (numbers/Ekman grab sample) for Kearl and Shipyard Lakes, Fall 2001

Major Taxon	Family (subfamily/ tribe)	Genus/Species	Kearl Lake									Shipyard lake									
			KEL-1	KEL-2	KEL-3	KEL-4	KEL-5	KEL-6	KEL-7	KEL-8	KEL-9	SHL-1	SHL-2	SHL-3	SHL-4	SHL-5	SHL-6	SHL-7	SHL-8	SHL-9	SHL-10
Oligochaeta	Naididae	*Dero*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
Hirudinea	Glossiphoniidae	*Glossiphonia complanata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
		Helobdella stagnalis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Gastropoda	Ancylidae	*Ferrissia*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Valvatidae	*Valvata tricarinata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Valvata sincera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
	Planorbidae	(i/d)[a]	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
		Armiger crista	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
		Gyraulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
Pelecypoda	Sphaeridae	(i/d)	0	0	0	0	0	0	0	1	8	1	0	0	0	0	0	0	0	0	0
Hydracarina	-[b]	-	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Cladocera	Chydoridae	-	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0
Copepoda - Cyclopoida	-	(i/d)	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cyclopidae	*Macrocyclops*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
Ostracoda	-	-	0	0	0	2	2	5	7	0	0	0	1	0	8	8	0	0	0	8	0
Amphipoda	Talitridae	*Hyalella azteca*	0	11	0	5	0	9	3	0	1	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Baetidae	(i/d)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Caenidae	*Caenis*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	20	0
Odonata - Anisoptera	Corduliidae	*Somatochlora*	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	Libellulidae	*Leucorrhinia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0
Trichoptera	Phryganeidae	*Phryganea*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Polycentropodidae	*Polycentropus*	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0
Diptera	Ceratopogonidae (Ceratopogoninae)	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
	Chaoboridae	*Chaoborus*	0	0	1	3	3	6	2	0	0	15	21	1	9	82	15	103	44	5	35
	Chironomidae	(i/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(Tanypodinae)	*Ablabesmyia*	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	26	0
		Procladius	2	2	3	1	2	7	5	1	8	0	0	1	11	1	0	0	0	1	0
		Tanypus	0	0	0	0	0	0	0	0	0	0	3	2	0	0	2	1	0	1	6
		Thienemannimyia couplex	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	27	0
	(Orthocladiinae)	*Psectrocladius*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	(Chironomini)	*Chironomus*	0	0	0	1	0	0	1	0	0	23	10	26	34	25	0	6	3	48	2
		Cladopelma	0	8	0	1	2	3	0	0	1	0	0	0	0	0	0	0	0	0	0
		Cryptochironomus	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
		Dicrotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0
		Einfeldia	1	0	0	0	0	5	16	2	7	0	0	0	0	0	0	0	0	1	0
		Endochironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Glyptotendipes	0	0	1	0	0	3	0	0	0	1	0	0	0	0	0	0	0	2	0
		Microtendipes	1	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	18	0
		Parachironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
		Polypedilum	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0
	(Tanytarsini)	*Paratanytarsus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Tanytarsus	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0	13	0
total			**4**	**21**	**5**	**14**	**9**	**53**	**37**	**6**	**37**	**40**	**35**	**30**	**70**	**117**	**17**	**111**	**50**	**248**	**44**

[a] (i/d) = immature or damaged specimen.
[b] - = not identified to this level.

Table IX.3 Supporting Data Collected During the Fall 2001 Benthic Surveys of the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek

River/Stream	Site	General Habitat Type	Sample Date	Sample Time	Location		Field Water Quality				Water Depth (m)	Current Velocity (m/s)	Bankfull Channel Width (m)	Wetted Channel Width (m)	Habitat Type	Amount of Benthic Algae (visual est.)	Benthic Algal Chlorophyll a (mg/m^2)	Macro-phyte cover (%)	Macrophyte Species	Bottom Sediments (lab analysis)				Substratum as Areal Cover (visual estimates)						
					UTM E (NAD 27)	UTM N (NAD 27)	Dissolved Oxygen (mg/L)	Conduc-tivity (µS/cm)	pH	Water Temp. (°C)										Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (%)	Sand/ Silt/ Clay (%)	Small Gravel (%)	Large Gravel (%)	Small Cobble (%)	Large Cobble (%)	Boulder (%)	Bedrock (%)
Mackay	MAR-E-1	erosional	28-Sep-01	9:48	460765	6336603	9.9	218	8.1	9.7	0.42	0.30	30	24	riffle	L	36	0	-	-	-	-	-	10	30	30	30	0	0	0
Mackay	MAR-E-2	erosional	28-Sep-01	10:09	460554	6336704	9.9	218	8.1	9.7	0.32	0.75	30	24	riffle	L	17	0	-	-	-	-	-	10	10	25	25	30	0	0
Mackay	MAR-E-3	erosional	28-Sep-01	10:45	460338	6336881	9.9	216	8.1	9.8	0.32	0.89	31	26	riffle	L	33	0	-	-	-	-	-	10	20	30	30	10	0	0
Mackay	MAR-E-4	erosional	28-Sep-01	10:55	460338	6336955	9.9	216	8.1	9.8	0.40	0.92	29	23	riffle	L	24	0	-	-	-	-	-	10	20	30	30	10	0	0
Mackay	MAR-E-6	erosional	28-Sep-01	12:19	460324	6337184	-[a]	-	-	10.5	0.44	1.35	45	32	riffle	M	19	0	-	-	-	-	-	0	10	15	30	25	20	0
Mackay	MAR-E-7	erosional	28-Sep-01	12:45	460423	6337407	-	-	-	10.5	0.35	0.71	45	34	riffle	M	48	0	-	-	-	-	-	10	55	30	5	0	0	0
Mackay	MAR-E-8	erosional	28-Sep-01	13:00	460424	6337463	-	-	-	10.9	0.46	0.69	44	36	riffle	M	42	0	-	-	-	-	-	10	35	45	10	0	0	0
Mackay	MAR-E-9	erosional	28-Sep-01	14:13	460312	6337932	-	-	-	10.9	0.35	0.52	38	29	riffle	M	43	0	-	-	-	-	-	15	35	40	10	0	0	0
Mackay	MAR-E-10	erosional	28-Sep-01	14:33	460315	6337986	-	-	-	10.9	0.34	0.51	38	29	riffle	M	28	0	-	-	-	-	-	15	35	40	10	0	0	0
Mackay	MAR-E-11	erosional	28-Sep-01	15:25	459607	6338675	-	-	-	11.4	0.30	0.63	26	21	riffle	M	14	0	-	-	-	-	-	15	25	30	25	0	5	0
Mackay	MAR-E-12	erosional	28-Sep-01	15:45	459562	6338696	-	-	-	11.4	0.42	0.49	24	21	run	M	39	0	-	-	-	-	-	10	20	30	30	10	0	0
Mackay	MAR-E-13	erosional	28-Sep-01	17:08	459539	6338991	-	-	-	11.3	0.44	0.42	39	35	riffle	H	23	0	-	-	-	-	-	5	30	40	20	5	0	0
Mackay	MAR-E-14	erosional	28-Sep-01	16:46	459544	6338995	-	-	-	11.3	0.32	0.53	40	32	riffle	H	36	0	-	-	-	-	-	5	30	40	20	5	0	0
Mackay	MAR-E-15	erosional	28-Sep-01	16:55	459576	6339020	-	-	-	11.3	0.30	0.52	39	35	riffle	H	48	0	-	-	-	-	-	0	15	35	25	10	15	0
Steepbank	STR-E-1	erosional	17-Sep-01	10:15	470908	6319817	11.0	313	8.3	10.0	0.36	0.63	22	12	run	L	62	0	-	-	-	-	-	35	5	20	37	3	0	0
Steepbank	STR-E-2	erosional	17-Sep-01	11:17	471008	6319843	11.2	313	8.3	10.2	0.32	0.76	27	13	riffle	N	8	0	-	-	-	-	-	10	20	40	30	0	0	0
Steepbank	STR-E-3	erosional	17-Sep-01	11:45	471035	6319972	11.2	312	8.0	10.4	0.32	0.17	28	17	riffle	L	3	0	-	-	-	-	-	15	5	25	45	10	0	0
Steepbank	STR-E-4	erosional	17-Sep-01	12:40	471555	6320300	11.6	311	8.5	10.9	0.24	0.60	24	12	run	L	24	0	-	-	-	-	-	5	10	20	30	30	5	0
Steepbank	STR-E-5	erosional	17-Sep-01	13:00	471791	6320168	12.0	310	8.6	11.4	0.38	0.52	22	14	run	L	62	0	-	-	-	-	-	10	15	10	25	25	15	0
Steepbank	STR-E-6	erosional	17-Sep-01	15:20	472970	6319858	11.7	307	8.6	12.3	0.34	0.62	33	23	riffle	M	-	0	-	-	-	-	-	0	0	5	25	50	20	0
Steepbank	STR-E-7	erosional	17-Sep-01	14:58	472971	6319869	11.7	307	8.6	12.3	0.40	0.69	22	14	riffle	M	33	0	-	-	-	-	-	0	0	5	25	50	20	0
Steepbank	STR-E-8	erosional	17-Sep-01	14:34	473028	6319884	11.9	306	8.7	12.3	0.46	0.33	20	13	riffle	H	71	0	-	-	-	-	-	0	0	20	10	40	30	0
Steepbank	STR-E-9	erosional	17-Sep-01	14:14	473092	6319894	12.1	306	8.6	11.8	0.32	1.02	26	25	rapid/run	M	21	0	-	-	-	-	-	0	0	10	10	60	20	0
Steepbank	STR-E-10	erosional	17-Sep-01	13:50	473112	6319812	12.1	306	8.6	11.8	0.24	0.44	32	26	riffle	M	77	0	-	-	-	-	-	0	15	20	15	30	20	0
Steepbank	STR-E-11	erosional	17-Sep-01	17:50	473143	6319377	10.3	307	8.6	12.4	0.40	0.32	24	23	riffle	M	-	0	-	-	-	-	-	0	10	20	20	0	50	0
Steepbank	STR-E-12	erosional	17-Sep-01	17:25	473192	6319373	10.3	307	8.6	12.4	0.32	0.34	24	22	riffle	L-M	-	0	-	-	-	-	-	5	5	5	20	35	30	0
Steepbank	STR-E-13	erosional	17-Sep-01	17:00	473351	6319360	10.7	307	8.6	12.4	0.26	0.32	22	13	riffle	L	52	0	-	-	-	-	-	0	10	10	20	20	40	0
Steepbank	STR-E-14	erosional	17-Sep-01	16:35	473476	6319348	11.4	306	8.7	12.4	0.44	0.43	16	10	run	L	80	0	-	-	-	-	-	0	15	0	15	50	20	0
Steepbank	STR-E-15	erosional	17-Sep-01	16:05	473528	6319325	11.4	306	8.7	12.4	0.43	0.44	16	12	run	L	37	0	-	-	-	-	-	0	10	30	20	30	10	0
Muskeg	MUR-E-1	erosional	14-Sep-01	13:50	463438	6332362	10.5	350	8.2	13.3	0.36	0.68	28	11	riffle	L	9	0	-	-	-	-	-	10	0	20	20	40	10	0
Muskeg	MUR-E-2	erosional	14-Sep-01	12:20	463658	6332427	10.1	342	8.2	12.0	0.46	0.67	26	12	run	M	43	0	-	-	-	-	-	5	10	65	20	0	0	0
Muskeg	MUR-E-3	erosional	14-Sep-01	11:35	463824	6332323	10.7	340	8.2	11.5	0.45	1.13	19	16	riffle	M	1	0	-	-	-	-	-	0	20	20	40	15	5	0
Muskeg	MUR-E-4	erosional	14-Sep-01	10:36	464010	6332090	10.7	338	7.9	10.7	0.31	0.97	19	14	riffle	M	17	0	-	-	-	-	-	0	20	60	20	0	0	0
Muskeg	MUR-E-5	erosional	14-Sep-01	10:10	464084	6332081	10.5	336	8.2	10.5	0.45	0.99	20	12	run	L	24	0	-	-	-	-	-	0	0	20	50	20	10	0
Muskeg	MUR-E-6	erosional	14-Sep-01	9:40	464187	6332081	10.6	336	8.2	10.5	0.55	0.91	16	15	riffle	M	72	0	-	-	-	-	-	0	0	<5	45+	45	5	0
Muskeg	MUR-E-7	erosional	12-Sep-01	16:45	465820	6333117	10.3	377	8.1	12.8	0.28	0.58	21	20	run	L	28	0	-	-	-	-	-	<5	10	75+	10	0	0	0
Muskeg	MUR-E-8	erosional	12-Sep-01	16:45	465819	6333169	10.3	377	8.1	12.8	0.36	1.00	23	22	run	L	25	0	-	-	-	-	-	<5	10	75+	10	0	0	0
Muskeg	MUR-E-9	erosional	12-Sep-01	16:45	465817	6333233	10.3	377	8.1	12.8	0.35	1.06	50	18	run	L	24	0	-	-	-	-	-	<5	10	75+	10	0	0	0
Muskeg	MUR-E-10	erosional	12-Sep-01	15:05	465232	6334259	10.4	378	8.1	12.4	0.38	0.34	15	16	riffle	L	7	0	-	-	-	-	-	10	0	10	60	10	0	10
Muskeg	MUR-E-11	erosional	12-Sep-01	17:40	465250	6334218	10.0	378	7.7	12.2	0.30	0.68	16	12	riffle	L	21	0	-	-	-	-	-	0	0	0	30	40	30	0
Muskeg	MUR-E-12	erosional	14-Sep-01	17:10	465587	6338157	10.4	331	8.0	12.9	0.40	0.32	18	14	run	M	25	0	-	-	-	-	-	10	10	20	30	30	0	0
Muskeg	MUR-E-13	erosional	14-Sep-01	16:38	465400	6338291	10.3	332	7.9	12.8	0.26	0.36	22	23	riffle	M	23	0	-	-	-	-	-	10	10	20	30	30	0	0
Muskeg	MUR-E-14	erosional	14-Sep-01	16:00	465374	6338546	10.1	332	7.9	12.7	0.44	0.19	12	12	run	H	43	10	*Potamogeton*	-	-	-	-	10	5	25	20	30	10	0
Muskeg	MUR-E-15	erosional	12-Sep-01	9:58	465406	6338472	9.2	378	7.8	11.6	0.32	0.67	19	13	riffle	M	10	5	*Potamogeton*	-	-	-	-	0	5	80	15	0	0	0
Muskeg	MUR-D-16	depositional	21-Sep-01	16:52	465367	6338970	8.7	418	7.8	11.5	0.50	0.00	13	12	run	L	-	40	*Ceratophyllum, Potamogeton, Nuphar*	83	9	8	1.48	95	0	0	5	0	0	0
Muskeg	MUR-D-17	depositional	21-Sep-01	16:11	465925	6339503	8.4	416	7.9	11.4	1.06	0.00	8	8	run	L	-	0	*Ceratophyllum, Potamogeton, Nuphar*	82	9	9	2.04	95	0	0	5	0	0	0
Muskeg	MUR-D-18	depositional	21-Sep-01	15:22	466321	6339827	7.4	413	7.9	11.5	1.10	0.01	12	11	run	L	-	15	*Ceratophyllum, Potamogeton*	80	-	-	1.44	100	0	0	0	0	0	0
Muskeg	MUR-D-19	depositional	21-Sep-01	14:55	466521	6339792	8.6	412	7.9	11.5	1.09	0.01	9	8	run	L	-	30	*Ceratophyllum, Potamogeton*	90	4	6	0.73	100	0	0	0	0	0	0
Muskeg	MUR-D-20	depositional	21-Sep-01	14:18	466516	6339833	8.3	413	7.9	11.5	0.69	0.00	12	11	run	L	-	0	-	79	11	10	2.14	100	0	0	0	0	0	0
Muskeg	MUR-D-21	depositional	20-Sep-01	17:17	466507	6340004	-	450	7.8	9.6	0.50	0.00	13	11	run	N	-	40	*Potamogeton*	-	-	-	8.47	100	0	0	0	0	0	0
Muskeg	MUR-D-22	depositional	20-Sep-01	17:00	466394	6340038	-	450	7.8	9.6	0.50	0.00	16	14	run	N	-	10	*Potamogeton*	94	2	4	0.43	100	0	0	0	0	0	0
Muskeg	MUR-D-23	depositional	20-Sep-01	16:34	466490	6340098	-	460	7.8	9.6	0.60	0.00	16	10	pool	N	-	15	*Potamogeton*	93	3	5	0.29	100	0	0	0	0	0	0
Muskeg	MUR-D-24	depositional	20-Sep-01	16:14	466563	6340190	-	-	-	-	0.30	0.00	10	7	run	N	-	10	*Potamogeton, P. richardsoni*	93	2	5	0.17	100	0	0	0	0	0	0
Muskeg	MUR-D-25	depositional	20-Sep-01	15:38	466568	6340249	-	460	7.8	9.6	0.35	0.00	10	10	run	N	-		*Potamogeton*	93	2	5	0.32	100	0	0	0	0	0	0
Muskeg	MUR-D-26	depositional	20-Sep-01	14:34	466563	6340384	-	450	7.6	10.0	0.40	0.00	10	8	run	N	-	10	*Potamogeton, P. richardsoni*	67	18	15	3.36	100	0	0	0	0	0	0
Muskeg	MUR-D-27	depositional	20-Sep-01	13:50	466593	6340524	-	460	7.7	9.5	0.30	0.00	8	8	run	L	-	60	*Potamogeton*	98	3	2	0.25	100	0	0	0	0	0	0
Muskeg	MUR-D-28	depositional	20-Sep-01	13:17	466703	6340701	-	450	7.8	9.0	1.00	0.00	6	6	run	L	-	5	*Potamogeton*	84	10	6	4.93	100	0	0	0	0	0	0
Muskeg	MUR-D-29	depositional	20-Sep-01	12:54	466883	6340860	-	440	7.9	9.0	1.50	0.00	10	7	backwater	N	-	10	*Potamogeton*	-	-	-	-	100	0	0	0	0	0	0
Muskeg	MUR-D-30	depositional	20-Sep-01	12:08	466771	6340865	-	440	7.9	9.5	1.11	0.04	8	6	run	N	-	10	*Potamogeton*	96	2	3	0.42	100	0	0	0	0	0	0
Clearwater d/s[b]	CLR-D-1	depositional	17-Sep-01	16:20	481179	6282749	10.4	257	3.9	14.7	0.68	0.69	-	-	run	N	-	0	-	95	2	3	0.02	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-2	depositional	18-Sep-01	9:30	480881	6282505	9.4	274	3.8	12.8	0.19	0.00	-	-	backwater	N	-	0	-	72	19	9	0.36	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-3	depositional	18-Sep-01	10:03	480705	6282560	9.5	256	3.9	12.9	0.35	0.24	-	-	run	N	-	0	-	95	1	4	0.10	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-4	depositional	18-Sep-01	11:15	480768	6282498	9.5	268	3.9	13.8	0.45	0.18	-	-	backwater	N	-	20	*Potamogeton*	71	17	12	0.57	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-5	depositional	18-Sep-01	11:49	480279	6282925	-	-	-	-	0.27	0.04	-	-	run	N	-	5	*Potamogeton*	23	51	26	2.20	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-6	depositional	18-Sep-01	12:40	480249	6283105	-	-	-	-	0.39	0.03	-	-	backwater	N	-	25	*P. richardsoni; Potamogeton*	32	43	25	1.82	100	0	0	0	0	0	0

