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**REPORT ON**

# OIL SANDS REGIONAL AQUATICS MONITORING PROGRAM (RAMP) 1999

**Submitted to:**

**RAMP Steering Committee**

**May 26, 2000** **992-2307**

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May 29, 2000 992-2307

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RE: Oil Sands Regional Aquatics Monitoring (RAMP) 1999 Report

Attached is the RAMP 1999 report.

Yours very truly,

**GOLDER ASSOCIATES LTD.**

Marie Lagimodiere

Marie Lagimodiere, MES, P.Biol.
Aquatic Biologist

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## EXECUTIVE SUMMARY

### Purpose and Scope

The area around Fort McMurray, Alberta is experiencing a large increase in oil sands mining and related developments. To integrate long-term monitoring of the aquatic environment in the Oil Sands Region, the Regional Aquatics Monitoring Program (RAMP) was developed as a multi-company program currently sponsored by Suncor Energy Inc., Oil Sands, Syncrude Canada Ltd., Albian Sands (Shell Canada Ltd.) and Mobil Oil Canada Properties.

The RAMP Steering Committee, formed in 1998 as the decision making body of RAMP, held five meetings in Fort McMurray in 1999. Highlights of 1999 include: finalizing the Terms of Reference for RAMP; holding community meetings in Fort Chipewyan and Fort McKay; establishing the scope of the 1999 monitoring program; achieving significant progress towards a core monitoring program; selecting a logo by holding a logo design contest in schools; issuing the first RAMP newsletter; developing a draft communication implementation plan; and completing planned monitoring activities.

The 1999 monitoring program was a continuation of long-term monitoring that began in 1997. To effectively evaluate aquatic ecosystems within the Oil Sands Region, 1999 monitoring focussed on the following areas potentially affected by development activities: Athabasca River; Athabasca River Delta; tributaries of the Athabasca River, including the Muskeg River (and tributaries to the Muskeg River), Steepbank River and McLean Creek; Shipyard Lake; and acid sensitive lakes.

The 1999 program consisted of three main components:

1) water and sediment quality in rivers and wetlands;
2) fish populations in rivers; and
3) water quality in acid sensitive lakes.

A Quality Assurance / Quality Control sampling program for water and sediment was developed in partnership with Alberta Environment. This field program focussed on the Muskeg River and Shipyard Lake.

The scope of the 1999 benthic invertebrate monitoring program included development of a study design for the Athabasca River and tributaries, and sampling of McLean Creek. Benthos in McLean Creek could not be sampled in fall 1999 due to low flows. The benthic study design is currently being developed and will be included in the 2000 report.

RAMP also has the flexibility to address issues that are not part of the core-monitoring program. In 1999, these issues were:

- assessing the potential to include mussels as one of the core monitoring components; and
- addressing community concerns about external abnormalities (e.g., tumours) in fish.

## *Water and Sediment Quality*

In 1999, RAMP continued to analyze the same set of water quality and sediment quality parameters analyzed in 1998. The scope of the 1999 water quality survey was:

- to resample Wapasu Creek and the mouths of the Steepbank and Muskeg rivers and Muskeg Creek, which were sampled in 1998;
- to sample the mouths of McLean Creek and tributaries to the Muskeg River;
- to expand seasonal sampling and toxicity testing in the Muskeg River;
- to monitor seasonal water temperatures in the Muskeg River, McLean Creek and the Alsands Drain; and
- to sample the Athabasca River far downstream of current oil sands developments (Athabasca River near Embarras and the Athabasca River Delta).

The scope of the sediment quality survey was to resample the mouth of the Muskeg River, and to sample the Athabasca Delta and the mouth of McLean Creek. The scope also included development of a sediment monitoring program for the Athabasca, Muskeg and Steepbank rivers, which will be provided in the 2000 report.

In 1999, winter water quality in the Athabasca River near the Embarras River and summer water quality in the Athabasca River Delta were generally consistent with historical data with a few exceptions. In 1999, total dissolved solids (TDS), total aluminum, total zinc and total barium concentrations were higher in the delta than in recent sampling events. Total aluminum, total zinc and pH were higher in the Athabasca River near Embarras in 1999. Total aluminum and total iron concentrations exceeded water quality guidelines for the protection of aquatic life, as they have in the past. Water from both locations was non-toxic (as defined by Microtox® testing) and contained non-detectable levels of naphthenic acids. Sediments from the Athabasca River Delta were found to be chronically toxic to three species of invertebrates. Methyl naphthalene was the only element present in concentrations exceeding the Canadian Sediment Quality Guidelines.

The water quality of the Athabasca River tributaries sampled in 1999 was generally consistent with historical trends. As in previous years, naphthenic acids were detected in the Muskeg River and the Alsands Drain. Naphthenic acids were detected for the first time in McLean and Muskeg creeks. Although chronic aquatic toxicity was again observed in the upper Muskeg River, water samples from the lower Muskeg River and other tributaries were non-toxic (as defined by Microtox® testing) in 1999. TDS and total aluminum concentrations were generally higher at more sampling locations than in previous years. High sulphate levels were also observed in water samples from the lower Muskeg River in 1999.

Sediment quality at the mouth of the Muskeg River in 1999 was generally consistent with data from 1997 and 1998. In 1999, PAH concentrations in the upper Muskeg River were similar to concentrations at the river mouth, with the exception of C2-substituted naphthalene, methyl benzo(a)pyrene, methyl dibenzothiophene and methyl fluorene; these substances were present at higher concentrations in the upper Muskeg River. Sediments from the mouth of McLean Creek were found to be chronically toxic to several species of invertebrates. They generally contained higher total metal and PAH concentrations than sediments from the Muskeg River. Sediment PAH concentrations in McLean Creek were also higher than PAH concentrations observed in sediments from the Athabasca River Delta.

## *Fish Populations*

In 1999, fisheries monitoring on the Athabasca River consisted of two components: spring fish inventory to document the presence and abundance of fish species within the Oil Sands Region and sentinel species monitoring.

Although reduced in scope, the spring 1999 fish inventory was a continuation of work done in previous years to evaluate possible year-to-year changes in the occurrence and abundance of the dominant fish species (i.e., walleye, lake whitefish, goldeye and longnose sucker). In general, species composition and relative abundance of fishes in the Athabasca River were similar to that observed in the spring of 1998. Walleye were captured in sufficient numbers to evaluate length and age distributions, and size-at-age over time. Length and age distributions remained consistent over time, although size-at-age showed greater variability. The change in size-at-age of walleye collected in 1999 suggests a possible decrease in food availability. The abnormally low water levels in the Athabasca River in 1998 and 1999 may have been related to this decrease.

Sentinel species monitoring was initiated in 1998 using longnose sucker. Due to concerns regarding the high mobility of longnose sucker, a small-bodied fish species that exhibits a smaller home range and reduced potential for large-scale movement was chosen. Reduced movement made it possible to select a reference site within the Oil Sands Region, as well as exposed sites in close proximity to mining activities. Using small-bodied fish species may facilitate the separation of potential effects of oil sands development from other influences related to the natural oil sands formation, the town of Fort McMurray and other upstream development.

The sentinel species selected for the Athabasca River was trout-perch. There was no evidence indicating that trout-perch downstream of Suncor's discharge were different from reference fish. With the exception of a possible reduction in energy storage, trout-perch downstream of the Muskeg River were also similar to fish collected below Suncor's discharge and from the reference site.

Tributaries to the Athabasca River are included in the monitoring program because they provide important habitat for many fish species. A small-bodied fish species, slimy sculpin, was selected as the sentinel species for the Muskeg and Steepbank rivers because it is resident in the tributaries throughout the year and it is less mobile, relative to larger species. Sculpin collected from a reference site on the upper Steepbank River were used to evaluate the performance of sculpin collected from a site on the Muskeg River downstream of mining development and a site on the lower portion of the Steepbank River adjacent to mining activity.

In general, sculpin from the Muskeg River were older than reference fish and had reduced body weight, condition, gonad weight and liver weight suggesting a response to lower food availability relative to the reference site. In addition, parasitism was observed on sculpin from the Muskeg River. Low water levels in this section of the river may have affected the availability and quality of instream habitat. Sculpin from the lower Steepbank River were older and larger (length, weight) than reference fish, but few other differences in whole-organism characteristics were observed.

The observed responses of slimy sculpin from the Muskeg River and lower Steepbank River need to be confirmed over time before definitive conclusions can be made. Future monitoring should include more detailed analysis of habitat characteristics at each site. As well, additional reference sites are needed to ensure the full range of natural variability in fish characteristics within the Oil Sands Region is accurately defined.

Power analysis of the trout-perch data confirmed that sample sizes were adequate to detect differences in all fish parameters had they existed. Power analysis also confirmed that sample sizes of sculpin were adequate to detect site differences in most parameters; however, more effort will be needed to collect higher numbers of males. In addition, improved techniques for ageing both trout-perch and slimy sculpin would increase confidence in age estimates.

## *Water Quality in Acid Sensitive Lakes*

In 1999, a long-term acidification monitoring network was established, which forms a new component of RAMP. The objective of this component is to monitor lake water chemistry as an early-warning indicator of excessive acidic deposition. During 1999, the 32 lakes forming the network were selected from a large number of candidate lakes sampled previously by AENV. A field program was implemented in July and August, 1999, to collect baseline water chemistry data for the selected lakes and to verify that the lake selection criteria were satisfied by the lakes.

The 1999 data indicate that the 32 lakes provided a reasonable cross-section of the wide range of water chemistry documented by previous water quality surveys in north-eastern Alberta. Most lakes were moderately to highly acid-sensitive and naturally acidic (with $pH<7$). There was a strong relationship between total alkalinity and pH. A number of other parameters (colour, conductivity and most anions and cations) were also correlated with pH. Colour and dissolved organic carbon concentration spanned wide ranges in the study lakes, from clear water to brown water. The 32 lakes also varied widely in nutrient and chlorophyll *a* concentrations and encompassed nearly the full range in lake trophic status in the province, from oligotrophic to hyper-eutrophic.

The lakes sampled in 1999 generally satisfied the selection criteria developed for this program and are thus suitable for continued monitoring under RAMP. Thus, no major modifications are required to this component in the near-future, though it will continue to evolve as new information and needs dictate.

## ACKNOWLEDGEMENTS

This report documents the results of the third year of the Oil Sands Regional Aquatics Monitoring Program (RAMP). Funding and in-kind support was provided by Suncor Energy Inc., Oil Sands, Albian Sands (Shell Canada Ltd.), Syncrude Canada Ltd., Mobil Oil Canada Properties Ltd. and Petro-Canada Resources.

Ian Mackenzie was the Chairperson of RAMP, Ken Shipley was the Vice Chairperson and John Gulley was the Secretary during 1999. The Golder Associates Ltd. (Golder) Project Manager was Marie Lagimodiere and the Project Director was John Gulley.

RAMP is a multi-stakeholder program, and benefits from the active participation of its member organizations. Several positive collaborations were achieved in 1999 and are reviewed below.

Winter water quality sampling was done by a crew consisting of Chris Bjornson (Golder), Jeff Brezenski (Golder), Charlie Voyager (Athabasca Chipewyan First Nation), Joe Marcel (Athabasca Chipewyan First Nation) and Basil Macdonald (Fort McKay).

Water quality sampling in spring was done by Jeff Brezenski (Golder), Bertha Ganter (Fort McKay Industry Relations Corporation [IRC]) and Charlie Voyager (Athabasca Chipewyan First Nation).

Alberta Environment (AENV) and RAMP collaborated on Muskeg River water quality sampling in summer and fall. Joint sampling of water and sediment quality was done as part of the QA/QC program and to compare results from different laboratories. The Alberta Research Council, Vegreville analyzed samples as part of the inter-quality assurance. Tony Calverley (Golder) and Bertha Ganter (Fort McKay IRC) worked with Mike Bilyk (AENV) and Morna Hussey (AENV) in the summer to conducted water quality sampling.

AENV contributed helicopter time for sampling on the upper Muskeg River during fall. AENV technicians involved in Muskeg River sampling were Mike Bilyk and Morna Hussey. They worked with Jeff Brezenski (Golder) to collect water samples from the Muskeg River and its tributaries. Jeff Brezenski and Russell Cardinal (Fort McKay) conducted fall water sampling in Shipyard Lake.

Marlene Evans, Jason Inkster and Charity Beres (Environment Canada, National Water Research Institute, Saskatoon), and Jumbo Fraser (Mikisew Cree First Nation) collected water and sediment samples for RAMP from the Athabasca

Delta. Marlene Evans also conducted polycyclic aromatic hydrocarbon (PAH) analysis on sediment samples from Kearl Lake and the upper Muskeg River.

Robert Grandjambe (Mikisew Creek First Nation) collected mussels from the Athabasca River Delta.

Mark Spafford (Alberta Pacific Forest Industries Inc. [Al-Pac]) conducted a fish health assessment training session in Fort Chipewyan. Four members of the Athabasca Chipewyan First Nation participated in the training session.

Benthic invertebrate sampling and reconnaissance was done by Zsolt Kovats (Golder), Russell Cardinal (Fort McKay) and Basil Macdonald (Fort McKay).

Terry Van Meer, Norm Jelfs and Melanie Ezekiel from Syncrude Canada Ltd. conducted the spring fisheries inventory on the Athabasca River.

The fall fisheries program was a collaborative effort between RAMP and Environment Canada staff who are working on the Panel on Energy Research and Development (PERD) program. Terry Van Meer, Norm Jelfs and Melanie Ezekiel from Syncrude Canada Ltd., and Wade Gibbons and Tony Calverley from Golder participated in fish collection on the Athabasca River. Joanne Parrott, Maria Colavecchia, and Gerald Tetreault from Environment Canada, and Wade Gibbons, Tony Calverley and Melanie Ezekiel sampled the tributaries and conducted fish biomarking. On-site laboratory space was provided by Suncor Energy Inc.

The acid sensitive lake monitoring program was developed and implemented through a joint effort of RAMP, AENV and Al-Pac. RAMP provided funds for field and analytical expenses. Dorothy Kelker from Al-Pac conducted the field program. AENV provided the data for the acid sensitive lakes section of the 1999 report.

The Regional Climatic and Hydrologic Monitoring Program provided the climate and hydrology information.

Twenty-five grade 7 and 8 students from Fort Chipewyan Community School, Fort McKay School, Westview School and Dickinsfield School participated in a contest to design a logo for RAMP. Syncrude provided a one-day educational aquatic field trip as a prize for winners of the logo contest.

The following Golder team members prepared sections of this report:

| | |
|---|---|
| Introduction | Marie Lagimodiere<br>John Gulley (technical review) |
| Climate and Hydrology Summary | Nathan Schmidt<br>Dejiang Long (technical review) |
| Quality Assurance/Quality Control | Tanis Dirks<br>Pat Tones (technical review) |
| Water and Sediment Quality | J.P. Bechtold (task manager)<br>Tanis Dirks<br>Mark Digel (technical review) |
| Fisheries | Wade Gibbons (task manager)<br>Scott Stoklosar<br>Dave Fernet (technical review)<br>Stella Swanson (technical review) |

The Acid Sensitive Lakes section was prepared by Zsolt Kovats (Golder) and reviewed by Dave Trew (AENV) and Brian Kemper (Kemper[2] & Associates). Pat Tones provided senior editorial review and Carole Collins (Golder) formatted the report.

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# 1 INTRODUCTION

## 1.1 OVERVIEW

The northeastern Alberta area is experiencing a large increase in oil sands development as well as other developments. Such growth highlights the need to integrate environmental monitoring activities so that potential cumulative effects can be identified and addressed. The coordination of monitoring data collection results in the development of a more complete, cost-effective database that is used by oil sands operators for their environmental management programs and for assessments of proposed oil sands developments.

With respect to the aquatic environment, monitoring data are collected through the Oil Sands Regional Aquatics Monitoring Program (RAMP). RAMP is a multi-stakeholder initiative, currently funded by Suncor Energy Inc., Oil Sands (Suncor), Syncrude Canada Ltd. (Syncrude), Albian Sands [Shell Canada Ltd. (Shell)] and Mobil Oil Canada Properties (Mobil).

The mandate of RAMP, as defined by its multi-stakeholder Steering Committee, is to determine, evaluate and communicate the state of the aquatic environment in the Athabasca 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.

The objectives of RAMP are to:

- monitor aquatic environments in the oil sands area to detect and assess cumulative effects and regional trends;
- collect baseline and historical data to characterize variability in the oil sands area;
- collect data against which predictions contained in environmental impact assessments (EIAs) can be verified;
- collect data that satisfies the monitoring required by regulatory approvals of oil sands developments;
- recognize and incorporate traditional knowledge into the monitoring and assessment activities;
- communicate monitoring activities, results and recommendations to communities in the Regional Municipality of Wood Buffalo, regulatory agencies, environmental committees/organizations and other interested parties; and

- review and adjust the program to reflect monitoring results, technological advances and community concerns.

RAMP has been in place since 1997; hence, three years of sampling have been completed. The focus of monitoring has been on the Athabasca, Steepbank and Muskeg rivers, wetlands occurring in the vicinity of current and proposed oil sands developments and, more recently, acid-sensitive lakes in northeastern Alberta. Sampling conducted to date includes surveys of water quality, sediment quality, benthic invertebrates, fish and wetlands vegetation. In addition, a radiotelemetry study of walleye (*Stizostedion vitreum*) and lake whitefish (*Coregonus clupeaformis*) was conducted in 1997 and 1998.

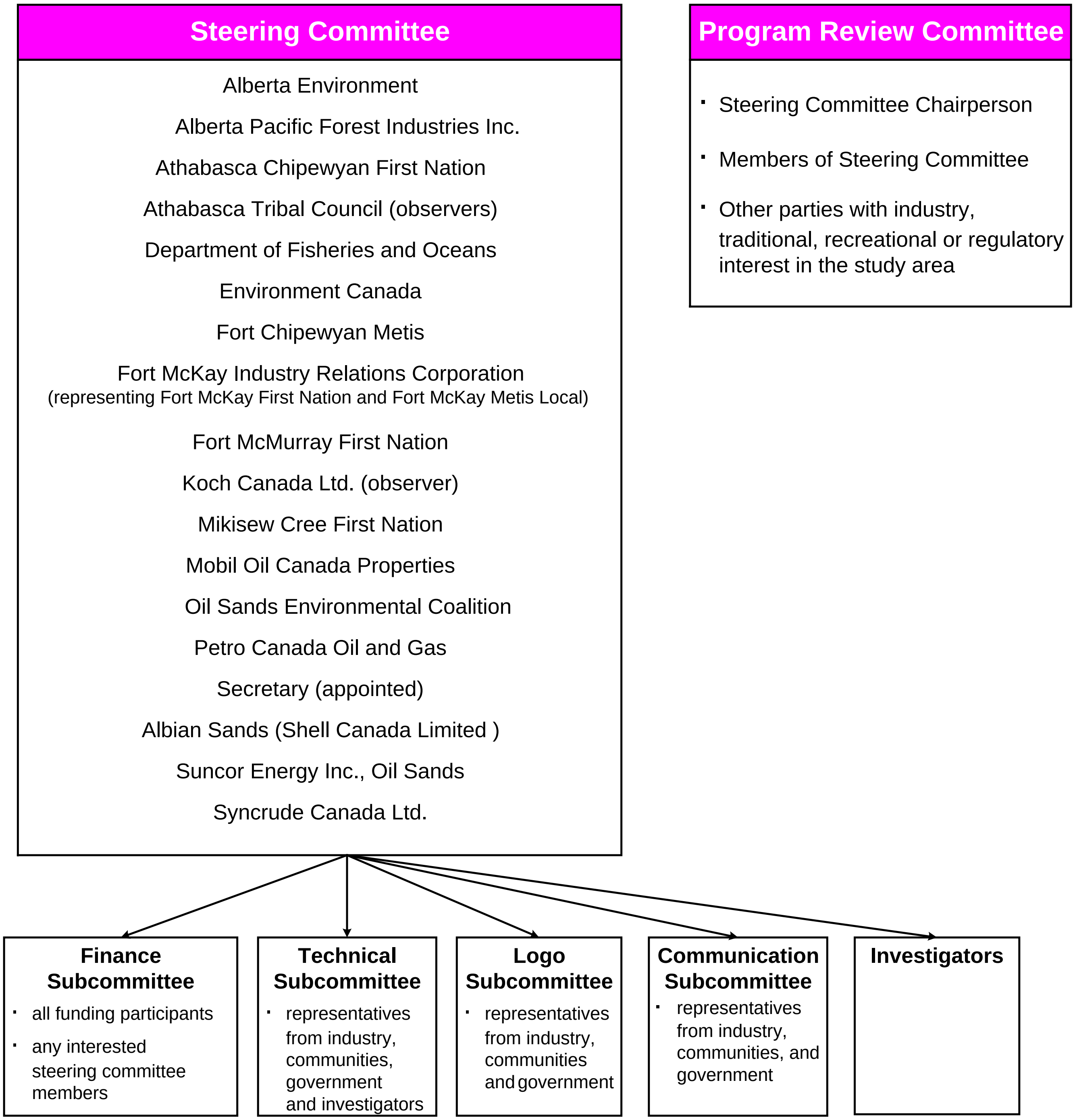
This report describes both the organizational framework and administrative activities of RAMP, and the results of the 1999 field program. The framework and administrative activities are described in Section 1 and the 1999 monitoring program is described in Sections 2 to 9. The results describe data collected for RAMP but do not generally include data from other sampling programs in the region.

## 1.2 1999 STEERING COMMITTEE ACTIVITIES

The Steering Committee is the decision making body of RAMP. It consists of funding and non-funding members. Membership on the Steering Committee currently consists of industry, regulators and communities (Figure 1.1). The Steering Committee has the following functions:

- to prioritize projects within the program objectives to maximize use of available resources;
- to review project progress against budget and schedule;
- to review project results for relevance to program objectives; and
- to communicate results and solicit input from interested parties.

**Figure 1.1 Oil Sands Regional Aquatics Monitoring Program Organizational Structure, December 1999**



The RAMP Steering Committee held five business meetings in 1999 (January 27, March 4, May 18, September 13 and December 7). All Steering Committee meetings were held in Fort McMurray. Highlights of 1999 include finalizing the Terms of Reference, holding community meetings in Fort Chipewyan and Fort McKay, achieving significant progress towards development of a core monitoring program, designing a logo, issuing the first RAMP newsletter and developing a draft communication plan.

Terms of Reference (TOR) for RAMP were finalized in March 1999. The TOR addresses topics including committee structure, representatives, meetings, decision-making and reporting requirements. The TOR outlines the structure of the organization, including membership and roles of the Steering Committee and Program Review Committee, as well as any other committees or subcommittees that may be formed. The organizational structure and membership of RAMP as of December 1999 is presented in Figure 1.1.

The Steering Committee creates subcommittees to conduct specific tasks, when necessary. In 1999 there were four subcommittees of RAMP: finance, technical, logo and communication.

The Finance Subcommittee consists of funding members and any other interested members of the Steering Committee. This subcommittee develops annual budgets and funding formulas. The Finance Subcommittee met in March to determine funding formulas for the year.

The purpose of the Technical Subcommittee is to prepare an annual monitoring program for review and approval by the Steering Committee. Members of the Technical Subcommittee met several times in the latter part of December 1998 and in early 1999 to develop a framework for a core monitoring program for RAMP and to scope the 1999 field program. As well, the Technical Subcommittee held a workshop on June 16 to refine the fall sampling plan for 1999.

A Logo Subcommittee was formed to develop a logo for RAMP. The subcommittee held a logo design contest for grades seven and eight students in four schools. The participating schools were: Athabasca Delta Community School (Fort Chipewyan), Westview School (Fort McMurray), Dickinsfield School (Fort McMurray) and Fort McKay School. Members of the logo committee visited each of the participating schools to describe what RAMP is and talk about the contest. The participating students were to design logos with an aquatic theme and depict how and why "water resources" are important from a First Nation, Metis Local, local community or personal perspective.

Twenty-five students took part in the contest. The RAMP Steering Committee selected a winning logo from each of the schools that best reflected the contest theme. From these four logos, a grand prize winner was selected. The winning logo was designed by a student from Westview School. The prize for the winning logo was $100 and an educational field trip. The three runners-up were also given a one-day educational aquatic field trip. All 25 students who participated in the contest received a RAMP T-shirt.

A Communication Subcommittee was formed to develop a RAMP communication implementation plan. The subcommittee consists of members from aboriginal communities, industry and government. Its purpose is to facilitate communication of RAMP's activities to its members and to communities in the Regional Municipality of Wood Buffalo, regulatory agencies, environmental committees/organizations and other interested parties. Activities of the Communication Subcommittee are described in Section 1.2.1.

### 1.2.1 Communication

One of the objectives of RAMP is to communicate monitoring activities, results and recommendations to its members and other interested parties. Other objectives of RAMP that involve communication are: satisfying regulatory requirements; reviewing and adjusting the program to reflect monitoring results, technological advances and community concerns; and incorporating traditional knowledge. Hence, RAMP needs to communicate to a variety of audiences in a number of different ways.

The Communication Subcommittee is developing a communication implementation plan. It outlines the means of communication, audiences, time frames for implementation, responsibilities and objectives to be achieved. There are four main means of communication about RAMP: 1) an annual monitoring report; 2) an annual summary report; 3) a newsletter; and 4) community meetings.

#### 1.2.1.1 Annual Monitoring Report

The annual monitoring report is this report and it describes the detailed monitoring activities and results. It is submitted to Alberta Environment to fulfill part of the regulatory requirements for a number of the industry participants in RAMP. It also provides the information on which to make decisions about mitigation and future monitoring directions. There have been RAMP annual reports for monitoring activities in 1997 (Golder 1998a), 1998 (Golder 1999a) and 1999 (the current report).

### 1.2.1.2 Annual Summary Report

The first annual summary report will be prepared in 2000. It will provide information about the current state of regional aquatic ecosystems, based on information collected as part of RAMP and describe the work being done by RAMP.

### 1.2.1.3 Newsletter

The first RAMP newsletter was issued in September 1999. Topics in the newsletter included an overview of RAMP, what it wants to achieve and what is currently being monitored. There were also discussions about how RAMP is related to programs such as the Regional Sustainable Development Strategy, the Regional Climatic and Hydrologic Monitoring Program, and existing federal and provincial programs. Community meetings and ways to provide feedback to RAMP were also highlighted. The logo contest results were described and the winning logo and one of the runner-up logos were included in the newsletter.

The RAMP newsletter is currently distributed to all its member organizations as well as the following:

- Fort McMurray Library;
- Oil Sands Interpretive Centre;
- Alberta Energy and Utilities Board (EUB);
- Wood Buffalo Environmental Association (WBEA); and
- Alberta Environment's Regional Sustainable Development Strategy (RSDS).

Any person or organization interested in the newsletter can be added to the mailing list. RAMP plans to produce two newsletters per year.

### 1.2.1.4 Community Meetings

Two community meetings were held in 1999, one in Fort Chipewyan and one in Fort McKay. The schedule for future community meetings will be determined by the Steering Committee in consultation with representatives of each community.

#### *Fort Chipewyan*

The Fort Chipewyan community meeting was held on the evening of May 17 at the community hall in Fort Chipewyan. About 20 Fort Chipewyan residents attended the meeting. RAMP representatives from Alberta Environment

(AENV), Mobil, Suncor, Department of Fisheries and Oceans (DFO), Environment Canada, Alberta-Pacific Forest Industries Inc. (Al-Pac) and Fort McKay Industries Relations Corporation (IRC) attended the meeting.

### *Fort McKay*

Two Fort McKay community meetings were held in Fort McKay on December 8 in the community hall. Thirty-one elders attended a lunchtime meeting and 9 community members attended an evening meeting. Fort McKay Industry Relations Corporation (IRC) facilitated the meeting.

RAMP representatives included Mobil, Syncrude, Suncor, Shell, Koch, Petro-Canada, Al-Pac, DFO, Environment Canada, AENV and the Athabasca Tribal Council (ATC). As well as the RAMP members, additional representatives from the federal and provincial government attended to provide information on related water initiatives. Additional AENV representatives included fisheries, hydrology and forestry staff from the regional offices. There were also federal representatives from the Northern River Basins Program (NRBS) that was completed in 1996 and from the Northern Rivers Ecosystem Initiative (NREI), which is a research program designed to follow up on NRBS recommendations.

## 1.2.2 Program Review Committee

Membership in the Program Review Committee typically consists of parties with an industrial, recreational or regulatory interest in the RAMP study area. The Program Review Committee has the following functions:

- to evaluate the program for technical merit and for relevance to the needs of the members; and
- to facilitate communication and linkage with other regional environmental initiatives.

The Steering Committee has agreed to hold the first meeting of the Program Review Committee in 2000.

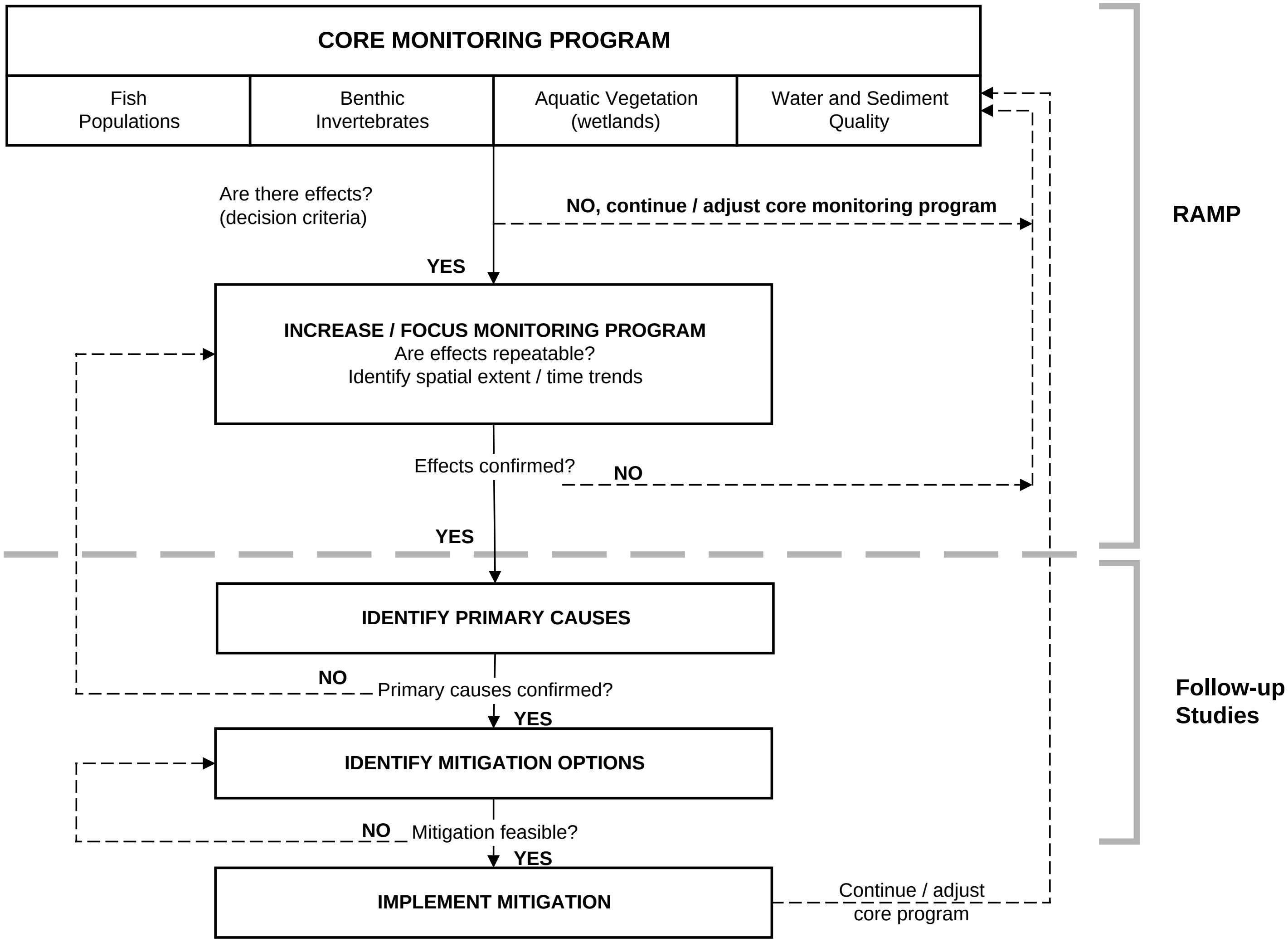
## 1.2.3 Core Program

The RAMP Technical Subcommittee is in the process of developing a core monitoring program for review by the Steering Committee. The Technical Subcommittee has provided scientific input for the core program and for the 1999 sampling program. In addition to the Technical Subcommittee, scientists from member organizations (e.g., AENV, DFO) have provided input into the design of the core program.

The core program outlines the main components of the program for each waterbody (i.e., water and sediment quality, fish populations, benthic invertebrates and wetlands vegetation) to provide consistency to the monitoring. It also defines sampling locations and frequencies. However, the program includes flexibility to allow for modification of sampling as issues arise.

If core monitoring results indicate a potential problem, further work will be done to determine if data on the effects are repeatable, and to further characterize the extent of the effect (Figure 1.2). If changes in the aquatic environment are confirmed, then causes will be investigated and mitigation options identified. Once mitigation is implemented, monitoring will continue to ensure that the expected improvement is attained.

**Figure 1.2 Core Monitoring Program**




(modified from Hodson et al. 1996).

# 2 1999 MONITORING PROGRAM

## 2.1 APPROACH

Historically, water quality monitoring and comparison to guideline criteria (e.g., chemical concentrations, toxicity testing) have been used to evaluate the potential impacts of human activities on aquatic systems. It is also beneficial to monitor biological communities that integrate the effects of complex and varied stressors on receptors (e.g., fish, benthic invertebrates, wetlands vegetation) to ensure there have been no adverse changes in the aquatic ecosystem due to human activities.

A receptor-oriented system 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 1999 monitoring program was a continuation of long-term monitoring that began in 1997. It consisted of three main components:

- Water and sediment quality in rivers and some wetlands which are indicators of habitat quality and potential chemical exposure of fish and invertebrates. Water and sediment quality are assessed by chemical analyses and toxicity bioassays.
- Fish populations in rivers which are bioindicators of ecosystem integrity. Emphasis is on regional fish resources and sentinel species.
- Water quality in acid sensitive lakes which is used as an early 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 potentially affected by development activities: 1) Athabasca River; 2) tributaries of the Athabasca River (i.e., Muskeg River and Steepbank River); 3) lakes and wetlands adjacent to developments; and 4) acid sensitive lakes.

Table 2.1 presents a summary of all geographic areas and aquatic components sampled by RAMP in 1999 and in previous years. Details on study design, sampling locations and methods are described in Section 3.

## Table 2.1 Overview of RAMP Sampling from 1997 to 1999

| Waterbody and Component | Sampling | | | | | |
|---|---|---|---|---|---|---|
| | 1997 | 1998 | 1999 | | | |
| | | | Winter | Spring | Summer | Fall |
| **Athabasca River** | | | | | | |
| water quality | ● | ● | ● | | | |
| sediment quality | ● | ● | | | | |
| benthic invertebrates | ● | | | | | |
| sentinel fish monitoring (longnose sucker) | | ● | | | | |
| sentinel fish monitoring (trout-perch) | | | | | | ● |
| fish inventory | ● | ● | | | | ● |
| fish tissue | | ● | | | | |
| **Athabasca River Delta** | | | | | | |
| water quality | | | | | ● | |
| sediment quality | | | | | ● | |
| mussels (sampling for species identification) | | | | | ● | |
| **Muskeg River** | | | | | | |
| water quality | ● | ● | ● | ● | ● | ● |
| toxicity testing | | ● | ● | ● | ● | ● |
| sediment quality | ● | ● | | | | ● |
| temperature (continuous during open water) | | | | ● | ● | ● |
| benthic invertebrates | | ● | | | | |
| sentinel fish monitoring (slimy sculpin) | | | | | | ● |
| fish inventory | ● | | | | | ● |
| fish fence | | ● | | | | |
| **Muskeg River Tributaries** | | | | | | |
| water quality | | ● | ● | | | ● |
| sediment quality (Jackpine Creek) | ● | | | | | |
| **Kearl Lake** | | | | | | |
| water quality | | ● | | | | |
| vegetation | ● | ● | | | | |
| **Isadore's Lake** | | | | | | |
| water quality | | ● | | | | |
| vegetation | ● | ● | | | | |
| **Steepbank River** | | | | | | |
| water quality | ● | ● | ● | | | |
| sediment quality | ● | ● | | | | |
| benthic invertebrates | | ● | | | | |
| fish inventory | ● | | | | | ● |
| sentinel fish monitoring (slimy sculpin) | | | | | | ● |
| **Shipyard Lake** | | | | | | |
| vegetation | ● | ● | | | | |
| water quality | | ● | | ● | ● | ● |
| **McLean Creek** | | | | | | |
| water quality | | | | | | ● |
| sediment quality | | | | | | ● |
| temperature (continuous during open water) | | | | | ● | ● |

| Waterbody and Component | Sampling | | | | | |
|---|---|---|---|---|---|---|
| | 1997 | 1998 | 1999 | | | |
| | | | Winter | Spring | Summer | Fall |
| **Mackay River** | | | | | | |
| water quality | | ● | | | | |
| sediment quality | ● | ● | | | | |
| benthic invertebrates | | ● | | | | |
| fish inventory | ● | | | | | |
| **Tar River** | | | | | | |
| water quality | | ● | | | | |
| sediment quality | | ● | | | | |
| **Ells River** | | | | | | |
| water quality | | ● | | | | |
| sediment quality | | ● | | | | |
| sentinel fish monitoring (evaluated as reference area) | | | | | | ● |
| **Poplar Creek** | | | | | | |
| sediment quality | ● | | | | | |
| **Acid Sensitive Lakes** | | | | | | |
| water quality | | | | | ● | |

### 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 over time may indicate chemical inputs from point and non-point sources. Measured concentrations of chemicals can be compared with water and sediment quality guidelines designed to protect aquatic life. Water and sediment quality surveys also provide valuable supporting data to interpret the results of biological surveys.

The scope of the 1999 water quality surveys was:

- to continue to monitor the same set of water quality parameters analyzed in 1998;
- to resample the mouths of the Steepbank and Muskeg rivers;
- to resample Wapasu and Muskeg creeks;
- to expand seasonal sampling and toxicity testing in the Muskeg River;
- to sample the mouths of tributaries to the Muskeg River (Stanley, Shelley and Jackpine creeks, and the Alsands drain);
- to sample the mouth of McLean Creek;
- to monitor seasonal water temperatures in the Muskeg River, McLean Creek and the Alsands drain; and

- to sample the Athabasca River near the Embarras River and the Athabasca River Delta, far downstream of current oil sands developments.

The scope of the 1999 sediment quality survey was:

- to continue to monitor the same set of sediment quality parameters analyzed in 1998, including sediment toxicity (i.e., bioassays using benthic invertebrates: *Chironomus tentans*, *Hyalella azteca* and *Lumbriculus variegatus*);
- to resample the mouth of the Muskeg River;
- to sample the mouth of McLean Creek;
- to sample the Athabasca River Delta; and
- to develop a sediment monitoring program for the Athabasca, Muskeg and Steepbank rivers.

### 2.1.2 Benthic Invertebrate Community

Benthic invertebrate (benthos) monitoring is an essential component of aquatic monitoring programs. Benthic invertebrates form communities that reflect the physical and chemical characteristics of their habitat. They also constitute a food source for many fish species, making them an important feature of fish habitat. Therefore, benthic invertebrate monitoring complements surveys of fish populations, and water and sediment quality, by providing an ecological indicator of the environmental quality. As well, benthic invertebrates are relatively sedentary, and hence are useful in examining spatial trends within a watercourse.

The scope of the 1999 benthic invertebrate program was:

- to collect benthos samples from McLean Creek (to further refine baseline information); and
- to develop a study design for the Athabasca River and tributaries based on data from RAMP 1997 and 1998 benthic surveys, previous surveys in the area, a literature review and consultation with scientific experts.

Sampling of benthos in McLean Creek was attempted in fall 1999. Erosional sites, which are typical habitat in McLean Creek could not be sampled due to low flows. One sample was collected in a depositional site at the mouth. However, this sample was not analyzed, as it was not considered to be representative of the benthic habitat in the creek.

The RAMP Technical Subcommittee is currently developing a benthic invertebrate study design that will be included in the 2000 report. Hence, there is no further discussion of benthic invertebrates in this report.

### 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 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 identified as important to subsistence, commercial and sport fisheries 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 the 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 of the fisheries component of the 1999 monitoring program was discussed during the RAMP Technical Subcommittee meeting on June 16, 1999. At this time, it was decided that RAMP should continue monitoring the mainstem Athabasca River in 1999, and also initiate fisheries monitoring on the Muskeg and Steepbank rivers. In both instances, sentinel fish species would be used to assess potential effects of stressors (e.g., industrial development) on fish populations. Briefly, the performance (e.g., growth, condition, reproductive parameters) of a sentinel species inhabiting a particular site of interest (e.g., Oil Sands Region) is characterized relative to reference and/or historical performance data. The underlying premise of the approach is that the status of the sentinel species is a reflection of the overall condition of the aquatic environment in which the fish resides (Munkittrick 1992).

#### 2.1.3.1 Athabasca River

Fisheries monitoring on the Athabasca River consisted of two components:

- spring fish inventory; and
- sentinel species monitoring.

Fish inventory surveys are conducted to document presence and relative abundance of fish species within the Oil Sands Region of the Athabasca River. Particular emphasis is placed on walleye, lake whitefish, goldeye and longnose sucker. The Muskeg River Mine Environmental Impact Assessment (EIA) (Shell 1997) and Project Millennium EIA (Suncor 1998) identified these species as Key Indicator Resources (KIRs) for the Athabasca River. Although reduced in scope, the 1999 fish inventory was a continuation of work done in previous years to evaluate possible year-to-year changes in the occurrence and abundance of dominate fish species (i.e., KIR species) within the Oil Sands Region. Data collected over time will be valuable in documenting potential changes in the fish community resident in the Oil Sands Region or utilizing the region on a seasonal basis.

Sentinel species monitoring conducted in 1999 represented a modification to the approach initiated in 1998 (Golder 1999a). Longnose sucker has been used as a sentinel species for monitoring the ecological integrity of the Athabasca River. This species was identified as a KIR species for the Athabasca River in several recent EIAs, and was also used as a sentinel species for pulp mill environmental effects monitoring (EEM) programs within the Athabasca River basin. However, concerns regarding the mobility of longnose sucker (or other large fish species) and therefore the amount of exposure to conditions within the Oil Sands Region have not been fully resolved. Monitoring a second sentinel species was recommended. The Technical Subcommittee decided that RAMP would initiate monitoring on a small-bodied fish species (i.e, trout-perch) that exhibits a smaller home range and reduced potential for large-scale movement (Minns 1995).

### 2.1.3.2 Muskeg and Steepbank Rivers

Tributaries of the Athabasca River within the Oil Sands Region are included in the monitoring program because they provide important habitat for many fish species, and because some, such as the Muskeg and Steepbank rivers, may be influenced by oil sands development. Fish communities within these rivers could be affected by potential changes in water quality and flow associated with mining activities. In addition to effects on resident species, tributaries have the potential to affect fish populations from the Athabasca River because these areas are important for critical life stages such as spawning, rearing and summer feeding. The Muskeg and Steepbank rivers have been identified as providing important habitats for walleye, Arctic grayling, northern pike, longnose sucker and white sucker (Bond and Machniak 1979; Machniak and Bond 1979).

Sentinel species monitoring on the Muskeg and Steepbank rivers focused on small-bodied fish species. Small fish species have been advocated as sentinel species for these rivers because the forage fish guild has been identified as a KIR for both systems, and they are resident to the tributaries throughout the year (i.e., they receive maximum exposure). Small-bodied species are typically less mobile relative to larger species (Minns 1995), such as pike or sucker, making it easier to select distinct reference and exposure sampling sites in small river systems. The RAMP Technical Subcommittee recommended that tributary monitoring using small-bodied sentinel species (i.e., slimy sculpin) commence in the fall 1999.

### 2.1.4 Acid Sensitive Lakes

In 1999 it was proposed that lakes representative of the wide range of water chemistry in north-eastern Alberta be selected for a long-term acidification monitoring network under RAMP. The objective of this new RAMP component is to monitor lake chemistry as an early-warning indicator of excessive acidic deposition. Acid-sensitive lakes are expected to show changes in their buffering capacities before soils or vegetation can provide a clear indication that acid limits are being reached. The program was designed as a partnership between RAMP, Al-Pac and Alberta Environment (AENV).

Recent Environmental Impact Assessments (EIAs) for oil sands developments indicate that although $SO_2$ emissions will remain relatively constant in this region, $NO_x$ emissions will increase as expansion progresses. These emissions can lead to the formation of acidic deposition, which may eventually result in acidification of poorly buffered lakes. Decreases in pH (i.e., increases in $H^+$ concentration) may have direct biological impacts, as well as indirect effects through the mobilization of other chemical constituents, notably metals.

Most of Alberta's lakes and streams are well buffered against acidification because they are situated on carbonate-rich bedrock and soils. However, a number of vulnerable waterbodies (i.e., those with low alkalinity) have been identified in certain of areas of the province. Most of these lakes are located in the northern uplands (Birch Mountains, Caribou Mountains, Muskeg Mountain Upland) and the Canadian Shield eco-regions of north-eastern Alberta (Saffran and Trew 1996). Some of these sensitive lakes are mineral systems in which alkalinity, a measure of inorganic buffering generated by the carbonate-bicarbonate-carbonic acid equilibrium, is directly linked to the acid neutralizing capacity (ANC). Other northern upland lakes classified as sensitive are highly coloured (i.e., brown water) systems located in watersheds dominated by organic soils. These lakes are often acidified by organic acids originating from peatland vegetation in their watersheds. Their buffering mechanisms may include organic substances and certain metal species. The presence of colour (brown water) is not necessarily indicative of organically buffered systems, since some lakes in the region can be brown coloured but are heavily minerally buffered.

The 1999 field program represented the initial effort to establish the RAMP network. In addition to the above overall objective, specific objectives were to verify that the selection criteria have been met and to establish a baseline data set for the monitoring network, beyond the historical data that were used for the selection of candidate lakes.

### 2.1.5 Specific Issues

While the RAMP program focuses on a core set of monitoring components, it also has the flexibility to adjust the program to reflect monitoring results, technological advances or community concerns. In 1999, two specific issues were addressed that are not currently part of the core monitoring program. These issues were:

- assessing the potential to include mussels as one of the core monitoring components; and
- addressing community concerns about external abnormalities (e.g., tumours) in fish.

#### *Mussels*

Mussels are bivalves that live attached to the substrate. These organisms filter water and suspended sediments and provide a time-integrated response to chemicals in their environment. They have been used in aquatic monitoring programs to evaluate trends in chemical levels.

Since freshwater mussels are found in the Athabasca River Delta, it has been suggested that they be included in the core monitoring program. The first step to assessing the feasibility of using mussels in the RAMP program was to identify the distribution and species of mussels that are present in the lower Athabasca River system. Fort Chipewyan residents have indicated that mussels are common in the Athabasca River Delta near Fort Chipewyan. In 1999, mussels were collected from the Athabasca River Delta for species identification. Two species of mussel were documented this year: *Anodonta grandis* and *Lampsilis radiata siliquoidea*. A reconnaissance-level survey was also done in some of the Athabasca River tributaries this fall. To date, mussels have been documented in the MacKay River, but not in the Muskeg or Steepbank rivers.

The Technical Subcommittee is continuing to discuss the potential for using mussels as a monitoring tool for RAMP. Research would need to be conducted to determine if it were feasible and practical to use mussels for monitoring in the Oil Sands Region. RAMP would not adopt this monitoring technique unless research showed that it could be practically applied to monitoring.

### *External Abnormalities in Fish*

In community meetings held in Fort McKay and Fort Chipewyan, community residents raised concerns regarding the presence of external abnormalities in fish. Community residents indicated that they have caught fish with tumours and deformities.

RAMP currently monitors for external abnormalities in fish as part of regular fish inventories and sentinel species monitoring. However, RAMP is also addressing these concerns by providing a mechanism for people in the communities to have fish analyzed should they catch a fish that is deformed or has external abnormalities such as tumours. In 1999 a Fort Chipewyan resident captured a walleye with an external abnormality. This fish was sent by RAMP (through Suncor) for analysis by DFO scientists. The analysis indicated that the fish had a tumour that is naturally occurring in walleye.

A training program for fish health assessments and collection was done in Fort Chipewyan in July 1999. The training program is currently being expanded to include representatives from all the communities that are members of RAMP. These representatives will be trained to conduct a basic fish health assessment, sample the fish and ship it to a lab for analysis. DFO will provide the analytical services on fish samples.

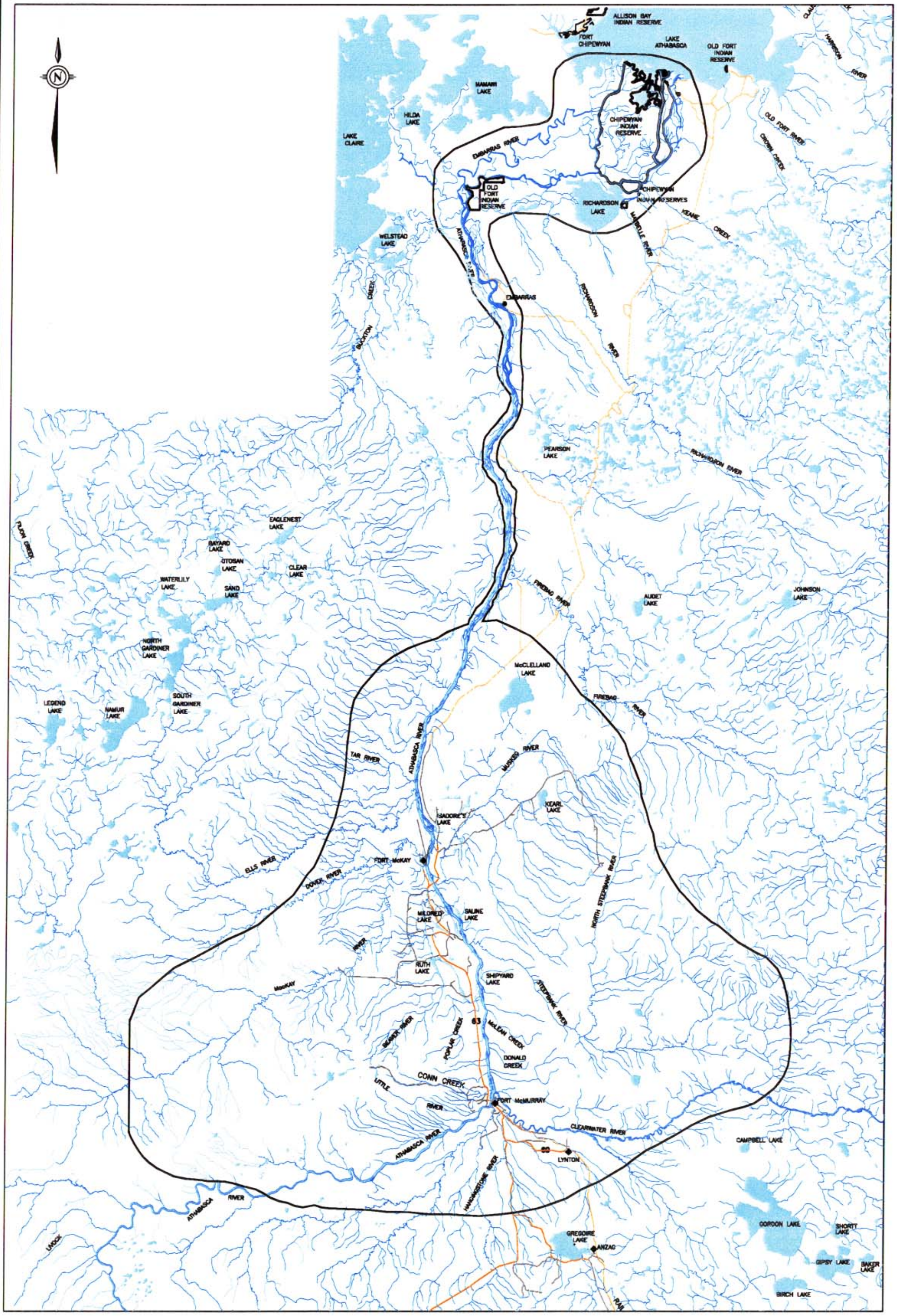
## 2.2 RAMP STUDY AREA

The study area for RAMP is similar to the regional study area developed for recent oil sands EIAs except that it extends farther downstream to include the Athabasca River Delta (Figure 2.1). The study area includes a number of watersheds that drain into the Athabasca River. As well, RAMP initiated acid sensitive lake monitoring in 1999. Hence, the study area also includes sensitive lakes that are within areas potentially affected by acidifying air emissions resulting from oil sands activities as well as control lakes outside of the deposition area (see Section 3.4, Figure 3.5).

In 1999, monitoring activity was focused in the following areas:

- Watersheds of the Muskeg and Steepbank rivers;
- McLean Creek;
- Ells River (potential reference tributary for fish);
- Athabasca River;

J:\1999\2307\6050\FIG2.1.dwg




**LEGEND**

— STUDY AREA

**REFERENCE**

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

0 10 20 30 40 50km

SCALE 1:1,250,000

Golder Associates

**RAMP**

**OIL SANDS REGIONAL AQUATICS MONITORING PROGRAM (RAMP) STUDY AREA 1997-1999**

| | | | |
|---|---|---|---|
| DRAWN: PSR | APPROVED: | DATE: 17 JAN. 2000 | |
| PROJECT: 992-2307.6050 | | FIGURE: **2.1** | |

- Athabasca River Delta;
- Shipyard Lake; and
- Acid Sensitive Lakes.

## 2.3 CLIMATIC AND HYDROLOGIC CONDITIONS

Monitoring of climatic and hydrologic conditions in the Oil Sands Region is accomplished via the Climatic and Hydrologic Monitoring Program. This program, which is currently operated by Suncor, Syncrude, Shell and Mobil has been in place since 1995. An annual report on the program will be issued in the first quarter of 2000. Summaries of historical information as well as data collected during 1999 will be included in the report (Golder 2000). 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 1999 conditions is provided as background information in this section.

The analysis of available data indicates that maximum daily stream discharges in 1999 were significantly lower than the long-term mean of annual maximum daily values (Table 2.2). Minimum daily discharges were comparable to the mean for most stations, though the minimum daily discharge in the Athabasca River in 1999 was relatively low and had a drought return period of 15 years.

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

| Stream<br>Station ID<br>Period of Record | Athabasca R.<br>07DA001<br>40 Years | Steepbank R.<br>07DA006[a]<br>26 Years | Muskeg R.<br>07DA008[a]<br>26 Years | Jackpine Cr.<br>S2[a]<br>23 Years | MacKay R.<br>07DB001[a]<br>27 Years | Firebag R.<br>07DC001[a]<br>24 Years |
|---|---|---|---|---|---|---|
| | **Maximum Mean Daily Discharge** | | | | | |
| 1999 value ($m^3/s$) | **2040** | **5.62** | **3.84** | **0.178** | **7.72** | **43.5** |
| average recorded ($m^3/s$) | **2460** | **35.6** | **26.5** | **7.54** | **126** | **104** |
| maximum recorded ($m^3/s$) | **4700** | **81.0** | **66.1** | **17.2** | **339** | **236** |
| flood return period (yr) | **< 2 years** | **< 2 years** | **< 2 years** | **< 2 years** | **< 2 years** | **< 2 years** |
| | **Minimum Mean Daily Discharge** | | | | | |
| 1999 value ($m^3/s$) | **97.5** | **0.417** | **0.225** | **0.000** | **0.173** | **9.14** |
| average recorded ($m^3/s$) | **136** | **0.294** | **0.277** | **0.007** | **0.352** | **8.00** |
| minimum recorded ($m^3/s$) | **92** | **0.022** | **0.095** | **0.000** | **0.023** | **4.24** |
| drought return period (yr) | **15 years** | **< 2 years** | **4 years** | **n/a** | **7 years** | **< 2 years** |

Source: Environment Canada, Water Survey Branch; Golder (2000).

Note [a] – Discharge data available only for period March to October.

The cumulative flow volume for the period from March to September 1999 (i.e., spring melt to late summer) was much lower than normal, with drought return periods of between 10 and 40 years (Table 2.3). For all of the gauged streams 1999 was drier than 1998, and for Jackpine Creek and the Steepbank and Muskeg rivers it was the driest year on record.

Field observations (Golder 2000) indicate that 1999 was a dry year in the Muskeg River and adjacent basins, as was 1998. Normally saturated muskeg areas were relatively dry and many upland streams ceased to flow by mid-summer.

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

| Stream<br>Station ID<br>Period of Record | Athabasca R.<br>07DA001<br>40 Years | Steepbank R.<br>07DA006<br>26 Years | Muskeg R.<br>07DA008<br>26 Years | Jackpine Cr.<br>S2<br>23 Years | MacKay R.<br>07DB001<br>27 Years | Firebag R.<br>07DC001<br>24 Years |
|---|---|---|---|---|---|---|
| 1999 value ($dam^3$) | 12,457,498 | 36,587 | 18,151 | 1,000 [(a)] | 28,526 | 405,669 |
| maximum recorded ($dam^3$) | 25,279,862 | 273,634 | 187,146 | 59,051 | 904,734 | 903,836 |
| average recorded ($dam^3$) | 16,818,987 | 134,019 | 104,684 | 27,402 | 430,574 | 605,260 |
| minimum recorded ($dam^3$) | 11,888,035 | 36,587 | 18,151 | 1,000 [(a)] | 28,526 | 344,469 |
| drought return period (yr) | 12 years | 40 years | 40 years | 40 years | 40 years | 12 years |

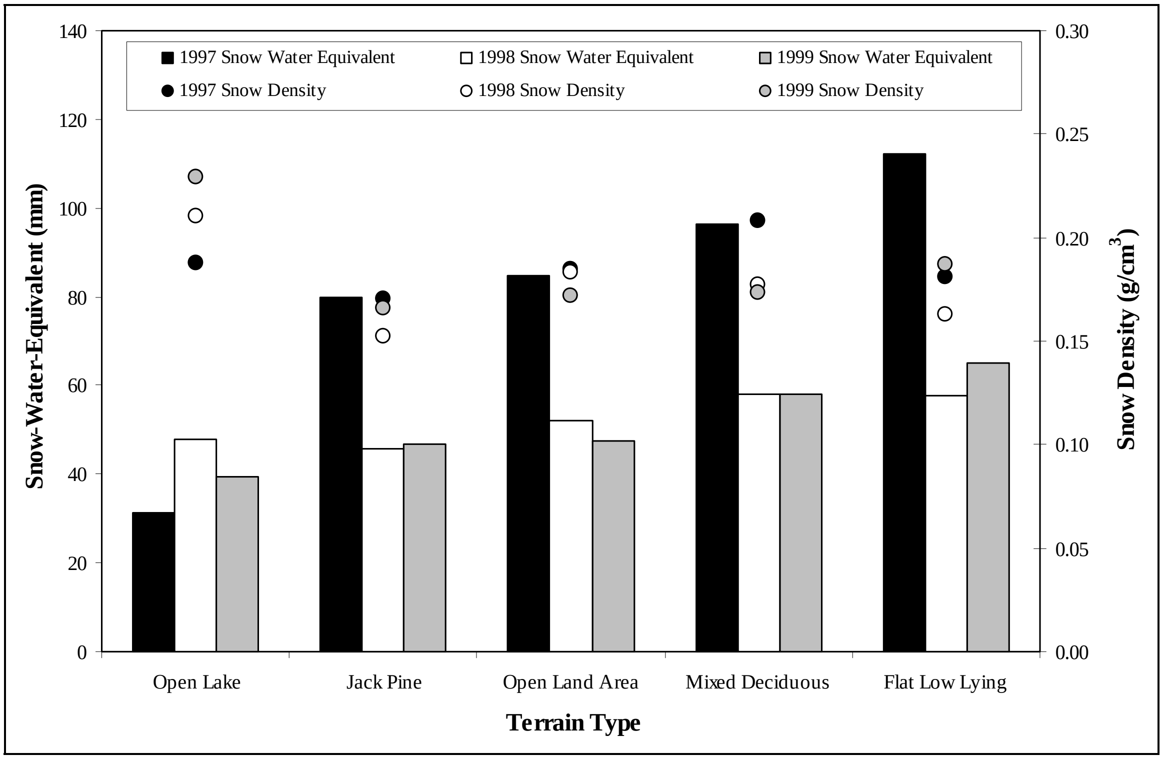
Source: Environment Canada, Water Survey Branch; Golder (2000).
Note [(a)] – 1999 value estimated from limited (April to August) data set.

The following conditions contributed to the extremely low streamflows observed in 1999:

- Low snow accumulation: Cumulative winter snowfall at Fort McMurray Airport in 1999 was the tenth lowest in 53 years of record (winter 1944/45 to 1998/99; no data available for winter 1991/92 to 1993/94). The measured snowfall for the winter of 1998/99 was 981 mm, compared to an average winter snowfall of 1506 mm. Measured snowfall for the winters of 1996/97 and 1997/98 were 937 mm and 714 mm, respectively. The accumulated snow depths measured in the Muskeg River basin in March 1999 were similar to those measured in 1998 and were approximately 65% of those measured in 1997 (Figure 2.2).

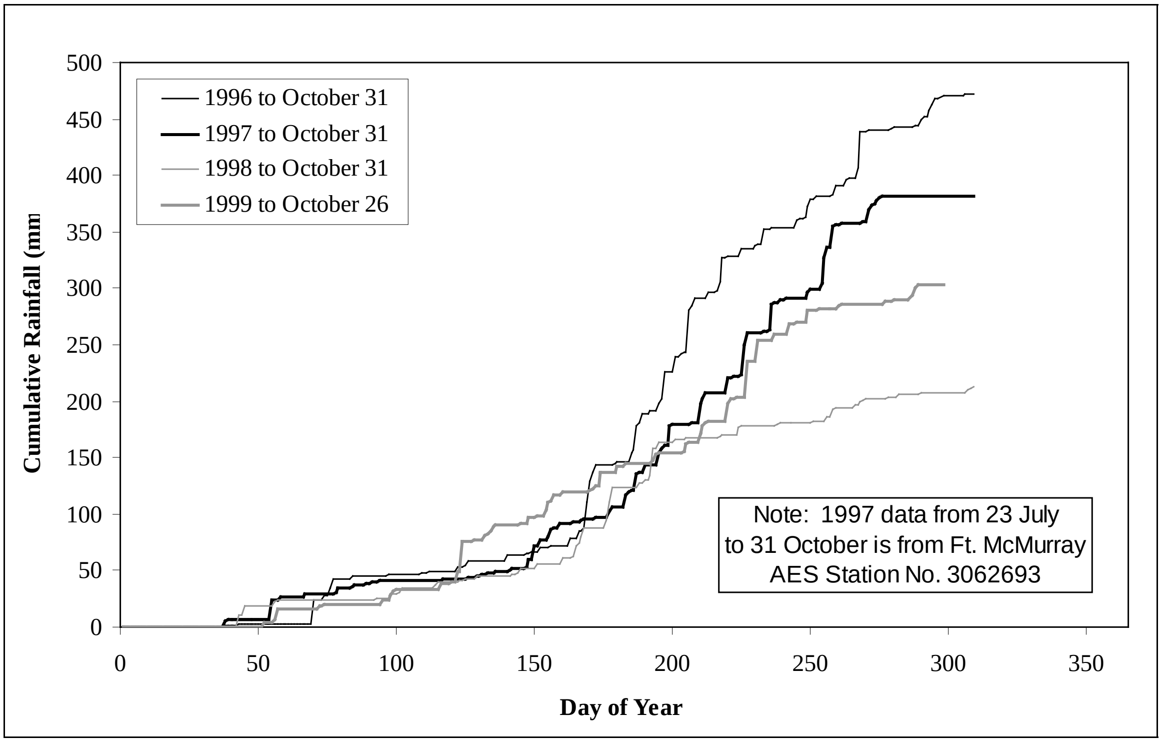
- Low rainfall: 1999 was the tenth driest in the 56 years of record (1944 to 1999) derived for Fort McMurray Airport. Total rainfall measured at the Aurora Climate Station (Figure 2.3) was somewhat higher in 1999 than 1998 (303 mm in 1999 versus 212 mm in 1998) but lower than that measured in 1996 and 1997 (303 mm in 1999 versus 474 mm in 1996 and 377 mm in 1997).
- Antecedent conditions: The preceding dry year in 1998 left the muskeg with capacity to store the 1999 snowmelt and rainfall. This resulted in lower than normal runoff during spring melt and summer rain events.

**Figure 2.2 Snow Accumulation in Muskeg River Basin, 1997 - 1999**




Source: (Golder 2000).

**Figure 2.3 Cumulative Annual Rainfall at Aurora Climate Station, 1996 - 1999**




Source: (Golder 2000).

Calculated potential and areal evapotranspiration for 1999 were found to be relatively normal and are not thought to be responsible for low streamflows in 1999 (Table 2.4).

**Table 2.4 Calculated Annual Evapotranspiration at Aurora Climate Station**

| | Calculated Annual Evapotranspiration (mm) | |
|---|---|---|
| | Potential | Areal |
| Aurora Climate Station 1999 | 750 | 355 |
| Aurora Climate Station 1998 | 852 | 387 |
| Fort McMurray Airport 1953-1993 Average | 782 | 312 |

Source: Golder (2000).

# 3 METHODS

## 3.1 ATHABASCA RIVER

### 3.1.1 Water and Sediment Quality

In 1999, water samples were collected in the Athabasca River near the Embarras River (March 5, 1999) and in the Athabasca River Delta (July 31, 1999). A composite sediment sample was collected from the Athabasca River Delta on July 31, 1999. Work in the river delta was completed in collaboration with Environment Canada. Sample sites are illustrated in Figure 3.1.

#### 3.1.1.1 Field Methods

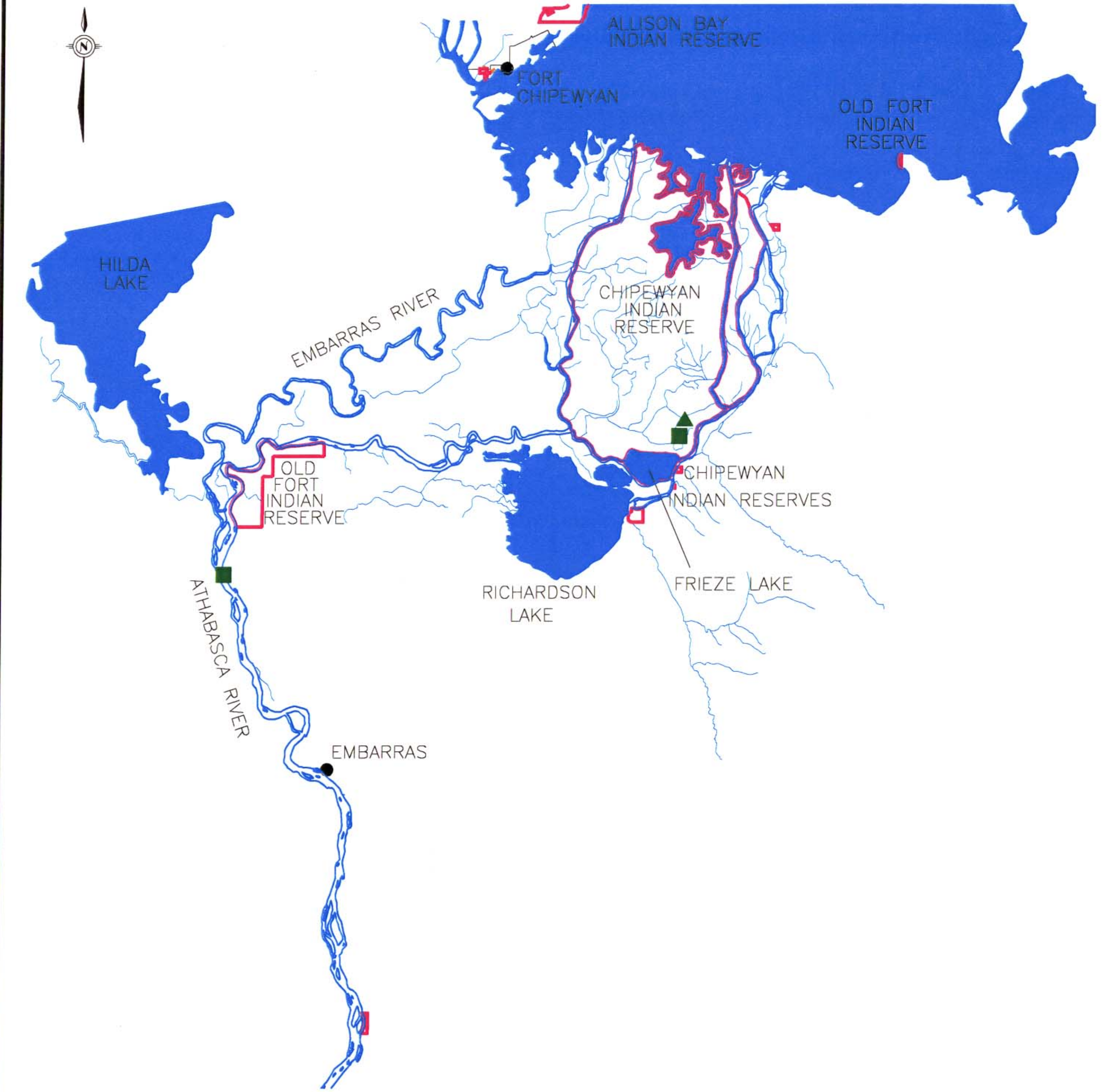
***Water Sampling***

On March 5, 1999, four evenly spaced holes were drilled through the ice on a transect across the Athabasca River, near the Embarras River. Two litres of water were collected from each hole using a clean, triple-rinsed 1 L glass bottle and combined to form one composite sample. In the Athabasca River Delta, one composite sample was created by combining water collected from Big Point, Goose Island and Embarras channels and an unnamed side channel. Approximately two litres of water were collected from each channel using a clean, triple-rinsed 1 L glass bottle. In both sampling events, water was collected from a depth of about 30 cm.

Each composite sample was split into two parts. One portion was shipped to Enviro-Test Laboratories (ETL) in Edmonton, Alberta for analysis of conventional parameters, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids. The other portion was sent to HydroQual Laboratories (HydroQual) in Calgary, Alberta, for chlorophyll *a* and Microtox® analysis. Descriptions of the analytical methods used by each laboratory are provided in Appendix I.

Field measurements, including dissolved oxygen (DO), pH, conductivity and temperature, were taken at the site near the Embarras River. For accuracy, all field probes were calibrated before use. As a result of equipment malfunction, field measurements could not be collected in the Athabasca River Delta. All samples were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.3-1 (Golder 1999b). Exact sample locations were determined by Global Positioning System (GPS).

J:\1999\2300\992-2307\6050\AREA_SAMPLE_SITES.dwg




**LEGEND**

- ■ WATER QUALITY SAMPLING SITE
- ▲ SEDIMENT QUALITY SAMPLING SITE

0 5 10 15 20 25km

SCALE 1:500,000

**REFERENCE**

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

Golder Associates

**1999 RAMP SAMPLES SITES, ATHABASCA RIVER AND THE ATHABASCA RIVER DELTA**

| | | |
|---|---|---|
| DRAWN: CG | APPROVED: | DATE: 17 JAN. 2000 |
| PROJECT: 992-2307 | | FIGURE: **3.1** |

### *Sediment Sampling*

Sediment samples were collected in the Athabasca River Delta from the same location as the water quality samples. Sediments were taken from the top 3 cm of the river bottom using a Ponar grab sampler. Four grab samples, one from each of the aforementioned channels, were mixed to form one composite sample, which was then split into three parts. One part was shipped to ETL and analyzed for carbon content, particle size, recoverable hydrocarbons and total metals. Another part of the composite sample was sent to HydroQual for toxicity testing using a midge larvae (*Chironomus tentans)*, an amphipod (*Hyalella azteca*) and an oligochaete worm (*Lumbriculus variegatus*). The final portion was sent to AXYS Analytical Services Ltd. (AXYS) in Sidney, B.C., and analyzed for polycyclic aromatic hydrocarbons (PAHs) and alkylated PAHs. Descriptions of the methods used by each laboratory can be found in Appendix I. Sediments were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.2-2 (Golder 1999b).

## 3.1.1.2 Data Analyses

Qualitative comparisons were used to characterize water and sediment quality in the Athabasca River near the Embarras River and the Athabasca River Delta. Historical information, where available, was summarized, and historical median, minimum and maximum values were developed (Appendix II). Information collected in 1999 was then compared qualitatively to the historical median values associated with each of the 1999 sampling sites. The 1999 and historical median values were also compared to relevant water and sediment quality guidelines. Trends in the complete data set were examined, and differences between new information and historical data were identified using the following criteria:

- a pH change of greater than 0.5 pH units;
- a minimum of an order of magnitude change for parameters reported with only one significant digit (e.g., 0.1 mg/L in 1999 versus a historical median concentration of 1 mg/L);
- a relative change of greater than 100% for parameters with more than one significant digit (e.g., 180 mg/L in 1999 versus a historical median concentration of 90 mg/L); or
- a relative change of greater than 40% for parameters with more than one significant digit, where 1999 concentrations were higher or lower than historical maximum or minimum, respectively.

These criteria are based on professional judgement and serve as general guidelines by which potentially significant changes could be identified.

Increased statistical analysis of the water quality data will be incorporated in future years, as the amount and number of years of data increases.

### 3.1.2 Fish Populations

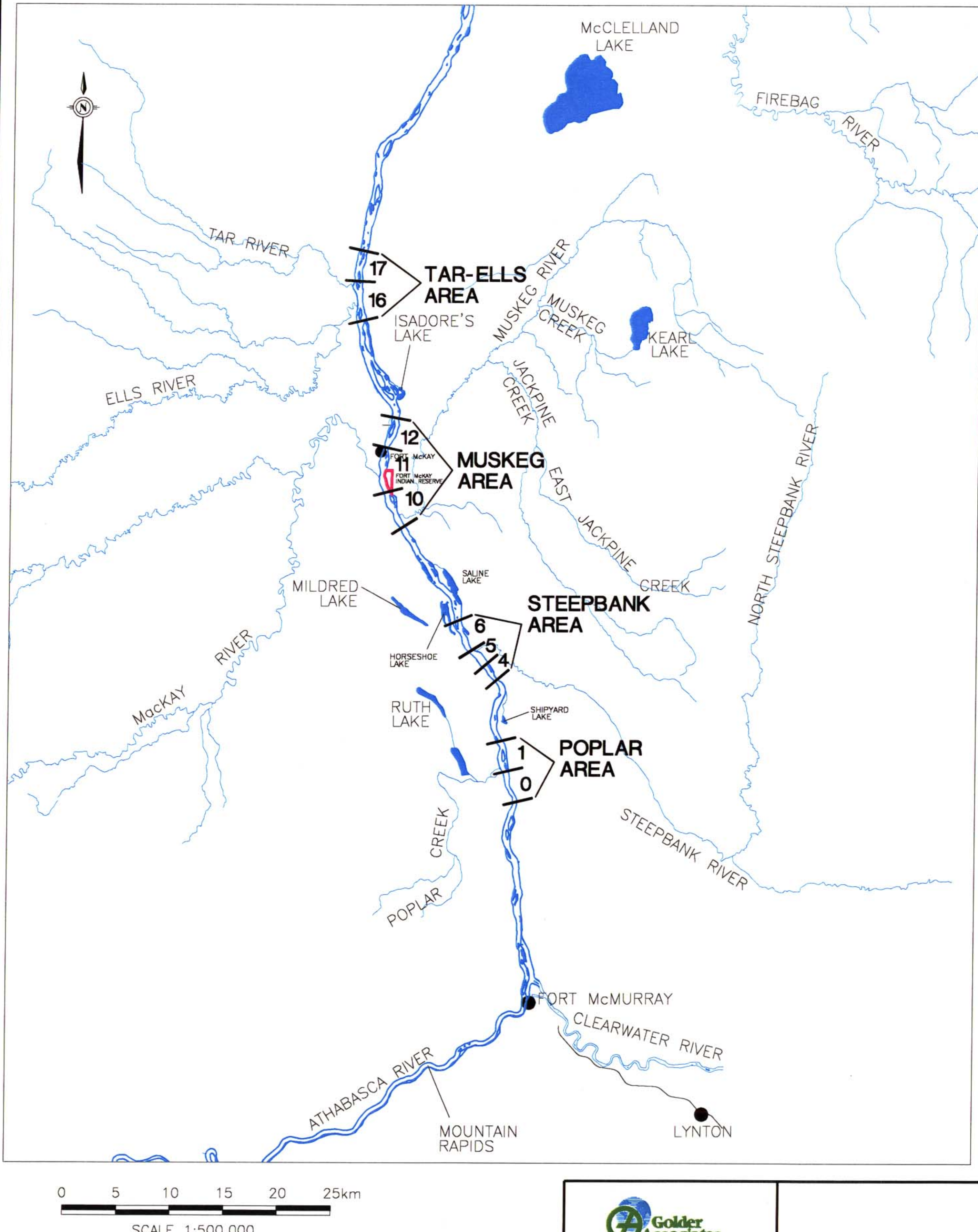
The 1999 fisheries component of RAMP was a continuation, as well as a refinement, of work initiated in 1997 (Golder 1998a) and 1998 (Golder 1999a). The objectives of the 1999 fisheries studies were to:

- obtain data on Key Indicator Resource (KIR) fish species of the Athabasca River to examine temporal variability in species composition/abundance and population parameters such as length-at-age, condition and length frequency distributions; and
- further develop sentinel fish species monitoring for the Athabasca River by evaluating the use of a small-bodied fish species as an additional sentinel species to longnose sucker (*Catostomus catostomus*).

The KIR fish inventory focused on the same oil sand river reaches previously surveyed in 1998 (Golder 1999a). Specifically, fish were surveyed in the Poplar Area (Reaches 0 and 1), the Steepbank Area (Reaches 4, 5 and 6), the Muskeg Area (Reaches 10, 11 and 12), and the Tar-Ells Area (Reaches 16 and 17) (Figure 3.2). The study region for sentinel species monitoring was more general, but included three specific areas: 1) a reference area located upstream of the Suncor Energy Inc. (Suncor) facilities and downstream of Fort McMurray; 2) an exposure area immediately downstream of the Suncor discharge; and 3) a second exposure area immediately downstream of the confluence of the Muskeg River.

#### 3.1.2.1 Fish Inventory

For a variety of logistical reasons, the fish inventory was not originally part of the 1999 RAMP fisheries component. It was later decided that, at minimum, inventory data during the spring would be valuable to document the presence and relative abundance of dominant fish species (e.g., KIR species) in the Oil Sands Region, particularly spring spawning fishes. The survey was conducted entirely by Syncrude Canada Ltd. (Syncrude) as an in-kind contribution to RAMP.

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**REFERENCE**

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

Golder Associates

**1999 RAMP FISHERIES INVENTORY MONITORING REACHES**

| DRAWN: CG | APPROVED: | DATE: 17 JAN. 2000 |
|---|---|---|
| PROJECT: 992-2307 | | FIGURE: **3.2** |

Environment Canada through the Program for Energy Research and Development (PERD) initiative collaborated with Syncrude to conduct additional sampling within the Oil Sands Region in the fall. Electrofishing was conducted to collect longnose sucker (sentinel species) from areas generally corresponding to the Poplar and Steepbank monitoring reaches. Although limited with regards to study area and sampling bias, incidental catch data provided some information regarding species composition and catch-per-unit-effort (CPUE) during the fall season. CPUE is measured as the number of fish captured plus the number of fish observed divided by the unit of time (e.g., seconds) of active fishing.

### *Field Collections*

The RAMP inventory was done at all four sampling areas from May 10-14, 1999. Fish were captured using an electrofishing boat (Smith-Root model SR18). Electrofishing was conducted along the right and left downstream bank of each sampling reach. Stunned fish were dip-netted from the water and placed in a flow-through live well prior to processing. CPUE was calculated to determine the relative abundance of fish species captured in each reach. Collection operations were consistent with the Alberta Environment Fisheries Management Division policy respecting injury to fish (AEP 1995).

All captured fish were identified to species and enumerated. Species codes and common/scientific names are presented in Table 3.1. Fork length (±0.1 cm) and body weight (±0.1 g) were measured for large fish species. For smaller species (e.g., flathead chub, emerald shiner), only fork length was measured. Fish were also examined for external pathology according to Golder Technical Procedure 8.1-3 (Golder 1999b). If discernible, sex and state of maturity of each fish were determined by external examination. Non-lethal ageing structures were taken from walleye (pelvic spine, fin ray), goldeye (fin ray), lake whitefish (scales) and longnose sucker (fin ray) according to methods outlined in MacKay et al. (1990).

### *Data Analyses*

When sample sizes were adequate (i.e., $n > 100$), size and age distributions for KIR species were generated and compared to distributions from previous years. Size-at-age relationships were also compared to spring data from 1997 and 1998 (i.e., years with adequate age data). Size-at-age was generated as an estimate of fish growth. Because condition factor varies seasonally and by gender (particularly during spawning season), condition of KIR species could not be accurately estimated using data from the spring inventory.

Statistical analysis was done using SYSTAT® statistical software (Wilkinson 1990). Analysis of covariance (ANCOVA) was used to compare size-at-age (length vs. age) among years.

**Table 3.1 Common Name, Scientific Name and Species Code of Fish from the Oil Sands Region, Athabasca River**

| Species Common Name | Scientific Name | Code[a] |
|---|---|---|
| Arctic grayling | *Thymallus arcticus* | ARGR |
| brook stickleback | *Culaea inconstans* | BRST |
| bull trout | *Salvelinus confluentus* | BLTR |
| burbot | *Lota lota* | BURB |
| cisco | *Coregonus artedi* | CISC |
| emerald shiner | *Notropis atherinoides* | EMSH |
| fathead minnow | *Pimephales promelas* | FTMN |
| finescale dace | *Phoxinus neogaeus* | FNDC |
| flathead chub | *Platygobio gracilis* | FLCH |
| goldeye | *Hiodon alosoides* | GOLD |
| Iowa darter | *Etheostoma exile* | IWDR |
| lake chub | *Couesius plumbeus* | LKCH |
| lake whitefish | *Coregonus clupeaformis* | LKWH |
| longnose dace | *Rhinichthys cataractae* | LNDC |
| longnose sucker | *Catostomus catostomus* | LNSC |
| mountain whitefish | *Prosopium williamsoni* | MNWH |
| ninespine stickleback | *Pungitius pungitius* | NNST |
| northern pike | *Esox lucius* | NRPK |
| northern redbelly dace | *Phoxinus eos* | NRDC |
| pearl dace | *Semotilus margarita* | PRDC |
| river shiner | *Notropis blennius* | RVSH |
| shiner species | *Notropis sp.* | SH Sp. |
| slimy sculpin | *Cottus cognatus* | SLSC |
| spoonhead sculpin | *Cottus ricei* | SPSC |
| spottail shiner | *Notropis hudsonius* | SPSH |
| sucker (unidentified) | *Catostomus sp.* | Su. Sp. |
| trout-perch | *Percopsis omiscomaycus* | TRPR |
| walleye | *Stizostedion vitreum* | WALL |
| white sucker | *Catostomus commersoni* | WHSC |
| yellow perch | *Perca flavescens* | YLPR |
| unidentified | | UNID |

[a] Coding system follows recommendations by MacKay et al. (1990).

### 3.1.2.2 Sentinel Fish Species Monitoring

Sentinel species monitoring for the Athabasca River focused on assessing the whole-organism response of trout-perch (*Percopsis omiscomaycus*) exposed to conditions potentially influenced by oil sands development. Trout-perch was selected *a priori* as a suitable sentinel species for the Oil Sands Region because:

- it is abundant and widely distributed within the Oil Sands Region (Bond 1980; Golder 1998a, 1999a);

- it is resident in the lower Athabasca River throughout the year (Bond 1980) and, therefore, exposed to oil sands-related stressors year-round;
- other studies on the Athabasca River have been done using trout-perch as a sentinel species (Spafford 1999); and
- gonadal development of trout-perch in the fall is sufficiently advanced to measure reproductive parameters such as gonad size, fecundity, and *in vitro* sex hormone production (Gibbons et al. 1998; Spafford 1999).

Final confirmation regarding the suitability of trout-perch as the sentinel species was dependent on capture success during the fall field study.

Monitoring work on trout-perch was a collaborative initiative between RAMP and PERD, with additional in-kind support provided by Syncrude and Suncor.

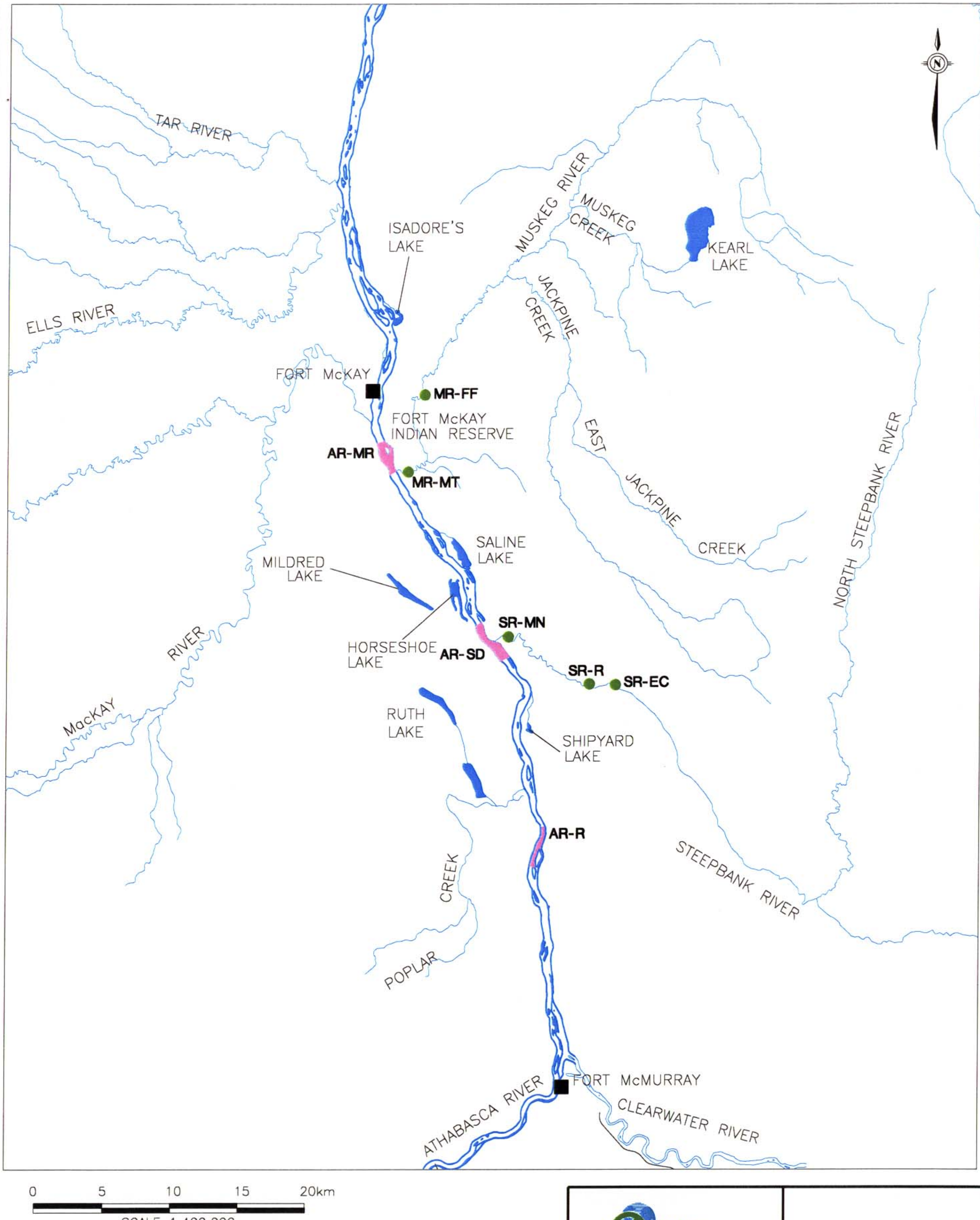
## *Fish Collections*

The field work on the Athabasca River was conducted during September 12-17, 1999. Fish were collected from three sites (Figure 3.3). The general location and UTM coordinates of each sampling site are provided in Table 3.2. Although there was some variation in bank type, all sites consisted of low velocity habitat and substrate dominated by sand/silt mixed with small to medium cobble (Appendix III). The Athabasca River downstream of the confluence of the Muskeg River (Site AR-MR) was moderately different in that the shallow littoral zone was wider than at the reference site and the site downstream of Suncor (sites AR-R and AR-SD).

**Table 3.2 General Location and UTM Co-ordinates of Sampling Sites for Trout-perch (*Percopsis omiscomaycus*), Athabasca River, Fall 1999**

| Site | General Location | UTMs[a] of Sampling Reach |
|---|---|---|
| AR-R | Reference site approx. 12 km upstream from Suncor, right upstream bank of river in the vicinity of the Northland Forest Products Ltd. sawmill (no known discharge). | U/S: 473465 E / 6302829 N<br>D/S: 473414 E / 6308161 N |
| AR-SD | Exposure site immediately downstream of Suncor's discharge and extending to just past Syncrude's water intake, right upstream bank of river. | U/S: 471925 E / 6317684 N<br>D/S: 469411 E / 6321820 N |
| AR-MR | Exposure site immediately downstream of the confluence of Muskeg River, left upstream bank of river. Majority of sampling at Lougheed Bridge. | U/S: 463372 E / 6332074 N<br>D/S: 462326 E / 6335050 N |

[a] Universal Transverse Mercator (UTM) taken at the upstream (U/S) and downstream (D/S) boundary of each sampling reach.




**LEGEND**

- SLIMY SCULPIN SAMPLING SITES
- TROUT-PERCH SAMPLING SITES

**REFERENCE**

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

Golder Associates

**1999 SENTINEL FISH MONITORING SITES**

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| PROJECT: 992-2307 | | FIGURE: 3.3 |

Fish were collected using a Smith-Root SR-18 electrofishing boat as well as a small-mesh beach seine (7 m x 1.2 m x 0.5 cm mesh size) along the slower margins of the river. Seining occurred during both day and night hours (easily accessible sites). Sampling was conducted following detailed methods outlined in Golder Technical Procedure 8.1-3 (Golder 1999b). All captured fish (including incidental species) were identified and enumerated.

Trout-perch were transported live to the on-site laboratory in aerated buckets, where they were immediately transferred to a larger aerated tank (40 L). Because *in vitro* production of sex steroids may be altered by handling and confinement stress (Jardine 1994), fish were held for 3-4 h prior to biomarking in an effort to standardize holding/travel time among sampling sites.

