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REPORT ON

OIL SANDS REGIONAL AQUATICS MONITORING PROGRAM (RAMP) 1997

Submitted to:

Suncor Energy Inc., Oil Sands
Syncrude Canada Ltd.
Shell Canada Limited

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EXECUTIVE SUMMARY

The area north of Fort McMurray is experiencing a large increase in oil sands mining and related developments. Such growth highlights the need to coordinate environmental monitoring activities so that potential cumulative effects can be identified and addressed. Additionally, regulatory monitoring requirements must be satisfied in a coordinated, cost-effective manner. Suncor Energy Inc., Oil Sands, Syncrude Canada Ltd. and Shell Canada Limited initiated the Regional Aquatics Monitoring Program (RAMP) in 1997 to address these issues. In the future, other oil sands operators in the region may also become involved in this program.

The RAMP is designed as a long-term monitoring program with sampling frequencies ranging from seasonal to once every few years. The 1997 program represents the first cycle of the RAMP. The program will likely evolve in subsequent years as input is solicited from a steering committee, local communities and other oil sands development stakeholders and as data collection provides new insight.

The objectives of the RAMP are to:

- monitor aquatic environments in the oil sands region to allow assessment of regional trends and cumulative effects;
- provide baseline data against which impact predictions of recent environmental impact assessments (EIAs) for oil sands developments will be verified; and
- design and execute a program which addresses the anticipated aquatic monitoring requirements of oil sands operators' environmental approvals.

The 1997 surveys included evaluation of water and sediment quality, benthic invertebrate community structure, fish habitat and fish populations and communities in the Athabasca River and selected tributaries, and species composition and distribution of aquatic vegetation in wetlands. Monitoring endpoints and level of effort varied by waterbody, depending on data available from previous surveys, the type of impacts predicted by EIAs and logistical constraints.

Water and Sediment Quality

The objectives of the water quality surveys were to:

- expand the available baseline data for dissolved metals and trace organic compounds;
- determine seasonal variation in water quality; and
- determine spatial variation in water quality in the oil sands area on a regional scale.

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Sediment quality surveys were carried out to:

- provide baseline data on natural variability in concentrations of metals and trace organic compounds in sediments in the oil sands area; and
- compare sediment quality the Athabasca River above and below the oil sands area.

Water quality surveys were conducted in spring, summer and fall in the Athabasca, Steepbank and Muskeg rivers. Sediment quality was evaluated during the fall in the Athabasca River, above and below the oil sands area, at the water quality and benthic invertebrate sampling locations. In addition, sediment was sampled in a number of rivers and streams within the RAMP study area (i.e., Muskeg, Steepbank and MacKay rivers; Poplar and Jackpine creeks). Sediment samples collected in the Athabasca River were also tested for toxicity to aquatic organisms, using a battery of standard toxicity tests.

Results of the 1997 water and sediment quality surveys were generally consistent with previous data. In the Athabasca River, no increases were found below the oil sands area in concentrations of parameters associated with natural deposits of oil sands or existing oil sands operations. The pronounced seasonal variation in suspended solids load, which is typical of this river, was also apparent in 1997. Sediment chemistry was also within previously-reported ranges, with the exception of certain metals, which were elevated in both areas sampled in 1997. Below the oil sands area, bottom sediments contained two to three-fold higher levels of hydrocarbons and PAHs than in the upstream sampling area, which reflect inputs from natural oil sands deposits through the study reach. Bottom sediments were not toxic in either of the sampling areas, as determined by laboratory tests.

Water quality of the Steepbank and Muskeg Rivers was similar in 1997 and was consistent with results of previous surveys. Both rivers were characterized by relatively clear water in all seasons, though suspended solids levels were slightly elevated in the spring in the Steepbank River. Dissolved salt and nutrient levels were low to moderate and concentrations of total metals were typically low. Naturally occurring hydrocarbons and naphthenic acids were occasionally detectable, but at very low levels. Trace organic compounds were not detected and no indication of toxicity was found. Seasonal variation in water quality was limited in these rivers, with only minor increases in levels of certain ions in winter and lower dissolved organic carbon concentration during spring snowmelt. Longitudinal trends were not apparent in the available data set.

Benthic Invertebrates

The objectives of the 1997 benthic invertebrate survey were to:

- select regional monitoring sites in the Athabasca, Steepbank and Muskeg rivers;
- conduct an initial survey of the Athabasca River, comparing benthic communities above and below the oil sands area; and
- build on the available baseline information to allow proper design of subsequent surveys.

Benthic invertebrates were surveyed in the Athabasca River above and below the oil sands area on both sides of the river. Sampling of one site each in the Steepbank and Muskeg rivers was planned but not completed due to high river discharge and ice build-up during the intended sampling period. The primary monitoring end-point investigated in the 1997 survey was community structure. The survey also included a preliminary assessment of mouth part deformities in chironomids (midge larvae) in the Athabasca River samples to investigate the feasibility of this monitoring tool in the oil sands area.

Results of the 1997 benthic invertebrate survey of the Athabasca River documented low to moderate invertebrate density and low taxonomic richness at all sampling sites. Chironomid midge larvae dominated all sites. Significant upstream-downstream and cross-channel differences were found in density, but not in taxonomic richness. The variation in community structure generally reflected habitat differences among sampling sites. The incidence of chironomid mouth part deformities was very low in both sampling areas. Overall, the 1997 survey did not provide consistent evidence of an influence of natural deposits of oil sands or oil sands operations on benthic communities.

Fish and Fish Habitat

The 1997 fish population study had the following objectives:

- examine year-to-year variability in fish population variables (e.g., length-at-age, size distribution) and species composition;
- document fish habitat associations by species and life stage and hence, allow the effects of natural variation in habitat availability to be taken into account when examining potential changes in fish populations;
- identify and evaluate potential reference areas for fish population monitoring;
- conduct a radiotelemetry study to address data gaps regarding fish spawning and overwintering areas and residence time in the oil sands region; and
- build on available baseline information to allow appropriate design of subsequent monitoring;

EXECUTIVE SUMMARY

Fisheries inventories were conducted within four distinct areas in the Athabasca River, which were referred to in this report as the Poplar, Steepbank, Muskeg and Tar-Ells River Areas. Basic population parameters, such as length-frequency distribution, length-at-age and CPUE, were documented. Length-frequency distributions for major fish species were similar for 1995, 1996 and 1997. Age-at-length relationships were determined for walleye, longnose sucker and lake whitefish. Data were grouped from the same season of different years to provide sufficient sample sizes. These graphs will form a baseline for future comparisons. Previously there were not enough age data available for these species to comprise an adequate sample size.

Field surveys were conducted in spring 1997 from the Mountain Rapids to Fort McMurray and just below Fort McMurray to determine their potential as reference areas for the Athabasca River RAMP study reaches. The areas surveyed were found inadequate for this purpose. However, a reach above the rapids might be adequate.

In conjunction with Athabasca River inventories, mapping of fish habitat types and determination of general fish habitat associations was conducted. Five dominant bank types noted for the Athabasca River constituted 88% of the shoreline areas in 1997: three erosional habitat types, one armoured habitat type and one depositional habitat type. Fish species most commonly used armoured and depositional habitats and one type of erosional habitat.

Two fish species were radio tagged in 1997 to address data gaps regarding fish spawning and overwintering areas and residence time in the oil sands region. Weekly flights followed the movements of 18 walleye and 18 lake whitefish. Results confirm the use of Mountain Rapids as a spawning area for lake whitefish. Information was also gathered concerning the frequent use of certain areas by each species such as: the mouth of the MacKay River by walleye and the area in the Athabasca River adjacent to Shipyard Lake by lake whitefish. Another finding was the location of two walleye and two lake whitefish near the mouths of Athabasca River tributaries, during the last 1997 flight (December 22), indicating that these fish might be overwintering in the Athabasca River.

The fisheries information for the Athabasca River gathered over the past few years can be used to better estimate the possible exposure and potential effects of oil sands developments at the population level. Most large fish species (e.g., goldeye, longnose sucker, lake whitefish) use the Athabasca River as a migration corridor to reach spawning areas. Within the Athabasca River these fish are most commonly found near the mouths of tributaries and within preferred habitat types (e.g., armoured banks). The mouths of the Muskeg, Steepbank, MacKay, Tar and Ells rivers, have been identified as important areas for rearing and feeding of walleye, northern pike, longnose sucker and white sucker. Hence, if oil sands developments effect habitat or water quality at the mouths of the tributaries, several life stages of these species could be affected.

EXECUTIVE SUMMARY

Fisheries inventories of the Steepbank, Muskeg and MacKay rivers were conducted in summer. There was no difference in relative abundance (catch-per-unit-effort) from 1995 and 1997 for the Steepbank River. Data from the Muskeg and MacKay Rivers were presented as a baseline for future comparisons. Species composition for all three of these watercourses is consistent with previous studies. The Ells and Tar rivers were identified through a literature review as potential reference areas for these watercourses.

Aquatic Vegetation

The objective of the aquatic vegetation surveys was to provide description of wetland types, plant species composition and vegetation health as a baseline for future monitoring.

Four wetlands were included in the 1997 summer survey: Shipyard Lake, Isadore's Lake, Kearl Lake and the Lease 25 Wetland (a reference area). Wetlands were classified according to the Alberta Wetland Inventory classification system. Wetland classes and vegetation communities were mapped on 1:10,000 or 1:20,000 scale aerial photographs and confirmed through field surveys. The field surveys included documenting species composition and percent cover, vegetation health characteristics (plant vigour) and field water quality and photographing vegetation.

Results of the 1997 wetland surveys of Shipyard Lake, Lease 25 Wetlands, Isadores' Lake, and Kearl Lake documented the occurrence of graminoid marshes, shrubby marshes, graminoid fens, shrubby fens, treed fens, shrubby swamps, treed swamps, shallow open water and lake wetland types. The dominant plant species included willow, river alder, Labrador tea, sedges, cattail, rushes, and bur-reeds. Plant health was generally good to very good. Water quality in the wetlands was neutral to slightly alkaline.

The variation in species composition, water quality and plant vigor generally reflected habitat differences due to dominant wetland types among sites surveyed. The 1997 surveys did not provide consistent evidence of an influence of oil sands operations on wetlands or associated plant communities. Data collected this year provides a baseline for future monitoring.

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1. INTRODUCTION

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, regulatory monitoring requirements must be satisfied in a coordinated, cost-effective manner.

Suncor Energy Inc., Oil Sands (Suncor), Syncrude Canada Ltd. (Syncrude) and Shell Canada Limited (Shell) initiated a Regional Aquatics Monitoring Program (RAMP) in 1997 to address these issues. In the future, other oil sands operators in the region may also become involved in this program.

The RAMP is designed as a long-term monitoring program with sampling frequencies ranging from seasonal to once every few years. The 1997 program is the first component of the overall RAMP program. The program will likely evolve in subsequent years as input is solicited from a steering committee, local communities and other oil sands development stakeholders and as data collection provides new insight.

The 1997 RAMP included sampling of water quality, sediment quality, benthic invertebrates, fish and surveys of wetlands vegetation. As well, radio transmitters were implanted in two Athabasca River fish species. This radiotelemetry study was initiated to follow the movements and identify overwintering and spawning sites of walleye and lake whitefish.

The results of the 1997 RAMP effort are presented in this report. Data from previous studies in the oil sands region, including those carried out under the Alberta Oil Sands Environmental Research Program (AOSERP) in the late 1970s, the Northern River Basins Study (NRBS) and baseline studies of environmental impact assessments (EIAs) for oil sands developments were used to provide a broader context for the 1997 data (Table 1.1).

Table 1.1 Aquatic Surveys Conducted in the Fort McMurray Oil Sands Area Since the Early 1970s

Project	Year	Watercourse	Description	Information	Reference
Syncrude baseline	1975	Athabasca River	Baseline studies of aquatic environments	W, F, B	McCart et al. (1977)
AOSERP	1976-1977	Athabasca and Muskeg rivers	Benthic habitat and communities	B	Barton and Wallace (1980)
AOSERP	1976-1977	Athabasca River	Fisheries resources downstream of Fort McMurray	F	Bond (1980)
AOSERP	1976-1978	Muskeg River, Jackpine Creek	An intensive study of the fish fauna	F	Bond and Machniak (1979)
AOSERP	1978	Athabasca River	Investigation of spring spawning fish populations	F	Tripp and McCart (1979)
GCOS (now Suncor) monitoring	1978	Athabasca River	Study of benthic invertebrates and sediment chemistry	W, B, S	Noton (1979)

Project	Year	Watercourse	Description	Information	Reference
AOSERP	1978	Athabasca River	Fisheries and habitat investigations of tributary streams	F	Tripp and Tsui (1980)
Alsands	1979	Unnamed lakes and ponds	Survey of lakes and ponds	W, F, P	Webb (1980)
AOSERP	1980	Firebag, Muskeg, Steepbank, Tar and Ells rivers	Aquatic biophysical inventory	F	Sekerak and Walder (1980)
Suncor monitoring	1981	Athabasca River	Survey of water quality and benthic invertebrates	W, B	Noton and Anderson (1982)
SandAlta	1981	Jackpine Creek and Muskeg River	Aquatic investigations in the Hartley (Jackpine) Creek area	F, B	O'Neil et al. (1982)
Suncor monitoring	1982	Athabasca River	Study of benthic invertebrates	B	Boerger (1983)
AEP monitoring	1977-1983	Athabasca River	AEP long-term monitoring of benthic invertebrate communities	B	Anderson (1991)
AEP monitoring	1970-1985	Athabasca River	Water quality surveys	W	Hamilton et al. (1985)
OSLO	1985	Athabasca and Muskeg rivers, Jackpine Creek and other Muskeg River tributaries	Aquatic baseline survey for the OSLO Oil sands Project	W, F, B	Beak (1986)
OSLO	1988	Athabasca and Muskeg rivers, Jackpine Creek and other Muskeg River tributaries	OSLO Project: Water quality and fisheries resources baseline studies	W, F, B	R.L. & L. (1989)
AEP monitoring	1988-1989	Athabasca River	Winter water quality surveys	W	Noton and Shaw (1989)
NRBS	1992	Athabasca River	A general fish and riverine habitat inventory	F	R.L. & L. (1994)
AEP monitoring	1990-1993	Athabasca River	Water quality surveys	W	Noton and Saffran (1995)
Suncor monitoring	1994	Athabasca River	Study of effects of TID seepage on benthic invertebrates	B	Golder (1994)
Aurora/ Steepbank mines baseline	1995	Athabasca, Muskeg and Steepbank rivers, Jackpine Creek and other Muskeg River tributaries	Aquatic baseline studies	W, F, B, S	Golder (1996a)
Aurora/ Steepbank mines baseline	1996	Athabasca River	1996 fisheries investigations: addendum to Golder (1996a)	F	Golder (1996b)
Muskeg River Mine baseline	1997	Athabasca and Muskeg rivers, Jackpine Creek and other Muskeg River tributaries	Aquatic baseline studies	W, F	Golder (1998)

NOTE: W = water quality, S = sediment quality, P = aquatic plants, B = benthic invertebrates, F = fisheries

1.1 OBJECTIVES

The objectives of the RAMP are to:

- design and execute a program which addresses the anticipated aquatic monitoring requirements of oil sands operators' environmental approvals;
- monitor aquatic environments in the oil sands region to allow assessment of regional trends and cumulative effects; and
- provide data against which impact predictions for water quality and aquatic resources will be verified.

1.2 SCOPE OF WORK

The RAMP is largely effects-oriented, and stresses the collection of biological data relevant to assessing effects on the aquatic ecosystem. In addition to traditional, chemistry-based monitoring, sensitive, biological indicators were chosen to allow early detection of potential effects related to oil sands developments. This will allow implementation of appropriate mitigative measures to halt or reverse effects which negatively impact aquatic ecosystems. The biological indicators identified for monitoring include benthic invertebrates and fish in the Athabasca River and its major tributaries and aquatic plants in wetlands. Water and sediment quality were also monitored to provide supporting data for the biological surveys.

1.2.1 Water and Sediment Quality

1.2.1.1 Rationale

Water and sediment quality monitoring is typically a regulatory requirement. 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 and objectives designed to protect aquatic life. Water and sediment quality surveys also provide valuable supporting data for biological surveys.

1.2.1.2 Objectives

The objectives of the water quality surveys were to:

- expand the available baseline data for dissolved metals and trace organic compounds;
- determine seasonal variation in water quality; and
- determine spatial variation in water quality in the oil sands area on a regional scale.
- Sediment quality surveys were carried out to:

- provide baseline data on natural variability in concentrations of metals and trace organic compounds in sediments in the oil sands area; and
- compare sediment quality the Athabasca River above and below the oil sands area.

1.2.1.3 Scope

Water quality surveys were conducted in spring, summer and fall in the Athabasca, Steepbank and Muskeg rivers. Water samples were analyzed for conventional parameters, major ions, nutrients, chlorophyll *a*, total metals, dissolved metals, selected oil sands-related organic compounds (i.e., recoverable hydrocarbons, naphthenic acids) and an indication of toxicity (Microtox® test).

Sediment quality was evaluated during the fall in the Athabasca River, above and below the oil sands area, at the water quality and benthic invertebrate sampling locations. In addition, sediment was sampled in a number of rivers and streams within the RAMP study area (i.e., Muskeg, Steepbank and MacKay rivers; Poplar and Jackpine creeks). Sediment samples were analyzed for metals and trace organic compounds (naphthenic acids, polycyclic aromatic hydrocarbons [PAHs] and alkylated PAHs). Sediment samples collected in the Athabasca River were also tested for toxicity to aquatic organisms, using a battery of standard toxicity tests (survival and growth of midge larvae, amphipods and aquatic worms).

Porewater quality was not assessed in 1997, but data reported by previous surveys were summarized to provide a basis for future comparisons.

1.2.2 Benthic Invertebrates

1.2.2.1 Rationale

Benthic invertebrate monitoring is an essential component of aquatic monitoring programs and is frequently a regulatory requirement for industries that discharge water to rivers and lakes. Benthic invertebrates (insects, crustaceans, worms and mollusks) form communities that reflect the physical and chemical characteristics of their habitat. They also constitute an important food source for many fish species (e.g., longnose sucker), which renders them an important feature of fish habitat. Therefore, benthic invertebrate monitoring complements surveys of water and sediment quality and fisheries, by providing a direct indication of the environmental quality of the waterbody monitored and the availability of invertebrate food for fish.

1.2.2.2 Objectives

The objectives of the benthic invertebrate study were to:

- select regional monitoring sites in the Athabasca, Steepbank and Muskeg rivers;
- conduct an initial survey of the Athabasca River, comparing benthic communities above and below the oil sands area; and
- build on the available baseline information to allow proper design of subsequent, larger-scale surveys to be conducted as part of RAMP.

1.2.2.3 Scope

Benthic invertebrates were surveyed in the Athabasca River above and below the oil sands area on both sides of the river, at the locations sampled for water and sediment quality. Sampling of one site each in the Steepbank and Muskeg rivers was planned but not completed due to high river discharge during the intended sampling period.

The primary monitoring end-point investigated in the 1997 survey was community structure. Invertebrate abundance data were analyzed to evaluate potential differences between upstream and downstream sites. The 1997 survey also included a preliminary assessment of mouth part deformities in chironomids (midge larvae) in the Athabasca River samples to investigate the feasibility of this monitoring tool in the oil sands area.

1.2.3 Fish Populations

1.2.3.1 Rationale

Fish populations were monitored because they are key components of aquatic food webs and represent an important recreational and subsistence resource for people. Some fish species (e.g., walleye, northern pike) are top predators and hence, integrators of effects at lower levels in the food web. Other species, such as longnose sucker, are in an intermediate position in the food web and could be indicators of changes in other components of the aquatic food web (e.g., benthic invertebrate communities).

1.2.3.2 Objectives

The 1997 fish population study had the following objectives:

- examine year-to-year variability in fish population variables (e.g., length-at-age, size distribution) and species composition;
- build on available baseline information to allow appropriate design of subsequent monitoring;
- document fish habitat associations by species and life stage;
- identify and evaluate potential reference areas for fish population monitoring; and

- conduct a radiotelemetry study to address data gaps regarding fish spawning and overwintering areas and residence time in the oil sands region (i.e., potential exposure to effects related to the oil sands developments).

1.2.3.3 Scope

Spring, summer and fall electrofishing surveys were conducted in the Athabasca River at 10 reaches to enhance the baseline information on seasonal and year-to-year variability in fish communities and populations. Sampling in the Muskeg and Steepbank rivers was conducted only in summer since it is the time when both resident species and species that spawn in the river are present (Golder 1996a).

Relative fish abundance (catch-per-unit-effort) and species composition were determined for all watercourses sampled. For the Athabasca River, length-at-age, length frequency distribution and habitat associations (by life stage) were determined. Fish habitat associations were documented to allow assessment of the effects of natural variation in habitat availability when examining potential changes in fish population demographics.

Potential reference areas were evaluated by examining relevant literature on species composition and habitat. As well, several reaches of the Athabasca River were examined in the field.

A radiotelemetry study was conducted with walleye and lake whitefish. The fish were tagged in October and their locations tracked until late December. A few winter flights will be necessary to verify the location of certain fish in the Athabasca River. These fish may be overwintering at the mouths of some Athabasca River tributaries, where they were last located. Consistent radiotracking will resume in the spring.

1.2.4 Aquatic Vegetation in Wetlands

1.2.4.1 Rationale

Wetland vegetation has been documented as an important biomonitoring parameter for examining potential effects to wetlands systems (Gorham et al. 1984). Changes in water level, circulation patterns and clarity caused by oil sands developments or water releases could be reflected in changes in the abundance and distribution of aquatic plants in wetlands. As such, an inventory of wetland plant species provides a baseline for future monitoring of wetlands. Wetland 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.

1.2.4.2 Objectives

The objective of the aquatic vegetation surveys was to provide a description of wetland types and composition and vegetation health as a baseline for future monitoring.

1.2.4.3 Scope

Four wetlands were included in the 1997 summer vegetation survey: Shipyard Lake, Isadore's Lake, Kearl Lake and the Lease 25 Wetland (a reference area). Wetland classes and vegetation communities were mapped on 1/10,000 or 1/20,000 scale aerial photographs and confirmed through field surveys. The field surveys included collecting species composition and percent cover data, recording vegetation health characteristics (plant vigour) and water quality parameters and photographing vegetation.

1.2.5 Summary of Scope

Table 1.2 summarizes the 1997 monitoring activities described in this report. Indicators selected for the first cycle of the RAMP included water and sediment chemistry, species composition and distribution of aquatic vegetation, benthic invertebrate community structure and chironomid deformities, fish habitat characteristics, fish population characteristics and fish community structure. Specific indicators and level of effort varied by waterbody, depending on data available from previous surveys, the type of impacts predicted by EIAs and logistical constraints.

Table 1.2 Summary of 1997 Monitoring Activities

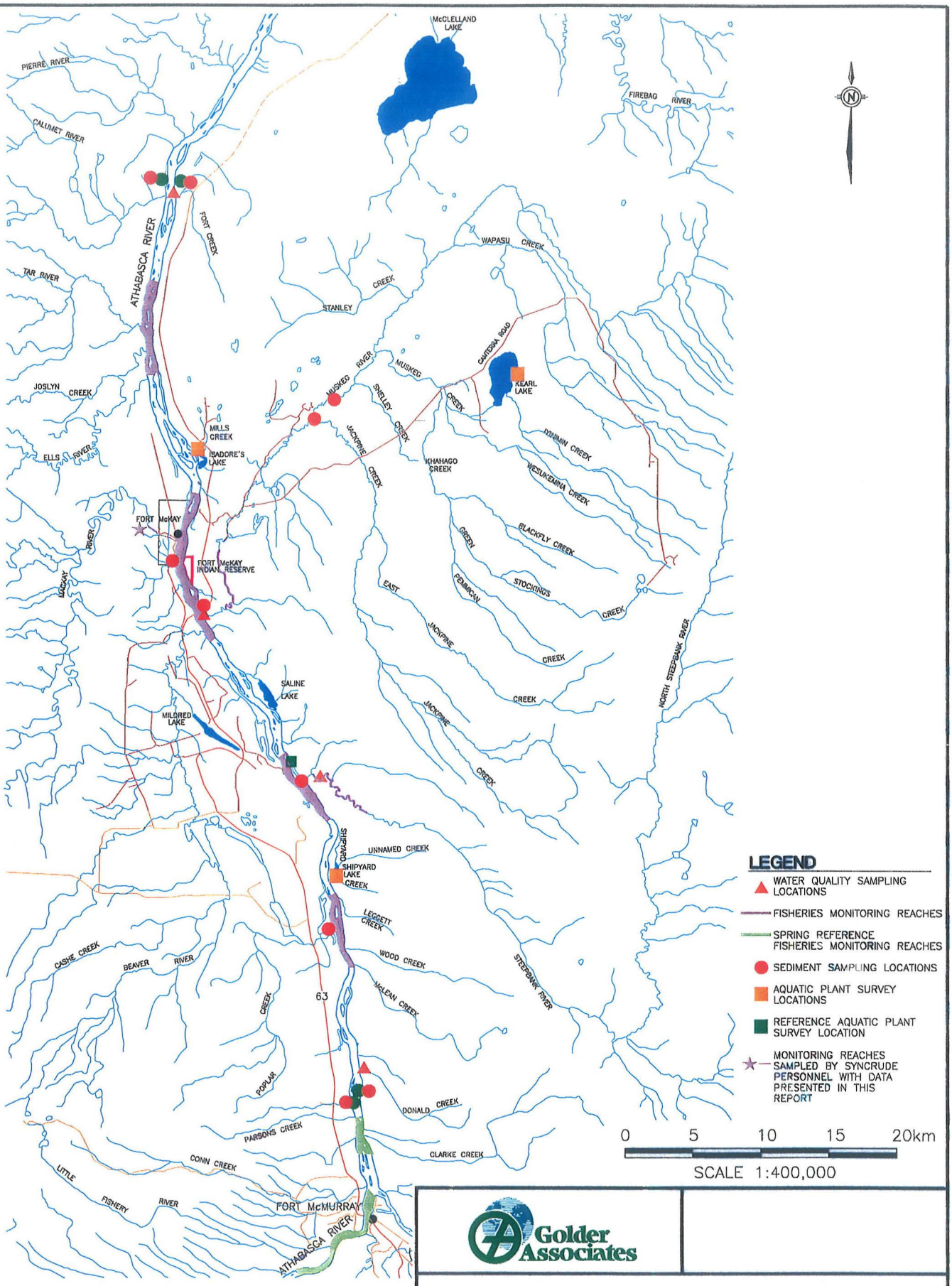
Location	Indicator	Season	Monitoring End-points
Athabasca River	water quality	fall	chemical concentrations, toxicity
	sediment quality	fall	chemical concentrations, toxicity
	benthic invertebrates	fall	community structure, chironomid deformities
	fish habitat and communities	spring, summer, fall	relative abundance, species composition, length-at-age relationships, length-frequency distribution, fish habitat associations
Tributaries	water quality	spring, summer, fall	chemical concentrations, toxicity
	sediment quality	fall	chemical concentrations, toxicity
	fish communities	summer	relative abundance, species composition
Wetlands	aquatic vegetation	summer	wetland classification and vegetation communities, species composition, percent cover, vegetation health

1.3 STUDY AREA

The RAMP study area is consistent with the regional study area used for recent oil sands EIAs. It encompasses a reach of the Athabasca River, from upstream of Fort McMurray to the Athabasca River Delta, including the watersheds of the Muskeg, Steepbank, MacKay and Firebag rivers.

During the 1997 program, sampling was conducted in the following waterbodies (Figure 1.1):

- Athabasca River from above Donald Creek to below Fort Creek;
- the lower reaches of the Muskeg and Steepbank rivers; and
- Kearl Lake, Lease 25 Wetlands, Shipyard Lake and Isadore's Lake.



REFERENCE

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

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RAMP 1997 MONITORING LOCATIONS

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2. METHODS

2.1 SURFACE WATER, SEDIMENT AND POREWATER QUALITY

2.1.1 Approach

Data collected in 1997 and by a number of previous surveys were summarized to describe existing water, sediment and porewater quality in the Athabasca River within the oil sands area and in the Muskeg and Steepbank rivers. Data were summarized by reach and season. Water and sediment quality were compared between the two sampling reaches in the Athabasca River (i.e., upstream and downstream of the oil sands area).

2.1.2 Surface Water Quality

2.1.2.1 Historical Data

Prior to 1997, surface water samples were collected in the oil sands area under the following programs:

- routine monitoring by Alberta Environmental Protection (AEP);
- Alberta Oil Sands Environmental Research Program (AOSERP);
- Other Six Leases Operations (OSLO) Project;
- Northern River Basins Study (NRBS); and
- baseline studies in support of Suncor's Steepbank Mine, Syncrude's Aurora Mine and Shell's Muskeg River Mine.

Data were summarized from the period of 1970 to 1997. Data collected by AEP and NRBS were obtained from the NAQUADAT database. Data collected during the OSLO Project in the Muskeg River basin and baseline data collected by Suncor, Syncrude and Shell, from 1995 to 1997, were obtained from the relevant reports. Original site codes of water quality sites used for the data summary presented in this report are listed in Table 2.1 and site locations are shown in Figure 2.1.

Table 2.1 Water Quality Sampling Sites

Site Description	Study and Site Code	Reference
Athabasca River above Fort McMurray	NAQUADAT Site 00AL07CC0500	NAQUADAT
	NAQUADAT Site 00AL07CC0600	NAQUADAT
Athabasca River near Donald Creek	RAMP monitoring Site ATR-W-1B	Present Report
	Suncor/Syncrude aquatic baseline Site AW004	Golder (1996a)
Athabasca River below existing oil sands operations	Suncor/Syncrude aquatic baseline Site AW009	Golder (1996a)
	Shell aquatic baseline Site ATR-W-7	Golder (1998)
Athabasca River below Fort Creek	NAQUADAT Site 00AL07DA4200	NAQUADAT
	NAQUADAT Site 00AL07DA4250	NAQUADAT
	NAQUADAT Site 00AL07DA4300	NAQUADAT
	RAMP monitoring Site A15	Present Report
Muskeg River at mouth	NAQUADAT Site 00AL07DA2600	NAQUADAT
	NAQUADAT Site 00AL07DA2650	NAQUADAT
	RAMP monitoring Site MUR-W-1	Present Report
	Suncor/Syncrude aquatic baseline Site 30	Golder (1996a)
Lower Muskeg River	NAQUADAT Site 00AL07DA2550	NAQUADAT
	Shell aquatic baseline Site WQ1	Golder (1998)
	RAMP monitoring Site MO1	Present Report
	Suncor/Syncrude aquatic baseline Site 18	Golder (1996a)
	OSLO Project Site 18	R.L.& L. (1989)
Upper Muskeg River	OSLO Project Site 1	R.L.& L. (1989)
	OSLO Project Site 2	R.L.& L. (1989)
	OSLO Project Site 3	R.L.& L. (1989)
	Suncor/Syncrude aquatic baseline Site 36	Golder (1996a)
Steepbank River at Mouth	NAQUADAT Site 00AL07DA1200	NAQUADAT
	Suncor/Syncrude aquatic baseline Site AW010	Golder (1996a)
	Suncor winter aquatic baseline site ("Mouth")	Golder (1997b)
	RAMP monitoring Site STR-W-8	Present Report
Lower Steepbank River	NAQUADAT Site 00AL07DA1150	NAQUADAT
Upper Steepbank River	Suncor/Syncrude aquatic baseline Site AW001	Golder (1996a)

2.1.2.2 1997 Survey

Sampling Dates and Site Locations

Water quality sampling was conducted in spring (May 6 to 13), summer (July 24 to 30) and fall (September 15 to 22 and October 2 to 15). Four locations were sampled in each of these seasons (Figure 1.1):

- grab samples were collected at the mouths of the Steepbank and Muskeg rivers; and

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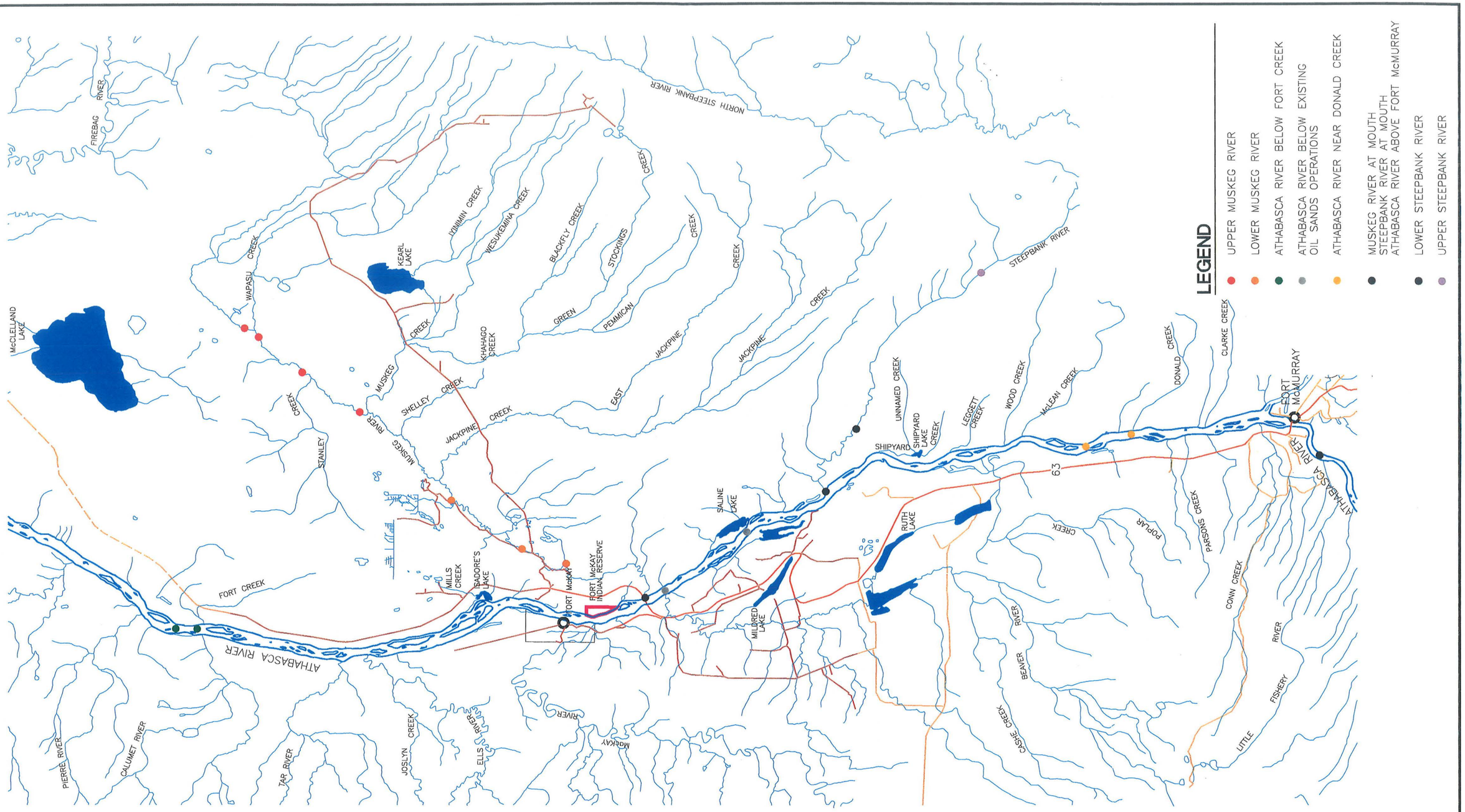


0 5 10 15 20km

SCALE

REFERENCE

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

Golder Associates

WATER QUALITY SAMPLING SITES

28 JAN 98	FIG. No. 2.1	DRAWN BY: CG/DC

- cross-channel composite samples were collected in the Athabasca River at one reference site upstream of the oil sands area (above Donald Creek) and at one site downstream of all existing and planned oil sands developments (below Fort Creek).

Sampling Methods

Water samples were collected according to Golder Technical Procedure 8.3-1 (Appendix I). Field parameters were measured at all water quality sites using the following instruments:

- 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.

Dissolved oxygen and pH meters were field-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.

Laboratory Analysis

Water samples were analyzed by Enviro-Test Laboratories (ETL) in Edmonton for conventional parameters, major ions, nutrients, total metals, dissolved metals, recoverable hydrocarbons and naphthenic acids (Table 2.2). Chlorophyll *a* and Microtox® were analyzed by HydroQual Laboratories (HydroQual) in Calgary. Descriptions of analytical methods are provided in Appendix II.

2.1.2.3 Data Summary Methods

Water quality data were summarized by river reach and season. Sites used to represent reaches are shown in Figure 2.1; site codes within each reach and data sources are listed in Table 2.1.

Seasons were defined as follows:

Table 2.2 Water Quality Parameters and Analytical Detection Limits

Parameter	Units	Detection Limit	Parameter	Units	Detection Limit
Conventional Parameters			**Total and Dissolved Metals**		
pH	-	-	Aluminum	mg/L	0.0003
Specific Conductance	µS/cm	0.2	Antimony	mg/L	0.0004
Colour	T.C.U.	3	Arsenic	mg/L	0.0004
Total Alkalinity	mg/L	5	Barium	mg/L	0.0001
Hardness	mg/L	1	Beryllium	mg/L	0.0005
Total Suspended Solids	mg/L	2	Boron	mg/L	0.002
Total Dissolved Solids	mg/L	10	Cadmium	mg/L	0.0001
Total Organic Carbon	mg/L	1	Chromium	mg/L	0.0004
Dissolved Organic Carbon	mg/L	1	Cobalt	mg/L	0.0001
Biochemical Oxygen Demand	mg/L	2	Copper	mg/L	0.0004
Chlorophyll *a*	µg/L	0.01	Iron	mg/L	0.01
Total Phenolics	mg/L	0.001	Lead	mg/L	0.00005
Major Ions			Lithium	mg/L	0.003
Calcium	mg/L	0.05	Manganese	mg/L	0.0001
Magnesium	mg/L	0.1	Mercury	mg/L	0.0002
Potassium	mg/L	0.01	Molybdenum	mg/L	0.00005
Sodium	mg/L	0.1	Nickel	mg/L	0.0001
Bicarbonate	mg/L	5	Selenium	mg/L	0.0004
Chloride	mg/L	0.5	Silicon	mg/L	0.006
Sulphate	mg/L	0.5	Silver	mg/L	0.0002
Sulphide	mg/L	0.002	Strontium	mg/L	0.00005
Nutrients			Titanium	mg/L	0.0003
Total Ammonia Nitrogen	mg/L	0.05	Uranium	mg/L	0.00005
Total Kjeldahl Nitrogen	mg/L	0.2	Vanadium	mg/L	0.0001
Nitrate + Nitrite Nitrogen	mg/L	0.05	Zinc	mg/L	0.002
Total Phosphorus	mg/L	0.003	**Other Parameters**		
Dissolved Phosphorus	mg/L	0.003	Recoverable Hydrocarbons	mg/L	1
			Naphthenic Acids	mg/L	1
			Microtox® IC50 and IC25	%	-

Winter: November, December, January, February, March

Spring: April, May

Summer: June, July, August

Fall: September, October

For reaches or parameters with a single sample per season, the raw data are shown in the data tables. For those with two samples per season, both measurements are shown as a range (minimum and maximum). For those with three or more samples per season, the median and the range are shown. To facilitate efficient presentation of results, only selected parameters are shown in the data tables. Complete data sets are presented in Appendix VII.

2.1.3 Sediment Quality

2.1.3.1 Historical data

Bottom sediment chemistry of the Athabasca River within the oil sands area was described in the 1970s and 1980s by Noton (1979), IEC Beak (1983)

and Beak (1988), although intensive sampling was not carried out in these studies. More recently, Golder (1994, 1996a) conducted small-scale sampling, as part of bioaccumulation studies examining the seepage from Suncor's Tar Island Dyke (TID) and baseline studies in support of the Steepbank Mine EIA. Small-scale sediment sampling for specific contaminants was also conducted by studies sponsored by the federal Panel for Energy Research and Development (PERD) (Brownlee 1990, Brownlee et al. 1993) and the NRBS (Crosley 1996, Brownlee at al. 1977).

Data collected during the present study and by Golder (1994, 1996a) were summarized to describe sediment quality in the oil sands region. During these surveys, sediment samples were collected and analyzed using consistent methods.

2.1.3.2 1997 Survey

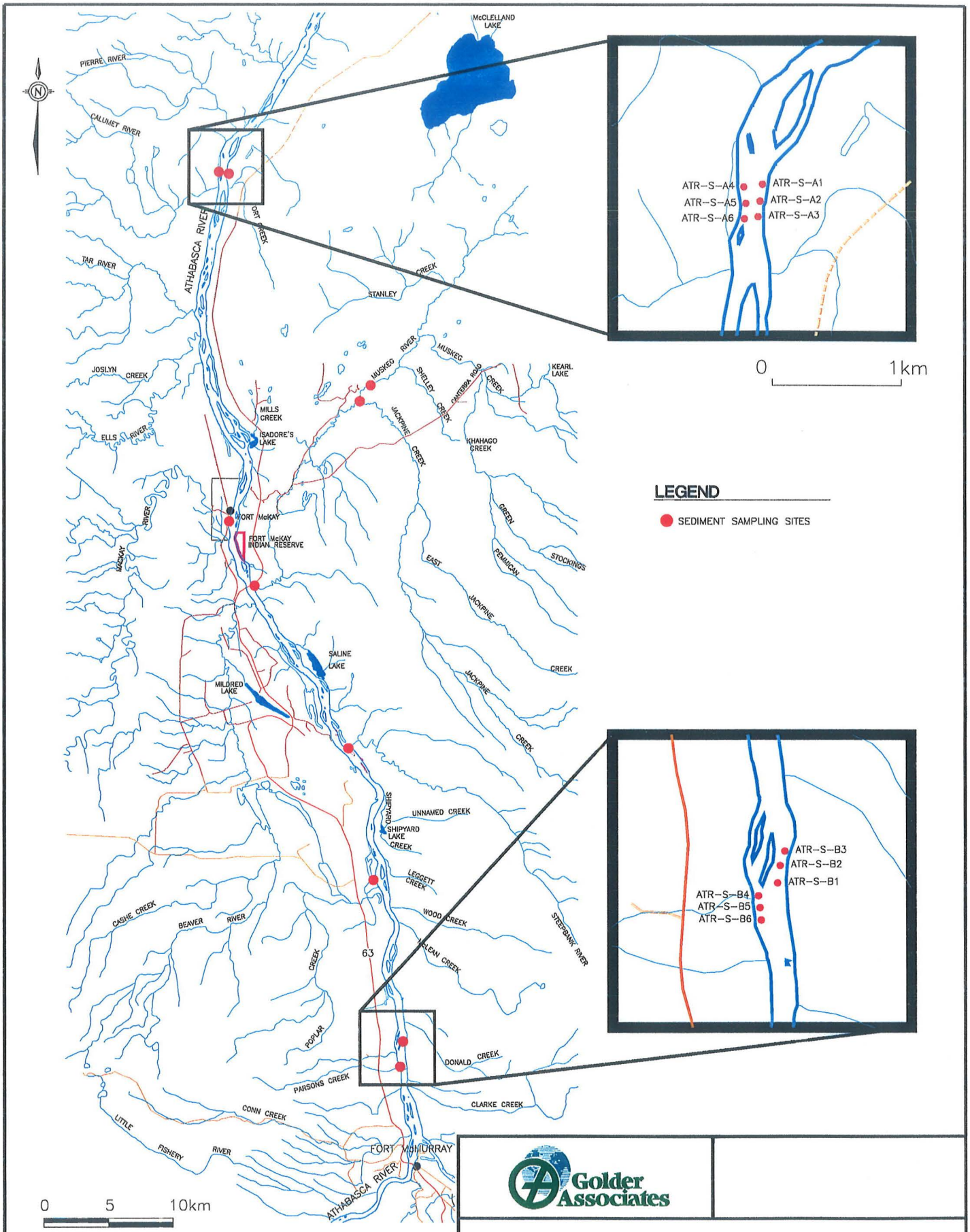
Sampling Dates and Site Locations

Sediment samples were collected during the fall in 1997 (October 2 to 15) from the Athabasca River and its tributaries (Figure 2.2). Sediment samples were collected for chemistry and toxicity analyses at two locations in the Athabasca River (above and below the oil sands area). The following tributary locations were sampled for sediment chemistry:

- Jackpine Creek at the mouth;
- MacKay River at mouth;
- Muskeg River at the mouth and above the mouth of Jackpine Creek;
- Poplar Creek at mouth, and
- Steepbank River at mouth.

Sampling Methods

Sediment samples were collected using an Ekman grab according to Golder Technical Procedure 8.2-2 (Appendix III). One composite sample was submitted for analysis from each site, consisting of the top 3 cm of sediment from five or six points at each site. The six individual sample points in each of the two study reaches in the Athabasca River corresponded to the benthic invertebrate sampling sites and are shown in Figure 2.2. To provide supporting data for the benthic invertebrate survey, individual grab samples were also collected at each of the 12 benthic invertebrate sites for separated analyses of sediment texture and total organic carbon (TOC).



LEGEND

- SEDIMENT SAMPLING SITES

REFERENCE

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

Golder Associates

SEDIMENT SAMPLING SITES

25 MAR 98	Figure 2.2	DRAWN BY: DC

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Laboratory Analysis

Sediment chemistry analyses of the composite samples included PAHs and alkylated PAHs, TOC, recoverable hydrocarbons, major ions, trace metals and texture (Table 2.3). The toxicity test battery included survival and growth of *Chironomus tentans* (midge larva), *Hyalella azteca* (amphipod) and *Lumbriculus* (oligochaete worm). Individual grab samples collected at the benthic invertebrate sites were analyzed for texture (% sand, silt and clay) and TOC.

Sediment chemistry analyses were performed by ETL in Edmonton. Toxicity tests were conducted by HydroQual in Calgary according to Environment Canada Protocols.

2.1.3.3 Data Summary Methods

Because of the limited amount of sediment quality data available at this time (i.e., single samples from most sites), nearly all of the available data are presented in this report. Exceptions include one site in the Athabasca River (at TID, west bank) and the two sites in the Steepbank River, where multiple samples were collected. For these sites, data are presented as concentration ranges.

2.1.4 Porewater Quality

Porewater is the water occupying the void spaces between sediment particles. Porewater quality data are limited in the oil sands area. The available data consist of analytical results for a few samples collected in 1994 and 1995 by Golder (1994, 1995, 1996a). These results were obtained from reference sites in the Athabasca River (upstream and across from Suncor) and sites adjacent to Suncor (at TID), from the Steepbank River (three relatively widely spaced sites) and from single sites at the mouth of the Muskeg River and the mouth of Jackpine Creek (Golder 1996a).

Porewater samples were not collected during the 1997 field program. However, the existing data were summarized in this report to provide a basis for potential future comparisons.