Table IX.3 Supporting Data Collected During the Fall 2001 Benthic Surveys of the Clearwater, MacKay, Steepbank and Muskeg Rivers, and Fort Creek

River/Stream	Site	General Habitat Type	Sample Date	Sample Time	Location		Field Water Quality				Water Depth (m)	Current Velocity (m/s)	Bankfull Channel Width (m)	Wetted Channel Width (m)	Habitat Type	Amount of Benthic Algae (visual est.)	Benthic Algal Chlorophyll *a* (mg/m^2)	Macro-phyte cover (%)	Macrophyte Species	Bottom Sediments (lab analysis)				Substratum as Areal Cover (visual estimates)						
					UTM E (NAD 27)	UTM N (NAD 27)	Dissolved Oxygen (mg/L)	Conduc-tivity (µS/cm)	pH	Water Temp. (°C)										Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (%)	Sand/ Silt/ Clay (%)	Small Gravel (%)	Large Gravel (%)	Small Cobble (%)	Large Cobble (%)	Boulder (%)	Bedrock (%)
Clearwater d/s	CLR-D-7	depositional	18-Sep-01	13:01	480764	6283773	-	-	-	-	0.31	0.16	-	-	run	N	-	0	-	90	5	5	0.09	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-8	depositional	18-Sep-01	13:28	480887	6283971	-	-	-	-	0.69	0.00	-	-	backwater	N	-	30	*P. richardsoni*	33	43	24	2.55	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-9	depositional	18-Sep-01	13:54	480772	6284161	-	-	-	-	0.63	0.00	-	-	backwater	N	-	8	*Potamogeton*	54	30	16	1.10	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-10	depositional	18-Sep-01	14:18	480187	6284159	-	-	-	-	0.53	0.00	-	-	backwater	N	-	0	-	65	23	11	0.84	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-11	depositional	18-Sep-01	14:45	480031	6284008	-	-	-	-	0.36	0.15	-	-	run	N	-	0	-	55	28	17	1.23	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-12	depositional	18-Sep-01	15:04	479679	6283967	-	-	-	-	0.75	0.01	-	-	backwater	N	-	50	*Potamogeton*	59	28	13	0.82	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-13	depositional	18-Sep-01	15:30	479587	6283988	-	-	-	-	0.71	0.00	-	-	backwater	N	-	0	-	82	11	7	0.11	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-14	depositional	18-Sep-01	16:03	479491	6284167	-	-	-	-	0.55	0.22	-	-	run	M	-	0	-	84	11	5	0.29	100	0	0	0	0	0	0
Clearwater d/s	CLR-D-15	depositional	18-Sep-01	16:25	479961	6284070	-	-	-	-	0.59	0.00	-	-	backwater	N	-	0	-	67	21	11	0.69	100	0	0	0	0	0	0
Clearwater u/s[b]	CLR-D-16	depositional	19-Sep-01	10:12	496210	6280246	-	-	-	-	0.54	0.14	-	-	backwater	N	-	70	*P. richardsoni*	39	38	23	2.25	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-17	depositional	19-Sep-01	10:44	496498	6280257	-	-	-	-	0.36	0.00	-	-	backwater	N	-	40	*Potamogeton*	36	43	21	2.86	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-18	depositional	19-Sep-01	11:07	497000	6280278	-	-	-	-	0.56	0.21	-	-	run	N	-	40	*P. richardsoni*	97	0	3	0.02	95	5	0	0	0	0	0
Clearwater u/s	CLR-D-19	depositional	19-Sep-01	11:35	498450	6279762	-	-	-	-	0.29	0.05	-	-	backwater	N	-	10	*P. richardsoni*	52	33	15	1.22	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-20	depositional	19-Sep-01	12:12	498574	6279643	-	-	-	-	0.21	0.08	-	-	backwater	N	-	10	*P. richardsoni*	65	22	13	0.86	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-21	depositional	19-Sep-01	12:30	498927	6279643	-	-	-	-	0.34	0.10	-	-	run	N	-	0	-	88	7	5	0.19	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-22	depositional	19-Sep-01	12:49	499184	6279627	-	-	-	-	0.77	0.23	-	-	run	N	-	0	-	92	4	4	0.02	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-23	depositional	19-Sep-01	13:21	499537	6279748	-	-	-	-	0.75	0.14	-	-	backwater	N	-	40	*P. richardsoni*	88	6	5	0.01	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-24	depositional	19-Sep-01	13:50	499598	6279368	-	-	-	-	0.60	0.07	-	-	run	N	-	20	*S. cuneata; Equisetum*	66	21	12	1.13	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-25	depositional	19-Sep-01	14:40	499433	6278949	-	-	-	-	0.59	0.01	-	-	run	N	-	0	-	41	28	31	2.89	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-26	depositional	19-Sep-01	15:01	499630	6278888	-	-	-	-	0.62	0.25	-	-	run	N	-	0	-	95	1	4	0.02	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-27	depositional	19-Sep-01	15:21	499888	6278860	-	-	-	-	0.54	0.00	-	-	backwater	N	-	0	-	94	2	4	0.03	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-28	depositional	19-Sep-01	15:46	499934	6279119	-	-	-	-	0.34	0.00	-	-	snye	N	-	0	-	49	33	18	2.49	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-29	depositional	19-Sep-01	16:15	499824	6279540	-	-	-	-	0.56	0.01	-	-	run	N	-	0	-	63	21	15	1.02	100	0	0	0	0	0	0
Clearwater u/s	CLR-D-30	depositional	19-Sep-01	16:38	499858	6279606	-	-	-	-	0.47	0.01	-	-	backwater	N	-	0	-	47	33	21	1.63	100	0	0	0	0	0	0
Fort Creek	FOC-D-1	depositional	11-Oct-01	13:00	461537	6363092	8.5	268	8.3	5.5	0.26	0.05	6	3	run	L	-	0	-	-	-	-	-	99	1	0	0	0	0	0
Fort Creek	FOC-D-2	depositional	11-Oct-01	13:22	-	-	8.5	268	8.3	5.5	0.32	0.10	6	3	run	L	-	0	-	-	-	-	-	99	1	0	0	0	0	0
Fort Creek	FOC-D-3	depositional	11-Oct-01	13:44	-	-	8.5	268	8.3	5.5	0.30	0.18	6	3	run	L	-	0	-	-	-	-	-	99	1	0	0	0	0	0
Fort Creek	FOC-D-4	depositional	11-Oct-01	14:06	-	-	8.5	268	8.3	5.5	0.20	0.05	6	3	run	L	-	0	-	-	-	-	-	99	1	0	0	0	0	0
Fort Creek	FOC-D-5	depositional	11-Oct-01	14:28	461566	6363095	8.5	268	8.3	5.5	0.22	0.00	6	3	run	L	-	0	-	-	-	-	-	99	1	0	0	0	0	0

[a] - = no data.

