Golder Associates Ltd.

10th Floor, 940 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
Telephone (403) 299-5600
Fax (403) 299-5606

REPORT ON

OIL SANDS REGIONAL AQUATICS MONITORING PROGRAM (RAMP) 1998

Submitted to:

RAMP Steering Committee

11 May, 1999 **982-2309**

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 this area, the Regional Aquatics Monitoring Program (RAMP) was developed as a multi-company program currently sponsored by Suncor Energy Inc., Oil Sands, Syncrude Canada Ltd., Shell Canada Limited and Mobil Oil Canada Properties.

RAMP includes three main aquatic systems potentially affected by existing, approved and planned oil sands development and related activities:

1) Athabasca River from above the oil sands development area (at Donald Creek) to downstream of all planned oil sands developments (at Fort Creek);
2) tributaries of the Athabasca River including the Muskeg and Steepbank rivers; and
3) wetlands including Isadore's, Shipyard and Kearl lakes.

The program also evaluated potential reference areas including: the Athabasca River about 200 km upstream of the oil sands developments (in the vicinity of Duncan Creek); the lower reaches of the Ells, Tar, MacKay and Firebag rivers; and the Spruce Pond wetlands. Reference areas are areas similar to the potentially affected areas and would be subject to the same natural changes, but not the changes caused by the development.

RAMP is an effects-based program. It stresses the collection of data needed to assess the effects of development on the aquatic environment. Sampling conducted to date consists of four core components:

- water and sediment quality;
- benthic invertebrates;
- fish populations; and
- aquatic vegetation in wetlands.

Although the field program has been in place since 1997 to collect baseline data, the RAMP organizational framework was initiated in 1998. A Steering Committee with representatives from industry, government and communities, was formed in 1998 as the decision making body of RAMP. This report describes and evaluates the results of the 1998 field program.

Water and Sediment Quality

The 1997 Athabasca River sampling program was expanded in 1998 to include the collection of water and sediment samples from both the east and west sides of the river at three sampling locations: near Donald Creek (reference site), near Fort Creek (below all existing and planned developments) and at a new site upstream of the Muskeg River (below existing oil sands developments). Water quality did not vary substantially among sites on the Athabasca River, except for naphthenic acids, which were present only on the west side of the river near Donald Creek. Water quality in 1998 was similar to water quality in 1997. Overall, Athabasca River waters were non-toxic (as defined by Microtox testing) and low in organic compounds. Total suspended solids (TSS) levels were low to moderate (i.e., <25 mg/L). These waters contain phosphorus, aluminum, arsenic, iron and manganese levels in excess of regulatory guidelines.

Athabasca River sediment monitored in the fall of 1998 tended to be rich in aluminum and iron. Generally, the sediment did not contain metals or polycyclic aromatic hydrocarbons (PAHs) at levels that exceed regulatory guidelines. The exceptions are arsenic and benzo(a)anthracene/chrysene. All sediment samples were non-toxic to several species of invertebrates. When the 1997 and 1998 sediment samples are considered together, organic and metal concentrations appear to have been directly related to the silt and clay content of the river sediments.

Water and sediment samples also were collected from five tributaries: the Steepbank, Muskeg, Tar and Ells rivers in the spring, summer and fall of 1998; and the MacKay River in the fall only. For most parameters, concentrations observed in 1998 were similar to historical data.

Water samples from all five tributaries were non-toxic to bacteria and contained low or non-detectable levels of phenolic compounds, total recoverable hydrocarbons and naphthenic acids. Samples from the upper Muskeg River and small Muskeg River tributaries showed baseline chronic toxicity to fathead minnows and *Ceriodaphnia dubia* in laboratory tests.

All tributaries had higher major ion concentrations in the fall of 1998 than observed in previous years. Since 1998 was a relatively dry year, it is postulated that groundwater, which tends to have higher concentrations of major ions, would make up a larger proportion of each river's inflows. Concentrations of iron, arsenic and aluminum in water collected from all the tributaries in 1998 and previous years generally exceeded guideline levels. Phosphorus levels also consistently exceeded guideline levels in all but the Muskeg River. Mercury and manganese concentrations were found, either in 1998 or in the historical data, to occasionally exceed guideline levels during at least one season in each of the five tributaries sampled.

Sediments from the Steepbank River generally had the highest organic carbon, PAHs and total recoverable hydrocarbon content of the five tributaries sampled, which reflects the higher oil sands content of Steepbank River sediments. Sediments from all tributaries, except the Tar River, contained benzo(a)anthracene/chrysene concentrations in excess of guideline levels.

Benthic Invertebrates

Information on the small animals that inhabit the bottom of the Athabasca River (i.e., benthic invertebrate data) is planned for collection every second year beginning in 1997; therefore, the Athabasca River was not sampled in 1998. The benthic invertebrate data collected in the fall of 1998 represents the results of an initial effort to establish a benthic invertebrate monitoring program in tributaries of the Athabasca River. Two reference tributaries (Tar and Ells rivers) proposed in the study design were dropped from the sampling program in 1998 because suitable habitat was not located during field surveys of the lower reaches of either river. The MacKay River was added as a potential reference river instead.

The Steepbank and MacKay rivers supported moderately diverse benthic communities, at low to moderate densities. Although the benthic community in the Muskeg River was moderate in density, it was more diverse. Differences among rivers and sampling sites could not be related to variation in habitat. Water levels and flows were very low in the fall of 1998, in contrast to 1997 when high flows prevented sampling. Because baseline data for typical hydrological conditions are needed, it is important to continue monitoring these tributaries.

Fish Habitat

Habitat mapping data are available for 1997 and 1998 for three habitat index sites on the Athabasca River (Poplar, Steepbank and Muskeg sites) that provide a sub-sample of habitats within the RAMP study area. The habitat index sites include all 15 different bank habitat types found in the RAMP study area. Minor changes in habitat occurred between 1997 and 1998. These changes are believed to reflect natural river processes, as well as significant differences in river discharge between 1997 and 1998. The channel of the lower Athabasca River is dynamic with continual formation and removal of sandbars, frequently altered flow patterns within the channel, and shifting patterns of erosion and deposition along the banks. In addition, much lower water levels in 1998 resulted in water receding from the banks in some areas, exposing bed material deposited along the banks. During the fall survey periods, the average discharge decreased from 1,110 m^3/s in 1997 to 288 m^3/s in 1998.

Fish Populations

The 1998 fisheries component of RAMP focussed on the mainstem Athabasca River, as well as two tributaries that may be influenced by future mining activity, the Muskeg and Steepbank rivers. Capture success using a fish fence on the Muskeg River was limited, due to the unusually early spring in the oil sands region.

A total of 16 species were captured in the Athabasca River during the spring, summer and fall fish inventories in 1998. The 1998 species list was almost identical to that documented in 1997. Combining catch data over all seasons, walleye was the most abundant species, followed by lake whitefish, goldeye, longnose sucker, white sucker and flathead chub. The first four species have been identified as key indicator resources (KIR) for the Athabasca River. Catch-per-unit-effort (CPUE) of walleye, goldeye and lake whitefish was markedly lower in 1998 than in 1997, but similar to estimates recorded in 1995. The CPUE for longnose sucker was similar among years. Overall, populations of the KIR species have not changed substantially over time, nor was there substantial evidence of stress at the population level.

Size-at-age relationships (an estimate of growth) of these four KIR species were highly variable among years. At any given age, walleye, goldeye and longnose sucker collected in 1998 were shorter than fish collected in 1997; however, results need to be confirmed over a longer period of time before definitive conclusions can be drawn. Possible differences observed in 1998 may have resulted from abnormally low water levels in the lower Athabasca River. The potential influence of reduced water levels on regional fish populations was also evident in the observed changes in habitat availability and fish-habitat associations relative to 1997.

Radio-tags were inserted in 18 walleye and 18 lake whitefish in 1997. Their movements were tracked during 26 flights over the Athabasca River from the Cascade Rapids to the Peace-Athabasca Delta between October 1997 and January 1999. The radiotelemetry study showed that lake whitefish moved through the oil sands region in the fall and continued to move upstream from Fort McMurray to spawning grounds near Mountain and Cascade rapids. Following spawning, most whitefish moved downstream beyond the survey area, presumably to overwinter in Lake Athabasca. Mouths of tributaries within the oil sands region also seemed to provide important foraging habitat for lake whitefish. Walleye movements in the fall were found to mimic the movement of lake whitefish. It was speculated that lake whitefish and/or their eggs provide an important food source for walleye. Walleye appear to overwinter in the Athabasca River or Lake Athabasca.

Traces of mercury, lead and some PAHs were found in fish tissues in both the oil sands and reference areas. Most of the 14 PAHs included in the analysis were not detected in tissues of the four fish tested (walleye, goldeye, lake whitefish and longnose sucker). Two PAHs (naphthalene and methyl naphthalene) were present near the detection limit in goldeye from the oil sands area and longnose sucker from the reference area. These results indicate that uptake of PAHs by these fish species is very limited. Low levels of lead and mercury were also detected; however, concentrations in fish from the oil sands region were lower than concentrations in fish from the reference area. None exceeded Canadian Consumption Guidelines.

A site on the Athabasca River in the vicinity of Duncan Creek was selected as a potential reference site for monitoring longnose sucker (i.e., sentinel species). Walleye, goldeye and lake whitefish could not be used due to their low abundance at this site. Size-at-age, age distribution, condition, liver size and fecundity were significantly different between the longnose suckers from the reference and the oil sands areas. These differences need to be confirmed in future years, to assess the usefulness of this site.

Wetlands

Wetlands monitoring was carried out in 1997 and 1998 to establish a baseline for vegetation communities, species composition and vegetation vigour. Water quality monitoring was added in 1998 and one additional wetlands (Spruce Pond) was assessed for suitability as a reference wetlands. Spruce Pond was found to be unsuitable because the water quality and community types differed from the three wetlands being monitored.

There was no change in the areas of different vegetation types in Kearl, Shipyard and Isadore's lakes except for a small (< 1 ha) reduction in the open treed swamps in Shipyard Lake. Vigour was very good in the grass and herb classes. However, vigour was lower in shrub classes in these three wetlands, likely due to low water levels in 1998.

Total dissolved solids (TDS) and major ion concentrations were generally higher than observed in previous years, which may also be related to the low precipitation rates in 1998. Nutrient levels were sufficient in all three wetlands to support productive plant communities. Concentrations of aluminum, arsenic, mercury, iron and manganese exceeded regulatory guidelines in one or more of the wetlands.

Conclusions

The lower water levels in 1998 affected all studies (i.e., water quality, benthic invertebrate habitat, fish habitat, fish populations and wetlands). The 1998 results highlight the effects of natural changes in hydrologic regime on the rivers and their inhabitants. Since these natural changes could be confounding factors in determining the effects of oil sands development, baseline data must include the range of hydrological conditions. Reference areas are also a good means of differentiating the effect of natural changes on aquatic organisms from changes caused by the development. All of the studies are in the process of determining optimal reference areas. With the exception of the effects of low water levels, the monitoring results for 1998 were similar to 1997 or 1995. The size-at-age relationships of walleye, goldeye and longnose sucker were the most variable among years; but further monitoring is required to evaluate this change.

LIST OF ACRONYMS

µg/kg	microgram/kilogram
µS/cm	micro Siemans/centimetre
AEP	Alberta Environmental Protection
AEPEA	Alberta Environmental Protection Enhancement Act
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
AOSERP	Alberta Oil Sands Environmental Research Program
APHA	American Public Health Association
AWI	Alberta Wetland Inventory
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
EEM	Environmental Effects Monitoring
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EROD	7-ethoxyresorufin-o-deethylase
ETL	Enviro-Test Laboratories
GIS	Geographic Information System
GPS	Global Positioning System
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
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
T.C.U.	True colour units
TDS	Total dissolved solids
TOC	Total organic carbon
TSS	Total suspended solids
UTM	Universal Transverse Mercator
YSI	Yellow Springs Instruments

ACKNOWLEDGEMENTS

This project was the second year of the Oil Sands Regional Aquatics Monitoring Program. Funding and in-kind support was provided by Suncor Energy Inc., Oil Sands, Shell Canada Limited, Syncrude Canada Ltd., and Mobil Oil Canada Properties Ltd. Environment Canada also provided in-kind support for the program through participation in the fall fisheries survey and by conducting laboratory analyses of fish tissues.

Chris Fordham was the Chairperson of RAMP. The Golder Project Manager was Marie Lagimodiere and the Project Director was John Gulley.

The field program for this study was extensive and included a number of people. We would like to thank Basil MacDonald of Fort McKay and Charlie Voyager of Fort Chipewyan for their participation in the Athabasca River fisheries survey. Terry Van Meer of Syncrude led the Athabasca River fisheries survey. Norm Jelfs and Janice Cursons of Syncrude participated in the fisheries and benthic surveys. Golder personnel involved in field sampling included Chris Briggs, Veronica Chisholm, Zane Gulley, Jeff Brezenski, Tony Calverley, Ken Allen, Colleen Rickard, Trina Hoffarth, Wade Gibbons and Marie Lagimodiere.

The following people prepared the report:

Water and sediment quality:	Zsolt Kovats (task manager) J.P. Bechtold Mark Digel (senior review)
Benthic Invertebrates	Zsolt Kovats
Wetlands	Veronica Chisholm (task manager) David Kerr (senior review)
Fisheries	Wade Gibbons (task manager) Stacey Rasmussen Tanis Dirks Chris Bjornson Dave Fernet (senior review) Stella Swanson (senior review)

Pat Tones provided senior editorial review. Carole Collins formatted the report.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF APPENDICES

1 INTRODUCTION

1.1 OVERVIEW

The area north of Fort McMurray is experiencing a large increase in oil sands mining and related developments. Such growth highlights the need to integrate environmental monitoring activities so that potential cumulative effects can be identified and addressed. Additionally, coordination of data collection to meet regulatory monitoring requirements will result in development of a more complete, cost-effective database that can be used by oil sands operators as input to their environmental management programs and proposed oil sands developments.

With respect to the aquatic environment, these monitoring and data collection activities are being addressed through the Oil Sands Regional Aquatics Monitoring Program (RAMP). RAMP is a multi-stakeholder initiative, currently sponsored by Suncor Energy Inc., Oil Sands (Suncor), Syncrude Canada Ltd. (Syncrude), Shell Canada Limited (Shell) and Mobil Oil Canada Properties (Mobil). It is designed as a long-term monitoring program with sampling frequencies ranging from seasonal to once every few years.

The program, has been in place since 1997, and hence two years of sampling have been completed. The focus of monitoring has been on the Athabasca, Steepbank and Muskeg rivers, and wetlands occurring in the vicinity of current and proposed oil sands developments. 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*) has been completed.

In 1998, significant progress was made in establishing an organizational framework for implementation of RAMP. This framework includes a Steering Committee with representatives from industry, government and communities.

This report describes both the organizational framework for RAMP and the results of the 1998 field program. The framework is described in Section 1.2 and the 1998 monitoring is described in Sections 2 to 6. The results describe RAMP collected data but do not generally include other sampling programs in the region.

1.2 FRAMEWORK

1.2.1 Organizational Activities

RAMP was initiated in 1997 in response to a condition in the Alberta Environmental Protection Enhancement Act (AEPEA) approval for Suncor's Steepbank Mine. The approval required a monitoring survey of the Athabasca River that included water quality, sediment quality, benthic invertebrates and sediment toxicity. Syncrude and Shell also anticipated similar requirements once approvals for Aurora Mine (Syncrude) and Muskeg River Mine (Shell) were granted. Hence, Suncor submitted a proposal to Alberta Environmental Protection (AEP) to conduct these surveys as a joint initiative between Suncor, Syncrude and Shell. Shell initially participated as an observer but became a funding partner in fall 1997. Mobil joined as a funding partner in fall 1998.

Following submission of the proposal to AEP, the 1997 field program was conducted. The results of the 1997 program were reported in the document entitled "Oil Sands Regional Aquatics Monitoring Program: 1997 Report" (Golder 1998a). This report was submitted to AEP as fulfillment of the AEPEA condition for Suncor. This report was also submitted to provincial and federal government agencies, Aboriginal communities and other oil sands stakeholders for review as part of the Shell Muskeg River Mine Environmental Impact Assessment (EIA). The 1998 field program was developed based on results of the 1997 study, general comments from reviewers, and issues raised during consultation for the Shell Muskeg River Mine and Suncor Project Millennium EIAs.

Industry representatives held an organizational meeting on July 15, 1998 with federal and provincial regulators. Representatives from Environment Canada, Department of Fisheries and Oceans (DFO) and AEP attended the meeting. Individuals from oil sands companies not currently involved in RAMP were also invited to learn about the program. Draft mandate, objectives and organizational structure were developed and discussed.

RAMP was to be composed of a Steering Committee, a Program Review Committee, a Science Advisory Committee, a Secretariat and Investigators. It was decided that the next step was to form a Steering Committee. It was agreed that there would be one AEP representative and one federal government representative (either Environment Canada or DFO) on the Steering Committee.

The first Steering Committee meeting took place in Fort McMurray on September 14, 1998. Individuals from industry, the provincial and federal governments, Fort Chipewyan and Fort McKay attended the meeting. The representatives from Fort Chipewyan and Fort McKay attended as observers. The purpose of the meeting was to initiate community consultation and involvement in RAMP. Representatives from Fort Chipewyan and Fort McKay were asked what their needs were in terms of RAMP and what would be the best way to involve the communities in RAMP. They indicated that RAMP should go to the communities to find out what the people wanted.

A community meeting on RAMP was held in Fort Chipewyan on the evening of October 28, 1998. Representatives from RAMP included Suncor, Syncrude, Shell, Mobil, AEP, Environment Canada, Fort McKay, Fort Chipewyan (Athabasca Chipewyan First Nation) and Golder. The Chairperson of RAMP gave a brief presentation on RAMP and then asked about community concerns. Fort Chipewyan was invited to be an active participant in RAMP. The community was invited to have up to three representatives on the Steering Committee, one from each group within the community (Mikisew Cree First Nation, Athabasca Chipewyan First Nation, Fort Chipewyan Metis Local 124). There was also a discussion of having a person from the community act as a liaison between RAMP and the community. As a follow-up to the meeting, RAMP agreed to participate in a community survey to get more input on concerns.

A community meeting is also planned for Fort McKay.

The second Steering Committee meeting held on November 5, 1998 in Fort McMurray focused on developing the RAMP mandate, objectives, terms of reference and a core program. A review of the RAMP program by Fort McKay and Fort Chipewyan was presented and discussed. Comments from the review will be integrated into the core monitoring program. A Technical Subcommittee was formed to start development of a core program.

1.2.2 Mandate and Objectives

The Steering Committee has defined the mandate and objectives for RAMP. The mandate is to determine, evaluate and communicate the state of the aquatic environment in the Athabasca Oil Sands Region.

The RAMP Steering Committee has drafted the following objectives:

- to monitor aquatic environments in the oil sands area to detect and assess cumulative effects and regional trends;
- to collect baseline and historical data to characterize variability in the oil sands area;

- to collect data against which predictions contained in EIAs can be verified;
- to collect data that satisfies the monitoring required by regulatory approvals of oil sands developments;
- to recognize and incorporate traditional knowledge into the monitoring and assessment activities;
- to communicate monitoring and assessment activities, results and recommendations to communities in the Regional Municipality of Wood Buffalo, regulatory agencies, environmental committees/organizations and other interested parties; and
- to review and adjust the program to reflect monitoring results, technological advances and community concerns.

1.2.3 Terms of Reference

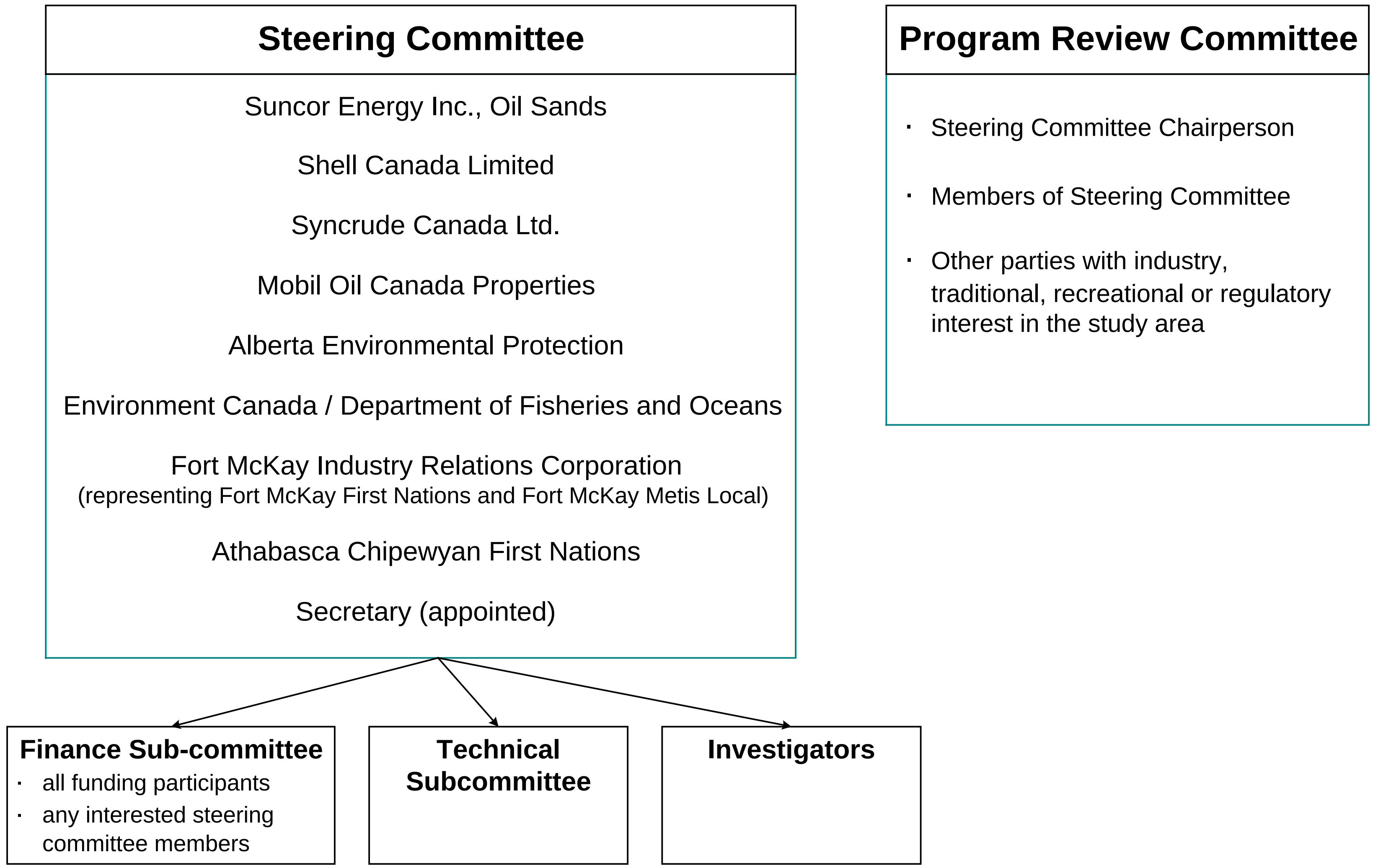
Terms of Reference for RAMP have been finalized and address topics including committee structure, representatives, meetings, decision-making and reporting requirements. The Terms of Reference outline the structure of the organization, including membership and roles of the Steering Committee and Program Review Committee and any other committees or subcommittees that may be formed. The current organizational structure of RAMP as of February 1999 is presented in Figure 1.1.

The Steering Committee is the decision making body of RAMP. It consists of funding and non-funding members. Membership currently consists of industry, regulators and communities. 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.

The Steering Committee has created two subcommittees: a Finance Subcommittee and a Technical Subcommittee. 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 purpose of the Technical Subcommittee is to prepare an annual monitoring program for review by the Program Review Committee, and for review and approval by the Steering Committee.

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



Membership in the Program Review Committee typically consists of parties with an industrial, recreational or regulatory interest in the 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.

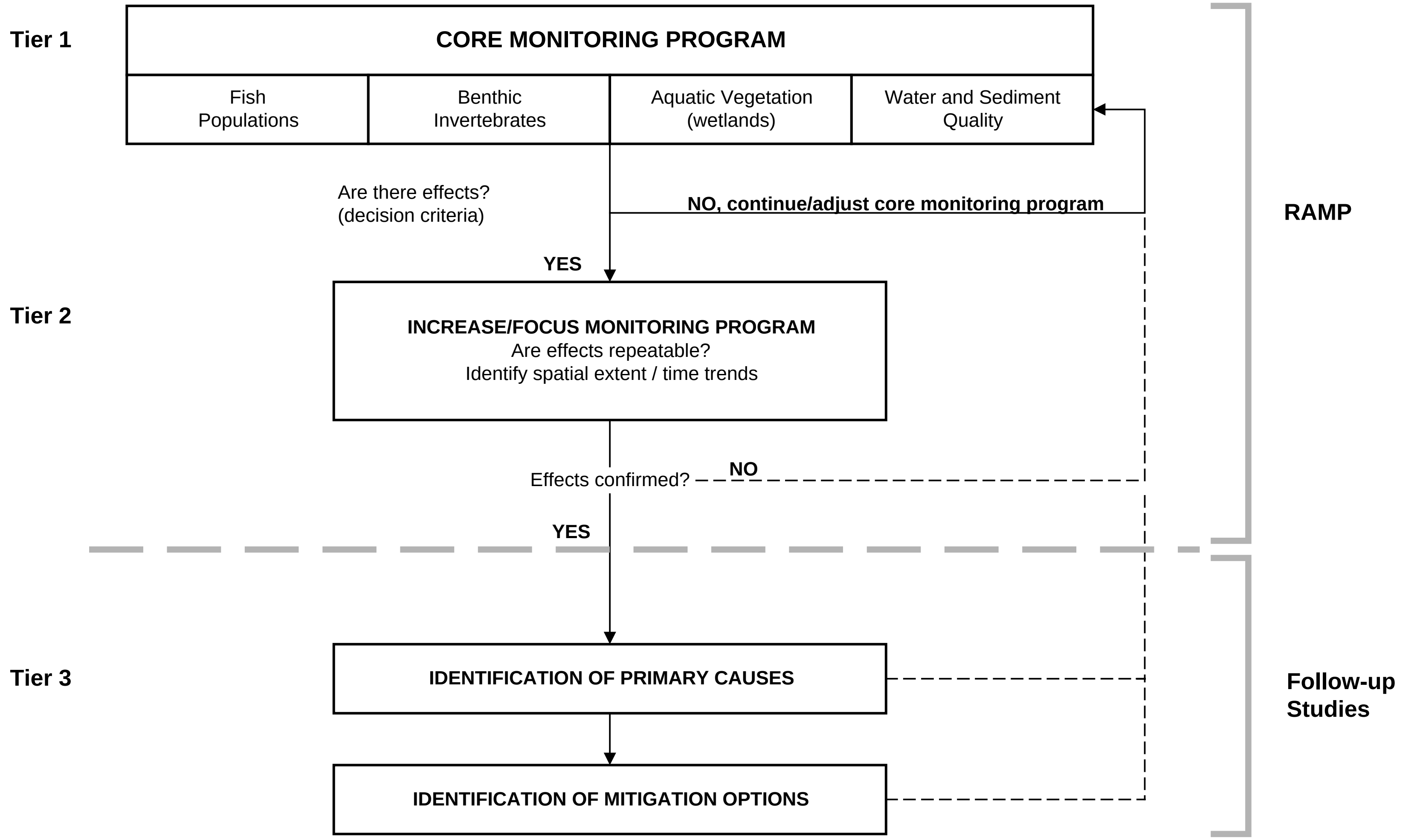
A Science Advisory Committee is part of the proposed organizational structure of RAMP, but has not yet been formed.

1.2.4 Core Program

The RAMP Steering Committee is in the process of developing a core monitoring program (end of 1998 to 1st quarter of 1999). The core program will outline 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 will also define sampling locations and frequencies. However, the program will include flexibility to allow for modification of sampling sites as issues arise.

If core monitoring results indicate a potential problem, further work will be done to determine if 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 1998 MONITORING PROGRAM

2.1 APPROACH

Historically, water quality monitoring and measurement against criteria have been used to evaluate potential impacts of human activities on aquatic systems (e.g., chemical concentrations, toxicity testing). However, water quality criteria may not be used exclusively to define environmental quality, or monitor ecosystem level changes over time. It may also be 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 these activities.

RAMP is largely a receptor-oriented program and 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. This approach will allow implementation of appropriate mitigation to address effects that negatively impact aquatic ecosystems.

The 1998 monitoring program was a continuation of long-term monitoring that began in 1997. It consisted of four core components:

- Water and sediment quality – indicator of habitat quality and potential chemical exposure of fish and invertebrates. Water and sediment quality are assessed by chemical analyses and toxicity bioassays.
- Benthic invertebrates – bioindicator of ecosystem integrity and quality of fish habitat.
- Fish populations – bioindicator of ecosystem integrity with emphasis on regional fish resources.
- Aquatic vegetation in wetlands – bioindicator of wetlands integrity.

To effectively evaluate aquatic ecosystems within the oil sands region, RAMP has focused on three main aquatic systems potentially affected by development activities: 1) Athabasca River; 2) tributaries of the Athabasca River (i.e., Muskeg River and Steepbank River); and 3) lakes and wetlands. Biological monitoring of wetlands habitat is focused on vegetation rather than fish or benthic invertebrates since vegetation is considered a more sensitive indicator of changes in wetlands (Gorham et al. 1984).

2.1.1 Water and Sediment Quality

Analysis of water and sediment chemistry provides a direct measure of the suitability of a waterbody to support aquatic life. Changes in water and sediment quality may indicate chemical inputs from point and non-point sources. Measured concentrations of chemicals can be compared with water 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 1998 water quality surveys was:

- to continue to monitor the same set of water quality parameters analyzed in 1997;
- to resample the Athabasca River (fall) and at the mouths of the Steepbank and Muskeg rivers (spring, summer and fall);
- to initiate sampling in the upper Muskeg River (fall), the Ells, Tar and MacKay rivers (spring, summer and fall), Wapasu Creek (winter) and Muskeg Creek (fall);
- to initiate toxicity testing in the tributaries to determine if baseline toxicity conditions exist (standard Environment Canada bioassays using fish, invertebrates, algae and bacteria); and
- to expand the Athabasca River survey by adding water quality sampling sites downstream of current oil sands developments.

The scope of the 1998 sediment quality survey was:

- to continue to monitor the same set of sediment quality parameters analyzed in 1997, including sediment toxicity (i.e., bioassays using benthic invertebrates: *Chironomus tentans*, *Hyalella azteca* and *Lumbriculus variegatus*);
- to resample the Athabasca, Steepbank, MacKay and Muskeg rivers (fall);
- to initiate sampling at the mouths of the Ells and Tar rivers (fall); and
- to expand the Athabasca River survey by adding sediment quality sampling sites downstream of current oil sands developments.

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 an important 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 Athabasca River was sampled in 1997. Since the sampling frequency is once every two years, the Athabasca River was not sampled in 1998. The scope of the 1998 benthic invertebrate study was:

- to initiate benthos monitoring on two tributaries, the Muskeg River and Steepbank River; and
- to identify and evaluate reference tributaries (refinement of study design).

2.1.3 Fish Populations

Monitoring of fish populations is a key component of RAMP. There are several reasons for evaluating fish populations. Fish integrate the effects of natural and anthropogenic factors and are, therefore, an important ecological indicator. Probably the most pertinent reason for the oil sands region 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 monitoring program. Firstly, it is necessary to ensure that fish populations which have been identified as important to subsistence, commercial and sport fisheries are not adversely affected by increased oil sands development. Of specific interest is the continued use of available fisheries resources for human consumption. 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 affects on ecological attributes such as growth, reproduction and survival. Early warning indicators are used to achieve this objective.

The scope of the 1998 fish monitoring program was:

- to obtain data on the same fish population parameters measured in previous years to examine year-to-year variability (e.g., length-at-age, length frequency distribution) in Athabasca River fish populations;

- to build on available baseline information for the Athabasca River to refine future fish monitoring activities;
- to document fish habitat associations in the Athabasca River by species and life stage;
- to evaluate potential reference areas for fish population monitoring on the Athabasca River;
- to initiate sentinel fish species monitoring in the Athabasca River using longnose sucker;
- to document the occurrence and movement of fish species in and out of the Muskeg and Steepbank rivers and reference tributaries; and
- to complete the radiotelemetry study initiated in 1997 to address data gaps regarding fish residency time within the oil sands region, and spawning and overwintering areas.

2.1.4 Aquatic Vegetation in Lakes and Wetlands

Wetlands vegetation has been documented as an important biomonitoring parameter for examining potential effects to wetlands systems (Gorham et al. 1984). Changes in water level, chemistry, circulation patterns and clarity could be reflected in changes in the abundance and distribution of aquatic plants in wetlands. As such, an inventory of wetlands plant species provides a baseline for future monitoring of wetlands. Wetlands vegetation has been selected as an indicator because changes in its abundance and distribution may influence the use of the wetlands by invertebrates, fish, waterfowl and wildlife.

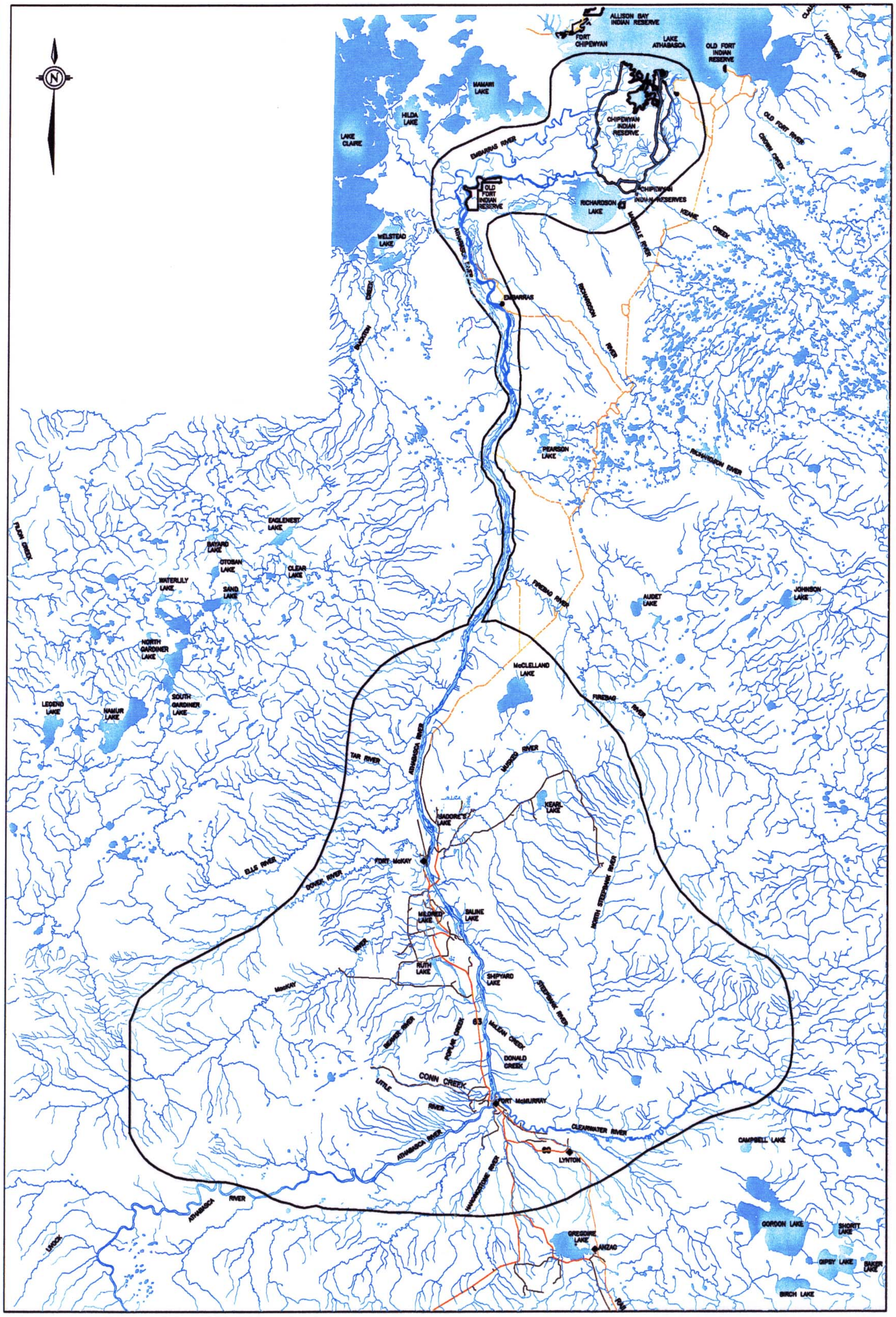
The scope of the aquatic vegetation surveys was:

- to further describe the vegetation communities in Isadore’s, Kearl and Shipyard lakes (second year of data to describe natural variability); and
- to identify and evaluate reference wetlands.

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 Delta (Figure 2.1). The study area includes a number of watersheds that drain into the Athabasca River.

J:\1999\2307\5000\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: 11 MAY 1999
PROJECT: 992-2307.5000		FIGURE: 2.1

In 1998, most of the monitoring activity was focused in the following areas:

- Athabasca River from above the oil sands developments (at Donald Creek) to downstream of all proposed oil sands developments (at Fort Creek);
- Athabasca River about 200 km upstream of the oil sands developments (potential reference area);
- lower reaches of the Muskeg and Steepbank rivers;
- lower reaches of the Ells, Tar, MacKay and Firebag rivers (potential reference tributaries);
- Isadore's, Shipyard and Kearl lakes; and
- spruce pond wetlands near Fort McMurray (potential reference area for wetlands).

2.3 CLIMATIC AND HYDROLOGIC CONDITIONS

The four core components of the 1998 monitoring program, water and sediment quality, benthic invertebrates, fish populations and aquatic vegetation, are all influenced by climatic conditions. In particular, changes that alter the quantity of water in the Athabasca River, the tributaries of the Athabasca River and the wetlands will influence these core components. Since changes in flows and water levels may affect both the success and the results of sampling throughout the study area, a summary of the 1998 conditions is provided as background information in this section. More detailed information is available in the Golder (1999a) report on the climatic and hydrologic monitoring program in 1998.

An analysis of data from long-term stream discharge gauging stations indicates that maximum stream discharges in 1998 were significantly lower than the long-term mean (Table 2.1). Minimum discharges were comparable to the mean. Return periods attached to these events were generally in the two to three year range.

However, the cumulative discharge for the period from March to September (i.e., spring melt to late summer) was much lower than normal, with drought return periods of between 10 and 30 years (Table 2.2). For all of the gauged streams, 1998 was the driest year since 1982 or 1983, although it was not the driest year on record.

Table 2.1 Maximum and Minimum Mean Daily Discharges in RAMP Study Area

Stream Station ID	Athabasca R. 07DA001	Steepbank R. 07DA006	Muskeg R. 07DA008	Jackpine Cr. 07DA009	MacKay R. 07DB001	Firebag R. 07DC001
			Maximum Mean Daily Discharge			
1998 value (m^3/s)	1810	15.8	9.14	2.08	40.6	56.4
average recorded (m^3/s)	2610	37.1	27.5	8.29	131	106
maximum recorded (m^3/s)	4700	81.0	66.1	17.2	339	236
return period (yr)	<2	<2	3	<2	3	<2
			Minimum Mean Daily Discharge			
1998 value (m^3/s)	106	0.421	0.346	0.000	0.332	9.35
average recorded (m^3/s)	137	0.288	0.280	0.007	0.359	7.95
minimum recorded (m^3/s)	92	0.022	0.095	0.000	0.023	4.24
return period (yr)	8	<2	<2	<2	<2	<2

Source: Environment Canada, Water Survey Branch.

Table 2.2 Cumulative Discharges in the RAMP Study Area from March to September

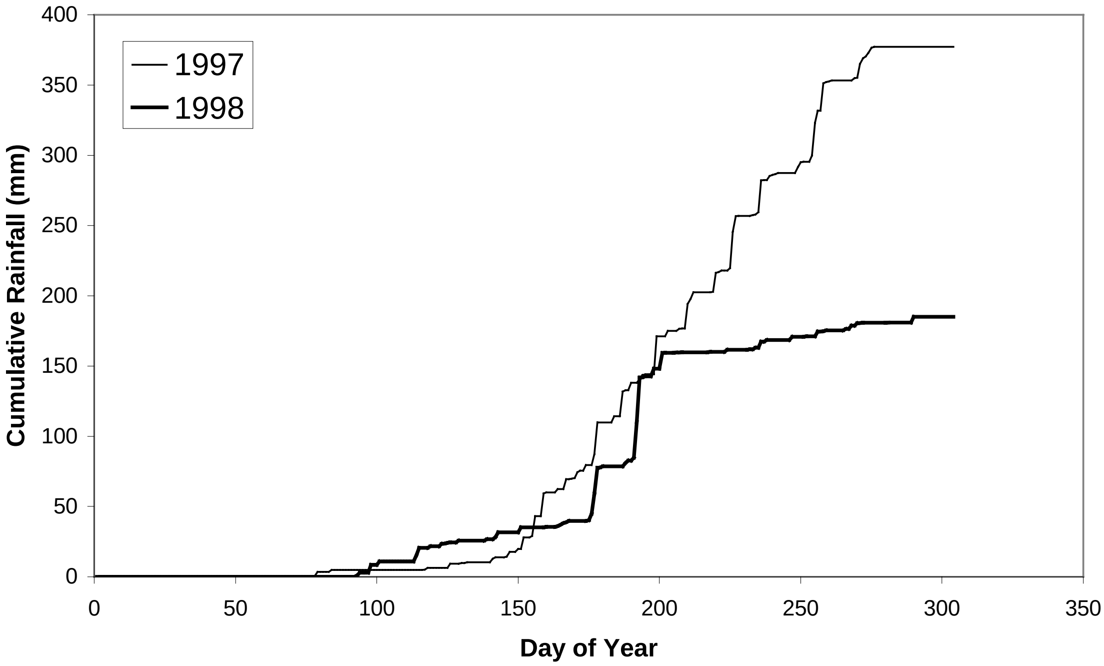
Stream Station ID	Athabasca R. 07DA001	Steepbank R. 07DA006	Muskeg R. 07DA008	Jackpine Cr. 07DA009	MacKay R. 07DB001	Firebag R. 07DC001
1998 value (dam^3)	13,023,417	66,816	58,336	10,517	182,224	413,522
average recorded (dam^3)	16,930,820	137,916	108,145	28,602	446,037	613,938
minimum recorded (dam^3)	11,888,035	44,336	26,125	4,525	129,845	344,469
return period (yr)	10	20	10	30	17	17

Source: Environment Canada, Water Survey Branch.

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

The low streamflows in 1998 can be attributed to two causes. Firstly, snow accumulations in the winter preceding the 1998 melt period were low. The measured snow depth in 1998 was approximately 65% of that measured in 1997. Secondly, rainfall in 1998 was the second lowest in a period of record extending from 1944 to 1998. Rainfall accumulations in 1998 were similar to those in 1997 (an average year) until late July, after which very little rain fell (Figure 2.2). The combination of these precipitation effects produced the dry muskeg and low streamflows observed in 1998.

Figure 2.2 Cumulative Rainfall in the RAMP Study Area in 1997 and 1998



Source: Environment Canada, Atmospheric Environment Service, Fort McMurray Airport Station 3062693.

3 METHODS

3.1 ATHABASCA RIVER

3.1.1 Water and Sediment Quality

3.1.1.1 The 1998 Study

In 1997, water and sediment samples were collected from the east side of the Athabasca River near Donald and Fort creeks. In 1998, RAMP was expanded to include one additional sampling site located just upstream of the Muskeg River. Water and sediments were collected from both the east and west sides of the Athabasca River. All 12 water and sediment samples were collected from the Athabasca River on September 16 and 17, 1998. Sample locations are illustrated in Figure 3.1.

3.1.1.2 Field Methods

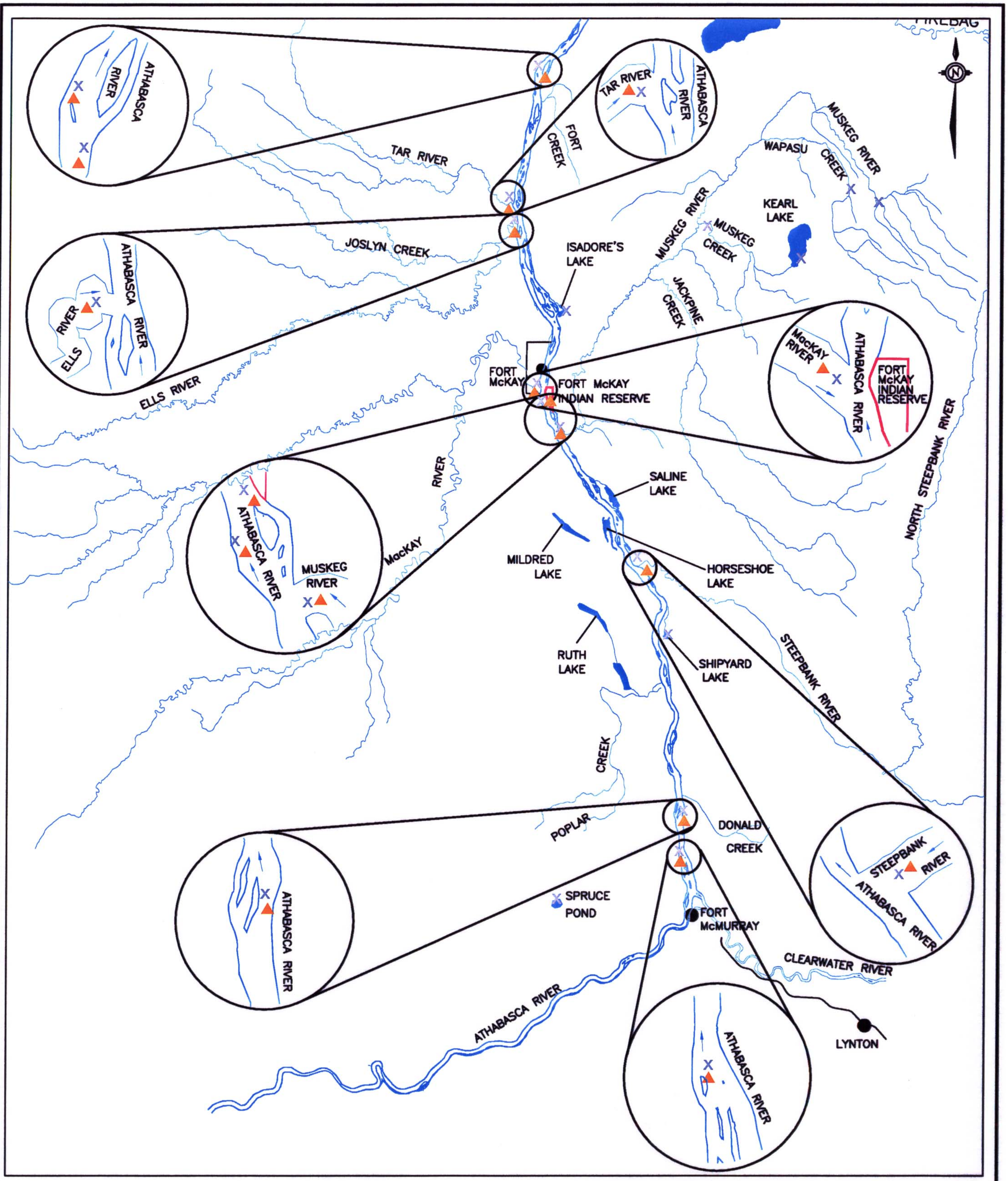
Water Sampling

At each sampling site on the Athabasca River, field crews collected a composite sample consisting of four to six grab samples evenly spaced across a quarter of the river width starting at the east or west river bank. Grab samples were collected from a depth of about 30 cm.

The composite sample created at each site was split into two parts. One portion was shipped to Enviro-Test Laboratories (ETL) in Edmonton, Alberta, and analyzed for 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 during each sampling event. For accuracy, all field probes were calibrated on each day before use, and all samples were collected, preserved, stored and shipped in accordance with Golder Associates Technical Procedure 8.3-1 (Golder 1999b).

J:\1999\992-2307\3000\ramp-sediment-sampling.dwg



LEGEND

X WATER QUALITY SAMPLING SITE

▲ SEDIMENT SAMPLING SITES

REFERENCE

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

NOTE

THE CIRCLED DETAILS IN THIS DRAWING ARE SCHEMATICS ONLY NOT TO SCALE

0 5 10 15 20 25km

Golder Associates

1998 RAMP WATER AND SEDIMENT SAMPLING SITES

DRAWN: BGM	APPROVED:	DATE: 30 APRIL 1999
PROJECT: 992-2307.3000		FIGURE: 3.1

Sediment Sampling

Although sediment samples were collected in the same general area as the water samples, sediments were sampled at sites closer to the river banks in sediment depositional areas. Sediments were collected from four to six locations at each sampling site. Sediments were taken from the top 3 cm of the river bottom using an Ekman grab sampler. The individual samples collected at each sampling site were mixed to form one composite sample for the site, 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 *Chironomus tentans* (midge larva), *Hyalella azteca* (amphipod) and *Lumbriculus variegatus* (oligochaete worm). The final portion was send to AXYS Analytical Services Ltd. (AXYS) in Sidney, B.C., and analyzed for polycyclic aromatic hydrocarbons (PAHs) and alkylated PAHs. PAH testing in 1998 used analytical techniques that provided lower detection limits than analyses reported in 1997. Descriptions of the methods used by each laboratory can be found in Appendix I.

3.1.1.3 Data Analyses

Qualitative comparisons were used to examine how water and sediment characteristics in the Athabasca River varied across the width and along the length of the river in 1998 and how these trends compared to data collected as part of the 1997 RAMP study (Golder 1998a). Historical information, where available, was summarized, and historical median, minimum and maximum values were developed. Information collected in 1998 was then compared qualitatively to the historical median values associated with each of the 1998 sampling sites. The 1998, 1997 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. Increased statistical analysis of the water quality data will be incorporated in future years, as the amount and number of years of data increases.

3.1.1.4 Quality Assurance and Quality Control

Water and sediment samples were collected in accordance to Golder Associates Technical Procedures 8.3-1 and 8.2-2, respectively (Golder 1999b). These two procedures outline correct sample collection, preservation, storage and handling protocols. They also provide specific guidelines for field record keeping and sample tracking. Water quality and sediment data were entered into the project database from the electronic files and paper reports received from the analytical laboratories. Approximately 50% of the data included in the project database was verified against each laboratory's final reports to ensure data accuracy. Less than 5% of the values contained in the program database were found to be entered incorrectly. These mistakes were corrected.

3.1.2 Fish Populations

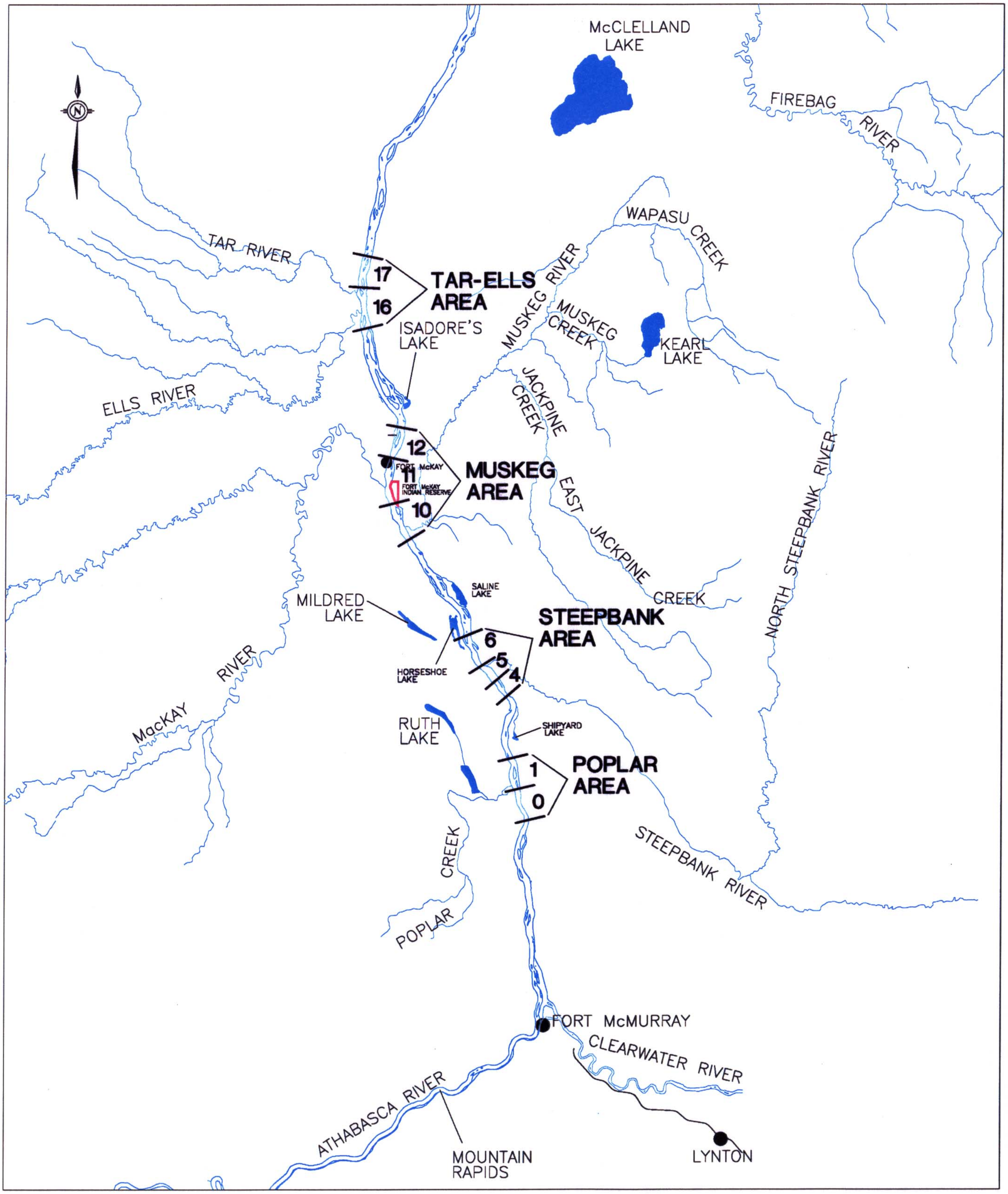
3.1.2.1 The 1998 Study

The 1998 fisheries component of the RAMP was a continuation of work initiated in 1997 (Golder 1998). The approaches being used to monitor fishes within the oil sands region include:

- monitoring fish species composition and abundance within specific habitats to detect changes in community structure;
- monitoring habitat quality for the selected reaches to detect changes in use by different life stages of fish;
- evaluating differences in whole-organism characteristics of a sentinel species resident to the oil sands area relative to an upstream reference population;
- investigating seasonal movements of fish to determine the residence time of different species in areas with exposure to oil sands-related discharges; and
- enhancing baseline information on fish population parameters (e.g., increased sample size for age distribution).

Fish population monitoring focused on Athabasca River reaches within the oil sands region previously surveyed for the Steepbank and Aurora mines (Golder 1996a, 1996b). River reaches were grouped according to four general sampling areas that were identified based on habitat characteristics, proximity to oil sands leases as well as existing and proposed discharges (Figure 2.4 in Golder 1998a). Sampling areas encompass the mouths of tributaries and hence were named according to the major tributary within each area. Throughout this report the sampling areas will be referred to as 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). For each reach, the specific location, in Universal Transverse Mercator (UTM) coordinates, and the general description are presented in Table 3.1.

J:\1998\982-2309\6053\AREAS.dwg



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.

Golder Associates

1998 RAMP
FISHERIES MONITORING REACHES

DRAWN: VS	APPROVED:	DATE: 22 JAN. 1999
PROJECT: 982-2309.6053		FIGURE: **3.2**

Table 3.1 UTM Coordinates and Description of Each Reach Sampled during Fish Collections within the Oil Sands Region, Athabasca River, 1998

Sampling Area	Reach	Differentially Corrected UTMs[a]	Reach Description
Poplar Area	0	U/S: 474670E, 6305866N D/S: 473911E, 6308221N	immediately upstream of McLean Creek to tip of island at beginning of Reach 1
	1	U/S: 473911E, 6308221N D/S: 473529E, 6310977N	tip of island to immediately downstream of Leggett Creek
Steepbank Area	4	U/S: 473176E, 6316814N D/S: 471760E, 6318696N	from trappers cabin upstream of Suncor bridge to downstream of unnamed island
	5	U/S: 471760E, 6318696N D/S: 470068E, 6320757N	unnamed island downstream of Suncor bridge to Syncrude dock and pumphouse
	6	U/S: 470068E, 6320757N D/S: 469416E, 6323065N	Syncrude dock/pumphouse to first island downstream of Syncrude sewage outfall
Muskeg Area	10	U/S: 464104E, 6331129N D/S: 462607E, 6334425N	from Beaver Creek to downstream end of Alexander Island
	11	U/S: 462607E, 6334425N D/S: 462357E, 6338248N	Alexander Island to downstream of island opposite Fort McKay
	12	U/S: 462357E, 6338248N D/S: 463284E, 6341263N	from island opposite Fort McKay to downstream of Height Island
Tar-Ells Area	16	U/S: 459827E, 6353379N D/S: 459767E, 6353583N	from small island upstream of Ells River to 100 m downstream of Tar River
	17	U/S: 459767E, 6353583N D/S: 459445E, 6356263N	from 100 m downstream of Tar River to downstream end of McDermott Island

[a] Universal Transverse Mercator (UTM) coordinates were taken at the right downstream bank at the beginning (upstream, U/S) and end (downstream, D/S) of each reach.

3.1.2.2 Fish Inventory

Fish inventory surveys were conducted to document presence and abundance of fish species within the oil sands region of the Athabasca River. Particular emphasis was placed on walleye, lake whitefish, goldeye and longnose sucker. The Shell Muskeg River Mine EIA (Shell 1997) and Suncor Project Millennium EIA (Suncor 1998) identified these species as Key Indicator Resources (KIRs) for the Athabasca River. The 1998 information supplemented data collected during previous studies, and continued the RAMP inventory initiated in 1997. Data collected over time will be valuable in documenting potential changes in the fish community resident in the oil sands region and/or utilizing the region on a seasonal basis.

An inventory of fish species was conducted at all four sampling areas during the spring (May 6-16), summer (July 22-26) and fall (Sept. 29 - Oct. 4) seasons. Sampling was conducted following detailed methods outlined in the Golder Technical Procedure 8.1-3 “Fish Inventory Methods” (Golder 1999b). Fish were captured using a Smith-Root model SR18 electrofishing boat. 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. The electrofishing unit was equipped with a timer that records the number of seconds of active electrofishing for each sampling effort. Catch-per-unit-effort (CPUE, number of fish (captured and observed) / unit of time fishing) was calculated to determine the relative abundance of fish species captured in each reach. Collection operations were consistent with the AEP Fisheries Management Division policy respecting injury to fish (AEP 1995a).

All captured fish were identified to species and enumerated. Species codes and common/scientific names are presented in Table 3.2. Fork length (± 0.1 cm) and body weight (±0.1 g) were measured for large fish species. For smaller species (e.g., trout-perch, 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. Fish population data were recorded in field logbooks and on RAMP catch and sample record forms. All data files were checked and verified against the original field data.

Non-lethal ageing structures were taken from walleye (pelvic spine, fin ray), goldeye (fin ray) and longnose sucker (fin ray) according to methods outlined in MacKay et al. (1990). Scales were also taken from prespawning lake whitefish during their fall migration to upstream spawning grounds (e.g., Mountain and Cascade rapids). An independent verification of age estimates of at least 15-20% of the total number of fish aged was conducted. If a final age could not be resolved, the fish was omitted from age analyses.