Each fish was rendered unconscious by concussion, followed by spinal severance, and measured for total length (±0.1 cm), fork length (±0.1 cm), body weight (±0.01g), carcass (i.e., eviscerated) weight (±0.01g), gonad weight (±0.001g) and liver weight (±0.001g). Otoliths and scales were removed from each fish for ageing. Otoliths were aged using the “crack-and-burn” procedure. Briefly, the otolith is cut along the transverse axis and held in an alcohol flame to char the cut surface and enhance the visual identification of growth annuli. Scales were used as secondary ageing structures and read, when required, from acetate imprints. An external and internal pathology examination was also conducted for each fish. All fish were processed according to methods described in Golder Technical Procedure 8.15-0 (Golder 1999b).

Whole livers were placed in a cryovial and frozen immediately in liquid nitrogen and stored at –80 °C pending mixed function oxygenase (MFO) analyses. This analyses was done as part of the PERD research lead by J. Parrott and J. Sherry, Environment Canada, National Water Research Institute, Burlington, Ontario. Induction of MFO activity was measured as a positive indicator of exposure to inducing compounds present in the Oil Sands Region (e.g., PAH compounds, chlorinated aromatic hydrocarbons and complex mixtures such as petroleum oils).

A sample of ovarian tissue from mature females was weighed (±0.001) and preserved in Gillson’s solution for fecundity analyses. The total number of eggs per sample was counted, and these results were used to estimate the total number of eggs per fish (total fecundity). Sub-samples of gonadal tissues from both male and female trout-perch were also taken to measure the *in vitro* production of sex steroids. The *in vitro* production of steroids has been used as a surrogate measurement of circulating blood levels of sex steroids in fish (McMaster et al. 1995). This technique is particularly useful for small fishes where the total volume of whole blood is insufficient to measure circulating sex steroids.

Steroid analyses were done as part of the M.Sc. thesis research of G. Tetreault from the University of Waterloo, Waterloo, Ontario as part of Environment Canada's PERD research.

At the time of writing this report, both MFO and *in vitro* steroid assays were ongoing and data were not available for inclusion.

## Data Analyses

Statistical analysis of sentinel fish species data was done using SYSTAT® statistical software (Wilkinson 1990). Analysis of Variance (ANOVA) was used to compare length, weight and age estimates among sites. Estimates of size-at-age (length vs. age), condition (carcass weight vs. length), gonad size, fecundity and liver size were evaluated using ANCOVA. With the exception of size-at-age and condition, carcass (i.e., eviscerated) weight was used as a covariate to adjust for any differences in body size. Using carcass weight instead of body weight eliminated possible confounding effects of altered organ weight (e.g., gonad weight, liver weight) on the interpretation of variables related to body weight. An assumption of the ANCOVA model is that the slopes of the regression lines are equal between regions. Therefore, differences in slopes were tested prior to conducting the ANCOVA. Generally, ANCOVA is fairly robust even when slopes are not equal, so slopes were considered different when $p<0.01$ (Paine 1998). Data were $\log_{10}$ transformed where appropriate and sexes were analyzed separately.

Using linear orthogonal contrasts (Hoke et al. 1990), statistical analyses were conducted to compare fish performance between:

- reference site vs. exposure site downstream of the Suncor discharge;
- exposure site downstream of the Suncor discharge vs. exposure site downstream of the Muskeg River confluence; and
- reference site vs. exposure site downstream of the Muskeg River confluence.

To control experiment-wise error, a significance level of $p=0.017$ (i.e., $\alpha$/no. of comparisons, 0.05/3) rather than $p=0.05$ was used (i.e., Bonferroni's adjustment).

Data were initially screened for potential outliers by visual examination of scatterplots and box plots. The procedure for removing outliers was based on the evaluation of Studentized Residuals (SR). Observations more than four standard deviations (i.e., SR>4) from the cell mean were removed and the analysis run again. If any new outliers (SR>4) occurred, they were also removed and the analysis was redone. No further outliers were deleted after this point. Adopting SR>4 as a cut-off is considered conservative, as greater than 99% of Studentized residuals were expected to have lower values (Grubbs 1971).

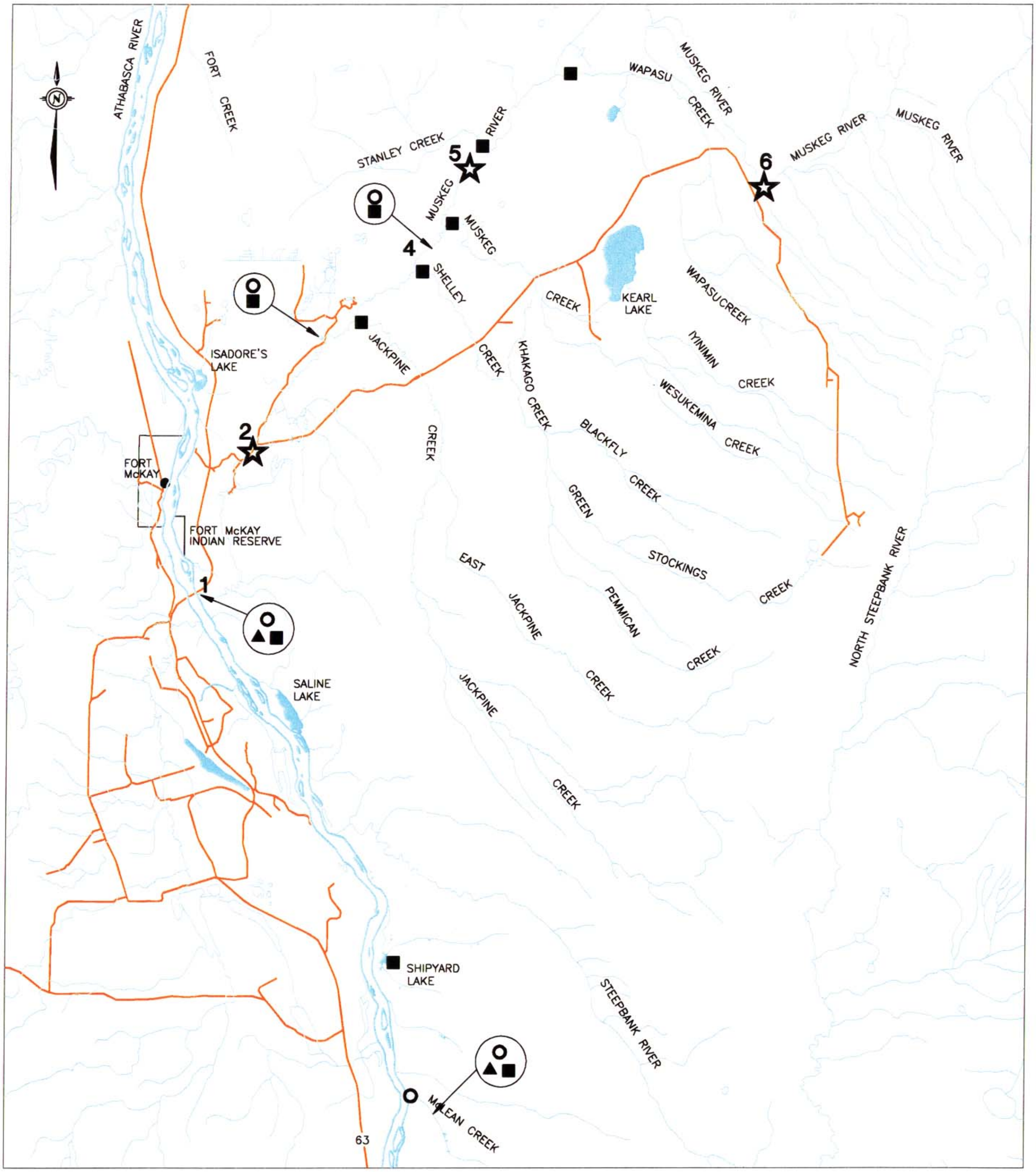
Because this is the first time RAMP has focused on trout-perch as a sentinel species, power analysis was done to evaluate the adequacy of sample sizes for detecting potential differences in fish performance. This information is valuable for refining the sampling design for subsequent sentinel monitoring surveys in future years. Specifically, power analysis was used to estimate the appropriate sample size required to detect a given effect size (or difference in performance between sites). Because the study design consists of three sites, simple power equations comparing two samples cannot be used. Cohen (1988) provides comprehensive methods for power analyses for more than two samples, and for a variety of statistical tests (e.g., ANOVA, ANCOVA). Power analyses were conducted using G*Power software (Faul and Erdfelder 1992), which performs computations based on methods described by Cohen (1988).

The effect size or difference one wishes to detect is not easily defined. The Environmental Effects Monitoring program for the pulp and paper industry have set an effect size of ±25% difference in gonad weight (Environment Canada, 1997). For the purposes of refining the RAMP study design, parameter-specific sample sizes were estimated for an effect size of 20, 30, and 50% (i.e., differences between sites). The mean squared error (MSE) term from the ANOVA or ANCOVA statistical model provided the estimate of among-site-variance for each fish parameter.

## 3.2 TRIBUTARIES OF THE ATHABASCA RIVER

### 3.2.1 Water and Sediment Quality

In 1999, RAMP continued monitoring the Steepbank River, Muskeg River, Muskeg Creek and Wapasu Creek, all of which had been monitored in 1997 and 1998. Stanley, Shelley, Jackpine and McLean creeks, and the Alsands Drain were added to RAMP in 1999 (Figure 3.4). Water and/or sediment samples were collected from each sample site in accordance with the sampling schedule summarized in Table 3.3. Water temperatures in the Muskeg River and the Alsands Drain were monitored throughout the spring, summer and fall of 1999. Water temperatures in McLean Creek were monitored in the summer and fall of 1999. Fall sampling in the Muskeg River watershed was completed in collaboration with Alberta Environment (AENV). RAMP also worked with AENV in the summer of 1999 in a test of laboratory quality assurance/quality control (QA/QC) procedures (see Section 4).




0 2.5 5 7.5 10 12.5km

SCALE 1:300,000

**LEGEND**

- ☆ Water quality, temperature and toxicity sampling site
- ■ Water quality sampling site
- O Water temperature sampling site
- ▲ Sediment quality sampling site
- 1 Muskeg River sample site number
- — Roads

**REFERENCE**

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

Golder Associates

**1999 RAMP SAMPLE SITES IN THE MUSKEG RIVER WATERSHED, McLEAN CREEK AND SHIPYARD LAKE**

| | | | |
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| PROJECT: 992-2307 | | FIGURE: **3.4** | |

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**Table 3.3 1999 Water and Sediment Sampling Schedule for Athabasca River Tributaries**

| Waterbody | Sample Location | Short Title | Sample Media | Sample Date |
|---|---|---|---|---|
| Steepbank River | mouth | STR-1 | water | March 4 (winter) |
| Muskeg River | mouth | MUR-1 | water | October 20 (fall)[(a)] |
| | | | sediment | October 20 (fall)[(a)] |
| | upstream of the Canterra Road crossing | MUR-2 | water | March 3 (winter)<br>May 5 (spring)<br>July 13 (summer)<br>October 18 (fall) |
| | upstream of Shelley Creek | MUR-4 | water | October 20 (fall) |
| | downstream from Stanley Creek | MUR-5 | water | March 2 (winter)<br>May 6 (spring)<br>July 13 (summer)<br>October 19 (fall) |
| | upstream of Wapasu Creek | MUR-6 | water | March 4 (winter)[(b)]<br>May 5 (spring)<br>July 13 (summer)<br>October 18 (fall) |
| Alsands Drain | mouth | ALD-1 | water | October 19 (fall)[(a)] |
| Jackpine Creek | mouth | JAC-1 | water | October 19 (fall)[(a)] |
| Shelley Creek | mouth | SHC-1 | water | October 19 (fall)[(a)] |
| Muskeg Creek | mouth | MUC-1 | water | October 19 (fall)[(a)] |
| Stanley Creek | mouth | STC-1 | water | October 19 (fall)[(a)] |
| Wapasu Creek | Canterra Road crossing | WAC-1 | water | March 2 (winter)<br>October 18 (fall) |
| McLean Creek | mouth | MCC-1 | water | September 23 (fall) |
| | | | sediment | September 23 (fall) |

(a) Joint sample collection by RAMP and AENV.

(b) River was completely frozen; no sample was taken.

### 3.2.1.1 Field Methods

#### *Water Sampling*

Water samples were collected from the centre of the Steepbank and Muskeg rivers and McLean Creek, approximately 100 m upstream of the Athabasca River. Water samples from the mainstem and upper portions of the Muskeg River, the remaining tributaries and the Alsands Drain were also collected from the centre of each watercourse, 50 to 100 m upstream of the stream mouth and/or access road. Grab samples were collected at each site from a depth of approximately 30 cm.

All samples were preserved, stored and shipped to ETL for analysis of conventional parameters, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids. Water samples from these sites were also sent to HydroQual for chlorophyll *a* and Microtox® analysis. Toxicity testing with algae (*Selenastrum capricornutum*), water flea (*Ceriodaphnia dubia*) and fathead minnow was also completed by HydroQual for all water samples taken from sample sites 2, 5 and 6 on the Muskeg River (see Figure 3.4 for site locations) and the winter water sample collected from Wapasu creek.

Field measurements, including DO, pH, conductivity and temperature, were taken during each sampling event. Exact locations of sampling sites were determined using a GPS unit. All samples were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.3-1 (Golder 1999b).

## *Thermographs*

Thermographs were installed at five locations in the Muskeg River and at one location in the Alsands Drain between May 5 and 6, 1999. Two thermographs were installed in McLean Creek on July 22, 1999 (Table 3.4). Thermographs were programmed to record water temperatures every 20 minutes. They were placed in areas where water depths exceeded 1 m at the time of installation and were covered with perforated PVC tubing. Six of the eight thermographs were retrieved in October. The two remaining thermographs were downloaded in the fall and reset to collect winter temperature data (Table 3.4).

**Table 3.4 Thermograph Locations in 1999**

| Waterbody | Site | Installation Date | Retrieval Date |
|---|---|---|---|
| Muskeg River | river mouth | May 5 | October 20 |
| | upstream of the Canterra Road crossing | May 5 | October 18[a] |
| | upstream of Shelley Creek | May 6 | October 20 |
| | downstream from Stanley Creek | May 6 | October 20 [a] |
| | upstream of Wapasu Creek | May 5 | October 18 |
| Alsands Drain | near mouth | May 5 | October 19 |
| McLean Creek | near mouth | July 22 | October 23 |
| | 100 m upstream of mouth | July 22 | October 23 |

[a] Data downloaded on this day, but thermograph left in place to record winter water temperatures.

## *Sediment Sampling Methods*

Sediment samples were collected from the Muskeg River and McLean Creek approximately 100 m upstream of the Athabasca River. Sediment samples were collected close to shore in depositional areas. Sediments were taken from the top

3 cm of the river bottom using an Eckman grab sampler. Four to six individual samples were collected at each sampling location and mixed to form one composite sample for the site.

The McLean Creek composite sample was split into three parts and shipped to ETL, HydroQual and AXYS for analysis of the same parameters described in Section 3.1.1.1. The Muskeg River composite sample was split into four parts; three parts were shipped to ETL, HydroQual and AXYS for analysis of the same parameters described in Section 3.1.1.1. The remaining portion was sent to Alberta Research Council's Vegreville laboratory (ARCV) for a duplicate PAH analysis (see Section 4)

#### 3.2.1.2 Data Analyses

Qualitative comparisons were used to characterize water and sediment quality in the Athabasca River tributaries. Historical information, where available, was summarized, and historical median, minimum and maximum values were developed (Appendix II). Information collected in 1999 was then compared qualitatively to the historical median values associated with each of the 1999 sampling sites. The 1999 and historical median values were also compared to relevant water and sediment quality guidelines. Trends in the complete data set were examined, and differences between new information and historical data were identified using the criteria described in Section 3.1.1.2. Increased statistical analysis of the water quality data will be incorporated in future years, as the amount and number of years of data increases.

### 3.2.2 Fish Populations

The objective of the 1999 tributary fisheries program was to initiate sentinel fish species monitoring on the Muskeg and Steepbank rivers using a small-bodied fish species. Monitoring focused on at least three specific study areas: 1) an exposure area located on the Muskeg River downstream of current and future mining developments; 2) an exposure area located on the Steepbank River in the vicinity of the Steepbank Mine; and 3) a reference area located on the Steepbank River upstream of the Steepbank Mine and timber harvesting operations. Due to substantial differences in habitat, as well ongoing (and predicted) mining development, a suitable reference site was not available on the upper Muskeg River.

Sentinel species monitoring on the Muskeg and Steepbank rivers evaluated the whole-organism response of slimy sculpin (*Cottus cognatus*). Slimy sculpin was selected as a potential sentinel species because:

- It occurs in both the Muskeg and Steepbank Rivers (Bond and Machniak 1979; Machniak and Bond 1979; Golder 1998a, 1999a; Parrott and Sherry 1999).
- It exhibits territorial behaviour limiting the potential for large-scale movement among reference and exposure study sites.
- Spawning occurs in the spring rather than multiple times throughout the spring-summer period (i.e., easier to evaluate reproductive effort).
- Gonadal development is sufficiently advanced in the fall to measure reproductive parameters such as gonad size, fecundity, and *in vitro* sex hormone production.

Final confirmation of slimy sculpin as the sentinel species was dependent on capture success during the fall field study.

As with the Athabasca River monitoring program, sentinel monitoring on the tributaries was a collaborative initiative between RAMP and PERD, with additional in-kind support provided by Syncrude and Suncor.

## *Fish Collections*

Field work on the Muskeg and Steepbank rivers was conducted during September 18-26, 1999. Slimy sculpin were collected from a total of five sites (Figure 3.3), three exposed sites and two reference sites. The general location and UTM coordinates of each sampling site are provided in Table 3.5. Overall, each site was dominated by shallow run/riffle habitat with cobble and/or boulder substrates (Appendix III). Some differences did exist among sites including reduced water depth at the Muskeg River, upstream of the mouth (site MR-MT) and smaller substrate and reduced habitat availability at the fish fence on the Muskeg River (site MR-FF). Habitat at the Steepbank River reference site (site SR-R) was the most homogenous in terms of substrate type and water depth/flow, probably reflecting a moderate increase in river gradient at this site. Habitat at the Steepbank River, near the mine (site SR-MN) was the most variable in terms of water depth, velocity and substrate size.

On the Muskeg River sampling was initially conducted at the site used previously for the fish fence study (MR-FF)(Golder 1999a). Although early capture success of slimy sculpin was good at this site, availability of suitable sampling habitat in this area was very limited due to beaver dams and reduced flow. Therefore, an alternative site located upstream from the confluence with the Athabasca River was also sampled (MR-MT).

**Table 3.5 General Location and UTM Co-ordinates of Sampling Sites for Slimy Sculpin (*Cottus cognatus*), Muskeg River and Steepbank River, Fall 1999**

| Site | General Location | UTMs[a] of Sampling Reach |
|---|---|---|
| ***Muskeg River*** | | |
| MR-FF | exposure site in the vicinity of past fish fence site, sampling area also extended approx. 750 m downstream to next available riffles | U/S: 465521 E / 6338751 N<br>D/S: 465556 E / 6337938 N |
| MR-MT | exposure site approx. 350 m upstream from the mouth of the Muskeg River (entering the Athabasca River) | U/S: 463947 E / 6331932 N<br>D/S: 463753 E / 6332261 N |
| ***Steepbank River*** | | |
| SR-MN | exposure site in the vicinity of Steepbank Mine, approx. 650 m upstream of confluence with the Athabasca River | U/S: 472493 E / 6319674 N<br>D/S: 471337 E / 6319947 N |
| SR-R | reference site in the vicinity of Bitumin Heights approx. 16 km upstream of the confluence with the Athabasca River | U/S: 479668 E / 6316295 N<br>D/S: 479397 E / 6316192 N |
| SR-EC | reference site – approx. 21 km upstream of the confluence with the Athabasca River | [b] 479457 E / 6316293 N |

[a] Universal Transverse Mercator (UTM) taken at the upstream (U/S) and downstream (D/S) boundary of each sampling reach.

[b] Point estimate within the general sampling reach.

On the Steepbank River, Environment Canada sampled an additional site (SR-EC) upstream of the RAMP reference site (SR-R). Preliminary research by Environment Canada indicated that this site is not strongly influenced by the oil sands formation and will help them identify potential effects related to natural sources of oil sands compounds at site SR-R1 (i.e., SR-R vs. SR-EC). This site is mentioned in this report for completeness; however, no statistical comparisons were made using site SR-EC. Environment Canada will be conducting these analyses as part of their PERD research.

Although unsuccessful, effort was made to collect sentinel fish from a separate reference river located on the west side of the Athabasca River. Based on discussion during the RAMP Technical Subcommittee meeting, two possible candidates were the Ells River and Dunkirk River. The Dunkirk River was accessible only by helicopter. Fish capture data reported by Alberta Pacific Ltd. (Mark Spafford, unpubl. data), as well as historical information (Machniak et al. 1980), indicated that capture success of slimy sculpin was low. In light of this information, effort was focussed on accessible sites on the Ells River located at the Fort McKay water intake facility and the terminus of old Highway 963 (location of the 1998 RAMP fish fence, Table 3.6). Two additional sites on the Ells River were also accessed by helicopter and sampled by Environment Canada (Table 3.6). These additional sites looked particularly promising due to the availability of moderately flowing run/riffle habitat and cobble/gravel substrate.

Unfortunately, no slimy sculpin (adults or immatures) were captured at any site on the Ells River.

**Table 3.6 Location, General Description and UTM Co-ordinates of Fish Collection Sites, Ells River, Fall 1999**

| Site | General Description | UTM's[(a)] of Sampling Reach |
|---|---|---|
| ER-R1 | approx. 0.5 km upstream from road access via old Highway 963 from Fort McKay | ≈ 45920 E / 635135 N[(b)] |
| ER-R2 | site accessed by helicopter approx. 12 km upstream of ER-R1 | 456590 E / 6346619 N |
| ER-R3 | in the vicinity of Fort MacKay water intake facility approx. 12 km upstream of ER-R2 | 455139 E / 6343450 N |
| ER-R4 | site accessed by helicopter approx. 26 km upstream of ER-R3 | 446314 E / 6343057 N |

(a) Universal Transverse Mercator co-ordinates (UTM).

(b) Estimated from topographical map 74 E/5.

Sculpin were collected using a backpack electrofisher (Smith-Root Type 15-D). In faster water, a pole seine (2 m by 1.2 m by 0.5 cm mesh size) was held downstream of the electrofisher to collect fish swept by the current. Sampling was conducted following detailed methods outlined in Golder Technical Procedure 8.1-3 (Golder 1999b). All fish species captured were identified and enumerated.

Sentinel fish were transported live to the on-site laboratory in aerated buckets, where they were immediately transferred to a larger aerated tank (40 L). Fish were held overnight (approx. 12 h) prior to processing in an effort to standardize holding/travel time among sampling sites. Sculpin were held longer than trout-perch (see Section 3.1.2.2) in response to the increased distance and/or remoteness of some of the collection sites, as well as increased sampling effort required per day to collect adequate numbers of fish. With a few minor exceptions, processing procedures were identical to methods described in Section 3.1.2.2 for the Athabasca River fish collection. Unlike trout-perch, only otoliths could be collected from slimy sculpin for ageing (sculpin have no scales), and total length, not fork length, was measured as a estimate of length (the tail is not forked). Liver samples for MFO analyses and gonadal tissues for *in vitro* sex steroid analyses were also collected from sculpin according to procedures outlined in Section 3.1.2.2. These analyses were done as part of the PERD research lead by J. Parrott and M. McMaster, Environment Canada, National Water Research Institute, Burlington, Ontario.

At the time of writing this report, both MFO and *in vitro* steroid assays were ongoing and data were not available for inclusion.

### *Data Analyses*

Statistical analysis of sentinel fish species data was done using SYSTAT® statistical software (Wilkinson 1990). Statistical procedures used to evaluate potential differences in whole-organism performance of slimy sculpin were the same as described previously for trout-perch (see Section 3.1.2.2). Analyses were conducted to compare fish performance between:

- Steepbank River reference site vs. Muskeg River exposure site; and
- Steepbank River reference site vs. Steepbank River exposure site.

As for trout-perch, power analysis was used to evaluate the adequacy of sample sizes for detecting potential site-differences in the performance of slimy sculpin. For simple two site comparisons (i.e., SR-R vs. MR-MT, SR-R vs. SR-MN), the equation used to estimate the appropriate sample size for a given effect size (or difference in performance between sites) is (from Alldredge 1987; Environment Canada and Department of fisheries and Oceans 1995):

$$n \geq 2(Z_{\alpha(2)} + Z_{\beta})^2(SD/\delta)^2 + 0.25Z_{\alpha(2)}^{\;2}$$

where $n$ is the number of samples, SD is the standard deviation (or root MSE from ANOVA/ANCOVA model), $\delta$ is the specified effect size, and $Z_{\alpha(2)}$ (two-tailed test) and $Z_{\beta}$ (one-tailed test) are the critical values of the standard normal deviates or Z-values. Parameter-specific sample sizes were estimated for an effect size of 20, 30 and 50% (i.e., differences between sites).

## 3.3 WETLANDS

### 3.3.1 Water Quality

Water samples were collected from the open water area in Shipyard Lake (Figure 3.4) on May 7, July 12 and October 18, 1999. During each sampling event, ten individual 1 L grab samples were collected and combined to form one composite sample. Sample bottles were placed approximately 30 cm below the water surface. The composite sample was divided into two parts, and one part was shipped to ETL and analyzed for conventional parameters, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids. The other part of the composite sample was sent to HydroQual for chlorophyll *a* and Microtox® analysis. Field measurements (i.e., DO, pH, conductivity and temperature) were taken at every sampling location.

Wetlands water quality data were analyzed by the same methods as those described in Section 3.2.1.2.

### 3.3.2 Sediment Quality

Five individual sediment samples were collected from Kearl Lake on October 20, 1998. Sediments were taken from the top 3 cm of the lake bottom using a Ponar grab sampler in accordance with Golder Technical Procedure 8.2-2 (Golder 1999b). Individual samples were combined to form one composite sample that was sent to Marlene Evans at Environment Canada for PAH analysis. Since the results of this analysis became available in 1999, they are included in this report.

## 3.4 ACID SENSITIVE LAKES

### 3.4.1 Lake Selection

Available historical data were examined to select lakes that would be suitable for the RAMP acidification monitoring network. A number of recent surveys have provided water chemistry data for about 470 lakes in northern Alberta (Erickson 1987; Saffran and Trew 1996; Al-Pac 1998 [unpublished data]). Historical data have also been compiled for many more lakes in this region (Saffran and Trew 1996).

Primary criteria for selecting lakes in north-eastern Alberta for the monitoring network included:

- moderate to high sensitivity to acidification, defined as total alkalinity <20 mg/L as $CaCO_3$;
- range in organic content, from clear water to brown water lakes;
- location along a gradient of acidic deposition radiating from the oil sands region, predicted in recent EIAs as Potential Acid Input (PAI; see below); and
- accessible by float plane to ensure a cost-effective program.

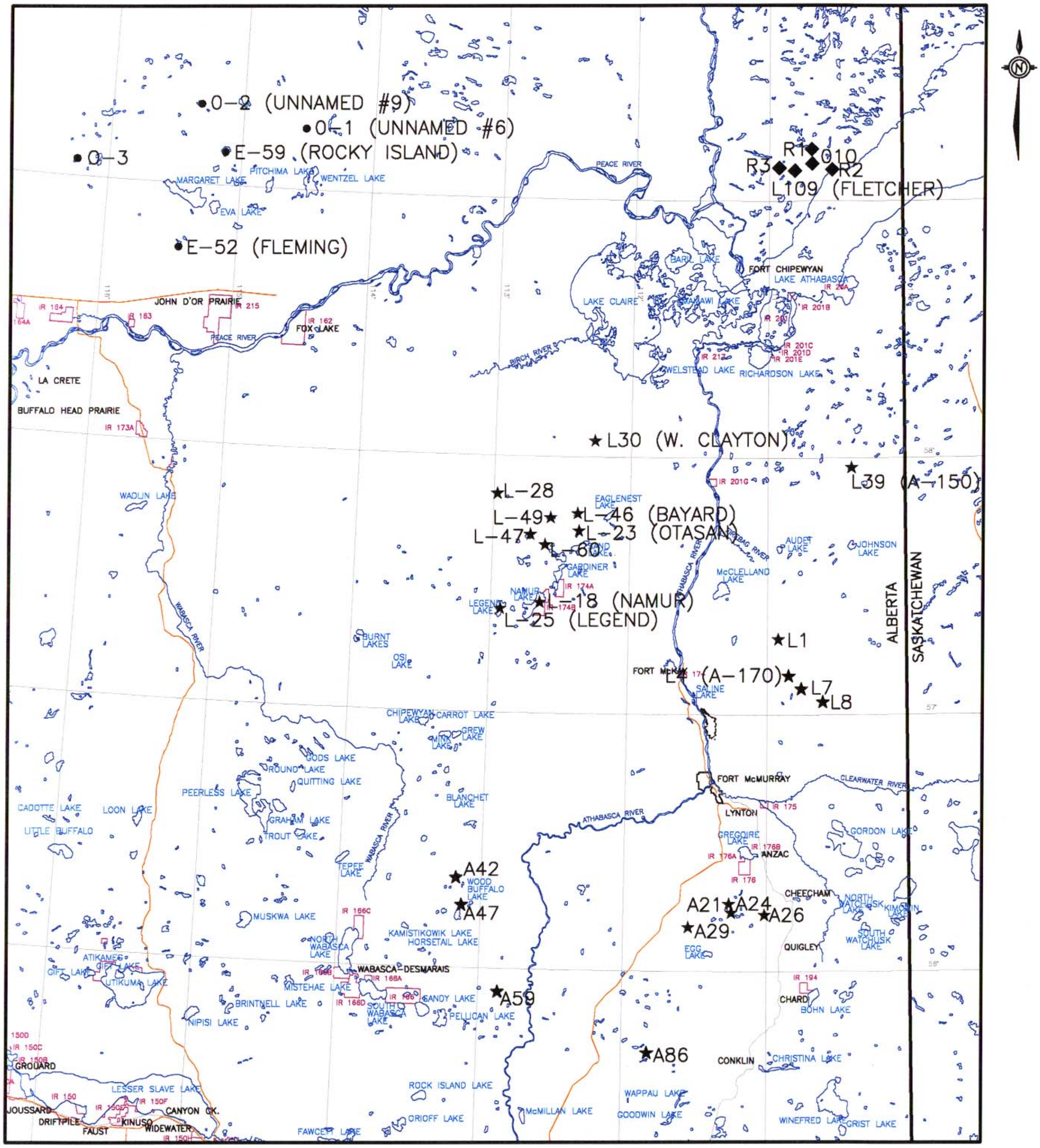
Additional considerations regarding lake selection included the necessity for “spatial controls” in areas distant from the oil sands region; inclusion of lakes that already have long-term data, such as L4, L7 and L25 (Saffran and Trew 1996); and, replication within each geographic area (Birch Mountains, Caribou Mountains, Muskeg Mountain Uplands, Canadian Shield) and lake type (clear water/brown water).

Classification of the lakes as “clear water” or “brown water” was based on an arbitrary criterion for dissolved organic carbon (DOC) concentration: lakes with ≤20 mg/L DOC were classified as clear water and those with >20 mg/L DOC were considered brown water. Selection of both lake types in the Caribou Mountains and on the Canadian Shield (i.e., the spatial controls) was hindered by the lack of historical DOC data. Therefore, for the purposes of selecting candidate lakes, it was assumed that Caribou Mountain lakes would likely be brown water and Shield lakes would likely be clear water. The validity of these assumptions was to be confirmed in 1999.

The predicted PAI levels (i.e., acidic deposition rates) used to select lakes were those generated for the Cumulative Effects Assessment (CEA) scenario in the Syncrude Mildred Lake Upgrader Project EIA – Supplemental Response (Syncrude 1999). This scenario corresponds to the combined future deposition rates from all oil sands and related developments planned at the time of completion of the EIA. The range of PAI for the selected lakes was from <0.15 $k_{eq}$ $H^+$/ha/a (spatial control lakes and lakes subject to a low rate of acidic deposition) to just above 0.5 $k_{eq}$ $H^+$/ha/a (lakes closest to oil sands developments) (Table 1). A critical load of 0.25 $k_{eq}$ $H^+$/ha/a was proposed recently by the Target Loading Subgroup (1996) to protect Alberta’s most sensitive lakes and soils from acidification. Therefore, the RAMP monitoring network was intentionally designed to incorporate lakes in areas receiving acidic deposition above and below the critical load.

Locations of the final set of 32 lakes chosen for the RAMP long-term acidification monitoring network are shown in Figure 3.5. Water chemistry and PAI data relevant to lake selection are provided in Table 3.7. The selected lakes included 12 brown water and 10 clear water lakes in the oil sands region, five lakes on the Canadian Shield and five lakes in the Caribou Mountains. A few of these lakes could not be sampled during the field program, because of poor access by fixed-wing aircraft (L68), or because the lakes could not be located using the available coordinates (O6, O8, O9). Therefore, four new lakes were chosen, based on ease of access (L8) and the approximate locations of O6, O8 and O9 (R1, R2, R3). The available data are also shown for these lakes in Table 1 (identified as “new”).

J:\2000\2300\002-2309\6610\LAKE_SAMPLE_LOCATIONS.dwg




0 20 40 60 80km

SCALE 1:2,500,000

## LEGEND

- ● CARIBOU MOUNTAINS
- ★ OIL SANDS AREA
- ◆ CANADIAN SHIELD

## REFERNCE

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.

Golder Associates

**LOCATIONS OF THE LAKES SURVEYED IN 1999**

| | | | |
|---|---|---|---|
| DRAWN: TVS | APPROVED: | DATE: 24 MAY 2000 | |
| PROJECT: 002-2309.6610 | | FIGURE: 3.5 | |

**Table 3.7 Characteristics of Lakes Selected for Long-term Acidification Monitoring, Showing Data Available at the Time of Lake Selection.**

| Lake[a] | Lake Type | Latitude | Longitude | PAI[b] (keq/ha/a) | Alkalinity (mg $CaCO_3$/L) | DOC (mg/L) | Max. Depth (m) | Comment for 1999 Program |
|---|---|---|---|---|---|---|---|---|
| **Oil Sands Region** | | | | | | | | |
| A21 | brown water | 56.2667 | 111.2583 | 0.15 – 0.25 | 2.0 | 19.8 | - | |
| A42 | brown water | 56.3500 | 113.1833 | <0.15 | 9.2 | 27.7 | - | |
| A59 | brown water | 55.9083 | 112.8667 | <0.15 | 2.5 | 40.3 | - | |
| L1 | brown water | 57.2853 | 110.9239 | 0.5 - 0.1 | 4.3 | -[c] | 0.9 | |
| L4 (A-170) | brown water | 57.1519 | 110.8514 | 0.25 - 0.50 | 10.4 | 27.0 | 1.3 | |
| L7 | brown water | 57.0903 | 110.7519 | 0.25 – 0.50 | 13.1 | 27.0 | 1.6 | |
| L8 | brown water | 57.0458 | 110.5975 | 0.25 – 0.50 | 14.2 | - | 1.2 | new |
| L28 | brown water | 57.8556 | 112.9717 | 0.15 – 0.25 | 0.0 | 28.1 | 1.8 | |
| L46 (Bayard) | brown water | 57.7725 | 112.3964 | 0.25 - 0.50 | 6.9 | 23.6 | 1.3 | |
| L47 | brown water | 57.6894 | 112.7361 | 0.15 – 0.25 | 7.9 | 21.7 | 1.5 | |
| L49 | brown water | 57.7600 | 112.5967 | 0.15 – 0.25 | 7.8 | 27.5 | 1.1 | |
| L60 | brown water | 57.6622 | 112.6125 | 0.15 – 0.25 | 15.7 | 25.5 | 3.0 | |
| L68 | brown water | 57.8367 | 112.4606 | 0.25 - 0.50 | 11.4 | 40.0 | 0.8 | not sampled |
| A24 | clear water | 56.2167 | 111.2500 | 0.15 – 0.25 | 1.3 | 12.9 | - | |
| A26 | clear water | 56.2167 | 111.1667 | 0.15 – 0.25 | 3.1 | 8.3 | - | |
| A29 | clear water | 56.1667 | 111.5417 | 0.15 – 0.25 | 3.2 | 10.5 | - | |
| A47 | clear water | 56.2417 | 113.1333 | <0.15 | 8.4 | 16.4 | - | |
| A86 | clear water | 55.6833 | 111.8250 | <0.15 | 7.8 | 13.4 | - | |
| L18 (Namur) | clear water | 57.4444 | 112.6211 | 0.15 – 0.25 | 18.9 | 7.9 | 27.0 | |
| L23 (Otasan) | clear water | 57.7072 | 112.3875 | 0.25 – 0.50 | 6.4 | 13.8 | 7.0 | |
| L25 (Legend) | clear water | 57.4122 | 112.9336 | 0.15 – 0.25 | 10.2 | 9.3 | 9.4 | |
| L30 (W Clayton) | clear water | 58.0514 | 112.2669 | 0.25 – 0.50 | 0.0 | 7.9 | 0.9 | |
| L39 (A-150) | clear water | 57.9600 | 110.3969 | <0.15 | 9.9 | 17.3 | 1.1 | |
| **Caribou Mountains** | | | | | | | | |
| E52 (Fleming) | brown water? | 58.7708 | 115.4342 | control | 13.0 | - | - | |
| E59 (Rocky Island) | brown water? | 59.1350 | 115.1336 | control | 15.0 | - | - | |
| O1 (Unnamed #6) | brown water? | 59.2378 | 114.5200 | control | 4.0 | - | - | |
| O2 (Unnamed #9) | brown water? | 59.3108 | 115.3589 | control | 8.0 | - | - | |
| O3 | brown water? | 59.0489 | 116.2556 | control | 10.0 | - | - | |
| **Canadian Shield** | | | | | | | | |
| L109 (Fletcher) | brown water? | 59.1205 | 110.8165 | control | 20.7 | - | - | |
| O6 | clear water? | 58.6417 | 110.2375 | control | 2.0 | - | - | not sampled |
| O8 | clear water? | 58.3800 | 110.1792 | control | 4.0 | - | - | not sampled |
| O9 | clear water? | 58.4964 | 110.3744 | control | 6.0 | - | - | not sampled |
| O10 | clear water? | 59.1358 | 110.6667 | control | 8.0 | - | - | |
| R1 | clear water? | 59.1985 | 110.6868 | control | - | - | - | new |
| R2 | clear water? | 59.1225 | 110.5142 | control | - | - | - | new |
| R3 | clear water? | 59.1268 | 110.9315 | control | - | - | - | new |

[a] E# = Erickson (1987); O# = Acid Lake Database, AENV.

[b] PAI = Potential Acid Input.

[c] - = no data at the time of lake selection.

It should be noted that the predicted levels of acidic deposition are subject to ongoing refinement, which may necessitate periodic re-examination of the suitability of the lakes selected for this program. For example, the most recent PAI predictions generated for the CEA scenario of the Suncor Firebag In-Situ Oil Sands Project EIA (Suncor 2000) differ from those of Syncrude (1999). The refined model results of Suncor (2000) suggest that even with the addition of a new oil sands development, the area of >0.25 $k_{eq}$ $H^+$/ha/a PAI would be about half of that predicted by Syncrude (1999). Based on the Suncor (2000) model predictions, only three (L1, L4, L7) of the 32 lakes selected for the acidification monitoring network are located within or close to the area where the critical load would be exceeded in the future.

### 3.4.2 Field Methods

The field program was implemented during the summer of 1999. Sampling was carried out by Ms. Dorothy Kelker and Mr. Mark Spafford of Al-Pac, as part of an ongoing lake survey program being conducted in ALPAC's Forestry Management Area. Alberta Environment field staff collaborated by supplying technical advice and equipment. Lakes were sampled once between July 12 and August 17, 1999. A fixed-wing aircraft was used to access the study lakes.

Vertically integrated euphotic zone samples were collected from a number of sites in each lake using weighted Tygon tubing. The euphotic zone was defined as the depth of 1% of surface penetrating light, using a Protomatic photometer. Individual samples were then combined to form a single composite sample for the entire lake. Samples for chemical analysis were kept on ice and in the dark, and shipped to the Limnology Laboratory, University of Alberta, Edmonton within 24 hours of collection. All data have been archived by AENV.

Bathymetric data were unavailable for most of the lakes surveyed. In order to determine the approximate location of maximum depth in each lake (the preferred location for physical measurements), cross-sectional depth surveys were conducted in each lake. A global positioning system (GPS) unit was used to establish a linear transect and depth measurements were made by sonar at 100 m intervals across the central portion of each lake. Subsequently, vertical profiles of dissolved oxygen, temperature, specific conductance and pH were measured at the deepest location with a Hydrolab H20. Secchi depth was also recorded.

Sub-samples of 150 mL volume were taken from the euphotic zone composite samples, for phytoplankton taxonomy and chlorophyll *a* analysis. The phytoplankton samples were preserved using Lugol's solution. Samples for chlorophyll *a* analysis were stored and shipped on ice. At each lake, one or two replicate zooplankton samples were collected as vertical hauls through the euphotic zone with a #20 mesh, conical plankton net. Zooplankton samples were preserved in approximately 8% formalin after anaesthetizing in Bromoseltzer. Plankton samples are being stored at AENV. Chlorophyll *a* samples were shipped to the Limnology Laboratory, University of Alberta, Edmonton, for analysis.

# 4 QUALITY ASSURANCE / QUALITY CONTROL

## 4.1 WATER AND SEDIMENT QUALITY

### 4.1.1 Field Sampling

#### 4.1.1.1 Methods

A field Quality Assurance/Quality Control (QA/QC) sampling program for water and sediment was developed in partnership with Alberta Environment (AENV). This field program focused on the Muskeg River and Shipyard Lake, because the majority of water and sediment sampling occurred in these areas. The QA/QC field sampling program included:

- using field blanks to detect potential sample contamination during sample collection, shipping and analysis;
- using trip blanks to determine if sample contamination occurred during transport;
- analyzing RAMP/AENV split water samples to check intra-laboratory precision (i.e., precision at one laboratory) and inter-laboratory analytical variation (i.e., precision between the laboratories: RAMP samples were analyzed by Enviro-Test Laboratories (ETL); AENV samples were analyzed by Alberta Research Council, Vegreville [ARCV]);
- analyzing RAMP/AENV split sediment samples to check inter-laboratory analytical variation (i.e., RAMP samples were analyzed by AXYS; AENV samples were analyzed by ARCV); and
- analyzing total and dissolved metal field blanks to check intra-laboratory precision, inter-laboratory analytical variation and to determine the accuracy of RAMP's dissolved metal filtering procedure.

A detailed QA/QC field sampling schedule is provided in Table 4.1.

All water and sediment samples were collected in accordance with Golder Associates Technical Procedures 8.3-1 and 8.2-2, respectively (Golder 1999b). These procedures outlined standard sample collection, preservation, storage and shipping protocols. They also provided specific guidelines for field record keeping and sample tracking.

**Table 4.1 1999 RAMP QA/QC Water and Sediment Sampling Program Schedule and Description**

| Season | Sample Site | QA/QC Sample(s) | Description |
|---|---|---|---|
| Winter | Muskeg River – Upstream of the Canterra Road crossing | field blank | analyzed to detect potential sample contamination during collection, shipping and analysis |
| | Not site specific | trip blank | analyzed to determine if sample contamination occurred during transport |
| Spring | Shipyard Lake | field blank | analyzed to detect potential sample contamination during collection, shipping and analysis |
| | Not site specific | trip blank | analyzed to determine if sample contamination occurred during transport |
| Summer | Muskeg River-Downstream of Stanley Creek | split sample[a] | ETL analyzed one portion of the split sample and ARCV analyzed the other portion of the split sample to check inter-laboratory analytical variation |
| | | total and dissolved metal field blanks - 6 sets[b] of total and dissolved metal field blanks (3 sets contain deionized water from ETL, 3 sets contain deionized water from ARCV) | four sets of total and dissolved metal blanks were analyzed by ETL (two sets contained ETL water, two sets contained ARCV water), the other two blanks (one set contained ETL water, one set contained ARCV water) were analyzed by ARCV. Results used to assess potential contamination during sample preparation and analysis, as well as to check inter-laboratory analytical variation, intra-laboratory precision and the accuracy of RAMP's dissolved metal sampling procedure |
| | Shipyard Lake | field blank | analyzed to detect potential sample contamination during collection, shipping and analysis |
| | Not site specific | trip blank | analyzed to determine if sample contamination occurred during transport |
| Fall | Muskeg River-Downstream of Stanley Creek | total and dissolved metal field blanks - 4 sets of total and dissolved metal field blanks (2 sets contained deionized water from ETL, 2 from ARCV) | two sets of total and dissolved metal blanks were analyzed by ETL (one set contained ETL water, one set contained ARCV water), the other two blanks (one set contained ETL water, one set contained ARCV water) were analyzed by ARCV. Results used to assess potential contamination during sample preparation and analysis, as well as to check inter-laboratory analytical variation and the accuracy of RAMP's dissolved metal sampling procedure |
| | | field blank | analyzed to detect potential sample contamination during collection, shipping and analysis |
| | Muskeg River Mouth | split water sample (split into 6 portions) | three portions of the split sample were analyzed by ETL and the remaining three portions were analyzed by ARCV to determine intra-laboratory precision and check inter-laboratory analytical variation |
| | | split sediment sample | one portion of the split sample was analyzed for polycyclic aromatic hydrocarbons (PAHs) by AXYS, the other portion of the split sample was analyzed for PAHs by ARCV to check inter-laboratory analytical variation |
| | Not site specific | trip blank | analyzed to determine if sample contamination occurred during transport |

[a] Split sample = one single sample is collected and split into two or more sample containers. They are labelled, preserved individually and submitted separately to the analytical laboratory or to two different laboratories. Split samples are analyzed for the full water or sediment quality suite of parameters.

[b] Sample set = two sample bottles: total and dissolved metals.

In addition, all instruments used to assess water quality in the field were calibrated before use. Water and sediment quality sites sampled by Golder were recorded using a Global Positioning System (GPS) unit. The water and sediment quality sites sampled by AENV (i.e., sites in the Athabasca River Delta) were recorded on a topographical map.

### 4.1.1.2 Results

### *Field and Trip Blanks*

Field and trip blanks were analyzed by ETL. Parameter concentrations in both field and trip blanks 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). Water quality parameters that exceeded five times the MDL are listed in Tables 4.2 and 4.3. Raw data are presented in Appendix II, Table II-10.

Water quality results of the winter field and trip blanks indicate potential sample contamination. However, it is difficult to determine if the deionized water was contaminated before it was used to prepare the field blank (i.e., the water was not purified properly in the lab), during field sampling procedures or during the laboratory analysis processes.

### *Split Water Samples*

In general, water quality data analyzed by ETL and ARCV are comparable. Analytical variation is low in the Muskeg River summer and fall split samples (Table 4.4). ARCV used lower detection limits for some water quality parameters. ETL reported higher levels of some total metals (i.e., aluminum, copper, lead, nickel, silver and zinc) and dissolved metals (i.e., aluminum, antimony, arsenic, iron, molybdenum and zinc) than ARCV in the water sample collected near Aurora Mine (Table 4.4). ETL also reported higher levels of total aluminum, total iron, total nickel and dissolved cobalt than ARCV in the water sample collected at the Muskeg River Mouth (Table 4.4).

**Table 4.2 Summary of Water Quality Parameters in Field Blanks that Exceed Five Times the Method Detection Limit**

| Parameter | Unit | Detection Limit | Season[a] | | | Comments[b] |
|---|---|---|---|---|---|---|
| | | | Winter | Spring | Summer | |
| **Chlorophyll *a*** | | | | | | |
| chlorophyll *a* | µg/L | < 1 | - | 67 | - | A |
| **Total Metals** | | | | | | |
| barium | µg/L | < 0.2 | 4.3 | - | - | B |
| calcium | µg/L | < 100 | 3700 | - | - | A |
| chromium | µg/L | < 0.8 | 7.8 | - | - | B |
| copper | µg/L | < 1 | 8 | - | - | B |
| iron | µg/L | < 20 | - | 130 | - | A |
| lead | µg/L | < 0.1 | 3.5 | 0.6 | - | B, B |
| magnesium | µg/L | < 20 | 780 | - | - | A |
| manganese | µg/L | < 0.2 | 3.6 | - | 11.1 | A, D |
| molybdenum | µg/L | < 0.1 | 0.6 | - | - | B |
| nickel | µg/L | < 0.2 | 6.3 | 1.1 | - | C, C |
| potassium | µg/L | < 20 | 430 | - | - | D |
| sodium | µg/L | < 200 | 1000 | - | - | A |
| strontium | µg/L | < 0.2 | 24 | - | - | A |
| zinc | µg/L | < 4 | - | - | 21 | C |
| **Dissolved Metals** | | | | | | |
| barium | µg/L | < 0.1 | 2.3 | - | - | A |
| chromium | µg/L | < 0.4 | 7.6 | - | - | B |
| copper | µg/L | < 0.6 | 5.0 | - | - | B / C |
| lead | µg/L | < 0.1 | - | 0.7 | - | C |
| manganese | µg/L | < 0.1 | 3.0 | 0.6 | 10.3 | A, A, A |
| molybdenum | µg/L | < 0.1 | 0.6 | - | 0.9 | B, A |
| nickel | µg/L | < 0.1 | 6.3 | 0.7 | - | C, A |
| strontium | µg/L | < 0.1 | 14 | - | - | A |
| zinc | µg/L | < 2 | - | 13 | - | C |

[a] - = parameter did not exceed five times the method detection limit; no parameters in the fall field blank was found at concentrations in excess of five times the method detection limit.

[b] A = Sample concentrations from the relevant season were outside the historic range and greater than levels in the field blank; therefore, relevant sample concentrations were adjusted based on this result.

B = Sample concentrations from the relevant season generally contained levels consistent with historic data; therefore, this findings was assumed to be an isolated error.

C = Concentration in the field blank was higher than levels observed in the majority of the water samples collected in same season; therefore, this findings was assumed to be an isolated error.

D = Same as “A”, but trip blank concentration > field blank concentration; therefore, relevant sample concentrations were adjusted based on trip blank result.

**Table 4.3 Summary of Water Quality Parameters in Trip Blanks that Exceed Five Times the Detection Limit**

| Parameter | Unit | Detection Limit | Season[a] Winter | Spring | Summer | Fall | Comments[b] |
|---|---|---|---|---|---|---|---|
| **Nutrients and Chlorophyll *a*** | | | | | | | |
| total phosphorus | µg/L | < 1 | - | - | - | 6 | A |
| chlorophyll *a* | µg/L | < 1 | - | 13 | - | 11 | B, C |
| **Total Metals** | | | | | | | |
| aluminum | µg/L | < 20 | 440 | - | - | - | D |
| barium | µg/L | < 0.2 | 14.4 | - | - | - | A |
| chromium | µg/L | < 0.8 | 8.1 | - | - | - | A |
| manganese | µg/L | < 0.2 | 2.4 | - | 127 | - | B, C |
| nickel | µg/L | < 0.2 | 5 | - | - | - | E |
| potassium | µg/L | < 20 | 610 | - | - | - | C |
| titanium | µg/L | < 0.6 | 3.6 | - | - | - | D |
| **Dissolved Metals** | | | | | | | |
| manganese | µg/L | < 0.1 | 1 | - | - | - | B |

(a) - = parameter did not exceed five times the method detection limit.

(b) A = Concentration in trip blank was higher than concentrations observed in the field blank, and water samples contained levels consistent with historic data; therefore, this findings was assumed to be an isolated error.

B = Concentration in trip blank was lower than concentrations observed in the corresponding field blank, and sample concentrations were adjusted based on field blank results.

C = Concentration in trip blank was higher than concentrations observed in the field blank, and sample concentrations were adjusted based on this result.

D = Concentration in trip blank was higher than concentrations observed in either the field or the water samples collected during that season; therefore, this findings was assumed to be an isolated error.

E = Concentration in trip blank was lower than concentrations observed in the corresponding field blank, but higher than levels observed in water samples collected from that season; therefore, this findings was assumed to be an isolated error.

**Table 4.4 Water Quality of Muskeg River Split Samples – RAMP Field QA/QC Program, 1999**

| Parameter | Units | Downstream Stanley Creek (summer) | | Mouth (fall) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ETL | ARCV | ETL | | | ARCV | | |
| potassium (K) | µg/L | 470 | - | 1820 | 2030 | 1890 | - | - | - |
| selenium (Se) | µg/L | < 0.8 | < 0.5 | < 0.8 | < 0.8 | < 0.8 | < 0.5 | < 0.5 | < 0.5 |
| silver (Ag) | µg/L | 1.2 | 0.01 | < 0.4 | < 0.4 | < 0.4 | < 0.005 | < 0.005 | < 0.005 |
| sodium (Na) | µg/L | 4600 | - | 20800 | 12700 | 12000 | - | - | - |
| strontium (Sr) | µg/L | 126 | 133 | 225 | 215 | 224 | 222 | 222 | 224 |
| titanium (Ti) | µg/L | < 0.6 | 1.1 | 1.5 | 1.9 | 2.3 | 2.5 | 2.4 | 4.0 |
| uranium (U) | µg/L | < 0.1 | 0.03 | 0.30 | 0.30 | 0.30 | 0.25 | 0.23 | 0.25 |
| vanadium (V) | µg/L | 0.4 | 0.3 | < 0.2 | < 0.2 | < 0.2 | 0.3 | 0.2 | 0.2 |
| zinc (Zn) | µg/L | 5 | 1 | 4 | < 4 | 10 | 1 | 1 | 1 |
| **Metals (Dissolved)** | | | | | | | | | |
| aluminum (Al) | µg/L | 10 | 3.5 | 10 | < 10 | < 10 | 2.0 | 2.1 | 1.8 |
| antimony (Sb) | µg/L | 0.90 | 0.01 | < 0.8 | < 0.8 | < 0.8 | 0.04 | 0.02 | 0.02 |
| arsenic (As) | µg/L | 2.3 | 0.3 | < 0.4 | < 0.4 | < 0.4 | 0.2 | 0.2 | 0.3 |
| barium (Ba) | µg/L | 63 | 64 | 79 | 72 | 82 | 78 | 78 | 79 |
| beryllium (Be) | µg/L | < 0.5 | < 0.04 | < 0.5 | < 0.5 | < 0.5 | < 0.04 | < 0.04 | < 0.04 |
| boron (B) | µg/L | 37 | 34 | 57 | 38 | 52 | 47 | 46 | 47 |
| cadmium (Cd) | µg/L | 0.1 | < 0.01 | < 0.1 | < 0.1 | < 0.1 | < 0.01 | 0.011 | < 0.01 |
| chromium (Cr) | µg/L | < 0.4 | 0.19 | < 0.4 | < 0.4 | < 0.4 | 0.10 | < 0.08 | < 0.08 |
| cobalt (Co) | µg/L | 0.2 | 0.05 | 0.2 | 0.2 | 0.1 | 0.05 | 0.04 | 0.06 |
| copper (Cu) | µg/L | 1.5 | < 0.08 | 1.6 | 1.0 | 1.0 | 0.55 | 0.68 | 0.80 |
| iron (Fe) | µg/L | 440 | 1066 | 340 | 370 | 340 | 115 | 106 | 97 |
| lead (Pb) | µg/L | 0.2 | < 0.01 | < 0.1 | < 0.1 | < 0.1 | 0.13 | 0.11 | 0.15 |
| lithium (Li) | µg/L | 8 | 7 | 10 | 10 | 11 | 11.5 | 11.2 | 12.1 |
| manganese (Mn) | µg/L | 64.8 | 50.6 | 13.0 | 13.4 | 12.9 | 11.6 | 11.7 | 11.5 |
| mercury (Hg) | µg/L | < 0.2 | - | < 0.01 | < 0.01 | < 0.01 | - | - | - |
| molybdenum (Mo) | µg/L | 6.1 | 0.05 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| nickel (Ni) | µg/L | 1.1 | < 0.06 | 2.8 | 2.0 | 1.9 | 0.14 | 0.36 | 0.21 |
| selenium (Se) | µg/L | < 0.4 | < 0.5 | < 0.4 | < 0.4 | < 0.4 | < 0.5 | < 0.5 | < 0.5 |
| silver (Ag) | µg/L | 1.3 | < 0.005 | < 0.2 | < 0.2 | < 0.2 | < 0.005 | < 0.005 | < 0.005 |
| strontium (Sr) | µg/L | 139 | 130 | 234 | 220 | 227 | 221 | 222 | 222 |
| titanium (Ti) | µg/L | 1.3 | 0.9 | 1.0 | 1.1 | 1.1 | 2.2 | 2.0 | 2.6 |
| uranium (U) | µg/L | < 0.1 | 0.04 | 0.2 | 0.3 | 0.2 | 0.24 | 0.25 | 0.20 |
| vanadium (V) | µg/L | 0.2 | 0.2 | 0.3 | 0.3 | < 0.1 | 0.2 | 0.2 | 0.2 |
| zinc (Zn) | µg/L | 5 | 2 | < 2 | < 2 | < 2 | 1 | 1 | 1 |

\- = No data.

ETL and ARCV have high analytical precision. There is little or no internal laboratory variation in the water quality results of the split water sample collected from the Muskeg River mouth (Table 4.4). However, slight differences are reported by ETL in levels of a few total metals (i.e., aluminum, sodium and zinc). ARCV reported slight differences in total chromium and dissolved nickel (Table 4.4).

### *Split Sediment Samples*

In general, the analytical variation between AXYS and ARCV is low, although AXYS and ARCV used slightly different detection limits on a variety of sediment quality parameters (Table 4.5). Slight variability is noted between AXYS and ARCV in levels of parameters in the naphthalene, anthracene/chrysene and phenanthrene/anthracene groups. Slight differences are also noted in benzo(g,h,i)perylene, substituted dibenzothiophene and methyl fluoranthene/pyrene (Table 4.5). AXYS could not confirm the results for naphthalene, benzo(a) anthracene/chrysene and benzo(g,h,i)perylene (i.e., the GCMS spectra used to develop the results were ill-defined).

### *Total and Dissolved Metal Field Blanks*

ETL and ARCV analyzed total and dissolved metal field blanks that were prepared downstream of Stanley Creek in summer and fall (Table 4.6). Deionized water from ETL and ARCV were used in these field blanks to determine inter-laboratory analytical variation and intra-laboratory precision.

In summer, ETL's analytical precision was high. There was little variation in water quality from the replicate ETL and ARCV field blanks, with the exception of total and dissolved iron in ETL water and total and dissolved barium in ARCV water (Table 4.6).

Slight differences in data occasionally occur because ARCV used lower detection limits for some water quality parameters (Table 4.6). However, ETL consistently reports significantly higher levels of total and dissolved aluminum, manganese and zinc in both types of deionized water. Levels of other elements (i.e., total and dissolved barium, copper, iron and lead) are occasionally above detection limits. ETL was notified of potential metal contamination in their analysis process, and they have since applied corrective action. ETL water quality results for these parameters are significantly lower in fall, and more comparable to ARCV's reported results (Table 4.6).

In fall, ETL reported elevated levels of calcium and magnesium in ARCV deionized water, possibly indicating that this laboratory water was not purified properly (Table 4.6).

Reported dissolved metal levels were occasionally greater than corresponding total metal concentrations (i.e., aluminum, antimony, barium, copper, iron and zinc) (Table 4.6). However, due to the sporadic occurrences of elevated dissolved metal levels, it is difficult to conclude whether this is a result of laboratory analysis or field filtering procedure error.

**Table 4.5 Sediment Quality of the Muskeg River Mouth Split Sample - RAMP Field QA/QC Program, 1999**

| Parameter | Units | AXYS | ARCV |
|---|---|---|---|
| **Target PAHs and Alkylated PAHs** | | | |
| naphthalene | ng/g | 18[(a)] | 13 |
| methyl naphthalenes | ng/g | 15 | 5 |
| C2 substituted naphthalenes | ng/g | 18 | < 4 |
| C3 substituted naphthalenes | ng/g | 16 | < 6 |
| C4 substituted naphthalenes | ng/g | < 2 | < 4 |
| acenaphthene | ng/g | < 4 | < 2 |
| methyl acenaphthene | ng/g | < 1 | 3 |
| acenaphthylene | ng/g | < 1 | < 4 |
| anthracene | ng/g | < 3 | < 1 |
| dibenzo(a,h)anthracene | ng/g | < 21 | < 4 |
| benzo(a)anthracene/chrysene | ng/g | 16[(a)] | 8 |
| methyl benzo(a)anthracene/chrysene | ng/g | < 3 | 6 |
| C2 substituted benzo(a)anthracene/chrysene | ng/g | < 2 | 8 |
| benzo(a)pyrene | ng/g | < 10 | < 7 |
| methyl b(b&k)f/methyl b(a)p | ng/g | < 9 | < 9 |
| C2 substituted b(b&k)f/b(a)p | ng/g | < 6 | < 6 |
| benzo(b&k)fluoranthene | ng/g | < 12 | < 6 |
| benzo(g,h,i)perylene | ng/g | 14[(a)] | 7 |
| biphenyl | ng/g | < 1 | < 2 |
| methyl biphenyl | ng/g | < 1 | < 2 |
| C2 substituted biphenyl | ng/g | < 1 | < 2 |
| dibenzothiophene | ng/g | < 1 | < 1 |
| methyl dibenzothiophene | ng/g | < 10 | < 2 |
| C2 substituted dibenzothiophene | ng/g | < 4 | 12 |
| C3 substituted dibenzothiophene | ng/g | < 4 | 29 |
| fluoranthene | ng/g | 3 | < 1 |
| methyl fluoranthene/pyrene | ng/g | 17 | 8 |
| fluorene | ng/g | 3 | < 2 |
| methyl fluorene | ng/g | < 2 | < 3 |
| C2 substituted fluorene | ng/g | < 3 | < 3 |
| indeno(c,d-123)pyrene | ng/g | < 13 | 4 |
| phenanthrene | ng/g | 10 | 16 |
| methyl phenanthrene/anthracene | ng/g | 24 | 33 |
| C2 substituted phenanthrene/anthracene | ng/g | 40 | 25 |
| C3 substituted phenanthrene/anthracene | ng/g | 51 | 31 |
| C4 substituted phenanthrene/anthracene | ng/g | 36 | 86 |
| pyrene | ng/g | 5 | 3 |

[(a)] Note from AXYS labs indicating that results could not be confirmed (i.e., peak detected but did not meet quantification criteria).

**Table 4.6 Water Quality of Total and Dissolved Metal Field Blanks (Muskeg River - Downstream Stanley Creek) - RAMP Field QA/QC Program, 1999**

| Parameter | Units | Summer | | | | | | Fall | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Results from ETL | | | | Results from ARCV | | Results from ETL | | Results from ARCV | |
| | | ETL water (Replicates) | | ARCV water (Replicates) | | ETL water | ARCV water | ETL water | ARCV water | ETL water | ARCV water |
| **Metals (Total)** | | | | | | | | | | | |
| aluminum (Al) | µg/L | 320 | 270 | 250 | 280 | 24 | < 1 | 30 | < 20 | < 1 | 1 |
| antimony (Sb) | µg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | **0.016** | < 0.004 | < 0.8 | < 0.8 | 0.02 | < 0.004 |
| arsenic (As) | µg/L | < 1 | < 1 | < 1 | < 1 | < 0.02 | < 0.02 | < 1 | < 1 | < 0.02 | 0.03 |
| barium (Ba) | µg/L | 0.9 | 0.3 | 6.4 | 0.4 | **0.5** | < 0.1 | 0.8 | 1.4 | < 0.1 | < 0.1 |
| beryllium (Be) | µg/L | < 1 | < 1 | < 1 | < 1 | < 0.04 | < 0.04 | < 1 | < 1 | 0.05 | < 0.04 |
| boron (B) | µg/L | 9 | 6 | 4 | < 4 | **0.7** | **1.1** | < 4 | < 4 | < 0.08 | < 0.08 |
| cadmium (Cd) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.02 | < 0.02 | < 0.2 | < 0.2 | < 0.02 | < 0.02 |
| calcium (Ca) | µg/L | < 100 | < 100 | < 100 | < 100 | 53 | < 10 | < 100 | 500 | 13 | < 0.01 |
| chromium (Cr) | µg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | **0.1** | < 0.1 | < 0.8 | < 0.8 | < 0.08 | < 0.08 |
| cobalt (Co) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.02 | < 0.02 | < 0.2 | < 0.2 | < 0.02 | < 0.02 |
| copper (Cu) | µg/L | 2 | 1 | < 1 | 1 | 0.4 | < 0.08 | 2 | < 1 | 0.12 | 0.08 |
| iron (Fe) | µg/L | 90 | < 20 | < 20 | < 20 | 32 | < 3 | < 20 | < 20 | < 3 | < 3 |
| lead (Pb) | µg/L | 0.4 | 0.1 | < 0.1 | 0.2 | 0.4 | **0.1** | < 0.1 | < 0.1 | < 0.01 | < 0.01 |
| lithium (Li) | µg/L | < 6 | < 6 | < 6 | < 6 | < 0.1 | < 0.1 | 77 | 86 | < 0.1 | < 0.1 |
| magnesium (Mg) | µg/L | 30 | < 20 | < 20 | < 20 | - | - | < 20 | 70 | - | - |
| manganese (Mn) | µg/L | 14.4 | 12.9 | 10.2 | 11.0 | 0.6 | < 0.01 | 0.8 | 1.1 | < 0.01 | 0.07 |
| mercury (Hg) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | - | - | < 0.2 | < 0.2 | - | - |
| molybdenum (Mo) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.02 | < 0.02 | < 0.1 | < 0.1 | < 0.02 | < 0.02 |
| nickel (Ni) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.06 | < 0.06 | 0.2 | < 0.2 | < 0.06 | < 0.06 |
| potassium (K) | µg/L | < 20 | < 20 | < 20 | < 20 | - | - | 20 | < 20 | - | - |
| selenium (Se) | µg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.5 | < 0.5 | < 0.8 | < 0.8 | < 0.5 | < 0.5 |
| silver (Ag) | µg/L | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.005 | < 0.005 | < 0.4 | < 0.4 | < 0.005 | < 0.005 |
| sodium (Na) | µg/L | < 200 | < 200 | < 200 | < 200 | - | - | 200 | 300 | - | - |
| strontium (Sr) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.5 | < 0.5 | < 0.2 | 1.0 | 0.01 | 0.03 |
| titanium (Ti) | µg/L | < 0.6 | < 0.6 | < 0.6 | < 0.6 | < 0.2 | < 0.2 | < 0.6 | 0.9 | < 0.2 | < 0.2 |
| uranium (U) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.003 | < 0.003 | < 0.1 | < 0.1 | 0.005 | 0.005 |
| vanadium (V) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | 0.027 | < 0.008 | < 0.2 | 0.6 | 0.09 | 0.09 |
| zinc (Zn) | µg/L | 7 | 9 | 4 | 4 | 4 | **0.2** | 9 | < 4 | 0.5 | < 0.2 |
| **Metals (Dissolved)** | | | | | | | | | | | |
| aluminum (Al) | µg/L | 260 | 260 | 260 | 240 | **0.3** | < 0.1 | < 10 | < 10 | 0.2 | 14.2 |
| antimony (Sb) | µg/L | < 0.8 | < 0.8 | < 0.8 | 0.9 | 2.8 | 5.9 | < 0.8 | < 0.8 | 0.6 | 2.4 |
| arsenic (As) | µg/L | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.02 | < 0.02 | < 0.4 | < 0.4 | < 0.02 | < 0.02 |
| barium (Ba) | µg/L | 0.4 | < 0.1 | 6.8 | < 0.1 | 0.15 | < 0.02 | 0.2 | 1.8 | 1.0 | < 0.02 |
| beryllium (Be) | µg/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.04 | < 0.04 | < 0.5 | < 0.5 | < 0.04 | < 0.04 |
| boron (B) | µg/L | < 2 | < 2 | < 2 | < 2 | < 0.08 | < 0.08 | < 2 | < 2 | 0.16 | < 0.08 |
| cadmium (Cd) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.01 | < 0.01 | < 0.1 | < 0.1 | 0.01 | 0.01 |
| chromium (Cr) | µg/L | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.1 | < 0.1 | < 0.4 | < 0.4 | < 0.08 | < 0.08 |
| cobalt (Co) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.02 | < 0.02 | < 0.1 | < 0.1 | < 0.02 | < 0.02 |
| copper (Cu) | µg/L | 1.8 | 1.1 | 0.9 | 1.1 | < 0.08 | **0.1** | < 0.6 | 1.4 | < 0.08 | < 0.08 |
| iron (Fe) | µg/L | 60 | < 10 | 30 | 20 | < 3 | < 3 | < 10 | 20 | 58 | < 3 |
| lead (Pb) | µg/L | 0.3 | 0.1 | < 0.1 | 0.2 | **0.1** | **0.1** | < 0.1 | < 0.1 | < 0.01 | < 0.01 |
| lithium (Li) | µg/L | < 3 | < 3 | < 3 | < 3 | < 0.1 | < 0.1 | 9 | 12 | 0.3 | < 0.1 |
| manganese (Mn) | µg/L | 12.8 | 11.8 | 9.5 | 10.4 | 0.5 | 0.5 | 0.1 | 1.0 | 8.2 | 0.4 |
| mercury (Hg) | µg/L | 0.2 | 0.2 | 0.1 | 0.1 | - | - | < 0.1 | < 0.1 | - | - |
| molybdenum (Mo) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.02 | < 0.02 | < 0.1 | < 0.1 | < 0.02 | < 0.02 |
| nickel (Ni) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | **0.11** | < 0.06 | < 0.1 | < 0.1 | < 0.06 | < 0.06 |
| selenium (Se) | µg/L | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.5 | < 0.5 | < 0.4 | < 0.4 | < 0.5 | < 0.5 |
| silver (Ag) | µg/L | < 0.2 | < 0.2 | < 0.2 | 0.4 | < 0.005 | < 0.005 | < 0.2 | < 0.2 | < 0.005 | < 0.005 |
| strontium (Sr) | µg/L | 0.1 | < 0.1 | < 0.1 | < 0.1 | 0.1 | < 0.004 | < 0.1 | 0.9 | - | - |
| titanium (Ti) | µg/L | 0.4 | < 0.3 | < 0.3 | < 0.3 | < 0.2 | < 0.2 | < 0.3 | 0.5 | < 0.2 | < 0.2 |
| uranium (U) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.003 | < 0.003 | < 0.1 | < 0.1 | 0.005 | 0.004 |
| vanadium (V) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.008 | < 0.008 | 0.2 | 0.3 | 0.09 | 0.033 |
| zinc (Zn) | µg/L | 3 | < 2 | < 2 | < 2 | 3.9 | **0.4** | 4 | 5 | 0.3 | 0.3 |

Bolded values = less than method detection limit.

- = No data.

## 4.1.2 Laboratory Analysis

### 4.1.2.1 Methods

As part of the laboratory QA/QC program, RAMP requested ETL to provide the results of the internal quality control checks on their analytical equipment and sampling procedures. The laboratory QA/QC program included:

- Using lab equipment blanks to detect contamination from analytical equipment. Equipment blanks were prepared in spring and summer by rinsing precleaned equipment with laboratory deionized water, and collecting and analyzing the rinsate.
- Using spiked samples to check for interference from the laboratory sample matrix. Spiked samples were prepared by adding a specified amount of a chemical to the sample and measuring the percent recoveries.
- Splitting a water sample collected in the field to check analytical precision.

### 4.1.2.2 Results

#### *Lab Equipment Blanks*

Levels of water quality parameters that were five times above the method detection limit in the spring and summer lab equipment blanks are provided in Table 4.7. Raw data are provided in Appendix II, Table II-10.

**Table 4.7 Summary of Water Quality Parameters in Lab Equipment Blanks That Exceed Five Times the Detection Limit**

| Parameter | Unit | Detection Limit | Season[a] | | Comment[b] |
|---|---|---|---|---|---|
| | | | Spring | Summer | |
| **Total Recoverable Hydrocarbons** | | | | | |
| total recoverable hydrocarbons | mg/L | < 0.5 | - | 12.1 | A |
| **Total Metals** | | | | | |
| manganese | µg/L | < 0.2 | - | 8.1 | B |
| nickel | µg/L | < 0.2 | - | 2.5 | A |
| silver | µg/L | < 0.4 | 5.9 | - | A |
| zinc | µg/L | < 4 | - | 24 | A |
| **Dissolved Metals** | | | | | |
| boron | µg/L | < 2 | 12 | - | A |
| zinc | µg/L | < 2 | 23 | - | A |

[a] Lab blanks were not included in the winter or fall sampling programs; - = parameter did not exceed five times the method detection limit.

[b] A = Concentration in lab blank was higher than concentrations observed in either the field blank, trip blank or the water samples collected during that season; therefore, this findings was assumed to be an isolated error.

B = Concentration in lab blank was lower than concentrations observed in the corresponding field blank, and sample concentrations were adjusted based on field blank results.

## *Spiked Samples*

ETL spiked samples to check for interference from the laboratory sample matrix. Percentage recovery of spring and summer spiked samples are shown in Table 4.8. Water quality parameters that had less than 80% recovery were total silver, total uranium, dissolved antimony and dissolved silver.

**Table 4.8 Percent Recovery of Water Quality Parameters in Spiked Samples, RAMP Laboratory QA/QC Program, 1999**

| Parameter | Percent Recovery | |
|---|---|---|
| | spring | summer |
| **Conventional Parameters** | | |
| calcium | 100 | 95 |
| chloride | 105 | 99 |
| dissolved organic carbon | 97 | 95 |
| magnesium | 101 | 103 |
| potassium | 93 | 97 |
| sodium | 97 | 99 |
| sulphate | 95 | 100 |
| sulphide | 109 | 111 |
| total organic carbon | 99 | 101 |
| **Nutrients** | | |
| nitrate + nitrite | 95 | 93 |
| nitrogen - ammonia | 109 | 94 |
| nitrogen - kjeldahl | 101 | 93 |
| phosphorus, total | 94 | 111 |
| phosphorus,total dissolved | 92 | 104 |
| **Organics** | | |
| naphthenic acids | 95 | 107 |
| total phenolics | 96 | 109 |
| **Metals (Total)** | | |
| aluminum (Al) | 94 | 97 |
| antimony (Sb) | 105 | 101 |
| arsenic (As) | 91 | 97 |
| barium (Ba) | 91 | 107 |
| beryllium (Be) | 93 | 94 |
| boron (B) | 121 | 105 |
| cadmium (Cd) | 95 | 97 |
| calcium (Ca) | 114 | 110 |
| chromium (Cr) | 102 | 104 |
| cobalt (Co) | 91 | 96 |
| copper (Cu) | 100 | 96 |
| iron (Fe) | 95 | 98 |
| lead (Pb) | 89 | 104 |
| lithium (Li) | 108 | 104 |
| magnesium (Mg) | 113 | 102 |
| manganese (Mn) | 90 | 96 |
| mercury (Hg) | 94 | 92 |
| molybdenum (Mo) | 117 | 102 |
| nickel (Ni) | 84 | 96 |
| potassium (K) | 95 | 97 |

| Parameter | Percent Recovery | |
|---|---|---|
| | spring | summer |
| selenium (Se) | 88 | 92 |
| silver (Ag) | 108 | 58 |
| sodium (Na) | 136 | 112 |
| strontium (Sr) | 99 | 113 |
| titanium (Ti) | 101 | 98 |
| uranium (U) | 79 | 102 |
| vanadium (V) | 101 | 98 |
| zinc (Zn) | 94 | 89 |
| **Metals (Dissolved)** | | |
| aluminum (Al) | 137 | 91 |
| antimony (Sb) | 98 | 41 |
| arsenic (As) | 101 | 95 |
| barium (Ba) | 100 | 108 |
| beryllium (Be) | 102 | 97 |
| boron (B) | 118 | 106 |
| cadmium (Cd) | 103 | 100 |
| chromium (Cr) | 93 | 104 |
| cobalt (Co) | 91 | 95 |
| copper (Cu) | 91 | 99 |
| iron (Fe) | 95 | 94 |
| lead (Pb) | 104 | 104 |
| lithium (Li) | 86 | 103 |
| manganese (Mn) | 98 | 92 |
| mercury (Hg) | 93 | 93 |
| molybdenum (Mo) | 121 | 100 |
| nickel (Ni) | 86 | 96 |
| selenium (Se) | 93 | 100 |
| silver (Ag) | 101 | 66 |
| strontium (Sr) | 86 | 105 |
| titanium (Ti) | 84 | 98 |
| uranium (U) | 104 | 101 |
| vanadium (V) | 93 | 97 |
| zinc (Zn) | 98 | 99 |

## *Split Samples*

ETL split spring and summer water samples collected from Shipyard Lake. The absolute and percent difference of each water quality parameter analyzed in the split samples are shown in Table 4.9. Water quality parameters that had a difference equal to or greater than 25% were a few total metals (i.e., aluminum, copper, molybdenum, zinc) and dissolved metals (i.e., aluminum, iron, mercury, nickel, titanium, vanadium, zinc). However, the numerical difference of these parameters in the split samples were insignificant. Absolute differences of total copper and dissolved nickel in summer were the only exception (Table 4.9).

**Table 4.9 Water Quality of Shipyard Lake Split Samples, RAMP Laboratory QA/QC Program, 1999**

| Parameter | Units | Spring | | | Summer | | |
|---|---|---|---|---|---|---|---|
| | | Split Sample | | Difference between Split Samples (% Difference) | Split Sample | | Difference between Split Samples (% Difference) |
| **Conventional Parameters** | | | | | | | |
| bicarbonate | mg/L | 186 | 189 | 3(2) | 131 | 132 | 1(1) |
| calcium | mg/L | 41.2 | 41.2 | 0(0) | 31.8 | 32.0 | 0.2(1) |
| carbonate | mg/L | < 5 | < 5 | 0(0) | 16 | 16 | 0(0) |
| chloride | mg/L | 9 | 9 | 0(0) | 8 | 8 | 0(0) |
| colour | T.C.U. | 30 | 30 | 0(0) | 40 | 40 | 0(0) |
| conductance | µS/cm | 334 | 311 | 23(7) | 275 | 274 | 1(0) |
| dissolved organic carbon | mg/L | 16 | 16 | 0(0) | 16 | 16 | 0(0) |
| hardness | mg/L | 142 | 143 | 1(1) | 120 | 122 | 2(2) |
| magnesium | mg/L | 9.5 | 9.7 | 0.2(2) | 9.9 | 10.1 | 0.2(2) |
| pH | - | 8.0 | 7.8 | 0.2(3) | 8.9 | 8.9 | 0(0) |
| potassium | mg/L | 1.5 | 1.5 | 0(0) | 0.5 | 0.5 | 0(0) |
| sodium | mg/L | 12 | 13 | 1(8) | 13 | 13 | 0(0) |
| sulphate | mg/L | 5.2 | 5.4 | 0.2(4) | 3.5 | 3.7 | 0.2(5) |
| sulphide | mg/L | 0.003 | 0.003 | 0(0) | < 0.003 | < 0.003 | 0(0) |
| total alkalinity | mg/L | 152 | 155 | 3(2) | 134 | 135 | 1(1) |
| total dissolved solids | mg/L | 220 | 210 | 10(5) | 220 | 210 | 10(5) |
| total organic carbon | mg/L | 18 | 19 | 1(5) | 18 | 19 | 1(5) |
| total suspended solids | mg/L | < 3 | < 3 | 0(0) | 4 | 4 | 0(0) |
| **Nutrients** | | | | | | | |
| nitrate + nitrite | mg/L | < 0.1 | < 0.1 | 0(0) | 0.1 | 0.1 | 0(0) |
| nitrogen - ammonia | mg/L | < 0.05 | < 0.05 | 0(0) | < 0.05 | < 0.05 | 0(0) |
| nitrogen - kjeldahl | mg/L | 0.9 | 0.9 | 0(0) | 0.8 | 0.8 | 0(0) |
| phosphorus, total | µg/L | 19 | 19 | 0(0) | 12 | 13 | 1(8) |
| phosphorus,total dissolved | µg/L | 14 | 14 | 0(0) | 4 | 4 | 0(0) |
| **Organics** | | | | | | | |
| naphthenic acids | mg/L | < 1 | < 1 | 0(0) | < 1 | < 1 | 0(0) |
| total phenolics | µg/L | 7 | 6 | 1(14) | 2 | 1 | 1(50) |
| **Metals (Total)** | | | | | | | |
| aluminum (Al) | µg/L | 30 | 40 | 10(25) | 70 | 70 | 0(0) |
| antimony (Sb) | µg/L | < 0.8 | < 0.8 | 0(0) | < 0.8 | < 0.8 | 0(0) |
| arsenic (As) | µg/L | < 1 | < 1 | 0(0) | < 1 | < 1 | 0(0) |
| barium (Ba) | µg/L | 33.9 | 32.6 | 1.3(4) | 21.6 | 21.8 | 0.2(1) |
| beryllium (Be) | µg/L | < 1 | < 1 | 0(0) | < 1 | < 1 | 0(0) |
| boron (B) | µg/L | < 4 | < 4 | 0(0) | 34 | 36 | 2(6) |
| cadmium (Cd) | µg/L | < 0.2 | < 0.2 | 0(0) | < 0.2 | < 0.2 | 0(0) |
| calcium (Ca) | µg/L | 36600 | 37500 | 900(2) | 32200 | 30500 | 1700(5) |
| chromium (Cr) | µg/L | < 0.8 | < 0.8 | 0(0) | < 0.8 | < 0.8 | 0(0) |
| cobalt (Co) | µg/L | < 0.2 | < 0.2 | 0(0) | < 0.2 | < 0.2 | 0(0) |

| Parameter | Units | Spring | | | Summer | | |
|---|---|---|---|---|---|---|---|
| | | Split Sample | | Difference between Split Samples (% Difference) | Split Sample | | Difference between Split Samples (% Difference) |
| copper (Cu) | µg/L | < 1 | < 1 | 0(0) | 1 | 4 | 3(75) |
| iron (Fe) | µg/L | 380 | 430 | 50(12) | 220 | 200 | 20(9) |
| lead (Pb) | µg/L | 0.4 | 0.4 | 0(0) | 0.1 | 0.2 | 0.1(50) |
| lithium (Li) | µg/L | 9 | 9 | 0(0) | 10 | 10 | 0(0) |
| magnesium (Mg) | µg/L | 8040 | 7840 | 200(2) | 9830 | 8720 | 1110(11) |
| manganese (Mn) | µg/L | 24.3 | 26.6 | 2.3(9) | 18.6 | 17.4 | 1.2(6) |
| mercury (Hg) | µg/L | < 0.2 | < 0.2 | 0(0) | < 0.2 | < 0.2 | 0(0) |
| molybdenum (Mo) | µg/L | 0.4 | 0.3 | 0.1(25) | 0.1 | 0.2 | 0.1(50) |
| nickel (Ni) | µg/L | 1.3 | 1.9 | 0.6(32) | 0.6 | 0.5 | 0.1(17) |
| potassium (K) | µg/L | 1200 | 1220 | 20(2) | 530 | 450 | 80(15) |
| selenium (Se) | µg/L | < 0.8 | < 0.8 | 0(0) | < 0.8 | < 0.8 | 0(0) |
| silver (Ag) | µg/L | < 0.4 | < 0.4 | 0(0) | < 0.4 | < 0.4 | 0(0) |
| sodium (Na) | µg/L | 11600 | 11100 | 500(4) | 11500 | 12900 | 1400(11) |
| strontium (Sr) | µg/L | 128 | 130 | 2(2) | 113 | 111 | 3(2) |
| titanium (Ti) | µg/L | 1.0 | 1.0 | 0(0) | < 0.6 | < 0.6 | 0(0) |
| uranium (U) | µg/L | < 0.1 | < 0.1 | 0(0) | < 0.1 | < 0.1 | 0(0) |
| vanadium (V) | µg/L | < 0.2 | < 0.2 | 0(0) | 0.2 | 0.2 | 0(0) |
| zinc (Zn) | µg/L | 7 | 9 | 2(22) | 12 | 9 | 3(25) |
| **Metals (Dissolved)** | | | | | | | |
| aluminum (Al) | µg/L | 10 | 10 | 0(0) | 10 | 20 | 20(50) |
| antimony (Sb) | µg/L | < 0.8 | < 0.8 | 0(0) | < 0.8 | 1.8 | 1(56) |
| arsenic (As) | µg/L | < 0.4 | 0.5 | 0.1(20) | 1.3 | 1.0 | 0.3(23) |
| barium (Ba) | µg/L | 30.8 | 25.8 | 5(16) | 17.1 | 17.0 | 0.1(1) |
| beryllium (Be) | µg/L | < 0.5 | < 0.5 | 0(0) | < 0.5 | < 0.5 | 0(0) |
| boron (B) | µg/L | 3 | < 2 | 1(34) | 35 | 35 | 0(0) |
| cadmium (Cd) | µg/L | < 0.1 | < 0.1 | 0(0) | < 0.1 | < 0.1 | 0(0) |
| chromium (Cr) | µg/L | 0.4 | 0.4 | 0(0) | < 0.4 | < 0.4 | 0(0) |
| cobalt (Co) | µg/L | 0.1 | 0.1 | 0(0) | 0.1 | 0.1 | 0(0) |
| copper (Cu) | µg/L | 0.9 | 1.0 | 0.1(10) | 1.6 | 1.6 | 0(0) |
| iron (Fe) | µg/L | 140 | 210 | 70(33) | 130 | 120 | 10(8) |
| lead (Pb) | µg/L | 0.2 | 0.2 | 0(0) | 0.2 | 0.2 | 0(0) |
| lithium (Li) | µg/L | 8 | 8 | 0(0) | 10 | 11 | 1(9) |
| manganese (Mn) | µg/L | 15.4 | 18.8 | 3.4(18) | 11.1 | 11.4 | 0.3(3) |
| mercury (Hg) | µg/L | 0.1 | 0.1 | 0(0) | 0.2 | 0.1 | 0.1(0) |
| molybdenum (Mo) | µg/L | 0.4 | 0.4 | 0(0) | 0.6 | 0.5 | 0.1(0) |
| nickel (Ni) | µg/L | 1.4 | 1.9 | 0.5(26) | 0.5 | 1.5 | 0.5(67) |
| selenium (Se) | µg/L | < 0.4 | < 0.4 | 0(0) | < 0.4 | < 0.4 | 0(0) |
| silver (Ag) | µg/L | < 0.2 | < 0.2 | 0(0) | < 0.2 | < 0.2 | 0(0) |
| strontium (Sr) | µg/L | 124 | 120 | 4(3) | 112 | 119 | 7(6) |
| titanium (Ti) | µg/L | 0.9 | 0.9 | 0(0) | < 0.3 | 0.4 | 0.1(25) |
| uranium (U) | µg/L | < 0.1 | < 0.1 | 0(0) | < 0.1 | < 0.1 | 0(0) |
| vanadium (V) | µg/L | 0.2 | 0.3 | 0.1(33) | 0.2 | 0.1 | 0.1(50) |
| zinc (Zn) | µg/L | 8 | 10 | 2(20) | < 2 | 4 | 2(50) |

### 4.1.3 Data Analysis

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

## 4.2 FISHERIES

### 4.2.1 Field Sampling

Fish collections for sentinel monitoring and inventory work were conducted in accordance to Golder Technical Procedure 8.1.3 (Golder 1999b). Sentinel species were processed according to procedures outlined in the Technical Procedure 8.15-0 (Golder 1999b). Detailed field notes were maintained in a bound notebook and fisheries data were recording using appropriate capture and biomarking data sheets.

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

Eggs for fecundity analyses were stored in labelled plastic vials filled with Gillson's solution (i.e., preservative) pending future laboratory analyses. Fish ageing structures (otoliths, scales) were stored in labelled plastic vials. Chain-of-custody forms were used when shipping these structures for ageing analyses.

### 4.2.2 Laboratory Analysis

Fish ageing was conducted by Northshore Environmental Services, Thunder Bay, Ontario. Jon Tost (proprietor) is recognized as an expert in ageing fish. Otoliths were the primary ageing structure, although scales were also used when necessary. Ageing structures were read independently at least three times and a numerical confidence level was assigned to each age estimate.

A single person (Golder Associates) 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%.

### 4.2.3 Data Analysis

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 IV.

# 5 ATHABASCA RIVER – RESULTS AND DISCUSSION

## 5.1 WATER AND SEDIMENT QUALITY

### 5.1.1 Water Quality

#### *Near the Embarras River*

Water collected from the Athabasca River near the Embarras River during the winter of 1999 was non-toxic (as defined by Microtox® testing) and contained non-detectable levels of naphthenic acids (Table 5.1). Concentrations of nutrients, major ions, metals and organics were consistent with historical data (Tables 5.1 and 5.2). However, in 1999, the Athabasca River was more basic (Appendix II, Table II-1) and contained more total zinc and aluminum than recently observed at this sampling location (Figures 5.1 and 5.2).

The pH and total zinc levels observed in 1999 did not exceed Alberta surface water guidelines for the protection of aquatic life and human health (Table 5.3). Total aluminum and iron concentrations exceeded water quality guidelines in 1999 (Table 5.3). Iron and aluminum levels have previously been observed to exceed guideline levels at this location in the Athabasca River (Figures 5.1 and 5.3).

Mercury concentrations in the Athabasca River have previously been observed to exceed the mercury guidelines upstream and downstream of Fort McMurray (Golder 1998b). However, the standard analytical detection limits for mercury exceed guideline levels, so it is unclear if mercury concentrations exceeded regulatory guidelines in 1999 at any of the Athabasca River sampling stations discussed herein (Table 5.3). The analytical detection limits reported in 1999 for total silver also exceed guidelines.

#### *Athabasca River Delta*

In the summer of 1999, water in the Athabasca River Delta was more basic and contained higher total dissolved solids (TDS), total aluminum, barium and zinc concentrations than typically observed in this area (Tables 5.1 and 5.2). Increased total metal levels may be the result of increased levels of total suspended solids (TSS), since dissolved metal concentrations were much smaller than the total metal concentrations. Sample waters collected in 1999 were non-toxic to bacteria and contained non-detectable levels of naphthenic acids.

**Table 5.1 Water Quality in the Athabasca River and the Athabasca River Delta**

| Parameter | Units | Near Embarras River (winter) | | Athabasca Delta (summer) | |
|---|---|---|---|---|---|
| | | 1999 | Historical Median[a] | 1999[b] | Historical Median[c] |
| **Field Measured** | | | | | |
| pH | | 8.2 | 7.4 | 8.2 | 7.7 |
| specific conductance | µS/cm | 473 | 459 | 255 | 240 |
| temperature | °C | 0.1 | 0.0 | - | 17.8 |
| dissolved oxygen | mg/L | 13.5 | 10.7 | - | 8.6 |
| **Conventional Parameters and Major Ions** | | | | | |
| chloride | mg/L | 38 | 32 | 6 | 6 |
| dissolved organic carbon | mg/L | 5 | 7 | 5 | 8 |
| sulphate | mg/L | 46 | 33 | 23 | 17 |
| total alkalinity | mg/L | 149 | 144 | 105 | 93 |
| total dissolved solids | mg/L | 300 | 265 | 190 | 141 |
| total organic carbon | mg/L | 6 | 8 | 6 | 10 |
| total suspended solids | mg/L | 5 | 4 | 157 | 92 |
| **Nutrients and Chlorophyll *a*** | | | | | |
| nitrate + nitrite | mg/L | 0.3 | 0.2 | < 0.1 | - |
| nitrogen – ammonia | mg/L | 0.08 | 0.05 | < 0.05 | - |
| nitrogen – total | mg/L | 0.8 | 0.8 | 0.7 | 0.6 |
| phosphorus, total | µg/L | 34 | 32 | 103 | 89 |
| chlorophyll *a* | µg/L | 0 | 0.3 | 7 | 1 |
| **Biochemical oxygen demand** | | | | | |
| biochemical oxygen demand | mg/L | < 2 | 0.6 | < 2 | - |
| **Toxicity[d]** | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | - | > 91 | - |
| Microtox IC25 @ 15 min | % | > 91 | - | > 91 | - |
| **Organics** | | | | | |
| naphthenic acids | mg/L | < 1 | - | < 1 | - |
| total phenolics | µg/L | 2 | 4 | < 1 | 3 |

[a] Based on information from NAQUADAT stations AB07DD0004/006/007/008.