Table 2.3 Sediment Quality Parameters and Analytical Detection Limits

Parameter	Units	Detection Limit	Parameter	Units	Detection Limit
Metals			**PAHs and Alkylated PAHs**		
Aluminum	mg/kg	10	Naphthalene	µg/g	0.003
Antimony	mg/kg	0.1	Acenaphthylene	µg/g	0.003
Arsenic	mg/kg	0.1	Acenaphthene	µg/g	0.003
Barium	mg/kg	0.5	Fluorene	µg/g	0.003
Beryllium	mg/kg	1	Dibenzothiophene	µg/g	0.003
Cadmium	mg/kg	0.5	Phenanthrene	µg/g	0.003
Calcium	mg/kg	100	Anthracene	µg/g	0.003
Chromium	mg/kg	0.5	Fluoranthene	µg/g	0.003
Cobalt	mg/kg	1	Pyrene	µg/g	0.003
Copper	mg/kg	1	Benzo(a)anthracene/chrysene	µg/g	0.003
Iron	mg/kg	1	Benzo(b&k)fluoranthene	µg/g	0.003
Lead	mg/kg	5	Benzo(a)pyrene	µg/g	0.003
Magnesium	mg/kg	10	Indeno(c,d-123)pyrene	µg/g	0.003
Manganese	mg/kg	0.1	Dibenzo(a,h)anthracene	µg/g	0.003
Mercury	mg/kg	0.01	Benzo(ghi)perylene	µg/g	0.003
Molybdenum	mg/kg	1	Methyl naphthalene	µg/g	0.003
Nickel	mg/kg	2	C2 substituted naphthalene	µg/g	0.02
Potassium	mg/kg	20	C3 substituted naphthalene	µg/g	0.02
Selenium	mg/kg	0.1	C4 substituted naphthalene	µg/g	0.02
Silver	mg/kg	1	Biphenyl	µg/g	0.02
Sodium	mg/kg	100	Methyl biphenyl	µg/g	0.02
Strontium	mg/kg	1	C2 substituted biphenyl	µg/g	0.02
Sulphur	mg/kg	100	Methyl acenaphthene	µg/g	0.02
Thallium	mg/kg	1	Methyl fluorene	µg/g	0.02
Tin	mg/kg	5	C2 substituted fluorene	µg/g	0.02
Titanium	mg/kg	5	Methyl phenanthrene/anthracene	µg/g	0.02
Vanadium	mg/kg	1	C2 substituted phenanthrene/anthracene	µg/g	0.02
Zinc	mg/kg	0.5	C3 substituted phenanthrene/anthracene	µg/g	0.02
Other Parameters			C4 substituted phenanthrene/anthracene	µg/g	0.02
Recoverable Hydrocarbons	mg/kg	100	Methyl dibenzothiophene	µg/g	0.02
Total Organic Carbon	%	-	C2 substituted dibenzothiophene	µg/g	0.02
% Sand	%	0.1	C3 substituted dibenzothiophene	µg/g	0.02
% Silt	%	0.1	C4 substituted dibenzothiophene	µg/g	0.02
% Clay	%	0.1	Methyl fluoranthene/pyrene	µg/g	0.02
-	-	-	Methyl benzo(a)anthracene/chrysene	µg/g	0.02
-	-	-	C2 substituted benzo(a)anthracene/chrysene	µg/g	0.02
-	-	-	Methyl benzo(b&k)fluoranthene/benzo(a)pyrene	µg/g	0.02
-	-	-	C2 substituted benzo(b&k)fluoranthene/benzo(a)pyrene	µg/g	0.02

2.1.5 Quality Assurance and Quality Control

2.1.5.1 Water Quality

Water samples were collected following Golder Technical Procedure 8.3-1 (Appendix I) which outlines sample collection, preservation, storage and handling procedures and provides specific guidelines for field record keeping and sample tracking. As part of the quality assurance and quality control (QA/QC) program for this study, triplicate samples and a field blank were collected from one randomly selected site during each sampling season.

Water chemistry data were entered into the project database from the electronic files received from the analytical laboratory. All data are stored in Microsoft Excel spreadsheet format. A portion of the analytical data (10%) was verified against the paper copies received from the analytical laboratory.

Quality Assurance Program for Naphthenic Acids Analysis

The aim of this program was to evaluate variation among laboratories in analytical results for naphthenic acids concentrations and to evaluate whether adding a preservative to water samples influences analytical results for this parameter. Syncrude Canada Research Laboratory (Syncrude) does not recommend preserving samples after collection, whereas ETL advocates that samples should be preserved. The description of the preservative used by ETL is provided in Appendix II.

Water samples were collected from three locations reported as having different levels of naphthenic acids, following Golder Technical Procedure 8.3-1 (Appendix I). The following samples were collected in 1997 and split before shipping to Syncrude and ETL for naphthenic acids analysis:

- one preserved sample from the Athabasca River upstream of TID, collected on July 29;
- three preserved replicate samples from Suncor's Southwest Drainage Ditch, collected on July 29;
- one preserved and one unpreserved sample from Suncor's Southwest Drainage Ditch, collected on September 16;
- two preserved samples of outflow from Suncor's Pond 5 East, collected on July 29 and September 29; and
- one preserved and one unpreserved sample of outflow from Suncor's Pond 5 East, collected on September 18.

Analytical results for naphthenic acids concentrations were compared between laboratories and between preserved and unpreserved samples.

2.1.5.2 Sediment Quality

Sediment samples were collected according to Golder Technical Procedure 8.2-2 (Appendix III). As part of the QA/QC program, a duplicate sediment sample was collected from the Athabasca River downstream of all oil sands developments (at Fort Creek) during the fall sampling trip.

Sediment chemistry data were entered into the project database from the electronic files received from the analytical laboratory.

2.2 BENTHIC INVERTEBRATES

2.2.1 Approach

Benthic invertebrate surveys carried out in the oil sands area have included baseline studies for EIAs, effluent and dike seepage monitoring, long-term monitoring, bioaccumulation studies and secondary production studies (Table 1.1). The majority of these studies concentrated on short reaches or individual tributary basins and none sampled at a sufficiently large scale to examine community changes at the regional scale. The objective of the 1997 survey was to initially assess benthic community structure in the Athabasca River above and below the oil sands area and to provide data for the design of future surveys at this scale and to select long-term monitoring sites in the Muskeg and Steepbank rivers.

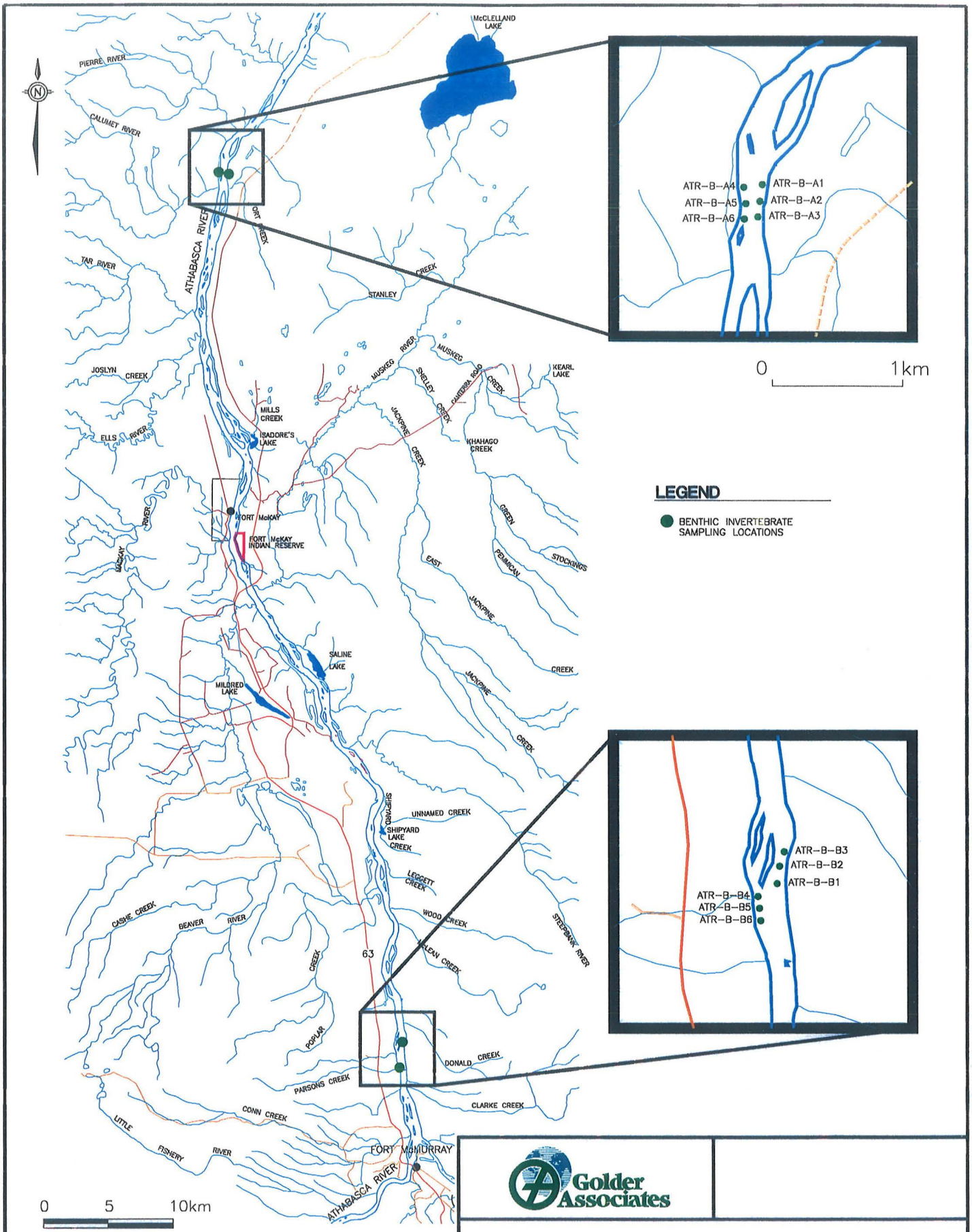
2.2.2 Study Design

2.2.2.1 Athabasca River

The study design for the Athabasca River included a reference area upstream from the oil sands area (at Donald Creek) and a sampling area below all existing and planned oil sands developments (below Fort Creek). Benthic invertebrates were sampled at each of three, randomly selected sites along both banks in these areas, for a total of 12 sites (Figure 2.3).

Data analysis conducted by Noton (1979) and Noton and Anderson (1982) showed that it is necessary to take seven to nine replicate samples to reliably estimate invertebrate density at each site within the reach adjacent to Suncor. Therefore, nine replicate samples were collected at each of the 12 sampling sites, for a total of 108 samples. Only a subset of these samples were analyzed in the laboratory, based on the procedure described in Section 2.2.4.

Since the focus of the monitoring program is to detect any effects of mine development on the native fauna of the river, the natural substratum was sampled using an Ekman grab. This approach also ensures that the organisms monitored are in close contact with the sediments, where



REFERENCE

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

Golder Associates

BENTHIC INVERTEBRATE SAMPLING SITES

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hydrophobic substances (e.g., higher molecular weight PAHs) and metals tend to accumulate.

2.2.2.2 Steepbank and Muskeg Rivers

In the Steepbank River, one site sampled during the 1995 baseline studies (SB003, near the mouth; Golder 1996a) was planned for resampling in 1997. Because of relatively easy access, high quality habitat and a position along the river where benthic communities could be exposed to all potential discharges from mine operations and reclaimed land, it was proposed as the regional monitoring site for the Steepbank River.

In the Muskeg River, one erosional site was selected in the reach located approximately 8 km upstream from the mouth, where the fish fence was operated during the 1995 baseline studies (Golder 1996a; Figure 1.1). This area represents the only accessible high quality invertebrate habitat in the lower reaches of the Muskeg River (i.e., erosional habitat that supports a diverse benthic fauna). Therefore, this site was proposed as the regional monitoring site for the Muskeg River.

Sampling was initially scheduled for late September 1997. However, at that time, unusually high water levels prevented field personnel from collecting samples at the proposed Muskeg River monitoring site. Sampling of the Muskeg and Steepbank River sites was attempted in early October. At this time, high water levels in the Muskeg River and ice accumulation on the bottom of the Steepbank River prevented sample collection. Because of these difficulties, benthic invertebrates were not sampled in the Muskeg and Steepbank rivers during the first cycle of RAMP. Earlier sampling will be necessary in these rivers during future RAMP surveys.

2.2.3 Sampling Methods

Benthic sampling was carried out according to Golder Technical Procedure 8.6-1 (Appendix IV). A pole-mounted Ekman grab of 0.023 m^2 bottom area was used to sample benthic invertebrates. This device was also used by a number of previous benthic surveys of the Athabasca River (Noton 1979, Noton and Anderson 1982, Golder 1996). Samples were taken from at least 1 m deep water to avoid sampling seasonally exposed areas. Contents of the Ekman grab were washed through a 250 µm mesh screen bucket in the field; the material retained by this mesh was preserved in 10% buffered formalin.

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 - Price or Marsh-McBirney current velocity meter;
- dissolved oxygen - YSI dissolved oxygen meter;
- pH - Horiba pH meter;
- conductivity - YSI conductivity meter; and
- temperature - hand-held thermometer or YSI conductivity meter.

Dissolved oxygen and pH meters were field-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.

Sites were permanently marked along the shoreline and were referenced using a Trimble GeoExplorer Global Positioning System (GPS) unit.

2.2.4 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 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. Subsampling was employed for large samples according to methods outlined by Wrona et al. (1982). Invertebrates were removed from the detritus under a dissecting microscope. All remaining 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 insects were identified to the lowest level possible, generally to family.

The desired number of replicate samples processed from each site was intended to provide a reliable estimate of mean densities of dominant invertebrates. This number was estimated by processing individual Ekman grab samples from two sites (A1 and B3; Figure 2.3) until variation in total density and densities of dominant taxa among replicates was acceptable (i.e., standard error of the mean was $\leq$25% for total density and densities of taxa constituting at least 5% of the total density at a site). Six samples were found to satisfy this criterion at both sites. To facilitate efficient sample processing, six pooled replicates were processed from the remaining sites. Subsampling in the laboratory, which introduces little additional variation, was used to reduce processing effort for composite samples to a reasonable level.

In addition to taxonomic identification, chironomid larvae were examined for the incidence of mouth part deformities, which can be identified as missing or deformed teeth on the mentum (Hudson and Ciborowski 1995). Elevated incidence of deformities in chironomid larvae were identified by recent studies as a potentially reliable early warning indicator of environmental degradation (Dickman et al. 1990 and 1992, Warwick 1990, Dermott 1991). The genus *Polypedilum* was selected for this analysis, because no other genera were found in sufficient numbers in the benthic samples to evaluate the incidence of deformities. One hundred and twenty-five individuals of *Polypedilum* were examined from each of the following three sampling areas, as recommended by Hudson and Ciborowski (1995):

- Athabasca River at Fort Creek, east bank, at Sites A1, A2 and A3;
- Athabasca River at Donald Creek, east bank, at Sites B1, B2 and B3; and
- Athabasca River at Donald Creek, west bank, at Sites B4 and B5.

Only small, early instar individuals of *Polypedilum* were found at Sites A3, A4 and A5 along the west bank of the river at Fort Creek and at Site B6, which precluded an evaluation of deformities at those sites.

To prepare microscope slides for evaluating deformities in chironomid larvae, head capsules were initially removed with a sharpened probe from randomly selected larvae from each sample used for this analysis. Heavily sclerotized head capsules were cleared in warm, 10% KOH, followed by rinsing with distilled water and 70% ethanol. Head capsules were mounted ventral side up on microscope slides in Hoyer's mounting medium. Slides were examined under a compound microscope at up to 400 X magnification.

The incidence of deformities in reference and exposure areas were compared with reports in the literature and the potential for the use of this technique as a monitoring tool in the oil sands area was evaluated.

2.2.5 Data Analysis

Analysis and interpretation of the 1997 benthic survey focused on comparing the reference area with the area below the oil sands region and investigating relationships between physical and chemical variables and benthic community structure. Graphical methods, parametric statistical tests and multivariate tools 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 graphically (as bar graphs) to provide an overview of the benthic fauna of the study area.

The relationship between benthic community composition and physical variables (current velocity, depth, percentages of sand, silt and clay in sediments, TOC) was examined using correlation analysis and Mantel's test (Rohlf 1993). A Spearman correlation matrix was generated between biological variables (total invertebrate density, taxonomic richness and densities of dominant invertebrates) and physical variables, and significant correlations were verified using scatter-plots. Mantel's test was used to calculate the correlation between the entire biological and physical data matrices. This test is useful to evaluate whether pairs of sites that appear similar according to the biological data set are also similar according to the physical data set.

Two-way analysis of variance (ANOVA, Sokal and Rohlf 1981) was used to compare total density and taxonomic richness among sites. This test can identify significant cross-river and upstream-downstream differences. The abundance data were log-transformed before statistical testing and results of analyses were considered significant at $P<0.05$.

In addition to the above quantitative methods, the benthic invertebrate abundance data were also examined qualitatively to identify potential habitat associations and relationships between sediment characteristics (texture, chemistry, toxicity) and community structure.

2.2.6 Quality Assurance and Quality Control

Benthic invertebrate samples were collected according to Golder Technical Procedure 8.6-1 (Appendix IV). Laboratory analysis of benthic invertebrate samples incorporated a QA/QC program, consisting of an evaluation of invertebrate removal efficiency in 10% of the samples (two individual replicate samples and one composite sample). Minimum removal efficiency of 95% was considered acceptable.

Quality control results are presented in Appendix VIII and indicate that the data quality objective of minimum 95% removal of invertebrates from the sorted fractions of samples was achieved in two of the samples. Only 93% removal efficiency was documented in the remaining sample. However, because only three additional invertebrates were recovered from the sorted fraction of the sample, data quality was considered acceptable.

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. All 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.

2.3 FISH POPULATIONS

2.3.1 Approach

The approach for the fish population component of the monitoring program consisted of:

- fisheries inventories for selected reaches in the Athabasca River and two Athabasca River tributaries (i.e., Muskeg and Steepbank rivers);
- habitat mapping and recording fish habitat associations for the Athabasca River reaches; and
- a radiotelemetry study of two fish species in the Athabasca River.

2.3.1.1 Athabasca River

Sampling reaches, both upstream (i.e., a reference area) and within the oil sands region, were selected for the spring component of the studies.

Sampling Areas Within the Oil Sands Region

Reaches in the oil sands region were selected in the areas previously surveyed for the Steepbank and Aurora mines (Golder 1996a, 1996b). Three sampling areas were identified based on habitat characteristics, proximity to oil sands leases as well as existing and proposed discharges (Golder 1997b) (Figure 2.4). An additional area (i.e., Poplar Creek Area) above these sites was also identified and sampled in the summer and fall seasons, as discharges could potentially be released by future developments in this area.

The 1997 fisheries component of the RAMP focused on addressing cumulative effects issues that were identified during previous baseline studies and EIAs (Golder 1996a, 1996b, BOVAR 1996) including:

- monitoring of fish species composition and abundance within specific habitats to detect changes in community structure;
- monitoring of habitat quality for the selected reaches to detect changes in use by different life stages of fish;
- investigation of seasonal movements of fish to determine the residence time of different species in areas of exposure to oil sands-related discharges; and
- enhancing baseline information on fish population parameters (eg., increased sample size for age distribution.

Reference Area

The use of a reference area is important to allow for appropriate interpretation of fisheries data. Reaches upstream of all oil sands developments were investigated in the spring field program. Three reaches above Fort McMurray and two reaches below Fort McMurray were surveyed (Figure 2.4). Their utility as reference areas was evaluated.

2.3.1.2 Muskeg and Steepbank Rivers

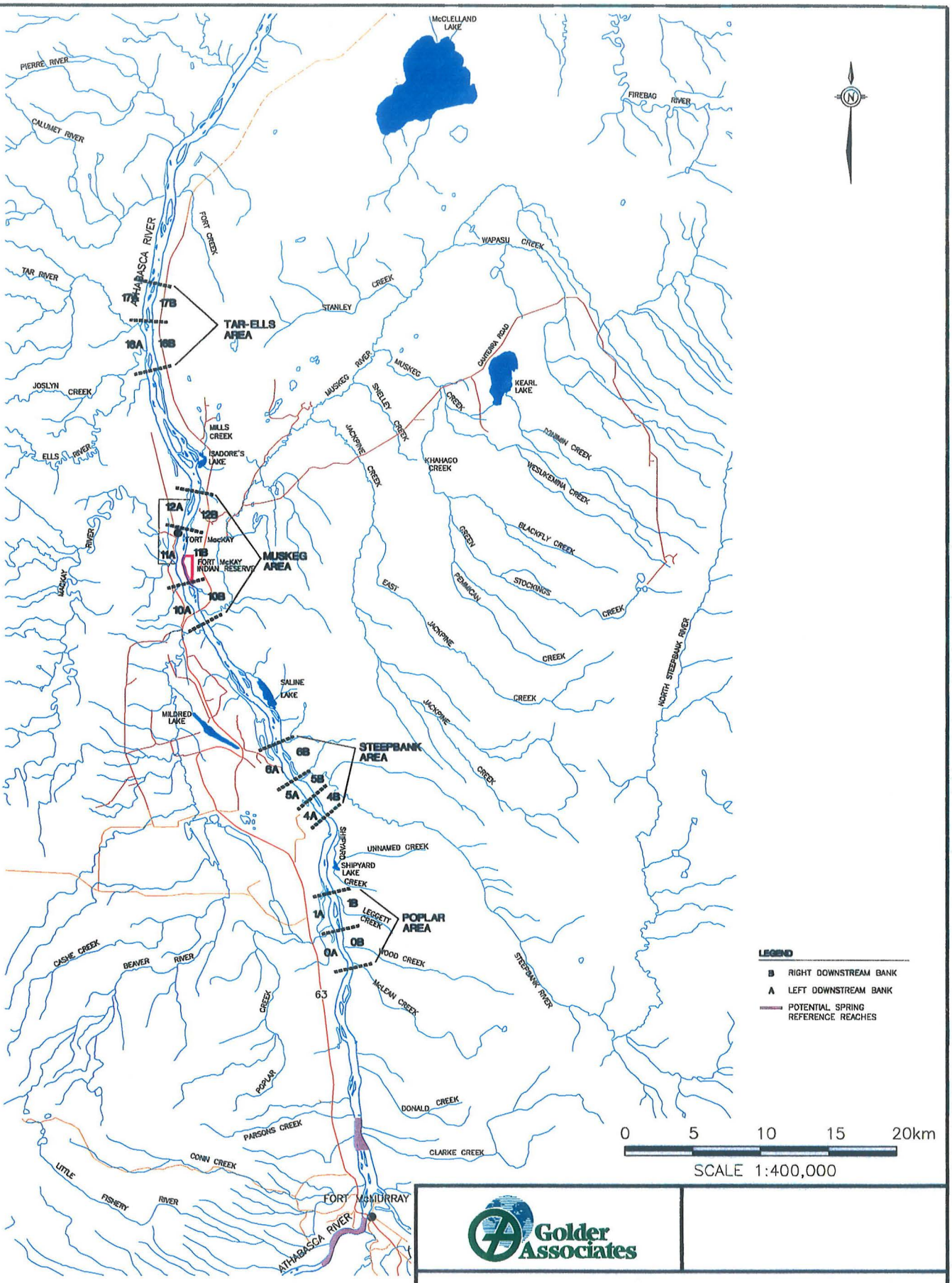
Fish communities within the Muskeg and Steepbank rivers could potentially be affected by oil sands developments due to potential changes in water quality and flow. Fisheries surveys were conducted in the summer, since this time period is most likely to represent the longest period of residence for fish species that enter these rivers to spawn (e.g., Arctic grayling, longnose sucker). In addition, both adult and young-of-the-year fish are present during mid-summer. Summer residents begin to migrate out of these rivers during August (Golder 1996a).

The sampling reaches were selected from the lower portion of the rivers so that combined effects of upstream development could be examined. However, the sampling reach on each river was located far enough upstream so that seasonal residents of the Steepbank and Muskeg rivers were sampled rather than Athabassca River fish.

Reference Areas

Potential reference rivers for the Muskeg and Steepbank rivers include the Tar, Ells and Firebag rivers. Habitat characteristics, fish populations and relative access to these rivers, as detailed in the literature, were examined to determine their suitability as reference areas. No sampling was performed at these rivers during the first year of the RAMP.

The MacKay River was first identified as a possible reference site; however, possible future projects within this watershed would make it inappropriate as such. Syncrude personnel conducted fisheries inventories of the MacKay River in summer 1997. Data generated by the Syncrude surveys were included in this report.



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REFERENCE

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

Golder Associates

RAMP FISHERIES MONITORING REACHES

23 MAR 98	FIGURE 2.4	DRAWN BY: CG/DC

2.3.2 Fish Inventory

2.3.2.1 Sampling Areas

Athabasca River

The location of each sampling reach on the Athabasca River is shown on Figure 2.4. Four main areas within the oil sands region were selected for sampling. These 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 Steepbank River Area (Reaches 4, 5 and 6), the Muskeg River Area (Reaches 10, 11 and 12), the Tar-Ells River Area (Reaches 16 and 17) and the Poplar Creek Area (Reaches 0 and 1). Sampling in Reaches 4 to 17 was conducted on a seasonal basis during the open-water season and included the following periods: spring (May 2 to 13), summer (July 26 to 30) and fall (October 2 to 15). Surveys for reaches 0 and 1 were conducted in the summer and fall at the same time as other reaches in the Athabasca River.

Muskeg and Steepbank Rivers

The study reach on the Steepbank River was selected based on habitat maps and results of the 1995 baseline studies (Golder 1996a). The reach provides diverse habitat with riffles, pools and low to high quality runs. Fish surveys were conducted in the summer (July 20).

The reach selected on the Muskeg River was located in the area where a fish fence was located in 1995 (Golder 1996a) (Figure 1.1; Table 2.4) since this area is easily accessible and provides diverse habitat. Sampling was conducted from July 20 to 21.

2.3.2.2 Methods

Sampling reaches and methods used in each section are listed in Table 2.4. The upper and lower extent of the sampling reaches on the Muskeg and Steepbank rivers were designated by physical landmarks where possible and referenced using a Trimble GeoExplorer model GPS so that the same reach can be sampled every year. All reaches on the Athabasca River were also GPS referenced. GPS data were differentially corrected and are presented in Table 2.4.

Fish inventory sampling was conducted following Golder Technical Procedure 8.1-3 (Appendix V) during the spring, summer and fall surveys. All fish in the 1997 RAMP inventory surveys of the Athabasca River were captured using a Smith-Root model SR18 electrofishing boatSampling for large fish species in the Muskeg and Steepbank rivers was primarily done with an inflatable boat equipped with a portable Smith-Root Model 5.0 GPP boat electrofishing unit. A fish permit (# 97-404) was issued by AEP to Syncrude personnel for all fisheries inventories.

Table 2.4 Summary of Fish Inventory Methods for RAMP 1997

STATION ID	WATERCOURSE	REACH DIFFERENTIALLY CORRECTED UTMs	DESCRIPTION	SEASON SAMPLED	INVENTORY METHOD
ATR-F-0A	ATHABASCA RIVER	474243E/6305989N - 473380E/6308275N	Opposite bank of tip of island to opposite McClean Creek	U	EF
ATR-F-0B	ATHABASCA RIVER	474670E/6305866N - 473911E/6308221N	A1 habitat just U/S of Mclean Creek to tip of island at beginning of Reach 1B	U, F	EF
ATR-F-01A	ATHABASCA RIVER	473402E/6308170N - **473073E/6310592N**	Tip of island to tip of Inglis Island	U, F	EF
ATR-F-01B	ATHABASCA RIVER	474670E/6305866N - 473529E/6310977N	Tip of island to mouth D/S of Leggett Creek	U	EF
ATR-F-04A	ATHABASCA RIVER	472848E/6316544N- 471436E/6318335N	LDB from first limestone pile opposite cabin opposite Suncor to LDB behind unnamed island below Suncor Bridge	P, U	EF
ATR-F-04B	ATHABASCA RIVER	473176E/6316814N - 471760E/6318696N	From Trapper's cabin U/S of Suncor Bridge to D/S of unnamed island	P, U, F	EF
ATR-F-05A	ATHABASCA RIVER	471436E/6318335N- 469596E/6320548N	RDB opposite D/S end of unnamed island below Suncor Bridge to RDB Syncrude dock and pumphouse	P, U, F	EF
ATR-F-05B	ATHABASCA RIVER	471760E/6318696N - 470068E/6320757N	RDB opposite unnamed island below Suncor Bridge to RDB opposite Syncrude Pumphouse and dock	P, U, F	EF
ATR-F-06A	ATHABASCA RIVER	469596E/6320548N-No Coordinates for end	RDB opposite Syncrude Pumphouse and dock to RDB to first island below Syncrude Sewage Outfall	P, U, F	EF
ATR-F-06B	ATHABASCA RIVER	470068E/6320757N - 469416E/6323065N	End of Reach 6B	U, F	EF
ATR-F-10A	ATHABASCA RIVER	463821E/6330612N - 462503E/6334330N	LDB from Beaver Creek confluence to LDB to opposite D/S end of Alexander Island	P, U, F	EF
ATR-F-10B	ATHABASCA RIVER	464104E/6331129N- 462607E/6334425N	RDB opposite Beaver Creek confluence to RDB behind D/S end of Alexander Island	P, U, F	EF
ATR-F-11A	ATHABASCA RIVER	462503E/6334330N - 462275E/6338118N	LDB opposite Alexander Island to LDB at top of Height Island	P, U, F	EF
ATR-F-11B	ATHABASCA RIVER	462607E/6334425N - 462357E/6338248N	From D/S end of Alexander Island to D/S of island opposite Fort McKay	P, U, F	EF
ATR-F-12A	ATHABASCA RIVER	462051E/6338237N-	End of Reach 11A	U, F	EF
ATR-F-12B	ATHABASCA RIVER	462357E/6338248N - 463284E/6341263N	From D/S of island opposite Fort McKay to D/S of Height Island	P, U, F	EF

KEY

SEASON
P = Spring
U = Summer
F = Fall

FISH INVENTORY METHODS
BP = Backpack Electrofisher
EF = Boat Electrofisher
GN = Gill Net
KS = Kick Sampling
MT = Minnow Trap
PE = Post-Emergent Fry Drift Trap
SN = Beach Seine
SL = Set Line

BENTHIC INVERTEBRATE SAMPLING METHODS
AS = Artificial Substrates
NC = Neill Cylinder
EG = Ekman Grab
KS = Kicknet Sample (for tissue analysis)

SAMPLING METHODS
SW = Surface Water Sample
CM = Composite Sample

ABBREVIATIONS
U/S = Upstream
D/S = Downstream
RDB = Right downstream bank
LDB = Left downstream bank
N/A - Not available

OTHER
UTM's in bold indicate uncorrected waypoint

Table 2.4 Summary of Fish Inventory Methods for RAMP 1997

STATION ID	WATERCOURSE	REACH DIFFERENTIALLY CORRECTED UTMs	DESCRIPTION	SEASON SAMPLED	INVENTORY METHOD
ATR-F-16A	ATHABASCA RIVER	459298E/6351019N - 459008E/6353899N	From small island U/S of Ells River to 100m D/S of Tar River	P, U, F	EF
ATR-F-16B	ATHABASCA RIVER	**459827E/6353379N** - 459767E/6353583N	Opposite bank of Tar River to tip of McDermott Island	U	EF
ATR-F-17A	ATHABASCA RIVER	459008E/6353899N - 459445E/6356263N	From 100m D/S of Tar River to bottom of McDermott Island	P, F	EF
ATR-F-17B	ATHABASCA RIVER	459767E/6353583N-	Southern tip of Daphne Island	U	EF
ATR-F-R01	ATHABASCA RIVER	467673E/6281275N - 469023E/6282131N	From Mountain Rapids D/S for 1km	P	EF
ATR-F-R02	ATHABASCA RIVER	473564E/6285590N - **474478E/6285776N**		P	EF
ATR-F-R03	ATHABASCA RIVER	**475947E/6285844N** - **475927E/6287366N**		P	EF
ATR-F-R04	ATHABASCA RIVER	475141E/6291516N - 474859E/6292801N		P	EF
ATR-F-R05	ATHABASCA RIVER	**475447E/6292812N** - **475285E/6294323N**	Mouth of Clark Creek	P	EF
MCR-F-1	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-2	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-3	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-4	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-5	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-6	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-7	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-8	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-9	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-10/11	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-11/12	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-13/14	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-15	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-16	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-17/18/1	MACKAY RIVER	N/A	MacKay River	U	EF
MCR-F-20/21	MACKAY RIVER	N/A	MacKay River	U	EF
MUR-F-1	MUSKEG RIVER	466047E/ 6339452N- 465392E/ 6338203N	Muskeg River fish fence	U	EF
STR-F-1	STEEPBANK RIVER	N/A	Upstream of mouth of Steepbank River	U	EF

Gee minnow traps were used to sample for smaller forage fish species in the Muskeg River. For all sampling techniques, catch-per-unit-effort (CPUE) data (number of fish/unit of sampling effort) were calculated to determine the relative abundance of fish species captured.

All captured fish were identified to species following the coding system recommended by Mackay et al. (1990), enumerated and recorded. Species codes, common and scientific names are presented in Table 2.5. Fork length and weight were measured for large fish species. Fish were also examined for external pathology according to Golder Technical Procedure 8.1-3 (Appendix V). Non-lethal aging structures were taken according to the recommendations in Mackay et al. (1990). In addition, if discernible by external examination, sex and state of maturity of individual fish were recorded. Fish population data were recorded in field logbooks and on RAMP catch and sample record forms.

Table 2.5 Fish Species Common and Scientific Names and Codes

Species Common Name	Scientific Name	Code
Arctic Grayling	*Thymallus arcticus*	ARGR
Brook Stickleback	*Culaea inconstans*	BRST
Bull Trout	*Salvelinus confluentus*	BLTR
Burbot	*Lota lota*	BURB
Cisco	*Coregonus artedii*	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	*Cotus 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

2.3.2.3 Data Analysis

All fish data collected during each survey were entered into a database using Microsoft Excel software. Statistical analyses and frequencies were done using Microsoft Excel software. CPUE values for each capture method (boat electrofishing and backpack electrofishing) were calculated for each species, from each section or reach, to determine relative abundance and enable, where possible, comparisons of 1997 catch results to previous studies. A paired T-test was used to compare CPUE values for the Steepbank River. The results were considered significant at $P<0.05$.

2.3.3 Habitat Evaluation and Fish-Habitat Associations

2.3.3.1 Approach

Fish habitat in the Athabasca River near oil sands operations was mapped in 1995 and 1996 from Willow Island downstream to Joslyn Creek (Golder 1996a, 1996b). Habitat maps were updated during the RAMP summer and fall sampling periods for the fisheries reaches inventoried in 1997.

In addition to mapping the type of habitat encountered, fish species utilization of each habitat type was recorded during fish sampling events in summer and fall 1997. Habitat use by specific fish species and life stages is compared to habitat availability in the study area.

2.3.3.2 Methods

All habitat mapping was conducted following the procedures set out in Golder Technical Procedure 8.5-1 (Appendix VI). 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 pool, riffles and runs. This classification system consists of three components: channel type, bank habitat type, and special habitat features.

The location and extent of each habitat unit was delineated on habitat base maps of the study area. These base maps were prepared from 1:50,000 topographic maps and aerial photographs of the Athabasca River. In 1997, portions of the Athabasca River were re-examined using the existing habitat maps and any changes in habitat types, either natural or man-made, were recorded. Habitat data were summarized according to Golder Technical Procedure 8.5-1 (Appendix VI).

2.3.4 Radiotelemetry Study

2.3.4.1 Approach

Data gaps concerning fish movements and residence time in the oil sands region as well as areas used for spawning and overwintering of fish species have been identified. A radiotelemetry study was initiated in fall 1997 to address these issues.

Two fish species were chosen for the initial phase of this study: walleye and lake whitefish. Transmitters were implanted in 18 walleye and 18 lake whitefish.

2.3.4.2 Fish Sampling and Tagging Procedures

Walleye and lake whitefish to be implanted with radio tags were captured during the fall fisheries inventory (October 2 to 15). The location, as well as the number of fish by species, released in the RAMP study area is shown in Figure 2.5. During sampling efforts, all walleye and lake whitefish weighing more than 675 g were retained. These fish were first placed in a small holding pen in the river for recuperation from the electrofishing. Selected fish were tagged on the day they were captured and were released at the end of the reach from which they originated.

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. All tagging equipment was arranged on a portable table and surgical equipment was placed in a disinfectant bath followed by a distilled water rinse.

Individual fish were placed in an anesthetic 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.

The surgical implantation technique was modified from Bidgood (1980) and Knecht et al. (1981). A 3 to 4 cm longitudinal, abdominal incision was made about 1 to 2 cm from the mid-ventral line, anterior to the pelvic fins. A large diameter (16 gauge) hypodermic needle was inserted through the skin about 2 cm posterior to the incision, into the abdominal cavity and out of the incision. Care was taken not to damage the 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

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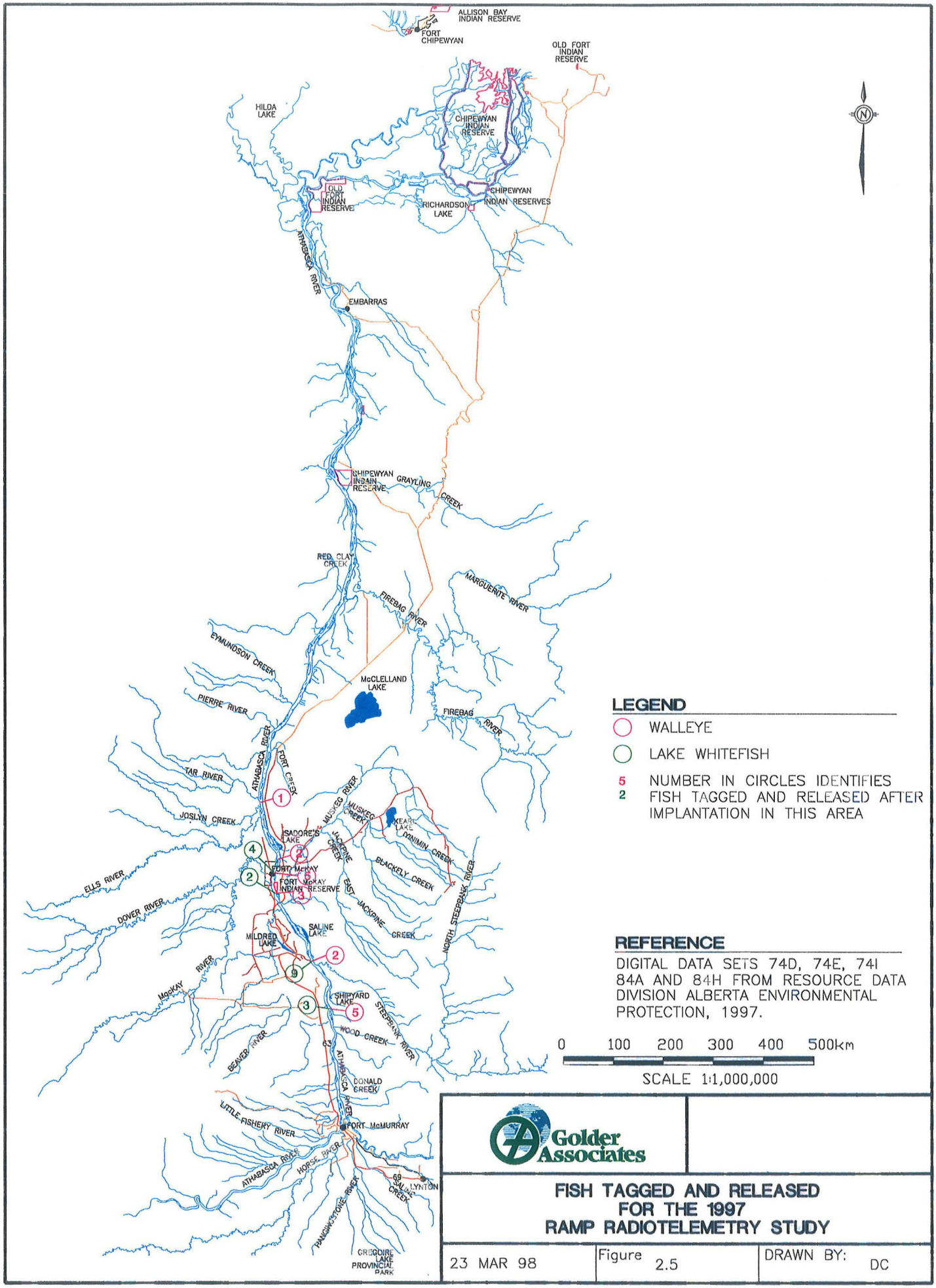


Golder Associates

FISH TAGGED AND RELEASED FOR THE 1997 RAMP RADIOTELEMETRY STUDY

23 MAR 98	Figure 2.5	DRAWN BY: DC

infection. Three sutures were used to close the incision and the incision area was treated with a fungicide (Methyl Blue). A liquid tissue adhesive was applied over the incision to seal it.

Following surgery the fish was returned to an isolated section of the flow-through live well in the boat and held for recovery. The fish was released after it was determined that it could swim strongly with no 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.

2.3.4.3 Radiotelemetry Equipment

Conventional pulsed radio transmitters (model MBFT-6), weighing 10.1 g (weight in air) were used for the study. They were supplied by Lotek Engineering Inc. The transmitters emit frequencies in the 150 MHz range, at a pulse rate of 60 beats per minute. They emit on an approximate 12 hours on/12 hours off per day cycle and have an average life expectancy of approximately 423 days.

A Telonics TR-2 receiver was used to locate the transmitter signals during ground and aerial surveys. One of the radio transmitters was not implanted into any fish and was set aside as a reference transmitter. It was turned on during the fall field program and was left running to mimic the activity of the implanted transmitters and to act as a check on the battery life. This reference transmitter was also used to test the telemetry equipment after it was set up in the aircraft to ensure it was operational for each flight.

2.3.4.4 Radiotelemetry Surveys

Fish locations were monitored and recorded approximately every week from a fixed-wing aircraft from October to December 1997. The aircraft flew from above the Mountain Rapids, situated above Fort McMurray, to the Peace-Athabasca Delta.

Nine aerial radiotelemetry surveys were conducted on the following dates: October 7, 21 and 28, November 4, 12 and 27, and December 5, 15 and 22. During each flight, the frequency and location of each transmitter that was located was recorded on navigation maps. As the most successful flights (i.e., when the largest number of fish were located) were early in the day, flights were scheduled as early as daylight permitted.

Fish were monitored from the time they were implanted with the transmitters until late December. Most of the fish appeared to move to Lake Athabasca; however two walleye were last monitored at the mouth of the MacKay River. One or two flights are expected to take place over the winter to verify the position of these fish. Regular monitoring will resume

in the spring and is expected to continue until fall 1998 since the transmitter batteries should retain power until then.

2.3.5 Quality Assurance and Quality Control

All samples were collected following Golder Technical Procedure 8.3-1 (Appendix V) and Golder Technical Procedure 8.5-1 (Appendix VI). Data files were checked and verified against the original field data. The fisheries and habitat associations data were entered into files by Syncrude personnel. A subsection (about 10%) of the data entered was verified by Golder personnel.

Fish aging structures were cleaned and prepared by two qualified fisheries technicians. Ages were read independently by both technicians as a measure of QA/QC. A second reading was performed when results diverged between these two people.

2.4 AQUATIC VEGETATION

2.4.1 Approach

The wetlands survey was conducted on Shipyard Lake, Lease 25 Wetlands (reference area), Isadores Lake and Kearl Lake. The objective of the wetlands survey was to document baseline conditions as a reference point for future monitoring. To document existing conditions each wetlands 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.

2.4.2 Wetlands Classification Systems

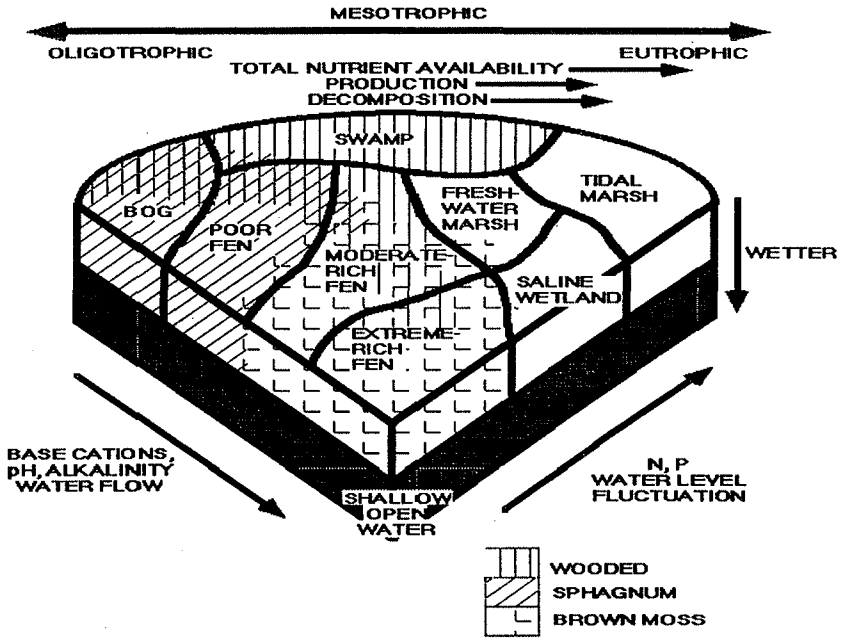
The National Wetlands Working Group (NWWG 1988) defined wetlands as:

"land that is saturated with water long enough to promote wetland or aquatic processes as indicated by hydric soil, hydrophytic vegetation, and various kinds of biological activity which are adapted to the wet environment".

This definition has been adopted in the Alberta Environment Protection Draft Wetland Policy (AEP 1997). In addition, wetlands in the province are classified according to the Alberta Wetland Inventory (AWI) as detailed by Halsey and Vitt (1996).

According to this classification system, wetlands are divided into 5 general types: bogs, fens, marshes, swamps and shallow open water. These wetlands are further described based on a combinations of factors, which include water level, water chemistry, floristic composition, topographic location, geomorphic basin configuration and other variables. These factors combine to form chemical and biotic gradients, which provides a framework for classifing wetlands as presented in Figure 2.6 and Table 2.6 (Nicholsol and Gignac 1995). Bogs, for example, are oligotrophic, acidic, with no flowing water whereas fens are mesotrophic, neutral to alkaline, with flowing water.

Figure 2.6 Wetlands Classification Based on Chemical and Biotic Gradients



Source: Halsey and Vitt 1996, modified from Vitt 1994

Changes in the chemical or biotic gradients could potentially effect wetlands properties, which may effect how the wetland functions within an ecosystem. Table 2.6 provides a summary of the properties associated with each general wetlands types. A change in pH from alkaline to acidic, for example, could significantly alter the growing conditions for some plant species such as marsh marigold and some sedge species. As such, monitoring species composition within wetlands, for example, provides some indication if wetlands properties are being significanty altered. Baseline vegetation surveys, therefore, provides a reference for furture comparisons.