For each KIR species, age and size distributions were generated from data collected from the spring, summer and fall seasons. When sample sizes were adequate, the 1998 age distributions and size-at-age relationships were compared to data from previous years (1995, 1997). Size-at-age was generated as an estimate of fish growth. Because of seasonal and gender differences in condition factors, condition of each KIR species was calculated using 1998 data collected during the summer when the variation in condition is minimized.

Statistical analysis of KIR species data was done using SYSTAT® statistical software (Wilkinson 1990). Analysis of variance (ANOVA) was used to compare length, weight and age estimates among years. Estimates of size-at-age (length vs. age) and condition (body weight vs. length) were evaluated using Analysis of Covariance (ANCOVA).

Table 3.2 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).

3.1.2.3 Habitat Evaluation and Fish-habitat Associations

One of the key issues regarding current and proposed oil sands development is the alteration of critical fish habitat that may inhibit or preclude future fish production. Habitat features (sandbars, shoals, snyes, backwater, bank stability) of large river systems such as the Athabasca River are often dynamic, dictated by annual variability in water level and discharge as well as hydro-morphological processes. It is important to document these natural changes in major habitat features over time to allow one to better evaluate potential changes related to increased mining activity.

Fish habitat in the Athabasca River near oil sands operations was originally mapped in 1995 and 1996 from Willow Island downstream to Joslyn Creek (Golder 1996a, 1996b). The location and extent of each habitat type was delineated on habitat base maps of the study area. These base maps were prepared from 1:50,000 scale topographic maps and aerial photographs of the Athabasca River. For the monitoring program, specific sections of the Athabasca River in the RAMP study area were selected as habitat index sites, to be monitored for potential changes in fish habitat availability. Four sites within the RAMP study area were selected for monitoring. These four sites are each associated with major tributary confluences and encompass ten reaches of the Athabasca River as described in Section 3.1.2.1.

During the summer and fall RAMP fisheries surveys in 1997 and 1998, the existing habitat maps from the baseline study were examined and updated to record any observed changes to habitat types, either natural or man-made. Although the original intent was to map each of the four fish sampling areas, the Tar-Ells Area was not done in 1998 because of mechanical problems with the boat near the completion of the summer survey.

All habitat mapping was conducted following the procedures described in the Golder Technical Procedure 8.5-1 "Watercourse Habitat Mapping System" (Golder 1999b). The Athabasca River was mapped according to the Large River Habitat Classification System. This system is used to map large rivers that show a limited amount of instream heterogeneity in that they lack distinctions between specific channel units such as pools, riffles and runs. This classification system consists of three components: channel type (unobstructed, singular or multiple islands), bank habitat type, and special habitat features. Table 3.3 describes one of these components, the bank habitat type.

Table 3.3 Description of Bank Habitat Types within the RAMP Study Area

Bank Habitat Type	Symbol	Bank Description
armoured/stable	A1	cobble/boulder - limited instream cover
	A2	cobble/boulder - instream cover, backwater areas
	A3	boulder/bedrock - instream cover
	A4	rip-rap – instream cover
canyon	C1	valley walls - cobble/boulder
	C2	steep bedrock banks
	C3	valley walls - gravel/cobble
depositional	D1	gentle slope - fines
	D2	gentle slope - gravel/cobble
erosional	E1	high, steep eroded bank - instream vegetation debris
	E2	same as E1 - no instream vegetation debris
	E3	steep bank - gravel/cobble/sand
	E4	steep eroding/slumping bank
	E5	low, steep bank
	E6	same as E5 with instream cover

Concurrent with the RAMP summer habitat evaluation and fisheries surveys, the abundance and life stage of fish species captured from each habitat type were also recorded. Fish species-habitat associations are useful for understanding fish utilization of available habitat and ramifications of potential habitat alteration.

3.1.2.4 Reference Site Evaluation

Fish monitoring programs must be designed to distinguish between natural variability and true impacts. There are two common study designs used to address this objective: 1) control-impact design (comparison between reference and exposed populations); and 2) time-trend analysis (following the exposed population over time). A combination of both approaches is preferred and both have been included in the RAMP.

To date, a suitable reference site for monitoring fish populations of the Athabasca River has been difficult to identify. Inventories conducted in 1997 (Golder 1998a) immediately downstream of Fort McMurray indicated that species composition and habitat characteristics were not comparable to the RAMP study reaches. As well, there was some concern regarding the mobility of large fish species and the close proximity of these potential reference sites to the oil sands region (i.e., fish at reference sites did not represent distinct populations). During the 1998 program, two areas were identified as potential reference areas:

- Athabasca River downstream of Duncan Creek was reported to have similar habitat characteristics and species composition as RAMP study reaches (R.L.&L. 1994; Sentar 1994). The presence of a series of downstream rapids limits extensive fish movement between study areas (Tripp and McCart 1979).
- Wabasca River was identified in the Northern River Basins Study (NRBS) as a natural oil sands area (Lockhart and Metner 1996). Since this river has natural oil sands deposits, but no oil sands development, it may be a suitable reference site to distinguish between natural effects and potential anthropogenic effects.

Both sites were initially evaluated using literature information on habitat suitability, species composition and the presence of confounding factors (e.g., industrial development). A summer field reconnaissance trip followed to conduct a fish inventory survey and to map dominant habitat features according to the methods outlined in Sections 3.1.2.2 and 3.1.2.3.

3.1.2.5 Sentinel Fish Species Monitoring

Sentinel species monitoring is a common and effective approach used to assess the effects of stressors (e.g., industrial development) on wild fish populations. Briefly, the performance (e.g., growth, condition, reproductive parameters) of a key 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).

The sentinel species approach is consistent with a framework proposed by Munkittrick and Dixon (1989a,b) and later revised by Gibbons and Munkittrick (1994) and Gibbons (1997). The influence of this framework is also seen in the detailed guidance for Environmental Effects Monitoring (EEM) for the pulp and paper industry (Environment Canada, Dept. of Fisheries and Oceans 1993), and for the Aquatic Effects Monitoring for all industries seeking water licenses in the Northwest Territories (GeoNorth and North/South Consultants 1997).

A sentinel species monitoring program was initiated during the fall 1998 survey for the following reasons.

- There was an opportunity to collect RAMP data at the same time that pulp and paper mills within the Athabasca River basin were conducting the second cycle of the EEM program. The resulting information will be important for evaluating cumulative effects assessment throughout the basin.
- Financial resources were available through in-kind contributions from Environment Canada's Program on Energy Research and Development (PERD) and local field assistance from Fort Chipewyan.
- Data from reference and oil sands fish would provide the estimates of variability necessary for refining the study design of a long-term sentinel species monitoring program.

Longnose sucker has been selected as a sentinel species for RAMP. This species was identified as a KIR species for the Athabasca River in several recent EIAs, and is also used as a sentinel species for pulp mill EEM programs within the Athabasca River basin. Longnose sucker has been identified as an optimal sentinel species due to an intermediate life span, fast growth rate, high fecundity, early maturation and its important role in the aquatic food web (Munkittrick 1992). These characteristics provide the maximum amount of information with the fastest response time to changes in the aquatic ecosystem.

Longnose sucker were collected during fish inventory surveys done in the fall (i.e., boat electrofishing, see Section 3.1.2.2) in the oil sands region and reference region (previously identified during the summer). Blood was collected from live fish via caudal puncture into 5.0 ml heparinized Vacuutainers® and placed on ice from 6 to 8 h. Plasma was collected after centrifugation, frozen in liquid nitrogen and stored at -20°C before assays for sex steroids and vitellogenin. Following blood collection, each fish was rendered unconscious by concussion, followed by spinal severance, and measured for fork length, body weight, gonad weight and liver weight. A sample of ovarian tissue from mature females was weighed and preserved in Gillson's solution for fecundity analyses. Pectoral fin rays were removed from each fish for ageing. Ageing measurements were obtained following procedures outline in MacKay et al. (1990). An independent verification of age estimates of at least 15-20% of the total number of fish aged indicated an error rate of less than 10%. An external and internal pathology examination was conducted for each fish. Approximately 1 g of liver tissue was placed in a cryovial, frozen immediately in liquid nitrogen, and stored at -80°C pending mixed function oxygenase (MFO) analyses. All fish data were collected following methods outlined in Golder Technical Procedures 8.1-3 (Golder 1999b) and 8.15-0 "Fish Health Assessment – Organics" (Golder 1999b). All data files were checked and verified against the original field data.

MFO, sex steroids and vitellogenin assays were conducted by the National Water Research Institute, Environment Canada, Burlington, Ontario through collaborations with Drs. J. Parrott and J. Sherry. Induction of MFO activity has been observed in fish exposed to some PAH compounds (e.g., benzo(a)pyrene), chlorinated aromatic hydrocarbons, and complex mixtures such as petroleum oils (Hodson et al. 1991). For this study, MFO activity was measured as a positive indicator of exposure to inducing compounds present in the oil sands region. Altered sex steroid levels (e.g., testosterone, 17 estradiol), and vitellogenin induction in male fish, were measured because they are endpoints commonly used as indicators of exposure to endocrine disrupting compounds. At the time of writing this report, only the MFO assays had been completed, while steroid and vitellogenin assays were still ongoing. Measurement of MFO activity was based on the catabolism of 7-ethoxyresorufin-o-deethylase (EROD) as described by van den Heuvel et al. (1995).

Size distributions for longnose sucker collected in the fall were generated for each region. The age distribution of sucker from the reference region was also generated and compared to the age distribution of fish from the oil sands region (seasons combined). Statistical analysis of sentinel fish species data was done using SYSTAT® statistical software (Wilkinson 1990). ANOVA was used to compare length, weight and age estimates between regions. Estimates of size-at-age (length vs. age), condition (body weight vs. length), gonad size and liver size were evaluated using ANCOVA. With the exception of size-at-age and condition, corrected body weight (body weight - gonad weight and liver weight) was used as a covariate to adjust for any differences in body size. Using corrected 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 $p < 0.01$ (PLA 1998). Nonparametric Kruskal-Wallis tests were used to compare MFO activity between fish from the reference site and oil sands region. Data were $\log_{10}$ transformed where appropriate and sexes were analyzed separately.

3.1.2.6 Radiotelemetry Study

It is important to determine how long fish remain within the oil sands region, because potential effects on fish populations will be a function of exposure. The life-history data gathered to date show that most of the small fish species remain in the Athabasca River over the entire year. However, many large fish species (e.g., goldeye, longnose sucker, lake whitefish) use the river as a migration corridor to reach spawning areas or feeding grounds. Most of these fish are thought to migrate downstream in the fall to overwinter in Lake Athabasca, but the 1997 radiotelemetry data indicated the possibility that some walleye and lake whitefish overwinter in the Athabasca River. The continuation of this study during the winter months and throughout the year was important to confirm whether certain fish overwinter in the Athabasca River, and to document seasonal movement.

Fish Sampling and Tagging Procedures

Two KIR fish species chosen for the study were walleye and lake whitefish. Eighteen walleye and eighteen lake whitefish captured during the fall 1997 fisheries inventory (October 2-15) were implanted with radio tags. The general location, as well as the number of each species released in the RAMP study area is shown in Table 3.4.

Fish were captured using a Smith-Root model SR18 electrofishing boat and placed in a small holding pen in the river to minimize capture and handling stress. Fish were tagged on the day they were captured and released at the downstream end of the reach from which they were caught. Fish were selected for radio tagging based on size and physical condition. A minimum weight was established to ensure that the transmitter did not weigh more than 2% of the fish’s body weight. In general, all walleye and lake whitefish weighing more than 675 g were considered for tagging. To limit radio tagging to spawning adults, only fish larger than 400 mm in fork length, or known to be adult fish following internal examination, were radio tagged.

Table 3.4 Collection Locations and Number of Walleye and Lake Whitefish Tagged for the 1997-1998 Radiotelemetry Study within the Oil Sands Region, Athabasca River

Distance Downstream of Fort McMurray (km)	Number of Each Species	
	Walleye	Lake Whitefish
25	5	3
37	2	9
53	3	2
57.5	5	4
60	2	0
73	1	0

Individual fish were placed in an anaesthetic bath of 4 g of tricaine methane sulfonate (MS-222) in 40 L of water for a period of two to four minutes. During this time the respiration rate and physical movements (coordination) of each fish was visually monitored until the fish was determined to be anaesthetized. Surgical equipment was washed in a disinfectant bath and rinsed with distilled water. The surgical implantation technique was modified from methods outlined by Bidgood (1980) and Knecht et al. (1981). A 3-4 cm longitudinal, abdominal incision was made 1-2 cm from the mid-ventral line, anterior to the pelvic fins. A hypodermic needle (16 gauge) was inserted through the skin approximately 2 cm posterior to the incision, into the abdominal cavity and out through the incision. Care was taken not to damage internal organs. The radio transmitter's whip antennae was then inserted in the hypodermic needle and drawn out of the body cavity through the needle hole. The radio transmitter was positioned inside the body under the incision and an antibiotic (Lyquamycin) was injected intraperitoneally to reduce the possibility of infection. The incision was sutured, treated with a fungicide (methyl blue) and sealed with liquid tissue adhesive.

Following surgery, fish were held in a flow-through live-well until they could swim strongly without disorientation. Holding times were minimized to reduce trauma. After each implant, the tag was tested using the telemetry receiver with the fish in the water to determine the exact operating frequency. All frequencies were entered into the receiver and recorded into the field log book.

Radiotelemetry Equipment

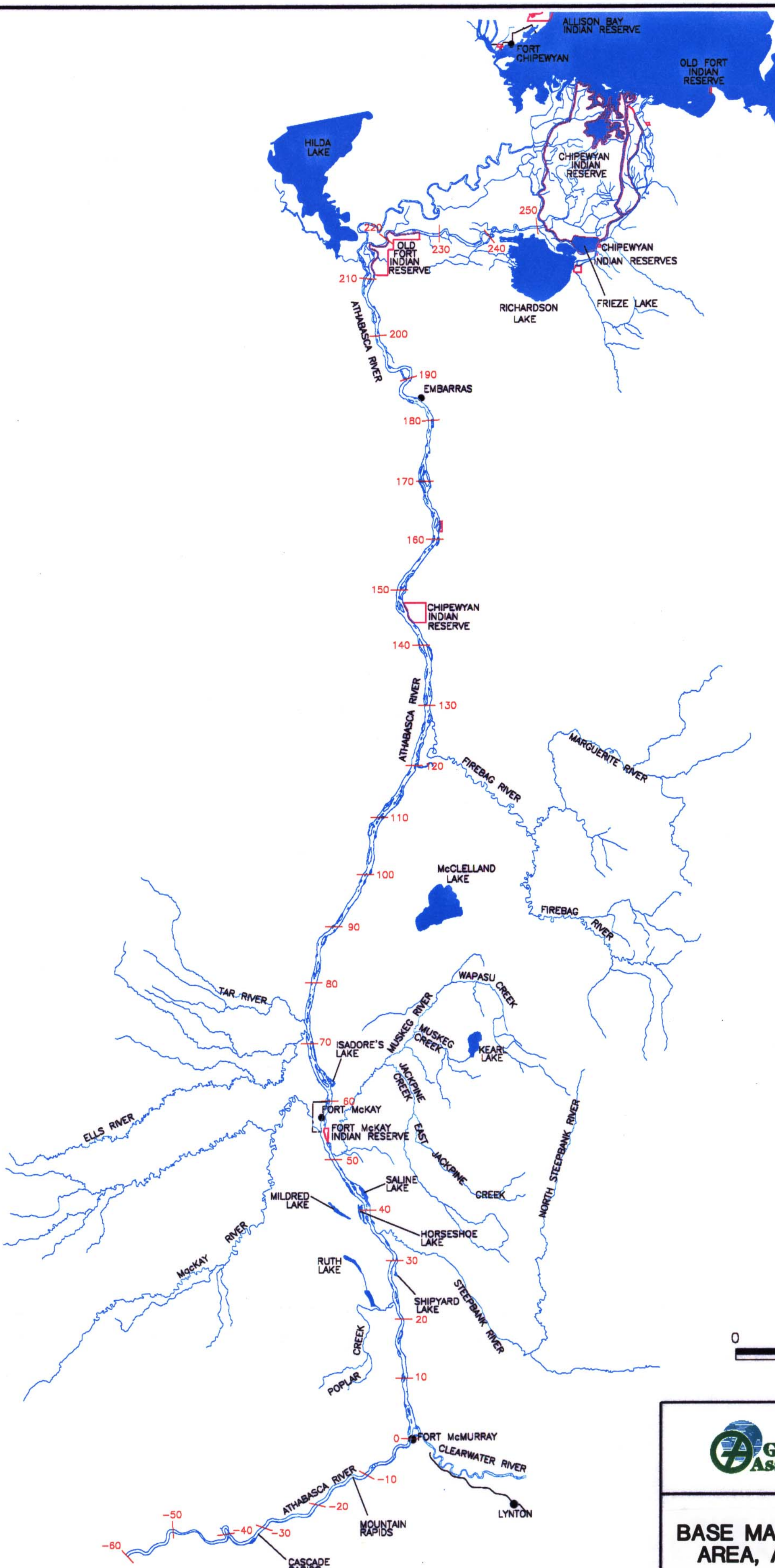
Conventional pulsed radio transmitters (Lotek Engineering Inc., Model MBFT-6) weighing 10.1 g (weight in air) were used for the study. The transmitters emit radio signals in the 150 MHz frequency range, at a pulse rate of 60 beats/min. The emission cycle is 12 h on/12 h off per day and the average life expectancy of each transmitter is approximately 423 d. A Telonics TR-2 receiver was used to locate the transmitter signals during aerial surveys. An additional radio transmitter was not implanted, but set aside as a reference transmitter. It was activated during the 1997 radio tagging program and was left running to mimic the activity of the implanted transmitters and to monitor battery life. The reference transmitter was also used to test the telemetry equipment in the aircraft to ensure it was operational for each flight.

The radio tags used for the RAMP study are high frequency transmitters. High frequencies travel through water with a greater loss of power than do low frequencies, so that low frequency transmitters provide stronger signals for fish in deep water. However, high frequency transmitters used in shallow water (i.e., depths <5 m) have a larger range at which the signals can be received during telemetry flights, making reception of the signals more certain. Habitat measurements conducted during the 1995 baseline studies for the Athabasca River in the oil sands area indicated that water depths in all but rare deep water areas were <5 m. Therefore, high frequency transmitters were selected for use in the RAMP study, as they would be extremely effective under these conditions. However, for radio tagged fish situated in deep water such as Lake Athabasca, reception of the radio signal would be disrupted.

Radiotelemetry Surveys

The positions of tagged fish were monitored and recorded from a fixed-wing aircraft from October 1997 to December 1998. Twenty-five aerial survey flights were conducted in total. Flights occurred twice monthly during the spring and fall in an effort to follow movements of prespawning walleye (spring) and lake whitefish (fall). Telemetry flights were concentrated during the fall and spring migration/spawning periods to attempt to locate the spawning sites used by these fish populations. Flights were reduced or discontinued at other times of the year. Flights were not conducted between December 22, 1997 - March 23, 1998 and April 16 - September 16, 1998. The survey flights covered the mainstem Athabasca River from above Cascade Rapids upstream of Fort McMurray, to the Peace-Athabasca Delta. To help identify and record the position of tagged fish, a base map of the study area was delineated into river kilometres (Figure 3.3). During each flight, the frequency and position (river kilometres and/or GPS latitude/longitude coordinates) of each located transmitter were recorded.

J:\1998\982-2309\6053\EVERY10.dwg



LEGEND

—10 DISTANCE IN km DOWNSTREAM FT. McMURRAY

—-10 DISTANCE IN km UPSTREAM FT. McMURRAY

REFERENCE

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

0 10 20 30 40 50km

SCALE 1:1,000,000

Golder Associates

BASE MAP OF RADIOTELEMETRY STUDY AREA, ATHABASCA RIVER, 1997-1998

DRAWN: VS	APPROVED:	DATE: 21 JAN. 1999
PROJECT: 982–2309.6053		FIGURE: **3.3**

During the walleye spawning season in the spring of 1998, only a small number of radio tagged walleye were located in the Athabasca River study area. Therefore, an additional telemetry flight was commissioned on June 23 to examine significant tributaries to check for the presence of radio tagged fish. The following tributary segments were covered:

- the Steepbank River from the mouth upstream to the North Steepbank River;
- the North Steepbank River from the mouth upstream for approximately 15 km;
- the Ells River from the mouth upstream for approximately 40 km as well as a 60 km section immediately downstream of Gardiner Lakes;
- the Muskeg River from the mouth upstream to Stanley Creek; and
- a short section of the Tar River near the river mouth.

3.1.2.7 Fish Tissue Analyses

Fish tissue analyses were included in the RAMP to monitor the ecosystem health of the Athabasca River (i.e., direct/indirect toxicity effects on fish) and to monitor the fish resource for suitability for human consumption. Fish flesh samples were collected from the sentinel species (longnose sucker) as well as species identified for human consumption (goldeye, walleye and lake whitefish). Tissues were collected from the reference and oil sands regions during the spring and fall, 1998 (Table 3.5). A target of five male and five female fish of each species were to be collected; however, this ratio varied with capture success. Whole carcasses were collected for goldeye, longnose sucker and lake whitefish and later filleted in the laboratory prior to analyses. For walleye, fillets were collected in the field to provide samples for tissue analyses as well as samples to be archived for future tainting studies. Samples were frozen on dry ice immediately after collection and sent on dry ice to Enviro-Test Laboratories, Edmonton, Alberta. Tissue sampling, storage and shipping procedures were done following Golder Technical Procedures 8.15-0 (Golder 1999b) and 8.16.0 “Fish Health Assessment – Metals” (Golder 1999b).

At the laboratory, tissue samples were composited by species and sex prior to being analyzed for PAHs, mercury and other trace metals. Chemical analyses were conducted according to methods described by U.S. EPA (1979) and APHA (1985) (Table 3.6). Detection limits are provided in Table 3.7.

Table 3.5 Season, Species and Number of Fish Collected for Fish Tissue Analyses from Oil Sands and Reference Regions, Athabasca River, 1998

	Spring	Fall	
Species	**Oil Sands**	**Oil Sands**	**Reference**
longnose sucker		5 females 5 males	6 females 8 males
goldeye	5 females 5 males		
walleye	4 females 6 males	3 females 4 males	2 females 4 males
lake whitefish		4 females 3 males	

Table 3.6 Analytical Methods for Measuring PAHs, Mercury and Other Trace Metals in Fish Tissues

Parameter	Methods
PAHs in solid samples	GC/MSD analysis, EPA method 3540 or 3545 (extraction), EPA method 8270 (analyses)
trace metals in tissue	inductively coupled plasma (ICP) scan, EPA method 200.7
mercury in tissue	spectrophotometrically, EPA method SW 846, APHA method 3112B

Table 3.7 Detection Limits of PAHs, Mercury and Other Trace Metals Measured in Fish Tissue

PAHs		Metals (Total)	
Parameter	**Detection Limit (µg/kg)**	**Parameter**	**Detection Limit (mg/kg)**
naphthalene	0.01	aluminum (Al)	0.2
methyl naphthalenes	0.01	antimony (Sb)	0.04
acenaphthene	0.01	arsenic (As)	0.2
acenaphthylene	0.01	barium (Ba)	0.08
fluorene	0.01	beryllium (Be)	0.2
phenanthrene/anthracene	0.01	boron (B)	2
dibenzo(a,h)anthracene	0.01	cadmium (Cd)	0.08
benzo(a)anthracene/chrysene	0.01	calcium (Ca)	10
benzo(a)pyrene	0.01	chromium (Cr)	0.2
benzo(b&k)fluoranthene	0.01	cobalt (Co)	0.08
benzo(g,h,i)perylene	0.01	copper (Cu)	0.08
fluoranthene	0.01	iron (Fe)	2
indeno(c,d-123)pyrene	0.01	lead (Pb)	0.04
pyrene	0.01	magnesium (Mg)	2
		manganese (Mn)	0.04
		mercury (Hg)	0.05
		molybdenum (Mo)	0.04
		nickel (Ni)	0.08
		phosphorus (P)	2
		potassium (K)	2
		selenium (Se)	0.2
		silver (Ag)	0.08
		sodium (Na)	2
		strontium (Sr)	0.04
		thallium (Tl)	0.04
		tin (Sn)	0.08
		vanadium (V)	0.08
		zinc (Zn)	0.2

3.2 TRIBUTARIES OF THE ATHABASCA RIVER

3.2.1 Water and Sediment Quality

3.2.1.1 The 1998 Study

Water and sediment sampling in tributaries of the Athabasca River was restricted to the Steepbank and Muskeg rivers in 1997. In 1998, RAMP was expanded to include Wapasu Creek, Muskeg Creek and the upper Muskeg River, as well as three reference tributaries, the MacKay, Ells and Tar rivers. Water, or water and sediment samples were collected from each sample site in accordance with the sampling design summarized in Table 3.8. Sample locations are illustrated in Figure 3.1.

Table 3.8 1998 Water and Sediment Sampling Schedule for Athabasca River Tributaries

Waterbody	Sample Location	Sample Media	Sample Date
Steepbank River	river mouth	water	May 12 (spring) July 22 (summer) September 15 (fall)
		sediment	September 15 (fall)
Muskeg River	river mouth	water	May 7 (spring) July 22 (summer) September 17 (fall)
		sediment	September 21 (fall)
	upstream of Wapasu Creek near the Canterra Road	water	September 17 (fall) December 8 (winter)
Tar River	river mouth	water	May 6 (spring) July 22 (summer) September 17 (fall)
		sediment	September 17 (fall)
Ells River	river mouth	water	May 12 (spring) July 22 (summer) September 17 (fall)
		sediment	September 17 (fall)
MacKay River	river mouth	water	September 23 (fall)
		sediment	September 23 (fall)
Muskeg Creek	river mouth	water	September 17 (fall)
Wapasu Creek	downstream of Lease 36	water	December 8 (winter)

3.2.1.2 Field Methods

Water Sampling Methods

Water samples from Steepbank, Tar, Ells, Muskeg (mouth) and MacKay rivers were collected from the centre of each tributary, approximately 100 m upstream of the Athabasca River. Water samples from the upper Muskeg River, Muskeg Creek and Wapasu Creek were also collected from the centre of each tributary, 50 to 100 m upstream of the stream mouth and/or access road. Two grab samples were collected at each site from a depth of approximately 30 cm.

All samples were preserved, stored and later shipped to ETL and HydroQual for the analyses described in Section 3.1.1.2. Toxicity testing with *Ceriodaphnia dubia*, fathead minnow and rainbow trout was also completed by HydroQual for water samples taken from the upper Muskeg River, Muskeg Creek and Wapasu Creek. Field measurements, including DO, pH, conductivity and temperature, were generally taken during each sampling event.

Sediment Sampling Methods

Sediment samples were also collected from each tributary, approximately 100 m upstream of the Athabasca River. However, as in the Athabasca River, sediment samples were taken closer to shore in sediment depositional areas. Composite sediment samples for each tributary were created using the same sampling procedure described in Section 3.1.1.2. Each composite sample was split in half. One part was shipped to ETL, while the other portion was sent to AXYS. Both portions were tested for the same parameters as described in Section 3.1.1.2. Toxicity testing was not done for any of the tributaries.

3.2.1.3 Data Analyses

Water and sediment data from the five sampled tributaries were analyzed by the same methods as those described in Section 3.1.1.3.

3.2.1.4 Quality Assurance and Quality Control

In addition to the quality assurance and quality control (QA/QC) process outlined in Section 3.1.1.4, three field blanks were prepared during the 1998 sampling program to detect potential sample contamination during sample collection, shipping and analysis. One split sediment sample was also analyzed by AXYS to assess the precision of their PAH analysis.

3.2.2 Benthic Invertebrates

3.2.2.1 The 1998 Study

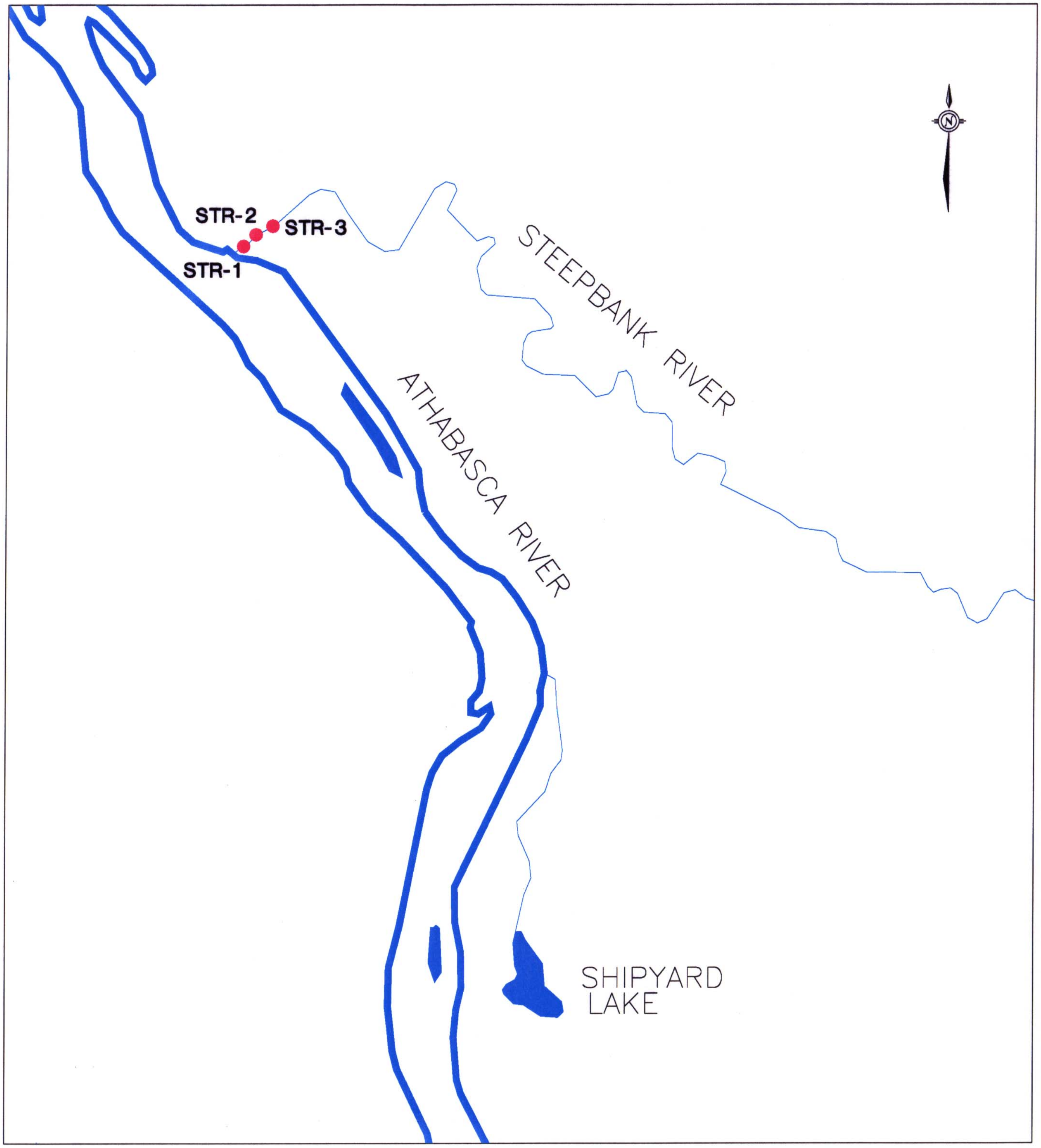
The fall 1998 benthic invertebrate survey of the Steepbank, Muskeg and MacKay rivers represents the first year of a long-term tributary monitoring program to assess the impacts of oil sands development. The objective of these surveys was to characterize natural variability in the Steepbank and Muskeg rivers and reference rivers (MacKay River) before the commencement of oil sands development and to provide data for the design of subsequent studies.

The initial design of these surveys included collecting five replicate benthic invertebrate samples at five erosional sites in each of the Steepbank, Muskeg, and two reference rivers (Tar and Ells rivers). Spacing of the five sites in each river was intended to encompass one to five kilometre long reaches, beginning just upstream of each river's mouth. The lower reaches of these rivers were selected because of relatively easy access and future exposure of benthic communities to the cumulative effects of all potential discharges from oil sands operations and reclaimed land.

The initial study design outlined above was modified slightly to accommodate the conditions encountered during a field reconnaissance carried out in mid-September, 1998. Modifications included the following.

- The Tar and Ells rivers were not sampled, because their discharge was too low in September. As a result, there were no suitable erosional areas in the lower reaches of these rivers. To compensate for the lack of reference rivers, the MacKay River was added to the fall surveys. Three erosional sites were established in the lower MacKay River.
- The number of sampling sites in each river was reduced to three, because there was not enough appropriate and accessible habitat in the lower reaches of the rivers surveyed to establish five sites.

Benthic invertebrate monitoring focused on the lower reaches of the Steepbank, Muskeg and MacKay rivers (Figures 3.4 and 3.5). Three sampling sites were established in each river selected for monitoring, within the first kilometre from the mouth. Site codes and UTM coordinates are provided for each sampling site in Table 3.9.



LEGEND

● BENTHIC INVERTEBRATE SAMPLING SITE

REFERENCE

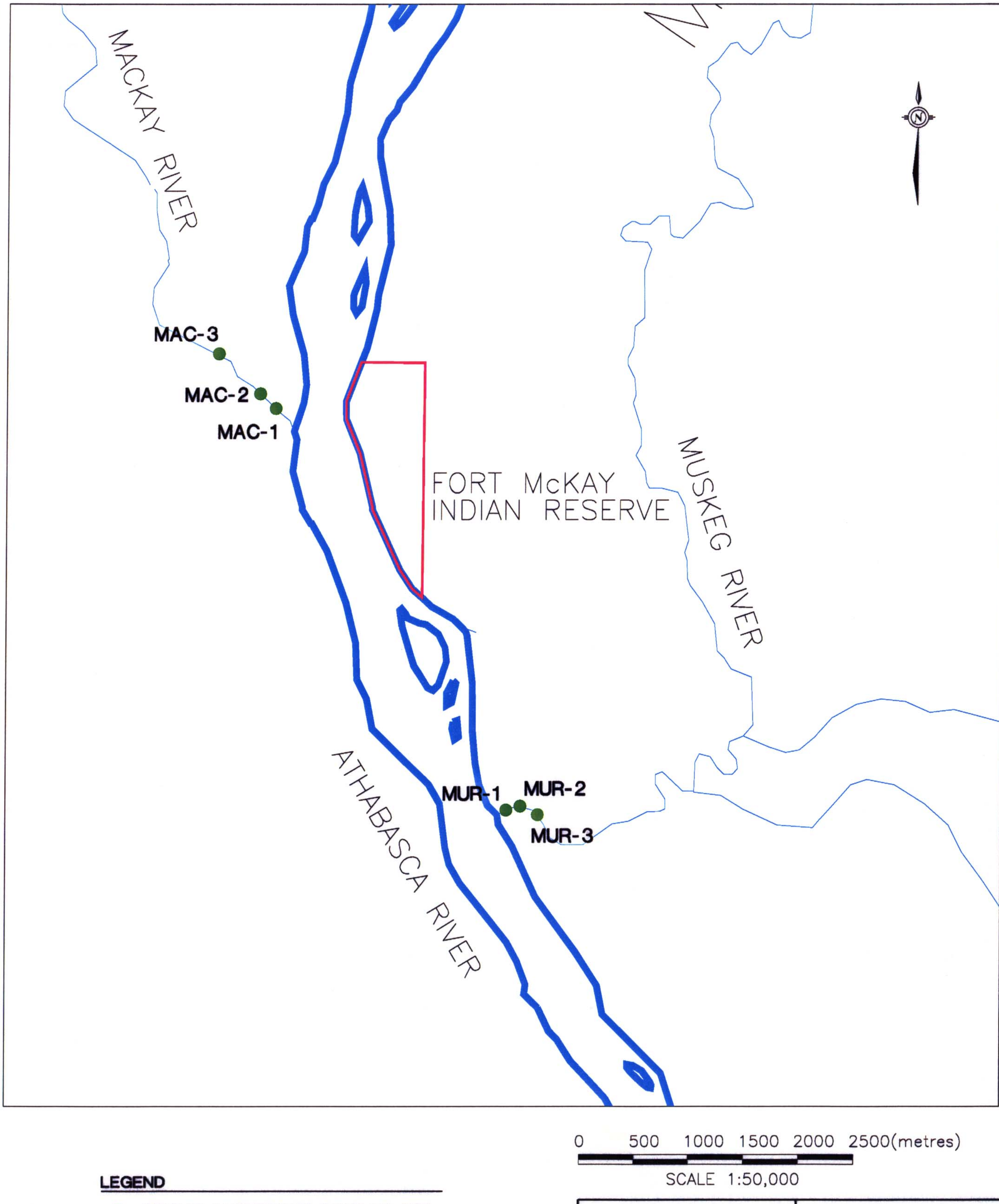
DIGITAL DATA SETS 74D, 74E, 74I 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

1998 RAMP
BENTHIC INVERTEBRATE SAMPLING SITES IN THE STEEPBANK RIVER

DRAWN: VS	APPROVED:	DATE: 22 JAN. 1999
PROJECT: 982-2309.6051		FIGURE: 3.4

J:\1998\982-2309\6051\detail.dwg



LEGEND

● BENTHIC INVERTEBRATE SAMPLING SITE

REFERENCE

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

Golder Associates

1998 RAMP
BENTHIC INVERTEBRATE SAMPLING SITES IN THE MACKAY AND MUSKEG RIVERS

DRAWN: VS	APPROVED: [signature]
DATE: 22 JAN. 1999	
PROJECT: 982-2309.6051	FIGURE: **3.5**

Table 3.9 Locations of Benthic Invertebrate Sampling Sites

River	Site	UTM East	UTM North
Steepbank River	STR-1	470879	6319616
	STR-2	471049	6319620
	STR-3	471144	6319845
Muskeg River	MUR-1	463520	6332173
	MUR-2	463687	6332237
	MUR-3	463791	6332317
MacKay River	MAC-1	461375	6335993
	MAC-2	461261	6336145
	MAC-3	460843	6336473

3.2.2.2 Field Methods

Benthic sampling was carried out from 18 to 23 September, 1998, according to Golder Technical Procedure 8.6-1 (Golder 1999b). A Neill cylinder of 0.093 m^2 bottom area was used to sample benthic invertebrates. All samples were collected from erosional (riffle) habitat. Samples were preserved in 70% ethanol.

Physical characteristics of the sampling sites were recorded to allow an analysis of the influence of such variation on the invertebrate community. Current velocity, water temperature, conductivity, dissolved oxygen, pH, and sample depth were measured at each sampling site using the following instruments:

- current velocity - Marsh-McBirney current velocity meter;
- dissolved oxygen - Yellow Springs Instruments (YSI) dissolved oxygen meter;
- pH - Horiba pH meter;
- conductivity - YSI conductivity meter; and
- temperature - hand-held thermometer or YSI conductivity meter.

In addition to these measurements, wetted width, substratum composition (as percentages of areal cover in standard particle size categories) and the abundance of benthic algae (visually estimated as low, moderate or high at each site) were recorded. Exact locations of all sampling sites were determined using a Trimble GeoExplorer Global Positioning System (GPS) unit.

3.2.2.3 Laboratory Methods

Benthic invertebrate samples were sorted and invertebrates were identified by J. Zloty, Ph.D., of Calgary, Alberta. First, samples were passed through a 250 µm mesh sieve to remove the preservative and fine sediments. The material retained by the sieve was elutriated to remove sand and gravel. The remaining organic material was separated into coarse and fine size fractions using a 1 mm sieve. The fine size fraction of large samples was subsampled using methods outlined by Wrona et al. (1982). Invertebrates were removed from the detritus under a dissecting microscope at a minimum of 12 X magnification. All sorted material was preserved for random checks of removal efficiency.

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

The initial study design included an analysis of chironomid mouth part deformities, if sufficient numbers of large specimens are collected during the fall survey. However, numbers of larger, late-instar animals required for this analysis were insufficient for analysis of mouth part deformities.

3.2.2.4 Data Analyses

Analysis and interpretation of the 1998 benthic survey results focused on describing community composition and natural variation in each river surveyed. Graphical methods and qualitative assessment were used to extract the maximum amount of information from the available data.

After deleting non-benthic and terrestrial taxa, invertebrate community variables such as total density, taxonomic richness (total taxa), and order-level community composition were examined as bar graphs of mean numbers per site, to provide an overview of the benthic fauna of the study area. Mean densities of common taxa defined as those constituting $\geq$1% of total density at a site, were tabulated for each site along with the standard error of the mean, to illustrate variability among replicate samples.

The benthic invertebrate abundance data were also examined qualitatively to identify potential habitat associations and relationships between key habitat variables and benthic community structure. In addition, Pearson correlation coefficients were calculated to assess relationships between current velocity and log-transformed densities of common invertebrates separately for each river (n=15 in each river). The variation in depth among samples and sites was insufficient to warrant an analysis. The amount of substratum data was insufficient for statistical analysis (n=3 in each river).

3.2.2.5 Quality Assurance and Quality Control

During the field survey, dissolved oxygen and pH meters were calibrated on each day before use. Accuracy of conductivity and temperature measurements was verified daily using a conductivity standard solution and a hand-held thermometer, respectively. Current velocity meters were maintained and calibrated at regular intervals to ensure accurate readings.

Laboratory analysis of benthic invertebrate samples incorporated a Quality Assurance program, consisting of an evaluation of invertebrate removal efficiency in 10% of the samples (five samples). Minimum removal efficiency of 95% was considered acceptable. Quality control results are presented in Appendix III and indicate that the data quality objective of minimum 95% removal of invertebrates from the sorted fractions of samples was achieved.

The benthic invertebrate abundance data were entered into the project database from the electronic files received from the taxonomist. During data manipulation, backup files were generated prior to each major operation, and appropriate logic checks were performed to ensure the accuracy of calculations. Benthic invertebrate data and results of analyses are stored in printed and electronic format with appropriate documentation and backups to ensure that analyses may be reproduced if necessary.

3.2.3 Fish Populations

3.2.3.1 The 1998 Study

Tributaries of the Athabasca River within the oil sands region have been included in the monitoring program because they provide important habitat for many fish species, and because some, such as the Muskeg River and Steepbank River, will be affected by oil sands development. Effects on tributaries have the potential to affect mainstem fish populations because of the importance of these areas 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 and white sucker (Bond and Machniak 1979; Machniak and Bond 1979). Fish communities within these rivers could be affected by potential changes in water quality and flow associated with mining activities. Based on habitat type and fish composition (Sekerak and Walder 1980), the Tar and Ells rivers may be suitable as reference tributaries for monitoring the integrity of the Muskeg and Steepbank rivers.

Previous studies on the Muskeg and Steepbank rivers have highlighted the need for a more reliable fish sampling method that provides uniform sampling efficiency. Fish fences were recommended as a reliable method to document fish population characteristics and numbers of fish using the tributaries. Ideally, fish fences could be deployed in both spring and fall to document fish movement in and out of the tributaries. Spring fences document numbers of spawning fish moving up into a tributary. Fall fences indicate whether a river is used for over-wintering. If large numbers of all species leave in the fall, it is unlikely that the tributary provides important overwintering habitat, at least for large fish species.

Two-way fish fences were designated for the Muskeg, Steepbank, Tar and Ells rivers. In the spring, fences were first installed on the Muskeg, Ells and Tar rivers (May 6-8, 1998) with the assistance of students from Keyano College, Fort McMurray. All field personnel were trained and coordinated by an experienced Golder field crew leader. Fences were placed as close to the mouth of each tributary as possible at a location where flow did not preclude sampling. Fish fences on the Tar and Ells rivers washed out shortly after installation. The lower portions of both rivers consist predominantly of soft substrates that were easily eroded/scoured. This quickly undermined the stability of the fences. Due to the problems with fences on the Tar and Ells rivers, no attempt was made to install a fence on the Steepbank River. No fences were installed during the fall sampling season.

3.2.3.2 Field Methods

The fish fence on the Muskeg River remained in place and was operated until May 14, 1998. Fish captured in the upstream and downstream portion of the fence were identified to species (see species codes, Table 3.2) and enumerated. Fork length and body weight of each fish was recorded. Non-lethal ageing structures were taken according to methods outlined in MacKay et al. (1990). 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 was determined by external examination. Forage fish were also surveyed in the vicinity of the fence by backpack electrofisher (Smith Root Model VII) and gee minnow traps. Fish were identified to species and the fork length and weight of each individual were recorded.

At each fish fence location, total stream discharge was measured according to Golder Technical Procedure 8.24-0 “Stream Discharge Measurement Methods” (Golder 1999b). Fish habitat maps were drawn at each fence location and included an area 500 m upstream and downstream of the fence. Mapping was done following procedures outlined in Golder Technical Procedure 8.5-1 using the “Stream Habitat Classification and Rating System” (Golder 1999b). This system is designed for small to mid-sized streams that exhibit greater heterogeneity in habitat type than large river systems. The approach is based on individual channel units (riffle/pool/run) in combination with depth, velocity and substrate characteristics.

3.3 WETLANDS

3.3.1 Water Quality

In the summer (August 12-15) of 1998, water samples were collected from four wetlands in the upper Athabasca River watershed. They included Shipyard Lake, Kearl Lake, Spruce Pond and Isadore's Lake. An additional water sample was collected from Kearl Lake in the fall (September 21) of 1998, and DO profiles for this lake were examined on December 9, 1998. The location of each wetlands is shown in Figure 3.1.

Water Sampling

Water samples were collected from three different locations in the open water areas present in each wetland. Sample bottles were placed approximately 30 cm below the water surface. The three samples were combined to form one composite sample, which was then split in half. One part of the composite sample was shipped to ETL and analyzed for conventional parameters, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids. The second grab sample was sent to HydroQual for chlorophyll *a* and Microtox® analysis. All sampling was done in accordance to Golder Associates Technical Procedure 8.3-1 (Golder 1999b). In addition to the QA/QC process outlined in Section 3.1.1.4, one field blank was prepared during the 1998 wetlands sampling program to examine potential sample contamination during sample collection, shipping and analysis. Wetlands water quality data were analyzed by the same methods as those described in Section 3.1.1.3.

Recording Winter DO Profiles

Upon arrival at Kearl Lake on December 9, 1998, two sample sites were selected based on safe access. Augers were used to drill through the overlying ice. DO measurements were taken at 25 cm intervals between the free water surface and the lake bottom using a YSI Model 57 DO meter. The DO meter was calibrated prior to use, and the DO probe was rinsed with distilled water between sample sites.

3.3.2 Aquatic Vegetation

3.3.2.1 The 1998 Study

The wetlands survey was conducted on Shipyard Lake, Isadore's Lake, Kearl Lake and Spruce Pond. These wetlands, except for Spruce Pond, were selected in the first year of the RAMP. The objective of this wetlands study is to provide a second year of inventory of vegetation species for RAMP. The data collected was used to further characterize natural variability in wetland types representative of the region, prior to the commencement of intensive oil sands development. The wetlands classification system used in this study is described in Appendix IX. The study design also provides the basis for subsequent applied studies in the future.

The initial design was modified slightly. Due to an access problem, Lease 25 wetland was replaced with Spruce Pond. In some wetlands, additional plots were added to augment the species composition data. Each wetland was classified and mapped according to the framework described by Halsey and Vitt (1996). Wetland types were mapped on aerial photographs prior to field investigations. Field investigations were conducted to document species composition and cover as well as plant health. Each lake was sampled along fixed transects and the data incorporated into the study area database. Further details on methodology are provided in the following sections.

3.3.2.2 Field Methods

Mapping Procedure

Wetland types, according to the Alberta Wetland Inventory (AWI) were prestratified (classified) on 1:10,000 and 1:20,000 black and white, aerial photographs prior to field investigations. Vegetation was examined in the field from August 12 to 17, 1998. Vegetation was documented by:

- mapping wetland classes on aerial photographs;
- photographing representative vegetation types from fixed points;
- conducting a vegetation survey along fixed transects by compiling a list of species present and relative percent cover within permanent sampling plots;
- recording vegetation vigour and health characteristics; and
- collecting water quality parameters, which are specified in the water quality section of this report.

Once the aerial photograph interpretation was complete, polygons were transferred to a 1:10,000 orthophotograph and areas estimated using Geographic Information System (GIS) software (ARCINFO). Associated attributes for each wetlands class were entered into a database and linked to the digitized map. No aerial photographs were available for the Spruce Pond wetland. In the absence of aerial photographs, a sketch of the spruce pond is provided.

Vegetation Survey Procedures

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

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

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

At each plot a 1 m by 1 m floating quadrat was used to obtain an estimate of cover for each plant species from the bottom of the lake to the surface. Plant covers were also estimated for species groups including emergent species (forbs, grasses, sedges and shrubs), submergent species, and algae species. The percent cover of open water was also estimated. When plants were too deep to see but still within the two metre depth range, plants were sampled with a rake and cover was estimated based on a minimum of three samples. Photographs were taken of community types at each transect. The bottom substrate was determined at each sample point where possible. It was classified as sand, rock, silt or clay; solid or muddy; and organic materials present or absent.

Species Determination

Species encountered during the sampling program were collected in plastic, zipper-close style bags and labelled according to location, date, and collector's name. For each species collected, an attempt was made to collect roots, stems, leaves and fruiting structure. Species were identified while still fresh using picture guides and botanical keys. Species that could not be identified in the field were pressed and dried for later comparisons with herbarium samples. Botanical keys and picture guides included: “An Identification Guide to Alberta Aquatic Plants” (Burland 1994), “Plants of the Western Boreal Forest and Aspen Parkland” (Johnson et al. 1995), the “Flora of Alberta” (Moss 1983) and “Carex of Saskatchewan” (Hudson 1977).

Plant Vigour

Plant vigour is a measure of the relative health of a plant (AEP 1994). Plant vigour was estimated using the guidelines detailed in the Ecological Land Survey Site Description Manual (AEP 1994). Vigour estimates were provided for each cover class.

3.3.2.3 Data Analyses

A database was developed to aid in all analyses. The database included tables on transects, plots, and species covers. It was linked to a table of plot photographs.

A set of plant community types were established for four wetlands by summarizing the species and covers at each sampling point and combining these into similar species groups. Then, data for each community were summarized to provide the mean and range of plant species and cover for each type, as well as the mean and range of the environmental features (depth, substrate, temperature, distance from shore, shelter). Differences in biological and environmental features between community types were investigated by non-parametric analysis of variance testing.

3.3.2.4 Quality Assurance and Quality Control

A quality assurance/quality control program for the study area included a minimum of a two person field crew, each recording and checking field data accuracy of pre-stratified map polygons by checking polygons in the field and comparing standard vegetation mapping evaluation criteria. Databases were checked by randomly selecting transects and plot data, and comparing these data to the original field data sheets. All quantitative analysis was checked through a similar random selection of analytical data and repetition of the analysis.

4 ATHABASCA RIVER RESULTS AND DISCUSSION

4.1 WATER AND SEDIMENT QUALITY

4.1.1 Water Quality

As shown in Table 4.1, water quality on the east and west sides of the Athabasca River was generally quite similar at each of the three main sampling locations (i.e., downstream of Donald Creek, upstream of the Muskeg River and upstream of Fort Creek). Major differences between east side and west side water quality are summarized in Table 4.2. In particular, naphthenic acid levels were below detection limits on the east side of the Athabasca River near Donald Creek, but they were around 20 mg/L in the composite sample from the west side of the river (Table 4.1).

Water quality did not vary substantially along the length of the Athabasca River. Aside from a few exceptions (e.g., high naphthenic acid concentration on the west side of the river near Donald Creek), parameter concentrations observed at one sample station were generally quite similar to those observed elsewhere in the river (Table 4.1). Water quality in the Athabasca River in 1998 was also generally consistent with patterns observed in 1997 and the available historical data.

Overall, Athabasca River waters were found to be non-toxic (as defined by Microtox® testing) and low in organics. Total suspended solids (TSS) levels were low to moderate (i.e., <25 mg/L) (Table 4.1).

It is important to note that Microtox® results presented in Table 4.1 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.

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 1998 at any of the Athabasca River sampling stations discussed herein (Table 4.3).

Table 4.1 Summary of Water Quality Results at Selected Points in the Athabasca River

Parameter	Units	Near Donald Creek				Upstream of Muskeg River			Downstream from Fort Creek			
		1998			Historical	1998		Historical	1998			Historical
		East Bank	West Bank	1997	Median	East Bank	West Bank	Median	East Bank	West Bank	1997	Median
Conventional Parameters and Major Ions												
conductance	µS/cm	308	310	236	187.5	303	299	268	328	290	227	265
dissolved organic carbon	mg/L	4	4	9	18	5	4	13.5	4	3	9	8.5
pH		8.1	8.1	8	7.55	8.2	8.2	7.755	8.1	8.2	7.9	8.3
total alkalinity	mg/L	107	106	92	80	104	106	98	90	107	89	106
total dissolved solids	mg/L	198	214	200	114	na[(a)]	164	150	184	162	140	160
total organic carbon	mg/L	5	4	14	24	5	4	10	6	5	13	-
total suspended solids	mg/L	22	20	57	50.2	13	15	15.6	17	14	47	36
Nutrients												
nitrogen – ammonia	mg/L	< 0.05	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05	-	0.34	0.17	< 0.05	-
nitrogen – kjeldahl	mg/L	0.3	0.5	< 0.2	0.88	< 0.2	< 0.2	0.68	0.4	< 0.2	0.5	-
phosphorus, total	mg/L	0.016	0.014	0.087	0.13	0.014	0.013	0.04	0.015	0.02	0.074	0.055
phosphorus, total dissolved	mg/L	0.007	0.007	0.022	0.013	0.009	0.007	< 0.01	0.009	0.014	0.019	0.0105
General Organics and Toxicity												
Microtox IC50 @ 15 min	%	> 91	> 91	-	> 91	> 91	> 91	-	> 91	> 91	-	-
Microtox IC25 @ 15 min	%	> 91	> 91	-	> 91	> 91	> 91	-	> 91	> 91	-	-
naphthenic acids	mg/L	< 1	20	< 1	< 1	3	5	< 1	< 1	< 1	< 1	-
total phenolics	mg/L	< 0.001	0.002	0.001	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.006
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	0.6	< 1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6	-
Metals (total)												
aluminum (Al)	mg/L	0.19	0.22	2.23	0.76	0.31	0.41	0.28	0.54	0.05	2.38	-
antimony (Sb)	mg/L	< 0.0008	< 0.0008	0.0012	< 0.0002	< 0.0008	< 0.0008	0.0005	< 0.0008	0.0009	0.0010	-
arsenic (As)	mg/L	< 0.001	< 0.001	0.0013	0.0008	< 0.001	< 0.001	-	< 0.001	< 0.001	0.0013	0.0008
barium (Ba)	mg/L	0.0529	0.0537	0.067	0.04	0.0519	0.0552	0.0758	0.0557	0.0524	0.0618	0.055
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	-
boron (B)	mg/L	0.045	0.041	0.025	0.09	0.025	0.022	0.033	0.035	0.019	0.024	-
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.001	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.001
chromium (Cr)	mg/L	< 0.0008	< 0.0008	0.0026	0.002	< 0.0008	< 0.0008	0.0043	< 0.0008	0.0012	0.0019	0.004
copper (Cu)	mg/L	0.002	0.002	0.0049	0.0025	0.005	0.005	0.0041	0.007	0.006	0.0023	0.002
iron (Fe)	mg/L	0.5	0.4	2.19	0.91	0.42	0.42	2.98	0.71	0.17	2.41	-
lead (Pb)	mg/L	0.0005	0.0006	0.0013	< 0.02	0.0003	0.0003	0.0016	0.001	0.0002	0.0013	-
manganese (Mn)	mg/L	0.0301	0.0233	0.0709	0.033	0.0219	0.0207	0.0739	0.0361	0.0045	0.0752	-

Table 4.1 Summary of Water Quality Results at Selected Points in the Athabasca River (continued)

		Near Donald Creek				Upstream of Muskeg River			Downstream from Fort Creek			
		1998			Historical	1998		Historical	1998			Historical
Parameter	Units	East Bank	West Bank	1997	Median	East Bank	West Bank	Median	East Bank	West Bank	1997	Median
mercury (Hg)	mg/L	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0002	< 0.0001	< 0.0002	< 0.0002	< 0.0001	< 0.0001
molybdenum (Mo)	mg/L	0.0011	0.001	0.0008	< 0.003	0.0009	0.0012	0.0009	0.0006	0.0008	0.0007	-
nickel (Ni)	mg/L	0.0051	0.0098	0.003	< 0.005	0.0154	0.0155	0.0071	0.0164	0.0154	0.0030	-
selenium (Se)	mg/L	< 0.0008	< 0.0008	0.0007	< 0.0002	< 0.0008	< 0.0008	< 0.0004	< 0.0008	< 0.0008	0.0007	< 0.0002
silver (Ag)	mg/L	< 0.0004	< 0.0004	< 0.0001	< 0.002	< 0.0004	< 0.0004	< 0.0001	< 0.0004	< 0.0004	< 0.0001	-
vanadium (V)	mg/L	0.0007	0.0007	0.0059	0.003	0.0009	0.0015	0.0097	0.0012	0.0002	0.0061	-
zinc (Zn)	mg/L	0.017	0.028	0.013	0.017	0.012	0.011	0.034	0.026	0.008	0.017	0.005
Metals (Dissolved)												
aluminum (Al)	mg/L	0.04	0.12	0.0443	-	0.06	0.03	0.0729	0.09	0.03	0.0363	-
antimony (Sb)	mg/L	< 0.0008	< 0.0008	0.0006	-	< 0.0008	< 0.0008	0.0006	< 0.0008	< 0.0008	0.0012	-
arsenic (As)	mg/L	< 0.0004	< 0.0004	0.0005	< 0.003	< 0.0004	< 0.0004	0.0006	< 0.0004	< 0.0004	0.0005	-
barium (Ba)	mg/L	0.0505	0.0496	0.0418	-	0.0502	0.0521	0.0396	0.0415	0.0367	0.0365	-
beryllium (Be)	mg/L	< 0.0005	< 0.0005	< 0.0005	-	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.001
boron (B)	mg/L	0.024	0.024	0.022	0.1	0.024	0.02	0.09	0.019	0.012	0.025	-
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	0.0001	-	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	0.0001	-
chromium (Cr)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.003	< 0.0004	< 0.0004	< 0.003	< 0.0004	< 0.0004	< 0.0004	-
cobalt (Co)	mg/L	0.0001	0.0008	0.0003	-	0.0012	0.0004	0.0003	0.0002	0.0006	0.0003	-
copper (Cu)	mg/L	0.0013	0.0015	0.0022	< 0.003	0.0014	0.0014	0.0042	0.0016	0.0011	0.0020	-
iron (Fe)	mg/L	0.1	0.1	0.14	-	0.15	0.1	< 0.01	0.25	0.1	0.14	-
lead (Pb)	mg/L	0.0002	0.0001	0.00052	-	0.0002	0.0002	0.00147	0.0003	0.0002	0.00067	-
manganese (Mn)	mg/L	0.0045	0.0047	0.0114	-	0.0101	0.0031	0.0102	0.0181	0.0048	0.0132	-
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.0002	-	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	-
molybdenum (Mo)	mg/L	0.001	0.001	0.00064	-	0.0009	0.0013	0.00075	0.0007	0.0005	0.00061	-
nickel (Ni)	mg/L	0.0027	0.0026	0.0016	-	0.0028	0.0028	0.0023	0.0028	0.0023	0.0016	-
selenium (Se)	mg/L	< 0.0004	< 0.0004	< 0.0004	0.00065	< 0.0004	< 0.0004	< 0.0002	< 0.0004	< 0.0004	< 0.0004	-
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	-	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-
vanadium (V)	mg/L	< 0.0001	< 0.0001	< 0.0001	-	< 0.0001	0.0001	0.0002	< 0.0001	< 0.0001	< 0.0001	-
zinc (Zn)	mg/L	0.004	0.005	0.014	-	0.005	0.005	0.023	0.009	0.005	0.019	-

[a] Total dissolved solids was reported as 958 mg/L; however, calcium, magnesium, chloride and sulphate concentrations do not support this result (Appendix Table II-1).