[b] pH and specific conductance measurements were measured in the lab, not in the field.

[c] Based on information from NAQUADAT stations AB07DD0160/170/220/230/240.

[d] Microtox® results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

**Table 5.2 Metal Levels in the Athabasca River and the Athabasca River Delta**

| Parameter | Units | Near Embarras River (winter) | | Athabasca Delta (summer) | |
|---|---|---|---|---|---|
| | | 1999 | Historical Median[a] | 1999 | Historical Median[b] |
| **Total Metals** | | | | | |
| aluminum (Al) | µg/L | 300 | 70 | 6890 | 600 |
| antimony (Sb) | µg/L | < 0.8 | - | < 0.8 | - |
| arsenic (As) | µg/L | < 1 | 0.4 | 2 | 1.4 |
| barium (Ba) | µg/L | 65 | 66 | 122 | 61 |
| cadmium (Cd) | µg/L | < 0.2 | 0 | < 0.2 | < 1 |
| chromium (Cr) | µg/L | 4 | 2 | 8 | 3 |
| copper (Cu) | µg/L | 2 | 1 | 5 | 3 |
| iron (Fe) | µg/L | 600 | 556 | 4560 | - |
| lead (Pb) | µg/L | 0.4 | - | 2.2 | - |
| manganese (Mn) | µg/L | 39 | - | < 127 | - |
| mercury (Hg) | µg/L | < 0.2 | < 0.1 | < 0.2 | < 0.1 |
| molybdenum (Mo) | µg/L | 1.8 | - | 1.1 | - |
| nickel (Ni) | µg/L | 4.2 | - | 6.3 | - |
| selenium (Se) | µg/L | < 0.8 | < 0.1 | < 0.8 | < 0.2 |
| silver (Ag) | µg /L | < 0.4 | - | < 0.4 | - |
| zinc (Zn) | µg/L | 18 | 4 | 17 | 9 |
| **Dissolved Metals** | | | | | |
| aluminum (Al) | µg/L | 100 | - | < 10 | - |
| antimony (Sb) | µg/L | 0.8 | - | < 0.8 | - |
| arsenic (As) | µg/L | < 0.4 | 0.5 | 0.6 | 0.9 |
| barium (Ba) | µg/L | 63 | - | 52 | - |
| cadmium (Cd) | µg/L | 0.3 | - | < 0.1 | - |
| chromium (Cr) | µg/L | < 0.4 | < 3 | < 0.4 | < 3 |
| copper (Cu) | µg/L | 1.6 | - | 1.5 | - |
| iron (Fe) | µg/L | 130 | - | 150 | - |
| lead (Pb) | µg/L | 0.6 | - | < 0.1 | - |
| manganese (Mn) | µg/L | 32.6 | - | < 10.3 | - |
| mercury (Hg) | µg/L | < 0.1 | - | < 0.1 | - |
| molybdenum (Mo) | µg/L | 1.9 | - | 0.1 | - |
| nickel (Ni) | µg/L | 2.4 | - | 1.1 | - |
| selenium (Se) | µg/L | < 0.4 | < 0.2 | < 0.4 | < 0.2 |
| silver (Ag) | µg/L | < 0.2 | - | < 0.2 | - |
| zinc (Zn) | µg/L | 12 | - | 3 | - |

[a] Based on information from NAQUADAT stations AB07DD0004/006/007/008.

[b] Based on information from NAQUADAT stations AB07DD0160/170/220/230/240.

**Table 5.3 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Athabasca River and the Athabasca River Delta**

| Parameter | Units | Guidelines for the Protection of | | | Near Embarras River (winter) | | Athabasca Delta (summer) | |
|---|---|---|---|---|---|---|---|---|
| | | Aquatic Life[a] | | Human Health[b] | 1999 | Historical Median | 1999 | Historical Median |
| | | Acute | Chronic | | | | | |
| **Nutrients** | | | | | | | | |
| phosphorus, total | µg /L | - | 50 | - | | | C | C |
| **Total Metals** | | | | | | | | |
| aluminum (Al) | µg /L | 750 | 100 | - | C | | A C | C |
| iron (Fe) | µg /L | - | 300 | 300 | C H | C H | C H | - |
| manganese (Mn) | µg /L | - | - | 50 | | - | H` | - |
| mercury (Hg)[c] | µg /L | 1.4 | 0.1 | 0.05 | C H` | H` | C H` | H` |
| silver (Ag) | µg /L | 3.4 - 9.0* | 0.1 | - | C` | - | C` | - |

[a] Guidelines taken from AENV (1999).

[b] Guidelines taken from U.S. EPA (1999).

[c] Using U.S. EPA and CCME guidelines, respectively, because Alberta mercury guidelines have not been finalized.

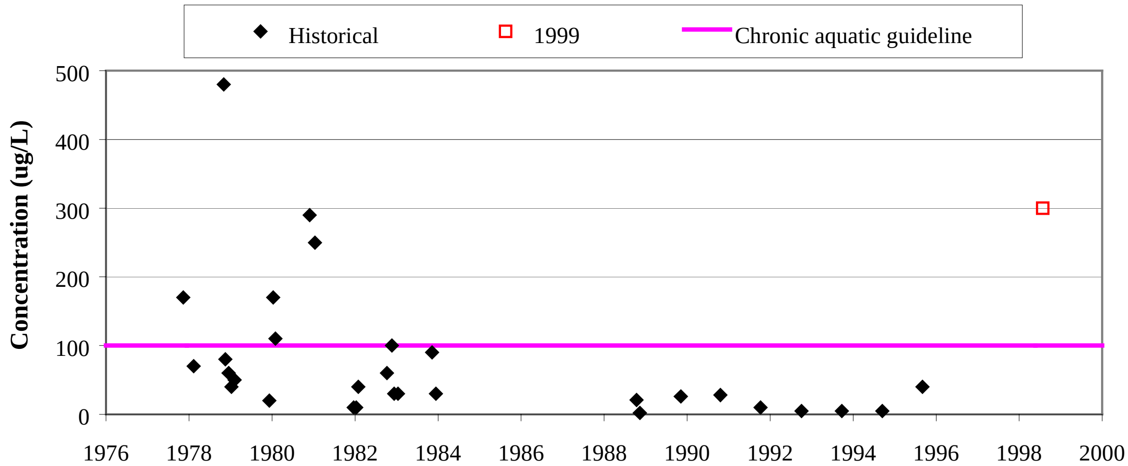
* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

A = acute aquatic guideline exceeded; C = chronic aquatic guideline exceeded; H = human health guideline exceeded.

- no guideline / no data.

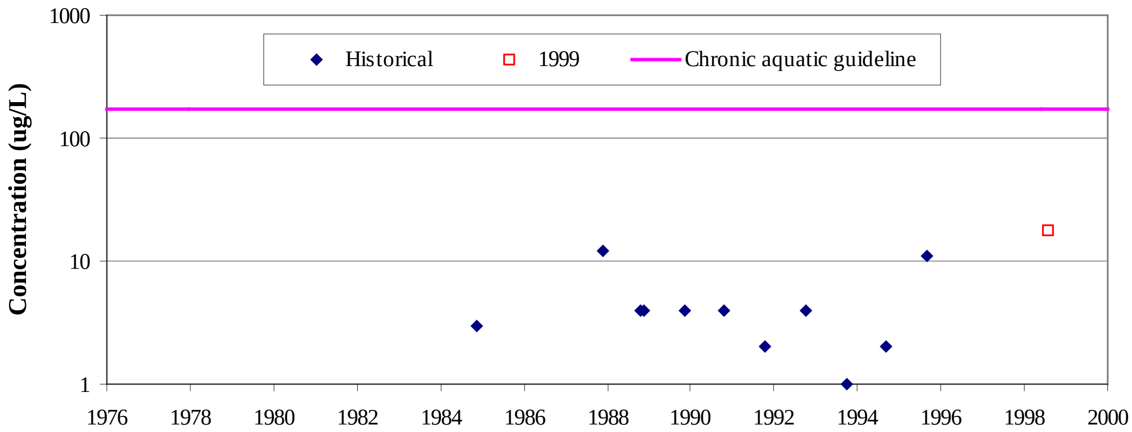
` Although substance concentrations were below detection limits, the analytical detection limit exceeded the relevant surface water guideline.

**Figure 5.1 Winter Total Aluminum Concentrations in the Athabasca River near the Embarras River**



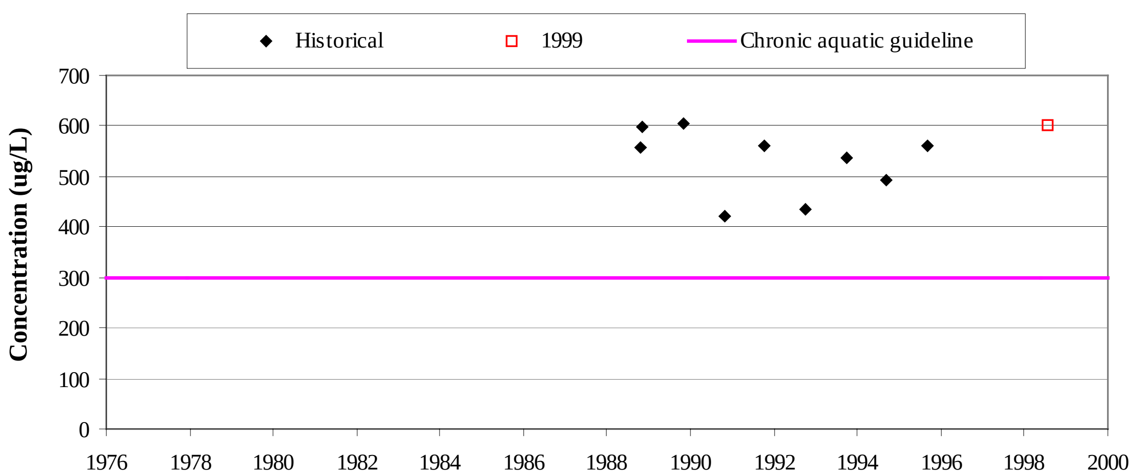

Guideline based on hardness of 150 mg/L; non-detects replaced with detection limit.

**Figure 5.2 Winter Total Zinc Levels in the Athabasca River near the Embarras River**




Guideline based on hardness of 150 mg/L; non-detects replaced with detection limit.

**Figure 5.3 Winter Total Iron Levels in the Athabasca River near the Embarras River**




Guideline based on hardness of 150 mg/L; non-detects replaced with detection limit.

As illustrated in Figures 5.4 and 5.5, TDS and total aluminum concentrations were higher in 1999 than in previous sampling events. The same was true for total barium (Appendix II, Table II-1). However, total barium concentrations in 1999 were below human health guidelines, and TDS levels in the delta were lower than TDS levels in the Athabasca River (Tables 5.1 and 5.3).

Although total aluminum levels in the Athabasca River Delta generally exceed the chronic aquatic guideline, total aluminum concentrations in 1999 exceeded both chronic and acute aquatic guidelines (Figure 5.5). Total phosphorus concentrations exceeded water quality guidelines in 1999. The historical median value for total phosphorus also exceeds the chronic aquatic guideline.

**Figure 5.4 Summer Total Dissolved Solids Levels in the Athabasca River Delta**

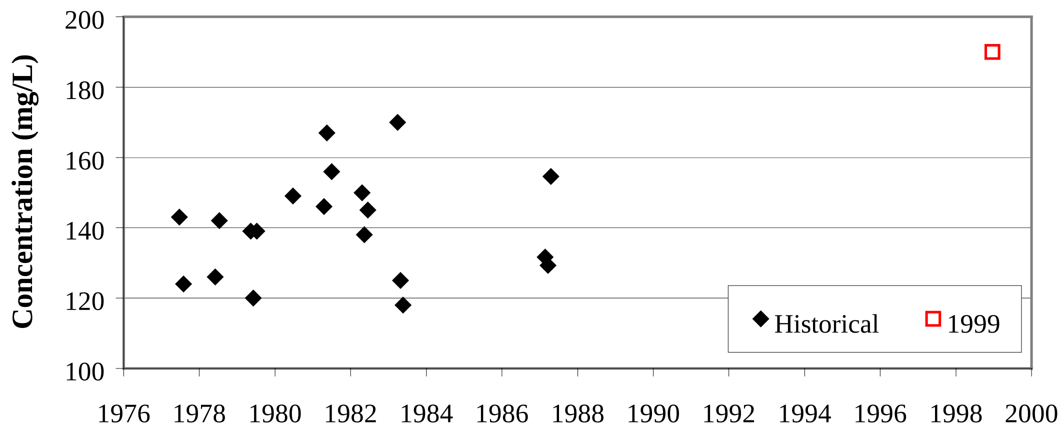
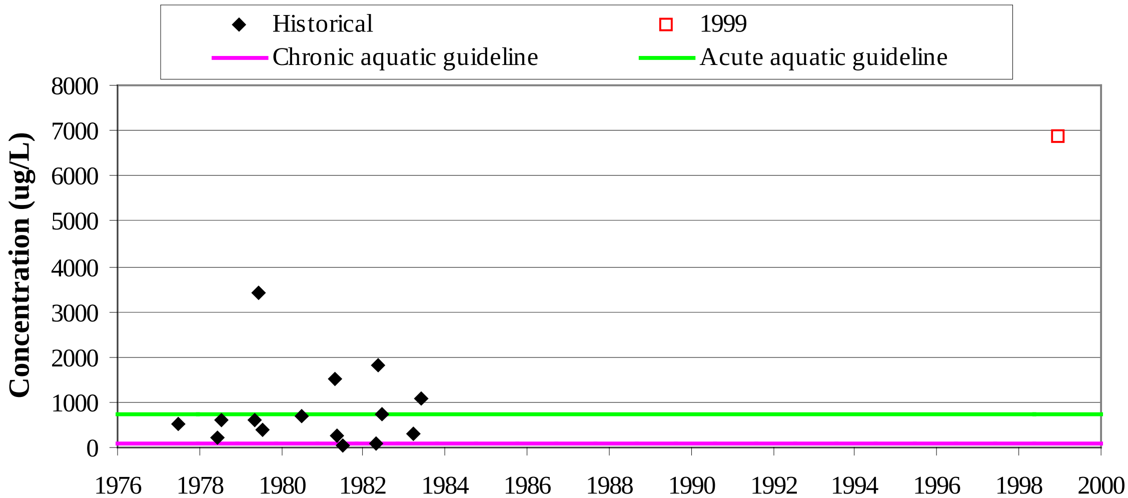



**Figure 5.5 Summer Total Aluminum Concentrations in the Athabasca River Delta**




Non-detects replaced with detection limit.

## 5.1.2 Sediment Quality

As indicated in Section 3.1.1.1, a single composite sediment sample was collected from the Athabasca River Delta in the summer of 1999. Sediment from the delta contained mainly silt, clay and some sand (Table 5.4). It was found to significantly affect the growth of *Lumbriculus variegatus* and the survival of *Chironomus tentans* and *Hyalella azteca*. PAH levels in the delta sediments are summarized in Table 5.5. Methyl naphthalene was the only compound present at concentrations in excess of Canadian Sediment Quality Guidelines.

**Table 5.4 Sediment Characteristics in the Athabasca River Delta**

| Parameter | Concentration |
|---|---|
| **Conventional Parameters (%)** | |
| partice size - % sand | 14 |
| partice size - % silt | 64 |
| partice size - % clay | 22 |
| total inorganic carbon | 0.8 |
| total organic carbon | 1.8 |
| **Toxicity (% of control)** | |
| *Chironomus tentans* - 10 day mortality | 42 |
| *C. tentans* - 10 day growth | nt |
| *Hyalella azteca* - 10 day mortality | 72 |
| *H. azteca* - 10 day growth | nt |
| *Lumbriculus variegatus* - 10 day mortality | nt |
| *L. variegatus* - 10 day growth | 62 |
| **Total Recoverable Hydrocarbons (mg/kg)** | |
| total recoverable hydrocarbons | 800 |
| **Total Metals (µg/g)** | |
| aluminum (Al) | 8850 |
| arsenic (As) | 5 |
| barium (Ba) | 166 |
| beryllium (Be) | < 1 |
| cadmium (Cd) | < 0.5 |
| chromium (Cr) | 25 |
| cobalt (Co) | 7 |
| copper (Cu) | 14 |
| iron (Fe) | 16800 |
| lead (Pb) | 10 |
| manganese (Mn) | 413 |
| mercury (Hg) | 0.09 |
| molybdenum (Mo) | < 1 |
| nickel (Ni) | 22 |
| selenium (Se) | 0.6 |
| silver (Ag) | < 1 |
| strontium (Sr) | 69 |
| titanium (Ti) | 26 |
| vanadium (V) | 21 |
| zinc (Zn) | 65 |

nt = non-toxic (insignificant difference between test and control sediments).

**Table 5.5 Concentration of Polycyclic Aromatic Hydrocarbons in Sediments from the Athabasca River Delta**

| Compound | Concentration (ng/g) |
|---|---|
| naphthalene | 19 |
| methyl naphthalenes | 35 |
| C2 substituted naphthalenes | 43 |
| C3 substituted naphthalenes | 54 |
| C4 substituted naphthalenes | 32 |
| acenaphthene | < 1.4 |
| methyl acenaphthene | 3.4 |
| acenaphthylene | < 4.3 |
| anthracene | < 3.7 |
| dibenzo(a,h)anthracene | < 6 |
| benzo(a)anthracene/chrysene | 31.2 |
| methyl benzo(a)anthracene/chrysene | 36 |
| C2 substituted benzo(a)anthracene/chrysene | 15 |
| benzo(a)pyrene | 13[(a)] |
| methyl b(b&k)f/methyl b(a)p | < 15 |
| C2 substituted b(b& k)f/b(a)p | < 13 |
| benzo(b&k)fluoranthene | 30 |
| benzo(g,h,i)perylene | 17 |
| biphenyl | 7.8 |
| methyl biphenyl | < 2.1 |
| C2 substituted biphenyl | < 1.7 |
| dibenzothiophene | < 2.8 |
| methyl dibenzothiophene | 17 |
| C2 substituted dibenzothiophene | 75 |
| C3 substituted dibenzothiophene | 110 |
| C4 substituted dibenzothiophene | - |
| fluoranthene | 6.5 |
| methyl fluoranthene/pyrene | 43 |
| fluorene | 3.2[(a)] |
| methyl fluorene | < 3.7 |
| C2 substituted fluorene | < 2.7 |
| indeno(c,d-123)pyrene | 11 |
| phenanthrene | 26 |
| methyl phenanthrene/anthracene | 69 |
| C2 substituted phenanthrene/anthracene | 64 |
| C3 substituted phenanthrene/anthracene | 71 |
| C4 substituted phenanthrene/anthracene | 350 |
| 1-methyl-7-isopropyl-phenanthrene | - |
| pyrene | 15 |

\- = no data.

(a) PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

### 5.1.3 Summary

In 1999, winter water quality in the Athabasca River near the Embarras River was consistent with historical data. Summer water quality in the Athabasca River Delta in 1999 was also generally consistent with historical data, with some exceptions. TDS, total aluminum and total barium levels were higher in 1999 than in recent sampling events. Sediments from the delta were found to be chronically toxic to three species of invertebrates. Methyl naphthalene was the only element present at concentrations in excess of Canadian Sediment Quality Guidelines.

## 5.2 FISH POPULATIONS

### 5.2.1 Fish Inventory

The total number of fish species captured during the spring fish inventory was 13 (Table 5.6). The 1999 species list was comparable to the list documented in the spring of 1998, when 16 fish species were captured (Golder 1999a). Arctic grayling, river shiner and yellow perch were not captured during the 1999 survey; however, capture of these species in 1998 was limited to a few individuals. Similarly, limited numbers of mountain whitefish and burbot were captured during the spring 1999 inventory; whereas neither species was captured during the 1998 spring inventory (Golder 1999a). In general, the relative abundance of each fish species captured in the spring was similar between 1998 and 1999. During the 1999 survey, walleye was the most abundant species, followed by goldeye, white sucker, longnose sucker and flathead chub. These five species accounted for 88% of the total catch in both 1998 (Golder 1999a) and 1999 (Table 5.6).

A summary of all fish species incidentally caught during the fall collection of longnose sucker by Environment Canada and Syncrude is summarized in Table 5.7. The results of the fall collection should be used with caution because sampling was biased towards capture of longnose sucker. The total number of fish species captured during the fall collection was nine. The species list was comparable to the list documented during the fall 1998 inventory, when 12 fish species were captured (Golder 1999a). Arctic grayling, mountain whitefish, spoonhead sculpin and trout-perch were not captured in 1999; however, their abundance in the spring of 1998 was also low. Lake whitefish was the most abundant fish species observed in the fall (Van Meer, unpubl. data). The timing of the field survey corresponded with the migration of lake whitefish from Lake Athabasca to spawning grounds upstream of Fort McMurray (Jones et al. 1978). Based on catch-per-unit effort (CPUE), estimates of abundance for walleye, goldeye, white sucker and northern pike were similar between 1998 and 1999; however, fewer longnose sucker were captured in 1999.

**Table 5.6 Total Number, Percent of Total Catch and CPUE of Each Fish Species Captured in the Oil Sands Region, Athabasca River, May 1999**

| Fish Species | Monitoring Reach[a] | | | | Total Number[a] | Percent[a] | CPUE[b] |
|---|---|---|---|---|---|---|---|
| | Poplar | Steepbank | Muskeg | Tar-Ells | | | |
| burbot | 1 | 1 | 1 | 0 | 3 | 0.79 | 0.02 |
| emerald shiner | 0 | 0 | 1 | 0 | 1 | 0.26 | 0.01 |
| flathead chub | 2 | 18 | 4 | 4 | 28 | 7.33 | 0.18 |
| goldeye | 18 | 21 | 35 | 8 | 82 | 21.47 | 0.84 |
| lake chub | 0 | 0 | 2 | 0 | 2 | 0.52 | 0.01 |
| lake whitefish | 0 | 0 | 2 | 2 | 4 | 1.05 | 0.04 |
| longnose sucker | 3 | 13 | 7 | 8 | 31 | 8.12 | 0.26 |
| mountain whitefish | 0 | 1 | 1 | 0 | 2 | 0.52 | 0.01 |
| northern pike | 3 | 7 | 9 | 6 | 25 | 6.54 | 0.34 |
| spoonhead sculpin | 0 | 0 | 0 | 1 | 1 | 0.26 | 0.01 |
| trout-perch | 0 | 0 | 7 | 0 | 7 | 1.83 | 4.66 |
| walleye | 37 | 77 | 41 | 13 | 168 | 43.98 | 1.08 |
| white sucker | 2 | 7 | 12 | 7 | 28 | 7.33 | 0.16 |
| **Total** | **66** | **145** | **122** | **49** | **382** | **100** | **7.62** |

[a] Captured only.

[b] CPUE, catch-per-unit-effort, is calculated from captured and observed fish (# fish/100 sec).

**Table 5.7 Total Number, Percent of Total Catch and CPUE of Each Fish Species Captured in the Oil Sands Region, Athabasca River, September 1999**

| Fish Species | Number[a] | Percent[a] | CPUE[b] |
|---|---|---|---|
| emerald shiner | 3 | 1.40 | 0.01 |
| flathead chub | 4 | 1.87 | 0.09 |
| goldeye | 43 | 20.09 | 0.40 |
| lake chub | 1 | 0.47 | 0.01 |
| lake whitefish | 68 | 31.78 | 7.24 |
| longnose sucker | 12 | 5.61 | 0.20 |
| mountain whitefish | 0 | 0 | 0.01 |
| northern pike | 33 | 15.42 | 0.19 |
| trout-perch | 0 | 0 | 0.06 |
| walleye | 21 | 9.81 | 0.13 |
| white sucker | 29 | 13.55 | 0.15 |
| **Total** | **214** | **100** | **8.49** |

[a] Captured only.

[b] CPUE is calculated from captured and observed fish (# fish/100 sec).

Walleye, lake whitefish, goldeye and longnose sucker have been identified as Key Indicator Resource (KIR) species for the Athabasca River. Based on data from the spring inventory, only walleye were collected in sufficient numbers to evaluate possible year-to-year changes in length distribution, age distribution and size-at-age. For length distributions, 1999 data were compared to RAMP data collected from 1995 (Golder 1996a), 1996 (Golder 1996b), 1997 (Golder 1998a) and 1998 (Golder 1999a). It was not possible to compare age distributions and size-at-age among all years due to limited sample sizes; however, comparisons were made using data from 1997-1999.

Length distributions of walleye from 1995 to 1999 are presented in Figure 5.6. In general, the distributions among years were very similar, consisting of two dominant modes centred about the 100-200 mm and 400-500 mm length classes. Based on the age distribution from 1998, these modes correspond approximately to age classes 0-3 years and 5-9 years, respectively. Smaller size classes were not represented in the 1999 distribution, probably because the fish inventory was not continued in the summer and fall. Data from 1998 indicated that 80% of walleye captured in the summer were juveniles; whereas 77% of the catch captured in spring were adults (Golder 1999a). Age distributions of walleye from 1997 to 1999 were also similar, consisting of a dominant mode ranging from four to eight years old fish (Figure 5.7). The absence of younger walleye (age 0-2 years) in 1999 again reflects seasonal differences in capture success of smaller individuals.

Annual size-at-age relationships (spring data only) for walleye from 1997 to 1999 are presented in (Figure 5.8). The slope of the regression line (i.e., rate of growth) for 1999 was significantly less than the slope for 1998 ($p=0.0002$). Figure 5.8 shows that walleye in 1999 were longer at a given age than walleye in 1998, until the relationship reversed at an estimated age of 7-8 years. There was no significant difference in slope relative to 1997 ($p=0.25$); however, walleye in 1999 were shorter at any given age (i.e., difference in intercepts, $p<0.001$). The reason for the change in size-at-age for walleye collected in 1999 is uncertain, but suggests a possible decrease in food availability (Gibbons and Munkittrick 1994). A similar conclusion was made in 1998 when it was found that walleye from 1998 were shorter at any given age relative to walleye collected from 1997 (Golder 1999a). Water levels in the Athabasca River during both 1998 and 1999 were extremely low relative to 1997 (Section 2.3). The effect this has had on food/habitat availability and quality is unknown.

**Figure 5.6 Length-frequency Distributions for Walleye in the Oil Sands Region, Athabasca River, 1995-1999**

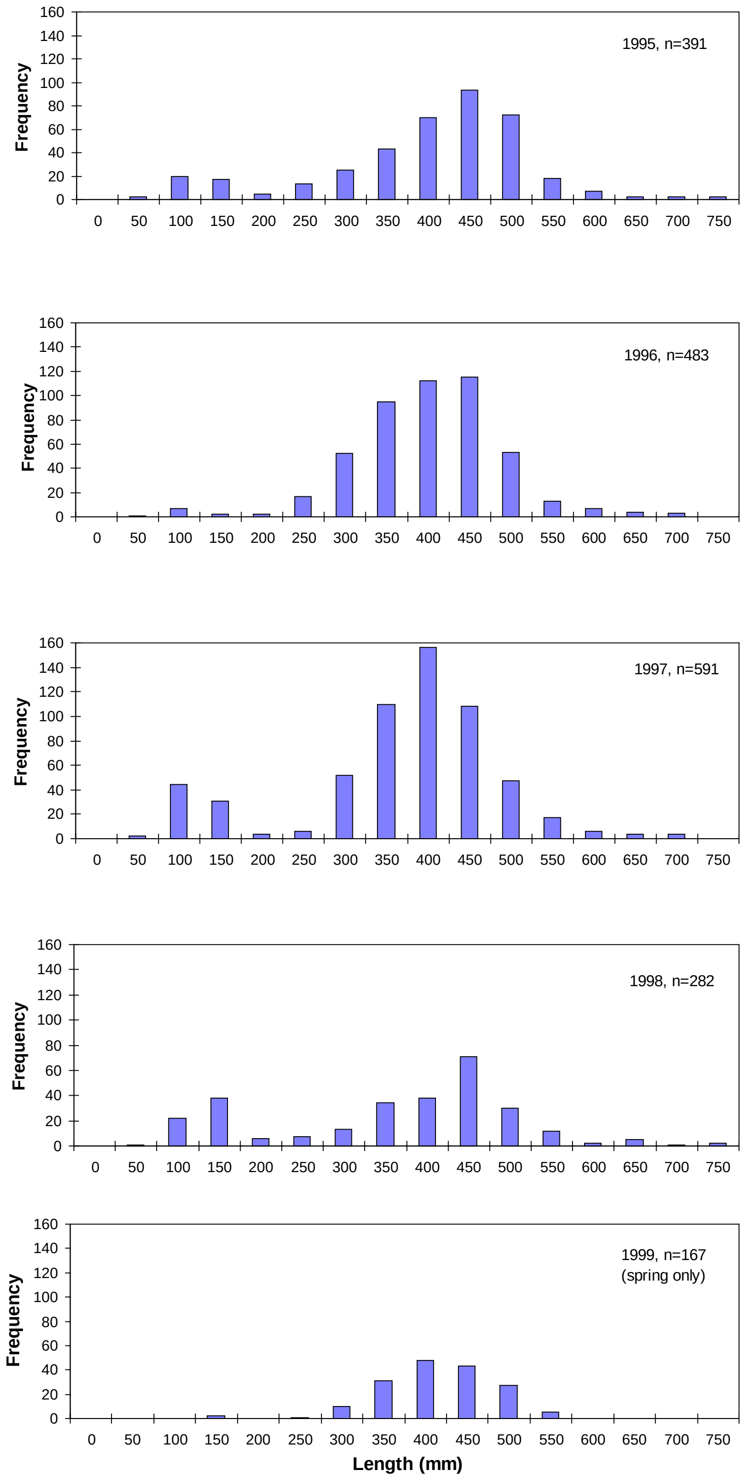


**Figure 5.7 Age-frequency Distributions for Walleye in the Oil Sands Region, Athabasca River, 1997-1999**

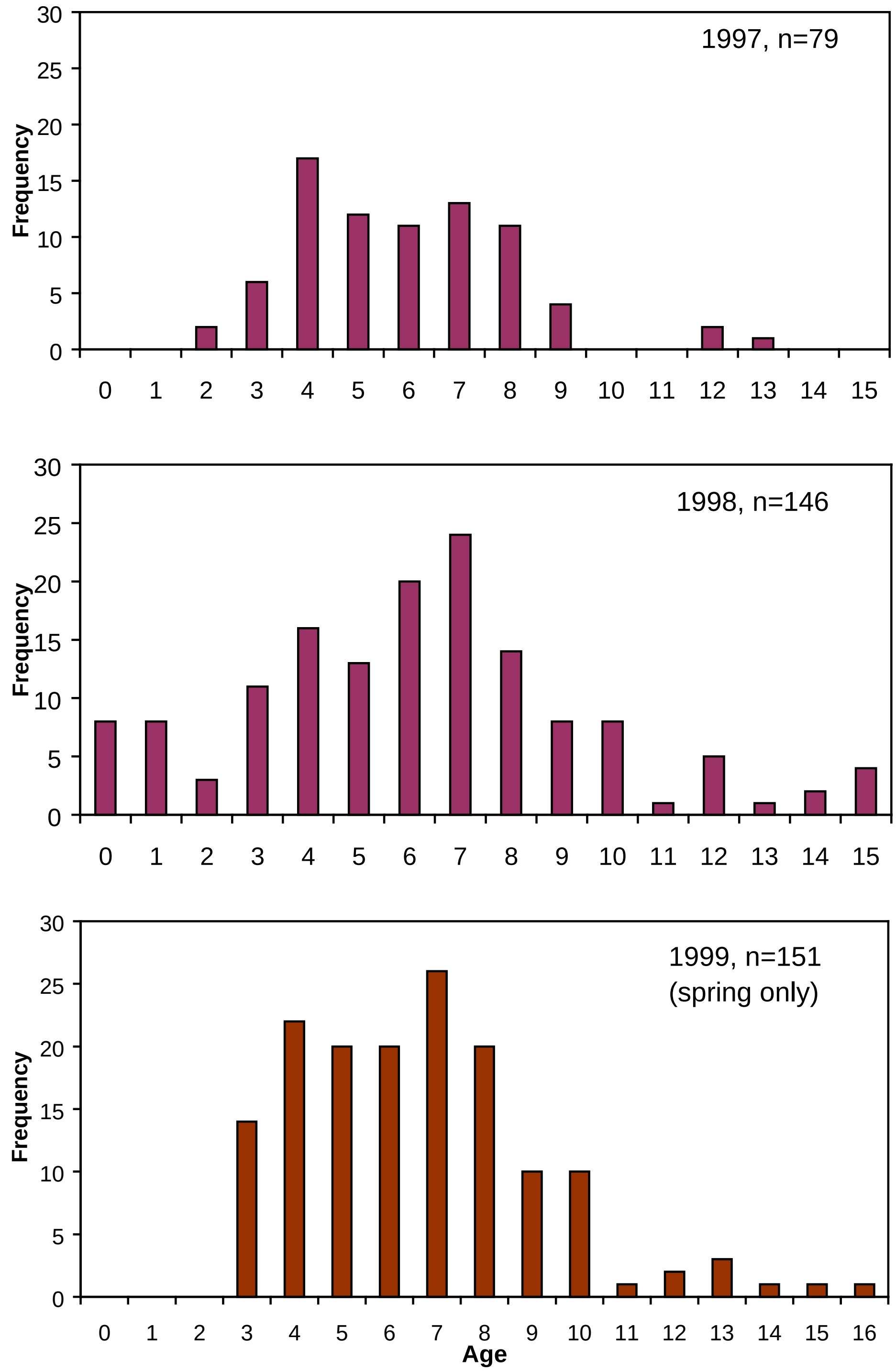
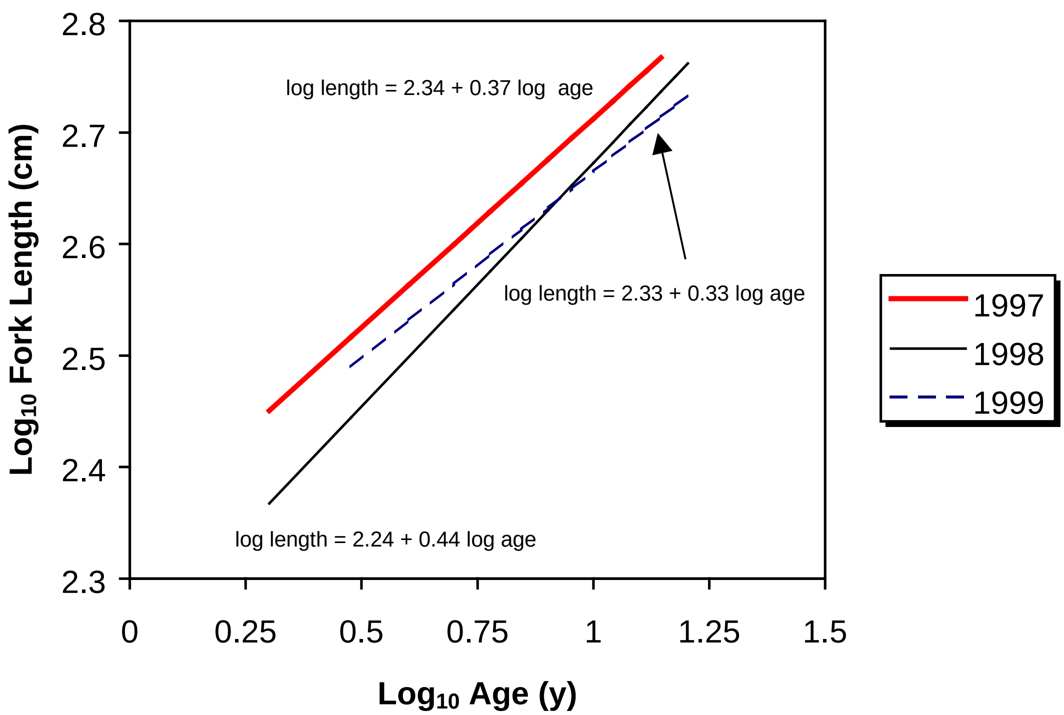


**Figure 5.8 Size-at-age Relationships for Walleye in the Oil Sands Region, Athabasca River, 1997-1999**




## 5.2.2 Sentinel Fish Species Monitoring

Thirteen species of fish were captured or observed during the collection of trout-perch (Table 5.8). Emerald shiner, trout-perch and flathead chub were the most abundant and widely distributed, small-bodied species. Of these three species, trout-perch remained the optimal species for sentinel monitoring on the Athabasca River because:

- many of the individuals captured were mature adults with obvious gonadal development;
- flathead chub can reach up to 25 cm fork length bringing into question their potential for large-scale movement; and
- gonadal development in emerald shiner during the fall survey was limited (making it difficult to assess reproductive parameters).

**Table 5.8 Total Number of Each Fish Species Caught and Observed at Each Sampling Site, Athabasca River, Fall 1999**

| Fish Species | Reference Site | Exposure Sites | | Total |
|---|---|---|---|---|
| | AR-R | AR-SD | AR-MR | |
| trout-perch | 435 | 517 | 311 | 1263 |
| emerald shiner | 893 | 833 | 381 | 2107 |
| flathead chub | 333 | 156 | 25 | 514 |
| lake chub | 4 | 140 | 1 | 145 |
| spottail shiner | 55 | 2 | 10 | 67 |
| sculpin sp. | 0 | 12 | 1 | 13 |
| longnose sucker | 54 | 37 | 11 | 102 |
| white sucker | 4 | 2 | 0 | 6 |
| goldeye | 10 | 59 | 16 | 85 |
| walleye | 10 | 18 | 3 | 31 |
| northern pike | 9 | 9 | 2 | 20 |
| lake whitefish | 14 | 7 | 50 | 71 |
| burbot | 1 | 0 | 2 | 3 |
| **Total** | **1822** | **1792** | **813** | **4,427** |
| electrofishing effort (sec) | 4737 | 4202 | 1678 | 10,617 |
| beach seining effort (m) | 0 | 595 | 215 | 810 |

[a] Total boat electrofishing and beach seining effort is also presented.

AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

Although boat electrofishing proved effective in capturing trout-perch, beach seining at night was valuable in increasing samples sizes at accessible sites. Trout-perch were often found in the late afternoon and evening presumably because they move to shallower waters at night to feed. Due to site differences in fish collection techniques (Table 5.8), catch-per-unit-effort could not be compared among sites. The abundance of female, male and immature trout-perch collected at the reference and exposure sites is presented in Table 5.9.

**Table 5.9 Total Number of Female, Male and Immature Trout-perch (*Percopsis omiscomaycus*) Captured for Processing, Athabasca River, Fall 1999**

| Sex | Reference Site | Exposure Sites | |
|---|---|---|---|
| | AR-R | AR-SD | AR-MR |
| female | 52 | 67 | 37 |
| male | 62 | 30 | 39 |
| immature [a] | 5 | 21 | 0 |
| total | 119 | 118 | 76 |

[a] Sacrificed due to unknown maturity.

AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

There were no large-scale differences in field water parameters measured at each fish collection site (Table 5.10). There was a small downstream decline in dissolved oxygen, but concentrations remained above the CCME guideline of 6.5 mg/L (and 9.5 mg/L for early life stages) for cold water biota (CCME 1999). Conductivity gradually increased with distance downstream. Conductivity measurements were much more variable downstream of Suncor's discharge (site SR-SD), probably reflecting variability in effluent concentration/mixing immediately downstream of the discharge.

**Table 5.10 Mean Values (± SD) of Field Water Parameters Measured at Each Fish Collection Site, Athabasca River, 1999**

| Field Parameter | Reference Site | Exposure Sites | |
|---|---|---|---|
| | AR-R | AR-SD | AR-MR |
| water temperature (°C) | 14.5 ± 1.0 | 14.4 ± 1.0 | 14.9 ± 0.1 |
| dissolved oxygen (mg/L) | 11.02 ± 1.50 | 9.93 ± 0.18 | 9.79 ± 0.16 |
| conductivity (µS/cm) | 294 ± 1 | 301 ± 20 | 330 ± 3 |
| pH | 8.36 ± 0.17 | 8.50 ± 0.21 | 8.33 ± 0.02 |

Means were calculated from measurements taken each time a site was sampled for sentinel fish (i.e., AR-R, *n*=2 sampling times; AR-SD, *n*=4; AR-MR, *n*=2).

AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

## 5.2.2.1 Fish Measurements

Based on external/internal pathology examinations of all trout-perch processed, the presence of abnormalities was low, ranging from 3-10% per site (Table 5.11). Trout-perch from the exposure sites did not exhibit increased abnormalities relative to reference fishes. In fact, trout-perch from the reference site (site AR-R) had the highest prevalence of abnormalities; mostly related to a few individuals that appeared to have a slightly enlarged spleen relative to remaining trout-perch.

Age distributions generated for each site (males and females combined) suggest that the age structure of adult trout-perch collected from each site is similar, and dominated by two and three year old individuals (Figure 5.9). Mean ages of male or female trout-perch were also similar among sites (Table 5.12). With the exception of the condition factor at the site downstream of the Muskeg River (site AR-MR), there were also no differences in body size among sites (Table 5.12). Male and female trout-perch from site AR-MR weighed less (i.e., they were thinner) at any given length relative to reference fish and fishes collected at site AR-SD.

**Table 5.11 Number of Trout-perch with Specific External/Internal Abnormalities, Athabasca River, Fall 1999**

| Abnormality | Reference Site | Exposure Sites | |
|---|---|---|---|
| | AR-R | AR-SD | AR-MR |
| fins (erosion, split, frayed) | 2 | 1 | 0 |
| tail immobility | 0 | 0 | 1 |
| spleen (enlarged) | 6 | 2 | 0 |
| internal parasites | 3 | 1 | 1 |
| unknown cysts (internal) | 0 | 0 | 1 |
| total no. fish evaluated | 119 | 100 | 76 |
| % affected[a] | 10.1 | 3.3 | 3.9 |

[a] An individual fish may exhibit more than one type of abnormality.
AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

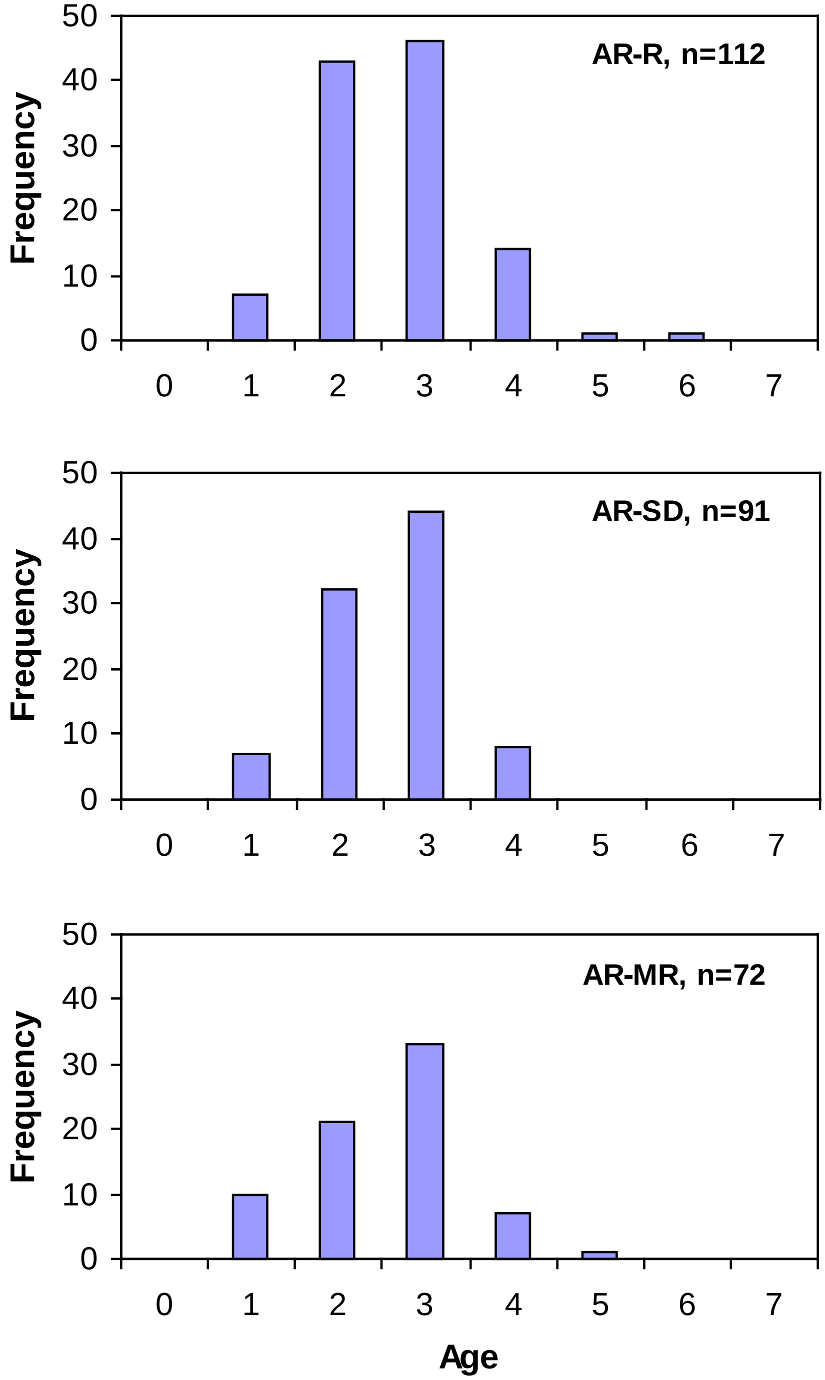
**Table 5.12 Mean ± SE (n) of Body Size, Age and Fecundity of Trout-perch, Athabasca River, Fall 1999**

| Sex | Parameter | Reference Site | Exposure Sites | |
|---|---|---|---|---|
| | | AR-R | AR-SD | AR-MR |
| Female | Fork Length (cm) | 7.4 ± 0.1 (52) A | 7.5 ± 0.1 (67) A | 7.5 ± 0.1 (37) A |
| | Body Weight (g) | 4.31 ± 0.13 (52) A | 4.57 ± 0.15 (67) A | 4.31 ± 0.19 (37) A |
| | K[a] | 0.91 ± 0.01 (52) A | 0.92 ± 0.01 (66) A | 0.87 ± 0.01 (37) B |
| | Age (y) | 2.8 ± 0.1 (51) A | 2.8 ± 0.1 (61) A | 2.6 ± 0.2 (34) A |
| | Fecundity (# eggs/g)[b] | 216 ± 11 (30) A | 282 ± 17 (29) A | 273 ± 21 (33) A |
| Male | Fork Length (cm) | 6.7 ± 0.1 (62) A | 6.6 ± 0.1 (30) A | 6.8 ± 0.1 (39) A |
| | Body Weight (g) | 3.20 ± 0.10 (62) A | 3.05 ± 0.14 (30) A | 3.28 ± 0.06 (39) A |
| | K | 0.94 ± 0.01 (62) A | 0.95 ± 0.01 (30) A | 0.90 ± 0.01 (39) B |
| | Age (y) | 2.5 ± 0.1 (61) A | 2.2 ± 0.2 (30) A | 2.5 ± 0.2 (38) A |

Note: Site differences in condition factor (K) and fecundity were tested using analysis of covariance. The remaining variables were examined using analysis of variance. Within a row, differences ($p<0.017$, Bonferroni's adjusted $\alpha$) among sites are denoted by different uppercase letters. Results followed by the same letter are not significantly different.
[a] $K = 100*(\text{carcass weight}/\text{fork length}^3)$.
[b] Fecundity standardized by fish size (i.e., # eggs/carcass weight).
AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

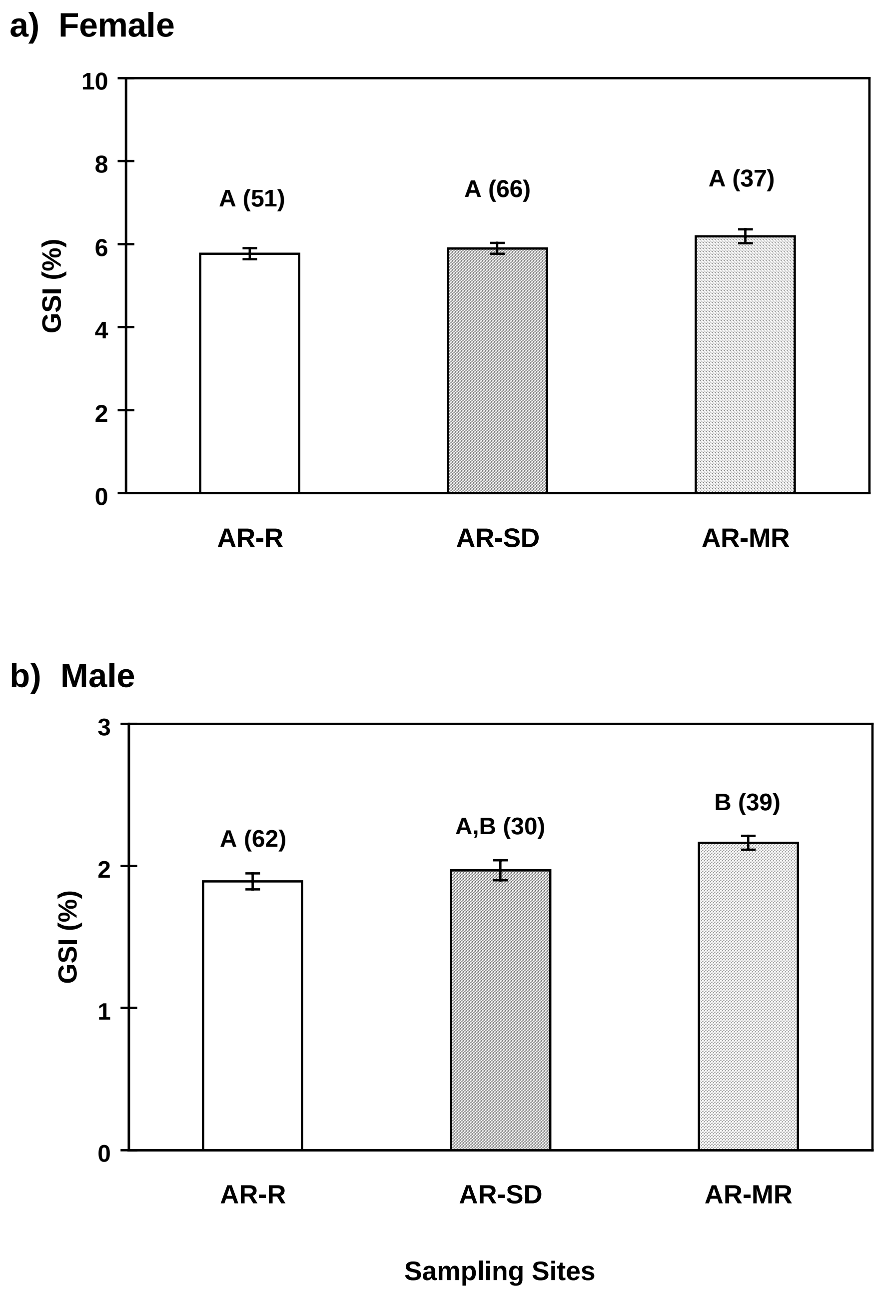
Ovary and testis weights were not significantly different among reference and exposure sites (Figure 5.10). Fecundity was also found to be similar among sites (Table 5.12), although the similarity in fecundity between the reference site and site AR-SD was borderline ($p=0.018 > \alpha=0.017$, Bonferroni's adjustment). Liver weights were similar among male trout-perch; however, females from site AR-MR had smaller livers compared to fishes from site AR-SD (Figure 5.11).

**Figure 5.9 Age-frequency Distributions for Trout-perch at Each Sampling Site, Athabasca River, Fall 1999**




AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

**Figure 5.10 Gonadosomatic Indices (GSI) of a) Female and b) Male Trout-perch, Athabasca River, Fall 1999 (a)**

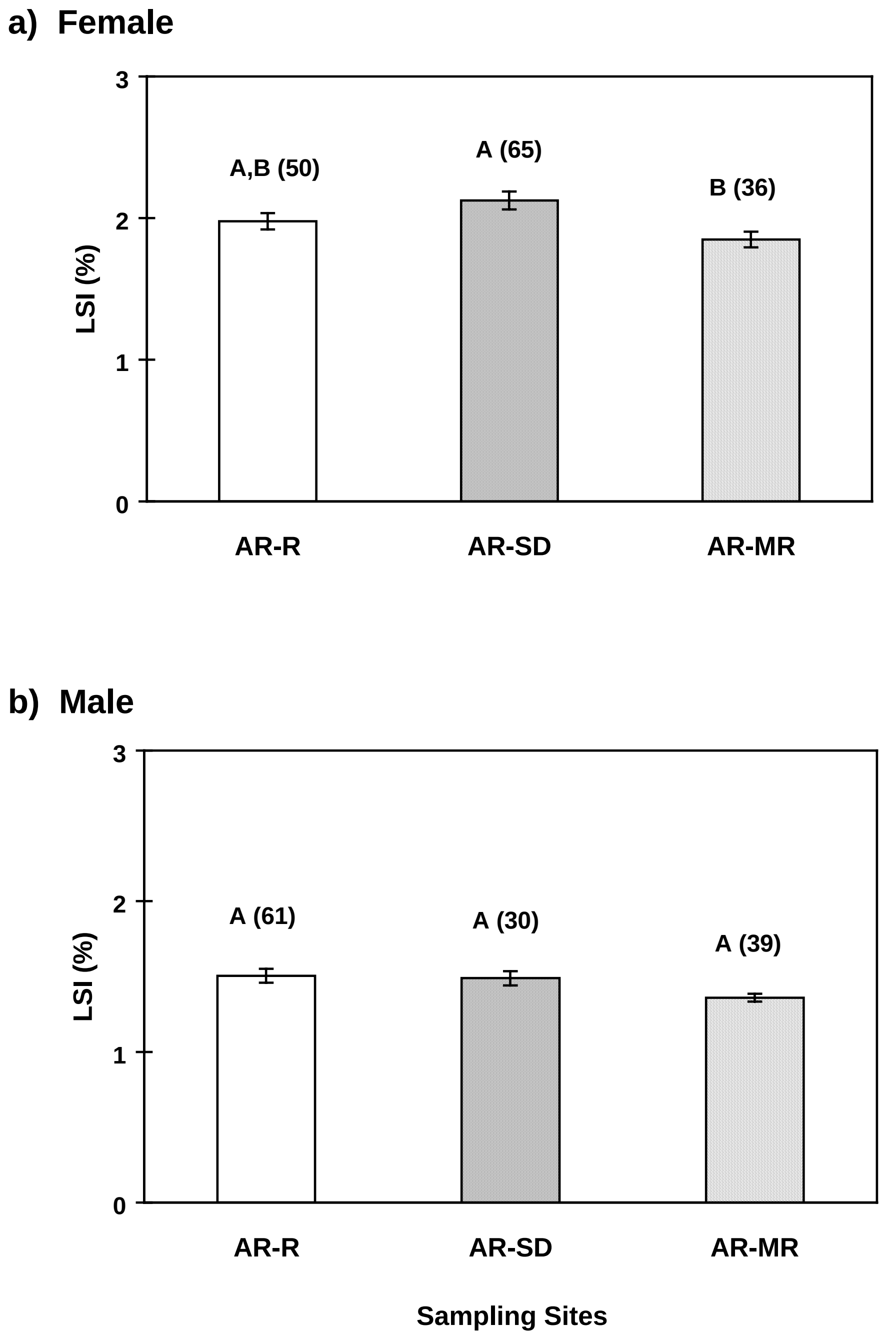



[a] Values represent the mean ± S.E. (sample sizes in parentheses). Differences ($p>0.017$, Bonferroni's adjustment) among sites are denoted by different letter superscripts.

AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

GSI = (gonad wt / carcass wt) x 100.

**Figure 5.11 Liver Somatic Index of a) Female and b) Male Trout-perch, Athabasca River, Fall 1999[a]**




[a] Values represent the mean ± S.E. (sample size in parentheses). Differences ($p>0.017$, Bonferroni's adjustment) among sites are denoted by different letter superscripts.

AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

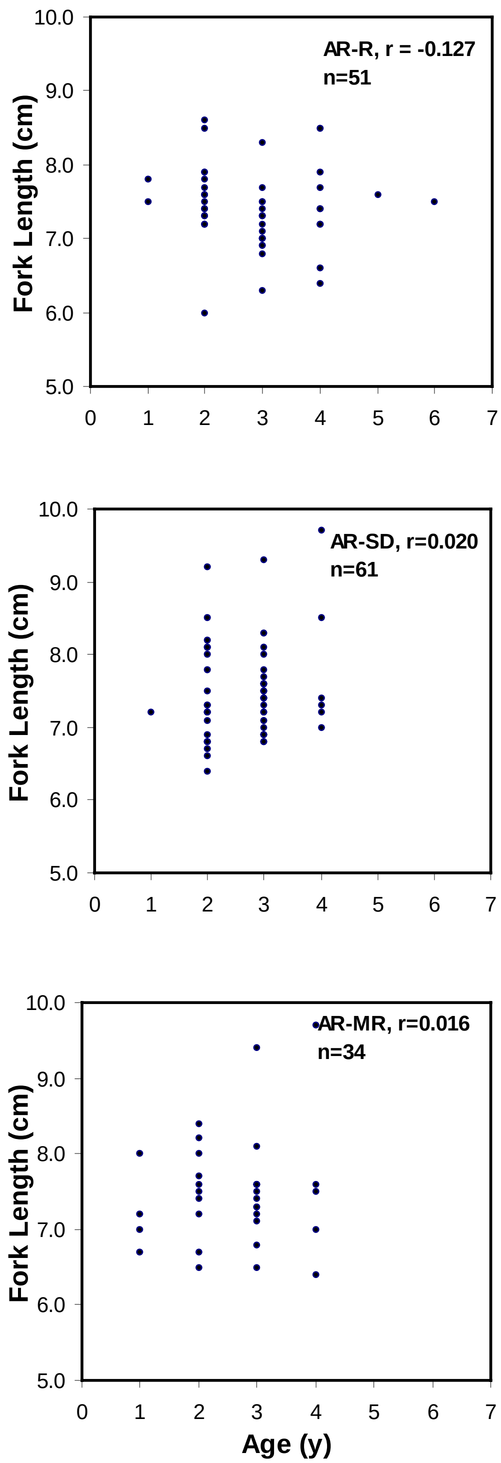
LSI = (liver wt / carcass wt) x 100.

Size-at-age relationships (i.e., growth) among sites could not be compared. In general, the relationship between fork length (or any other estimate of size) and age of trout-perch was extremely variable and poor (Figure 5.12, 5.13). Typically, the size of adult fish increases with age in a linear fashion until an upper asymptote is reached. However, trout-perch from the Athabasca River, particularly from sites AR-R and AR-MR, do not exhibit a consistent increase in size over time. The reason for the observed variability is unknown. Similar results were not reported for other species (e.g., KIR species) collected from the Oil Sands Region during the 1998 RAMP (Golder 1999a). Some of the size-at-age variability may be related to difficulties experienced in ageing trout-perch. Although other studies have had success in ageing trout-perch using otoliths (Gibbons et al. 1998) and scales (Spafford 1999), ageing trout-perch from the Oil Sands Region was difficult due to the presence of false or incomplete annuli and inconsistencies in the definition of the first annulus (J. Tost, Northshore Environmental, pers. comm.). The crack-and-burn procedure used for preparing otoliths may not be as effective for ageing trout-perch as the simpler method of reading ground and polished whole otoliths. Ages derived from scales, although limited due to problems with storage, did not significantly improve the results generated from otoliths.

Overall, there were few differences in whole organism characteristics of trout-perch among the three study sites. With the possible exception of fecundity, trout-perch collected downstream of Suncor's discharge (Site AR-SD) showed no differences in body size, age or organ metrics relative to fish collected from the reference site. Trout-perch downstream of the Muskeg River did show some preliminary evidence of reduced levels of energy storage (e.g., reduced condition and female liver size) (Gibbons and Munkittrick 1994). However, unless coupled with other changes in body size, gonad size, fecundity and male liver size, this response does not provide sufficient weight of evidence for a biologically significant change.

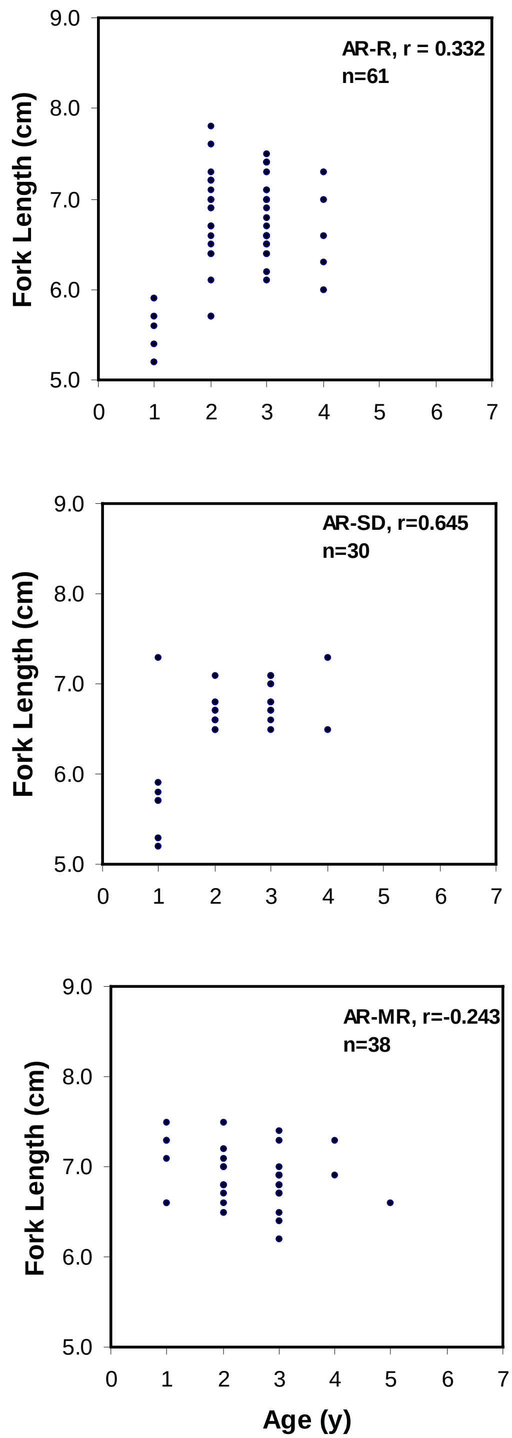
The response (or lack of response) of trout-perch collected at the potentially "exposed" sites is not consistent with results documented for longnose sucker in 1998 (Table 5.13). There are numerous potential reasons why the discrepancy in responses may exist including species differences in life history, longevity, habitat preferences and resource utilization. However, it is particularly important to note that the reference site for trout-perch was located within the Oil Sands Region (yet upstream of potential mining influences); whereas, the reference site for longnose sucker was located a substantial distance upstream of Fort

**Figure 5.12 Plot of Fork Lengths vs. Age for Female Trout-perch, Athabasca River, Fall 1999**




AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

**Figure 5.13 Plot of Fork Length vs. Age for Male Trout-perch, Athabasca River, Fall 1999**




AR-R = Athabasca River reference site; AR-SD = Athabasca River downstream of Suncor discharge; AR-MR = Athabasca River downstream of Muskeg River.

McMurray and beyond the influence of the oil sands formation. The sampling design for trout-perch provides a better assessment of the potential effects specific to mining activities; whereas, the study of longnose sucker could not separate the combined influences of the oil sands formation, mining activities and the town of Fort McMurray. In addition, the reference site for the longnose sucker study was not ideal due to some differences in habitat conditions and distance from the Oil Sands Region (Golder 1999a).

Recent research by Environment Canada (J. Parrott, and J. Sherry, Burlington, Ontario) evaluated longnose sucker from the original upstream reference site, a reference site within the oil sands formation, and from an exposure site downstream of current mining activities. Although this research is still ongoing, the information will provide further clarification of the response of longnose sucker collected downstream of the oil sands developments (assuming movement of sucker among sites is minimal). Mixed function oxygenase (MFO) data for trout-perch will also add to our understanding of exposure-response relationships within the Oil Sands Region.

Although it is assumed that trout-perch are less mobile than larger fish species of the region, there is limited information that describes the extent of their movement. As such, it is difficult to definitively rule out the possibility that the similarities among responses of trout-perch are related to their ability to move from one site to the next. MFO data will help to define exposure relationships (and hence movement potential); however, there may be a need to specifically evaluate the assumption of mobility of trout-perch within the Oil Sands Region.

**Table 5.13 Comparative Summary of Changes in Whole-organism Characteristics of Longnose Sucker (fall, 1998) and Trout-perch (fall, 1999) Collected from the Oil Sands Region, Athabasca River**

| Parameter | Longnose Sucker[a] | Trout-perch |
|---|---|---|
| fork length | + | O |
| body weight | + | O |
| condition | - | 0/-[b] |
| age | O | O |
| gonad Size | O | O |
| fecundity | - | O |
| liver size | - | 0/-[b][c] |

[a] Data from Golder (1999a).

[b] Separate response for sites AR-SD / AR-MR.

[c] Decreased liver weight in females only.

[d] + signifies an increase relative to reference data; - signifies a decrease; O signifies no change.

### 5.2.2.2 Sample Size Considerations

The number of fish needed to detect a 20, 30 and 50% difference (i.e., effect size or $\delta$) in each fish parameter between sites is summarized in Table 5.14. The final results indicated that the minimum numbers of fish needed from each site were approximately 62 females and 94 males to detect a 20% difference between sites; 31 females and 46 males to detect a 30% difference; and 14 females and 20 males to detect a 50% difference. For a given effect size, the estimated sample size is related to the amount of variability observed in a particular parameter within and between study sites. From these analyses, it is apparent that estimates of age and fecundity are the most variable and require greater sample sizes relative to other measurements. The observed variability in age of adult fish is common (and real), particularly when using capture techniques that are only moderately size selective. However, as discussed previously, improved ageing techniques may also contribute to reducing some of the observed variability. Similarly, fecundity estimates are also often variable, particularly in the fall when there is still a great deal of ovarian development yet to occur prior to spring/summer spawning.

**Table 5.14 Number of Trout-Perch per Site Needed to Detect Parameter Differences of 20, 30 and 50% between Sites**

| Parameter | Sex | Estimated Sample Size (# fish/site)[a] | | |
|---|---|---|---|---|
| | | ES=20% | ES=30% | ES=50% |
| fork length | female | 4 | 4 | 3 |
| | male | 5 | 3 | 3 |
| body weight | female | 33 | 17 | 8 |
| | male | 33 | 17 | 8 |
| condition | female | 4 | 3 | 3 |
| | male | 4 | 3 | 3 |
| age | female | 62 | 31 | 14 |
| | male | 94 | 46 | 20 |
| gonad weight | female | 27 | 14 | 7 |
| | male | 25 | 13 | 6 |
| fecundity | female | 73 | 36 | 16 |
| liver weight | female | 25 | 13 | 6 |
| | male | 24 | 13 | 6 |

[a] Calculations were done using $\log_{10}$ transformed data, power=0.80 and $\alpha$=0.05.
ES = effect size or $\delta$.

For both female and male trout-perch, sufficient sample sizes were collected from each site to detect at least a 30% difference among sites, and in some cases a 20% difference. The number of males captured at site AR-SD was lower than other sites, but was adequate for all measurements except age. Furthermore, sample sizes of trout-perch were more than adequate to detect the recommended effects size criterion of ±25% gonad weight used for the pulp and paper Environmental Effects Monitoring (EEM) program (Environment Canada 1997).

### 5.2.3 Summary

Fisheries monitoring on the Athabasca River consisted of two components: 1) spring fish inventory; and 2) sentinel species monitoring.

In general, species composition and relative abundance of fishes within the Oil Sands Region were similar to that observed in the spring of 1998. Walleye was the only KIR species that was captured in sufficient numbers to evaluate length and age distributions, and size-at-age over time. Both length and age distributions remained consistent over time, although due to the lack of summer data, smaller and younger individuals were absent from the spring 1999 collection. Comparisons of size-at-age between 1997 to 1999 indicated that walleye captured in 1999 were generally shorter at a given age relative to 1997, and longer than 1998 walleye, until the relationship reversed at age 7 to 8 years. The reason for the change in size-at-age of walleye collected in 1999 is uncertain, but suggests a possible decrease in food availability. The abnormally low water levels in the Athabasca River in 1998 and 1999 may have been related to this decrease.

Based on abundance, distribution and gonadal development, trout-perch was the optimal small-bodied species for sentinel monitoring on the Athabasca River. Due to the reduced potential for large-scale movement, use of a small-bodied species facilitated selection of a reference site within the Oil Sands Region, as well as “exposed” sites in close proximity to mining/refinery activities. The resulting sampling design made it possible to specifically test the potential effects of oil sands development, separate from other influences related to the natural oil sands formation, the town of Fort McMurray and other upstream anthropogenic development. There was no evidence indicating that trout-perch collected downstream of Suncor’s discharge were different from reference fish. With the exception of a possible reduction in energy storage, trout-perch downstream of the Muskeg River were also similar to fish collected below the Suncor discharge and from the reference site. Power analyses confirmed that sample sizes were adequate to detect site differences in fish parameters had they existed. Future work on trout-perch within the Oil Sands Region will need to evaluate the most effective and accurate technique for estimating age, as well as the mobility of this species.

# 6 TRIBUTARIES - RESULTS AND DISCUSSION

## 6.1 WATER AND SEDIMENT QUALITY

### 6.1.1 Water Quality

#### 6.1.1.1 McLean Creek

Water quality data collected from McLean Creek in the fall of 1999 were consistent with historical data, with some exceptions. Naphthenic acids were detected at the mouth of McLean Creek in 1999 for the first time (Table 6.1). Chloride, sulphate, total dissolved solids (TDS) and barium concentrations were higher in 1999 than in 1998 and 1995 (Tables 6.1 and 6.2); pH levels were lower in 1999 than in 1998 or 1995; and dissolved iron, aluminum and manganese concentrations were lower in 1999 than in 1998 (dissolved metal levels were not measured in 1995). Median, minimum and maximum water temperatures observed in the summer and fall of 1999 are summarized in Table 6.3.

Total aluminum, iron and manganese concentrations in 1999 exceeded water quality guidelines (Table 6.4). This was consistent with levels observed in 1998. Detection limits reported in 1999 for total mercury and total silver exceed guideline levels, so these elements could not be evaluated with respect to regulatory guidelines.

#### 6.1.1.2 Steepbank River

Water quality at the mouth of the Steepbank River in the winter of 1999 was consistent with historical data, with some exceptions (Tables 6.1 and 6.2). The concentrations of some parameters, including total phosphorus, iron and lead, were lower in 1999 than in previous sampling events, while dissolved iron, aluminum and manganese levels were higher in 1999 than previously observed in 1997. Sample waters were non-toxic to *Ceriodaphnia dubia* and fathead minnows. None of the parameters detected at the mouth of the Steepbank River in 1999 were found to exceed surface water quality guidelines for the protection of aquatic life or human health (Table 6.4).

**Table 6.1 Water Quality in McLean Creek and the Steepbank River**

| Parameter | Units | McLean Creek (Fall) | | | Steepbank River (Winter) | |
|---|---|---|---|---|---|---|
| | | 1999 | 1998[a] | 1995[b] | 1999 | Historical Median[c] |
| **Field Measured** | | | | | | |
| pH | | 7.1 | 8.3 | 8.0 | 7.7 | 8.0 |
| specific conductance | µS/cm | 658 | 650 | 307 | 572 | 481 |
| temperature | °C | 10.8 | 4 | - | 0.1 | 0.3 |
| dissolved oxygen | mg/L | 13.4 | 8.5 | - | 10.5 | 13.3 |
| **Conventional Parameters and Major Ions** | | | | | | |
| chloride | mg/L | 165 | 73 | 11 | 6 | 7 |
| dissolved organic carbon | mg/L | 14 | 13 | 21 | 8 | 11 |
| sulphate | mg/L | 56 | 38 | 11 | 17 | 12 |
| total alkalinity | mg/L | 251 | 195 | 133 | 342 | 314 |
| total dissolved solids | mg/L | 620 | 440 | 167 | 390 | 354 |
| total organic carbon | mg/L | 15 | 16 | - | 9 | 11 |
| total suspended solids | mg/L | 5 | 13 | 1 | < 3 | 3 |
| **Nutrients and Chlorophyll *a*** | | | | | | |
| nitrate + nitrite | mg/L | < 1 | 0.05 | 0.004 | 0.2 | 0.4 |
| nitrogen – ammonia | mg/L | < 0.05 | < 0.05 | < 0.01 | 0.06 | 0.04 |
| nitrogen – total | mg/L | 0.4 | 0.7 | < 0.1 | 0.7 | 1.0 |
| phosphorus, total | µg/L | 15 | 12 | 42 | 10 | 46 |
| chlorophyll *a* | µg/L | -* | 2 | - | 0 | 0.2 |
| **Biochemical Oxygen Demand** | | | | | | |
| biochemical oxygen demand | mg/L | 4 | < 2 | - | < 2 | 0.8 |
| **Toxicity** | | | | | | |
| *Ceriodaphnia dubia*, 7 day reproduction - IC25 | % | - | - | - | > 100 | - |
| *C. dubia*, 7 day mortality - LC50 | % | - | - | - | > 100 | - |
| fathead minnow 7 day growth - IC25 | % | - | - | - | > 100 | - |
| fathead minnow 7 day mortality - LC50 | % | - | - | - | > 100 | - |
| **Organics** | | | | | | |
| naphthenic acids | mg/L | 2 | < 1 | < 1 | < 1 | 2 |
| total phenolics | µg/L | < 1 | 2 | < 1 | 2 | 3 |

(a) Based on unpublished data from Suncor Energy Inc.

(b) Based on information from Golder (1996a).

(c) Based on information from Golder (1998a) and NAQUADAT station AB07DA0260.

* Data discarded due to issues with data quality.

## Table 6.2 Metal Levels in McLean Creek and the Steepbank River

| Parameter | Units | McLean Creek (Fall) | | | Steepbank River (Winter) | |
|---|---|---|---|---|---|---|
| | | 1999 | 1998[a] | 1995[b] | 1999 | Historical Median[c] |
| **Total Metals** | | | | | | |
| aluminum (Al) | µg/L | 330 | 560 | 60 | 90 | 40 |
| antimony (Sb) | µg/L | < 0.8 | < 0.8 | < 0.2 | 1.1 | < 0.4 |
| arsenic (As) | µg/L | < 1 | < 1 | 0.8 | < 1 | 0.3 |
| barium (Ba) | µg/L | 55 | 39 | 20 | 103 | 75 |
| cadmium (Cd) | µg/L | < 0.2 | < 0.2 | 3 | < 0.2 | < 0.2 |
| chromium (Cr) | µg/L | 2 | 1 | < 2 | 3 | 5 |
| copper (Cu) | µg/L | 4 | 2 | - | 2 | 2 |
| iron (Fe) | µg/L | 660 | 920 | 410 | 170 | 905 |
| lead (Pb) | µg/L | 0.2 | 1 | < 20 | 0.3 | 3.3 |
| manganese (Mn) | µg/L | 64 | 68 | 20 | 22 | 19 |
| mercury (Hg) | µg/L | < 0.2 | < 0.2 | < 0.05 | < 0.2 | < 0.15 |
| molybdenum (Mo) | µg/L | 0.5 | 0.2 | 4 | 0.6 | < 3 |
| nickel (Ni) | µg/L | 3 | 5 | < 5 | 4 | 2 |
| selenium (Se) | µg/L | < 0.8 | < 0.8 | < 0.2 | < 0.8 | < 0.2 |
| silver (Ag) | µg/L | < 0.4 | < 0.4 | < 2 | < 0.4 | < 1 |
| zinc (Zn) | µg/L | 17 | 10 | 24 | 10 | 67 |
| **Dissolved Metals** | | | | | | |
| aluminum (Al) | µg/L | 10 | 45 | - | 20 | 5.8 |
| antimony (Sb) | µg/L | < 0.8 | 0.8 | - | 1 | < 0.4 |
| arsenic (As) | µg/L | 1 | < 0.4 | - | < 0.4 | < 0.4 |
| barium (Ba) | µg/L | 44 | 36 | - | 95 | 70 |
| cadmium (Cd) | µg/L | < 0.1 | < 0.1 | - | < 0.1 | < 0.1 |
| chromium (Cr) | µg/L | 1.2 | < 0.4 | - | < 0.4 | < 0.4 |
| copper (Cu) | µg/L | 3 | 1 | - | 1 | 0.8 |
| iron (Fe) | µg/L | 250 | 460 | - | 200 | < 10 |
| lead (Pb) | µg/L | < 0.1 | 0.3 | - | 0.2 | 0.2 |
| manganese (Mn) | µg/L | 22 | 64 | - | 18 | 0.3 |
| mercury (Hg) | µg/L | < 0.1 | < 0.1 | - | < 0.1 | < 0.2 |
| molybdenum (Mo) | µg/L | 0.4 | 0.2 | - | 0.7 | 0.5 |
| nickel (Ni) | µg/L | 3 | 4 | - | 2 | 0.6 |
| selenium (Se) | µg/L | < 0.4 | < 0.4 | - | < 0.4 | < 0.4 |
| silver (Ag) | µg/L | < 0.2 | < 0.2 | - | < 0.2 | < 0.2 |
| zinc (Zn) | µg/L | 3 | 3 | - | 4 | 6 |

[a] Based on unpublished data from Suncor Energy Inc.

[b] Based on information from Golder (1996a).

[c] Based on information from Golder (1998a) and NAQUADAT station AB07DA0260.

**Table 6.3 Summer and Fall Water Temperatures in McLean Creek, 1999**

| Location | Season | |
|---|---|---|
| | Summer | Fall |
| **Mouth** | | |
| median | 19.4 | 11.8 |
| minimum | 14.5 | -3.9 |
| maximum | 24.9 | 24.8 |
| n | 2902 | 3773 |
| **100 m upstream** | | |
| median | 13.5 | 4.9 |
| minimum | 7.7 | -0.1 |
| maximum | 19.5 | 12.4 |
| n | 2901 | 3774 |

n = number of data.

**Table 6.4 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in McLean Creek and the Steepbank River**

| Parameter | Units | Guidelines for the Protection of | | | McLean Creek (Fall) | | | Steepbank R. (Winter) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic Life[a] | | Human Health[b] | | | | | Historical |
| | | Acute | Chronic | | 1999 | 1998 | 1995 | 1999 | Median |
| **Nutrients** | | | | | | | | | |
| nitrogen - total | mg/L | - | 1 | - | | | | | C |
| **Total metals** | | | | | | | | | |
| aluminum (Al) | µg/L | 750 | 100 | - | C | C | | | |
| iron (Fe) | µg/L | - | 300 | 300 | C H | C H | C H | | C H |
| lead (Pb) | µg/L | 140 - 190* | 5.3 - 7.4* | - | | | C` | | |
| manganese (Mn) | µg/L | - | - | 50 | H | H | | | |
| mercury (Hg) [c] | µg/L | 1.4 | 0.1 | 0.05 | C H` | C H` | | C H` | C H` |
| silver (Ag) | µg/L | 11 - 20* | 0.1 | - | C` | C` | C` | C` | C` |

[a] Guidelines taken from AENV (1999).

[b] Guidelines taken from U.S. EPA (1999).

[c] Using U.S. EPA and CCME guidelines, respectively, because Alberta mercury guidelines have not been finalized.

* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

C = chronic aquatic guideline exceeded; H = human health guideline exceeded.

- No guideline.

` Although substance concentrations were below detection limits, the analytical detection limit exceeded the relevant surface water guideline.

## 6.1.1.3 Muskeg River

Seasonal water quality samples were collected from three locations in the Muskeg River. Two additional locations were sampled in the fall of 1999. Seasonal and spatial trends observed in 1999 are summarized in Table 6.5.

Generally, seasonal variations observed in 1999 were consistent with historical trends, with the exception of increasing nickel concentrations in the winter of 1999 and relatively high pH levels in the spring of 1999 (Tables 6.6 and 6.7). Spatial variations observed along the length of the Muskeg River in 1999 were generally unique to this year (i.e., they were not reflected in the historical data).

Site-specific differences observed in 1999, in comparison to relevant historical data, are summarized in Table 6.8. Naphthenic acids were detected at the mouth and in the upper reaches of the Muskeg River in 1999. Waters collected near Stanley Creek in the winter of 1999 were chronically toxic to *Ceriodaphnia dubia* and fathead minnows (Table 6.6). Sample waters collected from the same location and the upper Muskeg River in the fall of 1999 were also chronically toxic to fathead minnows. There is no clear indication what agent(s) may be responsible for these results. Additional chronic toxicity testing in the upper Muskeg River will be completed in 2000; if chronic toxicity continues to be detected, a Toxicity Identification and Evaluation (TIE) will be initiated. Median, minimum and maximum water temperatures observed in the spring, summer and fall of 1999 are summarized in Table 6.9.

As in previous years, total iron concentrations throughout the Muskeg River in 1999 exceeded surface water guidelines for the protection of aquatic life and human health (Figure 6.1). Manganese levels in 8 of the 13 samples collected from the Muskeg River in 1999 exceeded the U.S. EPA human health guideline (Tables 6.10 and 6.11). Historically, Muskeg River waters generally contain manganese levels in excess of this guideline (Figure 6.2). A total phenolics concentration of 120 µg/L was observed in the upper Muskeg River in the spring of 1999 (Table 6.6); the chronic aquatic guideline for total phenolics is 5 µg/L. Other substances found at concentrations in excess of surface water quality guidelines in 1999 included total aluminum (five samples), total nitrogen (three samples), total phosphorus (nine samples) and total silver (one sample) (Tables 6.10 and 6.11).

## Table 6.5 Seasonal and Spatial Trends Observed in the Muskeg River, 1999

| Trend Observed in 1999 | Affected Parameters | Trend Present in Historical Dataset | Additional Comments |
|---|---|---|---|
| **Seasonal** | | | |
| concentrations were lowest in the spring and highest in the fall / winter | specific conductance | weak trend observed | in previous years, summer levels generally higher than fall concentrations |
| | total alkalinity | | |
| | TDS | | |
| | total and dissolved barium | yes, total barium levels highest in late fall and winter | limited historical data |
| | total and dissolved nickel | no trend observed | limited historical data |
| | total and dissolved manganese | yes (totals only) | only in upper Muskeg River in 1999 |
| high levels in spring | pH | no trend observed | |
| high levels in winter | ammonia | yes, at two of the three sample sites | |
| summer peak | temperature | yes | |
| **Spatial** | | | |
| concentrations increased with distance downstream | temperature | no trend observed | |
| | dissolved oxygen | yes, in winter and summer | |
| | TDS | no trend observed | |
| | specific conductance | no trend observed | opposite trend observed in winter and spring; no trend observed in summer and fall |
| | total aluminum | no trend observed | |
| | total and dissolved barium | no trend observed | limited historical data |
| concentrations decreased with distance downstream | total phosphorus | no trend observed | |
| | total iron (winter and fall) | yes | |
| | total and dissolved manganese | no trend observed | |
| concentrations highest in upper Muskeg River | total and dissolved organic carbon | no trend observed | |

## Table 6.6 Water Quality in the Muskeg River, 1999

| Parameter | Units | Mouth (Site 1) | Canterra Road Crossing (Site MUR-2) | | | | Upstream of Shelley Creek | Downstream of Stanley Creek (Site MUR-5) | | | | Upstream of Wapasu Creek (Site MUR-6) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Fall) | Winter | Spring | Summer | Fall | (Site MUR-4) | Winter | Spring | Summer | Fall | Spring | Summer | Fall |
| **Field Measured** | | | | | | | | | | | | | | |
| pH | | 8.0 | 7.8 | 8.4 | 7.9 | 8.1 | *7.8* | 7.3 | 8.2 | 7.9 | 7.7 | 10.3 | 7.5 | 7.9 |
| specific conductance | µS/cm | 655 | 660 | 387 | 375 | 635 | *491* | 545 | 231 | 371 | 439 | 220 | 316 | 352 |
| temperature | °C | 3.9 | 0.2 | 9.0 | 21.8 | 3.3 | - | 0.2 | 8.4 | 18.7 | 2.4 | 2.6 | 15.7 | 1.6 |
| dissolved oxygen | mg/L | 12.3 | 9.1 | 10.0 | 8.5 | 8.4 | - | 0.9 | 8.9 | 5.5 | 8.6 | 5.3 | 7.2 | 3.4 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | | | | |
| chloride | mg/L | 6 | 2 | 6 | 2 | 5 | 4 | 3 | 2 | 1 | 2 | 2 | 1 | 1 |
| dissolved organic carbon | mg/L | 16 | 12 | 11 | 16 | 15 | 15 | 12 | 16 | 16 | 14 | 27 | 22 | 18 |
| sulphate | mg/L | 91 | 99 | 27 | 16 | 81 | 5 | 6 | 6 | 5 | 5 | 13 | 6 | 6 |
| total alkalinity | mg/L | 280 | 282 | 183 | 193 | 281 | 255 | 305 | 151 | 206 | 250 | 102 | 172 | 214 |
| total dissolved solids | mg/L | 405 | 470 | 240 | 240 | 460 | 350 | 280 | 220 | 240 | 330 | 190 | 240 | 270 |
| total organic carbon | mg/L | 16 | 14 | 14 | 19 | 17 | 18 | 15 | 16 | 19 | 17 | 32 | 27 | 22 |
| total suspended solids | mg/L | 3 | < 3 | 10 | 3 | < 3 | 8 | 7 | < 3 | < 3 | < 3 | < 3 | 5 | 16 |
| **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 |
| nitrogen - ammonia | mg/L | < 0.05 | 0.28 | < 0.05 | < 0.05 | < 0.05 | 0.08 | 0.96 | 0.06 | 0.07 | 0.14 | < 0.05 | < 0.05 | < 0.05 |
| nitrogen - total | mg/L | 0.6 | 1 | 0.7 | 0.8 | 0.7 | 0.8 | 1.1 | 0.7 | 1 | 0.7 | 1.3 | 1 | 1.5 |
| phosphorus, total | µg/L | 8 | 17 | 39 | 21 | 16 | 31 | 39 | 46 | 42 | 38 | 101 | 38 | 143 |
| chlorophyll *a* | µg/L | -* | 0 | -* | 0 | -* | -* | 0 | -* | 0 | -* | -* | 0 | -* |
| **Biochemical Oxygen Demand** | | | | | | | | | | | | | | |
| biochemical oxygen demand | mg/L | < 2 | < 2 | 2 | < 2 | < 2 | < 2 | 3 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 |
| **Toxicity** | | | | | | | | | | | | | | |
| *Ceriodaphnia dubia*, 7 day reproduction - IC25 | % | - | > 100 | > 100 | > 100 | > 100 | - | 83 | - | > 100 | > 100 | > 100 | > 100 | > 100 |
| *C. dubia*, 7 day mortality - LC50 | % | - | > 100 | > 100 | > 100 | > 100 | - | > 100 | 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| fathead minnow 7 day growth - IC25 | % | - | > 100 | > 100 | > 100 | > 100 | - | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 |
| fathead minnow 7 day mortality - LC50 | % | - | > 100 | > 100 | > 100 | > 100 | - | > 100 | > 100 | > 100 | 9.1 | > 100 | > 100 | 13 |
| **Organics** | | | | | | | | | | | | | | |
| naphthenic acids | mg/L | 1 | 1 | < 1 | 4 | < 1 | < 1 | < 1 | 2 | < 1 | 1 | 2 | < 1 | < 1 |
| total phenolics | µg/L | 2 | 2 | 3 | 5 | 3 | 3 | 2 | 7 | 2 | 2 | 120 | 5 | 3 |
| **Metals (total)** | | | | | | | | | | | | | | |
| aluminum (Al) | µg/L | 290 | 270 | 350 | 250 | 60 | 40 | 70 | 90 | 70 | < 20 | 30 | 280 | 50 |
| antimony (Sb) | µg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 |
| arsenic (As) | µg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 |

| Parameter | Units | Mouth (Site 1) | Canterra Road Crossing (Site MUR-2) | | | | Upstream of Shelley Creek | Downstream of Stanley Creek (Site MUR-5) | | | | Upstream of Wapasu Creek (Site MUR-6) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Fall) | Winter | Spring | Summer | Fall | (Site MUR-4) | Winter | Spring | Summer | Fall | Spring | Summer | Fall |
| barium (Ba) | μg/L | 82 | 90 | 57 | 57 | 80 | 69 | 81 | 48 | 59 | 62 | 18 | 37 | 42 |
| cadmium (Cd) | μg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| chromium (Cr) | μg/L | < 0.8 | 3.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 |
| copper (Cu) | μg/L | 2 | 2 | < 1 | 1 | 2 | 3 | < 1 | < 1 | 1 | 1 | < 1 | 2 | 1 |
| iron (Fe) | μg/L | 420 | 1270 | 1860 | 550 | 840 | 1460 | 3300 | 1760 | 1720 | 1980 | 1200 | 570 | 2350 |
| lead (Pb) | μg/L | < 0.1 | 0.3 | 0.2 | 0.2 | < 0.1 | < 0.1 | 0.6 | 0.2 | 0.3 | < 0.1 | < 0.1 | 0.3 | < 0.1 |
| manganese (Mn) | μg/L | 16.4 | 386 | 117 | < 127 | 24.1 | 76.5 | 563 | 56 | < 127 | 193 | 88.7 | < 127 | 335 |
| mercury (Hg) | μg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| molybdenum (Mo) | μg/L | < 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | < 0.1 | < 0.1 | 0.1 | < 0.1 | < 0.1 | 0.2 | 0.1 | < 0.1 |
| nickel (Ni) | μg/L | 3 | 5.2 | 1.4 | 1 | 3.4 | 1.9 | 2.6 | 0.6 | 0.8 | 0.9 | 0.8 | 1.2 | 1.6 |
| selenium (Se) | μg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 |
| silver (Ag) | μg/L | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | 1.2 | < 0.4 | 1 | < 0.4 | < 0.4 |
| zinc (Zn) | μg/L | 4 | 9 | 10 | 15 | 6 | 10 | 14 | 10 | 5 | 7 | 6 | 13 | 6 |
| **Metals (dissolved)** | | | | | | | | | | | | | | |
| aluminum (Al) | μg/L | 10 | 10 | < 10 | 230 | < 10 | < 10 | 20 | 20 | 10 | < 10 | 10 | 260 | < 10 |
| antimony (Sb) | μg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | 0.9 | < 0.8 | < 0.8 | < 0.8 | < 0.8 |
| arsenic (As) | μg/L | < 0.4 | < 0.4 | < 0.4 | 0.5 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | - | < 0.4 | < 0.4 | 0.7 | < 0.4 |
| barium (Ba) | μg/L | 79.3 | 93.3 | 51.9 | 57.3 | 81.8 | 57.2 | 84 | 42.4 | 62.8 | 61.4 | 18.4 | 34 | 31.6 |
| cadmium (Cd) | μg/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 |
| chromium (Cr) | μg/L | < 0.4 | < 0.4 | 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | 0.6 | < 0.4 | < 0.4 |
| copper (Cu) | μg/L | 1.6 | 1 | 0.8 | 1.5 | 1.9 | < 0.6 | 0.6 | 0.8 | 1.5 | < 0.6 | < 0.6 | 1.1 | < 0.6 |
| iron (Fe) | μg/L | 340 | 340 | 350 | 350 | 420 | 290 | 380 | 410 | 440 | 300 | 940 | 480 | 820 |
| lead (Pb) | μg/L | < 0.1 | 0.3 | < 0.1 | 0.2 | < 0.1 | < 0.1 | 0.1 | 0.2 | 0.2 | < 0.1 | < 0.1 | 0.2 | < 0.1 |
| manganese (Mn) | μg/L | 13 | 377 | 54.3 | 24.2 | 17.3 | 75.6 | 498 | 47 | 55 | 191 | 74.3 | 60.4 | 332 |
| mercury (Hg) | μg/L | < 0.01 | < 0.1 | < 0.1 | 0.2 | < 0.01 | < 0.01 | < 0.1 | < 0.1 | < 0.2 | < 0.01 | < 0.1 | 0.1 | < 0.01 |
| molybdenum (Mo) | μg/L | 0.1 | 0.1 | 0.2 | < 0.9 | 0.1 | < 0.1 | < 0.1 | 0.1 | - | < 0.1 | 0.2 | < 0.9 | 0.1 |
| nickel (Ni) | μg/L | 2.8 | 3.9 | 0.6 | 1.4 | 3.3 | 1 | 2 | < 0.7 | 1.1 | 1 | < 0.7 | 0.9 | 0.9 |
| selenium (Se) | μg/L | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 |
| silver (Ag) | μg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | 1.3 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| zinc (Zn) | μg/L | < 2 | 4 | 6 | 10 | 2 | 6 | 2 | 13 | 5 | < 2 | 6 | 9 | 2 |

* Data discarded due to issues with data quality.