Table 2.6 Summary of General Wetland Types and their Properties

	Bogs	Fens	Marshes	Swamps	Shallow Open Water
Peat-forming	yes (*Sphagnum*)	yes (sedges, brown moss)	no	no	no
pH	strongly acidic	acidic to neutral	neutral to slightly alkaline	neutral to moderately acidic	variable
Water Level	at or near surface	at or near surface	fluctuates seasonally	at or near surface	intermittent or permanently flooded
Flowing Water	no	yes	yes	yes	yes
Nutrients	low	medium to high	high	high	variable
Minerals	low	medium to high	medium	medium	high
Dominant Vegetation	*Sphagnum*, ericaceous shrubs	sedges, grasses, reeds, brown moss	emergent sedges, grasses, rushes, reeds, submerged and floating aquatics	deciduous or coniferous trees or shrubs, herbs, some mosses	emergent vegetation

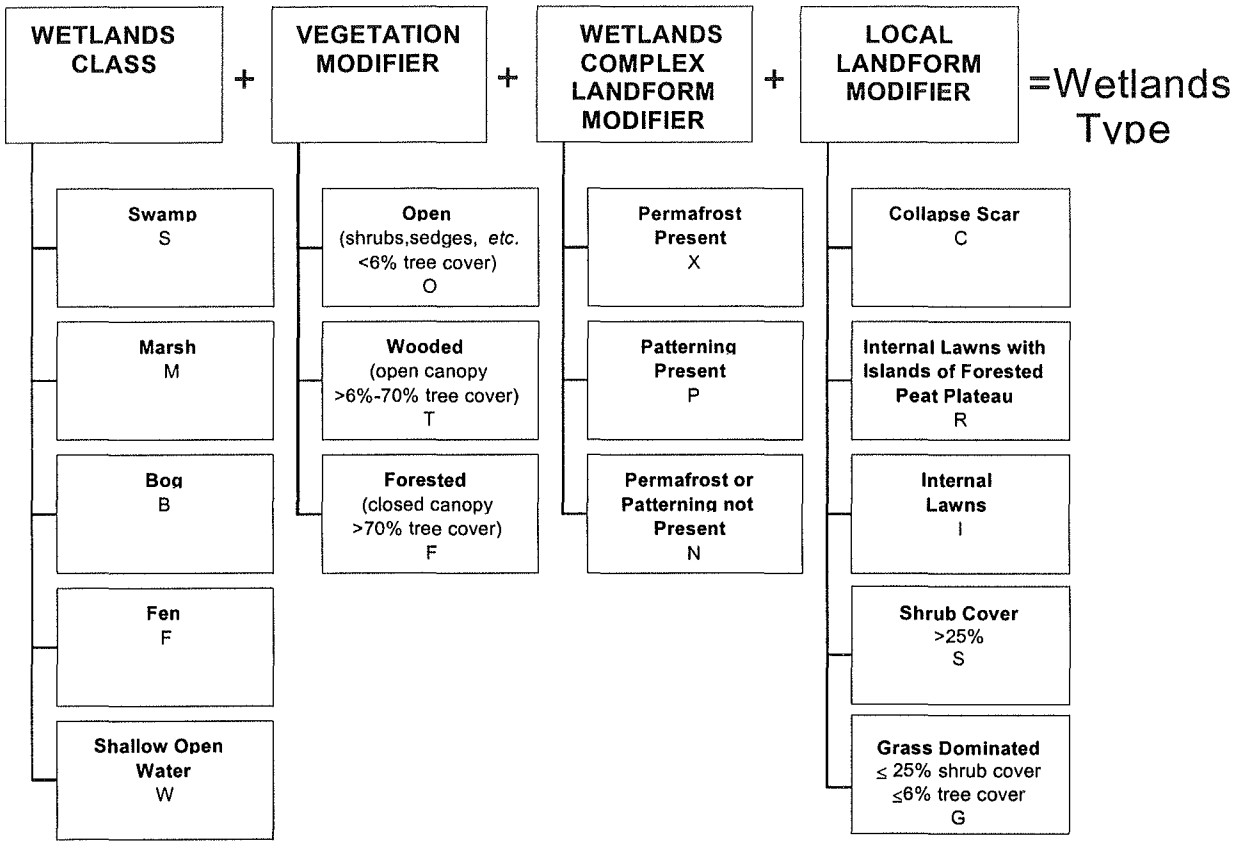
All of these wetlands properties are encorporated in the AWI classification. The classification contains four descriptive levels: the wetlands class, the vegetation modifier, the wetlands complex landform modifier, and the local landform modifier (Figure 2.7). Approximately 14 of all the possible combinations occur in Alberta. For example, a wetland type denoted as FONG, is characterized as a fen (F), that is open (O), without permafrost (N) with grasses dominant (G).

2.4.3 Field Investigation

Wetland types, according to the AWI, were prestratified (classified) on 1:10,000 and 1:20,000 black and white, aerial photographs prior to field investigations. All wetlands were surveyed from canoe. Vegetation was examined on 22 and 26 July 1997 to determine baseline conditions, refine prestratification and to act as a point of reference for future vegetation monitoring. Vegetation was documented by;

- mapping wetland classes on aerial photographs;
- photographing vegetation 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 (water depth, temperature, disolved oxygen percent, dissolved oxygen, conductivity, salinity, dissoved soilds, and pH,).

Figure 2.7 Flow Chart Representation of Wetlands Classification Process



Local Land Modifier without internal lawns = N

Source: Nesby 1997

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 bar, plots were marked with flagging tape. All sampling locations were marked on aerial photographs. Coordinates (UTM) obtained through Global Positioning System (GPS) were also recorded.

Vegetation surveyes were conducted on 1 x 1 meter plots. Percent cover was estimated for each cover class or layer, including open water, aquatic plants, herbs, grasses and shrubs. In addition, all species observed in each plot were recorded with a relative percent cover. Plant species were identified according to Moss (1986), Flora of Alberta.

Water quality parameters were measured at the begining of each transect using a Hydrolab Surveyer 4 and MiniSonde multiprobe. Water quality parameters measured included water depth (depth), temperature (temp), dissolved oxygen percent (DO %), dissolved oxygen (DO), conductivity (SPC), salinity (Sal), total dissolved solids (TDS) and pH.

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

2.4.4 Wetland Mapping

Wetlands were identified on 1:10,000 or 1:20,000 scale, black and white aerial photographs. The aerial photographs were prestratified according to the AWI classification.

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 orthophotgraphs, however, were available for Kearl Lake and Lease 25 Wetlands. In the absence of an orthophotograph, aerial photographs were scanned and polygons digitized. Areas of wetlands were estimated using an Autocad system.

3. RESULTS

3.1 SURFACE WATER, SEDIMENT AND POREWATER QUALITY

3.1.1 Surface Water Quality

Surface water quality of the oil sands area is unique in Alberta. Rivers and streams are frequently underlain by oil sands, which contribute varying amounts of naturally occurring hydrocarbons to surface waters. Small streams are largely fed by muskeg drainage water, which is reflected in their water chemistry. These influences are much less pronounced in the Athabasca River, which derives most of its flow from upstream sources.

In the sections that follow, water, sediment and porewater quality are described in the oil sands area. Selected parameters are shown in Tables 3.1 to 3.7. Complete water and sediment quality data sets are provided in Appendix VII.

3.1.1.1 Athabasca River

Point Source Inputs

Major point sources of wastewaters discharged to the Athabasca River upstream of the oil sands area were identified by Hamilton et al. (1985), Noton and Shaw (1989) and Noton and Saffran (1995) as effluents from five pulp mills and sewage from five communities. Effects of these inputs are most pronounced during the winter low-flow period when the river's dilution capacity is the lowest. The type and severity of these effects were described in detail by these authors. In general, the effects of upstream point sources were not found to extend into the oil sands reach of the Athabasca River, because of the high dilution capacity of the river.

Within the oil sands area, the Athabasca River receives mine drainage waters, refinery wastewater, treated sewage and dike seepage water from Suncor and treated sewage and mine runoff from Syncrude. The effects of these discharges on water quality were not discernible during any of the above three large-scale investigations of water quality, or subsequent baseline studies. Smaller-scale surveys by Syncrude and Suncor documented localized effects in the immediate vicinity of the Suncor plant, recorded as increases in the concentrations of dissolved solids, TOC, oil and grease, total phenolics, ammonia and odour (McCart et al. 1977, Noton and Anderson 1982). These increases were minor in most cases and were restricted to single sites, or were inconsistent among sampling times. Only odour was consistently elevated for some distance downstream.

Summary of the Existing Information

Water quality of the lower Athabasca River has been monitored extensively by AEP since the 1970s. Data were summarized in three AEP reports (Hamilton et al. 1985, Noton and Shaw 1989, Noton and Saffran 1995) and are available from NAQUADAT. Recent surveys during baseline studies for the Steepbank and Aurora Mine EIAs (Golder 1996a), RAMP and 1997 baseline studies for the Muskeg River Mine Project (Golder 1998) generated additional information. To provide an overview of water quality in the lower Athabasca River, the data gathered from these sources were summarized for the following four areas (Figure 2.1):

- upstream of Fort McMurray, near the southern limit of the oil sands area;
- near the mouth of Donald Creek, between Fort McMurray and existing oil sands operations;
- near Saline Lake and just upstream of the Muskeg River, below existing oil sands operations; and
- downstream from Fort Creek, below all existing and proposed oil sands operations.

Water quality of the lower Athabasca River has not changed measurably over the last two decades. It is characterized by a typical pH range of 7 to 8 and moderate levels of dissolved salts (total dissolved solids), hardness and alkalinity (Table 3.1). Spring and summer high flows usually cause a large increase in suspended sediment load during these seasons, which is reflected in elevated concentrations of nutrients (e.g., total phosphorus) and a number of metals measured as totals (e.g., aluminum, iron, manganese). Total alkalinity, total dissolved solids and total hardness are typically highest in the winter, reflecting seasonal changes in hydrology. Nutrient levels are indicative of moderate enrichment, largely from natural sources (Chambers 1996). Levels of dissolved metals, PAHs and naturally occurring hydrocarbons are generally low.

Microtox® tests have not provided evidence of toxicity in river water. Although not explicit in Table 3.1, results of 1997 monitoring were consistent with previous data for the lower Athabasca River. Recent toxicity studies conducted under PERD also documented detectable but low levels of trace organic compounds (PAHs and chlorophenolic compounds) in Athabasca River water and found low or no acute or chronic toxicity to a variety of test organisms (Brownlee 1990, Dutka et al. 1990, 1991, McInnis et al. 1992, 1994, Xu et al. 1992, Brownlee et al. 1993, Golder 1996a).

Table 3.1 Water Quality of the Lower Athabasca River (1976-1997)

Parameter	Units	Upstream Fort McMurray				Near Donald Creek			Below Existing Oil Sands Operations			Below Fort Creek			
		Winter	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Conventional Parameters and Nutrients															
pH	-	7.88	8.01	7.98	7.90	7.81 - 8.10	7.63	7.82-8.00	7.94	7.63 - 8.00	-	7.92	8.20	7.95	8.30
Total Alkalinity	mg/L	169	102	98	110	76 - 97	88	92-95	104	90 - 94	-	144	99	90	104
Total Dissolved Solids	mg/L	243	159	144	158	140 - 141	120	146-200	146 - 240	123 - 158	-	-	46	182	140-160
Total Suspended Solids	mg/L	2	82	127	19	19 - 181	624	4-57	30 - 190	624 - 676	-	3	215	266	36
Total Hardness	mg/L	190	114	105	124	111	114	100-104	121	101 - 118	-	158	103	92	105.7
Dissolved Organic Carbon	mg/L	8.0	10.0	8.0	8.0	7.1 - 11.0	16.7	9.0-9.2	7.6	13.0 - 16.1	-	6.8	11.0	12.7	8.8
Total Kjeldahl Nitrogen	mg/L	0.54	0.87	0.81	0.62	1.20	-	-	-	0.20	-	0.33	1.20	1.01	0.50
Total Ammonia	mg/L	0.03	0.02	0.01	0.01	<0.01 - <0.05	0.04	<0.01-<0.05	<0.01	0.04 - <0.05	-	0.06	0.05	0.03	<0.05
Total Phosphorus	mg/L	0.022	0.110	0.128	0.033	0.140 - 0.144	0.390	0.084-0.087	0.120	0.298 - 0.440	0.080	0.029	0.082	0.290	0.058
Dissolved Phosphorus	mg/L	0.012	0.013	0.013	0.007	0.020	-	0.022	-	0.019	0.010	0.020	0.015	0.018	0.013
Metals (Total)															
Aluminum (Al)	mg/L	0.055	0.844	0.908	0.23	0.17 - 5.18	8.64	0.11-2.23	0.15 - 4.05	10.1 - 14.1	3.89	0.0155	3.66	6.13	2.38
Arsenic (As)	mg/L	0.0004	0.0012	0.0012	0.001	0.0006 - 0.002	0.007	0.0005-0.0013	0.0008 - 0.0017	0.0057 - 0.007	0.0015	0.0004	0.0011	0.0045	0.0008
Cadmium (Cd)	mg/L	0.001	0.001	<0.001	<0.001	<0.0002 - <0.003	<0.003	<0.002-<0.003	<0.0002 - <0.003	0.0002 - <0.003	<0.0002	0.001	<0.001	0.001	0.001
Chromium (Cr)	mg/L	0.003	0.0045	0.004	0.0025	<0.002 - 0.0051	0.003	<0.002-0.0026	<0.002 - 0.0051	<0.002 - 0.0197	0.0043	0.0025	0.005	0.00995	0.003
Copper (Cu)	mg/L	0.001	0.004	0.005	0.0015	<0.001 - 0.007	-	0.049	0.004 - 0.0061	0.0181	0.0041	0.0015	0.002	0.008	0.002
Iron (Fe)	mg/L	0.17	3.21	3.12	0.35	0.43 - 5.24	17.90	0.91-2.19	0.43 - 3.76	17.60 - 19.40	2.98	0.46	5.04	16.10	2.41
Manganese (Mn)	mg/L	-	-	-	-	0.040 - 0.106	0.509	0.033-0.071	0.044 - 0.101	0.408 - 0.534	0.074	-	0.120	-	0.075
Mercury (Hg)	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0002 - <0.05	<0.05	<0.0001-<0.05	<0.0002 - <0.05	<0.0001 - <0.05	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Vanadium (V)	mg/L	<0.002	0.002	0.005	-	<0.002 - 0.013	0.009	<0.0001	0.004 - 0.011	0.015 - 0.038	0.010	<0.002	0.009	0.023	0.006
Zinc (Zn)	mg/L	0.007	0.015	0.013	0.007	-	-	0.014	-	-	0.034	-	-	-	0.005
Metals (Dissolved)															
Aluminum (Al)	mg/L	0.010	0.068	<0.002-0.020	0.020	0.241	0.016	0.044	0.057	0.050	0.073	-	0.415	0.026	0.036
Arsenic (As)	mg/L	0.0005	0.0009	0.0009	0.0006	0.001	<0.0004	0.0005	0.0006	0.0006	0.0006	-	0.0012	0.0005	0.0005
Cadmium (Cd)	mg/L	<0.001	<0.001-0.006	<0.001	-	<0.0001	0.0028	0.0001	<0.0001	0.0002	0.0001	-	0.0001	0.0002	0.0001
Chromium (Cr)	mg/L	0.003	0.003	0.003	0.003	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	-	0.0007	<0.0004	<0.0004
Copper (Cu)	mg/L	<0.001	<0.001-0.003	0.002	-	0.0043	0.0022	0.0022	0.0024	0.006	0.0042	-	0.0049	0.003	0.002
Iron (Fe)	mg/L	0.11	0.1	0.07	0.12	1.14	0.1	0.14	0.32	0.08	<0.01	-	1.93	0.43	0.14
Manganese (Mn)	mg/L	-	-	-	-	0.074	0.003	0.011	0.024	0.001	0.010	-	0.092	0.025	0.013
Mercury (Hg)	mg/L	-	-	-	-	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	-	<0.0002	<0.0002	<0.0002
Vanadium (V)	mg/L	<0.001	<0.001-<0.002	<0.001	-	0.0012	<0.0001	<0.0001	0.0002	<0.0001	0.0002	-	0.002	0.0001	<0.0001
Zinc (Zn)	mg/L	0.002	<0.001	<0.001	-	-	0.038	0.014	0.006	0.027	0.023	-	0.015	0.016	0.019
Organics															
Naphthenic Acids	mg/L	-	-	-	-	<1 - 2	<1	<1	<1	<1	ND	-	1	-	-
Recoverable Hydrocarbons	mg/L	-	-	-	-	<0.5 - <1	1	<1	<0.5 - <1	<0.5 - <1	-	-	<0.5	-	-
PAHs and Alkylated PAHs	µg/L	-	-	-	-	ND	ND	ND	ND - 0.03	ND	-	-	-	-	-
Target PANHs	µg/L	-	-	-	-	ND	ND	ND	ND	ND	-	-	-	-	-
Phenolics	µg/L	-	-	-	-	ND	ND	-	ND	ND	-	-	-	-	-
Volatile organics	µg/L	-	-	-	-	ND	-	-	ND	-	-	-	-	-	-
Toxicity															
Microtox IC50	%	-	-	-	-	100	100	>100	91 - 100	100	-	-	-	-	-
Microtox IC25	%	-	-	-	-	100	100	>100	91 - 100	100	-	-	-	-	-

NOTES: - = No data; ND = Not detected; PAH = Polycyclic aromatic hydrocarbon; PANH = Polycyclic aromatic nitrogen heterocycle
Median concentrations (n>2), ranges (n=2), or measured concentrations (n=1) are presented

3.1.1.2 Muskeg River

The Muskeg River is characterized by clear water in all seasons (i.e., low total suspended solids levels), low to moderate dissolved salt concentrations, moderate nutrient levels and pH ranging between 7 and 8 (Table 3.2). This river drains areas with substantial muskeg cover, which is reflected in elevated dissolved organic carbon levels. Concentrations of total metals are near the detection limits with the exception of slightly elevated levels of iron, manganese, silicon and strontium. Naturally occurring hydrocarbons and naphthenic acids are occasionally detectable, but at very low levels. Trace organic compounds were not detected at the mouth of the river in 1997 and river water was not toxic to bacteria (Microtox® test). Seasonal variation in water quality is limited, with only minor increases in levels of certain ions in winter and lower dissolved organic carbon concentration during spring snowmelt. Longitudinal trends are not apparent in the available data set.

3.1.1.3 Steepbank River

Water quality of the Steepbank River is similar to that in the Muskeg River. It is also characterized by relatively clear water in all seasons except during spring when total suspended sediments are elevated (Table 3.3). Dissolved salt concentrations are low to moderate and pH ranges between 7 and 8. Nutrient levels are moderate and slightly higher than in the Muskeg River. Dissolved organic carbon levels are high, reflecting inputs of muskeg drainage water. Concentrations of total metals are near the detection limits with the exception of slightly elevated levels of aluminum, boron, iron, silicon, strontium and zinc, which is typical of rivers in the oil sands area (Golder 1996a). Naturally occurring hydrocarbons and naphthenic acids are occasionally detectable, but at very low levels. Trace organic compounds were not detected. River water was not toxic to bacteria in samples collected in fall 1995 (Microtox® test).

3.1.1.4 Inter-laboratory Comparisons for Naphthenic Acids Analysis

Differences between naphthenic acids concentrations reported by ETL and Syncrude were generally within acceptable limits (Table 3.4). The largest differences were reported in samples from the Southwest Drainage Ditch (7 versus 17.4 mg/L) and from Pond 5 East (65 versus 90 mg/L). Differences between ETL and Syncrude results tended to increase as naphthenic acid levels increased, though this trend was not entirely consistent. Analyses of triplicate samples yielded very similar results for both laboratories.

Based on results for the two samples that were submitted preserved and unpreserved to each laboratory, preservation does not appear to result in a consistent bias at Syncrude. The single set of results reported by ETL showed a relatively large difference between preserved and unpreserved samples, with the higher concentration in the unpreserved sample.

Table 3.2 Water Quality of the Muskeg River (1972-1997)

Parameter	Units	At Mouth				Lower Muskeg River				Upper Muskeg River			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Conventional Parameters and Nutrients													
pH	-	7.50	7.70	8.01	8.00-9.20	7.40	7.50	7.80	7.72	7.43	7.50	7.62	7.65
Total Alkalinity	mg/L	257	113	148	153	259	101	170	136	301	128	196	171
Total Dissolved Solids	mg/L	331	143	202	184	303	138	195	162	327	135	211	23
Total Suspended Solids	mg/L	4	1	3	6	6	5	3	3	10	3	4	-
Total Hardness	mg/L	253	111	153	148	253	74	156	141	291	125	177	168
Dissolved Organic Carbon	mg/L	21.4	15.8	24.0	24.0	20.0	17.3	22.5	25.3	21.5	16.8	24.5	24.5
Total Kjeldahl Nitrogen	mg/L	1.11	0.60-0.76	1.05	0.70	1.30	0.86	1.04	0.90	1.50	0.81	1.04	0.85
Total Ammonia	mg/L	0.23	<0.03	0.04	0.05	0.59-1.63	<0.05	-	-	0.82	0.05	0.14	0.07
Total Phosphorus	mg/L	0.027	0.034	0.029	0.045	0.038	0.031	0.025	0.028	0.099	0.031	0.055	0.037
Dissolved Phosphorus	mg/L	0.008	<0.02	0.015	0.014	<0.02	0.60	-	-	-	-	-	-
Metals (Total)													
Aluminum (Al)	mg/L	0.01	0.01	0.05	0.06	0.04	0.07	0.05	0.04	0.03	0.03	0.04	0.02
Arsenic (As)	mg/L	0.0002	0.0003	<0.0004	0.001	<0.0004	<0.0004	<0.005	0.001-<0.005	0.0004	0.0004	0.0002	0.0005
Cadmium (Cd)	mg/L	0.001	<0.002	<0.001	0.003	<0.0002-0.001	<0.0002	-	-	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	mg/L	0.003	0.002	0.002	0.006	<0.0004-0.01	<0.0004	-	-	<0.001	0.001	0.001	0.001
Copper (Cu)	mg/L	0.001	0.001	0.004	0.001	0.002	0.0008	-	-	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	mg/L	1.37	0.56	0.84	1.14	2.42	0.79	-	-	6.2	1.06	2.71	1.17
Manganese (Mn)	mg/L	0.660	0.034	0.036	0.053	0.430-0.660	-	-	-	1.150	0.027	0.135	0.066
Mercury (Hg)	mg/L	0.0001	<0.0002	<0.0002	<0.05	0.0001	0.0001	<0.0001	0.0001	0.0001	0.0001	<0.0001	0.0001
Vanadium (V)	mg/L	<0.002	0.0015	0.002	0.002	0.0005	0.0004	-	-	<0.001	0.001	<0.001	0.001
Zinc (Zn)	mg/L	0.003	0.007	0.015	0.021	0.013-0.03	0.011	-	-	0.006	0.002	0.001	0.011
Metals (Dissolved)													
Aluminum (Al)	mg/L	-	0.032	0.009	0.027	-	0.032	-	-	-	-	-	-
Arsenic (As)	mg/L	<0.0008	<0.0004	<0.0004-<0.0005	<0.001	0.0004	0.0005	0.0004	0.0004	0.0005	0.0005	0.00025	<0.0002-0.0003
Cadmium (Cd)	mg/L	<0.001	<0.0001	0.0001-<0.001	<0.0001	-	<0.0001	-	-	-	-	-	-
Chromium (Cr)	mg/L	0.004	<0.0004	<0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.005	0.003	<0.003
Copper (Cu)	mg/L	0.001	0.0013	0.0009-<0.001	0.0011	-	0.0013	-	-	-	-	-	-
Iron (Fe)	mg/L	0.48	1.03	0.12-0.41	0.25	-	1.03	-	-	-	-	-	-
Manganese (Mn)	mg/L	-	0.036	0.020	0.030	-	0.036	-	-	-	-	-	-
Mercury (Hg)	mg/L	-	<0.0002	<0.0002	0.0002	-	<0.0002	-	-	-	-	-	-
Vanadium (V)	mg/L	<0.001	0.0001	<0.0001-<0.001	-	-	0.0001	-	-	-	-	-	-
Zinc (Zn)	mg/L	<0.001	0.008	0.001-0.017	-	-	0.008	-	-	-	-	-	-
Organics													
Naphthenic Acids	mg/L	-	1	<1	<1	<1	4	-	-	-	<1	<1	-
Recoverable Hydrocarbons	mg/L	-	0.5	<0.75	<1	2	<0.5	-	-	0.4	<0.1	0.15	0.25
PAHs and Alkylated PAHs	µg/L	-	-	ND	ND	ND	-	-	-	-	-	-	-
Target PANHs	µg/L	-	ND	ND	ND	ND	-	-	-	-	-	-	-
Phenolics	µg/L	-	ND	ND	ND	ND	-	-	-	-	-	-	-
Toxicity													
Microtox IC50	%	-	>100	>100	>100	>99	>91	-	-	-	>100	>100	-
Microtox IC25	%	-	>100	100	>100	-	>91	-	-	-	>100	>100	-

NOTES: - = No data; ND = Not detected; PAH = Polycyclic aromatic hydrocarbon; PANH = Polycyclic aromatic nitrogen heterocycle
Median concentrations (n>2), ranges (n=2), or measured concentrations (n=1) are presented

Table 3.3 Water Quality of the Steepbank River (1972-1997)

Parameter	Units	At Mouth				Lower Steepbank River				Upper Steepbank River		
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Spring	Summer	Fall
Conventional Parameters and Nutrients												
pH	-	7.9	7.8	8.0	7.8	7.8	7.5	7.8	7.5	7.4	7.7	7.7
Total Alkalinity	mg/L	306	87	90	109	314	68	85	89	98	80	106
Total Dissolved Solids	mg/L	350	125	100	126	353	88	114	105	111	87	115
Total Suspended Solids	mg/L	3	39	3	16	5	50	10	9	< 0.4	4	< 0.4
Total Hardness	mg/L	236	77	95	100	246	76	91	97	83	83	75
Dissolved Organic Carbon	mg/L	10.1	14.1	22.9	19.7	14.8	17.0	21.5	22.0	15.7	23.3	22.6
Total Kjeldahl Nitrogen	mg/L	0.75	1.10	0.62-1.00	0.20	0.77	0.95	0.96	1.10	-	-	-
Total Ammonia	mg/L	0.05	0.03	0.07	< 0.035	-	-	-	-	0.02	0.07	0.03
Total Phosphorus	mg/L	0.050	0.098	0.093	0.117	0.060	0.048	0.042	0.046	0.171	0.123	0.114
Dissolved Phosphorus	mg/L	< 0.02	0.030	0.020	0.019	-	-	-	-	-	-	-
Metals (Total)												
Aluminum (Al)	mg/L	0.12	0.67	0.04	0.44	0.03	0.53	0.10	0.13	< 0.01	0.05	0.02
Arsenic (As)	mg/L	0.0004	0.0005	0.0004	0.0007	-	-	< 0.005	0.004	0.0004	0.0004	< 0.0002
Cadmium (Cd)	mg/L	0.0002	< 0.0016	0.002	0.003	-	-	-	-	< 0.003	0.005	< 0.003
Chromium (Cr)	mg/L	<0.0027	0.0018	0.004	0.003	-	-	-	-	< 0.002	0.005	0.003
Copper (Cu)	mg/L	0.0017	0.00215	0.007	0.00135	-	-	-	-	< 0.001	-	-
Iron (Fe)	mg/L	1.07	1.30	0.67	0.74	-	-	-	-	0.81	0.74	0.57
Manganese (Mn)	mg/L	0.021	0.051	0.032	0.033	-	-	-	-	0.028	0.046	0.014
Mercury (Hg)	mg/L	< 0.0002	< 0.0251	< 0.0012	< 0.001	0.0001	< 0.0001	0.0001	0.0001	< 0.05	< 0.05	< 0.05
Vanadium (V)	mg/L	0.0006	0.003	0.005	0.002	-	-	-	-	0.004	0.004	< 0.002
Zinc (Zn)	mg/L	0.067	0.0195	0.025	0.016	-	-	-	-	0.162	0.029	0.012
Metals (Dissolved)												
Aluminum (Al)	mg/L	0.006	0.160	0.019	0.059	-	-	-	-	-	-	-
Arsenic (As)	mg/L	< 0.0004	0.0005	0.0005	0.0004	0.0006	0.0005	0.0004	0.0005	-	-	-
Cadmium (Cd)	mg/L	< 0.0001	< 0.0001	0.0007	0.0001	-	< 0.001	< 0.001	-	-	-	-
Chromium (Cr)	mg/L	< 0.0004	< 0.0004	< 0.0004	< 0.0004	0.003	0.003	0.003	0.003	-	-	-
Copper (Cu)	mg/L	0.0008	0.002	0.0012	0.0009	-	0.003	0.001	-	-	-	-
Iron (Fe)	mg/L	< 0.01	1.08	0.39	0.29	-	0.33	0.34	-	-	-	-
Manganese (Mn)	mg/L	0.0003	0.053	0.024	0.018	-	-	-	-	-	-	-
Mercury (Hg)	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	-	-	-	-	-	-	-
Vanadium (V)	mg/L	< 0.0001	0.0007	0.0001	< 0.0001	-	< 0.001	< 0.001	-	-	-	-
Zinc (Zn)	mg/L	0.006	0.009	0.028	0.013	-	< 0.001	< 0.001	-	-	-	-
Organics												
Naphthenic acids	mg/L	2	1.5	< 1	< 1	-	-	-	-	< 1	< 1	< 1
Recoverable Hydrocarbons	mg/L	< 1	< 0.75	< 1	< 0.85	-	-	-	-	1	2	< 1
PAHs and Alkylated PAHs	µg/L	ND	ND	ND	ND	-	-	-	-	-	-	-
PANHs	µg/L	ND	ND	ND	ND	-	-	-	-	-	-	-
Phenolics	µg/L	ND	ND	ND	ND	-	-	-	-	-	-	-
Volatile organics	µg/L	-	ND	-	-	-	-	-	-	-	-	-
Toxicity												
Microtox IC50	%	>91	>100	99.5	>100	-	-	-	-	>100	>100	>100
Microtox IC25	%	>91	>100	>100	>100	-	-	-	-	>100	>100	>100

NOTES: - = No data; ND = Not Detected; PAH = Polycyclic aromatic hydrocarbon; PANH = Polycyclic aromatic nitrogen heterocycle
Median concentrations (n>2), ranges (n=2), or measured concentrations (n=1) are presented

Overall, differences between naphthenic acids concentrations reported by ETL and Syncrude were not large enough to affect data interpretation and preserving samples does not appear to greatly influence results reported by Syncrude. However, some of the differences in naphthenic acids concentrations reported by the two laboratories, and differences in ETL's results for preserved and unpreserved samples were of sufficient magnitude to warrant continued focus on quality assurance for this parameter.

Table 3.4 Comparison of Naphthenic Acids Concentrations Reported by ETL and Syncrude in Water Samples

Location	Sample Date	ETL[a] Result (mg/L)	Syncrude[b] Result (mg/L)	Difference (mg/L)
Preserved Samples				
Athabasca River upstream of TID	29/7/97	<1	0.3	<1
Suncor's Southwest Drainage Ditch - Replicate 1	29/7/97	37	broken	-
Suncor's Southwest Drainage Ditch - Replicate 2	29/7/97	39	34.8	4.2
Suncor's Southwest Drainage Ditch - Replicate 3	29/7/97	36	35.7	0.3
Suncor's Southwest Drainage Ditch	16/9/97	7	17.4	10.4
Outflow from Suncor's Pond 5 East	29/7/97	65	66.3	1.3
Outflow from Suncor's Pond 5 East	18/9/97	broken	68.5	-
Outflow from Suncor's Pond 5 East	29/9/97	63	71.1	8.1
Unpreserved Samples				
Suncor's Southwest Drainage Ditch	16/9/97	22	19.2	2.8
Outflow from Suncor's Pond 5 East	18/9/97	90	65.0	25.0

[a]Enviro-Test Laboratories
[b]Syncrude Canada Research Laboratory

3.1.2 Sediment Quality

3.1.2.1 Athabasca River

Bottom sediments of the Athabasca, Peace, Smoky and Wapiti rivers were sampled during the Northern River Basins Study (NRBS) for assessment of PAHs, polychlorinated biphenyls (PCBs) and pulp mill-related organic compounds (Crosley 1996, Brownlee et al. 1997). Crosley (1996) reported an increase in total PAHs in the clay-silt fraction of bottom sediments from approximately 1 µg/g in the upper and mid-reaches of the Athabasca River to >2 µg/g above Fort McMurray. This increase was followed by a minor decline near Fort McKay. Crosley (1996) suggested that the increase in the lower reaches of the river was most likely due to natural sources, and speculated that the decline in sediment PAH levels between Fort McMurray and Fort McKay suggests that oil sands industries "are not contributing significant PAHs to river sediments".

An earlier study by Brownlee et al. (1997) reported comparable PAH levels in the clay-silt fraction of sediments from the same rivers. Brownlee (1997) sampled five sites in the upper to mid-reaches of the Athabasca River and three sites in the lower reaches (above Horse River, above Firebag River and at the mouth). Levels of individual PAHs varied little among sites, with the exception of naphthalene and phenanthrene, which occurred at lowest concentrations in the oil sands reach. Sediment PAH concentrations

reported by this study were also lower in the Athabasca River than in the Peace and Wapiti rivers.

Bottom sediment quality of three closely-spaced sites near Suncor's TID was assessed in 1994 and 1995 by Golder Associates (1994, 1996a). The presence of varying amounts of oil sands was reflected in detectable, but generally low levels of PAHs in both years and relatively high hydrocarbon content at all three sites in 1995 (Table 3.5; recoverable hydrocarbons were not measured in 1994). Levels of metals were typical of the bottom sediments of large rivers in Alberta (e.g., Shaw et al. 1994). Microtox® tests of sediment extracts in 1994 did not detect toxicity to bacteria at any of the sites sampled. Due to differences in analytical methods, analyte lists and detection limits, these results are not directly comparable to those of the NRBS.

Bottom sediments of the Athabasca River were most recently sampled in two areas during the fall field program of the RAMP in 1997. The sample collected below the oil sands area contained higher levels of hydrocarbons and PAHs than the upstream sample (Table 3.5), which conflicts with the findings of Crosley (1996). Levels of metals were similar to those reported in previous samples from this river. No toxicity to aquatic organisms was detected using a standard battery of sediment toxicity tests (Table 3.5).

The limited data available on sediment quality of the lower Athabasca River do not reveal consistent spatial trends related to potential PAH releases from oil sands operations, but suggest there is an increase in natural input of PAHs in the oil sands area relative to the upper reaches of the river.

3.1.2.2 Athabasca River Tributaries

Bottom sediment samples were collected in fall 1997 from a number of rivers and streams in the oil sands area. Bottom sediment samples were also collected in 1995 from the Steepbank River as part of baseline studies for the Aurora and Steepbank Mines. Levels of metals were typically lower in the Steepbank River than in the Athabasca River (Table 3.6) or the North Saskatchewan River (Shaw et al. 1994). Concentrations of PAHs and total recoverable hydrocarbons were higher in the Steepbank River than those in the Athabasca River, especially at the mouth, where bottom sediments contain large amounts of oil sands.

Table 3.5 Sediment Quality of the Athabasca River (1994, 1995, 1997)

Parameter	Units	1994[1]			1995[2]			1997[3]	
		1 km Above TID West Bank	At TID East Bank	At TID West Bank	1 km Above TID West Bank	At TID East Bank	At TID West Bank	At Donald Creek	At Fort Creek
Total Organic Carbon	Weight %	1.07	1.31	0.49-1.61	1.39	0.49	1.02	0.67	2.32
Recoverable Hydrocarbons	µg/g	-	-	-	2160	450	703	423	1190
Metals									
Aluminum	µg/g	6420	7670	4250-7740	3910	3730	4890	10700	7790
Arsenic	µg/g	1.7	2.1	1.3-2.0	0.6	0.9	1.0	5.6	5.1
Cadmium	µg/g	<0.3	<0.3	<0.3	<0.3	0.6	0.5	<0.5	<0.5
Chromium	µg/g	15.3	17.3	13.4-17.2	13.9	11.1	12.4	19.0	20.2
Copper	µg/g	5.1	7.9	3.6-8.6	4.6	3.6	6.5	15	15
Iron	µg/g	13600	16400	10200-14800	11000	9820	13100	15000	15500
Lead	µg/g	3	6	6-8	4	5	5	9	8
Mercury	µg/g	0.023	0.03	<0.02-0.03	0.03	0.04	0.03	0.05	0.06
Nickel	µg/g	15.0	18.0	14.0-19.0	13.8	11.8	15.6	16.0	19.0
Molybdenum	µg/g	1.0	1.2	0.9-1.4	<0.3	0.4	0.5	<1	<1
Vanadium	µg/g	18.8	19.4	14-19.8	14.7	12.8	14.5	28.0	18.5
Zinc	µg/g	35.6	43.6	26.3-46.1	29.9	27.6	39.6	53.0	57.4
PAHs									
Phenanthrene	µg/g	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
Benz(a)anthracene/Chrysene	µg/g	2.1	<0.01	<0.01-0.02	0.03	<0.01	0.01	0.02	0.025
Benzo(a)pyrene	µg/g	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.006
Fluoranthene	µg/g	0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.006
Pyrene	µg/g	1.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Total PAHs	µg/g	4.30	-	0.50	0.66	0.07	0.13	0.48	1.203
Toxicity									
Microtox Screen	% Control	73-99	118	91-120	-	-	-	-	-
C. tentans 10-day Survival Test	% Control	-	-	-	-	-	-	NT	NT
C. tentans 10-day Growth Test	% Control	-	-	-	-	-	-	NT	NT
L. variegatus 10-day Survival Test	% Control	-	-	-	-	-	-	NT	NT
L. variegatus 10-day Growth Test	% Control	-	-	-	-	-	-	NT	NT
H. azteca 10-day Survival Test	% Control	-	-	-	-	-	-	NT	NT
H. azteca 10-day Growth Test	% Control	-	-	-	-	-	-	NT	NT

NOTES:

[1]Golder (1994);[2]Golder (1996a);[3]Samples collected in fall 1997 for RAMP

- = No data; NT = Not toxic

PAH = Polycyclic aromatic hydrocarbon; TID = Tar Island Dyke

Table 3.6 Sediment Quality in the Muskeg River, Steepbank River, MacKay River, Jackpine Creek and Poplar Creek (1995, 1997)

Parameter	Units	Muskeg River at Mouth	Muskeg River upstream Jackpine Creek	Steepbank River at Mouth[1]	Steepbank River 17 km above Mouth[2]	MacKay River at Mouth	Jackpine Creek at Mouth	Poplar Creek at Mouth
Total Organic Carbon	%	2.98	4.5	0.86-3.51	1.36-2.17	1.37	2.0	1.82
Recoverable Hydrocarbons	mg/kg	3440	3690	5720-17833	154-247	4180	5660	6670
Metals								
Aluminum (Al)	mg/kg	2970	5820	2070-3333	3950-4990	5650	3060	5330
Arsenic (As)	mg/kg	1.0	2.4	1-2.1	1.1-1.7	4.5	1.2	3.1
Cadmium (Cd)	mg/kg	<0.5	<0.5	<0.5-0.3	<0.3	<0.5	<0.5	<0.5
Chromium (Cr)	mg/kg	6.9	12.3	5.5-7.9	13.4-17.7	12.9	7.8	12.7
Copper (Cu)	mg/kg	7	10	2.3-7	3.4-5.7	11	7	11
Iron (Fe)	mg/kg	11200	23000	6800-10237	10400-12600	14400	5430	10200
Lead (Pb)	mg/kg	<5	<5	<5-4	2.0-4	6	<5	6
Mercury (Hg)	mg/kg	0.04	0.04	<20-0.03	<20-28	0.05	0.03	0.05
Molybdenum (Mo)	mg/kg	<1	<1	<0.3-0.9	<0.3-1	<1	<1	<1
Nickel (Ni)	mg/kg	6	9	7-8.9	10.5-14.6	12	6	13
Silver (Ag)	mg/kg	<1	<1	<1	<0.2-0.2	<1	<1	<1
Vanadium (V)	mg/kg	9	16	7.0-13	13-15.4	16	11	13
Zinc (Zn)	mg/kg	26.4	37.9	15.7-24.2	22.8-30.5	44.3	22.2	36.2
PAHs								
Phenanthrene	µg/g	0.007	0.009	<0.01-0.31	-	0.080	<0.003	0.015
Fluoranthene	µg/g	0.003	0.006	0.023-0.12	-	0.022	0.004	0.005
Pyrene	µg/g	0.012	0.015	0.072-0.2	-	0.047	0.006	0.010
Benzo(a)anthracene/Chrysene	µg/g	0.035	0.057	0.17-1.9	-	0.11	0.034	0.025
Benzo(a)pyrene	µg/g	0.013	0.016	0.097-0.21	-	0.023	0.015	0.007
Total PAHs	µg/g	1.712	3.888	14.352-57.420	-	11.679	2.027	1.658

Notes: - = No data

[1]RAMP 1997 pooled with Golder (1996a)

[2]Golder (1996a)

3.1.3 Porewater Quality

The limited porewater data from the oil sands area suggest that the chemical composition of porewaters can vary greatly, depending on the amount of oil sands in the substratum. The concentrations of dissolved salts varied widely in porewater samples collected in 1995 from the Athabasca, Steepbank and Muskeg rivers and Jackpine Creek (Table 3.7; Golder 1996a). Dissolved salt levels were lowest in the Muskeg River and Jackpine Creek and highest in the Steepbank River, also likely reflecting the relative amounts of oil sands in the samples. Ammonia level varied moderately among sites, with a high value at one site in the Steepbank River. Naphthenic acids concentrations were variable but low at all sites. Naturally occurring PAHs were detectable at one site in the Athabasca River and all three sites in the Steepbank River, but not in the Muskeg River or Jackpine Creek. One sample from the Steepbank River (15 km from the mouth) contained PAHs at levels higher than previously found in process-affected porewaters adjacent to TID (Golder 1994, 1995). None of the samples were toxic to bacteria (Microtox®).

3.2 BENTHIC INVERTEBRATES

3.2.1 Background Information

The fall 1997 benthic invertebrate survey of the Athabasca River provided data for an initial comparison of the benthic communities of reaches above and below the oil sands area and information for use during the design phase of future regional biomonitoring. The survey was restricted to the dominant, depositional habitat type in the lower Athabasca River. Four areas were sampled, consisting of one area near each bank, upstream (at Donald Creek) and downstream (at Fort Creek) from the oil sands area (Figure 2.3). Three sites sampled in each area provided estimates of site-to-site (within-area) variation for use in statistical tests comparing sampling areas. Small scale (within-site) variation provided by replicate samples from a site was not considered relevant for comparisons of sampling areas.

3.2.2 Benthic Habitat

Benthic invertebrate sampling sites were characterized by low current velocity and predominantly sand or finer sediments (Table 3.8). The following points summarize habitat characteristics at the sampling sites:

- current velocity was low overall, but was generally faster near Donald Creek (0.21 to 0.44 m/s) than at Fort Creek (0 to 0.22 m/s);

Table 3.7 Porewater Chemistry and Toxicity in the Athabasca, Steepbank and Muskeg Rivers and Jackpine Creek (1994, 1995)

Site	Sodium (mg/L)	Total Dissolved Solids (mg/L)	Naphthenic Acids (mg/L)	Total Ammonia (mg/L)	Recoverable Hydrocarbons (mg/L)	Total PAHs (µg/L)	Microtox IC50 (%)
Athabasca R. 1 km above TID, West Bank	1210	3220	17	0.78	<1	0.04	>100
Athabasca River at TID, West Bank	12.8	259	<1	0.58	<1	ND	>100
Athabasca River at TID, East Bank	423	1730	<1	0.59	<1	ND	>100
Steepbank River at the mouth	12.6-26.5	240-374	2-4	0.47-0.62	<1-16	ND-0.84	>100
Steepbank River, 15 km from the mouth	380-5120	1370-14500	3-16	0.50-3.01	3-138	1.21-33.75	>100
Steepbank River, 25 km from the mouth	11.5-26.1	125-228	<1-5	0.03-0.06	<1-1	ND-0.03	>100
Muskeg River at the mouth	11.0	130	<1	<0.01	<1	ND	>100
Jackpine Creek at the mouth	10.5	168	<1	0.01	<1	ND	>100

NOTES:
TID = Tar Island Dyke
ND = Not detected
PAH = Polycyclic aromatic hydrocarbon
Data from Golder (1996a)

Table 3.8 Habitat Characteristics and Field Water Quality Measurements at the Benthic Invertebrate Sampling Sites

Site	Bank	Current Velocity (m/s)	Depth (m)	Sediment Composition				Field Water Quality Measurements			
				Sand (%)	Silt (%)	Clay (%)	Total Organic Carbon (%)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Water Temperature (°C)
Athabasca River at Donald Creek											
B1	East	0.38	1.12	40	36	24	0.81	9.8	140	7.8	7.0
B2	East	0.37	1.20	34	34	32	1.47	8.8	130	7.4	8.5
B3	East	0.44	1.08	52	26	22	1.01	9.5	140	8.0	7.0
B4	West	0.25	1.30	66	14	20	0.47	10.8	190	7.5	7.5
B5	West	0.21	1.04	58	20	22	1.22	10.0	180	7.6	8.5
B6	West	0.37	0.90	84	4	12	0.14	10.0	180	7.7	8.5
Athabasca River at Fort Creek											
A1	East	0.08	1.20	61	17	22	2.08	10.5	150	8.6	8.6
A2	East	0.00	1.00	56	18	26	2.99	9.8	170	8.4	4.5
A3	East	0.00	1.20	65	17	18	1.71	10.0	170	8.5	5.0
A4	West	0.05	1.20	68	16	16	1.52	11.1	180	8.7	3.5
A5	West	0.15	1.00	74	11	15	1.72	11.1	180	8.7	3.5
A6	West	0.22	1.19	65	16	19	2.52	11.1	200	8.7	3.0

- depth was typically about 1 m at all sites;
- bottom sediment composition varied more near Donald Creek, where sand content ranged from 34 to 84%. At Fort Creek, sand content varied between 56 and 74%. In particular, bottom sediments at Site B6 near Donald Creek contained more sand than any other sites (84%);
- TOC content of bottom sediments was relatively low and variable among sites. Sediments from the sites sampled near Fort Creek had slightly higher TOC levels, with the highest values at Sites A2 and A6;
- dissolved oxygen concentration was similar at all sites;
- pH and conductivity were in the expected ranges at all sites; both of these parameters were slightly higher at the downstream sites (A1 to A6), but differed little across the river; and
- water temperature was moderately variable, reflecting the sampling date (i.e., lower temperatures were measured at sites sampled later in the field program).

Overall, the differences among sampling sites in current velocity and sediment characteristics appear sufficient to cause some variation in benthic community structure. The relationships between habitat variables and densities of common invertebrates and overall community structure are discussed below.