Table 4.2 Summary of the Major Differences Observed Between Water Quality Samples Collected from the Athabasca River in 1998 and Previously Collected Information

Sample Location	East vs. West[a,b]	1998 vs. 1997[(a,b)]	1998 vs. Historical Median[(a,b)]
near Donald Creek	naphthenic acids (w)	TSS (97) organic carbon (97) phosphorus (97) total metals (97) conductance (98) total alkalinity (98) TKN (98)	TSS (h) organic carbon (h) total metals (h) TKN (h) conductance (98) total alkalinity (98)
near the Muskeg River	TDS (e)	Not sampled in 1997	DOC (h) TKN (h) total iron (h) total zinc (h) dissolved lead (h) naphthenic acids (98) dissolved iron (98)
near Fort Creek	chloride (e) sodium (e) T & D aluminum (e) T & D iron (e) T & D manganese (e) T & D zinc (e)	TSS (97) total aluminum (97) total iron (97) conductance (98) TDS (98) ammonia (98) total nickel (98)	TSS (h) total phenolics (h)

(a) Location where, or year in which, higher value was found is indicated in brackets: e = east side of the Athabasca River, w = west side of the river, 98 = 1998, 97 = 1997 and h = historical.

(b) TSS = total suspended solids, TDS = total dissolved solids, T & D = total and dissolved, TKN = total kjeldahl nitrogen and DOC = dissolved organic carbon.

Table 4.3 Water Quality Results for the Athabasca River that Exceed Regulatory Guidelines

Parameter	Units	Guidelines[a] for the Protection of:				Near Donald Creek				Upstream of Muskeg River			Downstream from Fort Creek			
		Aquatic Life		Human Health		1998			Historical	1998		Historical	1998			Historical
		Acute	Chronic	Carcinogen	Non-carcinogen	East Bank	West Bank	1997	Median	East Bank	West Bank	Median	East Bank	West Bank	1997	Median
Nutrients																
phosphorus, total	mg/L		0.05					C	C						C	C
General Organics and Toxicity																
total phenolics	mg/L		0.005													C
Metals (Total)																
aluminum (Al)	mg/L		0.1			C	C	C	C	C	C	C	C		C	
arsenic (As)	mg/L	0.36	0.01	0.000018		HC *	HC *	HC	HC	HC *	HC *		HC *	HC *	HC	HC
barium (Ba)	mg/L		1		1											
iron (Fe)	mg/L		1		0.3	HNC	HNC	C HNC	HNC	HNC	HNC	C HNC	HNC		C HNC	
lead (Pb)	mg/L	0.17	0.007						C *							
manganese (Mn)	mg/L				0.05			HNC				HNC			HNC	
mercury (Hg)	mg/L	0.002	1E-05		0.00014	C HNC*	C HNC*	C *	C HNC*	C HNC*	C HNC*	C *	C HNC*	C HNC*	C *	C *

[a] Derivation of guidelines shown in Appendix Table II-8.

*Although lab reported non-detectable levels of the substance, the method detection limit exceeds the guideline limit.

C = chronic guideline exceeded; HNC = human health non-carcinogen guidelines exceeded; HC = human health carcinogen guideline exceeded. Refer to Appendix Table II-8 for more information on guidelines.

4.1.2 Sediment Quality

All sediment samples collected in the fall of 1998 were non-toxic to several species of invertebrates. Athabasca River sediments tended to be aluminum and iron rich, with non-detectable levels of antimony, beryllium, cadmium, molybdenum and silver (Table 4.4). Generally, they did not contain metals or PAHs at levels that exceed regulatory guidelines. The exceptions are arsenic and benzo(a)anthracene or chrysene (Table 4.6).

Sediments taken from the east side of the Athabasca River near Donald Creek and upstream of the Muskeg River contained more silt, clay and organic matter than sediments collected from the west side of the river (Tables 4.4 and 4.5). PAH concentrations were also higher on the east side of the river at these two sampling locations. The reverse was observed near Fort Creek. At this sampling site, sediments taken from the west side of the Athabasca River contained more silt, clay and organic matter, and generally had higher PAH levels, than those collected from the east side of the river (Tables 4.4 and 4.5).

Sediment chemistry data from 1997 generally fell within the range established by the two sediment samples collected from each sampling location in 1998 (Tables 4.4 and Appendix III, Table III-1). When all of the sediment samples collected from the Athabasca River in 1997 and 1998 are considered together, organic and metal concentrations appear to have been directly related to the silt and clay content of the river sediments. Areas where the river sediments contained a greater proportion of silt and clay were generally the same areas that contained the higher metal, PAH and recoverable hydrocarbon concentrations (Table 4.4).

It is important to note that the total PAH concentrations presented in Table 4.4 for the 1997 sediment samples may not be as accurate as those reported in 1998. Detection limits were much higher in 1997 than in 1998 (see Table 4.4). As a result, the 1998 data set contains a larger number of detectable PAHs than observed in 1997. Total PAH levels were calculated by adding together the concentrations of individual PAHs. Non-detectable results were assigned a value of zero in this calculation. Since the 1997 data set contains a large number of non-detectable results, a large number of individual PAHs were eliminated from the total PAH calculation. Therefore, the total PAH concentrations reported in Table 4.4 for sediment collected in 1997 likely underestimate true total PAH concentrations.

Table 4.4 Summary of Sediment Quality Results for the Athabasca River

Parameter	Units	Near Donald Creek			Near the MacKay River		Downstream from Fort Creek		
		1998					1998		
		East	West	1997	East	West	East	West	1997
Conventional Parameters									
particle size - % sand	%	70	83	56	60	71	74	43	65
particle size - % silt	%	20	10	24	22	17	15	36	16
particle size - % clay	%	10	7	22	18	12	11	21	19
total inorganic carbon	% by wt	0.62	0.63	-	0.65	0.95	0.77	1	-
total organic carbon	% by wt	0.92	0.43	0.81	1.57	0.67	0.65	2.02	1.72
General Organics and Toxicity[a]									
Chironomus tentans - 10d mortality		NT	NT	NT	NT	NT	NT	NT	NT
Chironomus tentans - 10d growth		NT	NT	NT	NT	NT	NT	NT	NT
Hyalella azteca - 10d mortality		NT	NT	NT	NT	NT	NT	NT	NT
Hyalella azteca - 10d growth		NT	NT	NT	NT	NT	NT	NT	NT
Lumbriculus variegatus - 10d mortality		NT	NT	NT	NT	NT	NT	NT	NT
Lumbriculus variegatus - 10d growth		NT	NT	NT	NT	NT	NT	NT	NT
total recoverable hydrocarbons	µg/g	653	214	423	555	406	581	900	1190
Metals (Total)									
aluminum (Al)	µg/g	8080	5990	10700	10900	9560	7630	9440	7790
antimony (Sb)	µg/g	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
arsenic (As)	µg/g	4.2	7.7	5.6	5.5	4.8	4.1	5.6	5.1
barium (Ba)	µg/g	106	132	168	188	172	138	178	144.5
beryllium (Be)	µg/g	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
cadmium (Cd)	µg/g	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
chromium (Cr)	µg/g	16.2	13.6	19	21.2	18.1	15.7	17.2	20.15
copper (Cu)	µg/g	10	9	15	15	12	10	16	15
iron (Fe)	µg/g	12500	11400	15000	16200	14500	12800	16100	15500
lead (Pb)	µg/g	8	8	9	10	9	8	9	8
manganese (Mn)	µg/g	283	251	381	386	329	293	419	382
mercury (Hg)	µg/g	0.04	0.03	0.05	0.04	0.04	0.03	0.06	0.055
molybdenum (Mo)	µg/g	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
nickel (Ni)	µg/g	13	14	16	19	17	14	20	19
selenium (Se)	µg/g	0.3	< 0.1	0.8	< 0.1	0.4	0.3	0.6	0.5
silver (Ag)	µg/g	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
strontium (Sr)	µg/g	40	44	52	57	65	52	73	53
vanadium (V)	µg/g	22	18	28	28	24	20	22	18.5
zinc (Zn)	µg/g	46.2	48	53	70.5	59.6	52.7	71.1	57.4
Target PAHs and Alkylated PAHs[b]									
naphthalene	µg/g	0.012	0.025	< 0.01	0.034	0.017	0.023	0.028	0.0055
acenaphthene	µg/g	< 0.0027	< 0.0021	< 0.01	0.004	< 0.002	*0.0035*	0.0035	< 0.003
acenaphthylene	µg/g	< 0.00064	< 0.00054	< 0.01	< 0.0013	< 0.00054	< 0.0012	< 0.0013	< 0.003
anthracene	µg/g	< 0.0039	< 0.002	< 0.01	< 0.0041	< 0.0012	< 0.0028	< 0.0024	< 0.003
dibenzo(a,h)anthracene	µg/g	< 0.0063	< 0.004	< 0.01	< 0.0053	< 0.0022	< 0.0043	< 0.006	< 0.003
benzo(a)Anthracene/Chrysene	µg/g	0.021	0.0081	0.02	0.0227	0.0133	0.0269	0.0462	0.025
benzo(a)pyrene	µg/g	*0.011*	< 0.0056	< 0.01	*0.01*	0.0051	< 0.01	*0.016*	0.006
fluoranthene	µg/g	0.0069	0.0031	< 0.01	*0.0062*	0.0036	0.0052	0.011	0.0055
fluorene	µg/g	0.0038	< 0.002	< 0.01	*0.0024*	0.0026	< 0.003	*0.0071*	0.0005
phenanthrene	µg/g	0.017	0.007	0.01	0.014	0.012	0.021	0.032	0.012
pyrene	µg/g	0.016	0.0059	< 0.01	0.013	0.0068	0.012	0.022	0.0095
total PAHs	µg/g	1.45	0.21	0.43	0.58	0.32	1.15	1.97	1.30

[a] PAH concentrations in italics are reported with the limitation that the GCMS spectra used to develop these values were ill-defined.

[b] NT = non-toxic.

PAH = polycyclic aromatic hydrocarbons.

Table 4.5 Summary List of the Major Differences Observed between Sediment Samples Collected from the Athabasca River in 1998 and Available Historical Information

Sample Location	East vs. West[(a,b)]	1998 vs. 1997[(a,b)]
near Donald Creek	silt (e) clay (e) organic matter (e) PAHs (e) TRH (e)	sand (98) metals (97)
near the Muskeg River	silt (e) clay (e) organic matter (e) PAHs (e) TRH (e) metals (e)	not sampled in 1997
near Fort Creek	silt (w) clay (w) organic matter (w) metals (w) PAHs (w) TRH (w)	TRH (97)

(a) Location where, or year in which, higher value was found is indicated in brackets: e = east side of the Athabasca River, w = west side of the river, 98 = 1998 and 97 = 1997.

(b) PAHs = polycyclic aromatic hydrocarbons and TRH = total recoverable hydrocarbons.

Table 4.6 Sediment Quality Results for the Athabasca River that Exceed Regulatory Guidelines

Parameter	Units	Sediment Guidelines[a]		Near Donald Creek			Near the MacKay River		Downstream from Fort Creek		
				1998					1998		
		ISQG[b]	PEL[c]	East	West	1997	East	West	East	West	1997
Metals (Total)											
arsenic (As)	µg/g	5.9	17		ISQG						
cadmium (Cd)	µg/g	0.6	3.5								
chromium (Cr)	µg/g	37.3	90								
copper (Cu)	µg/g	35.7	197								
lead (Pb)	µg/g	35	91.3								
mercury (Hg)	µg/g	0.17	0.486								
zinc (Zn)	µg/g	123	315								
Target PAHs and Alkylated PAHs											
naphthalene	µg/g	0.035	0.391								
acenaphthene	µg/g	0.007	0.089			ISQG[d]					
Acenaphthylene	µg/g	0.006	0.128			ISQG[d]					
anthracene	µg/g	0.047	0.245								
dibenzo(a,h)anthracene	µg/g	0.006	0.135	ISQG[d]		ISQG[d]					
benzo(a)Anthracene/Chrysene	µg/g	0.032	0.385							ISQG	
benzo(a)pyrene	µg/g	0.032	0.782								
fluoranthene	µg/g	0.111	2.355								
fluorene	µg/g	0.021	0.144								
phenanthrene	µg/g	0.042	0.515								
pyrene	µg/g	0.053	0.875								

(a) Sediment guideline values taken from CCME (1998).

(b) ISQG = interim freshwater sediment quality guidelines.

(c) PEL = probable effect levels.

(d) Although lab reported non-detectable levels of substance, the method detection limit exceeds the guideline limit.

4.2 FISH POPULATIONS

4.2.1 Fish Inventory

A total number of fish species captured during the spring, summer and fall fish inventories of the oil sands region was 16 (Table 4.7). The 1998 species list was almost identical to the species documented in 1997 (Golder 1998), with minor differences including the absence of spottail shiner and the addition of spoonhead sculpin. Combining catch data over all seasons, walleye was the most abundant species, followed, in decreasing order of abundance, by lake whitefish, goldeye, longnose sucker, white sucker and flathead chub. The order of dominance is similar to what was observed by Bond (1980), except he found walleye to be less abundant than longnose sucker. Bond (1980) did not collect fish in the summer, which may explain the difference. During the 1998 RAMP survey, walleye were the most abundant during the summer (see Figure 4.1).

Because walleye, lake whitefish, goldeye and longnose sucker have been identified as KIRs for the Athabasca River, the following paragraphs provide greater detail regarding the status of these species within the oil sands region. When possible, the 1998 data were compared to data collected during 1995 (Golder 1996a), 1996 (Golder 1996b) and 1997 (Golder 1998a). Direct comparisons with these studies were possible because of the consistency in sampling gear, sampling methodology and timing.

Table 4.7 Total Number of Each Fish Species Captured in the Oil Sands Region, Athabasca River, 1998

Fish Species	Season			Total	Percent
	Spring	Summer	Fall		
Arctic Grayling	1	0	12	13	0.93
burbot	0	3	0	3	0.21
emerald shiner	4	48	17	69	4.91
flathead chub	48	59	8	115	8.19
goldeye	76	57	62	195	13.88
lake chub	2	4	0	6	0.43
lake whitefish	5	6	196	207	14.73
longnose sucker	45	7	132	184	13.10
mountain whitefish	0	2	3	5	0.36
northern pike	20	13	17	50	3.56
river shiner	1	16	0	17	1.21
spoonhead sculpin	1	28	1	30	2.14
trout-perch	12	94	4	110	7.83
walleye	135	90	58	283	20.14
white sucker	54	6	55	115	8.19
yellow perch	2	1	0	3	0.21
Total	**406**	**434**	**565**	**1405**	**100**

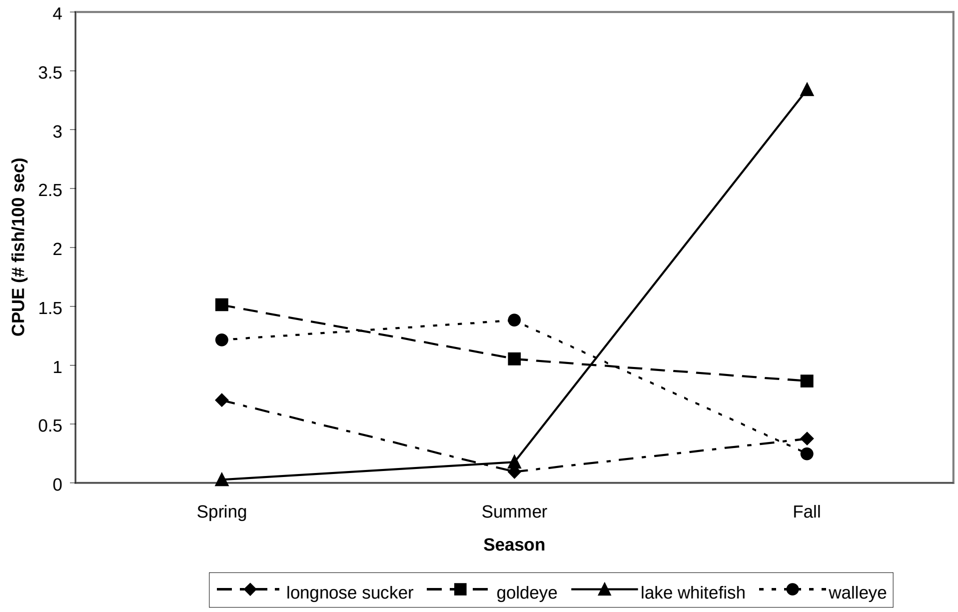
Walleye

Walleye were found within the oil sands region during the spring, summer and fall (Figure 4.1). Consistent with the spring spawning period, a majority of walleye captured in the spring were adults (77%). Conversely, approximately 80% of walleye found in the summer were juveniles that were likely utilizing the oil sands region as feeding and rearing grounds. Walleye were evenly distributed among the sampling reaches within the oil sands region (Figure 4.2). Catch-per-unit-effort among years indicated that the relative abundance of walleye in 1998 was moderately lower than in 1995 or 1997 (Figure 4.3). Although the reduction was not substantial, it was consistent with the trend also observed in goldeye and lake whitefish.

Size distributions of walleye from 1995 to 1998 are presented in Figure 4.4. In general, the distributions among years are very similar, consisting of two dominant modes centred about the 100-200 mm and 400-500 mm length classes. Based on the age distribution for 1998, these modes correspond approximately to age classes 0-3 y and 5-9 y, respectively (Figure 4.5). It was not possible to compare age distributions among all years due to limited sample sizes; however, a comparison between 1997 and 1998 indicated there was little change in the range of age classes represented in each year.

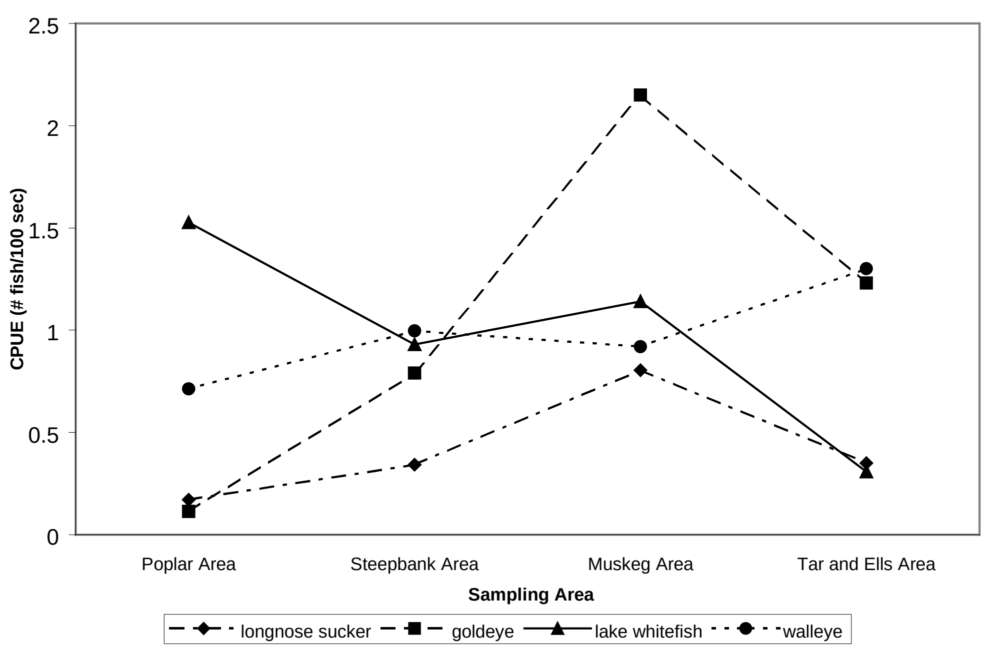
Size-at-age, as an estimate of growth, was calculated for 1998 (Table 4.8). When compared to 1997, the slope (i.e., rate of growth) of the regression line for each year was similar ($p=0.59$), but the intercept was significantly smaller in 1998 ($p<0.00001$). This indicates that at any given age, walleye collected in 1998 were shorter than fish in 1997. The reason for decreased size-at-age in walleye collected in 1998 is uncertain, but suggests a possible decrease in habitat availability or food resources (Gibbons and Munkittrick 1994). However, there was no significant change in condition factor from 1995 to 1998 (Table 4.9), which often covaries with size-at-age in response to altered food supply.

Figure 4.1 Seasonal Catch-per-unit-effort (Captured and Observed) of KIR Species within the Oil Sands Region, Athabasca River, 1998[(a)]



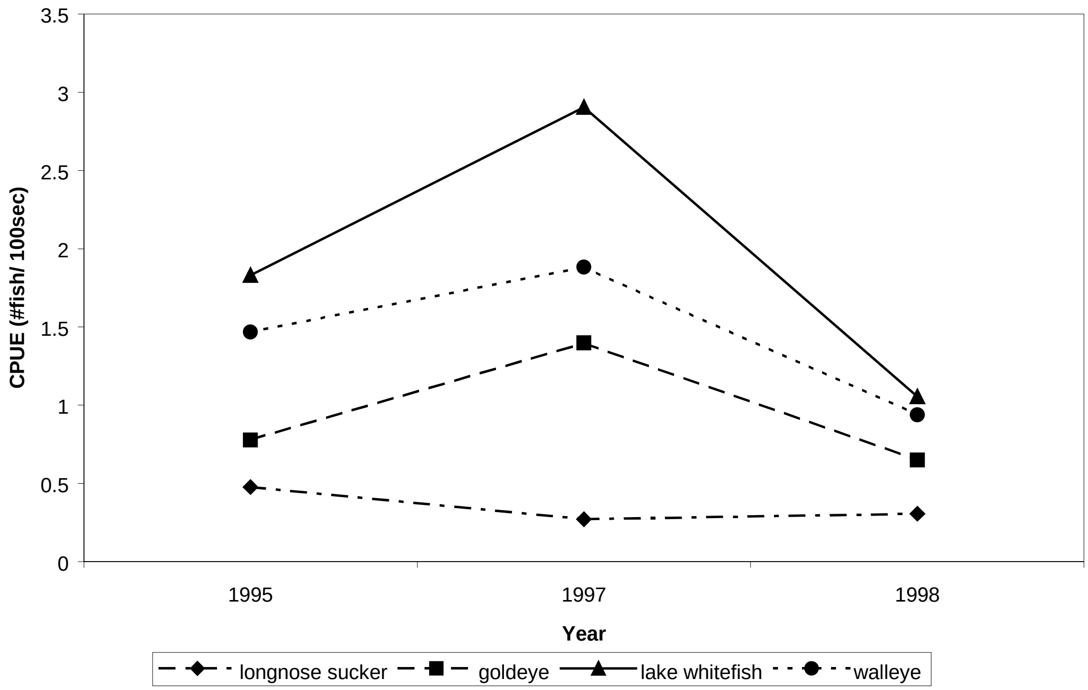
(a) Catch data from individual sampling areas are combined.

Figure 4.2 Catch-per-unit-effort (Captured and Observed) of KIR Species at each Sampling Area within the Oil Sands Region, Athabasca River, 1998[(a)]



(a) Catch data from the spring, summer and fall sampling seasons are combined.

Figure 4.3 Annual Catch-per-unit-effort (Captured and Observed) of KIR Species within the Oil Sands Region, Athabasca River[a]



[a] Catch data from the Poplar and Steepbank sampling areas are combined. In 1995, the Poplar sampling area extended 4 km upstream to Willow Island, and the Steepbank sampling area extended 3 km downstream to Saline Lake

Figure 4.4 Length-Frequency Distributions for Walleye in the Oil Sands Region, Athabasca River

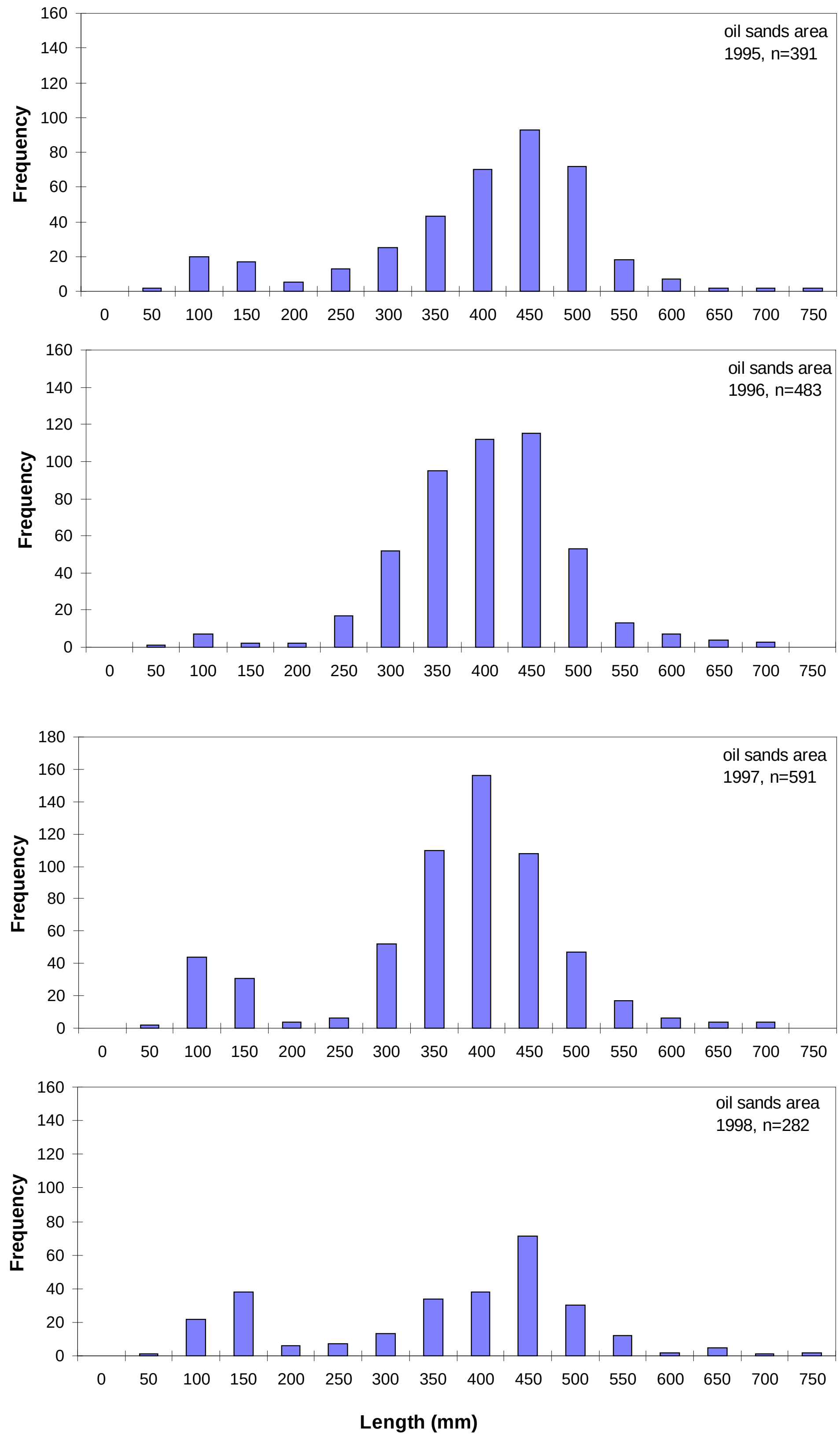


Figure 4.5 Age-Frequency Distributions for Walleye in the Oil Sands Region, Athabasca River

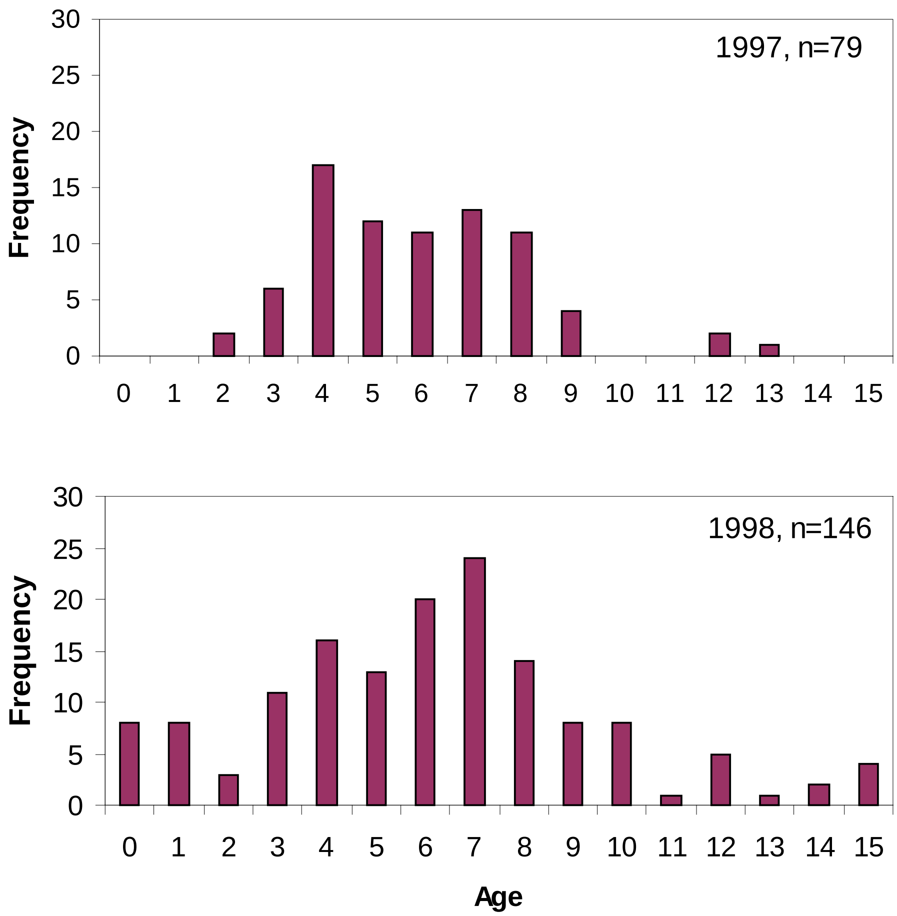


Table 4.8 Regression Estimates for Size-at-age Relationships ($\log_{10}$ fork length vs. $\log_{10}$ age) for KIR Species from the Oil Sands Region, Athabasca River, 1998

Species	Slope	Intercept	*n*[(a)]	p-value[(a)]	r[(a)]
walleye	0.46	2.21	137	p<0.00001	0.80
lake whitefish	0.27	2.41	116	p<0.00001	0.69
goldeye	0.47	2.14	96	p<0.00001	0.66
longnose sucker	0.56	2.08	79	p<0.00001	0.90

(a) n, sample size; p-value, probability level; r^2, coefficient of determination.

Table 4.9 Mean Condition Factor ± SE (*n*) of KIR Species Collected during Summer Inventories from the Oil Sands Region, Athabasca River, 1995-1998

Species	1995	1996	1997	1998
walleye	1.09 ± 0.08 (113) A	1.03 ± 0.01 (197) A	1.05 ± 0.02 (95) A	1.23 ± 0.11 (55) A
lake whitefish	1.58 ± 0.04 (17) A	1.54 ± 0.04 (11) A	1.42 ± 0.07 (14) B	1.56 ± 0.06 (6)
goldeye	1.14 ± 0.01 (161) A	1.09 ± 0.02 (107) A	1.11 ± 0.02 (44) A	0.98 ± 0.04 (56) B
longnose sucker	1.29 ± 0.04 (37) A	1.32 ± 0.06 (15) A	1.16 ± 0.05 (16) A	1.02 ± 0.06 (6)

Annual differences in condition factor were tested using analysis of covariance. Within a row, differences (p<0.05) in condition among years are denoted by different uppercase letters.

With the exception of decreased size-at-age in 1998, the walleye population does not appear to have changed significantly over time, nor is there substantial evidence suggesting stress at the population level. The age and size distributions provide valuable information regarding successful recruitment and sustainability of the population from one year to the next. Based on this information, walleye utilizing the oil sands region do not exhibit substantial changes from 1995-1998.

Lake Whitefish

The highest numbers of lake whitefish were found in the oil sands region in the fall (Figure 4.1) during their migration from Lake Athabasca to spawning grounds upstream of Fort McMurray (Jones et al. 1978). Based on CPUE estimates for the spring and summer, very few whitefish utilize the oil sands region of the Athabasca River prior to the spawning run. Small numbers have been found in the lower reaches of the Muskeg River (Bond and Machniak 1979) and Steepbank River (Machniak and Bond 1979) during spring migrations of other species such as Arctic grayling, longnose sucker and white sucker. Lake whitefish were found throughout the oil sands region, although the greatest abundance was found in the Poplar Area (Figure 4.2). It is suspected that the time of sampling and the upstream progression of migrating whitefish in part, dictate where the greatest numbers of whitefish will be found within the oil sands area. The relative abundance of whitefish was substantially lower in 1998 relative to 1997 or 1995 (Figure 4.3). Jones et al. (1978) found that the largest number of whitefish arrived in the oil sands region during the first two weeks of October. Fish inventories conducted in 1995 and 1997 commenced in late September and continued until mid-October, whereas the 1998 survey was completed October 4, 1998. As such, it is possible the greatest part of the spawning run had not yet passed through the oil sands region during the time of the 1998 survey.

Not surprisingly, the size and age distributions for lake whitefish were dominated by larger and older individuals (Figures 4.6, 4.7). There was little variability in size distributions among years. The spawning population of whitefish appeared to range from 350-550 mm in length and > 4 y in age. This corresponds closely with what was documented by Jones et al. (1978) during a study of spawning whitefish upstream of Fort McMurray. The size-at-age relationship for lake whitefish is provided in Table 4.8; however, no comparisons with previous years were possible due to limited sample sizes. Summer condition of lake whitefish was significantly lower in fish collected during 1997 (Table 4.9). The reason for this is unknown; however, lake whitefish are not abundant in the oil sands region at this time, and the comparisons were limited by low sample sizes.

More age data collected over time are necessary to provide valuable information regarding time trends in size-at-age and age distribution. Because a majority of whitefish collected within the oil sands region are adults migrating to spawning grounds, complete size/age distributions (i.e., distributions that include smaller and younger individuals) could not be generated. However, using the available information, the status of the prespawning population can be monitored over time.

Goldeye

The relative abundance of goldeye exhibited a modest decline from spring to fall, 1998 (Figure 4.1). This trend in abundance has also been reported in other studies conducted within the oil sands region of the Athabasca River (Trip and McCart 1979; Jones et al. 1980; Golder 1996b). It has been suggested that goldeye begin to leave the region in early fall to overwinter in Lake Athabasca (Trip and Tsui 1980). Goldeye found in the oil sands region were mostly juvenile or of unknown maturity (68%). Previous AOSERP studies have also

Figure 4.6 Length-Frequency Distributions for Lake Whitefish in the Oil Sands Region, Athabasca River, 1998

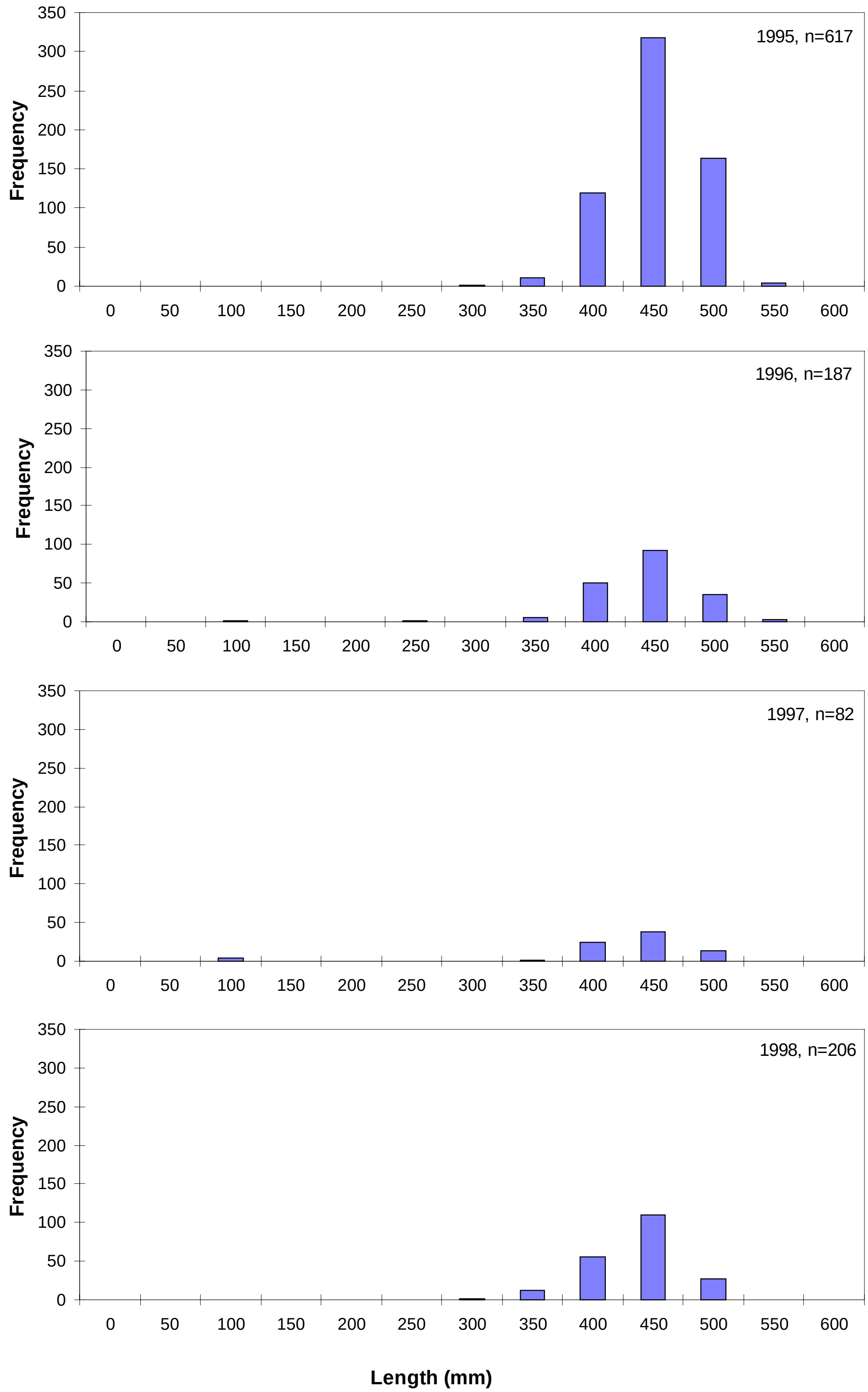
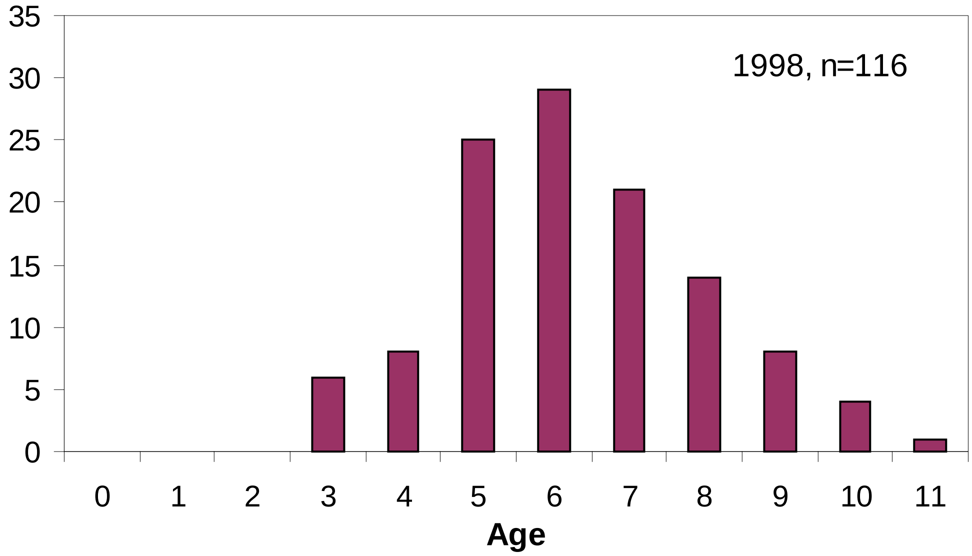


Figure 4.7 Age-Frequency Distributions for Lake Whitefish in the Oil Sands



Region, Athabasca River, 1998

shown that goldeye utilizing the Athabasca River are large juveniles that migrate from the Peace-Athabasca Delta to summer feeding grounds (Jones et al. 1978; Tripp and McCart 1979). Within the oil sands region, goldeye were most abundant in the Muskeg Area and Tar-Ells Area (Figure 4.2). Data collected during 1997 (Golder 1998a) indicated that goldeye were fairly ubiquitous with respect to habitat selection and used habitat according to availability. During the 1998 habitat survey (see Section 4.2.2.1), habitat types A1 (cobble/boulder banks), A2 (cobble/boulder, backwater areas), E2 (steep eroded bank) and a combination of D1-E5 (gentle slope, fines/low steep bank) were more abundant in the Muskeg Area relative to other areas. In addition, water levels in late summer/early fall of 1998 were substantially lower than usual (e.g., September 1997, 1050 m^3/s; September 1998, 381m^3/s - as measured at Water Survey of Canada gauging station downstream of Fort McMurray) and may have influenced the distribution of goldeye within the oil sands region (e.g., fish were concentrated in larger, deeper pools). The relative abundance of goldeye in 1998 was similar to what was documented in 1995 (Figure 4.3). Abundance was higher in 1997, largely due to high capture success in the spring and fall.

Size distributions of goldeye from 1995 to 1997 were consistent (Figure 4.8). In general, the distributions consisted of two dominant modes centred about the 200-250 mm and 325-350 mm length classes. The 1998 distribution suggests a similar modal pattern, although the larger mode is not as dominant as in previous years. The reason for this is uncertain; however, the 1998 distribution is limited by low sample size. The age distribution for 1998 did not show the bimodal pattern evident in the size distributions (Figure 4.9). The age range for goldeye found within the oil sands region was 0-9 y. Fish that were 2-3 y old were the most abundant. This corresponds with the contention that most goldeye using the Athabasca River are juveniles, but does not support the size distributions. It is doubtful that the sample size per age class is sufficient to provide an accurate representation of the age distribution.

The size-at-age relationship for goldeye is presented in Table 4.8. When compared to 1995 (the only year with sufficient sample size), the slopes were not significantly different ($p=0.20$), but the intercept of the regression line for 1998 was smaller ($p<0.00001$). The analysis indicates that for any given age, the length of goldeye captured in 1998 was shorter than fish captured in 1997. Interestingly, condition factor for goldeye remained the same between 1995-1997, but was significantly lower in 1998 (Table 4.9). A decline in size-at-age and condition suggests a food/habitat limitation. The influence of low discharge levels of the Athabasca River during 1998 is unknown, but presumably could affect habitat availability and feeding efficiency. Continued monitoring over time is necessary to determine whether the response persists.

Figure 4.8 Length-Frequency Distributions for Goldeye in the Oil Sands Region, Athabasca River, 1998

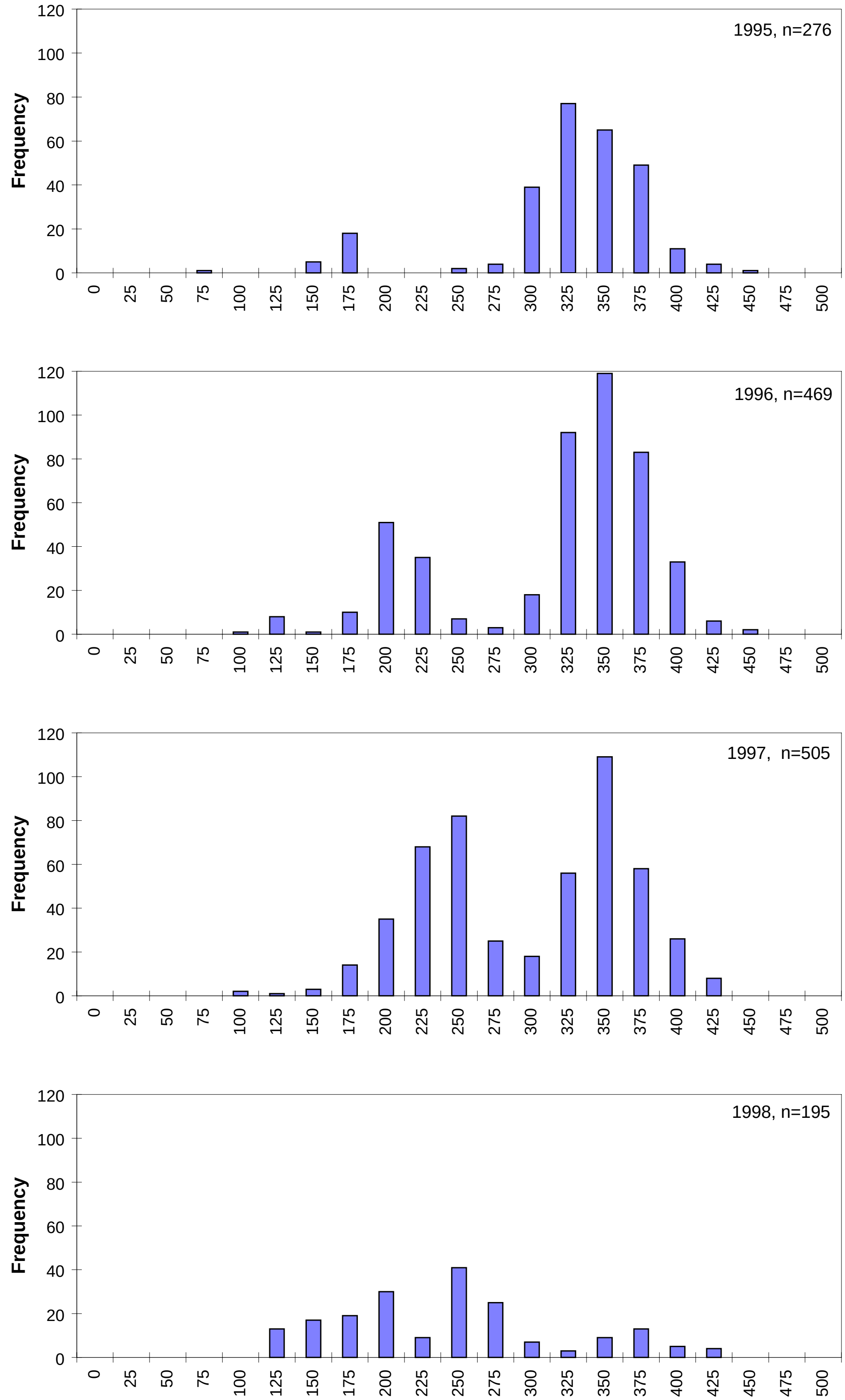
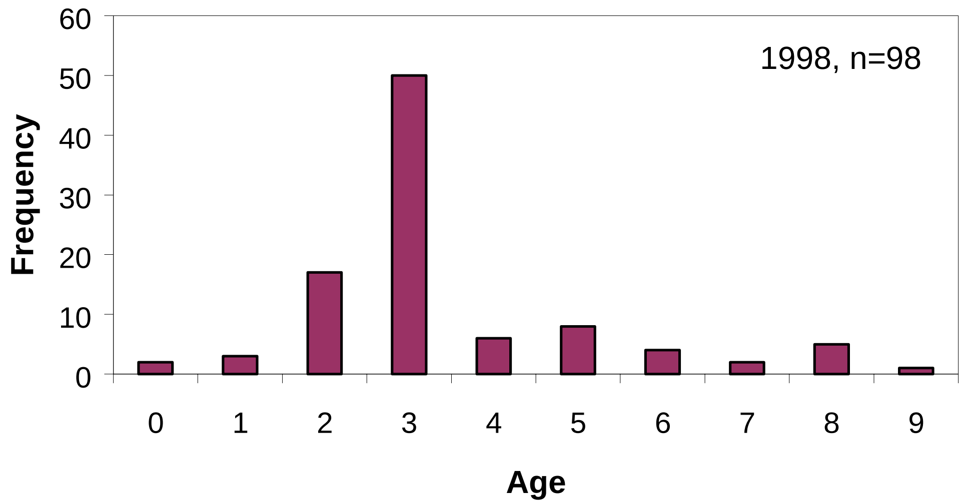


Figure 4.9 Age-Frequency Distributions for Goldeye in the Oil Sands Region, Athabasca River, 1998



Longnose Sucker

Relative abundance of longnose sucker was highest during the spring survey and corresponded with the April/May spawning period (Figure 4.1). Within the oil sands region, sucker were most abundant in the Muskeg Area (Figure 4.2). Both the Muskeg and MacKay rivers enter the Athabasca River within this area and are known to support significant spawning runs of longnose sucker (Bond and Machniak 1977, 1979; Machniak et al. 1980; Golder 1996a). Annual catch-per-unit-effort of longnose sucker was similar for 1995, 1997 and 1998 (Figure 4.3).

Size distributions of longnose sucker from 1995-1998 are presented in Figure 4.10. In general, the distributions among years are very similar, consisting of a dominant mode centred about 450-500 mm length classes, and a second, less distinct mode at 100-200 mm length classes. This pattern is similar to the distribution of sucker migrating up the Muskeg River (Bond and Machniak 1979) and Steepbank River (Machniak and Bond 1979). Based on the age distribution for 1998, the dominant mode corresponds approximately with age classes 7-10 y and the smaller mode roughly corresponds with ages 3-5 y (Figure 4.11). The 1998 age distribution is consistent with the distribution for 1997, although the 1998 distribution includes greater representation of older individuals (15-18 y). This discrepancy is likely, in part, a function of differences in sample sizes between the two years.

The size-at-age relationship for longnose sucker collected from the oil sands region in 1998 is presented in Table 4.8. When compared to 1997, the slope of the regression line for 1998 was significantly greater ($p=0.00001$). Plotting the separate regression lines shows that sucker in 1998 were shorter for the entire sampled age range, until the relationship reversed at an estimated age of about 18 y (Figure 4.12). In other words, the discrepancy in length is large at early ages, but becomes less pronounced in older age classes. This pattern seems to indicate a recent reduction in recruitment size (i.e., length) of longnose sucker, although there was no obvious shift noted in the length frequency distributions. Interestingly, no differences were observed in condition factor among years (Table 4.9).

With the exception of size-at-age, recent temporal trends in length and age frequency distributions, relative abundance and condition factor did not indicate substantial changes in longnose sucker found within the oil sands region. This is not consistent, however, with initial comparisons made between sucker from the oil sands region and a reference population unexposed to oil sands deposits (see Section 4.2.3.1). The discrepancy in results highlights the need for different approaches (of different scope and perspective) to ensure the protection of regional fishes and the aquatic environment.

Figure 4.10 Length-Frequency Distributions for Longnose Sucker in the Oil Sands Region, Athabasca River

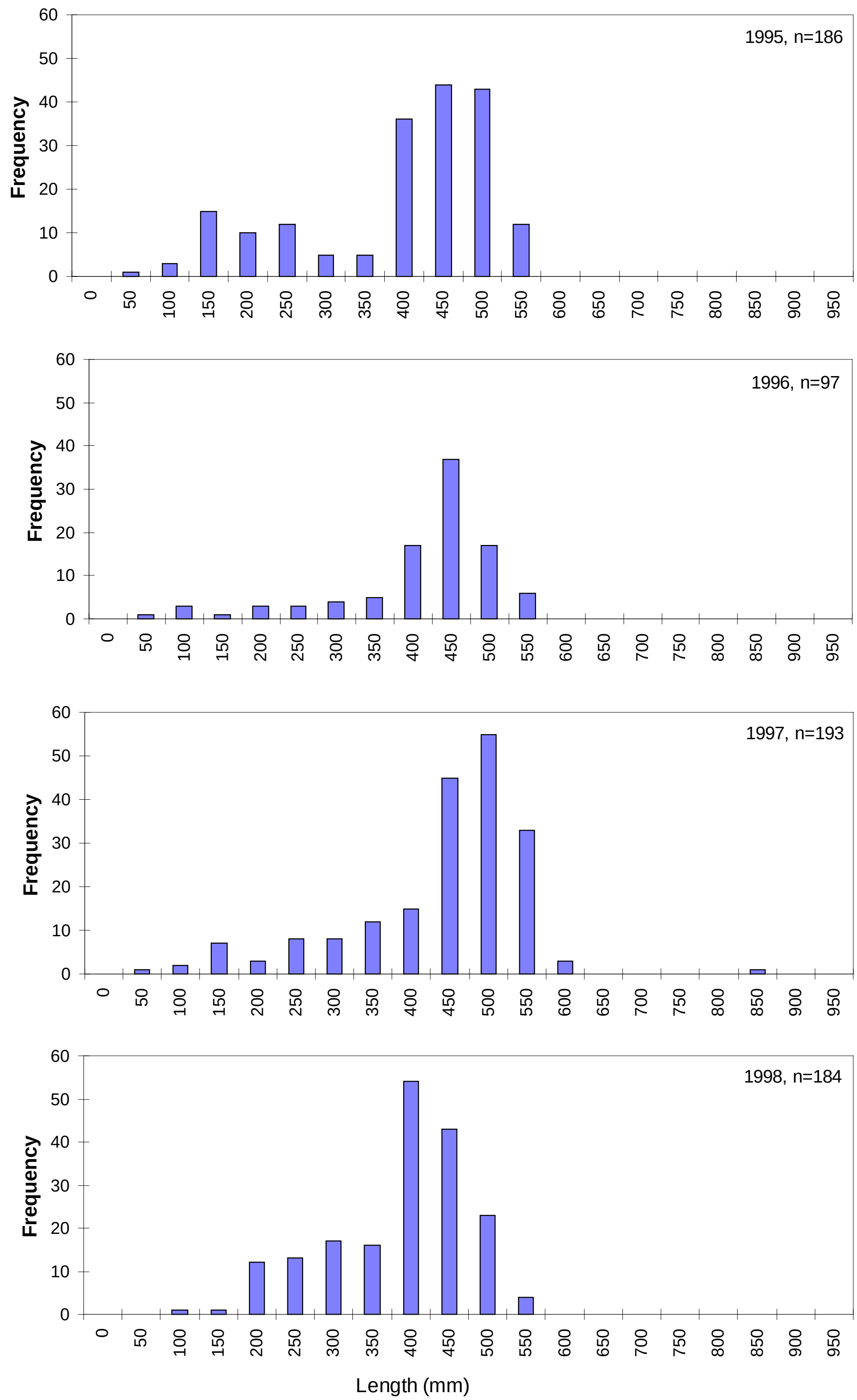


Figure 4.11 Age-Frequency Distributions for Longnose Sucker in the Oil Sands Region, Athabasca River

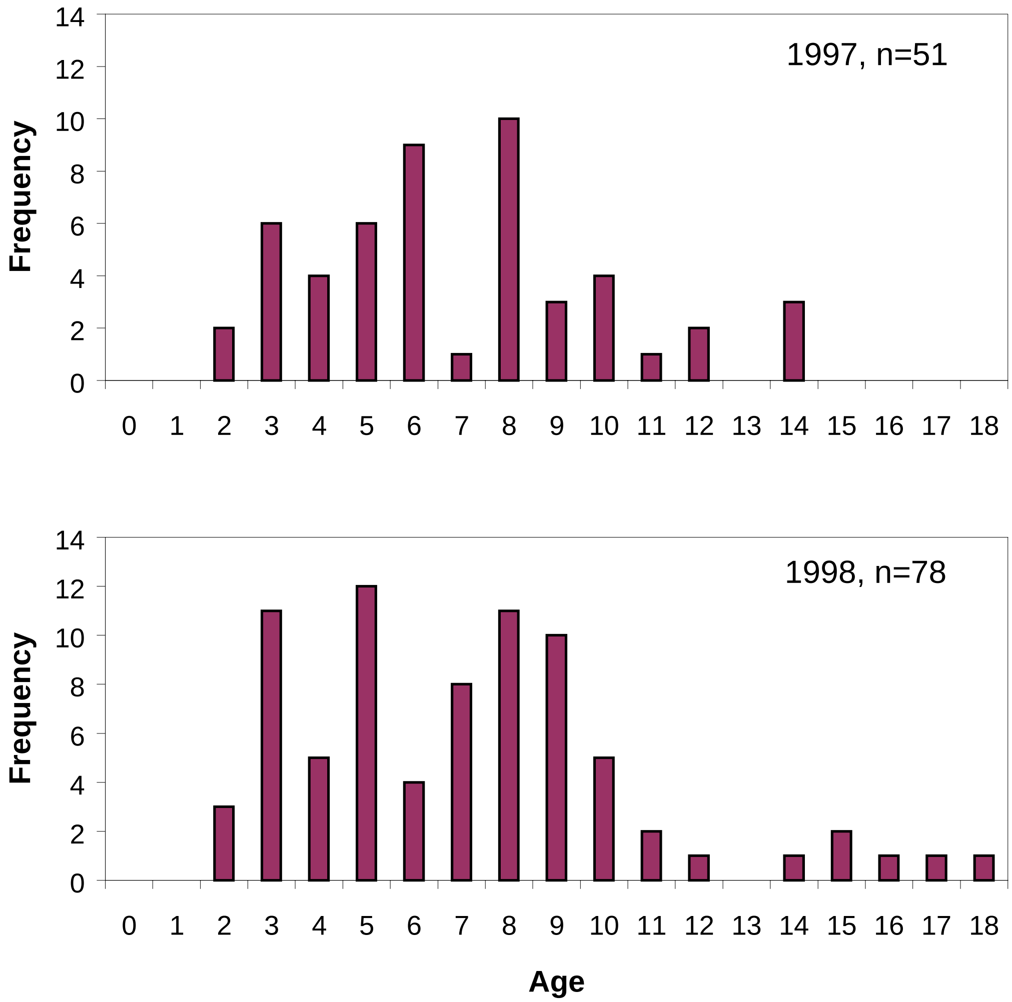
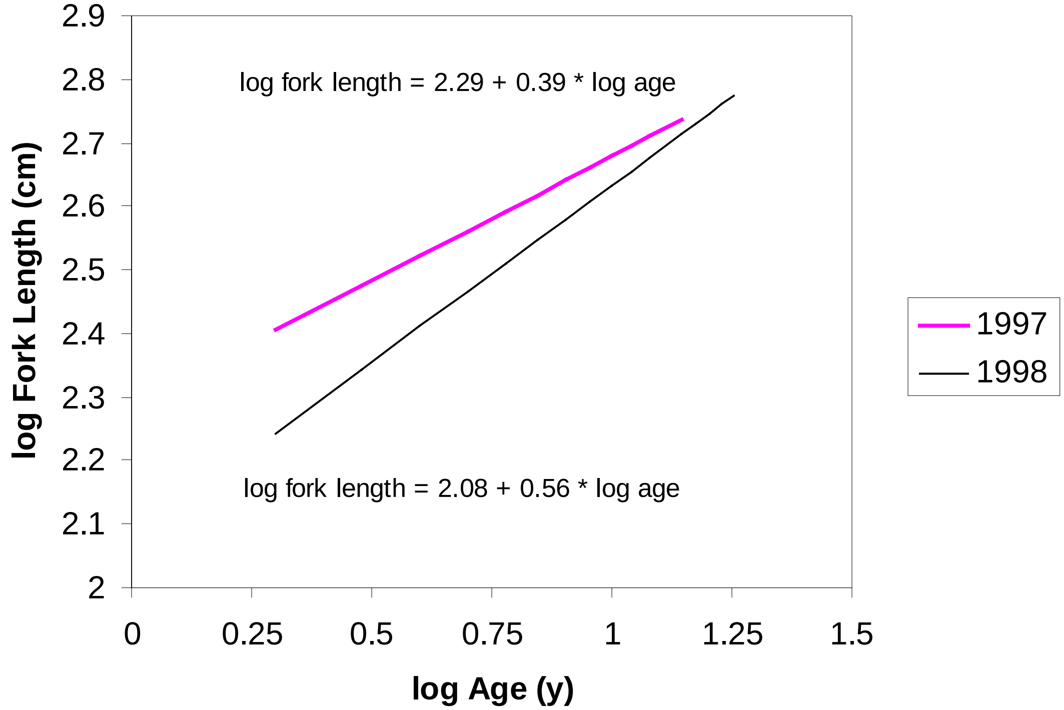


Figure 4.12 Size-at-age Relationship for Longnose Sucker Caught in the Oil Sands Region, Athabasca River



4.2.2 Habitat Evaluation and Fish-habitat Associations

4.2.2.1 Habitat Evaluation

A description of available aquatic habitats within the overall RAMP study area is presented in the report for the first year of the RAMP (Golder 1998a). Habitat mapping data are available from year one and two of the RAMP for three of the four habitat index sites. Table 4.10 presents the comparative results of the habitat evaluation conducted at the three RAMP index sites in 1997 and 1998. The results are presented as the amount of shoreline habitat within each of the habitat mapping categories, as a percentage of the total length of shoreline within each of the index sites and within the total index area. Individual habitat maps for each of the three RAMP habitat index sites from 1998 have been provided in Appendix V.