## Table 6.7 Historical Water Quality in the Muskeg River (Median Values)

| Parameter | Units | Mouth (Site 1) (Fall)[a] | Canterra Road Crossing (Site MUR-2)[b] | | | | Upstream of Shelley Creek (Site MUR-4)[c] | Downstream of Stanley Creek (Site MUR-5)[d] | | | | Upstream of Wapasu Creek (Site MUR-6)[e] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Winter | Spring | Summer | Fall | | Winter | Spring | Summer | Fall | Spring | Summer | Fall |
| **Field Measured** | | | | | | | | | | | | | | |
| pH | | 8.4 | 7.7 | 7.8 | 7.9 | 7.8 | *7.8* | 7.2 | 7.6 | 7.3 | 7.6 | 7.4 | 7.5 | 7.7 |
| specific conductance | µS/cm | 394 | 470 | 196 | 316 | 269 | *326* | 550 | 243 | 275 | 316 | 245 | 382 | 352 |
| temperature | °C | 6.8 | 0.0 | 8.2 | 16.0 | 7.3 | 4.0 | 0.3 | 13.5 | 15.5 | 3.0 | 7.0 | 15.0 | 5.0 |
| dissolved oxygen | mg/L | 11.0 | 6.8 | 9.5 | 9.0 | 9.4 | 11.4 | 2.7 | 10.0 | 7.3 | 10.5 | 7.6 | 4.1 | 8.1 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | | | | |
| chloride | mg/L | 2.7 | 6 | 2 | 4 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 |
| dissolved organic carbon | mg/L | 24 | 20 | 17 | 23 | 25 | - | 15 | - | 22 | 23 | 21 | 25 | 24 |
| sulphate | mg/L | 4 | 5 | 4 | 5 | 4 | 3 | 2 | 1 | 1 | 3 | 4 | 4 | 1 |
| total alkalinity | mg/L | 150 | 259 | 102 | 170 | 141 | 166 | 299 | 133 | 152 | 174 | 94 | 183 | 167 |
| total dissolved solids | mg/L | 177 | 303 | 136 | 195 | 162 | 175 | 320 | 134 | 190 | 174 | 135 | 219 | 172 |
| total organic carbon | mg/L | 24 | 22 | 18 | 24 | 26 | 24 | 17 | 18 | 25 | 24 | 17 | 25 | 23 |
| total suspended solids | mg/L | 3.7 | 6 | 5 | 3 | 3 | 5 | 18 | 1 | 4 | 4 | 5 | 4 | 4 |
| **Nutrients and Chlorophyll *a*** | | | | | | | | | | | | | | |
| nitrate + nitrite | mg/L | < 0.02 | 0.3 | < 0.016 | 0.04 | 0.01 | 0.017 | 0.01 | 0.01 | 0.02 | 0.03 | < 0.05 | < 0.05 | 0.03 |
| nitrogen - ammonia | mg/L | 0.055 | 1.11 | < 0.05 | 0.05 | 0.04 | 0.05 | 0.75 | 0.04 | 0.03 | 0.06 | 0.05 | < 0.05 | 0.08 |
| nitrogen - total | mg/L | 0.65 | 1.6 | 0.8 | 1.06 | 0.93 | 0.907 | 1.77 | 0.71 | 0.87 | 0.77 | 0.83 | 1.04 | 1.29 |
| phosphorus, total | µg/L | 34 | 38 | 31 | 25 | 28 | 34.5 | 103 | 34 | 36 | 35 | 30 | 50.5 | 36 |
| chlorophyll *a* | µg/L | < 1 | < 1 | 4 | 1 | 1 | - | < 0.1 | - | 2 | 0.4 | - | - | < 1 |
| **Biochemical Oxygen Demand** | | | | | | | | | | | | | | |
| biochemical oxygen demand | mg/L | 1.3 | 3 | 2 | 0.5 | 2 | 1.7 | 2 | 1 | 0.5 | 0.8 | 0.6 | 0.5 | 1.9 |
| **Toxicity** | | | | | | | | | | | | | | |
| *Ceriodaphnia dubia*, 7 day reproduction - IC25 | % | - | > 100 | > 100 | > 100 | - | - | > 100 | > 100 | > 100 | - | - | - | 35 |
| *C. dubia*, 7 day mortality - LC50 | % | - | > 100 | > 100 | > 100 | - | - | > 100 | > 100 | > 100 | - | - | - | > 100 |
| fathead minnow 7 day growth - IC25 | % | - | > 100 | > 100 | > 100 | - | - | 73.3 | > 100 | 24.4 | - | - | - | 12 |
| fathead minnow 7 day mortality - LC50 | % | - | > 100 | > 100 | > 100 | - | - | > 100 | > 100 | 82.2 | - | - | - | > 100 |
| **Organics** | | | | | | | | | | | | | | |
| naphthenic acids | mg/L | < 1 | < 1 | 4 | - | - | - | - | - | - | - | - | - | 12 |
| total phenolics | µg/L | < 1 | - | - | - | - | - | < 1 | - | < 1 | < 1 | - | 4 | 5 |
| **Metals (total)** | | | | | | | | | | | | | | |
| aluminum (Al) | µg/L | 90 | 40 | 70 | 50 | 35 | 15 | 20 | < 100 | 60 | 10 | 41 | 34 | 50 |
| antimony (Sb) | µg/L | < 0.5 | < 0.4 | < 0.4 | - | - | - | - | - | - | - | < 0.4 | 0.8 | < 0.8 |
| arsenic (As) | µg/L | 0.95 | < 0.4 | < 0.4 | < 5 | 1.5 | 0.35 | < 0.2 | 0.4 | < 0.2 | 0.3 | 0.5 | < 0.4 | 1 |
| barium (Ba) | µg/L | 30 | 71 | 25 | - | - | - | 80 | - | 45 | 20 | 14 | 24 | 88 |
| cadmium (Cd) | µg/L | < 1.6 | 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 0.2 | < 1 | < 1 | < 0.2 | < 1 |

| Parameter | Units | Mouth (Site 1) (Fall)[(a)] | Canterra Road Crossing (Site MUR-2)[(b)] | | | | Upstream of Shelley Creek (Site MUR-4)[(c)] | Downstream of Stanley Creek (Site MUR-5)[(d)] | | | | Upstream of Wapasu Creek (Site MUR-6)[(e)] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Winter | Spring | Summer | Fall | | Winter | Spring | Summer | Fall | Spring | Summer | Fall |
| chromium (Cr) | µg/L | 4.5 | 10 | 5 | < 1 | 8 | < 1 | 1 | < 1 | 3 | < 1 | < 1 | < 0.4 | < 1 |
| copper (Cu) | µg/L | 1.3 | 2 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | 1.1 | 1 | < 1 |
| iron (Fe) | µg/L | 960 | 2420 | 690 | 1300 | 990 | 1070 | 6200 | 1150 | 1920 | 1410 | 585 | 300 | 1210 |
| lead (Pb) | µg/L | 1.2 | 4 | < 2 | 2 | < 2 | < 2 | 2 | < 2 | < 0.5 | < 2 | 1 | 0.3 | 2 |
| manganese (Mn) | µg/L | 48 | 545 | 38 | 29 | < 53 | 62.5 | 561 | 30 | 69 | 70 | 18 | 24 | 84 |
| mercury (Hg) | µg/L | < 0.3 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.08 | < 0.1 | < 0.05 | < 50 | < 0.1 | < 0.1 | < 0.1 | < 0.1 |
| molybdenum (Mo) | µg/L | < 3 | < 0.1 | 0.2 | - | - | - | < 3 | - | < 3 | < 3 | 0.1 | 0.1 | 0.1 |
| nickel (Ni) | µg/L | 5 | 1 | < 1 | 1 | < 1 | < 1 | < 1 | 1 | 9 | < 1 | 3 | < 0.6 | 1 |
| selenium (Se) | µg/L | < 0.3 | < 0.4 | < 0.4 | < 0.2 | < 0.2 | 0.45 | < 0.2 | 0.4 | < 0.2 | 0.2 | < 0.4 | < 0.4 | < 0.8 |
| silver (Ag) | µg/L | < 0.4 | < 1 | < 1 | - | - | - | < 0.1 | - | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.4 |
| zinc (Zn) | µg/L | 16 | 22 | 7 | 8 | 2 | 2 | 15 | 1 | < 1 | 10 | 17 | 8 | 20 |
| **Metals (dissolved)** | | | | | | | | | | | | | | |
| aluminum (Al) | µg/L | 58.45 | - | 32 | - | - | - | - | - | - | - | - | - | 10 |
| antimony (Sb) | µg/L | < 0.8 | - | < 0.4 | - | - | - | - | - | - | - | - | - | < 0.8 |
| arsenic (As) | µg/L | < 0.4 | 0.4 | 0.5 | 0.35 | 0.4 | - | - | - | - | - | 0.5 | 0.25 | < 0.3 |
| barium (Ba) | µg/L | 58.6 | - | 19 | - | - | - | - | - | - | - | - | - | 42.2 |
| cadmium (Cd) | µg/L | < 0.1 | - | < 0.1 | - | - | - | - | - | - | - | - | - | < 0.1 |
| chromium (Cr) | µg/L | < 1.7 | < 3 | < 3 | < 3 | < 3 | - | - | - | - | - | 5 | 3 | < 3 |
| copper (Cu) | µg/L | 1.2 | - | 1.3 | - | - | - | - | - | - | - | - | - | 1 |
| iron (Fe) | µg/L | 345 | - | 1030 | - | - | - | - | - | - | - | - | - | 890 |
| lead (Pb) | µg/L | 0.6 | - | 0.37 | - | - | - | - | - | - | - | - | - | 0.2 |
| manganese (Mn) | µg/L | 32.45 | - | 36 | - | - | - | - | - | - | - | - | - | 626 |
| mercury (Hg) | µg/L | 0.2 | - | < 0.2 | - | - | - | - | - | - | - | - | - | < 0.1 |
| molybdenum (Mo) | µg/L | 0.14 | - | 0.13 | - | - | - | - | - | - | - | - | - | < 0.1 |
| nickel (Ni) | µg/L | 2.4 | - | 1 | - | - | - | - | - | - | - | - | - | 3.3 |
| selenium (Se) | µg/L | < 0.4 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | - | - | - | - | - | < 0.4 | < 0.2 | < 0.2 |
| silver (Ag) | µg/L | < 0.2 | - | < 0.2 | - | - | - | - | - | - | - | - | - | < 0.2 |
| zinc (Zn) | µg/L | 4 | - | 8 | - | - | - | - | - | - | - | - | - | 10 |

[(a)] Based on information from Golder (1996a, 1999a), R.L.&L. (1982) and NAQUADAT stations AB07DA0620/630.
[(b)] Based on information from Shell (1975), Golder (1998a, 1998b), R.L.&L. (1982, 1989), unpublished monitoring data from Syncrude Canada Ltd. and NAQUADAT station AB07DA0610.
[(c)] Based on information from R.L.&L. (1989).
[(d)] Based on information from R.L.&L. (1989), unpublished monitoring data from Syncrude Canada Ltd. and NAQUADAT station AB07DA2750.
[(e)] Based on information from R.L.&L. (1989), Golder (1999a) and NAQUADAT station AB07DA0440.
\- = no data.

## Table 6.8 Site-specific Variations in Muskeg River Water Quality, 1999

| Variation | Sampling Event | Affected Parameters at Sample Site | | | | |
|---|---|---|---|---|---|---|
| | | Mouth (MUR-1) | Canterra Road Crossing (MUR-2) | Upstream of Shelley Creek (MUR-4) | Downstream of Stanley Creek (MUR-5) | Upstream of Wapasu Creek (MUR-6) |
| 1999 levels **higher** then historical median values | winter | - | • ammonia<br>• total phosphorus<br>• total nickel | - | • total aluminum | - |
| | spring | - | • total and dissolved barium<br>• pH<br>• total iron | - | • TDS<br>• total manganese<br>• total zinc<br>• pH | • pH<br>• total phosphorus |
| | summer | - | | - | • TDS | • total aluminum |
| | fall | • TDS<br>• total barium<br>• total aluminum | • total phosphorus | • TDS<br>• total alkalinity | • TDS<br>• total manganese | • TSS<br>• total phosphorus |
| | every sampling event | - | • TDS<br>• total alkalinity<br>• sulphate<br>• total aluminum | - | • sulphate (weak trend) | • sulphate (weak trend)<br>• total iron<br>• total manganese |
| 1999 levels **lower** then historical median values | winter | - | • total chromium<br>• total iron | - | • TSS<br>• total phosphorus | - |
| | spring | - | • dissolved aluminum<br>• dissolved lead<br>• dissolved iron<br>• total chromium | - | | • total zinc<br>• total lead |
| | summer | | • total iron | | | |
| | fall | • total phosphorus<br>• total chromium<br>• total manganese<br>• total zinc<br>• total iron<br>• dissolved aluminum<br>• dissolved manganese | | • total aluminum | | • naphthenic acids<br>• total barium<br>• total and dissolved zinc<br>• dissolved manganese |
| | every sampling event | - | • total lead | - | | • dissolved chromium |

= no sample collected.

blank cell = no parameters higher or lower than historical medium values.

**Table 6.9 Spring, Summer and Fall Water Temperatures in the Muskeg River**

| Location | Season | | |
|---|---|---|---|
| | Spring | Summer | Fall |
| **MUR-1** | | | |
| median | 10.6 | 17.8 | 8.6 |
| minimum | 5.9 | 11.9 | 1.4 |
| maximum | 19.6 | 26.6 | 17.0 |
| n | 1899 | 6624 | 3553 |
| **MUR-2** | | | |
| median | 9.6 | 18.3 | 10.3 |
| minimum | 6.7 | 13.5 | 2.3 |
| maximum | 17.6 | 22.7 | 15.4 |
| n | 1906 | 6624 | 3440 |
| **MUR-4** | | | |
| median | 8.7 | 17.2 | 10.5 |
| minimum | 5.4 | 12.4 | 2.6 |
| maximum | 16.8 | 21.3 | 14.4 |
| n | 1836 | 6624 | 3563 |
| **MUR-5** | | | |
| median | 8.7 | 17.1 | 10.2 |
| minimum | 5.9 | 12.4 | 2.9 |
| maximum | 16.8 | 20.5 | 14.2 |
| n | 1844 | 6624 | 3563 |
| **MUR-6** | | | |
| median | 4.0 | 10.2 | 6.5 |
| minimum | 0.7 | 5.7 | 1.2 |
| maximum | 7.4 | 12.2 | 10.7 |
| n | 1913 | 6624 | 3425 |

n = number of data.

Note: Locations one to six on the Muskeg River are shown in Figure 3.4.

**Figure 6.1 Total Iron Concentrations in the Muskeg River**

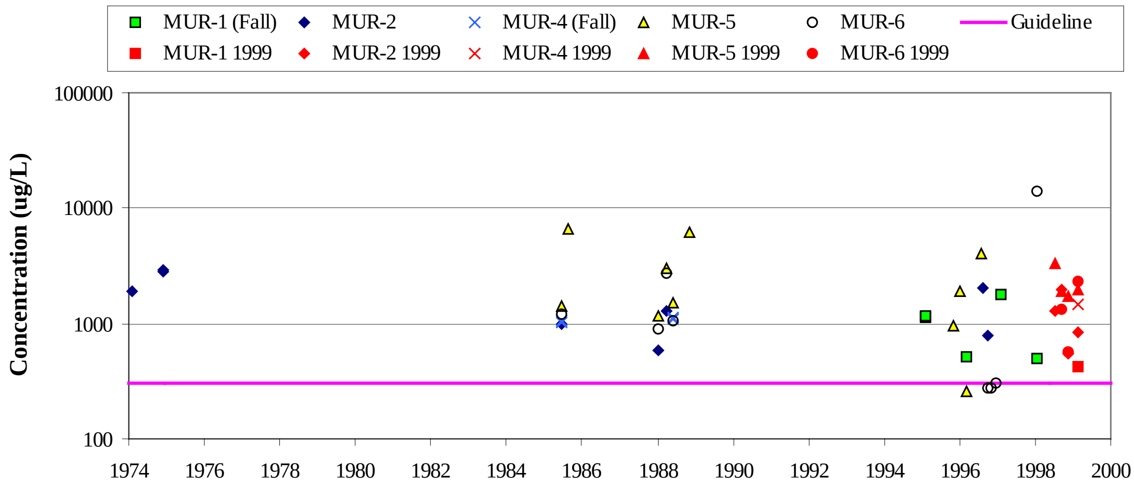
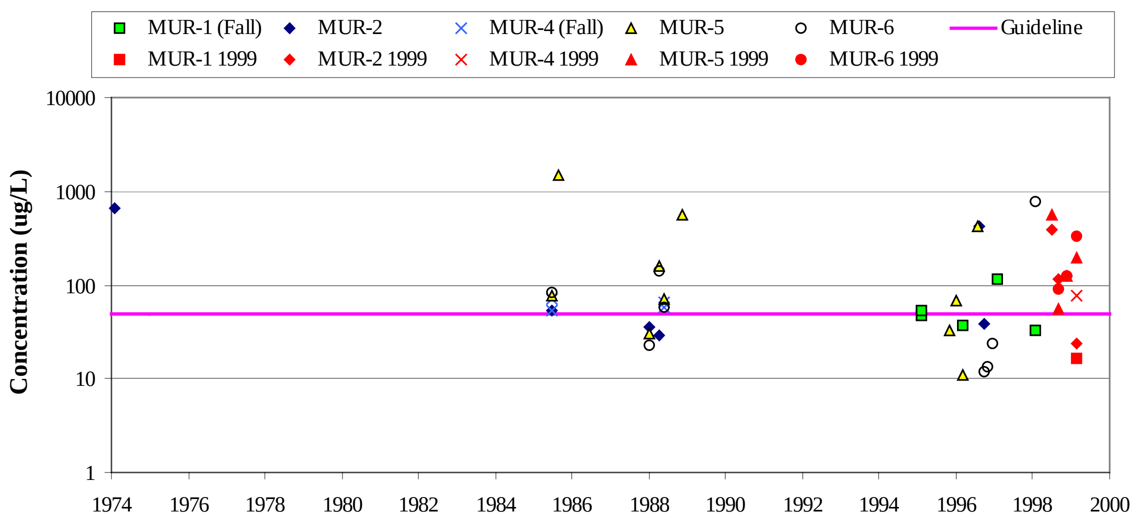



**Figure 6.2 Total Manganese Concentrations in the Muskeg River**




Non-detects replaced with detection limit.

**Table 6.10 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Lower Muskeg River**

| Parameter | Units | Guidelines for the Protection of | | | Mouth (MUR-1) | | Canterra Road Crossing (MUR-2) | | | | | | | | Upstream of Shelley Creek (MUR-4) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic life[a] | | Human | | | Winter | | Spring | | Summer | | Fall | | | |
| | | Acute | Chronic | Health[b] | Fall 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median | Fall 1999 | Historical Median |
| **Nutrients** | | | | | | | | | | | | | | | | |
| nitrogen - total | mg/L | - | 1 | - | | | | C | | | | C | | | | |
| **Total Metals** | | | | | | | | | | | | | | | | |
| aluminum (Al) | µg/L | 750 | 100 | - | C | | C | | C | | C | | | | | |
| iron (Fe) | µg/L | - | 300 | 300 | C H | C H | C H | C H | C H | C H | C H | C H | C H | C H | C H | C H |
| manganese (Mn) | µg/L | - | - | 50 | | | H | H | H | | H` | | | H` | H | H |
| mercury (Hg)[c] | µg/L | 1.4 | 0.1 | 0.05 | C H` | C H` | C H` | H` | C H` | H` | C H` | H` | C H` | H` | C H` | H` |
| silver (Ag) | µg/L | 3.4 - 23* | 0.1 | - | C` | C` | C` | C` | C` | C` | C` | | C` | | C` | |

[a] Guidelines taken from AENV (1999).

[b] Guidelines taken from U.S. EPA (1999).

[c] Using U.S. EPA and CCME guidelines, respectively, because Alberta mercury guidelines have not been finalized

* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

C = chronic aquatic guideline exceeded; H = human health guideline exceeded.

- No guideline.

` Although substance concentrations were below detection limits, the analytical detection limit exceeded the relevant surface water guideline.

Blank cell = no guideline exceeded.

**Table 6.11 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Upper Muskeg River**

| Parameter | Units | Guidelines for the Protection of | | | Downstream of Stanley Creek (MUR-5) | | | | | | | | Upstream of Wapasu Creek (MUR-6) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Winter | | Spring | | Summer | | Fall | | Spring | | Summer | | Fall | |
| | | Aquatic life[a] | | Human Health[b] | | | | | | | | | | | | | | |
| | | Acute | Chronic | | 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median |
| **Nutrients** | | | | | | | | | | | | | | | | | | |
| nitrogen - total | mg/L | - | 1 | - | C | C | | | | | | | C | | | C | C | C |
| phosphorus, total | µg/L | - | 50 | - | | C | | | | | | | C | | | C | C | |
| **Total Phenolics** | | | | | | | | | | | | | | | | | | |
| total phenolics | µg/L | - | 5 | - | | | C | | | | | | C | | | | | |
| **Total Metals** | | | | | | | | | | | | | | | | | | |
| aluminum (Al) | µg/L | 750 | 100 | - | | | | | | | | | | | C | | | |
| iron (Fe) | µg/L | - | 300 | 300 | C H | C H | C H | C H | C H | C H | C H | C H | C H | C H | C H | | C H | C H |
| manganese (Mn) | µg/L | - | - | 50 | H | H | H | | H` | H | H | H | H | | H` | | H | H |
| mercury (Hg) [c] | µg/L | 1.4 | 0.1 | 0.05 | C H` | H` | C H` | | C H` | A C H` | C H` | H` | C H` | H` | C H` | H` | C H` | H` |
| silver (Ag) | µg/L | 3.4 - 23* | 0.1 | - | C` | | C` | | C | | C` | | C | | C` | | C` | C` |

(a) Guidelines taken from AENV (1999).

(b) Guidelines taken from U.S. EPA (1999).

(c) Using U.S. EPA and CCME guidelines, respectively, because Alberta mercury guidelines have not been finalized.

* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

C = chronic aquatic guideline exceeded; H = human health guideline exceeded.

- No guideline.

` Although substance concentrations were below detection limits, the analytical detection limit exceeded the relevant surface water guideline.

blank cell = no guideline exceeded.

### 6.1.1.4 Muskeg River Tributaries

#### *Alsands Drain*

Two water samples have been collected from the Alsands Drain: one in 1997 and a second in the fall of 1999. In both years, sample waters were non-toxic to bacteria and contained detectable levels of naphthenic acids (Table 6.12). Total suspended solids (TSS), TDS, sulphate, total aluminum, iron and nickel concentrations were higher in 1999 than in 1997 (Tables 6.12 and 6.13). Median, minimum and maximum water temperatures observed in the spring, summer and fall of 1999 are summarized in Table 6.14.

In 1999, total nitrogen, aluminum, iron and manganese concentrations exceeded surface water quality guidelines (Table 6.15). All of these elements, with the exception of total aluminum, were also found to exceed guidelines in 1997.

#### *Jackpine Creek*

Sample waters collected from the mouth of Jackpine Creek in the fall of 1999 were non-toxic to bacteria and contained non-detectable levels of naphthenic acids (Table 6.12). TDS, total aluminum, barium, iron and manganese levels in 1999 were higher than historical median values (Tables 6.12 and 6.13). Dissolved nickel levels were also higher in 1999 than in previous years. Trends in total aluminum and TDS concentrations are illustrated in Figures 6.3 and 6.4. Plots were not generated for barium, manganese, iron or nickel because of data limitations (i.e., less than 4 historical points of data).

Iron concentrations exceeded surface water guidelines for the protection of aquatic life and human health in 1999 and in previous sampling events (Table 6.15). In 1999, total aluminum and manganese concentrations were higher than guideline levels. Neither mercury nor silver was detected at the mouth of Jackpine Creek in 1999. However, analytical detection limits reported for these metals exceed chronic aquatic guidelines.

#### *Shelley Creek*

No historical data are available to describe fall water quality in Shelley Creek. Sample waters collected from Shelley Creek in the fall of 1999 were non-toxic to bacteria (Table 6.12). Low levels of naphthenic acids were detected, and Shelley Creek contained high TDS, total phosphorus, iron and manganese concentrations in comparison to other streams in the Muskeg River watershed. Total phosphorus, iron and manganese concentrations exceeded surface water quality guidelines (Table 6.15).

**Table 6.12 Water Quality in the Alsands Drain and Jackpine, Shelley and Stanley Creeks**

| Parameter | Units | Alsands Drain (Fall) | | Jackpine Creek (Fall) | | Shelley Creek (Fall 1999) | Stanley Creek (Fall) | |
|---|---|---|---|---|---|---|---|---|
| | | 1999 | 1997 | 1999 | Historical Median[a] | | 1999 | 1976[b] |
| **Field Measured** | | | | | | | | |
| pH | | 7.9 | 7.5 | 7.8 | 8.2 | 7.2 | 9.2 | 7.7 |
| specific conductance | µS/cm | 887 | 629 | 413 | 220 | 1172 | - | 315 |
| temperature | °C | 3.5 | - | 3.6 | 6.5 | 4.3 | 2.2 | 10.0 |
| dissolved oxygen | mg/L | 12.8 | - | 10.4 | 9.6 | 0.9 | 7.6 | 9.3 |
| **Conventional Parameters and Major Ions** | | | | | | | | |
| chloride | mg/L | 1 | 2 | 6 | 2 | 80 | - | 0.4 |
| dissolved organic carbon | mg/L | 12 | 18 | 19 | 25 | 29 | - | 8 |
| sulphate | mg/L | 205 | 102 | < 3 | 4 | 10 | - | 1 |
| total alkalinity | mg/L | 324 | 247 | 227 | 111 | 354 | - | 156 |
| total dissolved solids | mg/L | 700 | 440 | 234 | 126 | 500 | - | 167 |
| total organic carbon | mg/L | 14 | 22 | 18 | 26 | 33 | 16 | 11 |
| total suspended solids | mg/L | 12 | 4 | 8 | 5 | 39 | - | 35 |
| **Nutrients** | | | | | | | | |
| nitrate + nitrite | mg/L | < 0.1 | < 0.05 | < 0.1 | < 0.003 | < 0.1 | < 0.1 | - |
| nitrogen – ammonia | mg/L | 0.4 | 0.6 | < 0.05 | 0.03 | 0.6 | < 0.05 | - |
| nitrogen – total | mg/L | 1.4 | 1.3 | 0.7 | 0.9 | 3.8 | 0.5 | 1.5 |
| phosphorus, total | µg/L | 15 | 17 | 42 | 25 | 331 | 26 | 245 |
| **Biochemical Oxygen Demand** | | | | | | | | |
| biochemical oxygen demand | mg/L | < 2 | 6 | < 2 | 1 | 7 | < 2 | - |
| **Toxicity**[c] | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | > 91 | > 91 | > 91 | > 91 | > 91 | - |
| Microtox IC25 @ 15 min | % | > 91 | > 91 | > 91 | > 91 | > 91 | > 91 | - |
| **Organics** | | | | | | | | |
| naphthenic acids | mg/L | 1 | 1 | < 1 | < 1 | 1 | < 1 | - |
| total phenolics | µg/L | 4 | 4 | 4 | 1 | 2 | 2 | - |

(a) Based on information from Golder (1996a, 1998b), R.L.&L. (1982, 1989) and NAQUADAT stations AB07DA0600.

(b) Based on information from NAQUADAT station AB07DA0490 (n=2).

(c) Microtox® results are interpreted as the percentage strength of sample water that had a non-toxic response. The higher the percentage, the less dilution required to make the sample non-toxic (i.e., higher percentages indicate lower toxicity). Since the test organisms live in water, there is always a slight dilution (<9%) of sample waters with the introduction of the test organisms; hence, a result of >91% (instead of a reading of 100%) indicates that test waters are non-toxic.

- = no data.

## *Stanley Creek*

Limited historical information is available to describe fall water quality in Stanley Creek. Major ions, TDS and dissolved oxygen levels in 1999 were consistent with historical data (Table 6.12). Stanley Creek was more basic in 1999 than when last sampled in 1976. Total aluminum and total phosphorus levels were lower in 1999 than in 1976. Naphthenic acid concentrations were below detection limits, and sample waters were non-toxic to bacteria. None of the parameters detected at the mouth of Stanley Creek in 1999 were found to exceed surface water quality guidelines for the protection of aquatic life and human health (Table 6.15).

**Table 6.13 Metal Levels in the Alsands Drain and Jackpine, Shelley and Stanley Creeks**

| Parameter | Units | Alsands Drain (Fall) | | Jackpine Creek (Fall) | | Shelley Creek | Stanley Creek (Fall) | |
|---|---|---|---|---|---|---|---|---|
| | | 1999 | 1997 | 1999 | Historical Median[a] | (Fall 1999) | 1999 | 1976[b] |
| **Total Metals** | | | | | | | | |
| aluminum (Al) | µg/L | 440 | 35 | 120 | 51 | 60 | 20 | 55 |
| antimony (Sb) | µg/L | < 0.8 | < 0.4 | < 0.8 | 0.4 | < 0.8 | < 0.8 | - |
| arsenic (As) | µg/L | < 1 | < 0.4 | < 1 | 0.5 | < 1 | < 1 | < 1 |
| barium (Ba) | µg/L | 189 | 118 | 49 | 19 | 175 | 37 | - |
| cadmium (Cd) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 1 | < 0.2 | < 0.2 | - |
| chromium (Cr) | µg/L | < 0.8 | < 0.4 | < 0.8 | 1.5 | 1.2 | < 0.8 | - |
| copper (Cu) | µg/L | 2 | 2.6 | < 1 | < 1 | < 1 | < 1 | - |
| iron (Fe) | µg/L | 1460 | 700 | 1570 | 580 | 5300 | 290 | - |
| lead (Pb) | µg/L | 0.9 | 0.3 | < 0.1 | < 2 | < 0.1 | < 0.1 | - |
| manganese (Mn) | µg/L | 253 | 244 | 58 | 16 | 1630 | 23.1 | - |
| mercury (Hg) | µg/L | < 0.2 | < 0.1 | < 0.2 | < 0.1 | < 0.2 | < 0.2 | < 0.2 |
| molybdenum (Mo) | µg/L | 0.3 | < 0.1 | 0.1 | 1.6 | 0.1 | < 0.1 | - |
| nickel (Ni) | µg/L | 3.5 | 0.4 | 1.6 | < 2.5 | 1.7 | 0.4 | - |
| selenium (Se) | µg/L | < 0.8 | < 0.4 | < 0.8 | < 0.2 | < 0.8 | < 0.8 | - |
| silver (Ag) | µg/L | < 0.4 | < 0.1 | < 0.4 | 5 | < 0.4 | < 0.4 | - |
| zinc (Zn) | µg/L | 11 | 10 | 7 | 26 | 5 | 4 | - |
| **Dissolved Metals** | | | | | | | | |
| aluminum (Al) | µg/L | < 10 | - | < 10 | 58 | < 10 | 20 | - |
| antimony (Sb) | µg/L | < 0.8 | - | < 0.8 | < 0.4 | < 0.8 | < 0.8 | - |
| arsenic (As) | µg/L | < 0.4 | - | < 0.4 | 0.4 | < 0.4 | < 0.4 | - |
| barium (Ba) | µg/L | 162 | - | 44 | 17 | 107 | 39 | - |
| cadmium (Cd) | µg/L | < 0.1 | - | < 0.1 | < 0.1 | < 0.1 | < 0.1 | - |
| chromium (Cr) | µg/L | < 0.4 | - | < 0.4 | < 3 | < 0.4 | < 0.4 | < 3 |
| copper (Cu) | µg/L | 0.8 | - | < 0.6 | 2.2 | 0.7 | 1.2 | - |
| iron (Fe) | µg/L | 540 | - | 280 | 340 | 1610 | 240 | - |
| lead (Pb) | µg/L | < 0.1 | - | < 0.1 | 0.7 | < 0.1 | < 0.1 | - |
| manganese (Mn) | µg/L | 254 | - | 49 | 44 | 1630 | 22 | - |
| mercury (Hg) | µg/L | < 0.1 | - | < 0.01 | < 0.2 | < 0.01 | < 0.01 | - |
| molybdenum (Mo) | µg/L | 0.2 | - | < 0.1 | 0.1 | < 0.1 | 0.2 | - |
| nickel (Ni) | µg/L | 3.3 | - | 1.2 | 0.2 | 1.4 | 0.2 | - |
| selenium (Se) | µg/L | < 0.4 | - | < 0.4 | < 0.2 | < 0.4 | < 0.4 | - |
| silver (Ag) | µg/L | < 0.2 | - | < 0.2 | < 0.2 | < 0.2 | < 0.2 | - |
| zinc (Zn) | µg/L | 4 | - | 2 | 16 | < 2 | 3 | - |

[a] Based on information from Golder (1997b), R.L.&L. (1982, 1989) and NAQUADAT stations AB07DA0600.

[b] Based on information from NAQUADAT station AB07DA0490 (n=2).

\- = no data.

### Table 6.14 Spring, Summer and Fall Water Temperatures in the Alsands Drain

| Statistic | Season | | |
|---|---|---|---|
| | Spring | Summer | Fall |
| median | 11.8 | 19.4 | 12.1 |
| minimum | 6.6 | 13.4 | -3.9 |
| maximum | 21.5 | 26.7 | 24.8 |
| n | 1903 | 6624 | 3916 |

n = number of data.

### Table 6.15 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in the Alsands Drain and Jackpine, Shelley and Stanley Creeks

| Parameter | Units | Guidelines for the Protection of | | | Alsands Drain (Fall) | | Jackpine Creek (Fall) | | Shelley Creek | Stanley Creek (Fall) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic life[a] | | Human | | | | Historical | | | |
| | | Acute | Chronic | Health[b] | 1999 | 1997 | 1999 | Median | (Fall 1999) | 1999 | 1976 |
| **Nutrients** | | | | | | | | | | | |
| nitrogen - total | mg/L | - | 1 | - | C | C | | | | | C |
| phosphorus, total | µg/L | - | 50 | - | | | | | C | | C |
| **Total Metals** | | | | | | | | | | | |
| aluminum (Al) | µg/L | 750 | 100 | - | C | | C | | | | - |
| iron (Fe) | µg/L | - | 300 | 300 | C H | C H | C H | C H | C H | | - |
| manganese (Mn) | µg/L | - | - | 50 | H | H | H | | H | | - |
| mercury (Hg)[c] | µg/L | 1.4 | 0.1 | 0.05 | C H` | H` | C H` | H` | C H` | C H` | C H` |
| silver (Ag) | µg/L | 3.4 - 30* | 0.1 | - | C` | | C` | | C` | C` | - |

[a] Guidelines taken from AENV (1999).

[b] Guidelines taken from U.S. EPA (1999).

[c] Using U.S. EPA and CCME guidelines, respectively, because Alberta mercury guidelines have not been finalized.

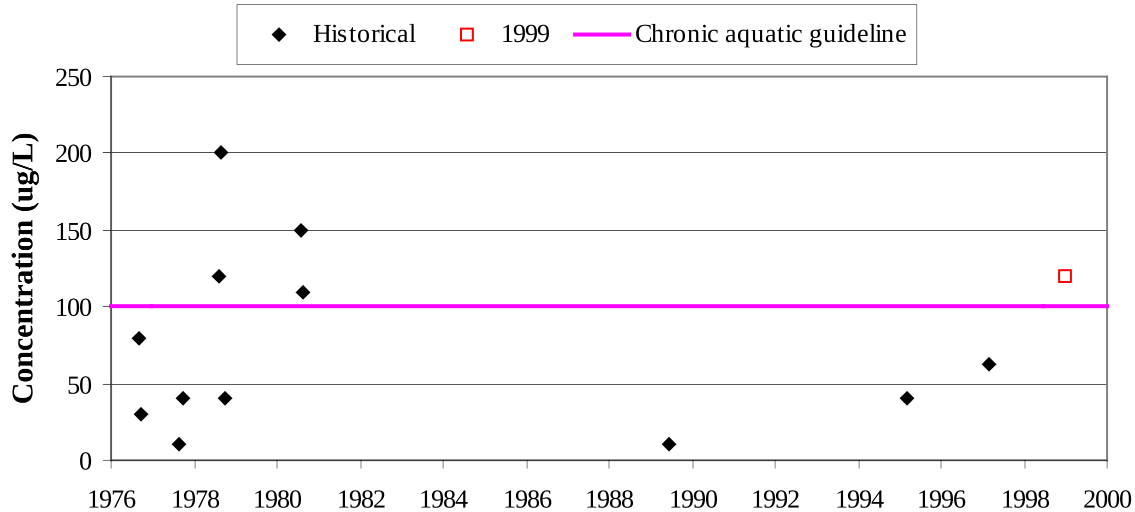
* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999) .

C = chronic aquatic guideline exceeded; H = human health guideline exceeded.

- No guideline / no data.

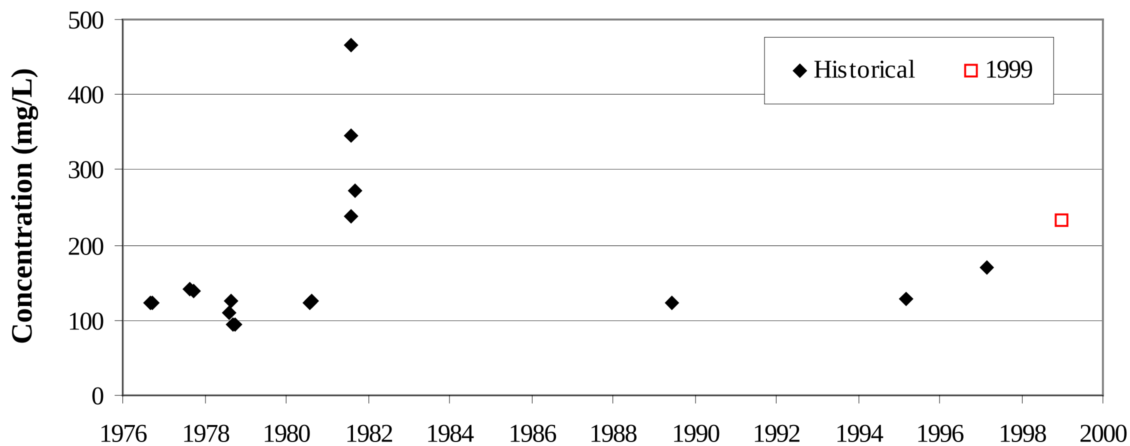
` Although substance concentrations were below detection limits, the analytical detection limit exceeded the relevant surface water guideline.

**Figure 6.3 Fall Total Aluminum Concentrations in Jackpine Creek**




Non-detects replaced with detection limit.

**Figure 6.4 Fall TDS Levels in Jackpine Creek**



### *Muskeg Creek*

As observed in 1998 (Golder 1999a), TDS and major ion concentrations at the mouth of Muskeg Creek were higher in 1999 than in previous years (Table 6.16). Total aluminum, total iron and total manganese levels were also higher in 1999 than in previous years (Tables 6.16 and 6.17). Naphthenic acids were present at detectable levels in 1999, but sample waters were non-toxic to bacteria.

Total iron and total manganese concentrations exceeded surface water quality guidelines in 1999 (Table 6.18); these guidelines have been exceeded in previous sampling events (Figures 6.5 and 6.6). Total aluminum concentrations were below guidelines in 1999 and in all previous sampling events. However, total aluminum levels in Muskeg Creek appear to be increasing over time (Figure 6.7), possibly in relation to increasing TSS levels in the creek (Figure 6.8).

### *Wapasu Creek*

Water samples collected from Wapasu Creek in the winter and fall of 1999 were non-toxic to bacteria and contained non-detectable levels of naphthenic acids (Table 6.16). The winter water sample was non-toxic to *Ceriodaphnia dubia* and fathead minnows. In both the fall and winter of 1999, TDS and chlorophyll *a* levels were higher in Wapasu Creek than in previous sampling events, while total phosphorus concentrations were lower in 1999 than in previous years (Appendix II, Table II-9). Total and dissolved metal concentrations in 1999 were comparable with historical median values, with the exception of total aluminum (winter only), total iron (winter and fall) and total zinc (winter only) (Table 6.17).

In the winter of 1999, total phosphorus, phenolics, aluminum, iron and manganese concentrations exceeded surface water guidelines (Table 6.15). All of these parameters, except for aluminum, have been observed at concentrations in excess of guideline levels in previous years. Total aluminum concentrations over time are illustrated in Figure 6.9. In the fall of 1999, only total iron and manganese concentrations exceeded guidelines. Historical median values for fall also exceed these guidelines.

## Table 6.16 Water Quality in Muskeg and Wapasu Creeks

| Parameter | Units | Muskeg Creek (Fall) 1999 | Muskeg Creek (Fall) Historical Median[a] | Wapasu Creek Winter 1999 | Wapasu Creek Winter Historical Median[b] | Wapasu Creek Fall 1999 | Wapasu Creek Fall Historical Median[c] |
|---|---|---|---|---|---|---|---|
| **Field Measured** | | | | | | | |
| pH | | 7.6 | 7.7 | 7.8 | 8.0 | 8.2 | 7.6 |
| specific conductance | µS/cm | 585 | 192 | 572 | - | 318 | 212 |
| temperature | °C | 2.8 | 5.0 | 0.4 | 0.0 | 4.0 | 3.0 |
| dissolved oxygen | mg/L | 7.2 | 10.7 | 4.3 | 9.0 | 8.6 | 11.6 |
| **Conventional Parameters and Major Ions** | | | | | | | |
| chloride | mg/L | 23 | 1 | 1 | 2 | 2 | 1 |
| dissolved organic carbon | mg/L | 21 | 25 | 8 | 31 | 18 | 13 |
| sulphate | mg/L | 8 | 3 | 8 | 6 | 5 | 2 |
| total alkalinity | mg/L | 297 | 110 | 327 | 231 | 176 | 119 |
| total dissolved solids | mg/L | 339 | 127 | 350 | 266 | 240 | 130 |
| total organic carbon | mg/L | 21 | 30 | 10 | 33 | 22 | 24 |
| total suspended solids | mg/L | 7 | 1 | 7 | 23 | 3 | 7 |
| **Nutrients and Chlorophyll *a*** | | | | | | | |
| nitrate + nitrite | mg/L | < 0.1 | 0.01 | < 0.1 | 0.1 | < 0.1 | 0.01 |
| nitrogen – ammonia | mg/L | 0.07 | 0.04 | 0.34 | 0.21 | < 0.05 | 0.07 |
| nitrogen - total | mg/L | 1.0 | 0.8 | 0.5 | 1.9 | 0.9 | 1.0 |
| phosphorus, total | µg/L | 42 | 34 | 96 | 200 | 20 | 37 |
| chlorophyll *a* | µg/L | -* | < 1 | 7 | < 1 | -* | 2 |
| **Biochemical Oxygen Demand** | | | | | | | |
| biochemical oxygen demand | mg/L | < 2 | 2 | 2 | < 2 | < 2 | 2 |
| **Toxicity** | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | > 91 | > 91 | > 91 | > 91 | - |
| Microtox IC25 @ 15 min | % | > 91 | > 91 | > 91 | > 91 | > 91 | - |
| *Ceriodaphnia dubia*, 7 day reproduction - IC25 | % | - | 15 | > 100 | > 100 | - | - |
| *C. dubia*, 7 day mortality - LC50 | % | - | > 100 | > 100 | > 100 | - | - |
| fathead minnow 7 day growth - IC25 | % | - | - | > 100 | > 100 | - | - |
| fathead minnow 7 day mortality - LC50 | % | - | - | > 100 | > 100 | - | - |
| **Organics** | | | | | | | |
| naphthenic acids | mg/L | 2 | < 1 | < 1 | < 1 | < 1 | - |
| total phenolics | µg/L | 5 | 5 | 6 | 6 | 2 | - |

(a) Based on information from Golder (1996a, 1999a), R.L.&L. (1989) and NAQUADAT stations AB07DA0500/530.

(b) Based on information from Golder (1999a), R.L.&L. (1989) and NAQUADAT station AB07DA0480.

(c) Based on information from R.L.&L. (1989) and NAQUADAT station AB07DA0480.

- = no data.

* Data discarded due to issues with data quality.

**Table 6.17 Metal Levels in Muskeg and Wapasu Creeks**

| Parameter | Units | Muskeg Creek (Fall) | | Wapasu Creek | | | |
|---|---|---|---|---|---|---|---|
| | | | | Winter | | Fall | |
| | | 1999 | Historical Median[(a)] | 1999 | Historical Median[(b)] | 1999 | Historical Median[(c)] |
| **Total Metals** | | | | | | | |
| aluminum (Al) | µg/L | 70 | 20 | 120 | 35 | 20 | 20 |
| antimony (Sb) | µg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | - |
| arsenic (As) | µg/L | < 1 | 0.7 | < 1 | < 1 | < 1 | 0.7 |
| barium (Ba) | µg/L | 51 | 53 | 66 | 59 | 29 | - |
| cadmium (Cd) | µg/L | < 0.2 | < 1 | < 0.2 | < 1 | < 0.2 | < 1 |
| chromium (Cr) | µg/L | < 0.8 | 1 | < 0.8 | 1.7 | < 0.8 | < 1 |
| copper (Cu) | µg/L | < 1 | < 1 | < 1 | 2 | < 1 | < 1 |
| iron (Fe) | µg/L | 1810 | 395 | 2370 | 1945 | 600 | 945 |
| lead (Pb) | µg/L | < 0.1 | < 2 | 0.6 | < 2 | < 0.1 | < 2 |
| manganese (Mn) | µg/L | 350 | 21 | 697 | 705 | 74 | 63 |
| mercury (Hg) | µg/L | < 0.2 | < 0.1 | < 0.2 | < 0.1 | < 0.2 | < 0.1 |
| molybdenum (Mo) | µg/L | < 0.1 | < 3 | < 0.1 | 0.4 | < 0.1 | - |
| nickel (Ni) | µg/L | 1.6 | < 1 | 3 | 4.1 | 2 | < 1 |
| selenium (Se) | µg/L | < 0.8 | 0.7 | < 0.8 | < 0.8 | < 0.8 | 0.4 |
| silver (Ag) | µg/L | < 0.4 | 3 | < 0.4 | < 0.4 | < 0.4 | - |
| zinc (Zn) | µg/L | 7 | 4 | 4 | 10 | < 4 | 4 |
| **Dissolved Metals** | | | | | | | |
| aluminum (Al) | µg/L | < 10 | 30 | 30 | 50 | < 10 | - |
| antimony (Sb) | µg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | - |
| arsenic (As) | µg/L | < 0.4 | < 0.5 | < 0.4 | < 1 | < 0.4 | < 1 |
| barium (Ba) | µg/L | 48 | 63 | 59 | 53.2 | 28 | - |
| cadmium (Cd) | µg/L | < 0.1 | < 0.1 | < 0.1 | 0.1 | < 0.1 | - |
| chromium (Cr) | µg/L | < 0.4 | < 3 | < 0.4 | < 3 | < 0.4 | < 3 |
| copper (Cu) | µg/L | < 0.6 | 0.7 | 0.7 | 2.6 | < 0.6 | - |
| iron (Fe) | µg/L | 350 | 1020 | 400 | 1130 | 420 | - |
| lead (Pb) | µg/L | < 0.1 | 0.1 | 0.2 | 0.8 | < 0.1 | - |
| manganese (Mn) | µg/L | 319 | 522 | 718 | 866 | 70 | - |
| mercury (Hg) | µg/L | < 0.01 | < 0.1 | < 0.1 | < 0.1 | < 0.01 | - |
| molybdenum (Mo) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | - |
| nickel (Ni) | µg/L | 1.1 | 3.5 | 2.9 | 3.3 | 0.7 | - |
| selenium (Se) | µg/L | < 0.4 | < 0.4 | < 0.4 | < 0.5 | < 0.4 | < 0.5 |
| silver (Ag) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | - |
| zinc (Zn) | µg/L | 2 | 4 | 5 | 12 | < 2 | - |

[(a)] Based on information from Golder (1996a 1999a), R.L.&L. (1989) and NAQUADAT stations AB07DA0500/530.

[(b)] Based on information from Golder (1999a), R.L.&L. (1989) and NAQUADAT station AB07DA0480.

[(c)] Based on information from R.L.&L. (1989) and NAQUADAT station AB07DA0480.

- = no data.

## Table 6.18 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in Muskeg and Wapasu Creeks

| Parameter | Units | Guidelines for the Protection of Aquatic Life[a] | | | Muskeg Creek (Fall) | | Upper Wapasu Creek | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Winter | | Fall | |
| | | Acute | Chronic | Health[b] | 1999 | Historical Median | 1999 | Historical Median | 1999 | Historical Median |
| **Nutrients** | | | | | | | | | | |
| nitrogen - total | mg/L | - | 1 | - | | | | C | | |
| phosphorus, total | µg/L | - | 50 | - | | | C | C | | |
| **Total Phenolics** | | | | | | | | | | |
| total phenolics | µg/L | - | 5 | - | | | C | C | | - |
| **Total Metals** | | | | | | | | | | |
| aluminum (Al) | µg/L | 750 | 100 | - | | | C | | | |
| iron (Fe) | µg/L | - | 300 | 300 | C H | C H | C H | C H | C H | C H |
| manganese (Mn) | µg/L | - | - | 50 | H | | H | H | H | H |
| mercury (Hg)[d] | µg/L | 1.4 | 0.1 | 0.05 | C H` | H` | C H` | H` | C H` | H` |
| silver (Ag) | µg/L | 3.4 - 23* | 0.1 | - | C` | A C | C` | C` | C` | - |

[a] Guidelines taken from AENV (1999).

(b) Guidelines taken from U.S. EPA (1999).

(c) Using U.S. EPA and CCME guidelines, respectively, because Alberta mercury guidelines have not been finalized.

* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

C = chronic aquatic guideline exceeded; H = human health guideline exceeded.

- No guideline / no data.

` Although substance concentrations were below detection limits, the analytical detection limit exceeded the relevant surface water guideline.

blank cells = no guideline exceeded.

## Figure 6.5 Fall Total Iron Concentrations in Muskeg Creek

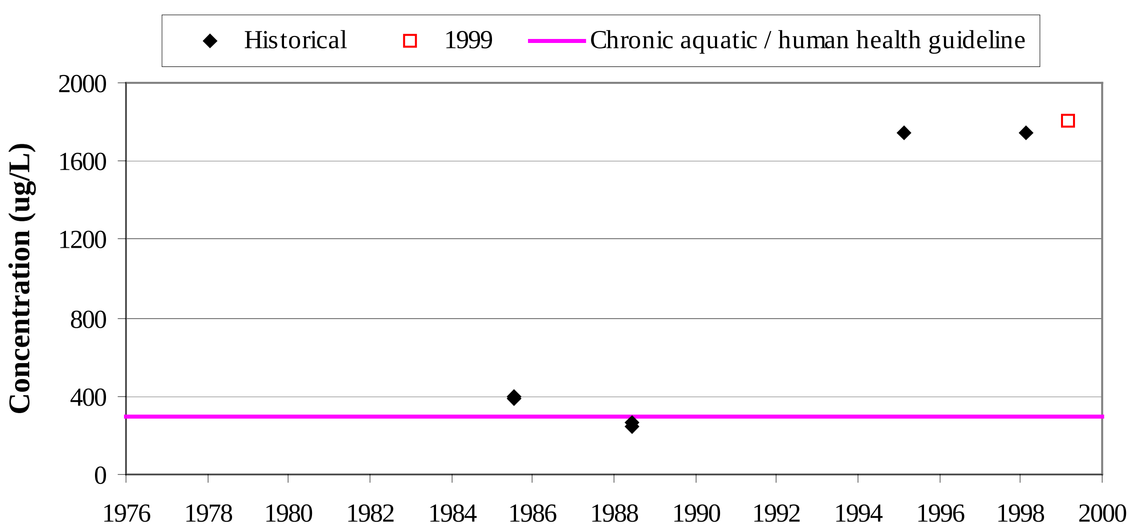


**Figure 6.6 Fall Total Manganese Concentrations in Muskeg Creek**

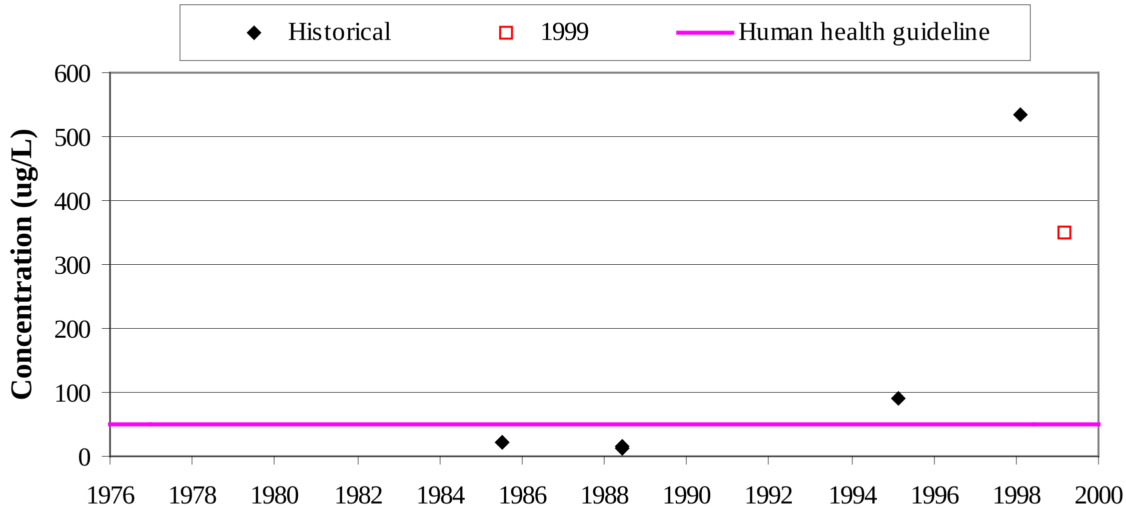
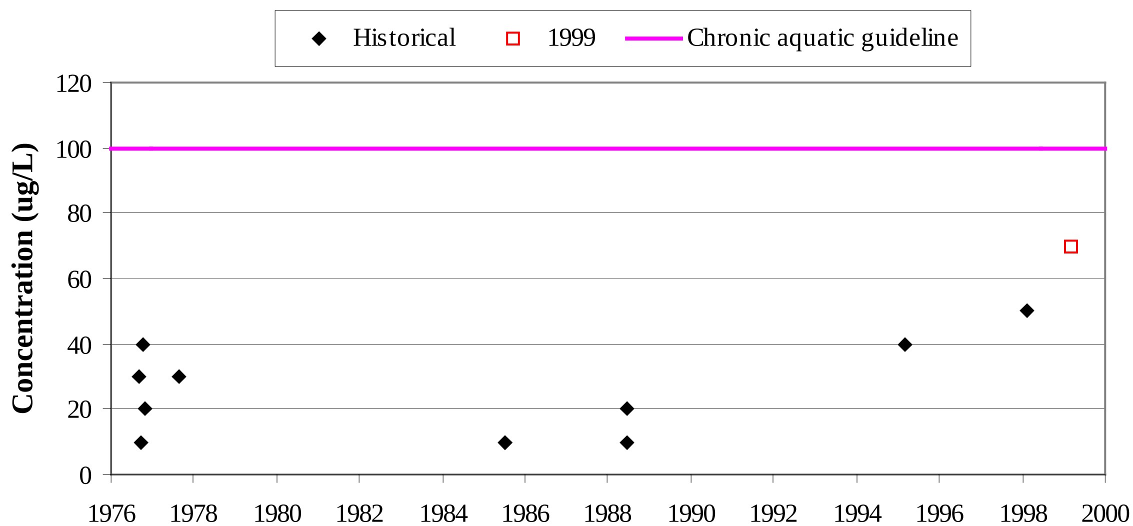
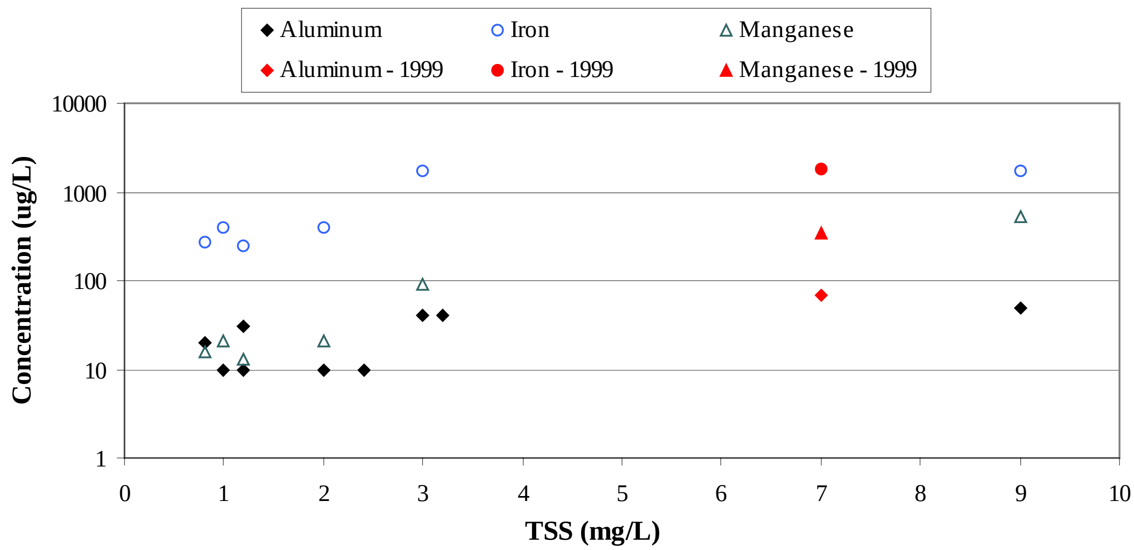



**Figure 6.7 Fall Total Aluminum Concentrations in Muskeg Creek**

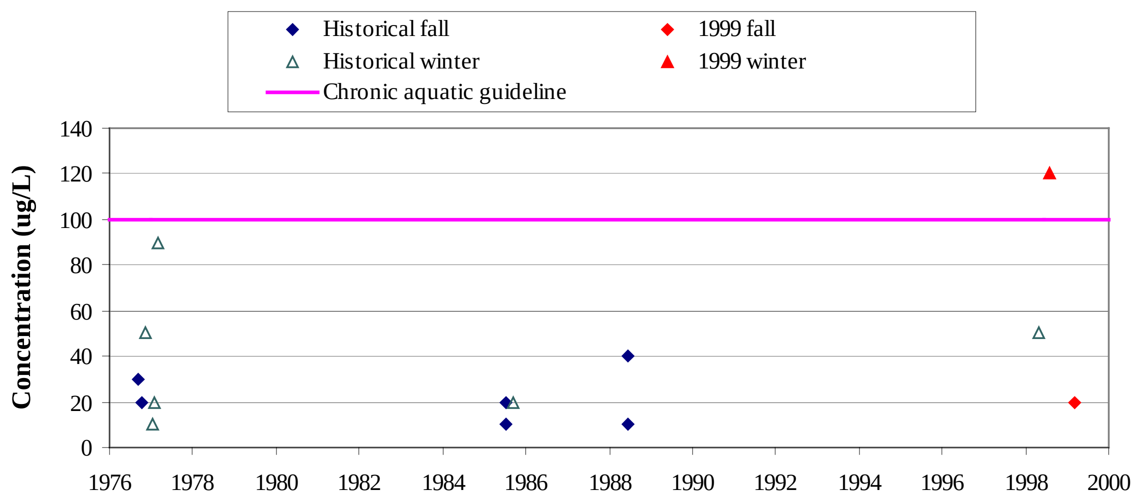



Non-detects replaced with detection limit.

## Figure 6.8 Total Metal Concentrations in Muskeg Creek Relative to TSS Levels




## Figure 6.9 Fall Total Aluminum Concentrations in Wapasu Creek



## 6.1.2 Sediment Quality

### 6.1.2.1 McLean Creek

Sediments collected from the mouth of McLean Creek in 1999 contained mainly silt, with some clay and little sand (Table 6.19). McLean Creek sediments were found to significantly affect the growth of two test organisms, *Chironomus tentans* and *Hyalella azteca*. Growth of *Lumbriculus variegatus* was not affected, and there was no significant mortality observed with any of the test species. Total aluminum, barium, cobalt, copper, magnesium, nickel, vanadium and zinc levels were higher at the mouth of McLean Creek than in sediments at the mouth of the Muskeg River.

Sediment from McLean Creek generally contained higher polycyclic aromatic hydrocarbon (PAH) concentrations than sediments from either the Muskeg River (Table 6.20) or the Athabasca River Delta (Table 5.5). Arsenic, methyl naphthalene, benzo(a)anthracene / chrysene, and phenanthrene levels at the mouth of McLean Creek exceeded Canadian Sediment Quality Guidelines (Table 6.21). Detection limits reported in 1999 for dibenzo(a,h)anthracene exceed the Canadian Interim Freshwater Guideline (Table 6.21), so it is unclear if sediment dibenzo(a,h)anthracene concentrations exceeded this guideline.

### 6.1.2.2 Muskeg River

Two sediment samples from the mouth of the Muskeg River were analyzed in 1999. One sample was collected in 1999; the other sample was collected by AENV in 1998 and submitted to RAMP for analysis in October 1999. Environment Canada submitted analytical results to RAMP in 1999 for a sediment sample that was collected from the upper Muskeg River in 1998. All of these results are discussed herein.

#### *Muskeg River Mouth*

Sand, silt and clay content of sediments collected in 1999 from the mouth of the Muskeg River was similar to samples from previous years (Table 6.19). Recoverable hydrocarbon concentrations were lower in the 1999 sample than in 1998 or 1997. In contrast, total aluminum, chromium and titanium levels were higher in 1999 than in previous years. The 1999 sediment sample did not significantly affect the growth or survival of three species of invertebrates.

## Table 6.19 Sediment Characteristics in the Muskeg River and McLean Creek

| Parameter | Units | Muskeg River (Mouth) | | | McLean Creek |
|---|---|---|---|---|---|
| | | 1999 | 1998 | 1997 | (1999) |
| **Conventional Parameters** | | | | | |
| partice size - % sand | % | 68 | 70 | 89 | 10 |
| partice size - % silt | % | 20 | 20 | 6.3 | 60 |
| partice size - % clay | % | 12 | 10 | 4.7 | 30 |
| total inorganic carbon | % by wt | 1.4 | 1.2 | - | 1.1 |
| total organic carbon | % by wt | 1.2 | 1.5 | 3.0 | 2.3 |
| **Toxicity** | | | | | |
| *Chironomus tentans* - 10 day mortality | % of control | nt | - | - | nt |
| *C. tentans* – 10 day growth | % of control | nt | - | - | 49 |
| *Hyalella azteca* - 10 day mortality | % of control | nt | - | - | nt |
| *H. azteca* - 10 day growth | % of control | nt | - | - | 68 |
| *Lumbriculus variegatus* - 10 day mortality | % of control | nt | - | - | nt |
| *L. variegatus* - 10 day growth | % of control | nt | - | - | nt |
| **Total Recoverable Hydrocarbons** | | | | | |
| total recoverable hydrocarbons | mg/kg | 800 | 2040 | 3440 | 900 |
| **Metals (total)** | | | | | |
| aluminum (Al) | µg/g | 9030 | 7480 | 2970 | 15500 |
| antimony (Sb) | µg/g | < 0.02 | < 0.1 | < 0.1 | - |
| arsenic (As) | µg/g | 3 | 3 | 1 | 6 |
| barium (Ba) | µg/g | 120 | 113 | 40 | 205 |
| beryllium (Be) | µg/g | < 1 | < 1 | < 1 | < 1 |
| cadmium (Cd) | µg/g | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| chromium (Cr) | µg/g | 25 | 14 | 7 | 29 |
| cobalt (Co) | µg/g | 5 | 6 | 3 | 12 |
| copper (Cu) | µg/g | 10 | 9 | 7 | 24 |
| iron (Fe) | µg/g | 16300 | 21000 | 11200 | 24600 |
| lead (Pb) | µg/g | 8 | 7 | < 5 | 12 |
| manganese (Mn) | µg/g | 576 | 583 | 373 | 682 |
| mercury (Hg) | µg/g | 0.05 | 0.03 | 0.04 | 0.04 |
| molybdenum (Mo) | µg/g | < 1 | < 1 | < 1 | < 1 |
| nickel (Ni) | µg/g | 18 | 14 | 6 | 33 |
| selenium (Se) | µg/g | 0.3 | 0.2 | < 0.1 | 0.4 |
| silver (Ag) | µg/g | < 1 | < 1 | < 1 | < 1 |
| strontium (Sr) | µg/g | 67 | 62 | 75 | 95 |
| titanium (Ti) | µg/g | 52 | 24 | 17 | 55 |
| vanadium (V) | µg/g | 22 | 20 | 9 | 38 |
| zinc (Zn) | µg/g | 39 | 45 | 26 | 81 |

- = no data.

nt = non-toxic (insignificant difference between test and control sediments).

**Table 6.20 Concentration of Polycyclic Aromatic Hydrocarbons in Sediments from McLean Creek and the Muskeg River**

| Parameter | Units | Muskeg River | | | | McLean Creek (1999) |
|---|---|---|---|---|---|---|
| | | Mouth | | | Upper (1998)[b] | |
| | | 1999 | 1998[a] | 1997 | | |
| naphthalene | ng/g | 14 | *18 | < 3 | 6 | 27 |
| methyl naphthalenes | ng/g | 20 | 15 | < 3 | 21 | 64 |
| C2 substituted naphthalenes | ng/g | 22 | 18 | < 20 | 97 | 81 |
| C3 substituted naphthalenes | ng/g | 23 | 16 | 40 | 27 | 92 |
| C4 substituted naphthalenes | ng/g | 4.5 | < 2.2 | 60 | 18 | 51 |
| acenaphthene | ng/g | < 2.6 | < 4 | < 3 | 0.4 | < 3.4 |
| methyl acenaphthene | ng/g | 2.8 | < 1.1 | < 20 | - | 8.4 |
| acenaphthylene | ng/g | < 3.5 | < 1 | < 3 | 0.4 | < 4 |
| anthracene | ng/g | < 2 | < 3.1 | < 3 | 0.4 | < 2.6 |
| dibenzo(a,h)anthracene | ng/g | < 3.7 | < 21 | < 3 | nd | < 10 |
| benzo(a)anthracene/chrysene | ng/g | 16.5 | *16 | 35 | 12 | 60.7 |
| methyl benzo(a)anthracene/chrysene | ng/g | 17 | < 2.5 | 70 | 5 | 56 |
| C2 substituted benzo(a)anthracene/chrysene | ng/g | 9.2 | < 1.7 | 130 | 5.2 | 10 |
| benzo(a)pyrene | ng/g | < 5.1 | < 10 | 13 | nd | < 14 |
| methyl b(b&k)f/methyl b(a)p | ng/g | < 12 | < 8.6 | 90 | 164 | < 31 |
| C2 substituted b(b& k)f/b(a)p | ng/g | < 9.2 | < 5.7 | 100 | - | < 14 |
| benzo(b&k)fluoranthene | ng/g | 11 | < 12 | 14 | 5.6 | 38 |
| benzo(g,h,i)perylene | ng/g | *11 | *14 | 12 | 14 | 24 |
| biphenyl | ng/g | 4.4 | < 1.1 | < 20 | - | 11 |
| methyl biphenyl | ng/g | < 2.3 | < 0.96 | < 20 | - | < 3.2 |
| C2 substituted biphenyl | ng/g | < 1.6 | < 0.55 | < 20 | - | < 3.3 |
| dibenzothiophene | ng/g | 1.9 | < 1.2 | < 3 | 2.6 | 3.6 |
| methyl dibenzothiophene | ng/g | 11 | < 10 | < 20 | 53 | 23 |
| C2 substituted dibenzothiophene | ng/g | 42 | < 4.2 | 110 | 98 | 76 |
| C3 substituted dibenzothiophene | ng/g | 82 | < 3.6 | 210 | 27 | 130 |
| fluoranthene | ng/g | 2.7 | 2.8 | 3 | 1.9 | 10 |
| methyl fluoranthene/pyrene | ng/g | 16 | 17 | 70 | - | 65 |
| fluorene | ng/g | 2 | 2.7 | < 3 | 2.8 | 5.6 |
| methyl fluorene | ng/g | < 1.9 | < 2.2 | < 20 | 29 | < 4.3 |
| C2 substituted fluorene | ng/g | < 2 | < 3 | 60 | 70 | < 2.7 |
| indeno(c,d-123)pyrene | ng/g | *6.4 | < 13 | 6 | nd | *14 |
| phenanthrene | ng/g | 14 | 9.8 | 7 | 11 | 45 |
| methyl phenanthrene/anthracene | ng/g | 41 | 24 | 40 | 42 | 120 |
| C2 substituted phenanthrene/anthracene | ng/g | 40 | 40 | 100 | 60 | 96 |
| C3 substituted phenanthrene/anthracene | ng/g | 36 | 51 | 180 | nd | 120 |
| C4 substituted phenanthrene/anthracene | ng/g | 150 | 36 | 110 | nd | 420 |
| pyrene | ng/g | 6 | 5.1 | 12 | 3.7 | 26 |

(a) Sample collected by AENV, submitted to RAMP for analysis in 1999.

(b) Sample analyzed by Environment Canada.

- = no data; nd = concentration < analytical detection limits.

* PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a large degree of error than those produced from clearly defined spectra).

**Table 6.21 Summary of Parameters Found to Exceed Canadian Sediment Quality Guidelines in McLean Creek and the Muskeg River**

| Parameter | Units | Sediment Guidelines[a] | | Muskeg River | | | | McLean Creek |
|---|---|---|---|---|---|---|---|---|
| | | | | Mouth | | | | |
| | | ISQG[b] | PEL[c] | 1999 | 1998 | 1997 | Upper | |
| **Metals (total)** | | | | | | | | |
| arsenic (As) | µg/g | 5.9 | 17 | | | | - | ISQG |
| **Target PAHs and Alkylated PAHs** | | | | | | | | |
| methyl naphthalene | ng/g | 20 | 201 | | | | ISQG | ISQG |
| dibenzo(a,h)anthracene | ng/g | 6.2 | 135 | | ISQG' | | - | ISQG' |
| benzo(a)anthracene/chrysene | ng/g | 32 | 385 | | | ISQG | | ISQG |
| phenanthrene | ng/g | 42 | 515 | | | | | ISQG |

(a) Guidelines taken from CCME (1999).

(b) ISQG = interim freshwater sediment quality guidelines.

(c) PEL = probable effect levels.

' Although substance concentrations were below detection limits, the analytical detection limit exceeded the relevant surface water guideline.

- = no data.

Sediment PAH levels in 1999 were generally consistent with the results of previous sampling events, with several exceptions. C4 substituted phenanthracene/anthracene and methyl naphthalene were present at higher concentrations in 1999 than in previous years (Table 6.20). Although benzo(a)anthracene/chrysene levels in 1997 exceeded the Canadian Sediment Quality Guideline, no parameter concentrations were found to exceed guidelines in 1999 (Table 6.21).

### *Upper Muskeg River*

Sediment chemistry in the upper Muskeg River is limited to a single PAH analysis. Generally, sediment PAH levels in the upper Muskeg River were similar to concentrations observed at the river mouth (Table 6.20). Exceptions included C2 substituted naphthalene, methyl benzo(a)pyrene, methyl dibenzothiophene and methyl fluorene, all of which were present at higher concentrations in the upper Muskeg River than at the river mouth. Concentrations of methyl naphthalene in the upper Muskeg River were slightly higher than the corresponding Canadian Sediment Quality Guideline (i.e., 21 ng/g versus 20 ng/g - Table 6.21). This was the only compound present at concentrations in excess of guideline levels.

### 6.1.3 Summary

Water quality in each of the Athabasca River tributaries sampled in 1999 was generally consistent with historical trends. As in previous years, naphthenic acids were detected in the Muskeg River and the Alsands Drain. Naphthenic acids were also detected, for the first time, in McLean Creek and Muskeg Creek. Chronic aquatic toxicity was again observed in the upper Muskeg River in 1999. Water samples from the other tributaries were non-toxic, as assessed by Microtox®. TDS and total aluminum concentrations were generally higher at more sample locations than in previous years. High sulphate levels were also observed in the lower Muskeg River in 1999.

Sediment quality in the Muskeg River in 1999 was generally consistent with historical data. PAH concentrations in the upper Muskeg River were similar to those observed at the river mouth, with the exception of C2 substituted naphthalene, methyl benzo(a)pyrene, methyl dibenzothiophene and methyl fluorene; these substances were present at higher concentrations in the upper Muskeg River. Sediments from the mouth of McLean Creek were found to be chronically toxic to several species of invertebrates. They generally contained higher total metal and PAH concentrations than sediments from the Muskeg River. Sediment PAH concentrations in McLean Creek were also higher than PAH levels observed in sediments from the Athabasca River Delta.

## 6.2 FISH POPULATIONS

### 6.2.1 Sentinel Fish Species Monitoring

Nine fish species were captured during collections of slimy sculpin from the Muskeg and Steepbank rivers (Table 6.22). Most were small-bodied fish species, although juvenile individuals of longnose sucker, burbot and Arctic grayling were also captured. Slimy sculpin was the most widely distributed small-bodied species. Relative abundance of slimy sculpin, as estimated by catch-per-unit-effort (CPUE), was similar among exposure sites, but was more than double at the reference site (Figure 6.10). The habitat at the Steepbank River reference site (SR-R) is dominated by moderately flowing riffles and runs with boulder/cobble substrate. These conditions are optimal for sculpin, although providing limited habitat diversity for other fish species (Table 6.22, Figure 6.10). The CPUE for all other species combined (i.e., incidental species) was more variable among sites, although CPUE estimates for species other than sculpin may be biased. The capture method and habitat type were specifically selected to collect slimy sculpin. The abundance of female, male and immature slimy sculpin collected at each site is presented in Table 6.23.

Water quality parameters measured in the field were similar at both fish collection sites on the Muskeg River (Table 6.24). Sites on the Steepbank River were generally cooler and had lower conductivity and higher pH relative to sites on the Muskeg River. The reference site on the Steepbank River was slightly cooler than the lower site at the Steepbank River mine (SR-MN), and had higher concentrations of dissolved oxygen. These conditions probably reflect the increased influence of headwater temperatures, as well as increased riffle habitat and turbulent flow. Dissolved oxygen at site SR-MN was lower relative to other sites, but was above the CCME guideline of 6.5 mg/L for cold water biota (CCME 1999). It was, however, just below the guideline of 9.5 mg/L stipulated to protect early life stages of coldwater biota (CCME 1999).

**Table 6.22 Total Number of Each Fish Species Caught and Observed at Each Sampling Site, Muskeg River and Steepbank River, Fall 1999**

| Fish Species | Muskeg River | | Steepbank River | | Total |
|---|---|---|---|---|---|
| | MR-FF | MR-MT | SR-MN | SR-R | |
| slimy sculpin | 54 | 65 | 118 | 118 | 435 |
| spoonhead sculpin | 1 | 10 | 8 | 0 | 19 |
| pearl dace | 27 | 46 | 70 | 17 | 160 |
| longnose dace | 9 | 8 | 105 | 33 | 155 |
| trout-perch | 21 | 14 | 55 | 9 | 99 |
| lake chub | ~100[(a)] | 0 | 42 | 0 | ~142 |
| longnose sucker[(b)] | 7 | 26 | 25 | 6 | 64 |
| burbot[(b)] | 0 | 4 | 3 | 0 | 7 |
| Arctic grayling[(b)] | 1 | 0 | 0 | 0 | 1 |
| **Total** | **~220** | **173** | **426** | **183** | **1,002** |
| electrofishing effort (sec) [(c)] | 3,267 | 5,071 | 9,343 | 3,584 | 21,265 |

[(a)] Estimate based on visual observation rather than actual capture.

[(b)] Juveniles and young-of-the-year.

[(c)] Total electrofishing effort is also presented.

MR-FF = Muskeg River fish fence; MR-MT = Muskeg River mouth; SR-MN = Steepbank River mine; SR-4 = Steepbank River reference.

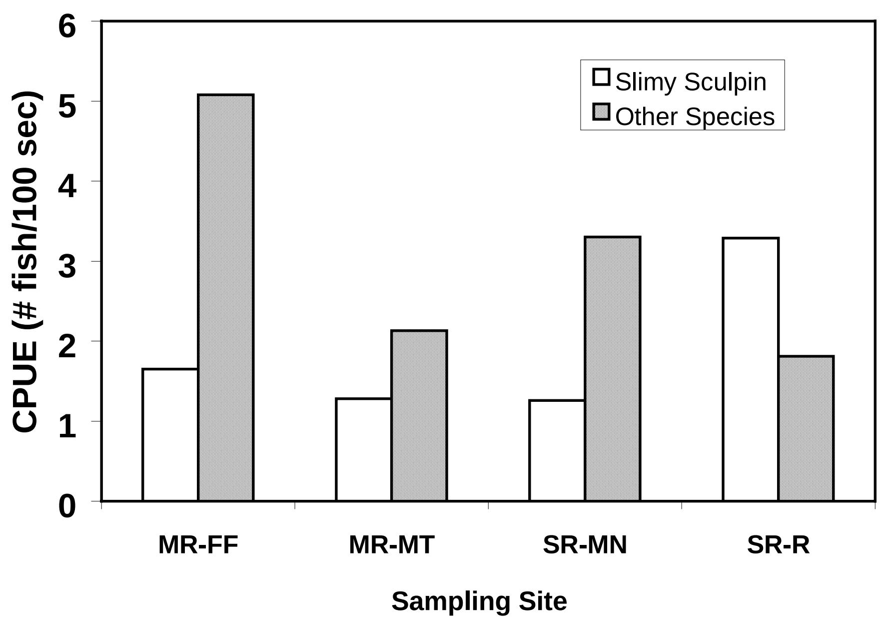
**Table 6.23 Total Number of Female, Male and Immature Slimy Sculpin (*Cottus cognatus*) for Processing, Muskeg and Steepbank Rivers, Fall 1999**

| Sex | Muskeg River | | Steepbank River | |
|---|---|---|---|---|
| | MR-FF | MR-MT | SR-MN | SR-R |
| female | 22 | 41 | 34 | 43 |
| male | 14 | 19 | 15 | 37 |
| immature [a] | 1 | 5 | 4 | 0 |
| **Total** | **37** | **65** | **53** | **80** |

[a] Sacrificed due to unknown maturity.

MR-FF = Muskeg River fish fence; MR-MT = Muskeg River mouth; SR-MN = Steepbank River mine; SR-4 = Steepbank River reference.

**Figure 6.10 Catch-Per-Unit-Effort of Slimy Sculpin and Other Species, Muskeg River and Steepbank River, Fall 1999**




MR-FF = Muskeg River fish fence; MR-MT = Muskeg River mouth; SR-MN – Steepbank River mine; SR-R = Steepbank River reference.

**Table 6.24 Mean Values (± SD) of Field Water Parameters Measured at Each Fish Collection Site, Muskeg and Steepbank Rivers, Fall 1999**

| Field Parameter | Muskeg River | | Steepbank River | |
|---|---|---|---|---|
| | MR-FF | MR-MT | SR-MN | SR-R |
| water temperature (°C) | 11.6 ± 0.5 | 11.5 ± 0.7 | 9.2 ± 0.8 | 7.8 |
| dissolved oxygen (mg/L) | 9.78 ± 0.97 | 10.57 ± 0.08 | 8.44 ± 0.18 | 12.88 |
| conductivity (µS/cm) | 588 ± 5 | 579 ± 2 | 439 ± 1 | 442 |
| pH | 8.08 ± 0.13 | 8.24 ± 0.23 | 8.62 ± 0.14 | 8.47 |

Means were calculated from measurements taken each time a site was sampled for sentinel fish (i.e., MR-FF, MR-MT and SR-MN, *n*=2; SR-R, *n*=1).

MR-FF = Muskeg River fish fence; MR-MT = Muskeg River mouth; SR-MN = Steepbank River mine; SR-4 = Steepbank River reference.

### 6.2.1.1 Fish Measurements

Based on external/internal pathology exams of slimy sculpin, the presence of abnormalities ranged from 13.5-78.5% per site (Table 6.25). The presence of small, white parasitic cysts within the body cavity was the most prevalent abnormality observed, particularly for sculpin from the mouth of the Muskeg River (site MR-MT). Severity of infestation typically ranged from a few cysts (49% of infected fishes) to moderate numbers of cysts (44%), with only a few fish that were heavily infested (7%). Although difficult to definitively confirm, the internal cyst is likely a life stage of a trematode fluke (Order: Stregeata) (Al Shostak, University of Alberta, pers. comm.) that uses snails and fish as intermediate hosts prior to parasitizing fish eating birds (final host). External cysts were similar in appearance to the internal cysts and were found on the lips, gills and around the eye. It is uncertain what effect the parasitism has on the health of infected sculpin, but it potentially could contribute to their overall stress level. The reason for the infestation is unknown and the occurrence of other abnormalities was low.

**Table 6.25 Number of Slimy Sculpin with Specific External/Internal Abnormalities, Muskeg and Steepbank Rivers, Fall 1999**

| Abnormality | Muskeg River | | Steepbank River | |
|---|---|---|---|---|
| | MR-FF | Site MR-MT | Site SR-MN | Site SR-R |
| parasitic cysts[a] - internal | 5 | 49 | 8 | 9 |
| - external | 0 | 7 | 0 | 2 |
| unknown cyst (testes) | 0 | 1 | 0 | 0 |
| tapeworm (Cestoda) | 0 | 0 | 1 | 1 |
| papiloma (mouth) | 0 | 1 | 1 | 0 |
| external discolouration | 0 | 0 | 0 | 1 |
| Total No. fish evaluated | 37 | 65 | 53 | 80 |
| % affected[b] | 13.5 | 78.5 | 18.9 | 13.8 |

[a] Trematode fluke (Order: Stregeata).

[b] An individual fish may exhibit more than one type of abnormality.

MR-FF = Muskeg River fish fence; MR-MT = Muskeg River mouth; SR-MN = Steepbank River mine; SR-4 = Steepbank River reference.

## *Muskeg River*

Due to the absence of appropriate reference sites on the Muskeg River, the performance of sculpin downstream of current (and future) mining developments on the Muskeg River were compared to reference sculpin from the Steepbank River. The test site on the Muskeg River used for these comparisons was site MR-MT. A limited number of sculpin were also collected from the fish fence site on the Muskeg River (site MR-FF), but were not used in statistical comparisons because:

- At site MR-FF, sculpin were collected from small, discrete riffle habitats that were widely separated by long portions of slow runs and pools resulting from beaver dams. Conversely, habitat at site MR-MT was more continuous/homogenous and more similar to reference conditions.
- Individuals collected from site MR-FF were generally small/young and few larger mature sculpin were captured.
- Greater numbers of adult sculpin were collected from site MR-MT, providing better estimates of fish parameters, and increasing statistical power of comparisons with reference fish.

Due to the distance between sites MR-FF and MR-MT (approx. 10 km), and differences in habitat conditions, it was not considered appropriate to pool data from these two sites.

With the obvious exception of one year old individuals, the age distribution of adult sculpin (males and females combined) from site MR-MT is similar to the reference site (Figure 6.11). The relative scarcity of one year old sculpin at site MR-MT is noteworthy and contributed to the observed difference in mean age of male sculpin (Table 6.26). There was no difference in female mean age, in part due to the higher numbers of one and two year old females, relative to males.

Both male and female sculpin from site MR-MT weighed less and were thinner (i.e., condition factors were lower) when compared to reference sculpin (Table 6.26).

Mean ovary weight was statistically smaller at site MR-MT (Figure 6.12a), although there was no difference in fecundity between sites (Table 6.26). Mean testis weight was also similar between sites (Figure 6.12b). Female liver weights were heavier at site MR-MT, but male liver weights were smaller (Figure 6.13).

**Table 6.26 Mean ± SE (n) of Body Size, Age and Fecundity of Slimy Sculpin, Muskeg and Steepbank Rivers, Fall 1999**

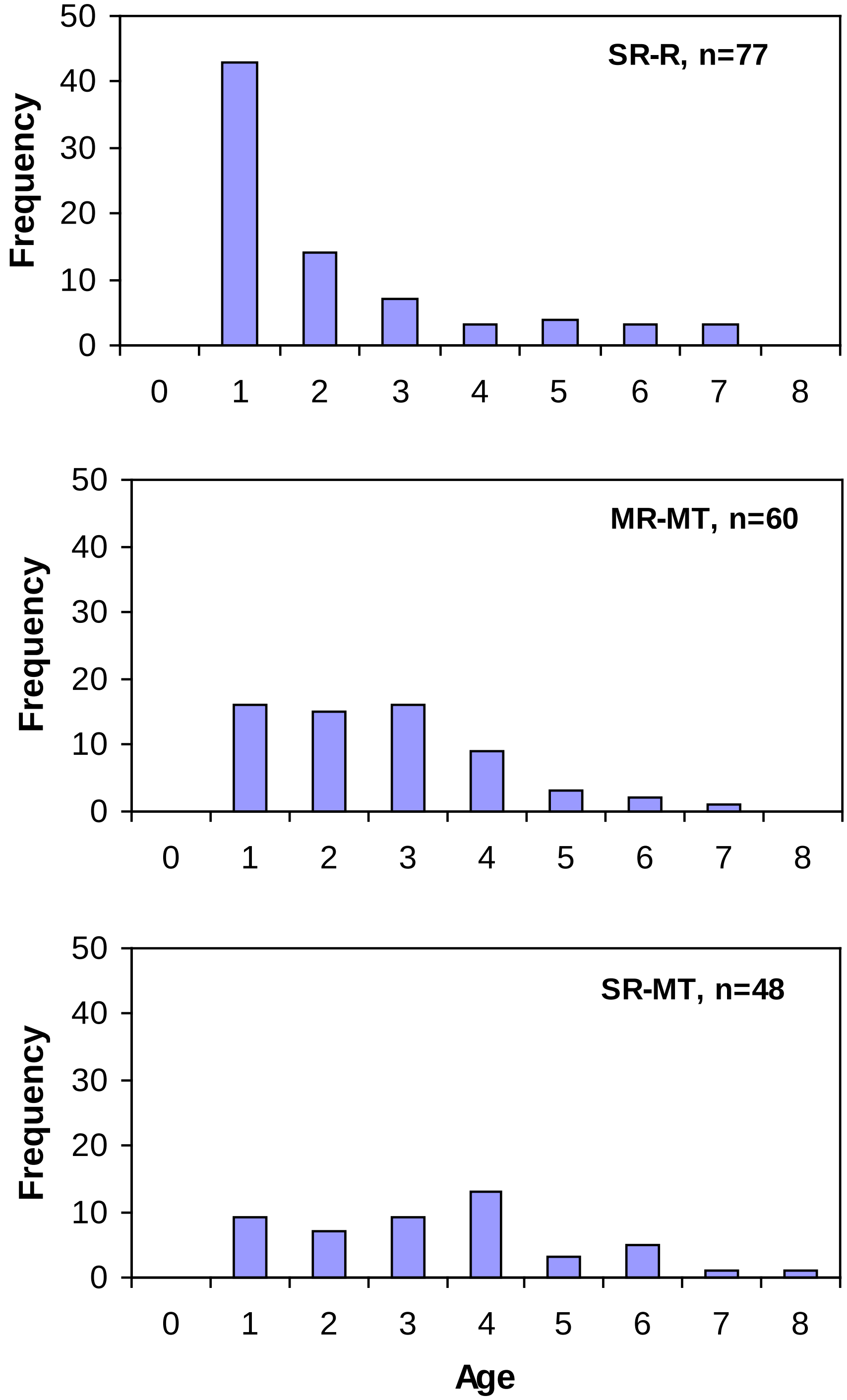
| Sex | Parameter | Reference Site | Exposure Sites | |
|---|---|---|---|---|
| | | SR-R | MR-MT | SR-MN |
| female | total length (cm) | 7.5 ± 0.2 (43) | 7.3 ± 0.1 (41) | 8.2 ± 0.1 (34) * |
| | body weight (g) | 4.48 ± 0.32 (43) | 3.55 ± 0.18 (41) * | 5.36 ± 0.30 (34) * |
| | K[a] | 0.87 ± 0.01 (42) | 0.78 ± 0.01 (39) * | 0.83 ± 0.02 (33) * |
| | age (y) | 2.3 ± 0.3 (42) | 2.5 ± 0.2 (41) | 3.3 ± 0.3 (34) * |
| | fecundity (# eggs/g)[b] | 63 ± 3 (29) | 55 ± 3 (30) | 59 ± 4 (30) |
| male | total length (cm) | 7.8 ± 0.1 (36) | 7.7 ± 0.1 (19) | 8.5 ± 0.1 (14) * |
| | body weight (g) | 4.85 ± 0.21 (37) | 4.21 ± 0.25 (19) * | 6.32 ± 0.58 (15) * |
| | K | 0.88 ± 0.01 (36) | 0.78 ± 0.02 (19) * | 0.86 ± 0.01 (15) |
| | age (y) | 1.9 ± 0.2 (35) | 2.6 ± 0.3 (19) * | 3.6 ± 0.4 (14) * |

Note: Site differences in condition factor (K) and fecundity were tested using analysis of covariance. The remaining variables were examined using analysis of variance. Outliers identified during these analyses were omitted when calculating the above mean values. Within a row, a difference ($p<0.05$) between reference and each exposed site is identified by an asterisk.