3.2.3 Benthic Communities

Total benthic invertebrate density was in the expected range (low to moderate) for the habitat type sampled at all sites. The lower Athabasca River provides poor habitat for benthic invertebrates because of its high suspended sediment load and predominantly depositional, shifting sand substratum. Density was highly variable near the east bank at Fort Creek and minimum density occurred near the west bank, also at Fort Creek (Figure 3.1; Table 3.9). Statistical testing showed significant upstream-downstream and cross-river differences in total density (two-way ANOVA; upstream-downstream, P=0.040; cross-river, P=0.025).

Taxonomic richness (total number of taxa at the lowest taxonomic level) was variable, but the ranges of richness values overlapped among areas (Figure 3.2). In absolute terms, richness was generally low, but was similar to previously reported values for depositional habitat in the lower Athabasca River (Noton 1979, Noton and Anderson 1982, Boerger 1983, Golder 1996a). Richness did not vary significantly among sampling areas (two-way ANOVA; upstream-downstream, P=0.763; cross-river, P=0.342).

Table 3.9 Common Benthic Invertebrates at Sites Sampled in the Athabasca River

Taxon	At Donald Creek, East Bank Sites B1 to B3			At Fort Creek, East Bank Sites A1 to A3		
	Mean Density (no./m^2)	Standard Error	% of Total Density	Mean Density (no./m^2)	Standard Error	% of Total Density
Nematoda	990	732	7.0	1880	880	7.7
Naididae	129	50	0.9	502	183	2.0
Tubificidae	215	66	1.5	1306	944	5.3
Hydracarina	0	0	0.0	215	90	0.9
Ostracoda	129	74	0.9	72	72	0.3
Perlodidae	0	0	0.0	72	52	0.3
Corixidae *(Callicorixa)*	0	0	0.0	0	0	0.0
Ceratopogonidae	0	0	0.0	143	103	0.6
Chironomidae						
Monodiamesa	158	115	1.1	100	38	0.4
Procladius	0	0	0.0	287	152	1.2
Chironomus	0	0	0.0	14	14	0.1
Harnischia complex	560	163	4.0	1823	638	7.4
Paralauterborniella	215	90	1.5	1349	671	5.5
Polypedilum	11295	4132	80.2	15974	7481	65.1
Micropsectra	0	0	0.0	186	100	0.8
Rheosmittia	0	0	0.0 (97.2%)	402	402	1.6 (99.2%)
Total Density	14092	3157	-	24527	8666	-
Total Taxa	14.0	1.0	-	14.0	3.1	-

Taxon	At Donald Creek, West Bank Sites B4 to B6			At Fort Creek, West Bank Sites A4 to A6		
	Mean Density (no./m^2)	Standard Error	% of Total Density	Mean Density (no./m^2)	Standard Error	% of Total Density
Nematoda	373	224	1.9	229	76	5.9
Naididae	287	207	1.4	488	274	12.5
Tubificidae	86	50	0.4	459	76	11.8
Hydracarina	0	0	0.0	0	0	0.0
Ostracoda	301	138	1.5	29	29	0.7
Perlodidae	230	230	1.2	57	57	1.5
Corixidae *(Callicorixa)*	0	0	0.0	316	188	8.1
Ceratopogonidae	29	29	0.1	373	160	9.6
Chironomidae						
Monodiamesa	330	187	1.7	0	0	0.0
Procladius	57	57	0.3	57	57	1.5
Chironomus	560	497	2.8	0	0	0.0
Harnischia complex	2612	1468	13.2	201	125	5.2
Paralauterborniella	545	274	2.8	430	86	11.0
Polypedilum	7922	3966	40.0	947	395	24.3
Micropsectra	316	235	1.6	0	0	0.0
Rheosmittia	6028	5942	30.4 (99.3%)	29	29	0.7 (92.7%)
Total Density	19819	756	-	3902	892	-
Total Taxa	11.0	3.1	-	12.3	2.2	-

Figure 3.1 Variation in Total Invertebrate Density Among the Benthic Invertebrate Sampling Sites in the Athabasca River

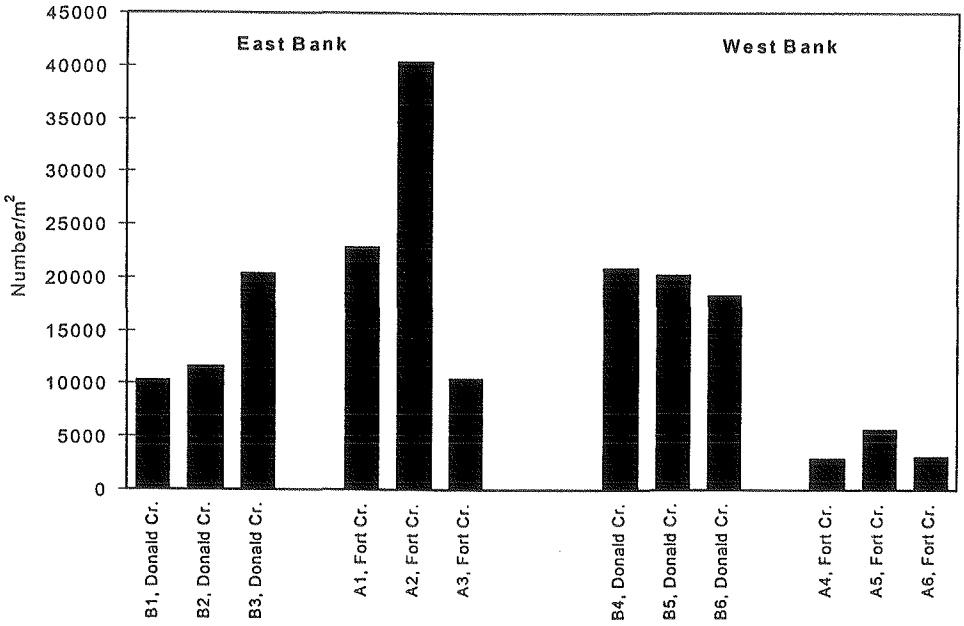
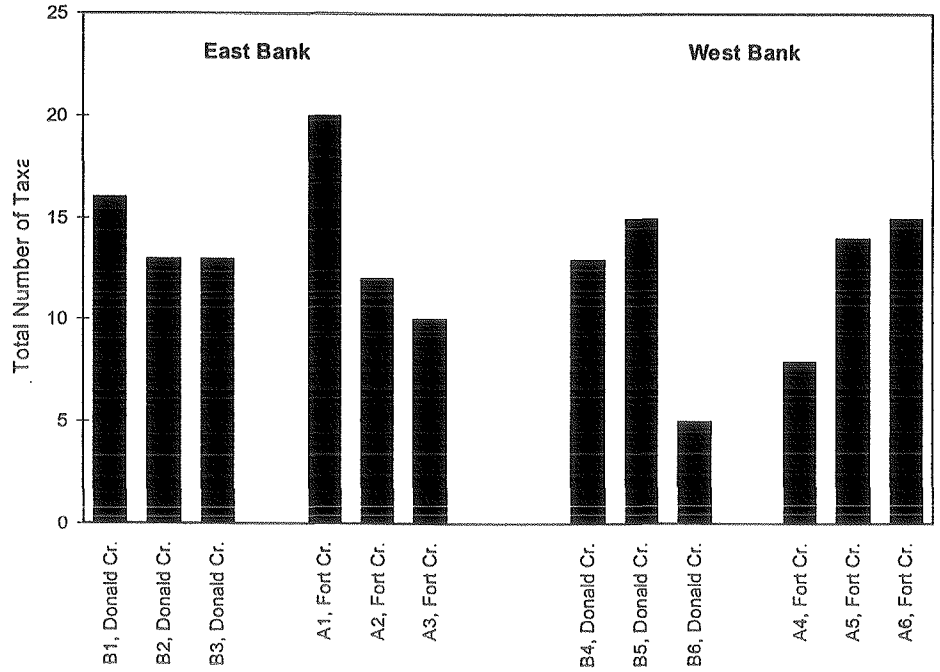


Figure 3.2 Variation in Taxonomic Richness Among the Benthic Invertebrate Sampling Sites in the Athabasca River



Three of the four sampling areas (Sites A1 to A3, B1 to B3 and B4 to B6) were dominated by chironomid midge larvae, with occasionally elevated numbers of oligochaete and nematode worms (Figure 3.3). In these areas, the remainder of benthic communities consisted of a variety of groups, typically at very low proportions. The fauna of Site B6 consisted exclusively of chironomid midge larvae of a single genus (*Rheosmittia*), which likely reflects the unique bottom sediment composition at this site (mostly sand) relative to other sites (see below).

Composition of the benthic community at Fort Creek on the west bank (where density was lowest; Figure 3.1) differed from those described above (Figure 3.3). Here, chironomids and oligochaetes dominated, with occasionally elevated proportions of water boatmen (Corixidae) and other dipterans (Ceratopogonidae). Although the fauna of this area appears more balanced than those of other areas when represented as proportions, it differs from other areas mostly because of very low chironomid densities.

The chironomid fauna of the sampling areas was dominated by *Polypedilum*, *Harnischia* complex and *Paralauterborniella* (Table 3.9). *Rheosmittia* was only common at one site (B6), which is not apparent from the area-means presented in Table 3.9. The dominant chironomid genera reflected the habitat available in the sampling areas. *Polypedilum* is a burrower, associated with plants and plant debris (Oliver and Roussel 1983, Merritt and Cummins 1984). *Paralauterborniella* usually occurs in standing waters and is also typically associated with aquatic plants. *Cyphomella*, which dominated the *Harnischia* complex at most sites, is a burrower in sandy rivers. *Rheosmittia* prefers areas with predominantly sand bottom; accordingly, this genus dominated the site with the highest proportion of sand in the substratum.

Results of correlation analysis to investigate relationships between habitat variables and densities of common invertebrates confirmed that part of the site-to-site variation was caused by differences in current velocity and sediment characteristics (Table 3.10). Significant correlations were generally consistent with habitat associations of benthic taxa that occur in depositional habitats (e.g., negative correlations with current velocity and % sand, positive correlations with TOC and fine sediments). Summary variables (total density and taxonomic richness) were not significantly correlated with habitat variables.

Despite these results for individual taxa, multivariate analysis of the relationship between overall community composition and habitat variables yielded non-significant results (Mantel's test; normalized Mantel statistic [matrix correlation coefficient]=0.29; P=0.18).

Figure 3.3 Composition of Benthic Invertebrate Communities in the Athabasca River at the Level of Major Taxonomic Group (EPT = Ephemeroptera, Plecoptera and Trichoptera Combined)

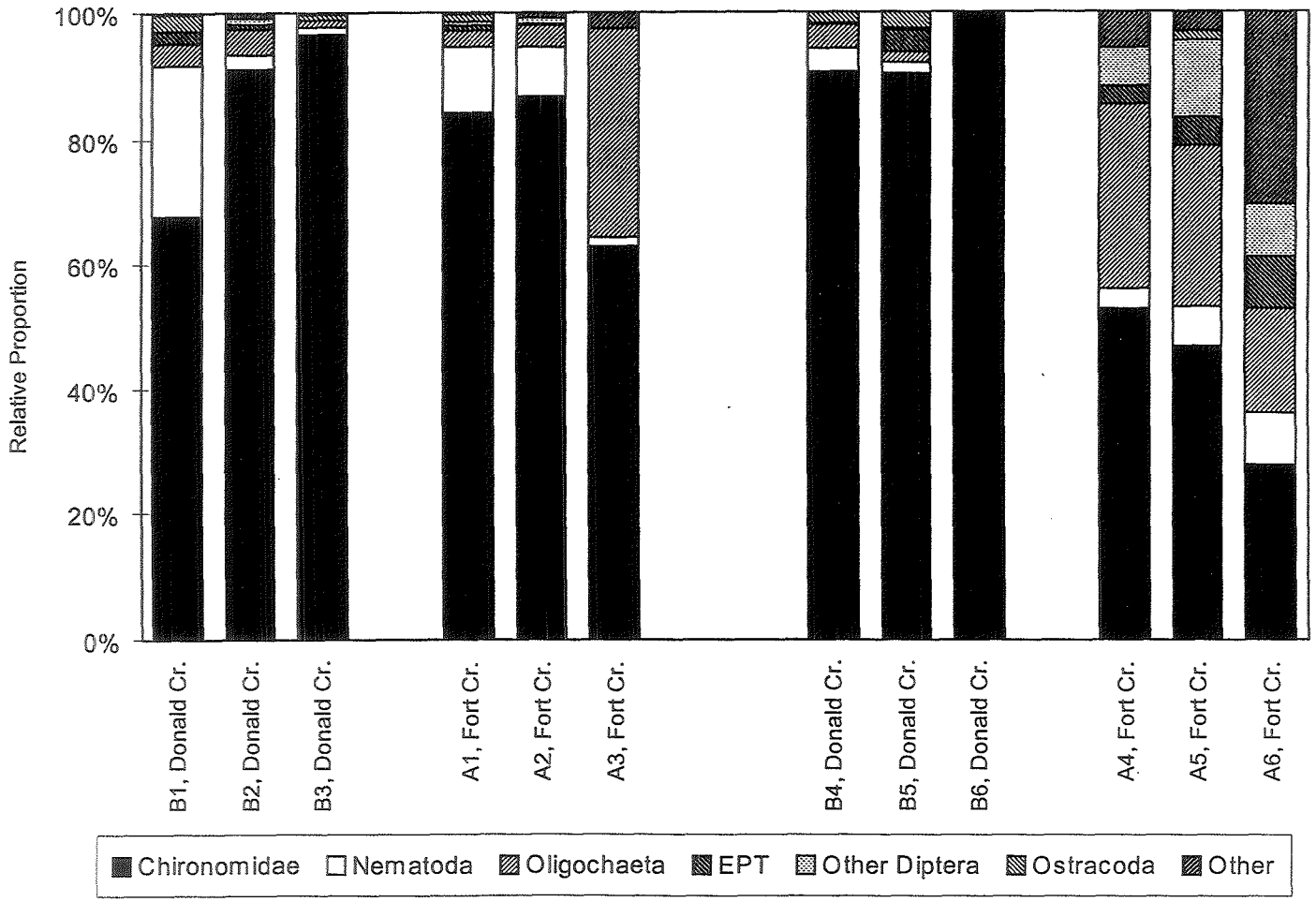


Table 3.10 Significant Correlations ($P<0.05$) Between Environmental Variables and Densities of Common Invertebrates

Taxon	Correlated Variable	Spearman Coefficient
Nematoda	% Clay	0.63
Naididae	Current velocity	-0.66
Tubificidae	Current velocity	-0.77
	TOC	0.76
Hydracarina	Current velocity	-0.71[(a)]
	TOC	0.60[(a)]
Ceratopogonidae	TOC	0.68
Monodiamesa	% Silt	0.59[(a)]
	% Clay	0.62[(a)]
Harnischia complex	% Clay	0.59
Polypedilum	% Sand	-0.61
	% Clay	0.73

NOTE: [(a)]Although correlation is significant, it is largely the result of higher or lower density in one sampling area relative to all other areas.

Qualitative examination of the benthic communities documented during the survey, in light of the habitat variables shown in Table 3.8, also yielded some indication of habitat-related variation in community structure. For example, the unique fauna of Site B6 was a reflection of the predominantly sand substratum at this site, and the highest total density occurred at the site (A2) with the highest TOC in bottom sediments. However, the habitat data did not provide an obvious explanation for low chironomid density at Sites A4, A5 and A6, which is the most obvious difference between these sites and others.

Additional supporting data collected during the fall field season included bottom sediment chemistry and toxicity, presented in Section 3.1.2. Based on analytical data for cross-channel composite samples, sediment chemistry differed between sites at Donald Creek from those at Fort Creek. Below the oil sands area (at Fort Creek), bottom sediments contained two to three-fold higher levels of hydrocarbons and PAHs than in the upstream sampling area (Donald Creek; Table 3.5). Levels of metals were similar in both areas and sediment toxicity was not found in standard tests using three different test species.

Since the sediment chemistry and toxicity data collected in 1997 were applicable to the entire width of the river in each sampling area, they could not be used to explain the cross-channel differences in invertebrate density found near Fort Creek. However, in light of the lack of toxicity in the composite sediment samples and the associations between densities of individual taxa and habitat variables discussed above, it is more likely that the observed patterns in community structure reflect differences in habitat characteristics among sites than variation in sediment quality

3.2.4 Chironomid Mouth Part Deformities

The aim of the 1997 RAMP survey of chironomid deformities was to initially examine the usefulness of this monitoring tool in the oil sands area. The dominant chironomid genus in the Athabasca River benthic samples (*Polypedilum*) was examined for the incidence of mouth part deformities.

This technique is potentially useful for monitoring the environmental quality of freshwater ecosystems, because it provides information on the effects of sediment-bound pollutants under field conditions. A number of authors have examined the incidence of deformities at sites along gradients in sediment contamination (summarized by Hudson and Ciborowski 1995) and found that deformities tend to be more common in polluted areas.

Physical wear and breakage of the teeth of the mentum were observed in a relatively large proportion of the larvae examined during this study (10 to 30%). These are not deformities, but rather signs of physical wear associated with living in sandy substratum typical of the lower Athabasca River. The incidence of deformities, defined as missing or deformed teeth on the mentum, was much lower, as summarized below:

- Sites A1, A2 and A3: 1 individual (0.8%)
- Sites B1, B2 and B3: 2 individuals (1.6%)
- Sites B4 and B5: 0 individuals

This range is in agreement with the typically low level of mentum deformities (0 to 5%) reported in the genus *Chironomus* collected from a variety of reference sites, or cultured in the laboratory (Hudson and Ciborowski 1995). This suggests that, sediments of the lower Athabasca River have little potential to cause deformities in chironomid larvae. Alternatively, there is some evidence to suggest that the genus *Polypedilum* is more resistant to mouth part deformities than the genus *Chironomus*. Very low incidence of mentum deformities (0 to 2.6%) was also reported in *Polypedilum* larvae collected from the Lake Huron-Lake Erie corridor of the Great Lakes (Hudson and Ciborowski 1995) and the St. Lawrence River (Warwick 1990). Sediments of these rivers are known to be polluted by a variety of organic compounds (e.g., polychlorinated biphenyls and pesticides). In these same rivers, *Chironomus* displayed a considerably higher incidence of deformities, in the 6-50% range (Warwick 1990, Hudson and Ciborowski 1995).

The available data on chironomid deformities in the lower Athabasca River remains very limited. At this time, it pertains to a single chironomid genus, which may be resistant to deformities. Therefore, no conclusions can be formulated regarding the potential of Athabasca River sediments to cause morphological deformities in invertebrates. Further studies of chironomid mouth part deformities are recommended to evaluate the usefulness of this

technique for the RAMP. These surveys should concentrate on other chironomid genera (preferably *Chironomus*) to allow a more sensitive evaluation of differences in the incidence of deformities between sampling areas.

3.3 FISH POPULATIONS

Surveys to gather information on fish populations in the study area were conducted in the spring, summer and fall of 1997. In addition, relevant data from studies conducted in 1995 (Golder 1996a) and 1996 (Golder 1996b) are presented. The seasonal distribution and abundance of all fish species is presented in relation to habitat use and availability. Population demographics such as length-weight relationships and migration patterns are presented for the major fish species. Preliminary results from the radiotelemetry study are presented in Section 3.3-4.

This section of the report presents information for the Athabasca River reaches, three Athabasca River tributaries: the Muskeg, Steepbank and MacKay rivers and evaluation of the potential reference areas.

3.3.1 Athabasca River

3.3.1.1 Reference Areas

Reaches above and below Fort McMurray were investigated in the spring as possible reference areas for the Athabasca River. Selection of these reaches was based on a number of criteria: access, costs of monitoring, fish composition and habitat characteristics.

Access to the reaches above Fort McMurray was restricted by the Mountain Rapids which were not passable by boat. Three reaches from Mountain Rapids to Fort McMurray were investigated and found inappropriate as reference areas. Fish species composition and habitat characteristics were not comparable to the sampling areas in the oil sands region. Preliminary results from the radiotelemetry study indicate that fish captured above Fort McMurray are likely part of the same population as those captured in the oil sands area which would therefore preclude the use of these reaches as reference sites.

Because of the lack of an appropriate boat launching site above Mountain Rapids, two sampling reaches below Fort McMurray were also investigated. However, this area is situated below Fort McMurray and hence downstream of municipal effluents making it inappropriate as a reference site. The fish in these reaches likely represent the same population as in the oil sands region, and therefore this area is not suitable as a reference site.

Further investigations are necessary to determine if a suitable reference site can be identified in the Athabasca River system. A reach above the Mountain Rapids that could be suitable as a reference area was identified from a literature review (R.L. & L. 1994). However, field investigations of fish habitats and species composition are needed to accurately assess the suitability of this reach as a reference site.

3.3.1.2 Fisheries

Several fisheries surveys of the Athabasca River have been conducted in the past (Figure 3.4). The AOSERP studies of the late 1970s were among the first to characterize the fish fauna of the Athabasca River (McCart et al. 1977, Bond 1980, Tripp and McCart 1979, Tripp and Tsui 1980). The Northern River Basins Study (NRBS) fish inventories in 1994 also included reaches within the RAMP study area (R.L. & L. 1994). Syncrude conducted fisheries inventories from 1989 to 1991 for the portion of the Athabasca River downstream of the Muskeg River to Fort Creek (Golder 1996a, Syncrude unpublished data). Studies were also conducted in 1995 for the Steepbank Mine EIA (Golder 1996a) and in 1996 for the Aurora Mine EIA (Golder 1996b).

Comparison of information from the AOSERP and NRBS studies to recent studies was done in Golder (1996a). Therefore, only brief summaries of historical information are given in this document.

Species composition in 1997, as well as in the 1995 (Golder 1996a) and 1996 (Golder 1996b) studies, was similar to that documented in the AOSERP studies. Sixteen species were captured in the reaches from Wood Creek to downstream of the Tar River (Table 3.11). The most abundant species captured in the study area were walleye, goldeye, white sucker, longnose sucker and lake whitefish (in the fall) (Table 3.12). Fish use of the Athabasca River near the study area is shown in Figure 3.5.

3.3.1.3 Life History Summaries

Fish population parameters, such as length-frequency distribution, catch-per-unit-effort (CPUE) and length-at-age are presented, where data were available, for five of the most abundant fish species in the Athabasca River (i.e., walleye, goldeye, longnose sucker, lake whitefish and northern pike).

Jasper National Park Boundary

R1

R2

R3

R4

R5

R6

R7

R8

R9

R10

HINTON

KNIGHT

WHITECOURT

BLUE RIDGE

FORT ASSINIBOINE

ATHABASCA

FORT CHIPEWYAN

Fort McKay

Fort McMurray

Macleod River

Pembina River

ATHABASCA RIVER

Lesser Slave Lake

Lake Claire

Lake Athabasca

PEACE RIVER

Pelican River

Pelican Rapids

Calling River

La Biche River

House River

Algar River

Grand Rapids

Cascade Rapids

Mountain Rapids

MacKay River

Muskeg River

Steepbank River

Firebag River

Horse River

Hangingstone River

Clearwater River

Christina River

LEGEND

- R.L. & L. (1994)
- Bond (1980)
- Machniak & Bond (1979)
- Tripp & McCart (1979)
- Tripp & Tsui (1980)
- Bond & Machniak (1979)
  O'Neil et. al. (1982)
  Beak (1986)
  R.L. & L. (1989)
- Golder (1996a)
- McCart et. al. (1977)
- Syncrude unpublished data
- Golder (1996b)
- RAMP (1997)

N

0 50 100 200 km

REFERENCE: Golder (1996a)

Figure 3.4
Fisheries Study Reaches on the Athabasca River

Golder Associates

PROJECT NO:	972-2320.6050
DATE:	28 January 1998
DRAWN BY:	RPunzalan
REVIEWED BY:	

\\1997\2020\aquatics\historic.grd PROJECT # 972-2320.6050

Table 3.11 Fish Species Use of the Athabasca River

Species	1997 Ramp Study	1996 Study[a]	Previous Studies[b]	Spawning	Rearing	Feeding	Overwintering	Migrating
[c]Arctic Grayling	●		●			✓	✓	✓
[c]Burbot	●	●	●	✓	✓	✓		✓
[c]Emerald Shiner	●	●	●	✓	✓	✓	✓?	✓
[c]Flathead Chub	●	●	●	✓	✓	✓	✓?	
[c]Goldeye	●	●	●	✓?	✓	✓		✓
[c]Lake Chub	●	●	●	✓	✓	✓	✓	
[c]Lake Whitefish	●	●	●	✓		✓		✓
[c]Longnose Sucker	●	●	●		✓	✓		✓
[c]Northern Pike	●	●	●			✓	✓	
[c]Spottail Shiner	●	●	●		✓	✓	✓	
[c]Trout-Perch	●	●	●		✓	✓	✓	
[c]Walleye	●	●	●		✓	✓		✓
[c]White Sucker	●	●	●		✓	✓		✓
Brassy Minnow			●			✓		
Brook Stickleback		●	●			✓		
Bull Trout			●			✓		
Fathead Minnow			●			✓		
Finescale Dace			●			✓		
Iowa Darter			●			✓		
Longnose Dace			●			✓		
Mountain Whitefish	●	●	●	✓		✓		
Ninespine Stickleback			●			✓		
Northern Redbelly Dace			●			✓		
Pearl Dace			●			✓		
River Shiner	●							
Slimy Sculpin			●	✓	✓	✓	✓	
Spoonhead Sculpin			●			✓		
Yellow Perch	●	●	●			✓		

[a] Golder 1996b

[b] Data from Bond 1980, McCart et al. 1977, Tripp and McCart 1979, Tripp and Tsui, 1980, R.L. & L. 1994, Syncrude's unpublished fish inventories 1989-91 and Golder 1996a.

[c] Common, widespread species in the Athabasca River. Note that Arctic grayling are mainly found in the tributaries during the open-water season.

● present in study area

✓ kind of habitat use

? may use habitat but use not confirmed

Table 3.12 Total Number of Each Species Captured from the Athabasca River in 1997

SPECIES	SPRING	SUMMER	FALL	TOTAL	PERCENT
Arctic Grayling			4	4	0.18
Burbot	9	4		13	0.59
Emerald Shiner		1		1	0.05
Fathead Minnow				0	0.00
Finescale Dace				0	0.00
Flathead Chub	135	87	46	268	12.23
Goldeye	259	45	201	505	23.04
Lake Chub	11	41	2	54	2.46
Lake Whitefish	3	19	65	87	3.97
Longnose Dace				0	0.00
Longnose Sucker	154	22	19	195	8.90
Mountain Whitefish	13	9	2	24	1.09
Northern Pike	18	47	22	87	3.97
Pearl Dace				0	0.00
River Shiner	3	5	1	9	0.41
Slimy Sculpin				0	0.00
Spoonhead Sculpin				0	0.00
Spottail Shiner	2	17		19	0.87
Trout-Perch	44	37	19	100	4.56
Walleye	337	144	111	592	27.01
White Sucker	169	14	39	222	10.13
Yellow Perch	2	10		12	0.55
Unidentified				0	0.00
TOTAL	**1159**	**502**	**531**	**2192**	

Walleye

Walleye were found in the Athabasca River during spring, summer and fall of 1997. Most of the adults that were captured in 1997 were caught in the spring season and were ripe or spent males. Few females caught were in spawning condition. Similar results were obtained in previous studies with the percentage of ripe or spent males ranging from 63 to 97% and no females in spawning condition (Tripp and McCart 1979, Golder 1996a).

Walleye were found to be well distributed throughout the RAMP study area as shown in Figure 3.6. However, Reach 5A (Steepbank River Area) showed a higher relative abundance than any other reach for the spring season. This may be an indication of spawning grounds within this area.

Young-of-the year (YOY) walleye were captured in the summer near the mouths of tributaries such as the Muskeg and MacKay rivers. The presence of YOY walleye near these watercourses suggests spawning in these tributaries. Juvenile and YOY walleye were captured in the Athabasca River study reaches in both 1995 and 1997 indicating that this area is used for rearing and summer feeding (Golder 1996a).

Jasper National Park Boundary

HINTON

KNIGHT

WHITECOURT

BLUE RIDGE

FORT ASSINIBOINE

ATHABASCA

Lesser Slave Lake

Macleod River

Pembina River

ATHABASCA RIVER

Calling River

La Biche River

Pelican River

Pelican Rapids

House River

Grand Rapids

Algar River

Cascade Rapids

Mountain Rapids

Horse River

Hangingstone River

Fort McMurray

Clearwater River

Christina River

MacKay River

Fort McKay

Muskeg River

Steepbank River

Firebag River

PEACE RIVER

Lake Claire

FORT CHIPEWYAN

Lake Athabasca

LEGEND

- Arctic Grayling
- Burbot
- Goldeye
- Lake Whitefish
- Longnose Sucker
- Mountain Whitefish
- Northern Pike
- Walleye
- White Sucker

0 50 100 200 km

N

REFERENCE: Golder (1996a)

Figure 3.5
Fish Use of the Athabasca River

Golder Associates

PROJECT NO:	972-2320.6050
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REVIEWED BY:	

i:\1997\2320\fishuse.cdr PROJECT # 972-2320.6050

Figures 3.7, 3.8 and 3.9 present the length-frequency distributions for the spring, summer and fall seasons of 1995, 1996 and 1997. Distributions are very similar for spring. Only slight differences were observed for the summer and fall as more smaller fish (likely juveniles) were captured in 1997. Water levels were lower in 1997 resulting in increased efficiency of observing and capturing smaller fish.

The length-at-age distribution for walleye is shown in Figure 3.10. The length-at-age distribution is based on data from the summer season of 1996 and 1997. Data from these year were combined to provide sufficient information to characterize the existing length-at-age relationship for walleye. These data will provide the baseline for future comparisons of length-at-age.

Figure 3.6 CPUE (Fish/100 sec.) for Walleye Caught in the Athabasca River, 1997

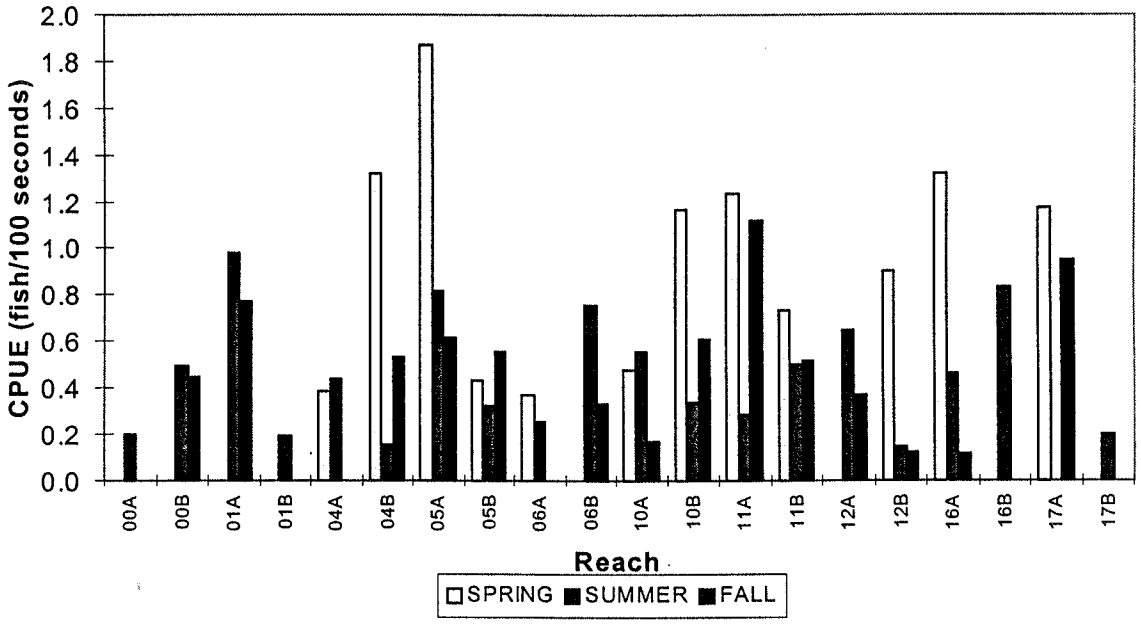


Figure 3.7 Length-Frequency Distribution for Walleye from the Athabasca River in Spring

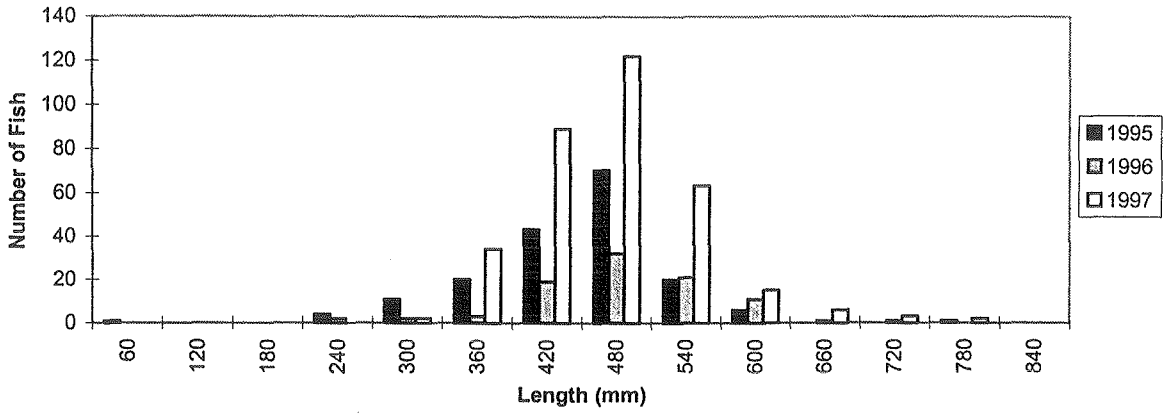


Figure 3.8 Length-Frequency Distribution for Walleye from the Athabasca River in Summer

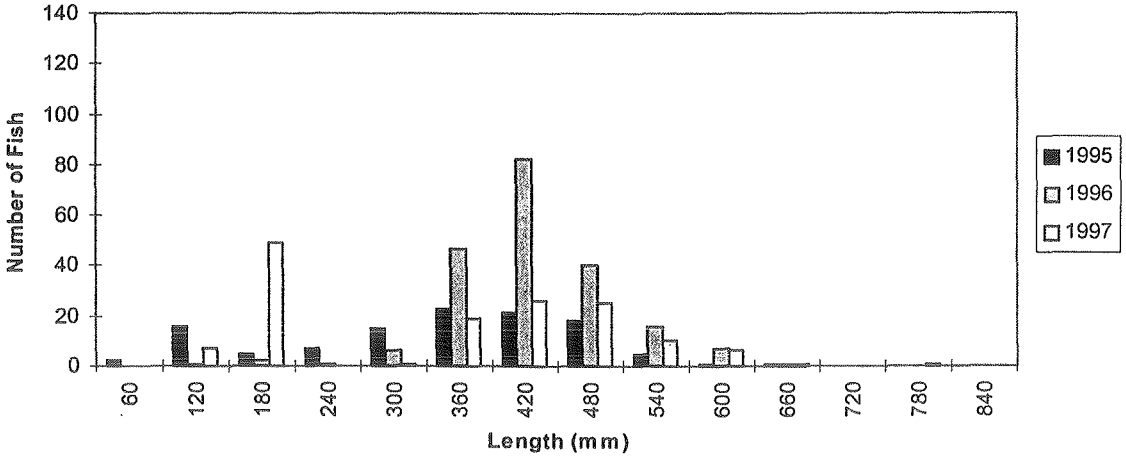


Figure 3.9 Length-Frequency Distribution for Walleye from the Athabasca River in Fall

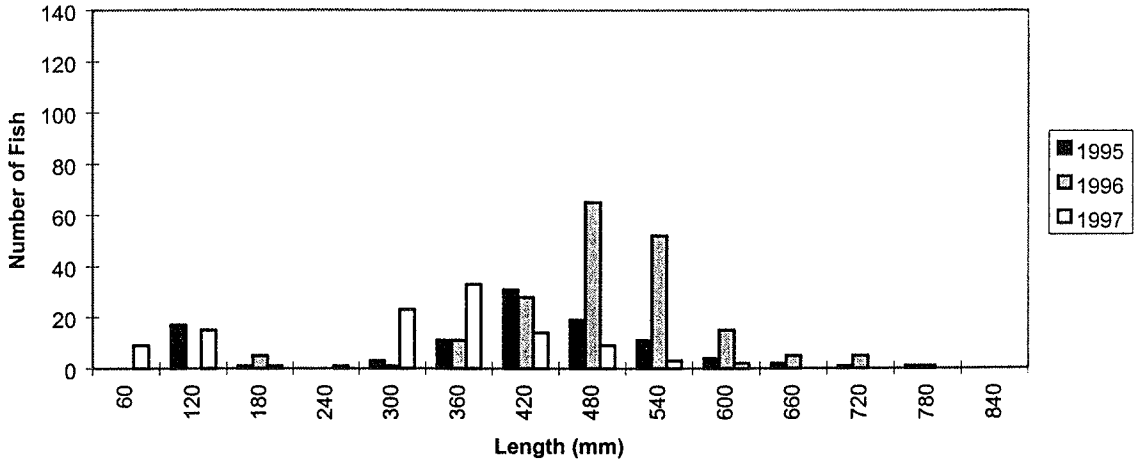
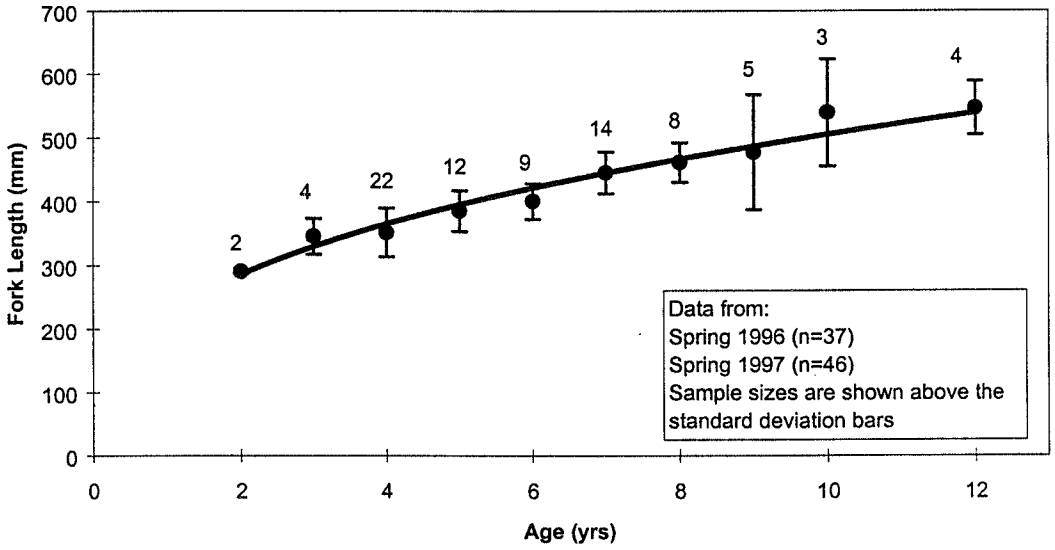


Figure 3.10 Length-at-age Distribution for Athabasca River Walleye



Goldeye

In 1997, goldeye were most abundant in the study area in spring and continued to be present in relatively high numbers throughout the summer (Figure 3.11). Relative abundance was lower in fall when goldeye left the study area, presumably to overwinter in Lake Athabasca (Tripp and Tsui

1980). This pattern of relative abundance has been reported in several previous studies (Tripp and McCart 1979, Bond 1980, Golder 1996b). In 1995 goldeye were also present during the open water season. However, abundance was highest during summer (Golder 1996a).

The AOSERP studies reported that goldeye found in the Athabasca River were immature fish that migrated from Lake Athabasca into the river to feed (Tripp and Tsui 1980, Tripp and McCart 1979). However, more recent studies, including the surveys done this year have indicated that a small proportion of goldeye that migrate into the Athabasca River are mature (Golder 1996a, 1996b). In 1997 about 0.05% of the goldeye captured were in spawning condition.

The highest concentrations of goldeye captured and observed in the 1997 surveys were in the Muskeg River Area (Reaches 10, 11 and 12) (Figure 3.11). Adult goldeye were also common in this area in the 1995 surveys (Golder 1996a). Although few juvenile goldeye were captured and observed in 1997, most juveniles were found during summer in the Muskeg River Area.

Length-frequency distributions for spring, summer and fall 1995, 1996 and 1997 are presented in Figures 3.12, 3.13 and 3.14. Results are similar from one year to the next. Fewer juvenile goldeye were captured in summer of 1997 than in previous years.

Longnose Sucker

Longnose sucker migrate upstream in the spring and move into the tributaries to spawn. They feed during the summer in the tributaries and in the mainstem Athabasca River and are believed to return to Lake Athabasca in the fall to overwinter (Tripp and McCart 1979, McCart et al. 1977, Golder 1996a).

In 1997, the majority (42%) of the adults captured in the Athabasca River were from the Muskeg River Area (reaches 10, 11 and 12) (Figure 3.15). Most fish were captured in the spring indicating that they remain in the tributaries in the summer. Only a few juveniles were captured in the different seasonal surveys. Most longnose sucker captured in the Athabasca River in the 1995 surveys were adults, although some fry were captured in the Muskeg River Area in late spring (Golder 1996a).

Length-frequency distributions for each season of the last three years are presented in Figures 3.16, 3.17 and 3.18. The distributions are similar for all three years.

Data from spring 1995 and 1996 were combined to determine the length-at-age relationship for Athabasca River longnose sucker (Figure 3.19). This graph will provide a baseline for future comparisons of length-at-age.