Table 4.10 Percent Bank Habitat Type for Areas within the Oil Sands Region, Athabasca River, 1997 and 1998

Bank Habitat Type	Poplar Area		Steepbank Area		Muskeg Area		Total	
	1997	1998	1997	1998	1997	1998	1997	1998
A1	7.7	7.2	7.8	6.1	12.7	11.5	9.4	8.3
A2	0.0	0.0	2.9	0.0	4.6	3.1	2.5	1.0
A3	0.0	0.0	0.8	1.3	0.0	0.0	0.3	0.4
A4	0.0	0.0	4.6	5.3	4.0	4.1	2.9	3.1
C1	0.0	0.0	0.0	0.0	1.2	1.3	0.4	0.4
C2	1.7	1.7	0.3	0.3	2.0	1.2	1.3	1.1
C3	3.4	3.4	0.0	0.0	0.0	3.3	1.1	2.2
D1	32.8	34.0	24.6	26.1	3.8	11.1	20.4	23.7
D2	1.5	1.5	0.0	0.0	0.0	1.6	0.5	1.0
E1	13.0	10.2	2.7	11.5	7.5	10.8	7.7	10.8
E2	1.6	0.0	0.0	10.7	26.6	27.4	9.4	12.7
E3	0.0	0.0	0.0	0.0	4.9	1.8	1.6	0.6
E4	0.0	0.0	0.0	0.0	0.6	0.6	0.2	0.2
E5	34.4	38.1	51.1	35.0	24.2	14.1	36.5	29.1
E6	2.4	2.2	3.7	2.0	0.0	0.0	2.0	1.4
E1-E5	1.7	1.7	0.0	0.0	0.0	0.0	0.6	0.6
A1-C2	0.0	0.0	1.6	1.7	0.0	0.0	0.5	0.6
D1-E5	0.0	0.0	0.0	0.0	2.8	2.9	0.9	1.0
E2-E1	0.0	0.0	0.0	0.0	1.8	1.8	0.6	0.6
E5-D1	0.0	0.0	0.0	0.0	2.4	2.5	0.8	0.8
E5-E3	0.0	0.0	0.0	0.0	1.0	1.0	0.3	0.3
E6-E5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

The habitat index sites provide a sub-sample of habitats within the RAMP study area. As was found for the overall RAMP study region (Golder 1998a), erosional shoreline types dominated available habitats within the index sites, followed by lesser amounts of rocky and depositional habitats. However, the specific habitat composition within the index sites was somewhat different than the overall RAMP study area. The specific percentage of erosional habitats for the combined index sites (average of 58%) was lower than for the overall RAMP study area (73%), while the percentages for rocky shorelines (18%) and depositional shorelines (24%) were higher for the index sites (compared to 14% and 13%, respectively). This trend simply shows that there is a somewhat greater availability of rocky shorelines and depositional areas in the regions of the selected tributary mouths and is not otherwise significant. The habitat index sites provide a good mix of habitat types for the monitoring program, including all 15 different bank habitat types found in the RAMP study area.

During the 1997 RAMP field studies, small changes in habitat availability were recorded for the habitat index sites, in comparison to the 1995/1996 baseline conditions. Some of these changes were a result of oil sands activities, and others were due to natural changes in river morphology. Within the Steepbank Area, man-made changes occurred as small amounts of E5 habitat were converted to A4 (rip-rap) habitat associated with the footings for the Suncor Bridge and armouring of a portion of the Tar Island Dyke. Other habitat changes reflect natural river processes, changes to flow patterns and shifting sediments which comprise most of the streambed.

By nature, the Athabasca River channel is dynamic, with much of the streambed and banks consisting of fine sediments. Shifting sediments due to fluvial processes and ice scouring results in continual formation and removal of sandbars, altered flow patterns within the channel and shifting patterns of deposition and erosion along the banks. Within the overall habitat index area, small changes in habitat availability from baseline conditions were recorded in areas that were not impacted by oil sands activities and which were believed to be the result of these natural processes. Some erosional (E5 and E6) and armoured (A1 and A2) habitats became depositional, while some depositional (D1) habitats became erosional. These changes are likely a result of changes in local flow patterns and the effects of flooding in the spring of 1997. One E5 habitat unit became an E6 unit as continued bank erosion resulted in debris falling into the stream, adding cover to the habitat unit.

For the total habitat index area, some changes in habitat composition occurred between 1997 and 1998 (Table 4.10). These changes include reductions in the relative proportions of A1, A2, E3, E5 and E6 habitats and increases in C3, D1, D2, E1 and E2 habitats. These changes in habitat composition are believed to reflect the natural river processes already described, as well as significant differences in river discharge between the 1997 and 1998 study periods.

Changes in local erosion/deposition patterns resulted in some armoured (A1 and A2) habitats and erosional (E2, E3, E5 and E6) habitats becoming depositional (D1 and D2) while some depositional (D1) habitats became erosional (E5 and E6). Overall, the amount of armoured and erosional habitat that became depositional was greater than the amount of depositional habitat that became erosional. The apparent increase in depositional habitat between 1997 and 1998 may also be, in part, a result of differences in river discharge during the habitat mapping periods. In 1997, the average discharge for the Athabasca River (as measured at the Water Survey of Canada gauging station downstream of Fort McMurray) for the summer and fall survey periods was 1641 m^3/s and 1110 m^3/s, respectively. During habitat analysis in 1998 the average discharge was 1126 m^3/s in the summer and 288 m^3/s in the fall. The much lower water levels in 1998, particularly in the fall, resulted in the water receding from the banks in some areas, exposing bed material deposited in front of the banks.

Other habitat changes resulting from natural processes were also recorded. Some low bank erosional habitats (E5 and E6) from the baseline and first year RAMP studies were classified as higher bank erosional habitats (E1 and E2) in 1998. This is likely due to continued erosion of the bank pushing the river edge inland and creating a higher bank profile.

4.2.2.2 Fish-Habitat Associations

Results of the surveys of habitat use by the fish species in the RAMP study area are presented in Tables 4.11 and 4.12 for the two years of the program. Fish-habitat association data were collected during the summer survey only. General fish-habitat associations are known from the baseline studies in 1995, but empirical data are only available from the RAMP studies in 1997 and 1998. Tables 4.11 and 4.12 present the number of fish for each species captured in each bank habitat type, as well as the percentage of use for each habitat type. Table 4.11 presents the habitat associations for KIR species and Table 4.12 for other dominant species in the RAMP study area.

Table 4.11 Fish Habitat Associations for KIR species in the Oil Sands Region, Summer 1997 and 1998

Habitat Type	Longnose Sucker		Goldeye		Lake Whitefish		Walleye	
	1997	1998	1997	1998	1997	1998	1997	1998
A1	8[(a)] (12.5)[(b)]	1 (12.5)	3 (2.2)	34 (22.8)	6 (9.4)	0	78 (9.5)	36 (20.6)
A2	0	0	3 (2.2)	1 (0.7)	0	0	5 (0.6)	0
A3	2 (3.1)	0	0	1 (0.7)	0	0	2 (0.2)	4 (2.3)
A4	0	0	1 (0.7)	15 (10.1)	0	0	111 (13.5)	7 (4.0)
C2	2 (3.1)	0	1 (0.7)	13 (8.7)	2 (3.1)	0	11 (1.3)	11 (6.3)
C3	0	0	3 (2.2)	0	2 (3.1)	0	12 (1.5)	2 (1.1)
D1	15 (23.4)	1 (12.5)	48 (35.0)	21 (14.1)	4 (6.3)	1 (4.3)	169 (20.5)	48 (27.4)
D2	17 (26.6)	0	0	2 (1.3)	0	8 (34.8)	6 (0.7)	4 (2.3)
E1	4 (6.3)	3 (37.5)	8 (5.8)	27 (18.1)	3 (4.7)	0	93 (11.3)	15 (8.6)
E2	11 (17.2)	1 (12.5)	11 (8.0)	20 (13.4)	9 (14.1)	2 (8.7)	38 (4.6)	21 (12.0)
E3	0	0	5 (3.6)	0	1 (1.6)	0	8 (1.0)	0
E4	0	0	0	0	0	0	17 (2.1)	0
E5	5 (7.8)	2 (25.0)	51 (37.2)	14 (9.4)	37 (57.8)	0	151 (18.3)	19 (10.9)
E6	0	0	1 (0.7)	1 (0.7)	0	0	6 (0.7)	1 (0.6)

[(a)] Number of fish for each species captured in each bank habitat type.

[(b)] Percentage of use for each habitat type.

Table 4.12 Fish Habitat Associations for Other Species in the Oil Sands Region, Summer 1997 and 1998

Habitat Type	Emerald Shiner		Flathead Chub		Lake Chub		Northern Pike		Trout-Perch	
	1997	1998	1997	1998	1997	1998	1997	1998	1997	1998
A1	0	9[(a)] (4.4)[(b)]	18 (6.4)	21 (27.6)	22 (20.2)	1 (16.7)	15 (9.6)	1 (3.6)	14 (8.0)	46 (9.4)
A2	0	0	12 (4.3)	0	0	0	2 (1.3)	0	0	0
A3	0	4 (1.9)	0	6 (7.9)	0	0	0	0	0	0
A4	0	36 (17.5)	1 (0.4)	1 (1.3)	2 (1.8)	0	3 (1.9)	1 (3.6)	9 (5.1)	5 (1.0)
C2	0	2 (1.0)	6 (2.1)	0	1 (0.9)	0	1 (0.6)	0	0	9 (1.8)
C3	0	0	13 (4.6)	0	0	0	0	0	2 (1.1)	0
D1	0	61 (29.6)	60 (21.3)	2 (2.6)	19 (17.4)	0	47 (30.1)	9 (32.1)	58 (33.0)	224 (45.8)
D2	0	14 (6.8)	56 (19.9)	1 (1.3)	0	0	1 (0.6)	0	0	11 (2.2)
E1	2 (50.0)	36 (17.5)	19 (6.7)	19 (25.0)	5 (4.6)	0	19 (12.2)	7 (25.0)	37 (21.0)	45 (9.2)
E2	0	13 (6.3)	23 (8.2)	13 (17.1)	25 (22.9)	5 (83.3)	10 (6.4)	4 (14.3)	1 (0.6)	66 (13.5)
E3	2 (50.0)	0	9 (3.2)	0	2 (1.8)	0	0	0	0	0
E4	0	0	0	0	0	0	0	0	14 (8.0)	0
E5	0	26 (12.6)	62 (22.0)	11 (14.5)	31 (28.4)	0	49 (31.4)	4 (14.3)	41 (23.3)	35 (7.2)
E6	0	4 (1.9)	3 (1.1)	1 (1.3)	2 (1.8)	0	9 (5.8)	0	0	1 (0.2)

[(a)] Number of fish for each species captured in each bank habitat type.

[(b)] Percentage of use for each habitat type.

The 1998 data show that, for all species combined, the bank habitat types that were most heavily used were D1 (32%), E1 (13%), A1 (13%), E2 (12%) and E5 (10%). These habitats were heavily used either because fish preferred them, or they were dominant habitat types. As in the 1997 RAMP study (Golder 1998a), D1 and A1 habitats would be considered preferred habitats since they were used in a higher proportion than they were available. Species that showed preference for D1 habitats included walleye, northern pike, emerald shiner and trout-perch; whereas species which selected A1 habitats included goldeye, walleye, flathead chub and lake chub. E1 and E2 were common habitat types and were utilized in approximately the same proportion as they were available, suggesting fish were not necessarily showing preference for these habitats. E5 habitat was the most abundant shoreline type but was used to a much lower degree than it was available, indicating most fish species were not selecting for this habitat type.

Habitat selection by the KIR species in 1998 showed some similarities as well as differences when compared to the fish-habitat associations reported for the 1997 RAMP study (Table 4.11). Walleye continued to show selectivity for rocky (armoured and canyon) and depositional shorelines. Erosional shorelines were used by walleye, but to a lesser extent than would be expected based on their availability. Selected habitat types for walleye included A1, A3, C2, and D1 shorelines. Goldeye were found to be associated with armoured and canyon shorelines to a much greater extent and with depositional shorelines to a lesser extent in the summer of 1998, relative to 1997. D1, E1, E2 and E5 habitats were commonly used by goldeye in both years, but A1, A4, and C2 habitats were used to a greater extent in 1998. Numbers for both lake whitefish and longnose sucker were too low from the summer of 1998 to determine trends in habitat use.

Northern pike were most commonly found in association with erosional or depositional habitats (Table 4.12). The most utilized bank types were D1, E1, E2 and E5, with the strongest selection for D1 and E1 habitats. A slightly higher use of A1 habitat was observed in 1997, compared to 1998. Among the forage fish species, trout-perch primarily utilized A1, D1 and E2 habitats, with a preference for D1 habitats associated with backwaters and other low velocity environments. Emerald shiner were most often found in association with A4, D1, E1 and E5 bank types, showing the strongest selectivity for A4 and E1 habitats which provide the highest degree of cover. Flathead chub made frequent use of a number of habitat types (A1, A3, E1, E2 and E5), but showed the strongest preference for rocky A1 and A3 shorelines as well as the deeper E1 habitats.

4.2.3 Reference Site Evaluation

4.2.3.1 Literature Evaluation

Wabasca River

The Wabasca River was not found to be suitable as a reference site for the oil sands region of the Athabasca River. There are similarities in specific habitat characteristics such as substrate type and dominant bank type (Table 4.13); however, the Wabasca River has a lower flow volume and is generally smaller and shallower than the Athabasca River downstream of Fort McMurray. Furthermore, the Wabasca River is part of the Peace River Basin not the Athabasca River Basin. Spatially, this increases the likelihood that reference and oil sands fish populations are distinct (i.e., not one large mobile population), but potentially introduces confounding factors related to differences in water chemistry, surficial sediments and physiography which may influence local fishes.

Data from Boag (1993) suggests that the fish community of the Wabasca River is less diverse than the Athabasca River, although three of the four KIR species are represented (Table 4.14). Estimates of catch-per-unit-effort were not documented; however, based on capture success, longnose sucker appears to be uncommon relative to species such as goldeye, walleye, flathead chub or trout-perch. Longnose sucker is a sentinel species for the RAMP and low capture success of this species, combined with the absence of lake whitefish, significantly limits the usefulness of the Wabasca River as a reference site.

Table 4.13 General Habitat Characteristics of the Wabasca River, Athabasca River near Duncan Creek and the Athabasca River within the Oil Sands Region

River	Discharge[(a)] (m^3/s)	Channel Characteristics	Dominant Bank Habitat	Dominant Substrate
Wabasca River[(b)]	76.5	unobstructed, meandering, shallow and narrow channel	erosional, slumping banks	sand and silt
Athabasca near Duncan Creek[(c)]	406	unobstructed, few meanders, areas of steep valley walls, with few islands	erosional-71% armoured/stable-22% depositional-7%	sand, silt covering small cobble
Athabasca - oil sands region[(c,d)]	587	unobstructed, islands and sandbars, backwater areas and snyes	erosional-73% armoured-14% depositional-13%	sand, silt with some cobble and bedrock

(a) Mean daily discharge averaged over 1981-1989.

(b) Information from Boag (1993).

(c) Information from R.L.& L. (1994) and Sentar (1994).

(d) Information from Golder (1998a).

Table 4.14 Fish Species Capture Data from Studies on the Wabasca River, Athabasca River near Duncan Creek, and Athabasca River within the Oil Sands Region

Species	Number of Fish Observed and Captured		
	Athabasca - Oil Sands Area	Wabasca River[a]	Athabasca near Duncan Creek[b]
lake whitefish	1718	0	0
walleye	664	28	110
goldeye	626	64	51
northern pike	133	1	38
burbot	19	4	91
yellow perch	8	0	0
mountain whitefish	4	0	253
Arctic grayling	3	0	3
white sucker	102	0	134
longnose sucker	67	4	948
trout-perch	589	90	198
flathead chub	313	31	603
spottail shiner	87	14	44
lake chub	70	0	128
river shiner	3	0	22
emerald shiner	2	2	174
longnose dace	0	0	21
shiner spp.	3	0	0
sucker spp.	0	0	689
cyprinid spp.	0	0	11
sculpin spp.	0	1	6
Total	**4411**	**239**	**3524**

[a] Data from Boag (1993), appendix d.

[b] Data from R.L.& L. (1994) and Sentar (1994).

Athabasca River near Duncan Creek

The region of the Athabasca River immediately downstream of Duncan Creek was considered the best available reference site for the RAMP. This potential reference area was initially given high consideration because it was part of the Athabasca River rather than a separate river system. As well, a series of rapids effectively limits large scale movement of mobile species between this area and the oil sands region. Based on information from the literature, habitat in the vicinity of Duncan Creek is similar to the oil sands region in terms of the sand/silt substrate and dominance of erosional bank type (Table 4.13). However, the upstream area is generally more confined and has fewer islands and sandbars and less backwater habitat. Both areas have tributaries entering the mainstem which potentially provide habitat for spawning, rearing and feeding.

The species assemblage recorded in the vicinity of Duncan Creek is similar to what has been documented in the oil sands region (Table 4.14), although mountain whitefish are much more common in the upstream reach. Existing information indicates that, with the exception of lake whitefish, dominant species of the oil sands region such as walleye, goldeye, northern pike and longnose sucker are abundant or at least present at the upstream site. Lake whitefish occur in the oil sands region in the fall during their migration from Lake Athabasca to spawning grounds upstream of Fort McMurray. Migration into the area near Duncan Creek is presumably limited by availability of appropriate spawning habitat, and the physical barrier posed by Mountain and Cascade rapids.

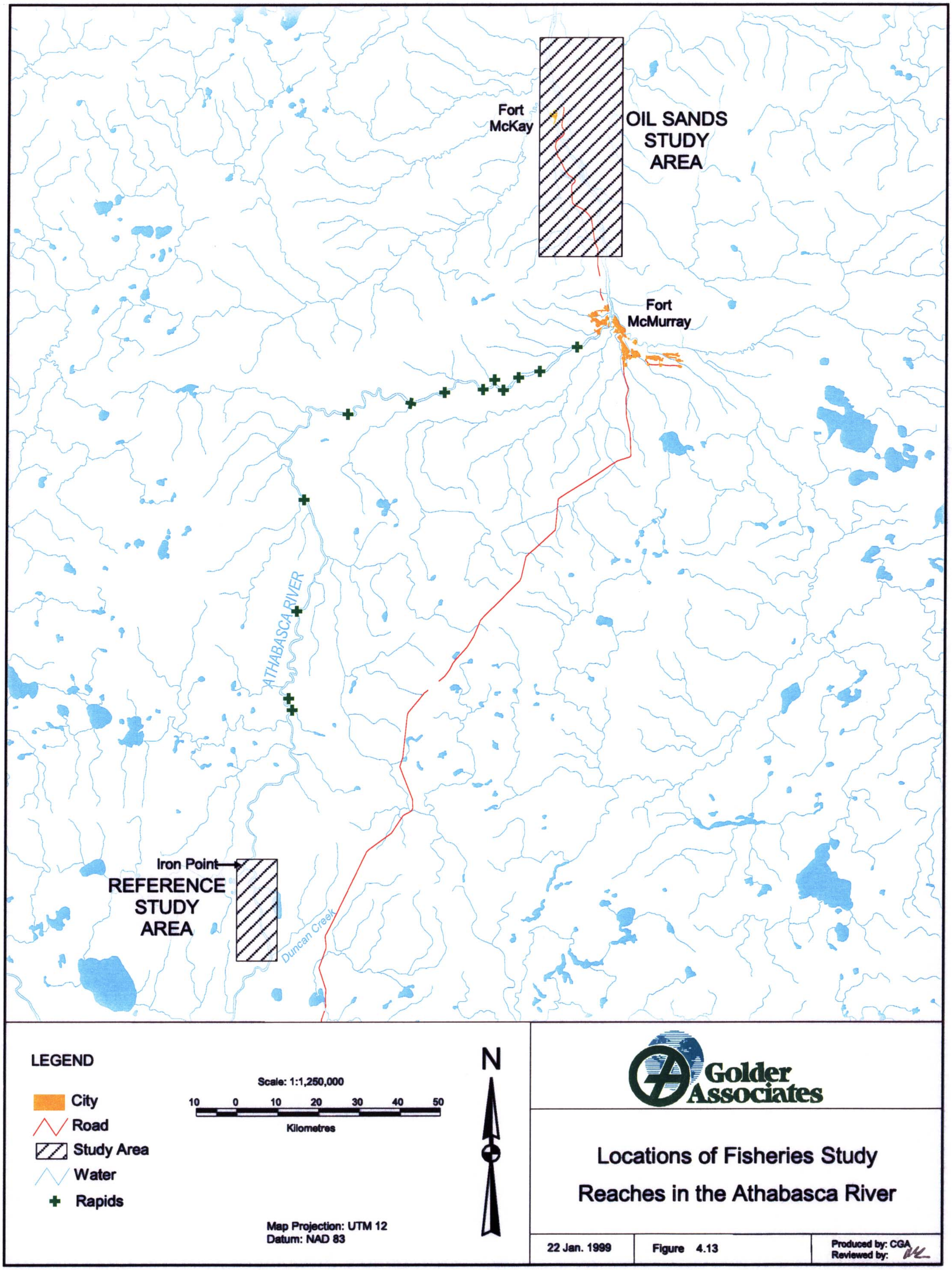
4.2.3.2 Reconnaissance Survey

Based on the literature evaluation, a reconnaissance survey trip was conducted only for the Athabasca River in the vicinity of Duncan Creek. The purpose of the survey was to collect fisheries and habitat data in a manner identical to the effort in the oil sands region to facilitate comparisons between areas, and to confirm or refute the suitability of the Athabasca River near Duncan Creek as a reference area. The reconnaissance survey was conducted during the period July 20-25, 1998 and additional fisheries sampling was conducted in the fall during the period October 5-10, 1998. The reconnaissance area included a 22 km section of the Athabasca River extending from 1 km upstream of the Duncan Creek confluence downstream to Iron Point (Figure 4.13).

Fisheries inventory sampling was conducted at three sites within the reconnaissance area, with each site including a 4 km section of river. Habitat mapping was conducted for two of the three fisheries sites, providing a total length of 8 km of mapped river.

Habitat Characterization

The Athabasca River at Duncan Creek is generally narrower (in terms of both average and maximum width) and consists of a single channel type (unobstructed), in comparison to the oil sands area where the river is wider and consists of a mix of unobstructed, single island and multiple island channel types. Table 4.15 presents a comparison of the availability of shoreline habitat types in the oil sands and reference areas and Appendix V presents the habitat maps for the two sites from the reference area at Duncan Creek.



Locations of Fisheries Study Reaches in the Athabasca River

22 Jan. 1999 Figure 4.13

Table 4.15 Percent Bank Habitat Type for Oil Sands and Reference (near Duncan Creek) Regions, Athabasca River, 1998

Bank Habitat Type	Region	
	Oil Sands	Reference
A1	7.9	19.5
A2	1.7	13.3
A3	0.3	0.0
A4	2.8	0.0
C1	0.4	0.0
C2	1.3	0.0
C3	2.1	0.0
D1	17.4	26.4
D2	0.5	5.6
E1	7.5	0.8
E2	12.8	0.0
E3	1.1	0.0
E4	0.6	5.2
E5	37.3	21.2
E6	1.5	7.9
E1-E5	0.3	0.0
A1-C2	0.5	0.0
D1-E5	1.0	0.0
E2-E1	0.6	0.0
E5-D1	0.8	0.0
E5-E3	0.3	0.0
E6-E5	1.2	0.0
Total	**100.0**	**100.0**

The distribution of habitat types for the oil sands area is 64% erosional, 19% depositional, 13% armoured and 4% canyon. The major shoreline types are more evenly distributed in the reference area with the exception of canyon habitat which is not present; 35% erosional, 32% depositional and 33% armoured. The oils sands area has a higher degree of habitat variety, showing 15 of the main bank habitat types, as compared to eight for the Duncan Creek area. This is due to the occurrence of small amounts of six bank habitat types in the oil sands area that are not present in the reference area, and the presence of significant amounts of E2 habitat in the oil sands area only (Table 4.15). The main bank habitat types, in order of abundance, include E5, D1, E2, A1 and E1 for the oil sands area, and D1, E5, A1, A2 and E6 in the reference area.

Fish Inventory

Fisheries inventory data for the reference area near Duncan Creek is presented in comparison to the oil sands region in Table 4.16. The table presents the percent composition and catch-per-unit-effort (CPUE) data for KIR species (summer and fall sampling combined).

Table 4.16 Percent Species Composition and CPUE for KIR Species in the Oil Sands and Reference (near Duncan Creek, Reach 6 only) Regions, Athabasca River, Summer and Fall, 1998

Species	Oil Sands Region			Reference Region		
	Total Number Captured	% of Catch	CPUE[a]	Total Number Captured	% of Catch	CPUE
longnose sucker	139	13.9	0.3	406	42.2	2.8
goldeye	119	11.9	0.9	26	2.7	0.1
lake whitefish	202	20.2	2.0	0	0.0	0.0
walleye	148	14.8	0.7	77	8.0	0.4
Total	608	60.9	3.9	509	53.0	3.3

[a] CPUE = Number of fish (captured and observed) per 100 seconds of boat electrofishing.

Lake whitefish is the dominant species in the oil sands area (20% of catch) in terms of total numbers. However, this species is present in large numbers in the fall only, when fish move up into the Athabasca River from Lake Athabasca during the fall spawning migration. Walleye (15%), goldeye (12%) and longnose sucker (14%) are represented by lower proportions of the catch than lake whitefish, but were roughly equal to one another. Both the oil sands and reference areas had similar proportions for the KIR species combined; 61% of the catch for the oil sands area and 53% for the reference area. However, relative proportions for the four individual species were different. Only three of the four KIR species were found to be present in the reference area, as lake whitefish were not encountered. In the reference area, longnose sucker were by far the dominant species (42% of the catch) with walleye (8%) and goldeye (3%) representing lower portions of the catch.

In terms of fish abundance, both areas had similar CPUE values; 3.9 fish/100 seconds of electrofishing in the oil sands area and 3.3 fish/100 seconds in the reference area. These results indicate that total fish abundance is very similar for the four KIR species combined. However, the relative abundances for the individual species is quite different. As mentioned, lake whitefish were not captured in the reference area. Longnose sucker were found to be much more abundant in the reference area than the oil sands area, while walleye and goldeye were less abundant (Table 4.16).

4.2.3.3 Synopsis

There are obviously some differences in habitat composition and availability between the oil sands and reference portions of the Athabasca River. This would be expected due to the distance between the two areas and natural, longitudinal changes in river and valley characteristics such as gradient, flow volume, confinement and substrate. However, the longitudinal river distance between the reference and oil sands areas is considered necessary to minimize mixing of the fish populations. The differences in habitat are not believed to be sufficient to exclude the use of the Duncan Creek site as a reference area. The availability of the dominant bank habitat types is similar enough to provide a useful reference site to evaluate potential impacts from oil sands activities. The good proportions of armoured, erosional and depositional habitat types present in the Duncan Creek area will, with monitoring, provide a good indication of natural levels of habitat change in the Athabasca River system.

There is concern regarding the differences in fish abundance between the oil sands and reference areas, specifically the absence of lake whitefish and low abundances of walleye and goldeye in the reference area. There does not appear to be a population of lake whitefish in this region of the Athabasca River that is independent of the Lake Athabasca population and which would provide a suitable reference population. Low abundances of walleye and goldeye may make it difficult to compare population parameters between the reference and oil sands areas for these species. However, longnose sucker is the key sentinel species and occurs in relatively high abundance in the reference area, providing a good reference to monitor population and fish health parameters for this species.

4.2.4 Sentinel Fish Species Monitoring

Ten incidental fish species were captured within the reference region of the Athabasca River during the fall sentinel species collection (Table 4.17). Longnose sucker, mountain whitefish, walleye, white sucker, flathead chub and northern pike were the most numerous species captured. The catch-per-unit-effort (CPUE) of longnose sucker in the reference area was substantially higher than was recorded in the oil sands region (Table 4.17, Figure 4.1).

Table 4.17 Percent Species Composition and CPUE for the Reference Area (near Duncan Creek, Reach 6), Fall 1998

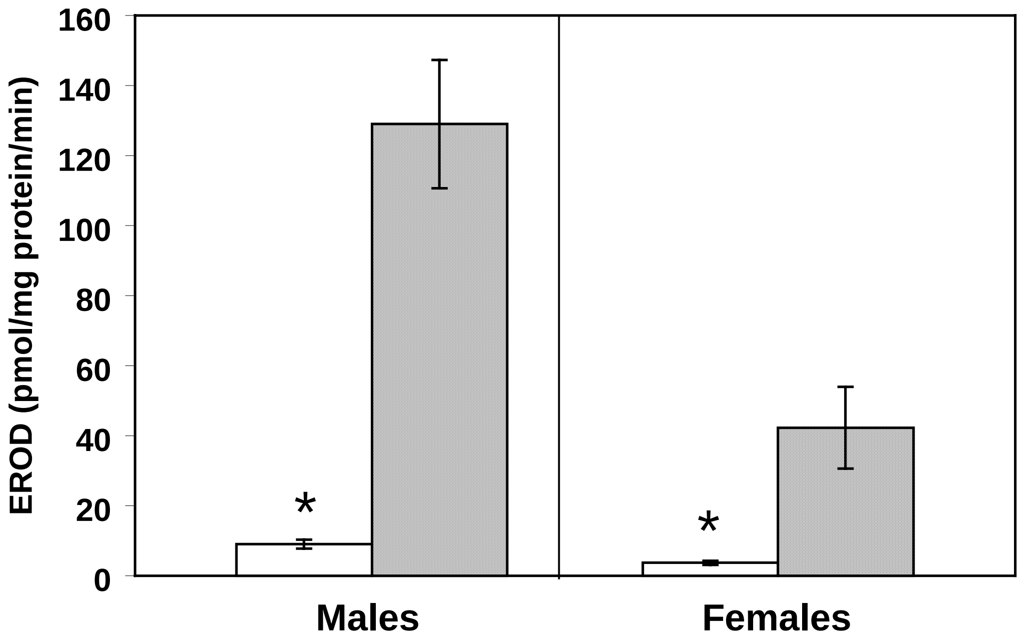
Species	Total Number Captured	% of Catch	CPUE[(a)]
longnose sucker	280	61.0	5.27
mountain whitefish	60	13.1	0.81
white sucker	31	6.8	0.37
flathead chub	30	6.5	0.35
walleye	23	5.0	0.32
northern pike	20	4.4	0.24
emerald shiner	9	2.0	1.88
trout-perch	5	1.1	0.42
goldeye	1	0.2	0.01

[(a)] CPUE = Number of fish (captured and observed) per 100 seconds of boat electrofishing.

Mean hepatic EROD activity in longnose sucker from the oil sands region was approximately 11-14 fold higher than in reference fish (Figure 4.14). A similar level of induction was documented in 1995 (Golder 1996d). Induced activity in fish within the oil sands region is not surprising, but does provide a positive indication of exposure and a baseline with which to make comparisons over time as mining activities increase. Sources of inducing compounds (e.g., PAHs) are largely related to natural deposits of bitumen within the region. Lockhart and Metner (1996) and Parrott et al. (1996a,b) have shown the presence of “natural” MFO-inducing chemicals in tributaries of the Athabasca and Peace rivers. However, mining of oil sands deposits may increase the release of the natural sources of inducing compounds to receiving waters.

Based on collections during the fall survey, the age distribution of longnose sucker collected from the oil sands region appears to be shifted towards older individuals relative to the reference region (Figure 4.15). Fish between 7-9 y were the most abundant age classes in the oil sands region; whereas, 4-6 y old fish were dominant in the reference region. The absence of younger individuals (ages 0-4 y) from the oil sands area is noteworthy; however, it is difficult to draw definitive conclusions given the limited sample size. A focused effort to sample small size and age classes is necessary in subsequent years to generate a more complete and accurate representation of age distribution. The mean age of mature male and female sucker was not found to be significantly different between the two regions (Table 4.18).

Figure 4.14 EROD Activity in Longnose Sucker from Reference (open bar) and Oil Sands (hatched bar) Regions, Athabasca River, Fall 1998[a]



[a] Values represent the mean +/- SE. A significant difference ($p<0.05$) between regions is identified with an asterisk.

Figure 4.15 Age-Frequency Distributions for Longnose Sucker in the Oil Sands and Reference Regions, Athabasca River, Fall 1998

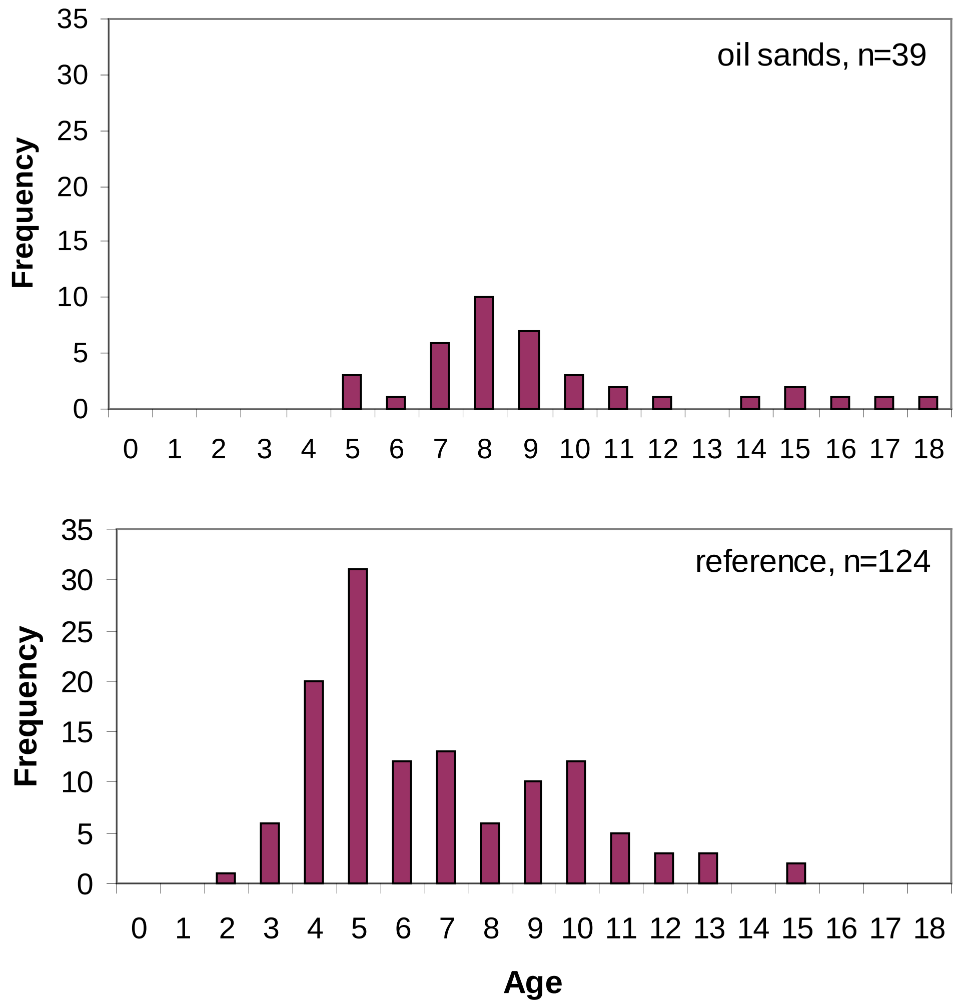


Table 4.18 Mean ± SE (n) of Body Size, Age and Organ Metrics of Longnose Sucker Collected from the Athabasca River, Fall, 1998

Sex	Parameter (Unit)	Reference Region	Oil Sands Region
male	fork length (cm)	37.3 ± 0.4 (43)*	41.3 ± 0.6 (36)
	body weight (g)	753 ± 41 (43)*	890 ± 55 (33)
	K[(a)]	1.44 ± 0.06 (43)*	1.22 ± 0.03 (33)
	age (y)	8.2 ± 0.4 (23)	9.3 ± 0.7 (19)
	LSI[(b)] (%)	2.06 ± 0.09 (23)*	1.58 ± 0.10 (13)
	GSI[(c)] (%)	4.94 ± 0.26 (23)	4.34 ± 0.21 (13)
female	fork length (cm)	39.2 ± 0.4 (88)*	43.8 ± 1.1 (13)
	body weight (g)	856 ± 27 (88)*	1,025 ± 85 (13)
	K	1.39 ± 0.02 (88)*	1.19 ± 0.02 (13)
	age (y)	9.6 ± 0.5 (29)	10.6 ± 0.9 (13)
	LSI (%)	2.26 ± 0.08 (22)*	1.72 ± 0.06 (12)
	GSI (%)	8.01 ± 0.26 (22)	7.57 ± 0.42 (12)
	fecundity (# eggs / g fish) [(d)]	38.3 ± 2.3 (22)*	28.2 ± 1.1 (11)

Note: Site differences in condition factor (K), gonadosomatic index (GSI), liversomatic index (LSI) and fecundity were tested using analysis of covariance. The remaining variables were examined using analysis of variance. Within a row, a difference ($p<0.05$) between reference and oil sand regions is identified with an asterisk.

[(a)] K = 100, (body weight/length^3).

[(b)] LSI = 100, (liver weight/corrected body weight).

[(c)] GSI = 100, (gonad weight/corrected body weight).

[(d)] Fecundity standardized by fish size (i.e., # of eggs/corrected body weight).

Mature male and female sucker collected from the oil sands region were longer and heavier compared to reference fish. However, a comparison of condition factor between regions indicated that oil sands fish were lighter at any given length relative to reference sucker (Table 4.18). Conversely, both male and female growth, as estimated by size-at-age, was greater at the oil sands region (Figures 4.16, 4.17). Gonad weights of male and female sucker were similar between regions (Table 4.19), but fecundity was found to be significantly lower in females from the oil sands region. Liver weight was also found to be lower among oil sands sucker (Table 4.19).

Figure 4.16 Size-at-age Relationships for Male Longnose Sucker from the Oil Sands and Reference Regions, Athabasca River, Fall 1998

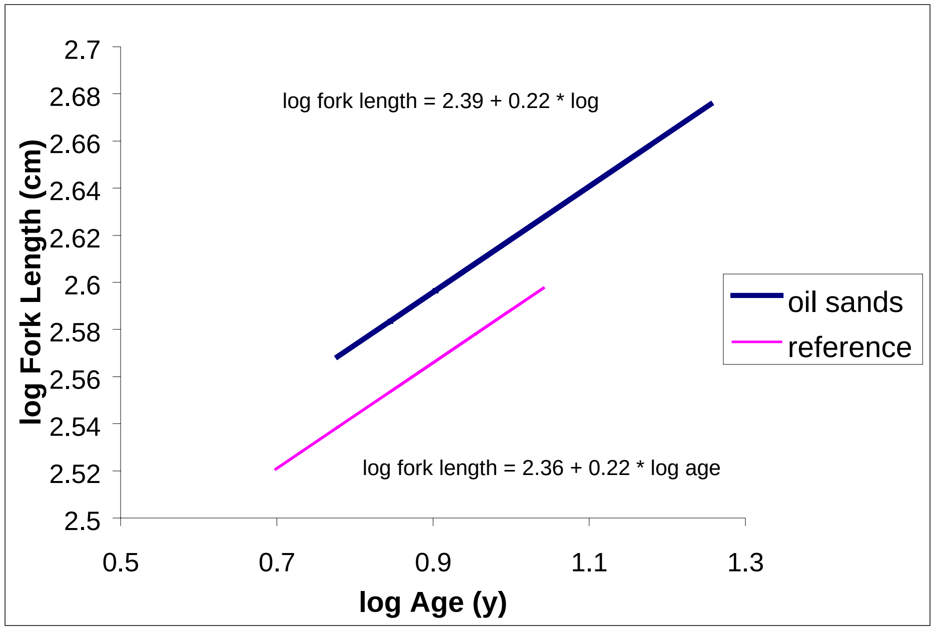


Figure 4.17 Size-at-age Relationships for Female Longnose Sucker from the Oil Sands and Reference Regions, Athabasca River, Fall 1998

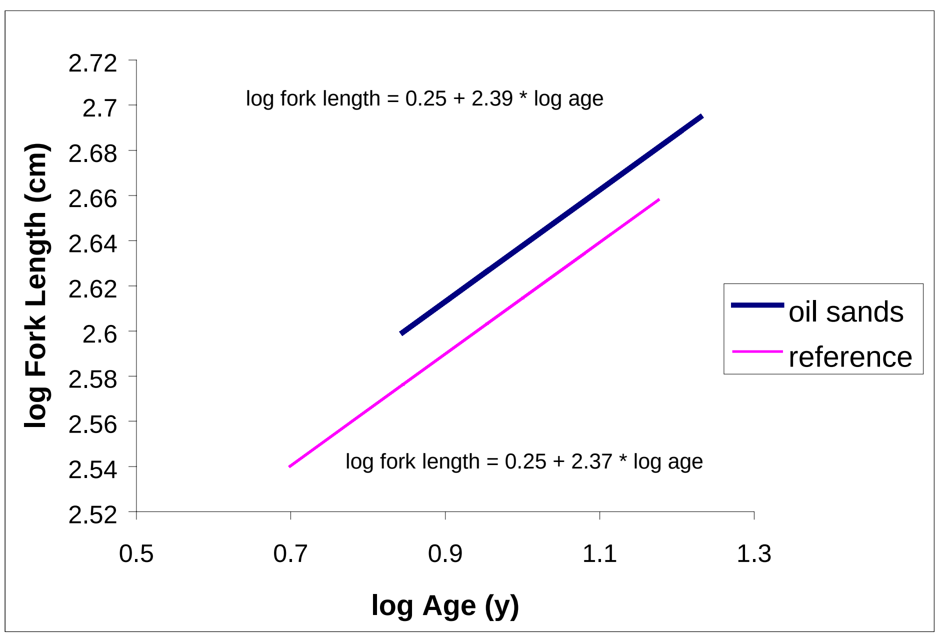


Table 4.19 Comparative Summary of Changes in Whole-organism Measurements of Longnose Sucker Collected from the Oil Sands Region Relative to Upstream Reference Fish during 1995 and 1998

Parameter	1995[a]	1998
size-at-age	+[b]	+
condition factor	+	-
gonad size	+	0
liver size	-	-
fecundity	0	+
MFO induction	+	+

[a] Golder (1996d).

[b] + signifies an increase relative to reference data, - signifies a decrease, 0 signifies no change.

The general response of longnose sucker within the oil sands region is complex. Increased size-at-age seems to suggest that fish within the oil sands region are able to allocate more energy towards somatic growth. This is often a response to an increase in food availability associated with relaxed competition (e.g., lower CPUE in oil sands region), or an increase in the amount of available habitat and resource (Gibbons and Munkittrick 1994). If increased energy is available, fish generally respond with a concomitant increase in condition (i.e., storage) and reproductive investment (e.g., gonad size, egg production). However, sucker within the oil sands region exhibit reduced condition and liver weight and either no change (gonad size) or decreased reproductive investment (fecundity). These data suggest some level of metabolic redistribution capable of altering growth and reproductive output resulting in inconsistencies in energy allocation (Gibbons and Munkittrick 1994).

Interestingly, the response measured during the current study is not consistent with the response identified in 1995 by Golder (1996d). During baseline work associated with Steepbank and Aurora mine developments, longnose sucker were collected from the oil sands region and compared to an upstream population of sucker investigated for the ALPAC pulp mill (Sentar 1994). The study indicated that sucker from the oil sands region showed increased growth, condition and gonad size suggesting a general response to increased food/habitat availability relative to the reference site (Table 4.19). The discrepancy in responses between the two studies makes it difficult, at this time, to make definitive conclusions regarding the status of longnose sucker within the oil sands region. However, it does highlight the need to continue to evaluate the sentinel species over time to develop a clearer picture of the temporal trend in the relative response of longnose sucker. This is particularly important given the increase in mining activity expected within the oil sands region in the near future. In addition, more effort is needed to ensure sample sizes are adequate to accurately and confidently estimate whole-organism and population level parameters.

4.2.5 Radiotelemetry Study

Information on size and maturity of 18 radio tagged walleye and 18 radio tagged lake whitefish is available in Golder (1998a). The movement data presented in this report were collected during 26 flights over the Athabasca River from the Cascade Rapids to the Peace-Athabasca Delta between October 7, 1997 and January 07, 1999. No flights occurred between December 22, 1997 and March 23, 1998, or between April 16, 1998 and September 16, 1998.

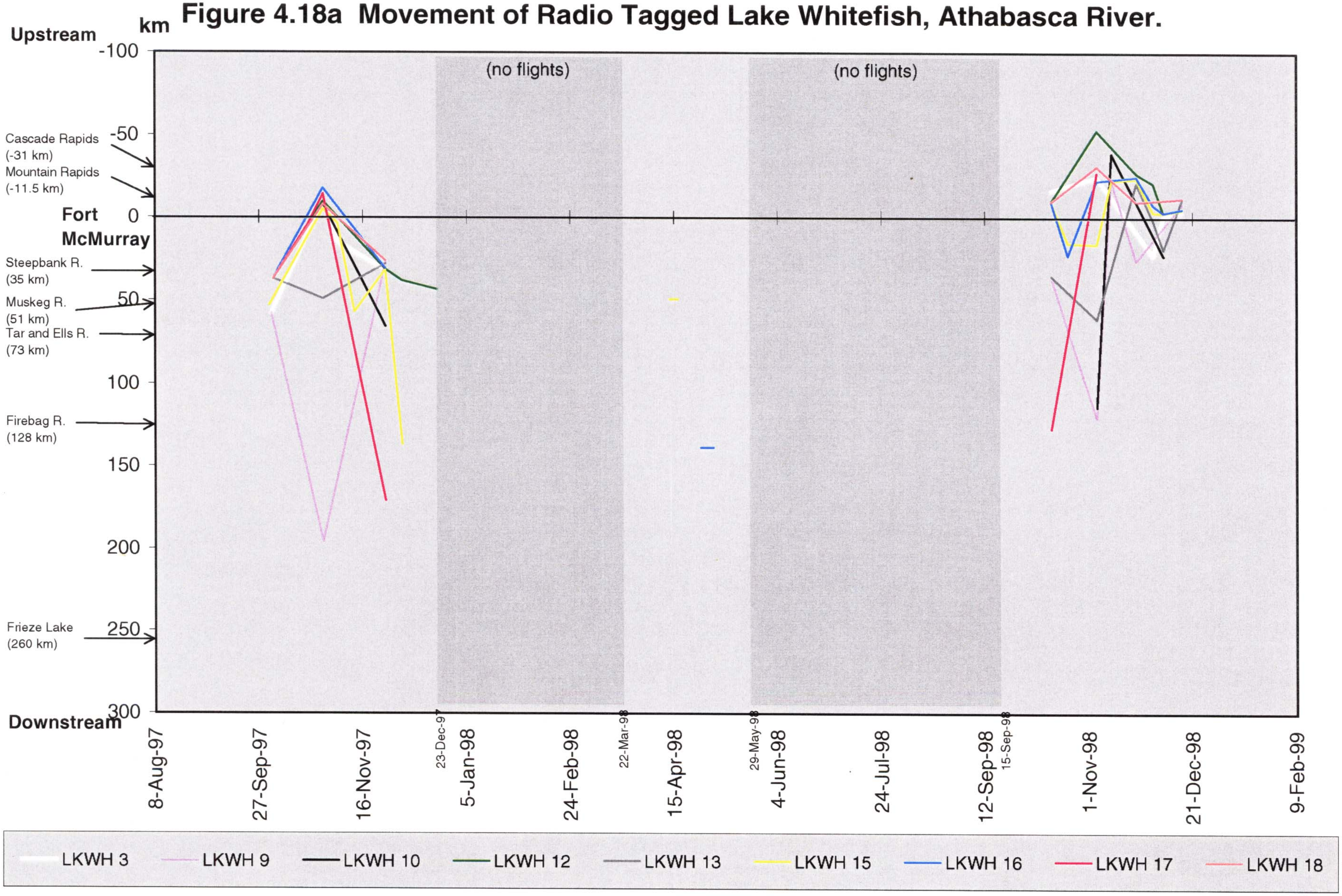
Movements of radio tagged fish are summarized in Figures 4.18a,b for lake whitefish, and in Figures 4.19a,b for walleye. Figures for each species are divided into fish for which large numbers of data points are available, and fish for which fewer locations were recorded. The figures show the locations of fish, by river kilometre, in relation to Fort McMurray (km 0.0) (see Figure 3.3). The exact date and location for each fish position is presented in Appendix VI.

Lake Whitefish

Fifteen of 18 radio tagged lake whitefish were adults in pre-spawning condition at the time of radio tagging (eight females, seven males), while three fish were of unknown maturity. Within three weeks of being radio tagged, nine of 18 lake whitefish were found upstream of Fort McMurray in the vicinity of Mountain Rapids (Figures 4.18a,b). None of these fish remained in this area past November 4, 1997. The rapid movement to and from the rapids area is believed to represent spawning movements for this species. Mountain and Cascade rapids have been identified as significant spawning areas for lake whitefish (Tripp and McCart 1979). Results of the current study were also consistent with the 1995 baseline study (Golder 1996a), which showed that a large influx of adult lake whitefish move through the oil sands region in the fall during the spawning migration.

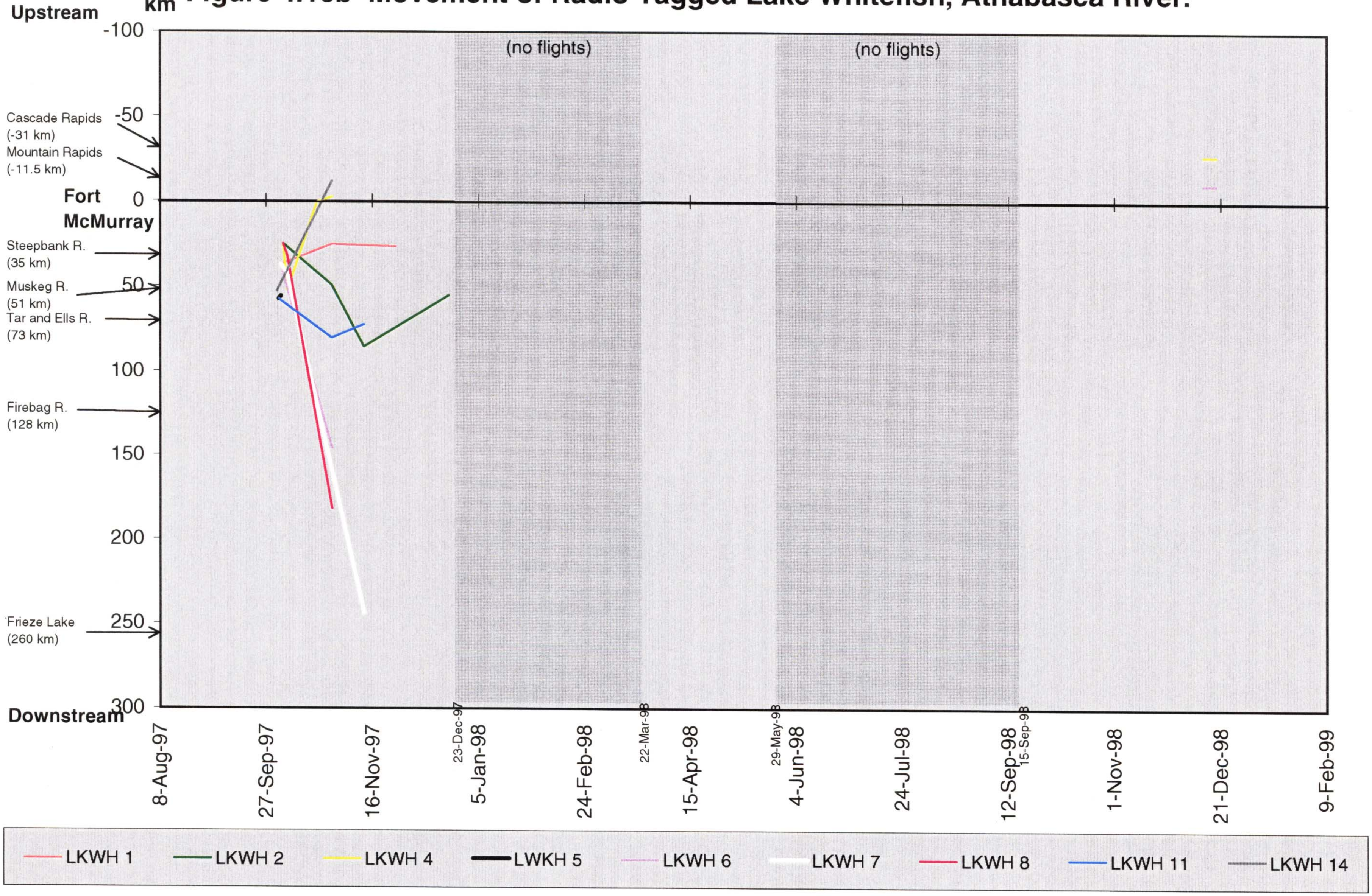
Six of nine fish from the rapids moved quickly downstream following the spawning period. These fish were found 31-170 km downstream of Fort McMurray and left the survey area by December 5 (Figure 4.18a). It is believed that these fish returned to Lake Athabasca and resided in the lake during the winter period. It is speculated that radio signals were not received during this time because fish were either beyond the telemetry survey area or in water too deep to allow signal reception. One other fish moved downstream immediately following the spawning season, and was still present in the oil sands area when

Figure 4.18a Movement of Radio Tagged Lake Whitefish, Athabasca River.



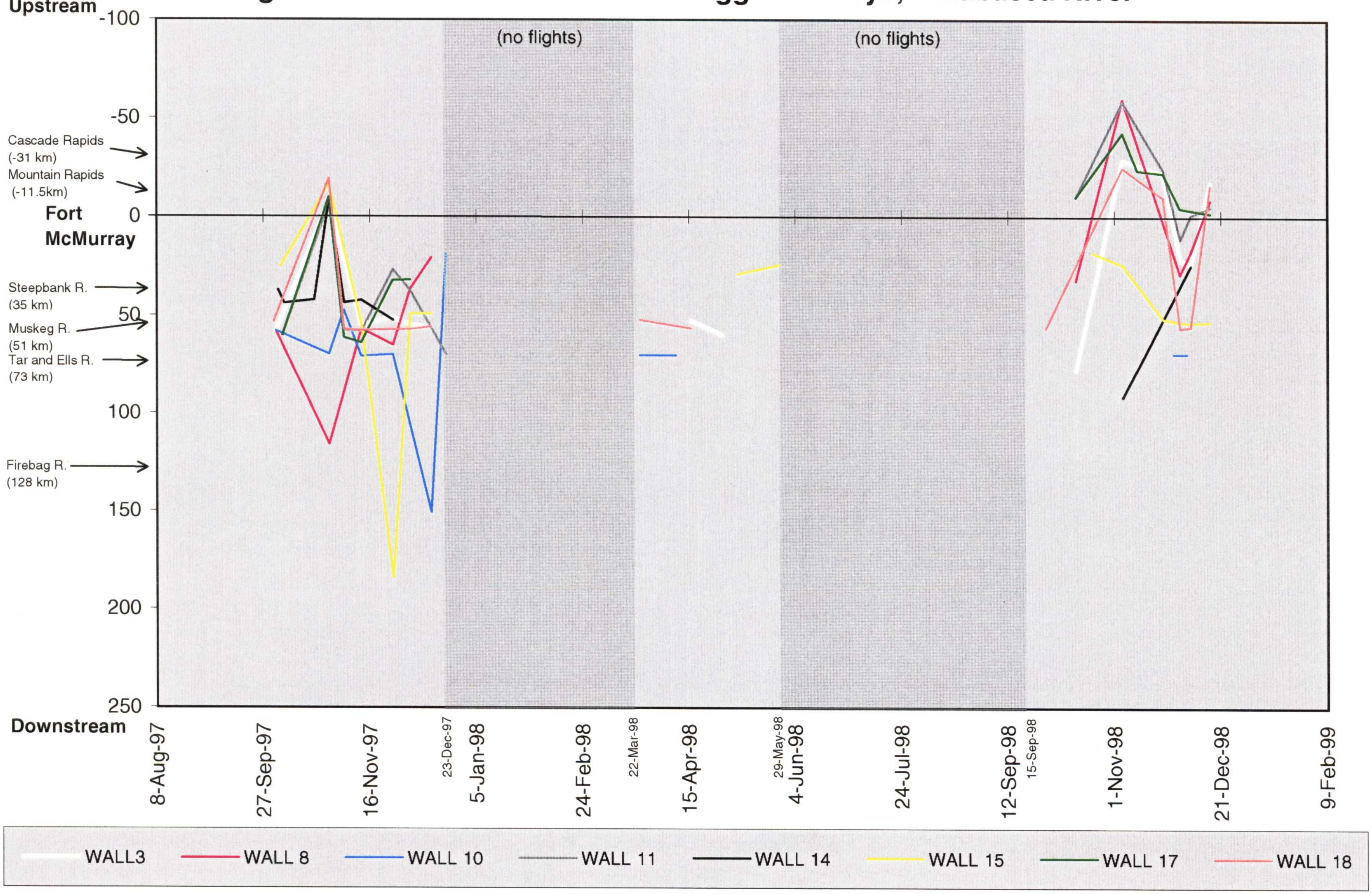
r:\1998\2300\982-2309\6044tel\telemet1.xls; lkwh graph 1

Figure 4.18b Movement of Radio Tagged Lake Whitefish, Athabasca River.