[a] K = 100*(carcass weight/total length$^3$).

[b] Fecundity standardized by fish size (i.e., # eggs/carcass weight).

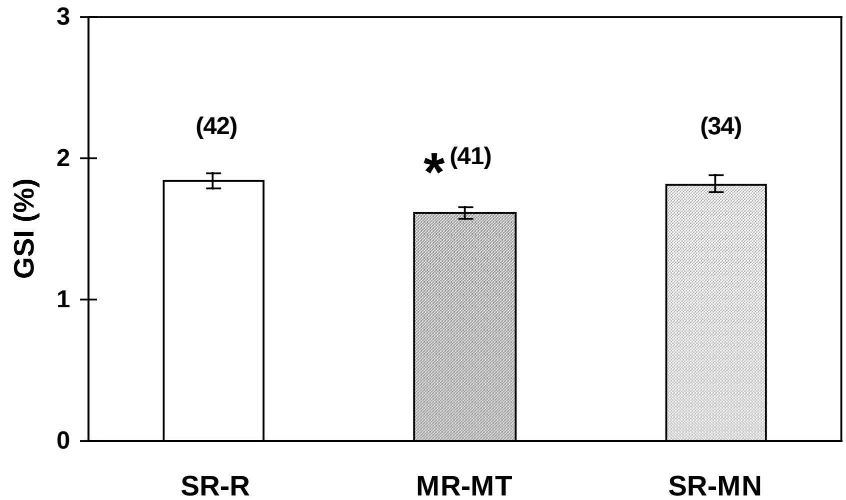
**Figure 6.11 Age-frequency Distribution for Slimy Sculpin, Muskeg and Steepbank Rivers, Fall 1999**



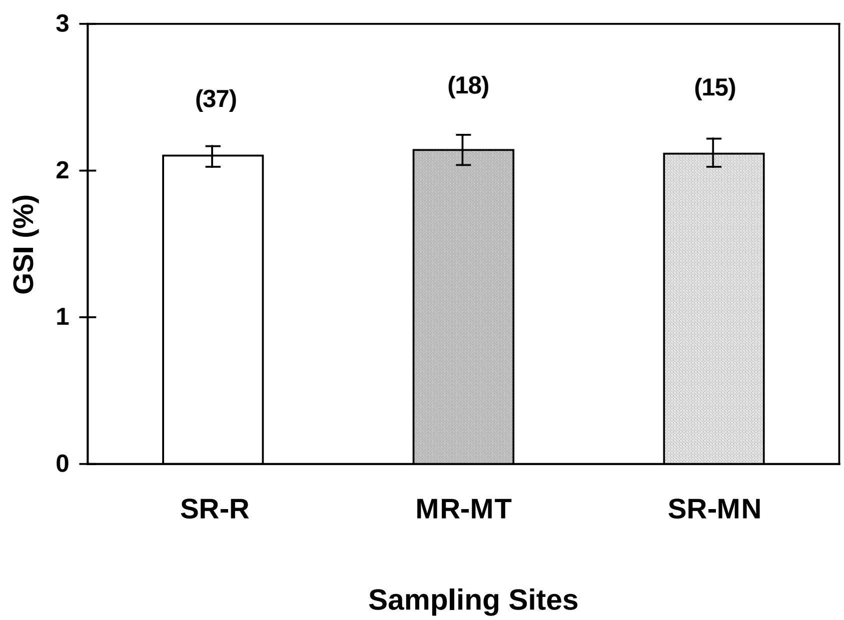

MR-FF = Muskeg River fish fence; MR-MT = Muskeg River mouth; SR-MN = Steepbank River mine; SR-4 = Steepbank River reference.

**Figure 6.12 Gonadosomatic Indices (GSI) of a) Female and b) Male Slimy Sculpin, Muskeg and Steepbank Rivers, Fall 1999[(a)]**

## a) Female



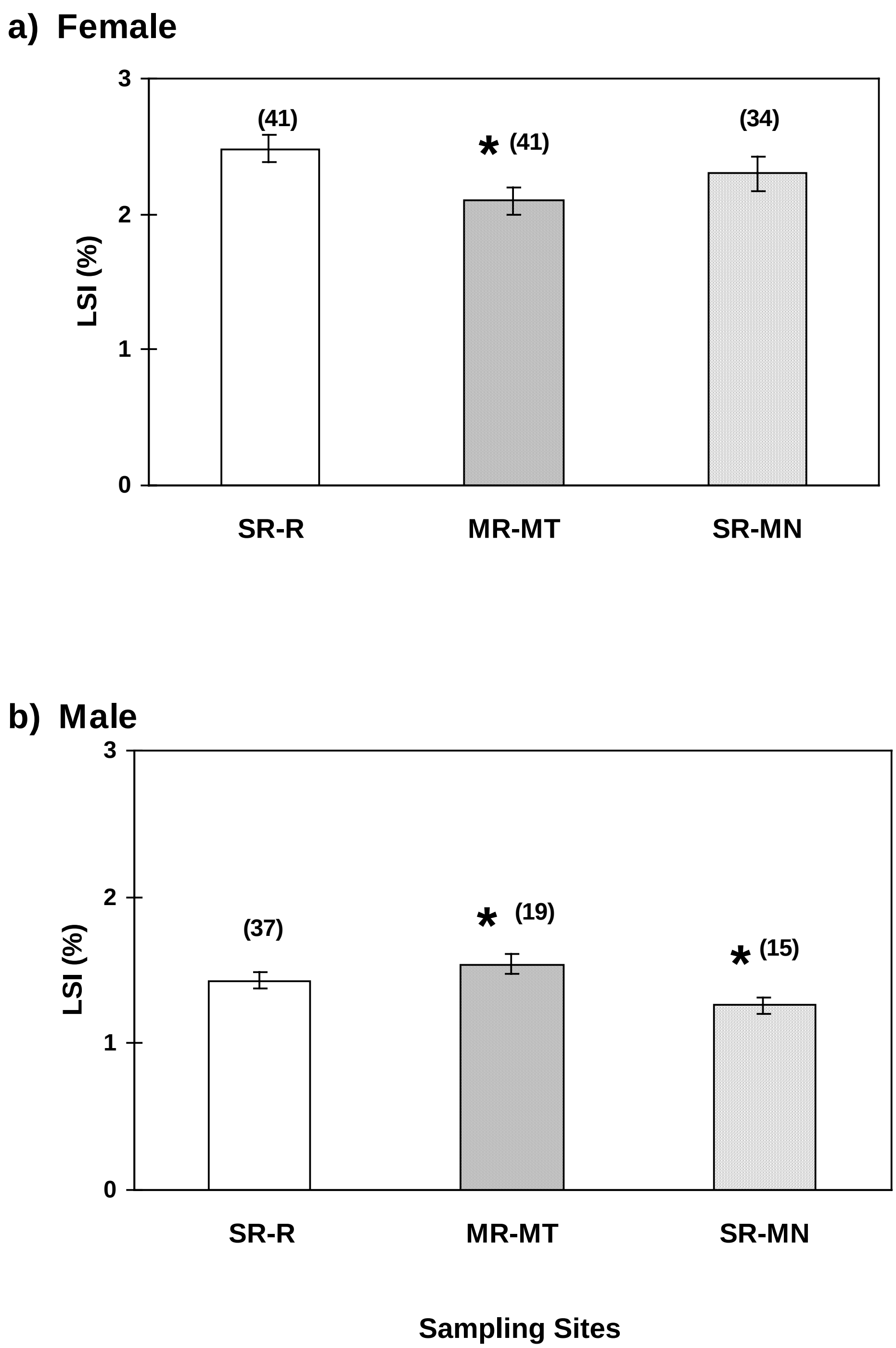

## b) Male




(a) Values represent mean ± S.E. (sample size in parentheses). A difference ($p < 0.05$) between reference and exposure sites is identified with an asterisk.

GSI = (gonad wt / carcass wt) * 100.

**Figure 6.13 Liver Somatic Index (LSI) of a) Female and b) Male Slimy Sculpin, Muskeg and Steepbank Rivers, Fall 1999[a]**




[a] Values represent mean ± S.E. (sample size in parentheses). A difference ($p < 0.05$) between reference and exposure sites is identified with an asterisk.

LSI = (liver wt / carcass wt) * 100.

Statistical comparisons of growth, as estimated by size-at-age, between site MR-MT and site SR-R were not possible. For female sculpin from the reference site, there was a definite positive relationship between total length and age; however, the relationship at site MR-MT was variable and poor (Figure 6.14). For male sculpin, size-at-age relationships at both sites were poor (Figure 6.15). The "strength" of the Pearson correlation coefficient at site SR-R was driven predominantly by one large male fish (length=13.6 cm, age=6 y). If this fish was removed, the coefficient changed from r=0.53 to r=0.25. The reason for the variability in size-at-age is unknown. It was evident while ageing sculpin that otoliths from some fish showed definite and clear annuli; whereas otoliths from other fish were difficult to read due to the presence of incomplete or false annuli (J. Tost, Northshore Environmental, pers. comm). However, strong size-at-age relationships for female sculpin from site SR-R (and site SR-MN, see section on Steepbank River) suggest that the ageing procedure was adequate, but the variability in otolith growth made it difficult to estimate age. For sculpin from site MR-MT, it is possible that some of the variability in growth is related to the high level of parasitism observed at this site. However, this does not explain the poor size-at-age relationship for males at site SR-R. The limited sample size of males at site MR-MT may also have contributed to the weak relationship at this site.

Table 6.27 provides a summary of the response of slimy sculpin collected from site MR-MT relative to reference fish. The percent difference was included to provide a better understanding of the magnitude of difference in individual fish characteristics. With the exception of male age, the magnitude of differences between sculpin from the Muskeg River and the reference site are not dramatic [i.e., <20%, Suter et al. (1995); Environment Canada (1997)]. In general, there is a tendency towards less energy expenditure (e.g., reduced body weight and gonad size) and storage (reduced condition, liver size), and increased mean age for sculpin from site MR-MT. This is often a response to reduced food availability.

Food may be less available for several reasons, such as an increase in competition, a decrease in the availability of habitat and/or a change in food base, or reduced ability to forage (Gibbons and Munkittrick 1994). No specific information was collected to compare food/habitat resource between these sites. In 1998, the density of benthic algae and invertebrate communities in the lower Muskeg River was moderately higher relative to the lower Steepbank River (Golder 1999a). However, site SR-R is located approximately 16 km from the confluence with the Athabasca River and may not be similar in productivity to the lower Steepbank River, particularly with regards to conditions specific to slimy sculpin. In addition, water levels at site MR-MT were low because of below-average annual precipitation in the area (see Section 2.3) and the presence of an upstream beaver dam. The reduction in flow may have altered the amount and quality of available habitat for fishes resident to that portion of the river. Finally, it is also possible that the high level of parasitism at site MR-MT may play a role in the metabolism of slimy sculpin.

**Figure 6.14 Plot of Total Length vs. Age for Female Slimy Sculpin, Muskeg and Steepbank Rivers, Fall 1999**

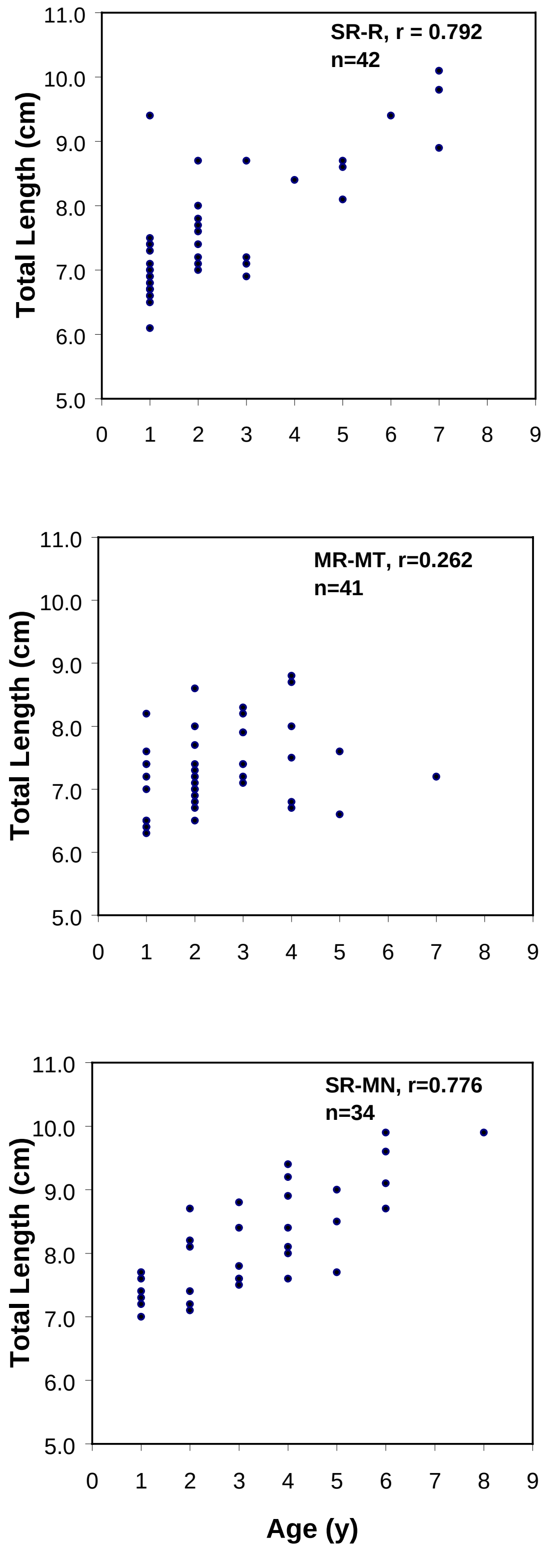


**Figure 6.15 Plot of Total Length vs. Age for Male Slimy Sculpin, Muskeg and Steepbank Rivers, Fall 1999**

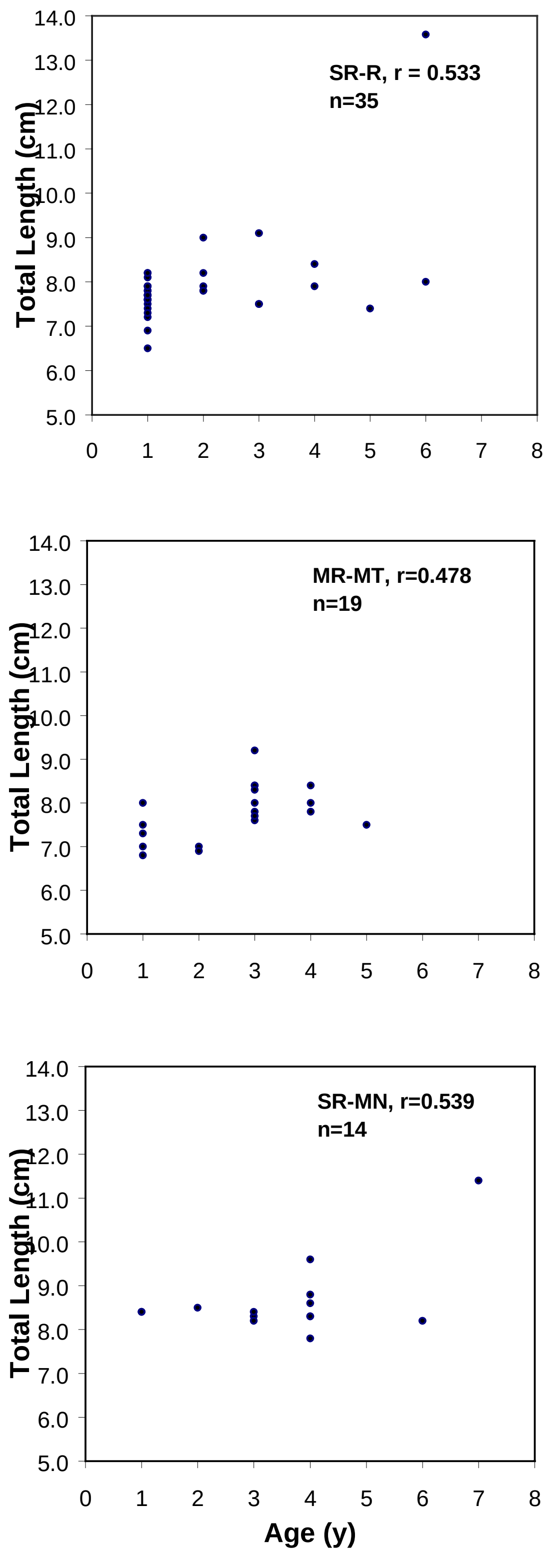


**Table 6.27 Summary of the Response of Slimy Sculpin from Site MR-MT Relative to Site SR-R, Muskeg and Steepbank Rivers, Fall 1999**

| Parameter | Female | | Male | |
|---|---|---|---|---|
| | Response[(a)] | % Difference[(b)] | Response | % Difference |
| total length | O | ns | O | ns |
| body weight | - | -17.68 | - | -13.38 |
| condition | - | -10.02 | - | -11.50 |
| age | O | ns | + | +51.95 |
| gonad weight | - | -9.46 | O | ns |
| fecundity | O | ns | na | na |
| liver weight | - | -14.98 | + | +15.02 |

[(a)] + signifies an increase relative to reference data, - signifies a decrease, O signifies no change.

[(b)] Percent difference is given where differences were significantly different. % Difference is for “exposed” relative to the reference site calculated using ANOVA/ANCOVA adjusted least squared means.

na – not available, ns – not significantly different.

MR-MT = Muskeg River at the mouth; SR-R = Steepbank River reference site.

The inconsistency between male and female liver size is difficult to explain. Both liver size and condition are descriptors of the energy storage in fish. As such, they tend to covary in response to increasing or decreasing food/habitat availability (as observed with female sculpin). The discrepancy in males may suggest some level of metabolic redistribution resulting in inconsistencies in energy allocation. Changes in liver size have also been associated with exposure to foreign chemical compounds (Sloof et al. 1983; Hodson et al. 1992; McMaster et al. 1991); however, one would expect a similar response in female sculpin.

The observed response of slimy sculpin from site MR-MT needs to be confirmed over time to identify whether it persists or it reflects something particular to 1999 (e.g., water levels at site MR-MT, parasitism). The MFO data will also provide information that will add to our understanding of exposure-response relationships between sites.

## *Steepbank River*

There were substantially fewer one year old sculpin collected from site SR-MN relative to the reference site (Figure 6.11). This was also observed at site MR-MT. As well, there were more three and four year old sculpin at site SR-MN than were found at site SR-R. Not surprisingly, mean ages of male and female slimy sculpin from site SR-MN were older than reference sculpin (Table 6.26).

Sculpin from site SR-MN were longer and heavier than reference fish (Table 6.26). There was no significant difference in male condition; however, female sculpin were statistically thinner at site SR-MN. The actual difference in female condition was only 5.5%, but substantial sample sizes and low variability allowed the detection of a small difference in condition (i.e., high statistical power).

Ovary and testis weights were not significantly different between site SR-MN and SR-R (Figure 6.12). Fecundity was also found to be similar between sites (Table 6.26). Liver weights were similar among female sculpin (Figure 6.13a); however, males at site SR-MN had smaller livers compared to reference sculpin (Figure 6.13b).

For female sculpin, total length was positively correlated with age at both sites (Figure 6.14). The slopes of regression lines for each site were not significantly different (p=0.017), but there was a small statistical difference (3.3%) between the intercepts of each line (p=0.049). Unfortunately, size-at-age relationships for male sculpin at both sites were variable and poorly correlated (Figure 6.15). The limited sample size of males at site SR-MN may have contributed to the weak relationship at this site; however, the sample size was much higher at the reference site with similar results. The reason for the poor size-at-age relationships in male slimy sculpin is unknown.

Table 6.28 summarizes the response of slimy sculpin from site SR-MN relative to sculpin from the reference site (SR-R). In general, fish collected at site SR-MN were older and larger (length and weight). However, there was no concomitant increase in reproductive effort (gonad size, fecundity) or energy stores (condition, liver size) that would suggest a response to increased food/habitat availability. In fact, female condition (small change) and male liver size were reduced relative to reference sculpin. An increase in mean age can result from an increase in juvenile and/or early life stage mortality or decreased recruitment (Gibbons and Munkittrick 1994). Decreased recruitment seems an unlikely mechanism because there is little evidence of reduced reproductive effort (e.g., gonad size, fecundity). However, there are other factors that could influence recruitment such as the quality of eggs produced, number of successful spawning individuals, availability and quality of spawning habitat and survival/growth of juveniles (Gibbons et al. 1998). The hypothesis of increased juvenile/early life stage mortality is consistent with the lower number of one year old individuals found at site SR-MN relative to site SR-R. An additional possibility is that older and larger individuals were collected at site SR-MN, perhaps as a function of habitat differences that favour these individuals (i.e., size partitioning by habitat type/dominance). As with the Muskeg River, sculpin from site SR-MT need be re-evaluated in the future to confirm the persistence and/or accuracy of the response before definitive conclusions can be made. MFO data will also facilitate our understanding of the observed exposure-response relationship.

**Table 6.28 Summary of the Response of Slimy Sculpin from Site SR-MN Relative to Site SR-R, Steepbank River, Fall 1999**

| Parameter | Female | | Male | |
|---|---|---|---|---|
| | Response[(a)] | % Difference[(b)] | Response | % Difference |
| total length | + | +9.01 | + | +8.43 |
| body weight | + | +23.98 | + | +28.43 |
| condition | - | -5.53 | O | 0 |
| age | + | +54.16 | + | +106.52 |
| size-at-age | + | +3.34 | na | na |
| gonad weight | O | ns | O | ns |
| fecundity | O | ns | na | na |
| liver weight | O | ns | - | -16.32 |

(a) + signifies an increase relative to reference data, - signifies a decrease, O signifies no change.

(b) Percent difference is given where differences were significantly different. % Difference is for “exposed” relative to the reference site calculated using ANOVA/ANCOVA adjusted least squared means.

na = not available, ns = not significantly different.

## *Reference Site Suitability*

The response of slimy sculpin at sites MR-MT and SR-MN were defined relative to slimy sculpin collected at the reference site SR-R. The assumption of the study design is that sculpin from site SR-R represent the natural or baseline condition for slimy sculpin. Despite efforts to select reference and exposure sites that were as similar as possible (habitat type, chemistry, flow, substrate, etc), it is difficult to meet this objective, particularly when sites are located on different river systems (e.g., MR-MT vs. SR-R). Based on CPUE data and habitat conditions, there is little doubt that site SR-R represents prime habitat for slimy sculpin. However, it is less obvious whether sites MR-MT and SR-MN provide the same level of habitat quality/quantity. As such, observed differences in whole-organism characteristics may be a function of habitat and/or anthropogenic influences. This is particularly true considering mining development in the vicinity of the Muskeg River is still limited, and there is no known direct influence of mining on the Steepbank River. As monitoring continues over time and mining development increases, the potential change in the relative response of slimy sculpin will be important to identify impacts on aquatic systems. Future monitoring should include more detailed analyses of habitat characteristics at each site in an effort to improve our understanding of habitat-response relationships.

Ideally, several reference sites should be sampled to ensure that the full range of natural variability in fish characteristics is more accurately defined. It is for this reason that effort was made to identify an additional reference site on the Ells River, although the effort was not successful. However, within the Oil Sands Region candidate reference sites of comparable habitat and fish communities to “exposed” sites are limited and, if available, often difficult to access. To ensure the success of the sentinel monitoring program for the Muskeg and Steepbank rivers, more effort is needed to identify other reference sites located within the Oil Sands Region.

#### 6.2.1.2 Sample Size Considerations

The number of fish needed to detect a 20, 30 and 50% difference in each fish parameter for each reference-exposure site comparison is summarized in Table 6.29. With the exception of mean age, sufficient sample sizes of female and male slimy sculpin were collected from each site to detect at least a 30% difference, and in some cases a 20% difference, between sites. As well, sample sizes for slimy sculpin were adequate to meet the pulp and paper environmental effects monitoring (EEM) criterion of detecting a difference in gonad weight of ±25% (Environment Canada 1997). In the future, greater numbers of male slimy sculpin need to be collected to ensure that sample sizes are more than adequate to meet minimum requirements, particularly for parameters such as body weight, liver weight and gonad size.

Variability in age of adult fish is common and for slimy sculpin it was not possible to detect a difference in mean age less than approximately 50%. However, with the exception of the comparison of female sculpin from site MR-MT vs. SR-R, a difference of greater than 50% in age was observed for all other site comparisons (Table 6.27, Table 6.28). As with trout-perch from the Athabasca River (Section 5.2.2), improved techniques for ageing slimy sculpin may help to reduce some of the uncertainty and observed variability in age. Estimates of total body weight, fecundity and liver weight were the next most variable parameters measured and required greater sample sizes relative to other parameters.

Excluding age, the final results indicated that the minimum number of fish needed to be collected from each site were approximately 62 females and 29 males to detect a 20% difference between sites; 31 females and 14 males to detect a 30% difference; and 13 females and 6 males to detect a 50% difference. In general, sample size requirements for comparisons between sites SR-R and SR-MN were higher than comparisons between sites SR-R and MR-MT. Because both comparisons involve a common reference site, the difference in sample size requirements reflects the difference in variability between sites MR-MT and SR-MN.

**Table 6.29 Number of Slimy Sculpin Per Site Needed to Detect Parameter Differences of 20, 30 and 50% (i.e., effect size) Between Sites**

| Parameter | Sex | Site SR-R vs MR-MT | | | Site SR-R vs SR-MN | | |
|---|---|---|---|---|---|---|---|
| | | ES=20% | ES=30% | ES=50% | ES=20% | ES=30% | ES=50% |
| total length | female | 7 | 4 | 2 | 7 | 4 | 2 |
| | male | 3 | 2 | 1 | 3 | 2 | 1 |
| body weight | female | 59 | 29 | 13 | 62 | 31 | 13 |
| | male | 28 | 14 | 6 | 29 | 14 | 7 |
| condition | female | 4 | 2 | 2 | 3 | 2 | 1 |
| | male | 3 | 2 | 1 | 2 | 2 | 1 |
| age | female | 186 | 90 | 38 | 209 | 101 | 43 |
| | male | 167 | 81 | 35 | 171 | 83 | 35 |
| size-at-age | female | 4 | 2 | 2 | 3 | 2 | 1 |
| | male | 3 | 2 | 1 | 3 | 2 | 1 |
| gonad weight | female | 12 | 6 | 3 | 14 | 7 | 4 |
| | male | 20 | 10 | 5 | 23 | 12 | 5 |
| fecundity | female | 46 | 23 | 10 | 49 | 24 | 10 |
| liver weight | female | 41 | 20 | 9 | 45 | 22 | 10 |
| | male | 24 | 12 | 6 | 25 | 12 | 6 |

[a] Calculations were done using $\log_{10}$ transformed data and setting power=0.80 and $\alpha$=0.05.

(ES) = effect size or $\delta$.

## 6.2.2 Summary

Based on abundance and distribution among study sites on the Muskeg River and Steepbank River, slimy sculpin was selected as the sentinel species. Sculpin collected from a reference site on the upper Steepbank River was used to evaluate the performance of sculpin collected from: 1) a site on the Muskeg River downstream of mining development; and 2) a site on the lower portion of the Steepbank River adjacent to mining activity.

In general, sculpin from the Muskeg River were older and had reduced body weight, condition, gonad weight and liver weight suggesting a response to lower food availability relative to the reference site. Low water levels in this section of the river may have affected availability and quality of instream habitat. As well, it is unknown what effect, if any, the observed parasitism has had on the metabolism of sculpin from the Muskeg River. Sculpin from the lower Steepbank River were older and larger (length, weight) than reference fish, but few other differences in whole-organism characteristics were observed. The reason for the increase in mean age is unknown, but can result from an increase in juvenile/early life stage mortality or decreased recruitment.

The observed responses of slimy sculpin from the Muskeg River and lower Steepbank River need to be confirmed over time before definitive conclusions can be made. Future monitoring should also include more detailed analyses of habitat characteristics at each site. As well, additional reference sites are needed to ensure the full range of natural variability in fish characteristics within the Oil Sands Region is accurately defined. Power analyses confirmed that sample sizes were adequate to detect site differences in most parameters; however, more effort is needed to collect higher numbers of males. In addition, improved techniques for ageing slimy sculpin would increase our confidence in age estimates.

# 7 WETLANDS - RESULTS AND DISCUSSIONS

## 7.1 WATER QUALITY

### 7.1.1 Shipyard Lake

Water samples were collected from Shipyard Lake in the spring, summer and fall of 1999. Water quality in the lake was generally consistent across the three seasons (Tables 7.1 and 7.2). Exceptions included:

- higher total aluminum concentrations in summer;
- higher total chromium concentrations in fall; and
- lower total zinc, dissolved manganese and dissolved mercury concentrations in fall.

In comparison to earlier sampling events in 1995 (spring and summer) and 1998 (summer only), Shipyard Lake waters were more basic and contained lower total suspended solids (TSS), iron, manganese, total phosphorus and dissolved aluminum concentrations in 1999 (Tables 7.1 and 7.2). Total nickel and chromium levels were lower in the spring and summer of 1999 than in 1995.

As in other years, the 1999 Shipyard Lake samples contained non-detectable levels of naphthenic acids and was non-toxic to bacteria (Table 7.1). Nutrient levels indicate that the lake is mesotrophic (Wetzel 1983). Total phenolic concentrations in spring and fall of 1999 exceeded chronic aquatic guidelines. Similarly, total iron levels in the spring of 1999 exceeded human health and chronic aquatic guidelines (Table 7.3). Guidelines for total iron concentrations were also exceeded in 1995.

Detection limits reported in 1999 for total mercury and total silver exceed guideline levels, so these elements were not evaluated with respect to water quality guidelines (Table 7.3). However, dissolved mercury concentrations were higher than human health guidelines in the spring and summer of 1999; dissolved mercury levels in the summer of 1999 were also higher than the chronic aquatic guideline.

**Table 7.1 Water Quality in Shipyard Lake**

| Parameter | Units | Spring | | Summer | | | Fall |
|---|---|---|---|---|---|---|---|
| | | 1999 | 1995[a] | 1999 | 1998[b] | 1995[a] | 1999 |
| **Field Measured** | | | | | | | |
| pH | | 8.0 | 6.9 | 8.9 | 7.5 | 7.4 | 8.7 |
| specific conductance | μS/cm | 314 | 241 | 264 | 329 | 274 | 333 |
| temperature | $^{o}$C | 10.9 | - | 22.8 | - | - | 2.2 |
| dissolved oxygen | mg/L | 7.8 | - | 14.0 | - | - | 8.2 |
| **Conventional Parameters and Major Ions** | | | | | | | |
| chloride | mg/L | 9.0 | 5.8 | 8.0 | 8.0 | 4.8 | 11 |
| dissolved organic carbon | mg/L | 16 | - | 16 | 16 | - | 17 |
| sulphate | mg/L | 5 | 4 | 4 | 3 | 2 | 6 |
| total alkalinity | mg/L | 152 | 109 | 134 | 161 | 135 | 165 |
| total dissolved solids | mg/L | 220 | - | 220 | 386 | 147 | 240 |
| total organic carbon | mg/L | 18 | 18 | 18 | 22 | 24 | 19 |
| total suspended solids | mg/L | < 3 | 155 | 4 | 11 | 180 | 5 |
| **Nutrients and Chlorophyll *a*** | | | | | | | |
| nitrate + nitrite | mg/L | < 0.1 | 0.01 | 0.1 | < 0.05 | 0.02 | < 0.1 |
| nitrogen - ammonia | mg/L | < 0.05 | < 0.01 | < 0.05 | 0.06 | 0.09 | < 0.05 |
| nitrogen - total | mg/L | 0.9 | 0.8 | 0.9 | 0.9 | 0.6 | 0.8 |
| phosphorus, total | μg/L | 19 | 31 | 12 | 29 | 34 | 17 |
| chlorophyll *a* | μg/L | -* | - | 3 | 6 | - | -* |
| **Biochemical oxygen demand** | | | | | | | |
| biochemical oxygen demand | mg/L | 3 | - | 3 | 2 | - | < 2 |
| **Toxicity** | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | - | > 91 | >91 | > 100 | > 91 |
| Microtox IC25 @ 15 min | % | > 91 | - | > 91 | >91 | > 100 | > 91 |
| **Organics** | | | | | | | |
| naphthenic acids | mg/L | < 1 | - | < 1 | < 1 | < 1 | < 1 |
| total phenolics | μg/L | 7 | - | 2 | 3 | - | 6 |

[a] Based on information from Golder (1996a).

[b] Based on information from Golder (1999a).

* Data discarded due to issues with data quality.

## Table 7.2 Metal Levels in Shipyard Lake

| Parameter | Units | Spring | | Summer | | | Fall |
|---|---|---|---|---|---|---|---|
| | | 1999 | 1995[(a)] | 1999 | 1998[(b)] | 1995[(a)] | 1999 |
| **Total Metals** | | | | | | | |
| aluminum (Al) | µg/L | 30 | 20 | 70 | 30 | 50 | 30 |
| antimony (Sb) | µg/L | < 0.8 | - | < 0.8 | < 0.8 | 0.2 | < 0.8 |
| arsenic (As) | µg/L | < 1 | 0.2 | < 1 | < 1 | < 1 | < 1 |
| barium (Ba) | µg/L | 34 | 20 | 22 | 35 | 30 | 27 |
| cadmium (Cd) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 3 | < 0.2 |
| chromium (Cr) | µg/L | < 0.8 | 7.0 | < 0.8 | < 0.8 | 9.0 | 1.5 |
| copper (Cu) | µg/L | < 1 | 1 | 1 | < 1 | - | < 1 |
| iron (Fe) | µg/L | 250 | 1150 | 220 | 2090 | 2650 | 270 |
| lead (Pb) | µg/L | 0.4 | 1.0 | 0.1 | 0.3 | < 20 | < 0.1 |
| manganese (Mn) | µg/L | 24 | 46 | < 127 | 98 | 180 | 15 |
| mercury (Hg) | µg/L | < 0.2 | < 50 | < 0.2 | < 0.2 | < 50 | < 0.2 |
| molybdenum (Mo) | µg/L | 0.4 | < 3 | 0.1 | < 0.1 | < 3 | 0.2 |
| nickel (Ni) | µg/L | 1 | 11 | 1 | 1 | 10 | 2 |
| selenium (Se) | µg/L | < 0.8 | < 0.2 | < 0.8 | < 0.8 | < 1 | < 0.8 |
| silver (Ag) | µg/L | < 0.4 | 1.1 | < 0.4 | < 0.4 | < 2 | < 0.4 |
| zinc (Zn) | µg/L | 7 | 17 | 12 | < 4 | 13 | < 4 |
| **Dissolved metals** | | | | | | | |
| aluminum (Al) | µg/L | 10 | - | 10 | 60 | - | < 10 |
| antimony (Sb) | µg/L | < 0.8 | - | < 0.8 | < 0.8 | - | < 0.8 |
| arsenic (As) | µg/L | < 0.4 | - | 1.3 | 0.5 | - | < 0.4 |
| barium (Ba) | µg/L | 31 | - | 17 | 33 | - | 28 |
| cadmium (Cd) | µg/L | < 0.1 | - | < 0.1 | 0.1 | - | < 0.1 |
| chromium (Cr) | µg/L | 0.4 | - | < 0.4 | < 0.4 | - | 0.8 |
| copper (Cu) | µg/L | 0.9 | - | 1.6 | 0.6 | - | 0.9 |
| iron (Fe) | µg/L | 140 | - | 130 | 1480 | - | 220 |
| lead (Pb) | µg/L | 0.2 | - | 0.2 | 0.1 | - | < 0.1 |
| manganese (Mn) | µg/L | 15 | - | 1 | 102 | - | 3 |
| mercury (Hg) | µg/L | 0.1 | - | 0.2 | < 0.1 | - | 0.03 |
| molybdenum (Mo) | µg/L | 0.4 | - | < 0.9 | < 0.1 | - | 0.2 |
| nickel (Ni) | µg/L | 0.7 | - | 0.5 | 0.3 | - | 1.8 |
| selenium (Se) | µg/L | < 0.4 | - | < 0.4 | < 0.4 | - | < 0.4 |
| silver (Ag) | µg/L | < 0.2 | - | < 0.2 | < 0.2 | - | < 0.2 |
| zinc (Zn) | µg/L | 8 | - | < 2 | < 2 | - | 3 |

[(a)] Based on information from Golder (1996a).

[(b)] Based on information from Golder (1999a).

**Table 7.3 Summary of Parameters Found to Exceed Surface Water Quality Guidelines in Shipyard Lake**

| Parameter | Units | Guidelines for the Protection of | | | Shipyard Lake | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic life[a] | | Human | Spring | | Summer | | | Fall |
| | | Acute | Chronic | Health[b] | 1999 | 1995 | 1999 | 1998 | 1995 | 1999 |
| **Total Phenolics** | | | | | | | | | | |
| total phenolics | µg/L | - | 5 | - | C | - | | | - | C |
| **Total Metals** | | | | | | | | | | |
| iron (Fe) | µg/L | - | 300 | 300 | C H | C H | | C H | C H | |
| lead (Pb) | µg/L | * | * | - | | | | | C` | |
| manganese (Mn) | µg/L | - | - | 50 | | | H` | H | H | |
| mercury (Hg)[c] | µg/L | 1.4 | 0.1 | 0.05 | C H` | A C H` | C H` | C H` | A C H` | C H` |
| silver (Ag) | µg/L | * | 0.1 | - | C` | C | C` | C` | C` | C` |

[a] Guidelines taken from AENV (1999).

[b] Guidelines taken from U.S. EPA (1999).

[c] Using U.S. EPA and CCME guidelines, respectively, because Alberta mercury guidelines have not been finalized.

* Guidelines are hardness dependant; calculated at each sample site using the U.S. EPA method described in AENV (1999).

C = chronic aquatic guideline exceeded; H = human health guideline exceeded.

- No guideline / no data.

` Although substance concentrations were below detection limits, the analytical detection limit exceeded the relevant surface water guideline.

Blank cells = no guideline exceeded.

## 7.2 SEDIMENT QUALITY

### 7.2.1 Kearl Lake

Environment Canada collected one sediment sample from Kearl Lake in 1998. The sample generally contained higher PAH concentrations than sediments collected from the Muskeg River in 1998 and 1999 (Table 7.4). Concentrations of methyl naphthalene and dibenzo(a,h)anthracene exceeded Canadian Sediment Quality Guidelines.

**Table 7.4 Concentration of Polycyclic Aromatic Hydrocarbons in Sediments from Kearl Lake and the Muskeg River**

| Parameter | Units | Muskeg River | | | | Kearl Lake |
|---|---|---|---|---|---|---|
| | | Mouth | | | Upper | |
| | | 1999 | 1998[(a)] | 1997 | 1998[(b)] | (1998)[(b)] |
| naphthalene | ng/g | 14 | *18 | < 3 | 6 | 26 |
| methyl naphthalenes | ng/g | 20 | 15 | < 3 | 21 | 57 |
| C2 substituted naphthalenes | ng/g | 22 | 18 | < 20 | 97 | 108 |
| C3 substituted naphthalenes | ng/g | 23 | 16 | 40 | 27 | 17 |
| C4 substituted naphthalenes | ng/g | 4.5 | < 2.2 | 60 | 18 | 19 |
| acenaphthene | ng/g | < 2.6 | < 4 | < 3 | 0.4 | 3.1 |
| methyl acenaphthene | ng/g | 2.8 | < 1.1 | < 20 | - | - |
| acenaphthylene | ng/g | < 3.5 | < 1 | < 3 | 0.4 | 1.6 |
| anthracene | ng/g | < 2 | < 3.1 | < 3 | 0.4 | 5.2 |
| dibenzo(a,h)anthracene | ng/g | < 3.7 | < 21 | < 3 | nd | 10 |
| benzo(a)anthracene/chrysene | ng/g | 16.5 | *16 | 35 | 12 | 21 |
| methyl benzo(a)anthracene/chrysene | ng/g | 17 | < 2.5 | 70 | 5 | 15 |
| C2 substituted benzo(a)anthracene/chrysene | ng/g | 9.2 | < 1.7 | 130 | 5.2 | 40 |
| benzo(a)pyrene | ng/g | < 5.1 | < 10 | 13 | nd | 13 |
| methyl b(b&k)f/methyl b(a)p | ng/g | < 12 | < 8.6 | 90 | 164 | 27 |
| C2 substituted b(b& k)f/b(a)p | ng/g | < 9.2 | < 5.7 | 100 | - | - |
| benzo(b&k)fluoranthene | ng/g | 11 | < 12 | 14 | 5.6 | 32 |
| benzo(g,h,i)perylene | ng/g | *11 | *14 | 12 | 14 | 31 |
| biphenyl | ng/g | 4.4 | < 1.1 | < 20 | - | - |
| methyl biphenyl | ng/g | < 2.3 | < 0.96 | < 20 | - | - |
| C2 substituted biphenyl | ng/g | < 1.6 | < 0.55 | < 20 | - | - |
| dibenzothiophene | ng/g | 1.9 | < 1.2 | < 3 | 2.6 | 4.3 |
| methyl dibenzothiophene | ng/g | 11 | < 10 | < 20 | 53 | 165 |
| C2 substituted dibenzothiophene | ng/g | 42 | < 4.2 | 110 | 98 | 87 |
| C3 substituted dibenzothiophene | ng/g | 82 | < 3.6 | 210 | 27 | 10 |
| fluoranthene | ng/g | 2.7 | 2.8 | 3 | 1.9 | 14 |
| methyl fluoranthene/pyrene | ng/g | 16 | 17 | 70 | - | - |
| fluorene | ng/g | 2 | 2.7 | < 3 | 2.8 | 19 |
| methyl fluorene | ng/g | < 1.9 | < 2.2 | < 20 | 29 | 69 |
| C2 substituted fluorene | ng/g | < 2 | < 3 | 60 | 70 | 171 |
| indeno(c,d-123)pyrene | ng/g | *6.4 | < 13 | 6 | nd | 43 |
| phenanthrene | ng/g | 14 | 9.8 | 7 | 11 | 38 |
| methyl phenanthrene/anthracene | ng/g | 41 | 24 | 40 | 42 | 205 |
| C2 substituted phenanthrene/anthracene | ng/g | 40 | 40 | 100 | 60 | 196 |
| C3 substituted phenanthrene/anthracene | ng/g | 36 | 51 | 180 | nd | 132 |
| C4 substituted phenanthrene/anthracene | ng/g | 150 | 36 | 110 | nd | nd |
| pyrene | ng/g | 6 | 5.1 | 12 | 3.7 | 9.0 |

[(a)] Sample collected by AENV, submitted to RAMP for analysis in 1999.

[(b)] Sample analyzed by Environment Canada.

- = no data; nd = concentration < analytical detection limits.

* PAH concentrations are reported with the limitation that the GCMS spectra used to develop these values were ill-defined (i.e., these numbers may contain a larger degree of error than those produced from clearly defined spectra).

# 8 ACID SENSITIVE LAKES – RESULTS AND DISCUSSION

## Field Parameters

The field data (i.e., lake depth; vertical profiles of temperature, pH, conductivity and dissolved oxygen; Secchi depth) collected during the summer of 1999 are provided in Appendix V. The correspondence between field and lab pH is examined in the following section. No further analysis of the field parameter data was carried out in 1999.

## pH and Alkalinity

Water chemistry variables related to acidity varied considerably among the lakes surveyed in 1999. Field pH ranged between 4 and 9, with about two-thirds of the 32 lakes having pH values <7 (Figure 8.1). All but one (R3) lab pH measurements were <7. The pH data indicate that the set of lakes selected for acidification monitoring was characterized by lower pH than typically observed in the province, which is consistent with their general acid-sensitivity. Two-thirds of Alberta lakes for which data are available have pH values >7.5 (Saffran and Trew 1996).

There was a reasonable correspondence between field and lab-measured pH for each lake, with seven exceptions (A26, A47, O10, O3, L25, L39, A42) (Figure 8.1). Field pH for Lake A26 was 16% lower than lab pH. For the remaining six lakes, field pH was 14 to 35% higher than lab pH. Most of these differences occurred closer to the high end of the pH range represented by the 1999 data set (Figure 8.1). Higher field pH relative to lab pH is frequently observed during field surveys because $CO_2$ production by algae in water samples during transport can cause a lowering of pH. For consistency with previous data summaries of acid sensitivity in Alberta (e.g., Saffran and Trew 1996), lab pH (data for all lakes are shown in Figure 8.5) was used as the primary measure of acidity in this document.

Total alkalinity also varied widely among lakes, with an overall range of 0 to 48.3 mg/L $CaCO_3$. The majority of total alkalinity data measured in 1999 coincided with the historical information (Figure 8.2; data for all lakes are shown in Figure 8.5), thus confirming the lake selection criteria. However, concentrations in four lakes (A26, L47, L46 and O3) were 2 to 3.5 times higher in 1999 than expected based on historical data, and those in two lakes (A47, L4) were 2 to 4 times lower. For comparison with this variation, the seasonal and year-to-year variation in water chemistry within lakes is illustrated for selected parameters in Appendix V (Tables V-1 to V-3), for three lakes, L4, L7 and L25 (data from AENV). The deviation from historical data in the lakes sampled in 1999 is not necessarily outside of the range of natural variation within a lake of low alkalinity, considering that total alkalinity may vary up to 2.5-fold between consecutive years and up to 5.6-fold from the minimum to the maximum value for the period of record (based on June/July averages in Lake L4).

On the basis of the 1999 alkalinity data, 21 of the 32 lakes were highly sensitive to acidic deposition (alkalinity of 0 to 10 mg/L as $CaCO_3$) and 7 lakes were moderately sensitive (11 to 20 mg/L) (Figure 8.2). Four lakes (L8, L46, O3, R3) showed only low sensitivity in 1999 (>20 mg/L). Of these lakes, only two (O3, R3, Figure 8.5) had alkalinity values that were substantially higher than the upper limit of the range intended for this monitoring program (0 to 20 mg/L as $CaCO_3$).

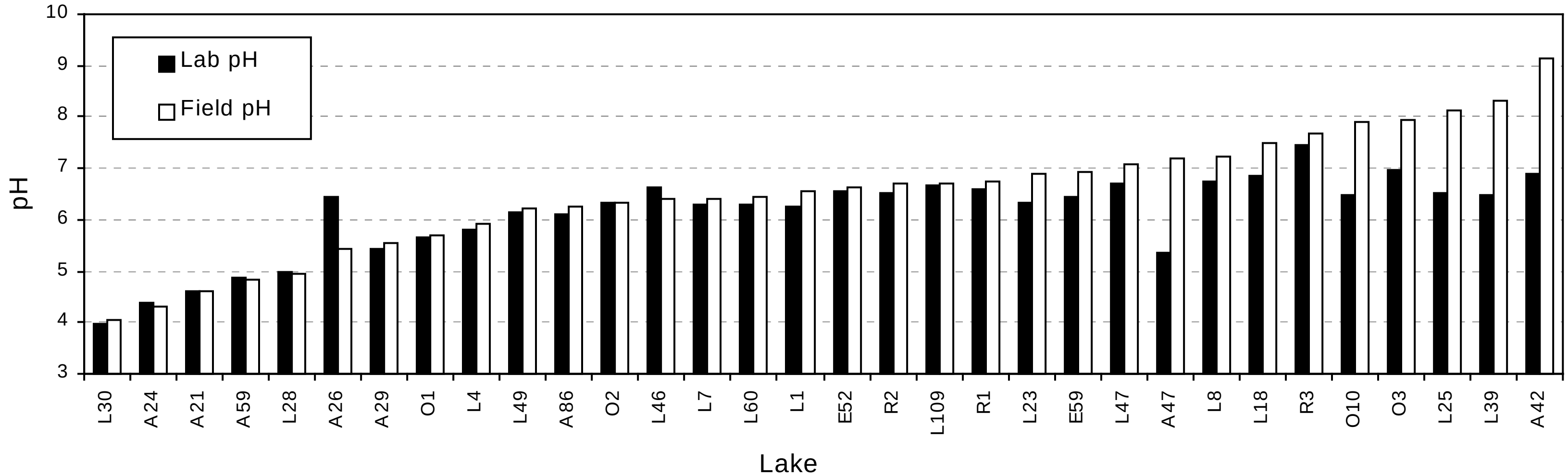
There was a strong, statistically significant relationship between log-alkalinity and pH (linear regression, $P<0.001$, $r^2=0.92$) (Figure 8.3). The “steepest” part of the curve is between alkalinity values of 0 and 10 mg/L. Accordingly, lakes below a total alkalinity of 10 mg/L are often called the “transition lakes” because they are particularly susceptible to acidification; in such lakes, small changes in alkalinity will result in rapid changes in pH.

## *Major Ions and Colour-Related Variables*

Concentrations of dissolved ions in the 32 lakes were low to moderate, with a total dissolved solids (TDS) range between 20 and 120 mg/L (Figure 8.4). Conductivity, TDS and concentrations of most ions varied among lakes without obvious grouping of lakes at any level, although there were occasional high measurements (e.g., TDS = 115 mg/L in Lake A59; Figure 8.4). The variation in sulphate concentration was discontinuous, with higher levels observed in a cluster of lakes in the Birch Mountains (L18, L60, L47, L46, L49), relative to all other lakes (Figure 8.4).

Colour and DOC concentration spanned wide ranges in the study lakes (Figure 8.5), as intended during the selection of lakes for this monitoring program. There was no obvious break-point between clear water and brown water lakes in terms of DOC or colour. Caribou Mountains lakes tended to have higher colour than Canadian Shield Lakes, as anticipated during lake selection, but a similar trend was not apparent in DOC concentration. There was a strong, significant relationship between DOC and colour, with two conspicuous outliers, lakes A42 and A59 (linear regression, $P<0.001$, $r^2=0.63$, A42 and A59 removed from the analysis). These two lakes had the highest TP concentrations in the data set (200.4 and 192.2 µg/L, respectively), with corresponding chlorophyll *a* concentrations in the range characteristic of algal blooms (112.4 and 75.6 µg/L).

**Figure 8.1 Comparisons of Field and Lab pH in the Lakes Sampled in 1999**



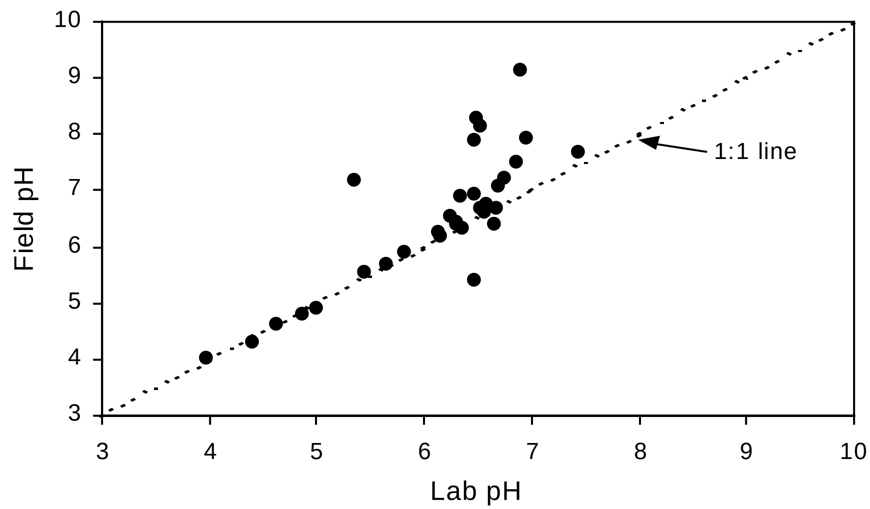



**Figure 8.2 Comparison of Historical Alkalinity Data with the 1999 Data**

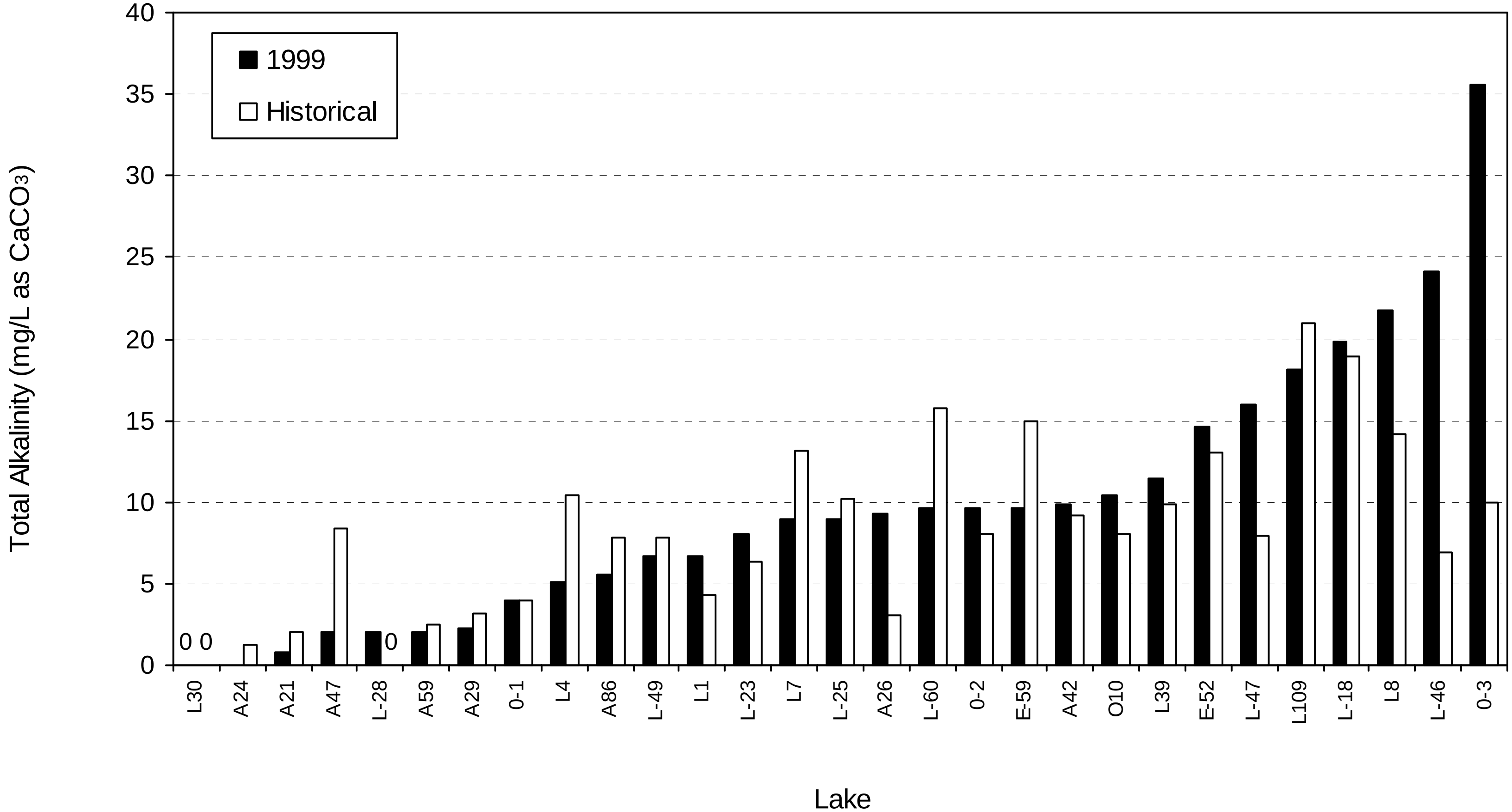


**Figure 8.3 pH as a Function of Total Alkalinity in the Lakes Sampled in 1999**

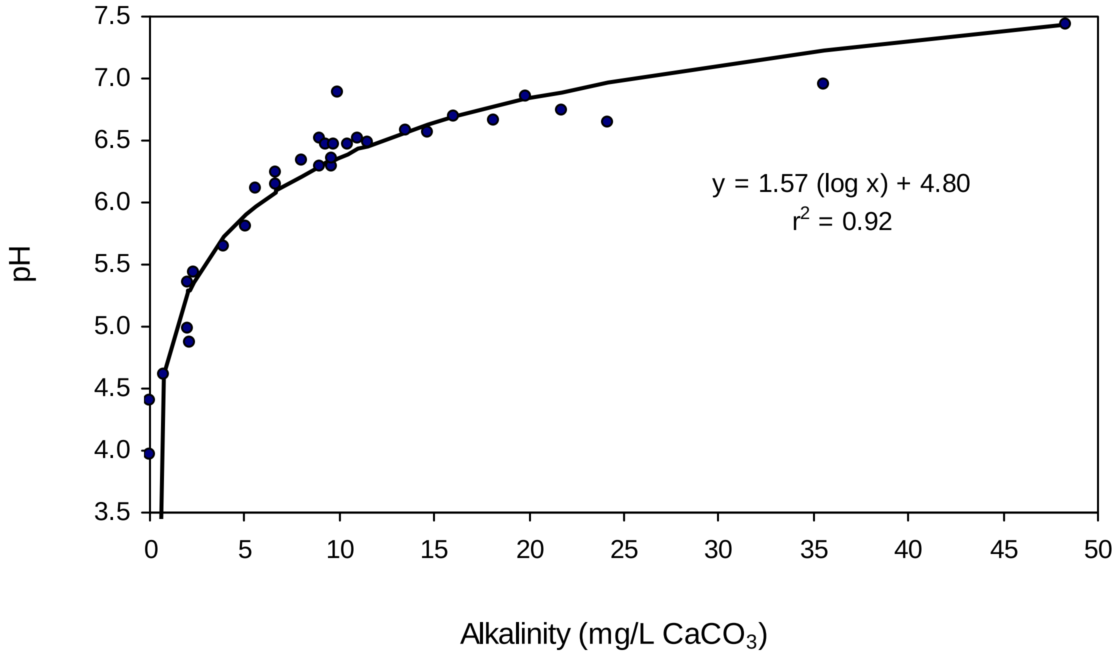


**Figure 8.4 Calcium, Sulphate, Total Dissolved Solids and Specific Conductance in the Lakes Sampled in 1999**

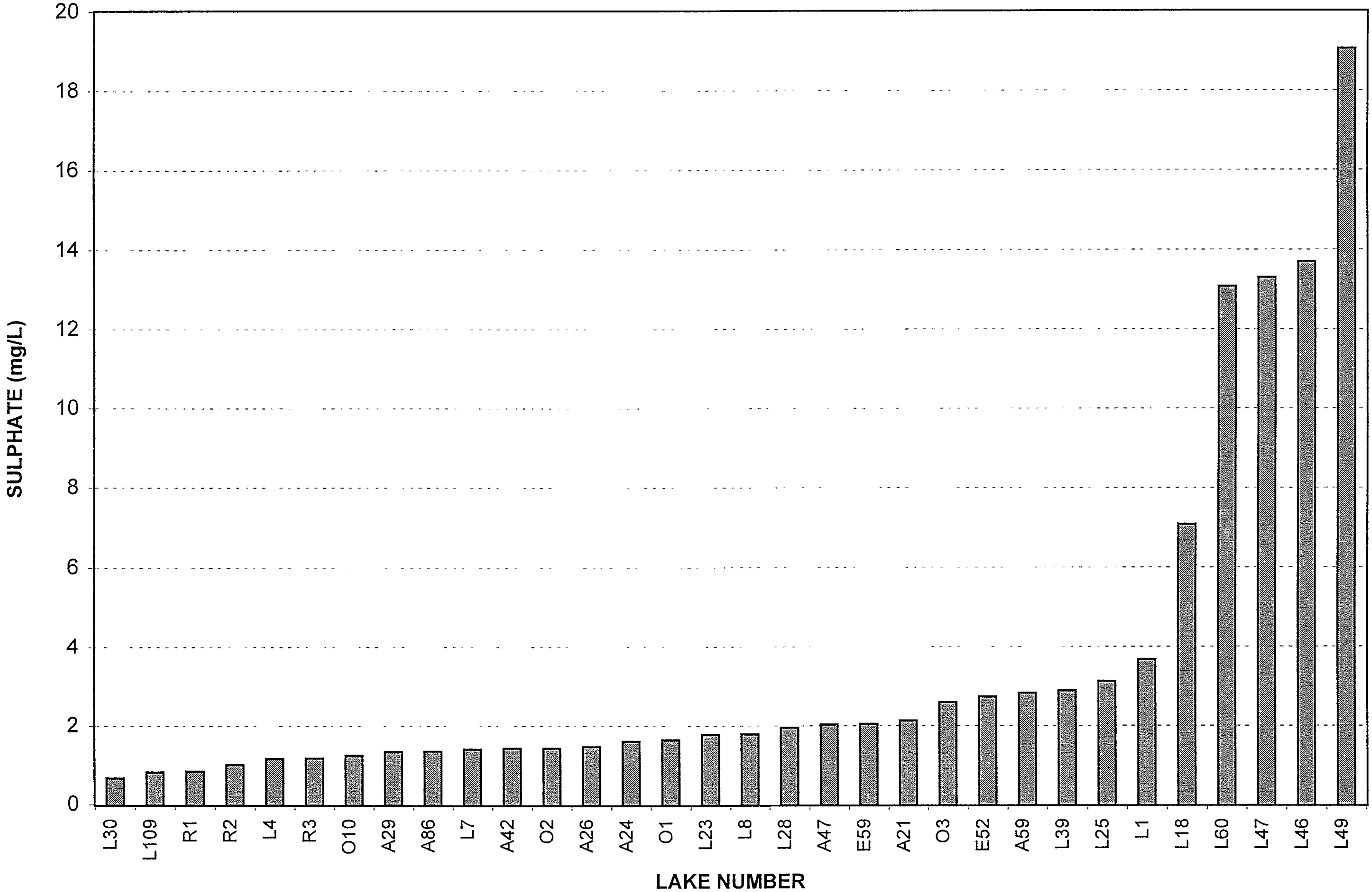
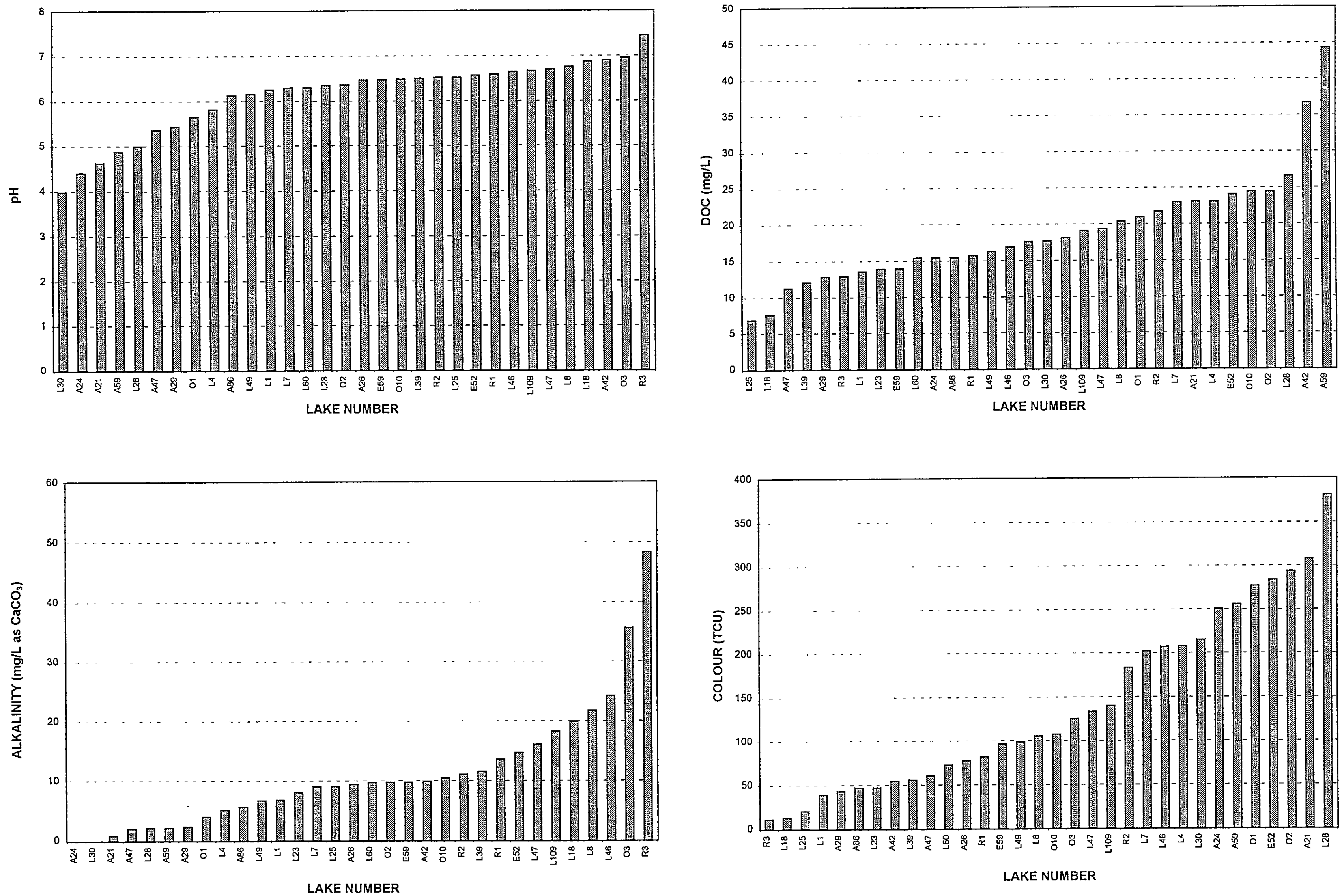


**Figure 8.5 pH, Total Alkalinity, Dissolved Organic Carbon and True Colour in the Lakes Sampled in 1999**



## Nutrients and Trophic Status

The 32 lakes varied widely in nutrient and chlorophyll concentrations. Total phosphorus (TP) concentration ranged from 8 to 200 µg/L (Figure 8.6). Based on chlorophyll *a* concentration (Figure 8.6), one lake was oligotrophic (<2.5 µ/L), 10 lakes were mesotrophic (2.5 to 8 µg/L), 14 lakes were eutrophic (8 to 25 µ/L) and 7 lakes were hyper-eutrophic (>25 µg/L) (trophic categories from Mitchell and Prepas 1980). As expected, there was a significant positive relationship between TP and chlorophyll *a* (linear regression, $P<0.001$, $r^2=0.55$) (Figure 8.7), though highly coloured lakes tended to have lower chlorophyll levels than expected based on TP. Concentrations of phosphorus and nitrogen variables were significantly inter-correlated with the exception of particulate nitrogen (PN) (Pearson correlations; $P<0.05$). The chlorophyll *a* : TP ratio was not affected by pH (Figure 8.7), but was significantly negatively correlated with colour, TDS and dissolved nitrogen parameters (Pearson correlations; $P<0.05$).

## Relationships with pH

As described above, pH was strongly related to log-alkalinity (Figure 8.3). In addition, the raw or log-transformed concentrations of most anions ($Cl^-$, log-$HCO_3^-$) and cations (log-$Ca^{+2}$, $K^+$, log-$Mg^{+2}$, $Na^+$) and conductivity were significantly positively correlated with pH, and colour was negatively correlated with pH (Pearson correlations, $P<0.05$). Of these, the strongest linear relationships were with log-$HCO_3^-$ ($r=0.96$), log-$Ca^{2+}$ ($r=0.88$) and log-$Mg^{2+}$ ($r=0.89$). There was no apparent relationship between pH and sulphate concentration.

## Suitability of the Lakes for the RAMP Acidification Monitoring Network

The lakes sampled in 1999 generally satisfied the selection criteria outlined in Section 3.1.1, and are thus suitable for continued monitoring under RAMP. Nearly all lakes were moderately to highly sensitive to acidification, with the exception of the two lakes with the highest total alkalinity values (O3 and R3, total alkalinity values of 35.5 and 48.3 mg/L, respectively). Since these lakes were less sensitive to acidification than originally intended for this monitoring program, they should be replaced with more acid-sensitive lakes in the future.

**Figure 8.6 Total Dissolved Nitrogen, Chlorophyll *a* and Total Phosphorus in the Lakes Sampled in 1999**

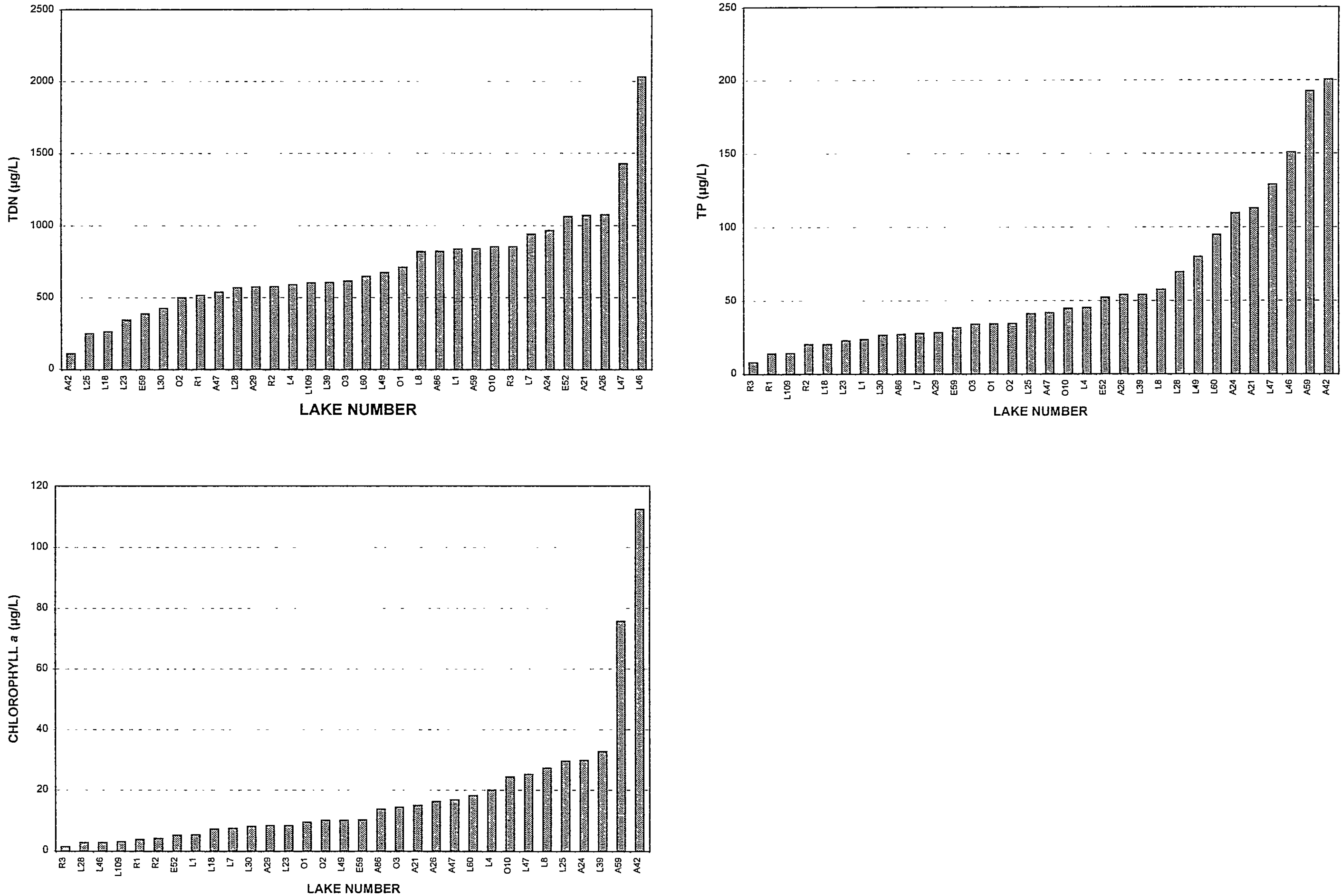
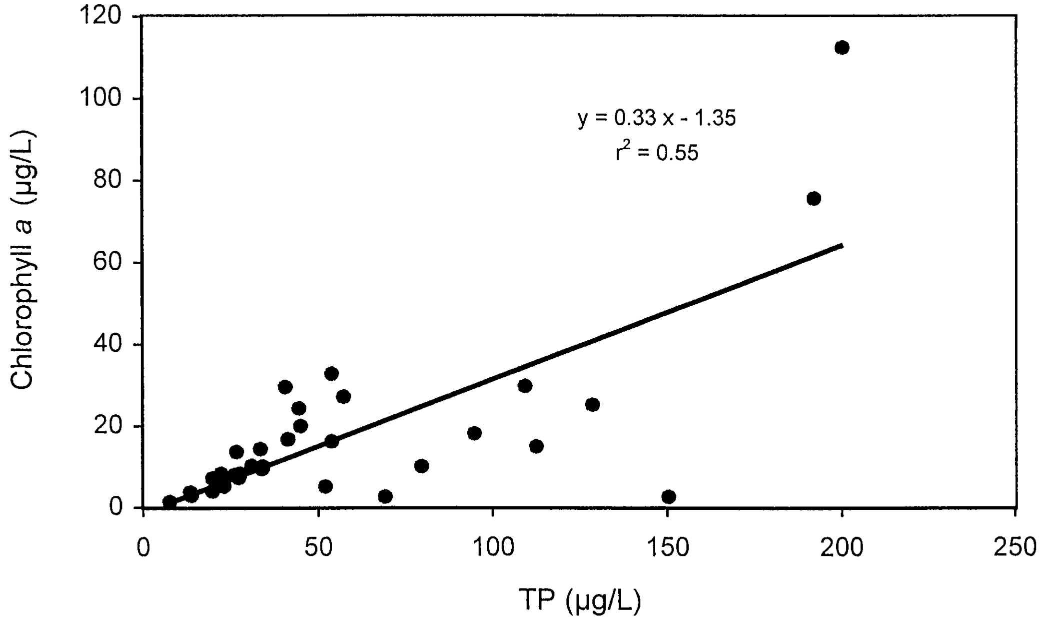
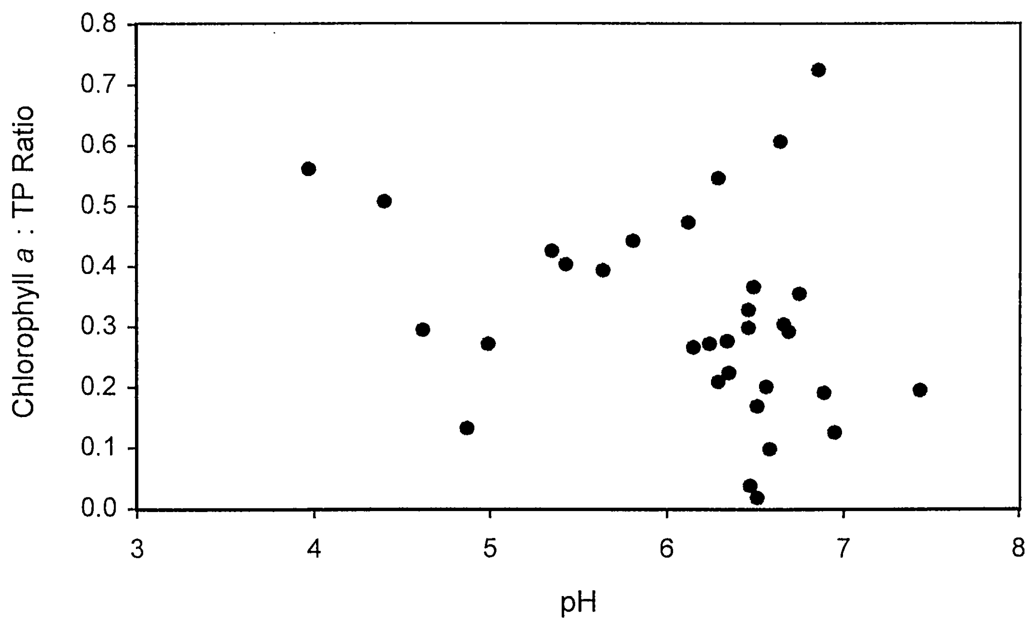


**Figure 8.7 Scatter-plots of Chlorophyll *a* versus TP and the Chlorophyll *a* : TP Ratio versus pH in the Lakes Sampled in 1999**



An additional issue regarding lake selection concerns the intended location of monitoring lakes along a gradient of acidic deposition radiating from the oil sands region. With the recent refinements to the modelling of acidic deposition in the oil sands area (i.e., Suncor 2000), the size of the area subject to deposition rates above the current guideline value of 0.25 $k_{eq}$ $H^+$/ha/a has become considerably smaller. As a result, only a very small subset of the 32 lakes sampled in 1999 are within (L1) or near (L4, L7) the 0.25 $k_{eq}$ $H^+$/ha/a deposition isopleth. Future oil sands developments may also alter deposition patterns and rates. Therefore, it may be useful to select a small number of additional lakes closer to the high deposition zone, if such lakes exist.

This lake monitoring program will continue to evolve as new information and needs dictate. Certain recommendations arising from the *$NO_x$/$SO_2$ Management Working Group Acid Deposition Science Colloquium*, held in Edmonton during March 20 to 22, 2000, are now being considered for implementation into this program. In addition, future evaluations of the data generated by this component would benefit from analyses of certain ionic ratios that can serve as sensitive indicators of acidification, and calculation of the critical load for each lake forming the RAMP network. Reevaluating sampling frequency, and potentially increasing it in a subset of the 32 lakes, may also be useful to better characterize seasonal variation.

# 9 SUMMARY AND CONCLUSIONS

## 9.1 SUMMARY

### 9.1.1 Water and Sediment Quality

Two water samples were collected from the Athabasca River in 1999: one near the Embarras River and one in the Athabasca River Delta. A composite sediment sample was also taken from the river delta. Sampling results indicate:

- Athabasca River waters were non-toxic to bacteria.
- Water quality near the Embarras River was generally consistent with historical data, with the exception of higher than normal total zinc and total aluminum concentrations.
- Total suspended solids (TSS), total dissolved solids (TDS), total aluminum and total barium levels in the Athabasca River Delta were higher in 1999 than typically observed in this area.
- Sediments from the Athabasca River Delta were found to significantly affect the growth and/or survival of several species of invertebrates.
- Methyl naphthalene was the only substance present in the delta sediments found to exceed sediment quality guidelines.

Seasonal water quality samples were collected from three locations on the Muskeg River in 1999. Water and/or sediment samples were also collected from the Steepbank River, the Alsands Drain and McLean, Jackpine, Shelley, Muskeg, Stanley and Wapasu creeks in 1999. Water quality in most of these streams was generally consistent with historical data. Some parameters exceeded regulatory guidelines as they have in the past. Key results from the 1999 water and sediment sampling program include:

- The continued presence of chronic toxicity in the upper Muskeg River under fall and winter conditions (assessed using the water flea *Ceriodaphnia dubia* and fathead minnows).
- Detectable levels of naphthenic acids (i.e., >1 mg/L) in the Muskeg River, the Alsands Drain, McLean Creek and Muskeg Creek.
- Higher than normal TDS and total aluminum concentrations at most water quality sampling sites.
- High PAH concentrations in sediments from McLean Creek, in comparison to sediments from the Muskeg River and the Athabasca River Delta.

- Sediments from McLean Creek were found to significantly affect the growth of several species of invertebrates; no toxic effects were observed with sediments from the mouth of the Muskeg River.
- Sediment PAH levels were generally consistent along the length of the Muskeg River.

### 9.1.2 Fish Populations

The fisheries component of the 1999 RAMP focused on the mainstem Athabasca River as well as the Muskeg and Steepbank rivers. Work on the Athabasca River represented a continuation of monitoring efforts conducted in previous years, although the fish inventory was limited to the spring, and sentinel monitoring focused on a small-bodied fish species. Sentinel monitoring using a small-bodied fish species was also initiated on the Muskeg and Steepbank rivers. Results of the 1999 fish component of RAMP indicate:

- A total of 13 species were captured in the Athabasca River during the spring fish inventory. Species composition and relative abundance was similar to that observed in the spring of 1998.
- Walleye was the only KIR species captured in sufficient numbers to evaluate population parameters. Age and length distributions were consistent with previous years, although size-at-age showed greater variability. The change in size-at-age of walleye in 1999 may suggest a possible decrease in food availability, perhaps related to abnormally low water levels in the Athabasca River in 1998 and 1999.
- Based on abundance, distribution and gonadal development, trout-perch was selected as the small-bodied sentinel species for the Athabasca River.
- Due to the reduced potential of large-scale movement, it was possible to collect trout-perch from a reference site located within the Oil Sands Region, as well as exposure sites near oil sands developments.
- Trout-perch collected downstream of Suncor's discharge and the confluence of the Muskeg River showed few differences in fish characteristics relative to reference fish or each other. Power analyses confirmed that samples sizes were adequate to detect differences had they existed. Future work evaluating the mobility of trout-perch may be needed.
- Based on distribution and gonadal development, slimy sculpin was selected as the small-bodied sentinel species for the Muskeg and Steepbank rivers.
- Attempts to collect slimy sculpin from a separate reference river were not successful due to poor access and/or capture success.

- Sculpin from the Muskeg River were older and had reduced body weight, condition, gonad size and liver size suggesting a response to lower food availability. Low water levels related, in part, to beaver dams may have affected habitat quality/quantity; it is unknown what effect the observed parasitism has had on metabolism.
- Sculpin from the lower Steepbank River were older and larger but showed few other differences in fish characteristics.
- Responses of slimy sculpin from the Muskeg and Steepbank rivers need to be confirmed over time before definitive conclusions can be made. Additional reference sites are needed to more accurately define the full range of natural variability in fish characteristics. As well, monitoring should include detailed characterization of the habitat at each site.
- Power analyses confirmed that sample sizes of sculpin were adequate to detect site differences in most parameters, although greater numbers of males is recommended.
- In general, improved techniques for ageing trout-perch and slimy sculpin is needed to increase our confidence in age estimates.

### 9.1.3 Wetlands

Seasonal water samples were collected from Shipyard Lake in 1999. A single sediment sample was collected from Kearl Lake in 1998 for PAH analysis by Environment Canada; sample results were submitted to RAMP in 1999. Results of the 1999 wetlands water and sediment quality sampling program indicate:

- Water quality in Shipyard Lake was generally consistent with historical data and consistent between seasons (spring, summer and fall of 1999).
- Shipyard Lake waters were non-toxic to bacteria and did not contain detectable levels of naphthenic acids.
- As in previous sampling events, total iron and total manganese levels in Shipyard Lake exceeded water quality guidelines in 1999; total phosphorus concentrations in Shipyard Lake in the spring of 1999 also exceeded the relevant water quality guideline.
- Sediments from Kearl Lake generally contained higher PAH concentrations than sediments from the Muskeg River.
- Methyl naphthalene and dibenzo(a,h)anthracene were the only substances present in Kearl Lake sediments found to exceed sediment quality guidelines.

### 9.1.4 Acid Sensitive Lakes

Water samples were collected from 32 acid sensitive lakes in north-eastern Alberta to establish a network of lakes for long-term monitoring of acidic deposition. These lakes were selected based on historical data collected by AENV. The field program was carried out during the summer of 1999. Results of the 1999 acid sensitive lakes component of RAMP indicate:

- Acid sensitive lakes in north eastern Alberta display a wide variation in water quality and productivity.
- Many of the lakes surveyed are naturally acidic (with pH<7) and most have lower pH than typically observed in other Alberta lakes.
- On the basis of the 1999 alkalinity data, 28 of the 32 lakes were moderately to highly sensitive to acidic deposition (alkalinity of 0 to 20 mg/L as $CaCO_3$) and four lakes showed low sensitivity (>20 mg/L).
- There was a strong relationship between total alkalinity and pH in the data set for the 32 lakes. A number of other parameters (colour, conductivity and most anions and cations) were also correlated with pH.
- Colour and DOC concentration spanned wide ranges in the study lakes, as intended during the selection of lakes for this monitoring program.
- The 32 lakes varied widely in nutrient and chlorophyll concentrations. Based on chlorophyll *a* concentration, one lake was oligotrophic (<2.5 µg/L), 10 lakes were mesotrophic (2.5 to 8 µg/L), 14 lakes were eutrophic (8 to 25 µg/L) and 7 lakes were hyper-eutrophic (>25 µg/L).
- The lakes sampled in 1999 generally satisfied the selection criteria developed for this program and are thus suitable for continued monitoring under RAMP. Potential minor modifications to the program include replacing two lakes of low acid sensitivity with more sensitive lakes and, if possible, adding lakes that are closer to the area of highest acidic deposition rate. This lake monitoring program will continue to evolve as new information and needs dictate.

### 9.1.5 Quality Assurance/Quality Control

The results of the RAMP QA/QC assessment of the field sampling and laboratory analysis indicate that water quality data analyzed by ETL, the sediment quality data analyzed by AXYS and data analysis performed by Golder are valid. A summary of the QA/QC assessment is provided below:

- ETL’s intra-laboratory precision is high.

- Inter-laboratory analytical variation for water quality is moderate; minor differences were found in data analyzed by ETL and ARCV because ARCV often used lower detection limits.
- Inter-laboratory analytical variation for sediment quality is low.
- In summer, ETL reported higher levels of metals than ARCV in the total and dissolved metal field blanks. ETL's levels of total and dissolved metals were more comparable to ARCV's results in fall.
- Dissolved metal levels reported by ETL and ARCV occasionally exceeded total metal levels. Because this occurred sporadically in both laboratories, the dissolved metal filtering procedure is deemed satisfactory.
- Analysis of lab equipment blanks and spiked samples indicate that laboratory sampling procedures are satisfactory.
- Less than 5% of the values from the laboratory reports were entered into the Golder database incorrectly. These mistakes were corrected.

The RAMP QA/QC assessment has identified two areas where ETL data quality can be improved: prevention of field and trip blank contamination and total and dissolved metal analysis. Golder's course of action and recommendations in these areas are described below.

The water quality results of the winter field and trip blank indicated that some contamination occurred. The source of the contamination (i.e., field sampling procedure, laboratory analysis process, improper purification of deionized water) is undetermined. To assure greater water quality data validity in the future, RAMP will request ETL to split a large sample of deionized water; one portion will remain in the laboratory, the other portion will be used for field blanks and trip blanks at the project site. All these will be analyzed. With this information, field and trip blank water quality data can be compared to the water quality of laboratory deionized water.

Total and dissolved metal field blanks analyzed by ETL in summer consistently reported higher levels of a few metals (i.e., aluminum, manganese and zinc) than levels reported by ARCV. Golder notified ETL of potential contamination in their analysis process and corrective action was employed. As a result, fall total and dissolved metal data may be of higher quality; summer data should be used with caution since reported levels may be overestimated.

Analysis of QA/QC samples (i.e., split samples, field and trip blanks, total and dissolved metal blanks and laboratory equipment blanks) indicate that minor variation in water and sediment quality data within and between laboratories can be expected. These differences may reflect slight errors in blank representation, field sampling technique or laboratory analysis.

## 9.2 CONCLUSIONS

As 1999 is only the third year of monitoring in a long-term program, it is too early to draw many conclusions. The 1999 water quality data were generally consistent with historical data on both the Athabasca River and the tributaries, although some values were higher (e.g., aluminum, total dissolved solids) or lower than before. As more data are added each year, the data set will begin to contain the full range of historical and natural variation. Many results from the fish study on the Athabasca River are consistent with 1998 results, including the fish species list, the relative abundance of fish species captured in the spring and estimates of abundance (for the most abundant species).

Some of the conclusions made a year ago have been born out with more data. Water quality guidelines cannot be met for all parameters and will not be suitable as a simplistic test for effects of the development. Tests of significant change, based on adequate data are the primary tool for assessment of effects related to oil sands development. Some guidelines are likely exceeded due to natural and historic conditions.

The preliminary conclusion made in 1998 (i.e., that annual differences in climatic and hydrologic conditions can affect water quality and fish populations) is supported by the results for 1999. Both 1998 and 1999 were dry years. Maximum daily stream discharges and the cumulative flow volume (from spring melt to late summer) were much lower than normal in 1999. For all gauged stations, 1999 was dryer than 1998, and for several streams it was the driest year on record. Due to these conditions, RAMP data represent the water quality deterioration under natural, near drought conditions (i.e., the concentrations of many constituents of the water are concentrated under these conditions and may exceed guideline levels). These conditions also provide useful data on the range of effects that occur under near-drought conditions. For example, the reason for the change in size-at-age for walleye in the Athabasca River in 1999 is uncertain, but the data suggest a possible decrease in food availability. A similar conclusion was made in 1998, when walleye were shorter for any given age relative to walleye caught in 1997. Examples are also available from the tributaries. In general, the sentinel fish species (slimy sculpin) from the Muskeg River had reduced body weight, condition, gonad weight and liver weight suggesting a response to lower food availability relative to the reference site. Reduced food availability may be due to low water levels, and therefore reduced habitat, in this section of the river. Without sufficient data to understand the effects of extreme natural conditions, they become confounding factors when interpreting mining-related effects. Therefore, the results for 1998 and 1999 may prove to be particularly useful in the future.

In addition to the collection of core information, a major goal of the initial years of this study is to refine the monitoring so that it is a better tool to assess the effects of the oil sands developments. Benefits of doing this have been demonstrated this year. Due to the reduced potential for large-scale movement, use of a small-bodied species in the Athabasca River (trout-perch) and the tributaries (slimy sculpin) facilitated selection of reference sites within the Oil Sands Region, as well as exposed sites in close proximity to mining activities. For example, the reference site for trout-perch was located within the oil sands region yet upstream of the mining influences; whereas the reference site used for longnose sucker in 1998 was located beyond the oil sands influence. The sampling design for the trout-perch provides a better assessment of the potential effects specific to mining activities; whereas, the study of longnose sucker could not separate the combined influences of the oil sands formation, mining activities and the town of Fort McMurray.

The 1999 field program demonstrated that adequate numbers of small-bodied sentinel fish could be collected in the Athabasca River and the tributaries. For both female and male trout-perch, sufficient sample sizes were collected from each site to detect at least a 30% difference among sites, and in some cases a 20% difference. Slimy sculpin was selected as the sentinel species on the Muskeg and Steepbank rivers. Power analysis confirmed that sample sizes were adequate to detect site differences in most parameters; however, more effort is needed to collect higher numbers of males and additional reference sites are needed to ensure the full range of natural variability in fish characteristics within the Oil Sands Region.

Overall, there were few differences in whole organism characteristics of trout-perch among the three study sites on the Athabasca River. There was no evidence indicating that trout-perch collected downstream of Suncor's discharge were different from reference fish. With the exception of a possible reduction in energy storage, trout-perch downstream of the Muskeg River were also similar to fish collected at the reference site and below the other exposed site. Power analysis confirmed that sample sizes were adequate to detect site differences in fish parameters had they existed. One of the major achievements in 1999, is that the studies have verified that RAMP now has an assessment tool in the form of this small-bodied fish, that has more precision (i.e., it can separate mining effects from general oil sands effects) and statistical strength (i.e., it can identify differences if they are present) than the tool used before.