Figure 3.11 CPUE (Fish/100 sec.) for Goldeye Caught in the Athabasca River, 1997

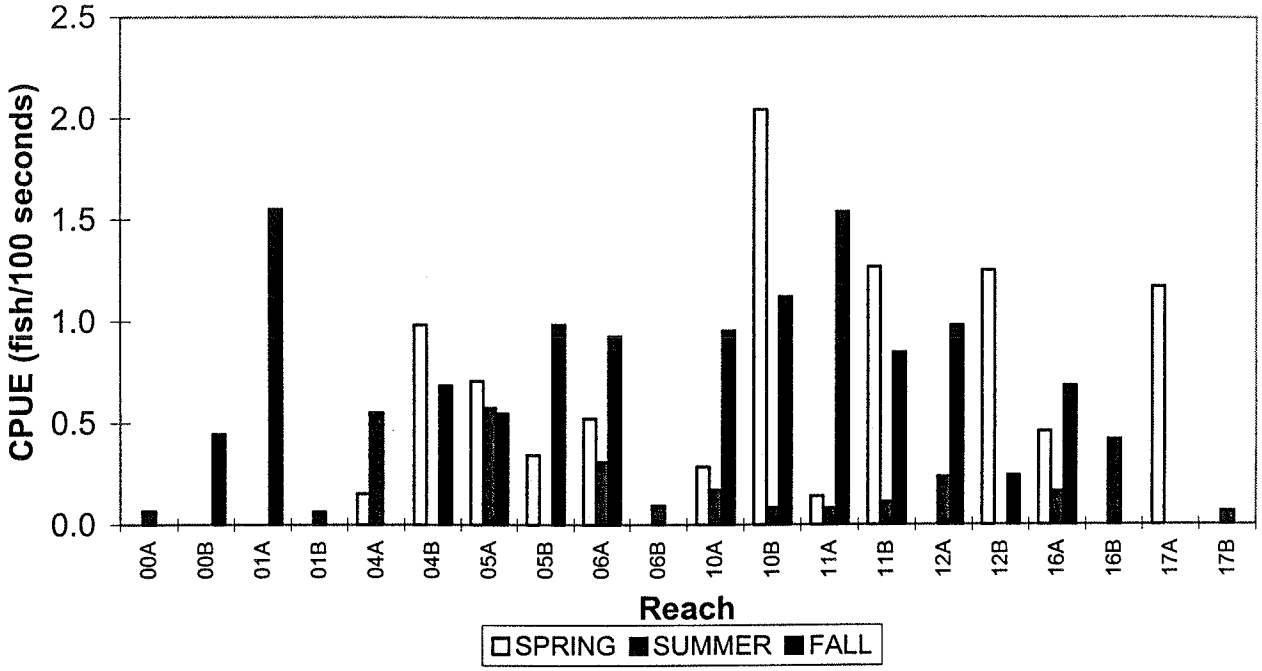


Figure 3.12 Length-Frequency Distribution for Goldeye from the Athabasca River in Spring

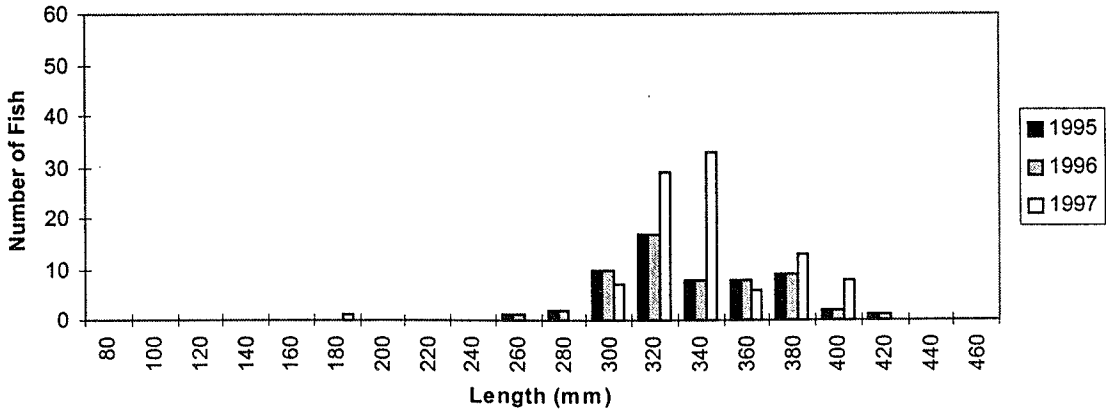


Figure 3.13 Length-Frequency Distribution for Goldeye from the Athabasca River in Summer

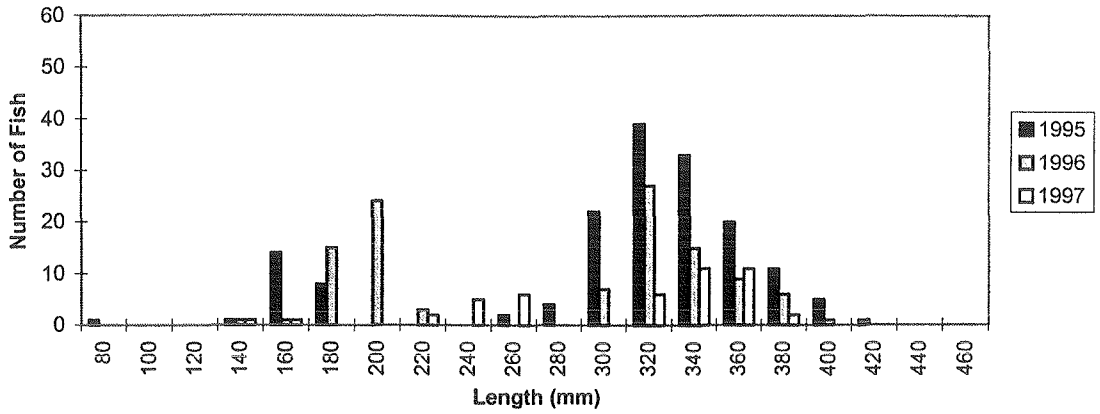


Figure 3.14 Length-Frequency Distribution for Goldeye from the Athabasca River in Fall

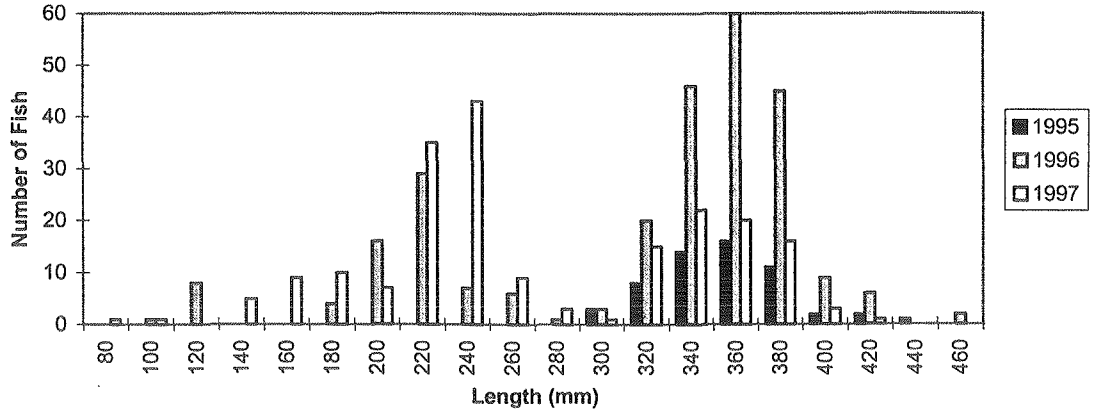


Figure 3.15 CPUE (Fish/100 sec.) for Longnose Sucker Caught in the Athabasca River, 1997

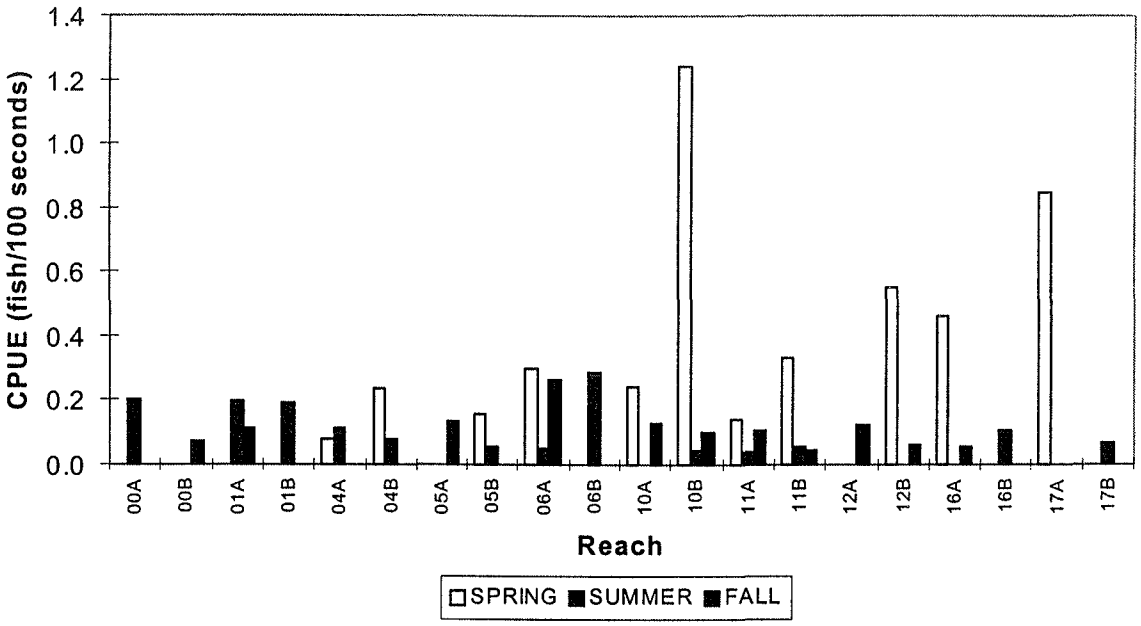


Figure 3.16 Length-Frequency Distribution for Longnose Sucker from the Athabasca River in Spring

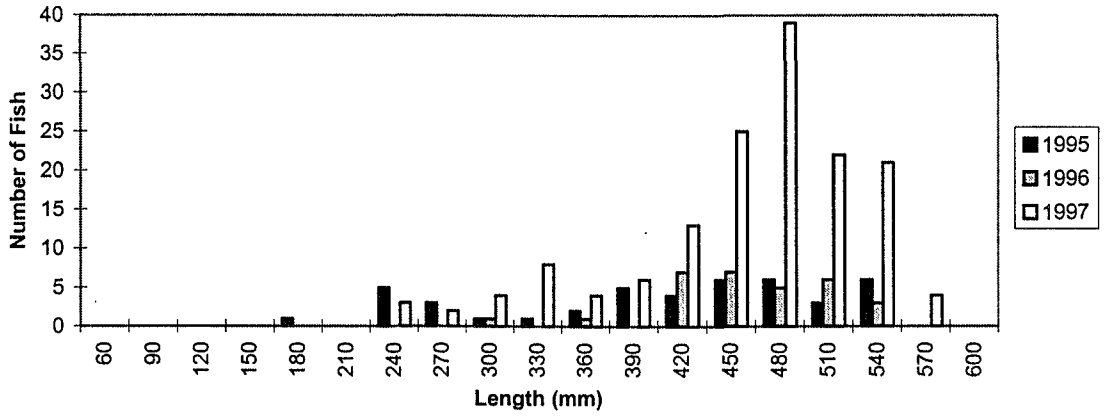


Figure 3.17 Length-Frequency Distribution for Longnose Sucker from the Athabasca River in Summer

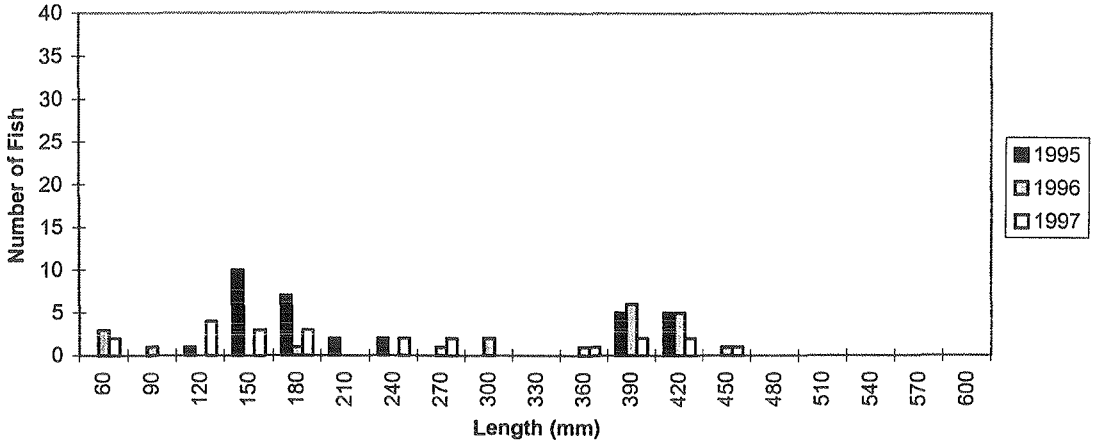


Figure 3.18 Length-Frequency Distribution for Longnose Sucker from the Athabasca River in Fall

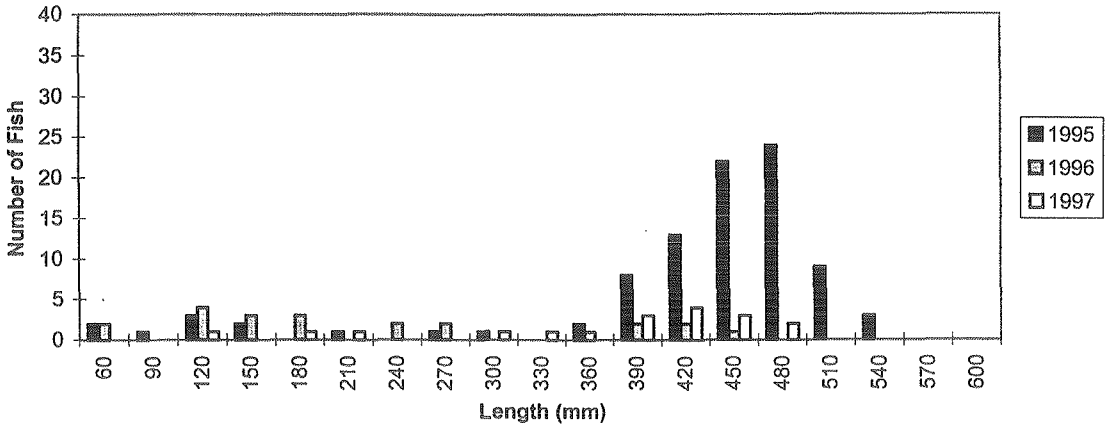
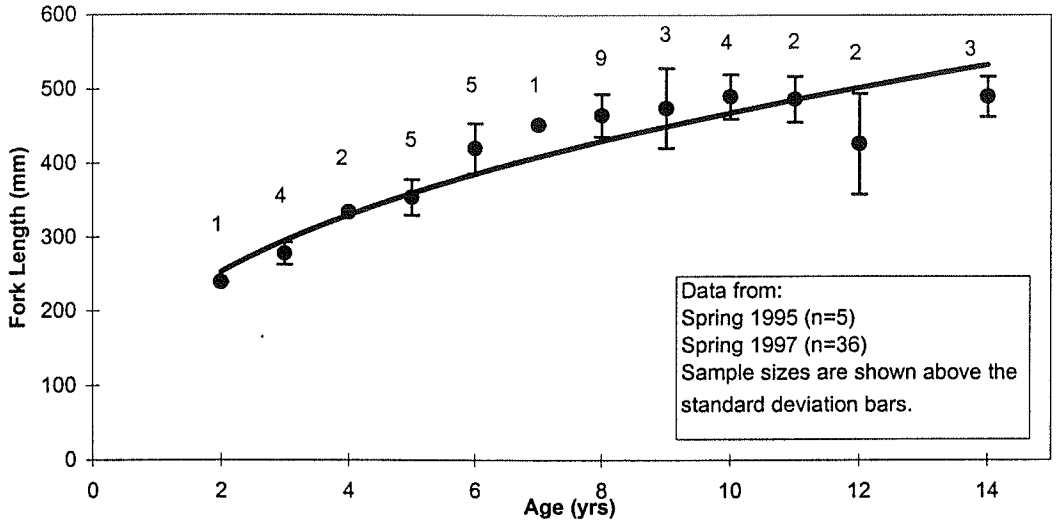


Figure 3.19 Length-at-age Distribution for Athabasca River Longnose Sucker



Lake Whitefish

Lake whitefish are residents of Lake Athabasca where they overwinter and spend the summer feeding (Bond 1980). Most lake whitefish spawn in lakes, but some populations such as those in the Peace-Athabasca Delta migrate upstream to spawn in the Athabasca River and some of its tributaries (McCart et al. 1977). Past studies indicate that lake whitefish spawn at the rapids upstream of Fort McMurray in the fall (Golder 1996a). One-half of the lake whitefish that were radio tagged for the 1997 RAMP radiotelemetry study were located at the rapids last fall, further validating past observations. The Athabasca River, especially at the mouths of tributaries, is an important feeding and resting area for lake whitefish moving upstream to spawn (Bond 1980, Golder 1996a).

Similar seasonal patterns of abundance and habitat use have been found in previous studies. In 1995, lake whitefish were captured throughout the open-water season although most individuals were captured in the fall (Golder 1996a). In summer 1995, adult lake whitefish were observed congregating at the mouth of the Steepbank River although they were uncommon elsewhere in the study area. Large numbers of lake whitefish were caught in the fall of 1996 in the RAMP study area (Golder 1996b).

In 1997, most lake whitefish were captured in fall, in the Muskeg River Area (reaches 10B and 11B associated with the mouth of the Muskeg River) (Figure 3.20). Some fish (20%) were also caught in the Steepbank River Area (reaches 6B, 5B encompassing the mouth of the Steepbank River and 5A) (Figure 3.20). Few lake whitefish were captured during the 1997 spring or summer inventories.

Length-frequency distributions are presented in Figures 3.21, 3.22 and 3.23. Results for spring inventories indicate that larger fish were captured in 1997 than in the previous two years. The distribution patterns for summer and fall are similar from one year to the next except for the number of fish captured, which varies according to the sampling effort.

Northern Pike

Northern pike spawn in the tributaries and in a few areas of the Athabasca River that exhibit flooded vegetation (R.L. & L. 1994, Golder 1996a, 1997a). Northern pike are thought to overwinter in the Athabasca River (Tripp and McCart 1979). The summer inventories in 1995 indicated that northern pike tend to remain in the tributaries or in the Athabasca River near the mouths of the tributaries (Golder 1996a). Northern pike were also consistently present in the 1996 inventories but in fairly low numbers (Golder 1996b). This pattern of abundance was also demonstrated in 1997 (Figure 3.24).

Juvenile northern pike were uncommon but still present at most sites surveyed in the 1995, 1996 and 1997 inventories. Adults were more common than juveniles and were most abundant at the mouths of tributaries or close to them (Golder 1996a 1996b).

Length-frequency distributions were generally comparable for 1995, 1996 and 1997 (Figures 3.25, 3.26 and 3.27). In summer 1996 larger northern pike were captured than in previous years.

Other Fish Species

In the 1997 surveys the largest number of white sucker was caught in the spring in the Muskeg River Area (reaches 10, 11 and 12). The breakdown of adults and juveniles showed that juvenile white sucker are uncommon in the electrofishing catch in 1997 and in 1995 (Golder 1996a). Only a few juveniles were captured in the local study area in spring of 1997.

Mountain whitefish also migrate within the Athabasca River system. Only 24 mountain whitefish were captured in 1997 (Table 3.12); most were found near or at the mouth of the Steepbank River. These results are comparable to those of the studies conducted in 1996 in the same area (Golder 1996b). Feeding migrations of mountain whitefish often occur in the tributaries but spawning and overwintering locations are unknown (Bond 1980).

Figure 3.20 CPUE (Fish/100 sec.) for Lake Whitefish Caught in the Athabasca River, 1997

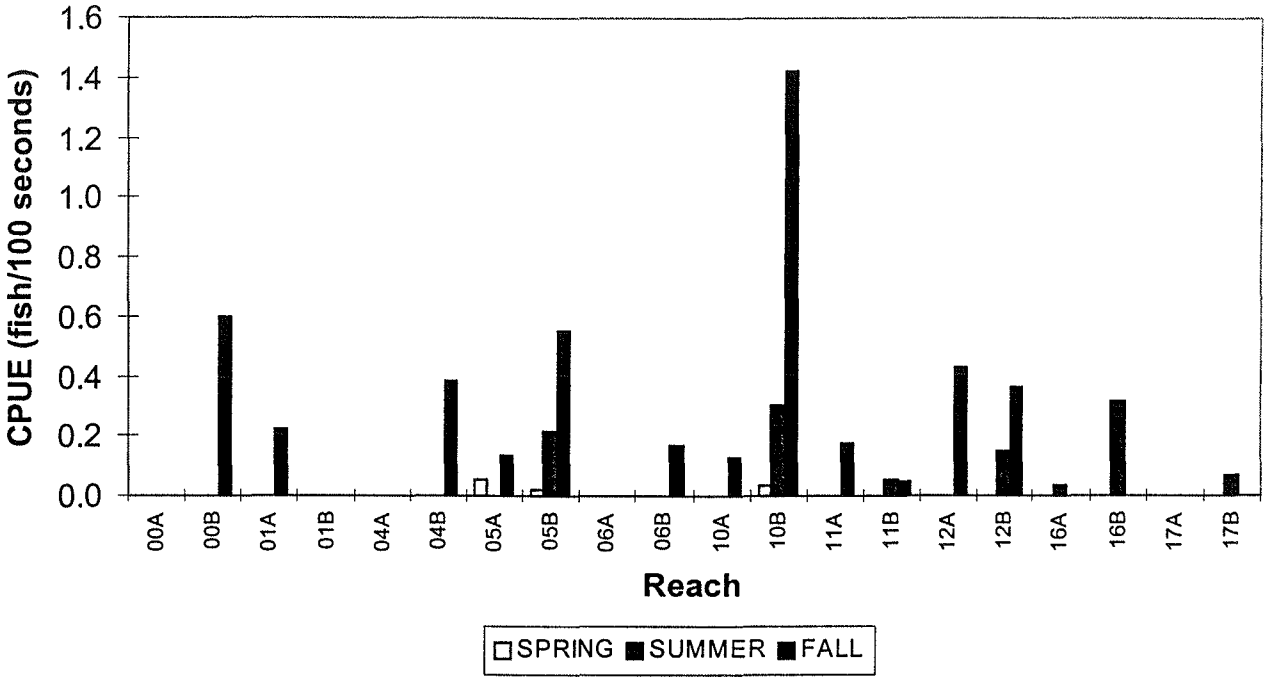


Figure 3.21 Length-Frequency Distribution for Lake Whitefish from the Athabasca River in Spring

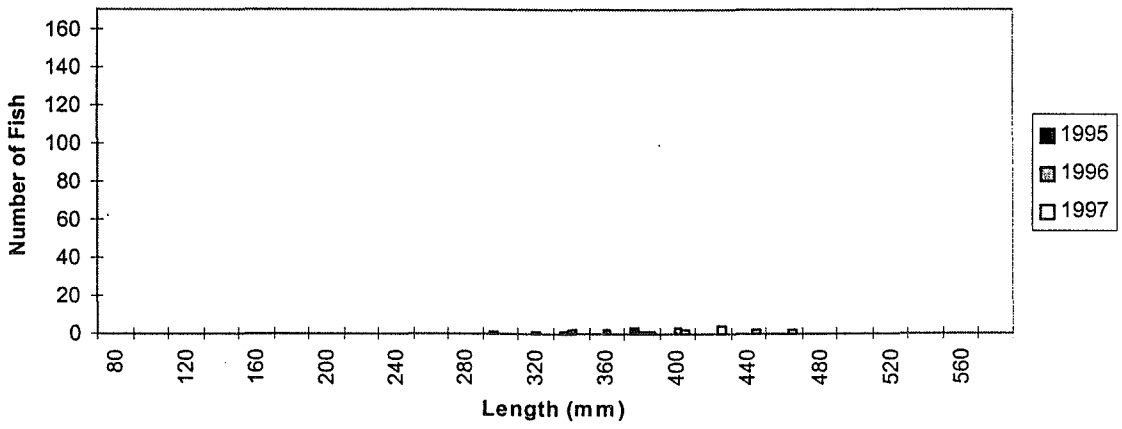


Figure 3.22 Length-Frequency Distribution for Lake Whitefish from the Athabasca River in Summer

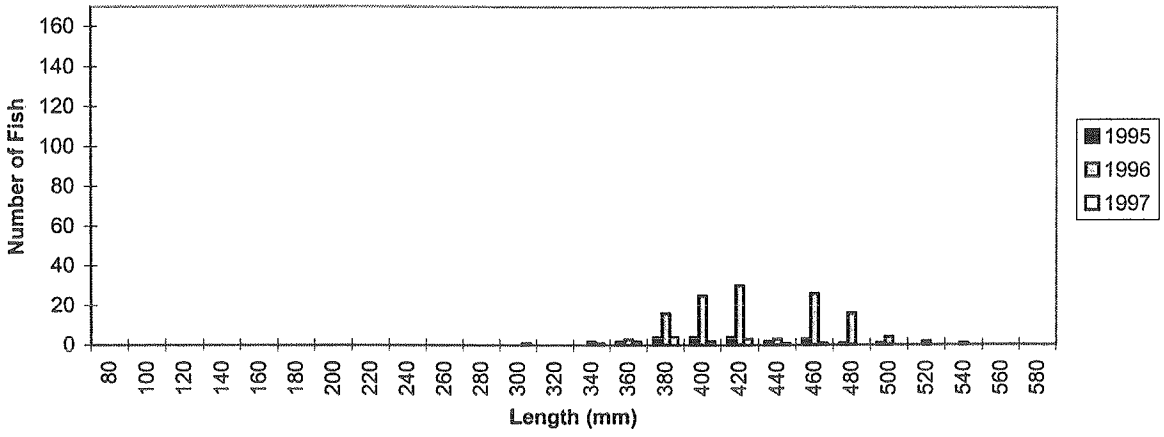


Figure 3.23 Length-Frequency Distribution for Lake Whitefish from the Athabasca River in Fall

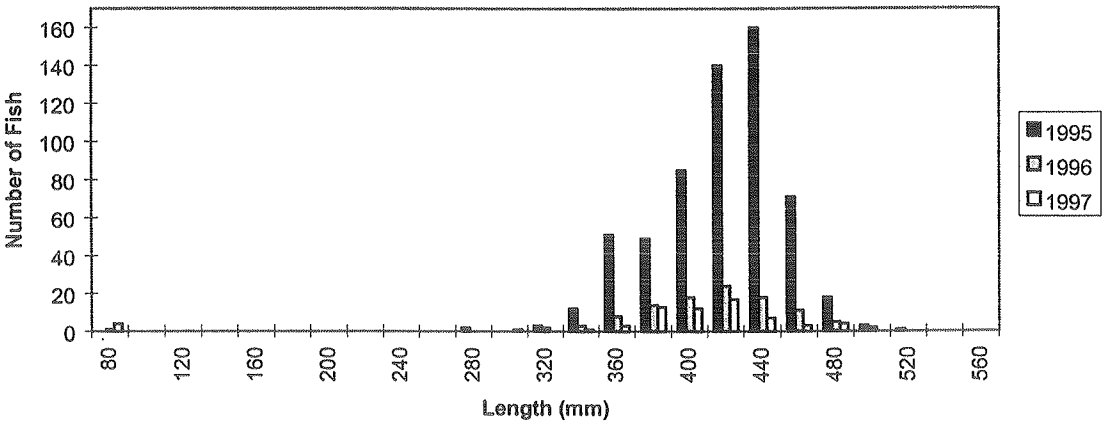


Figure 3.24 Length-at-age Distribution for Athabasca River Lake Whitefish

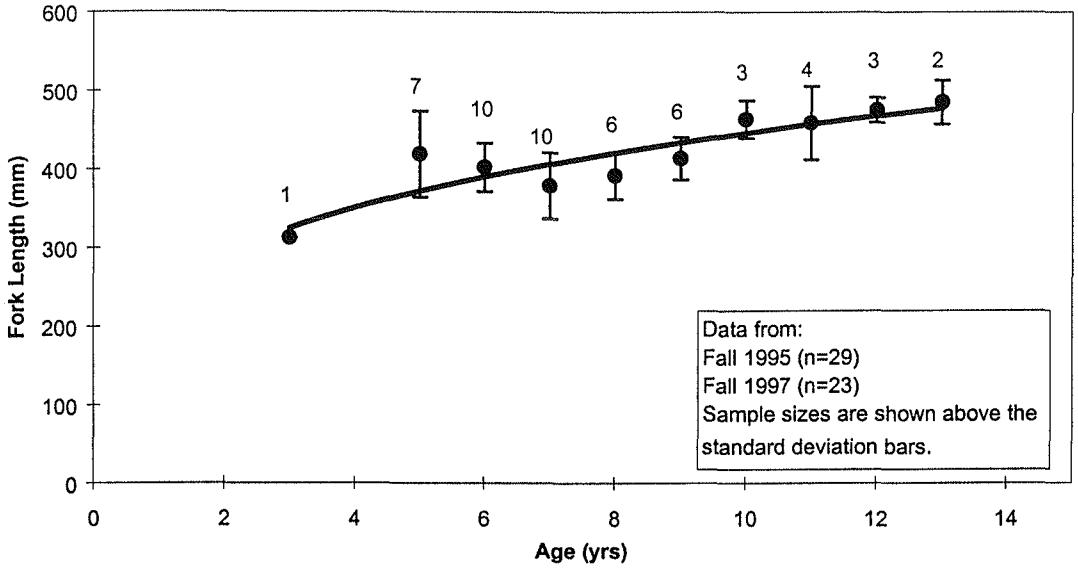


Figure 3.25 CPUE (Fish/100 sec.) for Northern Pike Caught in the Athabasca River, 1997

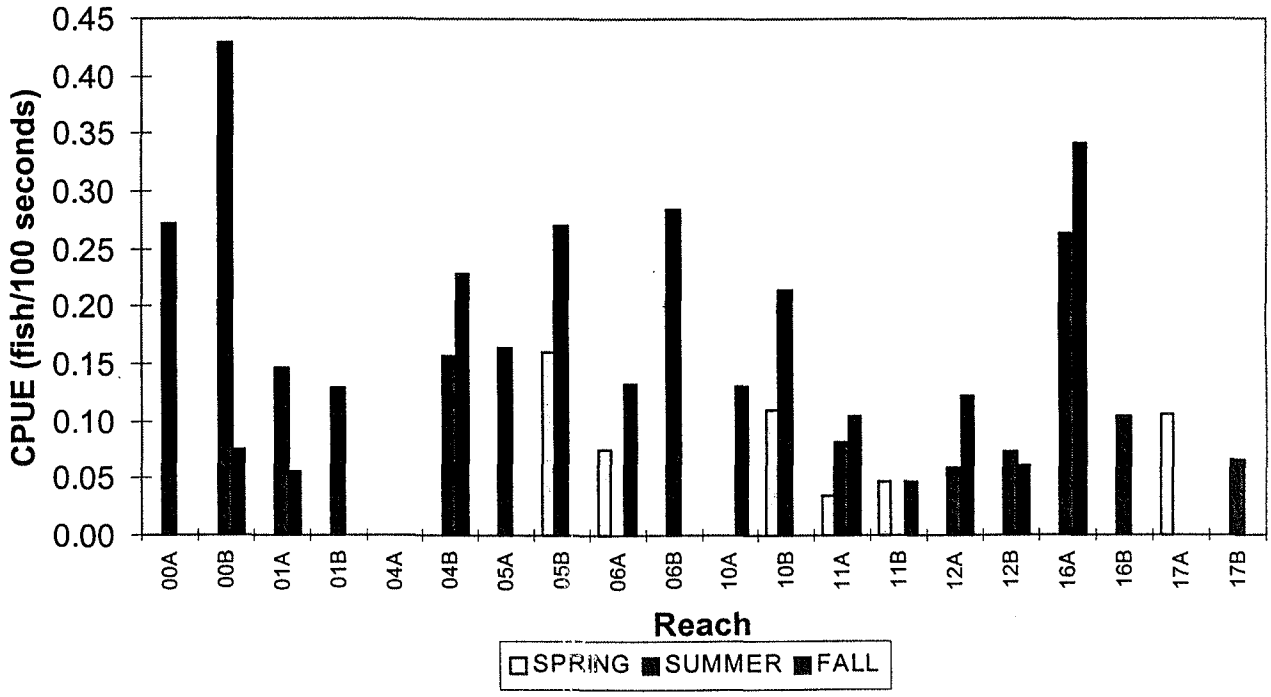


Figure 3.26 Length-Frequency Distribution for Northern Pike from the Athabasca River in Spring

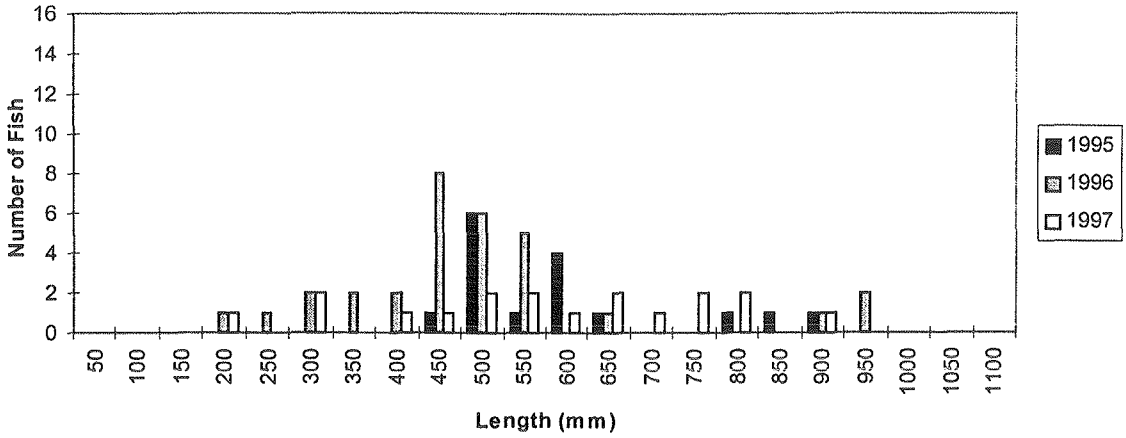


Figure 3.27 Length-Frequency Distribution for Northern Pike from the Athabasca River in Summer

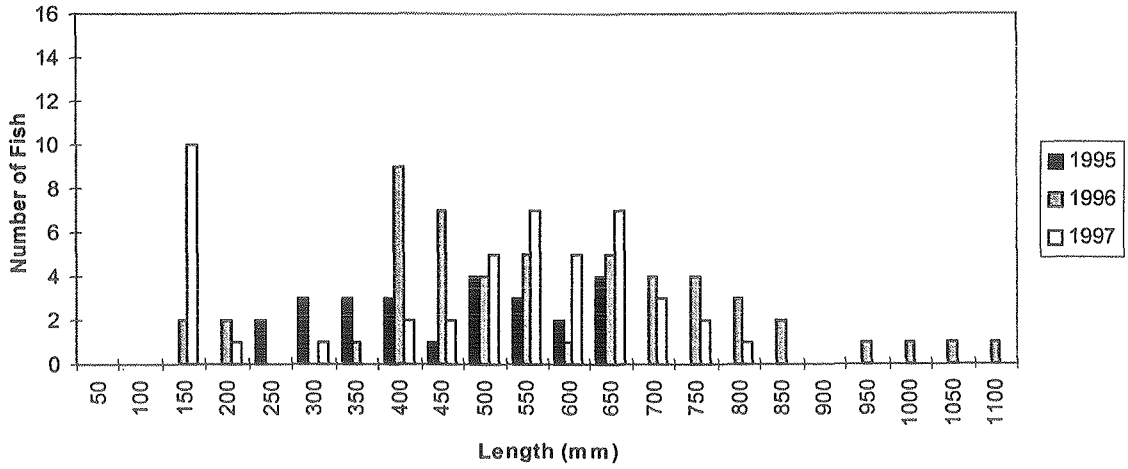
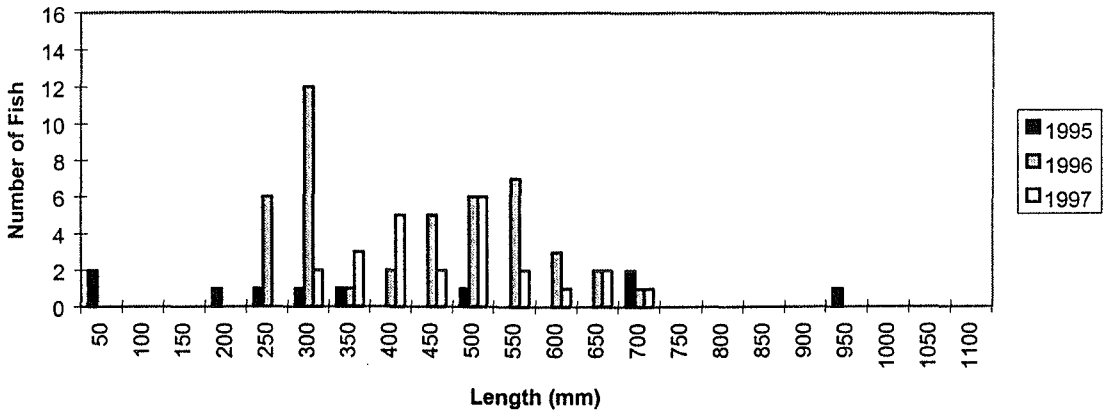


Figure 3.28 Length-Frequency Distribution for Northern Pike from the Athabasca River in Fall



Arctic grayling migrate up tributaries in spring to spawn and remain there until late fall when they return to the Athabasca River to overwinter. This species is scarce in the Athabasca River as is reflected by the low numbers found in different studies. No Arctic grayling were captured in the Athabasca River in 1995 or 1996 (Golder 1996a, 1996b). However, they are occasionally found in the mainstem Athabasca in late fall, when they leave the tributaries (Syncrude unpublished data). Four Arctic grayling were captured in the fall 1997 inventories (Table 3.12). These fish were found in the vicinity of Wood Creek and the Muskeg and MacKay rivers.

Burbot are found in the mainstem Athabasca River throughout the open-water season, although some burbot may migrate back to Lake Athabasca to avoid warm water temperatures in the summer (Bond 1980). In 1997 burbot comprised a small proportion (0.6%) of the catch. Burbot spend part of the winter in Lake Athabasca but migrate into the river to spawn during late winter (January or February).

Yellow perch are uncommon in the Athabasca River (Tripp and Tsui 1980). Only 7 perch were captured in the RAMP study area in 1996 (Golder 1996b). Two perch were captured in spring 1997 at the mouth of Poplar Creek, possibly moving downstream from Poplar Creek (Table 3.12).

Small fish species captured in the Athabasca River in 1997 were emerald shiner, flathead chub, lake chub, river shiner, spottail shiner and trout-perch. This is a similar species composition to that reported in 1995 except that in 1995 spoonhead and slimy sculpin were also captured (Golder 1996a).

3.3.2 Athabasca River Habitat Evaluation and Fish-Habitat Associations

Habitat Mapping and Assessment

In spring 1992, R.L. & L. Environmental Services Ltd. was contracted by the Northern River Basins Study to conduct a baseline fish/fish habitat inventory of the Athabasca River and the lower reaches of major tributaries. Field studies of habitat characteristics were conducted at ten representative reaches between Jasper Lake in Jasper National Park and Lake Athabasca (Figure 3.4). The information was required for evaluating the effects of current and future development on the resident and migratory fish populations of the Athabasca River.

Within each of the ten reaches studied, intensive survey sites were chosen to be representative of the river reach in which they were located. Existing habitat conditions were documented at each site in detail including depth, velocity, substrate and instream cover. Observations of habitat selection by fish species with regard to water temperature and turbidity were noted. Habitat types were identified and mapped based on a classification system developed for the use on the Peace River by R.L. & L. (Hildebrand 1990), which was adapted for the Athabasca River (R.L. & L. 1994). This system consists of three components: channel type, bank habitat type and special features (e.g., snyes, backwaters, rapids).

One of the study reaches from the 1992 baseline study included the present RAMP study area. This reach was approximately 125 km long and extended from Fort McMurray to the Firebag River (R.L. & L. 1994) (Figure 3.28). This reach was characterized by a Type M channel (multiple channel) due to the presence of numerous islands. Type U (unobstructed channel) was the second most abundant channel type, followed by Type S (singular island). Erosional bank habitat types were dominant; depositional habitats and limited amounts of armoured/stable bank habitats were also noted. Shoals and tributary confluences were the common special habitat features recorded (R.L. & L. 1994).

To provide consistency in habitat evaluations, the major channel and bank habitat categories of this mapping system were incorporated into the Golder Technical Procedure for habitat mapping which is described in detail in Appendix VI. This procedure was used to map habitats in selected areas in 1995, 1996 and 1997 (Golder 1996a, 1996b, 1997a).

In 1995, Golder (1996a) mapped habitats in a 25 km section of the Athabasca River upstream of the Muskeg River as part of the aquatics baseline study for the Steepbank Mine (Figure 3.29). Continuing downstream from this section in 1996, Golder (1996b) mapped an area on the Athabasca River from Saline Lake to Sutherland Island (Figure 3.29). The data collected were included in an addendum to the aquatic baseline report for Syncrude's Aurora Mine Environmental Impact Assessment. Effort was concentrated in the area 10 km downstream of the Peter

Loughheed Bridge which is located at the mouth of the Muskeg River (Figure 3.28). Golder used the same reaches boundaries (i.e., reaches 0 to 17) for areas studied in the Athabasca River as Syncrude used in their 1989 to 1991 fisheries inventories.

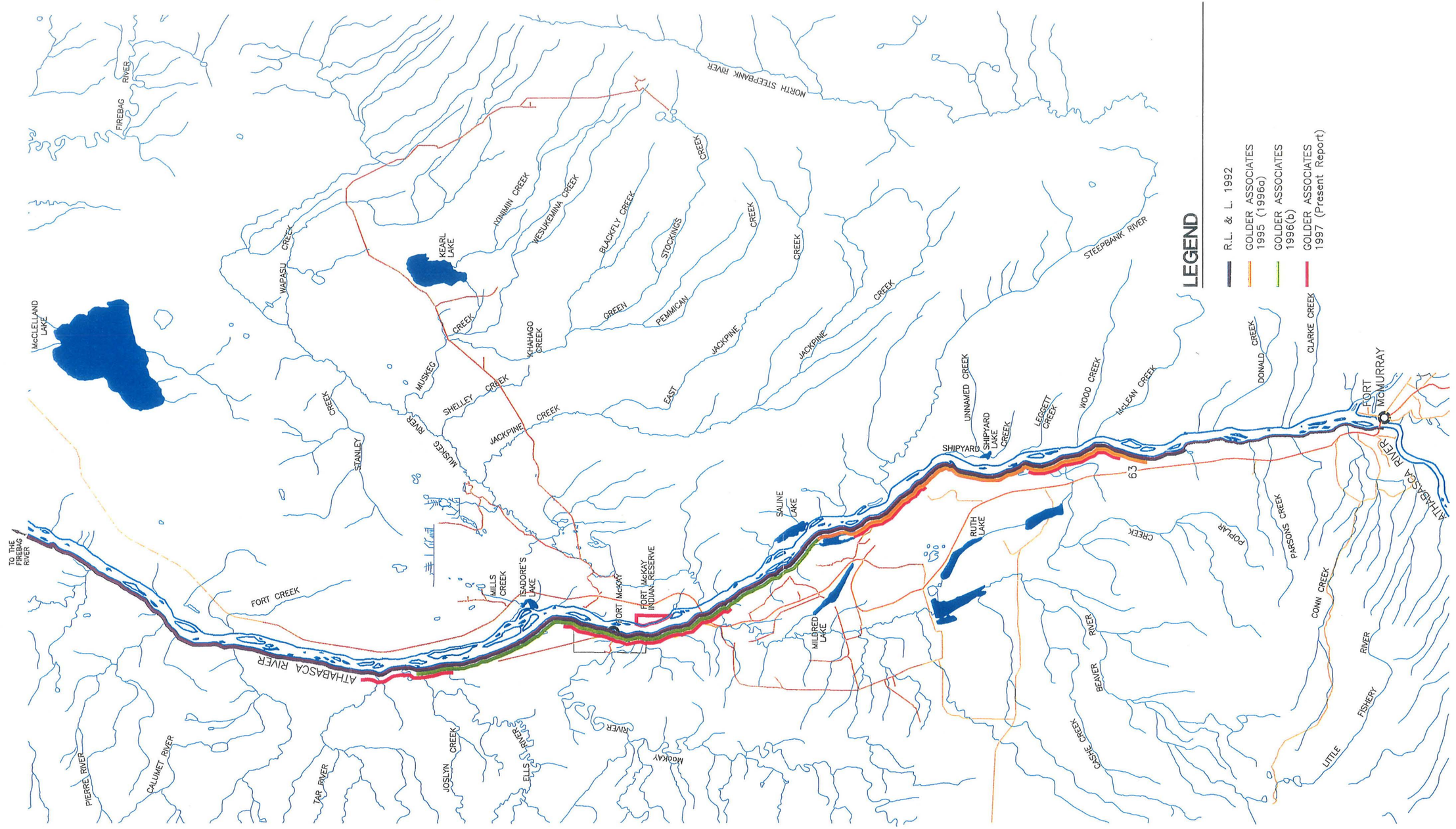
The habitat mapping results indicated that the Athabasca River provides turbid, cool-water habitat with dynamic shifting-sand channels and limited instream cover. Compared to the larger study area covered by R.L. & L. in 1992, the Athabasca River within the RAMP study area has fewer islands (Golder 1996a). Unobstructed channel, at 47%, was found to be the major channel type, although islands and sand bars were common, forming both singular island (32%) and multiple channels (21%). Major habitat features include backwaters and snyes associated with islands, sandbars and certain bank habitat types with irregular shorelines (e.g., armoured, canyon). Tributary confluences were also significant habitat features with respect to fish distribution. The substrate is almost entirely sand, although there are a few areas where bedrock substrate is predominant. Instream cover is minimal except for that provided by depth and turbidity, or associated with specific erosional bank habitat types that have resulted in the deposition of debris along the river margins.

Bank habitat types present along the shoreline areas in the RAMP study reaches were heavily dominated by sandy erosional habitats (73%). Although sand substrates were predominant throughout the Athabasca River channel, armoured habitats associated either with flat bedrock slabs or sandstone cliffs accounted for 14% of available shoreline areas. Depositional shorelines composed of fine sediments constituted the remaining 13% of shoreline habitats. Within these three major categories, there were 15 different bank habitat types present in the RAMP study reaches. Bank habitat types are briefly described in Table 3.13 and defined in detail in Appendix VI.

Table 3.13 Description of Bank Habitat Types Within the RAMP Study Area

Habitat Type	Description
A1	Cobble / boulder - limited instream cover
A2	Cobble / boulder - instream cover, backwater 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

J:\1997\2320\6050\HABMAP.dwg



0 5 10 15 20km

SCALE

REFERENCE

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

Golder Associates

HABITAT MAPPING OF THE ATHABASCA RIVER

25 MAR 98	Figure 3.29	DRAWN BY: VS/DC

Photograph 1 E1 Habitat Type - High, steep eroded bank with instream vegetative debris. (Left corner of photo) with an E5, low bank habitat (right of photo).

Photograph 2 E5 Habitat Type - Low, steep bank with no instream vegetative cover

Photograph 3 A1 Habitat Type - Cobble/ boulder bank with limited instream debris cover

Photograph 4 D1 Habitat Type - Depositional banks with gentle slope, made of fine sediments.

Photograph 5 A4 Habitat Type - Rip-Rap boulder type shoreline with instream debris cover.

Photograph 6 C2 Habitat Type - Steep bedrock/ canyon shoreline.

Overall, there were five dominant bank habitat types which constituted 88% of all shoreline areas: three erosional habitats, Type E1 - 7% (Photo 1), E2 - 24% and E5 - 36% (Photo 2); one armoured habitat, Type A1 - 8% (Photo 3); and one depositional habitat, Type D1 - 13% (Photo 4).

In 1997, available fish habitats in the Athabasca River were re-evaluated at four sites in the RAMP study area and the relevant habitat maps were updated. These four areas encompass the mouths of major tributaries within the RAMP study area and hence are referred to as the Poplar, Steepbank, Muskeg and Tar-Ells River Areas (Figure 2.4). These four regions provide a subsample of previously mapped areas which will be monitored during future RAMP studies to document natural and anthropogenic changes in available fish habitat that may occur. The existing habitat maps prepared by Golder in 1995 and 1996 were used during the re-evaluation process and were updated as necessary during field investigations in 1997. The most recent habitat maps of the four re-evaluated sections of the river are presented in Appendix IX.

Fish Habitat Associations

During fisheries inventory sampling efforts, captured fish were enumerated according to the habitat type they were associated with at the time of capture, which could reflect preferences either during summer foraging, fall migrations and fall spawning (lake whitefish only). Habitat type was primarily recorded with respect to bank habitat type and, to a lesser extent, with special habitat features. Fish-habitat associations were recorded by life stage as well as by species.

During previous fisheries assessments (Golder 1996a), some general qualitative fish-habitat associations had been defined. Walleye were found to prefer armoured shorelines, particularly those associated with sandstone cliffs, as well as large backwater areas and tributary confluences. Goldeye were captured primarily in backwater areas along non-armoured shorelines, as were northern pike which also preferred tributary confluences. Lake whitefish were found to use backwater and tributary confluences as staging and resting areas.

More detailed quantitative investigations were conducted during sampling efforts in 1997 to define fish habitat associations with respect to specific bank habitat types. Results of the fish habitat association survey are presented on Table 3.14, which shows the number of fish for each species captured in each bank habitat type. For each species, Table 3.14 also shows the percentage of use for each bank habitat type. With respect to determining habitat preferences for each species, selectivity for a bank habitat type is assumed if the fish species uses the habitat at a noticeably higher percentage than it occurs in the study area.

For all fish species combined there were three bank habitat types which were most heavily used. In order of use, these types were D1 (Depositional)

(24%), E5 (Erosional) (22%) and A1 (Armoured) (19%) (Table 3.14). Habitats were heavily used because either they were preferred by fish or they were a predominant habitat type.

D1 and A1 habitats would be considered to be preferred habitats since they were used in a higher proportion than they are available. D1 habitats were associated primarily with depositional backwater areas and preferential use of D1 areas likely reflects a strong selectivity by most fish species for backwater habitats, which are the primary type of velocity shelter in the study area. A1 habitats are associated with rocky bedrock areas and were found to be preferred habitats due primarily to heavy use by lake whitefish and, to a lesser extent, walleye.

In contrast, erosional E5 habitat was used in a lower proportion than it is available. Although fish are commonly using E5 habitats, this use appears to be due to the common occurrence of this habitat type rather than to selectivity by fish species.

Erosional habitats were most commonly used by walleye; 43% of walleye captured were associated with this habitat type (Table 3.14). Rocky bedrock or cliff shorelines were the next most frequently used habitat type at 36%, followed by depositional habitats at 21%. However, only rocky and depositional shorelines would be considered preferred habitats since they were being selected by walleye, whereas erosional habitats were used to a lesser extent than would be expected based on their availability.

Walleye were found to be primarily associated with five different bank habitat types; A1, A4, D1, E1 and E5 (Table 3.14) (Photos 1-6). As described, some of the principal bank habitat types in the RAMP study reaches include A1, D1 and E5 habitats. Therefore, it is not surprising to find a large number of fish associated with these three habitat types. The A4 and E1 habitats are much less common, but appeared to be preferred by walleye. A4 habitat consists of artificial rip-rap boulders which would provide excellent instream cover while E1 habitats include instream and/or overhead cover from eroded bank material and vegetation. Walleye would prefer these types of habitat as they provide cover, which is lacking through most of the river channel. In addition, A1 and D1 habitats were found to be used to a larger extent than would be expected based on their level of availability, supporting conclusions from previous studies that suggest walleye also prefer armoured shorelines and depositional backwater areas.

With respect to special habitat features, walleye also showed a marked preference for tributary confluences. These included the mouths of major tributaries such as Poplar Creek, and the Muskeg, Mackay, Ells and Tar rivers. Fry and juvenile walleye could also be found in association with minor drainages such as unnamed tributaries and seepages (TC1 habitat feature - Appendix IX).