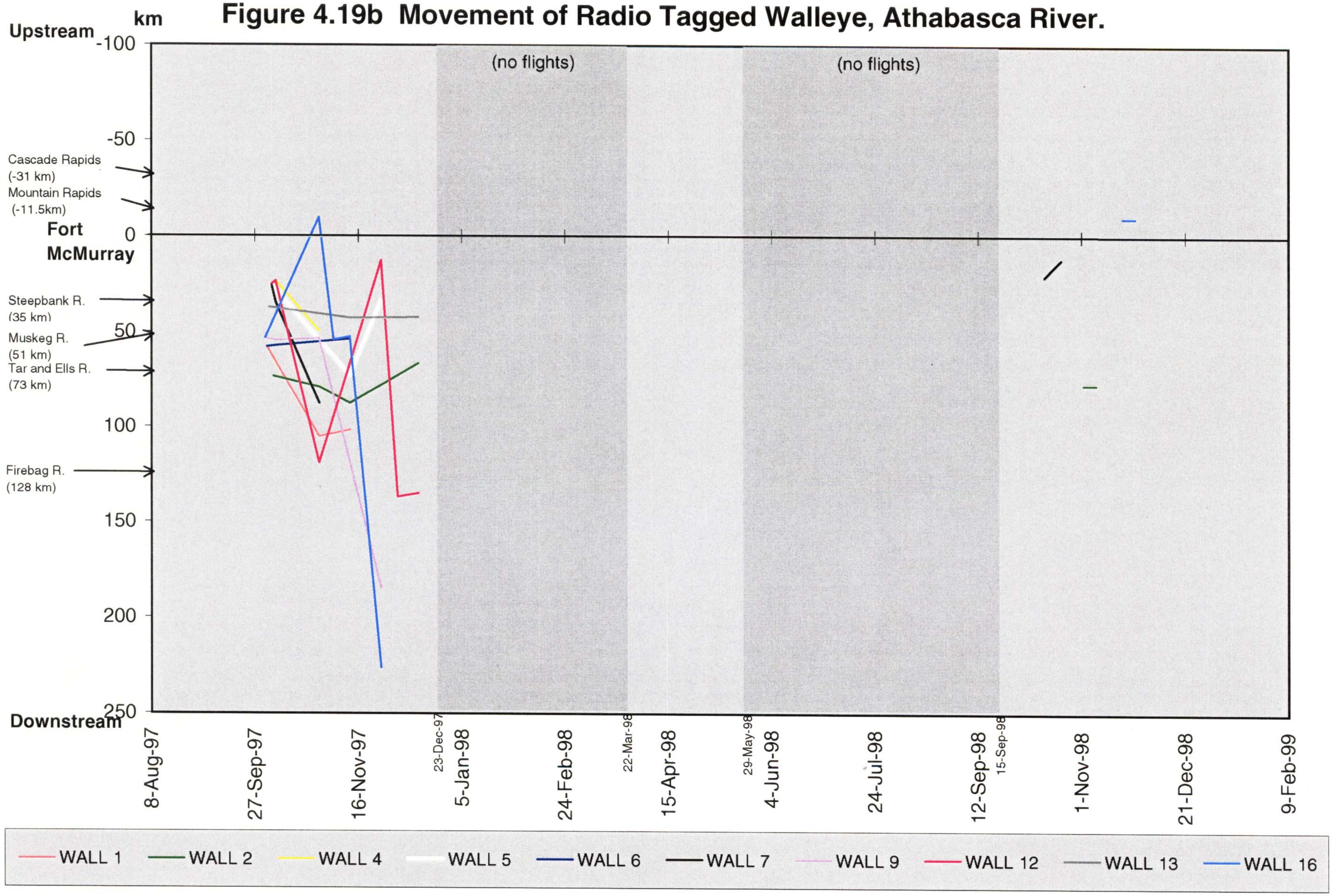
r:\1998\2300\982-2309\6044tel\telemet1.xls; lkwh graph 2

Figure 4.19a Movement of Radio Tagged Walleye, Athabasca River



r:\1998\2300\982-2309\6044tel\telemet1.xls; wall graph 1

Figure 4.19b Movement of Radio Tagged Walleye, Athabasca River.



r:\1998\2300\982-2309\6044tel\telemet1.xls; wall graph 2 flights were discontinued on December 22, 1997. As this fish was not found in the Athabasca River during early spring flights in 1998, it may have returned to Lake Athabasca later in the winter. Bond (1980) has suggested that a minority of lake whitefish may overwinter in the Athabasca River rather than in Lake Athabasca. The final two of nine fish from the rapids disappeared from the telemetry area immediately following the spawning season (Figure 4.18b). Although no downstream movement was recorded, these fish may have rapidly returned to Lake Athabasca between telemetry flights. One of these fish was later recorded returning to the rapids area during the 1998 spawning season.

The other nine of eighteen radio tagged lake whitefish did not move upstream following radio tagging. Five fish remained primarily in the oil sands area between the Steepbank River area downstream to the Tar River, although one of these fish moved downstream out of the oil sands region before returning later in the fall (Figure 4.18a,b). Four of the five fish disappeared from the survey area prior to discontinuing the telemetry flights for the winter. The fifth fish was still present on December 22, but was not found in the spring of 1998. All five fish are believed to have returned to Lake Athabasca. Three of the remaining four radio tagged fish moved considerable distances downstream immediately following tagging (Figure 4.18b), after which they disappeared from the Athabasca River and are believed to have returned to Lake Athabasca. The final radio tagged lake whitefish was only recorded once during the first telemetry flight and was found near the release location.

Three of nine individuals which did not move upstream to the rapids were of unknown sexual maturity and may have been juvenile, non-spawning fish. The remaining six fish were known to be adults in pre-spawning condition. Individuals which made immediate and large-scale downstream movements following tagging may have been affected by the surgical procedure such that their normal spawning activity was interrupted. The single adult fish which remained in the oil sands area may have a) interrupted spawning activity in response to surgery, b) moved to and from the spawning grounds and completed spawning activities between telemetry flights, or c) spawned at sites within the oil sands region. To date, there is little information which indicates that lake whitefish spawn within the oil sands region. Adult fish which did not move upstream in the fall of 1997, were found in the rapids area during the 1998 spawning season.

When telemetry flights resumed on March 23, 1998 there were no lake whitefish recorded in the survey area. Later in the spring, two lake whitefish were found in the Athabasca River, one near the Firebag River and one near the Muskeg River. These fish are indicative of the low-level use of the Athabasca River in the spring and summer, as documented during the baseline inventory studies conducted in 1995 (Golder 1996a).

The number of radio tagged lake whitefish in the Athabasca River increased dramatically in the fall of 1998 as the fall spawning population returned. Eleven of eighteen radio tagged fish returned to the oil sands area in October. Fish were first located immediately upstream of the Firebag River suggesting rapid upstream movement, presumably from Lake Athabasca. The other seven radio tagged fish were not recorded anytime during 1998 possibly due to transmitter failure, fish mortality, fish movement into tributary streams or fish remaining in Lake Athabasca.

All 11 radio tagged lake whitefish recorded during the fall, 1998 were eventually located upstream of Fort McMurray. Locations include Mountain Rapids and Cascade Rapids, points between the two sets of rapids, and upstream of Cascade Rapids. In addition, one fish was recorded in the Clearwater River during a specific flight that included this river system as part of the flight path. Fish were present upstream of Fort McMurray from October 14 to December 16, indicating a much longer spawning period in 1998 as compared to 1997. This may be a result of the unusually mild fall weather experienced in 1998. No fish were found within the survey area during the January 7, 1999 flight suggesting that fish had moved downstream, presumably to Lake Athabasca.

In general, lake whitefish were observed to move upstream of Fort McMurray (i.e., Mountain and Cascade rapids) in the fall, presumably to spawn. Following the spawning period, most whitefish moved downstream likely to overwinter in Lake Athabasca. In both years of the telemetry study, lake whitefish were often recorded near the mouths of the Steepbank, Muskeg, Tar, Ells and Firebag rivers, indicating that these rivers may provide important foraging or holding habitats for this species.

Walleye

Because walleye were not in pre-spawning condition at the time of tagging, it was difficult to ascertain life history stage or state-of-maturity of these fish (Golder 1998a). The movement of walleye (Figures 4.19a,b) was much more sporadic than observed for lake whitefish. Eight of 18 radio tagged walleye moved upstream immediately after release, while the other ten fish moved downstream. Seven of the walleye that moved upstream moved above Fort McMurray and appeared to mimic the lake whitefish spawning migration. As was found for the spawning lake whitefish, these seven walleye were present upstream in the vicinity of Mountain Rapids by October 28, 1997 and had left the area upstream of Fort McMurray by November 4. These fish tended to be larger than the other tagged walleye and are believed to move with the lake whitefish run to feed on migrating or post-spawning lake whitefish and possibly lake whitefish spawn. The 11 radio tagged walleye that remained downstream of Fort

McMurray made various movements, both upstream and downstream, within the oil sands region and beyond (Figures 4.19a,b).

Four walleye appeared to have returned to Lake Athabasca in the fall, as they showed distinct and consistent downstream movements before moving beyond the telemetry study area in late November. Nine radio tagged walleye were still present in the Athabasca River in mid- to late December; eight in the oil sands region and one near the Firebag River confluence. Three of these fish were still present in the oil sands area when telemetry flights resumed in the spring of 1998, indicating that they likely overwintered in the area. The other six fish are believed to have returned to Lake Athabasca sometime between December 22 and March 23 telemetry flights.

In total, only four of 18 radio tagged walleye were recorded in the Athabasca River during the 1998 spring telemetry flights. During the walleye spawning period in April/May, these fish were located near tributary confluences, including Poplar Creek, and the Muskeg, Tar and Ells rivers. With the limited number of fish in the telemetry area, it was not possible to determine specifically where walleye spawning activity was taking place. Tripp and McCart (1979) suggest that walleye spawn mainly in Richardson Lake and in tributaries of the Athabasca River (e.g., Muskeg and Steepbank rivers); whereas Bond (1980) suggests that walleye spawn in rocky areas in the Athabasca and Clearwater rivers. Low numbers of radio tagged walleye recorded in the Athabasca River during the spring spawning period could be, in part, due to fish spawning in the Lake Athabasca area, or moving into tributaries of the Athabasca River (i.e., out of the telemetry survey area). However, no radio tagged fish were found in the Muskeg, Steepbank, Ells or Tar rivers during a flight over these tributaries conducted on June 23, 1998.

During the resumption of telemetry flights in the fall of 1998, 11 radio tagged walleye were located in the study area. This suggested that walleye returned to the Athabasca River in larger numbers during either the summer or fall seasons. The exact time of this movement was not determined as telemetry flights were not conducted between May 28 and September 10, 1998. Most of walleye located at the start of the fall monitoring period were undergoing upstream movements and, as in the fall of 1997, appeared to mimic the lake whitefish spawning run. Again, the radio tagged walleye closely followed the movements of spawning lake whitefish. This included moving further upstream of Fort McMurray, using both Cascade and Mountain rapids, and remaining upstream of Fort McMurray for a much longer period of time relative to what was observed in 1997. These results indicate that lake whitefish and/or eggs are likely an important food resource for the walleye population and that, at least in the fall, walleye movements are largely dictated by lake whitefish movements.

4.2.6 Fish Tissue Analyses

Results indicated that there was very limited uptake of PAHs in fish. Longnose sucker composite samples showed detectable naphthalene and methyl naphthalene levels of 0.01 μg/kg in both males and females collected from the reference area (Table 4.20). However, all other PAH parameters were not detected in longnose sucker from either the oil sands or reference areas (detection limits = 0.01 μg/kg). Although close to the detection limit of the analyses, methyl naphthalene was also measured in female walleye caught in the oil sands area during the fall of 1998 (Table 4.21). No other PAH parameters were found in walleye from either the oil sands or reference areas (detection limits range from 0.01 μg/kg to 0.02 μg/kg). Both naphthalene and methyl naphthalene levels were detected in goldeye caught in the oil sands area during the spring of 1998 (Table 4.22). Tissue from female goldeye contained levels of 0.02 μg/kg of both substances, whereas male tissue contained naphthalene levels of 0.02 μg/kg and methyl naphthalene levels of 0.03 μg/kg. No other PAH parameters were found in goldeye from either oil sands or reference areas (detection limits = 0.01 μg/kg). No PAH parameters were detected in lake whitefish (detection limits = 0.01 μg/kg) (Table 4.22).

Arsenic was not detected in any fish tissue samples collected from the oil sands or reference region (detection limit = 0.2 mg/kg) (Tables 4.20 to 4.22). Detectable levels of lead were found in both female and male longnose sucker collected from the reference area, but was not detected in sucker tissue collected from the oil sands region (Table 4.20). Walleye tissue from the oil sands area also contained detectable levels of lead; tissue samples from male walleye caught in the spring showed lead levels of 0.05 mg/kg, whereas females caught in the fall showed lead levels of 0.1 mg/kg (Table 4.21). Lead was not measured in spring females or fall males from the oil sands area or in either sex from the reference area. Male lake whitefish caught in the oil sands area in fall, 1998, also contained detectable levels of lead (0.06 mg/kg) (Table 4.22). Neither female whitefish nor goldeye contained detectable levels of lead in their tissue. None of the fish tissue samples exceeded the Canadian consumption guideline for lead of 0.5 mg/kg (Health Canada 1981).

Table 4.20 Tissue Concentrations of Chemicals in Longnose Sucker from Oil Sands and Reference Regions, Athabasca River, Fall 1998

Parameter	Units	Oil Sands		Reference	
		Female	Male	Female	Male
Total Metals					
aluminum	mg/kg	1.4	0.7	1.7	0.8
antimony	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04
arsenic	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
barium	mg/kg	0.16	0.19	0.23	0.22
beryllium	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
boron	mg/kg	< 2	< 2	< 2	< 2
cadmium	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
chromium	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
cobalt	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
copper	mg/kg	0.28	0.29	0.34	0.5
iron	mg/kg	6	6	8	7
lead	mg/kg	< 0.04	< 0.04	0.05	0.04
manganese	mg/kg	0.3	0.5	0.29	0.29
mercury	mg/kg	0.08	0.07	0.3	0.24
molybdenum	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04
nickel	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
selenium	mg/kg	0.3	< 0.2	0.3	0.4
silver	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
sodium	mg/kg	433	440	503	392
strontium	mg/kg	1.04	0.38	0.52	0.38
thallium	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04
tin	mg/kg	3.58	3.64	3.67	3.77
vanadium	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
zinc	mg/kg	3.5	3.5	5.6	6.3
Target PAHs and Alkylated PAHs					
naphthalene	µg/kg	< 0.01	< 0.01	0.01	0.01
methyl naphthalenes	µg/kg	< 0.01	< 0.01	0.01	0.01
acenaphthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
acenaphthylene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
dibenzo(a,h)anthracene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
benzo(a)Anthracene/Chrysene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
benzo(a)pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
benzo(b&k)fluoranthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
benzo(g,h,i)perylene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
fluoranthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
fluorene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
indeno(c,d-123)pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
phenanthrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01

Table 4.21 Tissue Concentrations of Chemicals in Walleye from Oil Sands and Reference Regions, Athabasca River, 1998

Parameter	Units	Oil Sands				Reference	
		Spring		Fall		Fall	
		Female	Male	Female	Male	Female	Male
Total Metals							
aluminum	mg/kg	0.9	0.8	1.2	0.9	0.7	0.8
antimony	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
arsenic	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
barium	mg/kg	< 0.08	< 0.08	0.08	0.09	< 0.08	0.09
beryllium	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
boron	mg/kg	< 2	< 2	2	< 2	< 2	< 2
cadmium	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
chromium	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
cobalt	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
copper	mg/kg	0.24	0.24	0.92	0.3	0.28	0.8
iron	mg/kg	4	5	5	5	4	9
lead	mg/kg	< 0.04	0.05	0.1	< 0.04	< 0.04	< 0.04
manganese	mg/kg	0.14	0.1	0.18	0.17	0.12	0.16
mercury	mg/kg	0.29	0.2	0.22	0.26	0.37	0.33
molybdenum	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
nickel	mg/kg	< 0.08	< 0.08	0.75	0.1	< 0.08	22.1
selenium	mg/kg	0.3	0.3	0.2	0.3	0.3	0.3
silver	mg/kg	< 0.08	< 0.08	< 0.08	0.1	< 0.08	< 0.08
sodium	mg/kg	496	549	320	321	265	302
strontium	mg/kg	0.1	0.35	0.47	0.6	0.19	0.51
thallium	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
tin	mg/kg	3.65	3.35	3.02	2.98	2.94	3.05
vanadium	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
zinc	mg/kg	3.5	4.3	3.8	3.3	4.1	4.4
Target PAHs and Alkylated PAHs							
naphthalene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
methyl naphthalenes	µg/kg	< 0.01	< 0.01	0.01	< 0.01	< 0.02	< 0.02
acenaphthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
acenaphthylene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
dibenzo(a,h)anthracene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
benzo(a)anthracene/chrysene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
benzo(a)pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
benzo(b&k)fluoranthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
benzo(g,h,i)perylene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
fluoranthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
fluorene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
indeno(c,d-123)pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
phenanthrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02
pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02	< 0.02

Table 4.22 Tissue Concentrations of Chemicals from Goldeye and Lake Whitefish from Oil Sands Region, Athabasca River, 1998

Parameter	Units	Spring		Fall	
		Goldeye		Lake Whitefish	
		Female	Male	Female	Male
Total Metals					
aluminum	mg/kg	0.6	0.7	0.6	1.5
antimony	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04
arsenic	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
barium	mg/kg	0.09	< 0.08	< 0.08	< 0.05
beryllium	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
boron	mg/kg	< 2	< 2	< 2	< 2
cadmium	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
chromium	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2
cobalt	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
copper	mg/kg	0.29	0.33	0.18	0.51
iron	mg/kg	9	8	5	12
lead	mg/kg	< 0.04	< 0.04	< 0.004	0.06
manganese	mg/kg	0.19	0.2	0.16	0.24
mercury	mg/kg	0.16	0.18	0.08	0.09
molybdenum	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04
nickel	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
selenium	mg/kg	0.6	0.6	0.2	0.2
silver	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
sodium	mg/kg	674	559	535	491
strontium	mg/kg	1.08	1.08	0.16	0.42
thallium	mg/kg	< 0.04	< 0.04	< 0.04	< 0.04
tin	mg/kg	3.43	3.7	3.62	3.73
vanadium	mg/kg	< 0.08	< 0.08	< 0.08	< 0.08
zinc	mg/kg	4.8	4	3.8	3.4
Target PAHs and Alkylated PAHs					
naphthalene	µg/kg	0.02	0.02	< 0.01	< 0.01
methyl naphthalenes	µg/kg	0.02	0.03	< 0.01	< 0.01
acenaphthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
acenaphthylene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
dibenzo(a,h)anthracene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
benzo(a)Anthracene/Chrysene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
benzo(a)pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
benzo(b&k)fluoranthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
benzo(g,h,i)perylene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
fluoranthene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
fluorene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
indeno(c,d-123)pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
phenanthrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01
pyrene	µg/kg	< 0.01	< 0.01	< 0.01	< 0.01

Detectable levels of mercury were found in all fish tissue samples collected in 1998. Mercury levels were 3-4 fold lower in longnose sucker tissues from the oils sands region relative to the reference region (Table 4.20). Mercury levels were also slightly lower in walleye tissue from the oil sands region compared to reference fish (Table 4.21). Levels of mercury in goldeye tissue were lower in females (0.16 mg/kg) than males (0.18 mg/kg). Similarly, female lake whitefish tissue contained lower mercury levels than male lake whitefish tissue (0.08 mg/kg and 0.09 mg/kg, respectively) (Table 4.22). None of the fish tissue samples collected in the oil sands or reference regions exceeded the Canadian consumption guideline for mercury of 0.5 mg/kg (Health Canada 1981).

Supporting data of all fish composited for tissue analyses have been provided in Appendix VII.

4.2.7 Summary

Overall, populations of walleye, goldeye, lake whitefish and longnose sucker (i.e., KIR species) have not changed substantially over time, nor was there substantial evidence suggesting stress at the population level. Size/age frequency distributions of each species were similar among years, although data collected during earlier years were sometimes limited. Because KIR species within the oil sands region will be monitored over time (i.e., time trend analysis), it is important to ensure that adequate sample sizes are obtained in future years. Size-at-age relationships (estimate of growth) were the most variable among years commonly showing that fish (walleye, goldeye, longnose sucker) collected in 1998 were shorter at any given age relative to data from previous years. This trend was most pronounced in longnose sucker where the discrepancy in length was largest at early ages, suggesting a recent reduction in recruitment size. Although these data suggest possible alterations in growth, results need to be confirmed over time before definitive conclusions can be made. This is particularly true for 1998 data due to abnormally low water levels documented in the lower Athabasca River. Observed changes in habitat availability and fish-habitat associations offered further evidence regarding the potential influence of reduced water levels on regional fish populations.

Based on a literature evaluation and reconnaissance survey, a site on the Athabasca River in the vicinity of Duncan Creek was selected as the most suitable reference site. A series of rapids effectively limits large-scale movement of mobile species between this area and the oil sands region. Differences in habitat were not believed to be sufficient to exclude the area as a reference. Due to the high abundance of longnose sucker, this area was excellent for collecting reference data for sentinel species monitoring; however, low abundance of walleye, goldeye and lake whitefish indicated it was not suitable for KIR species monitoring.

Sentinel species monitoring using longnose sucker indicated significant differences in size-at-age, age distribution, condition, liver size and fecundity between reference and oil sands fish. The response suggests some level of metabolic redistribution consistent with inconsistencies in energy allocation. The observed response in longnose sucker needs to be confirmed in future years to investigate whether it persists or it reflects something particular to 1998 (e.g., low water levels, limited samples sizes). Interestingly, results from the sentinel species evaluation (reference-oil sands comparison) were not consistent with results from the KIR species analysis (time trend analysis). Both are legitimate approaches to monitoring fish populations within the oil sands region; however, they offer different perspectives. Including both in the RAMP ensures the protection of regional fishes and the aquatic environment.

Results from the radiotelemetry study indicated that lake whitefish in the fall moved through the oil sands region and continued upstream of Fort McMurray to access spawning grounds in the vicinity of Mountain and Cascade rapids. Following spawning, most whitefish moved downstream beyond the survey area, presumably to overwinter in Lake Athabasca. The mouths of tributaries within the oil sand region also seemed to provide important foraging or holding habitat for lake whitefish. Walleye movements in the fall were found to mimic the movement of lake whitefish. It was speculated that lake whitefish and/or their eggs provide an important food resource for walleye.

There was no evidence indicating declining quality of fish tissue for consumption. Tissue analyses indicated limited uptake of PAHs by walleye, goldeye, lake whitefish or longnose sucker. Low levels of lead and mercury were detected; however, none exceeded Canadian Consumption Guidelines.

5 ATHABASCA RIVER TRIBUTARIES RESULTS AND DISCUSSION

5.1 WATER AND SEDIMENT QUALITY

5.1.1 Water Quality

5.1.1.1 Steepbank River

Water quality samples collected in the spring and summer of 1998 indicated that conditions in the Steepbank River were generally consistent with historical trends. Dissolved organic carbon (DOC), total organic carbon (TOC), pH and total dissolved solids (TDS) levels, as well as nutrient and dissolved metal concentrations, measured in 1998 were similar to data collected in previous years (Table 5.1). Total metal levels in 1998 tended to be lower than those previously observed at the river mouth, likely as a result of the lower TSS levels observed in 1998 (Table 5.1). Spring and summer river waters were found to be non-toxic, as assessed by Microtox®. Water temperatures ranged from 9.5 to 22.1 ^{o}C in the spring and from 9.0 to 24 ^{o}C in the summer (Table 5.2).

Some of the spring and summer patterns held true for fall water quality. Water samples collected in 1998 were non-toxic, contained low or non-detectable levels of phenolic compounds, naphthenic acids and total recoverable hydrocarbons (Table 5.1). Total and dissolved metal concentrations in the fall of 1998 were consistent with sample TSS levels and historical trends. However, bicarbonate, calcium, chloride, magnesium and sodium concentrations in the Steepbank River in the fall of 1998 were higher than results from earlier sampling events (Appendix Table II-2). This, in turn, resulted in the higher conductance, TDS and total alkalinity levels recorded in 1998 and shown in Table 5.1. Water temperatures in the fall of 1998 ranged from 7.3 to 25.5 ^{o}C (Table 5.2).

The high salt concentrations observed in the fall of 1998 may be the result of below average precipitation. As discussed in Section 2.3, 1998 was a relatively dry year. Groundwater inflows to the Steepbank River may have represented a larger proportion of the overall inflow to the river in 1998.

In 1998, phosphorus, aluminum and iron concentrations in the Steepbank River exceeded guideline levels during spring and summer (Table 5.3). Iron and aluminum levels in the fall of 1998 also exceeded regulatory guidelines. Similar trends were observed in the spring and fall of 1997. Other elements which have been observed at concentrations in excess of guideline levels, either in 1998 or in previous sampling events, are summarized in Table 5.3.

Table 5.1 Summary of Water Quality Results at the Mouth of the Steepbank River

Parameter	Units	Spring			Summer			Fall		
		1998	1997	Historical Median	1998	1997	Historical Median	1998	1997	Historical Median
Conventional Parameters and Major Ions										
conductance	µS/cm	175	107	233	165	-	178	516	141	215
dissolved organic carbon	mg/L	12	12	16.3	17	-	23	11	16	23
pH		7.9	7.8	7.9	8.1	-	8.0	8.4	7.8	7.8
total alkalinity	mg/L	78	53	120	80	-	90	263	63	110
total dissolved solids	mg/L	120	106	134	132	-	100	320	120	126
total organic carbon	mg/L	17	20	-	25	-	21	14	25	-
total suspended solids	mg/L	23	70	1	27	-	3	5	35	1
Nutrients										
nitrogen – ammonia	mg/L	< 0.05	< 0.05	0.01	< 0.05	-	0.07	< 0.05	< 0.05	< 0.01
nitrogen – kjeldahl	mg/L	0.6	1.1	-	0.7	-	0.81	< 0.2	0.15	-
phosphorus, total	mg/L	0.058	0.08	0.111	0.055	-	0.093	0.008	0.045	0.14
phosphorus, total dissolved	mg/L	0.016	0.03	-	0.03	0.02	-	0.006	0.019	-
General Organics and Toxicity										
Microtox IC50 @ 15 min	%	> 91	-	> 91	> 91	> 91	> 91	> 91	-	> 91
Microtox IC25 @ 15 min	%	> 91	-	> 91	> 91	> 91	> 91	> 91	-	> 91
naphthenic acids	mg/L	< 1	2	1	< 1	-	< 1	< 1	< 1	< 1
total phenolics	mg/L	< 0.001	-	0.0035	0.009	-	0.004	0.002	0.001	< 0.001
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	1	2.9	-	< 1	< 0.5	< 0.5	< 1
Metals (Total)										
aluminum (Al)	mg/L	0.17	1.79	0.01	0.36	-	0.04	0.12	0.862	0.05
antimony (Sb)	mg/L	< 0.0008	< 0.0004	0.0002	< 0.0008	-	< 0.0002	< 0.0008	0.0007	< 0.0002
arsenic (As)	mg/L	< 0.001	0.0007	0.0003	< 0.001	-	0.0004	< 0.001	0.0008	0.0002
barium (Ba)	mg/L	0.248	0.033	0.04	0.028	-	0.03	0.0519	0.024	0.03
beryllium (Be)	mg/L	< 0.001	< 0.001	0.001	< 0.001	-	0.001	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.353	0.042	0.12	0.046	-	0.08	0.2	0.024	0.1
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	0.003	< 0.0002	-	< 0.003	< 0.0002	< 0.0002	< 0.003
chromium (Cr)	mg/L	< 0.0008	0.0015	0.002	< 0.0008	-	0.004	< 0.0008	< 0.0004	0.01
copper (Cu)	mg/L	0.001	0.0026	0.002	0.001	-	0.007	0.003	0.001	0.004
iron (Fe)	mg/L	0.46	2.43	0.42	0.85	-	0.67	0.47	1.3	0.7
lead (Pb)	mg/L	< 0.0001	0.0013	0.02	0.0006	-	< 0.02	0.0011	0.0007	< 0.02
manganese (Mn)	mg/L	0.0185	0.0664	0.035	0.0515	-	0.032	0.0191	0.0526	0.015
mercury (Hg)	mg/L	< 0.0002	< 0.0002	0.00005	< 0.0002	-	< 0.00005	< 0.0002	< 0.0001	< 0.00005
molybdenum (Mo)	mg/L	0.0003	0.0002	0.003	0.0002	-	< 0.003	0.0005	0.0002	< 0.003
nickel (Ni)	mg/L	0.0043	0.0007	0.005	0.001	-	< 0.005	0.0052	0.0015	0.007
selenium (se)	mg/L	< 0.0008	< 0.0004	0.0002	< 0.0008	-	< 0.0002	< 0.0008	0.0007	< 0.0002
silver (Ag)	mg/L	< 0.0004	< 0.001	0.002	< 0.0004	-	< 0.002	< 0.0004	< 0.0001	< 0.002
vanadium (V)	mg/L	0.0006	0.004	0.002	0.0012	-	0.0045	0.0004	0.0017	0.002
zinc (Zn)	mg/L	0.061	0.018	0.021	< 0.004	-	0.025	0.01	0.012	0.016
Metals (Dissolved)										
aluminum (Al)	mg/L	0.03	0.16	-	0.01	0.0188	-	0.07	0.0591	-
antimony (Sb)	mg/L	0.0031	< 0.0004	-	< 0.0008	0.0005	-	0.0008	0.0007	-
arsenic (As)	mg/L	< 0.0004	0.0005	-	0.0008	0.0005	-	< 0.0004	0.0004	-
barium (Ba)	mg/L	0.829	0.0227	-	0.0232	0.0245	-	0.0523	0.0163	-
beryllium (Be)	mg/L	< 0.0005	< 0.0005	-	< 0.0005	< 0.0005	-	< 0.0005	< 0.0005	-
boron (B)	mg/L	0.314	0.035	-	0.043	0.06	-	0.243	0.023	-
cadmium (Cd)	mg/L	0.0001	< 0.0001	-	< 0.0001	0.0007	-	< 0.0001	0.0001	-
chromium (Cr)	mg/L	0.0006	< 0.0004	-	< 0.0004	< 0.0004	-	< 0.0004	< 0.0004	-
copper (Cu)	mg/L	0.003	0.002	-	< 0.0006	0.0012	-	0.0028	0.0009	-
iron (Fe)	mg/L	0.33	1.08	-	0.27	0.39	-	0.22	0.29	-
lead (Pb)	mg/L	0.00045	0.00076	-	< 0.0001	0.00606	-	0.0011	0.00059	-
manganese (Mn)	mg/L	0.0149	0.0531	-	0.0015	0.0241	-	0.0138	0.0179	-
mercury (Hg)	mg/L	< 0.0001	< 0.0002	-	< 0.0001	< 0.0002	-	< 0.0001	< 0.0002	-
molybdenum (Mo)	mg/L	0.00044	0.00016	-	0.0002	0.0002	-	0.0005	0.00022	-
nickel (Ni)	mg/L	0.0041	0.0015	-	0.0003	0.0017	-	0.0038	0.0008	-
selenium (Se)	mg/L	< 0.0004	< 0.0004	-	0.0004	< 0.0004	-	< 0.0004	< 0.0004	-
silver (Ag)	mg/L	< 0.0002	< 0.0002	-	< 0.0002	< 0.0002	-	< 0.0002	< 0.0002	-
vanadium (V)	mg/L	0.0004	0.0007	-	0.0015	< 0.0001	-	< 0.0001	< 0.0001	-
zinc (Zn)	mg/L	0.069	0.009	-	< 0.002	0.028	-	0.015	0.013	-

Table 5.2 Summary of Water Temperatures at the Ells, Tar, Steepbank and Muskeg Rivers

Season	Ells River			Tar River			Steepbank River			Muskeg River		
	median	min	max	median	min	max	median	min	max	median	min	max
spring[(a)]	17.3	11.7	23.9	14.4	8.5	21.6	15.8	9.5	22.1	16.1	8.7	22.3
summer (n = 2208)	20.0	11.5	27.0	17.2	8.3	26.5	16.1	9.0	24.0	18.2	11.0	23.6
fall (n = 1011)	15.1	5.1	25.4	15.0	3.5	25.2	14.4	7.3	25.5	16.1	1.9	25.7

(a) For the Ells, Tar and Muskeg Rivers, n = 471; for the Steepbank River, n = 447.

Table 5.3 Summary of Water Quality Results for the Mouth of the Steepbank River that Exceed Regulatory Guidelines

Parameter	Units	Guidelines[(a)] for the Protection of:				Spring			Summer			Fall		
		Aquatic Life		Human Health										
		Acute	Chronic	Carcinogen	Non-carcinogen	1998	1997	Historical Median	1998	1997	Historical Median	1998	1997	Historical Median
Nutrients														
phosphorus, total	mg/L		0.05			C	C	C	C		C			C
General Organics and Toxicity														
total phenolics	mg/L		0.005						C					
Metals (Total)														
aluminum (Al)	mg/L		0.1			C	C		C			C	C	
arsenic (As)	mg/L	0.36	0.01	0.000018		HC *	HC	HC	HC *		HC	HC *	HC	HC
cadmium (Cd)	mg/L	0.007	0.0018					C			C *			C *
iron (Fe)	mg/L		1		0.3	HNC	C HNC	HNC	HNC		HNC	HNC	C HNC	HNC
lead (Pb)	mg/L	0.17	0.007					C			C *			C *
manganese (Mn)	mg/L				0.05		HNC		HNC				HNC	
mercury (Hg)	mg/L	0.002	0.000012		0.00014	C HNC*	C HNC*	C	C HNC*		C *	C HNC*	C *	C *
zinc (Zn)	mg/L	0.19	0.05			C								

(a) Derivation of guidelines shown in Appendix Table II-10.

* Although lab reported non-detectable levels of substance, the method detection limit exceeds the guideline limit.

C = chronic guideline exceeded; HNC = human health non-carcinogen guidelines exceeded; HC = human health carcinogen guideline exceeded. Refer to Appendix Table II-8 for more information on guidelines.

5.1.1.2 Muskeg River

River Mouth

Spring, summer and fall water quality observed at the mouth of the Muskeg River in 1998 was generally consistent with historical seasonal information (Table 5.4). Exceptions to this general trend include higher calcium, sulphate and bicarbonate concentrations in the summer and fall of 1998 (Table II-3), which resulted in the higher TDS, conductance and total alkalinity measurements reported for the summer and fall of 1998 (Table 5.4). Since 1998 was a relatively dry year, groundwater inflows may have represented a larger proportion of the overall inflow to the river in the summer and fall of 1998, resulting in higher concentrations of major ions observed at the river mouth.

Muskeg River waters have been found to be consistently non-toxic and contain non-detectable levels of naphthenic acids during all seasons and under all flow conditions (Table 5.4). Iron and arsenic concentrations at the mouth of the Muskeg River generally exceeded regulatory guidelines in the spring, summer and fall of 1998 and in previous years (Table 5.5). Total phenolics, phosphorus, aluminum, mercury, zinc, cadmium and manganese concentrations have also been found to exceed guideline levels either in 1998 or in previous years. In 1998, water temperatures at the mouth of the Muskeg River were found to vary from 8.7 to 22.3 ^{o}C in the spring and from 1.9 to 25.7 ^{o}C in the fall (Table 5.2).

Upper Muskeg River

Fall and winter water quality in the upper Muskeg River in 1998 was generally consistent with historical information (Table 5.6). Differences between water quality samples collected in 1998 and in previous years are summarized in Table 5.7.

Table 5.4 Summary of Water Quality Results at the Mouth of the Muskeg River

Parameter	Units	Spring		Summer			Fall		
		1998	Historical Median	1998	1997	Historical Median	1998	1997	Historical Median
Conventional Parameters and Major Ions									
conductance	µS/cm	246	280	351	281	279	627	220	310
dissolved organic carbon	mg/L	11	16	17	18	24	11	17	24
pH		8.1	8.0	8.4	8.4	8.0	8.3	7.8	7.9
total alkalinity	mg/L	113	144	167	144	147	264	105	153
total dissolved solids	mg/L	150	167	220	190	208	482	184	169
total organic carbon	mg/L	16	19	24	24	22	12	24	24
total suspended solids	mg/L	6	< 0.4	16	6	4	3	70	4
Nutrients									
nitrogen – ammonia	mg/L	< 0.05	< 0.01	< 0.05	< 0.05	0.01	0.05	0.06	0.04
nitrogen – kjeldahl	mg/L	1	-	0.9	0.6	1.21	0.6	0.7	0.6
phosphorus, total	mg/L	0.02	0.031	0.022	0.027	0.025	0.008	0.072	0.04
phosphorus, total dissolved	mg/L	0.009	-	0.016	0.015	-	0.008	0.014	-
General Organics and Toxicity									
Microtox IC50 @ 15 min	%	> 91	> 91	> 91	> 91	> 91	> 91	> 91	> 91
Microtox IC25 @ 15 min	%	> 91	> 91	> 91	> 91	> 91	> 91	> 91	> 91
naphthenic acids	mg/L	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
total phenolics	mg/L	< 0.001	0.006	0.009	< 0.001	0.001	0.001	< 0.001	0.0005
total recoverable hydrocarbons	mg/L	< 0.5	3	3	< 0.5	< 1	< 0.5	< 0.5	< 1
Metals (Total)									
aluminum (Al)	mg/L	0.12	< 0.01	0.06	0.073	0.049	0.12	1.2	0.055
antimony (Sb)	mg/L	0.0038	< 0.0002	< 0.0008	0.0005	< 0.0002	< 0.0008	0.0005	< 0.0002
arsenic (As)	mg/L	< 0.001	0.0002	< 0.001	0.0005	0.0002	< 0.001	0.0009	0.001
barium (Ba)	mg/L	0.734	0.03	0.0527	0.0333	0.03	0.0917	0.0384	0.03
beryllium (Be)	mg/L	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.041	0.055	0.062	0.052	0.1	0.028	0.034	0.1
cadmium (Cd)	mg/L	0.0006	< 0.003	< 0.0002	< 0.0002	< 0.001	< 0.0002	< 0.0002	0.003
chromium (Cr)	mg/L	< 0.0008	< 0.002	< 0.0008	< 0.0004	0.003	< 0.0008	0.0007	0.006
copper (Cu)	mg/L	< 0.001	0.001	< 0.001	0.0077	0.004	0.001	0.0016	0.001
iron (Fe)	mg/L	0.41	0.525	0.54	0.69	0.84	0.49	1.81	1.12
lead (Pb)	mg/L	0.0005	< 0.02	0.0003	0.0008	< 0.02	0.0008	0.0012	< 0.02
manganese (Mn)	mg/L	0.018	0.0315	0.0364	0.0403	0.0355	0.0331	0.115	0.0505
mercury (Hg)	mg/L	< 0.0002	< 0.00005	< 0.0002	< 0.0001	0.000075	< 0.0002	< 0.0001	< 0.000075
molybdenum (Mo)	mg/L	0.0002	0.0005	0.0002	0.0002	< 0.003	0.0003	< 0.0001	0.001
nickel (Ni)	mg/L	0.0034	< 0.005	< 0.0002	0.0016	< 0.005	0.006	0.0016	0.005
selenium (Se)	mg/L	< 0.0008	< 0.0002	< 0.0008	< 0.0004	< 0.0002	< 0.0008	< 0.0004	< 0.0002
silver (Ag)	mg/L	< 0.0004	< 0.002	< 0.0004	< 0.0001	< 0.002	< 0.0004	< 0.0001	0.0025
vanadium (V)	mg/L	0.0005	< 0.002	0.0029	0.0003	< 0.002	0.0002	0.0029	0.002
zinc (Zn)	mg/L	0.074	0.0065	< 0.004	0.009	0.031	0.016	0.016	0.025
Metals (Dissolved)									
aluminum (Al)	mg/L	0.03	-	< 0.01	0.0094	-	0.09	0.0269	-
antimony (Sb)	mg/L	0.0037	-	< 0.0008	0.0008	-	< 0.0008	-	-
arsenic (As)	mg/L	< 0.0004	< 0.0005	0.0005	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.001
barium (Ba)	mg/L	0.795	-	0.0484	0.0291	-	0.0929	0.0243	-
beryllium (Be)	mg/L	< 0.0005	< 0.005	< 0.0005	< 0.0005	< 0.005	< 0.0005	< 0.0005	-
boron (B)	mg/L	0.266	0.11	0.054	0.053	0.09	0.025	0.033	0.085
cadmium (Cd)	mg/L	< 0.0001	< 0.001	< 0.0001	0.0001	< 0.001	< 0.0001	< 0.0001	-
chromium (Cr)	mg/L	0.0005	-	< 0.0004	< 0.0004	< 0.003	< 0.0004	< 0.0004	0.0005
copper (Cu)	mg/L	0.0026	0.001	0.0006	0.0009	< 0.001	0.0013	0.0011	-
iron (Fe)	mg/L	0.29	0.48	0.14	0.41	0.12	0.44	0.25	-
lead (Pb)	mg/L	0.00045	-	0.0004	0.00381	-	0.0009	0.0003	-
manganese (Mn)	mg/L	0.0115	-	0.0013	0.0199	-	0.0354	0.0295	-
mercury (Hg)	mg/L	< 0.0001	-	< 0.0001	< 0.0002	-	< 0.0001	0.0002	-
molybdenum (Mo)	mg/L	0.00029	-	0.0001	0.00009	-	0.0002	0.00008	-
nickel (Ni)	mg/L	0.0027	-	0.0002	0.0008	-	0.0044	0.0004	-
selenium (Se)	mg/L	< 0.0004	< 0.0005	< 0.0004	< 0.0004	< 0.0005	< 0.0004	0.0004	< 0.0005
silver (Ag)	mg/L	< 0.0002	-	< 0.0002	< 0.0002	-	< 0.0002	< 0.0002	-
vanadium (V)	mg/L	0.0004	< 0.001	0.0005	< 0.0001	< 0.001	< 0.0001	0.0002	-
zinc (Zn)	mg/L	0.074	< 0.001	< 0.002	0.017	0.001	0.004	0.014	-

Table 5.5 Water Quality Results for the Mouth of the Muskeg River that Exceed Regulatory Guidelines

Parameter	Units	Guidelines[a] for the Protection of: Aquatic Life		Human Health		Spring		Summer			Fall		
		Acute	Chronic	Carcinogen	Non-carcinogen	1998	Historical Median	1998	1997	Historical Median	1998	1997	Historical Median
Nutrients													
phosphorus, total	mg/L		0.05									C	
General Organics and Toxicity													
total phenolics	mg/L		0.005				C	C					
Metals (Total)													
aluminum (Al)	mg/L		0.1			C					C	C	
arsenic (As)	mg/L	0.36	0.01	0.000018		HC *	HC	HC *	HC	HC	HC *	HC	HC
cadmium (Cd)	mg/L	0.007	0.0018				C *						C
iron (Fe)	mg/L		1		0.3	HNC	HNC	HNC	HNC	HNC	HNC	C HNC	C HNC
lead (Pb)	mg/L	0.17	0.007				C *			C *			C *
manganese (Mn)	mg/L				0.05							HNC	HNC
mercury (Hg)	mg/L	0.002	0.000012		0.00014	C HNC*	C *	C HNC*	C *	C	C HNC*	C *	C *
zinc (Zn)	mg/L	0.19	0.05			C							

[a] Derivation of guidelines shown in Table II-10.

* Although lab reported non-detectable levels of substance, the method detection limit exceeds the guideline limit.

C = chronic guideline exceeded; HNC = human health non-carcinogen guidelines exceeded; HC = human health carcinogen guideline exceeded. Refer to Appendix Table II-8 for more information on guidelines.

Table 5.6 Water Quality in the Upper Muskeg River

Parameter	Units	Fall			Winter		
			Historical			Historical	
		1998	median	n	1998	median	n
Conventional Parameters and Major Ions							
conductance	µS/cm	441	277	4	556	530	11
dissolved organic carbon	mg/L	24	25	3	24	22	11
pH		7.3	7.7	4	7.0	7.4	11
total alkalinity	mg/L	235	166	6	318	305	12
total dissolved solids	mg/L	320	172	6	340	336	12
total organic carbon	mg/L	30	23	6	34	22	12
total suspended solids	mg/L	25	3	6	176	8	12
Nutrients							
nitrogen – ammonia	mg/L	0.3	0.1	2	1.2	1.0	1
nitrogen – kjeldahl	mg/L	1.6	1.1	6	3.9	1.4	12
phosphorus, total	mg/L	0.27	0.04	6	2.31	0.09	12
phosphorus, total dissolved	mg/L	0.02	-	-	0.04	-	-
General Organics and Toxicity							
acute aquatic toxicity[a]	TUa	0	-	-	0	-	-
chronic aquatic toxicity[b]	TUc	2.9	-	-	0	-	-
naphthenic acids	mg/L	12	-	-	< 2	-	-
total phenolics	mg/L	0.005	-	-	0.012	-	-
total recoverable hydrocarbons	mg/L	0.6	0.3	2	< 0.5	0.3	1
Metals (Total)							
aluminum (Al)	mg/L	0.11	0.05	6	0.17	0.035	12
antimony (Sb)	mg/L	< 0.0008	-	-	< 0.0008	-	-
arsenic (As)	mg/L	< 0.001	0.00055	4	< 0.001	0.0004	1
barium (Ba)	mg/L	0.088	-	-	0.2	-	-
beryllium (Be)	mg/L	< 0.001	-	-	< 0.001	-	-
boron (B)	mg/L	0.008	0.035	2	0.081	0.06	1
cadmium (Cd)	mg/L	< 0.0002	< 0.001	2	< 0.0002	< 0.001	1
chromium (Cr)	mg/L	< 0.0008	0.0035	2	0.0056	< 0.001	1
copper (Cu)	mg/L	< 0.001	< 0.001	2	0.001	< 0.001	1
iron (Fe)	mg/L	13.9	1.13	2	31.9	7.8	1
lead (Pb)	mg/L	0.0003	0.002	2	0.0008	< 0.002	1
manganese (Mn)	mg/L	0.786	0.071	2	0.75	1.2	1
mercury (Hg)	mg/L	< 0.0002	< 0.0001	6	0.0003	< 0.0001	12
molybdenum (Mo)	mg/L	0.0001	-	-	0.0003	-	-
nickel (Ni)	mg/L	0.004	0.001	2	0.0128	< 0.001	1
selenium (Se)	mg/L	< 0.0008	0.00055	2	< 0.0008	0.0009	1
silver (Ag)	mg/L	< 0.0004	-	-	< 0.0004	-	-
vanadium (V)	mg/L	0.0004	< 0.001	2	0.0005	< 0.001	1
zinc (Zn)	mg/L	0.051	0.0135	2	0.044	0.002	1
Metals (Dissolved)							
aluminum (Al)	mg/L	0.01	-	-	0.08	-	-
antimony (Sb)	mg/L	< 0.0008	-	-	< 0.0008	-	-
arsenic (As)	mg/L	< 0.0004	0.00025	2	0.0005	0.0004	11
barium (Ba)	mg/L	0.0422	-	-	0.125	-	-
beryllium (Be)	mg/L	< 0.0005	-	-	< 0.0005	-	-
boron (B)	mg/L	0.003	0.075	4	< 0.002	0.105	10
cadmium (Cd)	mg/L	< 0.0001	-	-	< 0.0001	-	-
chromium (Cr)	mg/L	< 0.0004	< 0.003	4	0.0016	< 0.003	11
copper (Cu)	mg/L	0.001	-	-	0.0014	-	-
iron (Fe)	mg/L	0.89	-	-	19	-	-
lead (Pb)	mg/L	0.0002	-	-	0.0008	-	-
manganese (Mn)	mg/L	0.626	-	-	0.751	-	-
mercury (Hg)	mg/L	< 0.0001	-	-	< 0.0001	-	-
molybdenum (Mo)	mg/L	< 0.0001	-	-	< 0.0001	-	-
nickel (Ni)	mg/L	0.0033	-	-	0.0043	-	-
selenium (Se)	mg/L	< 0.0004	0.0002	2	< 0.0004	< 0.0002	11
silver (Ag)	mg/L	< 0.0002	-	-	< 0.0002	-	-
vanadium (V)	mg/L	< 0.0001	-	-	< 0.0001	-	-
zinc (Zn)	mg/L	0.01	-	-	0.018	-	-

[a] Calculated based on LC_{50} results from the 96 hr rainbow trout survival test; TUa = 100 / LC_{50} value; a result of 0 = non-toxic.

[b] Calculated based on IC_{25} results from the 7 d *Ceriodaphnia dubia* reproduction test; TUc = 100 / IC_{25} value; a result of 0 = non-toxic.

Table 5.7 Summary List of the Major Differences Observed between Water Quality Samples Collected from the Upper Muskeg River in 1998 and in Previous Years

Season	Parameter: Higher in 1998	Parameter: Lower in 1998
Fall	• total dissolved solids • total suspended solids (TSS) • total phosphorus • biochemical oxygen demand (BOD_5) • total aluminum • total iron • total manganese	• total and dissolved boron • total chromium • total lead
Winter	• TSS • total kjeldahl nitrogen • total phosphorus • BOD_5 • total aluminum • total iron • total zinc	• dissolved boron

Total aluminum, iron, manganese and zinc levels were higher in 1998 than in previous years. This may have been the result of above average suspended sediment loads (e.g., TSS levels of 176 mg/L in December 1998 compared to a historical median TSS value of 8 mg/L – Table 5.7). Organic loading to the Muskeg River may have been higher in 1998 than in previous years, as suggested by the higher than normal 5 day BOD readings observed during both sampling events (Table II-4).

In the fall of 1998, sample waters from the upper Muskeg River contained 12 mg/L of naphthenic acids (Table 5.6). They were also chronically toxic to fathead minnows and *Ceriodaphnia dubia* (Appendix Table II-4), with an associated chronic aquatic toxicity value of 2.9 TUc (chronic toxicity units) (Table 5.6). No acute aquatic toxicity was observed. Waters collected from the same location on December 8, 1998, were non-toxic (chronic or acute) and contained non-detectable levels of naphthenic acids.

Iron and manganese concentrations in the upper Muskeg River exceeded regulatory guidelines in 1998 and in previous years (Table 5.8). Total phenolics, phosphorus, aluminum and mercury concentrations exceeded guideline levels in the upper Muskeg River in the winter of 1998. Chronic toxicity levels, as defined by *Ceriodaphnia dubia* test results, detected in the fall of 1998 exceeded the regulatory guideline of 1.0 TUc. Other elements that have been observed at concentrations in excess of guideline levels, either in 1998 or in previous sampling events, are summarized in Table 5.8.

Table 5.8 Water Quality Results for the Upper Muskeg River that Exceed Regulatory Guidelines

Parameter	Units	Guidelines for the protection of[a]				Fall		Winter	
		Aquatic life		Human health			Historical		Historical
		acute	chronic	carcinogen	non-carcinogen	1998	Median	1998	Median
Nutrients									
phosphorus, total	mg/L		0.05			C		C	C
General Organics and Toxicity									
total phenolics	mg/L		0.005					C	
chronic aquatic toxicity	TUc		1			C			
Metals (Total)									
aluminum	mg/L		0.1					C	
arsenic	mg/L	0.36	0.01	0.000018		HC*	HC	HC*	HC
iron	mg/L		1		0.3	C HNC	C HNC	C HNC	C HNC
manganese	mg/L				0.05	HNC	HNC	HNC	HNC
mercury	mg/L	0.0024	1E-05		0.00014	C HNC*	C*	C HNC	C*

[a] Derivation of guidelines shown in Appendix Table II-10.

* Although lab report non-detectable levels of substance, the method detection limit exceeds the guideline limit.

5.1.1.3 MacKay River

The MacKay River was only sampled once in 1998, on September 23. Water quality in the MacKay River was consistent with the quality observed in the Muskeg River. Nutrient, metal, TOC and DOC levels measured in 1998 were comparable to historical data, and major ion concentrations were higher in the fall of 1998 than in previous years (Tables 5.9 and II-5). Phosphorus, aluminum, arsenic and iron levels at the mouth of MacKay River exceeded regulatory guidelines in the fall of 1998 and in previous years (Table 5.10).

5.1.1.4 Ells and Tar Rivers

Water quality data collected from the mouths of the Ells and Tar rivers in the spring, summer and fall of 1998 were generally consistent with available historical data. The exceptions include TSS concentrations at the mouth of the Tar River in the spring of 1998 that were much lower than would be expected based on historical trends (Table 5.9). Consistent with the other tributaries, TDS, calcium, manganese and sulphate concentrations at the mouth of the Tar River were also generally higher in the summer and fall of 1998 than in previous years (Table II-6). This trend was less apparent in the Ells River.

Table 5.9 Summary of Water Quality Results at the Mouth of the Ells, Tar and MacKay Rivers

Parameter	Units	Ells River						Tar River						MacKay River (Fall)	
		Spring		Summer		Fall		Spring		Summer		Fall			
		1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median
Conventional Parameters and Major Ions															
conductance	µS/cm	197	210	247	186	249	193	270	276	307	281	493	331	576	270
dissolved organic carbon	mg/L	12	18	16	14	12	20	10	23	13	14	12	12	20	30
pH		8	7.8	8.1	7.9	7.9	8.0	7.9	7.8	8.1	7.9	8.1	7.8	8.3	7.9
total alkalinity	mg/L	74	78	103	76	101	105	105	106	134	118	210	145	202	121
total dissolved solids	mg/L	130	148	166	87	174	107	180	191	208	169	330	204	342	172
total organic carbon	mg/L	15	20	20	17	13	22	12	23	18	14	15	14	26	34
total suspended solids	mg/L	25	21	< 2	23	8	28	76	167	12	13	75	5	< 2	11
Nutrients															
nitrogen – ammonia	mg/L	< 0.05	-	< 0.05	-	0.11	-	0.02	-	< 0.05	-	0.05	-	< 0.05	-
nitrogen - total kjeldahl	mg/L	0.3	1.5	0.9	0.9	0.5	0.9	0.8	2.1	0.8	1.0	0.6	0.5	1.3	1.1
phosphorus, total	mg/L	0.05	0.10	0.03	0.1	0.01	0.1	0.13	0.12	0.08	0.09	0.08	0.11	0.01	0.05
phosphorus, total dissolved	mg/L	0.02	-	0.02	-	0.01	-	0.03	-	0.04	-	0.02	-	0.004	-
General Organics and Toxicity															
Microtox IC50 @ 15 min	%	-	-	> 91	-	> 91	-	> 91	-	> 91	-	> 91	-	-	-
Microtox IC25 @ 15 min	%	-	-	>91	-	>91	-	>91	-	>91	-	>91	-	-	-
naphthenic acids	mg/L	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-	< 1	-
total phenolics	mg/L	< 0.001	0.006	0.008	0.005	0.004	0.003	< 0.001	0.007	0.007	-	0.004	-	0.004	-
total recoverable hydrocarbons	mg/L	< 0.5	-	2.5	-	0.7	-	< 0.5	-	< 0.5	-	1.1	-	0.8	-
Metals (Total)															
aluminum (Al)	mg/L	1.51	0.15	0.28	0.19	0.06	0.21	0.6	0.57	0.54	0.43	0.47	0.20	0.05	0.15
antimony (Sb)	mg/L	0.003	-	< 0.0008	-	< 0.0008	-	< 0.0008	-	< 0.0008	-	< 0.0008	-	< 0.0008	-
arsenic (As)	mg/L	0.001	-	0.001	0.005	< 0.001	< 0.001	< 0.001	-	0.002	0.005	0.002	0.012	< 0.001	0.004
barium (Ba)	mg/L	0.361	-	0.0378	-	0.0379	-	0.0386	-	0.0488	-	0.0685	-	0.0487	-
beryllium (Be)	mg/L	< 0.001	-	< 0.001	-	< 0.001	-	< 0.001	-	< 0.001	-	< 0.001	-	< 0.001	-
boron (B)	mg/L	0.49	-	0.084	-	0.067	-	0.006	-	0.085	-	0.145	-	0.14	-
cadmium (Cd)	mg/L	0.0004	-	< 0.0002	< 0.001	< 0.0002	0.004	< 0.0002	-	< 0.0002	-	< 0.0002	-	< 0.0002	-
chromium (Cr)	mg/L	0.002	-	< 0.0008	0.017	< 0.0008	0.003	0.0009	-	< 0.0008	-	0.0013	-	< 0.0008	-
copper (Cu)	mg/L	0.003	-	0.01	0.014	0.002	0.006	0.002	-	0.002	-	0.004	-	0.001	-
iron (Fe)	mg/L	1.62	-	0.59	0.3	0.45	0.1	1.56	-	1.33	-	2.63	-	0.31	-
lead (Pb)	mg/L	0.0006	-	0.0013	-	0.0004	-	0.0019	-	0.0006	-	0.0011	-	0.0002	-
manganese (Mn)	mg/L	0.0504	-	0.0461	-	0.0245	-	0.0485	-	0.0589	-	0.169	-	0.0238	-
mercury (Hg)	mg/L	< 0.0002	0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	< 0.0002	< 0.0001	0.0002	< 0.00015	< 0.0002	< 0.0001

Table 5.9 Summary of Water Quality Results at the Mouth of the Ells, Tar and MacKay Rivers (continued)

Parameter	Units	Ells River						Tar River						MacKay River	
		Spring		Summer		Fall		Spring		Summer		Fall		(Fall)	
		1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median
molybdenum (Mo)	mg/L	0.0008	-	0.0009	-	0.0008	-	0.0011	-	0.0013	-	0.002	-	0.0006	-
nickel (Ni)	mg/L	0.0031	-	0.0029	-	0.0064	-	0.0042	-	0.0029	-	0.0122	-	0.0027	-
selenium (Se)	mg/L	< 0.0008	-	< 0.0008	-	< 0.0008	-	< 0.0008	-	< 0.0008	-	< 0.0008	-	< 0.0008	-
silver (Ag)	mg/L	< 0.0004	-	< 0.0004	-	< 0.0004	-	< 0.0004	-	< 0.0004	-	< 0.0004	-	< 0.0004	-
vanadium (V)	mg/L	0.0038	-	0.002	-	0.0017	-	0.0022	0.002	0.0027	0.002	0.0017	< 0.001	< 0.0002	-
zinc (Zn)	mg/L	0.068	-	0.019	0.01	0.016	0.012	0.038	-	0.011	-	0.019	-	0.004	-
Metals (Dissolved)															
aluminum (Al)	mg/L	0.04	-	< 0.01	-	0.05	-	0.04	-	0.01	-	0.02	-	0.01	-
antimony (Sb)	mg/L	0.003	-	< 0.0008	-	< 0.0008	-	0.0052	-	< 0.0008	-	< 0.0008	-	< 0.0008	-
arsenic (as)	mg/L	0.0009	0.0007	0.001	0.0003	0.0006	0.0019	< 0.0004	0.0028	0.0012	0.0004	0.0007	0.0007	0.0004	0.001
barium (Ba)	mg/L	0.703	-	0.0336	-	0.0371	-	0.881	-	0.0391	-	0.0538	-	0.0471	-
beryllium (Be)	mg/L	< 0.0005	-	< 0.0005	-	< 0.0005	-	< 0.0005	< 0.005	< 0.0005	-	< 0.0005	-	< 0.0005	-
boron (B)	mg/L	0.274	0.1	0.082	0.2	0.076	-	0.333	0.17	0.075	0.13	0.134	0.13	0.181	0.155
cadmium (Cd)	mg/L	0.0001	0.001	< 0.0001	-	< 0.0001	-	< 0.0001	< 0.001	< 0.0001	-	< 0.0001	-	< 0.0001	< 0.3
chromium (Cr)	mg/L	0.0005	< 0.003	< 0.0004	0.003	< 0.0004	0.0055	0.004	< 0.003	< 0.0004	< 0.003	< 0.0004	< 0.003	< 0.0004	< 0.003
copper (Cu)	mg/L	0.0028	0.002	0.001	-	0.0013	-	0.0027	0.001	0.0012	-	0.0205	-	0.0019	-
iron (Fe)	mg/L	0.46	0.28	0.11	-	0.23	-	0.5	< 0.001	0.44	-	0.36	-	0.23	-
lead (Pb)	mg/L	0.00087	-	< 0.0001	-	0.0003	-	0.00047	-	< 0.0001	-	0.0002	-	0.0001	-
manganese (Mn)	mg/L	0.0178	-	0.0013	-	0.0244	-	0.0286	-	0.0029	-	0.132	-	0.0106	-
mercury (Hg)	mg/L	< 0.0001	-	< 0.0001	-	< 0.0001	-	< 0.0001	-	< 0.0001	-	< 0.0001	-	< 0.0001	-
molybdenum (Mo)	mg/L	0.00098	-	0.001	-	0.0008	-	0.00112	-	0.0014	-	0.0018	-	0.0005	-
nickel (Ni)	mg/L	0.0056	-	0.0014	-	0.0031	-	0.0033	-	0.0019	-	0.0051	-	0.0023	-
selenium (Se)	mg/L	0.0008	0.0004	< 0.0004	0.0002	< 0.0004	< 0.0002	< 0.0004	0.0005	< 0.0004	< 0.0002	< 0.0004	< 0.0002	< 0.0004	< 0.0002
silver (Ag)	mg/L	< 0.0002	-	< 0.0002	-	< 0.0002	-	< 0.0002	-	< 0.0002	-	< 0.0002	-	< 0.0002	-
vanadium (V)	mg/L	0.0006	< 0.001	0.0012	-	< 0.0001	-	0.0015	< 0.001	0.0021	-	< 0.0001	-	0.0002	-
zinc (Zn)	mg/L	0.063	-	< 0.002	-	0.005	-	0.082	< 0.001	< 0.002	-	0.009	-	0.005	-

Table 5.10 Water Quality Results for the Mouths of the Ells, Tar and MacKay Rivers that Exceed Regulatory Guidelines

		Guidelines[(a)] for the Protection of:				Ells River						Tar River						MacKay River (Fall)	
						Spring		Summer		Fall		Spring		Summer		Fall			
		Aquatic Life		Human Health															
Parameter	Units	Acute	Chronic	Carcinogen	Non-carcinogen	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median	1998	Historical Median
Nutrients																			
phosphorus, total	mg/L		0.05			C	C		C		C	C	C	C	C	C	C		C
General Organics and Toxicity																			
total phenolics	mg/L		0.005				C	C					C	C					
Metals (Total)																			
aluminum (Al)	mg/L		0.1			C	C	C	C		C	C	C	C	C	C	C		C
arsenic (As)	mg/L	0.36	0.01	0.000018		HC		HC	HC	HC *	HC *	HC *		HC	HC	HC	C HC	HC *	HC
cadmium (Cd)	mg/L	0.01	0.0018								C								
iron (Fe)	mg/L		1		0.3	C HNC		HNC		HNC		C HNC		C HNC		C HNC		HNC	
manganese (Mn)	mg/L				0.05	HNC								HNC		HNC			
mercury (Hg)	mg/L	0	1E-05		0.00014	C HNC*	C	C HNC*	C *	C HNC*	C *	C HNC*	C *	C HNC*	C *	C HNC	C HNC*	C HNC*	C *
zinc (Zn)	mg/L	0.19	0.05			C													

[(a)] Derivation of guidelines shown in Appendix Table II-10.