[b] Clearwater d/s = Clearwater River downstream of Christina River; Clearwater u/s = Clearwater River upstream of Christina River.

Table IX.4 Supporting Data Collected During the Fall 2001 Benthic Surveys of Kearl and Shipyard Lakes

				Location				Field Water Quality				Bottom Sediments (lab analysis)					
Lake	Site	Sample Date	Sample Time	UTM E (NAD 27)	UTM N (NAD 27)	Water Depth (cm)	Secchi Depth (m)	Dissolved Oxygen (mg/L)	Conduc-tivity (µS/cm)	pH	Water. Temp (°C)	Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (%)	Macro-phyte cover (%)	Macrophyte Species
Kearl	KEL-1	19-Sep-01	11:32	485099	6350483	2.0	1.5	8.3	176	7.7	14.4	21	33	47	29.40	0	-
Kearl	KEL-2	19-Sep-01		485229	6350252	2.1	1.5	8.3	176	7.7	14.4	15	35	50	35.80	10-20	*Potamogeton, Nuphar*
Kearl	KEL-3	19-Sep-01		485297	6349844	2.1	1.5	8.3	176	7.7	14.4	9	34	56	38.70	0	-
Kearl	KEL-4	19-Sep-01		485461	6349516	2.4	1.5	8.3	176	7.7	14.4	10	36	54	32.30	0	-
Kearl	KEL-5	19-Sep-01		485467	6349207	2.3	1.5	8.3	176	7.7	14.4	7	39	55	32.70	0	-
Kearl	KEL-6	19-Sep-01		485205	6348643	2.2	1.5	8.3	176	7.7	14.4	5	26	69	32.10	0	-
Kearl	KEL-7	19-Sep-01		485408	6348168	2.1	1.5	8.3	176	7.7	14.4	4	31	64	33.80	0	-
Kearl	KEL-8	19-Sep-01		485235	6347831	1.8	1.5	8.3	176	7.7	14.4	6	30	64	34.30	0	-
Kearl	KEL-9	19-Sep-01		485150	6347598	1.9	1.5	8.3	176	7.7	14.4	-[a]	-	-	33.30	0	-
Kearl	KEL-10	19-Sep-01	14:00	485446	6347567	1.8	1.5	8.3	176	7.7	14.4	4	29	67	33.60	0	-
Shipyard	SHL-1	25-Sep-01	12:15	473401	6314055	2.8	1.4	2.3	350	6.8	11.7	1	49	50	4.49	0	-
Shipyard	SHL-2	25-Sep-01		473365	6313559	2.0	1.3	3.5	373	7.3	12.5	1	43	56	4.57	1	-
Shipyard	SHL-3	25-Sep-01		473350	6313235	1.3	1.3	3.6	375	7.3	12.9	4	36	60	14.40	0	-
Shipyard	SHL-4	25-Sep-01		473237	6313087	1.8	1.7	3.5	374	7.2	12.8	2	34	64	15.40	5	-
Shipyard	SHL-5	25-Sep-01		473521	6313091	1.8	1.8	2.6	378	7.2	13.0	1	39	60	9.22	0	-
Shipyard	SHL-6	25-Sep-01		473724	6313152	2.0	1.6	3.4	380	7.2	13.0	2	35	63	8.88	0	-
Shipyard	SHL-7	25-Sep-01		473465	6313052	1.9	1.8	2.5	378	7.2	13.8	1	42	57	10.50	1	-
Shipyard	SHL-8	25-Sep-01		473252	6313194	1.8	1.8	3.7	376	7.3	13.7	2	43	56	11.30	5	-
Shipyard	SHL-9	25-Sep-01		473411	6313404	1.7	1.7	3.0	376	7.2	13.2	1	41	58	9.28	0	-
Shipyard	SHL-10	25-Sep-01	16:00	473302	6313593	1.7	1.7	3.3	375	7.2	13.1	2	35	64	9.82	0	-

[a] - = no data.

APPENDIX X

FISH COLLECTION DATA
MUSKEG RIVER FISH FENCE, SPRING 2001
AND FISH INVENTORY, MUSKEG RIVER
AND JACKPINE CREEK, SUMMER 2001

Table X.1 Muskeg River Fish Fence Results, Spring 2001

Date	Trap Box	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage	Maturity	Age (yrs)	Aging Structure	External Tag Number	Comments	Condition: Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	Total Score
05-May-01	upstream	NRPK	655	1955	0.70	U	A	mature		fin ray	1003		N	N	N	0	0	0	0	0	**0**
12-May-01	upstream	WHSC	461	1650	1.68	M	A	spent	15	fin ray	2876		N	N	N	0	0	0	0	0	**0**
12-May-01	upstream	WHSC	359	630	1.36	F	A	spent	9	fin ray	2878		N	N	N	0	0	0	0	0	**0**
13-May-01	upstream	WHSC	480	2025	1.83	M	A	ripe	17	fin ray	2884		N	N	N	0	0	0	0	0	**0**
13-May-01	upstream	WHSC	532	2350	1.56	F	A	spent	13	fin ray	2885		N	N	N	0	1	0	0	0	**10**
13-May-01	upstream	WHSC	470	1600	1.54	M	A	spent	9	fin ray	2886		N	N	N	0	0	0	3	0	**30**
13-May-01	upstream	WHSC	425	1190	1.55	M	A	spent	8	fin ray	2888		N	N	N	0	0	0	0	0	**0**
13-May-01	upstream	NRPK	540	1100	0.70	U	A	spent	4	fin ray	2889		N	N	N	0	0	0	0	0	**0**
14-May-01	upstream	WHSC	486	1790	1.56	F	A	spent	9	fin ray	2890		N	N	N	0	0	0	0	0	**0**
16-May-01	upstream	WHSC	2480	536	0.00	F	A	ripe	15	fin ray	2893		N	N	N	0	0	0	0	0	**0**
16-May-01	upstream	WHSC	2170	521	0.01	F	A	ripe	13	fin ray	2894	caudal fin severely eroded	N	N	N	0	0	0	3	0	**30**
16-May-01	upstream	WHSC	1230	428	0.02	F	A	ripe	5	fin ray	2895		N	N	N	0	0	0	0	0	**0**
16-May-01	upstream	WHSC	2285	514	0.00	F	A	ripe	15	fin ray	2896		N	N	N	0	1	0	0	0	**10**
16-May-01	upstream	WHSC	875	367	0.05	M	A	ripe	9	fin ray	2897	split dorsal fin	N	N	N	0	0	0	1	0	**10**
16-May-01	upstream	WHSC	463	1705	1.72	M	A	ripe	16	fin ray	2901		N	N	N	0	0	0	0	0	**0**
16-May-01	upstream	WHSC	529	2300	1.55	F	A	ripe	14	fin ray	2902		N	N	N	0	0	0	0	0	**0**
16-May-01	upstream	WHSC	450	1350	1.48	M	A	ripe	7	fin ray	2904		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	430	1170	1.47	M	A	ripe	7	fin ray	2907		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	458	1825	1.90	F	A	spent	15	fin ray	2908		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	402	1015	1.56	F	A	mature	8	fin ray	2909		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	512	2185	1.63	F	A	spent	18	fin ray	2911		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	545	2505	1.55	F	A	ripe	15	fin ray	2912		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	528	2210	1.50	F	A	spent	15	fin ray	2913		N	N	N	0	1	0	0	0	**10**
18-May-01	upstream	WHSC	422	1105	1.47	M	A	ripe	6	fin ray	2914		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	534	2305	1.51	M	A	spent		fin ray	2916		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	390	860	1.45	F	A	mature	7	fin ray	2917		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	496	2205	1.81	F	A	mature	10	fin ray	2921		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	538	2535	1.63	M	A	mature	17	fin ray	2922	left operculum eroded	N	N	N	0	0	0	0	1	**10**

Table X.1 Muskeg River Fish Fence Results, Spring 2001(continued)

Date	Trap Box	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage	Maturity	Age (yrs)	Aging Structure	External Tag Number	Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	Total Score
													Condition								
18-May-01	upstream	WHSC	563	2915	1.63	F	A	spent	17	fin ray	2923		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	459	1450	1.50	M	A	mature	13	fin ray	2925		N	N	N	0	0	0	0	0	**0**
04-May-01	upstream	NRPK	900	4700	0.64	F	A	ripe		fin ray	2951		N	N	N	0	0	0	0	0	**0**
05-May-01	upstream	NRPK	650	1810	0.66	M	A	mature	4	fin ray	2954		N	N	N	0	0	0	0	0	**0**
05-May-01	upstream	NRPK	659	1975	0.69	M	A	mature	4	fin ray	2955		N	N	N	0	0	0	0	0	**0**
06-May-01	D-2-way downstream	LNSC	420	960	1.30	F	A	mature	9	fin ray	2956		N	N	N	0	0	0	0	0	**0**
07-May-01	D-2-way downstream	WHSC	371	750	1.47	M	A	ripe	11	fin ray	2958	caudal fin severely eroded	N	N	N	0	0	0	3	0	**30**
07-May-01	D-2-way downstream	NRPK	505	850	0.66	U	A	mature	4	fin ray	2959		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	490	1760	1.50	M	A	spent	16	fin ray	2960		N	N	N	0	0	0	0	0	**0**
07-May-01	upstream	NRPK	861	5225	0.82	F	A	ripe		fin ray	2961		N	N	N	0	0	0	0	0	**0**
07-May-01	upstream	NRPK	561	995	0.56	M	A	mature	7	fin ray	2962		N	N	N	0	0	0	0	0	**0**
07-May-01	upstream	NRPK	540	1050	0.67	M	A	mature	4	fin ray	2963		N	N	N	0	0	0	0	0	**0**
11-May-01	upstream	WHSC	395	910	1.48	M	A	ripe	10	fin ray	2964		N	N	N	0	0	0	0	0	**0**
11-May-01	upstream	NRPK	595	1450	0.69	U	A	mature	4	fin ray	2967		N	N	N	0	0	0	0	0	**0**
12-May-01	upstream	WHSC	508	2080	1.59	M	A	ripe	17	fin ray	2968		N	N	N	0	1	0	0	0	**10**
12-May-01	upstream	WHSC	431	1160	1.45	M	A	ripe	10	fin ray	2969		N	N	N	0	0	0	0	0	**0**
12-May-01	upstream	WHSC	415	1050	1.47	F	A	mature	8	fin ray	2972		N	N	N	0	0	0	0	0	**0**
12-May-01	upstream	WHSC	485	1780	1.56	F	A	spent	7	fin ray	2973		N	N	N	0	0	0	0	0	**0**
12-May-01	upstream	NRPK	515	960	0.70	F	A	spent	3	fin ray	2974		N	N	N	0	0	0	0	0	**0**
28-Apr-01	upstream	NRPK	480	800	0.72	M	A	mature		fin ray	2977		N	N	N	0	0	0	0	0	**0**
01-May-01	upstream	NRPK	555	1270	0.74	F	A	mature	4	fin ray	2979		N	N	N	0	0	0	0	0	**0**
02-May-01	upstream	NRPK	598	1675	0.78	U	A	mature	6	fin ray	2980		N	N	N	0	0	0	0	0	**0**
02-May-01	upstream	NRPK	525	1050	0.73	F	A	mature	3	fin ray	2981		N	N	N	0	0	0	0	0	**0**
02-May-01	upstream	NRPK	482	860	0.77	M	A	mature	5	fin ray	2983		N	N	N	0	0	0	0	0	**0**
02-May-01	upstream	NRPK	571	1490	0.80	M	A	mature	9	fin ray	2984		N	N	N	0	0	0	0	0	**0**
03-May-01	D-2-way downstream	NRPK	571	1490	0.80	M	A	mature	4	fin ray	2984	recaptured fish	N	N	N	0	0	0	0	0	**0**
02-May-01	upstream	NRPK	542	1225	0.77	M	A	mature	4	fin ray	2985		N	N	N	0	0	0	0	0	**0**

Table X.1 Muskeg River Fish Fence Results, Spring 2001(continued)