In 1999, a long-term acidification monitoring network was established, which forms a new component of RAMP. The objective of this component is to monitor lake water chemistry as an early-warning indicator of excessive acidic deposition. During 1999, the 32 lakes forming the network were selected from a large number of candidate lakes. A field program was implemented to collect baseline water chemistry data and to verify that the lake selection criteria were satisfied by the candidate lakes. The 1999 data indicate that most of the selected lakes were moderately to highly acid-sensitive and provided a reasonable cross-section of the wide range of water chemistry in north-eastern Alberta. Thus, no major modifications are required to this component in the near-future, though it is expected to evolve as new information and needs dictate.

# 10 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

Respectfully submitted,

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# 12 GLOSSARY AND LIST OF ACRONYMS

## 12.1 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. |
| 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. |
| 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). |
| 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. |
| 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. |
| $m^3/s$ | 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., $CaCo_3$). |

| | |
|---|---|
| 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. |
| 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. |

## 12.2 LIST OF ACRONYMS

| | |
|---|---|
| µg/kg | microgram/kilogram |
| µS/cm | micro Siemans/centimetre |
| ACFN | Athabasca Chipewyan First Nation |
| AENV | Alberta Environment |
| AEP | Alberta Environmental Protection |
| Al-Pac | Alberta Pacific Forest Industries Inc. |
| ANCOVA | Analysis of covariance |
| ANOVA | Analysis of variance |
| AOSERP | Alberta Oil Sands Environmental Research Program |
| ARCV | Alberta Research Council-Vegreville |
| ATC | Alberta Tribal Council |
| AXYS | AXYS Analytical Services Ltd. |
| CCME | Canadian Council of Ministers of the Environment |
| CPUE | Catch-per-unit-effort |
| DFO | Department of Fisheries and Oceans |
| DO | Dissolved oxygen |
| DOC | Dissolved organic carbon |
| D/S | Downstream |
| EEM | Environmental Effects Monitoring |

| | |
|---|---|
| EIA | Environmental Impact Assessment |
| ETL | Enviro-Test Laboratories |
| EUB | Alberta Energy and Utilities Board |
| GPS | Global Positioning System |
| IRC | Industry Relations Corporation |
| ISQG | Interim Freshwater Sediment Quality Guidelines |
| KIR | Key Indicator Resource |
| km | kilometre |
| m | metre |
| $m^3/s$ | cubic metres per second |
| MDL | Method detection limit |
| MFO | Mixed function oxygenase |
| mg/kg | milligram/kilogram |
| mg/L | milligram/litre |
| MSE | Mean Squared Error |
| NRBS | Northern Rivers Basins Program |
| NREI | Northern Rivers Ecosystem Initiative |
| PAH | Polycyclic aromatic hydrocarbons |
| PEL | Probable Effect Level |
| PERD | Environment Canada’s Program on Energy Research and Development |
| QA/QC | Quality assurance/Quality control |
| RAMP | Regional Aquatics Monitoring Program |
| SR | Studentized Residuals |
| T.C.U. | True colour units |
| TDS | Total dissolved solids |
| TOR | Terms of Reference |
| TSS | Total suspended solids |
| U/S | Upstream |
| U.S. EPA | United States Environmental Protection Agency |
| UTM | Universal Transverse Mercator |
| WBEA | Wood Buffalo Environmental Association |
| Yr | Year |

# APPENDIX I

# LABORATORY 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 |

| Parameter | Units | Detection Limits | Analytical Methods[a] |
|---|---|---|---|
| manganese (Mn) | µg/L | 0.2 | SW6010 |
| 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. |

**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

# WATER QUALITY DATA

**Table II-1. Water Quality in the Athabasca River**

| Parameter | Units | Near the Embarras River (Winter) | | | | | Athabasca River Delta (Summer) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1977-1996)[a] | | | | | Historical (1977-1987)[b] | | | |
| | | 1999 | median | min | max | count | 1999 | median | min | max | count |
| **Field measured** | | | | | | | | | | | |
| pH | | 8.2 | 7.4 | 6.6 | 7.9 | 9 | 8.2 | 7.7 | 7.3 | 8.7 | 5 |
| Specific Conductance | µS/cm | 473 | 459 | 150 | 1500 | 14 | 255 | 240 | 13 | 3000 | 15 |
| Temperature | $^{o}C$ | 0.1 | 0.0 | -0.3 | 0.4 | 21 | - | 17.8 | 9.0 | 21.2 | 21 |
| Dissolved Oxygen | mg/L | 13.5 | 10.7 | 3.0 | 12.0 | 12 | - | 8.6 | 4.7 | 9.7 | 16 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 182 | 177 | 168 | 250 | 11 | 129 | 117 | 108 | 126 | 3 |
| Calcium | mg/L | 47 | 42 | 38 | 106 | 31 | 31 | 28 | 25 | 34 | 20 |
| Carbonate (CO3) | mg/L | < 5 | < 0.5 | < 0.5 | < 0.5 | 1 | < 5 | - | - | - | - |
| Chloride | mg/L | 38 | 32 | 22 | 150 | 32 | 6 | 6 | 5 | 17 | 20 |
| Colour | T.C.U. | 18 | 15 | < 5 | 32 | 24 | 40 | 30 | 15 | 60 | 9 |
| Conductance | µS/cm | 518 | 445 | 350 | 1205 | 31 | 255 | 238 | 187 | 300 | 20 |
| Dissolved Organic Carbon | mg/L | 5 | 7 | 5 | 30 | 24 | 5 | 8 | 2 | 32 | 14 |
| Hardness | mg/L | 171 | 154 | 139 | 372 | 13 | 139 | 100 | 88 | 110 | 6 |
| Magnesium | mg/L | 13 | 12 | 10 | 27 | 31 | 8 | 7 | 6 | 9 | 20 |
| pH | | 7.6 | 7.7 | 7.2 | 8.3 | 32 | 8.2 | 7.9 | 7.4 | 8.3 | 20 |
| Potassium | mg/L | 1.7 | 1.5 | 0.1 | 7.1 | 30 | 0.8 | 1.0 | 0.8 | 1.4 | 17 |
| Sodium | mg/L | 40 | 30 | 21 | 121 | 32 | 7 | 9 | 7 | 14 | 20 |
| Sulphate | mg/L | 46 | 33 | 22 | 186 | 32 | 23 | 17 | 11 | 26 | 20 |
| Sulphide | mg/L | < 0.003 | - | - | - | - | < 0.003 | - | - | - | - |
| Total Alkalinity | mg/L | 149 | 144 | 125 | 242 | 32 | 105 | 93 | 79 | 119 | 21 |
| Total Dissolved Solids | mg/L | 300 | 265 | 220 | 722 | 31 | 190 | 141 | 118 | 170 | 20 |
| Total Organic Carbon | mg/L | 6 | 8 | 5 | 20 | 23 | 6 | 10 | 2 | 36 | 18 |
| Total Suspended Solids | mg/L | 5 | 4 | < 0.4 | 206 | 34 | 157 | 92 | 13 | 1374 | 23 |
| **Nutrients and Chlorophyll *a*** | | | | | | | | | | | |
| Nitrate + Nitrite | mg/L | 0.3 | 0.2 | 0.2 | 0.6 | 3 | < 0.1 | - | - | - | - |
| Nitrogen - Ammonia | mg/L | 0.08 | 0.05 | 0.03 | 0.07 | 6 | < 0.05 | - | - | - | - |
| Nitrogen - Kjeldahl | mg/L | 0.5 | 0.6 | 0.4 | 1.2 | 17 | 0.7 | 0.6 | 0.3 | 1.0 | 12 |
| Phosphorus, Total | µg/L | 34 | 32 | 21 | 410 | 29 | 103 | 89 | 26 | 930 | 24 |
| Phosphorus,Total Dissolved | µg/L | 16 | 18 | 12 | 24 | 7 | 6 | - | - | - | - |
| Chlorophyll *a* | µg/L | 0 | 0.3 | 0.2 | 0.4 | 7 | 7 | 1 | < 1 | 8 | 6 |
| **Biochemical Oxygen Demand** | | | | | | | | | | | |
| Biochemical Oxygen Demand | mg/L | < 2 | 0.6 | < 0.1 | 2 | 9 | < 2 | - | - | - | - |
| **Toxicity** | | | | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | - | - | - | - | > 91 | - | - | - | - |
| Microtox IC25 @ 15 min | % | > 91 | - | - | - | - | > 91 | - | - | - | - |
| **Organics** | | | | | | | | | | | |
| Naphthenic acids | mg/L | < 1 | - | - | - | - | < 1 | - | - | - | - |
| Total Phenolics | µg/L | 2 | 4 | < 1 | 24 | 11 | < 1 | 3 | 3 | 6 | 3 |
| Total Recoverable Hydrocarbons | mg/L | < 0.5 | - | - | - | - | < 0.5 | - | - | - | - |
| **Metals (Total)** | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 300 | 70 | < 10 | 480 | 30 | 6890 | 600 | 50 | 3400 | 15 |
| Antimony (Sb) | µg/L | < 0.8 | - | - | - | - | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 1 | 0.4 | 0.3 | 0.6 | 11 | 2 | 1.4 | 0.6 | 1.5 | 3 |
| Barium (Ba) | µg/L | 65 | 66 | 58 | 70 | 10 | 122 | 61 | 54 | 71 | 3 |
| Beryllium (Be) | µg/L | < 1 | < 1 | < 1 | < 1 | 1 | < 1 | - | - | - | - |
| Boron (B) | µg/L | 35 | - | - | - | - | 18 | - | - | - | - |
| Cadmium (Cd) | µg/L | < 0.2 | 0 | < 1 | 2 | 10 | < 0.2 | < 1 | < 1 | < 1 | 3 |
| Calcium (Ca) | µg/L | 50100 | - | - | - | - | 34300 | - | - | - | - |
| Chromium (Cr) | µg/L | 4 | 2 | < 1 | 6 | 10 | 8 | 3 | 3 | 4 | 3 |
| Cobalt (Co) | µg/L | 0.5 | < 1 | < 1 | 3 | 10 | 2 | < 1 | < 1 | 2 | 3 |
| Copper (Cu) | µg/L | 2 | 1 | < 1 | 3 | 10 | 5 | 3 | 3 | 4 | 3 |
| Iron (Fe) | µg/L | 600 | 556 | 421 | 605 | 9 | 4560 | - | - | - | - |
| Lead (Pb) | µg/L | 0.4 | - | - | - | - | 2.2 | - | - | - | - |
| Lithium (Li) | µg/L | 13 | - | - | - | - | 10 | - | - | - | - |
| Magnesium (Mg) | µg/L | 19020 | - | - | - | - | 9790 | - | - | - | - |
| Manganese (Mn) | µg/L | 39 | - | - | - | - | < 127 | - | - | - | - |

**Table II-1. Water Quality in the Athabasca River**

| Parameter | Units | Near the Embarras River (Winter) | | | | | Athabasca River Delta (Summer) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1977-1996)[a] | | | | | Historical (1977-1987)[b] | | | |
| | | 1999 | median | min | max | count | 1999 | median | min | max | count |
| Mercury (Hg) | μg/L | < 0.2 | < 0.1 | < 0.1 | 0.8 | 32 | < 0.2 | < 0.1 | < 0.1 | 0.3 | 20 |
| Molybdenum (Mo) | μg/L | 1.8 | - | - | - | - | 1.1 | - | - | - | - |
| Nickel (Ni) | μg/L | 4.2 | - | - | - | - | 6.3 | - | - | - | - |
| Potassium (K) | μg/L | 2120 | - | - | - | - | 2350 | - | - | - | - |
| Selenium (Se) | μg/L | < 0.8 | < 0.1 | < 0.1 | < 0.2 | 11 | < 0.8 | < 0.2 | < 0.2 | < 0.2 | 3 |
| Silver (Ag) | μg/L | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - |
| Sodium (Na) | μg/L | 47800 | - | - | - | - | 7700 | - | - | - | - |
| Strontium (Sr) | μg/L | 300 | - | - | - | - | 240 | - | - | - | - |
| Titanium (Ti) | μg/L | 7 | < 10 | < 10 | < 50 | 8 | 141 | - | - | - | - |
| Uranium (U) | μg/L | 0.6 | - | - | - | - | 0.6 | - | - | - | - |
| Vanadium (V) | μg/L | 2 | < 2 | < 2 | < 2 | 1 | 17 | - | - | - | - |
| Zinc (Zn) | μg/L | 18 | 4 | < 1 | 12 | 11 | 17 | 9 | 4 | 13 | 3 |
| **Metals (Dissolved)** | | | | | | | | | | | |
| Aluminum (Al) | μg/L | 100 | - | - | - | - | < 10 | - | - | - | - |
| Antimony (Sb) | μg/L | 0.8 | - | - | - | - | < 0.8 | - | - | - | - |
| Arsenic (As) | μg/L | < 0.4 | 0.5 | < 0.2 | 10 | 15 | 0.6 | 0.9 | 0.2 | 6.1 | 16 |
| Barium (Ba) | μg/L | 63 | - | - | - | - | 52 | - | - | - | - |
| Beryllium (Be) | μg/L | < 0.5 | < 1 | < 1 | < 1 | 9 | < 0.5 | < 1 | < 1 | < 1 | 3 |
| Boron (B) | μg/L | 3 | 50 | < 20 | 60 | 11 | 11 | 30 | 10 | 60 | 5 |
| Cadmium (Cd) | μg/L | 0.3 | - | - | - | - | < 0.1 | - | - | - | - |
| Chromium (Cr) | μg/L | < 0.4 | < 3 | < 1 | 5 | 13 | < 0.4 | < 3 | < 3 | 6 | 10 |
| Cobalt (Co) | μg/L | 0.2 | - | - | - | - | < 0.1 | - | - | - | - |
| Copper (Cu) | μg/L | 1.6 | - | - | - | - | 1.5 | - | - | - | - |
| Iron (Fe) | μg/L | 130 | - | - | - | - | 150 | - | - | - | - |
| Lead (Pb) | μg/L | 0.6 | - | - | - | - | < 0.1 | - | - | - | - |
| Lithium (Li) | μg/L | 9 | - | - | - | - | 4 | - | - | - | - |
| Manganese (Mn) | μg/L | 32.6 | - | - | - | - | < 10.3 | - | - | - | - |
| Mercury (Hg) | μg/L | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - |
| Molybdenum (Mo) | μg/L | 1.9 | - | - | - | - | 0.1 | - | - | - | - |
| Nickel (Ni) | μg/L | 2.4 | - | - | - | - | 1.1 | - | - | - | - |
| Selenium (Se) | μg/L | < 0.4 | < 0.2 | < 0.2 | 0.3 | 8 | < 0.4 | < 0.2 | < 0.2 | 0.8 | 11 |
| Silver (Ag) | μg/L | < 0.2 | - | - | - | - | < 0.2 | - | - | - | - |
| Strontium (Sr) | μg/L | 322 | - | - | - | - | 191 | - | - | - | - |
| Titanium (Ti) | μg/L | 0.8 | - | - | - | - | 1.8 | - | - | - | - |
| Uranium (U) | μg/L | 0.6 | - | - | - | - | 0.5 | - | - | - | - |
| Vanadium (V) | μg/L | 0.2 | - | - | - | - | < 0.1 | - | - | - | - |
| Zinc (Zn) | μg/L | 12 | - | - | - | - | 3 | - | - | - | - |

[a] Based on information from NAQUADAT stations AB07DD0004/006/007/008.

[b] Based on information from NAQUADAT stations AB07DD0160/170/220/230/240.

**Table II-2. Water Quality in McLean Creek and the Steepbank River**

| Parameter | Units | McLean Creek (Fall) | | | Steepbank River (Winter) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Historical (1989-1997)[c] | | | |
| | | 1999 | 1998[a] | 1995[b] | 1999 | median | min | max | n |
| **Field measured** | | | | | | | | | |
| pH | | 7.1 | 8.3 | 8.0 | 7.7 | - | 7.7 | 8.4 | 2 |
| Specific Conductance | µS/cm | 658 | 650 | 307 | 572 | - | 413 | 548 | 2 |
| Temperature | °C | 10.8 | 4 | - | 0.1 | 0.3 | 0.2 | 0.5 | 4 |
| Dissolved Oxygen | mg/L | 13.4 | 8.5 | - | 10.5 | 13.3 | 12.7 | 13.8 | 4 |
| **Conventional Parameters and Major Ions** | | | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 305 | 238 | 162 | 417 | - | 371 | 378 | 2 |
| Calcium | mg/L | 60 | 56 | 39 | 73 | 62 | 61 | 64 | 3 |
| Carbonate (CO3) | mg/L | < 5 | < 5 | < 0.5 | < 5 | < 0.5 | < 0.5 | < 5 | 3 |
| Chloride | mg/L | 165 | 73 | 11 | 6 | 7 | 7 | 8 | 5 |
| Colour | T.C.U. | 50 | 80 | - | 20 | 35 | 20 | 95 | 5 |
| Conductance | µS/cm | 1000 | 664 | 307 | 689 | 595 | 588 | 610 | 3 |
| Dissolved Organic Carbon | mg/L | 14 | 13 | 21 | 8 | 11 | 9 | 13 | 5 |
| Hardness | mg/L | 219 | 199 | 142 | 280 | 244 | 229 | 265 | 4 |
| Magnesium | mg/L | 17 | 15 | 11 | 24 | 20 | 19 | 22 | 3 |
| pH | | 8.3 | 8.1 | 8.0 | 7.6 | 7.9 | 7.8 | 8.2 | 4 |
| Potassium | mg/L | 2 | 2 | 1 | 3 | 2 | 2 | 2 | 4 |
| Sodium | mg/L | 140 | 68 | 14 | 50 | 42 | 40 | 46 | 5 |
| Sulphate | mg/L | 56 | 38 | 11 | 17 | 12 | 10 | 14 | 5 |
| Sulphide | µg/L | 4 | < 2 | - | < 3 | - | < 2 | < 5 | 2 |
| Total Alkalinity | mg/L | 251 | 195 | 133 | 342 | 314 | 304 | 330 | 4 |
| Total Dissolved Solids | mg/L | 620 | 440 | 167 | 390 | - | 350 | 357 | 2 |
| Total Organic Carbon | mg/L | 15 | 16 | - | 9 | 11 | 11 | 13 | 3 |
| Total Suspended Solids | mg/L | 5 | 13 | 1 | < 3 | 3 | < 0.4 | 4 | 5 |
| **Nutrients and Chlorophyll *a*** | | | | | | | | | |
| Nitrate + Nitrite | mg/L | < 1 | 0.05 | 0.004 | 0.2 | 0.35 | 0.33 | 0.36 | 3 |
| Nitrogen - Ammonia | mg/L | < 0.05 | < 0.05 | < 0.01 | 0.06 | 0.04 | 0.03 | 0.06 | 5 |
| Nitrogen - Kjeldahl | mg/L | 0.4 | 0.7 | - | 0.5 | 0.6 | 0.29 | 0.9 | 5 |
| Phosphorus, Total | µg/L | 15 | 12 | 42 | 10 | - | 41 | 50 | 2 |
| Phosphorus,Total Dissolved | µg/L | 5 | 6 | - | 5 | - | 8 | < 20 | 2 |
| Chlorophyll *a* | µg/L | - | 2 | - | 0 | 0.2 | - | - | 1 |
| **Biochemical Oxygen Demand** | | | | | | | | | |
| Biochemical Oxygen Demand | mg/L | 4 | < 2 | - | < 2 | 0.8 | 0.2 | 1 | 5 |
| **Toxicity** | | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | > 91 | > 100 | > 91 | > 91 | - | - | 1 |
| Microtox IC25 @ 15 min | % | > 91 | > 91 | > 100 | > 91 | > 91 | - | - | 1 |
| Algal Growth Inhibition Test (72 h) - IC25 | % | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - IC50 | % | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - LOE | % | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - NOE | % | - | - | - | 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LC25 | % | - | - | - | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LC50 | % | - | - | - | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LOEC | % | - | - | - | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - NOEC | % | - | - | - | 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC25 | % | - | - | - | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC50 | % | - | - | - | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - LOE | % | - | - | - | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - NOE | % | - | - | - | 100 | - | - | - | - |
| Fathead Minnow 7d Growth - IC25 | % | - | - | - | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - IC50 | % | - | - | - | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - LOEC | % | - | - | - | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - NOEC | % | - | - | - | 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LC25 | % | - | - | - | > 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LC50 | % | - | - | - | > 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LOEC | % | - | - | - | > 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - NOEC | % | - | - | - | 100 | - | - | - | - |
| **Organics** | | | | | | | | | |
| Naphthenic acids | mg/L | 2 | < 1 | < 1 | < 1 | 2 | - | - | 1 |
| Total Phenolics | µg/L | < 1 | 2 | < 1 | 2 | 3 | < 1 | 5 | 4 |
| Total Recoverable Hydrocarbons | mg/L | < 0.5 | < 0.5 | < 1 | < 0.5 | < 1 | - | - | 1 |
| **Metals (Total)** | | | | | | | | | |
| Aluminum (Al) | µg/L | 330 | 560 | 60 | 90 | 40 | 13 | 131 | 4 |

**Table II-2. Water Quality in McLean Creek and the Steepbank River**

| Parameter | Units | McLean Creek (Fall) | | | Steepbank River (Winter) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Historical (1989-1997)[c] | | | |
| | | 1999 | 1998[a] | 1995[b] | 1999 | median | min | max | n |
| Antimony (Sb) | µg/L | < 0.8 | < 0.8 | < 0.2 | 1.1 | < 0.4 | - | - | 1 |
| Arsenic (As) | µg/L | < 1 | < 1 | 0.8 | < 1 | 0.3 | < 0.2 | 0.6 | 4 |
| Barium (Ba) | µg/L | 55 | 39 | 20 | 103 | 75 | 70 | 80 | 4 |
| Beryllium (Be) | µg/L | < 1 | < 1 | < 1 | < 1 | - | < 1 | < 1 | 2 |
| Boron (B) | µg/L | 201 | 74 | 80 | 343 | - | 240 | 284 | 2 |
| Cadmium (Cd) | µg/L | < 0.2 | < 0.2 | 3 | < 0.2 | < 0.2 | < 0.2 | 2 | 3 |
| Calcium (Ca) | µg/L | 60700 | 54900 | - | 69200 | 63200 | - | - | 1 |
| Chromium (Cr) | µg/L | 1.6 | 1.1 | < 2 | 3.2 | - | < 0.4 | 5 | 2 |
| Cobalt (Co) | µg/L | 0.4 | 0.5 | < 3 | < 0.2 | - | < 0.5 | 1 | 2 |
| Copper (Cu) | µg/L | 4 | 1.5 | - | 2 | - | 2 | 2 | 2 |
| Iron (Fe) | µg/L | 660 | 920 | 410 | 170 | 905 | 610 | 1110 | 4 |
| Lead (Pb) | µg/L | 0.2 | 1 | < 20 | 0.3 | - | < 0.3 | 3.3 | 2 |
| Lithium (Li) | µg/L | 32 | 20 | 7 | 31 | - | 23 | 27 | 2 |
| Magnesium (Mg) | µg/L | 19900 | 14200 | - | 23220 | 20800 | - | - | 1 |
| Manganese (Mn) | µg/L | 64 | 68 | 20 | 22 | - | 16 | 21 | 2 |
| Mercury (Hg) | µg/L | < 0.2 | < 0.2 | < 0.05 | < 0.2 | < 0.15 | < 0.05 | < 50 | 4 |
| Molybdenum (Mo) | µg/L | 0.5 | 0.2 | 4 | 0.6 | - | 0.6 | < 3 | 2 |
| Nickel (Ni) | µg/L | 2.5 | 4.5 | < 5 | 3.7 | - | < 0.5 | 1.5 | 2 |
| Potassium (K) | µg/L | 2430 | 1840 | - | 1830 | 2010 | - | - | 1 |
| Selenium (Se) | µg/L | < 0.8 | < 0.8 | < 0.2 | < 0.8 | < 0.2 | < 0.1 | < 0.4 | 4 |
| Silver (Ag) | µg/L | < 0.4 | < 0.4 | < 2 | < 0.4 | - | < 0.1 | < 1 | 2 |
| Sodium (Na) | µg/L | 188000 | 66350 | - | 50600 | 45600 | - | - | 1 |
| Strontium (Sr) | µg/L | 266 | 193 | 96 | 316 | - | 258 | 291 | 2 |
| Titanium (Ti) | µg/L | 8 | 8 | 7 | 2 | 5 | - | - | 1 |
| Uranium (U) | µg/L | 0.4 | 0.2 | - | 0.2 | 0.2 | - | - | 1 |
| Vanadium (V) | µg/L | 0.9 | 1.4 | < 2 | < 0.2 | < 2 | 0.5 | < 2 | 3 |
| Zinc (Zn) | µg/L | 17 | 10 | 24 | 10 | 67 | 12 | 160 | 3 |
| **Metals (Dissolved)** | | | | | | | | | |
| Aluminum (Al) | µg/L | 10 | 45 | - | 20 | 5.8 | - | - | 1 |
| Antimony (Sb) | µg/L | < 0.8 | 0.8 | - | 1 | < 0.4 | - | - | 1 |
| Arsenic (As) | µg/L | 1 | < 0.4 | - | < 0.4 | < 0.4 | - | - | 1 |
| Barium (Ba) | µg/L | 44 | 36 | - | 95 | 70 | - | - | 1 |
| Beryllium (Be) | µg/L | < 0.5 | < 0.5 | - | < 0.5 | - | < 0.5 | < 1 | 2 |
| Boron (B) | µg/L | 150 | 76 | - | 336 | 265 | - | - | 1 |
| Cadmium (Cd) | µg/L | < 0.1 | < 0.1 | - | < 0.1 | < 0.1 | - | - | 1 |
| Chromium (Cr) | µg/L | 1.2 | < 0.4 | - | < 0.4 | < 0.4 | - | - | 1 |
| Cobalt (Co) | µg/L | 0.3 | 0.4 | - | 0.2 | 0.1 | - | - | 1 |
| Copper (Cu) | µg/L | 3.0 | 1.1 | - | 1.0 | 0.8 | - | - | 1 |
| Iron (Fe) | µg/L | 250 | 460 | - | 200 | < 10 | - | - | 1 |
| Lead (Pb) | µg/L | < 0.1 | 0.3 | - | 0.2 | 0.2 | - | - | 1 |
| Lithium (Li) | µg/L | 34 | - | - | 34 | 24 | - | - | 1 |
| Manganese (Mn) | µg/L | 22 | 64 | - | 18 | 0.3 | - | - | 1 |
| Mercury (Hg) | µg/L | < 0.1 | < 0.1 | - | < 0.1 | < 0.2 | - | - | 1 |
| Molybdenum (Mo) | µg/L | 0.4 | 0.2 | - | 0.7 | 0.51 | - | - | 1 |
| Nickel (Ni) | µg/L | 2.7 | 3.6 | - | 2.4 | 0.6 | - | - | 1 |
| Selenium (Se) | µg/L | < 0.4 | < 0.4 | - | < 0.4 | < 0.4 | - | - | 1 |
| Silver (Ag) | µg/L | < 0.2 | < 0.2 | - | < 0.2 | < 0.2 | - | - | 1 |
| Strontium (Sr) | µg/L | 263 | 184 | - | 331 | 239 | - | - | 1 |
| Titanium (Ti) | µg/L | 0.9 | 1.8 | - | 1.5 | 0.4 | - | - | 1 |
| Uranium (U) | µg/L | 0.3 | 0.2 | - | 0.2 | 0.2 | - | - | 1 |
| Vanadium (V) | µg/L | 0.9 | < 0.1 | - | < 0.1 | < 0.1 | - | - | 1 |
| Zinc (Zn) | µg/L | 3 | 3 | - | 4 | 6 | - | - | 1 |

[a] Based on unpublished data from Suncor Energy Inc.

[b] Based on information from Golder (1996a).

[c] Based on information from Golder (1998a) and NAQUADAT station AB07DA0260.

**Table II-3. Water Quality in Shipyard Lake**

| Parameter | Units | Shipyard Lake | | | | | |
|---|---|---|---|---|---|---|---|
| | | Spring | | Summer | | | Fall |
| | | 1999 | 1995[(a)] | 1999 | 1998[(b)] | 1995[(a)] | 1999 |
| **Field measured** | | | | | | | |
| pH | | 8.0 | 6.9 | 8.9 | 7.5 | 7.4 | 8.7 |
| Specific Conductance | µS/cm | 314 | 241 | 264 | 329 | 274 | 333 |
| Temperature | $^oC$ | 10.9 | - | 22.8 | - | - | 2.2 |
| Dissolved Oxygen | mg/L | 7.8 | - | 14.0 | - | - | 8.2 |
| **Conventional Parameters and Major Ions** | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 186 | 133 | 131 | 196 | 165 | 201 |
| Calcium | mg/L | 41 | 33 | 32 | 44 | 41 | 42 |
| Carbonate (CO3) | mg/L | < 5 | < 5 | 16 | < 5 | < 5 | < 5 |
| Chloride | mg/L | 9.0 | 5.8 | 8.0 | 8.0 | 4.8 | 11 |
| Colour | T.C.U. | 30 | - | 40 | 80 | - | 30 |
| Conductance | µS/cm | 334 | 241 | 275 | 329 | 274 | 358 |
| Dissolved Organic Carbon | mg/L | 16 | - | 16 | 16 | - | 17 |
| Hardness | mg/L | 142 | 112 | 120 | 149 | 135 | 152 |
| Magnesium | mg/L | 10 | 7 | 10 | 10 | 8 | 11 |
| pH | | 8.0 | 6.9 | 8.9 | 7.5 | 7.4 | 8.1 |
| Potassium | mg/L | 1.5 | - | 0.5 | 0.8 | 0.8 | 1 |
| Sodium | mg/L | 12 | - | 13 | 12 | 9 | 16 |
| Sulphate | mg/L | 5 | 4 | 4 | 3 | 2 | 6 |
| Sulphide | µg/L | 3 | < 5 | < 3 | < 2 | < 5 | 5 |
| Total Alkalinity | mg/L | 152 | 109 | 134 | 161 | 135 | 165 |
| Total Dissolved Solids | mg/L | 220 | - | 220 | 386 | 147 | 240 |
| Total Organic Carbon | mg/L | 18 | 18 | 18 | 22 | 24 | 19 |
| Total Suspended Solids | mg/L | < 3 | 155 | 4 | 11 | 180 | 5 |
| **Nutrients and Chlorophyll *a*** | | | | | | | |
| Nitrate + Nitrite | mg/L | < 0.1 | 0.01 | 0.1 | < 0.05 | 0.02 | < 0.1 |
| Nitrogen - Ammonia | mg/L | < 0.05 | < 0.01 | < 0.05 | 0.06 | 0.09 | < 0.05 |
| Nitrogen - Kjeldahl | mg/L | 0.9 | 0.7 | 0.8 | 0.9 | 0.5 | 0.8 |
| Phosphorus, Total | µg/L | 19 | 31 | 12 | 29 | 34 | 17 |
| Phosphorus,Total Dissolved | µg/L | 14 | 19 | 4 | 24 | 15 | 7 |
| Chlorophyll *a* | µg/L | - | - | 3 | 6 | - | - |
| **Biochemical Oxygen Demand** | | | | | | | |
| Biochemical Oxygen Demand | mg/L | 3 | - | 3 | 2 | - | < 2 |
| **Toxicity** | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | - | > 91 | >91 | > 100 | > 91 |
| Microtox IC25 @ 15 min | % | > 91 | - | > 91 | >91 | > 100 | > 91 |
| **Organics** | | | | | | | |
| Naphthenic acids | mg/L | < 1 | - | < 1 | < 1 | < 1 | < 1 |
| Total Phenolics | µg/L | 7 | - | 2 | 3 | - | 6 |
| Total Recoverable Hydrocarbons | mg/L | < 0.5 | - | < 0.5 | < 0.5 | < 1 | < 0.5 |
| **Metals (Total)** | | | | | | | |
| Aluminum (Al) | µg/L | 30 | 20 | 70 | 30 | 50 | 30 |
| Antimony (Sb) | µg/L | < 0.8 | - | < 0.8 | < 0.8 | 0.2 | < 0.8 |
| Arsenic (As) | µg/L | < 1 | 0.2 | < 1 | < 1 | < 1 | < 1 |
| Barium (Ba) | µg/L | 34 | 20 | 22 | 35 | 30 | 27 |
| Beryllium (Be) | µg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 |
| Boron (B) | µg/L | < 4 | 40 | 34 | 42 | 30 | 27 |
| Cadmium (Cd) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 3 | < 0.2 |
| Calcium (Ca) | µg/L | 36600 | 35100 | 32200 | 49600 | - | 43200 |
| Chromium (Cr) | µg/L | < 0.8 | 7.0 | < 0.8 | < 0.8 | 9.0 | 1.5 |

**Table II-3. Water Quality in Shipyard Lake**

| Parameter | Units | Shipyard Lake | | | | | |
|---|---|---|---|---|---|---|---|
| | | Spring | | Summer | | | Fall |
| | | 1999 | 1995[a] | 1999 | 1998[b] | 1995[a] | 1999 |
| Cobalt (Co) | µg/L | < 0.2 | 0.6 | < 0.2 | < 0.2 | < 3 | < 0.2 |
| Copper (Cu) | µg/L | < 1 | 1 | 1 | < 1 | - | < 1 |
| Iron (Fe) | µg/L | 250 | 1150 | 220 | 2090 | 2650 | 270 |
| Lead (Pb) | µg/L | 0.4 | 1.0 | 0.1 | 0.3 | < 20 | < 0.1 |
| Lithium (Li) | µg/L | 9 | 5 | 10 | 9 | 7 | 11 |
| Magnesium (Mg) | µg/L | 8040 | 7740 | 9830 | 9550 | - | 11300 |
| Manganese (Mn) | µg/L | 24 | 46 | < 127 | 98 | 180 | 15 |
| Mercury (Hg) | µg/L | < 0.2 | < 50 | < 0.2 | < 0.2 | < 50 | < 0.2 |
| Molybdenum (Mo) | µg/L | 0.4 | < 3 | 0.1 | < 0.1 | < 3 | 0.2 |
| Nickel (Ni) | µg/L | 1 | 11 | 1 | 1 | 10 | 2 |
| Potassium (K) | µg/L | 1200 | 1780 | 530 | 800 | - | 1140 |
| Selenium (Se) | µg/L | < 0.8 | < 0.2 | < 0.8 | < 0.8 | < 1 | < 0.8 |
| Silver (Ag) | µg/L | < 0.4 | 1.1 | < 0.4 | < 0.4 | < 2 | < 0.4 |
| Sodium (Na) | µg/L | 11600 | 8400 | 11500 | 14500 | - | 14200 |
| Strontium (Sr) | µg/L | 128 | 83 | 113 | 132 | 116 | 133 |
| Titanium (Ti) | µg/L | 1 | < 3 | < 0.6 | < 0.6 | 20 | 1 |
| Uranium (U) | µg/L | < 0.1 | < 0.4 | < 0.1 | < 0.1 | - | < 0.1 |
| Vanadium (V) | µg/L | < 0.2 | < 2 | 0.2 | < 0.2 | < 2 | 0.2 |
| Zinc (Zn) | µg/L | 7 | 17 | 12 | < 4 | 13 | < 4 |
| **Metals (Dissolved)** | | | | | | | |
| Aluminum (Al) | µg/L | 10 | - | 10 | 60 | - | < 10 |
| Antimony (Sb) | µg/L | < 0.8 | - | < 0.8 | < 0.8 | - | < 0.8 |
| Arsenic (As) | µg/L | < 0.4 | - | 1.3 | 0.5 | - | < 0.4 |
| Barium (Ba) | µg/L | 31 | - | 17 | 33 | - | 28 |
| Beryllium (Be) | µg/L | < 0.5 | - | < 0.5 | < 0.5 | - | < 0.5 |
| Boron (B) | µg/L | 3 | - | 35 | 33 | - | 26 |
| Cadmium (Cd) | µg/L | < 0.1 | - | < 0.1 | 0.1 | - | < 0.1 |
| Chromium (Cr) | µg/L | 0.4 | - | < 0.4 | < 0.4 | - | 0.8 |
| Cobalt (Co) | µg/L | 0.1 | - | 0.1 | < 0.1 | - | 0.1 |
| Copper (Cu) | µg/L | 0.9 | - | 1.6 | 0.6 | - | 0.9 |
| Iron (Fe) | µg/L | 140 | - | 130 | 1480 | - | 220 |
| Lead (Pb) | µg/L | 0.2 | - | 0.2 | 0.1 | - | < 0.1 |
| Lithium (Li) | µg/L | 8 | - | 10 | 7 | - | 11 |
| Manganese (Mn) | µg/L | 15 | - | 1 | 102 | - | 3 |
| Mercury (Hg) | µg/L | 0.1 | - | 0.2 | < 0.1 | - | 0.03 |
| Molybdenum (Mo) | µg/L | 0.4 | - | < 0.9 | < 0.1 | - | 0.2 |
| Nickel (Ni) | µg/L | 0.7 | - | 0.5 | 0.3 | - | 1.8 |
| Selenium (Se) | µg/L | < 0.4 | - | < 0.4 | < 0.4 | - | < 0.4 |
| Silver (Ag) | µg/L | < 0.2 | - | < 0.2 | < 0.2 | - | < 0.2 |
| Strontium (Sr) | µg/L | 124 | - | 112 | 131 | - | 135 |
| Titanium (Ti) | µg/L | 0.9 | - | < 0.3 | < 0.3 | - | 0.4 |
| Uranium (U) | µg/L | < 0.1 | - | < 0.1 | < 0.1 | - | 0.3 |
| Vanadium (V) | µg/L | 0.2 | - | 0.2 | < 0.1 | - | 0.1 |
| Zinc (Zn) | µg/L | 8 | - | < 2 | < 2 | - | 3 |

[a] Based on information from Golder (1996a).

[b] Based on information from Golder (1999a).

**Table II-4. Water Quality in the Muskeg River: Sample Stations MUR-1 and MUR-4**

| Parameter | Units | River Mouth (MUR-1) (Fall) | | | | | Upstream of Shelley Creek (MUR-4) (Fall) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1972 - 1998)[a] | | | | | Historical (1985-1988)[b] | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n |
| **Field measured** | | | | | | | | | | | |
| pH | | 8.0 | 8.4 | 7.8 | 9.2 | 3 | - | 7.8 | 7.5 | 8.0 | 4 |
| Specific Conductance | µS/cm | 655 | - | 177 | 610 | 2 | - | 326 | 274 | 380 | 4 |
| Temperature | $^oC$ | 3.9 | - | 1.5 | 12.0 | 2 | - | 4.0 | 1.5 | 6.0 | 4 |
| Dissolved Oxygen | mg/L | 12.3 | - | 9.5 | 12.5 | 2 | - | 11.4 | 9.6 | 12.2 | 4 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 341 | 183 | 123 | 321 | 6 | 311 | 202 | 179 | 226 | 4 |
| Calcium | mg/L | 108 | 42 | 26 | 111 | 9 | 72 | 43 | 38 | 48 | 4 |
| Carbonate (CO3) | mg/L | - | < 0.5 | 0 | < 5 | 6 | < 5 | - | < 0.5 | < 0.5 | 2 |
| Chloride | mg/L | 5.8 | 2.7 | 1.4 | 18.1 | 9 | 4.0 | 2.6 | 1.6 | 3.7 | 4 |
| Colour | T.C.U. | 35 | 50 | 30 | 120 | 3 | 60 | 150 | 100 | 200 | 4 |
| Conductance | µS/cm | 666 | 284 | 193 | 627 | 9 | 491 | - | - | - | - |
| Dissolved Organic Carbon | mg/L | 16 | 24 | 11 | 27 | 7 | 15 | - | - | - | - |
| Hardness | mg/L | 343 | 148 | 96 | 353 | 9 | 244 | 153 | 137 | 170 | 4 |
| Magnesium | mg/L | 19 | 9 | 7 | 18 | 9 | 16 | 11 | 10 | 12 | 4 |
| pH | | 8.2 | 7.9 | 7.6 | 8.3 | 9 | 7.8 | - | - | - | - |
| Potassium | mg/L | 1.9 | 1.0 | 0.5 | 1.5 | 9 | 1.3 | 0.9 | 0.8 | 1.0 | 4 |
| Sodium | mg/L | 13 | 11 | 8 | 27 | 9 | 8 | 11 | 10 | 12 | 4 |
| Sulphate | mg/L | 91 | 4 | 1 | 95 | 9 | 5 | 3 | 2 | 4 | 4 |
| Sulphide | µg/L | < 3 | < 3 | < 2 | < 5 | 3 | < 3 | - | - | - | - |
| Total Alkalinity | mg/L | 280 | 150 | 101 | 264 | 9 | 255 | 166 | 147 | 185 | 4 |
| Total Dissolved Solids | mg/L | 405 | 177 | 120 | 482 | 8 | 350 | 175 | 151 | 200 | 4 |
| Total Organic Carbon | mg/L | 16 | 24 | 12 | 29 | 5 | 18 | 24 | 22 | 27 | 4 |
| Total Suspended Solids | mg/L | 3 | 4 | 1 | 70 | 8 | 8 | 5 | 4 | 7 | 4 |
| **Nutrients** | | | | | | | | | | | |
| Nitrate + Nitrite | mg/L | < 0.1 | < 0.02 | < 0.002 | 0.1 | 7 | < 0.1 | 0.02 | 0.01 | 0.03 | 4 |
| Nitrogen - Ammonia | mg/L | < 0.05 | 0.06 | 0.04 | 0.09 | 4 | 0.08 | 0.05 | 0.04 | 0.07 | 4 |
| Nitrogen - Kjeldahl | mg/L | 0.6 | 0.65 | 0.55 | 0.7 | 5 | 0.8 | 0.89 | 0.84 | 1.34 | 4 |
| Nitrogen - Total | mg/L | 0.6 | | | | | 0.8 | | | | |
| Phosphorus, Total | µg/L | 8 | 34 | 8 | 600 | 8 | 31 | 34.5 | 32 | 38 | 4 |
| Phosphorus,Total Dissolved | µg/L | 5 | 14 | 8 | 16 | 3 | 7 | - | - | - | - |
| **Biochemical Oxygen Demand** | | | | | | | | | | | |
| Biochemical Oxygen Demand | mg/L | < 2 | 1 | < 0.1 | 4 | 4 | < 2 | 2 | 1 | 2 | 4 |
| **Toxicity** | | | | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | > 91 | > 91 | > 100 | 4 | > 91 | - | - | - | - |
| Microtox IC25 @ 15 min | % | > 91 | > 91 | > 91 | > 100 | 4 | > 91 | - | - | - | - |
| **Organics** | | | | | | | | | | | |
| Naphthenic acids | mg/L | 1 | < 1 | < 1 | < 1 | 4 | < 1 | - | - | - | - |
| Total Phenolics | µg/L | 2 | < 1 | < 1 | 2 | 5 | 3 | - | - | - | - |
| Total Recoverable Hydrocarbons | mg/L | < 0.5 | < 0.8 | < 0.5 | < 1 | 4 | < 0.5 | 0.3 | 0.1 | 0.5 | 4 |
| **Metals (Total)** | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 290 | 90 | 30 | 1200 | 7 | 40 | 15 | < 10 | 20 | 4 |
| Antimony (Sb) | µg/L | < 0.8 | < 0.5 | < 0.2 | < 0.8 | 3 | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 1 | 1.0 | < 0.2 | 14 | 6 | < 1 | 0.4 | 0.2 | 0.5 | 4 |
| Barium (Ba) | µg/L | 82 | 30 | 20 | 91.7 | 5 | 69 | - | - | - | - |
| Beryllium (Be) | µg/L | < 1 | < 1 | < 1 | 3 | 5 | < 1 | - | - | - | - |
| Boron (B) | µg/L | 41 | 34 | 28 | 160 | 5 | 34 | 45 | 30 | 70 | 4 |
| Cadmium (Cd) | µg/L | < 0.2 | < 1.6 | < 0.2 | 4 | 6 | < 0.2 | < 1 | < 1 | < 1 | 4 |
| Calcium (Ca) | µg/L | 104000 | - | 36300 | 114000 | 2 | 73100 | - | - | - | - |
| Chromium (Cr) | µg/L | < 0.8 | 4.5 | 0.7 | 8 | 6 | < 0.8 | < 1 | < 1 | 12 | 4 |
| Cobalt (Co) | µg/L | < 0.2 | 2.6 | 0.2 | 6 | 6 | < 0.2 | - | - | - | - |
| Copper (Cu) | µg/L | 2 | 1.3 | < 1 | 4 | 6 | 3 | < 1 | < 1 | < 1 | 4 |

**Table II-4. Water Quality in the Muskeg River: Sample Stations MUR-1 and MUR-4**

| Parameter | Units | River Mouth (MUR-1) (Fall) | | | | | Upstream of Shelley Creek (MUR-4) (Fall) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1972 - 1998)[a] | | | | | Historical (1985-1988)[b] | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n |
| Iron (Fe) | µg/L | 420 | 960 | 490 | 1810 | 6 | 1460 | 1070 | 1030 | 1110 | 4 |
| Lead (Pb) | µg/L | < 0.1 | 1.2 | 0.3 | < 20 | 5 | < 0.1 | < 2 | < 2 | < 2 | 4 |
| Lithium (Li) | µg/L | 12 | 8 | 6 | 10 | 5 | 12 | - | - | - | - |
| Magnesium (Mg) | µg/L | 19000 | - | 7880 | 18200 | 2 | 18300 | - | - | - | - |
| Manganese (Mn) | µg/L | 16 | 48 | 33 | 115 | 5 | 77 | 63 | 53 | 70 | 4 |
| Mercury (Hg) | µg/L | < 0.2 | < 0.3 | < 0.1 | < 50 | 7 | < 0.2 | < 0.08 | < 0.05 | < 0.1 | 4 |
| Molybdenum (Mo) | µg/L | < 0.1 | < 3 | < 0.1 | 5 | 5 | < 0.1 | - | - | - | - |
| Nickel (Ni) | µg/L | 3 | 5 | < 0.5 | 15 | 5 | 1.9 | < 1 | < 1 | < 1 | 4 |
| Potassium (K) | µg/L | 1820 | - | 1380 | 1710 | 2 | 1500 | - | - | - | - |
| Selenium (Se) | µg/L | < 0.8 | < 0.3 | < 0.2 | < 0.8 | 4 | < 0.8 | 0.5 | < 0.2 | 0.8 | 4 |
| Silver (Ag) | µg/L | < 0.4 | < 0.4 | < 0.1 | 3 | 5 | < 0.4 | - | - | - | - |
| Sodium (Na) | µg/L | 20800 | - | 8000 | 8600 | 2 | 11000 | - | - | - | - |
| Strontium (Sr) | µg/L | 225 | 97 | 72 | 196 | 5 | 165 | - | - | - | - |
| Titanium (Ti) | µg/L | 1.5 | 6 | 2 | 17 | 4 | 0.7 | - | - | - | - |
| Uranium (U) | µg/L | 0.3 | < 250 | < 0.1 | < 500 | 4 | < 0.1 | - | - | - | - |
| Vanadium (V) | µg/L | < 0.2 | 2 | 0.2 | 3 | 5 | < 0.2 | < 1 | < 1 | < 1 | 4 |
| Zinc (Zn) | µg/L | 4 | 16 | 8 | 33 | 5 | 10 | 2 | < 1 | 4 | 4 |
| **Metals (Dissolved)** | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 10 | - | 27 | 90 | 2 | < 10 | - | - | - | - |
| Antimony (Sb) | µg/L | < 0.8 | < 0.8 | - | - | 1 | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 0.4 | < 0.4 | < 0.4 | < 1 | 3 | < 0.4 | - | - | - | - |
| Barium (Ba) | µg/L | 79 | - | 24 | 93 | 2 | 57 | - | - | - | - |
| Beryllium (Be) | µg/L | < 0.5 | - | < 0.5 | < 0.5 | 2 | < 0.5 | - | - | - | - |
| Boron (B) | µg/L | 57 | 29 | 10 | 160 | 4 | 40 | - | - | - | - |
| Cadmium (Cd) | µg/L | < 0.1 | - | < 0.1 | < 0.1 | 2 | < 0.1 | - | - | - | - |
| Chromium (Cr) | µg/L | < 0.4 | < 1.7 | < 0.4 | 4 | 4 | < 0.4 | - | - | - | - |
| Cobalt (Co) | µg/L | 0.2 | - | 0.2 | 0.2 | 2 | 0.1 | - | - | - | - |
| Copper (Cu) | µg/L | 1.6 | - | 1.1 | 1.3 | 2 | < 0.6 | - | - | - | - |
| Iron (Fe) | µg/L | 340 | - | 250 | 440 | 2 | 290 | - | - | - | - |
| Lead (Pb) | µg/L | < 0.1 | - | 0.3 | 0.9 | 2 | < 0.1 | - | - | - | - |
| Lithium (Li) | µg/L | 10 | - | 7 | 9 | 2 | 19 | - | - | - | - |
| Manganese (Mn) | µg/L | 13 | - | 30 | 35 | 2 | 76 | - | - | - | - |
| Mercury (Hg) | µg/L | < 0.01 | - | < 0.1 | 0.2 | 2 | < 0.01 | - | - | - | - |
| Molybdenum (Mo) | µg/L | 0.1 | - | 0.08 | 0.2 | 2 | < 0.1 | - | - | - | - |
| Nickel (Ni) | µg/L | 2.8 | - | 0.4 | 4.4 | 2 | 1.0 | - | - | - | - |
| Selenium (Se) | µg/L | < 0.4 | < 0.4 | < 0.4 | < 0.5 | 3 | < 0.4 | - | - | - | - |
| Silver (Ag) | µg/L | < 0.2 | - | < 0.2 | < 0.2 | 2 | < 0.2 | - | - | - | - |
| Strontium (Sr) | µg/L | 234 | - | 74 | 193 | 2 | 171 | - | - | - | - |
| Titanium (Ti) | µg/L | 1 | - | 0.6 | 1.5 | 2 | 1.2 | - | - | - | - |
| Uranium (U) | µg/L | 0.2 | 0.5 | - | - | 1 | < 0.1 | - | - | - | - |
| Vanadium (V) | µg/L | 0.3 | < 0.1 | - | - | 1 | 0.2 | - | - | - | - |
| Zinc (Zn) | µg/L | < 2 | 4 | - | - | 1 | 6 | - | - | - | - |

[a] Based on information from Golder (1996a, 1998b, 1999a), R.L.&L. (1982) and NAQUADAT stations AB07DA0620/630.

[b] Based on information from R.L.&L. (1989).

**Table II-5. Water Quality in the Muskeg River: Sample Station MUR-2**

| Parameter | Units | Winter | | | | | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1974 - 1998) | | | | | Historical (1977 - 1998) | | | | | Historical (1976 - 1998) | | | | | Historical (1976 - 1985) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| **Field measured** | | | | | | | | | | | | | | | | | | | | | |
| pH | | 7.8 | 7.7 | - | - | 1 | 8.4 | - | 7.8 | 7.8 | 2 | 7.9 | - | 7.7 | 8.1 | 2 | 8.1 | - | 7.6 | 8.0 | 2 |
| Specific Conductance | µS/cm | 660 | 470 | - | - | 1 | 387 | 196 | - | - | 1 | 375 | 316 | - | - | 1 | 635 | 269 | - | - | 1 |
| Temperature | °C | 0.2 | 0.0 | 0.0 | 0.5 | 18 | 9.0 | 8.2 | 0.0 | 13.5 | 10 | 21.8 | 16.0 | 13.0 | 21.0 | 20 | 3.3 | 7.3 | 0.0 | 12.0 | 14 |
| Dissolved Oxygen | mg/L | 9.1 | 6.8 | 1.8 | 10.4 | 8 | 10.0 | 9.5 | 6.2 | 11.8 | 7 | 8.5 | 9.0 | 5.2 | 11.8 | 21 | 8.4 | 9.4 | 5.0 | 13.6 | 14 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | | | | | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 344 | - | 313 | 350 | 2 | 223 | 123 | 93 | 134 | 3 | 236 | - | 201 | 207 | 2 | 343 | - | 172 | 310 | 2 |
| Calcium | mg/L | 111 | 72 | 18 | 90 | 25 | 57 | 27 | 16 | 66 | 12 | 56 | 46 | 28 | 67 | 23 | 104 | 37 | 27 | 81 | 17 |
| Carbonate (CO3) | mg/L | < 5 | < 5 | - | - | 1 | < 5 | < 0.5 | 0 | < 5 | 3 | < 5 | - | 0 | < 0.5 | 2 | < 5 | 0 | - | - | 1 |
| Chloride | mg/L | 2.0 | 5.6 | 0.5 | 13.0 | 27 | 6.0 | 1.9 | 1.6 | 5.5 | 12 | 2.0 | 4.2 | 1.6 | 14.4 | 23 | 5.0 | 2.6 | 1.7 | 29.7 | 17 |
| Colour | T.C.U. | 50 | 48 | 25 | 100 | 14 | 40 | 65 | 40 | 80 | 6 | 100 | 100 | 30 | 130 | 15 | 50 | 100 | 30 | 150 | 11 |
| Conductance | µS/cm | 695 | 478 | 120 | 596 | 24 | 399 | 188 | 115 | 450 | 11 | 389 | 315 | 170 | 442 | 22 | 654 | 265 | 160 | 504 | 16 |
| Dissolved Organic Carbon | mg/L | 12 | 20 | 10 | 37 | 23 | 11 | 17 | 8 | 34 | 10 | 16 | 23 | 6 | 53 | 20 | 15 | 25 | 7 | 29 | 12 |
| Hardness | mg/L | 357 | 253 | 134 | 281 | 12 | 192 | 86 | 60 | 229 | 7 | 195 | 153 | 108 | 196 | 12 | 342 | 141 | 132 | 232 | 7 |
| Magnesium | mg/L | 19 | 17 | 5 | 21 | 25 | 12 | 7 | 4 | 17 | 12 | 14 | 11 | 8 | 14 | 23 | 20 | 10 | 8 | 17 | 17 |
| pH | | 7.3 | 7.4 | 7.2 | 8.6 | 27 | 7.8 | 7.5 | 7.4 | 8.2 | 11 | 8.0 | 7.8 | 7.2 | 8.3 | 22 | 8.0 | 7.7 | 7.3 | 8.1 | 16 |
| Potassium | mg/L | 1.7 | 1.4 | 0.5 | 1.9 | 23 | 2.0 | 1.5 | 1.0 | 2.6 | 12 | 0.6 | 0.5 | 0.0 | 0.9 | 23 | 1.8 | 0.7 | 0.3 | 1.5 | 17 |
| Sodium | mg/L | 11 | 15 | 3 | 22 | 24 | 8 | 7 | 4 | 15 | 12 | 8 | 12 | 7 | 22 | 23 | 12 | 12 | 7 | 39 | 17 |
| Sulphate | mg/L | 99 | 5 | 1 | 43 | 25 | 27 | 4 | 2 | 7 | 12 | 16 | 5 | 1 | 9 | 23 | 81 | 4 | 0 | 12 | 17 |
| Sulphide | µg/L | < 3 | 10 | < 2 | 10 | 4 | < 3 | 3 | - | - | 1 | < 3 | - | - | - | - | < 3 | - | - | - | - |
| Total Alkalinity | mg/L | 282 | 259 | 61 | 333 | 24 | 183 | 102 | 56 | 254 | 12 | 193 | 170 | 100 | 232 | 23 | 281 | 141 | 105 | 267 | 17 |
| Total Dissolved Solids | mg/L | 470 | 303 | 79 | 476 | 27 | 240 | 136 | 72 | 297 | 12 | 240 | 195 | 112 | 276 | 23 | 460 | 162 | 121 | 319 | 17 |
| Total Organic Carbon | mg/L | 14 | 22 | 10 | 38 | 25 | 14 | 18 | 8 | 35 | 11 | 19 | 24 | 6 | 53 | 22 | 17 | 26 | 20 | 31 | 16 |
| Total Suspended Solids | mg/L | < 3 | 6 | 2 | 72 | 27 | 10 | 5 | < 1 | 36 | 12 | 3 | 3 | < 0.4 | 6 | 23 | < 3 | 3 | < 0.4 | 10 | 17 |
| **Nutrients and Chlorophyll *a*** | | | | | | | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | mg/L | 0.1 | - | < 0.05 | 0.3 | 2 | < 0.1 | < 0.016 | < 0.003 | < 0.05 | 3 | < 0.1 | - | 0.025 | 0.055 | 2 | < 0.1 | - | < 0.002 | 0.014 | 2 |
| Nitrogen - Ammonia | mg/L | 0.28 | - | 0.59 | 1.63 | 2 | < 0.05 | - | 0.04 | < 0.05 | 2 | < 0.05 | 0.05 | - | - | 1 | < 0.05 | 0.04 | - | - | 1 |
| Nitrogen - Kjeldahl | mg/L | 0.9 | 1.3 | 0.4 | 3 | 23 | 0.7 | 0.8 | 0.04 | 2.1 | 11 | 0.8 | 1.02 | 0.48 | 1.66 | 22 | 0.7 | 0.92 | 0.35 | 2.18 | 14 |
| Nitrogen - Total | mg/L | 1 | | | | | 0.7 | | | | | 0.8 | | | | | 0.7 | | | | |
| Phosphorus, Total | µg/L | 17 | 37.5 | 22 | 190 | 24 | 39 | 31 | < 20 | 90 | 11 | 21 | 25 | < 5 | 53 | 22 | 16 | 28 | 17 | 70 | 16 |
| Phosphorus,Total Dissolved | µg/L | 7 | < 20 | - | - | 1 | 24 | < 20 | - | - | 1 | 9 | - | - | - | - | 9 | - | - | - | - |
| Chlorophyll *a* | µg/L | 0 | < 1 | < 1 | 6 | 9 | - | - | < 1 | 4 | 2 | 0 | 1 | < 1 | 8 | 6 | - | 1 | < 1 | 10 | 7 |
| **Biochemical Oxygen Demand** | | | | | | | | | | | | | | | | | | | | | |
| Biochemical Oxygen Demand | mg/L | < 2 | - | 2 | 4 | 2 | 2 | - | 0.8 | 3 | 2 | < 2 | 0.5 | - | - | 1 | < 2 | 1.5 | - | - | 1 |
| **Toxicity** | | | | | | | | | | | | | | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | > 99 | - | - | 1 | > 91 | - | - | - | - | > 91 | > 91 | - | - | 1 | > 91 | - | - | - | - |
| Microtox IC25 @ 15 min | % | > 91 | - | - | - | - | > 91 | - | - | - | - | > 91 | > 91 | - | - | 1 | > 91 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - IC25 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - IC50 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - LOEC | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - NOEC | % | 100 | - | - | - | - | 100 | - | - | - | - | 100 | - | - | - | - | 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC25 | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC50 | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - LOEC | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - NOEC | % | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LC25 | % | > 100 | - | - | - | - | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LC50 | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LOEC | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - NOEC | % | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | - | - | - | - |

**Table II-5. Water Quality in the Muskeg River: Sample Station MUR-2**

| Parameter | Units | Winter | | | | | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1974 - 1998) | | | | | Historical (1977 - 1998) | | | | | Historical (1976 - 1998) | | | | | Historical (1976 - 1985) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| Fathead Minnow 7d Growth - IC25 | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - IC50 | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - LOEC | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - NOEC | % | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LC25 | % | > 100 | - | - | - | - | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LC50 | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LOEC | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - NOEC | % | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | - | - | - | - |
| **Organics** | | | | | | | | | | | | | | | | | | | | | |
| Naphthenic acids | mg/L | 1 | < 1 | - | - | 1 | < 1 | 4 | - | - | 1 | 4 | - | - | - | - | < 1 | - | - | - | - |
| Total Phenolics | µg/L | 2 | - | - | - | - | 3 | - | - | - | - | 5 | - | - | - | - | 3 | - | - | - | - |
| Total Recoverable Hydrocarbons | mg/L | < 0.5 | 2 | - | - | 1 | < 0.5 | - | < 0.1 | < 0.5 | 2 | < 0.5 | < 0.1 | - | - | 1 | 0.5 | 0.2 | - | - | 1 |
| **Metals (Total)** | | | | | | | | | | | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 270 | 40 | < 10 | 580 | 23 | 350 | 70 | < 10 | 231 | 11 | 250 | 50 | < 10 | 420 | 22 | 60 | 35 | < 10 | 320 | 14 |
| Antimony (Sb) | µg/L | < 0.8 | < 0.4 | - | - | 1 | < 0.8 | < 0.4 | - | - | 1 | < 0.8 | - | - | - | - | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 1 | < 0.4 | - | - | 1 | < 1 | - | 0.3 | < 0.4 | 2 | < 1 | - | 0.4 | < 5 | 2 | < 1 | 1.5 | 1 | < 5 | 3 |
| Barium (Ba) | µg/L | 89.7 | 71.2 | - | - | 1 | 57.1 | 25.4 | - | - | 1 | 57.2 | - | - | - | - | 80.1 | - | - | - | - |
| Beryllium (Be) | µg/L | < 1 | < 1 | - | - | 1 | < 1 | < 1 | - | - | 1 | < 1 | - | - | - | - | < 1 | - | - | - | - |
| Boron (B) | µg/L | 40 | 58 | - | - | 1 | 23 | - | 45 | 60 | 2 | 62 | 40 | - | - | 1 | 41 | 10 | - | - | 1 |
| Cadmium (Cd) | µg/L | < 0.2 | - | < 0.2 | 1 | 2 | < 0.2 | - | < 0.2 | < 1 | 2 | < 0.2 | < 1 | - | - | 1 | < 0.2 | < 1 | - | - | 1 |
| Calcium (Ca) | µg/L | 118300 | 72500 | - | - | 1 | 58700 | 23400 | - | - | 1 | 56700 | - | - | - | - | 109000 | - | - | - | - |
| Chromium (Cr) | µg/L | 3.8 | - | < 0.4 | 10 | 2 | < 0.8 | - | < 0.4 | 5 | 2 | < 0.8 | < 1 | - | - | 1 | < 0.8 | 8 | - | - | 1 |
| Cobalt (Co) | µg/L | 0.4 | 0.5 | - | - | 1 | 0.3 | < 0.5 | - | - | 1 | < 0.2 | - | - | - | - | 0.2 | - | - | - | - |
| Copper (Cu) | µg/L | 2 | 2 | - | - | 1 | < 1 | - | 0.8 | < 1 | 2 | 1 | < 1 | - | - | 1 | 2 | < 1 | - | - | 1 |
| Iron (Fe) | µg/L | 1270 | 2420 | 1900 | 2900 | 4 | 1860 | - | 590 | 790 | 2 | 550 | 1300 | - | - | 1 | 840 | 990 | - | - | 1 |
| Lead (Pb) | µg/L | 0.3 | - | 0.5 | 7 | 2 | 0.2 | - | 0.4 | < 2 | 2 | 0.2 | 2 | - | - | 1 | < 0.1 | < 2 | - | - | 1 |
| Lithium (Li) | µg/L | 14 | 12 | - | - | 1 | 8 | 6 | - | - | 1 | 9 | - | - | - | - | 14 | - | - | - | - |
| Magnesium (Mg) | µg/L | 19820 | 16900 | - | - | 1 | 13300 | 6840 | - | - | 1 | 13600 | - | - | - | - | 20900 | - | - | - | - |
| Manganese (Mn) | µg/L | 386.4 | - | 430 | 660 | 2 | 117 | - | 36 | 39.3 | 2 | < 127 | 29 | - | - | 1 | 24.1 | < 53 | - | - | 1 |
| Mercury (Hg) | µg/L | < 0.2 | < 0.1 | < 0.1 | 0.5 | 25 | < 0.2 | < 0.1 | < 0.05 | 0.3 | 11 | < 0.2 | < 0.1 | < 0.1 | < 0.2 | 22 | < 0.2 | < 0.1 | 0.05 | 0.4 | 16 |
| Molybdenum (Mo) | µg/L | 0.2 | < 0.1 | - | - | 1 | 0.1 | 0.2 | - | - | 1 | 0.2 | - | - | - | - | 0.1 | - | - | - | - |
| Nickel (Ni) | µg/L | 5.2 | 1.3 | - | - | 1 | 1.4 | - | < 0.4 | < 1 | 2 | 1 | 1 | - | - | 1 | 3.4 | < 1 | - | - | 1 |
| Potassium (K) | µg/L | 12690 | 1470 | - | - | 1 | 2070 | 1570 | - | - | 1 | 610 | - | - | - | - | 1940 | - | - | - | - |
| Selenium (Se) | µg/L | < 0.8 | < 0.4 | - | - | 1 | < 0.8 | - | 0.2 | < 0.4 | 2 | < 0.8 | < 0.2 | - | - | 1 | < 0.8 | < 0.2 | - | - | 1 |
| Silver (Ag) | µg/L | < 0.4 | < 1 | - | - | 1 | < 0.4 | < 1 | - | - | 1 | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - |
| Sodium (Na) | µg/L | 23100 | 13400 | - | - | 1 | 7900 | 6200 | - | - | 1 | 7800 | - | - | - | - | 12200 | - | - | - | - |
| Strontium (Sr) | µg/L | 181 | 178 | - | - | 1 | 114 | 59.4 | - | - | 1 | 137 | - | - | - | - | 210 | - | - | - | - |
| Titanium (Ti) | µg/L | 5 | < 50 | 4 | < 50 | 6 | 4.7 | < 10 | 3.6 | < 10 | 3 | < 0.6 | - | < 50 | < 50 | 2 | 2.6 | - | < 50 | < 50 | 2 |
| Uranium (U) | µg/L | 0.4 | < 0.1 | - | - | 1 | 0.2 | < 0.1 | - | - | 1 | < 0.1 | - | - | - | - | 0.2 | - | - | - | - |
| Vanadium (V) | µg/L | < 0.2 | 0.5 | - | - | 1 | 0.6 | - | 0.4 | < 1 | 2 | 0.3 | 1 | - | - | 1 | < 0.2 | < 1 | - | - | 1 |
| Zinc (Zn) | µg/L | 9 | - | 13 | 30 | 2 | 10 | - | 3 | 11 | 2 | 15 | 8 | - | - | 1 | 6 | 2 | - | - | 1 |
| **Metals (Dissolved)** | | | | | | | | | | | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 10 | - | - | - | - | < 10 | 31.5 | - | - | 1 | 230 | - | - | - | - | < 10 | - | - | - | - |
| Antimony (Sb) | µg/L | < 0.8 | - | - | - | - | < 0.8 | < 0.4 | - | - | 1 | < 0.8 | - | - | - | - | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 0.4 | 0.4 | < 0.2 | 20 | 23 | < 0.4 | 0.5 | < 0.2 | 0.6 | 10 | 0.5 | 0.35 | < 0.2 | 5 | 20 | < 0.4 | 0.4 | < 0.2 | 12 | 13 |
| Barium (Ba) | µg/L | 93.3 | - | - | - | - | 51.9 | 19 | - | - | 1 | 57.3 | - | - | - | - | 81.8 | - | - | - | - |
| Beryllium (Be) | µg/L | < 0.5 | - | - | - | - | < 0.5 | < 0.5 | - | - | 1 | < 0.5 | - | - | - | - | < 0.5 | - | - | - | - |
| Boron (B) | µg/L | 31 | 115 | 30 | 260 | 14 | 26 | 110 | 39 | 200 | 7 | 43 | 100 | 10 | 180 | 9 | 41 | 135 | < 50 | 220 | 8 |
| Cadmium (Cd) | µg/L | < 0.1 | - | - | - | - | < 0.1 | < 0.1 | - | - | 1 | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - |

**Table II-5. Water Quality in the Muskeg River: Sample Station MUR-2**

| Parameter | Units | Winter | | | | | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1974 - 1998) | | | | | Historical (1977 - 1998) | | | | | Historical (1976 - 1998) | | | | | Historical (1976 - 1985) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| Chromium (Cr) | µg/L | < 0.4 | < 3 | < 3 | 7 | 22 | 0.4 | < 3 | < 0.4 | 6 | 10 | < 0.4 | < 3 | < 3 | 16 | 21 | < 0.4 | < 3 | < 3 | 7 | 13 |
| Cobalt (Co) | µg/L | 0.4 | - | - | - | - | 0.2 | 0.2 | - | - | 1 | 0.2 | - | - | - | - | 0.2 | - | - | - | - |
| Copper (Cu) | µg/L | 1 | - | - | - | - | 0.8 | 1.3 | - | - | 1 | 1.5 | - | - | - | - | 1.9 | - | - | - | - |
| Iron (Fe) | µg/L | 340 | - | - | - | - | 350 | 1030 | - | - | 1 | 350 | - | - | - | - | 420 | - | - | - | - |
| Lead (Pb) | µg/L | 0.3 | - | - | - | - | < 0.1 | 0.37 | - | - | 1 | 0.2 | - | - | - | - | < 0.1 | - | - | - | - |
| Lithium (Li) | µg/L | 14 | - | - | - | - | 9 | 5 | - | - | 1 | 9 | - | - | - | - | 12 | - | - | - | - |
| Manganese (Mn) | µg/L | 377 | - | - | - | - | 54.3 | 36.3 | - | - | 1 | 24.2 | - | - | - | - | 17.3 | - | - | - | - |
| Mercury (Hg) | µg/L | < 0.1 | - | - | - | - | < 0.1 | < 0.2 | - | - | 1 | 0.2 | - | - | - | - | < 0.01 | - | - | - | - |
| Molybdenum (Mo) | µg/L | 0.1 | - | - | - | - | 0.2 | 0.13 | - | - | 1 | < 0.9 | - | - | - | - | 0.1 | - | - | - | - |
| Nickel (Ni) | µg/L | 3.9 | - | - | - | - | 0.6 | 1 | - | - | 1 | 1.4 | - | - | - | - | 3.3 | - | - | - | - |
| Selenium (Se) | µg/L | < 0.4 | < 0.2 | < 0.2 | 0.9 | 22 | < 0.4 | < 0.2 | < 0.2 | < 0.5 | 10 | < 0.4 | < 0.2 | < 0.2 | 0.8 | 20 | < 0.4 | < 0.2 | < 0.2 | < 0.5 | 11 |
| Silver (Ag) | µg/L | < 0.2 | - | - | - | - | < 0.2 | < 0.2 | - | - | 1 | < 0.2 | - | - | - | - | < 0.2 | - | - | - | - |
| Strontium (Sr) | µg/L | 198 | - | - | - | - | 120 | 52.9 | - | - | 1 | 144 | - | - | - | - | 211 | - | - | - | - |
| Titanium (Ti) | µg/L | 1.5 | - | - | - | - | 1 | 0.8 | - | - | 1 | 0.7 | - | - | - | - | 1.2 | - | - | - | - |
| Uranium (U) | µg/L | 0.3 | - | - | - | - | 0.1 | < 0.05 | - | - | 1 | < 0.1 | - | - | - | - | 0.2 | - | - | - | - |
| Vanadium (V) | µg/L | < 0.1 | - | - | - | - | 0.3 | 0.1 | - | - | 1 | 0.2 | - | - | - | - | < 0.1 | - | - | - | - |
| Zinc (Zn) | µg/L | 4 | - | - | - | - | 6 | 8 | - | - | 1 | 10 | - | - | - | - | 2 | - | - | - | - |

Based on information from Shell (1975), Golder (1998a, 1998b), R.L.&L. (1982, 1989), unpublished monitoring data from Syncrude Canada Ltd. and NAQUADAT station AB07DA0610.

**Table II-6. Water Quality in the Muskeg River: Sample Station MUR-5**

| Parameter | Units | Winter | | | | | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1985 - 1998) | | | | | Historical (1988 - 1998) | | | | | Historical (1988 - 1998) | | | | | Historical (1985 - 1996) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| **Field measured** | | | | | | | | | | | | | | | | | | | | | |
| pH | | 7.3 | 7.2 | 6.8 | 8.4 | 3 | 8.2 | 7.6 | - | - | 1 | 7.9 | 7.3 | 7.2 | 7.4 | 3 | 7.7 | 7.6 | 7.4 | 7.9 | 3 |
| Specific Conductance | µS/cm | 545 | 550 | 514 | 581 | 3 | 231 | 243 | - | - | 1 | 371 | 275 | 223 | 390 | 3 | 439 | 316 | 181 | 430 | 3 |
| Temperature | °C | 0.2 | 0.3 | 0.0 | 0.5 | 3 | 8.4 | 13.5 | - | - | 1 | 18.7 | 15.5 | 15.0 | 19.3 | 3 | 2.4 | 3.0 | 0.4 | 5.0 | 3 |
| Dissolved Oxygen | mg/L | 0.9 | 2.7 | 0.8 | 2.9 | 3 | 8.9 | 10.0 | - | - | 1 | 5.5 | 7.3 | 5.4 | 8.8 | 3 | 8.6 | 10.5 | 9.4 | 10.6 | 3 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | | | | | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 372 | 364 | 358 | 388 | 3 | 184 | 162 | - | - | 1 | 251 | 185 | 149 | 257 | 3 | 305 | 212 | 132 | 255 | 3 |
| Calcium | mg/L | 84 | 83 | 82 | 88 | 3 | 42 | 34 | - | - | 1 | 56 | 43 | 40 | 60 | 3 | 71 | 47 | 28 | 58 | 3 |
| Carbonate (CO3) | mg/L | < 5 | - | < 0.5 | < 0.5 | 2 | < 5 | < 0.5 | - | - | 1 | < 5 | - | < 0.5 | < 0.5 | 2 | < 5 | - | < 0.5 | < 0.5 | 2 |
| Chloride | mg/L | 3.0 | 3.1 | 2.4 | 4.3 | 3 | 2.0 | 1.7 | - | - | 1 | 1.0 | 0.5 | -0.5 | 1.7 | 3 | 2.0 | 1.4 | 0.9 | 2.4 | 3 |
| Colour | T.C.U. | 40 | 100 | 20 | 200 | 3 | 70 | 80 | - | - | 1 | 150 | 100 | 80 | 100 | 3 | 50 | 100 | 60 | 150 | 3 |
| Conductance | µS/cm | 572 | 553 | - | - | 1 | 304 | - | - | - | - | 390 | - | 240 | 284 | 2 | 479 | 211 | - | - | 1 |
| Dissolved Organic Carbon | mg/L | 12 | 15 | - | - | 1 | 16 | - | - | - | - | 16 | - | 20 | 25 | 2 | 14 | 23 | - | - | 1 |
| Hardness | mg/L | 289 | 288 | 285 | 303 | 3 | 146 | 125 | - | - | 1 | 199 | 157 | 139 | 209 | 3 | 240 | 168 | 105 | 204 | 3 |
| Magnesium | mg/L | 19 | 20 | 20 | 20 | 3 | 10 | 10 | - | - | 1 | 14 | 12 | 10 | 14 | 3 | 16 | 12 | 9 | 14 | 3 |
| pH | | 7.2 | 7.1 | - | - | 1 | 7.6 | - | - | - | - | 7.6 | - | 7.1 | 7.4 | 2 | 8.1 | 7.5 | - | - | 1 |
| Potassium | mg/L | 1.4 | 1.2 | 1.2 | 1.7 | 3 | 1.5 | 1.1 | - | - | 1 | 0.6 | 0.7 | 0.4 | 0.9 | 3 | 1.3 | 0.7 | 0.5 | 1.1 | 3 |
| Sodium | mg/L | 8 | 9 | 9 | 10 | 3 | 4 | 5 | - | - | 1 | 6 | 4 | 4 | 7 | 3 | 7 | 6 | 4 | 7 | 3 |
| Sulphate | mg/L | 6 | 2 | 1 | 2 | 3 | 6 | 1 | - | - | 1 | 5 | 1 | 0 | 1 | 3 | 5 | 3 | 1 | 3 | 3 |
| Sulphide | µg/L | < 3 | < 5 | - | - | 1 | 30 | - | - | - | - | < 3 | - | < 5 | < 5 | 2 | < 3 | < 5 | - | - | 1 |
| Total Alkalinity | mg/L | 305 | 299 | 294 | 318 | 3 | 151 | 133 | - | - | 1 | 206 | 152 | 122 | 211 | 3 | 250 | 174 | 108 | 209 | 3 |
| Total Dissolved Solids | mg/L | 280 | 320 | 305 | 332 | 3 | 220 | 134 | - | - | 1 | 240 | 190 | 152 | 213 | 3 | 330 | 174 | 154 | 215 | 3 |
| Total Organic Carbon | mg/L | 15 | 17 | 16 | 22 | 3 | 16 | 18 | - | - | 1 | 19 | 25 | 20 | 25 | 3 | 17 | 24 | 21 | 24 | 3 |
| Total Suspended Solids | mg/L | 7 | 18 | 10 | 24 | 3 | < 3 | 1 | - | - | 1 | < 3 | 4 | 1 | 16 | 3 | < 3 | 4 | < 0.4 | 7 | 3 |
| **Nutrients and Chlorophyll *a*** | | | | | | | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | mg/L | < 0.1 | 0.01 | 0.005 | 0.05 | 3 | < 0.1 | 0.01 | - | - | 1 | 0.1 | 0.022 | 0.017 | 0.113 | 3 | < 0.1 | 0.026 | 0.003 | 0.032 | 3 |
| Nitrogen - Ammonia | mg/L | 0.96 | 0.75 | 0.58 | 0.82 | 3 | 0.06 | 0.04 | - | - | 1 | 0.07 | 0.03 | < 0.01 | 0.13 | 3 | 0.14 | 0.06 | 0.04 | 0.08 | 3 |
| Nitrogen - Kjeldahl | mg/L | 1.1 | 1.76 | 1.47 | 3.4 | 3 | 0.7 | 0.7 | - | - | 1 | 0.9 | 0.85 | 0.68 | 1.02 | 3 | 0.7 | 0.74 | 0.54 | 1.08 | 3 |
| Nitrogen - Total | mg/L | 1.1 | | | | | 0.7 | | | | | 1 | | | | | 0.7 | | | | |
| Phosphorus, Total | µg/L | 39 | 103 | 65 | 110 | 3 | 46 | 34 | - | - | 1 | 42 | 36 | 35 | 50 | 3 | 38 | 35 | 17 | 46 | 3 |
| Phosphorus,Total Dissolved | µg/L | 5 | 4 | - | - | 1 | 28 | - | - | - | - | 17 | - | 17 | 23 | 2 | 12 | 14 | - | - | 1 |
| Chlorophyll *a* | µg/L | 0 | < 0.1 | - | - | 1 | - | - | - | - | - | 0 | - | 1.5 | 2.5 | 2 | - | 0.4 | - | - | 1 |
| **Biochemical Oxygen Demand** | | | | | | | | | | | | | | | | | | | | | |
| Biochemical Oxygen Demand | mg/L | 3 | 1.9 | 0.6 | 4.6 | 3 | < 2 | 1 | - | - | 1 | < 2 | 0.54 | 0.4 | 0.6 | 3 | < 2 | 0.8 | < 0.1 | 1.1 | 3 |
| **Toxicity** | | | | | | | | | | | | | | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | - | - | - | - | > 91 | - | - | - | - | - | - | - | - | - | > 91 | - | - | - | - |
| Microtox IC25 @ 15 min | % | > 91 | - | - | - | - | > 91 | - | - | - | - | - | - | - | - | - | > 91 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - IC25 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - IC50 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - LOEC | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - NOEC | % | 100 | - | - | - | - | 100 | - | - | - | - | 100 | - | - | - | - | 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC25 | % | 83 | > 100 | - | - | 1 | - | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC50 | % | > 100 | > 100 | - | - | 1 | 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - LOEC | % | 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - NOEC | % | 50 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LC25 | % | > 100 | - | - | - | - | - | > 100 | - | - | 1 | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LC50 | % | > 100 | > 100 | - | - | 1 | 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LOEC | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - NOEC | % | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | - | - | - | - |

**Table II-6. Water Quality in the Muskeg River: Sample Station MUR-5**

| Parameter | Units | Winter | | | | | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1985 - 1998) | | | | | Historical (1988 - 1998) | | | | | Historical (1988 - 1998) | | | | | Historical (1985 - 1996) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| Fathead Minnow 7d Growth - IC25 | % | > 100 | 73.3 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | 24.4 | - | - | 1 | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - IC50 | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | 84.2 | - | - | 1 | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - LOEC | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - |
| Fathead Minnow 7d Growth - NOEC | % | 100 | 50 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | 50 | - | - | 1 | 100 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LC25 | % | > 100 | - | - | - | - | > 100 | > 100 | - | - | 1 | > 100 | - | - | - | - | 4.3 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LC50 | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | 82.2 | - | - | 1 | 9 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LOEC | % | > 100 | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | > 100 | 50 | - | - | 1 | 12.5 | - | - | - | - |
| Fathead Minnow 7d Mortality Test - NOEC | % | 100 | 50 | - | - | 1 | 100 | 100 | - | - | 1 | 100 | 25 | - | - | 1 | 6.25 | - | - | - | - |
| **Organics** | | | | | | | | | | | | | | | | | | | | | |
| Naphthenic acids | mg/L | < 1 | - | - | - | - | 2 | - | - | - | - | < 1 | - | - | - | - | 1 | - | - | - | - |
| Total Phenolics | µg/L | 2 | < 1 | - | - | 1 | 7 | - | - | - | - | 2 | - | < 1 | < 1 | 2 | 2 | < 1 | - | - | 1 |
| Total Recoverable Hydrocarbons | mg/L | < 0.5 | - | 0.5 | 0.6 | 2 | < 0.5 | < 0.1 | - | - | 1 | < 0.5 | 0.1 | - | - | 1 | 0.7 | - | < 0.1 | 0.4 | 2 |
| **Metals (Total)** | | | | | | | | | | | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 70 | 20 | < 10 | 50 | 3 | 90 | < 100 | - | - | 1 | 70 | 60 | 30 | 100 | 3 | < 20 | 10 | 10 | 50 | 3 |
| Antimony (Sb) | µg/L | < 0.8 | - | - | - | - | < 0.8 | - | - | - | - | < 0.8 | - | - | - | - | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 1 | < 0.2 | < 0.2 | 0.4 | 3 | < 1 | 0.4 | - | - | 1 | < 1 | < 0.2 | < 0.2 | 0.2 | 3 | < 1 | 0.3 | < 0.2 | 0.4 | 3 |
| Barium (Ba) | µg/L | 81 | 80 | - | - | 1 | 48 | - | - | - | - | 59 | - | 40 | 50 | 2 | 62 | 20 | - | - | 1 |
| Beryllium (Be) | µg/L | < 1 | < 1 | - | - | 1 | < 1 | - | - | - | - | < 1 | - | 1 | 2 | 2 | < 1 | 4 | - | - | 1 |
| Boron (B) | µg/L | 34 | 50 | 40 | 60 | 3 | 20 | < 10 | - | - | 1 | 34 | 30 | 20 | 40 | 3 | 33 | < 10 | < 10 | < 50 | 3 |
| Cadmium (Cd) | µg/L | < 0.2 | < 1 | < 0.2 | < 1 | 3 | < 0.2 | < 1 | - | - | 1 | < 0.2 | < 0.2 | < 0.2 | < 1 | 3 | < 0.2 | < 1 | < 0.2 | < 1 | 3 |
| Calcium (Ca) | µg/L | 83100 | - | - | - | - | 44700 | - | - | - | - | 50200 | - | - | - | - | 70800 | - | - | - | - |
| Chromium (Cr) | µg/L | < 0.8 | - | < 1 | 1 | 2 | < 0.8 | < 1 | - | - | 1 | < 0.8 | 3 | < 1 | 13 | 3 | < 0.8 | < 1 | < 1 | 3 | 3 |
| Cobalt (Co) | µg/L | 1.2 | - | - | - | - | < 0.2 | - | - | - | - | < 0.2 | - | 0.7 | 0.8 | 2 | < 0.2 | 1 | - | - | 1 |
| Copper (Cu) | µg/L | < 1 | - | < 1 | < 1 | 2 | < 1 | < 1 | - | - | 1 | 1 | < 1 | < 0.2 | 1.3 | 3 | 1 | < 1 | < 1 | 1.6 | 3 |
| Iron (Fe) | µg/L | 3300 | 6200 | 4090 | 6550 | 3 | 1760 | 1150 | - | - | 1 | 1720 | 1920 | 960 | 3020 | 3 | 1980 | 1410 | 260 | 1500 | 3 |
| Lead (Pb) | µg/L | 0.6 | 2 | 0.8 | 2 | 3 | 0.2 | < 2 | - | - | 1 | 0.3 | < 0.5 | < 0.3 | < 2 | 3 | < 0.1 | < 2 | < 0.3 | < 2 | 3 |
| Lithium (Li) | µg/L | 12 | 11 | - | - | 1 | < 6 | - | - | - | - | 8 | - | 4 | 7 | 2 | 75 | 4 | - | - | 1 |
| Magnesium (Mg) | µg/L | 19420 | - | - | - | - | 10300 | - | - | - | - | 10600 | - | - | - | - | 16300 | - | - | - | - |
| Manganese (Mn) | µg/L | 563 | 561 | 426 | 1500 | 3 | 56 | 30 | - | - | 1 | < 127 | 69 | 33 | 160 | 3 | 193 | 70 | 11 | 77 | 3 |
| Mercury (Hg) | µg/L | < 0.2 | < 0.1 | < 0.05 | < 50 | 3 | < 0.2 | < 0.05 | - | - | 1 | < 0.2 | < 50 | < 0.05 | < 50 | 3 | < 0.2 | < 0.1 | < 0.05 | < 50 | 3 |
| Molybdenum (Mo) | µg/L | < 0.1 | < 3 | - | - | 1 | 0.1 | - | - | - | - | < 0.1 | - | < 3 | < 3 | 2 | < 0.1 | < 3 | - | - | 1 |
| Nickel (Ni) | µg/L | 2.6 | < 1 | < 0.5 | < 1 | 3 | 0.6 | 1 | - | - | 1 | 0.8 | 8.6 | < 1 | 26.1 | 3 | 0.9 | < 1 | < 0.5 | < 1 | 3 |
| Potassium (K) | µg/L | 950 | - | - | - | - | 1440 | - | - | - | - | 470 | - | - | - | - | 1480 | - | - | - | - |
| Selenium (Se) | µg/L | < 0.8 | < 0.2 | < 0.2 | 0.5 | 3 | < 0.8 | 0.4 | - | - | 1 | < 0.8 | < 0.2 | < 0.2 | < 0.2 | 3 | < 0.8 | 0.2 | < 0.2 | 0.6 | 3 |
| Silver (Ag) | µg/L | < 0.4 | < 0.1 | - | - | 1 | < 0.4 | - | - | - | - | 1.2 | - | < 0.1 | < 0.1 | 2 | < 0.4 | < 0.1 | - | - | 1 |
| Sodium (Na) | µg/L | 7400 | - | - | - | - | 4800 | - | - | - | - | 4600 | - | - | - | - | 6700 | - | - | - | - |
| Strontium (Sr) | µg/L | 164 | 183 | - | - | 1 | 82.7 | - | - | - | - | 126 | - | 75 | 103 | 2 | 144 | 55 | - | - | 1 |
| Titanium (Ti) | µg/L | < 0.6 | - | - | - | - | 1.7 | - | - | - | - | < 0.6 | - | - | - | - | < 0.6 | - | - | - | - |
| Uranium (U) | µg/L | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - |
| Vanadium (V) | µg/L | < 0.2 | < 1 | < 1 | < 2 | 3 | 0.4 | 1 | - | - | 1 | 0.4 | 3 | < 1 | 3 | 3 | < 0.2 | < 2 | < 1 | 2 | 3 |
| Zinc (Zn) | µg/L | 14 | - | 5 | 24 | 2 | 10 | 1 | - | - | 1 | 5 | < 1 | - | - | 1 | 7 | - | 4 | 16 | 2 |
| **Metals (Dissolved)** | | | | | | | | | | | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 20 | - | - | - | - | 20 | - | - | - | - | 10 | - | - | - | - | < 10 | - | - | - | - |
| Antimony (Sb) | µg/L | < 0.8 | - | - | - | - | < 0.8 | - | - | - | - | 0.9 | - | - | - | - | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - | 2.3 | - | - | - | - | < 0.4 | - | - | - | - |
| Barium (Ba) | µg/L | 84 | - | - | - | - | 42 | - | - | - | - | 63 | - | - | - | - | 61 | - | - | - | - |
| Beryllium (Be) | µg/L | < 0.5 | - | - | - | - | < 0.5 | - | - | - | - | < 0.5 | - | - | - | - | < 0.5 | - | - | - | - |
| Boron (B) | µg/L | 40 | - | - | - | - | 23 | - | - | - | - | 37 | - | - | - | - | 40 | - | - | - | - |
| Cadmium (Cd) | µg/L | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | 0.1 | - | - | - | - | < 0.1 | - | - | - | - |

**Table II-6. Water Quality in the Muskeg River: Sample Station MUR-5**

| Parameter | Units | Winter | | | | | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1985 - 1998) | | | | | Historical (1988 - 1998) | | | | | Historical (1988 - 1998) | | | | | Historical (1985 - 1996) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| Chromium (Cr) | µg/L | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - |
| Cobalt (Co) | µg/L | 0.3 | - | - | - | - | 0.1 | - | - | - | - | 0.2 | - | - | - | - | 0.1 | - | - | - | - |
| Copper (Cu) | µg/L | 0.6 | - | - | - | - | 0.8 | - | - | - | - | 1.5 | - | - | - | - | < 0.6 | - | - | - | - |
| Iron (Fe) | µg/L | 380 | - | - | - | - | 410 | - | - | - | - | 440 | - | - | - | - | 300 | - | - | - | - |
| Lead (Pb) | µg/L | 0.1 | - | - | - | - | 0.2 | - | - | - | - | 0.2 | - | - | - | - | < 0.1 | - | - | - | - |
| Lithium (Li) | µg/L | 13 | - | - | - | - | 6 | - | - | - | - | 8 | - | - | - | - | 17 | - | - | - | - |
| Manganese (Mn) | µg/L | 498 | - | - | - | - | 47 | - | - | - | - | 55 | - | - | - | - | 191 | - | - | - | - |
| Mercury (Hg) | µg/L | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | < 0.2 | - | - | - | - | < 0.01 | - | - | - | - |
| Molybdenum (Mo) | µg/L | < 0.1 | - | - | - | - | 0.1 | - | - | - | - | 5.2 | - | - | - | - | < 0.1 | - | - | - | - |
| Nickel (Ni) | µg/L | 2 | - | - | - | - | < 0.7 | - | - | - | - | 1.1 | - | - | - | - | 1 | - | - | - | - |
| Selenium (Se) | µg/L | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - | < 0.4 | - | - | - | - |
| Silver (Ag) | µg/L | < 0.2 | - | - | - | - | < 0.2 | - | - | - | - | 1.3 | - | - | - | - | < 0.2 | - | - | - | - |
| Strontium (Sr) | µg/L | 188 | - | - | - | - | 79.7 | - | - | - | - | 139 | - | - | - | - | 155 | - | - | - | - |
| Titanium (Ti) | µg/L | < 0.3 | - | - | - | - | 0.3 | - | - | - | - | 1.3 | - | - | - | - | < 0.3 | - | - | - | - |
| Uranium (U) | µg/L | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - |
| Vanadium (V) | µg/L | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | 0.2 | - | - | - | - | 0.3 | - | - | - | - |
| Zinc (Zn) | µg/L | 2 | - | - | - | - | 13 | - | - | - | - | 5 | - | - | - | - | < 2 | - | - | - | - |

Based on information from R.L.&L. (1989), unpublished monitoring data from Syncrude Canada Ltd. and NAQUADAT station AB07DA2750.