* Although lab report non-detectable levels of substance, the method detection limit exceeds the guideline limit.

C = chronic guideline exceeded; HNC = human health non-carcinogen guidelines exceeded; HC = human health carcinogen guideline exceeded. Refer to Appendix Table II-10 for more information on guidelines.

In 1998, samples from both rivers were non-toxic (by Microtox®) and had non-detectable levels of naphthenic acids (Table 5.9). Iron concentrations in the mouth of both the Ells and Tar rivers exceeded guideline levels in 1998 (Table 5.10). Aluminum, arsenic and total phosphorus concentrations in both rivers generally exceeded regulatory guidelines in 1998 and in previous years. Other elements that have been observed at concentrations in excess of guideline levels are summarized in Table 5.10. Water temperatures at the mouth of these two rivers varied from 8.5 to 23.9 ^{o}C in the spring and from 3.5 to 25.4 ^{o}C in the fall (Table 5.2).

5.1.1.5 Wapasu Creek

Water quality data collected from Wapasu Creek in 1998 were generally consistent with historical trends, with the exception of some parameters. In 1998, organic carbon, nutrient and total iron concentrations were lower than in previous years (Table 5.11). Bicarbonate, conductance, zinc and TDS levels were higher than historical median values. The sample collected in the winter of 1998 was non-toxic and contained non-detectable levels of naphthenic acids (Table 5.11). Iron, phosphorus and manganese concentrations exceeded guideline levels in 1998 and in previous years (Table 5.12). Total phenolics, arsenic and mercury have also been found, either in 1998 or in earlier years, to exceed regulatory guidelines.

5.1.1.6 Muskeg Creek

Water quality at the mouth of Muskeg Creek was different in the fall of 1998 than in previous years (Table 5.11). Differences between the two data sets included higher concentrations of the following elements in 1998 compared to historical levels:

- calcium
- chloride
- sodium
- bicarbonate
- conductance
- TDS
- hardness
- BOD
- ammonia
- total iron
- total manganese

The Muskeg River watershed experienced lower than normal precipitation rates in 1998 (Golder 1999a). Therefore, groundwater inflows may have represented a larger proportion of the overall flow in Muskeg Creek in the fall of 1998, resulting in the relatively high levels of major ions observed at the river mouth. A large proportion of the total aluminum and manganese detected in the 1998 sample were present in their dissolved form (Table 5.11).

Table 5.11 Summary of Water Quality Results in Muskeg and Wapasu Creeks

Parameter	Units	Wapasu Creek			Muskeg Creek		
			Historical			Historical	
		1998	median	n	1998	median	n
Conventional Parameters and Major Ions							
conductance	µS/cm	524	410	5	671	199	8
dissolved organic carbon	mg/L	11	34	4	21	25	8
pH		7.4	7.1	4	7.4	7.2	9
total alkalinity	mg/L	292	216	6	313	107	15
total dissolved solids	mg/L	300	241	6	378	115	15
total organic carbon	mg/L	14	33	6	27	30	13
total suspended solids	mg/L	23	23	6	9	1	15
Nutrients							
nitrogen – ammonia	mg/L	0.2	0.5	2	0.3	0.04	6
nitrogen – kjeldahl	mg/L	0.4	2.2	6	1.1	0.8	13
phosphorus, total	mg/L	0.06	0.20	6	0.07	0.03	15
phosphorus, total dissolved	mg/L	0.02	-	-	0.03	-	-
General Organics and Toxicity							
acute aquatic toxicity[(a)]	TUa	0	-	-	0	-	-
chronic aquatic toxicity[(b)]	TUc	0	-	-	6.7	-	-
naphthenic acids	mg/L	< 1	-	-	< 1	< 1	2
total phenolics	mg/L	0.006	-	-	0.005	-	-
total recoverable hydrocarbons	mg/L	< 0.5	0.6	2	< 0.5	0.1	7
Metals (Total)							
aluminum (Al)	mg/L	0.05	0.025	6	0.05	0.01	15
antimony (Sb)	mg/L	< 0.0008	-	-	< 0.0008	-	-
arsenic (As)	mg/L	< 0.001	0.0009	2	< 0.001	0.00035	10
barium (Ba)	mg/L	0.0588	-	-	0.0668	0.03	2
beryllium (Be)	mg/L	< 0.001	-	-	< 0.001	< 0.001	2
boron (B)	mg/L	0.081	0.115	2	0.15	0.06	8
cadmium (Cd)	mg/L	< 0.0002	< 0.001	2	< 0.0002	< 0.001	8
chromium (Cr)	mg/L	0.0024	0.0015	2	< 0.0008	0.001	8
copper (Cu)	mg/L	0.002	< 0.001	2	< 0.001	< 0.001	8
iron (Fe)	mg/L	2.07	11.86	2	1.75	0.33	8
lead (Pb)	mg/L	0.001	< 0.002	2	0.0002	< 0.002	8
manganese (Mn)	mg/L	0.87	0.52	2	0.534	0.0185	8
mercury (Hg)	mg/L	0.0004	< 0.0001	6	< 0.0002	< 0.0001	13
molybdenum (Mo)	mg/L	0.0004	-	-	< 0.0001	< 0.003	2
nickel (Ni)	mg/L	0.0041	< 0.001	2	0.0042	< 0.001	8
selenium (Se)	mg/L	< 0.0008	0.0005	2	< 0.0008	0.00045	6
silver (Ag)	mg/L	< 0.0004	-	-	< 0.0004	0.0025	2
vanadium (V)	mg/L	0.0002	< 0.001	2	0.0004	< 0.001	8
zinc (Zn)	mg/L	0.014	0.0055	2	0.004	0.0055	8
Metals (Dissolved)							
aluminum (Al)	mg/L	0.05	-	-	0.03	-	-
antimony (Sb)	mg/L	< 0.0008	-	-	< 0.0008	-	-
arsenic (As)	mg/L	< 0.0004	< 0.001	4	0.0005	< 0.001	3
barium (Ba)	mg/L	0.0532	-	-	0.0627	-	-
beryllium (Be)	mg/L	< 0.0005	-	-	< 0.0005	-	-
boron (B)	mg/L	< 0.002	0.13	4	0.08	0.1	7
cadmium (Cd)	mg/L	0.0001	-	-	< 0.0001	-	-
chromium (Cr)	mg/L	< 0.0004	< 0.003	4	0.0008	< 0.003	7
copper (Cu)	mg/L	0.0026	-	-	0.0007	-	-
iron (Fe)	mg/L	1.13	-	-	1.02	-	-

Parameter	Units	Wapasu Creek 1998	Wapasu Creek Historical median	Wapasu Creek Historical n	Muskeg Creek 1998	Muskeg Creek Historical median	Muskeg Creek Historical n
lead (Pb)	mg/L	0.0008	-	-	0.0001	-	-
manganese (Mn)	mg/L	0.866	-	-	0.522	-	-
mercury (Hg)	mg/L	< 0.0001	-	-	< 0.0001	-	-
molybdenum (Mo)	mg/L	< 0.0001	-	-	< 0.0001	-	-
nickel (Ni)	mg/L	0.0033	-	-	0.0035	-	-
selenium (Se)	mg/L	< 0.0004	< 0.0005	4	< 0.0004	< 0.0005	3
silver (Ag)	mg/L	< 0.0002	-	-	< 0.0002	-	-
vanadium (V)	mg/L	< 0.0001	-	-	< 0.0001	-	-
zinc (Zn)	mg/L	0.012	-	-	0.004	-	-

(a) Calculated based on LC_{50} results from the 96 hr rainbow trout survival test; TUa = 100 / LC_{50} value; a result of 0 = non-toxic.

(b) Calculated based on IC_{25} results from the 7 d *Ceriodaphnia dubia* reproduction test; TUc = 100 / IC_{25} value; a result of 0 = non-toxic.

Iron concentrations at the mouth of Muskeg Creek exceeded guideline levels in 1998 and in previous years (Table 5.12). Total phosphorus and manganese levels exceeded regulatory guidelines in 1998. Sample waters collected in 1998 were not acutely toxic to rainbow trout, but they were chronically toxic to *Ceriodaphnia dubia* (Appendix Table II-8). Test results show that these sample waters had a chronic aquatic toxicity value of 6.7 TUc (Table 5.11). For comparison, chronic toxicity values associated with mine waters from Suncor Energy Inc's Lease 86/17 operation vary from 1.4 to 14 TUc (Suncor 1998), and the regulatory guideline for chronic aquatic toxicity is 1.0 TUc (AEP 1995b).

Table 5.12 Water Quality Results for Muskeg and Wapasu Creeks that Exceed Regulatory Guidelines

Parameter	Units	Guidelines for the protection of[a] Aquatic life acute	Aquatic life chronic	Human health carcinogen	Human health non-carcinogen	Wapasu Creek 1998	Wapasu Creek Historical Median	Muskeg Creek 1998	Muskeg Creek Historical Median
Nutrients									
phosphorus, total	mg/L		0.05			C	C	C	
General Organics and Toxicity									
total phenolics	mg/L		0.005			C			
chronic aquatic toxicity	TUc		1					C	
Metals (Total)									
aluminum	mg/L		0.1						
arsenic	mg/L	0.36	0.01	0.000018		HC*	HC	HC*	HC
iron	mg/L		1		0.3	C HNC	C HNC	C HNC	HNC
manganese	mg/L				0.05	HNC	HNC	HNC	
mercury	mg/L	0.0024	1E-05		0.00014	C HNC	C*	C HNC*	C*

(a) Derivation of guidelines shown in Appendix Table II-10.

* Although lab reported non-detectable levels of the substance, the method detection limit exceeds the guideline limit.

5.1.1.7 Quality Assurance and Quality Control

Three trip blanks were prepared during the 1998 water quality sampling program. One blank was prepared during each of the spring, summer and fall sampling events. Non-detectable results were reported for almost all conventional parameters, nutrients and organics (Table 5.13). Toxicity testing (by Microtox®) also showed no toxicity for all three blank samples. Some detectable metal concentrations were observed in the summer trip blank (Table 5.13). However, all detectable levels were less than five times the corresponding method detection limit (MDL). Blank concentrations that are less than five times the MDL are considered to represent an acceptable level of analytical "noise" associated with sample preparation and measurement.

The concentrations of three metal species, manganese, potassium and zinc, in the fall trip blank were more than five times greater than the corresponding MDLs (Table 5.13). Similarly, barium, boron, manganese, nickel, strontium and zinc concentrations detected in the spring trip blank were more than five times larger than the corresponding appropriate MDLs. Reported detection limits for each of these parameters were adjusted so that they were equivalent to substance concentrations observed in the spring and fall trip blanks (e.g., the detection limit for total zinc for samples analyzed in the fall of 1998 was changed from 0.004 to 0.024 mg/L).

In 10 cases, reported dissolved metal levels were greater than corresponding total metal concentrations (e.g., boron and barium in the Ells and Tar rivers, Table 5.9). These errors represent a small portion of the overall data set, which contains over 500 individual data points.

Table 5.13 QA/QC Samples Collected in 1998 as Part of RAMP

Parameter	Units	Blank Samples Prepared While Sampling at			
		Muskeg River (spring)	Tar River (summer)	Spruce Pond (summer)	Steepbank River (fall)
Conventional Parameters					
bicarbonate (HCO3)	mg/L	< 5	< 5	< 5	< 5
calcium	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
carbonate (CO3)	mg/L	< 5	< 5	< 5	< 5
chloride	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
colour	T.C.U.	< 3	< 3	< 3	< 3
conductance	µS/cm	3.5	1.8	3.2	3.3
dissolved organic carbon	mg/L	1	< 1	< 1	< 1
hardness	mg/L	< 1	< 1	< 1	< 1
magnesium	mg/L	< 0.1	< 0.1	< 0.1	< 0.1
pH		6	5.7	6	6.1
potassium	mg/L	< 0.1	< 0.1	< 0.1	< 0.1
sodium	mg/L	< 1	< 1	< 1	< 1
sulphate	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
sulphide	mg/L	0.006	< 0.002	< 0.002	< 0.002
total alkalinity	mg/L	< 5	< 5	< 5	< 5
total dissolved solids	mg/L	< 10	18	< 10	< 10
total organic carbon	mg/L	1	< 1	< 1	1
total suspended solids	mg/L	< 2	3	< 2	4
Nutrients					
nitrate + nitrite	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
nitrogen – ammonia	mg/L	< 0.05	< 0.05	< 0.05	< 0.05
nitrogen – kjeldahl	mg/L	< 0.2	0.5	< 0.2	< 0.2
phosphorus, total	mg/L	< 0.001	0.006	0.008	0.004
phosphorus, total dissolved	mg/L	< 0.001	< 0.002	< 0.002	0.005
General Organics and Toxicity					
biochemical oxygen demand	mg/L	< 2	< 2	< 2	< 2
chlorophyll “a”	mg/L	< 0.001	< 0.001	< 0.001	0.001
Microtox IC50 @ 15 min	%	> 91	> 91	> 91	> 91
Microtox IC25 @ 15 min	%	> 91	> 91	> 91	> 91
naphthenic acids	mg/L	< 1	< 1	< 1	< 1
total phenolics	mg/L	< 0.001	< 0.001	< 0.001	< 0.001
total recoverable hydrocarbons	mg/L	< 0.5	< 0.5	< 0.5	< 0.5
Metals (Total)					
aluminum (Al)	mg/L	0.03	0.05	0.03	0.05
antimony (Sb)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008
arsenic (As)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001
barium (Ba)	mg/L	0.0333	0.0002	0.0005	0.0008
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.254	< 0.004	0.005	< 0.004
cadmium (Cd)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
calcium (Ca)	mg/L	0.1	< 0.1	< 0.1	0.4
chromium (Cr)	mg/L	< 0.0008	< 0.0008	< 0.0008	0.0024
cobalt (Co)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
copper (Cu)	mg/L	0.001	< 0.001	< 0.001	< 0.001
iron (Fe)	mg/L	< 0.02	< 0.02	0.04	0.07

Table 5.13 QA/QC Samples Collected in 1998 as Part of RAMP (continued)

Parameter	Units	Blank Samples Prepared While Sampling at			
		Muskeg River (spring)	Tar River (summer)	Spruce Pond (summer)	Steepbank River (fall)
lead (Pb)	mg/L	0.0002	0.0003	< 0.0001	0.0003
lithium (Li)	mg/L	< 0.006	< 0.006	< 0.006	< 0.006
magnesium (Mg)	mg/L	0.02	< 0.02	< 0.02	0.04
manganese (Mn)	mg/L	0.0007	0.0005	0.0009	0.0015
mercury (Hg)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
molybdenum (Mo)	mg/L	0.0002	< 0.0001	< 0.0001	0.0002
nickel (Ni)	mg/L	< 0.0002	0.0007	< 0.0002	0.0004
potassium (K)	mg/L	< 0.02	0.09	< 0.02	0.13
selenium (Se)	mg/L	< 0.0008	< 0.0008	< 0.0008	< 0.0008
silver (Ag)	mg/L	0.0003	< 0.0004	< 0.0004	< 0.0004
sodium (Na)	mg/L	< 0.2	< 0.2	< 0.2	< 0.2
strontium (Sr)	mg/L	0.0005	0.0002	0.0004	0.0008
titanium (Ti)	mg/L	< 0.0006	< 0.0006	< 0.0006	0.0008
uranium (U)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
vanadium (V)	mg/L	< 0.0002	0.0003	< 0.0002	0.0002
zinc (Zn)	mg/L	0.034	0.007	0.006	0.024
Metals (Dissolved)					
aluminum (Al)	mg/L	0.03	< 0.01	< 0.01	0.02
antimony (Sb)	mg/L	0.0043	< 0.0008	0.0005	< 0.0008
arsenic (As)	mg/L	< 0.0004	< 0.0004	0.001	< 0.0004
barium (Ba)	mg/L	0.0332	0.0005	0.0001	0.0003
beryllium (Be)	mg/L	< 0.00005	< 0.0005	< 0.0005	< 0.0005
boron (B)	mg/L	0.256	0.004	0.009	0.002
cadmium (Cd)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
chromium (Cr)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004
cobalt (Co)	mg/L	< 0.0001	< 0.0001	< 0.0001	0.0001
copper (Cu)	mg/L	0.0019	< 0.0006	0.0006	< 0.0006
iron (Fe)	mg/L	< 0.01	< 0.01	< 0.01	< 0.01
lead (Pb)	mg/L	0.0003	< 0.0001	< 0.0001	0.0001
lithium (Li)	mg/L	< 0.003	< 0.003	< 0.003	< 0.003
manganese (Mn)	mg/L	0.0016	0.0003	0.0004	0.0007
mercury (Hg)	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001
molybdenum (Mo)	mg/L	0.00019	< 0.0001	< 0.0001	0.0001
nickel (Ni)	mg/L	0.001	< 0.0001	< 0.0001	0.0001
selenium (Se)	mg/L	< 0.0004	< 0.0004	0.0032	< 0.0004
silver (Ag)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002
strontium (Sr)	mg/L	0.0039	0.0004	0.0003	0.0004
titanium (Ti)	mg/L	< 0.0003	< 0.0003	< 0.0003	< 0.0003
uranium (U)	mg/L	< 0.00005	< 0.0001	< 0.0001	< 0.0001
vanadium (V)	mg/L	0.0002	< 0.0001	< 0.0001	< 0.0001
zinc (Zn)	mg/L	0.031	< 0.002	0.002	0.007

5.1.1.8 Summary

Waters sampled from the Steepbank, Tar, Ells and MacKay rivers were non-toxic to bacteria, and they generally contained low or non-detectable levels of phenolic compounds, total recoverable hydrocarbons and naphthenic acids (Tables 5.1 and 5.9). Chronic aquatic toxicity was observed in the Upper Muskeg River and Muskeg Creek (Tables 5.6 and 5.11). In all tributaries, major ion concentrations were higher in the fall of 1998 than in previous years. Higher major ion concentrations may have been related to 1998 being a relatively dry year and groundwater making up a larger proportion of each river's inflows. The generally low concentrations of TSS observed at the mouths of the five main tributaries (i.e., Steepbank, Muskeg, Ells, Tar and MacKay rivers) in 1998 are consistent with a lower proportion of surface runoff. Concentrations of iron, arsenic and aluminum in these same tributaries (i.e., Steepbank, Muskeg, Ells, Tar and MacKay rivers) generally exceeded guideline levels in 1998 and in previous years (Tables 5.3, 5.5, 5.8 and 5.10). Phosphorus levels consistently exceeded guideline levels in all but Muskeg Creek and the Muskeg River in 1998 and in previous years. Historical information, as well as data collected in 1998, indicate that mercury and manganese concentrations occasionally exceeded guideline levels during at least one season in each of the seven sampled tributaries that were sampled.

5.1.2 Sediment Quality

5.1.2.1 Steepbank River

Sediment samples have been collected from the mouth of the Steepbank River in the fall of 1995, 1997 and 1998. The 1998 sample contained less sand and total recoverable hydrocarbons than sediments collected from the same location the year before (Table 5.14). Total metal concentrations were also generally higher in 1998 than in 1997, while total PAH levels were similar in 1997 and 1998. The highest PAH and total recoverable hydrocarbons concentrations were observed in 1995. Total metal levels in the 1995 samples were lower than those found in the 1998 sediment sample and were similar to those observed in 1997.

5.1.2.2 Muskeg River

Sediments from the mouth of the Muskeg River have been sampled twice. Once each year as part of RAMP. As with the Steepbank River, the 1998 Muskeg River sample contained less sand and total recoverable hydrocarbons than sediments collected from the same location in 1997 (Table 5.14). PAH levels were also lower in 1998 than in 1997, while total metal concentrations were generally higher in 1998.

Table 5.14 Summary of Sediment Quality Results at Five Tributaries of the Athabasca River

Parameter	Units	Ells River	Tar River	MacKay River		Muskeg River		Steepbank River			
				1998	1997	1998	1997	1998 Duplicates		1997	1995
Conventional Parameters											
particle size - % sand	%	81	75	89	74	70	89	76	-	93	-
particle size - % silt	%	12	13	6	10.3	20	6.3	14	-	1.3	-
particle size - % clay	%	7	12	5	15.7	10	4.7	10	-	5.7	-
total inorganic carbon	% by wt	0.09	0.08	0.19	-	1.2	-	0.26	-	-	-
total organic carbon	% by wt	0.95	0.87	1.56	1.37	1.5	2.98	1.85	-	0.86	3.4
General Organics											
total recoverable hydrocarbons	µg/g	2660	1820	11300	4180	2040	3440	7200	-	10100	17200
Metals (Total)											
aluminum (Al)	µg/g	1710	5620	2550	5650	7480	2970	8040	-	2070	2330
antimony (Sb)	µg/g	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.2
arsenic (As)	µg/g	1.7	3.2	1.8	4.5	3.2	1	3.8	-	2.1	1.3
barium (Ba)	µg/g	45.1	96.9	27.2	70	113	40.1	73	-	27.1	31
beryllium (Be)	µg/g	< 1	< 1	< 1	< 1	< 1	< 1	< 1	-	< 1	0.3
cadmium (Cd)	µg/g	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	-	< 0.5	< 0.3
chromium (Cr)	µg/g	3.2	9.7	4.5	12.9	13.9	6.9	14.1	-	5.5	8.2
copper (Cu)	µg/g	5	8	4	11	9	7	7	-	7	2.5
iron (Fe)	µg/g	6510	9010	6730	14400	21000	11200	13400	-	6800	7410
lead (Pb)	µg/g	< 5	7	5	6	7	< 5	6	-	< 5	3
manganese (Mn)	µg/g	141	155	134	302	583	373	255	-	102	100
mercury (Hg)	µg/g	0.01	0.03	0.02	0.05	0.03	0.04	0.05	-	0.03	< 20
molybdenum (Mo)	µg/g	< 1	< 1	< 1	< 1	< 1	< 1	< 1	-	< 1	0.8
nickel (Ni)	µg/g	7	8	4	12	14	6	11	-	7	7.1
selenium (Se)	µg/g	0.1	0.3	< 0.1	0.3	0.2	< 0.1	< 0.1	-	0.1	< 0.2
silver (Ag)	µg/g	< 1	< 1	< 1	< 1	< 1	< 1	< 1	-	< 1	< 0.2
strontium (Sr)	µg/g	17	25	15	34	62	75	23	-	11	10.9
vanadium (V)	µg/g	4	16	9	16	20	9	23	-	7	12.4
zinc (Zn)	µg/g	30.5	33.4	37.9	44.3	45.1	26.4	39.1	-	22	16.3
Target PAHs and Alkylated PAHs[(a)]											
naphthalene	µg/g	< 0.0061	0.015	< 0.02	0.008	*0.018*	< 0.003	*0.01*	*0.012*	< 0.003	0.005
acenaphthene	µg/g	< 0.011	< 0.0023	< 0.035	0.016	< 0.004	< 0.003	< 0.03	< 0.02	0.012	0.04
acenaphthylene	µg/g	< 0.0042	< 0.0006	< 0.015	0.004	< 0.001	< 0.003	< 0.015	< 0.013	0.008	< 0.01
anthracene	µg/g	< 0.026	< 0.0013	< 0.03	< 0.003	< 0.0031	< 0.003	< 0.036	< 0.023	0.004	< 0.01
dibenzo(a,h)anthracene	µg/g	< 0.013	< 0.0049	< 0.05	< 0.003	< 0.021	< 0.003	< 0.032	< 0.035	< 0.003	0.10
benzo(a)Anthracene/Chrysene	µg/g	0.092	0.019	0.22	0.11	*0.016*	0.035	0.26	0.26	0.17	1.90
benzo(a)pyrene	µg/g	< 0.039	< 0.0072	< 0.092	0.023	< 0.01	0.013	< 0.06	< 0.1	0.097	0.21
fluoranthene	µg/g	< 0.015	*0.0024*	< 0.021	0.022	0.0028	0.003	< 0.03	< 0.029	0.023	0.12
fluorene	µg/g	< 0.017	< 0.0023	< 0.044	0.011	0.0027	< 0.003	< 0.04	< 0.04	0.005	0.03
phenanthrene	µg/g	*0.024*	0.01	*0.034*	0.08	0.0098	0.007	*0.059*	*0.055*	0.02	0.31
pyrene	µg/g	0.032	0.0082	0.073	0.047	0.0051	0.012	0.081	0.076	0.072	0.20
total PAHs	µg/g	4.49	0.57	6.26	9.88	0.29	1.47	13.7	12.8	11.9	50.9

[(a)] PAH = polycyclic aromatic hydrocarbons; PAH concentrations in italics 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 spectrum).

5.1.2.3 MacKay River

Sediments collected at the mouth of the MacKay River in the fall of 1998 had a higher sand content that those collected in 1997 (Table 5.14). Total recoverable hydrocarbon concentrations were higher in 1998, while total metal and PAH concentrations were lower in 1998.

5.1.2.4 Ells and Tar Rivers

The fall of 1998 was the first time sediments had been collected from the mouth of the Ells and Tar rivers as part of RAMP. Particle size analysis showed that sediments from these small tributaries were quite similar in terms of their sand, silt and clay content (Table 5.14). Metal concentrations were generally higher and PAH levels tended to be lower in the Tar River sample compared to the one taken from the Ells River.

5.1.2.5 Quality Assurance and Quality Control

A split sample from the Steepbank River was prepared and analyzed by AXYS to examine the precision of their analytical methodology. PAH concentrations reported for the two split samples varied by a maximum of 69% with a mean variation of 21% (Table 5.14). These results are consistent with normal lab variability; they indicate that the analytical instrumentation used to measure sediment PAH levels was precise in its measurements and that AXYS personnel were consistent in their interpretation of these measurements.

5.1.2.6 Summary

With the exceptions of one or two measurements, sediments from the Steepbank River had the highest organic carbon, PAH and total recoverable hydrocarbon content of the five sampled tributaries (Table 5.14). PAH concentrations in these sediments also tended to exceed regulatory guidelines, more often than sediments from the other Athabasca River tributaries (Table 5.15). Total metal levels varied among the different tributaries, with no tributary consistently containing sediments with higher metal levels (Table 5.14).

Table 5.15 Sediment Quality Results for Five Athabasca River Tributaries that Exceed Regulatory Guidelines

		Sediment Guidelines[a]								Steepbank River			
						MacKay River		Muskeg River		1998			
Parameter	**Units**	**ISQG[b]**	**PEL[c]**	**Ells River**	**Tar River**	**1998**	**1997**	**1998**	**1997**	**Duplicates**		1997	1995
Metals (Total)													
Mercury (Hg)	µg/g	0.17	0.486										PEL[d]
Target PAHs and Alkylated PAHs													
Acenaphthene	µg/g	0.007	0.089	ISQG[d]		ISQG[d]	ISQG			ISQG[d]	ISQG[d]	ISQG	ISQG
Acenaphthylene	µg/g	0.006	0.128			ISQG[d]				ISQG[d]	ISQG[d]	ISQG	ISQG[d]
Dibenzo(a,h)anthracene	µg/g	0.006	0.135	ISQG[d]		ISQG[d]		ISQG[d]		ISQG[d]	ISQG[d]		ISQG
Benzo(a)Anthracene/Chrysene	µg/g	0.032	0.385	ISQG		ISQG	ISQG		ISQG	ISQG	ISQG	ISQG	PEL
Benzo(a)pyrene	µg/g	0.032	0.782	ISQG[d]		ISQG[d]				ISQG[d]	ISQG[d]	ISQG	ISQG
Fluorene	µg/g	0.021	0.144			ISQG[d]				ISQG[d]	ISQG[d]		ISQG
Phenanthrene	µg/g	0.042	0.515				ISQG			ISQG	ISQG		ISQG
Pyrene	µg/g	0.053	0.875			ISQG				ISQG	ISQG	ISQG	ISQG

[a] Sediment guideline values taken from CCME (1998).

[b] ISQG = interim freshwater sediment quality guidelines.

[c] PEL = probable effect levels.

[d] Although lab reported non-detectable levels of the substance, the method detection limit is higher than the guideline limit.

Benzo(a)anthracene/chrysene concentrations in excess of guideline levels were common to all tributaries, except the Tar River (Table 5.15). Acenaphthene, acenaphthylene, dibenzo(a,h)anthracene, benzo(a)pyrene and fluorene levels in all tributaries were below detection limits. As the detection limits for these substances were above regulatory guidelines, these PAHs were not evaluated with respect to guideline levels (Table 5.15).

As observed in the Athabasca River, tributary sediments with high sand content tended to have low total metal concentrations (Table 5.14). In three sampled tributaries (Muskeg, MacKay and Steepbank rivers), the high sand content in tributary sediments was also accompanied by high total recoverable hydrocarbon concentrations (Table 5.14). The same was true for PAHs in the Muskeg River. However, the reverse pattern was observed in the MacKay and Steepbank rivers, where sediments with high sand content generally contained lower PAH concentrations than sediments with lower sand content (Table 5.14). While no clear trend emerged between PAH concentrations and sand content, tributary sediments with high sand content generally had high metal and total recoverable hydrocarbons levels relative to low sand content sediments collected from the same general area.

5.2 BENTHIC INVERTEBRATES

5.2.1 Benthic Habitat

Benthic invertebrate sampling sites were characterized by low to moderate current velocity and water depth <30 cm, which reflects the extreme low-flow conditions throughout the oil sands area during the fall 1998 sampling program (Table 5.16). The Steepbank and Muskeg rivers were similar in terms of depth and current velocity. MacKay River sites were shallower, with slower currents, and can only be classified as marginal erosional habitat.

The substratum was dominated by gravel and cobble in the Steepbank and Muskeg rivers, with relatively low among-site variability in the relative proportion of each size class (Table 5.16). The one exception is Site STR-3 in the Steepbank River, where the substratum consisted mostly of cobbles. More variation in bottom characteristics was found in the MacKay River, where one site (MAC-1) was dominated by sand and finer sediments. Low proportions of boulders and bedrock were present at the other two sites, in addition to the dominant gravel and cobble.

Table 5.16 Habitat Characteristics and Field Water Quality Measurements at the Benthic Invertebrate Sampling Sites

Variable	Units	Steepbank River			Muskeg River			MacKay River		
		STR-1	STR-2	STR-3	MUR-1	MUR-2	MUR-3	MAC-1	MAC-2	MAC-3
sampling date	-	18-Sep-98	18-Sep-98	18-Sep-98	21-Sep-98	21-Sep-98	21-Sep-98	23-Sep-98	23-Sep-98	23-Sep-98
wetted width	m	8	N/A	11	18	20	20	15	50	60
habitat	-	riffle	riffle	riffle	riffle	riffle	riffle	riffle	riffle	riffle
current velocity	m/s	0.56	0.41	0.57	0.50	0.35	0.39	0.27	0.32	0.15
depth	m	0.24	0.28	0.21	0.22	0.25	0.23	0.26	0.17	0.17
substratum:										
sand/silt/clay	%	20	5	0	5	10	5	60	5	5
small gravel	%	20	20	5	25	25	30	10	15	25
large gravel	%	25	30	10	25	25	25	15	10	15
small cobble	%	25	25	40	25	25	20	10	30	10
large cobble	%	10	10	45	15	5	10	5	20	10
boulder	%	0	5	0	5	5	5	0	5	5
bedrock	%	0	5	0	0	5	5	0	15	30
field water quality:										
pH	-	8.4	8.6	8.6	8.4	8.4	8.5	8.6	8.5	8.7
conductivity	µS/cm	510	510	480	610	590	620	N/A	N/A	N/A
dissolved oxygen	mg/L	n/a*	n/a*	n/a*	9.5	8.4	7.9	8.2	8.1	7.7
water temperature	^{o}C	6.0	8.0	8.5	12.0	12.0	11.5	10.0	11.0	11.0
benthic algae	-	n/a	n/a	M	L-M	L	M	L	L	M

Notes: n/a = not available; L = Low; M = Moderate.

*Data are not available due to malfunctioning equipment.

Based on field water quality measurements, pH varied little among sites and rivers. Conductivity, an indicator of the concentration of dissolved salts, was elevated in both the Steepbank and Muskeg rivers relative to typical values in Alberta rivers in the open-water season. This is a likely result of a greater proportion of groundwater contributing to the flow in these rivers compared to typical fall hydrological conditions, resulting from reduced surface water inputs during a period of extreme low-flow. Dissolved oxygen concentration was within the expected range in the Muskeg and MacKay rivers. The small variation in water temperature may reflect diurnal temperature fluctuation, or differences in hydrology among rivers.

Overall, habitat differences among sampling sites were minor within and between the Steepbank and Muskeg rivers, with the possible exception of Site STR-3 in the Steepbank River, where the proportion of gravel in the substratum was lower relative to other sites. Current velocity was slower at the MacKay River sites and the substratum was more variable; these habitat differences are a potential cause of differences in the benthic community between this river and the Steepbank and Muskeg rivers.

5.2.2 Benthic Communities

Total benthic invertebrate density was low in the Steepbank River and low to moderate in the Muskeg and MacKay rivers (Figure 5.1). Density was most variable in the MacKay River, where the greatest among-site variation in habitat features was also found.

Taxonomic richness (total number of taxa at the lowest taxonomic level) was less variable, and tended to increase in an upstream direction from the mouth in each river (Figure 5.1). Richness values were average to above average relative to Alberta rivers in general. In particular, the Muskeg River supported a diverse benthic fauna, with an overall mean of 41 taxa per site, compared to 23 and 28 taxa in the Steepbank and MacKay rivers, respectively.

There were a number of consistent differences among rivers in taxonomic composition, which were noticeable at the level of major taxon (Figure 5.2). The bulk of total invertebrate density consisted of mayflies and chironomids in the Steepbank and MacKay rivers, though the relative importance of these groups were reversed between rivers. This appears to reflect habitat differences between these rivers: mayflies were the dominant taxon at two sites in the Steepbank River and common at the third, which is consistent with the more erosional nature of this river. In contrast, the dominance of chironomids in the MacKay

Figure 5.1 Variation in Total Invertebrate Density and Taxonomic Richness Among the Benthic Invertebrate Sampling Sites in the Steepbank, Muskeg and MacKay Rivers

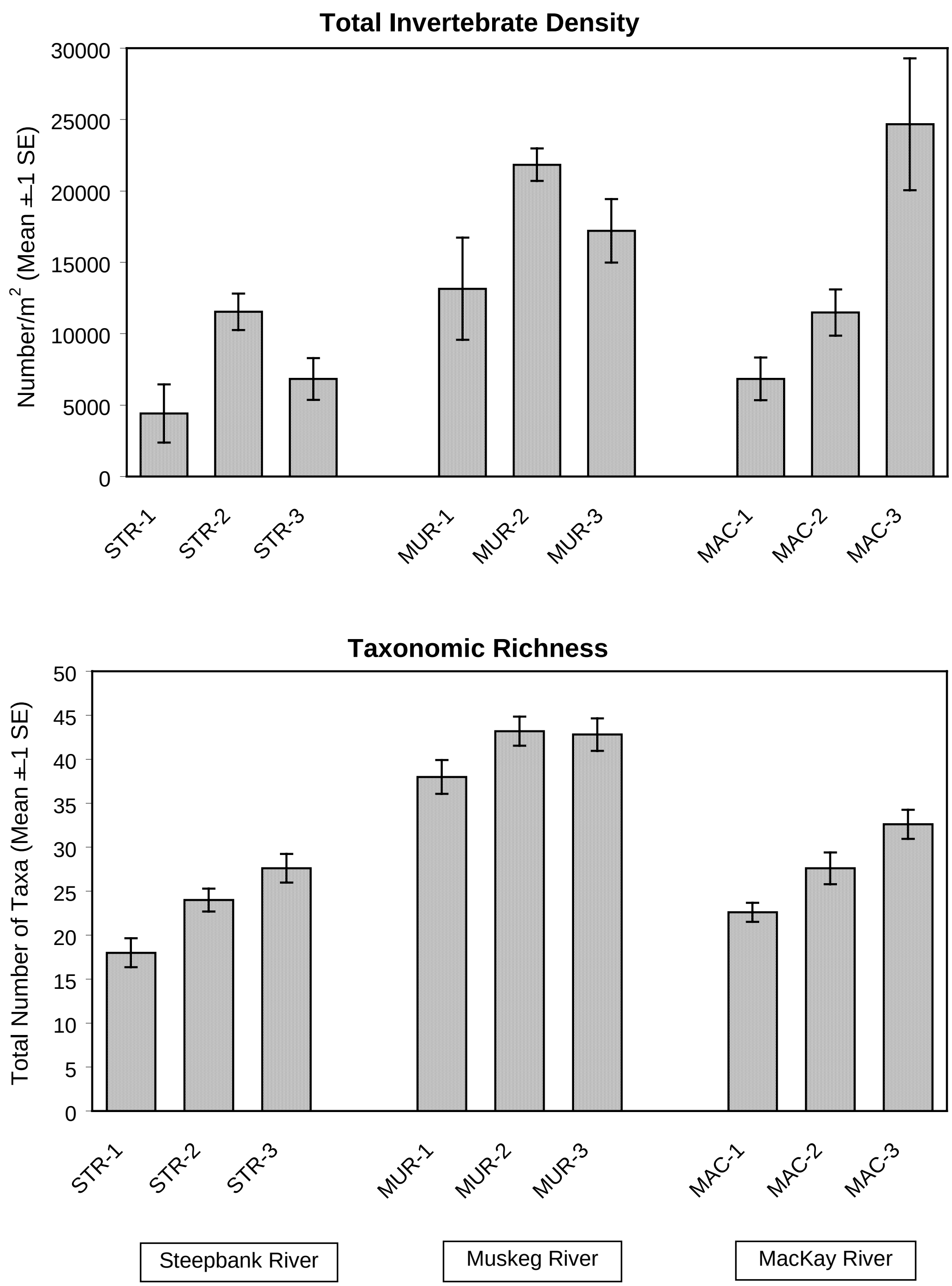
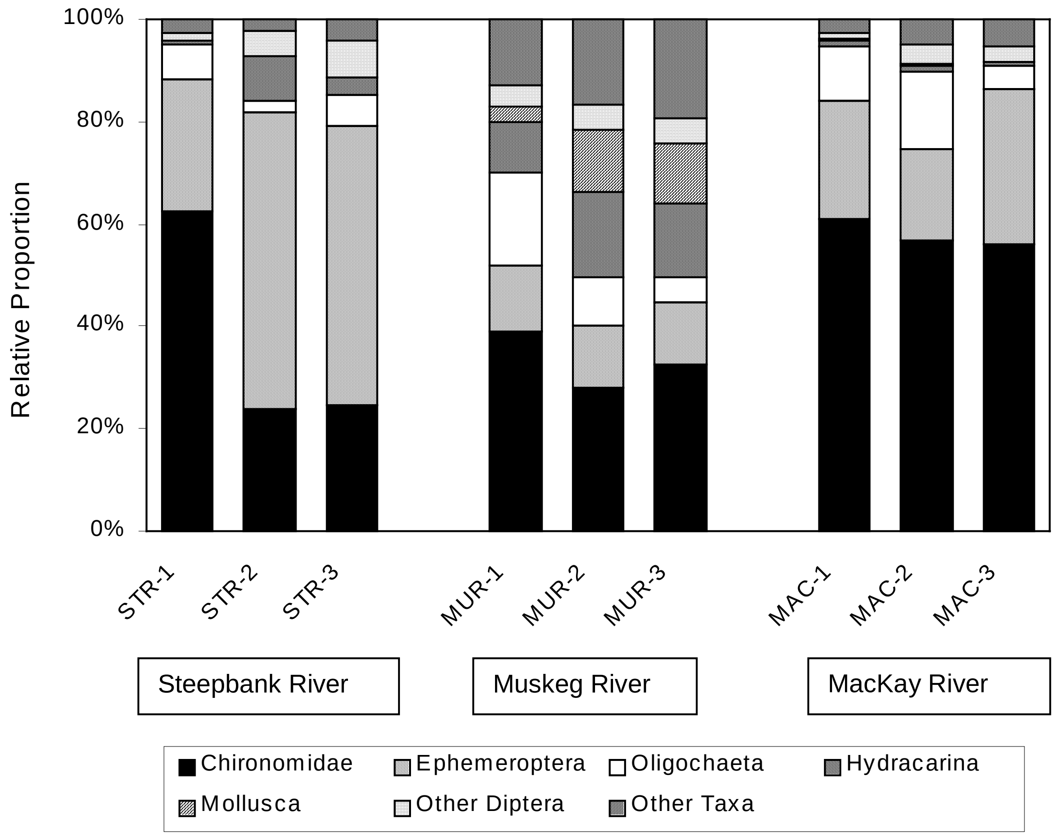


Figure 5.2 Composition of Benthic Invertebrate Communities at the Level of Major Taxonomic Group in the Steepbank, Muskeg and MacKay Rivers



River is indicative of a more depositional environment, which is also evident in the habitat data summarized in Table 5.16. The greater diversity in the Muskeg River was also apparent at this coarse level of assessment. The extreme dominance by mayflies or chironomids was absent in this river; rather, four major groups (Chironomidae, Ephemeroptera, Oligochaeta, Hydracarina) accounted for the majority of total density in this river. This greater variety is also reflected in the higher taxonomic richness shown in Figure 5.1.

At a finer taxonomic resolution, the benthic fauna of the Steepbank River was numerically dominated by the mayfly *Baetis* and a number of common chironomid genera (Table 5.17). Water mites (Hydracarina), oligochaete worms (Tubificidae, Naididae, Enchytraeidae) and blackflies (*Simulium*) were also abundant in this river, though their relative abundances varied among sites. All of these taxa except blackflies were also abundant in the Muskeg River, but the relative abundance of *Baetis* was lower (Table 5.18). There were a large number of additional common invertebrates in this river, including fingernail clams

(*Pisidium*), limpets (*Ferrissia*), riffle beetles (*Optioservus*), ostracods, stoneflies (*Chloroperlidae*) and dance flies (*Hemerodromia*). In particular, fingernail clams were much more common in the Muskeg River than in the Steepbank River, which suggests that the Muskeg River sites were more depositional. The fauna of the MacKay River resembled that of the Steepbank River. *Baetis*, chironomid midges and oligochaetes were dominant in this river, with a greater dominance of chironomid midges and oligochaete worms relative to *Baetis* (Table 5.19). Few other common taxa were present in this river.

Qualitative examination of the benthic communities in light of the habitat variables shown in Table 5.11 did not reveal any obvious and consistent relationships between benthic habitat and community structure in the rivers sampled. The differences in benthic fauna among rivers also could not be explained based on the habitat data. For example, the greater proportion of mollusks in the Muskeg River suggests a more depositional environment, but lowest current velocities were consistently measured in the MacKay River.

Within each river, there were a number of significant correlations between current velocity and densities of common invertebrates (Table 5.20). All significant correlations in the Steepbank and Muskeg rivers were negative and consistent with ecological characteristics of the invertebrates in the analysis: oligochaetes, mollusks and chironomids are typically found in greater numbers in slower waters. Examination of scatter-plots confirmed that these correlations represented consistent trends.

Correlations between current velocity and invertebrate density are more difficult to interpret in the MacKay River. Significant correlations with Tubificidae, *Ferrissia* and *Phaenopsectra* were likely spurious, resulting from atypically high or low densities near either limit of the range in current velocity. The significant negative correlation with *Baetis* density is counter to the erosional habitat preference of this genus, whereas the negative correlation with *Polypedilum* density appears valid.

These results suggest that the variation among sites in current velocity, and potentially other habitat features, are not consistently reflected in the biological data. This may be a consequence of sampling a relatively small number of sites, which does not allow a sensitive analysis, and the atypically low flows prevailing during the field survey. If significant changes in flows occurred in the weeks preceding the field program, instantaneous habitat measurements may not yield an accurate reflection of the physical conditions that shaped the benthic communities.

Table 5.17 Densities of Common Benthic Invertebrates at Sites Sampled in the Steepbank River

Site STR-1

Taxon	Mean Density (no./m^2)	Standard Error	% of Total Density
Polypedilum	1426	653	32.3
Baetis	979	559	22.2
Rheotanytarsus	431	323	9.8
Tubificidae	284	132	6.4
Saetheria	216	144	4.9
Thienemanniella	191	63	4.3
Cricotopus/Orthocladius	147	72	3.3
Tvetenia	125	43	2.8
Ephemerella	110	88	2.5
Nematoda	95	32	2.1
Orthocladiinae	75	46	1.7
Thienemannimyia complex	55	44	1.2
			(93.7%)
Total Invertebrates	4411	2043	-
Total Taxa	18.0	1.6	-

Site STR-2

Taxon	Mean Density (no./m^2)	Standard Error	% of Total Density
Baetis	6296	735	54.6
Hydracarina	1036	225	9.0
Polypedilum	750	207	6.5
Rheotanytarsus	585	194	5.1
Thienemannimyia complex	416	71	3.6
Tvetenia	312	97	2.7
Simulium	290	105	2.5
Hemerodromia	231	57	2.0
Ephemerella	187	70	1.6
Tubificidae	161	77	1.4
Saetheria	139	62	1.2
Cricotopus/Orthocladius	136	40	1.2
Nematoda	121	61	1.0
			(92.4%)
Total Invertebrates	11539	1282	-
Total Taxa	24.0	1.3	-

Site STR-3

Taxon	Mean Density (no./m^2)	Standard Error	% of Total Density
Baetis	3265	737	47.8
Rheotanytarsus	436	236	6.4
Simulium	345	190	5.1
Tvetenia	268	103	3.9
Hydracarina	220	97	3.2
Enchytraeidae	211	56	3.1
Polypedilum	211	56	3.1
Thienemannimyia complex	196	60	2.9
Ephemerella	189	90	2.8
Naididae	176	67	2.6
Rhithrogenia	174	83	2.5
Eukiefferiella	143	88	2.1
Cricotopus/Orthocladius	112	69	1.6
Heptagenia	110	56	1.6
Saetheria	110	35	1.6
Hemerodromia	108	42	1.6
Ostracoda	95	87	1.4
Hydropsyche	81	21	1.2
			(94.5%)
Total Invertebrates	6827	1470	-
Total Taxa	27.6	1.6	-

Table 5.18 Densities of Common Benthic Invertebrates at Sites Sampled in the Muskeg River

Site MUR-1				Site MUR-2			
Taxon	**Mean Density ($no./m^2$)**	**Standard Error**	**% of Total Density**	**Taxon**	**Mean Density ($no./m^2$)**	**Standard Error**	**% of Total Density**
Cladotanytarsus	1650	588	12.5	Hydracarina	3637	177	16.6
Baetis	1551	416	11.8	*Baetis*	2407	446	11.0
Hydracarina	1289	451	9.8	*Lopescladius*	1604	273	7.3
Naididae	1250	615	9.5	*Pisidium*	1492	289	6.8
Tubificidae	1164	445	8.9	*Optioservus*	1399	184	6.4
Ostracoda	587	173	4.5	*Polypedilum*	1228	371	5.6
Polypedilum	587	153	4.5	Tubificidae	1058	181	4.8
Lopescladius	557	138	4.2	*Ferrissia*	1049	343	4.8
Thienemannimyia complex	513	223	3.9	Naididae	944	272	4.3
Hemerodromia	398	135	3.0	*Hemerodromia*	900	126	4.1
Corynoneura	363	143	2.8	*Cladotanytarsus*	827	96	3.8
Rheotanytarsus	343	115	2.6	Ostracoda	678	262	3.1
Nematoda	282	107	2.1	Chloroperlidae	614	153	2.8
Cricotopus/Orthocladius	279	140	2.1	*Corynoneura*	563	202	2.6
Micropsectra	268	87	2.0	*Micropsectra*	422	57	1.9
Collembola	222	71	1.7	Nematoda	416	76	1.9
Pisidium	222	60	1.7	*Thienemannimyia complex*	279	38	1.3
Chloroperlidae	194	62	1.5	*Nilotanypus*	238	58	1.1
Optioservus	169	81	1.3				(90.4%)
Thienemanniella	152	51	1.2				
			(91.6%)				
Total Invertebrates	13149	3586	-	Total Invertebrates	21844	1144	-
Total Taxa	38.0	1.9	-	Total Taxa	43.2	1.7	-

Site MUR-3			
Taxon	**Mean Density ($no./m^2$)**	**Standard Error**	**% of Total Density**
Hydracarina	2473	278	14.4
Baetis	1828	384	10.6
Pisidium	1652	782	9.6
Lopescladius	1562	131	9.1
Polypedilum	1100	248	6.4
Optioservus	906	173	5.3
Chloroperlidae	891	131	5.2
Hemerodromia	585	114	3.4
Naididae	550	125	3.2
Cladotanytarsus	493	105	2.9
Nematoda	389	72	2.3
Collembola	387	95	2.3
Tubificidae	332	118	1.9
Ferrissia	321	84	1.9
Rheotanytarsus	317	126	1.8
Thienemannimyia complex	277	99	1.6
Ceratopogoninae	268	92	1.6
Stempellina	266	37	1.5
Micropsectra	264	39	1.5
Corynoneura	264	128	1.5
Cricotopus/Orthocladius	222	60	1.3
Orthocladiinae	211	73	1.2
			(90.5%)
Total Invertebrates	17200	2227	-
Total Taxa	42.8	1.9	-

Table 5.19 Densities of Common Benthic Invertebrates at Sites Sampled in the MacKay River

Site MAC-1

Taxon	Mean Density (no./m^2)	Standard Error	% of Total Density
Polypedilum	1976	381	28.9
Baetis	1542	437	22.6
Cladotanytarsus	801	255	11.7
Tubificidae	656	136	9.6
Rheotanytarsus	194	77	2.8
Stempellina	167	156	2.4
Thienemannimyia complex	156	92	2.3
Psectrocladius	150	51	2.2
Micropsectra	132	50	1.9
Thienemanniella	114	30	1.7
Orthocladiinae	97	43	1.4
Nematoda	90	29	1.3
Tanytarsus	88	56	1.3
Hydracarina	79	26	1.2
			(91.3%)
Total Invertebrates	6838	1498	-
Total Taxa	22.6	1.1	-

Site MAC-2

Taxon	Mean Density (no./m^2)	Standard Error	% of Total Density
Polypedilum	2482	1106	21.6
Baetis	1951	332	17.0
Rheotanytarsus	1223	441	10.7
Enchytraeidae	1188	383	10.3
Thienemannimyia complex	900	308	7.8
Cladotanytarsus	572	213	5.0
Micropsectra	352	107	3.1
Naididae	304	64	2.6
Nematoda	286	22	2.5
Ceratopogoninae	257	42	2.2
Tubificidae	220	168	1.9
Hemerodromia	183	42	1.6
Corynoneura	158	47	1.4
Saetheria	154	90	1.3
Thienemanniella	150	47	1.3
Hydracarina	141	9	1.2
			(91.6%)
Total Invertebrates	11482	1616	-
Total Taxa	27.6	1.8	-

Site MAC-3

Taxon	Mean Density (no./m^2)	Standard Error	% of Total Density
Baetis	7372	1757	29.9
Polypedilum	2169	394	8.8
Cladotanytarsus	2145	492	8.7
Thienemannimyia complex	1978	323	8.0
Phenopsectra	1331	680	5.4
Micropsectra	1184	245	4.8
Rheotanytarsus	1120	226	4.5
Psectrocladius	1047	727	4.2
Enchytraeidae	603	82	2.4
Tanytarsus	565	265	2.3
Chironomini	502	138	2.0
Naididae	462	93	1.9
Nematoda	425	66	1.7
Saetheria	422	153	1.7
Hemerodromia	396	113	1.6
Isoperla	387	100	1.6
Stempellina	387	158	1.6
Ceratopogoninae	339	90	1.4
			(92.5%)
Total Invertebrates	24675	4620	-
Total Taxa	32.6	1.7	-

Table 5.20 Correlations Between Current Velocity and Densities of Common Benthic Invertebrates (Pearson Coefficients, n=15)

Taxon	Steepbank River	Muskeg River	MacKay River
Nematode worms (Nematoda)	-0.159	-0.244	-0.149
Oligochaete worms			
Enchytraeidae	0.235	-0.427	-0.131
Naididae	-0.051	-0.019	-0.254
Tubificidae	**-0.628***	-0.192	**0.635***
Water mites (Hydracarina)	-0.423	-0.513	-0.062
Ostracods (Ostracoda)	-0.119	-0.192	-0.351
Limpets *(Ferrissia)*	0.139	**-0.719****	**0.639***
Fingernail clams *(Pisidium)*	-[a]	**-0.696****	-[a]
Mayflies *(Baetis)*	-0.208	-0.044	**-0.572***
Stoneflies (Chloroperlidae)	0.146	**-0.597***	-0.054
Riffle beetles *(Optioservus*	-[a]	-0.503	0.160
Dance flies *(Hemerodromia)*	-0.228	**-0.537***	-0.168
Biting midges (Ceratopogoninae)	-0.072	-0.426	-0.263
Chironomid midges			
Thienemannimyia complex	0.084	-0.145	-0.422
Phenopsectra	-[a]	-[a]	**-0.743****
Polypedilum	-0.240	**-0.748****	**-0.570***
Cladotanytarsus	0.329	-0.086	-0.475
Micropsectra	-0.029	-0.296	-0.294
Rheotanytarsus	-0.118	-0.271	-0.098
Corynoneura	-0.191	**-0.584***	0.090
Lopescladius	0.062	**-0.609***	0.103
Psectrocladius	-[a]	-[a]	-0.443
Tvetenia	-0.392	0.062	-0.214

Notes:

[a] taxon was absent from river.

* = $P \leq 0.05$.

** = $P \leq 0.01$.

5.2.3 Summary

The benthic invertebrate data collected during the fall 1998 field program of the RAMP represents the results of an initial effort to establish a benthic invertebrate monitoring program in tributaries of the Athabasca River. The survey provided data for an initial assessment of natural variability in benthic community structure in these rivers and information for designing subsequent surveys.

The extreme low-flows prevailing in the oil sands area during the 1998 field program made sampling site selection difficult. Suitable erosional habitat was not located in the lower reaches of either of the proposed reference rivers (Tar and Ells rivers), which resulted in dropping these rivers from the tributary benthic monitoring program in 1998. To maintain sampling areas, the MacKay River was added as a potentially suitable reference river; however, flows and substratum differed from the other two rivers. Therefore, it may be useful to revisit the Tar and Ells rivers under higher flow to reassess their suitability as reference rivers.

The Steepbank and MacKay rivers supported moderately diverse benthic faunas, at low to moderate densities in fall, 1998. The fauna of the Muskeg River was moderate in density but was more diverse. In addition to mayflies and chironomids, which dominated the Steepbank and MacKay rivers, this river also supported a greater variety of non-insect taxa (worms, snails and clams) and non-chironomid insects in the orders Ephemeroptera, Trichoptera, Plecoptera, Coleoptera, Hemiptera, and Diptera. Although the influence of habitat variation was apparent in a number of significant correlations between current velocity and densities of common invertebrates in the Muskeg River, differences among rivers could not be related to variation in habitat.

The 1988 tributary surveys were carried out under extreme low-flows resulting in marginal erosional habitats, a condition which is likely reflected in the biological data. Benthic surveys of tributaries were not carried out in the previous year, because flows were unusually high. Therefore, data are still lacking for a year with “typical” hydrological conditions. Furthermore, data from several years are required to describe natural variability even under relatively constant flow regimes. These points emphasize the need to continue monitoring these rivers to accumulate an adequate baseline database in the vicinity of the Steepbank and Muskeg rivers before intensive oil sands development begins.

5.3 FISH POPULATIONS

No fish were captured in the upstream trap of the spring fish fence on the Muskeg River in 1998. Capture success in the downstream trap was also very limited (Table 5.21). The fish fence was operational by May 8, 1998, but missed the runs of species such as Arctic grayling, longnose sucker and white sucker. Timing of the fence operation with spawning runs was particularly difficult in 1998 due to the unusually early spring in the oil sands region.

Table 5.21 Summary of Fish Caught in the Downstream Trap of the Counting Fence in the Muskeg River, Spring, 1998

Species	Date of Operation, May 1998						
	8	9	10	11	12	13	14
Arctic grayling	1	0	0	0	0	1	0
mountain whitefish	0	0	0	0	0	0	1
longnose sucker	2	0	3	0	1	1	6
white sucker	0	0	0	0	0	0	2
fathead minnow	2	0	0	0	0	0	0
northern redbelly dace	2	0	1	0	0	0	0
spoonhead sculpin	1	0	0	0	0	0	0

Sampling the upstream migration of Arctic grayling is always difficult even under “normal” conditions. As with many spring spawning species, migration of grayling often begins with ice break-up and increasing water temperatures. However, the run of Arctic grayling typically precedes most other species. Previous fish fence studies on the Muskeg River (Bond and Machniak 1977, 1979) had fences in place as early as April 27, immediately after ice left the system. In both studies, it was concluded that the upstream migration of grayling was well under way when the fence operation began.

It was surprising to catch so few longnose or white sucker in early May. Based on several fish fence studies conducted on the Muskeg River and Steepbank River, much higher numbers of both species were expected during the operational period in 1998 (Table 5.22). Again, the most obvious explanation was the abnormally early spring in 1998 that probably resulted in upstream migrations of spawning populations substantially earlier than in previous years.