Table 3.14 Total Number and Percent Fish, Observed and Captured, by Habitat Type for the Athabasca River, 1997

BANK HABITAT TYPE	% BANK HABITAT TYPE	SPECIES																														TOTAL 'N' OF FISH PER HABITAT TYPE	TOTAL '%' OF FISH PER HABITAT TYPE
		LKWH		WALL		GOLD		NRPK		BURB		YLPR		MNWH		ARGR		WHSC		LNSC		TRPR		FLCH		SPSH		LKCH		RVSH		EMSH		Shinner Sp.			
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%		
A1	8.1	575	33.5	103	15.5	34	5.4	17	12.8	1	5.3							2	2.0	12	17.9	51	8.7	40	12.8			16	22.9	1	33.3					852	19.3
A2	2			3	0.5	2	0.3	1	0.8	2	10.5													8	2.6											16	0.4
A3	0.1			1	0.2															1	1.5															2	0.1
A4	1.8	11	0.6	109	16.4	5	0.8	2	1.5	1	5.3							1	1.0			7	1.2	1	0.3			3	4.3							140	3.2
C1	0.2					1	0.2															1	0.2	1	0.3											3	0.1
C2	1.1	371	21.6	13	2.0	20	3.2	1	0.8	1	5.3					2	66.7	3	2.9	2	3.0			16	5.1			1	1.4							430	9.6
C3	0.7	9	0.5	9	1.4	9	1.4															1	0.2	11	3.5											39	0.9
D1	13.1	228	13.3	134	20.2	93	14.9	38	28.6	1	5.3	6	75.0	1	25.0			32	31.4	11	16.4	366	62.1	53	16.9	71	81.6	10	14.3					2	66.7	1046	23.7
E1	7.3	75	4.4	84	12.7	76	12.1	11	8.3	3	15.8	1	12.5	1	25.0	1	33.3	10	9.8	5	7.5	29	4.9	18	5.8	1	1.1	3	4.3	1	33.3	1	50.0			320	7.3
E2	24	18	1.0	40	6.0	172	27.5	12	9.0	2	10.5							24	23.5	12	17.9	77	13.1	33	10.5			18	25.7	1	33.3					409	9.3
E3	0.9	7	0.4	9	1.4	42	6.7	2	1.5									8	7.8					10	3.2			1	1.4			1	50.0			80	1.8
E4	2.6			11	1.7																	12	2.0													23	0.5
E5	36.4	366	21.3	142	21.4	161	25.7	44	33.1	8	42.1	1	12.5	2	50.0			22	21.6	24	35.8	43	7.3	120	38.3	15	17.2	17	24.3					1	33.3	966	21.9
E6	1.4	58	3.4	6	0.9	11	1.8	5	3.8													2	0.3	2	0.6			1	1.4							85	1.9
Totals		1718	-	664	-	626	-	133	-	19	-	8	-	4	-	3	-	102	-	67	-	589	-	313	-	87	-	70	-	3	-	2	-	3	-	4411	

Lake whitefish exhibited a strong preference for rocky shoreline types, with 56% of fish captured in armoured and canyon habitats combined. This species showed a particular preference for A1 and C2 (Photo 6) bank types which were both utilized to a much higher degree than their availability would suggest. Use of erosional habitat types by lake whitefish was 31%, which was much lower than the amount of available erosional habitat (73%). Use of depositional D1 bank types at 13% was equal to the available percentage, suggesting lake whitefish were not strongly selecting backwaters. Lake whitefish have previously been reported to prefer backwater habitats and mouths of different creeks as staging and resting areas during the fall migration through the study area. With 98% of lake whitefish captured during the fall sampling period and with most fish being pre-spawning adults, it may be that this association with rocky substrates is a related to either a migration, staging, pre-spawning or spawning behaviours.

Goldeye were found to utilize bank habitats in very close approximation to their availability; erosional habitats 74%, depositional 15% and rocky armoured/canyon areas 11%. The most commonly used bank types included D1, E1, E2 and E5 habitats (Table 3.14), with a very slight preference for D1, and E1 areas. It appears that this species is fairly ubiquitous with respect to habitat selection, utilizing each of the available habitat types according to their availability and probably the type of seasonal activity. Certain habitat types would be preferred during migrations and others during rearing and foraging. There appears to be a small preference for backwater habitats, which would be frequented by goldeye during rearing/foraging periods and also erosional E1 habitats which provide instream cover along the banks. Otherwise, goldeye appear to use the minor backwater areas and velocity shelters associated with small bank features available in each of the habitat types.

Northern pike were found most commonly associated with erosional bank types (55%), followed by depositional (29%) and rocky (16%) shorelines. The most utilized bank types were A1, D1 and E5 shorelines. A strong preference was shown for D1 habitats. The preference for D1 habitats would be due to northern pike selecting large backwater areas as is typical for this species. In addition, there is a similar preference shown by minnows and other prey species for D1 areas making these good feeding habitats. Northern pike were also commonly encountered at tributary confluences.

The two sucker species which were captured in the study area showed different patterns of habitat selection. White sucker showed a strong preference (31%) for depositional D1 bank types most often associated with the larger backwater areas. Longnose sucker on the other hand showed a strong preference (22%) for rocky A1 bank habitats.

Table 3.14 shows results for seven forage species. Habitat associations were examined for all species combined. As a group, forage fish showed a

very strong preference (47%) for D1 bank habitats which would be present in the shallow, low velocity depositional areas generally preferred by these fish, such as backwaters and downstream of bank protrusions, islands and sandbars. Unlike the other forage fish species, flathead chub demonstrated a preference for rocky shorelines rather than depositional ones, which may be associated with walleye fry distribution.

The results for other fish species captured during sampling efforts are also presented in Table 3.14. However, these species were not captured in sufficient numbers to allow analysis of habitat associations.

Table 3.15 presents a summary of the habitat preferences by fish species that were described in detail in this section of the report. This information may be useful in determining the extent of potential exposure to different developments' waters (e.g., discharges

Table 3.15 Summary of Habitat Preferences for Major Fish Species in the Athabasca River, 1997

Species	Habitat Preferences
Walleye	1) Rocky bedrock / cliff shorelines 2) Depositional bank types 3) Mouths of tributaries such as Poplar Creek, Muskeg, Mackay, Ells and Tar rivers
Lake whitefish	1) Armoured and canyon shorelines
Goldeye	1) Erosional bank types 2) Depositional bank types 3) Rocky / armoured and canyon shorelines 4) Minor backwater areas
Northern pike	1) Depositional bank types 2) Backwater areas 2) Erosional bank types 4) Tributary confluences
Longnose sucker	1) Rocky / armoured shorelines
White sucker	1) Depositional bank types 2) Backwater areas
Forage fish	1) Depositional bank types 2) Backwater areas

3.3.3 Athabasca River Tributaries

3.3.3.1 Reference Areas

Historical data indicate that the lower reaches of the Tar and Ells rivers may be suitable as reference sites (Sekerak and Walder 1980). Further investigations of the Firebag River are necessary before it can be designated as a reference site. More recent fisheries surveys of these three rivers could enhance the understanding of fish utilization of tributaries on a regional basis and assess the feasibility of using these as reference areas for the Muskeg and Steepbank rivers.

3.3.3.2 Fisheries

Fish inventories were conducted in the Steepbank and Muskeg rivers in the summer. The selected reach on the Muskeg River is situated where a fish fence was operated in 1995 (Golder 1996a), while the reach on the Steepbank River is within an area that was previously inventoried in 1995 (Golder 1996a). However, 1995 data for the Muskeg River reach were gathered by different methods (fish fence versus boat electrofishing) so abundance data is not comparable. However, for the Steepbank River sampling in 1997 was within the same reach sampled in 1995 and sampling was done with the same methods. Hence, a statistical comparison of relative abundance was appropriate.

Syncrude conducted some fisheries surveys in June 1997 on the MacKay River. General species composition and abundance are presented in this section. As the reaches inventoried in 1997 differ from historical studies (Sekerak and Walder 1980) only species composition is compared.

Muskeg River

The total number of each species captured in the Muskeg River and the CPUE is shown in Table 3.16. The species composition is comparable to that of previous studies (Machniak and Bond 1979, R.L. and L. 1989, Golder 1996a, 1998). White sucker, longnose sucker, lake chub and Arctic grayling were the most common species captured. Mountain whitefish were also present but represented only 3% of the total catch. Forage fish that were captured included spoonhead sculpin.

Table 3.16 Total Number of Each Species Captured and Catch-Per-Unit-Effort from the Muskeg River, Summer 1997

Species	Total	Percent	CPUE (fish/100 sec)
Time Sampled (s)	**3284**		
Arctic Grayling	6	6.67	0.18
Lake Chub	8	8.89	0.24
Longnose Sucker	15	16.67	0.46
Mountain Whitefish	3	3.33	0.09
Spoonhead Sculpin	2	2.22	0.06
White Sucker	56	62.22	1.71
TOTAL	**90**	**100.00**	-

Steepbank River

Fish species abundance and the CPUE for the Steepbank River RAMP reach are listed in Table 3.17. Forty fish were captured in summer 1997. Species composition is similar to that found in previous studies (R.L. & L. 1989, Golder 1996a). The was no significant difference in mean CPUE between 1997 and 1995 ($p > 0.05$).

Longnose sucker were the most abundant fish species in 1997 followed by burbot. Other sportfish species captured included mountain whitefish, walleye, northern pike and goldeye.

Table 3.17 Total Number of Each Species Captured and Catch-per-Unit-Effort From the Steepbank River, Summer 1997

Species	1997 Total	1997 Percent	1997 CPUE (fish/100 sec)	1995 CPUE (fish/100 sec)
Time Sampled (s)	1600			
Burbot	8	20.00	0.50	0.00
Goldeye	1	2.50	0.06	0.52
Lake Chub	1	2.50	0.06	0.12
Longnose Dace	3	7.50	0.19	0.25
Longnose Sucker	16	40.00	1.0	0.22
Mountain Whitefish	3	7.50	0.19	0.08
Northern Pike	2	5.00	0.13	0.18
Trout Perch	2	5.00	0.13	0.00
Walleye	3	7.50	0.19	0.03
White Sucker	1	2.50	0.06	0.00
TOTAL	40	100.00	-	-

MacKay River

A total of 347 fish was captured in the MacKay River in spring 1997 (Table 3.18). Walleye were the most commonly encountered species (n = 85), followed by longnose sucker (n = 68), white sucker (n = 50) and northern pike (n = 37). Sportfish species that were found in small numbers included: goldeye, mountain whitefish and Arctic grayling. Large numbers of flathead and lake chub were also captured. The species composition observed in 1997 is comparable to that reported by Sekerak and Walder (1980).

3.3.3.3 Summary of Findings

The information gathered on the Steepbank and Muskeg rivers has highlighted the need to define a more reliable sampling method that provides uniform sampling efficiencies. To date, different methods (e.g., gill nets, minnow traps, portable and backpack electrofishing and fish fences) have been used to gather fish population data (e.g., length-frequency distribution, length-at-age). The use of electrofishing, gillnets and minnow traps has been successful in defining species composition and relative abundance. However, efficiencies of these methods vary under different flow conditions and it is often not possible to capture enough fish to yield representative population data. Adequate data were gathered when fish fences were used in the past (R.L. & L. 1989, Golder 1996a). This fish capture method is the only reliable method used to date to collect consistent reliable fish population information.

Table 3.18 Total Number of Each Species Captured and Catch-per-Unit-Effort From the MacKay River, Spring 1997

Species	Total	Percent	CPUE
Time Sampled (s)	**17642**		
Arctic Grayling	2	0.58	0.0001
Flathead Chub	43	12.39	0.0024
Goldeye	12	3.46	0.0007
Lake Chub	40	11.53	0.0023
Longnose Dace	1	0.29	0.0001
Longnose Sucker	68	19.60	0.0039
Mountain Whitefish	7	2.02	0.0004
Northern Pike	37	10.66	0.0021
Spoonhead Sculpin	1	0.29	0.0001
Trout Perch	1	0.29	0.0001
Walleye	85	24.50	0.0048
White Sucker	50	14.41	0.0028
TOTAL	**347**	**100.00**	**0.0197**

3.3.4 Radiotelemetry Study

General information, including capture/release locations, frequencies and basic measurements on 18 walleye and 18 lake whitefish that were radio tagged is presented in Table 3.19.

The radio transmitters utilized for this study were high frequency units and are, therefore, best suited to the shallow depths typical of the riverine habitats in the study area and are effective under these conditions. However, for fish that move to deeper areas (>5 m), reception of the telemetry signal can be disrupted, as the range of a radio transmitter decreases almost exponentially as depth increases (Winter 1983); the higher the radio frequency used, the more restraining are the effects of depth (Oregon Fish and Wildlife 1988). Therefore, individuals that were not located for the last three flights (7, 8 and 9) or that were last located downstream of the Firebag River, were assumed to have moved into the deeper waters of Lake Athabasca.

Nine flights were conducted to follow the movements of walleye and lake whitefish that were radio tagged in the fall of 1997. Results of the radiotelemetry program are presented in detail in Appendix X. This appendix presents individual maps for each radio-tagged fish, showing all sites from which the individual transmitter signal was received during the aerial surveys, illustrating the movements for each fish. A summary of these results is presented in this section.

Table 3.19 Summary of Capture and Tagging Information for Walleye and Lake Whitefish from the Athabasca River, Fall 1997

Date	Capture Location	Release Location	Species	Fork Length (mm)	Weight (g)	Stage	Sex	Maturity	Floy Tag Number	Radio Tag Frequency (MHz)
2/10/97	Reach 10B	10B-11B	WALL	431	960	A	U	UN	2644	150.324
2/10/97	Reach 10B	10B-11B	WALL	414	690	A	U	UN	2645	150.454
2/10/97	Reach 10B	10B-11B	WALL	440	900	A	U	UN	2646	150.424
2/10/97	Reach 10B	10B-11B	LKWH	482	1990	A	F	PS	2647	150.394
2/10/97	Reach 10B	10B-11B	LKWH	407	1280	A	F	PS	2648	150.364
3/10/97	Reach 11A	11A-12B	WALL	655	3630	A	U	UN	2686	150.303
3/10/97	Reach 11A	11A-12B	WALL	468	1090	A	U	UN	2687	150.104
3/10/97	Reach 11A	11A-12B	WALL	534	1770	A	U	UN	2688	150.131
3/10/97	Reach 11A	11A-12B	LKWH	424	1290	A	F	PS	2689	150.164
3/10/97	Reach 11A	11A-12B	LKWH	455	1360	A	F	PS	2690	150.193
3/10/97	Reach 11A	11A-12B	LKWH	424	1540	A	F	PS	2691	150.274
3/10/97	Reach 11A	11A-12B	LKWH	420	1300	A	M	PS	2692	150.253
3/10/97	Reach 11A	11A-12B	WALL	430	870	A	U	UN	2694	150.334
3/10/97	Reach 11A	11A-12B	WALL	411	770	A	U	UN	2695	150.223
4/10/97	Reach 5B	5A-6A	LKWH	420	1200	A	M	PS	2426	150.233
4/10/97	Reach 5B	5A-6A	LKWH	448	1450	A	U	UN	2427	150.311
4/10/97	Reach 5B	5A-6A	LKWH	496	1850	A	M	PS	2428	150.463
4/10/97	Reach 5B	5A-6A	LKWH	475	1640	A	M	PS	2429	150.294
4/10/97	Reach 5B	5A-6A	LKWH	415	930	A	M	PS	2430	150.264
4/10/97	Reach 5B	5A-6A	LKWH	456	1490	A	U	UN	2431	150.212
4/10/97	Reach 5B	5A-6A	LKWH	429	1500	A	F	PS	2432	150.113
4/10/97	Reach 5B	5A-6A	LKWH	465	1790	A	F	PS	2433	150.473
4/10/97	Reach 5B	5A-6A	LKWH	399	970	A	M	PS	2434	150.443
4/10/97	Reach 5A	5A-6A	WALL	439	870	A	U	UN	2435	150.383
4/10/97	Reach 5A	5A-6A	WALL	480	1100	A	U	UN	2436	150.403
5/10/97	Reach 1A	1A- Bottom	LKWH	410	960	A	U	UN	2416	150.243
5/10/97	Reach 1A	1A- Bottom	LKWH	420	1310	A	M	PS	2417	150.173
5/10/97	Reach 1A	1A- Bottom	LKWH	390	1000	A	F	PS	2418	150.144
5/10/97	Reach 1A	1A- Bottom	WALL	503	1220	A	U	UN	2419	150.371
5/10/97	Reach 1A	1A- Bottom	WALL	495	1310	A	U	UN	2420	150.154
5/10/97	Reach 1A	1A- Bottom	WALL	524	2010	A	U	UN	2421	150.183
5/10/97	Reach 1A	1A- Bottom	WALL	451	930	A	U	UN	2422	150.282
5/10/97	Reach 1A	1A- Bottom	WALL	435	940	A	U	UN	2423	150.412
6/10/97	Reach 10A	12B-Bottom	WALL	605	2820	A	U	UN	4537	150.353
6/10/97	Reach 10A	12B-Bottom	WALL	475	1210	A	U	SD	4738	150.433
6/10/97	Reach 17A	16B-17B	WALL	545	1670	A	U	UN	4545	150.123

3.3.4.1 Lake Whitefish

Eighteen lake whitefish were radio-tagged during the fall boat electrofishing surveys on the Athabasca River. Tagged lake whitefish ranged in length from 390 to 496 mm and 930 to 1850 g in weight (Table 3.19). All fish were classified as adults (Table 3.19). Although these fish were captured within the known spawning period for this species, the individuals captured were not yet in spawning condition: half of the tagged fish were classified as unknown stage and the other half were at a pre-spawning development stage. The sex of these fish was determined for 15 of the 18 fish; eight females, seven males and one fish of unknown sex. Eight of the tagged lake whitefish were captured in the Steepbank River Area (Reaches 4, 5 and 6) of which five fish were identified as males, two as females and one fish as sex unknown. The other 8 lake whitefish were captured at the bottom of the Poplar Creek Area (Reach 1A) and in the Muskeg River Area (Reaches 10, 11 and 12). Findings are discussed for each flight. A summary of findings is also provided for each species at the end of this section.

Flight One (October 7)

Of the total number of radio-tagged lake whitefish, four were located during the first flight, between the Steepbank and Muskeg river areas (Figure 3.30). Two of these fish were found near the mouth of the MacKay River.

Flight Two (October 21)

Only two lake whitefish were located during the second flight (150.173 - L4 and 150.463 - L17) (Figure 3.31). Both fish were found just below Fort McMurray.

Flight Three (October 28)

Sixteen tagged lake whitefish were located during the third flight. Nine of these were located at or near Mountain Rapids (Figure 3.32). As two of these fish were already in close proximity to this area the previous week, the spawning period for this species at this site may have started around the second week of October.

Two fish were located at the mouth of the Muskeg River. One fish, identified at the frequency 150.113 (L1), was located in the area adjacent to Shipyard Lake. Three of the fish moved further downstream from their tagging/release locations and were either found further downstream or not located in the Athabasca River system on any of the following flights (Figure 3.33). The lake whitefish at frequencies 150.212 (L6) and 150.243 (L8) were last located near the mouth or downstream of Grayling Creek. These fish may have migrated downstream to overwinter in Lake Athabasca.

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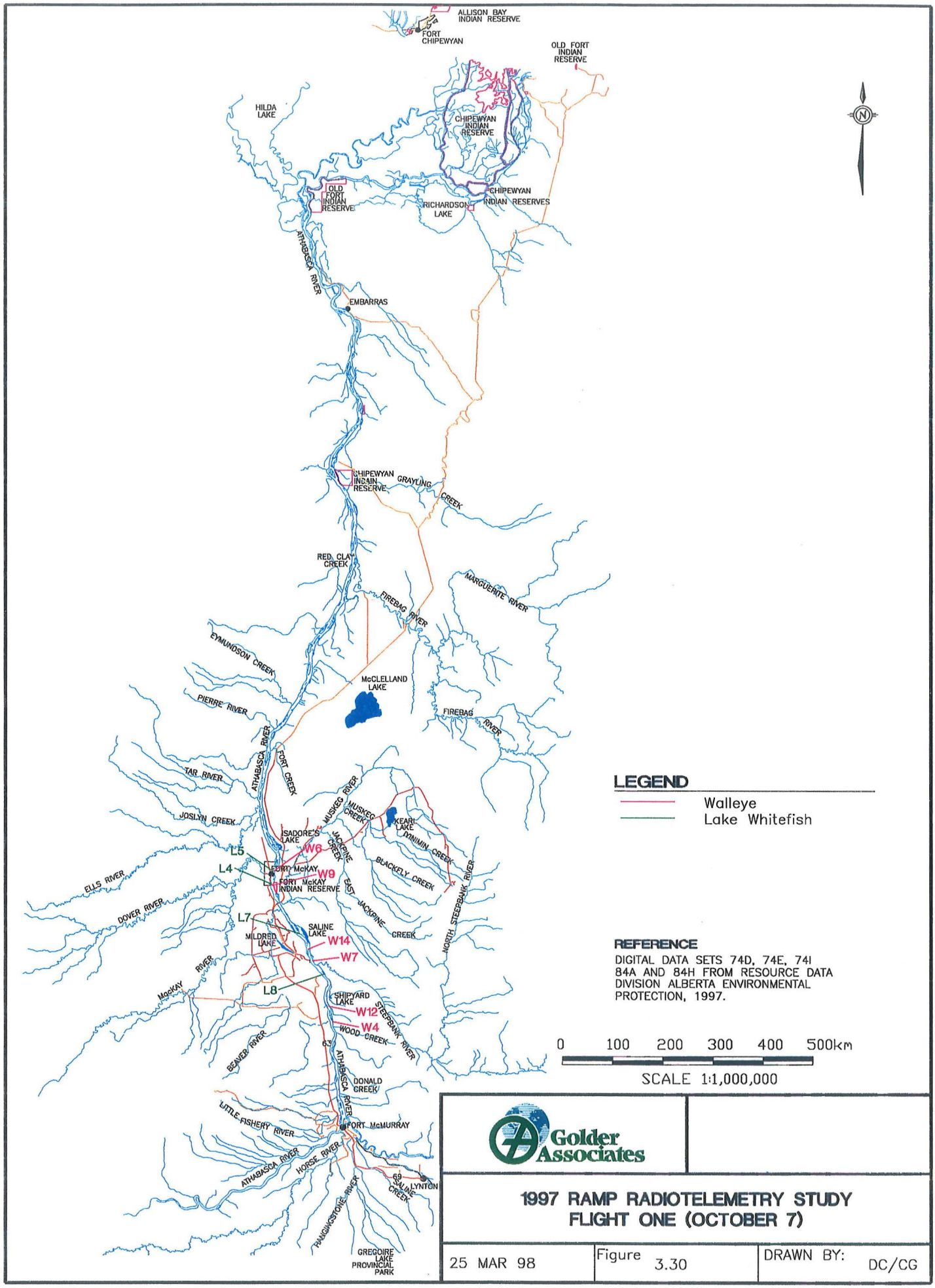

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY
FLIGHT ONE (OCTOBER 7)

25 MAR 98	Figure 3.30	DRAWN BY: DC/CG

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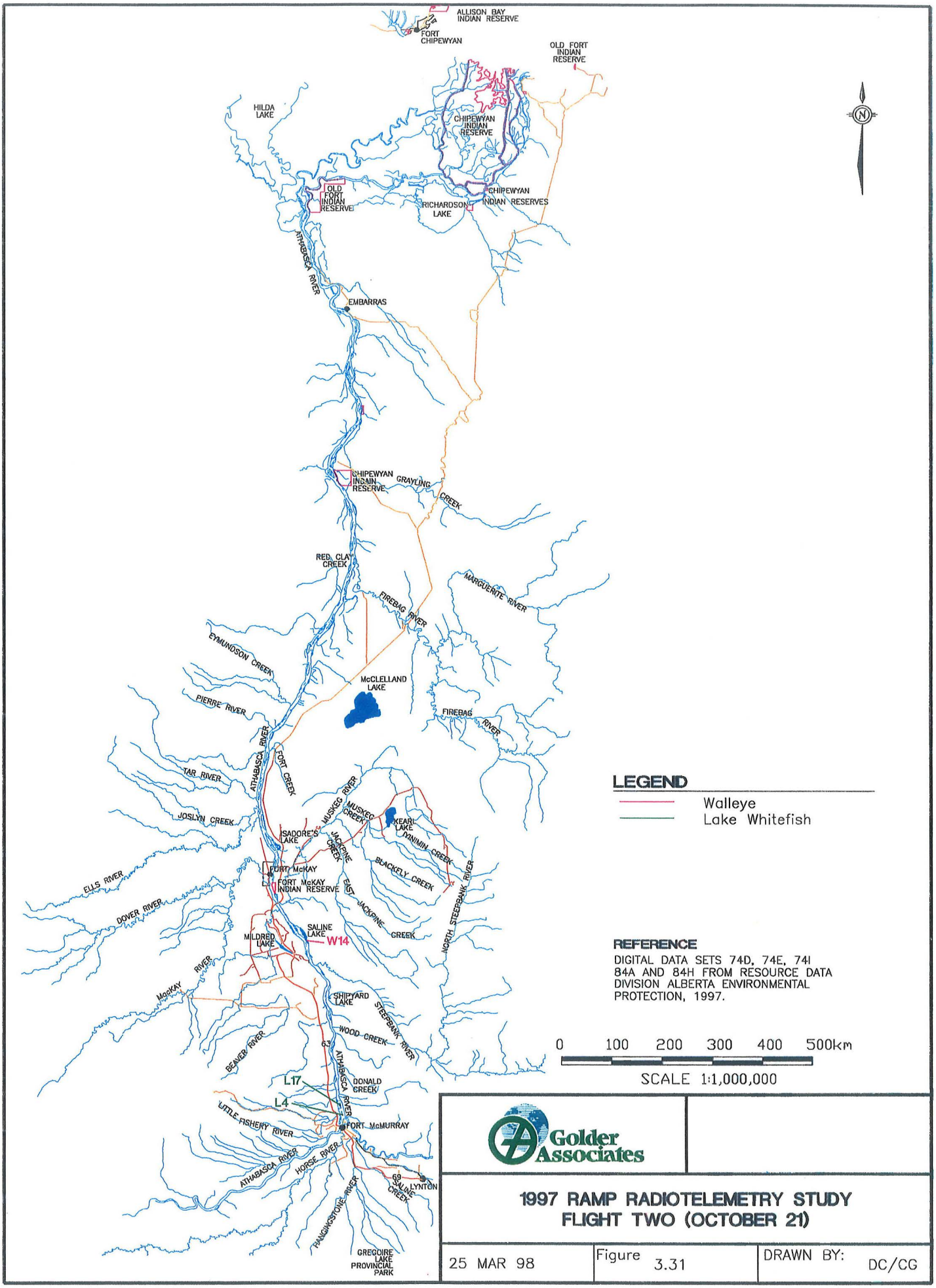

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY FLIGHT TWO (OCTOBER 21)

25 MAR 98	Figure 3.31	DRAWN BY: DC/CG

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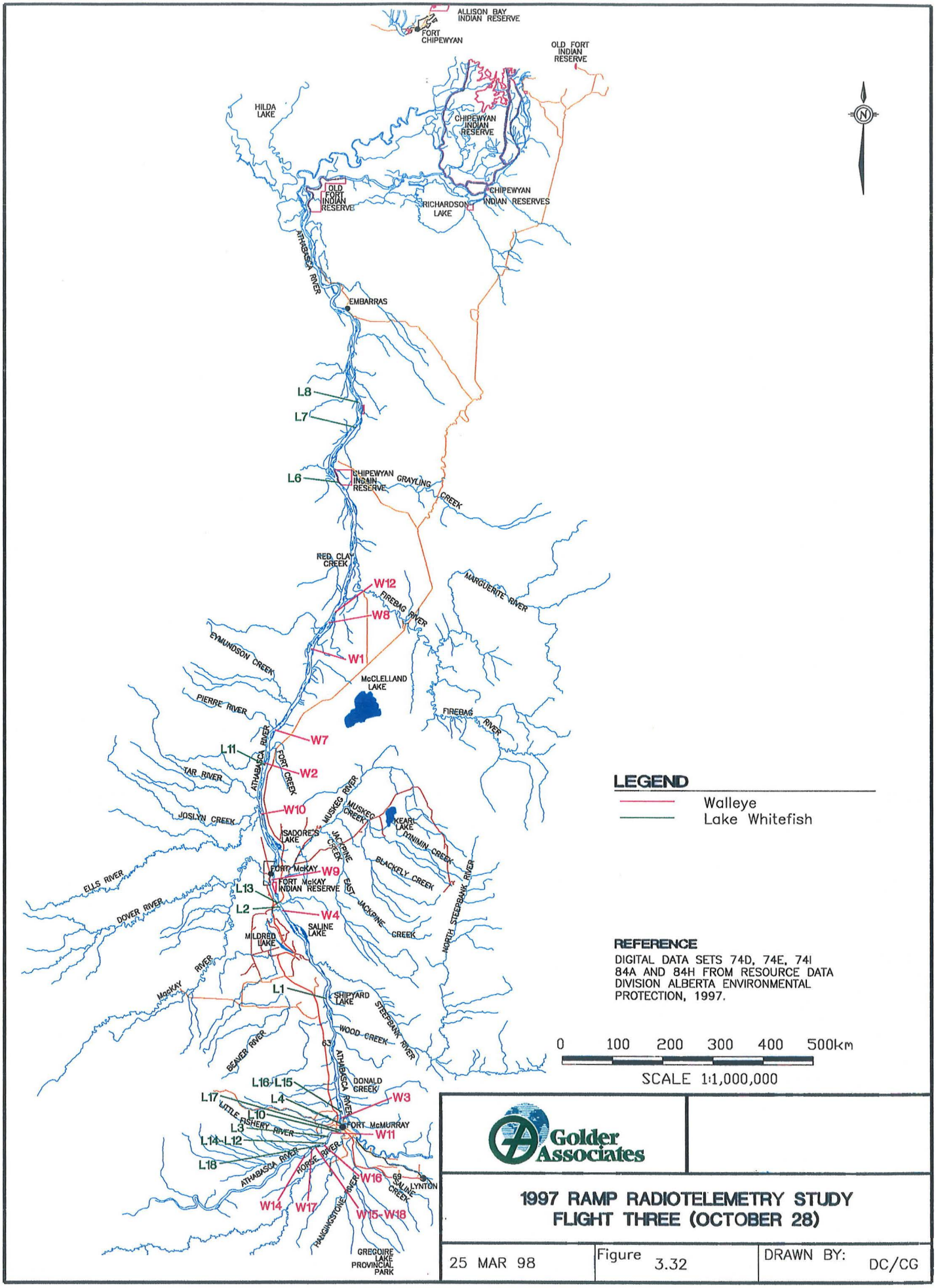

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY
FLIGHT THREE (OCTOBER 28)

25 MAR 98	Figure 3.32	DRAWN BY: DC/CG

Flight Four (November 4)

Two lake whitefish were located during the fourth flight (Figure 3.33). The fish at frequency 150.164 (L3) was located near Stoney Island (between Donald and McClean creeks). The other fish (150.394 - L15) was located just downstream of Fort McMurray, only a few kilometers from the position recorded the previous week.

With the exception of these two lake whitefish, most of the fish that were identified at the Mountain Rapids the previous week moved out of this area by week four. Lake whitefish spawning in this area probably ended by the beginning of November.

Flight Five (November 12)

Four lake whitefish were located on week five of this study. These fish were found from the mouth of the MacKay River to as far downstream as within the limits of Wood Buffalo National Park (past Grayling Creek) (Figure 3.34). The lake whitefish at frequency 150.394 (L15), previously logged in flights three and four near Fort McMurray, moved downstream near the mouth of the MacKay River. The fish at frequency 150.274 (L11) was located within a few kilometers of its last known position, in the vicinity of the Ells River.

Flight Six (November 27)

Ten of the tagged lake whitefish were located during the sixth flight. Eight of these fish were found in the area adjacent to Shipyard Lake (Figure 3.35). Lake whitefish often exhibit schooling behaviour (Scott and Crossman 1973) which might account for the high number of fish within this one area. The fish identified at frequency 150.394 (L15), which was also in the Shipyard Lake region, was located downstream of the Firebag River during flight seven (Figure 3.36), indicating a progressive downstream movement. Most of the other fish located in the Shipyard Lake area were not located on any of the following flights. These fish may also have moved further downstream in the direction of the Peace-Athabasca Delta.

One fish (150.463 - L17) was located downstream of Grayling Creek during flight six. Since this fish was not picked up on any of the following flights, and considering its last known position, it is assumed it has migrated to the lake to overwinter.

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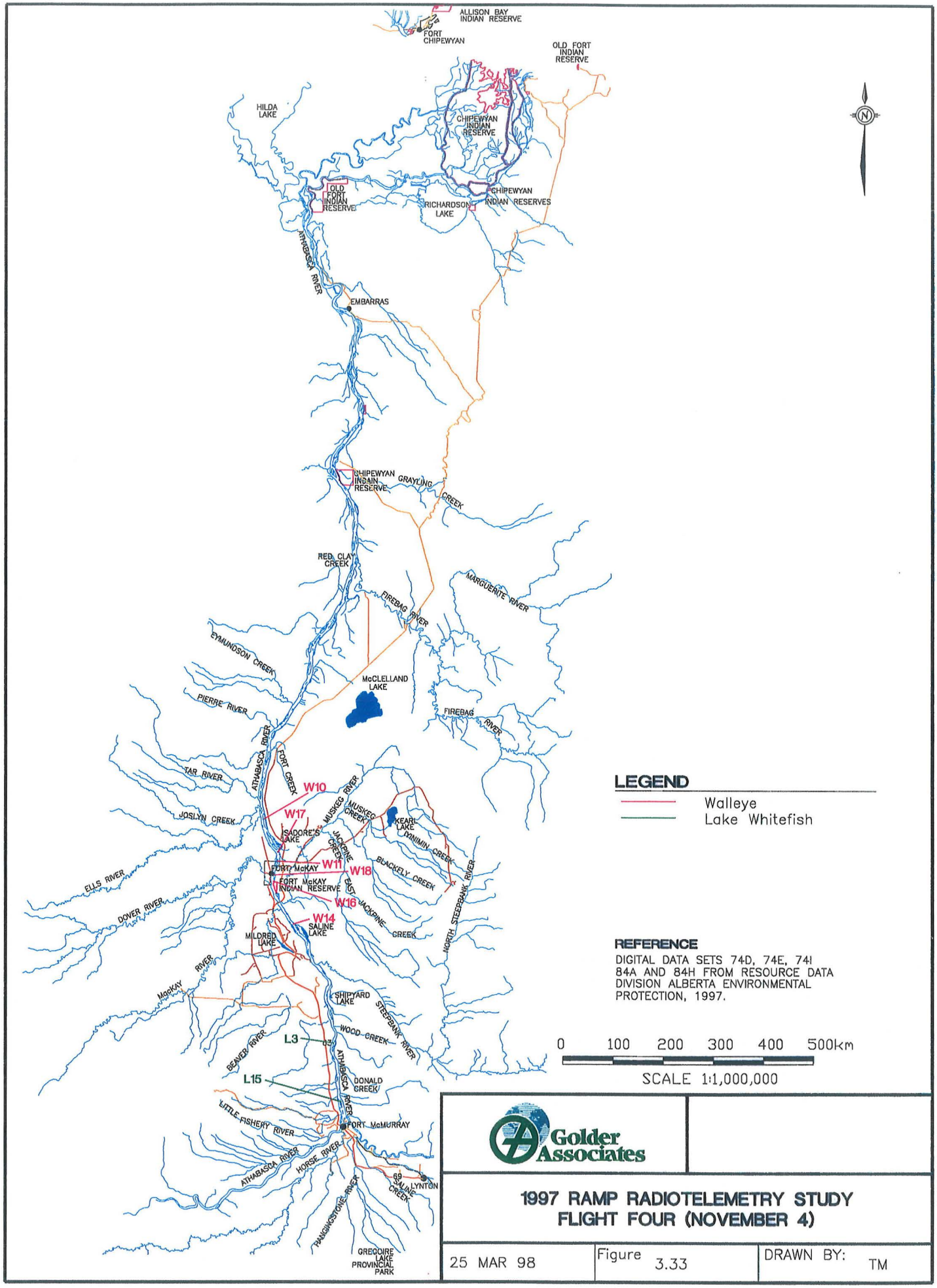

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY
FLIGHT FOUR (NOVEMBER 4)

25 MAR 98	Figure 3.33	DRAWN BY: TM

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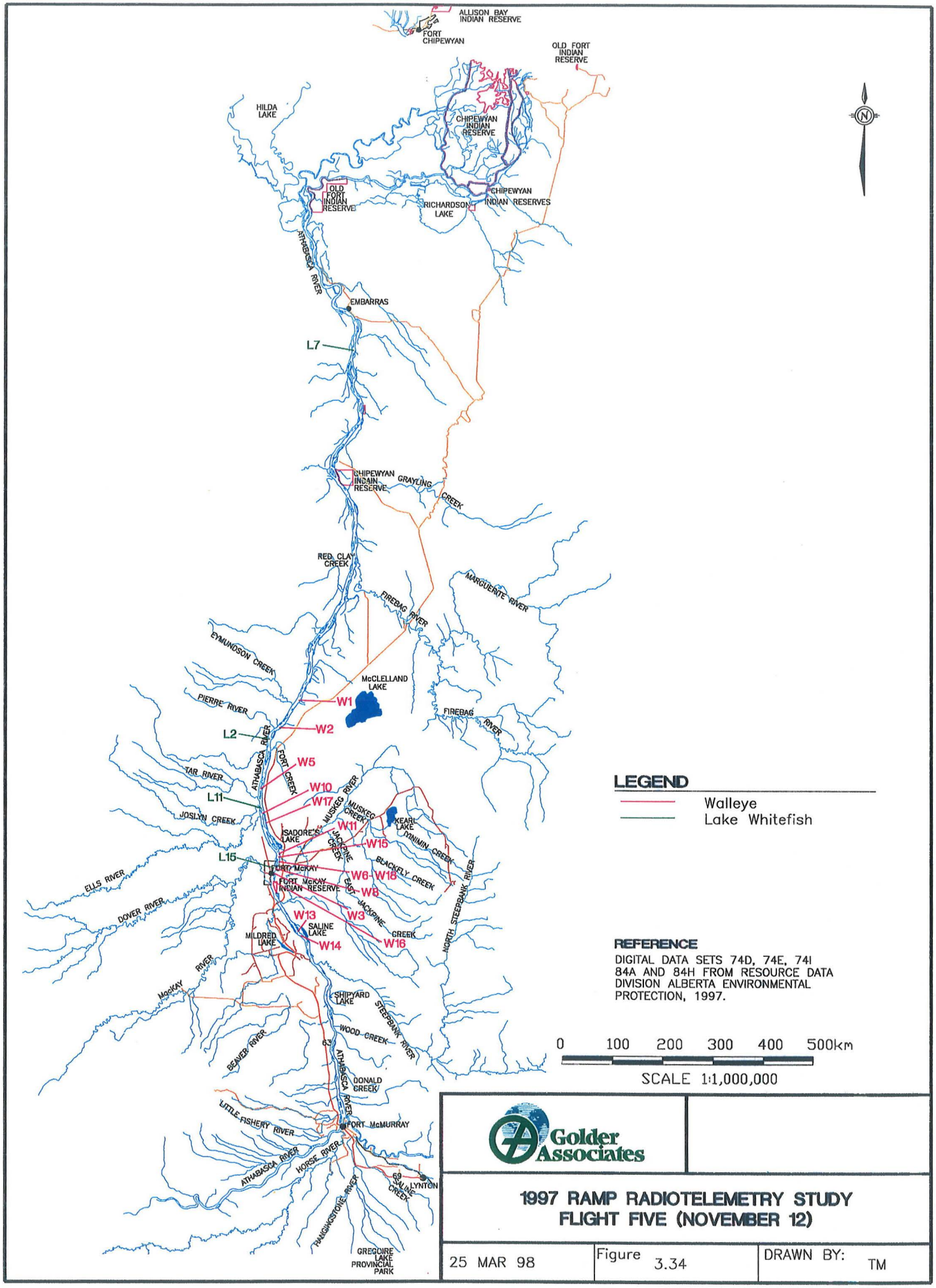

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY
FLIGHT FIVE (NOVEMBER 12)

25 MAR 98	Figure 3.34	DRAWN BY: TM

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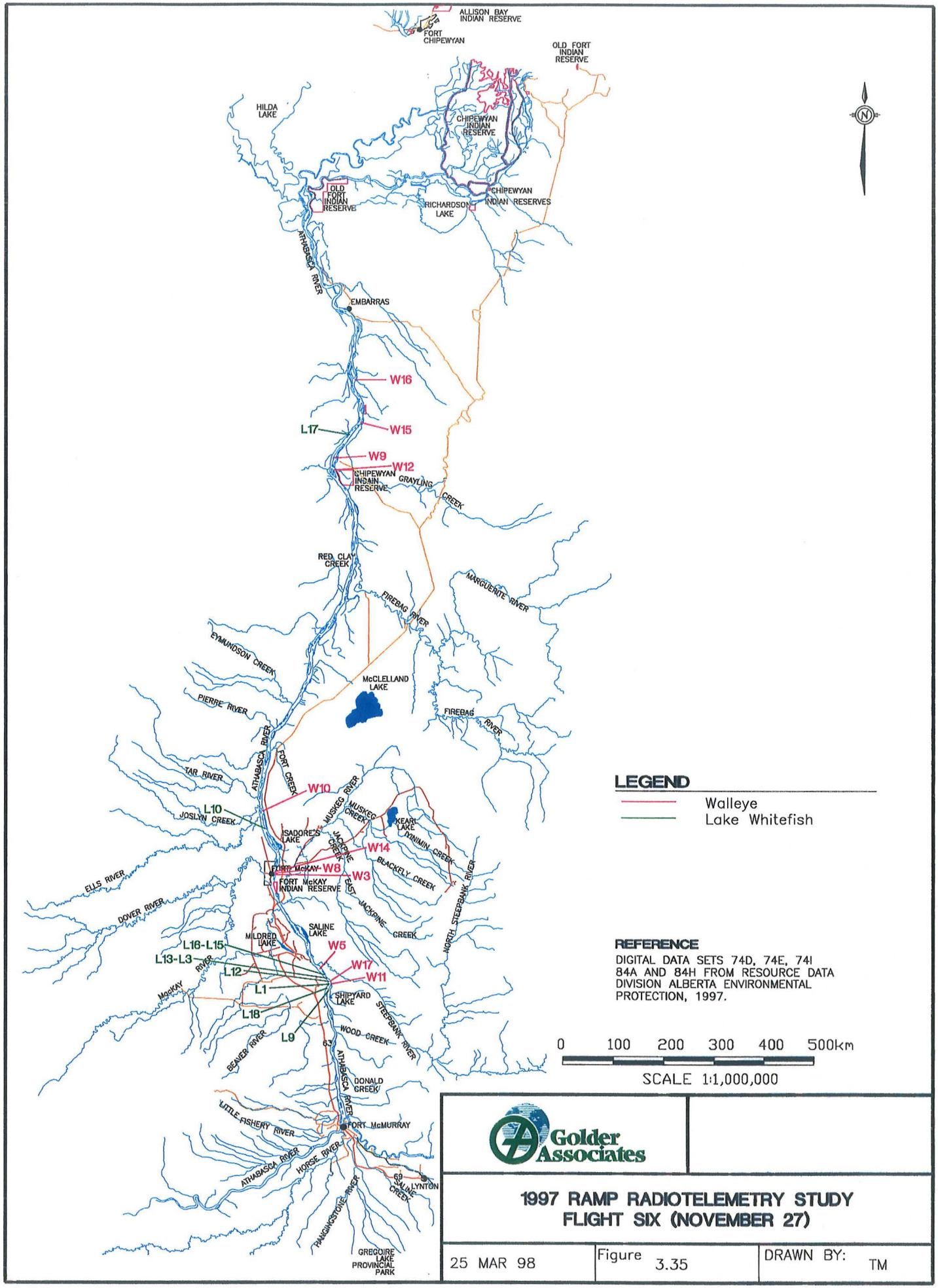

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY
FLIGHT SIX (NOVEMBER 27)

25 MAR 98	Figure 3.35	DRAWN BY: TM

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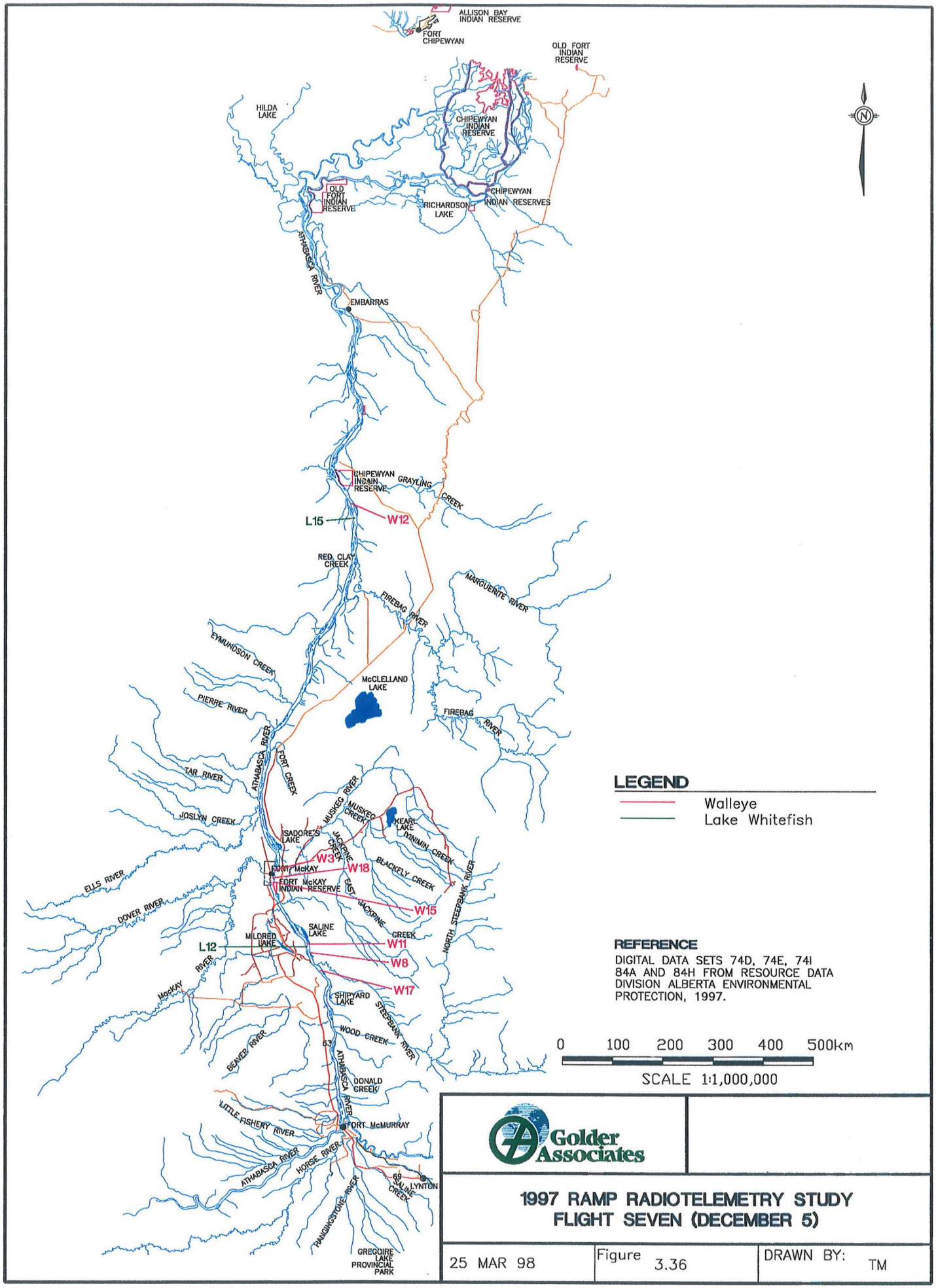

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY
FLIGHT SEVEN (DECEMBER 5)

25 MAR 98	Figure 3.36	DRAWN BY: TM

Flight Seven (December 5)

Only two lake whitefish were located during flight seven (Figure 3.36). One fish (150.294 - L12) was found in the area adjacent to Saline Lake while the other (150.394 - L15) was located downstream of the Firebag River.