**Table II-7. Water Quality in the Muskeg River: Sample Station MUR-6**

| Parameter | Units | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1974 - 1998) | | | | | Historical (1974 - 1998) | | | | | Historical (1974 - 1998) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| **Field measured** | | | | | | | | | | | | | | | | |
| pH | | 10.3 | 7.4 | - | - | 1 | 7.5 | 7.5 | - | - | 1 | 7.9 | - | 7.6 | 7.8 | 2 |
| Specific Conductance | µS/cm | 220 | 245 | - | - | 1 | 316 | 382 | - | - | 1 | 352 | - | 303 | 400 | 2 |
| Temperature | °C | 2.6 | 7.0 | 4.5 | 14.0 | 5 | 15.7 | 15.0 | 10.8 | 17.0 | 7 | 1.6 | 5.0 | 0.4 | 10.5 | 5 |
| Dissolved Oxygen | mg/L | 5.3 | 7.6 | 4.0 | 9.5 | 5 | 7.2 | 4.1 | 0.0 | 6.2 | 7 | 3.4 | 8.1 | 3.9 | 10.2 | 4 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 124 | - | 84 | 160 | 2 | 210 | 179 | 123 | 257 | 3 | 261 | 240 | 204 | 287 | 3 |
| Calcium | mg/L | 30 | 24 | 19 | 36 | 6 | 49 | 49 | 27 | 75 | 10 | 57 | 44 | 31 | 67 | 7 |
| Carbonate (CO3) | mg/L | < 5 | - | < 0.5 | < 5 | 2 | < 5 | < 5 | < 0.5 | < 5 | 3 | < 5 | - | < 0.5 | < 5 | 2 |
| Chloride | mg/L | 2.0 | 1.1 | 0.4 | 1.4 | 6 | 1.0 | 1.5 | 0.2 | 2.7 | 10 | 1.0 | 1.3 | 1.1 | 1.9 | 7 |
| Colour | T.C.U. | 120 | - | 25 | 70 | 2 | 100 | 70 | 55 | 100 | 5 | 60 | 100 | 70 | 140 | 4 |
| Conductance | µS/cm | 231 | 151 | 120 | 250 | 5 | 334 | 320 | 188 | 479 | 9 | 410 | 280 | 248 | 441 | 5 |
| Dissolved Organic Carbon | mg/L | 27 | 21 | 11 | 28 | 4 | 22 | 25 | 22 | 26 | 7 | 18 | 24 | 23 | 25 | 4 |
| Hardness | mg/L | 110 | 80 | 75 | 133 | 5 | 176 | 157 | 104 | 222 | 7 | 208 | 182 | 146 | 240 | 6 |
| Magnesium | mg/L | 9 | 8 | 7 | 11 | 6 | 13 | 14 | 9 | 18 | 10 | 16 | 15 | 12 | 17 | 7 |
| pH | | 7.2 | 7.5 | 7.0 | 8.2 | 5 | 7.3 | 7.8 | 7.4 | 8.0 | 9 | 7.2 | 7.6 | 7.3 | 8.0 | 5 |
| Potassium | mg/L | 3.3 | 1.2 | 0.9 | 2.0 | 6 | 0.3 | 0.7 | 0.2 | 1.7 | 10 | 1.3 | 1.0 | 0.3 | 1.7 | 7 |
| Sodium | mg/L | 3 | 3 | 2 | 5 | 6 | 5 | 5 | 2 | 8 | 10 | 7 | 6 | 5 | 7 | 7 |
| Sulphate | mg/L | 13 | 4 | 2 | 8 | 6 | 6 | 4 | 0 | 9 | 10 | 6 | 1 | 0 | 5 | 7 |
| Sulphide | µg/L | 7 | 72 | - | - | 1 | 7 | - | 101 | 146 | 2 | 14 | < 2 | - | - | 1 |
| Total Alkalinity | mg/L | 102 | 94 | 69 | 138 | 6 | 172 | 183 | 101 | 266 | 10 | 214 | 167 | 127 | 235 | 7 |
| Total Dissolved Solids | mg/L | 190 | 135 | 79 | 150 | 5 | 240 | 219 | 181 | 311 | 8 | 270 | 172 | 158 | 320 | 7 |
| Total Organic Carbon | mg/L | 32 | 17 | 12 | 29 | 6 | 27 | 25 | 17 | 27 | 10 | 22 | 23 | 21 | 30 | 7 |
| Total Suspended Solids | mg/L | < 3 | 5 | 1 | 6 | 6 | 5 | 4 | 1 | 7 | 10 | 16 | 4 | 0.4 | 25 | 7 |
| **Nutrients and Chlorophyll *a*** | | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | mg/L | < 0.1 | - | < 0.003 | < 0.05 | 2 | < 0.1 | < 0.05 | 0.029 | < 0.05 | 3 | < 0.1 | 0.028 | 0.009 | < 0.05 | 3 |
| Nitrogen - Ammonia | mg/L | < 0.05 | - | < 0.01 | 0.05 | 2 | < 0.05 | < 0.05 | < 0.01 | 0.14 | 3 | < 0.05 | 0.08 | 0.05 | 0.27 | 3 |
| Nitrogen - Kjeldahl | mg/L | 1.3 | 0.83 | 0.72 | 0.95 | 5 | 1 | 1.04 | 0.5 | 1.31 | 9 | 1.5 | 1.26 | 0.59 | 5.5 | 7 |
| Nitrogen - Total | mg/L | 1.3 | | | | | 1 | | | | | 1.5 | | | | |
| Phosphorus, Total | µg/L | 101 | 30 | < 20 | 90 | 6 | 38 | 50.5 | < 20 | 75 | 10 | 143 | 36 | 25 | 269 | 7 |
| Phosphorus,Total Dissolved | µg/L | 66 | - | - | - | - | 21 | - | - | - | - | 29 | 23 | - | - | 1 |
| Chlorophyll *a* | µg/L | - | - | - | - | - | 0 | - | - | - | - | - | < 1 | < 1 | 14 | 3 |
| **Biochemical Oxygen Demand** | | | | | | | | | | | | | | | | |
| Biochemical Oxygen Demand | mg/L | < 2 | 0.6 | - | - | 1 | < 2 | 0.5 | - | - | 1 | < 2 | 1.9 | 1.6 | 6 | 3 |
| **Toxicity** | | | | | | | | | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | - | - | - | - | > 91 | - | - | - | - | > 91 | - | > 91 | > 91 | 2 |
| Microtox IC25 @ 15 min | % | > 91 | - | - | - | - | > 91 | - | - | - | - | > 91 | - | > 91 | > 91 | 2 |
| Algal Growth Inhibition Test (72 h) - IC25 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - IC50 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - LOEC | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | - | - | - | - |

**Table II-7. Water Quality in the Muskeg River: Sample Station MUR-6**

| Parameter | Units | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1974 - 1998) | | | | | Historical (1974 - 1998) | | | | | Historical (1974 - 1998) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| Algal Growth Inhibition Test (72 h) - NOEC | % | 100 | - | - | - | - | 100 | - | - | - | - | 100 | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC25 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | 35 | - | - | 1 |
| Ceriodaphnia 7 d Reproduction Test - IC50 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | > 100 | - | - | 1 |
| Ceriodaphnia 7 d Reproduction Test - LOEC | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | 25 | - | - | 1 |
| Ceriodaphnia 7 d Reproduction Test - NOEC | % | 100 | - | - | - | - | 100 | - | - | - | - | 100 | 12.5 | - | - | 1 |
| Ceriodaphnia 7 d Mortality Test - LC25 | % | - | - | - | - | - | > 100 | - | - | - | - | > 100 | > 100 | - | - | 1 |
| Ceriodaphnia 7 d Mortality Test - LC50 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | > 100 | - | - | 1 |
| Ceriodaphnia 7 d Mortality Test - LOEC | % | 50 | - | - | - | - | > 100 | - | - | - | - | > 100 | > 100 | - | - | 1 |
| Ceriodaphnia 7 d Mortality Test - NOEC | % | 25 | - | - | - | - | 100 | - | - | - | - | 100 | 100 | - | - | 1 |
| Fathead Minnow 7d Growth - IC25 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | 12 | - | - | 1 |
| Fathead Minnow 7d Growth - IC50 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | 39 | - | - | 1 |
| Fathead Minnow 7d Growth - LOEC | % | > 100 | - | - | - | - | > 100 | - | - | - | - | > 100 | 50 | - | - | 1 |
| Fathead Minnow 7d Growth - NOEC | % | 100 | - | - | - | - | 100 | - | - | - | - | 100 | 25 | - | - | 1 |
| Fathead Minnow 7d Mortality Test - LC25 | % | > 100 | - | - | - | - | 35 | - | - | - | - | 6.4 | 49 | - | - | 1 |
| Fathead Minnow 7d Mortality Test - LC50 | % | > 100 | - | - | - | - | > 100 | - | - | - | - | 13 | > 100 | - | - | 1 |
| Fathead Minnow 7d Mortality Test - LOEC | % | > 100 | - | - | - | - | 50 | - | - | - | - | 12.5 | > 100 | - | - | 1 |
| Fathead Minnow 7d Mortality Test - NOEC | % | 100 | - | - | - | - | 25 | - | - | - | - | 6.25 | 100 | - | - | 1 |
| **Organics** | | | | | | | | | | | | | | | | |
| Naphthenic acids | mg/L | 2 | - | - | - | - | < 1 | - | - | - | - | < 1 | 12 | - | - | 1 |
| Total Phenolics | μg/L | 120 | - | - | - | - | 5 | 4 | - | - | 1 | 3 | 5 | - | - | 1 |
| Total Recoverable Hydrocarbons | mg/L | < 0.5 | < 0.1 | - | - | 1 | < 0.5 | 0.1 | - | - | 1 | < 0.5 | 0.5 | < 0.1 | 0.6 | 3 |
| **Metals (Total)** | | | | | | | | | | | | | | | | |
| Aluminum (Al) | μg/L | 30 | 41 | 10 | 220 | 5 | 280 | 34 | 10 | 70 | 7 | 50 | 50 | < 10 | 120 | 7 |
| Antimony (Sb) | μg/L | < 0.8 | < 0.4 | - | - | 1 | < 0.8 | 0.8 | - | - | 1 | < 0.8 | < 0.8 | - | - | 1 |
| Arsenic (As) | μg/L | < 1 | - | < 0.4 | 0.5 | 2 | < 1 | < 0.4 | < 0.2 | 5 | 3 | < 1 | 1 | 0.4 | 9 | 5 |
| Barium (Ba) | μg/L | 18 | 13.5 | - | - | 1 | 37 | - | 20.9 | 27.5 | 2 | 42 | 88 | - | - | 1 |
| Beryllium (Be) | μg/L | < 1 | < 1 | - | - | 1 | < 1 | - | < 1 | < 1 | 2 | < 1 | < 1 | - | - | 1 |
| Boron (B) | μg/L | < 4 | - | 18 | 20 | 2 | 32 | 18 | 17 | 20 | 3 | 11 | 20 | 8 | < 50 | 3 |
| Cadmium (Cd) | μg/L | < 0.2 | - | < 0.2 | < 1 | 2 | < 0.2 | < 0.2 | < 0.2 | < 1 | 3 | < 0.2 | < 1 | < 0.2 | < 1 | 3 |
| Calcium (Ca) | μg/L | 31400 | - | - | - | - | 49600 | - | - | - | - | 59900 | 70500 | - | - | 1 |
| Chromium (Cr) | μg/L | < 0.8 | - | < 0.4 | < 1 | 2 | < 0.8 | < 0.4 | < 0.4 | < 1 | 3 | < 0.8 | < 1 | < 0.8 | 6 | 3 |
| Cobalt (Co) | μg/L | < 0.2 | < 0.5 | - | - | 1 | < 0.2 | - | < 0.5 | < 0.5 | 2 | < 0.2 | 0.4 | - | - | 1 |
| Copper (Cu) | μg/L | < 1 | - | < 1 | 1.1 | 2 | 2 | 1 | 0.9 | 1.3 | 3 | 1 | < 1 | < 1 | < 1 | 3 |
| Iron (Fe) | μg/L | 1200 | - | 280 | 890 | 2 | 570 | 300 | 280 | 2700 | 3 | 2350 | 1210 | 1050 | 13900 | 3 |
| Lead (Pb) | μg/L | < 0.1 | - | 0.6 | 2 | 2 | 0.3 | 0.3 | 0.2 | < 2 | 3 | < 0.1 | 2 | 0.3 | 2 | 3 |
| Lithium (Li) | μg/L | < 6 | - | - | - | - | 7 | - | - | - | - | 9 | 9 | - | - | 1 |
| Magnesium (Mg) | μg/L | 8660 | - | - | - | - | 13000 | - | - | - | - | 16500 | 17400 | - | - | 1 |
| Manganese (Mn) | μg/L | 89 | - | 12 | 23 | 2 | < 127 | 23.9 | 13.4 | 140 | 3 | 335 | 84 | 58 | 786 | 3 |
| Mercury (Hg) | μg/L | < 0.2 | < 0.1 | < 0.05 | 0.2 | 6 | < 0.2 | < 0.1 | < 0.05 | < 0.2 | 9 | < 0.2 | < 0.1 | < 0.05 | 4.3 | 7 |
| Molybdenum (Mo) | μg/L | 0.2 | 0.1 | - | - | 1 | 0.1 | - | 0.1 | 0.1 | 2 | < 0.1 | 0.1 | - | - | 1 |
| Nickel (Ni) | μg/L | 0.8 | - | < 0.4 | 3 | 2 | 1.2 | < 0.6 | < 0.4 | < 1 | 3 | 1.6 | 1 | < 1 | 4 | 3 |

**Table II-7. Water Quality in the Muskeg River: Sample Station MUR-6**

| Parameter | Units | Spring | | | | | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1974 - 1998) | | | | | Historical (1974 - 1998) | | | | | Historical (1974 - 1998) | | | |
| | | 1999 | median | min | max | n | 1999 | median | min | max | n | 1999 | median | min | max | n |
| Potassium (K) | µg/L | 3370 | - | - | - | - | 290 | - | - | - | - | 1570 | 2110 | - | - | 1 |
| Selenium (Se) | µg/L | < 0.8 | - | 0.3 | < 0.4 | 2 | < 0.8 | - | < 0.2 | < 0.4 | 2 | < 0.8 | < 0.8 | < 0.2 | 0.9 | 3 |
| Silver (Ag) | µg/L | 1 | < 0.1 | - | - | 1 | < 0.4 | - | < 0.1 | < 0.1 | 2 | < 0.4 | < 0.4 | - | - | 1 |
| Sodium (Na) | µg/L | 4100 | - | - | - | - | 5000 | - | - | - | - | 5800 | 5600 | - | - | 1 |
| Strontium (Sr) | µg/L | 58.8 | 35.6 | - | - | 1 | 112 | - | 56.9 | 79.9 | 2 | 120 | 164 | - | - | 1 |
| Titanium (Ti) | µg/L | 1.1 | - | < 0.4 | < 10 | 2 | < 0.6 | 1.2 | 0.4 | < 50 | 3 | 0.9 | - | 2.8 | < 50 | 2 |
| Uranium (U) | µg/L | < 0.1 | < 0.1 | - | - | 1 | < 0.1 | - | < 0.1 | < 0.1 | 2 | < 0.1 | < 0.1 | - | - | 1 |
| Vanadium (V) | µg/L | < 0.2 | - | < 0.2 | < 1 | 2 | 0.2 | < 0.2 | < 0.2 | < 1 | 3 | < 0.2 | < 1 | 0.4 | < 1 | 3 |
| Zinc (Zn) | µg/L | 6 | - | < 1 | 17 | 2 | 13 | 8 | < 1 | 15 | 3 | 6 | 20 | < 7 | 51 | 3 |
| **Metals (Dissolved)** | | | | | | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 10 | - | - | - | - | 260 | - | - | - | - | < 10 | 10 | - | - | 1 |
| Antimony (Sb) | µg/L | < 0.8 | - | - | - | - | < 0.8 | - | - | - | - | < 0.8 | < 0.8 | - | - | 1 |
| Arsenic (As) | µg/L | < 0.4 | 0.5 | 0.3 | 0.7 | 4 | 0.7 | 0.25 | < 0.2 | 0.6 | 6 | < 0.4 | < 0.3 | < 0.2 | < 0.4 | 3 |
| Barium (Ba) | µg/L | 18 | - | - | - | - | 34 | - | - | - | - | 32 | 42.2 | - | - | 1 |
| Beryllium (Be) | µg/L | < 0.5 | - | - | - | - | < 0.5 | - | - | - | - | < 0.5 | < 0.5 | - | - | 1 |
| Boron (B) | µg/L | 6 | 130 | 100 | 140 | 3 | 23 | 70 | 20 | 90 | 4 | 13 | 50 | 3 | 110 | 5 |
| Cadmium (Cd) | µg/L | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | < 0.1 | < 0.1 | - | - | 1 |
| Chromium (Cr) | µg/L | 0.6 | 5 | < 3 | 8 | 3 | < 0.4 | 3 | < 3 | 6 | 4 | < 0.4 | < 3 | < 0.4 | < 3 | 5 |
| Cobalt (Co) | µg/L | 0.1 | - | - | - | - | 0.1 | - | - | - | - | 0.2 | 0.2 | - | - | 1 |
| Copper (Cu) | µg/L | < 0.6 | - | - | - | - | 1.1 | - | - | - | - | < 0.6 | 1 | - | - | 1 |
| Iron (Fe) | µg/L | 940 | - | - | - | - | 480 | - | - | - | - | 820 | 890 | - | - | 1 |
| Lead (Pb) | µg/L | < 0.1 | - | - | - | - | 0.2 | - | - | - | - | < 0.1 | 0.2 | - | - | 1 |
| Lithium (Li) | µg/L | 5 | - | - | - | - | 7 | - | - | - | - | 8 | 7 | - | - | 1 |
| Manganese (Mn) | µg/L | 74 | - | - | - | - | 60 | - | - | - | - | 332 | 626 | - | - | 1 |
| Mercury (Hg) | µg/L | < 0.1 | - | - | - | - | 0.1 | - | - | - | - | < 0.01 | < 0.1 | - | - | 1 |
| Molybdenum (Mo) | µg/L | 0.2 | - | - | - | - | < 0.9 | - | - | - | - | 0.1 | < 0.1 | - | - | 1 |
| Nickel (Ni) | µg/L | < 0.7 | - | - | - | - | 0.9 | - | - | - | - | 0.9 | 3.3 | - | - | 1 |
| Selenium (Se) | µg/L | < 0.4 | < 0.4 | < 0.2 | 0.9 | 4 | < 0.4 | < 0.2 | < 0.2 | 0.5 | 6 | < 0.4 | < 0.2 | < 0.2 | < 0.4 | 3 |
| Silver (Ag) | µg/L | < 0.2 | - | - | - | - | < 0.2 | - | - | - | - | < 0.2 | < 0.2 | - | - | 1 |
| Strontium (Sr) | µg/L | 55.7 | - | - | - | - | 118 | - | - | - | - | 121 | 147 | - | - | 1 |
| Titanium (Ti) | µg/L | 0.4 | - | - | - | - | < 0.3 | - | - | - | - | 0.3 | < 0.3 | - | - | 1 |
| Uranium (U) | µg/L | < 0.1 | - | - | - | - | < 0.1 | - | - | - | - | < 0.1 | < 0.1 | - | - | 1 |
| Vanadium (V) | µg/L | 0.2 | - | - | - | - | 0.1 | - | - | - | - | < 0.1 | < 0.1 | - | - | 1 |
| Zinc (Zn) | µg/L | 6 | - | - | - | - | 9 | - | - | - | - | 2 | 10 | - | - | 1 |

Based on information from R.L.&L. (1989), Golder (1999a) and NAQUADAT station AB07DA0440.

**Table II-8. Water Quality in Tributaries of the Lower Muskeg River**

| Parameter | Units | Alsands Drain (Fall) | | Jackpine Creek (Fall) | | | | | Shelley Creek | Stanley Creek (Fall) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Historical (1976 - 1997)[a] | | | | | | |
| | | 1999 | 1997 | 1999 | median | min | max | count | (Fall 1999) | 1999 | 1976[b] |
| **Field measured** | | | | | | | | | | | |
| pH | | 7.9 | 7.5 | 7.8 | 8.2 | 7.8 | 8.3 | 3 | 7.2 | 9.2 | 7.7 |
| Specific Conductance | µS/cm | 887 | 629 | 413 | 220 | - | - | 1 | 1172 | - | 315 |
| Temperature | $^{o}C$ | 3.5 | - | 3.6 | 6.5 | 0.0 | 11.4 | 14 | 4.3 | 2.2 | 10.0 |
| Dissolved Oxygen | mg/L | 12.8 | - | 10.4 | 9.6 | 6.3 | 12.6 | 14 | 0.9 | 7.6 | 9.3 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 396 | 302 | 276 | 141 | 102 | 514 | 5 | 432 | - | - |
| Calcium | mg/L | 171 | 109 | 57 | 27 | 19 | 119 | 17 | 84 | - | 44 |
| Carbonate (CO3) | mg/L | < 5 | < 5 | - | < 0.5 | 0 | < 5 | 5 | - | - | - |
| Chloride | mg/L | 1 | 2 | 5.6 | 2 | 1 | 16 | 17 | 80 | - | 0.4 |
| Colour | T.C.U. | 30 | 60 | 49 | 118 | 35 | 150 | 10 | 165 | - | - |
| Conductance | µS/cm | 934 | 629 | 413 | 200 | 120 | 551 | 16 | 1172 | - | 315 |
| Dissolved Organic Carbon | mg/L | 12 | 18 | 19 | 25 | 18 | 36 | 11 | 29 | - | 8 |
| Hardness | mg/L | 523 | 335 | 200 | 103 | 77 | 362 | 9 | 265 | - | 152 |
| Magnesium | mg/L | 23 | 15 | 14 | 8 | 6 | 16 | 17 | 14 | - | 10 |
| pH | | 8.0 | 7.5 | 7.9 | 7.6 | 7.3 | 7.9 | 16 | 7.2 | - | 7.7 |
| Potassium | mg/L | 2.1 | 2.4 | 1.4 | 0.7 | 0.2 | 3.5 | 17 | 3.1 | - | 0.7 |
| Sodium | mg/L | 7 | 7 | 18 | 12 | 9 | 36 | 17 | 96 | - | 2 |
| Sulphate | mg/L | 205 | 102 | < 3 | 4 | 0.1 | 10 | 17 | 10 | - | 1 |
| Sulphide | µg/L | 4 | 8.5 | 6 | 6 | - | - | 1 | 53 | 3 | - |
| Total Alkalinity | mg/L | 324 | 247 | 227 | 111 | 80 | 422 | 17 | 354 | - | 156 |
| Total Dissolved Solids | mg/L | 700 | 440 | 234 | 126 | 94 | 466 | 17 | 500 | - | 167 |
| Total Organic Carbon | mg/L | 14 | 22 | 18 | 26 | 24 | 40 | 14 | 33 | 16 | 11 |
| Total Suspended Solids | mg/L | 12 | 4 | 8 | 5 | < 0.4 | 52 | 17 | 39 | - | 35 |
| **Nutrients** | | | | | | | | | | | |
| Nitrate + Nitrite | mg/L | < 0.1 | < 0.05 | < 0.1 | < 0.003 | < 0.002 | < 0.05 | 5 | < 0.1 | < 0.1 | - |
| Nitrogen - Ammonia | mg/L | 0.4 | 0.6 | < 0.05 | 0.03 | 0.01 | < 0.05 | 3 | 0.6 | < 0.05 | - |
| Nitrogen - Kjeldahl | mg/L | 1.4 | 1.3 | 0.7 | 0.9 | 0.5 | 3.4 | 12 | 3.8 | 0.5 | 1.5 |
| Phosphorus, Total | µg/L | 15 | 17 | 42 | 25 | 10 | 60 | 17 | 331 | 26 | 245 |
| Phosphorus,Total Dissolved | µg/L | 5 | 8 | 14 | 14 | - | - | 1 | 36 | 12 | - |
| **Biochemical Oxygen Demand** | | | | | | | | | | | |
| Biochemical Oxygen Demand | mg/L | < 2 | 6 | < 2 | 1 | 0.6 | 3 | 3 | 7 | < 2 | - |
| **Toxicity** | | | | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | > 91 | > 91 | - | > 91 | > 91 | 2 | > 91 | > 91 | - |
| Microtox IC25 @ 15 min | % | > 91 | > 91 | > 91 | - | > 91 | > 91 | 2 | > 91 | > 91 | - |
| **Organics** | | | | | | | | | | | |
| Naphthenic acids | mg/L | 1 | 1 | < 1 | - | 0 | < 1 | 2 | 1 | < 1 | - |
| Total Phenolics | µg/L | 4 | 4 | 4 | - | < 1 | 1 | 2 | 2 | 2 | - |
| Total Recoverable Hydrocarbons | mg/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 0.4 | < 1 | 3 | 1.1 | 0.8 | - |
| **Metals (Total)** | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 440 | 35 | 120 | 51 | < 10 | 200 | 12 | 60 | 20 | 55 |
| Antimony (Sb) | µg/L | < 0.8 | < 0.4 | < 0.8 | - | < 0.2 | 0.4 | 2 | < 0.8 | < 0.8 | - |
| Arsenic (As) | µg/L | < 1 | < 0.4 | < 1 | 0.5 | 0.2 | < 5 | 5 | < 1 | < 1 | < 1 |
| Barium (Ba) | µg/L | 189 | 118 | 49 | - | 18 | 20 | 2 | 175 | 37 | - |
| Beryllium (Be) | µg/L | < 1 | < 1 | < 1 | - | < 1 | 1 | 2 | < 1 | < 1 | - |
| Boron (B) | µg/L | 56 | 53 | 66 | 30 | 30 | 39 | 3 | 169 | 18 | - |
| Cadmium (Cd) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 1 | < 0.2 | 4 | 3 | < 0.2 | < 0.2 | - |
| Calcium (Ca) | µg/L | 171000 | 108850 | 55800 | 20600 | - | - | 1 | 79800 | 37800 | - |
| Chromium (Cr) | µg/L | < 0.8 | < 0.4 | < 0.8 | 1.5 | < 1 | 12 | 3 | 1.2 | < 0.8 | - |
| Cobalt (Co) | µg/L | 0.5 | 0.6 | 0.3 | - | 1.4 | 9 | 2 | 1.2 | < 0.2 | - |
| Copper (Cu) | µg/L | 2 | 2.6 | < 1 | < 1 | < 1 | 3.8 | 3 | < 1 | < 1 | - |
| Iron (Fe) | µg/L | 1460 | 700 | 1570 | 580 | 570 | 1120 | 3 | 5300 | 290 | - |
| Lead (Pb) | µg/L | 0.9 | 0.3 | < 0.1 | < 2 | 1.2 | < 20 | 3 | < 0.1 | < 0.1 | - |

**Table II-8. Water Quality in Tributaries of the Lower Muskeg River**

| Parameter | Units | Alsands Drain (Fall) | | Jackpine Creek (Fall) | | | | | Shelley Creek | Stanley Creek (Fall) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Historical (1976 - 1997)[a] | | | | | | |
| | | 1999 | 1997 | 1999 | median | min | max | count | (Fall 1999) | 1999 | 1976[b] |
| Lithium (Li) | µg/L | 109 | 9 | 79 | - | 8 | 9 | 2 | 134 | 78 | - |
| Magnesium (Mg) | µg/L | 24100 | 15500 | 14900 | 6390 | - | - | 1 | 14300 | 10100 | - |
| Manganese (Mn) | µg/L | 253 | 244 | 58 | 16 | 4 | 21 | 3 | 1630 | 23.1 | - |
| Mercury (Hg) | µg/L | < 0.2 | < 0.1 | < 0.2 | < 0.1 | < 0.05 | 0.3 | 13 | < 0.2 | < 0.2 | < 0.2 |
| Molybdenum (Mo) | µg/L | 0.3 | < 0.1 | 0.1 | - | 0.2 | 3.0 | 2 | 0.1 | < 0.1 | - |
| Nickel (Ni) | µg/L | 3.5 | 0.4 | 1.6 | < 2.5 | < 1 | < 5 | 3 | 1.7 | 0.4 | - |
| Potassium (K) | µg/L | 2510 | 2495 | 1550 | 1020 | - | - | 1 | 3380 | 1180 | - |
| Selenium (Se) | µg/L | < 0.8 | < 0.4 | < 0.8 | < 0.2 | < 0.2 | < 0.4 | 3 | < 0.8 | < 0.8 | - |
| Silver (Ag) | µg/L | < 0.4 | < 0.1 | < 0.4 | - | < 0.1 | 5 | 2 | < 0.4 | < 0.4 | - |
| Sodium (Na) | µg/L | 7700 | 7000 | 17100 | 9500 | - | - | 1 | 97100 | 24100 | - |
| Strontium (Sr) | µg/L | 293 | 225 | 171 | - | 77.7 | 94 | 2 | 435 | 75 | - |
| Titanium (Ti) | µg/L | 13 | 1 | 3 | 8 | 1 | < 50 | 3 | 4 | < 0.6 | - |
| Uranium (U) | µg/L | 0.5 | < 0.1 | 0.1 | - | < 0.1 | < 500 | 2 | < 0.1 | < 0.1 | - |
| Vanadium (V) | µg/L | 1.8 | 0.2 | 0.8 | < 1.8 | < 1 | < 2 | 3 | 1.7 | < 0.2 | - |
| Zinc (Zn) | µg/L | 11 | 10 | 7 | 26 | 2 | 186 | 3 | 5 | 4 | - |
| **Metals (Dissolved)** | | | | | | | | | | | |
| Aluminum (Al) | µg/L | < 10 | - | < 10 | 58 | - | - | 1 | < 10 | 20 | - |
| Antimony (Sb) | µg/L | < 0.8 | - | < 0.8 | < 0.4 | - | - | 1 | < 0.8 | < 0.8 | - |
| Arsenic (As) | µg/L | < 0.4 | - | < 0.4 | 0.35 | < 0.2 | 1.1 | 10 | < 0.4 | < 0.4 | - |
| Barium (Ba) | µg/L | 162 | - | 44 | 17 | - | - | 1 | 107 | 39 | - |
| Beryllium (Be) | µg/L | < 0.5 | - | < 0.5 | < 0.5 | - | - | 1 | < 0.5 | < 0.5 | - |
| Boron (B) | µg/L | 45 | - | 54 | 110 | 40 | 480 | 11 | 166 | 17 | 65 |
| Cadmium (Cd) | µg/L | < 0.1 | - | < 0.1 | < 0.1 | - | - | 1 | < 0.1 | < 0.1 | - |
| Chromium (Cr) | µg/L | < 0.4 | - | < 0.4 | < 3 | < 0.4 | 8.0 | 11 | < 0.4 | < 0.4 | < 3 |
| Cobalt (Co) | µg/L | 0.3 | - | 0.2 | 0.2 | - | - | 1 | 0.9 | < 0.1 | - |
| Copper (Cu) | µg/L | 0.8 | - | < 0.6 | 2.2 | - | - | 1 | 0.7 | 1.2 | - |
| Iron (Fe) | µg/L | 540 | - | 280 | 340 | - | - | 1 | 1610 | 240 | - |
| Lead (Pb) | µg/L | < 0.1 | - | < 0.1 | 0.7 | - | - | 1 | < 0.1 | < 0.1 | - |
| Lithium (Li) | µg/L | 21 | - | 23 | 8 | - | - | 1 | 55 | 15 | - |
| Manganese (Mn) | µg/L | 254 | - | 49 | 44 | - | - | 1 | 1630 | 22 | - |
| Mercury (Hg) | µg/L | < 0.1 | - | < 0.01 | < 0.2 | - | - | 1 | < 0.01 | < 0.01 | - |
| Molybdenum (Mo) | µg/L | 0.2 | - | < 0.1 | 0.1 | - | - | 1 | < 0.1 | 0.2 | - |
| Nickel (Ni) | µg/L | 3.3 | - | 1.2 | 0.2 | - | - | 1 | 1.4 | 0.2 | - |
| Selenium (Se) | µg/L | < 0.4 | - | < 0.4 | < 0.2 | < 0.1 | < 0.4 | 8 | < 0.4 | < 0.4 | - |
| Silver (Ag) | µg/L | < 0.2 | - | < 0.2 | < 0.2 | - | - | 1 | < 0.2 | < 0.2 | - |
| Strontium (Sr) | µg/L | 304 | - | 180 | 71 | - | - | 1 | 405 | 77 | - |
| Titanium (Ti) | µg/L | 1.3 | - | < 0.3 | 0.4 | - | - | 1 | 0.9 | 2.3 | - |
| Uranium (U) | µg/L | 0.5 | - | < 0.1 | < 0.05 | - | - | 1 | < 0.1 | < 0.1 | - |
| Vanadium (V) | µg/L | < 0.1 | - | 0.3 | 0.3 | - | - | 1 | 0.7 | 0.3 | - |
| Zinc (Zn) | µg/L | 4 | - | 2 | 16 | - | - | 1 | < 2 | 3 | - |

[a] Based on information from Golder (1996a, 1998b), R.L.&L. (1982, 1989) and NAQUADAT stations AB07DA0600.

[b] Based on information from NAQUADAT station AB07DA0490 (n=2).

**Table II-9. Water Quality in Tributaries of the Upper Muskeg River**

| Parameter | Units | Muskeg Creek (Fall) | | | | | Wapasu Creek Winter | | | | | Wapasu Creek Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1976-1998)[b] | | | | | Historical (1985-1988)[b] | | | | | Historical (1976-1988)[c] | | | |
| | | 1999 | median | min | max | count | 1999 | median | min | max | n | 1999 | median | min | max | n |
| **Field measured** | | | | | | | | | | | | | | | | |
| pH | | 7.6 | 7.7 | 7.3 | 7.8 | 5 | 7.8 | 8.0 | - | - | 1 | 8.2 | 7.6 | 7.4 | 7.9 | 4 |
| Specific Conductance | µS/cm | 585 | 192 | 80 | 240 | 5 | 572 | - | - | - | - | 318 | - | 190 | 234 | 2 |
| Temperature | °C | 2.8 | 5.0 | 0.0 | 13.0 | 9 | 0.4 | 0.0 | 0.0 | 0.5 | 5 | 4.0 | 3.0 | 0.0 | 10.0 | 6 |
| Dissolved Oxygen | mg/L | 7.2 | 10.7 | 4.4 | 14.5 | 8 | 4.3 | 9.0 | - | - | 1 | 8.6 | 11.6 | 5.0 | 14.4 | 5 |
| **Conventional Parameters and Major Ions** | | | | | | | | | | | | | | | | |
| Bicarbonate (HCO3) | mg/L | 362 | 130 | 119 | 382 | 6 | 398 | - | 229 | 356 | 2 | 215 | 140 | 122 | 154 | 4 |
| Calcium | mg/L | 66 | 22 | 19 | 71 | 11 | 78 | 65 | 41 | 72 | 6 | 44 | 29 | 25 | 47 | 6 |
| Carbonate (CO3) | mg/L | - | < 0.5 | < 0.5 | < 5 | 4 | < 5 | < 5 | - | - | 1 | < 5 | - | < 0.5 | < 0.5 | 2 |
| Chloride | mg/L | 23.1 | 1.3 | 0.3 | 36 | 11 | 1.0 | 1.7 | 1.4 | 2.7 | 6 | 2.0 | 1.2 | 0.7 | 2.2 | 6 |
| Colour | T.C.U. | 68 | 150 | 120 | 200 | 5 | 25 | - | 60 | 100 | 2 | 60 | - | 100 | 100 | 2 |
| Conductance | µS/cm | 585 | 226 | 192 | 671 | 6 | 600 | 425 | 310 | 524 | 6 | 339 | 240 | 210 | 310 | 4 |
| Dissolved Organic Carbon | mg/L | 21 | 25 | 6 | 31 | 6 | 8 | 31 | 11 | 37 | 5 | 18 | 13 | - | - | 1 |
| Hardness | mg/L | 237 | 83 | 76 | 244 | 11 | 311 | 222 | 154 | 282 | 6 | 172 | 112 | 97 | 159 | 6 |
| Magnesium | mg/L | 17 | 7 | 7 | 16 | 11 | 28 | 15 | 13 | 25 | 6 | 15 | 10 | 8 | 10 | 6 |
| pH | | 7.8 | 7.4 | 7.2 | 8.1 | 7 | 7.4 | 7.1 | 6.9 | 7.4 | 5 | 7.7 | - | 7.1 | 7.4 | 2 |
| Potassium | mg/L | 2.1 | 0.9 | 0.3 | 1.8 | 11 | 1.5 | 1.4 | 1.1 | 1.5 | 6 | 1.0 | 0.9 | 0.4 | 1.2 | 6 |
| Sodium | mg/L | 44 | 16 | 6 | 64 | 11 | 7 | 9 | 8 | 18 | 6 | 6 | 6 | 3 | 10 | 6 |
| Sulphate | mg/L | 8 | 3 | 1 | 7 | 11 | 8 | 6 | 5 | 8 | 6 | 5 | 2 | 1 | 5 | 6 |
| Sulphide | µg/L | 4 | < 2 | - | - | 1 | < 3 | 5 | - | - | 1 | < 3 | - | - | - | - |
| Total Alkalinity | mg/L | 297 | 110 | 98 | 313 | 11 | 327 | 231 | 173 | 292 | 6 | 176 | 119 | 100 | 165 | 6 |
| Total Dissolved Solids | mg/L | 339 | 127 | 106 | 378 | 11 | 350 | 266 | 189 | 300 | 6 | 240 | 130 | 105 | 186 | 6 |
| Total Organic Carbon | mg/L | 21 | 30 | 26 | 53 | 10 | 10 | 33 | 14 | 45 | 6 | 22 | 24 | 20 | 33 | 6 |
| Total Suspended Solids | mg/L | 7 | 1 | 1 | 9 | 11 | 7 | 23 | 5 | 59 | 6 | 3 | 7 | 1 | 22.4 | 6 |
| **Nutrients and Chlorophyll *a*** | | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | mg/L | < 0.1 | 0.012 | < 0.003 | < 0.05 | 6 | < 0.1 | - | < 0.1 | 0.10 | 2 | < 0.1 | 0.01 | 0.003 | 0.01 | 4 |
| Nitrogen - Ammonia | mg/L | 0.07 | 0.04 | 0.03 | 0.28 | 5 | 0.34 | - | 0.2 | 0.22 | 2 | < 0.05 | 0.07 | 0.02 | 0.09 | 4 |
| Nitrogen - Kjeldahl | mg/L | 1.0 | 0.8 | 0.5 | 1.3 | 10 | 0.5 | 1.8 | 0.4 | 2.6 | 6 | 0.9 | 1.0 | 0.4 | 2.1 | 6 |
| Phosphorus, Total | µg/L | 42 | 34 | 16 | 66 | 11 | 96 | 200 | 59 | 340 | 6 | 20 | 37 | 22 | 180 | 6 |
| Phosphorus,Total Dissolved | µg/L | 14 | 30 | - | - | 1 | 10 | 16 | - | - | 1 | 14 | - | - | - | - |
| Chlorophyll *a* | µg/L | - | < 1 | 0 | < 1 | 5 | 7 | < 1 | - | - | 1 | - | - | < 1 | 2 | 2 |
| **Biochemical Oxygen Demand** | | | | | | | | | | | | | | | | |
| Biochemical Oxygen Demand | mg/L | < 2 | 2 | 0.2 | 8 | 5 | 2 | - | 2 | < 2 | 2 | < 2 | 2 | 1 | 3 | 4 |
| **Toxicity** | | | | | | | | | | | | | | | | |
| Microtox IC50 @ 15 min | % | > 91 | > 91 | > 91 | > 100 | 3 | > 91 | > 91 | - | - | 1 | > 91 | - | - | - | - |
| Microtox IC25 @ 15 min | % | > 91 | > 91 | > 91 | > 100 | 3 | > 91 | > 91 | - | - | 1 | > 91 | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - IC25 | % | - | - | - | - | - | > 100 | - | - | - | - | - | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - IC50 | % | - | - | - | - | - | > 100 | - | - | - | - | - | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - LOEC | % | - | - | - | - | - | > 100 | - | - | - | - | - | - | - | - | - |
| Algal Growth Inhibition Test (72 h) - NOEC | % | - | - | - | - | - | 100 | - | - | - | - | - | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LC25 | % | - | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LC50 | % | - | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - LOEC | % | - | > 100 | - | - | 1 | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Ceriodaphnia 7 d Mortality Test - NOEC | % | - | 100 | - | - | 1 | 100 | 100 | - | - | 1 | - | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC25 | % | - | 15 | - | - | 1 | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - IC50 | % | - | 56 | - | - | 1 | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - LOEC | % | - | 25 | - | - | 1 | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Ceriodaphnia 7 d Reproduction Test - NOEC | % | - | 12.5 | - | - | 1 | 100 | 100 | - | - | 1 | - | - | - | - | - |
| Fathead Minnow 7d Growth - IC25 | % | - | - | - | - | - | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Fathead Minnow 7d Growth - IC50 | % | - | - | - | - | - | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Fathead Minnow 7d Growth - LOEC | % | - | - | - | - | - | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Fathead Minnow 7d Growth - NOEC | % | - | - | - | - | - | 100 | 100 | - | - | 1 | - | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LC25 | % | - | - | - | - | - | > 100 | 92 | - | - | 1 | - | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LC50 | % | - | - | - | - | - | > 100 | > 100 | - | - | 1 | - | - | - | - | - |
| Fathead Minnow 7d Mortality Test - LOEC | % | - | - | - | - | - | > 100 | 100 | - | - | 1 | - | - | - | - | - |
| Fathead Minnow 7d Mortality Test - NOEC | % | - | - | - | - | - | 100 | 50 | - | - | 1 | - | - | - | - | - |
| **Organics** | | | | | | | | | | | | | | | | |
| Naphthenic acids | mg/L | 2 | - | < 1 | < 1 | 2 | < 1 | < 1 | - | - | 1 | < 1 | - | - | - | - |
| Total Phenolics | µg/L | 5 | 5 | - | - | 1 | 6 | 6 | - | - | 1 | 2 | - | - | - | - |
| Total Recoverable Hydrocarbons | mg/L | 0.8 | 0.5 | < 0.1 | < 1 | 6 | < 0.5 | - | < 0.5 | 0.6 | 2 | 1.1 | 0.2 | < 0.1 | 1.7 | 4 |

**Table II-9. Water Quality in Tributaries of the Upper Muskeg River**

| Parameter | Units | Muskeg Creek (Fall) | | | | | Wapasu Creek – Winter | | | | | Wapasu Creek – Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Historical (1976-1998)[b] | | | | | Historical (1985-1988)[b] | | | | | Historical (1976-1988)[c] | | | |
| | | 1999 | median | min | max | count | 1999 | median | min | max | n | 1999 | median | min | max | n |
| **Metals (Total)** | | | | | | | | | | | | | | | | |
| Aluminum (Al) | µg/L | 70 | 20 | < 10 | 50 | 11 | 120 | 35 | < 10 | 90 | 6 | 20 | 20 | < 10 | 40 | 6 |
| Antimony (Sb) | µg/L | < 0.8 | < 0.8 | - | - | 1 | < 0.8 | < 0.8 | - | - | 1 | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 1 | 0.7 | 0.2 | 12 | 8 | < 1 | - | 0.4 | < 1 | 2 | < 1 | 0.7 | 0.2 | < 5 | 5 |
| Barium (Ba) | µg/L | 51 | - | 40 | 67 | 2 | 66 | 59 | - | - | 1 | 29 | - | - | - | - |
| Beryllium (Be) | µg/L | < 1 | - | < 1 | < 1 | 2 | < 1 | < 1 | - | - | 1 | < 1 | - | - | - | - |
| Boron (B) | µg/L | 86 | 55 | < 10 | 150 | 6 | 31 | - | 70 | 81 | 2 | 14 | 45 | < 10 | 50 | 4 |
| Cadmium (Cd) | µg/L | < 0.2 | < 1 | < 0.2 | < 3 | 6 | < 0.2 | - | < 0.2 | < 1 | 2 | < 0.2 | < 1 | < 1 | < 1 | 4 |
| Calcium (Ca) | µg/L | 67200 | 72500 | - | - | 1 | 76000 | 75500 | - | - | 1 | 46600 | - | - | - | - |
| Chromium (Cr) | µg/L | < 0.8 | 1 | < 0.8 | 11 | 6 | < 0.8 | - | 1 | 2.4 | 2 | < 0.8 | < 1 | < 1 | < 1 | 4 |
| Cobalt (Co) | µg/L | 0.4 | - | 0.4 | 6 | 2 | 0.7 | 2.7 | - | - | 1 | < 0.2 | - | - | - | - |
| Copper (Cu) | µg/L | < 1 | < 1 | < 1 | < 1 | 6 | < 1 | - | < 1 | 2 | 2 | < 1 | < 1 | < 1 | < 1 | 4 |
| Iron (Fe) | µg/L | 1810 | 395 | 250 | 1750 | 6 | 2370 | - | 1820 | 2070 | 2 | 600 | 945 | 270 | 1800 | 4 |
| Lead (Pb) | µg/L | < 0.1 | < 2 | 0.2 | 20 | 6 | 0.6 | - | 1 | < 2 | 2 | < 0.1 | < 2 | < 2 | < 2 | 4 |
| Lithium (Li) | µg/L | 95 | - | 7 | 28 | 2 | 9 | 11 | - | - | 1 | 7 | - | - | - | - |
| Magnesium (Mg) | µg/L | 19000 | 16000 | - | - | 1 | 27620 | 24400 | - | - | 1 | 15900 | - | - | - | - |
| Manganese (Mn) | µg/L | 350 | 21 | 13 | 534 | 6 | 697 | - | 540 | 870 | 2 | 74 | 63 | 27 | 96 | 4 |
| Mercury (Hg) | µg/L | < 0.2 | < 0.1 | < 0.05 | 1.2 | 10 | < 0.2 | < 0.1 | < 0.1 | 0.4 | 6 | < 0.2 | < 0.1 | < 0.05 | < 0.2 | 6 |
| Molybdenum (Mo) | µg/L | < 0.1 | - | < 0.1 | < 3 | 2 | < 0.1 | 0.4 | - | - | 1 | < 0.1 | - | - | - | - |
| Nickel (Ni) | µg/L | 1.6 | < 1 | < 1 | 10 | 6 | 3 | - | < 1 | 4.1 | 2 | 2 | < 1 | < 1 | < 1 | 4 |
| Potassium (K) | µg/L | 2360 | 2160 | - | - | 1 | 840 | 2140 | - | - | 1 | 1110 | - | - | - | - |
| Selenium (Se) | µg/L | < 0.8 | 0.7 | < 0.2 | 0.8 | 5 | < 0.8 | - | 0.6 | < 0.8 | 2 | < 0.8 | 0.4 | < 0.2 | 0.8 | 4 |
| Silver (Ag) | µg/L | < 0.4 | - | < 0.4 | 3 | 2 | < 0.4 | < 0.4 | - | - | 1 | < 0.4 | - | - | - | - |
| Sodium (Na) | µg/L | 46900 | 63000 | - | - | 1 | 5400 | 8800 | - | - | 1 | 6100 | - | - | - | - |
| Strontium (Sr) | µg/L | 243 | - | 89 | 296 | 2 | 93 | 130 | - | - | 1 | 96 | - | - | - | - |
| Titanium (Ti) | µg/L | 1.7 | 7 | 1.5 | < 50 | 3 | 2.2 | 2.2 | - | - | 1 | < 0.6 | - | - | - | - |
| Uranium (U) | µg/L | 0.1 | - | 0.2 | < 500 | 2 | 0.1 | 0.1 | - | - | 1 | < 0.1 | - | - | - | - |
| Vanadium (V) | µg/L | 0.8 | < 1 | 0.4 | < 2 | 6 | < 0.2 | - | 0.2 | < 1 | 2 | < 0.2 | < 1 | < 1 | < 1 | 4 |
| Zinc (Zn) | µg/L | 7 | 4 | 2 | 24 | 6 | 4 | - | 5 | 14 | 2 | < 4 | 4 | 2 | 16 | 4 |
| **Metals (Dissolved)** | | | | | | | | | | | | | | | | |
| Aluminum (Al) | µg/L | < 10 | 30 | - | - | 1 | 30 | 50 | - | - | 1 | < 10 | - | - | - | - |
| Antimony (Sb) | µg/L | < 0.8 | < 0.8 | - | - | 1 | < 0.8 | < 0.8 | - | - | 1 | < 0.8 | - | - | - | - |
| Arsenic (As) | µg/L | < 0.4 | < 0.5 | < 0.2 | < 1 | 3 | < 0.4 | < 1 | < 0.4 | < 1 | 5 | < 0.4 | < 1 | - | - | 1 |
| Barium (Ba) | µg/L | 48 | 63 | - | - | 1 | 59 | 53.2 | - | - | 1 | 28 | - | - | - | - |
| Beryllium (Be) | µg/L | < 0.5 | < 0.5 | - | - | 1 | < 0.5 | < 0.5 | - | - | 1 | < 0.5 | - | - | - | - |
| Boron (B) | µg/L | 108 | 90 | 40 | 170 | 6 | 35 | 80 | < 2 | 300 | 5 | 14 | - | 60 | 130 | 2 |
| Cadmium (Cd) | µg/L | < 0.1 | < 0.1 | - | - | 1 | < 0.1 | 0.1 | - | - | 1 | < 0.1 | - | - | - | - |
| Chromium (Cr) | µg/L | < 0.4 | < 3 | 0.8 | < 3 | 6 | < 0.4 | < 3 | < 0.4 | 6 | 5 | < 0.4 | - | < 3 | < 3 | 2 |
| Cobalt (Co) | µg/L | 0.3 | 0.7 | - | - | 1 | 2.3 | 2.8 | - | - | 1 | 0.2 | - | - | - | - |
| Copper (Cu) | µg/L | < 0.6 | 0.7 | - | - | 1 | 0.7 | 2.6 | - | - | 1 | < 0.6 | - | - | - | - |
| Iron (Fe) | µg/L | 350 | 1020 | - | - | 1 | 400 | 1130 | - | - | 1 | 420 | - | - | - | - |
| Lead (Pb) | µg/L | < 0.1 | 0.1 | - | - | 1 | 0.2 | 0.8 | - | - | 1 | < 0.1 | - | - | - | - |
| Lithium (Li) | µg/L | 33 | 26 | - | - | 1 | 9 | 7 | - | - | 1 | 7 | - | - | - | - |
| Manganese (Mn) | µg/L | 319 | 522 | - | - | 1 | 718 | 866 | - | - | 1 | 70 | - | - | - | - |
| Mercury (Hg) | µg/L | < 0.01 | < 0.1 | - | - | 1 | < 0.1 | < 0.1 | - | - | 1 | < 0.01 | - | - | - | - |
| Molybdenum (Mo) | µg/L | < 0.1 | < 0.1 | - | - | 1 | < 0.1 | < 0.1 | - | - | 1 | < 0.1 | - | - | - | - |
| Nickel (Ni) | µg/L | 1.1 | 3.5 | - | - | 1 | 2.9 | 3.3 | - | - | 1 | 0.7 | - | - | - | - |
| Selenium (Se) | µg/L | < 0.4 | < 0.4 | < 0.2 | 1.2 | 3 | < 0.4 | < 0.5 | < 0.4 | < 0.5 | 5 | < 0.4 | < 0.5 | - | - | 1 |
| Silver (Ag) | µg/L | < 0.2 | < 0.2 | - | - | 1 | < 0.2 | < 0.2 | - | - | 1 | < 0.2 | - | - | - | - |
| Strontium (Sr) | µg/L | 250 | 274 | - | - | 1 | 110 | 123 | - | - | 1 | 96 | - | - | - | - |
| Titanium (Ti) | µg/L | 0.7 | 0.5 | - | - | 1 | 1.6 | 0.6 | - | - | 1 | < 0.3 | - | - | - | - |
| Uranium (U) | µg/L | 0.2 | 0.2 | - | - | 1 | 0.1 | 0.1 | - | - | 1 | < 0.1 | - | - | - | - |
| Vanadium (V) | µg/L | 0.4 | < 0.1 | - | - | 1 | < 0.1 | < 0.1 | - | - | 1 | < 0.1 | - | - | - | - |
| Zinc (Zn) | µg/L | 2 | 4 | - | - | 1 | 5 | 12 | - | - | 1 | < 2 | - | - | - | - |

[a] Based on information from Golder (1996a, 1999a), R.L.&L. (1989) and NAQUADAT stations AB07DA0500/530.

[b] Based on information from Golder (1999a), R.L.&L. (1989) and NAQUADAT station AB07DA0480.

[c] Based on information from R.L.&L. (1989) and NAQUADAT station AB07DA0480.

**Table II-10. Water Quality of Field Blanks, Trip Blanks and Lab Blanks, RAMP QA/QC Program, 1999**

| Parameter | Units | Field blanks | | | | Trip blanks | | | | Lab blanks | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | winter | spring | summer | fall | winter | spring | summer | fall | spring | summer |
| **Conventional Parameters** | | | | | | | | | | | |
| bicarbonate | mg/L | 7 | < 5 | < 5 | < 5 | 8 | < 5 | < 5 | - | - | - |
| calcium | mg/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | - | < 0.5 | < 0.5 |
| carbonate | mg/L | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | < 5 | - | - | - |
| chloride | mg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | - | < 1 | < 1 |
| colour | T.C.U. | 3 | 10 | < 3 | 8 | 3 | 5 | < 3 | - | < 3 | < 3 |
| conductance | μS/cm | 2.7 | 2.8 | 5.8 | 1.8 | 3.7 | 4.1 | 1.4 | - | - | - |
| dissolved organic carbon | mg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | - | < 1 | < 1 |
| hardness | mg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | - | < 1 | < 1 |
| magnesium | mg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | - | < 0.1 | < 0.1 |
| pH | | 5.9 | 5.3 | 5.8 | 5.5 | 6.1 | 6.2 | 5.5 | - | - | - |
| potassium | mg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | - | < 0.1 | < 0.1 |
| sodium | mg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | - | < 1 | < 1 |
| sulphate | mg/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | - | < 0.5 | < 0.5 |
| sulphide | mg/L | < 0.003 | < 0.003 | < 0.003 | < 0.003 | < 0.003 | < 0.003 | < 0.003 | < 0.003 | < 0.003 | < 0.003 |
| total alkalinity | mg/L | 6 | < 5 | < 5 | < 5 | 7 | < 5 | < 5 | - | - | - |
| total dissolved solids | mg/L | < 10 | 20 | 10 | < 10 | < 10 | 20 | < 10 | - | < 10 | < 10 |
| total organic carbon | mg/L | 1 | 1 | < 1 | < 1 | 1 | < 1 | < 1 | < 1 | < 1 | < 1 |
| total suspended solids | mg/L | < 3 | < 3 | < 3 | < 3 | < 3 | 10 | < 3 | - | < 3 | < 3 |
| **Nutrients** | | | | | | | | | | | |
| nitrate + nitrite | mg/L | < 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 | - | < 0.05 | < 0.05 | < 0.05 | < 0.05 |
| nitrogen - kjeldahl | mg/L | < 0.2 | - | 0.3 | < 0.2 | < 0.2 | - | 0.3 | < 0.2 | < 0.2 | 0.2 |
| phosphorus, total | μg/L | < 2 | - | < 1 | < 1 | < 2 | < 1 | < 1 | 6 | < 1 | < 1 |
| phosphorus,total dissolved | μg/L | < 2 | < 1 | 1 | < 1 | < 2 | < 1 | < 1 | < 1 | < 1 | 2 |
| **General Organics and Toxicity** | | | | | | | | | | | |
| biochemical oxygen demand | mg/L | - | 3 | < 2 | < 2 | - | < 2 | < 2 | < 2 | < 2 | < 2 |
| chlorophyll "a" | μg/L | - | 67 | 3 | 3 | - | 13 | 1 | 11 | - | - |
| Microtox IC50 @ 15 min | % | - | > 91 | > 91 | > 91 | - | > 91 | > 91 | > 91 | - | - |
| Microtox IC25 @ 15 min | % | - | > 91 | > 91 | > 91 | - | > 91 | > 91 | > 91 | - | - |
| naphthenic acids | mg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 |
| total phenolics | μg/L | < 1 | < 1 | 1 | 1 | < 1 | 3 | < 1 | 2 | < 1 | < 1 |
| total recoverable hydrocarbons | mg/L | < 0.5 | < 0.5 | 1.2 | 2.1 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 12.1 |
| **Metals (Total)** | | | | | | | | | | | |
| aluminum (Al) | μg/L | 30 | 30 | 80 | < 20 | 440 | 20 | 40 | 60 | < 20 | 70 |
| antimony (Sb) | μg/L | < 0.8 | 3.6 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 |
| arsenic (As) | μg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 |
| barium (Ba) | μg/L | 4.3 | 0.9 | 0.7 | 0.7 | 14.4 | 0.9 | 0.5 | 0.4 | 0.5 | < 0.2 |
| beryllium (Be) | μg/L | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 |
| boron (B) | μg/L | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | 11 | < 4 | < 4 | 7 |
| cadmium (Cd) | μg/L | < 0.2 | < 0.2 | < 2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| calcium (Ca) | μg/L | 3700 | < 100 | < 100 | 200 | 100 | < 100 | 100 | < 100 | < 100 | < 100 |
| chromium (Cr) | μg/L | 7.8 | < 0.8 | < 0.8 | < 0.8 | 8.1 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 |
| cobalt (Co) | μg/L | < 0.2 | < 0.2 | < 2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| copper (Cu) | μg/L | 8 | 1 | 1 | 1 | 2 | < 1 | < 1 | 1 | < 1 | 2 |
| iron (Fe) | μg/L | 30 | 130 | 20 | < 20 | 90 | < 20 | < 20 | 180 | 90 | 30 |
| lead (Pb) | μg/L | 3.5 | 0.6 | 0.2 | < 0.1 | 0.3 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | 0.2 |
| lithium (Li) | μg/L | < 6 | < 6 | < 6 | < 6 | < 6 | < 6 | < 6 | < 6 | < 6 | < 6 |
| magnesium (Mg) | μg/L | 780 | 40 | 20 | 40 | 50 | < 20 | 40 | < 20 | < 20 | < 20 |
| manganese (Mn) | μg/L | 3.6 | 1.1 | 11.1 | < 0.2 | 2.4 | 0.2 | 127 | 0.4 | 0.2 | 8.1 |
| mercury (Hg) | μg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| molybdenum (Mo) | μg/L | 0.6 | < 0.1 | < 0.1 | < 0.1 | 0.5 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 |
| nickel (Ni) | μg/L | 6.3 | 1.1 | < 0.2 | < 0.2 | 5 | < 0.2 | < 0.2 | 0.7 | 0.4 | 2.5 |
| potassium (K) | μg/L | 430 | < 20 | < 20 | 80 | 610 | 80 | < 20 | 50 | < 20 | < 20 |
| selenium (Se) | μg/L | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 | < 0.8 |
| silver (Ag) | μg/L | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | 5.9 | < 0.4 |
| sodium (Na) | μg/L | 1000 | < 200 | < 200 | < 200 | 300 | < 200 | < 200 | < 200 | < 200 | < 200 |
| strontium (Sr) | μg/L | 24 | 1 | 0.2 | 0.5 | 0.9 | < 0.2 | 0.3 | < 0.2 | < 0.2 | < 0.2 |
| titanium (Ti) | μg/L | 1.2 | < 0.6 | < 0.6 | < 0.6 | 3.6 | < 0.6 | < 0.6 | < 0.6 | < 0.6 | < 0.6 |
| uranium (U) | μg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 |
| vanadium (V) | μg/L | < 0.2 | < 0.2 | 0.5 | < 0.2 | 1.1 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 |
| zinc (Zn) | μg/L | 4 | 16 | 21 | < 4 | 16 | 7 | < 4 | < 4 | 18 | 24 |

**Table II-10. Water Quality of Field Blanks, Trip Blanks and Lab Blanks, RAMP QA/QC Program, 1999**

| Parameter | Units | Field blanks | | | | Trip blanks | | | | Lab blanks | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | winter | spring | summer | fall | winter | spring | summer | fall | spring | summer |
| **Metals (Dissolved)** | | | | | | | | | | | |
| aluminum (Al) | µg/L | 30 | 20 | 20 | < 10 | 10 | - | - | - | < 10 | < 10 |
| antimony (Sb) | µg/L | < 0.8 | 0.9 | < 0.8 | 1.0 | < 0.8 | - | - | - | < 0.8 | < 0.8 |
| arsenic (As) | µg/L | < 0.4 | < 0.4 | 2.0 | < 0.4 | < 0.4 | - | - | - | < 0.4 | < 0.4 |
| barium (Ba) | µg/L | 2.3 | < 0.1 | 0.5 | 0.1 | 0.2 | - | - | - | < 0.1 | < 0.1 |
| beryllium (Be) | µg/L | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | - | - | - | < 0.5 | < 0.5 |
| boron (B) | µg/L | < 2 | 3 | < 2 | 3 | < 2 | - | - | - | 12 | 2 |
| cadmium (Cd) | µg/L | 0.2 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | - | - | - | < 0.1 | < 0.1 |
| chromium (Cr) | µg/L | 7.6 | < 0.4 | < 0.4 | < 0.4 | < 0.4 | - | - | - | < 0.4 | < 0.4 |
| cobalt (Co) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | - | - | - | < 0.1 | < 0.1 |
| copper (Cu) | µg/L | 5.0 | 0.8 | 1.6 | < 0.6 | 0.7 | - | - | - | < 0.6 | < 0.6 |
| iron (Fe) | µg/L | < 10 | 20 | < 10 | 30 | < 10 | - | - | - | < 10 | 10 |
| lead (Pb) | µg/L | 0.4 | 0.7 | 0.2 | < 0.1 | 0.3 | - | - | - | < 0.1 | < 0.1 |
| lithium (Li) | µg/L | < 3 | < 3 | < 3 | < 3 | < 3 | - | - | - | < 3 | < 3 |
| manganese (Mn) | µg/L | 3.0 | 0.6 | 10.3 | < 0.1 | 1 | - | - | - | < 0.1 | < 0.1 |
| mercury (Hg) | µg/L | < 0.1 | 0.1 | 0.3 | < 0.01 | < 0.1 | - | - | < 0.01 | 0.2 | < 0.1 |
| molybdenum (Mo) | µg/L | 0.6 | < 0.1 | 0.9 | < 0.1 | < 0.1 | - | - | - | < 0.1 | < 0.1 |
| nickel (Ni) | µg/L | 6.3 | 0.7 | < 0.1 | < 0.1 | 0.3 | - | - | - | < 0.1 | < 0.1 |
| selenium (Se) | µg/L | < 0.4 | < 0.4 | 0.4 | < 0.8 | < 0.4 | - | - | - | < 0.4 | < 0.4 |
| silver (Ag) | µg/L | < 0.2 | < 0.2 | < 0.2 | < 0.2 | < 0.2 | - | - | - | < 0.2 | < 0.2 |
| strontium (Sr) | µg/L | 14 | < 0.1 | 0.3 | 0.3 | 0.2 | - | - | - | < 0.1 | < 0.1 |
| titanium (Ti) | µg/L | < 0.3 | < 0.3 | 0.4 | < 0.3 | < 0.3 | - | - | - | < 0.3 | < 0.3 |
| uranium (U) | µg/L | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | - | - | - | < 0.1 | < 0.1 |
| vanadium (V) | µg/L | < 0.1 | 0.2 | 0.2 | < 0.1 | < 0.1 | - | - | - | 0.3 | 0.2 |
| zinc (Zn) | µg/L | 4 | 13 | 7 | < 2 | 3 | - | - | - | 23 | 7 |

- = No data.

# APPENDIX III

# PHOTOS OF SENTINEL FISH SAMPLING SITES, FALL 1999

# Photographs – Athabasca River

Photograph A.1 Site AR-R, Athabasca River, Fall 1999 (view faces upstream).

Photograph A.2 Site AR-SD, Athabasca River, Fall 1999 (view faces downstream).

Photograph A.3 Site AR-MR, Athabasca River, Fall 1999 (view faces downstream).

## Photographs – Muskeg River

Photograph A.4 Site MR-FF, Muskeg River, Fall 1999 (view faces downstream).

Photograph A.5 Site MR-MT, Muskeg River, Fall 1999 (view faces downstream).

## Photographs – Steepbank River

Photograph A.6 Site SR-MN, Steepbank River, Fall 1999 (view faces upstream).

Photograph A.7 Site SR-R, Steepbank River, Fall 1999 (view faces downstream).

# APPENDIX IV

# SENTINEL FISH SPECIES DATA

**Legend**

Sex:
M = male
F = female
I = immature

Maturity Stage:
SD = seasonal development
IM = immature
MA = maturing

Mesenteric Fat:
0 = none
1 = < 50% of cecum covered
2 = 50% of cecum covered

# Trout-perch from the Athabasca River

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 1 | | 4.8 | 1.30 | | I | | | 0.010 | | | | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 2 | | 4.5 | 0.99 | | I | | | 0.010 | | | | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 3 | | 6.4 | 2.85 | | F | | 2 | 0.050 | 0.120 | | | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 4 | | 4.4 | 0.94 | | I | | | | | | | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 5 | | 4.6 | 1.05 | | I | | | | | | | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 6 | | 4.8 | 1.32 | | I | | | | | | | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 7 | | 6.8 | 3.58 | 3.04 | F | SD | 3 | 0.062 | 0.173 | | 1 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 8 | | 6.9 | 3.72 | 3.12 | F | SD | 2 | 0.066 | 0.187 | | 1 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 9 | | 5.1 | 1.50 | 1.30 | I | SD | 0 | 0.019 | | | 0 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 10 | 4.7 | 4.2 | 0.85 | 0.61 | I | IM | 0 | 0.019 | | | 0 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 11 | 5.7 | 5.1 | 1.51 | 1.35 | I | SD | 0 | 0.018 | | | 1 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 12 | 9.5 | 8.5 | 5.75 | 4.98 | F | SD | 2 | 0.086 | 0.272 | | 1 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 13 | 5.6 | 5.0 | 1.36 | 1.18 | I | IM | 1 | 0.013 | 0.010 | | 1 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 14 | 5.1 | 4.6 | 0.99 | 0.89 | I | IM | 0 | 0.011 | | | 0 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 15 | 5.4 | 4.8 | 1.24 | 1.11 | I | IM | 0 | 0.014 | 0.013 | | 1 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 17 | 5.8 | 5.2 | 1.60 | 1.38 | I | IM | 1 | 0.019 | 0.016 | | 1 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 18 | 5.6 | 5.0 | 1.24 | 1.13 | I | IM | 1 | 0.015 | 0.006 | | 1 | |
| 13/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 19 | 5.6 | 5.0 | 1.27 | 1.11 | I | IM | 1 | 0.018 | 0.006 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 27 | 8.2 | 7.4 | 4.53 | 4.00 | F | SD | 3 | 0.081 | 0.225 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 28 | 5.4 | 4.9 | 1.29 | 1.14 | I | | 0 | 0.190 | 0.007 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 29 | 8.1 | 7.2 | 4.31 | 3.90 | F | | 2 | 0.059 | 0.244 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 30 | 7.5 | 6.8 | 3.30 | 3.00 | F | | 2 | 0.040 | 0.040 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 31 | 7.4 | 6.9 | 3.11 | 2.80 | F | | 3 | 0.051 | 0.108 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 32 | 7.9 | 7.0 | 3.40 | 3.17 | M | | 3 | 0.037 | 0.050 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 33 | 7.2 | 6.5 | 2.97 | 2.82 | M | | 2 | 0.030 | 0.040 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 34 | 6.6 | 5.9 | 2.41 | 2.13 | M | | 1 | 0.034 | 0.046 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 35 | 6.1 | 5.5 | 1.92 | 1.79 | I | | 1 | 0.030 | 0.028 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 36 | 5.4 | 4.9 | 1.28 | 1.18 | I | | 0 | 0.017 | 0.006 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 37 | 6.5 | 6.0 | 2.02 | 1.81 | I | | 1 | 0.026 | 0.019 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 38 | 5.4 | 5.0 | 1.33 | 1.21 | I | | 1 | 0.019 | 0.011 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 39 | 5.3 | 4.8 | 1.17 | 1.06 | I | | 1 | 0.016 | 0.005 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 40 | 5.8 | 5.3 | 1.59 | 1.40 | M | | 1 | 0.026 | 0.027 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 41 | 5.4 | 5.0 | 1.31 | 1.20 | I | | 1 | 0.017 | 0.004 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 42 | 6.1 | 5.7 | 1.69 | 1.50 | M | | 1 | 0.017 | 0.015 | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 43 | 5.6 | 4.9 | 1.34 | 1.16 | U | | 1 | 0.027 | | | | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 44 | 8.0 | 7.1 | 4.82 | 4.16 | M | SD | 3 | 0.052 | 0.088 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 45 | 7.4 | 6.6 | 3.33 | 2.96 | M | SD | 3 | 0.056 | 0.058 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 46 | 7.3 | 6.6 | 3.37 | 3.01 | M | SD | 3 | 0.046 | 0.040 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 47 | 7.3 | 6.4 | 3.05 | 2.65 | M | SD | 3 | 0.033 | 0.066 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 48 | 6.7 | 6.1 | 2.62 | 2.33 | M | SD | 3 | 0.049 | 0.059 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 49 | 5.7 | 5.2 | 1.72 | 1.40 | I | MA | 1 | 0.031 | 0.025 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 50 | 4.9 | 4.5 | 0.96 | 0.83 | I | IM | 1 | 0.013 | 0.004 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 51 | 5.4 | 4.9 | 1.34 | 1.18 | I | IM | 1 | 0.018 | | | 2 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 52 | 5.5 | 4.8 | 1.30 | 1.11 | I | IM | 1 | 0.020 | 0.005 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 53 | 5.0 | 4.7 | 0.99 | 0.88 | I | IM | 1 | 0.003 | 0.005 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 55 | 7.9 | 7.1 | 4.41 | 3.83 | M | SD | 3 | 0.056 | 0.073 | | 2 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 56 | 7.1 | 6.5 | 2.87 | 2.56 | M | SD | 2 | 0.033 | 0.056 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 57 | 7.7 | 7.1 | 3.40 | 2.95 | F | SD | 3 | 0.051 | 0.141 | 769 | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 58 | 7.6 | 6.8 | 3.16 | 2.66 | F | SD | 2 | 0.059 | 0.116 | 536 | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 59 | 8.2 | 7.4 | 4.80 | 4.11 | F | SD | 3 | 0.180 | 0.248 | | 0 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 60 | 8.8 | 8.1 | 5.43 | 4.71 | F | SD | 3 | 0.087 | 0.269 | 819 | 0 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 61 | 7.6 | 6.9 | 3.23 | 2.78 | F | SD | 3 | 0.067 | 0.144 | 600 | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 62 | 7.5 | 6.7 | 3.23 | 2.77 | M | SD | 2 | 0.043 | 0.065 | | 1 | |
| 14/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 63 | 8.7 | 7.8 | 5.15 | 4.36 | F | SD | 3 | 0.133 | 0.267 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 64 | 8.4 | 7.5 | 4.20 | 3.64 | F | SD | 3 | 0.081 | 0.214 | | 1 | |

# Trout-perch from the Athabasca River

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 65 | 7.7 | 6.9 | 3.52 | 2.99 | F | SD | 3 | 0.086 | 0.184 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 66 | 7.5 | 6.8 | 3.32 | 2.80 | F | SD | 2 | 0.065 | 0.150 | 381 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 67 | 7.7 | 6.9 | 3.59 | 3.07 | F | SD | 3 | 0.073 | 0.213 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 68 | 7.2 | 6.5 | 2.81 | 2.54 | M | SD | 4 | 0.038 | 0.053 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 69 | 8.4 | 7.6 | 4.44 | 3.82 | F | SD | 3 | 0.095 | 0.243 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 70 | 6.2 | 5.7 | 1.76 | 1.53 | M | SD | 1 | 0.030 | 0.022 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 71 | 8.1 | 7.4 | 3.64 | 3.16 | F | SD | 3 | 0.065 | 0.165 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 72 | 7.3 | 6.6 | 2.93 | 2.61 | M | SD | 2 | 0.041 | 0.067 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 73 | 7.3 | 6.7 | 2.82 | 2.51 | M | SD | 3 | 0.046 | 0.062 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 74 | 5.6 | 5.0 | 1.38 | 1.22 | I | IM | 1 | 0.017 | 0.007 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 75 | 10.1 | 9.7 | 7.96 | 7.18 | F | SD | 4 | 0.094 | 0.354 | | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 76 | 7.7 | 7.0 | 3.65 | 3.14 | F | SD | 4 | 0.060 | 0.159 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 77 | 7.5 | 6.7 | 3.18 | 2.84 | M | SD | 2 | 0.051 | 0.067 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 78 | 8.0 | 7.2 | 3.90 | 3.39 | F | SD | 3 | 0.059 | 0.212 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 79 | 8.1 | 7.4 | 4.14 | 3.63 | F | SD | 3 | 0.073 | 0.177 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 80 | 8.3 | 7.5 | 4.45 | 3.92 | F | SD | 3 | 0.078 | 0.220 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 81 | 7.9 | 7.1 | 3.75 | 3.34 | M | SD | 2 | 0.054 | 0.062 | | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 82 | 8.4 | 7.7 | 5.14 | 4.17 | F | SD | 3 | 0.107 | 0.301 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 83 | 8.4 | 7.6 | 4.96 | 4.05 | F | SD | 3 | 0.093 | 0.257 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 84 | 5.9 | 5.2 | 1.80 | 1.54 | I | MA | 1 | 0.022 | 0.015 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 85 | 7.5 | 6.8 | 3.42 | 3.04 | M | SD | 2 | 0.055 | 0.057 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 86 | 8.0 | 7.2 | 4.26 | 3.74 | F | SD | 2 | 0.064 | 0.204 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 87 | 7.7 | 7.0 | 3.70 | 3.20 | M | SD | 3 | 0.054 | 0.051 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 88 | 8.0 | 7.2 | 3.99 | 3.52 | F | SD | 4 | 0.055 | 0.210 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 89 | 8.4 | 7.6 | 4.75 | 4.15 | F | SD | 3 | 0.074 | 0.263 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 90 | 7.3 | 6.8 | 3.15 | 2.83 | M | SD | 2 | 0.029 | 0.049 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 91 | 8.4 | 8.1 | 6.13 | 5.28 | F | SD | 2 | 0.092 | 0.308 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 92 | 5.9 | 5.6 | 1.69 | 1.44 | I | IM | 1 | 0.023 | 0.005 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 93 | 8.2 | 7.4 | 5.73 | 3.65 | F | SD | 4 | 0.090 | 0.217 | | 2 | spleen: enlarged |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 94 | 8.1 | 7.5 | 4.62 | 3.84 | F | SD | 3 | 0.125 | 0.295 | | 2 | spleen: enlarged |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 95 | 5.7 | 5.2 | 1.48 | 1.29 | M | SD | 1 | 0.019 | 0.022 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 96 | 6.1 | 5.8 | 2.09 | 1.84 | M | SD | 1 | 0.024 | 0.041 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 97 | 7.4 | 6.6 | 3.42 | 2.96 | F | SD | 2 | 0.062 | 0.170 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 98 | 8.2 | 7.4 | 4.63 | 3.77 | F | SD | 4 | 0.124 | 0.286 | | 1 | spleen: enlarged |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 99 | 9.1 | 8.6 | 5.96 | 4.97 | F | SD | 2 | 0.116 | 0.366 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 100 | 8.3 | 7.6 | 4.13 | 3.71 | M | SD | 2 | 0.050 | 0.062 | | 2 | spleen: enlarged |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 102 | 7.1 | 6.4 | 2.92 | 2.50 | M | SD | 2 | 0.037 | 0.038 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 103 | 7.3 | 6.6 | 2.98 | 2.56 | M | SD | 4 | 0.049 | 0.060 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 104 | 7.0 | 6.4 | 2.74 | 2.36 | M | SD | 2 | 0.034 | 0.035 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 105 | 7.4 | 6.9 | 3.12 | 2.74 | M | SD | 2 | 0.046 | 0.061 | | 2 | spleen: enlarged |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 106 | 8.3 | 7.8 | 4.76 | 4.14 | M | SD | 2 | 0.072 | 0.076 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 107 | 8.2 | 7.3 | 4.47 | 3.77 | F | SD | 3 | 0.215 | 0.090 | 371 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 108 | 7.8 | 7.1 | 3.97 | 3.40 | M | SD | 3 | 0.061 | 0.104 | | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 109 | 7.9 | 7.1 | 3.54 | 3.05 | F | SD | 3 | 0.056 | 0.178 | | 1 | spleen: enlarged |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 110 | 8.6 | 7.8 | 5.04 | 4.27 | F | SD | 1 | 0.084 | 0.310 | 1116 | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 111 | 7.2 | 6.4 | 2.75 | 2.49 | M | SD | 3 | 0.028 | 0.051 | | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 112 | 8.1 | 7.5 | 4.00 | 3.39 | F | SD | 3 | 0.082 | 0.193 | 822 | 1 | spleen: enlarged |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 113 | 9.0 | 8.3 | 6.80 | 5.69 | F | SD | 3 | 0.105 | 0.380 | 1246 | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 114 | 6.9 | 6.2 | 2.65 | 2.34 | M | SD | 3 | 0.033 | 0.039 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 115 | 7.8 | 7.0 | 3.83 | 3.36 | M | SD | 2 | 0.054 | 0.075 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 116 | 8.3 | 7.5 | 4.60 | 3.93 | F | SD | 1 | 0.061 | 0.244 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 117 | 7.9 | 7.2 | 4.30 | 3.57 | F | SD | 4 | 0.082 | 0.223 | 785 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 118 | 7.9 | 7.2 | 4.11 | 3.56 | F | SD | 2 | 0.067 | 0.197 | | 1 | spleen: enlarged |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 119 | 8.0 | 7.4 | 3.87 | 3.30 | F | SD | 3 | 0.066 | 0.211 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 120 | 7.6 | 6.9 | 3.34 | 2.82 | F | SD | 3 | 0.050 | 0.156 | | 1 | |

# Trout-perch from the Athabasca River

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 121 | 6.5 | 5.9 | 2.17 | 1.94 | M | SD | 1 | 0.037 | 0.024 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 122 | 8.0 | 7.3 | 4.33 | 3.71 | F | SD | 3 | 0.085 | 0.179 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 123 | 7.7 | 7.0 | 3.62 | 3.10 | M | SD | 2 | 0.047 | 0.073 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 124 | 7.2 | 6.5 | 2.88 | 2.45 | M | SD | 3 | 0.028 | 0.050 | | 2 | numerous parasites (gills, mesentaric fat, intestines) |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 125 | 7.3 | 6.6 | 2.88 | 2.52 | M | SD | 3 | 0.048 | 0.057 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 126 | 8.0 | 7.5 | 4.04 | 3.68 | M | SD | 3 | 0.045 | 0.068 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 127 | 8.0 | 7.3 | 3.96 | 3.40 | F | SD | 3 | 0.082 | 0.177 | 485 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 128 | 8.0 | 7.3 | 3.88 | 3.22 | F | SD | | 0.054 | 0.210 | 785 | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 129 | 8.2 | 7.5 | 4.35 | 3.62 | F | SD | 3 | 0.064 | 0.213 | 719 | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 130 | 7.8 | 7.0 | 3.69 | 3.26 | M | SD | | 0.047 | 0.075 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 131 | 7.0 | 6.4 | 2.65 | 2.30 | M | SD | 2 | 0.035 | 0.039 | | 0 | fins; moderate active erosion with some hemorraging (tail fin) |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 132 | 7.9 | 7.3 | 4.53 | 3.72 | F | SD | 2 | 0.083 | 0.211 | 886 | 2 | fins: light active erosion (tail fin) |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 133 | 7.4 | 6.8 | 3.33 | 2.90 | M | SD | 3 | 0.050 | 0.069 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 134 | 8.7 | 7.7 | 5.76 | 4.80 | F | SD | 4 | 0.102 | 0.330 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 135 | 7.9 | 7.0 | 3.90 | 3.44 | M | SD | 3 | 0.030 | 0.075 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 136 | 8.0 | 7.3 | 3.88 | 3.59 | M | SD | 3 | 0.054 | 0.100 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 137 | 7.4 | 6.7 | 3.11 | 2.71 | M | SD | 2 | 0.049 | 0.067 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 138 | 6.8 | 6.0 | 2.55 | 2.27 | M | SD | 4 | 0.040 | 0.040 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 139 | 7.8 | 7.2 | 3.91 | 3.30 | F | SD | 2 | 0.081 | 0.165 | | 1 | liver: general discolouration (pale); colour change in whole liver |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 140 | 7.6 | 6.9 | 3.68 | 3.28 | M | SD | 2 | 0.046 | 0.072 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 141 | 6.4 | 5.7 | 1.97 | 1.76 | M | SD | 2 | 0.033 | 0.031 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 142 | 8.5 | 7.6 | 5.13 | 4.42 | F | SD | 2 | 0.103 | 0.225 | 810 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 143 | 7.7 | 7.2 | 3.79 | 3.42 | M | SD | 2 | 0.043 | 0.084 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 144 | 6.6 | 6.1 | 2.35 | 2.10 | M | SD | 2 | 0.025 | 0.030 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 145 | 7.8 | 7.0 | 3.49 | 3.12 | M | SD | 3 | 0.031 | 0.051 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 146 | 7.8 | 7.0 | 3.54 | 3.19 | M | SD | 2 | 0.039 | 0.060 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 147 | 7.3 | 6.4 | 3.02 | 2.68 | M | SD | 3 | 0.027 | 0.020 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 148 | 8.5 | 7.6 | 5.10 | 4.65 | F | SD | 2 | 0.100 | 0.287 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 149 | 7.5 | 6.6 | 3.25 | 2.79 | M | SD | 3 | 0.041 | 0.066 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 150 | 7.8 | 7.0 | 4.18 | 3.51 | F | SD | 3 | 0.108 | 0.274 | 1370 | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 151 | 7.5 | 6.7 | 3.37 | 2.86 | M | SD | 3 | 0.079 | 0.043 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 152 | 8.0 | 7.4 | 4.22 | 3.70 | M | SD | 3 | 0.067 | 0.081 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 153 | 8.0 | 7.3 | 4.20 | 3.65 | F | SD | 2 | 0.060 | 0.186 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 154 | 7.1 | 6.5 | 2.54 | 2.26 | M | SD | 2 | 0.040 | 0.048 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 155 | 7.7 | 6.9 | 3.36 | 3.02 | M | SD | 3 | 0.036 | 0.072 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 156 | 8.1 | 7.5 | 3.98 | 3.43 | F | SD | 3 | 0.072 | 0.242 | 1452 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 157 | 8.1 | 7.2 | 3.88 | 3.50 | M | SD | 2 | 0.045 | 0.082 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 158 | 8.2 | 7.3 | 3.86 | 3.32 | F | SD | 3 | 0.061 | 0.266 | 1889 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 159 | 8.3 | 7.5 | 4.09 | 3.68 | M | SD | 2 | 0.043 | 0.084 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 160 | 8.2 | 7.5 | 3.88 | 3.40 | F | SD | 4 | 0.045 | 0.161 | 984 | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 161 | 8.0 | 7.3 | 3.75 | 3.40 | M | SD | 1 | 0.038 | 0.064 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 162 | 7.7 | 7.0 | 3.31 | 2.98 | M | SD | 2 | 0.036 | 0.066 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 163 | 7.5 | 6.6 | 3.15 | 2.84 | M | SD | 1 | 0.043 | 0.065 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 164 | 6.8 | 6.2 | 2.36 | 2.13 | M | SD | 3 | 0.027 | 0.040 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 165 | 8.2 | 7.6 | 4.43 | 3.81 | F | SD | 3 | 0.060 | 0.250 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 166 | 7.5 | 6.7 | 3.08 | 2.78 | M | SD | 3 | 0.038 | 0.039 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 167 | 7.1 | 6.5 | 2.63 | 2.32 | F | SD | 2 | 0.037 | 0.131 | 676 | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 168 | 8.4 | 7.6 | 4.46 | 3.74 | F | SD | | 0.074 | 0.321 | 2428 | 1 | other:  white dots on intestine; taken for microscopic inspection |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 169 | 7.8 | 7.0 | 3.40 | 3.07 | M | SD | 2 | 0.033 | 0.076 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 170 | 8.2 | 7.5 | 4.11 | 3.55 | F | SD | 3 | 0.054 | 0.204 | 1455 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 171 | 8.2 | 7.4 | 3.98 | 3.46 | F | SD | 3 | 0.056 | 0.163 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 172 | 7.9 | 7.0 | 3.52 | 3.16 | M | SD | 3 | 0.040 | 0.064 | | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 173 | 7.6 | 6.7 | 3.30 | 2.94 | M | SD | 2 | 0.034 | 0.065 | | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 174 | 7.4 | 6.7 | 2.90 | 2.67 | M | SD | 3 | 0.038 | 0.066 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 175 | 7.2 | 6.5 | 2.77 | 2.47 | M | SD | 2 | 0.030 | 0.055 | | 0 | |

# Trout-perch from the Athabasca River

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 176 | 7.6 | 6.9 | 3.30 | 2.99 | M | SD | 3 | 0.042 | 0.072 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 177 | 7.6 | 6.8 | 3.58 | 3.14 | M | SD | 3 | 0.049 | 0.079 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 178 | 8.0 | 7.3 | 4.25 | 3.81 | M | SD | 4 | 0.050 | 0.082 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 179 | 8.8 | 8.0 | 5.94 | 4.93 | F | SD | 3 | 0.147 | 0.353 | 1177 | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 180 | 8.2 | 7.6 | 4.19 | 3.60 | F | SD | | 0.060 | 0.198 | 440 | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 181 | 8.0 | 7.2 | 3.85 | 3.28 | F | SD | 2 | 0.268 | 0.056 | | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 182 | 8.8 | 8.0 | 5.42 | 4.71 | F | SD | 2 | 0.133 | 0.308 | 1721 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 183 | 8.0 | 7.2 | 4.06 | 3.30 | F | SD | 3 | 0.086 | 0.255 | 1305 | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 184 | 8.6 | 7.7 | 5.25 | 4.59 | F | SD | | 0.091 | 0.272 | | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 185 | 7.3 | 6.6 | 2.94 | 2.65 | M | SD | 2 | 0.029 | 0.052 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 186 | 8.3 | 7.9 | 4.46 | 3.92 | F | SD | | 0.077 | 0.199 | 901 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 187 | 9.2 | 8.3 | 6.18 | 5.28 | F | SD | 3 | 0.146 | 0.417 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 188 | 9.5 | 8.5 | 6.55 | 5.80 | F | SD | 4 | 0.100 | 0.332 | 1287 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 189 | 10.4 | 9.3 | 9.10 | 7.83 | F | SD | 3 | 0.192 | 0.498 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 190 | 8.8 | 8.3 | 5.67 | 4.97 | F | SD | 3 | 0.097 | 0.297 | 1233 | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 191 | 8.3 | 7.6 | 4.68 | 3.93 | F | SD | 3 | 0.075 | 0.281 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 192 | 7.3 | 6.6 | 3.29 | 2.93 | M | SD | 2 | 0.046 | 0.071 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 193 | 7.8 | 7.0 | 4.22 | 3.57 | F | SD | 3 | 0.102 | 0.219 | 600 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 194 | 8.6 | 7.8 | 4.70 | 4.03 | F | MA | | 0.081 | 0.230 | 870 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 195 | 7.4 | 6.6 | 3.17 | 2.89 | M | SD | 3 | 0.034 | 0.051 | | 2 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 196 | 7.9 | 7.2 | 3.94 | 3.44 | F | SD | 3 | 0.057 | 0.180 | 630 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 197 | 7.7 | 7.1 | 3.63 | 3.13 | F | SD | 2 | 0.059 | 0.191 | 742 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 198 | 7.1 | 6.5 | 3.05 | 2.75 | M | SD | 3 | 0.040 | 0.062 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 199 | 7.6 | 6.8 | 3.38 | 2.96 | F | SD | 3 | 0.050 | 0.164 | 713 | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 200 | 8.2 | 7.5 | 4.56 | 3.96 | F | SD | 2 | 0.095 | 0.212 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 201 | 8.0 | 7.3 | 4.00 | 3.58 | M | SD | 1 | 0.054 | 0.076 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 202 | 7.8 | 7.0 | 3.93 | 3.43 | F | SD | | 0.079 | 0.177 | 997 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 203 | 9.2 | 8.4 | 5.72 | 5.00 | F | SD | | 0.086 | 0.303 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 204 | 8.1 | 7.3 | 4.05 | 3.60 | F | SD | 2 | 0.080 | 0.176 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 205 | 7.6 | 6.8 | 3.44 | 3.13 | M | SD | 3 | 0.041 | 0.065 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 206 | 7.2 | 6.6 | 2.96 | 2.56 | M | SD | 2 | 0.047 | 0.041 | | 0 | numerous parasites |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 207 | 10.2 | 9.2 | 7.27 | 6.46 | F | SD | 2 | 0.115 | 0.300 | 2445 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 208 | 7.6 | 6.8 | 3.45 | 3.01 | F | SD | 3 | 0.061 | 0.165 | | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 209 | 8.3 | 7.3 | 4.75 | 4.04 | F | SD | 3 | 0.068 | 0.283 | 1449 | 0 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 210 | 8.4 | 7.6 | 5.11 | 4.52 | F | SD | 3 | 0.072 | 0.259 | 1625 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 211 | 9.0 | 8.1 | 5.83 | 5.10 | F | SD | 2 | 0.081 | 0.331 | 1757 | 1 | |
| 15/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 212 | 9.0 | 8.2 | 6.10 | 5.28 | F | SD | 2 | 0.111 | 0.350 | 2520 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 213 | 7.8 | 7.1 | 3.64 | 3.28 | M | SD | 3 | 0.056 | 0.076 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 214 | 8.6 | 7.8 | 4.88 | 4.26 | F | SD | 2 | 0.093 | 0.270 | 1414 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 215 | 8.1 | 7.3 | 3.78 | 3.32 | F | SD | 2 | 0.073 | 0.201 | 1267 | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 216 | 8.0 | 7.1 | 3.58 | 3.16 | F | SD | 3 | 0.058 | 0.183 | 1270 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 217 | 7.5 | 6.7 | 3.27 | 2.81 | F | SD | 2 | 0.062 | 0.184 | 1204 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 218 | 8.2 | 7.3 | 4.31 | 3.79 | F | SD | 4 | 0.075 | 0.207 | 1082 | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 219 | 8.0 | 7.4 | 4.34 | 3.75 | F | SD | 3 | 0.089 | 0.229 | 1155 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Suncor Discharge | ARSD | TRPR | 220 | 7.5 | 6.7 | 3.41 | 3.09 | M | SD | 3 | 0.045 | 0.045 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 221 | 9.0 | 8.2 | 5.19 | 4.20 | F | SD | 2 | 0.080 | 0.282 | 2025 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 222 | 7.5 | 6.8 | 3.13 | 2.87 | M | SD | 3 | 0.047 | 0.054 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 223 | 8.3 | 7.4 | 4.17 | 3.46 | F | SD | 2 | 0.076 | 0.237 | 642 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 224 | 8.9 | 8.4 | 5.03 | 4.38 | F | SD | 2 | 0.106 | 0.304 | 1241 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 225 | 8.6 | 7.6 | 4.57 | 4.00 | F | SD | 3 | 0.068 | 0.212 | 1302 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 226 | 7.8 | 7.2 | 3.74 | 3.16 | F | SD | 1 | 0.094 | 0.217 | 922 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 227 | 8.0 | 7.1 | 3.84 | 3.36 | M | SD | 1 | 0.055 | 0.078 | | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 228 | 7.8 | 7.1 | 3.66 | 3.10 | F | SD | 3 | 0.061 | 0.244 | 935 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 229 | 7.2 | 6.5 | 2.77 | 2.43 | M | SD | 3 | 0.037 | 0.053 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 230 | 7.8 | 7.0 | 2.89 | 3.42 | F | SD | 4 | 0.070 | 0.188 | | 1 | |