Due to limited capture success, no analyses were conducted on fish health or population parameters. Fork length, body weight, life stage, sex and maturity of all fish collected were recorded and the data have been presented in Appendix VIII. Fish ages were not determined. In addition, results of the forage fish survey in the vicinity of the fence on the Muskeg River are provided in Appendix VIII. Appendix VIII also includes fish habitat maps for fish fence sites on the Muskeg, Ells and Tar rivers.

Table 5.22 Total Catch of Longnose Sucker and White Sucker in Upstream Traps of Several Spring Fish Fence Operations in the Muskeg and Steepbank Rivers between May 8-14

Day (May)	Muskeg R., 1976[a]		Muskeg R., 1977[b]		Muskeg R., 1995[c]		Steepbank R., 1977[d]	
	LNSC[e]	WHSC	LNSC	WHSC	LNSC	WHSC	LNSC	WHSC
8	79	270	102	562	3	0	137	51
9	359	561	63	282	199	86	137	16
10	398	407	42	110	0	0	105	40
11	134	203	49	187	1	9	83	33
12	164	112	22	81	9	2	160	16
13	133	93	148	44	3	0	156	13
14	144	35	42	30	92	202	95	4

[a] Data from Bond and Machniak (1977).
[b] Data from Bond and Machniak (1979).
[c] Data from Machniak and Bond (1979).
[d] Data from Golder (1996a).
[e] LNSC = longnose sucker, WHSC = white sucker.

Improved methods will be required if fish fences are to be used for future monitoring of the Muskeg and Steepbank rivers. Clearly, upstream fish migrations are dictated by specific cues such as ice break-up, increasing water levels and higher water temperature, rather than by calendar date. Equipment needs to be on site prior to ice break-up to minimize preparation time. As well, ice conditions, water levels and temperature need to be monitored daily, and field crews need to be available in short notice (1-2 d), in an effort to deploy the fences as early as possible.

6 WETLANDS RESULTS AND DISCUSSIONS

6.1 WATER QUALITY

6.1.1 Shipyard Lake

In the summer of 1998, Shipyard Lake contained much lower levels of TSS (11 mg/L) than in 1995 (180 mg/L), when it was last sampled (Table 6.1). Large changes in TSS often correlate with major shifts in the concentrations of total aluminum, iron and other metals commonly bound to suspended sediments. However, total metal levels in 1998 were generally comparable to those observed in 1995, since a large proportion of the detectable metals were present in their dissolved form. High dissolved metal concentrations may be the result of evaporation.

TDS levels were higher in 1998 (386 mg/L) than in 1995 (147 mg/L) (Table 6.1). Calcium, magnesium and other major ion concentrations were also generally higher in 1998. These results are consistent with the observation that 1998 was a relatively dry year.

Shipyard Lake water contained non-detectable levels of naphthenic acids and was non-toxic to bacteria in 1995 and 1998 (Table 6.1). Nutrient levels indicate that the lake is mesotrophic (Wetzel 1983). Iron and manganese levels in 1998 and 1995 exceeded regulatory guidelines (Table 6.2). Detection limits reported in 1998 for arsenic and mercury exceed guideline levels, so these elements were not evaluated with respect to regulatory guidelines (Table 6.2).

6.1.2 Isadore's Lake

The water sample collected from Isadore's Lake in the summer of 1998 was quite different from the sample collected in 1997 (Table 6.1). The 1998 sample contained higher concentrations of phosphorus, total dissolved solids (TDS), calcium, magnesium, aluminum, arsenic, barium, boron, copper, manganese and nickel than the corresponding 1997 sample. Sulphate levels in Isadore's Lake were higher in 1997 and 1998 than in any of the other sampled wetlands (Appendix Table II-9).

Table 6.1 Summary of Water Quality Results for Various Wetlands in the Oil Sands Region, Athabasca River Floodplain

		Kearl Lake								
		Summer		Fall		Spruce Pond (summer)	Shipyard Lake (summer)		Isadore's Lake (summer)	
Parameter	Units	1998	Historical median	1998	Historical median		1998	1995	1998	1997
Conventional Parameters and Major Ions										
conductance	µS/cm	169	171	182	169	567	329	274	454	319
dissolved organic carbon	mg/L	15	23	15	23	20	16	-	9	11
pH		7.8	7.9	8.1	7.6	8.6	7.5	7.4	8.0	8.4
total alkalinity	mg/L	82	85	88	85	307	161	135	146	129
total dissolved solids	mg/L	192	93	94	96	298	386	147	322	236
total organic carbon	mg/L	19	26	18	26	26	22	24	9	12
total suspended solids	mg/L	7	2	4	2	147	11	180	< 2	2
Nutrients										
nitrogen - ammonia	mg/L	0.07	0.04	0.08	0.12	0.28	0.06	0.093	< 0.05	< 0.05
nitrogen - kjeldahl	mg/L	0.8	1.0	0.9	1.5	3.8	0.9	0.5	0.6	0.4
phosphorus, total	mg/L	0.018	0.016	0.012	0.0335	0.593	0.029	0.034	0.029	0.016
phosphorus, total dissolved	mg/L	0.017	0.0096	0.012	-	0.147	0.024	0.015	0.028	0.008
General Organics and Toxicity										
Microtox IC50 @ 15 min	%	> 91	> 91	> 91	> 91	> 91	>91	> 91	>91	-
Microtox IC25 @ 15 min	%	> 91	> 91	> 91	> 91	> 91	>91	> 91	>91	-
naphthenic acids	mg/L	< 1	< 1	< 1	< 1	13	< 1	< 1	2	< 1
total phenolics	mg/L	0.005	-	0.005	-	0.011	0.003	-	0.001	< 0.001
total recoverable hydrocarbons	mg/L	< 0.5	< 0.55	< 0.5	0.4	< 0.5	< 0.5	< 1	< 0.5	< 0.5
Metals (Total)										
aluminum (Al)	mg/L	0.03	0.005	0.13	< 0.01	2.35	0.03	0.05	0.18	0.018
antimony (Sb)	mg/L	< 0.0008	-	0.0023	-	< 0.0008	< 0.0008	0.0002	< 0.0008	< 0.0004
arsenic (As)	mg/L	< 0.001	0.0002	< 0.001	< 0.00025	0.002	< 0.001	< 0.001	0.002	< 0.0004
barium (Ba)	mg/L	0.0161	0.0105	0.115	0.02	0.0846	0.0346	0.03	0.0737	0.0003
beryllium (Be)	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
boron (B)	mg/L	0.043	0.055	0.012	0.06	1.07	0.042	0.03	0.047	0.009
cadmium (Cd)	mg/L	< 0.0002	0.001	< 0.0002	< 0.001	< 0.0002	< 0.0002	< 0.003	< 0.0002	< 0.0002
chromium (Cr)	mg/L	< 0.0008	0.001	< 0.0008	< 0.002	0.0013	< 0.0008	0.009	< 0.0008	0.0014
copper (Cu)	mg/L	< 0.001	0.001	0.001	< 0.001	0.004	< 0.001	-	0.003	0.0009
iron (Fe)	mg/L	0.08	0.08	0.19	0.07	5.66	2.09	2.65	0.27	0.21
lead (Pb)	mg/L	0.0002	< 0.011	0.0003	< 0.002	0.0016	0.0003	< 0.02	0.001	0.0087
manganese (Mn)	mg/L	0.0314	0.035	0.0499	0.011	0.362	0.0983	0.18	0.0528	0.0005
mercury (Hg)	mg/L	< 0.0002	0.0001	0.0003	< 0.000075	< 0.0002	< 0.0002	< 0.00005	< 0.0002	0.0001
molybdenum (Mo)	mg/L	< 0.0001	0.002	0.0009	0.003	0.0007	< 0.0001	< 0.003	0.0001	< 0.0001
nickel (Ni)	mg/L	0.0009	0.001	0.0057	< 0.001	0.0042	0.0009	0.01	0.0026	0.001
selenium (Se)	mg/L	< 0.0008	0.0002	< 0.0008	0.00025	< 0.0008	< 0.0008	< 0.001	< 0.0008	< 0.0004
silver (Ag)	mg/L	< 0.0004	< 0.002	< 0.0004	0.003	0.0004	< 0.0004	< 0.002	< 0.0004	< 0.0001
vanadium (V)	mg/L	< 0.0002	0.002	< 0.0002	< 0.002	0.0078	< 0.0002	< 0.002	< 0.0002	0.0004
zinc (Zn)	mg/L	0.007	0.016	0.007	0.011	0.037	< 0.004	0.013	0.011	0.013
Metals (Dissolved)										
aluminum (Al)	mg/L	0.01	-	0.03	-	0.01	0.06	-	0.06	-
antimony (Sb)	mg/L	< 0.0008	-	< 0.0008	-	0.0008	< 0.0008	-	< 0.0008	-
arsenic (As)	mg/L	0.0006	-	< 0.0004	-	0.0021	0.0005	-	0.0022	-
barium (Ba)	mg/L	0.015	-	0.0178	-	0.0107	0.0332	-	0.0758	-
beryllium (Be)	mg/L	< 0.0005	0.001	< 0.0005	-	< 0.0005	< 0.0005	-	< 0.0005	-
boron (B)	mg/L	0.039	-	0.05	-	0.858	0.033	-	0.038	-
cadmium (Cd)	mg/L	< 0.0001	-	< 0.0001	-	< 0.0001	0.0001	-	< 0.0001	-
chromium (Cr)	mg/L	< 0.0004	-	< 0.0004	-	< 0.0004	< 0.0004	-	< 0.0004	-
copper (Cu)	mg/L	0.0006	-	0.0014	-	0.0012	0.0006	-	0.0037	-
iron (Fe)	mg/L	0.1	-	0.09	-	0.23	1.48	-	0.2	-
lead (Pb)	mg/L	0.0001	-	0.0003	-	0.0004	0.0001	-	0.0012	-
manganese (Mn)	mg/L	0.008	-	0.0038	-	0.0943	0.102	-	0.0508	-
mercury (Hg)	mg/L	< 0.0001	-	< 0.0001	-	< 0.0001	< 0.0001	-	< 0.0001	-
molybdenum (Mo)	mg/L	< 0.0001	-	< 0.0001	-	0.0005	< 0.0001	-	< 0.0001	-
nickel (Ni)	mg/L	0.001	-	0.0016	-	0.0018	0.0003	-	0.0025	-
selenium (Se)	mg/L	< 0.0004	-	< 0.0004	-	0.0004	< 0.0004	-	< 0.0004	-
silver (Ag)	mg/L	< 0.0002	-	< 0.0002	-	< 0.0002	< 0.0002	-	< 0.0002	-
vanadium (V)	mg/L	< 0.0001	-	0.0001	-	0.0027	< 0.0001	-	< 0.0001	-
zinc (Zn)	mg/L	0.011	-	0.005	-	0.023	< 0.002	-	0.003	-

Table 6.2 Water Quality Results for Various Wetlands in the Oil Sands Region that Exceed Regulatory Guidelines

Parameter	Units	Guidelines[a] for the protection of:				Kearl Lake				Spruce Pond (summer)	Shipyard Lake (summer)		Isadore's Lake (summer)	
		Aquatic life		Human Health		Summer		Fall						
		Acute	Chronic	Carcinogen	Non-carcinogen	1998	Historical median	1998	Historical median		1998	1995	1998	1997
Nutrients														
phosphorus, total	mg/L		0.05							C				
General Organics and Toxicity														
total phenolics	mg/L		0.005							C				
Metals (Total)														
aluminum (Al)	mg/L		0.1					C		C			C	
arsenic (As)	mg/L	0.36	0.01	0.000018		HC *	HC	HC *	HC *	HC	HC *	HC *	HC	HC *
boron (B)	mg/L		0.5							C				
cadmium (Cd)	mg/L	0.007	0.0018									C *		
iron (Fe)	mg/L		1		0.3					C HNC	C HNC	C HNC		
lead (Pb)	mg/L	0.17	0.007				C *					C *		C
manganese (Mn)	mg/L				0.05					HNC	HNC	HNC	HNC	
mercury (Hg)	mg/L	0.002	1.2E-05		0.00014	C HNC*	C	C HNC	C *	C HNC*	C HNC*	C *	C HNC*	C

[a] Derivation of guidelines shown in Appendix Table II-10.

* Although lab reported non-detectable levels of substance, the method detection limit exceeds the guideline limit.

C = chronic guideline exceeded; HNC = human health non-carcinogen guidelines exceeded; HC = human health carcinogen guideline exceeded. Refer to Appendix Table II-8 for more information on guidelines.

In 1998, total aluminum, arsenic and manganese concentrations exceeded regulatory guidelines, whereas lead and mercury were the only substances found to exceed guideline levels in 1997 (Table 6.2). Naphthenic acids and phenolic compounds were detectable in 1998 (Table 6.1). These substances were undetectable in 1997. In 1997 and 1998, Isadore's Lake received only natural runoff waters; no human related waters have been released to this lake. Differences between the 1998 and 1997 data may be due in part to increased evaporation in 1998. Under such conditions, chemical loading to the lake may have been similar, but the incoming mass would reside in a smaller volume of water, resulting in higher concentrations. Sample waters from Isadore's Lake were found to be non-toxic to bacteria. Nutrient concentrations indicate that this is a mesotrophic lake (Wetzel 1983).

DO profiles measured in Kearl Lake on December 9, 1998 are summarized in Table 6.3. At both sample sites, DO levels were generally near saturation until within 25 cm of the lake bottom.

Table 6.3 Dissolved Oxygen Levels Measured at Various Depths in Kearl Lake on December 9, 1998

Depth (m)	Dissolved Oxygen Levels (mg/L) at Sample Site 1	Dissolved Oxygen Levels (mg/L) at Sample Site 2
water surface	12.1	10.8
0.25	11.7	10.7
0.5	11.6	10.5
0.75	11.6	5.6
1	11.7	bottom
1.25	11.6	
1.5	8.0	
1.75	bottom	

6.1.3 Kearl Lake

Kearl Lake water quality in the summer and fall of 1998 was generally quite similar to historical trends, with the following exceptions:

- TDS and total aluminum concentrations were higher in 1998 (Table 6.1).
- Total cadmium, chromium, molybdenum and vanadium levels were lower in the summer of 1998 than in previous sampling events.
- Water samples collected in the fall of 1998 contained higher levels of total barium, iron and manganese than previously observed in the lake.

Despite these differences, Kearl Lake water quality was relatively consistent through the summer and fall seasons, as indicated by the similarities between all of the summer and fall data collected to date (Table 6.1 and Appendix Table II-9). Overall, Kearl Lake is a clear water lake with low total suspended solids (TSS <10 mg/L) and low organic content. The lake appears to be mesotrophic, as defined by Wetzel (1983). It has been found to contain aluminum, arsenic and mercury concentrations in excess of guideline levels (Table 6.2).

6.1.4 Spruce Pond

Water quality in Spruce Pond in the summer of 1998 was very different from the water quality observed in any of the other wetlands (Table 6.1). Spruce Pond was the most basic of the four wetlands, with a pH of 8.6. It contained higher levels of total alkalinity, TSS, total phenolics, naphthenic acids and total metals than any other wetland sampled in 1998. High nutrients and chlorophyll *a* concentrations (Tables 6.1 and II-9) indicate that the trophic status of Spruce Pond is hyper-eutrophic, as defined by Wetzel (1983). The concentrations of seven elements (phosphorus, total phenolics, total aluminum, arsenic, boron, iron and manganese) were found to exceed guideline levels (Table 6.2). Particle bound metals represented a large proportion of the detectable total metals observed in Spruce Pond in summer of 1998, as indicated by low corresponding dissolved metal levels (Table 6.1).

Calcium, magnesium and chloride levels observed in Spruce Pond are similar to historical levels in Kearl Lake (Table II-9), indicating that the unusual water quality observed in this lake may not have resulted entirely from increased evaporation. Instead, the high bicarbonate, carbonate and sodium concentrations observed in this lake (Table II-9) suggest that it receives a greater proportion of groundwater inflow than the other wetlands.

The presence of sulphides and a five-day biochemical oxygen demand (BOD_5) greater than 90 mg/L also indicates that Spruce Pond is rich in organic material, the breakdown of which may result in anoxic conditions and the production of hydrogen sulphide. Therefore, the unusual characteristics of Spruce Pond may be due to high organic and groundwater inputs, relative to the other sampled wetlands. Overall, water quality in Spruce Pond was very different from the other three wetlands sampled in the summer of 1998 as part of RAMP. This wetland contained murky waters rich in nutrients and organics, and a thriving algal population.

6.1.5 Quality Assurance and Quality Control

Measured concentrations in the trip blank analyzed with the wetlands samples were less than method detection limits for most of the test parameters (Table 5.13). Low levels of aluminum, boron, iron and several other metal species were measured in the blank sample. However, all detectable levels were less than five times the corresponding method detection limit (MDL), with the exception of dissolved selenium. Blank concentrations that are less than five times the MDL are considered to represent an acceptable level of analytical “noise” associated with sample preparation and measurement. Detection limits for dissolved selenium were adjust to 0.0032 mg/L to reflect the concentration detected in the trip blank.

Total organic carbon (TOC) levels reported for Spruce Pond (26 mg/L) could be too low. The measured concentration of naphthenic acids was 13 mg/L and the BOD_5 was 90+ mg/L, whereas the measured TOC levels were equivalent to those reported for the other three wetlands, which contained <3 mg/L of both BOD_5 and naphthenic acids (Appendix Table II-9).

The wetlands water quality data set may contain several errors, as indicated by dissolved metal readings which exceed corresponding total metal concentrations (e.g., zinc in Kearl Lake and aluminum in Shipyard Lake). Total organic carbon levels reported for Spruce Pond (i.e., 26 mg/L) could also be too low.

It is important to note that these potential errors affect <5 % of the information collected in the 1998 wetlands survey. ETL and HydroQual, the two laboratories which analyzed the wetland water quality samples, also adhere to their own standards of practice and routinely check the accuracy and precision of their equipment.

6.2 AQUATIC VEGETATION

6.2.1 Shipyard Lake

6.2.1.1 General Description

Shipyard Lake is a riparian wetlands complex located adjacent to Suncor’s Steepbank/Millennium Mine within the Athabasca River floodplain. The wetlands complex is 159.6 ha in size and is predominantly a shallow open water - marsh wetland complex. The main watercourses within the Shipyard Lake drainages include Unnamed Creek, which enters the wetland from the northeast and several small channels and creeks, which enter the wetland from the southeast. Shipyard Creek, a narrow channel to the north, provides the outlet to the Athabasca River.

Analysis of peat depth in Shipyard Lake indicates that it has been isolated from the Athabasca River for several hundred years (Golder 1996c). Review of past aerial photographs and maps confirms that the general shape and vegetation patterns within the wetlands have not changed substantially in the past 53 years (Golder 1996c).

6.2.1.2 Wetlands Complexes and Species Composition

The wetlands associated with Shipyard Lake include shallow open water, graminoid marshes, shrubby marshes, shrubby swamps and wooded swamps. Wooded and shrubby swamps occur in the transition between the marsh and forested upland associated with the escarpment. The amount of available wetland habitat has not changed considerably since the 1997 inventory. Marshes occupy the majority (130.3 ha or 77.3%) of the wetlands complex. Shallow open water, which represents the main basin, occupies 26.9 ha or 16%. Wooded swamps occupy 26.9 ha or 6.7 % and largely occur around the perimeter of the marsh-shallow open water areas (Figure 6.1).

There has been a small reduction (<1 ha) in the size of wooded swamp. This loss is associated with the clearing of upland vegetation at the top of the escarpment to facilitate infrastructures (access road and buildings) associated with the Steepbank Mine. The change in wooded swamp however, is not at a mapable scale to accurately quantify changes. The general distribution and size of the wetlands are shown in Table 6.4 and in Figure 6.1.

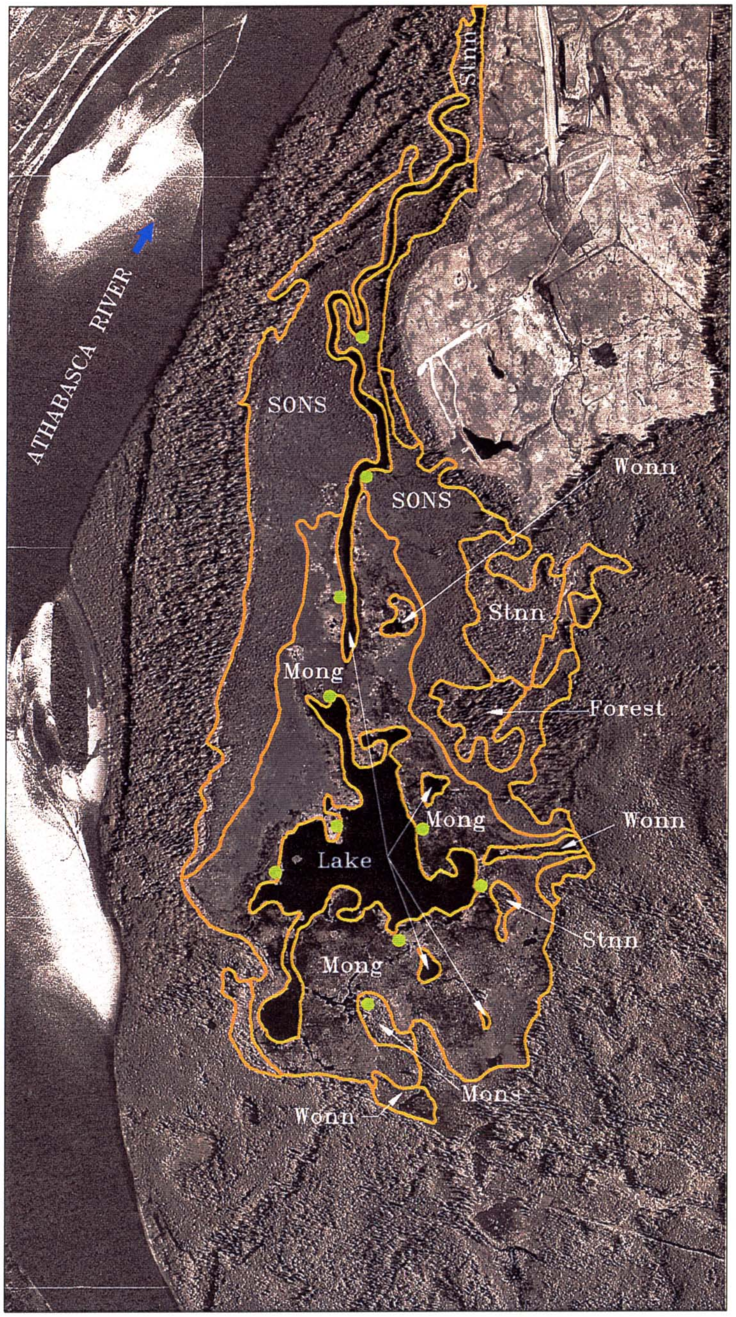
Table 6.4 Wetlands Represented in Shipyard Lake

AWI Class	AWI Subclass	Number of Wetland Types	Areas of Shipyard Lake (ha)	Areas of Shipyard Lake (%)
marsh **(M)**	open non-patterned shrubby marsh **(Mons)**	4	59.6	35.4
	open non-patterned graminoid marsh **(Mong)**	3	70.7	41.9
shallow open water	shallow open water **(Wonn)**	9	26.9	16.0
swamp	open treed swamp **(Stnn**)	4	11.3	6.7
Total		20	168.5	100.0

Note: AWI = Alberta Wetland Inventory

J:\1998\2309\6052\SHIPYARD.dwg

J:\1998\2309\6052\SHIPYARD.jpg



0 500 1000 metres

LEGEND

Mong – Graminoid Marsh
Mons – Shrubby Marsh
Sons – Shrubby Swamp
Stnn – Treed Swamp
● TRANSECT LOCATIONS

REFERENCE

The Orthoshop (Photo Date 1997)
The Forestry Corp.

Golder Associates

SHIPYARD LAKE WETLANDS

27 Mar. 1998	Figure 6.1	DRAWN BY: CG

Marshes (Mong & Mons)

The water levels fluctuate in marshes during the course of the year and they have a relatively high water flow (Halsey and Vitt 1996). While high concentrations of nitrogen and phosphorus allow for high plant productivity in marshes, decomposition rates are also high. For this reason, little peat accumulates in these wetlands, and mosses and lichens are uncommon. Marshes have poor to very poor drainage, and have a hydric to subhydric moisture regime. The nutrient regime is medium to very rich due to occasional slow-moving water. Water is above the level of the rooting zone of the plants for all or part of the year. The results of the water quality assessments for Shipyard Lake are discussed in Section 6.1.1.1 and Table 6.1.

Marshes are subdivided into graminoid (Mong) and shrubby marshes (Mons) based on dominant species composition. Six vegetation transects were located in graminoid marshes and two transects within a shrubby marsh. Limited access precluded additional surveys in shrubby marshes.

Graminoid marshes surveyed within Shipyard Lake were on “floating vegetated mats.” As a result, the root system was not in the sediment. There were three distinct communities of graminoid marshes in Shipyard Lake, which include cattail emergent, sedge emergent and horsetail emergent.

Cattail Emergent

There were three transects of nine plots in total within the cattail emergent community. This community surrounds the shallow open water areas and often occurs as floating mats within the lake. According to Lieffers (1984), cattails are most dominant with increased water levels and usually occur at the inner edge of the emergent zone. Water sedge appears to contribute to the substrate matrix of the cattail stands on floating mats, which is consistent with Lieffers (1984). According to Lieffers (1984), the cattail-dominated communities will gradually shift to the sedge dominated communities under stable water levels, as nutrients become depleted and substrates become more stable with reduced water circulation.

Species richness ranged from two to 12 species with a mean richness of five (Table 6.5). There were three plots that consisted of only two species (cattail and duckweed). The most common species that occurred within the cattail community included rat root, water sedge, bur-reed, spike rush, marsh cinquefoil and small white pond lily. Species composition did not change substantially from 1997; however, two plots did show increases in herbaceous species. Both plots had either increases or new occurrences of purple willow herb, northern bedstraw, marsh cinquefoil and marsh skullcap. This change in species composition is attributed to lower water levels in the Lake. Small white pond-lily was the only rare plant observed in the lake. This is consistent with the data collected in 1997. Appendix X contains a plant species list.

Table 6.5 Species Richness of Wetlands Community Types in Shipyard Lake

Wetland Type	Community Type	No. of Plots	Mean Richness	Min. Richness	Max. Richness
graminoid marsh (MONG)	cattail emergent	9	5	2	12
graminoid marsh (MONG)	sedge emergent	6	5	5	23
graminoid marsh (MONG)	horsetail emergent	3	2	2	3
shrubby marsh (MONS)	willow	3	5	3	10
shallow open water (WONN)	yellow pond-lily submergent	3	2	2	3
shallow open water (WONN)	coontail submergent	3	2	2	3

Sedge Emergent

The sedge emergent community occurred in adjacent small pockets within the cattail emergent community. This community was dominated by water sedge, *Carex interior*, and *Carex lasiocarpa*. There were two transects with six plots in total located within the sedge emergent community. Species richness varied from four to 12 species with a mean richness of five. Other species occurring within this community included common spike rush, rat root and water arum.

Horsetail Emergent

The horsetail (common horsetail and common scouring rush) emergent community occurred where the main basin flowed into the narrow channel in the north end of the lake. There was one transect with three plots. The plots are monospecific (with only two species). The co-dominant species is largely duck weed. The substrate is predominantly silty mud.

Willow Emergent

Willow species, primarily beaked willow, dominated the shrubby marshes. Due to limited access, there was only one transect of three plots within this community type. A number of willow species were dead. This is probably attributable to large fluctuations in annual water levels in the lake. The species richness ranged from three to 10 with a mean of five. Water arum, marsh cinquefoil, marsh marigold, northern bedstraw, tufted loosestrife and purple willowherb occurred within this community type. Both water arum and marsh cinquefoil, growing from detached mounds of substrate from the bases of dead willows, formed new floating mats of vegetation. The coalescing and redistribution of the mats over time lead to an expansion of graminoid marshes within the basin.

Shallow Open Water (Wonn)

The Shallow Open Water subclass is generally less than 2 m in depth during midsummer (Halsey and Vitt 1996). Submergent and/or floating vegetation is present, representing the mid position between terrestrial and aquatic environments. This wetlands class, as observed in Shipyard Lake, was often associated with other wetlands types such as marshes. The dominant aquatic macrophytes or submergent vegetation include mare's tail, coontail, common duckweed, and water milfoil.

Yellow Pond-Lily Submergents

The yellow pond-lily submergent community supports a bed of floating aquatic plants. The plants float freely either in the water or on its surface. Dominant plants that float on the surface include common duckweed and yellow pond-lily. Dominant plants that float below the surface include water milfoil, common bladderwort, white water buttercup, hornwort, sago pondweed, clasping-leaf pondweed, flat-stemmed pondweed, large-sheath pondweed, thread-leaved pondweed and Fries' pondweed. A total of three plots were sampled within the pond-lily/submergent community. Ten species were recorded among those plots although the average number of species per plot was four species (Table 6.5). Yellow pond-lily occurs in every plot and has a mean cover of 26.3%. Water milfoil, filamentous algae, sago pondweed, clasping-leaf pondweed, hornwort and flat-stemmed pondweed occurred in more than 25% of the plots surveyed. The yellow pond-lily/submergent community type was mainly observed within the main open water area and channel, which extended to the north. The substrate was silty mud.

Coontail/Hornwort Submergent

Beds of floating and rooted vascular plants occur mainly in the Hornwort/Duckweed community type. Dominant plants that float on the surface include common and star duckweed. Some of the rooted vascular plants include water milfoil, sago pondweed and clasping-leaf pondweed. These plants commonly root in sandy, silty bottoms of lakes. A total of one transect and three plots were sampled within the hornwort/duckweed community type. Eleven species were recorded among the plots surveyed although the average species per plot was between two and three species (Table 6.5). Hornwort occurs in 70% of the plots and has a mean cover of 32%. Water milfoil, sago pondweed and clasping-leaf pondweed occurred in more than two of plots surveyed. The hornwort/duckweed community type was mainly observed in the main basin of the lake where water depth exceeded two metres.

Open Wooded Swamps (Stnn)

Swamps often exist where there are bodies of water that flood frequently or where water levels fluctuate (e.g., along peatland margins). They are non-peaty wetlands that can be forested, wooded, or shrubby (Figure 6.1). Few mosses and lichens grow in swamps due to the fluctuating water levels. Peat accumulation is low due to high decomposition rates. Common species within swamps include tamarack, birch, willow, alder and black spruce.

Two types of swamps, coniferous and deciduous, are recognized by the AWI classification system (Halsey and Vitt 1996). Coniferous swamps (Stnn) exist around the outer perimeter of Shipyard Lake. Due to limited access, no plots were surveyed within this wetland class. Aerial photograph interpretation, however, indicates that this class occupies 11.3 ha or 6.3% of this wetland complex. Coniferous swamps have a dense tree cover (>70%) composed of black spruce and tamarack. Shrub cover is generally greater than 25%, willow dominated, with few bryophytes (i.e., liverworts, mosses).

6.2.1.3 Vegetation Vigour

Vegetation vigour, recorded for each cover class observed, is presented in Table 6.6. Generally, the overall vigour rating (AEP 1994) for all cover classes was very good (VG) for the majority of the shrub, herb and aquatic cover types. One plot, however, had vigour measurements for the shrub class of 40% dead (D) and 60% poor (P). The aquatic class, in this plot was observed to be 30% dead or necrotic, 30% poor and 40% good (G). This plot, located adjacent to the north channel, has lower water levels and is believed to be a poorer growing environment for shrubs and aquatic plants. The presence of necrotic plants in marshes is not unexpected due to lower water levels in 1998.

Table 6.6 Average Percent Plant Vigour for Wetland Communities in Shipyard Lake

Wetlands		% Vigour																			
		Shrub					Grass					Herb					Aquatics				
Type	Community	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total
MONG	cattail	-	-	-	-	0	-	20	20	60	100	-	-	-	100	100		30	20	50	100
MONG	sedge	-	-	-	-	0	30	20	-	50	100	-	-	-	100	100	-	-	40	60	100
MONG	horsetail	-	-	-	-	0	-	-	-			-	-	-	-	0	30	-	20	50	100
MONS	willow	40	10	10	40	100	-	-	20	80	100	-	20	40	40	100	-	-	-	-	0
WONN	yellow pond-lily	-	-	-	-	0	-	-	-	-	0	-	-	-	-	-	-	-	40	60	100
WONN	coontail	-	-	-	-	0	-	-	-	-	0	-	-	-	100	100	-	-	-	100	100

D = Dead; P = Poor; G = Good; VG = Very Good

6.2.2 Isadore's Lake

6.2.2.1 General Description

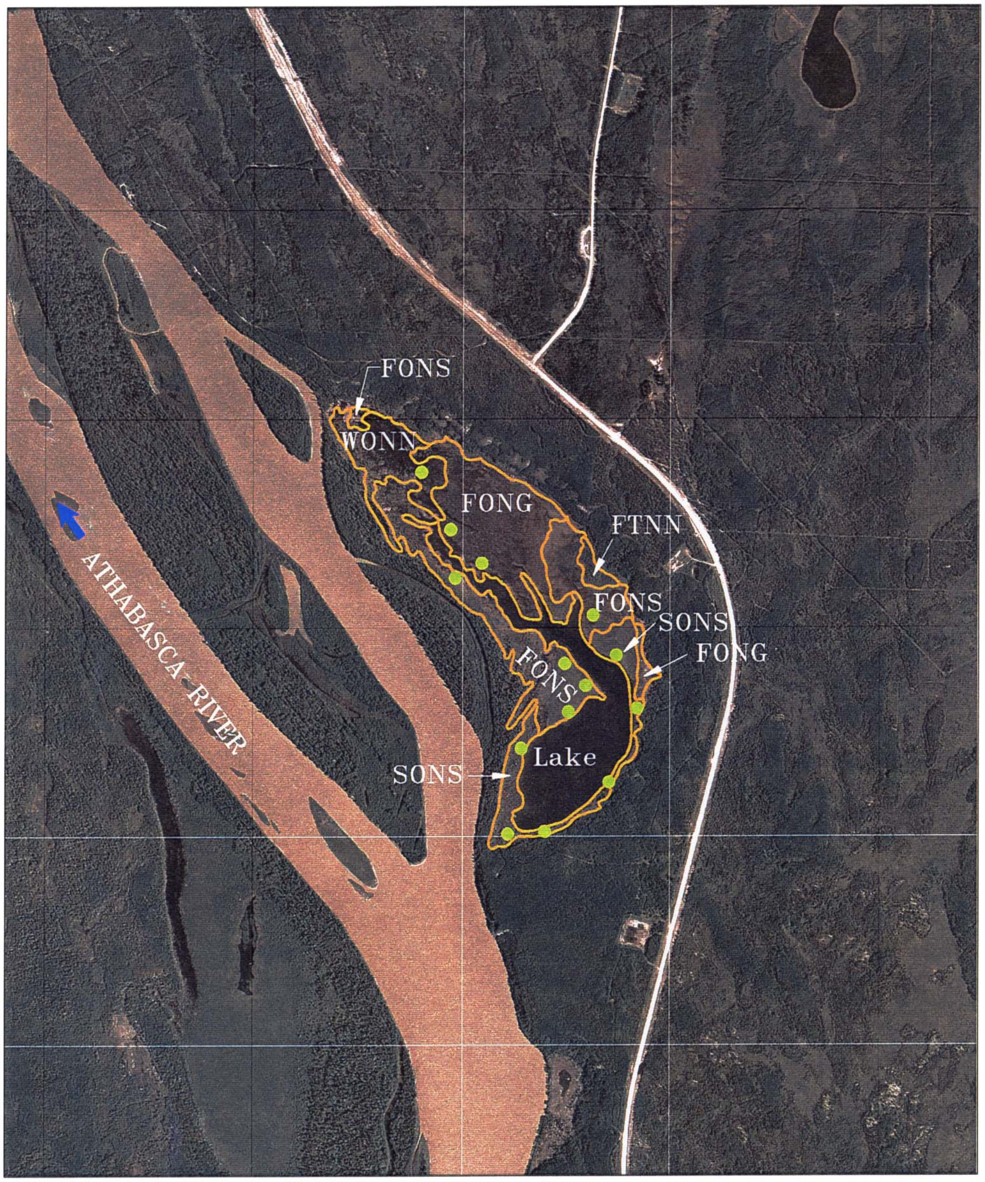
Isadore's Lake is a riparian wetland complex situated in the Athabasca River floodplain, adjacent to Shell Canada Limited, the proposed Muskeg River Mine Project. It is one of several oxbow lakes that occur within the floodplain of the Athabasca River. The lake consists of an open water fen complex dominated by sedges and cattail, with low shrub and wooded fens that occur along the outer perimeter. The wetland complex is approximately 130 ha in size. A channel situated north of the lake provides an outlet to the Athabasca River (Figure 6.2).

6.2.2.2 Wetland Complex and Plant Species Composition

Isadore's Lake is 149.6 ha in size. Table 6.7 shows the relative size and distribution of wetland types associated with this lake. The dominant wetland type is the open, non-patterned shrubby fen (FONS), occupying 46.5 ha (31.1%) of the lake. Together with the open, non-patterned, graminoid fen (FONG), which comprises 33.6 ha (22.5%), these two fen types make up over half (53.6%) of the lake's area. Figure 6.2 illustrates the wetlands of Isadore's Lake. No plots were surveyed in the open shrubby swamp or wooded fen wetland classes.

There were no changes in the size of wetlands compared to the 1997 survey. No clearing or development had occurred in the immediate vicinity of the lake since the 1997 survey. There was one additional transect added in 1998 to document the occurrence of the reed grass community.

J:\1997\2320\ISADORE.dwg



0 500 1000 metres

LEGEND

Fons – Shrubby Fen
Fong – Graminoid Fen
Ftnn – Treed Swamp
Sons – Shrubby Swamp
Wonn – Shallow Open Water
● TRANSECT LOCATIONS

REFERENCE

The Orthoshop (Photo Date 1997)
The Forestry Corp.

Golder Associates

ISADORE'S LAKE WETLANDS

22 Jan. 1999	Figure 6.2	DRAWN BY: CG

Table 6.7 Wetlands Represented in Isadore's Lake

AWI Class	AWI Subclass	Number of Wetland Types	Areas of Isadore's Lake (ha)	(%)
Fen **(F)**	Open, non-patterned, shrubby fen **(Fons)**	3	46.5	31.1
	Open, non-patterned, graminoid fen **(Fong)**	2	33.6	22.5
	Wooded fen, no internal lawns **(Ftnn)**	1	2.2	1.5
Swamp (S)	Open shrubby swamp	1	14.2	9.5
Shallow Open Water	Shallow Open Water **(Wonn)**	1	14.8	10.0
Lake		1	38.3	25.6
Total		10	149.6	100.0

AWI = Alberta Wetland Inventory.

Graminoid Fen (Fong)

Graminoid fens tend to have a hygric to subhygric moisture regime, poorly to very poorly drained soils, and a medium to rich nutrient regime (Halsey and Vitt 1987). Shrub cover was very sparse, consisting of only dwarf birch and willow species. Graminoid fens occupied 33.6 ha of the wetlands complex. Sedges and cattail, with some willow species dominated plots within this type. Herbaceous and aquatic plants observed included wild mint, twinflower, northern bedstraw, marsh cinquefoil, water arum, yellow pond-lily, and common bladderwort. Brown moss was also present. The three community types observed in Isadore's Lake included sedge emergent, cattail-sedge emergent and reed grass emergent. All three communities occurred adjacent to the shallow open water.

Sedge Emergent

The sedge emergent community occurred in adjacent small pockets within the cattail emergent community. This community was dominated by water sedge, *Carex interior* and *Carex lasiocarpa*. Two transects with six plots were located within the sedge emergent community. Species richness varied from four to 12 species with a mean richness of five (Table 6.8). Other species occurring within this community included common cattail, spike rush, water arum, marsh cinquefoil, marsh skullcap, wild mint, tufted loosestrife and bur-reed.

Table 6.8 Species Richness of Wetlands Community Types in Isadore's Lake

Wetland Type	Community Type	No. of Plots	Mean Richness	Min. Richness	Max. Richness
graminoid fen (FONG)	sedge emergent	6	5	4	12
graminoid fen (FONG)	cattail – sedge emergent	9	5	2	12
graminoid marsh (FONG)	reed grass emergent	3	6	4	8
shrubby marsh (FONS)	labrador tea – sedge	6	6	4	18
shallow open water (WONN)	yellow pond-lily submergent	2	3	2	5
shallow open water (WONN)	milfoil submergent	3	2	2	3

Sedge-Cattail Emergent

There were three transects with nine plots located within the cattail emergent community. This community surrounds the shallow open water areas and often occurs as floating mats within the lake. According to Lieffers (1984), cattails are most dominant with increased water levels and usually occur at the inner edge of the emergent zone. Water sedge appears to contribute to the substrate matrix of the cattail stands on floating mats, which is consistent with Lieffers (1984). Floating mats vary in size and shape and may periodically be redistributed around the open water margins due to changes in wind direction and fetch conditions. According to Lieffers (1984), the cattail-dominated communities will gradually shift to the sedge dominated communities under stable water levels, as nutrients become depleted and substrates become more stable with reduced water circulation.

Species richness ranged from two to 12 species with a mean richness of five (Table 6.8). There were three plots that consisted of only two species (cattail and duckweed). The most common species that occurred within the cattail community included rat root, water sedge, bur-reed, spike rush, marsh cinquefoil and small white pond lily. Species composition did not change substantially in 1997; however, some plots did show increases in the number of herbaceous species. Both plots had either increases or new occurrences of purple willow herb, northern bedstraw, marsh cinquefoil and marsh skullcap. This change in species composition is attributed to lower water levels in the lake. Small white pond-lily was the only rare plant observed in the lake. This is consistent with the data collected in 1997.

Reed Grass Emergent

The reed grass emergent community occurred on the east side of the lake. The species associated with this included cattail, beaked sedge, turned sedge, sedge (unidentified; no seed heads), water arum, baltic rush, chara, and filamentous green algae. The reed grass community was only observed in Isadore's Lake. According to (Dirschl and Coupland 1972; Dirschl et al. 1974), reed grass is abundant in rarely flooded zones in the deltas of the Saskatchewan and the Peace-Athabasca rivers. This may indicate that the water levels in Isadore's Lake are more stable than Shipyard Lake, where the community did not occur.

Shrubby Fen (Fons)

Shrubby fens border the lake basin. Shrubby fens occupied 46.5 ha (31.6%) of the wetland complex. Two plots within the shrubby fen wetland type were surveyed. In wetter areas, plots were dominated by willow. In drier areas, shrubs observed included Labrador tea, velvet-leaved, blueberry, bearberry, leather-leaf, bilberry, low bush cranberry and stunted tamarack (Appendix X).

Labrador Tea - Sedge

The Labrador tea-sedge community occurred on drier sites at the outer perimeter of the lake. There were 2 transects of 6 plots sampled within this community type. There were 18 species observed in this community type but the mean richness was 6 species. Species that occurred in this community included dwarf birch, willow, velvet-leaved, blueberry, bearberry, leather-leaf, bilberry, low bush cranberry, tamarack, black spruce, cloudberry, common pink wintergreen, narrow-leaved willow herb, marsh skullcap, marsh cinquefoil, water sedge, sheathed sedge, and two-seeded sedge.

Shallow Open Water (Wonn)

The shallow open water class comprised 14.8 ha or 10.0% of this wetland complex, consisting of one dominant, sub-rounded open water area, elongated to the Northwest (Figure 6.2). Submergent species observed included coontail, water-milfoil and mare's tail. Floating emergent species included common duckweed and yellow pond-lily. Approximately 5% of the surveyed plots consisted of emergent and shrub plants dominated by sedge and willow.

Yellow Pond-Lily Submergent

The yellow pond-lily submergent community supports a bed of floating aquatic plants. The plants float freely either in the water or on its surface. Dominant plants that float on the surface include common duckweed and yellow pond-lily. Dominant plants that float below the surface include water milfoil, common bladderwort, white water buttercup, coontail, sago pondweed, flat-stemmed pondweed, and filamentous algae. One transect with two plots was sampled within the pond-lily/submergent community. Five species were recorded among those plots although the average number of species per plot was three species. Water milfoil, filamentous algae, sago pondweed, hornwort and flat-stemmed pondweed occurred within some of the plots surveyed. The yellow pond-lily/submergent community type was mainly observed within the main open water area and channel, which extended to the north. The substrate was silty mud.

Coontail/Duckweed Submergent

Beds of floating and rooted vascular plants occur mainly in the coontail/duckweed community type. Dominant plants that float on the surface include common and star duckweed. Some of the rooted vascular plants include water milfoil, sago pondweed and clasping-leaf pondweed. These plants commonly root in sandy, silty bottoms of lakes. A total of one transect and three plots were sampled within the hornwort/duckweed community type. Six species were recorded among the plots surveyed although the average number of species per plot was two species. Hornwort occurs in the majority of the plots surveyed. Water milfoil, sago pondweed occurred in more than two of plots surveyed. The hornwort/duckweed community type was mainly observed in the main basin of the lake where water depth exceeded two metres.

Milfoil Submergent

The Milfoil community supports rooted and floating vascular plants. Some of the rooted vascular plants are characterized by floating leaves, which include water milfoil, clasping-leaf pondweed, flat-stemmed pondweed, sago pondweed, large-sheath pondweed, floating-leaf pondweed and yellow pond-lily. These plants commonly root in the silty bottom of lakes. The dominant plants that float on the surface include star duckweed, white water buttercup and common bladderwort. Five plots were sampled within the milfoil community type. Five species were recorded among the plots surveyed although the average number of species per plot was three species. Flat-stemmed pondweed, *Chara* spp. and filamentous algae occurred in more than 25% of plots surveyed. The community commonly occurs on silty or clay mud.

6.2.2.3 Vegetation Vigour

Vegetation vigour was recorded for each cover class for Isadore's Lake and is presented in Table 6.9. Overall, vigour was high, ranging from good to very good. The grass and herb classes had very good vigour. The shrub classes in this wetlands had lower vigour results, which ranged from dead to good. The shrubs, predominantly willow, were necrotic (dead). Plant necrosis, represented as brown spots on leaves and stems, was observed in cattail and sedges. A few shrubs had necrotic leaves or brown spots on leaves and stems. Similar conditions were recorded in all wetlands surveyed.

Table 6.9 Percent Plant Vigour for Each Cover Type for Isadore's Lake

Wetlands		% Vigour																			
		Shrub					Grass					Herb					Aquatics				
Type	Community	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total
FONG	sedge	-	-	-	-	0	-	50	-	50	100	-	-	-	100	100	50	-	50	-	100
FONG	sedge – cattail	-	-	-	-	0	30	20	-	50	100	-	-	-	100	100				-	100
FONG	reed grass	-	-	-	-	0	-	-	20	80	100	-	-	20	80	100	30	-	20	50	100
FONS	labrador tea-sedge	10	10	40	40	100	-	50	-	50	100	-	-	-	-	0	-	-	-	-	0
WONN	yellow pond-lily	-	-	-	-	0	-	100	-	-	100	-	-	-	-	-	-	-	40	60	100
WONN	milfoil	-	-	-	-	0	-	-	-	-	0	-	-	-	-	-	10	10	-	80	100

D = Dead; P = Poor; G = Good; VG = Very Good

6.2.3 Kearl Lake

6.2.3.1 General Description

Kearl Lake is a large lake-wetlands complex located approximately 12 km east of the Athabasca River along the Muskeg River Drainage System. The lake and associated wetlands occupies an area of approximately 955 ha. Graminoid and shrubby fens border the lake.

Wetland Complex and Plant Species Composition

Table 6.10 and Figure 6.3 show the distributions and size of wetlands associated with Kearl Lake. Approximately 547 ha (57.3%) of the Kearl Lake wetlands complex is dominated by open water. Open, non-patterned, graminoid fen (FONG) comprises the largest area (162.9 ha or 17.1 %) of the three fen types making up the wetlands complex.

Table 6.10 Alberta Wetland Inventory Wetlands Represented in Kearl Lake

AWI Class	AWI Subclass	Number of Wetland Types	Areas of Kearl Lake (ha)	(%)
fen **(F)**	open, non-patterned, shrubby fen **(Fons)**	2	137.7	14.4
	open, non-patterned, graminoid fen **(Fong)**	1	162.9	17.1
	wooded fen, no internal lawns **(Ftnn)**	2	106.8	11.2
lake		1	547.3	57.3
Total		6	954.7	100.0

Graminoid Fen (Fong)

Graminoid fens border the lake and occupy 162.9 ha. Graminoid fen plots were dominated by sedges and cattail with some willow. Herbaceous and aquatic plants observed included: wild mint, twin flower, northern bedstraw, marsh cinquefoil, water arum, yellow pond-lily, and common bladderwort. Brown moss was also present.

Cattail Emergent

The cattail community surrounds the main lake basin. There were 15 plots within the cattail emergent community surveyed in 1998. Similar to Shipyard and Isadore's Lake, sedge appears to contribute to the substrate matrix of the cattail stands. Sedge communities occupy the outer perimeter of the cattail community, which appear to be displacing the cattail dominant community. The mean richness was five species, however 20 species were observed in this community type. The most common species that occurred within the cattail community included: duckweed, two-seeded sedge, bristle stalk sedge, beaked sedge, sheathed sedge, bur-reed, spike rush, water arum, marsh cinquefoil, tufted loosestrife, narrow-leaved willowherb, wild mint and small white pond lily. Species composition did not change substantially from 1997; however, some plots did show increases in herbaceous species. This was probably due to the slightly drier conditions in 1998. Small white pond-lily, which was also observed in Shipyard Lake was identified in Kearl Lake.

J:\1997\2320\1000\KEARL.dwg

LEGEND

Fong – Graminoid Fen
Fons – Shrubby Fen
Ftnn – Treed Fen
● TRANSECT LOCATIONS

0 500 1000(m)

SCALE 1:30,000

REFERENCE

THE ORTHOSHOP (PHOTO DATE 1997)
THE FORESTRY CORP.

Golder Associates

KEARL LAKE

22 Jan 1999	Figure 6.3	DRAWN BY: RFM

Sedge Emergent

The sedge emergent community occurred along the outer perimeter of the lake and generally surrounded the cattail dominant community. This community included water sedge, beaked sedge, brownish sedge, two-seeded sedge, northern bog sedge, bristle stalked sedge and sheathed sedge. There were 10 plots located within the sedge emergent community. Species richness varied from six to 12 species with a mean richness of eight (Table 6.11). Other species occurring within this community included cattail, rat root, cloudberry, blunt-leaved sandwort, wild mint, tufted loosestrife, lapland buttercup and willow.

Water Arum Emergent

Water arum, marsh cinquefoil, bur-reed, creeping spike rush characterizes the water arum community. In addition, there are populations of submerged and floating plants that include the pondweeds, water milfoil, white water buttercup, star duckweed and hornwort. A total of 3 plots were sampled within the arrowhead/submergent community. Ten species were recorded among those plots although the average species per plot had between 4 and 5 species (Table 6.11). Water arum occurs in every plot. Other species, which occurred in the plots surveyed included: cattail, sedge, bur-reed, marsh cinquefoil, water parsnip, clasping-leaf pondweed, *Chara* spp., and filamentous algae. The arum/submergent community type was mainly observed on the eastside of the lake and commonly occurred on silty mud.

Table 6.11 Species Richness of Wetlands Community Types in Kearl Lake

Wetland Type	Community Type	No. of Plots	Mean Richness	Min. Richness	Max. Richness
graminoid fen (FONG)	cattail emergent	15	5	2	20
graminoid fen (FONG)	sedge emergent	10	8	6	12
graminoid fen (FONG)	water arum emergent	3	4	4	5
shallow open water (WONN)	yellow pond-lily submergent	3	2	1	3
shallow open water (WONN)	floating leaf pondweed submergent	2	2	2	2

Shallow Open Water

Shallow open water is distinguished by its association with other wetland forms such as fens or marshes. The shallow open water wetlands exceeds two metres in depth and is defined as "lake" on Figure 6.3. There is considerable overlap in the Alberta Wetland Inventory (Halsey and Vitt 1996) system between lakes and shallow open water. For the purposes of this study, the lake basin is considered a shallow open water wetland. Yellow pond-lily, floating-leaf pondweed and white stem pondweed were the three distinct communities that occurred within the lake.

Yellow Pond-Lily Submergents

The yellow pond-lily submergent community supports a bed of floating aquatic plants. The plants float freely either in the water or on its surface. For the purposes of this study, yellow pond lily is classified as a submergent. Common duckweed often formed the co-dominant species within this community. Other macrophytes that were observed within this community included small-leaf pondweed and flat stemmed pondweed. A total of 3 plots were sampled within the yellow pond-lily/submergent community. Species richness was lower for this community type in Kearl Lake than Isadore's or Shipyard lakes.

Floating Leaf Pondweed Submergent

The floating leaf pondweed community type was mainly observed in the main basin of the lake where water depth exceeded two metres. Clasping leaf pondweed and flat leaf pondweed were also observed within this community type.

6.2.3.2 Vegetation Vigour

Vegetation vigour was recorded for each cover class and is presented in Table 6.12. Overall, vigour was high, ranging from good to very good. The grass and herb classes had very good vigour. The shrub classes in this wetlands had lower vigour results, ranging from dead to good. The shrubs, predominantly willow, were necrotic (dead) with few leaves. Plant necrosis represented as brown spots on leaves and stem was observed in cattail and sedges. A few shrubs had necrotic leaves or brown spots on leaves and stems. Similar conditions were recorded in all wetlands surveyed. Visible injuries, such as plant necrosis, are attributed to low water levels in July, 1998.

Table 6.12 Average Percent Plant Vigour for Community Types in Kearl Lake

		% Vigour																			
Wetlands		Shrub					Grass					Herb					Aquatics				
Type	Community	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total
FONG	Cattail	-	-	-	-	0	20	20	60		100	-	-	-	100	100	-	-	-	100	100
FONG	Sedge	-	-	-	-	0	-	-	50	50	100	-	-	-	100	100	-	-	-	100	100
FONG	Water Arum	-	-	-	-	0	-	-	20	80	100	-	-	20	80	100	30	-	20	50	100
WONN	Yellow Pond-Lily	-	-	-	-	0	-	100	-	-	100	-	-	-	-	-	-	-	20	80	100
WONN	Floating Leaf Pondweed	-	-	-	-	0	-	-	-	-	0	-	-	-	-	-	-	-	20	80	100

6.2.4 Spruce Pond

6.2.4.1 General Description

The Spruce Pond was a potential reference wetland investigated in this study. The wetland is located approximately 20 km northwest of the town of Fort McMurray. Graminoid, shrub and wooded fens surround the small open water area. Similar to the previous wetlands, cattails, sedges, and willows are the dominant plant species. The aerial extent of wetlands types was not estimated due to the lack of air photographs in this region; however, the dominant types, as estimated from field surveys are described in the following sections.

Graminoid Fen

The dominant wetland type is an open, non-patterned, graminoid fen (FONG). There are three vegetation communities that occur within this wetland type.

Cattail – Sedge Emergent

The cattail-sedge community occurs adjacent to the open water and often occurs as floating mats. There were 15 plots located within the cattail emergent community. Species richness ranged from five to 18 with a mean species mean richness of seven. Herbaceous and aquatic plants observed included: marsh cinquefoil, water arum, water hemlock, yellow-water crowfoot, and water parsnip. Aquatic grasses may include narrow leaved bur-reed, sedges and rushes. Tufted loosestrife was observed on drier sites. Ragged moss and brown moss were also present. Species richness ranged from 5 to 10 species within this community type. The relatively high richness is attributed to an increase in nutrient conditions in this fen complex.

Sedge Emergent

Water sedge and awned sedge dominated the sedge community. The species richness ranged from three to five species with a mean richness of four. Herbaceous and aquatic plants observed included: cattail, marsh cinquefoil, and marsh reed grass.

Water Arum Emergent

The water arum community is dominated by water arum, sedge and marsh cinquefoil. This community occupies the open water portion of Spruce Pond. Species richness ranges from three to eight species. Herbaceous and aquatic plants observed included: marsh cinquefoil, marsh skullcap, water parsnip, water sedge and cattail. Species richness ranged from five to eight species with a mean richness of six species.

Shrubby Fen

The shrubby fen occurs adjacent to the graminoid wetlands. The willow emergent was the only shrubby fen community identified.

Willow Emergent

Willow species dominated the shrubby fen. Due to limited access there was only one transect of three plots within this community type. The species richness ranged from four to eight with a mean of six. Water arum, marsh cinquefoil, marsh marigold, northern bedstraw, marsh skullcap and purple willowherb occurred within this community type. Species richness ranged from four to nine species with a mean richness of five.

Shallow Open Water (Wonn)

The shallow open water was less than one metre in depth. Emergent plant species appear to be invading the open water area. Cattail and sedges form floating substrates in the wetland. The only vegetation community that was observed in this wetland type was the coontail submergent type.

Coontail Submergent

Submergent species observed included coontail and mare’s tail. Floating emergent species included common duckweed. There were three plots surveyed within this community type. One of the surveyed plots consisted of emergent and shrub plants dominated by sedge and willow. The mean species richness was three.

6.2.4.2 Vegetation and Vigour

Vegetation vigour was recorded for each cover class. Overall, vigour was moderate, ranging from fair to very good. Water levels in Spruce Pond had decreased from previous years. This change in water levels resulted in poor seed growth in sedges and necrotic leaves in willows, cattails, sedges, march cinquefoil, water arum, water parsnip and marsh skullcap. Similar conditions were recorded in all wetlands surveyed.

7 SUMMARY AND CONCLUSION

7.1 SUMMARY

7.1.1 Water and Sediment Quality

The 1997 Athabasca River water and sediment sampling program was expanded in 1998 to include the collection of water and sediment samples from the east and west sides of the Athabasca River at three sampling locations: near Donald Creek, near Fort Creek and at a new site near the Muskeg River. Results of the 1998 water and sediment sampling indicate:

- In general, trends observed in 1998 were consistent with historical data.
- River waters were non-toxic to bacteria, but contained phosphorus, aluminum, arsenic, iron and manganese levels in excess of regulatory guidelines.
- Sediments from the Athabasca River were non-toxic to several species of invertebrates.
- Sediment contained high levels of aluminum and iron.
- Arsenic and benzo(a)anthracene/chrysene sediment concentrations occasionally exceeded guideline levels.

Water and sediment samples were collected in the spring, summer and fall of 1998 from four tributaries: the Steepbank, Muskeg, Tar and Ells rivers. Water and sediment samples were collected from the MacKay River in the fall. Water samples were collected from the Muskeg River (upstream of Wapasu Creek, Wapasu Creek and Muskeg Creek in fall and/or winter. Water quality at these locations was generally consistent with historical data. Some parameters exceeded regulatory guidelines as they have in the past and parameters that are likely associated with the increased proportion of groundwater were higher. Results of the 1998 sampling indicate:

- For most parameters, conditions observed in 1998 were similar to historical data.
- Water samples from all five tributaries were non-toxic to bacteria and contained low or non-detectable levels of phenolic compounds, total recoverable hydrocarbons and naphthenic acids.
- All tributaries had higher major ion concentrations in the fall of 1998 than observed in previous years, probably related to 1998 being a relatively dry year and groundwater making up a larger proportion of each river's inflows.

- Concentrations of iron, arsenic and aluminum in waters collected from all of the tributaries in 1998 and in previous years generally exceeded guideline levels. Phosphorus levels also consistently exceeded guideline levels in all but the Muskeg River in 1998 and in previous years. Mercury and manganese concentrations were found, either in 1998 or in the historical data, to occasionally exceed guideline levels during at least one season in each of the five tributaries sampled.
- Sediments from the Steepbank River generally had the highest organic carbon, polycyclic aromatic hydrocarbons (PAHs) and total recoverable hydrocarbon content of the five tributaries sampled.
- Sediments from all tributaries, except Tar River, contained benzo(a)anthracene/chrysene concentrations in excess of guidelines levels.