Date	Trap Box	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage	Maturity	Age (yrs)	Aging Structure	External Tag Number	Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	Total Score
													Condition								
03-May-01	upstream	NRPK	651	1875	0.68	M	A	mature	4	fin ray	2986		N	N	N	0	0	0	0	0	**0**
03-May-01	upstream	NRPK	561	1135	0.64	U	A	mature	7	fin ray	2987		N	N	N	0	0	0	0	0	**0**
03-May-01	upstream	LNSC	420	880	1.19	F	A	mature	8	fin ray	2988		N	N	N	0	0	0	0	0	**0**
03-May-01	upstream	NRPK	568	1410	0.77	M	A	mature	7	fin ray	2989		N	N	N	0	0	0	3	0	**30**
03-May-01	upstream	NRPK	612	1510	0.66	M	A	mature	4	fin ray	2990		N	N	N	0	0	0	0	0	**0**
03-May-01	upstream	NRPK	554	1190	0.70	M	A	mature	5	fin ray	2991		N	N	N	0	0	0	0	0	**0**
04-May-01	upstream	NRPK	605	1290	0.58	U	A	mature			2993	fins severely eroded	N	N	N	0	0	0	3	0	**30**
04-May-01	upstream	LNSC	395	750	1.22	M	A	ripe	9	fin ray	2994		N	N	N	0	0	0	0	0	**0**
04-May-01	upstream	NRPK	532	1100	0.73	M	A	ripe	5	fin ray	2996		N	N	N	0	0	0	0	0	**0**
12-May-01	upstream	NRPK	590	1260	0.61	U	A	spent	4	fin ray	2997		N	N	N	0	0	0	0	0	**0**
13-May-01	upstream	NRPK	680	2400	0.76	F	A	ripe	7	fin ray	2998		N	N	N	0	0	0	0	0	**0**
13-May-01	upstream	WHSC	475	1590	1.48	M	A	ripe	12	fin ray	2999		N	N	N	0	0	0	0	0	**0**
13-May-01	upstream	WHSC	485	1450	1.27	M	A	ripe	17	fin ray	3000		N	N	N	0	0	0	0	0	**0**
21-May-01	upstream	WHSC	466	1605	1.59	F	A	mature	7	fin ray	3476		N	N	N	0	0	0	0	0	**0**
21-May-01	upstream	WHSC	371	725	1.42	U	U	U	8	fin ray	3478		N	N	N	0	0	0	0	0	**0**
20-May-01	upstream	LNSC	426	950	1.23	F	A	mature	10	fin ray	3481		N	N	N	0	0	0	0	0	**0**
19-May-01	upstream	LNSC	543	2720	1.70	F	A	mature	17	fin ray	3482		N	N	N	0	0	0	0	0	**0**
19-May-01	upstream	WHSC	525	1435	0.99	F	A	mature	21	fin ray	3483	tumor on caudal	N	N	N	0	3	0	0	0	**30**
19-May-01	upstream	WHSC	404	640	0.97	M	A	ripe	5	fin ray	3484		N	N	N	0	0	0	0	0	**0**
19-May-01	upstream	NRPK	545	1005	0.62	U	A	mature	3	fin ray	3485		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	NRPK	541	960	0.61	U	A	mature	6	fin ray	3486		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	556	2785	1.62	F	A	spent	16	fin ray	3487		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	495	1650	1.36	M	A	ripe	11	fin ray	3488		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	505	1875	1.46	M	A	ripe	18	fin ray	3489	caudal fin eroded	N	N	N	0	0	0	3	0	**30**
18-May-01	upstream	WHSC	410	1125	1.63	M	A	ripe	5	fin ray	3490		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	475	1505	1.40	M	A	ripe	13	fin ray	3491		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	565	2180	1.21	F	A	ripe	15	fin ray	3493		N	N	N	0	0	0	0	0	**0**
18-May-01	upstream	WHSC	531	2285	1.53	F	A	mature	17	fin ray	3494		N	N	N	0	0	0	0	0	**0**

Table X.1 Muskeg River Fish Fence Results, Spring 2001(continued)

Date	Trap Box	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage	Maturity	Age (yrs)	Aging Structure	External Tag Number	Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	Total Score
													Condition								
18-May-01	upstream	WHSC	488	1865	1.60	F	A	spent	13	fin ray	3498		N	N	N	0	0	0	0	0	**0**
21-May-01	upstream	LNSC	377	635	1.19	M	A	spent	10	fin ray	3977		N	N	N	0	0	0	0	0	**0**
21-May-01	upstream	WHSC	378	700	1.30	M	A	ripe	10	fin ray	3978		N	N	N	0	0	0	0	0	**0**
21-May-01	upstream	WHSC	400	930	1.45	F	A	mature	7	fin ray	3979		N	N	N	0	0	0	0	0	**0**
21-May-01	D-2-way downstream	WHSC	560	2360	1.34	M	A	mature	21	fin ray	3981		N	N	N	0	0	0	0	0	**0**
21-May-01	upstream	WHSC	425	1200	1.56	F	A	ripe	6	fin ray	3982		N	N	N	0	0	0	0	0	**0**
21-May-01	upstream	WHSC	370	800	1.58	M	A	ripe	11	fin ray	3983		N	N	N	0	0	0	0	0	**0**
21-May-01	D-2-way downstream	WHSC	554	2345	1.38	M	A	spent	16	fin ray	3984		N	N	N	0	0	0	0	0	**0**
23-May-01	upstream	WHSC	536	2220	1.44	F	A	ripe	12	fin ray	3988		N	N	N	0	0	0	0	0	**0**
23-May-01	D-2-way downstream	WHSC	390	870	1.47	M	A	spent	5	fin ray	3989		N	N	N	0	0	0	0	0	**0**
23-May-01	upstream	WHSC	450	1530	1.68	M	A	spent	10	fin ray	3990		N	N	N	0	0	0	0	0	**0**
24-May-01	upstream	WHSC	523	2210	1.54	F	A	mature	16	fin ray	3991		N	N	N	0	0	0	0	0	**0**
24-May-01	upstream	WHSC	526	2275	1.56	M	A	mature	18	fin ray	3993		N	N	N	0	0	0	0	0	**0**
24-May-01	upstream	WHSC	502	1860	1.47	M	A	ripe	13	fin ray	3994		N	N	N	0	0	0	0	0	**0**
24-May-01	D-2-way downstream	WHSC	502	1860	1.47	M	A	mature			3994	recaptured fish	N	N	N	0	0	0	0	0	**0**
24-May-01	upstream	LNSC	426	945	1.22	F	A	mature		fin ray	3995		N	N	N	0	0	0	3	0	**30**
24-May-01	upstream	NRPK	540	760	0.48	U	A	mature			3996	fins severely eroded	N	N	N	0	0	0	3	0	**30**
24-May-01	upstream	WHSC	472	1550	1.47	M	A	ripe	14	fin ray	3997		N	N	N	0	0	0	0	0	**0**
24-May-01	upstream	WHSC	464	1360	1.36	M	A	mature	16	fin ray	3998		N	N	N	0	0	0	0	0	**0**
25-May-01	D-2-way downstream	WHSC	550	2609	1.57	M	A	spent	18	fin ray	3999		N	N	N	0	0	0	0	0	**0**
01-May-01	D-2-way downstream	WHSC	230	170	1.40	U	J	immature	4	fin ray			N	N	N	0	0	0	0	0	**0**
02-May-01	upstream	WHSC	240			M	A	mature	3	fin ray		Incidental mort	N	N	N	0	0	0	0	0	**0**
02-May-01	upstream	WHSC	208			M	A	mature	4	fin ray		Incidental mort	N	N	N	0	0	0	0	0	**0**
02-May-01	D-2-way downstream	BRST	65			U	A	mature					N	N	N	0	0	0	0	0	**0**

Table X.1 Muskeg River Fish Fence Results, Spring 2001(continued)

Date	Trap Box	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage	Maturity	Age (yrs)	Aging Structure	External Tag Number	Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	Total Score
													Condition								
03-May-01	D-2-way downstream	LKCK	87	4	0.61	U	A	mature					N	N	N	0	0	0	0	0	0
03-May-01	upstream	NRPK	404	425	0.64	U	A	mature	2	fin ray			N	N	N	0	0	0	0	0	0
03-May-01	upstream	NRPK	356	290	0.64	U	J	immature	2	fin ray			N	N	N	0	0	0	0	0	0
04-May-01	upstream	WHSC	210	110	1.19	U	J	immature					N	N	N	0	0	0	0	0	0
04-May-01	upstream	WHSC	205	90	1.04	U	U	immature					N	N	N	0	0	0	0	0	0
06-May-01	D-2-way downstream	NRPK	452	710	0.77	M	U	mature	5	fin ray			N	N	N	0	0	0	0	0	0
15-May-01	upstream	NRPK	501	935	0.74	M	A	spent		fin ray		trap mort.	N	N	N	0	0	0	0	0	0
20-May-01	upstream	LNSC	380	885	1.61	F	A	mature	10	fin ray		no tag	N	N	N	0	0	0	0	0	0
21-May-01	upstream	LNSC	220	100	0.94	U	J	immature		fin ray			N	N	N	0	0	0	0	0	0
22-May-01	upstream	WHSC	225	150	1.32	M	A	mature		fin ray			N	N	N	0	0	0	0	0	0
22-May-01	upstream	WHSC	163	50	1.15	F	A	mature					N	N	N	0	0	0	0	0	0
23-May-01	upstream	LNSC	178	65	1.15	U	J	immature	3	scales			N	N	N	0	0	0	0	0	0
23-May-01	upstream	LNSC	162	50	1.18	U	J	immature	2	scales			N	N	N	0	0	0	0	0	0
23-May-01	D-2-way downstream	WHSC	419	1060	1.44	M	A	spent	7	fin ray		fence mort.	N	N	N	0	0	0	0	0	0
24-May-01	upstream	WHSC	301	375	1.38	U	J	immature	3	fin ray			N	N	N	0	0	0	0	0	0
24-May-01	upstream	LNSC	246	225	1.51	U	J	immature	3	fin ray			N	N	N	0	0	0	0	0	0
24-May-01	upstream	WHSC	301	350	1.28	U	J	immature	4	fin ray			N	N	N	0	0	0	0	0	0
24-May-01	upstream	WHSC	272	270	1.34	M	A	mature	3	fin ray			N	N	N	0	0	0	0	0	0
24-May-01	upstream	WHSC	271	270	1.36	M	A	ripe	4	fin ray			N	N	N	0	0	0	0	0	0
24-May-01	upstream	WHSC	235	170	1.31	U	U	immature	4	fin ray			N	N	N	0	0	0	0	0	0
24-May-01	upstream	WHSC	240	165	1.19	U	J	immature	3	fin ray			N	N	N	0	0	0	0	0	0

Table X.2 Muskeg River Summer Inventory Results, August 11-12, 2001

Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage Code	Maturity	External Tag		Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Number	Colour		Condition								Total Score
EMSH	91.00	5	0.66	U	U	UN				N	N	N	0	0	0	0	0	0
EMSH	80.00	4	0.78	U	U	UN				N	N	N	0	0	0	0	0	0
EMSH	81.00	4	0.75	U	U	UN				N	N	N	0	0	0	0	0	0
EMSH	81.00	4	0.75	U	U	UN				N	N	N	0	0	0	0	0	0
EMSH	79.00	4	0.81	U	U	UN				N	N	N	0	0	0	0	0	0
EMSH	81.00	4	0.75	U	U	UN				N	N	N	0	0	0	0	0	0
EMSH	80.00	4	0.78	U	U	UN				N	N	N	0	0	0	0	0	0
EMSH	78.00	4	0.84	U	U	MA				N	N	N	0	0	0	0	0	0
EMSH	80.00	4	0.78	U	U	MA				N	N	N	0	0	0	0	0	0
EMSH	79.00	4	0.81	U	U	MA				N	N	N	0	0	0	0	0	0
EMSH	84.00	5	0.84	U	U	MA				N	N	N	0	0	0	0	0	0
LKCH	68.00		0.00	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	81.00	6	1.13	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	94.00	9	1.08	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	82.00	7	1.27	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	108.00	15	1.19	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	88.00	8	1.17	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	61.00	2	0.88	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	80.00	3	0.59	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	80.00	6	1.17	U	A	MA				N	N	N	0	0	0	0	0	0
LKCH	62.00	4	1.68	U	J	IM				N	N	N	0	0	0	0	0	0
LKCH	61.00		0.00	U	U	UN				N	N	N	0	0	0	0	0	0
LKCH	66.00		0.00	U	U	UN				N	N	N	0	0	0	0	0	0
LKCH	72.00		0.00	U	U	UN				N	N	N	0	0	0	0	0	0
LKCH	58.00		0.00	U	U	UN				N	N	N	0	0	0	0	0	0
LKCH				U	U	UN			unknown F lkch?	N	N	N	0	0	0	0	0	0
LKCH	55.00	1	0.60	U	U	UN				N	N	N	0	0	0	0	0	0

Table X.2 Muskeg River Summer Inventory Results, August 11-12, 2001 (continued)

Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage Code	Maturity	External Tag		Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Number	Colour		Condition								Total Score
LKCH	62.00	3	1.26	U	U	MA				N	N	N	0	0	0	0	0	0
LNDC	55.00		0.00	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	394.00	705	1.15	F	A	MA	1460	brown		N	N	N	0	0	0	0	0	0
LNSC	32.00	1	3.05	U	F	IM				N	N	N	0	0	0	0	0	0
LNSC	185.00	223	3.52	U	J	IM			very pale	N	N	N	0	0	0	0	0	0
LNSC	169.00	50	1.04	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	151.00	55	1.60	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	100.00	25	2.50	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	111.00	25	1.83	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	112.00	25	1.78	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	71.00	5	1.40	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	75.00	5	1.19	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	170.00	60	1.22	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	191.00	85	1.22	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	102.00	15	1.41	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	135.00	31	1.26	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	150.00	40	1.19	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	120.00	19	1.10	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	152.00	45	1.28	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	175.00	55	1.03	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	185.00	60	0.95	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	78.00	4	0.84	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	155.00	35	0.94	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	198.00	80	1.03	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	155.00	44	1.18	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	180.00	73	1.25	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	160.00	54	1.32	U	J	IM				N	N	N	0	0	0	0	0	0