# Trout-perch from the Athabasca River

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 231 | 8.9 | 8.0 | 5.02 | 4.35 | F | SD | 1 | 0.090 | 0.334 | 1060 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 232 | 8.4 | 7.6 | 4.26 | 3.72 | F | SD | 3 | 0.064 | 0.259 | 900 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 233 | 10.4 | 9.4 | 8.29 | 7.28 | F | SD | 3 | 0.130 | 0.504 | 2117 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 234 | 8.1 | 7.3 | 3.59 | 3.24 | M | SD | 1 | 0.044 | 0.069 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 235 | 8.4 | 7.6 | 4.74 | 4.19 | F | SD | 2 | 0.070 | 0.262 | 873 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 236 | 8.0 | 7.4 | 3.63 | 3.17 | M | SD | 3 | 0.048 | 0.090 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 237 | 7.5 | 6.8 | 3.33 | 2.94 | F | SD | 3 | 0.051 | 0.158 | 460 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 238 | 10.3 | 9.7 | 7.45 | 6.62 | F | SD | 4 | 0.101 | 0.346 | 1526 | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 239 | 8.4 | 7.6 | 4.30 | 3.77 | F | SD | 3 | 0.251 | 0.247 | 662 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 240 | 8.2 | 7.3 | 4.15 | 3.55 | F | SD | 3 | 0.058 | 0.265 | 784 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 241 | 8.9 | 8.0 | 5.11 | 4.42 | F | SD | 2 | 0.089 | 0.285 | 1062 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 242 | 7.7 | 6.9 | 3.48 | 3.01 | M | SD | 4 | 0.044 | 0.073 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 243 | 7.5 | 6.8 | 3.63 | 3.27 | M | SD | 2 | 0.037 | 0.065 | | 0 | paralyzed from the dorsal fin down (gone white) |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 244 | 7.9 | 7.2 | 3.79 | 3.33 | F | SD | 3 | 0.056 | 0.173 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 245 | 7.6 | 6.9 | 3.29 | 2.95 | M | SD | 3 | 0.041 | 0.069 | | 1 | few observed parasites (intestine) |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 246 | 7.8 | 7.5 | 3.19 | 2.88 | M | SD | 1 | 0.038 | 0.054 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 247 | 8.1 | 7.2 | 4.31 | 3.70 | F | SD | 2 | 0.091 | 0.204 | 672 | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 248 | 8.3 | 7.6 | 4.27 | 3.73 | F | SD | 4 | 0.066 | 0.224 | 1204 | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 249 | 7.9 | 7.1 | 3.66 | 3.28 | M | SD | 2 | 0.049 | 0.073 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 250 | 7.3 | 6.6 | 2.92 | 2.69 | M | SD | 2 | 0.034 | 0.044 | | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 251 | 7.1 | 6.4 | 2.61 | 2.35 | M | SD | 3 | 0.041 | 0.059 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 252 | 7.3 | 6.8 | 3.04 | 2.76 | M | SD | 2 | 0.040 | 0.074 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 253 | 7.8 | 7.0 | 3.47 | 2.99 | F | SD | 1 | 0.062 | 0.149 | 637 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 254 | 7.3 | 6.7 | 2.74 | 2.48 | M | SD | 3 | 0.036 | 0.047 | | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 255 | 7.3 | 6.7 | 2.99 | 2.68 | M | SD | 3 | 0.030 | 0.055 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 256 | 7.6 | 6.9 | 3.09 | 2.71 | M | SD | 3 | 0.057 | 0.053 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 257 | 7.4 | 6.6 | 3.05 | 2.79 | M | SD | 1 | 0.039 | 0.060 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 258 | 8.4 | 7.7 | 4.59 | 4.06 | F | SD | 2 | 0.062 | 0.250 | 875 | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 259 | 7.0 | 6.4 | 2.44 | 2.15 | F | SD | 4 | 0.038 | 0.103 | 510 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 260 | 8.9 | 8.1 | 5.65 | 4.89 | F | SD | 3 | 0.101 | 0.321 | 1284 | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 261 | 7.2 | 6.5 | 2.78 | 2.38 | F | SD | 3 | 0.047 | 0.159 | 477 | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 262 | 7.4 | 6.7 | 3.03 | 2.69 | F | SD | 1 | 0.046 | 0.130 | 526 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 263 | 7.5 | 6.8 | 3.00 | 2.73 | M | SD | 3 | 0.039 | 0.063 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 264 | 8.4 | 7.5 | 4.35 | 3.78 | F | SD | | 0.072 | 0.242 | 611 | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 265 | 7.5 | 6.8 | 3.30 | 2.96 | M | SD | 3 | 0.044 | 0.056 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 266 | 7.4 | 6.9 | 3.79 | 3.35 | M | SD | 3 | 0.050 | 0.082 | | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 267 | 7.4 | 6.6 | 3.01 | 2.69 | M | SD | 5 | 0.034 | 0.056 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 268 | 7.8 | 7.3 | 3.32 | 2.99 | M | SD | 3 | 0.044 | 0.057 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 269 | 8.4 | 7.5 | 4.64 | 4.04 | F | SD | 2 | 0.058 | 0.231 | 1155 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 270 | 9.1 | 8.1 | 5.63 | 4.89 | F | SD | | 0.092 | 0.245 | 531 | 2 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 271 | 7.5 | 6.8 | 3.30 | 2.97 | M | SD | 2 | 0.040 | 0.080 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 272 | 7.5 | 6.7 | 3.15 | 2.88 | F | SD | 2 | 0.039 | 0.146 | 348 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 273 | 8.0 | 7.1 | 3.54 | 3.20 | M | SD | | 0.040 | 0.048 | | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Muskeg Confluence | ARMR | TRPR | 274 | 8.0 | 7.3 | 3.67 | 3.30 | M | SD | 4 | 0.044 | 0.064 | | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 275 | 8.9 | 8.5 | 5.82 | 5.27 | F | SD | 2 | 0.116 | 0.275 | | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 276 | 8.9 | 7.9 | 5.19 | 4.52 | F | SD | 4 | No Sample | 0.232 | | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 277 | 9.4 | 8.5 | 6.75 | 6.03 | F | SD | 4 | 0.116 | 0.315 | 805 | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 278 | 8.4 | 7.8 | 5.31 | 4.56 | F | SD | 2 | 0.092 | 0.256 | | 0 | |
| 16/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 279 | 8.4 | 7.5 | 4.78 | 4.04 | F | SD | 6 | 0.094 | 0.225 | 611 | 1 | |
| 16/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 280 | 8.3 | 7.9 | 4.75 | 4.05 | F | SD | 2 | 0.068 | 0.236 | 384 | 0 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 281 | 7.8 | 7.0 | 4.12 | 3.53 | F | SD | 3 | 0.064 | 0.266 | 851 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 282 | 7.8 | 7.2 | 3.78 | 3.32 | F | SD | 3 | 0.067 | 0.182 | 819 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 283 | 6.7 | 6.0 | 2.36 | 2.10 | F | SD | 2 | 0.035 | 0.060 | | 0 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 284 | 6.8 | 6.3 | 2.68 | 2.35 | F | SD | 3 | 0.030 | 0.125 | 444 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 285 | 7.6 | 6.8 | 3.29 | 2.90 | F | SD | 3 | 0.053 | 0.157 | 603 | 0 | |

# Trout-perch from the Athabasca River

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 286 | 7.4 | 6.6 | 2.92 | 2.57 | M | SD | 3 | 0.039 | 0.055 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 287 | 8.4 | 7.5 | 4.29 | 3.78 | F | SD | 2 | 0.053 | 0.228 | 874 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 288 | 8.5 | 7.6 | 4.28 | 3.80 | F | SD | 2 | 0.056 | 0.268 | 1212 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 289 | 7.2 | 6.6 | 3.03 | 2.67 | M | SD | 2 | 0.036 | 0.041 | | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 290 | 5.7 | 5.2 | 1.28 | 1.16 | M | SD | 1 | 0.020 | 0.019 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 291 | 7.1 | 6.5 | 2.67 | 2.41 | M | SD | 3 | 0.033 | 0.032 | | 1 | light active erosion (tail fin eroded on ventral side) |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 292 | 8.0 | 7.2 | 3.75 | 3.30 | F | SD | 4 | 0.056 | 0.174 | 655 | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 293 | 7.4 | 6.6 | 3.08 | 2.79 | M | SD | 3 | 0.039 | 0.054 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 294 | 7.1 | 6.3 | 2.51 | 2.27 | M | SD | 4 | 0.022 | 0.049 | | 0 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 295 | 8.3 | 7.7 | 4.56 | 4.05 | F | SD | 2 | 0.060 | 0.259 | | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 296 | 8.2 | 7.4 | 4.36 | 3.96 | M | SD | 3 | 0.057 | 0.107 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 297 | 8.0 | 7.2 | 3.84 | 3.43 | F | SD | 2 | 0.064 | 0.187 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 298 | 7.9 | 7.0 | 3.59 | 3.09 | F | SD | 3 | 0.063 | 0.168 | 743 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 299 | 8.5 | 7.9 | 4.97 | 4.29 | F | SD | 2 | 0.096 | 0.310 | 1302 | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 300 | 8.2 | 7.4 | 4.01 | 3.48 | F | SD | 4 | 0.063 | 0.190 | 496 | 1 | tumor/parasite above anal fin, on liver; few parasites on intestine |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 301 | 8.2 | 7.6 | 4.23 | 3.74 | F | SD | 5 | 0.067 | 0.208 | 1109 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 302 | 8.2 | 7.3 | 4.22 | 3.86 | M | SD | 2 | 0.050 | 0.065 | | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 303 | 8.1 | 7.3 | 4.05 | 3.48 | M | SD | 4 | 0.045 | 0.062 | | 1 | few observed parasites (pancreas) |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 304 | 8.2 | 7.4 | 4.32 | 3.75 | F | SD | 2 | 0.084 | 0.245 | 735 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 305 | 7.7 | 6.9 | 3.47 | 3.14 | M | SD | 3 | 0.043 | 0.054 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 306 | 6.3 | 5.7 | 1.97 | 1.72 | M | SD | 1 | 0.036 | 0.030 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 307 | 7.3 | 6.6 | 2.86 | 2.52 | M | SD | 3 | 0.044 | 0.039 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 308 | 7.2 | 7.0 | 3.87 | 3.39 | F | SD | 3 | 0.069 | 0.175 | | 2 | other: bottom half of tail missing |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 309 | 8.4 | 7.7 | 4.57 | 3.94 | F | SD | 3 | 0.068 | 0.291 | 707 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 310 | 7.7 | 7.0 | 3.40 | 3.10 | M | SD | 3 | 0.041 | 0.057 | | 0 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 311 | 7.9 | 7.2 | 3.65 | 3.31 | M | SD | 2 | 0.036 | 0.071 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 312 | 7.8 | 7.0 | 3.52 | 3.29 | M | SD | 4 | 0.038 | 0.052 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 313 | 8.0 | 7.4 | 3.90 | 3.36 | F | SD | 2 | 0.075 | 0.216 | 909 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 314 | 6.3 | 5.7 | 2.06 | 1.90 | M | SD | 2 | 0.014 | 0.031 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 315 | 7.2 | 6.4 | 2.76 | 2.44 | F | SD | 4 | 0.037 | 0.130 | 475 | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 316 | 8.2 | 7.3 | 4.09 | 3.60 | F | SD | 2 | 0.070 | 0.200 | 660 | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 317 | 5.9 | 5.4 | 1.57 | 1.40 | M | SD | 1 | 0.024 | 0.025 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 318 | 7.9 | 7.2 | 4.05 | 3.60 | M | SD | 2 | 0.083 | 0.071 | | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 319 | 8.2 | 7.4 | 4.15 | 3.80 | M | SD | 3 | 0.047 | 0.064 | | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 320 | 7.9 | 7.1 | 3.82 | 3.45 | M | SD | 2 | No Sample | 0.073 | | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 321 | 6.2 | 5.6 | 1.92 | 1.73 | M | SD | 1 | 0.033 | 0.030 | | 1 | liver: pale |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 322 | 7.3 | 6.5 | 2.95 | 2.68 | M | SD | 3 | 0.033 | 0.039 | | 2 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 323 | 7.3 | 6.6 | 2.91 | 2.54 | F | SD | 4 | 0.040 | 0.149 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 324 | 8.2 | 7.4 | 4.24 | 3.60 | F | SD | 2 | 0.089 | 0.235 | | 1 | liver: white liquid cyst on liver (1.5x1.5mm) |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 325 | 7.2 | 6.4 | 2.86 | 2.63 | M | SD | 2 | 0.039 | 0.058 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 326 | 7.4 | 6.7 | 3.17 | 2.97 | M | SD | 2 | 0.043 | 0.047 | | 1 | |
| 17/9/99 | 1999 | Fall | Athabasca | Reference | ARR | TRPR | 327 | 7.6 | 6.9 | 3.27 | 2.86 | F | SD | 3 | 0.036 | 0.124 | 362 | 1 | |

# Slimy Sculpin from the Muskeg and Steepbank Rivers

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 328 | 8.8 | | 6.56 | 5.82 | F | SD | 4 | 0.105 | 0.108 | 519 | 0 | moderate parasites (intestine) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 329 | 8.2 | | 5.28 | 4.63 | F | SD | 3 | 0.104 | 0.068 | 291 | 0 | moderate parasites (intestine and liver) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 330 | 8.4 | | 5.58 | 4.93 | M | SD | 3 | 0.086 | 0.103 | | 0 | moderate parasites (left opercula, internal parasites in dorsal cavity) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 331 | 8.7 | | 6.99 | 6.11 | F | SD | 4 | 0.122 | 0.109 | 320 | 1 | moderate parasites |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 333 | 8.0 | | 4.47 | 3.84 | M | SD | 3 | 0.072 | 0.106 | | 0 | numerous parasites (intestine, testes) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 334 | 7.1 | | 2.56 | 2.21 | F | SD | 3 | 0.027 | 0.037 | 174 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 336 | 7.5 | | 3.86 | 3.41 | M | SD | 5 | 0.044 | 0.064 | | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 337 | 7.5 | | 4.14 | 3.55 | M | SD | 1 | 0.069 | 0.105 | | 0 | moderate parasites (intestine) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 338 | 6.4 | | 2.28 | 1.99 | F | SD | 1 | 0.053 | 0.031 | 72 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 339 | 7.2 | | 3.35 | 2.90 | F | SD | 3 | 0.075 | 0.060 | 177 | 1 | moderate parasites |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 341 | 6.5 | | 2.30 | 1.97 | F | SD | 2 | 0.040 | 0.032 | 96 | 1 | moderate parasites |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 342 | 7.0 | | 3.42 | 2.99 | M | SD | 2 | 0.042 | 0.061 | | 0 | numerous parasites (external and on muscle) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 343 | 7.2 | | 3.21 | 2.77 | F | SD | 1 | 0.054 | 0.050 | 103 | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 344 | 7.3 | | 3.44 | 3.04 | F | SD | 2 | 0.042 | 0.047 | 141 | 1 | moderate parasites |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 345 | 7.1 | | 2.71 | 2.39 | F | SD | 2 | 0.034 | 0.034 | | 1 | numerous parasites (gills, body cavity) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 346 | 7.0 | | 3.05 | 2.53 | F | SD | 2 | 0.068 | 0.053 | 95 | 1 | moderate parasites |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 348 | 7.0 | | 2.54 | 2.43 | M | SD | 1 | 0.034 | 0.026 | | 0 | numerous parasites (gills and head, body cavity) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 349 | 6.6 | | 2.85 | 2.41 | F | SD | 5 | 0.101 | 0.047 | 184 | 1 | moderate parasites (internal and external) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 350 | 7.2 | | 3.30 | 3.08 | F | SD | 7 | 0.063 | 0.046 | 171 | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 351 | 7.8 | | 4.40 | 3.93 | M | SD | 4 | 0.051 | 0.069 | | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 352 | 6.3 | | 2.21 | 1.94 | F | SD | 1 | 0.038 | 0.025 | | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 353 | 5.2 | | 1.31 | 1.11 | I | IM | 0 | 0.029 | | | 0 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 354 | 7.4 | | 3.44 | 3.01 | F | SD | 3 | 0.059 | 0.054 | | 2 | few parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 355 | 7.6 | | 4.27 | 3.73 | F | SD | 1 | 0.120 | 0.057 | | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 356 | 7.3 | | 2.99 | 2.60 | M | SD | 1 | 0.030 | 0.059 | | 0 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 357 | 7.4 | | 3.89 | 3.35 | F | SD | 3 | 0.070 | 0.063 | 189 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 359 | 7.5 | | 3.55 | 2.96 | F | SD | 4 | 0.084 | 0.056 | 170 | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 360 | 7.6 | | 3.81 | 3.33 | M | SD | 3 | 0.049 | 0.072 | | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 361 | 6.8 | | 2.67 | 2.33 | F | SD | 4 | 0.058 | 0.035 | 125 | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 362 | 5.0 | | 1.16 | 0.98 | I | IM | 0 | 0.036 | 0.004 | | 0 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 363 | 7.0 | | 3.02 | 2.67 | F | SD | 2 | 0.045 | 0.040 | 152 | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 364 | 6.8 | | 2.86 | 2.50 | F | SD | 2 | 0.069 | 0.033 | 103 | 0 | few parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 365 | 7.9 | | 4.62 | 4.08 | F | SD | 3 | 0.142 | 0.079 | | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 366 | 6.7 | | 3.00 | 2.75 | F | SD | 2 | 0.040 | 0.034 | 62 | 1 | moderate parasites (intestines) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 367 | 6.7 | | 2.63 | 2.30 | F | SD | 4 | 0.040 | 0.031 | 108 | 0 | moderate parasites (intestines) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 368 | 7.4 | | 3.68 | 2.98 | F | SD | 1 | 0.058 | 0.045 | 182 | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 369 | 7.0 | | 3.05 | 2.70 | F | SD | 1 | 0.067 | 0.037 | 150 | 0 | moderate parasites (body cavity) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 371 | 6.5 | | 2.30 | 2.03 | F | SD | 1 | 0.040 | 0.027 | | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 372 | 8.0 | | 4.10 | 3.74 | M | SD | 4 | 0.036 | 0.082 | | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 373 | 6.8 | | 2.96 | 2.61 | M | SD | 1 | 0.042 | 0.051 | | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 374 | 6.9 | | 3.02 | 2.70 | F | SD | 2 | 0.046 | 0.043 | 184 | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 375 | 4.5 | | 0.68 | 0.58 | I | IM | 0 | 0.008 | 0.002 | | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 377 | 5.2 | | 1.15 | 1.05 | I | IM | | 0.013 | | | 1 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 378 | 6.5 | | 2.15 | 1.92 | F | SD | 1 | 0.034 | 0.029 | 60 | 0 | few parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 379 | 4.5 | | 0.79 | 0.68 | I | IM | | 0.014 | | | 0 | few parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 380 | 7.1 | | 3.01 | 2.66 | M | SD | 1 | 0.030 | 0.046 | | 0 | moderate parasites (internal) |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 381 | 6.2 | | 1.79 | 1.56 | M | SD | 2 | 0.029 | 0.028 | | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 382 | 7.2 | | 2.88 | 2.57 | F | SD | 4 | 0.040 | 0.044 | 106 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 383 | 7.1 | | 3.11 | 2.72 | M | SD | 2 | 0.068 | 0.056 | | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 384 | 7.2 | | 3.48 | 3.14 | F | SD | 2 | 0.084 | 0.046 | | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 385 | 7.4 | | 3.50 | 3.07 | F | SD | 3 | 0.069 | 0.054 | 150 | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 386 | 7.0 | | 2.76 | 2.38 | F | SD | 3 | 0.028 | 0.051 | 180 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 387 | 6.8 | | 1.97 | 1.78 | F | SD | 2 | 0.026 | 0.038 | 123 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 388 | 6.5 | | 2.70 | 2.40 | F | SD | 1 | 0.045 | 0.034 | 95 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 389 | 6.7 | | 2.84 | 2.51 | M | SD | 2 | 0.033 | 0.046 | | 0 | moderate parasites (internal) |

# Slimy Sculpin from the Muskeg and Steepbank Rivers

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 390 | 7.0 | | 3.07 | 2.72 | M | SD | 3 | 0.032 | 0.051 | | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 391 | 5.9 | | 1.97 | 1.85 | F | SD | 1 | 0.034 | 0.014 | 79 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 392 | 6.9 | | 2.93 | 2.59 | M | SD | 3 | 0.032 | 0.062 | | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 393 | 6.9 | | 2.83 | 2.55 | F | SD | 2 | 0.044 | 0.033 | 107 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 394 | 6.1 | | 1.91 | 1.68 | F | SD | | 0.040 | 0.023 | 63 | 1 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 395 | 6.5 | | 2.14 | 1.89 | M | SD | 1 | 0.022 | 0.041 | | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 396 | 5.3 | | 1.18 | 1.02 | F | SD | 1 | 0.016 | 0.016 | 41 | 0 | |
| 18/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 397 | 4.8 | | 1.12 | 0.96 | I | IM | 0 | 0.008 | 0.003 | | 0 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 398 | 7.7 | | 4.55 | 3.99 | F | SD | 1 | 0.117 | 0.086 | 283 | 0 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 399 | 8.1 | | 5.10 | 4.37 | F | SD | 2 | 0.165 | 0.084 | 327 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 400 | 7.6 | | 3.95 | 3.51 | F | SD | 3 | 0.078 | 0.053 | 220 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 401 | 8.4 | | 6.26 | 5.54 | F | SD | 4 | 0.126 | 0.093 | 682 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 402 | 8.4 | | 5.72 | 4.99 | M | SD | 1 | 0.064 | 0.121 | | 0 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 403 | 8.3 | | 5.50 | 4.58 | M | SD | 3 | 0.059 | 0.058 | | 0 | numerous parasites (intestine contains segmented worm) |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 404 | 8.8 | | 6.79 | 5.94 | M | SD | 4 | 0.093 | 0.158 | | 0 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 405 | 8.4 | | 5.48 | 5.00 | M | SD | 1 | 0.061 | 0.093 | | 0 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 406 | 7.8 | | 4.53 | 3.97 | F | SD | 3 | 0.111 | 0.102 | 291 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 407 | 8.2 | | 5.20 | 4.59 | M | SD | 3 | 0.074 | 0.097 | | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 408 | 8.7 | | 6.41 | 5.52 | F | SD | 2 | 0.147 | 0.126 | 257 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 410 | 5.3 | | 1.53 | 1.23 | U | IM | 0 | 0.023 | 0.010 | | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 412 | 8.1 | | 4.94 | 4.26 | F | SD | 4 | 0.117 | 0.091 | 303 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 414 | 8.0 | | 4.69 | 4.12 | F | SD | 4 | 0.075 | 0.118 | 241 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 415 | 9.6 | | 8.31 | 7.10 | F | SD | 6 | 0.237 | 0.139 | 433 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 416 | 7.2 | | 3.33 | 2.94 | F | SD | 1 | 0.054 | 0.051 | 194 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 418 | 9.0 | | 7.06 | 6.21 | F | SD | 5 | 0.174 | 0.123 | 246 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 419 | 7.4 | | 3.78 | 3.34 | F | SD | 1 | 0.059 | 0.050 | 121 | 1 | other: papiloma on lower lip |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 420 | 7.6 | | 3.94 | 3.55 | F | SD | 3 | 0.055 | 0.056 | 136 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 421 | 7.1 | | 5.14 | 4.59 | F | SD | 2 | 0.075 | 0.092 | 537 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 422 | 8.2 | | 5.05 | 4.45 | F | SD | 2 | 0.107 | 0.072 | | 0 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 423 | 11.4 | | 13.36 | 12.61 | M | SD | 7 | 0.163 | 0.186 | | 0 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 424 | 7.7 | | 4.07 | 3.66 | F | SD | 5 | 0.108 | 0.064 | 164 | 0 | few parasites |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 425 | 8.4 | | 5.18 | 4.55 | F | SD | 3 | 0.210 | 0.083 | | 1 | few parasites |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 426 | 7.2 | | 3.61 | 3.31 | F | SD | 2 | 0.072 | 0.044 | 130 | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 427 | 9.9 | | 7.83 | 7.13 | F | SD | 6 | 0.132 | 0.108 | 302 | 0 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 428 | 8.4 | | 6.28 | 5.72 | M | SD | 3 | 0.087 | 0.123 | | 1 | |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 429 | 8.9 | | 6.30 | 5.61 | F | SD | 4 | 0.096 | 0.101 | 473 | 0 | few parasites |
| 19/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 430 | 9.9 | | 9.50 | 8.57 | F | SD | 8 | 0.183 | 0.145 | 481 | 0 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 431 | 8.7 | | 7.20 | 6.52 | F | SD | 6 | 0.108 | 0.099 | 222 | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 432 | 7.6 | | 3.72 | 3.35 | F | SD | 4 | 0.066 | 0.054 | 187 | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 433 | 7.0 | | 3.05 | 2.71 | F | SD | 1 | 0.069 | 0.051 | 93 | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 435 | 8.5 | | 5.07 | 4.61 | F | SD | 5 | 0.087 | 0.078 | 308 | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 436 | 8.3 | | 5.12 | 4.65 | M | SD | 4 | 0.058 | 0.101 | | 0 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 439 | 8.2 | | 4.89 | 4.40 | M | SD | 6 | 0.050 | 0.095 | | 0 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 440 | 7.8 | | 4.59 | 4.05 | M | SD | 4 | 0.046 | 0.073 | | 0 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 441 | 8.3 | | 5.44 | 4.87 | M | SD | 4 | 0.073 | 0.093 | | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 442 | 7.3 | | 3.49 | 3.25 | F | SD | 1 | 0.036 | 0.047 | | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 443 | 9.6 | | 9.26 | 8.42 | M | SD | 4 | 0.077 | 0.194 | | 1 | few parasites |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 444 | 8.8 | | 6.44 | 5.75 | F | SD | 3 | 0.115 | 0.101 | 234 | 1 | few parasites |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 445 | 8.3 | | 5.18 | 4.68 | M | SD | | 0.058 | 0.117 | | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 447 | 7.6 | | 4.09 | 3.69 | F | SD | 1 | 0.058 | 0.053 | 194 | 0 | few parasites |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 448 | 9.4 | | 8.77 | 7.76 | F | SD | 4 | 0.138 | 0.129 | | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 449 | 8.6 | | 5.77 | 5.46 | M | SD | 4 | 0.045 | 0.136 | | 0 | few parasites |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 450 | 9.2 | | 8.12 | 7.15 | F | SD | 4 | 0.141 | 0.167 | 495 | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 451 | 9.1 | | 6.85 | 6.24 | F | SD | 6 | 0.095 | 0.101 | 231 | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 452 | 8.5 | | 6.18 | 5.44 | M | SD | 2 | 0.062 | 0.137 | | 0 | few parasites |

# Slimy Sculpin from the Muskeg and Steepbank Rivers

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 453 | 5.1 | | 1.29 | 1.15 | I | IM | | 0.032 | | | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 454 | 7.7 | | 4.38 | 3.87 | F | SD | 1 | 0.082 | 0.075 | 225 | 0 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 455 | 7.5 | | 3.66 | 3.36 | F | SD | 3 | 0.137 | 0.054 | 184 | 1 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 456 | 5.5 | | 1.61 | 1.41 | I | IM | | 0.024 | 0.007 | | 0 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 457 | 5.4 | | 1.26 | 1.12 | I | IM | 0 | 0.019 | | | 0 | |
| 20/9/99 | 1999 | Fall | Steepbank River | SB Mine | SRMN | SLSC | 458 | 7.4 | | 3.84 | 3.46 | F | SD | 2 | 0.067 | 0.068 | 249 | 1 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 459 | 7.0 | | 2.99 | 2.67 | M | SD | 1 | 0.015 | 0.038 | | 0 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 460 | 6.8 | | 2.97 | 2.68 | F | SD | 1 | 0.046 | 0.044 | 144 | 0 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 461 | 6.5 | | 2.30 | 2.08 | F | SD | 1 | 0.032 | 0.038 | 123 | 1 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 462 | 7.6 | | 3.73 | 3.30 | M | SD | 1 | 0.022 | 0.078 | | 0 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 463 | 7.5 | | 3.91 | 3.44 | M | SD | 2 | 0.052 | 0.064 | | 1 | few parasites |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 464 | 6.8 | | 2.68 | 2.32 | F | SD | 1 | 0.033 | 0.041 | 95 | 1 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 465 | 6.3 | | 2.18 | 1.88 | M | SD | 1 | 0.038 | 0.024 | | 0 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 466 | 6.7 | | 2.50 | 2.17 | F | SD | 1 | 0.055 | 0.045 | 123 | 1 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 468 | 6.9 | | 2.78 | 2.40 | F | SD | 2 | 0.060 | 0.046 | 90 | 0 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 469 | 7.3 | | 3.32 | 2.92 | F | SD | 2 | 0.039 | 0.065 | 146 | 1 | few parasites |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 470 | 6.3 | | 2.25 | 2.00 | F | SD | 1 | 0.030 | 0.030 | 123 | 1 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 471 | 7.7 | | 4.45 | 3.94 | F | SD | 2 | 0.076 | 0.062 | 219 | 1 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 472 | 7.2 | | 3.19 | 2.77 | F | SD | 3 | 0.048 | 0.045 | 138 | 1 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 473 | 7.1 | | 2.94 | 2.53 | M | SD | 1 | 0.036 | 0.073 | | 0 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 474 | 6.8 | | 2.76 | 2.43 | F | SD | 3 | 0.041 | 0.036 | 103 | 1 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 475 | 6.6 | | 2.50 | 2.13 | M | SD | 1 | 0.028 | 0.043 | | 0 | few parasites |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 476 | 6.8 | | 2.73 | 2.37 | F | SD | 2 | 0.049 | 0.039 | 129 | 0 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 477 | 6.3 | | 2.37 | 2.07 | M | SD | 1 | 0.028 | 0.038 | | 0 | |
| 20/9/99 | 1999 | Fall | Muskeg River | Fish Fence | MRFF | SLSC | 478 | 7.1 | | 3.24 | 2.84 | F | SD | | 0.068 | 0.072 | 213 | 1 | |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 480 | 6.9 | | 2.73 | 2.39 | M | SD | 2 | 0.044 | 0.043 | | 0 | few parasites (intestine) |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 481 | 8.6 | | 5.96 | 5.46 | F | SD | 2 | 0.081 | 0.091 | | 0 | |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 482 | 8.0 | | 4.68 | 4.20 | F | SD | 4 | 0.096 | 0.061 | | 1 | |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 483 | 9.2 | | 6.91 | 5.53 | M | SD | 3 | 0.094 | 0.058 | | 0 | |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 484 | 8.0 | | 4.74 | 4.34 | M | SD | 1 | 0.058 | 0.081 | | 0 | few parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 485 | 7.4 | | 2.74 | 2.40 | F | SD | 2 | 0.035 | 0.052 | | 1 | few parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 486 | 8.0 | | 4.51 | 4.02 | F | SD | 2 | 0.042 | 0.064 | | 1 | few parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 487 | 6.4 | | 2.41 | 2.14 | F | SD | 1 | 0.039 | 0.033 | 102 | 1 | few parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 488 | 8.4 | | 5.57 | 5.00 | M | SD | 3 | 0.094 | 0.111 | | 1 | few parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 489 | 8.3 | | 5.57 | 4.95 | F | SD | 3 | 0.124 | 0.071 | 197 | 1 | few parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 490 | 8.4 | | 4.57 | 4.05 | M | SD | 4 | 0.059 | 0.106 | | 0 | few parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 491 | 7.8 | | 4.38 | 3.93 | M | SD | 3 | 0.048 | 0.083 | | 0 | moderate parasites (head, pectoral fin, gills, testes, intestine); lip growth |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 492 | 8.3 | | 4.47 | 3.92 | M | SD | 3 | 0.057 | 0.098 | | 0 | numerous parasites (intestine and bottom lip) |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 494 | 7.7 | | 4.41 | 3.83 | M | SD | 3 | 0.086 | 0.090 | | 0 | moderate parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 495 | 7.7 | | 4.22 | 3.75 | F | SD | 2 | 0.085 | 0.056 | 263 | 0 | moderate parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 496 | 7.6 | | 3.95 | 3.44 | F | SD | 5 | 0.056 | 0.050 | 113 | 0 | few parasites (intestine) |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 497 | 7.9 | | 3.04 | 2.81 | F | SD | 3 | 0.053 | 0.037 | | 0 | few parasites |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 498 | 7.2 | | 3.17 | 2.74 | F | SD | 2 | 0.067 | 0.049 | 258 | 1 | numerous parasites (intestine and right eye) |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 499 | 8.2 | | 3.32 | 3.02 | F | SD | 1 | 0.053 | 0.042 | 173 | 0 | few parasites (intestine) |
| 21/9/99 | 1999 | Fall | Muskeg River | Near Mouth | MRMT | SLSC | 500 | 7.4 | | 3.78 | 3.35 | F | SD | 1 | 0.057 | 0.064 | 264 | 1 | moderate parasites |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 502 | 7.8 | | 4.96 | 4.31 | M | SD | 2 | 0.077 | 0.095 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 503 | 7.9 | | 5.26 | 4.46 | M | SD | 2 | 0.106 | 0.095 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 504 | 7.5 | | 4.22 | 3.69 | M | SD | 1 | 0.050 | 0.077 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 505 | 7.2 | | 3.78 | 3.28 | F | SD | 2 | 0.056 | 0.074 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 506 | 9.4 | | 9.11 | 7.82 | F | SD | 1 | 0.199 | 0.161 | 476 | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 507 | 7.3 | | 4.17 | 3.36 | F | SD | 1 | 0.034 | 0.035 | 83 | 1 | few parasites (large ligula) |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 508 | 7.6 | | 4.46 | 3.87 | M | SD | 1 | 0.051 | 0.099 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 509 | 8.0 | | 4.70 | 4.18 | M | SD | | 0.039 | 0.084 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 510 | 7.5 | | 4.24 | 3.72 | M | SD | 3 | 0.040 | 0.078 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 511 | 6.6 | | 2.68 | 2.32 | F | SD | 1 | 0.051 | 0.039 | | 1 | |

## Slimy Sculpin from the Muskeg and Steepbank Rivers

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 512 | 7.4 | | 3.89 | 3.39 | M | SD | 5 | 0.038 | 0.078 | | 0 | liver: slightly pale |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 513 | 6.7 | | 2.96 | 2.55 | F | SD | 1 | 0.078 | 0.046 | 158 | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 514 | 6.5 | | 2.70 | 2.41 | F | SD | 1 | 0.021 | 0.037 | 157 | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 515 | 8.1 | | 5.00 | 4.37 | F | SD | 5 | 0.072 | 0.103 | 355 | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 516 | 7.7 | | 4.96 | 4.50 | M | SD | 1 | 0.076 | 0.083 | | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 517 | 6.8 | | 3.17 | 2.75 | F | SD | 1 | 0.054 | 0.049 | 183 | 1 | few parasites (intestine) |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 518 | 8.7 | | 6.95 | 5.88 | F | SD | 5 | 0.177 | 0.134 | 439 | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 519 | 6.9 | | 3.02 | 2.59 | F | SD | 1 | 0.075 | 0.050 | 155 | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 520 | 7.9 | | 4.92 | 4.34 | M | SD | 1 | 0.035 | 0.077 | | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 521 | 7.4 | | 4.00 | 3.50 | M | SD | 1 | 0.056 | 0.034 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 522 | 7.1 | | 3.54 | 3.19 | F | SD | 1 | 0.068 | 0.078 | 239 | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 523 | 8.6 | | 6.09 | 5.46 | F | SD | 5 | 0.198 | 0.103 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 524 | 8.4 | | 6.45 | | F | SD | 4 | 0.124 | 0.120 | 410 | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 525 | 7.7 | | 4.51 | 3.88 | M | SD | 1 | 0.036 | 0.081 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 526 | 6.5 | | 2.69 | 2.38 | M | SD | 1 | 0.023 | 0.039 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 527 | 7.8 | | 4.24 | 3.65 | M | SD | 1 | 0.050 | 0.043 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 528 | 7.5 | | 3.82 | 3.50 | F | SD | 1 | 0.091 | 0.054 | 143 | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 529 | 9.8 | | 9.48 | 8.48 | F | SD | 7 | 0.144 | 0.193 | 654 | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 530 | 8.0 | | 4.78 | 4.28 | M | SD | | 0.085 | 0.097 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 531 | 7.6 | | 4.02 | 3.69 | F | SD | 2 | 0.046 | 0.066 | 232 | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 532 | 7.8 | | 4.86 | 4.29 | M | SD | 1 | 0.070 | 0.095 | | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 533 | 6.9 | | 3.11 | 2.79 | F | SD | 1 | 0.085 | 0.043 | | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 534 | 6.7 | | 2.96 | 2.63 | F | SD | 1 | 0.091 | 0.041 | | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 535 | 7.8 | | 4.30 | 3.87 | F | SD | 2 | 0.106 | 0.078 | | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 536 | 13.6 | | 10.20 | 11.06 | M | SD | 6 | 0.213 | 0.325 | | 1 | few parasites (internal) |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 537 | 7.4 | | 3.72 | 3.30 | F | SD | 2 | 0.081 | 0.052 | 130 | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 538 | 9.0 | | 7.79 | 7.05 | M | SD | 2 | 0.157 | 0.171 | | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 539 | 8.2 | | 4.93 | 4.53 | M | SD | 1 | 0.069 | 0.089 | | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 540 | 7.6 | | 4.69 | 4.19 | M | SD | 1 | 0.074 | 0.111 | | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 541 | 7.4 | | 4.25 | 3.81 | F | SD | 1 | 0.094 | 0.059 | 233 | 0 | few parasites |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 542 | 8.4 | | 5.55 | 4.99 | M | SD | 4 | 0.069 | 0.113 | | 0 | few parasites (internal) |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 543 | 6.8 | | 2.99 | 2.71 | F | SD | 1 | 0.068 | 0.066 | 226 | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 544 | 6.6 | | 2.61 | 2.35 | F | SD | | 0.050 | 0.036 | 120 | 1 | few parasites (parasites on tail) |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 545 | 7.6 | | 4.54 | 4.06 | M | SD | 1 | 0.068 | 0.088 | | 0 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 546 | 8.7 | | 6.51 | 5.67 | F | SD | 2 | 0.186 | 0.116 | 440 | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 547 | 6.6 | | 2.74 | 2.44 | F | SD | 1 | 0.070 | 0.036 | 161 | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 548 | 7.6 | | 4.27 | 3.83 | M | SD | 1 | 0.049 | 0.078 | | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 549 | 8.1 | | 5.20 | 4.69 | M | SD | 1 | 0.070 | 0.090 | | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 550 | 9.1 | | 7.48 | 6.64 | M | SD | 3 | 0.086 | 0.139 | | 1 | |
| 22/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 551 | 7.7 | | 4.50 | 4.13 | M | SD | 1 | 0.048 | 0.098 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 552 | 7.2 | | 3.96 | 3.59 | M | SD | 1 | 0.042 | 0.069 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 553 | 7.7 | | 4.50 | 4.04 | M | SD | 1 | 0.058 | 0.101 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 554 | 7.5 | | 4.23 | 3.81 | M | SD | 3 | 0.039 | 0.101 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 555 | 6.1 | | 2.41 | 2.14 | F | SD | 1 | 0.062 | 0.036 | 157 | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 556 | 8.2 | | 4.99 | 4.32 | M | SD | 2 | 0.067 | 0.088 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 557 | 7.9 | | 4.65 | 4.18 | M | SD | 4 | 0.061 | 0.100 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 558 | 8.9 | | 6.75 | 5.97 | F | SD | 7 | 0.127 | 0.127 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 559 | 6.9 | | 3.07 | 2.83 | M | SD | 1 | 0.041 | 0.030 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 560 | 8.0 | | 4.96 | 4.39 | F | SD | 2 | 0.127 | 0.086 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 561 | 7.3 | | 3.69 | 3.51 | M | SD | 1 | 0.038 | 0.078 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 562 | 7.9 | | 4.88 | 4.34 | M | SD | 1 | 0.068 | 0.092 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 563 | 7.1 | | 3.55 | 3.24 | F | SD | 3 | 0.084 | 0.058 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 564 | 8.0 | | 4.85 | 4.18 | M | SD | 6 | 0.070 | 0.084 | | 0 | few parasites (external parasite on left eye) |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 637 | 7.7 | | 4.89 | 4.27 | F | SD | 2 | 0.136 | 0.078 | 142 | 1 | few parasites |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 638 | 8.7 | | 7.65 | 6.80 | F | SD | 3 | 0.181 | 0.133 | 369 | 0 | |

## Slimy Sculpin from the Muskeg and Steepbank Rivers

| Date | Year | Season | Waterbody | Location | Site | Species | Fish # | Total Length (cm) | Fork Length (cm) | Total Weight (g) | Carcass Weight (g) | Sex | Maturity Stage | Age | Liver Weight (g) | Gonad Weight (g) | Fecundity (# eggs) | Mesentaric Fat | External Pathology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 639 | 10.1 | | 9.69 | 8.36 | F | SD | 7 | 0.164 | 0.172 | | 1 | skin: discolouration |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 640 | 9.4 | | 9.61 | 8.48 | F | SD | 6 | 0.239 | 0.154 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 641 | 7.9 | | 4.80 | 4.29 | M | SD | 1 | 0.053 | 0.103 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 642 | 8.2 | | 5.50 | 4.98 | M | SD | 1 | 0.071 | 0.106 | | 0 | few parasites (near anus) |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 643 | 7.0 | | 3.40 | 2.96 | F | SD | 1 | 0.054 | 0.048 | 146 | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 644 | 7.1 | | 3.47 | 3.12 | F | SD | 2 | 0.085 | 0.057 | 223 | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 645 | 6.7 | | 3.14 | 2.73 | F | SD | 1 | 0.087 | 0.048 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 646 | 6.9 | | 3.30 | 2.94 | F | SD | 3 | 0.096 | 0.047 | 149 | 1 | few parasites |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 647 | 7.2 | | 3.54 | 3.18 | F | SD | 3 | 0.061 | 0.062 | 209 | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 648 | 6.7 | | 2.91 | 2.59 | F | SD | 1 | 0.074 | 0.039 | 144 | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 649 | 6.7 | | 3.01 | 2.65 | F | SD | 1 | 0.053 | 0.064 | 207 | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 650 | 7.8 | | 4.48 | 4.09 | M | SD | 2 | 0.048 | 0.085 | | 0 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 651 | 7.0 | | 3.42 | 3.01 | F | SD | 2 | 0.065 | 0.046 | | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 652 | 7.4 | | 3.77 | 3.41 | F | SD | 1 | 0.082 | 0.055 | 304 | 1 | |
| 23/9/99 | 1999 | Fall | Steepbank River | Reference | SRR | SLSC | 653 | 7.0 | | 3.09 | 2.70 | F | SD | 1 | 0.060 | 0.050 | 195 | 1 | |

# APPENDIX V

# WATER CHEMISTRY DATA FOR ACID SENSITIVE LAKES

**Table V-1 Baseline data for 32 lakes sampled in north-eastern Alberta, July 12 to August 17, 1999.**

| Lake | Latitude | Longitude | Sample Date | Field pH | Lab pH | Tot. Alk. (mg/L $CaCO_3$) | Spec. Cond. (µS/cm) | TDS (mg/L) | Turb. (NTU) | TSS (mg/L) | Colour (TCU) | $Na^+$ (mg/L) | $K^+$ (mg/L) | $Ca^{+2}$ (mg/L) | $Mg^{+2}$ (mg/L) | $HCO_3^-$ (mg/L) | $Cl^-$ (mg/L) | $SO_4^{-2}$ (mg/L) | PN (µg/L) | TDN (µg/L) | $NH_4^+$ (µg/L) | $NO_2$+ $NO_3$ (µg/L) | TP (µg/L) | DP (µg/L) | PC (µg/L) | DOC (mg/L) | Chl. *a* (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Oil Sands Region** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A21 | 56 2667 | 111 2583 | 27-Jul-99 | 4 62 | 4 62 | 0 8 | 17 3 | 70 5 | 6 5 | 14 1 | 308 | 0 99 | 0 48 | 1 63 | 0 55 | 0 9 | 0 1 | 2 1 | - | 1,068 | 63 | 72 | 113 | 67 | - | 23.0 | 14 9 |
| A24 | 56 2167 | 111 2500 | 27-Jul-99 | 4 31 | 4 40 | 0 0 | 14 1 | 41 5 | 8 1 | 8 0 | 250 | 0 57 | 0 45 | 0 88 | 0 35 | - | 0 1 | 1 6 | - | 965 | 91 | 12 | 109 | 62 | - | 15 5 | 29 7 |
| A26 | 56 2167 | 111.1667 | 27-Jul-99 | 5 43 | 6.46 | 9 3 | 13 9 | 55 5 | 1 6 | 2 3 | 77 | 0 90 | 0 64 | 4 29 | 0 94 | 11 4 | 0 2 | 1 5 | - | 1,074 | 33 | 3 | 54 | 22 | - | 18 1 | 16 1 |
| A29 | 56 1667 | 111.5417 | 27-Jul-99 | 5 55 | 5 43 | 2 3 | 12.0 | 28 5 | 1 4 | 1 2 | 43 | 0 70 | 0 35 | 1 17 | 0.48 | 2 8 | 0.1 | 1 3 | - | 572 | 13 | 2 | 28 | 7 | - | 12 8 | 8 2 |
| A42 | 56 3500 | 113 1833 | 12-Jul-99 | 9 15 | 6 89 | 9 9 | 31 4 | -[a] | 15 0 | - | 54 | 8 13 | 0 34 | 4 82 | 1 19 | 12 0 | 0 3 | 1 4 | - | 105 | 8 | <1 | 200 | 13 | - | 36.6 | 112 4 |
| A47 | 56.2417 | 113 1333 | 27-Jul-99 | 7 20 | 5 35 | 2 0 | 29 1 | 27 5 | 3 0 | 6 6 | 60 | 0 75 | 0 53 | 1 32 | 0.46 | 2 4 | 0 1 | 2 0 | - | 536 | 55 | 4 | 41 | 10 | - | 11 3 | 16 7 |
| A59 | 55.9083 | 112 8667 | 27-Jul-99 | 4 82 | 4 87 | 2 1 | 21 2 | 115 0 | 7 8 | 70 0 | 256 | 2 50 | 0.44 | 2.78 | 0 77 | 2.5 | 0 1 | 2 8 | - | 838 | 9 | 5 | 192 | 42 | - | 44 3 | 75 6 |
| A86 | 55 6833 | 111 8250 | 27-Jul-99 | 6 26 | 6 12 | 5 6 | 22 2 | 45 0 | 1 2 | 2 0 | 47 | 0.78 | 1.45 | 1 89 | 0 88 | 6 8 | 0 2 | 1 3 | - | 819 | 18 | 3 | 27 | 9 | - | 15 5 | 13 6 |
| L1 | 57 2853 | 110 9239 | 03-Aug-99 | 6.55 | 6 24 | 6 7 | 27 4 | 48 0 | 0 8 | 1 4 | 38 | 0.75 | 0 28 | 2 73 | 1 31 | 8 2 | 0 1 | 3.7 | 154 | 836 | 24 | 1 | 23 | 8 | 1,497 | 13.6 | 5 2 |
| L7 | 57 0903 | 110 7519 | 03-Aug-99 | 6.41 | 6.29 | 9 0 | 31.1 | 66.5 | 0 9 | 1 6 | 202 | 0.92 | 0 51 | 4 18 | 1 39 | 10 9 | 0 1 | 1.4 | 96 | 939 | 22 | 3 | 27 | 15 | 1,030 | 22 9 | 7.3 |
| L8 | 57 0458 | 110.5975 | 03-Aug-99 | 7 23 | 6.75 | 21 7 | 54.8 | 79 0 | 3 9 | 6 6 | 105 | 2.56 | 0 29 | 5 87 | 2 72 | 26 5 | 0.1 | 1.8 | 453 | 817 | 17 | 1 | 57 | 13 | 3,434 | 20 3 | 27.1 |
| L18 (Namur) | 57 4444 | 112.6211 | 12-Aug-99 | 7.51 | 6.86 | 19 9 | 60.7 | 45 0 | 0 5 | 0 4 | 13 | 2 56 | 1.07 | 6.13 | 2 02 | 24 2 | 0.1 | 7 1 | 98 | 258 | 15 | 2 | 20 | 8 | 649 | 7 6 | 7 1 |
| L23 (Otasan) | 57 7072 | 112 3875 | 17-Aug-99 | 6 91 | 6 34 | 8 0 | 26.1 | 50 5 | 1 3 | 1 7 | 47 | 0 91 | 0 42 | 3.01 | 1 08 | 9.8 | - | 1 8 | - | 340 | 17 | 1 | 22 | 7 | - | 13 9 | 8.2 |
| L25 (Legend) | 57 4122 | 112 9336 | 12-Aug-99 | 8.14 | 6 51 | 9 0 | 28 6 | 22 5 | 3 5 | 3 9 | 20 | 0 98 | 0 60 | 3 27 | 0 94 | 10.9 | 0.1 | 3 1 | 349 | 246 | 2 | 1 | 41 | 7 | 2,292 | 6 8 | 29 5 |
| L28 | 57 8556 | 112.9717 | 12-Aug-99 | 4 93 | 4 99 | 2 1 | 21 7 | 82 5 | 1 7 | 0 3 | 381 | 1 41 | 0 47 | 2 17 | 0 70 | 2 5 | 0 1 | 1 9 | 55 | 567 | 10 | 18 | 69 | 59 | 636 | 26 5 | 2 6 |
| L30 (W Clayton) | 58.0514 | 112 2669 | 03-Aug-99 | 4 04 | 3 97 | 0.0 | 21 0 | 37 5 | 4 1 | 5 0 | 215 | 0 61 | 0.17 | 0.70 | 0 19 | - | - | 0 7 | 204 | 422 | 3 | 3 | 26 | 8 | 4,279 | 17 7 | 8 0 |
| L39 (A-150) | 57.9600 | 110 3969 | 03-Aug-99 | 8 30 | 6.49 | 11 5 | 30 6 | 61 5 | 9 1 | 16 4 | 55 | 5.39 | 0 47 | 3 13 | 1 48 | 14 0 | 0.6 | 2 9 | 879 | 602 | 6 | 1 | 54 | 4 | 9,885 | 12 1 | 32 7 |
| L4 (A-170) | 57 1519 | 110 8514 | 03-Aug-99 | 5 93 | 5 81 | 5 1 | 23 8 | 64 0 | 1 4 | 7 9 | 208 | 1 02 | 0 22 | 3 31 | 1.13 | 6 2 | 0 6 | 1 2 | 310 | 588 | 4 | 2 | 45 | 13 | 3,512 | 23 0 | 19 9 |
| L46 (Bayard) | 57 7725 | 112 3964 | 12-Aug-99 | 6 40 | 6 64 | 24 2 | 89 4 | 93 0 | 15 0 | 3 6 | 207 | 5.16 | 1.07 | 7 81 | 2 88 | 29 4 | 0 1 | 13 7 | 266 | 2,028 | 597 | 60 | 150 | 98 | 1,980 | 16 9 | 2 6 |
| L47 | 57 6894 | 112 7361 | 12-Aug-99 | 7 09 | 6 69 | 16 0 | 71 5 | 66.5 | 15 0 | 11 8 | 133 | 3 62 | 1.05 | 7 32 | 2 42 | 19 5 | 0 1 | 13 3 | 407 | 1,425 | 82 | 26 | 129 | 56 | 3,537 | 19 3 | 25 1 |
| L49 | 57.7600 | 112.5967 | 12-Aug-99 | 6 21 | 6.15 | 6.6 | 67.2 | 75 5 | 4 6 | 4 3 | 98 | 4.33 | 0 88 | 5.43 | 1 89 | 8 1 | - | 19.0 | 276 | 672 | 15 | 13 | 80 | 39 | 1,987 | 16 3 | 10.0 |
| L60 | 57 6622 | 112 6125 | 17-Aug-99 | 6.45 | 6 29 | 9 6 | 57.0 | 74.4 | 2 5 | 3 5 | 72 | 3 08 | 0.59 | 5.24 | 1.78 | 11 8 | - | 13 1 | - | 644 | - | 1 | 95 | 40 | - | 15 4 | 18 1 |
| **Caribou Mountains** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| E52 (Fleming) | 58 7708 | 115.4342 | 06-Aug-99 | 6 63 | 6 56 | 14 7 | 45 2 | 86.1 | 1 2 | 2 8 | 283 | 1 50 | 0 80 | 7 23 | 1 63 | 17 9 | 0 8 | 2 7 | 69 | 1,060 | 11 | 48 | 52 | 40 | 717 | 24 0 | 5 1 |
| E59 (Rocky Island) | 59 1350 | 115 1336 | 06-Aug-99 | 6 94 | 6 46 | 9 7 | 29 4 | 43 0 | 2 1 | 2 2 | 96 | 0.48 | 0 27 | 4 24 | 1 12 | 11 8 | 0 2 | 2.0 | 132 | 384 | 16 | 3 | 31 | 8 | 967 | 13 9 | 10 2 |
| O1 (Unnamed #6) | 59 2378 | 114 5200 | 06-Aug-99 | 5 71 | 5 64 | 3 9 | 20 8 | 55.0 | 0 7 | 0 8 | 277 | 0 42 | 0 23 | 3 23 | 0 73 | 4 8 | 0 2 | 1 6 | 95 | 708 | 27 | 9 | 34 | 20 | 793 | 20 9 | 9 4 |
| O2 (Unnamed #9) | 59.3108 | 115 3589 | 06-Aug-99 | 6 33 | 6.35 | 9 7 | 31 1 | 72 5 | 1 0 | 1 0 | 294 | 0 54 | 0 16 | 5.42 | 1 36 | 11 8 | 0 1 | 1 4 | 113 | 500 | 10 | 6 | 34 | 21 | 868 | 24 4 | 10 0 |
| O3 | 59.0489 | 116 2556 | 06-Aug-99 | 7 95 | 6 95 | 35.5 | 59.7 | 73 9 | 2 4 | 2 4 | 124 | 1.64 | 0 34 | 8 13 | 2 74 | 43.3 | 0 1 | 2 6 | 256 | 614 | 13 | 5 | 34 | 12 | 1,771 | 17 6 | 14 3 |
| **Canadian Shield** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L109 (Fletcher) | 59.1205 | 110.8165 | 03-Aug-99 | 6 70 | 6 66 | 18.2 | 51 2 | 69 5 | 0 9 | 0.1 | 140 | 2.04 | 0.43 | 6 01 | 2 24 | 22 1 | 1 6 | 0.8 | 59 | 601 | 13 | 4 | 14 | 8 | 1,020 | 19 1 | 2 9 |
| O10 | 59 1358 | 110.6667 | 03-Aug-99 | 7 92 | 6 47 | 10.4 | 33 7 | 80 5 | 4 7 | 10.9 | 107 | 5 24 | 0.50 | 3 94 | 1 43 | 12 7 | 0 9 | 1.2 | 721 | 851 | 3 | 1 | 45 | 5 | 10,235 | 24 4 | 24 3 |
| R1 | 59 1985 | 110 6868 | 03-Aug-99 | 6.76 | 6.58 | 13 5 | 39.4 | 55 4 | 1 4 | 1.2 | 81 | 1 63 | 0.39 | 4 54 | 1.57 | 16 5 | 1 0 | 0.8 | 83 | 515 | 6 | 4 | 14 | 6 | 2,030 | 15 8 | 3 7 |
| R2 | 59.1225 | 110 5142 | 03-Aug-99 | 6.69 | 6.51 | 11.0 | 36.9 | 74 0 | 1 4 | 1.6 | 183 | 1.58 | 0 28 | 4.59 | 1 56 | 13 4 | 1.0 | 1 0 | 107 | 574 | <1 | 1 | 20 | 10 | 2,334 | 21 7 | 4 0 |
| R3 | 59.1268 | 110 9315 | 03-Aug-99 | 7.68 | 7.44 | 48 3 | 106.1 | 85.0 | 0 4 | 0 1 | 11 | 3 16 | 1 64 | 11 50 | 4 78 | 58.9 | 1 2 | 1.2 | 44 | 852 | 2 | 1 | 8 | 4 | 1,454 | 12 9 | 1 3 |

[a] - = no data

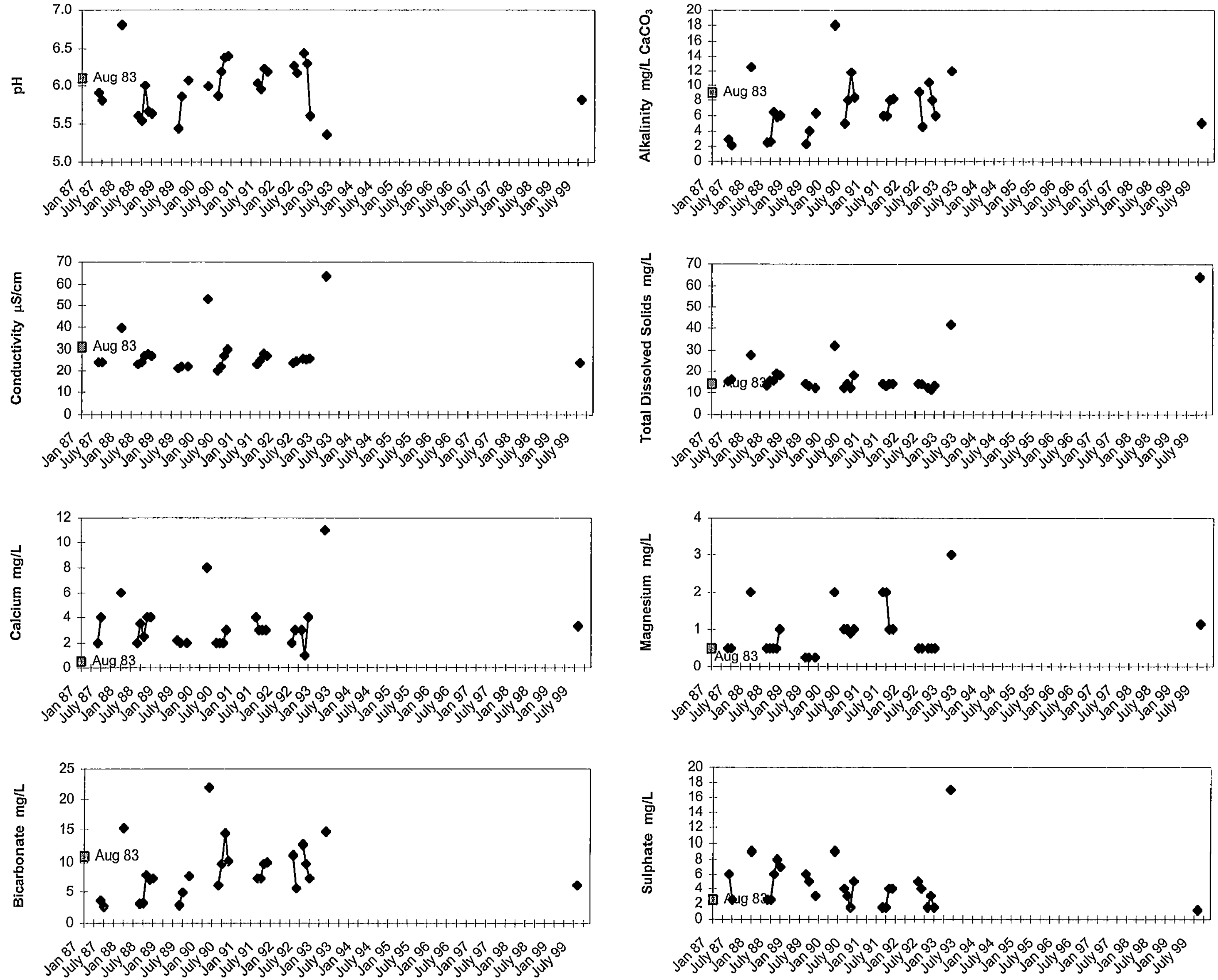


**Figure V-1. Selected data for L4 (1983 - 1999), showing seasonal and year-to-year variability. Data from AENV.**

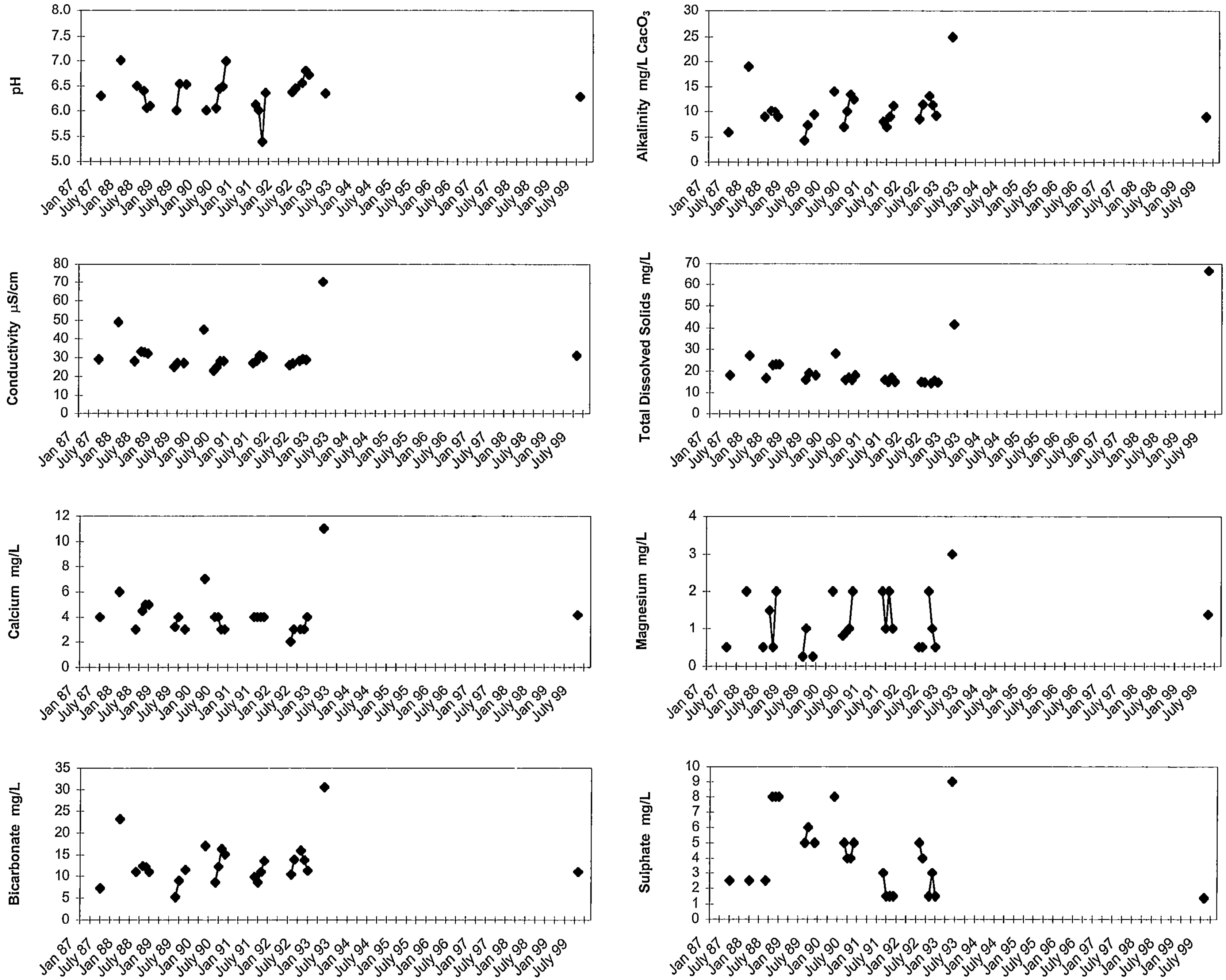


**Figure V-2. Selected data for L7 (1987 - 1999), showing seasonal and year-to-year variability. Data from AENV.**

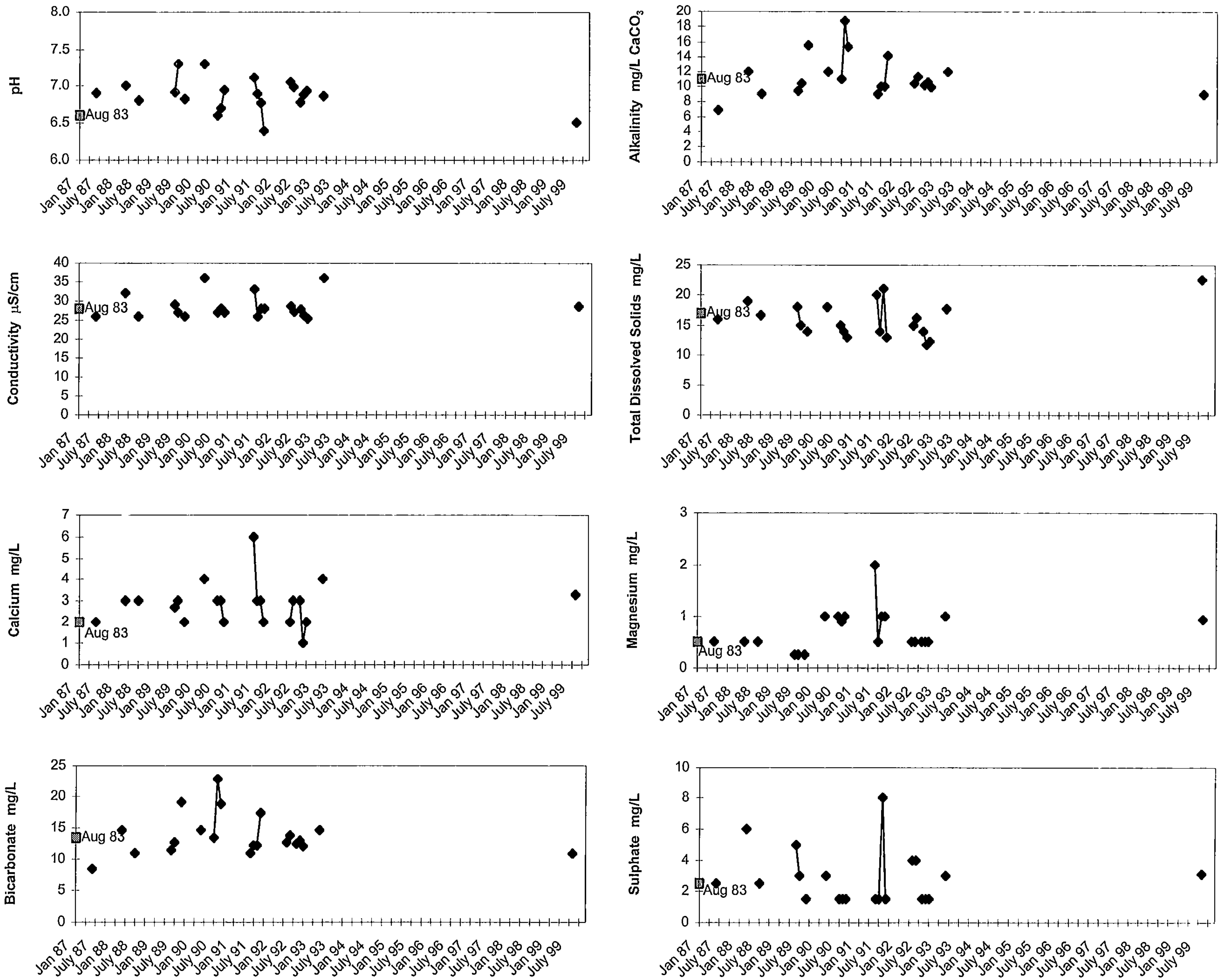


**Figure V-3. Selected data for L25, Legend L. (1983 - 1999), showing seasonal and year-to-year variability. Data from AENV.**

## FIELD DATA FOR ACID SENSITIVE LAKES

**Lake:** O10 **Date:** 1-Aug-99
**Region:** Canadian Shield **Time:** 14:20

**Secchi depth (m):** 0.4 **Max. depth (m):** 1.8

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 17.0 | 7.89 | 20 | 10.3 |
| 0.3 | 16.4 | 7.93 | 20 | 10.3 |
| 0.5 | 16.3 | 7.92 | 20 | 10.3 |
| 0.7 | 16.2 | 7.86 | 19 | 10.3 |
| 0.9 | 16.0 | 7.69 | 19 | 10.2 |
| 1.1 | 15.8 | 7.18 | 19 | 9.9 |
| 1.3 | 15.7 | 6.92 | 20 | 9.7 |
| 1.5 | 15.7 | 6.72 | 20 | 9.2 |

**Lake:** R1 **Date:** 1-Aug-99
**Region:** Canadian Shield **Time:** 15:30

**Secchi depth (m):** 1.75 **Max. depth (m):** 14.3

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 17.4 | 6.83 | 24 | 8.7 |
| 1 | 16.5 | 6.76 | 23 | 8.9 |
| 2 | 16.3 | 6.70 | 24 | 8.8 |
| 3 | 16.2 | 6.65 | 24 | 8.7 |
| 4 | 16.2 | 6.63 | 24 | 8.4 |
| 5 | 16.1 | 6.60 | 24 | 8.4 |
| 6 | 16.1 | 6.58 | 24 | 8.3 |
| 7 | 15.9 | 6.49 | 24 | 7.9 |
| 8 | 15.9 | 6.43 | 24 | 7.7 |

**Lake:** R2 **Date:** 1-Aug-99
**Region:** Canadian Shield **Time:** 16:30

**Secchi depth (m):** 1.3 **Max. depth (m):** 3.7

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 17.7 | 6.77 | 23 | 8.9 |
| 0.5 | 17.6 | 6.69 | 23 | 8.9 |
| 1 | 17.1 | 6.64 | 22 | 8.8 |
| 1.5 | 16.3 | 6.54 | 22 | 8.7 |
| 2 | 16.3 | 6.52 | 22 | 8.6 |
| 2.5 | 16.2 | 6.48 | 22 | 8.5 |

**Lake:** R3 **Date:** 1-Aug-99
**Region:** Canadian Shield **Time:** 17:30

**Secchi depth (m):** 5.75 **Max. depth (m):** 10.9

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 18.6 | 7.69 | 69 | 8.8 |
| 1 | 18.5 | 7.68 | 69 | 8.8 |
| 2 | 18.0 | 7.68 | 69 | 8.7 |
| 3 | 17.9 | 7.67 | 69 | 8.7 |
| 4 | 17.9 | 7.65 | 69 | 8.4 |
| 5 | 17.8 | 7.64 | 69 | 8.7 |
| 6 | 17.6 | 7.51 | 69 | 8.4 |
| 7 | 15.8 | 6.97 | 69 | 7.7 |
| 8 | 12.4 | 6.80 | 69 | 6.4 |

**Lake:** L109 **Date:** 1-Aug-99
**Region:** Canadian Shield **Time:** 13:00

**Secchi depth (m):** 1.75 **Max. depth (m):** 13.1

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 17.6 | 6.76 | 33 | 8.0 |
| 1 | 17.0 | 6.70 | 33 | 7.9 |
| 2 | 16.9 | 6.67 | 32 | 7.8 |
| 3 | 16.8 | 6.64 | 32 | 7.8 |
| 4 | 16.8 | 6.64 | 32 | 7.7 |
| 5 | 16.6 | 6.51 | 32 | 7.3 |
| 6 | 15.6 | 6.31 | 32 | 5.6 |
| 7 | 13.2 | 6.23 | 33 | 4.9 |
| 8 | 11.1 | 6.23 | 33 | 4.9 |
| 9 | 9.6 | 6.19 | 33 | 4.7 |
| 10 | 8.9 | 6.19 | 33 | 5.0 |
| 11 | 8.0 | 6.16 | 33 | 4.3 |
| 12 | 7.4 | 6.08 | 34 | 2.7 |

**Lake:** E52 **Date:** 5-Aug-99
**Region:** Caribou Mtns. **Time:** 11:15

**Secchi depth (m):** 0.8 **Max. depth (m):** 19.3

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 16.5 | 6.71 | 38 | 8.4 |
| 1.5 | 16.5 | 6.63 | 38 | 8.3 |
| 2 | 16.5 | 6.61 | 38 | 8.3 |
| 3 | 16.2 | 6.61 | 38 | 8.4 |
| 4 | 15.1 | 6.56 | 38 | 8.2 |
| 5 | 14.5 | 6.52 | 38 | 8.1 |
| 6 | 13.1 | 6.44 | 38 | 7.8 |
| 7 | 12.9 | 6.41 | 38 | 7.5 |
| 8 | 12.8 | 6.40 | 38 | 7.4 |
| 9 | 12.7 | 6.40 | 38 | 7.3 |
| 10 | 12.5 | 6.38 | 38 | 7.2 |
| 11 | 12.5 | 6.35 | 38 | 7.0 |

**Lake:** E59 **Date:** 5-Aug-99
**Region:** Caribou Mtns. **Time:** 14:25

**Secchi depth (m):** 1.3 **Max. depth (m):** 10

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 17.9 | 7.03 | 24 | 9.1 |
| 1 | 17.1 | 6.94 | 24 | 9.2 |
| 2 | 16.3 | 6.75 | 24 | 9.0 |
| 3 | 14.9 | 6.39 | 24 | 8.1 |
| 4 | 14.0 | 6.09 | 24 | 6.5 |
| 5 | 13.9 | 6.05 | 24 | 6.1 |
| 6 | 13.6 | 6.22 | 24 | 7.4 |
| 7 | 13.4 | 6.29 | 24 | 7.4 |
| 8 | 13.4 | 6.27 | 24 | 7.4 |
| 9 | 13.3 | 6.29 | 24 | 7.4 |
| 10 | 13.1 | 6.20 | 24 | 6.7 |

**Lake:** O1 **Date:** 5-Aug-99
**Region:** Caribou Mtns. **Time:** 12:45

**Secchi depth (m):** 0.9 **Max. depth (m):** 2

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 18.5 | 5.81 | 16 | 8.3 |
| 0.5 | 18.5 | 5.71 | 16 | 8.3 |
| 1 | 18.5 | 5.64 | 16 | 8.2 |
| 1.25 | 16.0 | 5.34 | 17 | 6.1 |

**Lake:** O2 **Date:** 5-Aug-99
**Region:** Caribou Mtns. **Time:** 15:45

**Secchi depth (m):** 0.8 **Max. depth (m):** 9.2

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 19.5 | 6.51 | 25 | 8.9 |
| 0.75 | 17.4 | 6.33 | 25 | 8.7 |
| 2 | 16.4 | 6.26 | 25 | 8.4 |
| 3 | 14.9 | 6.20 | 25 | 8.3 |
| 4 | 13.8 | 6.14 | 25 | 8.2 |
| 5 | 13.6 | 6.06 | 24 | 8.0 |
| 6 | 12.9 | 5.95 | 24 | 7.7 |
| 7 | 12.2 | 5..8 | 23 | 7.4 |
| 8 | 11.9 | 5.72 | 23 | 7.0 |
| 9 | 11.8 | 5.70 | 23 | 6.8 |

**Lake:** O3 **Date:** 5-Aug-99
**Region:** Caribou Mtns. **Time:** 17:05

**Secchi depth (m):** 1 **Max. depth (m):** 2.2

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 20.7 | 8.04 | 52 | 9.4 |
| 0.5 | 20.1 | 7.95 | 51 | 9.3 |
| 1 | 17.9 | 7.14 | 52 | 8.6 |
| 1.5 | 16.5 | 6.79 | 53 | 7.7 |

| | | | |
|---|---|---|---|
| **Lake:** | A21 | **Date:** | 25-Jul-99 |
| **Region:** | Oil Sands Area | **Time:** | 12:39 |

**Secchi depth (m):** 0.5 **Max. depth (m):** 1

| Depth | Temp ($^oC$) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 14.6 | 4.65 | 12 | 8.1 |
| 0.3 | 14.6 | 4.65 | 13 | 8.1 |
| 0.5 | 14.7 | 4.62 | 12 | 8.1 |
| 0.7 | 14.7 | 4.59 | 12 | 8.1 |

| | | | |
|---|---|---|---|
| **Lake:** | A24 | **Date:** | 25-Jul-99 |
| **Region:** | Oil Sands Area | **Time:** | 13:15 |

**Secchi depth (m):** 0.5 **Max. depth (m):** 0.9

| Depth | Temp ($^oC$) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.6 | 4.39 | 10 | 7.9 |
| 0.3 | 15.6 | 4.38 | 11 | 7.7 |
| 0.5 | 15.6 | 4.31 | 10 | 7.7 |
| 0.7 | 15.6 | 4.31 | 10 | 7.6 |
| 0.9 | 15.6 | 4.25 | 10 | 7.7 |

| | | | |
|---|---|---|---|
| **Lake:** | A26 | **Date:** | 25-Jul-99 |
| **Region:** | Oil Sands Area | **Time:** | 13:50 |

**Secchi depth (m):** 0.5 **Max. depth (m):** 1.1

| Depth | Temp ($^oC$) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.9 | 5.64 | 10 | 8.4 |
| 0.3 | 15.9 | 5.48 | 10 | 8.5 |
| 0.5 | 15.9 | 5.43 | 10 | 8.3 |
| 0.7 | 15.9 | 5.41 | 10 | 8.3 |
| 0.9 | 15.9 | 5.36 | 10 | 8.3 |
| 1.1 | 15.9 | 5.32 | 10 | 8.2 |

| | | | |
|---|---|---|---|
| **Lake:** | A29 | **Date:** | 25-Jul-99 |
| **Region:** | Oil Sands Area | **Time:** | 11:50 |

**Secchi depth (m):** N/A (bottom visible) **Max. depth (m):** 0.75

| Depth | Temp ($^oC$) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.5 | 5.67 | 8 | 8.2 |
| 0.2 | 15.6 | 5.70 | 8 | 8.1 |
| 0.5 | 15.6 | 5.55 | 8 | 8.1 |
| 0.7 | 15.6 | 5.55 | 8 | 8.1 |

| | | | |
|---|---|---|---|
| **Lake:** | A42 | **Date:** | 17-Jul-99 |
| **Region:** | Oil Sands Area | **Time:** | N/A |

**Secchi depth (m):** 0.3 **Max. depth (m):** 0.9

| Depth | Temp ($^oC$) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 22.4 | 9.26 | 33 | 9.8 |
| 0.3 | 22.5 | 9.25 | 48 | 9.3 |
| 0.5 | 22.5 | 9.15 | 48 | 9.7 |
| 0.7 | 22.5 | 9.24 | 47 | 9.6 |
| 0.9 | 21.5 | 8.85 | 45 | 8.1 |

| | | | |
|---|---|---|---|
| **Lake:** | A47 | **Date:** | 25-Jul-99 |
| **Region:** | Oil Sands Area | **Time:** | 15:21 |

**Secchi depth (m):** N/A (bottom visible) **Max. depth (m):** 1.3

| Depth | Temp ($^oC$) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 17.3 | 7.31 | 22 | 9.2 |
| 0.3 | 17.4 | 7.23 | 22 | 9.1 |
| 0.5 | 17.2 | 7.20 | 22 | 9.1 |
| 0.7 | 17.2 | 7.21 | 22 | 9.1 |
| 0.9 | 17.2 | 7.16 | 22 | 9.1 |
| 1.1 | 17.3 | 7.17 | 22 | 9.1 |

**Lake:** A59 **Date:** 25-Jul-99
**Region:** Oil Sands Area **Time:** 17:15

**Secchi depth (m):** 0.3 **Max. depth (m):** 1.1

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 17.9 | 4.83 | 15 | 7.9 |
| 0.3 | 17.9 | 4.87 | 16 | 7.8 |
| 0.5 | 17.9 | 4.82 | 16 | 7.8 |
| 0.7 | 17.9 | 4.81 | 15 | 7.7 |
| 0.9 | 17.9 | 4.79 | 15 | 7.7 |
| 1.1 | 17.9 | 4.77 | 15 | 7.7 |

**Lake:** A86 **Date:** 25-Jul-99
**Region:** Oil Sands Area **Time:** 10:50

**Secchi depth (m):** 2.2 **Max. depth (m):** 2.6

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 17.8 | 6.51 | 17 | 7.8 |
| 0.5 | 17.8 | 6.26 | 17 | 7.8 |
| 1 | 17.8 | 6.19 | 17 | 7.8 |
| 1.5 | 17.8 | 6.15 | 17 | 7.8 |
| 2 | 17.8 | 6.13 | 17 | 7.8 |
| 2.5 | 17.8 | 6.13 | 17 | 7.7 |

**Lake:** L1 **Date:** 31-Jul-99
**Region:** Oil Sands Area **Time:** 17:30

**Secchi depth (m):** N/A (bottom visible) **Max. depth (m):** 0.9

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.5 | 6.72 | 16 | 9.3 |
| 0.3 | 15.5 | 6.60 | 16 | 9.3 |
| 0.5 | 15.5 | 6.55 | 15 | 9.3 |
| 0.7 | 15.5 | 6.56 | 15 | 9.3 |
| 0.9 | 15.6 | 6.52 | 15 | 9.3 |

| Lake: | L4 (A-170) | Date: | 31-Jul-99 |
|---|---|---|---|
| Region: | Oil Sands Area | Time: | 21:25 |

**Secchi depth (m):** 2 **Max. depth (m):** 1.9

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.4 | 6.09 | 13 | 8.7 |
| 0.5 | 15.3 | 5.93 | 13 | 8.7 |
| 1 | 15.3 | 5.85 | 13 | 8.7 |
| 1.5 | 15.3 | 5.86 | 13 | 8.7 |

| Lake: | L7 | Date: | 31-Jul-99 |
|---|---|---|---|
| Region: | Oil Sands Area | Time: | 15:20 |

**Secchi depth (m):** 1.1 **Max. depth (m):** 2

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.7 | 6.53 | 18 | 8.8 |
| 0.5 | 15.7 | 6.41 | 18 | 8.7 |
| 1 | 15.6 | 6.31 | 18 | 8.7 |
| 1.5 | 15.6 | 6.30 | 18 | 8.6 |

| Lake: | L8 | Date: | 31-Jul-99 |
|---|---|---|---|
| Region: | Oil Sands Area | Time: | 16:15 |

**Secchi depth (m):** 1.1 **Max. depth (m):** 1.8

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.2 | 7.33 | 34 | 9.3 |
| 0.5 | 15.2 | 7.23 | 34 | 9.3 |
| 1 | 15.2 | 7.18 | 34 | 9.2 |
| 1.5 | 14.7 | 6.91 | 33 | 8.7 |

**Lake:** L18 (Namur) **Date:** 10-Aug-99
**Region:** Oil Sands Area **Time:** 10:25

**Secchi depth (m):** 4 **Max. depth (m):** 25.2

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.5 | 7.58 | 53 | 9.0 |
| 1 | 15.5 | 7.51 | 52 | 8.9 |
| 2 | 15.6 | 7.51 | 53 | 8.9 |
| 3 | 15.6 | 7.52 | 52 | 8.9 |
| 4 | 15.6 | 7.52 | 53 | 8.9 |
| 5 | 15.6 | 7.53 | 52 | 8.9 |
| 6 | 15.6 | 7.55 | 53 | 8.9 |
| 7 | 15.5 | 7.54 | 53 | 8.9 |
| 8 | 15.5 | 7.45 | 53 | 8.8 |
| 9 | 15.4 | 7.33 | 53 | 8.7 |
| 10 | 15.3 | 7.19 | 53 | 8.4 |
| 11 | 15.3 | 7.13 | 53 | 8.3 |
| 12 | 14.8 | 6.94 | 53 | 7.7 |
| 13 | 13.7 | 6.67 | 53 | 6.4 |
| 14 | 13.0 | 6.57 | 53 | 6.3 |
| 15 | 12.3 | 6.48 | 53 | 6.0 |
| 16 | 12.2 | 6.48 | 53 | 6.1 |
| 17 | 11.9 | 6.48 | 52 | 6.2 |
| 18 | 11.3 | 6.46 | 52 | 6.3 |
| 19 | 11.0 | 6.43 | 52 | 6.1 |
| 20 | 10.5 | 6.40 | 52 | 5.8 |
| 21 | 10.4 | 6.36 | 52 | 5.4 |
| 22 | 10.0 | 6.30 | 52 | 4.6 |
| 23 | 9.7 | 6.26 | 53 | 3.8 |
| 24 | 9.4 | 6.22 | 54 | 2.7 |

**Lake:** L23 (Otasan) **Date:** 15-Aug-99
**Region:** Oil Sands Area **Time:** 10:28

**Secchi depth (m):** 2.7 **Max. depth (m):** 8.6

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 16.9 | 6.97 | 22 | 8.7 |
| 1 | 16.8 | 6.91 | 22 | 8.7 |
| 2 | 16.5 | 6.76 | 22 | 8.6 |
| 3 | 16.4 | 6.69 | 22 | 8.5 |
| 4 | 16.3 | 6.65 | 22 | 8.4 |
| 5 | 16.1 | 6.56 | 22 | 8.2 |
| 6 | 16.1 | 6.52 | 22 | 8.0 |
| 7 | 16.0 | 6.48 | 22 | 7.9 |
| 8 | 15.8 | 6.24 | 23 | 6.9 |

**Lake:** L25 (Legend) **Date:** 10-Aug-99
**Region:** Oil Sands Area **Time:** 11:30

**Secchi depth (m):** 1.3 **Max. depth (m):** 9.6

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 16.4 | 8.40 | 24 | 9.2 |
| 1 | 16.4 | 8.14 | 24 | 9.2 |
| 2 | 16.4 | 8.04 | 24 | 9.3 |
| 3 | 16.4 | 8.06 | 24 | 9.3 |
| 4 | 16.4 | 8.08 | 24 | 9.2 |
| 5 | 16.4 | 8.07 | 24 | 9.2 |
| 6 | 16.4 | 7.98 | 24 | 9.1 |
| 7 | 16.3 | 7.70 | 23 | 8.9 |
| 8 | 15.9 | 6.29 | 24 | 6.7 |
| 9 | 15.6 | 6.12 | 25 | 5.2 |

**Lake:** L28 **Date:** 10-Aug-99
**Region:** Oil Sands Area **Time:** 13:55

**Secchi depth (m):** 0.6 **Max. depth (m):** 1.3

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.4 | 5.06 | 17 | 7.8 |
| 0.3 | 15.3 | 4.98 | 17 | 7.7 |
| 0.5 | 15.4 | 4.93 | 17 | 7.8 |
| 0.7 | 15.3 | 4.96 | 17 | 7.8 |
| 0.9 | 15.4 | 4.92 | 17 | 7.7 |
| 1.1 | 15.3 | 4.88 | 17 | 7.7 |

**Lake:** L30 (Clayton) **Date:** 2-Aug-99
**Region:** Oil Sands Area **Time:** 10:25

**Secchi depth (m):** 0.6 **Max. depth (m):** 1.5

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 14.0 | 3.99 | 12 | 8.7 |
| 0.5 | 13.9 | 4.04 | 12 | 8.6 |
| 1 | 13.9 | 4.02 | 12 | 8.6 |

**Lake:** L39 (A150) **Date:** 1-Aug-99
**Region:** Oil Sands Area **Time:** 10:40

**Secchi depth (m):** 0.4 **Max. depth (m):** 1.2

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 16.0 | 8.34 | 19 | 9.7 |
| 0.3 | 16.0 | 8.31 | 19 | 9.7 |
| 0.5 | 16.0 | 8.30 | 19 | 9.7 |
| 0.7 | 15.9 | 8.26 | 19 | 9.7 |
| 0.9 | 15.9 | 8.25 | 19 | 9.6 |

**Lake:** L46 (Bayard) **Date:** 10-Aug-99
**Region:** Oil Sands Area **Time:** 16:25

**Secchi depth (m):** 0.7 **Max. depth (m):** 1.7

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 16.8 | 6.48 | 80 | 3.8 |
| 0.3 | 16.8 | 6.42 | 80 | 3.7 |
| 0.5 | 16.8 | 6.40 | 80 | 3.6 |
| 0.7 | 16.8 | 6.39 | 80 | 3.6 |
| 0.9 | 16.8 | 6.39 | 80 | 3.6 |
| 1.1 | 16.8 | 6.37 | 80 | 3.5 |
| 1.3 | 16.8 | 6.36 | 80 | 3.5 |

**Lake:** L47 **Date:** 10-Aug-99
**Region:** Oil Sands Area **Time:** 13:08

**Secchi depth (m):** 0.7 **Max. depth (m):** 0.9

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.3 | 7.10 | 62 | 8.5 |
| 0.3 | 15.3 | 7.12 | 62 | 8.5 |
| 0.5 | 15.3 | 7.09 | 62 | 8.5 |
| 0.7 | 15.3 | 7.06 | 62 | 8.5 |

**Lake:** L49 **Date:** 10-Aug-99
**Region:** Oil Sands Area **Time:** 15:30

**Secchi depth (m):** 0.6 **Max. depth (m):** 1.3

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 15.5 | 6.29 | 59 | 8.0 |
| 0.3 | 15.5 | 6.26 | 59 | 8.0 |
| 0.5 | 15.5 | 6.21 | 59 | 8.0 |
| 0.7 | 15.5 | 6.20 | 59 | 7.9 |
| 0.9 | 15.5 | 6.18 | 59 | 8.0 |
| 1.1 | 15.5 | 6.16 | 59 | 7.9 |

**Lake:** L60 **Date:** 15-Aug-99
**Region:** Oil Sands Area **Time:** 12:20

**Secchi depth (m):** 1 **Max. depth (m):** 3.4

| Depth | Temp (°C) | pH | Cond. (µS/cm) | D.O. (mg/L) |
|---|---|---|---|---|
| 0.1 | 18.7 | 6.53 | 52 | 7.2 |
| 0.5 | 18.8 | 6.45 | 52 | 7.2 |
| 1 | 18.2 | 6.38 | 52 | 7.0 |
| 1.5 | 17.5 | 6.31 | 52 | 6.7 |
| 2 | 17.2 | 6.23 | 52 | 6.3 |
| 2.5 | 16.7 | 5.89 | 55 | 2.0 |