7.1.2 Benthic Invertebrate Community

The benthic invertebrate data collected during the fall 1998 field program of the RAMP represents the results of an initial effort to establish a benthic invertebrate monitoring program in tributaries of the Athabasca River. Because benthic invertebrate data for the Athabasca River are collected every second year beginning in 1997, the Athabasca River was not sampled in 1998. The results for the 1998 sampling indicate:

- Suitable erosional habitat was not located in the lower reaches of either of the proposed reference rivers (Tar and Ells rivers). Therefore, these rivers were dropped and the MacKay River was added to the tributary monitoring program in 1998.
- The Steepbank and MacKay rivers supported moderately diverse benthic faunas, at low to moderate densities in the fall of 1998. The fauna of the Muskeg River was moderate in density but was more diverse. Differences among rivers could not be related to variation in habitat.
- Water levels and flows were very low in the fall of 1998, in contrast to 1997, when high flows prevented sampling. Because data are still lacking for a year with “typical” hydrological conditions, it is important to continue monitoring these rivers to accumulate an adequate baseline database. The 1998 data will be used to design subsequent benthos surveys of tributaries of the Athabasca River.

7.1.3 Fish Populations

The fisheries component of the 1998 RAMP represented a continuation of work conducted in 1997 (Golder 1998). The information supplemented data collected during previous studies, and was used to evaluate the status of fish populations within the oil sands region. The 1998 program focused on the mainstem Athabasca River as well as tributaries (i.e., Muskeg and Steepbank rivers) that may be influenced by future mining activity. Results of the 1998 fish component of the RAMP indicate:

- A total of 16 species were captured during the spring, summer and fall fish inventories. Species assemblage and dominance was similar to that observed in 1997.
- Catch-per-unit-effort (CPUE) of walleye, goldeye and lake whitefish was markedly lower than in 1997, but similar to estimates recorded for 1995. CPUE for longnose sucker was similar among years.
- Overall, populations of walleye, goldeye, lake whitefish and longnose sucker (i.e., KIR species) have not changed substantially over time, nor was there substantial evidence suggesting stress at the population level.
- Size-at-age relationships (estimate of growth) of KIR species were the most variable among years; however, results need to be confirmed over time before definitive conclusions can be made.
- Possible differences observed in 1998 may be influenced by abnormally low water levels documented in the lower Athabasca River.
- Observed changes in habitat availability and fish-habitat associations relative to 1997 offered further evidence regarding the potential influence of reduced water levels on regional fish populations.
- A site on the Athabasca River in the vicinity of Duncan Creek was selected as the most suitable reference site for monitoring the sentinel fish species. Low abundance of walleye, goldeye and lake whitefish precluded their use for KIR species monitoring.
- Sentinel species monitoring using longnose sucker indicated significant differences in size-at-age, age distribution, condition, liver size and fecundity between fish from the reference area and the oil sands region. The response highlights inconsistencies in energy allocation, but needs to be confirmed in future years.
- Radiotelemetry results confirmed that lake whitefish move through the oil sands region during their migration to spawning grounds upstream of Fort McMurray. Walleye were found to mimic this movement, presumably to feed on lake whitefish and/or their eggs. Lake whitefish appeared to overwinter in Lake Athabasca, whereas walleye are believed to overwinter in the Athabasca River or Lake Athabasca.
- Tissue analyses indicated limited uptake of PAHs by walleye, goldeye, lake whitefish or longnose sucker. Low levels of lead and mercury were detected; however, none exceeded Canadian Consumption Guidelines.
- Capture success using a fish fence in the Muskeg River was limited. Timing of the fence operation with spring spawning runs was late in

1998 due to the unusually early spring in the oil sands region. Improved methods/procedures are required before fish fences can be used for future monitoring.

7.1.4 WETLANDS

Water samples were collected from Shipyard Lake, Isadore's Lake, Kearl Lake and Spruce Pond in the summer of 1998. Kearl Lake was re-sampled in the fall of 1998.

- Total dissolved solids (TDS) and major ion concentrations were generally higher than observed in previous years, which may be related to the low precipitation rates observed in 1998.
- Kearl Lake is a clear water (TSS <10 mg/L), mesotrophic lake with low organic content. It has been found to contain aluminum, arsenic and mercury concentrations in excess of regulatory guideline levels.
- Shipyard Lake is a mesotrophic lake. Naphthenic acids were non-detectable. Iron and manganese concentrations were in excess of regulatory guidelines.
- Isadore's Lake, also a mesotrophic system, contained the highest sulphate concentrations of any of the sampled wetlands. Aluminum, arsenic and manganese concentrations exceeded regulatory guidelines in 1998, whereas lead and mercury levels were above guideline levels in 1997.
- Water quality in Spruce Pond was very different from the water quality observed in any of the other wetlands. This lake was hyper-eutrophic and contained phosphorus, total phenolics, total aluminum, arsenic, boron, iron and manganese concentrations that exceeded guideline levels.

The vegetation component of the 1998 RAMP represents a continuation of work conducted in 1997 (Golder 1998). This is the second year of data collection to establish a baseline of vegetation communities, species composition and vegetation vigour in Kearl Lake, Shipyard Lake, Isadore's Lake and a potential reference wetlands (Spruce Pond).

- Kearl Lake is a large shallow upland lake that is bordered by graminoid and shrubby fens. There has been no change in the size of these wetlands types since 1997.
- Vegetation vigour in Kearl Lake was good to very good for herb and grass cover types. Vigour was lower in shrub cover types, ranging from poor to good. Lower vigour in shrubs was associated with low water levels.

- Shipyard Lake is a riparian wetlands complex in the Athabasca River floodplain. Airphotos and maps indicate that the general shape and vegetation patterns in Shipyard Lake have not changed in the past 53 years.
- The Shipyard Lake wetlands consist of graminoid marshes, shrubby marshes, shrubby swamps, shallow open water and open treed swamps. There were no changes in the size of wetlands types from 1997 except for a small (< 1 ha) change in open treed swamps.
- Vegetation vigour in Shipyard Lake was very good in most cover types. One vegetation plot showed poor vigour due to low water levels.
- Isadore's Lake is a riparian wetlands complex and oxbow lake occurring within the Athabasca River floodplain. It consists of an open water fen complex dominated by sedges and cattail, with low shrub and wooded fens occurring along the outer perimeter. There have been no changes in the size of the wetlands since the 1997 survey.
- Vegetation vigour in grass and herb classes in Isadore's Lake was very good. The shrub classes had lower vigour results, ranging from good to dead.
- Spruce Pond was evaluated as a potential reference site for wetlands monitoring. It was found to be unsuitable as a reference site as it has neither the community types found in riparian wetlands (Isadore's and Shipyard lakes) or upland wetlands (Kearl Lake).
- All wetlands studied in 1998 had poor vigour in shrub classes, likely due to low water levels.

7.2 CONCLUSIONS

As 1998 is only the second year of monitoring in a long-term program, it is too early to draw many conclusions. A preliminary conclusion is that annual differences in climatic and hydrologic conditions can affect the water quality, wetlands vegetation, fish and invertebrate habitat and fish populations. It is necessary to continue the monitoring program to develop a consistent long-term database and suitable reference sites. This will allow separation of hydrologic effects, which could be substantial, from potential effects due to the oil sands development. The more years of baseline data that are gathered the easier it will be to meet this challenge.

The water and sediment data indicate that water quality guidelines cannot be met for all parameters even under the current level of development in the region. Some guidelines are likely exceeded due to natural and historic conditions 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.

With the exception of the effects of low water levels and flows, the monitoring results for 1998 were similar to 1997 or 1995 (a year in which a significant amount of data was collected for oil sands Environmental Impact Assessments). The size-at-age relationships of walleye, goldeye and longnose sucker were the most variable among years. Data for fish collected in 1998 show that the fish were shorter at any given age relative to data from previous years. It is too early to draw conclusions; this change may also be related to the hydrologic changes in 1998.

The monitoring to date includes both studies to fill in information gaps and long-term monitoring. RAMP is committed to a core program where quality and continuity are maintained unchanged over time. Additional studies may be added or deleted depending on issues and resources, but the goal is to maintain the integrity of the core program. One of the essential functions of this program is that it will provide answers to the fundamental question of whether or not there is a significant negative effect related to oil sands development. The statistical and other tests used to answer this question require data that are comparable over adequate periods of time.

8 CLOSURE

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

Respectfully submitted,

GOLDER ASSOCIATES LTD.

Written by:	Reviewed by:
Veronica Chisholm, BES Vegetation Specialist	David A. Fernet, M.Sc., P.Biol. Principal
Wade N. Gibbons, Ph.D., Senior Aquatic Biologist	John Gulley, M.Sc., P.Biol. Oil Sands Project Director
Marie Lagimodiere, MES, P.Biol. Aquatic Biologist	Pat Tones, Ph.D. Associate
Chris Bjornson, B.Sc. Fisheries Biologist	Mark Digel, M.Sc., M.E.Des. Sr. Water Quality Specialist
Zsolt Kovats, M.Sc. Aquatic Biologist	David S. Kerr, M.Sc., P.Ag. Principal
Jean-Philippe Bechtold, M.A.Sc., P.Biol. Water Quality Specialist	

9 REFERENCES

Alberta Environmental Protection (AEP). 1994. Ecological Land Survey Site Description Manual. Edmonton, Alberta.

Alberta Environmental Protection (AEP). 1995a. Electrofishing policy respecting injuries to fish. Alberta Fisheries Management Division. Edmonton, Alberta.

Alberta Environmental Protection (AEP). 1995b. Water quality based effluent limits procedures manual. Environmental Regulatory Service. Edmonton, Alberta.

American Public Health Association (APHA). 1985. Standard methods for examination of water and wastewater. 16th ed. American Public Health Association, Washington, D.C.

Bidgood, B.F. 1980. Field surgical procedure for implantation of radio tags in fish. Alberta and Wildlife Div., Fish. Res. Rep. 20, Edmonton, Alberta.

Boag, T.D. 1993. A general fish and riverine habitat inventory, Peace and Slave rivers Apr. 1 to June, 1992. Northern River Basins Study Project Report No. 9.

Bond, W.A. 1980. Fishery resources of the Athabasca River downstream of Fort McMurray, Alberta: Volume I. Prepared for the Alberta Oil Sands Environmental Resource Program by the Freshwater Institute, Winnipeg, Manitoba, AOSERP. Report 89. 81 p.

Bond, W.A. and K. Machniak. 1977. Interim report on an intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Prepared for the Alberta Oil Sands Environmental Resource Program by the Freshwater Institute, Winnipeg, Manitoba, AOSERP. Report 26. 137 p.

Bond, W.A. and K. Machniak. 1979. An intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Prepared for the Alberta Oil Sands Environmental Resource Program by the Freshwater Institute, Winnipeg, Manitoba, AOSERP. Report 76.

Burland, G.R. 1994. An identification guide to Alberta aquatic plants. Prepared for Alberta Environment Protection. Edmonton, Alberta

Canadian Council of Ministers of the Environment (CCME). 1998. Canadian sediment quality guidelines for the protection of aquatic life: introduction and summary tables. In: Canadian environmental quality guidelines. 1998. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

Dirschl, J.J. and R.T. Coupland. 1972. Vegetation patterns and site relationships in the Saskatchewan River Delta. Can. J. Bot. 50: 647-675.

Dirschl, J.J., D.L. Dabbs and G.C. Gentles. 1974. Landscape classification and plant successional trends: Peace-Athabasca Delta. Canadian Wildlife Series Report. No. 30. Information Canada. Ottawa.

Environment Canada and Dept. of Fisheries and Oceans. 1993. Technical guidance document for aquatic environmental effects monitoring related to federal Fisheries Act requirements. Environment Canada, Ottawa, Ontario.

Environmental Protection Agency (EPA). 1979. Methods for chemical analysis of water and wastes. (EPA-600/4-79-020) U.S. Environmental Protection Agency, EMSL, Cincinnati, OH, 45268.

GeoNorth and North/South Consultants. 1997. Guidance for northern aquatic effects monitoring. Prepared for Water Resources Division, Department of Indian Affairs and Northern Development, Yellowknife, NT.

Gibbons, W.N. 1997. Suitability of small fish species for monitoring the effects of pulp mil effluent on fish populations. Ph.D. Thesis. University of Waterloo, Waterloo, ON, Canada.

Gibbons, W.N. and K.R. Munkittrick. 1994. A sentinel monitoring framework for identifying fish population responses to industrial discharges. J. Aquat. Ecosyst. Health 3:227-237.

Golder Associates Ltd. 1996a. Aquatic baseline report for the Athabasca, Steepbank and Muskeg rivers in the vicinity of the Steepbank and Aurora mines. Final report for Suncor Inc., Oil sands Group. 164 p. + App.

Golder Associates Ltd. 1996b. 1996 fisheries investigations of the Athabasca River: addendum to Syncrude Aurora Mine environmental baseline program. Final report for Syncrude Canada Ltd.

Golder Associates Ltd. 1996c. Shipyard Lake Environmental Baseline Group. Fort McMurray, Alberta. 2 pp+Appendix.

Golder Associates Ltd. 1996d. Athabasca River water releases impact assessment. Final report for Suncor Inc., Oil Sands Group. 123 p. + App.

Golder Associates Ltd. 1997. Steepbank Mine winter aquatic baseline report, February 1997. Final report to Suncor Inc., Oil Sands Group. 24 p. + App.

Golder Associates Ltd. 1998a. Oil Sands Regional Aquatics Monitoring Program (RAMP) 1997. Final report for Suncor Energy Inc. Oil Sands Group, Syncrude Canada Ltd., and Shell Canada Ltd. 141 p. + App.

Golder Associates Ltd. 1998b. Aquatic resources baseline study for the Muskeg River Mine Project. Final report to Shell Canada Limited, Calgary, Alberta. 90 p.+App.

Golder Associates Ltd. 1999a. Climatic and hydrologic monitoring program in 1998. Final Report submitted to Mobil Oil Canada Properties, Shell Canada Limited, Suncor Energy Inc. Oil Sands Group and Syncrude Canada Ltd.

Golder Associates Ltd. 1999b. Oil sands regional monitoring program: field technical procedures.

Gorham, E., S.E. Bayley and D.W. Schindler. 1984. Ecological effects of acid deposition upon peatlands: a neglected field in "acid rain" research. Can. J. Fish Aquat. Sci. 41:1256-1268.

Halsey, L. and D.H. Vitt. 1996. Alberta wetland inventory standards – Version 10.0. *In* Nesby, R. (ed.). Alberta Vegetation Inventory Standards Manual. 1997. Alberta Environmental Protection, Resource Data Division.

Health Canada. 1981. Canadian Food and Drugs Act and Regulations (including amendments to December 17, 1997). Minister of Supply and Services Canada. Ottawa.

Hodson, P.V., P.J. Kloepper-Sams, K.R. Munkittrick, W.L. Lockhart, D.A. Metner, P.L. Luxon, I.R. Smith, M.M. Gagnon, M. Servos and J.F. Payne. 1991. Protocols for measuring mixed function oxygenases of liver. Can. Tech. Rpt Fish. Aquat. Sci. No. 1829.

Hodson, P.V., K.R. Munkittrick, R. Stevens, and A. Colodey. 1996. A tier-testing strategy for managing programs of environmental effects monitoring. Water Qual. Res. J. Can. Volume 31 (No. 2):215-224.

Hudson, J.H. 1977. Carex in Saskatchewan. Bison Publishing House. Saskatoon, Saskatchewan.

Johnson, D.L., Kershaw, A. MacKinnon, J. Pojar, T. Goward and D. Vitt. 1995. Plants of the western boreal forest and aspen parkland. Lone Pine Publishing and Canadian Forestry Service. Edmonton, Alberta.

Jones, M.L., G.J. Mann, and P.J. McCart. 1978. Fall fisheries investigations in the Athabasca and Clearwater rivers upstream of Fort McMurray: Volume I. Prepared for the Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute, Winnipeg, Manitoba. AOSERP Report 36. 71 p

Knecht, C.D., A.R. Allen, D.J. Williams and J.H. Johnson. 1981. Fundamental techniques in veterinary surgery, 2nd edition. W.B. Saunders Co., Philadelphia, PA.

Lieffers, V.J. 1984. Emergent plant communities of Oxbow Lakes in Northeastern Alberta: Salinity, Water Level Fluctuation and Succession. Can. J. Bot. 65:310-316.

Lockhart, W.L. and D.A. Metner. 1996. Analysis for liver mixed-function oxygenase in fish, Peace, Athabasca and Slave River drainages, September to December, 1994. Northern River Basins Study Technical Report No. 104.

Machniak, K. and W.A. Bond. 1979. An intensive study of the fish fauna of the Steepbank River watershed of northeastern Alberta. Prepared for the Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute, Winnipeg, Manitoba. AOSERP Report 61. 194 p.

Machniak, K., W.A. Bond, M.R. Orr, D. Rudy, and D. Miller. 1980. Fisheries and aquatic habitat investigations in the MacKay River watershed of northeastern Alberta. Prepared for the Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute, Winnipeg, Manitoba. AOSERP Report 93. 173 p

MacKay, W.C., G.R. Ash, and H.J. Norris. (eds.). 1990. Fish ageing methods for Alberta. R.L. & L. Environmental Services Ltd. in assoc. with Alberta Fish and Wildl. Div. and Univ. of Alberta, Edmonton. 113 p.

Moss, E.H. 1983. Flora of Alberta (2nd Ed. Revised by J.G. Packer). University of Toronto Press. Toronto, Ontario. 687 p.

Munkittrick, K.R. 1992. A review and evaluation of study design considerations for site-specifically assessing the health of fish populations. J. Aquat. Ecosyst. Health 1:283-293.

Munkittrick, K.R. and D.G. Dixon. 1989. An holistic approach to ecosystem health assessment using fish population characteristics. In M. Munawar, G. Dixon, C.I. Mayfield, T. Reynoldson, and M. H. Sadar, eds. *Environmental bioassay techniques and their application*. Hydrobiol. 188/189: 122-135.

Munkittrick, K.R. and D.G. Dixon. 1989. Use of white sucker (*Catostomus commersoni*) populations to assess the health of aquatic ecosystems exposed to low-level contaminant stress. Can. J. Fish. Aquat. Sci. 46: 1455-1462.

Paine, Ledge and Associates (PLA). 1998. Manual on statistical analysis of environmental data. Volume II. Prepared for CANMET/MMSL-INTEMIN, Vancouver, BC. 228p.

Parrott, J.L., P.V. Hodson, D.E. Tillitt, D.T. Bennie and M.E. Comba. 1996a. Accumulation of fish mixed function oxygenase inducers by semipermeable membrane devices in river water and effluents, Athabasca River, August and September, 1994. Northern River Basins Study Technical Report No. 83.

Parrott, J.L., J.J. Whyte, S.M. Backus and M.E. Comba. 1996b. Accumulation of fish mixed function oxygenase inducers by semipermeable membrane devices in river water and effluents, Athabasca, Peace and Wapiti Rivers, August and September, 1995. Northern River Basins Study Technical Report No. 127.

R.L.&.L. Environmental Services Ltd. (R.L.&L.) 1982. Aquatic investigations in the Hartley Creek area, 1981 (Sandalta Project). Report prepared for Gulf Canada Resources Inc., Calgary, Alberta. May 1982.

R.L.&L. 1989. OSLO Project: water quality and fisheries resources baseline studies. December 1989.

R.L.&L. 1994. A general fish and riverine habitat inventory, Athabasca River April to May 1992. Final report for the Northern River Basins Study Project No. 32.

Sekerak, A.D. and G.L. Walder. 1980. Aquatic biophysical inventory of major tributaries in the AOSERP study area. Volume I: summary report. Prepared for Alberta Oil Sands Environmental Research Program by LGL Ltd. Env. Res. Assoc. AOSERP Rep. 114. 100p.

Sentar Consultants. 1994. A baseline monitoring study on the Athabasca River between the town of Athabasca and the Grand Rapids, 1991. Prepared for Alberta Pacific Forest Industries Inc. Edmonton, Alberta.

Shell Canada Limited. 1997. Muskeg River Mine Project EIA. Prepared by Golder Associates Ltd. Volumes 1,2,3, and 5.

Suncor Energy Inc. Oil Sands Group. 1998. Project Millennium Application - Environmental impact assessment. Volume 2A: Introduction, Air Quality, Aquatics. Prepared by Golder Associates Ltd.

Tripp, D.B. and P.J. McCart. 1979. Investigations of the spring spawning fish populations in the Athabasca and Clearwater rivers upstream from Fort McMurray: Volume I. Prepared for Alberta Oil Sands Environmental Research Program by Aquatic Environmental Limited. AOSERP Report 84. 128 p.

Tripp, D.B. and P.T.P. Tsui. 1980. Fisheries and habitat investigations of tributary streams in the southern portion of the AOSERP study area: Volume I: summary and conclusions. Prepared for the Alberta Oil Sands Environmental Research Program by Aquatic Environments Limited. AOSERP Report 92. 224 p.

van den Heuvel, M.R., K.R. Munkittrick, J.J. Stegeman and D.G. Dixon. 1995. Second-round interlaboratory comparison of hepatic ethoxyresorufin-*O*-deethylase activity in white sucker (*Catostomus commersoni*) exposed to bleached-kraft pulp mill effluent. Environ. Toxicol. Chem. 14:1513-1520.

Wetzel, R.G., 1983. Limnology, 2nd Edition. Saunders College Publishing, Toronto, Ontario, Canada. 767 pp.

Wilkinson, L. 1990. SYSTAT: the system for statistics. SYSTAT Inc., Evanston, IL, USA.

Wrona, F.J., M. Culp and R.W. Davies. 1982. Macroinvertebrate subsampling: a simplified apparatus and approach. Can. J. Fish Aquat. Sci. 39:1051-1054.

10 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.
Backwater	Discrete, localized area exhibiting reverse flow direction and, generally, lower stream velocity than main current; substrate similar to adjacent channel with more fines.
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.
Bitumen	Bitumen is a component of oil sand. It is a highly viscous, tarry, black hydrocarbon material having an API gravity of about 9° (specific gravity about 1.0). It is a complex mixture of organic compounds. Carbon accounts for 80 to 85% of the elemental composition of bitumen, hydrogen -10%, sulphur ~ 5%. Nitrogen, oxygen, and trace elements make up the remainder.
Bottom Sediments	Material which lie on the bottom of a body of water. Examples include soft mud, silt, sand, gravel, rock and organic litter.
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.
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.
GIS	Geographical Information System. Pertains to a type of computer software that is designed to develop, manage, analyze and display spatially referenced data.
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.
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 (>44µm) and a fines (<44µm) 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., $CaCo_3$).

Orthophoto	Photograph copy prepared from airphotos in which the displacements of an image due to distortions have been removed.
Overwintering Habitat	Habitat used during the winter as a refuge and for feeding.
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.
Rearing Habitat	Habitat used by young fish for feeding or as a refuge from predators.
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.
Snye	Discrete section on non-flowing water connected to a flowing channel only at its downstream end, generally formed in a side channel or behind a peninsula (bar).
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).
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.
Watershed	The total area that contributes water to a stream.
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.

APPENDIX I

LABORATORY ANALYTICAL METHODS

APPENDIX II

WATER QUALITY DATA

APPENDIX III

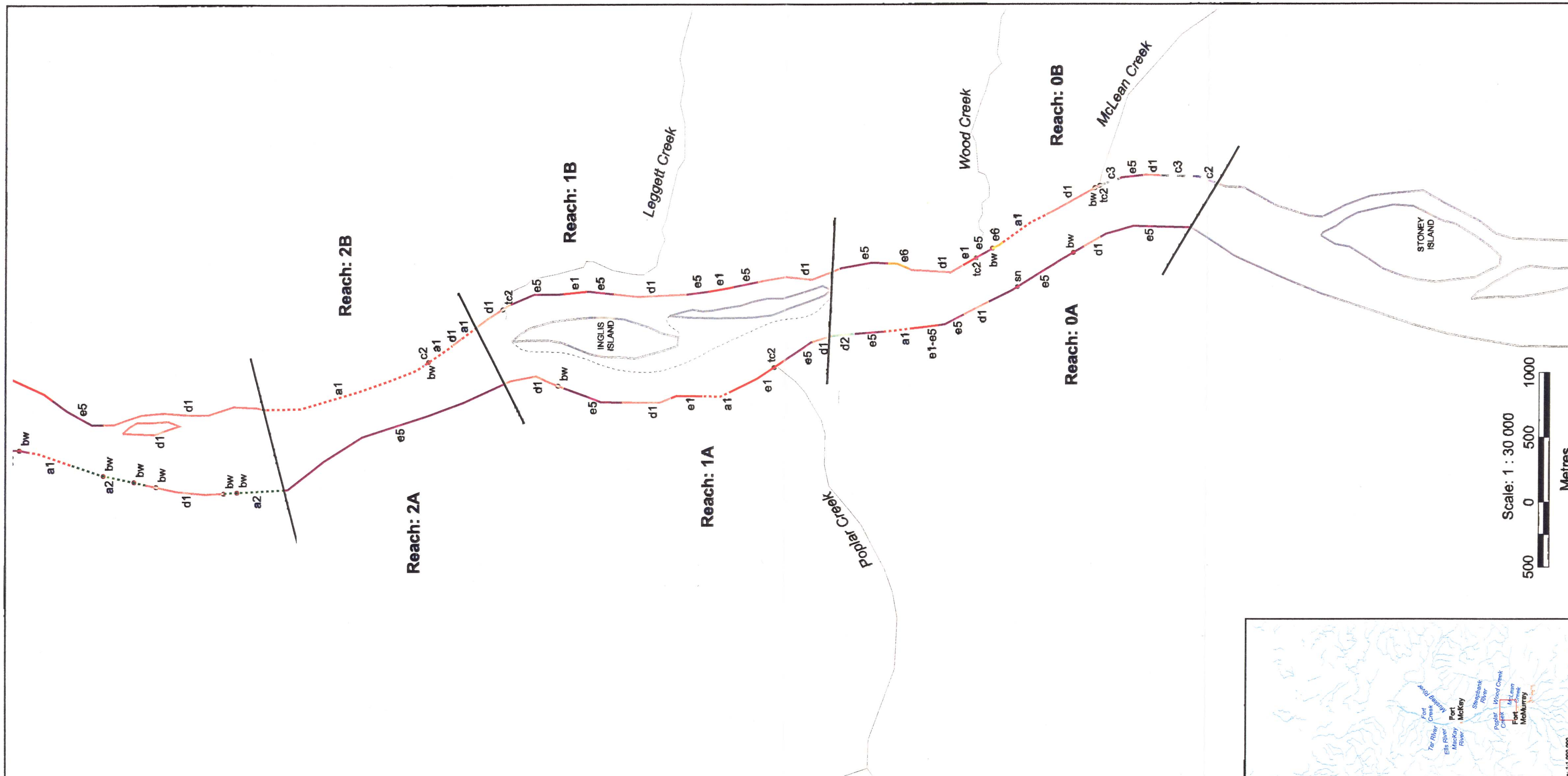
SEDIMENT DATA

APPENDIX IV

BENTHIC INVERTEBRATE DATA

APPENDIX V

ATHABASCA RIVER HABITAT MAPS, 1998



A1 cobble / boulder - limited instream cover	D2 gentle slope - gravel / cobble	Sandbar	
A2 cobble / boulder - instream cover, BW areas	E1 high, steep eroded bank - vegetation debris	tc confluence area of tributary tc1 - intermittent flow tc2 - flowing, width < 5m tc3 - flowing, width 5-15m	
A3 boulder / bedrock - instream cover	E2 same as E1 - no instream debris	sn snye	
A4 Rip-Rap - instream cover	E3 steep bank - gravel / cobble / sand	bw backwater area	
C1 valley walls - cobble / boulder	E4 steep, eroding / slumping bank		
C2 steep bedrock banks	E5 low, steep bank		
C3 valley walls - gravel / cobble	E6 same as E5 with instream cover		
D1 gentle slope - fines	Unclassified		

Reaches: 0,1,2,3,4,5,6,
10,11,12,13,14
Last update: 1998

Reaches: 16,17
Last update: 1997

Reaches: 8,9,15
Last update: 1996

Reaches: 7
Last update: 1995

Source: Golder 1996a, 1996b,
Present Report

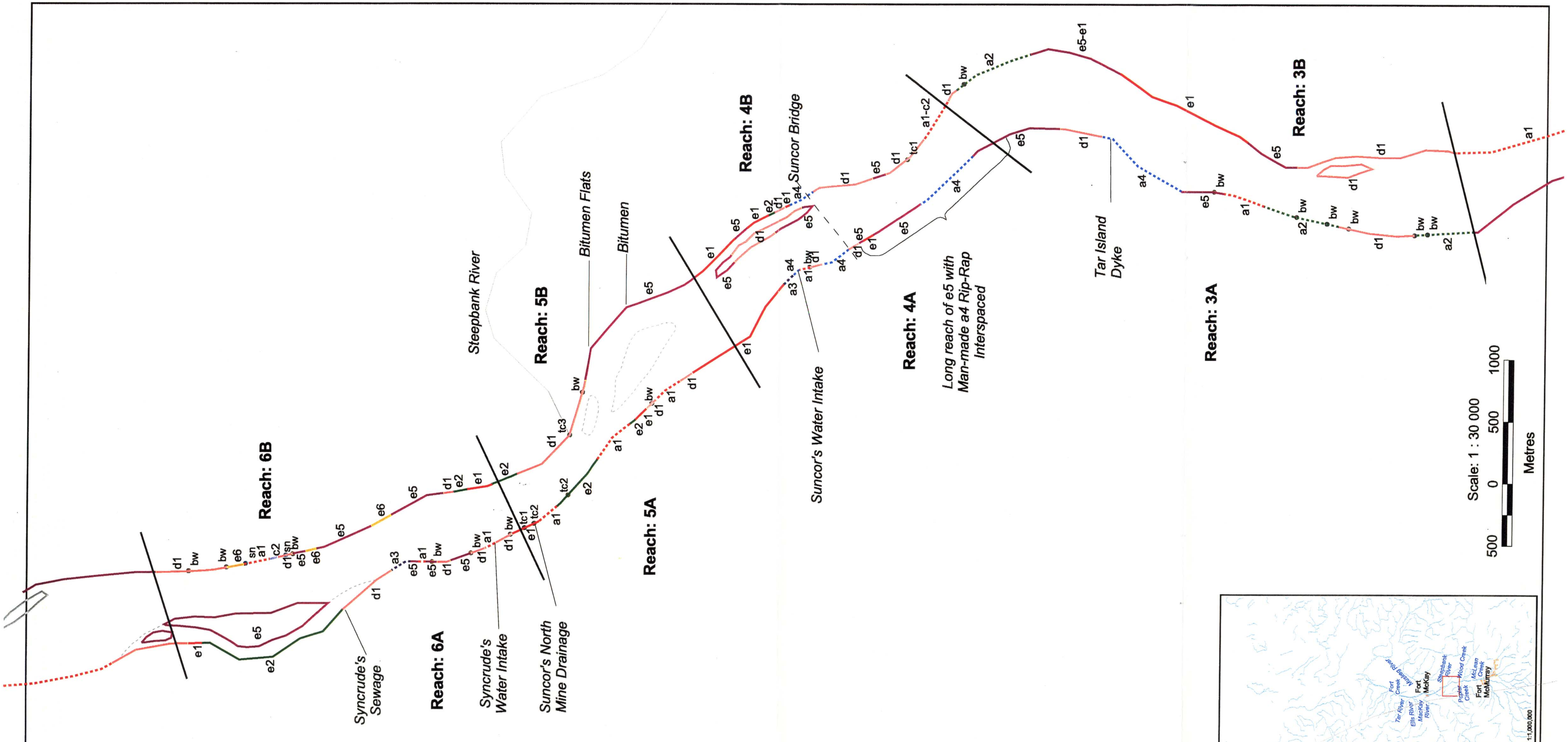
Map Projection: UTM 12
Datum: NAD 83

Golder Associates

Updated Habitat Map of Fish Collection Reaches within the Poplar Area, Athabasca River, Summer 1998

22 Jan. 1999	Figure V - 1	Produced by: CGA Reviewed by:

I:\1998\982-2309\arcview\carrie.apr



- A1 cobble / boulder - limited instream cover
- A2 cobble / boulder - instream cover, BW areas
- A3 boulder / bedrock - instream cover
- A4 Rip-Rap - instream cover
- C1 valley walls - cobble / boulder
- C2 steep bedrock banks
- C3 valley walls - gravel / cobble
- D1 gentle slope - fines
- D2 gentle slope - gravel / cobble
- E1 high, steep eroded bank - vegetation debris
- E2 same as E1 - no instream debris
- E3 steep bank - gravel / cobble / sand
- E4 steep, eroding / slumping bank
- E5 low, steep bank
- E6 same as E5 with instream cover
- Unclassified
- Sandbar
- tc confluence area of tributary
  - tc1 - intermittent flow
  - tc2 - flowing, width < 5m
  - tc3 - flowing, width 5-15m
- sn snye
- bw backwater area

Reaches: 0,1,2,3,4,5,6, 10,11,12,13,14
Last update: 1998

Reaches: 16,17
Last update: 1997

Reaches: 8,9,15
Last update: 1996

Reaches: 7
Last update: 1995

Source: Golder 1996a, 1996b, Present Report

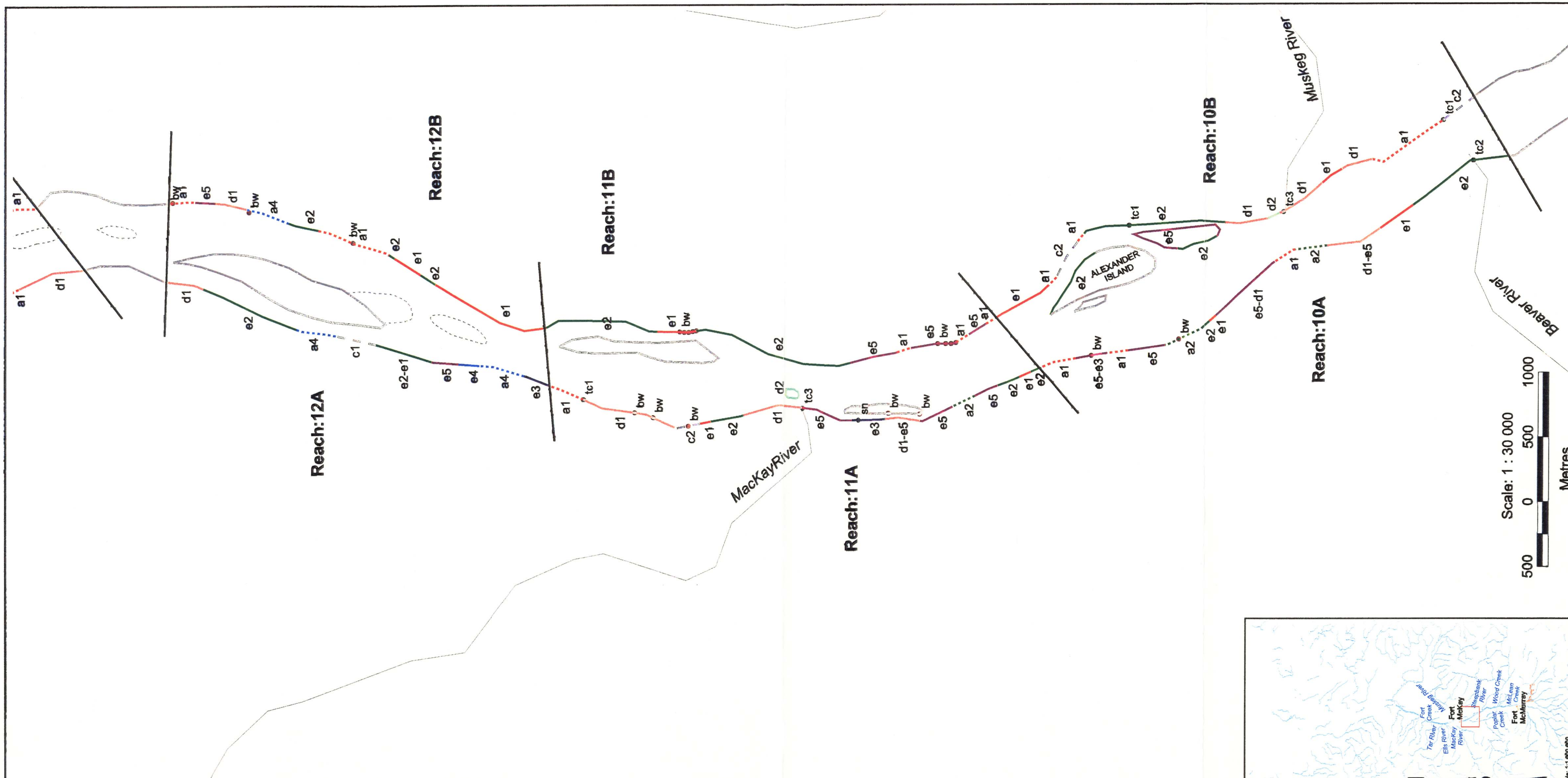
Map Projection: UTM 12
Datum: NAD 83

I:\1998\982-2309\arcview\carrie.apr

Golder Associates

Updated Habitat Map of Fish Collection Reaches within the Steepbank Area, Athabasca River, Summer 1998

22 Jan. 1999	Figure V - 2	Produced by: CGA Reviewed by:



A1 cobble / boulder - limited instream cover
A2 cobble / boulder - instream cover, BW areas
A3 boulder / bedrock - instream cover
A4 Rip-Rap - instream cover
C1 valley walls - cobble / boulder
C2 steep bedrock banks
C3 valley walls - gravel / cobble
D1 gentle slope - fines
D2 gentle slope - gravel / cobble
E1 high, steep eroded bank - vegetation debris
E2 same as E1 - no instream debris
E3 steep bank - gravel / cobble / sand
E4 steep, eroding / slumping bank
E5 low, steep bank
E6 same as E5 with instream cover
Unclassified
Sandbar
tc confluence area of tributary
tc1 - intermittent flow
tc2 - flowing, width < 5m
tc3 - flowing, width 5-15m
sn snye
bw backwater area

Reaches: 0,1,2,3,4,5,6,
10,11,12,13,14
Last update: 1998

Reaches: 16,17
Last update: 1997

Reaches: 8,9,15
Last update: 1996

Reaches: 7
Last update: 1995

Source: Golder 1996a, 1996b,
Present Report

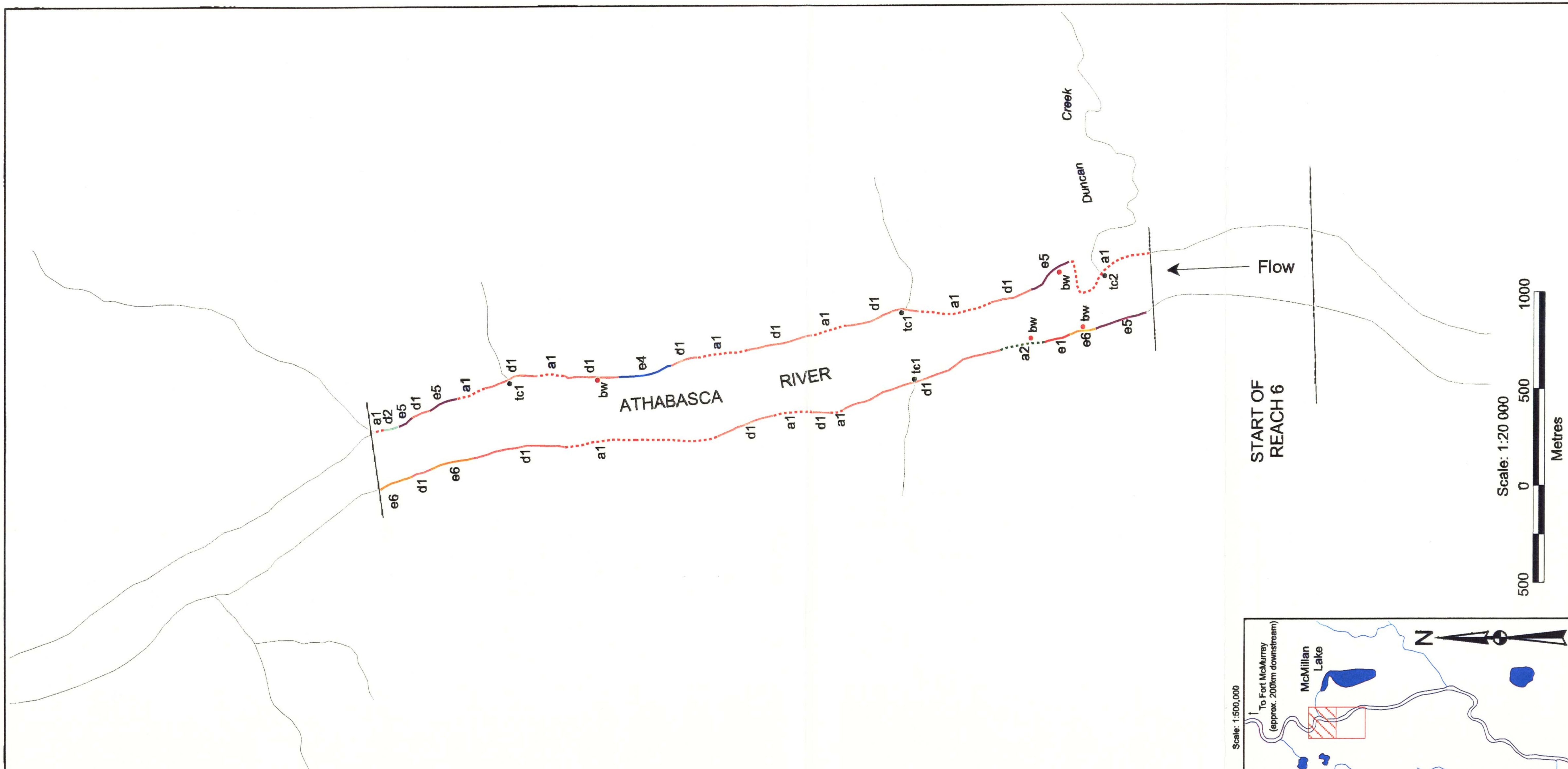
Map Projection: UTM 12
Datum: NAD 83

Golder Associates

Updated Habitat Map of Fish Collection Reaches within the Muskeg Area, Athabasca River, Summer 1998

22 Jan. 1999	Figure V - 3	Produced by: CGA Reviewed by:

I:\1998\982-2309\arcview\carrie.apr



a1 cobble / boulder - limited instream cover	d2 gentle slope - gravel / cobble
a2 cobble / boulder - instream cover, bw areas	e1 high, steep eroded bank - vegetation debris
a3 boulder / bedrock - instream cover	e2 same as e1 - no instream debris
a4 rip-rap - instream cover	e3 steep bank - gravel / cobble / sand
c1 valley walls - cobble / boulder	e4 steep, eroding / slumping bank
c2 steep bedrock banks	e5 low, steep bank
c3 valley walls - gravel / cobble	e6 same as e5 with instream cover
d1 gentle slope - fines	unclassified

tc confluence area of tributary
tc1 - intermittent flow
tc2 - flowing, width < 5m
tc3 - flowing, width 5-15m

bw backwater area

Source: Present report

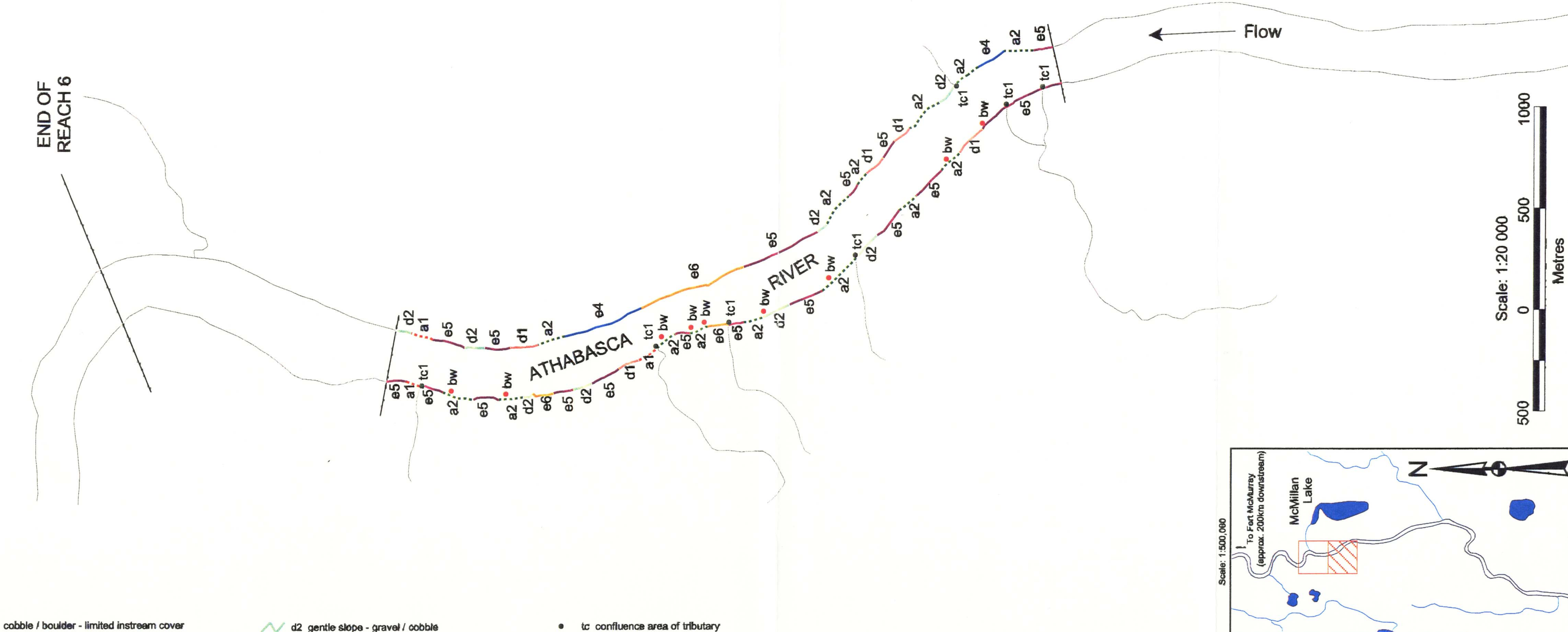
Map Projection: UTM 12
Datum: NAD 83

Golder Associates

Habitat Map of Reference Area (Downstream Portion of Reach 6), Athabasca River, Summer 1998

22 January 1999	Figure V - 4	Produced by: CGA Reviewed by:

k\1998\982-2309\camemcmillan.apr



a1 cobble / boulder - limited instream cover
a2 cobble / boulder - instream cover, bw areas
a3 boulder / bedrock - instream cover
a4 rip-rap - instream cover
c1 valley walls - cobble / boulder
c2 steep bedrock banks
c3 valley walls - gravel / cobble
d1 gentle slope - fines
d2 gentle slope - gravel / cobble
e1 high, steep eroded bank - vegetation debris
e2 same as e1 - no instream debris
e3 steep bank - gravel / cobble / sand
e4 steep, eroding / slumping bank
e5 low, steep bank
e6 same as e5 with instream cover
unclassified
tc confluence area of tributary
tc1 - intermittent flow
tc2 - flowing, width < 5m
tc3 - flowing, width 5-15m
bw backwater area

Source: Present report

Map Projection: UTM 12
Datum: NAD 83

Golder Associates

Habitat Map of Reference Area (Upstream Portion of Reach 6), Athabasca River, Summer 1998

22 January 1999 | Figure V - 5 | Produced by: CGA Reviewed by:

k1\988962-2309\carriemcmillan.apr

APPENDIX VI

RADIOTELEMETRY DATA

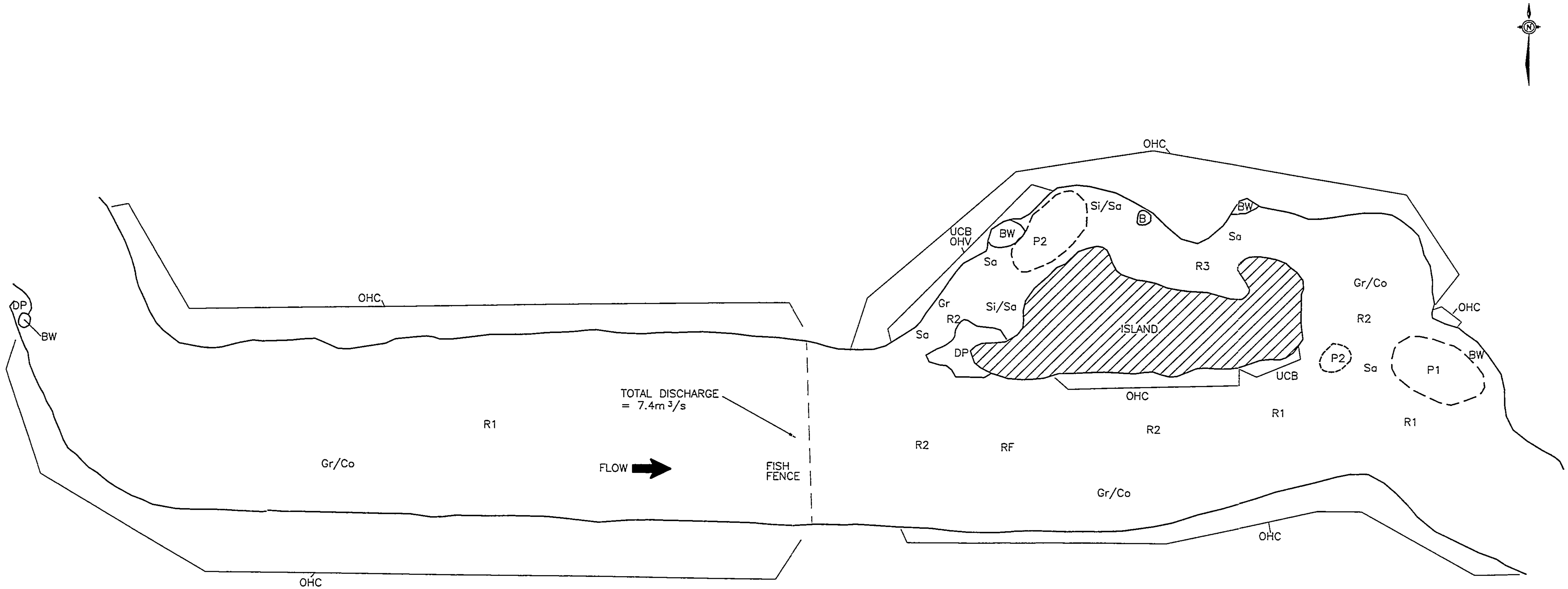
APPENDIX VII

BIOMARKING DATA

APPENDIX VIII

TRIBUTARY INFORMATION

J:\1998\2300\982-2309\6053\MUSKEG.DWG



Legend

Habitat Units
R1 – high quality run
R2 – moderate quality run
P1 – high quality pool
P2 – moderate quality pool

Substrate Type & Size
B – boulder
Co – cobble
Gr – gravel
Sa – sand
Si – silt

Features
BW – backwater
DP – debris pile
OHC – overhead cover
OHV – overhanging vegetation
UCB – undercut bank

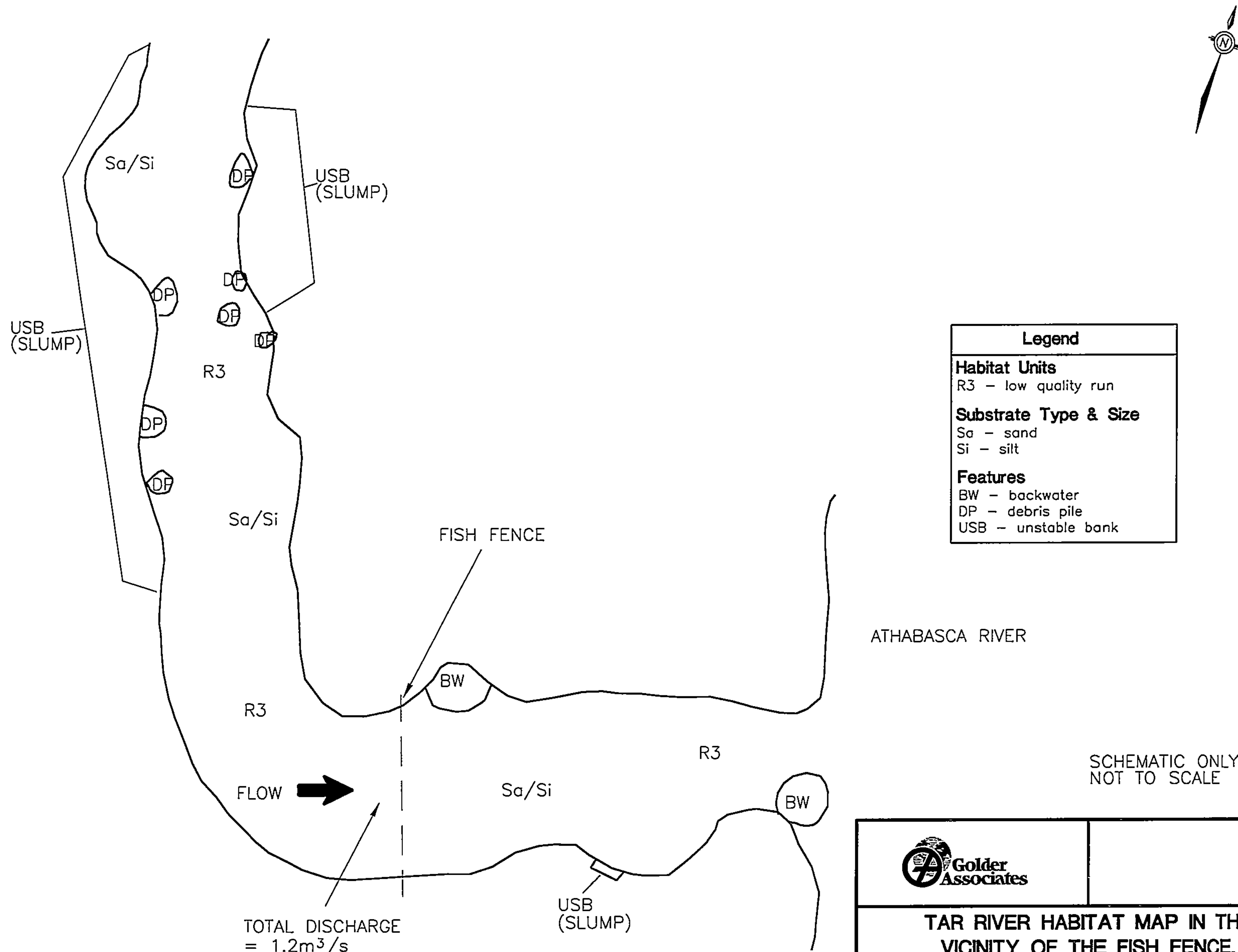
SCHEMATIC ONLY
NOT TO SCALE

Golder Associates

MUSKEG RIVER HABITAT MAP IN THE VICINITY OF THE FISH FENCE, MAY 1998

DRAWN: DC	APPROVED:	DATE: 28 JAN. 1999
PROJECT: 982-2309		FIGURE: VII-1

J:\1998\2300\982-2309\6053\TAR.DWG

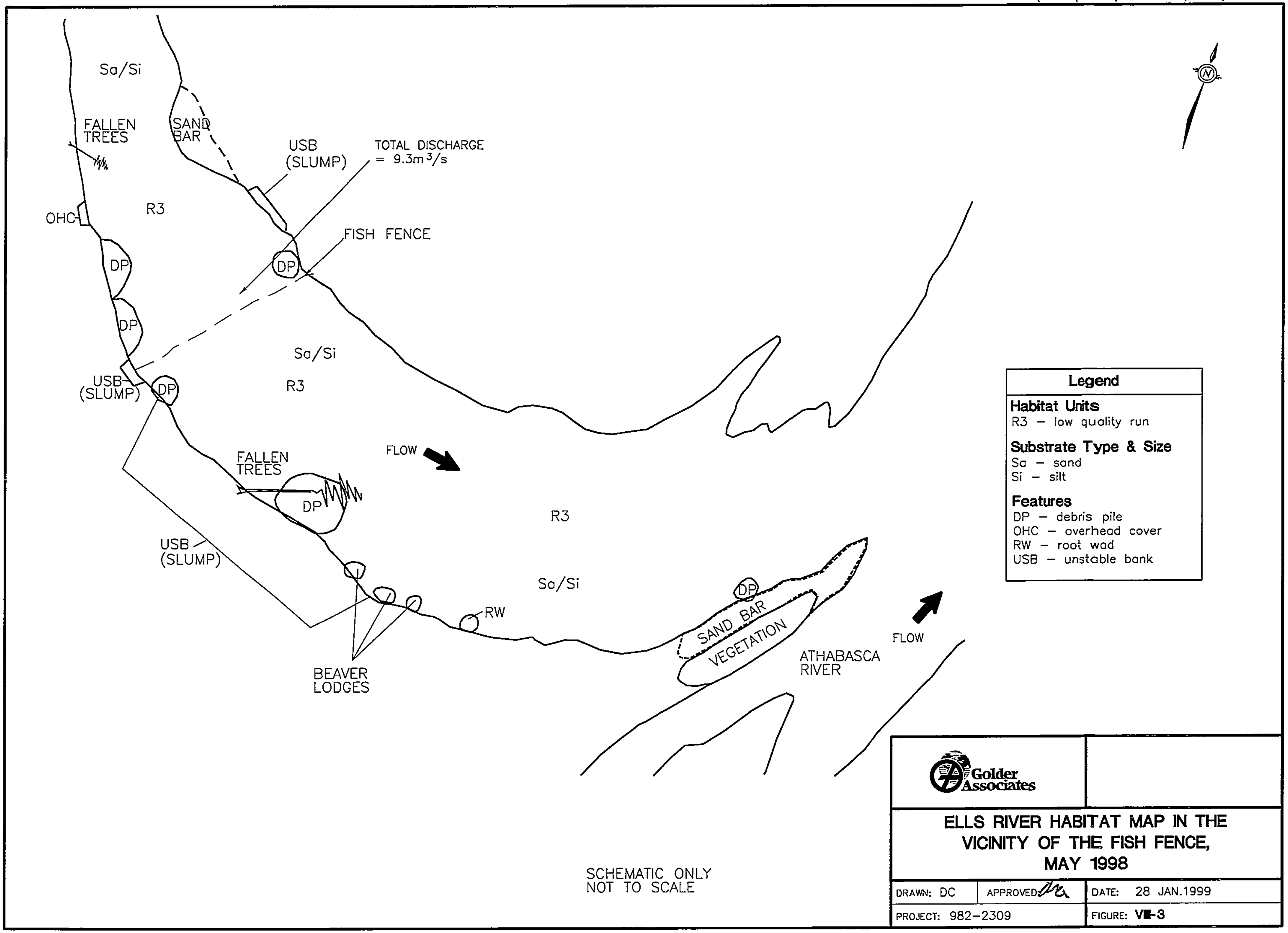


Golder Associates

TAR RIVER HABITAT MAP IN THE VICINITY OF THE FISH FENCE, MAY 1998

DRAWN: VS	APPROVED:	DATE: 28 JAN.1999
PROJECT: 982-2309.6053		FIGURE: VIII-2

J:\1998\2300\982-2309\6053\ELS.DWG



ELLS RIVER HABITAT MAP IN THE VICINITY OF THE FISH FENCE, MAY 1998

DRAWN: DC | APPROVED: | DATE: 28 JAN.1999
PROJECT: 982-2309 | FIGURE: VII-3

APPENDIX IX

WETLANDS CLASSIFICATION SYSTEM

APPENDIX X

AQUATIC PLANT SPECIES LIST