Flight Eight (December 15)

There were no lake whitefish located during flight eight.

Flight Nine (December 22)

Two lake whitefish were located on December 22 (Figure 3.38). The fish identified as 150.144 (L2) was located near the mouth of the MacKay River, while the other fish (150.294 - L12) was found in the area adjacent to Saline Lake. It is not clear if these fish will overwinter in these areas or migrate downstream at a later date.

Summary of Findings

Information from the radiotelemetry study indicates that the spawning period for lake whitefish ranged from the second week of October until the beginning of November. One-half of the tagged fish were located upstream from their capture/release sites at Mountain Rapids on the third flight. This area was identified as a spawning ground for lake whitefish by Tripp and McCart (1979) and R.L. & L. (1994).

Lake whitefish movements varied from one flight to the next. Individual fish did not seem to favor a particular area for a long period of time. However, a certain number of fish were associated with the mouths of Athabasca River tributaries, such as the Ells, MacKay and Steepbank rivers. A number of fish were also found in the area adjacent to Shipyard Lake in the same week.

Few fish were located by the beginning of December. The group of fish located in the area adjacent to Shipyard Lake on flight six may have migrated to Lake Athabasca to overwinter. Two fish (150.233 and 150.463) were both found in areas that were downstream of Grayling Creek on flight five and six respectively, and are therefore believed to have migrated to Lake Athabasca.

Five of the radio-tagged lake whitefish were last located at sites downstream of the Firebag River or Grayling Creek. These areas could be considered far enough downstream to indicate that these fish may have migrated to Lake Athabasca to overwinter. However, as there are no clear data on the position of the other tagged fish, further investigations are

needed to clarify the presence of lake whitefish in the Athabasca River during the winter months.

3.3.4.2 Walleye

In total, 111 walleye were captured during the fall boat electrofishing surveys on the Athabasca River, of which 18 were radio tagged. The 18 tagged walleye ranged from 411 to 655 mm in length and 690 to 3630 g in weight. All fish were classified as adults (Table 3.19). More than half (56 %) of the walleye that were radio tagged were captured from the Muskeg River Area (reaches 10, 11 and 12) which had the highest capture rate of all four sampling areas.

Flight One (October 7)

Six walleye were located during the first flight (Figure 3.30). There were all found in close proximity to the release areas between the Poplar Creek and Muskeg River Areas, at the mouths of Leggett Creek and MacKay River and in the area adjacent to Saline and Shipyard lakes (Appendix X).

Flight Two (October 21)

Only one walleye was located during the second flight (frequency 150.403 - W14). It was found in the area adjacent to Saline Lake, close to the location it was identified at in the first flight (Figure 3.31).

Flight Three (October 28)

A large number of fish were located during the third flight. Seven of the fifteen walleye found during this flight were located at Mountain Rapids (Figure 3.32). These results indicate a close association between walleye and lake whitefish during the latter species' spawning activities.

The other eight walleye were located in the Muskeg and Tar-Ells River areas, associated with the mouths of the Muskeg, MacKay, Ells and Tar rivers and downstream of Fort Creek (150.371 - W12, 150.303 - W8 and 150.104 -W1) (Figure 3.32). Although these fish were located much further downstream than other fish in the study, on following flights they were recorded moving upstream, showing the extent of the walleye movements in the river.

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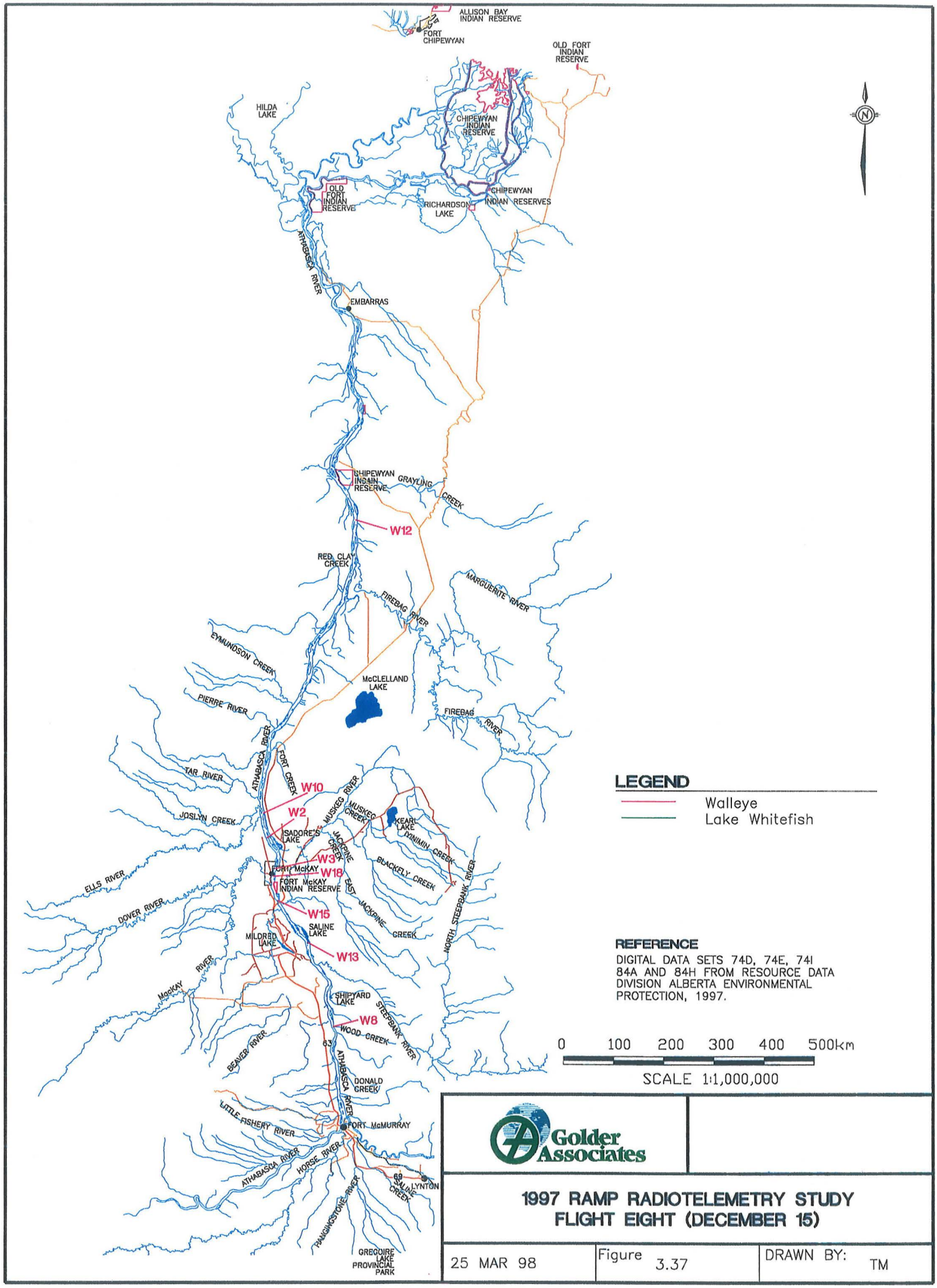

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY
FLIGHT EIGHT (DECEMBER 15)

25 MAR 98	Figure 3.37	DRAWN BY: TM

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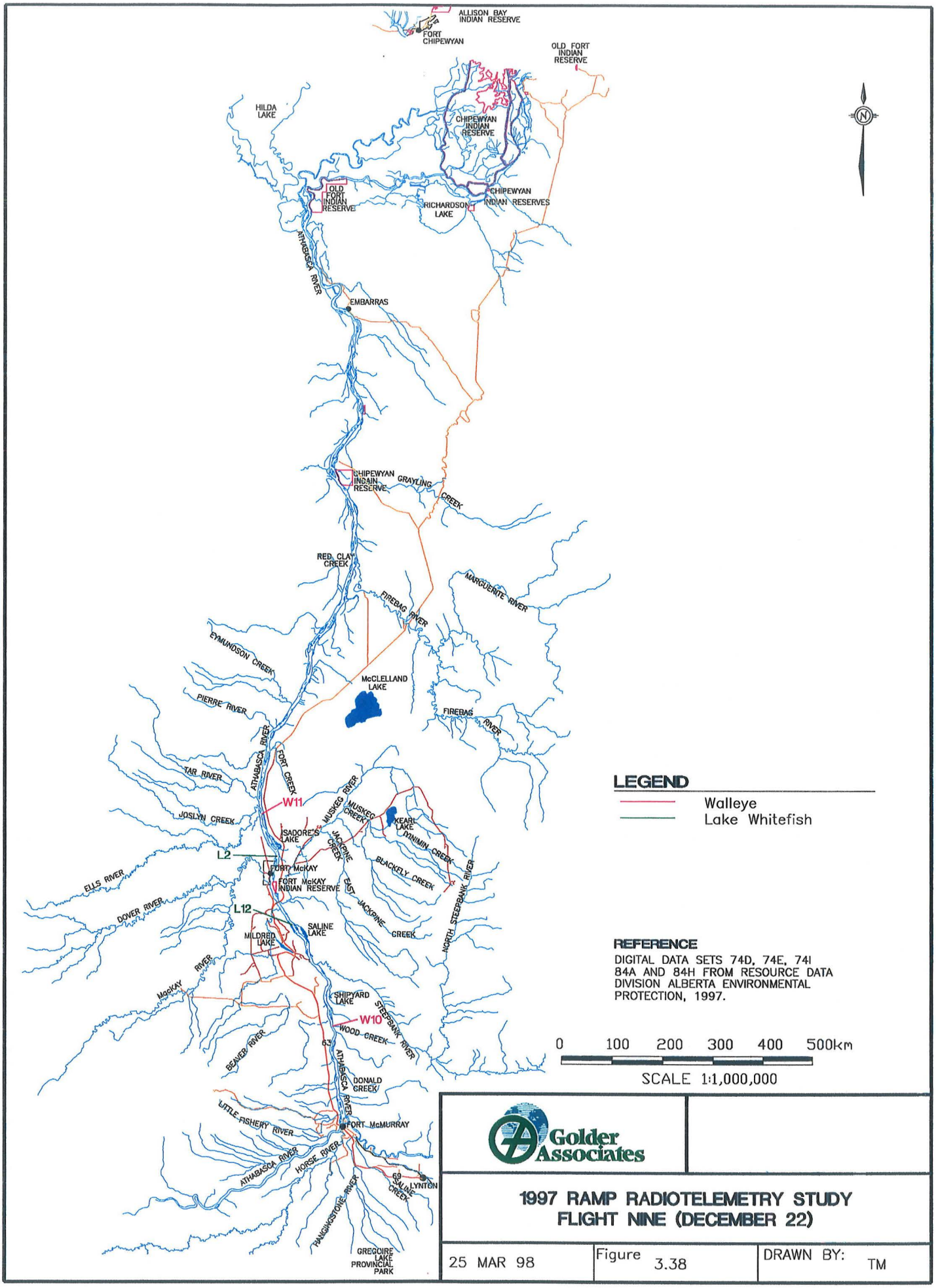

Golder Associates

1997 RAMP RADIOTELEMETRY STUDY
FLIGHT NINE (DECEMBER 22)

25 MAR 98	Figure 3.38	DRAWN BY: TM

Flight Four (November 4)

Six of the tagged walleye were located during the fourth flight between the mouth of the MacKay and Ells rivers and in the area adjacent to Saline Lake (Figure 3.33). None of the walleye located at Mountain Rapids during the previous flight were found at that location during flight four. The individuals that were located at this site moved downstream to the Muskeg River Area (frequencies 150.353 - W11, 150.424 - W16, 150.433 -W17 and 150.454 - W18) and in the area adjacent to Saline Lake (150.403 - W14).

Flight Five (November 12)

Fourteen of the total number of walleye tagged for this study were located during flight five. One-half of these fish were found at and around the mouth of the MacKay River (Figure 3.34). The other seven fish were located downstream of Fort Creek (150.104 - W1 and 150.123 - W2), within the area adjacent to Saline Lake and at the mouths of the Ells and Tar rivers.

Four of the tagged walleye were not located on the subsequent flights. The last recorded position of two of these fish was downstream of the Firebag River indicating that they were probably moving downstream to Lake Athabasca. These fish may have moved to overwintering sites in the lake. The last known positions of the walleye at frequencies 150.154 (W4) and 150.223 (W6) were near the mouths of the Muskeg and MacKay rivers, respectively (Figure 3.34).

Flight Six (November 27)

At week six of the telemetry study, eleven tagged walleye were located. Their positions ranged from an area adjacent to Shipyard Lake to downstream of the Firebag River (Figure 3.35). Two fish were located in the area adjacent to Shipyard Lake and one near the mouth of the Steepbank River. Four walleye were located near the mouths of the MacKay (3) and Ells River (1) A few fish (4) moved downstream, either near or past the mouth of Grayling Creek, two of which (150.324 -W9 and 150.424 - W16) were not located in subsequent flights. These fish may have migrated to Lake Athabasca to overwinter. These two fish were captured and released within the Muskeg River Area and were located near the mouth of the MacKay River during previous flights, indicating that this area is favored by walleye.

As for the other two walleye that moved past Grayling Creek, one fish (150.371 - W12) moved about 38 km upstream in the following two weeks and the other (150.412 - W15) migrated upstream near the mouth of the MacKay River. Both these fish had been released near the mouth of Leggett Creek and subsequently moved downstream.

Flight Seven (December 5)

Seven tagged walleye were located week during flight seven (Figure 3.36). Of these, three fish were still found in the vicinity of the MacKay River (150.131 - W3, 150.412 - W15 and 150.454 - W18) having been located in this area on previous flights. The walleye with frequency 150.412 was located downstream of Grayling Creek during the previous flight but moved back upstream near the mouth of the MacKay River during flight seven.

Three of the located walleye were found within and upstream of the Steepbank River Area (Figure 3.36).

Flight Eight (December 15)

A total of eight fish was identified near the mouths of the Muskeg, MacKay and Ells rivers and from Wood Creek to the area adjacent to Saline Lake during this eight flight (Figure 3.37). The fish within the Muskeg and Tar-Ells River Area were also located in these areas on previous flights. However, two walleye identified at frequencies 150.353 (W11) and 150.303 (W8) progressively moved upstream from near the MacKay River to as high as Wood Creek by week eight, indicating that fish vary in the extent of movement within the Athabasca River.

Flight Nine (December 22)

Only two walleye were located during this last flight of the 1997 field season. One fish (150.353 - W11), located in the area adjacent to Saline Lake on flight seven was found near the mouth of the Ells River on this flight. The other fish (150.334 - W10) migrated from the area it had been located in for the past weeks (mouth of the Ells River) to the Poplar Creek Area (between Wood and McClean creeks) (Figure 3.38).

Summary of Findings

Walleye movements varied greatly over the fall monitoring period. A general pattern was not observed. Rather, walleye seem to use different areas of the Athabasca River at different times of the fall season. Seven of the tagged walleye moved to the Mountain Rapids following the spawning migration of lake whitefish. Four walleye were located in the vicinity of the MacKay River during consecutive flights, indicating this area is favored by walleye. Many walleye were found at the mouths of Athabasca River tributaries, such as the MacKay, Muskeg and Ells rivers.

Seven walleye were located in the last two weeks of December (flights eight and nine). These fish could be overwintering at the mouths of certain tributaries (MacKay, Ells, Muskeg and Steepbank rivers and Wood Creek) and possibly in the areas adjacent to Saline and Shipyard lakes, where they

were last located. Winter flights are needed to verify the position of these fish.

It is not known if the other walleye are still in the Athabasca River or have moved to Lake Athabasca. Historical studies hypothesized that walleye migrate to the lake to overwinter (Tripp and McCart 1979). However, this assumption could not be verified with study results to date.

3.4 AQUATIC VEGETATION

3.4.1 Shipyard Lake

3.4.1.1 General Description

Shipyard Lake is a riparian wetlands complex located adjacent to Suncor's Steepbank 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 dominant vegetation are cattails, sedges and willows. The main water courses 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.

3.4.1.2 Wetlands Complexes and Species Composition

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).

The broad wetlands classes are shown in Table 3.20 and in Figure 3.39. Plots surveyed with percent cover are presented in Table 3.21.

Table 3.20 Alberta Wetland Inventory Wetlands Represented in Shipyard Lake

AWI Class	AWI Subclass	Number of Wetland Types	Areas of Shipyard Lake	
			(ha)	(%)
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

Shipyard Lake is a large riparian wetlands complex that includes shrubby marshes (Mons), graminoid marshes (Mong), shallow open water (Wonn), and open treed swamps (Stnn) (Table 3.20 and Figure 3.39). Marshes occupy the majority of the Shipyard Lake wetlands complex occurring on 130.3 ha or 77.3 %. Shallow open water occupies 26.9 ha or 16 % of the wetland complex. Treed swamps occupy 26.9 ha or 6.7 % and largely occur around the perimeter of the marsh-shallow open water areas (Figure 3.39). A brief description of these wetland types is provided as follows:

Table 3.21 Vegetation Cover Percent for Shipyard Lake

Plot I.D		Veg. Type				% Cover by Category						
*Transect	Plot no.	Wetland	Dominant	Co-Dominant 1	Co-Dominant 2	% Shrub	% Grass	% Herb	% Aquatics	% Open Water	% Bare	Total
SL/1	1	Wonn	Open Water			-	-	-	1	99		100
SL/1	2	Mong	Cattail	Sedge		-	-	-	75	25		100
SL/1	3	Mong	Cattail			-	-	-	75	25		100
SL/2	1	Mong	Cattail	Sedge	Marsh Cinquefoil	-	-	10	70	20		100
SL/3	1	Wonn	Open Water			-	-	-	5	95		100
SL/3	2	Mong	Cattail	Water Arum		-	-	-	70	30		100
SL/4	1a	Mong	Horsetail			-	-	-	80	20		100
SL/4	2	Mons	Willow	Water Arum	Sedge	60	-	-	20	10		100
SL/4	1b	Wonn	Open Water			-	-	-	-	100		100
SL/5	1	Wonn	Open Water			-	-	-	-	100		100
SL/5	2	Mong	Cattail	Sedge		-	-	5	85	10		100

*Transects were recorded on aerial photographs during the time of sampling

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 a 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. They are dominated instead by sedges, rushes and cattails. 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 or the year.

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

Graminoid marshes occupy 70.7 ha, or 41.9 % and shrubby marshes occurred on 59.6 ha, or 35.4 % of the wetland complex. Graminoid

marshes surveyed within Shipyard Lake were on "floating vegetated mats". As a result, the root system was not in the sediment. The species composition consisted of aquatic macrophytes or submergent vegetation such as coontail and mare's tail. The emergent vegetation was dominated by cattail and sedges (Table 3.22). The herb layer is composed of water arum, white pond lily, yellow pond lily, common bladderwort, marsh cinquefoil, rat root and water parsnip, spike-rush, bulrush and rush (Table 3.22). Brown moss may also be present. However, no mosses were observed during field investigations. Shrubby marshes were composed primarily of willows (Table 3.22).

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 (Table 3.22).

Open Treed 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 3.39). 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 near 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 class (Table 3.21 and Figure 3.39). 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).

3.4.1.3 Water Quality

Water quality parameters were measured at the beginning of each transect in the area of deepest water. The pH, salinity and conductivity measurements provide some indication of the growing environments the plants are adapted to. Although marshes are generally adapted to fluctuations in water quality; large or sudden increases may result in toxicity effects (i.e., necrosis or chlorosis) in plant species. A change in pH,

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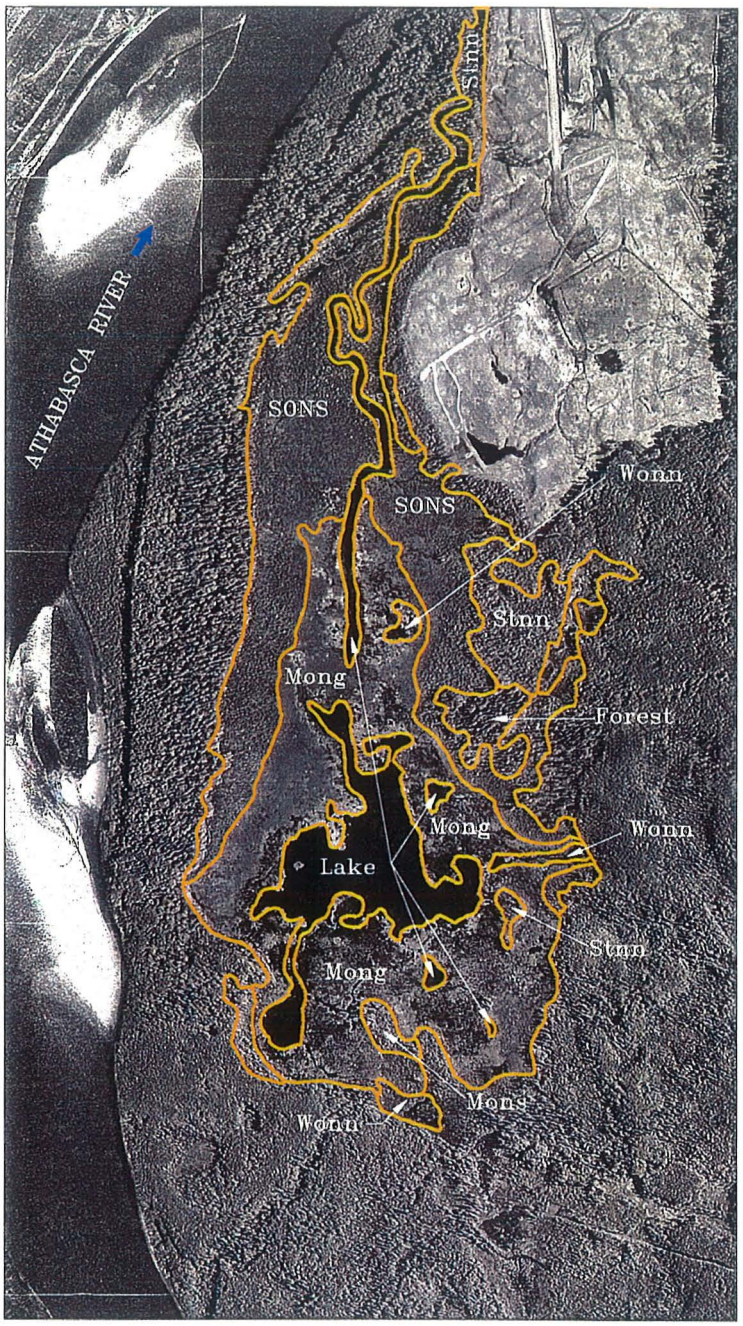


0 500 1000 metres

LEGEND

Mong – Graminoid Marsh
Mons – Shrubby Marsh
Sons – Shrubby Swamp
Stnn – Treed Swamp

REFERENCE

The Orthoshop
The Forestry Corp.

Golder Associates

SHIPYARD LAKE WETLANDS

27 Mar. 1998	Figure 3.39	DRAWN BY: CG

Table 3.22 Plant Species and Percent Cover for Shipyard Lake

		%																														
Plot I.D.		Shrubs		Grasses	Forbs		Aquatics																									
Transect	Plot no.	Beaked Willow	Total	Total	Nortern Bedstraw	Total	Sedge I	Awned Sedge	Beaked Sedge	Purple-leaved Willowherb	Wire rush	spiked water milfoil	Cattail	Common scouring-rush	White Pond Lily	Tufted Loosestrife	Smart Weed	Duck weed	Coontail	Small-Leavewate Arum	Arum- Leaved Arrowhead	Common Blatter Wort	Rat Root	Water Parsnip	Yellow Pond Weed	Yellow Crowfoot	Water - Crowfoot	Marsh Cinqifoil	Marsh Sinquefoil	Sedge IV	Water Arum	Total
SL/1	1		0	0		0																										0
SL/1	2		0	0		0	15	5	5			5	50					<5	<5	10	10											100
SL/1	3		0	0		0						5	70		20			<5	<5			5										100
SL/2	1		0	0		0	5	5	5		10		40			5		<5				<5	5	5			<5		10	5	5	100
SL/3	1		0	0		0							100																			100
SL/3	2		0	0		0				10			60		10			<5					<5									20	100
SL/4	1a		0	0		0						5	10	85				<5	<5													100
SL/4	2	100	100	0		0	10		10			5	5				10	<5	<5						5		5				50	100
SL/4	1b		0	0		0						45					45	10														100
SL/5	1		0	0		0												100														100
SL/5	2		0	0	100	100	5		5	5	5		30			5		5					10	5			5	10			10	100

SL/1 1 was a water sampling plot only

for example, has been documented to delay flowering in some plants (Gordham et al 1984). Water quality parameters such as pH, salinity and conductivity are the most often used to assess wetland plant growing environments. The baseline water parameters, presented in Table 3.23 indicate that Shipyard Lake's pH was neutral (ranging from 6.99 to 7.26) .which is typical of marsh systems (Table 2.6). The salinity was generally low ranging from 0.13 to 0.16 g/l. Conductivity measurements range from 0.228 to 0.331 mS/cm. Dissolved oxygen percent, recorded as percent saturation, ranged from 27.8 to 50.8 % saturation. Dissolved oxygen, expressed as miligrams per litre, ranged from 1.81 to 4.13 mg/l.

Table 3.23 Water Quality Parameters Recorded in Shipyard Lake

Transect	Depth (m)	Temp. (°C)	DO% (% saturation)	DO (mg/l)	Cond. (mS/cm)	Sal. (g/l)	TDS (g/l)	pH
1	>2m	17.71	43.7	3.87	0.331	0.16	0.21	7.07
2	>2m	19.08	27.8	2.45	0.283	0.14	0.18	7.26
3	>2m	21.01	28.1	2.44	0.301	0.15	0.19	7.19
4	>2m	21.21	23.0	1.81	0.228	0.14	0.18	6.99
5	>2m	23.09	50.8	4.13	0.279	0.13	0.18	7.10
5	>2m	24.6	29.8	2.33	0.321	0.16	0.21	6.99

3.4.1.4 Vegetation Vigour

Vegetation vigour, recorded for each cover class observed, is presented in Table 3.24. Generally, the overall vigour rating (AEP 1994) for all cover classes was very good for the majority of the shrub, herb and aquatic cover types. Transect SL/4-Plot 2, 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 annual fluctuations of water levels, providing constantly changing growth conditions.

Table 3.24 Percent Plant Vigour For Each Cover Type for Shipyard Lake

Plot I.D.		% Vigour																			
		Shrub					Grass					Herb					Aquatics				
Transect	Plot no.	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total
SL/1	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
SL/1	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	20	10	-	70	100
SL/1	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	20	10	-	70	100
SL/2	1	-	-	-	-	0	-	-	-	-	0	-	-	-	100	100	10	-	10	80	100
SL/3	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	20	80	100
SL/3	2	-	-	-	-	0	-	-	-	-	0	-	-	-	100	100	10	-	10	80	100
SL/4	1a	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	5	-	10	85	100
SL/4	2	40	60-	-	-	0	-	-	-	-	0	-	-	-	-	0	30	30	40	-	100
SL/4	1b	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	100 -	100
SL/5	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	100 -	100
SL/5	2	-	-	-	-	0	-	-	-	-	0	-	-	-	100	100	10	-	10	80	100

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

3.4.2 Lease 25 Wetlands

3.4.2.1 General Description

Lease 25 wetlands is a riparian wetlands complex located within the Athabasca River floodplain north of the Steepbank River. It is approximately 52.7 ha in size. The basin is surrounded by graminoid, shrub and treed fens. The vegetation is dominated by cattails, sedges, river alder and willows. A narrow channel to the north provides an outlet to the Athabasca River.

3.4.2.2 Wetland Complex and Plant Species Composition

Lease 25 Wetlands is a riparian wetlands complex comprised of shallow open water, graminoid fen, shrubby fen and treed fens (Figure 3.40). This wetland complex is approximately 52.7 ha is size. Table 3.25 provides a summary of the broad characteristic wetlands classes while Table 3.26 shows the percent cover of tree, shrub, herb, grasses, aquatic and open water classes. Table 3.27 shows the plant species recorded for each plot surveyed along representative transects.

The dominant wetland complex is an open, non-patterned, shrubby fen (Fons) comprising 43.5% of the wetlands (Table 3.25 and Figure 3.40). A dominant, linear shallow open water basin is bordered by Fons wetlands, as well as graminoid fen types. These types, in turn, transition to an open treed fen (Ftnn) along the margin of the wetlands. The characteristics of these wetland types are described as follows.

Table 3.25 Alberta Wetland Inventory Wetlands Represented in Lease 25 Wetlands

AWI Class	AWI Subclass	Number of Wetland Types	Areas of Lease 25 Wetlands (ha)	(%)
Fen (F)	Open, non-patterned, shrubby fen (Fons)	2	22.9	43.5
	Open, non-patterned, graminoid fen (Fong)	2	12.7	24.1
	Wooded fen, no internal lawns (Ftnn)	2	5.0	9.5
Shallow Open Water	Shallow open water (Wonn)	3	2.8	5.3
Lake		1	9.3	17.6
Total		10	52.7	100.0

Shallow Open Water (Wonn)

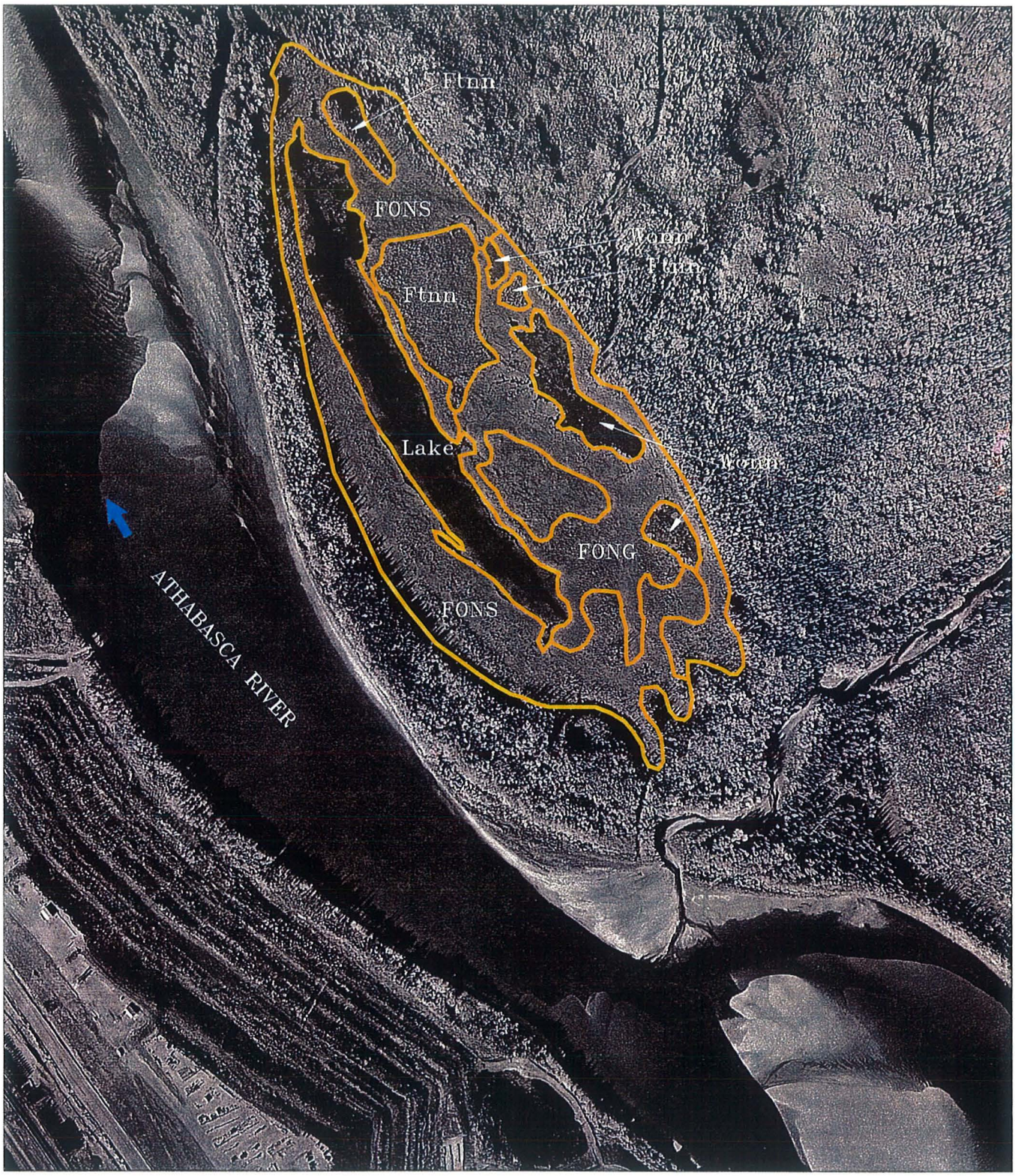
There are three distinct shallow open water wetlands that occupy 2.8 ha of the Lease 25 Wetlands. The wetlands consist primarily of submergent and emergent vegetation. Four plots within these areas were surveyed. The submergent vegetation consisted of coontail, small-leaved pondweed, flat-leaved pondweed, northern water-milfoil and white buttercup (Table 3.27). Less frequently observed were the free-floating aquatic plants, which consisted of small yellow pond-lily, and common duckweed (Table 3.27). Emergent vegetation consisted of cattail, sedges, narrow-leaved bur-reed, water arum, small-leaved arrowhead, and marsh cinquefoil (Table 3.27).

Graminoid Fen (Fong)

Graminoid fens are distinguished from graminoid marshes by the presence of mosses. The rate of decomposition is slower in these wetlands (Halsey and Vitt 1996). For this reason, peat accumulates and mosses and lichens are common (Halsey and Vitt 1996). Fens are also characterized by water flow (i.e., they may have inflow and outflow) (Table 2.6). Graminoid fens occupy 12.7 ha of the wetland complex. Graminoid fens plots were dominated by sedges and cattail (Table 3.26 and Table 3.27). Herbaceous and aquatic plants observed included: marsh cinquefoil, water arrum, yellow pond-lily, water hemlock, yellow-water crowfoot, and water arum. 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.

Shrubby Fen (Fons)

In shrub-dominated fens, shorter birch and willow are common. Shrub-dominated fens were located adjacent to graminoid fens and comprised 22.9 ha of the wetlands complex (Table 3.25). Shrubs observed include willow, and river alder. Other plants observed included sedges, cattail, rushes,



LEGEND

Fons – Shrubby Fen
Fong – Graminoid Fen
Ftnn – Treed Fen
Wonn – Shallow Open Water

0 100 200 300(m)

SCALE 1:10,000

REFERENCE

SCANNED AIRPHOTO FROM GEOGRAPHIC AIR SURVEY LTD. (24–09–94)

Golder Associates

LEASE 25 WETLANDS

27 MAR 98	Figure 3.40	DRAWN BY: RFM

Table 3.26 Vegetation Cover Percent for Lease 25 Wetlands

Transect	Plot no.	Wetland	Dominant	Co-Dominant 1	Co-Dominant 2	% Tree	% Shrub	% Grass	% Herb	% Aquatics	% Open Water	Total
L25/1	1	Wonn	Open Water	Duckweed	Coontail						100	100
L25/1	2	Fong	Sedge						5	80	20	105
L25/1	3	Wonn	Open Water	Sedge			10			30	60	100
L25/1	4	Fons	River Alder	Willow			60		10	20	10	100
L25/2	1	Wonn	Open Water								100	100
L25/2	2	Fong	Sedge	Cattail	Water Arum					80	20	100
L25/2	3	Fong	Sedge	Cattail						60	40	100
L25/2	4	Fons	Willow	River Alder			60		10	30		100
L25/2	5	Ftnn	Tamarack	Willow	Labrador Tea	50	30		20			100
L25/3	1	Wonn	Yellow Pond Lily	Open Water						70	30	100
L25/3	2	Fong	Sedge	Alder			20		5	35	40	100

*Transects were recorded on aerial photographs during the time of sampling

purple-leaved willowherb, water hemlock and water arum. Mosses included peat moss, and golden moss.

Open Treed Fens (Ftnn)

Shrubby fens transition to open treed fens at the margin of Lease 25 Wetlands. The open treed fen is dominated by tamarack with some black spruce. Treed fen comprised approximately 5 ha of the wetland complex. Only one plot was surveyed in the treed fen wetland. The tree layer was dominated by tamarack (50% of the plot) and a shrub layer consisting of river alder, willow, and Labrador tea (30% of the plot). Other plants observed included cattail, purple-leaved willowherb, marsh cinquefoil, and sedges (Table 3.27). Mosses included peat moss and golden moss.

3.4.2.3 Water Quality

Water quality parameters were only measured in the shallow open water classes where water depths ranged from 1.5 meters to >2 meters. The baseline water parameters are presented in Table 3.28. The pH ranged from 7.28 to 8.59 and was higher than Shipyard Lake. The salinity was generally lower than Shipyard Lake and ranged from 0.10 g/l to 0.11 g/l. Conductivity was also lower than Shipyard Lake, which ranged from 0.219 mS/cm to 0.239 mS/cm.

Table 3.27 Plant Species and Percent Cover for Lease 25 Wetlands

Plot I.D.			%																												
			Tree	Shrubs				Grasses	Aquatics																						
Transect	Plot no.	Wetlands Class	Tamarack	Willow I	River Alber	Labrador tea	Total	Total	Northern Bedstraw	Total	Sedge I	Awned Sedge	Narrow-leaved bur-reed	Cattail	Purple-leaved Willowherb	Wire Rush	Rush	Yellow Water Crowfoot	Narrow Leaved Bur-Reed	Tufted Loosestrife	Common Duckweed	Coontail	Northern Water Milfoil	Small-leaved pondweed	Flat-leaved pondweed	Small-Leavewate Arum	Common Blatter Wort	Yellow Pnd Lilly	Water hemlock	Marsh Cinqifoil	Water Arum	Total
L25/1	1	Wonn					0	0		0											30	40	20			5	5					100
L25/1	2	Fong					0	0	100	100	20	20	10	5			5	5		5	5					5				5	10	100
L25/1	3	Wonn		100			100	0		100	30	20	20			5				5	5			5	5		<5				<5	100
L25/1	4	Fons		30	70		100	0	100	100	30	30																		40		100
L25/2	1	Wonn					0	0		0	90			10																		100
L25/2	2	Fong					0	0		0	25	15	10	15	5						10	5				5			5		10	100
L25/2	3	Fong					0	0		0	50			50																		100
L25/2	4	Fons		70	30		0	0		0	25	25		30		5					<5								<5		10	100
L25/2	5	Ftnn	100		60	40	100	0		0	30			20	10		10			20										10		100
L25/3	1	Wonn					0	0		0																		100				100
L25/3	2	Fong		10	90		100		100	100	60	10		30																		100

Table 3.28 Water Quality Parameters Recorded for Lease 25 Wetland

Transect	Depth (m)	Temp. (°C)	DO% (% saturation)	DO (mg/l)	Cond. (mS/cm)	Sal. (g/l)	TDS (g/l)	pH
1	1.6m	19.68	73.5	6.53	0.239	0.11	0.153	7.37
1	>2m	19.16	111.8	9.51	0.228	0.11	0.145	8.09
2	>2m	18.83	93.7	8.54	0.219	0.10	0.140	7.28
3	1.8m	21.31	153.8	13.13	0.223	0.10	0.142	8.59
3	1.5m	21.22	144.8	12.55	0.226	0.11	0.145	8.28

3.4.2.4 Vegetation Vigour

Vegetation vigour was recorded for each cover class observed and is presented in Table 3.29. Generally, the overall vigour was high, ranging from good to very good. Shrub vigour results, ranged from poor to very good. A few shrubs, predominantly willow, were necrotic (dead). Plant necrosis was observed in cattail and sedges. The tufted loosestrife suffered from insect damage. Similar conditions were recorded in all wetlands surveyed. Overall, necrosis, although recorded in some plants, was minimal in this wetland. Necrosis in plants is typical for the time of year surveyed.

Table 3.29 Percent Plant Vigour for Each Cover Type for Lease 25 Wetlands

		% Vigour																			
Plot I.D.		Shrub					Grass					Herb					Aquatics				
Transect	Plot no.	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total
L25/1	1					0					0					0					0
L25/1	2					0					0					0	20	10		70	100
L25/1	3			20	80	0					0					0	10	10		80	100
L25/1	4	20	10		70	100					0				100	100	10			90	100
L25/2	1					0					0					0			10	90	100
L25/2	2					0					0					0	10	10		80	100
L25/2	3					0					0					0	10		10	80	100
L25/2	4	10		10	80	0					0					0			20	80	100
L25/2	5	10			90	0					0					0		20	20	60	100
L25/3	1					0					0					0	20			80	100
L25/3	2			20	80	100													10	90	

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

3.4.3 Isadore's Lake

3.4.3.1 General Description

Isadore's Lake is a riparian wetland situated in the Athabasca River floodplain adjacent to Shell's proposed Muskeg River Mine Project. It is an open water fen complex dominated by cattails and sedges, with low shrub and treed fens along the outer perimeter. The wetland complex is approximately 130 ha in size. A channel situated north of the lake provides an outlet to the Athabasca River.

3.4.3.2 Wetland Complex and Plant Species Composition

Isadore's lake wetlands complex is 149.6 ha in size. The lake basin is 38.3 ha in size. Table 3.30 shows the wetland types associated with this complex. Table 3.31 shows the vegetation percent cover classes while Table 3.32 shows the plant species recorded for each plot surveyed. Figure 3.41 illustrates the wetlands of Isadore's Lake. There were only 2 transects and 8 plots surveyed in this wetland complex. No plots were surveyed in the open shrubby swamp or treed fen wetland classes.

Table 3.30 Alberta Wetland Inventory Wetlands Represented in Isadore's Lake

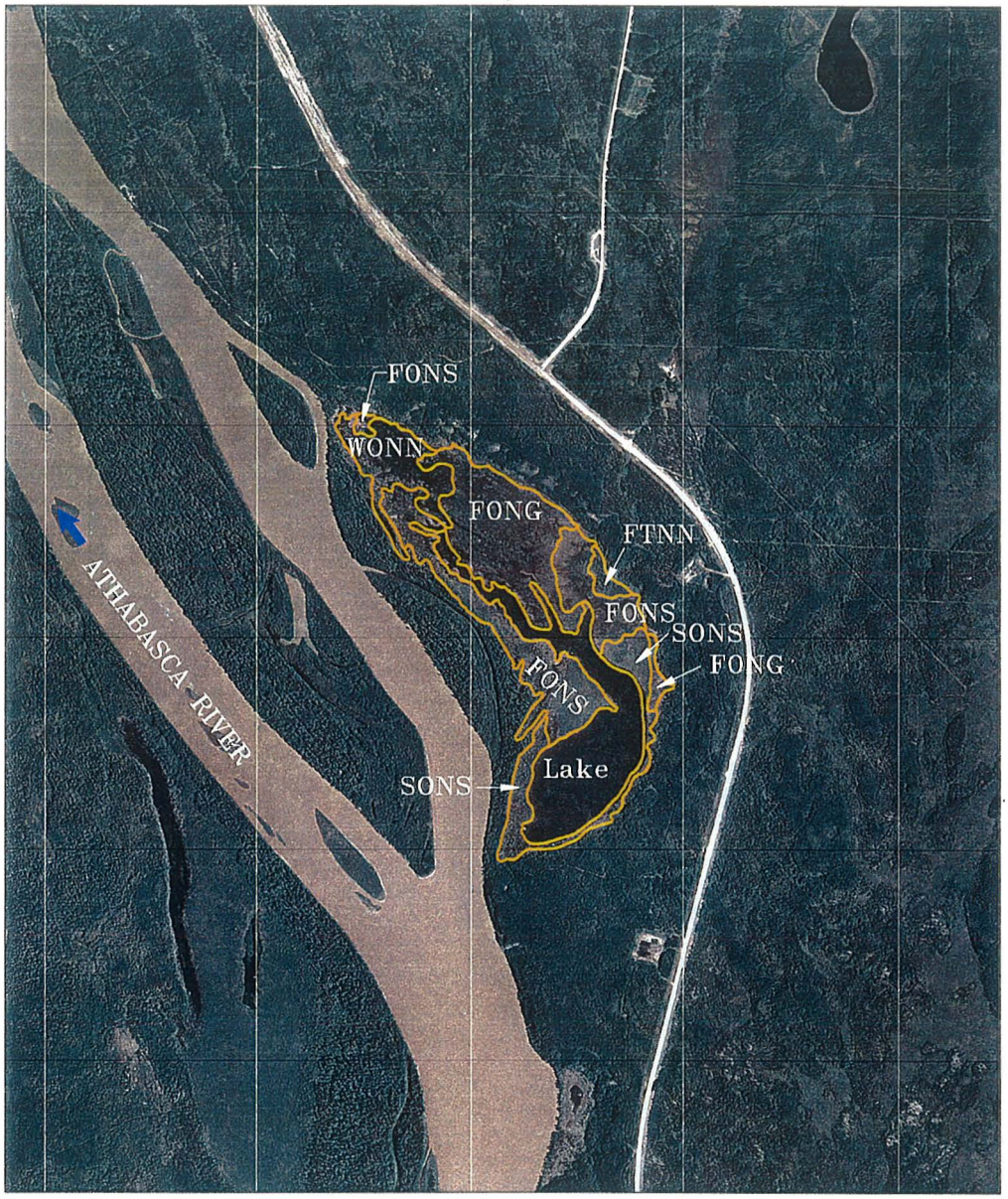
AWI Class	AWI Subclass	Number of Wetland Types	Areas of Lease 25 Wetlands	
			(ha)	(%)
Fen **(F)**	Open, non-patterned, shrubby fen **(Fons)**	3	46.5	31.1
	Open, non-patterned, graminoid fen **(Fong)**	2	33.6	22.5
	Wooded fen, no internal lawns **(Ftnn)**	1	2.2	1.5
Swamp (S)	Open shrubby swamp	1	14.2	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

Shallow Open Water (Wonn)

The shallow open water class comprised 14.8 ha or 31.1% of this wetland complex consisting of one dominant, sub-rounded open water area, elongated to the Northwest (Figure 3.30). Submergent species observed included coontail, water-milfoil and mare's tail. Floating emergents included common duckweed and yellow pond-lily. Approximately 5% of the surveyed plots consisted of emergent and shrub plants dominated by sedge and willow.