Table X.2 Muskeg River Summer Inventory Results, August 11-12, 2001 (continued)

Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage Code	Maturity	External Tag		Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Number	Colour		Condition								Total Score
LNSC	112.00	19	1.35	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	80.00	6	1.17	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	72.00	5	1.34	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	65.00	1	0.36	U	J	IM				N	N	N	0	3	0	0	0	30
LNSC	72.00	4	1.07	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	145.00	38	1.25	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	120.00	20	1.16	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	130.00	25	1.14	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	60.00	2	0.93	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	164.00	51	1.16	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	131.00	29	1.29	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	150.00	40	1.19	U	J	IM				N	N	N	0	0	0	0	0	0
LNSC	109.00	16	1.24	U	U	UN				N	N	N	0	0	0	0	0	0
MNWH	400.00	935	1.46	U	A	MA			3 wounds (lesions on abdomen l &r side)	N	N	N	0	0	0	0	0	0
MNWH	165.00	40	0.89	U	F	IM				N	N	N	0	0	0	0	0	0
MNWH	85.00	2	0.33	U	F	IM				N	N	N	0	0	0	0	0	0
MNWH	85.00	3	0.49	U	F	IM				N	N	N	0	0	0	0	0	0
MNWH	90.00	5	0.69	U	F	IM				N	N	N	0	0	0	0	0	0
MNWH	64.00	1	0.38	U	F	IM				N	N	N	0	0	0	0	0	0
MNWH	80.00	3	0.59	U		IM				N	N	N	0	0	0	0	0	0
NRPK	591.00	1345	0.65	U	A	MA	1461	brown		N	N	N	0	0	0	0	0	0
NRPK	501.00	940	0.75	U	A	MA	1462	brown		N	N	N	0	0	0	0	0	0
NRPK	570.00	1250	0.67	U	A	MA	1472	brown		N	N	N	0	0	0	0	0	0
NRPK	454.00	1120	1.20	U	A	MA	1401	brown		N	N	N	0	3	0	0	0	30
SPSC	70.00	4	1.17	U	A	MA				N	N	N	0	0	0	0	0	0
SPSC	79.00	7	1.42	U	A	MA				N	N	N	0	0	0	0	0	0
SPSC	80.00	8	1.56	M	J	IM				N	N	N	0	0	0	0	0	0

Table X.2 Muskeg River Summer Inventory Results, August 11-12, 2001 (continued)

Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage Code	Maturity	External Tag		Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Number	Colour		Condition								Total Score
SPSC	40.00		0.00	U	J	IM				N	N	N	0	0	0	0	0	0
SPSC	65.00	3	1.09	U	U	MA				N	N	N	0	0	0	0	0	0
TRPR	80.00	8	1.56	U	A	MA				N	N	N	0	0	0	0	0	0
TRPR	52.00	4	2.84	U	A	MA				N	N	N	0	0	0	0	0	0
TRPR	70.00	4	1.17	U	A	MA				N	N	N	0	0	0	0	0	0
TRPR	78.00	4	0.84	U	A	MA				N	N	N	0	0	0	0	0	0
TRPR	65.00	4	1.46	U	A	MA				N	N	N	0	0	0	0	0	0
TRPR	54.00	1	0.64	U	A	MA				N	N	N	0	0	0	0	0	0
WALL	80.00	6	1.17	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	105.00	11	0.95	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	90.00	8	1.10	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	79.00	4	0.81	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	90.00	4	0.55	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	78.00	4	0.84	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	85.00	7	1.14	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	95.00	7	0.82	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	70.00	4	1.17	U	J	IM				N	N	N	0	0	0	0	0	0
WALL	95.00	7	0.82	U	U	UN				N	N	N	0	0	0	0	0	0
WHSC	405.00	745	1.12	F	A	MA	1451	brown		N	N	N	0	0	0	0	0	0
WHSC	360.00	555	1.19	M	A	MA	1452	brown		N	N	N	0	1	0	0	0	10
WHSC	398.00		0.00	F	A	MA	1453	brown		N	N	N	0	0	0	0	0	0
WHSC	368.00	703	1.41	F	A	MA	1454	brown		N	N	N	0	0	0	0	0	0
WHSC	350.00	627	1.46	M	A	MA	1455	brown		N	N	N	0	2	0	0	0	20
WHSC	390.00	799	1.35	F	A	MA	1456	brown	fresh wound on back	N	N	N	0	0	0	0	0	0
WHSC	401.00	738	1.14	F	A	MA	1457	brown		N	N	N	0	0	0	0	0	0
WHSC	381.00	738	1.33	F	A	MA	1458	brown		N	N	N	0	0	0	0	0	0
WHSC	376.00	725	1.36	F	A	MA	1459	brown	body flacid	N	N	N	0	0	0	0	0	0

Table X.2 Muskeg River Summer Inventory Results, August 11-12, 2001 (continued)

Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Stage Code	Maturity	External Tag		Comments	Eyes	Gills	Pseudo-branchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Number	Colour		Condition								Total Score
WHSC	390.00	805	1.36	F	A	MA	1463	brown		N	N	N	0	0	0	0	0	0
WHSC	400.00	860	1.34	F	A	MA	1464	brown		N	N	N	0	0	0	0	0	0
WHSC	388.00	795	1.36	F	A	MA	1467	brown		N	N	N	0	0	0	0	0	0
WHSC	358.00	635	1.38	F	A	MA	1468	brown		N	N	N	0	0	0	0	0	0
WHSC	399.00	826	1.30	F	A	MA	1469	brown		N	N	N	0	0	0	0	0	0
WHSC	386.00	845	1.47	F	A	MA	1470	brown		N	N	N	0	0	0	0	0	0
WHSC	373.00	690	1.33	F	A	MA	1471	brown	flacid stomach	N	N	N	0	0	0	0	0	0
WHSC	355.00	535	1.20	U	A	MA	1473			N	N	N	0	3	0	0	0	30
WHSC	375.00	680	1.29	F	A	MA	1474		lesion on abdomen	N	N	N	0	0	0	0	0	0
WHSC	80.00	6	1.17	U	A	MA				N	N	N	0	0	0	0	0	0
WHSC	395.00		0.00	F	A	MA	1475	brown	flesh wound on abdomen	N	N	N	0	0	0	0	0	0
WHSC	145.00	35	1.15	U	J	IM				N	N	N	0	0	0	0	0	0
WHSC	120.00	21	1.22	U	J	IM				N	N	N	0	0	0	0	0	0
WHSC	72.00	5	1.34	U	J	IM				N	N	N	0	0	0	0	0	0
WHSC	75.00	5	1.19	U	J	IM				N	N	N	0	0	0	0	0	0
WHSC	140.00	32	1.17	U	J	IM				N	N	N	0	0	0	0	0	0

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
BP	LKCH	42.00	1	0.81	U	IM	N	N	N	0	0	0	0	0	0
BP	SPSC	62.00	3	1.26	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	82.00	5	0.91	U	UN	N	N	N	0	0	0	0	0	0
BP	LNSC	88.00	8	1.17	U	IM	N	N	N	0	0	0	0	0	0
BP	SPSC	64.00	3	1.14	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	51.00	1	0.75	U	IM	N	N	N	0	0	0	0	0	0
BP	SPSC	66.00	3	1.04	U	UN	N	N	N	0	0	0	0	0	0
BP	SLSC	58.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	BRST	55.00	2	1.20	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	68.00	3	0.95	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	52.00	1	0.71	U	IM	N	N	N	0	0	dorsal	0	0	30
BP	LKCH	44.00	1	1.17	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	51.00	1	0.75	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	42.00	1	1.35	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	44.00	1	1.17	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	50.00	1	0.80	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	78.00	5	1.05	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	102.00	9	0.85	U	MA	N	N	N	0	0	0	0	0	0
BP	SPSC	80.00	6	1.17	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	70.00	3	0.87	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	88.00	7	1.03	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	56.00	2	1.14	U	IM	N	N	N	0	0	0	0	0	0
BP	BRST	51.00	2	1.51	U	MA	N	N	N	0	0	0	0	0	0

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001 (continued)

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
BP	BRST	54.00	2	1.27	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	67.00	3	1.00	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	71.00	4	1.12	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	58.00	2	1.03	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	51.00	2	1.51	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	81.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	SPSC	69.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	82.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	48.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	64.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	88.00	8	1.17	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	78.00	8	1.69	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	73.00	4	1.03	U	MA	N	N	N	0	0	0	0	0	0
BP	SPSC	61.00	3	1.32	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	42.00	1	1.35	U	IM	N	N	N	0	0	0	0	0	0
BP	SPSC	70.00	4	1.17	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	51.00	1	0.75	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	83.00	6	1.05	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	48.00	2	1.81	U	IM	N	N	N	0	0	0	0	0	0
BP	BRST	56.00	2	1.14	U	MA	N	N	N	0	0	0	0	0	0
BP	LNSC	108.00	13	1.03	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	88.00	4	0.59	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	46.00	2	2.05	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	72.00	4	1.07	U	MA	N	N	N	0	0	0	0	0	0

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001 (continued)

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
BP	SPSC	62.00	3	1.26	U	UN	N	N	N	0	0	0	0	0	0
BP	SPSC	60.00	2	0.93	U	UN	N	N	N	0	0	0	0	0	0
BP	SPSC	31.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH		-	-	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH		-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH		-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH		-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	51.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	72.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	78.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	91.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	73.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	63.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	43.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	48.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	89.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LNDC	80.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	41.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	BRST	52.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	58.00	-	-	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	51.00	-	-	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	52.00	-	-	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	38.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	82.00	-	-	U	MA	N	N	N	0	0	0	0	0	0

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001 (continued)

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
BP	LKCH	70.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	42.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	42.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	42.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	BRST	60.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	BRST	60.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	108.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	62.00	-	-	U	UN	N	N	N	0	0	0	0	0	0
BP	SPSC	58.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	52.00	-	-	U	UN	N	N	N	0	0	0	0	0	0
BP	LKCH	43.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
BP	LKCH	72.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	80.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	69.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	LKCH	72.00	-	-	U	MA	N	N	N	0	0	0	0	0	0
BP	NRPK	201.00	-	-	U	IM	N	N	N	0	0	0	0	0	0
MN	LNSC	91.00	-	-	U	IM									
MN	LKCH	64.00	-	-	U	UN									
MN	LKCH	60.00	-	-	U	UN									
MN	LNSC	82.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	82.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LNSC	82.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LNSC	92.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	62.00	-	-	U	UN	-	-	-	-	-	-	-	-	-

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001 (continued)

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
MN	LKCH	42.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	60.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	49.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	73.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	75.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	65.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	52.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	71.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	76.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	54.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	44.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	80.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	48.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	86.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	88.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	51.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	79.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	43.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	83.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	84.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	72.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	79.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	72.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	89.00	-	-	U	MA	-	-	-	-	-	-	-	-	-

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001 (continued)

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
MN	LKCH	78.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	73.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	82.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	78.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LNSC	76.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LNSC	82.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LNSC	70.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	89.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LNSC	80.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	61.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	69.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	43.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	49.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	71.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	50.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	48.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	56.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	43.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	53.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	48.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	68.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	82.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	68.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LNSC	81.00	-	-	U	IM	-	-	-	-	-	-	-	-	-

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001 (continued)

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
MN	LKCH	20.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	58.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	63.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	50.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	48.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	50.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	88.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	90.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	72.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	81.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	64.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	93.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	60.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	62.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	41.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	62.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	58.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	78.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	72.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	83.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	71.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	43.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	48.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	54.00	-	-	U	IM	-	-	-	-	-	-	-	-	-

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001 (continued)

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
MN	LKCH	79.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	68.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	72.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	69.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	61.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	52.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	73.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	76.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	60.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	62.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	68.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	43.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	70.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	38.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	63.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	58.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	48.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	51.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	72.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	43.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	68.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	54.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	32.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	44.00	-	-	U	UN	-	-	-	-	-	-	-	-	-

Table X.3 Jackpine Creek Summer Inventory Results, August 8-9, 2001 (continued)

Capture Method	Species	Fork Length (mm)	Weight (g)	Condition Factor	Sex	Maturity	Eyes	Gills	Pseudobranchs	Thymus	Skin	Body Deformities	Fins	Opercles	
							Condition								Total Score
MN	LKCH	59.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	61.00	-	-	U	MA	-	-	-	-	-	-	-	-	-
MN	LKCH	40.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	34.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	46.00	-	-	U	IM	-	-	-	-	-	-	-	-	-
MN	LKCH	58.00	-	-	U	UN	-	-	-	-	-	-	-	-	-
MN	LKCH	60.00	-	-	U	MA	-	-	-	-	-	-	-	-	-

Note: BP = backpack electroshocking; MN = minnow traps.
IM = immature; UN = unknown; MA = mature.

APPENDIX XI

VEGETATION DATA

Table XI.1 Total Plant Species Observed during the 2001 Field Investigation

Layer	Species Name	Common Name
shrub	*Alnus crispa*	green alder
	Andromeda polifolia	bog rosemary
	Betula glandulosa	bog birch
	Chamaedaphne calyculata	leatherleaf
	Cornus stolonifera	red-osier dogwood
	Kalmia polifolia	northern laurel
	Larix laricina	tamarack
	Ledum groenlandicum	common Labrador tea
	Myrica gale	sweet gale
	Oxycoccus microcarpus	small bog cranberry
	Picea mariana	black spruce
	Salix maccalliana	velvet-fruited willow
	Salix pedicellaris	bog willow
forb	*Acorus calamus*	ratroot
	Bidens cernua	nodding beggarticks
	Caltha palustris	marsh-marigold
	Ceratophyllum demersum	hornwort
	Cicuta bulbifera	bulb-bearing water-hemlock
	Drosera rotundifolia	round-leaved sundew
	Epilobium angustifolium	common fireweed
	Epilobium palustre	marsh willowherb
	Equisetum hyemale	common scouring-rush
	Galium boreale	northern bedstraw
	Galium triflorum	sweet-scented bedstraw
	Hippuris vulgaris	common mare's-tail
	Lemna minor	common duckweed
	Lycopus uniflorus	northern water-horehound
	Lysimachia thyrsiflora	tufted loosestrife
	Lythrum salicaria	purple loosestrife
	Mentha arvensis	wild mint
	Menyanthes trifoliata	buck-bean
	Myriophyllum exalbescens	spiked water-milfoil
	Nuphar variegatum	yellow pond-lily
	Nymphaea tetragona	white water-lily
	Potamogeton alpinus	alpine pondweed
	Potamogeton gramineus	various-leaved pondweed
	Potamogeton natans	floating-leaf pondweed
	Potamogeton richardsonii	clasping-leaf pondweed
	Potamogeton zosteriformis	flat-stemmed pondweed

Table XI.1 Total Plant Species Observed during the 2001 Field Investigation (cont.)

Layer	Species Name	Common Name
forb continued	*Potentilla palustris*	marsh cinquefoil
	Ranunculus circinatus	firm white water crowfoot
	Rumex occidentalis	western dock
	Sagittaria cuneata	arum-leaved arrowhead
	Scutellaria galericulata	marsh skullcap
	Sium suave	water parsnip
	Smilacina trifolia	three-leaved Solomon's-seal
	Sonchus arvensis	perennial sow-thistle
	Sparganium angustifolium	narrow-leaved bur-reed
	Sparganium eurycarpum	giant bur-reed
	Typha angustifolia	narrow-leaved cattail
	Typha latifolia	common cattail
	Urtica dioica	common nettle
	Utricularia intermedia	flat-leaved bladderwort
	Utricularia vulgaris	common bladderwort
	Utricularia vulgaris	common bladderwort
	Calamagrostis canadensis	bluejoint
grass	*Carex aquatilis*	water sedge
	Carex athrostachya	long-bracted sedge
	Carex gynocrates	northern bog sedge
	Carex lenticularis	lens-fruited sedge
	Carex limosa	mud sedge
	Carex livida	livid sedge
	Carex pedunculata	
	Carex retrorsa	turned sedge
	Carex rostrata	beaked sedge
	Carex sartwellii	Sartwell's sedge
	Carex utriculata	small bottle sedge
	Carex viridula	green sedge
	Aulacomnium palustre	tufted moss
moss	*Brachythecium acutum*	
	Brachythecium rivulare	
	Brachythecium turgidum	
	Pleurozium schreberi	Schreber's moss
	Rhizomnium pseudopunctatum	
	Sphagnum angustifolium	peat moss
	Sphagnum riparium	shore-growing peat moss
	Tomenthypnum nitens	golden moss
	Cladina rangiferina	reindeer lichen
lichens	*Ramalina pollinaria*	
	Usnea alpina	old man's beard
	Usnea cavernosa	old man's beard
	Xanthoria fallax	

Table XI.2 Percent Cover and Class for Isadore's Lake

	Scientific Name	IL-T1-P1	IL-T1-P2	IL-T2-P1	IL-T2-P2	IL-T2-P3	IL-T3-P1	IL-T3-P2	IL-T3-P3	IL-T4-P1	IL-T4-P2	IL-T5-P1	IL-T5-P2	IL-T5-P3	IL-T5-P4	IL-T5-P5	IL-T6-P1	IL-T6-P2	IL-T6-P3	IL-T7-P1	IL-T7-P2	IL-T8-P1	IL-T8-P2
shrub	Alnus crispa										3.5	0.1	0.1	0.1									
	Andromeda polifolia											1.5						0.1	1.5				
	Betula glandulosa													7.5			7.5	3.5					
	Chamaedaphne calyculata											9	3.5	0.1			1.5		1.5				
	Cornus stolonifera										3.5												
	Kalmia polifolia																	0.1	1.5				
	Larix laricina											0.1	0.1	0.1			1.5	1.5	3.5				
	Ledum groenlandicum											1.5	1.5	0.1			1.5	0.1			0.1		
	Myrica gale											7.5	7.5	3.5			17.5	37.5	3.5				
	Oxycoccus microcarpus											3.5	7.5	3.5			0.1	0.1	1.5				
	Picea mariana											3.5	0.1					0.1	1.5				
	Salix maccalliana												0.1	1.5				0.1			0.1		
	Salix pedicellaris													0.1									
forb	Ceratophyllum demersum	3.5		7.5	7.5	1.5	3.5		0.1	17.5										1.5		7.5	1.5
	Drosera rotundifolia											0.1	0.1						0.1				
	Epilobium angustifolium																						1.5
	Equisetum hyemale																			3.5			
	Galium boreale										3.5												
	Galium triflorum																0.1						
	Hippuris vulgaris																				0.1		
	Lemna minor		0.1							37.5							0.1				0.1		0.1
	Mentha arvensis										3.5												
	Menyanthes trifoliata																			0.1			1.5
	Potamogeton richardsonii							1.5															1.5
	Potamogeton zosteriformis	37.5		1.5			3.5	1.5												3.5		3.5	
	Potentilla palustris											1.5	0.1	1.5			1.5	1.5			0.1		
	Ranunculus circinatus																						
	Sagittaria cuneata				1.5	3.5	7.5		3.5														
	Scutellaria galericulata																0.1						
	Sium suave																				0.1		3.5
	Smilacina trifolia																	0.1					
	Sonchus arvensis																						0.1
	Sparganium angustifolium					7.5																	
	Sparganium eurycarpum		7.5						17.5														
	Typha angustifolia		62.5																				
	Typha latifolia				1.5	17.5			37.5					3.5		17.5	3.5	3.5				1.5	17.5

Table XI.2 Percent Cover and Class for Isadore's Lake (continued)

	Scientific Name	IL-T1-P1	IL-T1-P2	IL-T2-P1	IL-T2-P2	IL-T2-P3	IL-T3-P1	IL-T3-P2	IL-T3-P3	IL-T4-P1	IL-T4-P2	IL-T5-P1	IL-T5-P2	IL-T5-P3	IL-T5-P4	IL-T5-P5	IL-T6-P1	IL-T6-P2	IL-T6-P3	IL-T7-P1	IL-T7-P2	IL-T8-P1	IL-T8-P2
graminoid	Calamagrostis canadensis										17.5	1.5		1.5			1.5	3.5					
	Carex aquatilis																				1.5		3.5
	Carex lenticularis																		0.1				
	Carex limosa										7.5		1.5	1.5			1.5	3.5			1.5		7.5
	Carex pedunculata																	0.1	1.5				
	Carex retrorsa																						0.1
	Carex viridula												1.5										
moss	Aulacomnium palustre											17.5	7.5	0.1			1.5	3.5	17.5				
	Brachythecium rivulare																3.5	0.1					
	Pleurozium schreberi											1.5											
	Sphagnum angustifolium												0.1	17.5			7.5	3.5					
	Sphagnum riparium											3.5											
	Tomenthypnum nitens												3.5										
lichen	Cladina rangiferina											0.1											
	Ramalina pollinaria											0.1	0.1					0.1	0.1				
	Usnea alpina											0.1											
	Usnea cavernosa												1.5										
	Xanthoria fallax											0.1	0.1						0.1				

Table XI.3 Percent Cover and Cover Class Kearl Lake

	Scientific Name	KL-T1-P1	KL-T1-P2	KL-T2-P1	KL-T2-P2	KL-T3-P1	KL-T3-P2	KL-T4-P1	KL-T4-P2	KL-T5-P1	KL-T5-P2	KL-T6-P1	KL-T6-P2	KL-T7-P1	KL-T7-P2	KL-T8-P1	KL-T8-P2	KL-T9-P1	KL-T9-P2
shrub	Salix maccalliana		3.5		0.1		0.1						0.1		0.1				0.1
	Salix pedicellaris		3.5				0.1								0.1		0.1		
forb	Caltha palustris				0.1						0.1				1.5		0.1		1.5
	Ceratophyllum demersum	3.5																	
	Cicuta bulbifera		0.1		0.1												0.1		0.1
	Epilobium palustre		0.1																
	Equisetum hyemale												0.1						
	Galium triflorum		3.5		0.1						0.1		0.1		0.1				0.1
	Lemna minor						0.1												
	Lycopus uniflorus				1.5		3.5		1.5		7.5		1.5		1.5		1.5		1.5
	Lysimachia thyrsiflora										3.5		3.5						
	Mentha arvensis		0.1																
	Myriophyllum exalbescens							1.5		1.5		62.5							
	Nymphaea tetragona						0.1												
	Potamogeton alpinus												1.5						
	Potamogeton gramineus			1.5															
	Potamogeton natans							1.5		3.5		3.5				0.1			
	Potamogeton richardsonii	0.1								3.5		0.1		0.1				3.5	
	Potentilla palustris		0.1		0.1		0.1				1.5				3.5		1.5		3.5
	Ranunculus circinatus			0.1						0.1		1.5							
	Rumex occidentalis		0.1		0.1		0.1				0.1								0.1
	Scutellaria galericulata				0.1														
	Sium suave				0.1						0.1						0.1		0.1
	Typha latifolia		3.5		1.5		1.5		62.5		17.5		1.5		3.5		7.5		7.5
	Urtica dioica			1.5	0.1														
	Utricularia vulgaris	0.1								0.1	0.1	1.5	1.5	1.5	0.1		1.5		
graminoid	Calamagrostis canadensis		17.5														7.5		17.5
	Carex aquatilis		17.5		3.5		3.5		3.5		7.5		3.5		3.5		3.5		
	Carex athrostachya				7.5		3.5								3.5		3.5		
	Carex gynocrates						1.5												
	Carex limosa										7.5								
	Carex livida																3.5		
	Carex rostrata																0.1		
	Carex sartwellii				3.5				1.5						3.5				
	Carex utriculata				3.5		7.5		1.5								1.5		
moss	Aulacomnium palustre																		0.1
	Brachythecium acutum																		3.5
	Brachythecium turgidum		3.5		3.5		0.1				3.5								
	Rhizomnium pseudopunctatum		3.5																
	Tomentypnum nitens		0.1																

Table XI.4 Percent Cover and Cover Class for Shipyard Lake

Scientific Name		SL-E9-01	SL-T1P1-09	SL-T1P2-09	SL-T3-P1	SL-T3-P2	SL-T6-P1	SL-T6-P2	SL-T6A-P1	SL-T6A-P2	SL-T8-P1	SL-T8-P2
shrub	no shrubs were recorded											
forb	Acorus calamus											3.5
	Bidens cernua					0.1				1.5		
	Ceratophyllum demersum	17.5	17.5	17.5	37.5		17.5	7.5	37.5		62.5	
	Cicuta bulbifera					0.1						
	Epilobium palustre									0.1		
	Equisetum hyemale	0.1										
	Galium triflorum					1.5						
	Lemna minor	17.5	0.1	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1
	Lysimachia thyrsiflora							1.5		0.1		
	Lythrum salicaria					0.1				0.1		
	Nuphar variegatum											0.1
	Nymphaea tetragona											
	Potamogeton zosteriformis	0.1	17.5				0.1					
	Potentilla palustris										0.1	0.1
	Sagittaria cuneata									1.5		0.1
	Sium suave					1.5				0.1		
	Typha latifolia		3.5			37.5		37.5		37.5		17.5
	Utricularia intermedia					0.1				0.1	0.1	0.1
graminoid	Carex athrostachya									0.1		
	Carex limosa					0.1						
	Carex rostrata					0.1						
moss	Brachythecium rivulare									0.1		

APPENDIX XII

WATER CHEMISTRY DATA FOR

ACID SENSITIVE LAKES SAMPLED IN 2001

Table XII.1 Water Chemistry Data for Acid Sensitive Lakes Sampled in 2001

Lake	Secchi Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (°C)	pH (field)	pH (lab)	Conductivity (field) (µS/cm)	Conduc-tivity (lab) (µS/cm)	Total Dissolved Solids (mg/L)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Colour (TCU)	Total Alkalinity (mg/L as $CaCO_3$)	Gran Alkalinity (mg/L as $CaCO_3$)	Dissolved Inorganic Carbon (mg/L)	Dissolved Organic Carbon (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Bicarbonate (mg/L)	Gran Bicarbonate (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Ion Balance (cations/ anions)	Iron (mg/L)	Silica (mg/L)	Ammonia (mg/L)	Nitrate + Nitrite (mg/L)	Total Nitrogen (mg/L)	Total Dissolved Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)	Chlorophyll a (µg/L)
Oil Sands Region																																		
A21	0.5	-[a]	11.4	4.93	5.02	10.9	16.2	54	3.20	-	322	1.8	0.55	0.4	23.3	1.730	0.5000	0.330	0.960	2.1	0.7	<0.3	1.3	2.77	1.03	-	0.012	0.007	2.731	1.783	2.724	0.058	0.0396	8
A24	0.6	10.3	8.4	4.48	4.80	-	16.7	52	2.70	8.80	270	1.2	0.00	0.3	16.6	1.020	0.3700	0.420	0.370	1.5	0.0	<0.3	1.0	2.35	0.68	<0.3	0.080	0.072	1.305	1.425	1.233	0.062	0.0465	4
A26	0.5	10.8	8.0	4.97	5.34	-	13.5	44	9.80	28.00	106	2.1	0.00	0.4	12.0	1.170	0.3600	0.410	0.610	2.6	0.0	<0.3	1.7	1.54	0.33	<0.3	0.016	0.013	2.995	0.733	2.982	0.066	0.0167	22
A29	0.7	-	11.2	6.06	5.93	7.4	12.9	43	2.30	-	103	3.1	0.56	0.7	17.1	1.600	0.4600	0.200	1.160	3.8	0.7	<0.3	0.5	2.30	0.09	-	0.023	0.006	1.754	0.875	1.748	0.032	0.0075	37
A42	0.2	-	10.5	7.57	6.66	26.4	34.8	108	26.00	-	92	11.3	10.63	1.8	49.8	5.510	1.3400	0.440	1.890	13.7	12.9	<0.3	0.7	1.97	0.03	-	-	-	-	-	-	0.256	0.0174	285
A59	0.7	-	11.1	5.37	5.41	16.1	22.3	61	1.30	-	261	3.5	1.61	0.3	31.3	3.100	0.7300	0.320	0.820	4.2	2.0	<0.3	1.0	2.79	0.32	-	0.012	0.016	1.341	0.978	1.325	0.036	0.0135	31
A86	1.3	-	12.2	7.02	6.56	16.6	22.6	18	1.70	0.75	43	6.1	4.01	1.2	17.7	2.110	0.8300	1.380	0.770	7.4	4.9	<0.3	1.3	1.56	0.03	-	0.011	0.006	2.386	0.945	2.380	0.028	0.0071	18
A300	0.3	-	10.4	7.45	6.96	34.0	41.9	64	17.00	10.00	56	15.3	14.48	2.9	32.2	5.870	1.2100	1.390	1.590	18.6	17.6	0.4	<0.5	1.57	0.03	-	0.101	0.004	6.188	2.235	6.184	0.168	0.0108	161
E15 (L15b)	0.6	11.1	12.2	7.51	7.12	51.7	57.1	219	4.00	18.00	103	21.9	22.88	4.0	81.2	9.020	1.9500	0.570	3.880	26.7	27.9	<0.3	<0.5	1.77	0.02	-	0.013	0.002	2.127	1.232	2.125	0.061	0.0097	47
L4 (A-170)	1.0	9.4	11.1	5.99	6.15	18.1	22.6	52	0.63	1.20	216	5.7	3.83	0.6	24.8	3.510	0.9300	0.130	0.430	6.9	4.7	<0.3	0.9	2.03	0.23	-	0.012	0.077	0.610	0.684	0.533	0.017	0.0089	13
L7	1.0	10.4	11.2	6.68	6.70	25.6	30.6	69	1.00	0.60	278	10.1	9.25	1.3	28.5	4.990	1.4700	0.240	0.780	12.3	11.3	<0.3	0.6	1.88	0.65	-	0.005	0.008	0.521	0.511	0.513	0.018	0.0117	5
L8	1.0	10.5	11.0	7.32	7.16	44.1	49.4	74	2.10	3.20	162	20.4	19.60	4.0	25.6	5.900	2.6700	0.110	2.540	24.9	23.9	<0.3	1.1	1.45	0.16	-	0.010	0.004	0.971	0.735	0.967	0.040	0.0130	25
L18 (Namur)	4.8	10.1	13.0	7.52	7.29	57.5	62.7	47	0.68	0.60	14	20.9	18.38	4.6	8.7	6.280	2.0900	1.400	2.450	25.4	22.4	<0.3	7.8	1.08	0.03	-	0.012	0.002	0.284	0.297	0.282	0.017	0.0109	5
L23 (Otasan)	1.8	11.1	9.1	7.02	6.80	10.0	25.8	45	2.40	3.00	44	8.7	6.31	1.5	13.6	2.890	1.0600	0.390	0.850	10.6	7.7	<0.3	1.3	1.36	0.08	1.0	0.022	0.009	0.828	0.787	0.819	0.015	0.0060	15
L25 (Legend)	1.3	10.2	11.4	7.09	6.91	25.4	30.3	38	3.20	4.80	46	10.5	7.69	2.2	11.0	3.510	1.0300	0.630	1.060	12.8	9.4	<0.3	2.6	1.20	0.06	-	0.012	0.003	0.445	0.386	0.442	0.042	0.0108	16
L28	0.4	12.1	5.9	5.32	5.31	-	20.7	63	4.30	10.20	466	3.0	0.89	0.4	28.2	2.150	0.6600	0.290	1.390	3.6	1.1	<0.3	1.2	2.62	1.63	2.7	0.013	0.053	1.984	0.850	1.931	0.087	0.0655	4
L29 (Clayton)	0.3	12.3	4.7	4.26	4.44	-	15.9	58	21.00	60.00	164	0.0	0.00	0.4	13.0	0.580	0.2000	0.110	1.430	0.0	0.0	0.3	0.7	4.42	0.22	<0.3	0.019	0.006	4.141	0.631	4.135	0.076	0.0064	35
L39 (A-150)	0.4	11.6	7.8	7.08	6.89	13.0	30.0	62	11.00	41.30	63	12.2	9.13	2.9	13.0	2.970	1.4000	0.550	1.650	14.9	11.1	0.4	1.1	1.28	<0.02	3.3	0.101	0.007	4.050	0.543	4.043	0.056	0.0058	66
L46 (Bayard)	0.6	11.9	6.9	7.02	6.90	42.0	58.0	64	13.00	3.80	233	11.8	10.01	1.8	23.2	5.310	2.0300	0.720	3.580	14.4	12.2	<0.3	11.3	1.28	1.38	4.4	0.025	0.055	1.761	1.003	1.707	0.156	0.1027	6
L47	0.3	12.2	6.0	6.94	6.76	43.0	59.2	102	53.00	148.00	111	10.7	9.08	1.9	18.4	5.680	1.8000	0.690	3.580	13.0	11.1	<0.3	13.1	1.25	0.60	1.4	0.215	0.073	3.443	2.180	3.370	0.214	0.0307	60
L49	0.5	11.7	6.2	6.45	6.43	43.0	59.3	98	14.00	16.20	179	6.8	4.99	1.0	19.9	5.110	1.6700	0.670	3.910	8.3	6.1	<0.3	14.4	1.31	1.00	3.0	0.082	0.279	4.436	1.968	4.157	0.126	0.0739	19
L60	0.9	11.0	7.8	7.18	7.02	45.0	60.9	77	5.20	4.83	152	16.1	14.20	2.9	17.3	6.510	2.2500	0.550	2.760	19.6	17.3	<0.3	9.3	1.25	0.81	0.7	0.047	0.009	2.640	1.591	2.631	0.094	0.0492	18
Caribou Mountains																																		
E52 (Fleming)	1.3	10.1	7.9	7.31	7.16	35.0	51.0	86	1.10	0.20	255	18.8	16.86	3.5	22.1	7.990	1.8600	0.580	1.250	22.9	20.6	<0.3	2.7	1.42	0.83	1.5	0.027	0.018	0.894	-	0.876	0.039	0.0329	7
E59 (Rocky Island)	1.4	11.3	5.2	7.10	6.87	13.0	29.2	44	1.10	1.60	94	9.7	7.14	1.8	12.0	4.130	1.0800	0.260	0.510	11.8	8.7	<0.3	2.1	1.34	0.18	<0.3	0.013	0.010	2.175	1.050	2.165	0.024	0.0104	7
E68 (Whitesand)	0.6	11.6	3.3	7.09	6.93	26.0	41.7	81	4.10	3.83	310	13.3	12.04	2.3	24.9	6.210	1.9300	0.190	1.450	16.2	14.7	<0.3	3.4	1.58	0.96	0.3	0.042	0.110	3.802	1.800	3.693	0.061	0.0284	10

Table XII-1 Water Chemistry Data for Acid Sensitive Lakes Sampled in 2001 (continued)

Lake	Secchi Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (°C)	pH (field)	pH (lab)	Conductivity (field) (µS/cm)	Conduc-tivity (lab) (µS/cm)	Total Dissolved Solids (mg/L)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Colour (TCU)	Total Alkalinity (mg/L as $CaCO_3$)	Gran Alkalinity (mg/L as $CaCO_3$)	Dissolved Inorganic Carbon (mg/L)	Dissolved Organic Carbon (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Bicarbonate (mg/L)	Gran Bicarbonate (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	Ion Balance (cations/ anions)	Iron (mg/L)	Silica (mg/L)	Ammonia (mg/L)	Nitrate + Nitrite (mg/L)	Total Nitrogen (mg/L)	Total Dissolved Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)	Chlorophyll a (µg/L)
O1 (Unnamed #6) (E55)	0.8	12.0	3.5	6.00	6.04	-	19.5	55	1.20	2.80	276	4.2	1.98	0.5	17.8	3.080	0.6700	0.140	0.330	5.1	2.4	<0.3	1.4	1.95	0.50	<0.3	0.007	0.046	2.159	2.425	2.113	0.031	0.0213	12
O2 (Unnamed #9) (E67)	0.8	10.5	7.2	6.89	6.75	14.0	30.3	63	0.89	-	302	10.1	8.56	1.7	24.2	5.290	1.3400	0.080	0.930	12.4	10.4	<0.3	1.1	1.84	0.85	0.9	0.023	0.014	2.318	0.848	2.303	0.029	0.0242	3
Canadian Shield																																		
A301	2.3	10.2	9.7	7.49	7.25	40.0	55.0	44	1.40	2.40	30	22.5	20.30	4.8	13.8	6.220	2.4730	0.590	1.530	27.5	24.8	1.4	1.2	1.16	0.03	1.5	0.011	0.012	1.085	-	1.072	0.015	0.0045	7
L107 (Weekes)	3.4	9.9	9.2	7.28	7.18	45.0	61.0	34	0.58	-	11	23.1	20.25	5.4	8.3	7.460	1.6000	0.650	2.990	28.2	24.7	2.6	0.9	1.17	<0.02	0.3	0.012	0.014	0.944	0.776	0.930	0.004	0.0023	3
L109 (Fletcher)	1.8	9.8	9.1	7.15	7.14	39.0	54.9	49	1.40	0.70	94	20.6	18.53	4.2	15.7	6.220	2.2900	0.600	2.040	25.1	22.6	2.1	0.6	1.25	0.64	2.5	0.017	0.012	1.834	0.918	1.822	0.012	0.0078	4
O10	0.5	11.7	5.3	7.17	6.77	16.0	32.7	54	6.40	37.00	63	11.1	9.18	2.4	14.8	3.260	1.4900	0.700	2.830	13.5	11.2	1.0	<0.5	1.65	0.02	1.1	0.039	0.006	2.484	2.248	2.478	0.053	0.0048	34
R1	2.4	10.6	8.5	7.30	7.12	26.0	41.6	40	0.96	1.50	51	15.6	13.79	3.1	23.9	4.810	1.6900	0.470	1.630	19.0	16.8	1.3	0.7	1.28	0.13	2.8	0.017	0.020	2.204	0.636	2.185	0.007	0.0038	4
QA/QC data																																		
field blank	-	-	-	-	5.24	-	2.0	<5	0.14	-	2	1.0	0.00	0.4	1.1	0.070	0.0100	0.020	0.110	1.3	0.0	<0.3	<0.5	-	<0.02	-	0.010	0.008	0.042	0.031	0.034	<0.001	0.0010	<2
A42 (split)	-	-	-	-	6.64	-	35.1	114	26.00	-	91	11.2	10.81	1.9	47.5	5.170	1.2800	-	-	13.7	13.2	<0.3	0.7	2.38	0.06	-	0.103	0.010	7.913	2.184	7.903	0.244	0.0168	268
A42 (duplicate)	-	-	-	-	6.65	-	34.3	106	27.00	-	99	11.2	10.81	1.7	46.9	5.400	1.3000	0.630	1.760	13.6	13.2	<0.3	0.7	2.01	0.05	-	0.337	0.007	9.076	4.137	9.070	0.256	0.0172	277
Analytical Detection Limits																																		
detection limit	-	-	-	-	-	-	0.3	5	0.04	0.02	1	-	0.25	0.1	0.1	0.003	0.0005	0.005	0.002	-	-	0.3	0.5	-	0.02	0.3	0.001	0.001	0.005	0.005	0.006	0.001	0.0005	2

[a] - = no data.

Table XII.2 Water Quality Profile Data for Acid Sensitive Lakes Sampled in 2001

Lake	Sample Date	Measurement Depth (m)	Dissolved Oxygen (mg/L)	pH	Conductivity (µS/cm)	Water Temperature (°C)	Photosynthetically Active Radiation (µmol/s/m²)
A21	10-Sep-01	0.025	-[(a)]	-	-	-	22.0
		0.1	-	4.93	10.9	11.4	13.1
		0.5	-	4.94	10.9	11.4	1.8
		1	-	4.92	10.8	11.4	0.7
A24	2-Oct-01	0.1	10.3	4.48	-	8.4	19.8
		0.5	10.4	4.46	-	8.4	2.1
		1	10.3	4.43	-	8.4	0.7
A26	3-Oct-01	0.1	10.8	4.97	-	8.0	60.0
		0.5	10.8	4.94	-	8.0	6.1
		1	10.8	4.93	-	8.0	0.8
A29	10-Sep-01	0.025	-	-	-	-	160.0
		0.1	-	6.06	7.4	11.2	105.0
		0.5	-	6.07	7.7	11.2	23.5
		1	-	6.04	7.5	11.2	6.5
A42	10-Sep-01	0.025	-	-	-	-	80.0
		0.1	-	7.57	26.4	10.5	31.0
		0.5	-	7.62	26.3	10.4	0.5
		1	-	7.55	26.4	10.4	0.1
A59	10-Sep-01	0.025	-	-	-	-	27.5
		0.1	-	5.37	16.1	11.1	17.5
		0.5	-	5.37	16.1	11.1	2.9
		1	-	5.38	16.1	11.1	1.1
		1.5	-	5.36	16.3	11.1	-
A86	10-Sep-01	0.025	-	-	-	-	540.0
		0.1	-	7.02	16.6	12.2	515.0
		0.5	-	6.98	16.6	12.3	320.0
		1	-	7	16.6	12.2	190.0
		1.5	-	6.97	16.6	12.3	103.0
		2	-	-	-	-	50.0
		2.5	-	-	-	-	28.0
E15 (L15b)	13-Sep-01	0.025	-	-	-	-	490.0
		0.1	11.1	7.51	51.7	12.2	320.0
		0.5	10.9	7.48	51.7	12.1	98.0
		1	10.9	7.5	51.8	12.1	10.5
L4 (A-170)	13-Sep-01	0.025	-	-	-	-	830.0
		0.1	9.4	5.99	18.1	11.1	550.0
		0.5	9.2	5.99	18.1	11.1	115.0
		1	9.2	5.99	18.1	11.1	30.0
		1.5	9.1	5.98	18.1	11.0	11.5

Table XII.2 Water Quality Profile Data for Acid Sensitive Lakes Sampled in 2001 (continued)

Lake	Sample Date	Measurement Depth (m)	Dissolved Oxygen (mg/L)	pH	Conductivity (µS/cm)	Water Temperature (°C)	Photosynthetically Active Radiation (µmol/s/m²)
L7	13-Sep-01	0.025	-	-	-	-	630.0
		0.1	10.4	6.68	25.6	11.2	540.0
		0.5	10.3	6.68	25.6	11.2	115.0
		1	10.3	6.69	25.6	11.2	22.6
		1.5	10.2	6.68	25.6	11.2	-
L8	13-Sep-01	0.025	-	-	-	-	652.0
		0.1	10.5	7.32	44.1	11.0	470.0
		0.5	10.4	7.33	44.1	11.0	130.0
		1	10.3	7.32	44.1	11.0	23.0
		1.4	10.3	7.32	44.1	11.0	7.5
L18 (Namur)	13-Sep-01	0.1	10.1	7.52	57.5	13.0	630.0
		0.5	-	-	-	-	320.0
		1	10.1	7.52	57.5	13.0	240.0
		1.5	-	-	-	-	183.0
		2	10.0	7.52	57.5	13.0	142.0
		3	10.0	7.53	57.5	13.0	95.0
		4	10.0	7.56	57.5	13.0	48.0
		5	9.8	7.56	57.4	12.9	37.0
		6	-	-	-	-	16.8
		7	-	-	-	-	12.1
		8	-	-	-	-	10.5
		9	-	-	-	-	7.5
L23 (Otasan)	3-Oct-01	0.1	11.1	7.02	10.0	9.1	110.0
		0.5	11.1	7.02	10.0	9.1	55.0
		1	11.0	7.02	10.0	9.1	22.0
		2	11.0	7.01	10.0	9.1	-
L25 (Legend)	13-Sep-01	0.025	-	-	-	-	470.0
		0.1	10.2	7.09	25.4	11.4	370.0
		0.5	10.1	7.08	25.4	11.4	188.0
		1	10.1	7.08	25.1	11.4	71.0
		1.5	-	-	-	-	30.0
		2	10.1	7.07	25.4	11.4	15.0
		2.5	-	-	-	-	9.8
		3	10.0	7.07	25.2	11.4	7.2
		4	9.9	7.06	25.4	11.4	-
		5	9.9	7.04	25.4	11.4	-
L28	3-Oct-01	0.025	-	-	-	-	250.0
		0.1	12.1	5.32	-	5.9	120.0
		0.5	12.0	5.31	-	5.9	4.7
		1	11.9	5.31	-	5.9	0.5

Table XII.2 Water Quality Profile Data for Acid Sensitive Lakes Sampled in 2001 (continued)

Lake	Sample Date	Measurement Depth (m)	Dissolved Oxygen (mg/L)	pH	Conductivity (µS/cm)	Water Temperature (°C)	Photosynthetically Active Radiation (µmol/s/m²)
L29 (Clayton)	4-Oct-01	0.025	-	-	-	-	160.0
		0.1	12.3	4.26	-	4.7	49.0
		0.5	12.3	4.25	-	4.7	0.5
L39 (A-150)	3-Oct-01	0.025	-	-	-	-	233.0
		0.1	11.6	7.08	13.0	7.8	118.0
		0.5	11.6	7.05	13.0	7.8	11.5
		1	11.5	7.04	13.0	7.8	2.1
L46 (Bayard)	3-Oct-01	0.2	11.9	7.02	42.0	6.9	68.0
		0.5	11.8	7.01	43.0	6.9	8.1
		1	11.9	7.02	43.0	6.8	1.0
L47	3-Oct-01	0.025	-	-	-	-	115.0
		0.1	12.2	6.94	43.0	6.0	49.7
		0.5	12.1	6.94	43.0	6.0	0.8
		1	12.0	6.91	43.0	6.0	0.3
L49	3-Oct-01	0.025	-	-	-	-	92.0
		0.1	11.7	6.45	43.0	6.2	55.0
		0.5	11.6	6.46	43.0	6.2	6.5
		1	11.6	6.45	43.0	6.2	1.0
L60	3-Oct-01	0.025	-	-	-	-	115.0
		0.1	11.0	7.18	45.0	7.8	89.0
		0.5	11.0	7.18	45.0	7.8	29.0
		1	10.9	7.17	45.0	7.8	7.0
		1.5	10.9	7.17	45.0	7.8	2.4
		2	10.9	7.16	45.0	7.8	1.1
E52 (Fleming)	4-Oct-01	0.025	-	-	-	-	198.0
		0.1	10.1	7.31	35.0	7.9	145.0
		0.5	10.1	7.31	35.0	7.9	31.0
		1	10.1	7.3	35.0	7.9	9.9
		2	10.0	7.3	35.0	7.9	2.5
		3	10.0	7.29	35.0	7.9	1.2
		4	10.0	7.29	35.0	7.9	0.6
		5	9.9	7.3	35.0	7.9	-
		6	10.0	7.29	35.0	7.9	-
		7	10.0	7.29	35.0	7.9	-
		8	9.9	7.29	35.0	7.7	-
E59 (Rocky Island)	4-Oct-01	0.1	11.3	7.1	13.0	5.2	230.0
		0.5	11.2	7.1	13.0	5.3	94.0
		1	11.2	7.08	13.0	5.3	35.0
		1.5	11.2	7.08	13.0	5.3	17.8
E68 (Whitesand)	4-Oct-01	0.1	11.6	7.09	26.0	3.3	295.0
		0.5	11.6	7.09	26.0	3.3	32.0
		1	11.6	7.09	26.0	3.3	4.9

Table XII.2 Water Quality Profile Data for Acid Sensitive Lakes Sampled in 2001 (continued)

Lake	Sample Date	Measure-ment Depth (m)	Dissolved Oxygen (mg/L)	pH	Conduc-tivity (µS/cm)	Water Tempera-ture (°C)	Photosyn-thetically Active Radiation (µmol/s/m²)
O1 (Unnamed #6) (E55)	4-Oct-01	0.1	12.0	6	-	3.5	225.0
		0.5	11.9	6.02	-	3.5	28.0
		1	11.9	6.02	-	3.5	3.5
		1.5	11.8	6.02	-	3.5	1.1
O2 (Unnamed #9) (E67)	4-Oct-01	0.1	10.5	6.89	14.0	7.2	300.0
		0.5	10.5	6.88	14.0	7.2	53.0
		1	10.4	6.81	14.0	7.2	8.5
		2	10.4	6.8	14.0	7.2	0.8
		3	10.4	6.84	14.0	7.2	0.4
		4	10.4	6.82	14.0	7.1	-
		6	10.4	6.81	14.0	7.1	-
A300	10-Sep-01	0.025	-	-	-	-	165.0
		0.1	-	7.45	34.0	10.4	101.0
		0.5	-	7.47	34.0	10.4	8.5
		1	-	7.49	33.9	10.4	-
		1.5	-	7.47	33.9	10.4	1.2
A301	5-Oct-01	0.1	10.2	7.49	40.0	9.7	130.0
		0.5	10.1	7.49	40.0	9.7	65.0
		1	10.1	7.49	40.0	9.7	43.0
		2	10.1	7.48	40.0	9.7	24.0
		3	10.0	7.48	40.0	9.7	12.5
		4	10.0	7.47	40.0	9.7	6.2
		5	-	-	-	-	3.5
		6	10.0	7.48	40.0	9.7	2.4
		7	-	-	-	-	0.6
		8	9.9	7.45	40.0	9.6	-
L107 (Weekes)	5-Oct-01	0.025	-	-	-	-	110.0
		0.1	9.9	7.28	45.0	9.2	105.0
		0.5	9.9	7.28	45.0	9.2	84.0
		1	9.8	7.28	45.0	9.2	56.0
		2	9.8	7.28	45.0	9.2	30.2
		3	9.7	7.27	45.0	9.2	19.6
L109 (Fletcher)	5-Oct-01	0.025	-	-	-	-	165.0
		0.1	9.8	7.15	39.0	9.1	133.0
		0.5	9.8	7.15	39.0	9.1	60.0
		1	9.7	7.15	39.0	9.1	29.0
		2	9.7	7.14	39.0	9.1	7.0
		3	9.6	7.13	39.0	9.1	2.8
		4	9.6	7.12	39.0	9.0	1.3
		5	9.5	7.08	39.0	8.8	0.9

Table XII.2 Water Quality Profile Data for Acid Sensitive Lakes Sampled in 2001 (continued)

Lake	Sample Date	Measurement Depth (m)	Dissolved Oxygen (mg/L)	pH	Conductivity (µS/cm)	Water Temperature (°C)	Photosynthetically Active Radiation (µmol/s/m²)
O10	5-Oct-01	0.025	-	-	-	-	169.0
		0.1	11.7	7.17	16.0	5.3	132.0
		0.5	11.7	7.15	16.0	5.3	33.0
		1	11.6	7.15	16.0	5.3	5.5
		1.5	11.6	7.14	16.0	5.3	2.5
R1	5-Oct-01	0.1	10.6	7.3	26.0	8.5	137.0
		0.5	10.5	7.3	26.0	8.6	81.0
		1	10.5	7.28	26.0	8.6	30.0
		2	10.5	7.29	26.0	8.5	16.1
		3	10.4	7.29	26.0	8.6	-
		4	10.4	7.28	26.0	8.5	4.3
		6	10.3	7.27	26.0	8.5	1.8
		7	-	-	-	-	0.5
		8	10.3	7.27	26.0	8.5	-
		10	10.3	7.25	26.0	8.1	-

[a] - = no data.