Graminoid Fen (Fong)

Graminoid fens occupied 33.6 ha of the wetlands complex. Plots within this type were dominated by sedges and cattail with some willow (Table 3.31 and Table 3.32). Herbaceous and aquatic plants observed included: wild mint, twinflower, northern bedstraw, marsh cinquefoil, water arrum, yellow pond-lily, and common bladderwort. Brown moss was also present.



0 500 1000 metres

LEGEND

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

REFERENCE

The Orthoshop
The Forestry Corp.

Golder Associates

ISADORE'S LAKE WETLANDS

27 Mar. 1998	Figure 3.41	DRAWN BY: CG

Shrubby Fen (Fons)

Shrubby fens border the lake basin. Shrubby fens occupied 46.5 ha 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 (Table 3.32).

Table 3.31 Vegetation Cover Percent for Isadore's Lake

Plot I.D		Veg. Type				% Cover by Category					
Transect	Plot no.	Wetland	Dominant	Co-Dominant 1	Co-Dominant 2	% Shrub	% Grass	% Herb	% Aquatics	% Open Water	Total
IL/1	1	Fong	Sedge			5	5	10	80		100
IL/1	2	Fons	Willow	Sedge		40	-	10	30	20	100
IL/1	3	Wonn	Open Water	Leather Leaf		5	0	0	5	90	100
IL/1	4	Fons	Bearberry	Lab Tea	Leather Leaf	85	0	5	5	5	100
IL/1	5	Fong	Cattail	Sedge	Leather Leaf	15	0	0	35	50	100
IL/1	6	Fong	Cattail	Open Water		0	0	0	20	80	100
IL/2	1	Wonn	Open Water	Sedge					30	70	100
IL/2	2	Fong	Cattail	Sedge					80	20	100

*Transects were recorded on aerial photographs during the time of sampling

3.4.3.3 Water Quality

Water quality parameters were recorded in shallow open water and in the lake basin (Table 3.33). Higher pH values, which ranged from 8.18 to 9.37, were recorded in this wetland complex. Salinity measurements ranged from 0.12 g/l to 0.17 g/l. Conductivity measurements, which ranged from 0.244 mS/cm 0.353 mS/cm were higher in Isadore's Lake than in the Lease 25 Wetlands but overall were similar to Shipyard Lake.

Table 3.32 Plant Species and Percent Cover for Isadore's Lake

		%																						
Plot I.D.		Shrubs									Grasses		Forbs				Aquatics							
Transect	Plot no.	Beaked Willow	Labrador Tea	Tamarack	Blueberry	Bear Berry	Leather Leaf	Low Bush cram	High Bush cram	Total	Tickle Grass.	Total	Northern Bedstraw	Wild Mint	Twin Flower	Total	Sedge I	Awned Sedge	Purple-leaved Willowherb	Cattail	Common Duckweed	Water airum	Sedge IV	Total
IL/1	1	100								100	100	100	50	50		100	30	20	20	10			20	100
IL/1	2									0		0	100			100					100			100
IL/1	3						100			100		0				0	25	25	50					100
IL/1	4		20	5	5	30	20	10	10	100		0			100	100				50			50	100
IL/1	5						100			100		0				0	30			60	5	5		100
IL/1	6																				100			100
IL/2	1																50			10	40			100
IL/2	2									0		0					20	10		70				100

Table 3.33 Water Quality Parameters Recorded in Isadore's Lake

Transect	Depth (m)	Temp. (°C)	DO% (% saturation)	DO (mg/l)	Cond. (mS/cm)	Sal. (g/l)	TDS (g/l)	pH
1	>2m	26.35	116.0	8.98	0.353	0.17	0.226	8.18
1	>2m	21.59	121.7	10.20	0.310	0.15	0.198	8.57
1	>2m	22.85	121.0	10.40	0.322	0.16	0.206	8.45
1	>2m	23.22	121.0	9.70	0.323	0.16	0.207	8.51
2	>2m	22.55	148.0	12.09	0.244	0.12	0.157	9.37
2	>2m	24.50	101.4	8.15	0.328	0.16	0.210	8.42

3.4.3.4 Vegetation Vigour

Vegetation vigour was recorded for each cover class and is presented in Table 3.34. 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 3.34 Percent Plant Vigour for Each Cover Type for Isadore's Lake

		% Vigour																			
Plot I.D.		Shrub					Grass					Herb					Aquatics				
Transect	Plot no.	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total
IL/1	1			5	95	100				100	100				100	100			5	95	100
IL/1	2			5	95	100					0				100	100	5		5	90	100
IL/1	3	10		20	70	100					0					0	10		20	70	100
IL/1	4			10	90	100					0					0	10	20	70		100
IL/1	5	20	20	60		100					0					0	20	20		60	100
IL/1	6					0					0					0	10	20	70		100
IL/2	1																10	40	60		100
IL/2	2																20	40	40		100

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

3.4.4 Kearl Lake

3.4.4.1 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. It is approximately 955 ha. in size. The lake is bordered by graminoid and shrubby fens. It is the only wetlands complex assessed that is not a riparian wetland but rather a large upland lake with a wetland border.

Wetland Complex and Plant Species Composition

The lake is bordered by graminoid and shrubby fens. Table 3.35 and Figure 3.42 show the distributions and size of wetlands associated with Kearl Lake.

Table 3.35 Alberta Wetland Inventory Wetlands Represented in Kearl Lake

AWI Class	AWI Subclass	Number of Wetland Types	Areas of Lease 25 Wetlands	
			(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 fens plots were dominated by sedges and cattail with some willow (Table 3.36 and Table 3.37). Herbaceous and aquatic plants observed include wild mint, twin flower, northern bedstraw, marsh cinquefoil, water arrum, yellow pond-lily, and common bladderwort. Brown moss was also present.

Shrubby Fen (Fons)

Shrubby fens occur along drainages and occupy 137.7 ha. Two plots within the shrubby fen wetland type were surveyed. In wetter areas, plots were dominated by willow. In drier areas, shrubs observed include labrador tea, velvet-leaved, blueberry, bearberry, leather-leaf, bilberry, low bush cranberry and stunted tamarack (Table 3.37).

J:\1997\2520\1000\KEARL.dwg

LEGEND

Fong – Graminoid Fen
Fons – Shrubby Fen
Ftnn – Treed Fen

0 500 1000(m)

SCALE 1:30,000

REFERENCE

THE ORTHOSHOP
THE FORESTRY CORP.

Golder Associates

KEARL LAKE

27 MAR 98	Figure 3.42	DRAWN BY: RFM

Table 3.36 Vegetation Cover Percent for Kearl Lake

Plot I.D.		Veg. Type			% Cover by category					
Transect	Plot no.	Dominant	Co-Dominant 1	Co-Dominant 2	% Shrub	% Grass	% Herb	% Aquatics	% Open Water	Total
KLV/1	1	Open Water	Yellow Pond Lily	Marsh Cinquefoil	-	-	-	5	95	100
KLV/1	2	Cattail	Sedge		-	-	-	75	25	100
KLV/1	3	Cattail	Sedge		-	-	-	90	10	100
KLV/2	1	Open Water			-	-	-		100	100
KLV/2	2	Cattail			-	-	-	80	20	100
KLV/2	3	Sedge	Cattail	Rush	-	-	5	75	20	100
KLV/3	1	Open Water			-	-	-	5	95	100
KLV/3	2	Sedge			5	5	5	60	25	100
KLV/3	3	Sedge			-	-	5	45	50	100

*Transects were recorded on aerial photographs during the time of sampling

Table 3.37 Plant Species and Percent Cover for Kearl Lake

		%																												
Plot I.D.		Shrubs			Grasses		Forbs				Aquatics																			
Transect	Plot no.	Beaked Willow	Willow I	Total	Bluejoint	Total	Northern Bedstraw	Marsh Skullcap	Northern Bedstraw	Total	Sedge I	Awned Sedge	Beaked Sedge	Wire Rush	Cattail	Marsh Cinquefoil	Rush	Common Duckwee	Yellow Ponf Lily	Small white Pond Lily	Common Bladderwort	Water Arium	Water Arium(Large Leaved)	Water Parsnip	Cow Parsnip	Sedge IV	Water Smartweed	Unidentified	Total
KLV/1	1			0		0				0	20				20	25		<1	30		5								100
KLV/1	2			0		0				0	20			5	35	10		<1			10						20		100
KLV/1	3			0		0				0	10			10	50						5						25		100
KLV/2	1			0		0				0																			0
KLV/2	2			0		0				0	10	10			40	10	5	<1			5						20		100
KLV/2	3			0		0				0	20				20	10	20									20	10		100
KLV/3	1			0		0				0						50				50									100
KLV/3	2	70	30	100	100	100	25	25	<1	50	10	10	10	5	10	10	10	<1				5		5	5			20	100
KLV/3	3			0		0	20	40	20	80	20	20		5	10	10	5	<1			5	5	5	5			10		100

3.4.4.2 Water Quality

Water quality parameters were recorded in shallow open water and in the lake basin (Table 3.38). The pH values ranged from 7.14 to 8.02. Salinity measurements were lower than Isadore's Lake, ranging from 0.5 g/l to 0.6 g/l. Conductivity measurement ranged from 0.127 mS/cm 0.138 mS/cm.

Table 3.38 Water Quality Parameters Recorded for Kearl Lake

Transect	Depth (m)	Temp. (°C)	DO% (% saturation)	DO (mg/l)	Cond. (mS/cm)	Sal. (g/l)	TDS (g/l)	pH
1	>2m	22.86	na	na	0.127	0.05	0.081	7.55
1	>2m	21.33	83	7.01	0.138	0.06	0.088	7.29
2	>2m	21.12	80.0	6.71	0.134	0.06	0.086	7.14
2	>2m	20.90	95.2	7.91	0.136	0.06	0.087	7.26
3	>2m	20.05	84.2	7.32	0.137	0.06	0.087	7.31
3	>2m	21.42	117.6	9.80	0.138	0.06	0.089	8.02

3.4.4.3 Vegetation Vigour

Vegetation vigour was recorded for each cover class and is presented in Table 3.39. 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.

Table 3.39 Percent Plant Vigour for Each Cover Type for Kearl Lake

		% Vigour																			
Plot I.D.		Shrub					Grass					Herb					Aquatics				
Transect	Plot no.	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total	D	P	G	VG	Total
KLV/1	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	50	-	50	-	100
KLV/1	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	30	20	50	-	100
KLV/1	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	30	-	20	50	100
KLV/2	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0		-	-	-	0
KLV/2	2	-	-	-	-	0	-	-	-	-	0	-	-	-	100	100	20	-	20	60	100
KLV/2	3	-	-	-	-	0	-	-	-	-	0	-	-	-	100	100	10	10	-	80	100
KLV/3	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
KLV/3	2	-	60	40	-	100	-	-	-	100	100	-	-	-	100	100	10	-	10	80	100
KLV/3	3	-	-	-	-	0	-	-	-		0	-	-	40	60	100	10	10	20	60	100

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

4. SUMMARY AND CONCLUSIONS

4.1 SURFACE WATER, SEDIMENT AND POREWATER QUALITY

Results of the 1997 water quality surveys were generally consistent with previous data for the Athabasca River and its major tributaries. No increases were found below the oil sands area in river water concentrations of parameters associated with natural deposits of oil sands or existing oil sands operations. Concentrations of sediment parameters were also within previously-reported ranges with the exception of certain metals, which were elevated in both sampling areas in 1997. Below the oil sands area, bottom sediments contained two to three-fold higher levels of hydrocarbons and PAHs than in the upstream sampling area. Sediment toxicity was not found in the two sampling areas. To provide additional supporting data for benthic invertebrate surveys, the sediment monitoring program may need to be expanded to include separate chemistry and toxicity data for each benthic invertebrate sampling area.

Porewater was not collected during the 1997 surveys. The addition of this medium to the sediment sampling program should be considered for future surveys.

4.2 BENTHIC INVERTEBRATES

Results of the 1997 benthic invertebrate survey of the Athabasca River documented low to moderate invertebrate density and low taxonomic richness at all sampling sites. Chironomid midge larvae dominated all sites. Significant upstream-downstream and cross-channel differences were found in density, but not in taxonomic richness. The variation in community structure generally reflected habitat differences among sampling sites. The 1997 survey did not provide consistent evidence of an influence of oil sands operations on benthic communities of the sampling areas.

Results of the 1997 survey indicate that variation among sites (within sampling areas) in invertebrate community characteristics is moderate to high in the Athabasca River. Since this may reduce the sensitivity of surveys, it should be taken into account when designing subsequent biomonitoring programs.

4.3 FISH POPULATIONS

4.3.1 Summary of Findings

Fisheries inventories were conducted within four distinct areas in the Athabasca River, which were referred to in this report as the Poplar,

Steepbank, Muskeg and Tar-Ells River Areas. Basic population parameters, such as length-frequency distribution, length-at-age and CPUE, were documented. Length-frequency distributions for major fish species were similar for 1995, 1996 and 1997. Age-at-length relationships were determined for walleye, longnose sucker and lake whitefish. Data were grouped from the same season of different years to provide sufficient sample sizes. These graphs will form a baseline for future comparisons. Previously there were not enough data available to comprise an adequate sample size.

In conjunction with Athabasca River inventories, mapping of fish habitat types and determination of general fish habitat associations was conducted. Five dominant bank types noted for the Athabasca River constituted 88% of the shoreline areas in 1997: three erosional habitat types (E1, E2, E5), one armoured habitat type (A1) and one depositional habitat type (D1). Three types of habitats were most heavily used by all species combined: D1, E5 and A1.

Fisheries inventories of the Steepbank, Muskeg and Mckay rivers were conducted in summer. There was no difference in relative abundance (catch-per-unit-effort) from 1995 and 1997 for the steepbank River. Data from the Musekg and macKay Rivers were presented as a baseline for future comparisons. Species composition for all three of these watercourses is consistent with previous studies.

Two fish species were radio tagged in 1997 to address data gaps regarding fish spawning and overwintering areas and residence time in the oil sands region. Weekly aerial flights followed the movements of 18 walleye and 18 lake whitefish. Results confirm the use of Mountain Rapids as a spawning area for lake whitefish. Information was also gathered concerning the frequent use of certain areas by each species such as: the mouth of the MacKay River by walleye and the area in the Athabasca River adjacent to Shipyard Lake by lake whitefish. Another interesting finding was the location of two walleye and two lake whitefish near the mouths of Athabasca River tributaries, during the last 1997 flight (December 22), indicating that these fish might be overwintering in the Athabasca River.

Field surveys were conducted in spring 1997 from the Mountain Rapids to Fort McMurray and just below Fort McMurray to determine their potential as reference areas for the Athabasca River RAMP study reaches. The areas surveyed were found inadequate for this purpose. However, a reach above the rapids might be adequate. As well, indicated the Ells and Tar rivers may be potential reference areas for the Muskeg and Steepbank rivers. Field surveys are needed to determine the actual feasibility of using these areas as reference areas.

4.3.2 Conclusions

The life history information gathered over the last few years has helped to focus the issues that need to be addressed in order to describe the basic biology of fish species in the Athabasca River and its tributaries. This information can be used to better estimate the possible exposure and potential effects of oil sands developments at the population level.

Most large fish species (e.g., goldeye, longnose sucker, lake whitefish) use the Athabasca River as a migration corridor to reach spawning areas. Within the Athabasca River these fish are most commonly found near the mouths of tributaries and within preferred habitat types (e.g., armoured banks). The mouths of the Muskeg, Steepbank, MacKay, Tar and Ells rivers, have been identified as important areas for rearing and feeding of walleye, northern pike, longnose sucker and white sucker. Hence, if oil sands developments effect habitat or water quality at the mouths of the tributaries, several life stages of these species could be affected.

Most large fish species in the lower Athabasca River are thought to migrate downstream in the fall to overwinter in Lake Athabasca. However, 1997 radiotelemetry data indicate the possibility that some walleye and lake whitefish overwinter in the Athabasca River. It is important to determine how long the fish remain within the oil sands area, as potential effects on fish populations would, in part, be a function of exposure. Winter flights would therefore be important to confirm if these fish overwinter in the Athabasca River.

Differences in sampling areas and effort have made it inappropriate to statistically compare population data from different years for most watercourses. However, qualitative comparisons of relative abundance, habitat selection and age-frequency distributions show similar results from 1995, 1996 and 1997. The fisheries inventories data gathered to date highlighted the need to define a uniform and consistent sampling program within the RAMP.

The information gathered on the Steepbank and Muskeg rivers has highlighted the need to define a more reliable sampling method that provides uniform sampling efficiencies. To date, different methods (e.g., gill nets, minnow traps, portable and backpack electrofishing and fish fences) have been used to gather fish population data (e.g., length-frequency distribution, length-at-age). The use of electrofishing, gillnets and minnow traps has been successful in defining species composition and relative abundance. However, efficiencies of these methods vary under different flow conditions and it is often not possible to capture enough fish to yield representative population data. Adequate data were gathered when fish fences were used in the past (R.L. & L. 1989, Golder 1996a). This fish capture method is the only reliable method used to date to document fish population characteristics and numbers of fish using the tributaries.

4.4 AQUATIC VEGETATION

Results of the 1997 wetland surveys of Shipyard Lake, Lease 25 Wetlands, Isadores' Lake, and Kearl Lake documented the occurrence of graminoid marshes, shrubby marshes, graminoid fens, shrubby fens, treed fens, shrubby swamps, treed swamps, shallow open water and lake wetland types. The dominant plant species included willow, river alder, Labrador tea, sedges, cattail, rushes, and bur-reeds. Plant health was generally good to very good. Water quality in the wetlands was neutral to slightly alkaline.

The variation in species composition, water quality and plant vigour generally reflected habitat differences due to dominant wetland types among sites surveyed. The 1997 surveys did not provide consistent evidence of an influence of oil sands operations on wetlands or associated plant communities. Data collected this year provides a baseline for future monitoring.

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6. 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.
Ambient	The conditions surrounding an organism or area, excluding any effects of human activities.
AEP	Alberta Environmental Protection
AOSERP	Alberta Oil sands Environmental Research Program.
ASWQO	Alberta Surface Water Quality Objectives. Numerical concentrations or narrative statements which have been established to support and protect the designated uses of water. These are minimum levels of quality, developed for Alberta watersheds, below which no waterbody is permitted to deteriorate. These objectives were established as minimum levels which would allow for the most sensitive use. These concentrations represent a goal which should be achieved or surpassed.
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 oilsand. 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.
BOD	Biochemical Oxygen Demand.
Bottom Sediments	Material which lie on the bottom of a body of water. Examples include soft mud, silt, sand, gravel, rock and organic litter.
Bottom-feeding Fish	Fish that feed on the sediment and/or organisms (i.e., benthic invertebrates) associated with the bottom of a waterbody.
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.
CPUE	Catch per unit of effort.
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.
Drainage Basin	The total area that contributes water to a stream. Also known as the watershed.
Effluent	Stream of water discharging from a source.
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.
Forage Area	The area used by an organism for hunting or gathering food.
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.
PANH	Polycyclic Aromatic Nitrogen Heterocycle.
PEL	Probable Effect Level. Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.
Porewater	Water that is present between the grains of a soil or rock.
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).
TEL	Threshold Effect Level. Concentration of a chemical in sediment or water below which adverse effects are expected to occur rarely.
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	See drainage basin.
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.
YOY	Young of the year. Fish from age 0 to the end of the first year after hatching.

7. 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.

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APPENDIX I

SURFACE WATER SAMPLING METHODS (TP 8.3-1)

1. PURPOSE

This document describes the sampling protocols used by Golder Associates to collect surface water samples. It contains sampling instructions and information concerning appropriate containers, preservation and handling of water quality samples.

2. APPLICABILITY

This technical procedure is applicable to any persons involved in the collection of surface water samples. It is applicable to all geographic areas.

3. DEFINITIONS

3.1 Analytical Request Form

Standard form provided by analytical laboratories. This form is filled out by the person collecting samples and is used to indicate how each sample is to be analyzed. This form is often combined with the Chain-of-Custody Form in a single document.

3.2 Chain-of-Custody Form

Standard form used to track the movement of sample containers from the time they leave the field until they arrive at the specified laboratory. The Chain-of-Custody form provides a clear record of sample transport and handling, thereby reducing the risk of sample loss during transport. This form may be combined with the Analytical Request Form in a single document.

3.3 Chemical Analysis

Analytical procedure used to measure the *amount* of a certain compound, or group of compounds, present in a sample.

3.4 Preservatives

Preservatives are used to maintain sample integrity from the time a sample is collected until it is analyzed. Sample preservation may involve adding acid or other fixatives to collected waters or simply keeping them refrigerated. Sample-specific requirements are outlined in this document (Table 1); preservatives, when required, are provided by the analytical laboratory.

3.5 Quality Assurance/Quality Control (QA/QC)

Quality Assurance refers to a detailed protocol used to produce high quality products, while Quality Control refers to the process by which this protocol is tested to ensure that final products are of the specified quality. With reference to water sampling, QA protocol includes the use trained personnel, proper sampling methods, clean containers and equipment, proper sample preservation and transportation and detailed documentation of the entire process; field, travel and other assorted test blanks are used for Quality Control testing.

3.6 Sample Types

3.6.1 Grab Samples

Sample containing water collected during a single sampling event (i.e., water taken from a given place at a given time).

3.6.2 Composite Samples

Sample containing a mixture of water collected from multiple locations or from different times at the same location.

3.6.3 Equipment Blanks

Equipment blanks are used to detect contamination from sampling equipment. They are prepared by rinsing precleaned equipment with deionized water and collecting the rinsate into an appropriate container.

3.6.4 Field Blanks

Field blanks are used to detect contamination during sample collection and transport. They are prepared during a sampling event by filling the appropriate container with deionized water. Field blanks are usually used in situations where there is reason to suspect that contamination will occur during sample collection and transport.

3.6.5 Travel Blanks

Travel blanks detect sample contamination during transport. Travel blanks consist of pre-filled bottles provided by the analytical lab. They accompany empty sample bottles to the field site, where they are left intact and unopened inside the shipping cooler. The unopened travel blanks are then returned to the analytical lab to be analyzed along with collected samples.

3.6.6 Field Spikes

Field spikes are used to measure the performance of the complete analytical system, including sample handling, preservation and storage, as well as interference from the sample matrix. To generate a field spike, field personnel fill the usual sampling container with sample, leaving a small amount of space at the top. They then add a specified amount of the chemical or compound of interest to the bottle and submit it with the rest of the samples. In general, field spikes are not recommended due to the logistical difficulties of transporting concentrated solutions in the field. If there is reason to doubt the performance of the sampling system, then a separate study involving field spikes should be carried out.

3.6.7 Standard Reference Samples

Standard reference samples, or blind QA samples, are samples of known concentration that are submitted to the analytical lab as a normal sample. The lab is not informed about the identity of the sample until after all analyses are complete.

3.6.8 Replicate Samples

Replicate samples are used to evaluate within-site variation. Replicate samples are collected by filling multiple containers at a single site. They are labelled and preserved individually and are submitted separately to the analytical laboratory. Check the SWI for the number of replicate samples required per sampling site.

3.6.9 Split Samples

Split samples are used to check analytical variation. A single sample (e.g. grab) is collected and is split into two sample containers. These are labelled and preserved individually and are submitted separately to the analytical laboratory.

3.7 Specific Work Instructions (SWI)

Detailed instructions in a standardized format provided to field personnel. The SWI describe all aspects of the work to be conducted, including personnel allocation, procedures to be used, time allocation and any additional information deemed necessary by the project or task manager.

3.8 Toxicity Analysis

Analytical procedure specifically designed to examine how the health of living organisms may be affected by exposure to a given substance or sample. Toxicity tests can be based on either: acute exposures (short-term exposures lasting only a small portion of the animals life cycle, e.g. 96 hours for rainbow trout); or, chronic exposures (longer-term exposures meant to represent a significant portion of the animal's life cycle, or a particularly sensitive portion of the animal's life cycle, e.g. 28 days for *Daphnia magna*). Responses measured in toxicity tests can be lethal (e.g. mortality), or sublethal (e.g., reduced growth or reproduction). Unlike other procedures, toxicity testing evaluates the sample as a whole, rather than describing its chemical make-up.

4. REFERENCES AND SUGGESTED READING

4.1 Sampling Methodology

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Clesceri, L.S., A.E. Greenberg and R.R. Trussell. 1989. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C., U.S.A.

4.2 Laboratory Capabilities and Pricing

- Chemex Labs (Alberta) Inc. 1995. Service Description and Price List
- Enviro-Test Labs. 1996. Service Description and Price List
- HydroQual Laboratories Ltd. 1996. Statement of Qualifications

5. DISCUSSION

5.1 General Safety

Refer to Golder Associates Ltd. Health and Safety Manual.

5.2 Sampling Procedures

Samples are collected as representative pieces of a larger puzzle. Ideally, they should describe all of the characteristics of the larger body from which they originate, which, by its very definition, is too large to analyze directly. As a result, it is very important to follow a well-organized sampling plan and to preserve sample integrity throughout the collection and transportation process.

5.2.1 General Practices

Usually, analytical laboratories will provide pre-cleaned sample containers, shipping containers, required forms for sample submission and specific sample shipping instructions. It is important to check with the lab that these arrangements have been made. Similarly, field crews should familiarize themselves with the SWI before initiating a sampling program. By reviewing the instructions, personnel can ensure that they have all of the equipment they require to fulfill the objectives of the sampling program. Field crews will also then be aware of the types of samples they are being asked to collect, be they grab samples, composite samples or QA/QC test blanks. Finally, sample crews should organize themselves such that samples will be collected and shipped during the early part of the work week (Monday to Wednesday) to help avoid delays caused by weekend shipping.

Sampling Locations

General sampling locations are described in SWI. However, field crews will have a certain degree of freedom in choosing the exact locations from which to take the samples. When selecting these sites, personnel should consider the layout of the local environment, project objectives and personal safety. They should then choose areas that are both easily accessible and representative of the target waterbody or waterbodies.

Once sampling sites have been identified, they must be accurately described relative to permanent landmarks, such as groundwater wells, outfalls or distinctive landscape features; measuring the distance from permanent landmarks to each site with an appropriate compass heading is recommended. Ideally, one should try to use the Global Positioning System (GPS), but locations can also be recorded as the perpendicular distance from the shoreline and the distance upstream or downstream of a permanent landmark.

Sample Collection

- Start sampling at the least contaminated site (i.e., the reference site) and move from there to the more contaminated areas.

- If sampling equipment must be used, then it must be cleaned before and after use. This may involve rinsing with ambient water, cleaning with soap and water, acid washing, rinsing with organic solvents or pure water, or a combination of these. Refer to the SWI for details.

- Each sample bottle must be labelled at the time of collection with either waterproof, permanent marker or using pre-printed waterproof labels. See section 5.3.2 for details of label format.

- When sampling, it is important to rinse sample containers 3 times before actually taking a sample. Rinse each bottle by partially filling it with ambient water, loosely attaching the cap and shaking the bottle; drain the water and repeat the process. As a general rule, rinse plastic bottles unless instructed otherwise by the analytical laboratory. Bottles that already contain the appropriate preservatives and containers for the following analyses should *not* be rinsed prior to taking the sample:
  - volatile organic compounds (VOCs), including total volatile hydrocarbons (TVH), total extractable hydrocarbons (TEH), BTEX (benzene, toluene, ethylbenzene and xylene) and total petroleum hydrocarbons (TPH; includes TVH, TEH and BTEX); and
  - bacteriological testing (e.g., fecal coliforms).

- Carefully fill sample containers, without splashing, leaving only enough space for preservatives (if required - see Table 1). Be sure to keep hands and fingers downstream of bottle opening and sample upstream of bridges, boats and yourself to prevent sample contamination. If no preservatives need to be added, completely fill the bottles and cap tightly. There should be as little air in the containers as possible, as it can affect sample integrity.

- Whenever possible, fill sample containers directly from the source, without using an intermediate container to transfer the sample. This avoids potential sample contamination due to carry-over from one sample to the next. Also, take care to avoid contaminating sample waters through contact with rubber, oil, gasoline and other machinery fluids, metal-based paints, cigarette ash, paper tissues and other such material.

- Sample bottles should then be stored appropriately (Table 1). In most cases, this will involve keeping the sample cool (4°C) and dark. Samples should never be allowed to freeze and should be shipped as soon as possible to the appropriate analytical lab, in coolers with reusable ice packs. If possible, avoid using bags of ice purchased from convenience stores; the water that leaks out of these bags as the ice melts may ruin sample labels.

- Chain-of-Custody and Analytical Request forms must accompany all samples (one set of forms per sample shipment). Prior to shipping, the person submitting the sample should inform the analytical lab by telephone or fax that the samples will be arriving. As well, he or she should check back later to confirm arrival of the samples and to explain analysis requests if needed.

5.2.2 Sampling for Metals

When collecting samples for a metals analysis, it is important that sample waters do not come into contact with any metal products. Samples for metals analysis also have other stringent collection and preservation requirements (Table 1). For example, waters collected for dissolved metal analysis have to be field-filtered using a 0.45 μm polycarbonate or cellulose acetate filter and then preserved with acid. Field crews need to be aware of these restrictions to ensure that samples are taken correctly and that they maintain their integrity until they can be analyzed. Special sampling and preservation instructions should be included in the SWI.

5.2.3 Sampling for Organic Chemicals

In addition to the general principles outlined above, there are specific protocols associated with sampling for organic measurements. As described above, sample bottles should *not* be rinsed prior to taking samples for certain organics analyses. It is also very important to completely fill each bottle, as certain organics will volatilize into the overlying air space and will be lost after opening the bottle. Finally, proper containers must be used when sampling for organics, since some bottles will release or absorb organic compounds when filled with water. Generally, glass containers are used, but certain tests may require other materials; be sure to obtain the appropriate sample bottles from the analytical laboratory and refer to the SWI.

5.3 Sample Documentation

The importance of proper sample documentation cannot be overemphasized. Lack of careful documentation can lead to misunderstandings and questionable test results. Components of proper documentation of field activities are described below.

5.3.1 Field Notebooks

Field notebooks must be kept, describing all field activities. Format of field notes and information to be recorded should follow Golder Associates' specific guidelines. During the field survey, field notes must be maintained in a permanent, safe location at the field site where samples are collected. If possible, new entries in the field note book should be photocopied at the end of each field day and copies should be stored in a safe place.

5.3.2 Sample Labels

Sample labels must contain the following information:

- Sample identifier (name of site or sample code);
- Date (written as day/month/year; month abbreviated as three letters) and time (24 hour clock) of collection;
- Initials of collector; and
- Analysis requested (this is usually done by the analytical laboratory in the form of a code on the sample bottle).

Fill out labels at the time of collection using waterproof ink and affix a label to each sample container. Plastic bottles may be labelled by writing directly on the bottle using a waterproof marker; however, this approach is not recommended if samples are transported over long distances (friction may rub label off) or if bags of ice are used to keep the samples cool (water may damage label information).

5.3.3 Custody Seals

If required for a project, numbered seals should be used to detect unauthorized tampering with samples in transit. Attach the seal in a way that it is necessary to break it to open the cooler containing the samples. The number on the custody seal should be recorded in the field note book and on the Chain-of-Custody and Analytical Request forms

5.3.4 Chain-of-Custody Forms and Analytical Request Forms

Chain-of-Custody and Analytical Request forms must accompany all samples submitted for analysis. These forms are usually combined as a single document. An example of Golder Associates' combined Chain-of-Custody and Analytical Request Form is provided in Appendix 1.

The combined form must be filled out completely and the white and yellow copies should be sent along with the samples being submitted. Field personnel should retain the pink copy after it is signed by the shipper. Depending on the shipping container, these forms can either be enclosed inside the sealed container or attached firmly to the outside of the container. In either case, it is advisable to enclose the forms within a waterproof plastic bag to guard against damage. It is important that each person having custody or control of the samples identify themselves on this form. This means that the person collecting the sample, any intermediate persons involved in packaging, storing or transporting the sample and the person accepting the sample on behalf of the analytical lab must all be identified.

5.4 Sample QA/QC

The main goal of sample QA/QC is to monitor for various sources of contamination during sample collection, transport and analysis. This process will involve the use of field, travel and other test blanks. QA/QC programs are designed on a project-specific basis. Details of individual QA/QC programs are described in the SWI.

6. EQUIPMENT AND MATERIALS

6.1 Sampling

The following is a list of sampling equipment generally recommended for surface water sampling:

- Pre-cleaned sample bottles and required preservatives (usually supplied by the analytical laboratory)
- Coolers and reusable ice packs
- Waterproof labels and permanent markers
- Sampling equipment (e.g. Kemmerer or Van Dorn bottles)

6.2 Site Location and Sample Documentation

For proper sample site identification and sample documentation, field crews may need:

- Bound, water-proof field logbooks
- Maps
- Air photos
- Indelible ink pens and pencils
- Long tape measure
- Survey flagging tape
- Compass
- GPS unit
- Combined Analytical Request and Chain-of-Custody forms

6.3 Health and Safety

The following health and safety equipment is recommended for surface water sampling:

- Waders and waterproof gloves
- Heavy socks, warm pants, rain gear and other articles of clothing suitable for prolonged water work
- Extra set of clothes
- First aid kit
- Approved personal floatation device for deep water or boat work

TABLE 1

SUMMARY OF SAMPLE COLLECTION, PRESERVATION AND STORAGE REQUIREMENTS

PARAMETER	BOTTLE TYPE	ETL[1] LABEL	SAMPLE PRESERVATION	PRESERVATIVE CODE (ETL)[1]	HOLDING TIME	COMMENTS
Conventional Chemistry						
pH to TDS + DOC	500 mL plastic	"routine"	in the dark at 4°C	-	**48 hrs.**	Note short holding time
TOC	100 mL amber glass	unlabelled	1 mL H_2SO_4	Fluorescent Red	5 days	Do not triple rinse
Major Ions						
Calcium to Sulphate	in "routine" bottle	n/a	-	-	-	
Sulphide	100 mL plastic	"Sulphide"	1 mL NaOH+ 2 mL zinc acetate	Orange	5 days	
Nutrients						
Ammonia, TKN & Total P	500 mL plastic	"nutrients"	2 mL H_2SO_4	Purple	10 days	Indicate on label that sample is preserved
Nitrate + Nitrite & Dissolved P	in "routine" bottle	n/a	-	-	-	
Bacterial						
Biochemical Oxygen Demand	1 L plastic	unlabelled	in the dark at 4°C	-	**48 hrs.**	Note short holding time
Coliforms	300 mL sterilized glass	unlabelled	in the dark at 4°C	-	**48 hrs.**	Note short holding time
Toxicity						
Daphnia magna 48 h. Static Acute	1 L clear glass / plastic	unlabelled	in the dark at 4°C	-	5 days	
Rainbow trout 24 and 96h Static Acute	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	5 days	
Algal Growth 72h Inhibition/Stimulation	1 L clear glass / plastic	unlabelled	in the dark at 4°C	-	3 days	
Ceriodaphnia dubia 7d Growth and Reproduction	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	3 days	
Fathead Minnow 7d Survival/Growth	20 L collapsible carboy	unlabelled	in the dark at 4°C	-	3 days	
Bacterial Luminescence (Microtox IC50 and IC20)	1 L clear glass	unlabelled	in the dark at 4°C	-	48 hrs.	Note short holding time
Other						
Total Recoverable Hydrocarbons	1 L amber glass	"oil & grease"	2 mL H_2SO_4	Purple	5 days	Do not triple rinse
Naphthenic acids	1 L amber glass	unlabelled	0.5g ascorbic acid + 2 NaOH pellets		10 days	Do not triple rinse; preservative in bottle
Total Phenolics	100 mL amber glass	unlabelled	1 mL H_2SO_4	Fluorescent Red	**24 hrs.**	Note short holding time Do not triple rinse
Chlorophyll *a*	500 mL plastic	"nutrient"	in the dark at 4°C	-	**48 hrs.**	Note short holding time Indicate on label that sample is unpreserved
Total Metals						
Aluminum to Zinc + Sb, As & Se	500 mL plastic	"metals"	2 mL NO_3	Blue	6 months	
Mercury (Hg)	250 mL plastic	"mercury"	2 mL NO_3 + dichromate	Yellow	30 days	
Dissolved metals						
Aluminum to Zinc + Sb, As & Se	500 mL plastic	"metals"	filter, 2 mL NO_3	Blue	6 months	See dissolved metals sampling protocol
Mercury (Hg)	250 mL plastic	"mercury"	filter, 2 mL NO3 + dichromate	Yellow	30 days	See dissolved metals sampling protocol
PAHs						
Naphthalene....	2 L clear glass	unlabelled	in the dark at 4°C	-	14 days	Bottle may be 4 L Do not triple rinse
Phenolics						
Phenol....	in PAH bottle	unlabelled	-	-	-	
Volatile Organics						
Acetone...	40 mL amber glass	unlabelled	Na2S2O3, 2 crystals, dark, 4°C	-	14 days	Do not triple rinse; preservative in bottle

NOTE: 1ETL = Enviro-Test Laboratories

APPENDIX 1

GOLDER ASSOCIATES' COMBINED CHAIN-OF-CUSTODY

AND ANALYTICAL REQUEST FORM

GOLDER ASSOCIATES LTD. Page ___ of ___

CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Field Sampler: (Signature) Shipment Date: _____

_____ Carrier: _____

Phone No._____ Waybill No.: _____

Ship To: Send Results To:

Project Name: _____ Project No. _____

P.O. No.: _____

Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished from lab by: (Signature)	Received by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): _____ Standard Turnaround Time: _____

PLEASE RETURN WHITE COPY TO GOLDER ASSOCIATES LTD.

GOLDER ASSOCIATES LTD.
CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Page ___ of ___

Field Sampler: (Signature)

Phone No.

Shipment Date:

Carrier:

Waybill No.:

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge):

Standard Turnaround Time:

PLEASE RETURN WHITE COPY TO GOLDER ASSOCIATES LTD.

APPENDIX II

LABORATORY ANALYTICAL METHODS

APPENDIX II
LABORATORY ANALYTICAL METHODS
(G = glass, P = plastic)

PARAMETER	ETL CODE	METHOD	DETECTION LIMIT	UNITS	REQUIRED VOLUME	CONTAINER TYPE	SAMPLE PRESERVATION	HOLDING TIME	COMMENTS
Field measured									
pH	-	Meter			-	-	-	-	
Specific Conductance	-	Meter		uS/cm	-	-	-	-	
Temperature	-	Meter		°C	-	-	-	-	
Dissolved Oxygen	-	Meter		mg/L	-	-	-	-	
WATER QUALITY PARAMETERS									
Group 1 - Conventional									
pH	PHW1W1	Meter	0.01		500 ml	"Routine" P	in the dark at 4 °C	48 hrs.	
Specific Conductance	ECW1W1	Meter	0.2	uS/cm					
Colour	CLO2W1	Colour disk	3	T.C.U.					
Total Alkalinity	TAL2W1	Titration	5	mg/L					
Total Hardness	HARD	Calculated	1	mg/L					
Bicarbonate	BIC1W1	Calculated	5	mg/L					
Carbonate	CO31W1	Calculated	5	mg/L					
Total Suspended Solids	TSS1W1	Gravimetric	2	mg/L				7 days	
Total Dissolved Solids	DSW1W1	Calculated	10	mg/L				7 days	
Total Organic Carbon	TOC1W1	n Infrared TO	1	mg/L	100 ml	"TOC" glass	1 ml H_2SO_4	5 days	
Dissolved Organic Carbon	DOC1W1	OC Analyzer	1	mg/L	in TOC bottle			5 days	filter at lab
Group 2 - Major Ions									
Calcium	ICPCAR	ICP	0.05	mg/L	500 ml	"Routine" P	in the dark at 4 °C	5 days	
Magnesium	ICPMGR	ICP	0.1	mg/L				5 days	
Potassium	ICPKR	ICP	0.1	mg/L				5 days	
Sodium	ICPNAR	ICP	1	mg/L				5 days	
Chloride	CHL1W1	Colorimetry	0.5	mg/L				14 days	
Sulphate	ICPSO4	Colorimetry	0.5	mg/L				5 days	
Sulphide	CUL2W1	Titration	0.002	mg/L	100 ml	"Sulphide" P	2 ml Zn acetate + 1 ml NaOH	5 days	
Group 3 - Nutrients									
Nitrogen - Ammonia	NH41W1	Colorimetry	0.05	mg/L	100 ml	"nutrients" P	2 ml H_2SO_4	10 days	
Nitrogen - Kjeldahl	TKN1W1	Colorimetry	0.2	mg/L	100 ml	"nutrients" P	2 ml H_2SO_4	5 days	
Nitrate + Nitrite	NO231W1	Colorimetry	0.05	mg/L	100 ml	"Routine" P	in the dark at 4 °C	48 hours	
Total Phosphorus	TPW1W1	Colorimetry	0.02	mg/L	50 ml	"nutrients" P	2 ml H_2SO_4	10 days	
Dissolved Phosphorus	TDP1W1	Colorimetry	0.02	mg/L	50 ml	"Routine" P	in the dark at 4 °C	5 days	filter and preserve at lab
Group 4 - BOD									
Biochemical Oxygen Demand	BOD1W1	Winkler	2	mg/L	1 L	"BOD" P	in the dark at 4 °C	48 hours	
Group 5 - Other									
Total Recoverable Hydrocarbons	HOG2W1	APHA 5520F	0.5	mg/L				5 days	
Naphthenic acids	NAP1W8	FTIR	1	mg/L	1 L	"Naph." G	0.5g asorbic acid + 2 NaOH pellets	10 days	
Microtox IC50 and IC20				%	1 L	"Micro." G	in the dark at 4 °C	5 days	done by Hydroqual
Total Phenolics	PHE1W1	EPA 420.2	0.001	mg/L	100 ml	"Phen." G	H_2SO_4 < pH 2	24 hrs.	
Chlorophyll "a"	CHP1W	Colorimetry							done by Hydroqual

LABORATORY ANALYTICAL METHODS

(G = glass, P = plastic)

PARAMETER	ETL CODE	METHOD	DETECTION LIMIT	UNITS	REQUIRED VOLUME	CONTAINER TYPE	SAMPLE PRESERVATION	HOLDING TIME	COMMENTS
Group 6 - Total Metals									
Aluminum (Al)	PMSALT	ICP	0.005	mg/L	500 ml	P	NO_3 < pH 2	28 days	
Antimony (Sb)	PMSSBT	AA	0.0004	mg/L					
Arsenic (As)	PMSAST	AA	0.0004	mg/L					
Barium (Ba)	PMSBAT	ICP	0.0002	mg/L					
Beryllium (Be)	PMSBET	ICP	0.001	mg/L					
Boron (B)	PMSBT	ICP	0.002	mg/L					
Cadmium (Cd)	PMSCDT	ICP	0.0002	mg/L					
Calcium (Ca)	PMSCAT	ICP	0.05	mg/L					
Chromium (Cr)	PMSCRT	ICP	0.0004	mg/L					
Cobalt (Co)	PMSCOT	ICP	0.0005	mg/L					
Copper (Cu)	PMSCUT	ICP	0.0004	mg/L					
Iron (Fe)	PMSFET	ICP	0.01	mg/L					
Lead (Pb)	PMSPBT	ICP	0.0001	mg/L					
Lithium (Li)	PMSLIT	ICP	0.003	mg/L					
Magnesium (Mg)	PMSMGT	ICP	0.01	mg/L					
Manganese (Mn)	PMSMNT	ICP	0.0001	mg/L	▼	▼	▼	▼	
Mercury (Hg)	PMSHGT	CVAA	0.0002	mg/L	250 ml	P	2 ml NO_3 + dichromate	30 days	
Molybdenum (Mo)	PMSMOT	ICP	0.0001	mg/L	500 ml	P	NO_3 < pH 2	28 days	
Nickel (Ni)	PMSNIT	ICP	0.0004	mg/L					
Phosphorus (P)		ICP		mg/L					
Potassium (K)	PMSKT	ICP	0.01	mg/L					
Selenium (Se)	PMSSET	AA	0.0004	mg/L					
Silicon (Si)	PMSSIT	ICP	0.007	mg/L					
Silver (Ag)	PMSAGT	ICP	0.001	mg/L					
Sodium (Na)	PMSNAT	ICP	0.1	mg/L					
Strontium (Sr)	PMSSTR	ICP	0.0001	mg/L					
Sulphur (S)	ICPST	ICP	0.5	mg/L					
Titanium (Ti)	PMSTIT	ICP	0.0004	mg/L					
Uranium (U)	PMSUT	ICP	0.0001	mg/L					
Vanadium (V)	PMSVT	ICP	0.0002	mg/L					
Zinc (Zn)	PMSZNT	ICP	0.002	mg/L	▼	▼	▼	▼	
Group 7 - Dissolved metals									
Aluminum (Al)		ICP	0.005	mg/L	500 ml	P	filter, NO_3 < pH 2	28 days	
Antimony (Sb)		AA	0.0004	mg/L					
Arsenic (As)		AA	0.0004	mg/L					
Barium (Ba)		ICP	0.0002	mg/L					
Beryllium (Be)		ICP	0.001	mg/L					
Boron (B)		ICP	0.002	mg/L					
Cadmium (Cd)		ICP	0.0002	mg/L					
Calcium (Ca)		ICP	0.05	mg/L					
Chromium (Cr)		ICP	0.0004	mg/L					
Cobalt (Co)		ICP	0.0005	mg/L					
Copper (Cu)		ICP	0.0004	mg/L					
Iron (Fe)		ICP	0.01	mg/L					
Lead (Pb)		ICP	0.0001	mg/L					
Lithium (Li)		ICP	0.003	mg/L					

LABORATORY ANALYTICAL METHODS

(G = glass, P = plastic)

PARAMETER	ETL CODE	METHOD	DETECTION LIMIT	UNITS	REQUIRED VOLUME	CONTAINER TYPE	SAMPLE PRESERVATION	HOLDING TIME	COMMENTS
Magnesium (Mg)		ICP	0.01	mg/L					
Manganese (Mn)		ICP	0.0001	mg/L					
Mercury (Hg)		CVAA	0.0002	mg/L	250 ml	P	filter, 2 ml NO_3 + dichromate	30 days	
Molybdenum (Mo)		ICP	0.0001	mg/L	500 ml	P	filter, NO_3 < pH 2	28 days	
Nickel (Ni)		ICP	0.0004	mg/L					
Phosphorus (P)		ICP		mg/L					
Potassium (K)		ICP	0.01	mg/L					
Selenium (Se)		AA	0.0004	mg/L					
Silicon (Si)		ICP	0.007	mg/L					
Silver (Ag)		ICP	0.001	mg/L					
Sodium (Na)		ICP	0.1	mg/L					
Strontium (Sr)		ICP	0.0001	mg/L					
Titanium (Ti)		ICP	0.0004	mg/L					
Uranium (U)		ICP	0.0001	mg/L					
Vanadium (V)		ICP	0.0002	mg/L					
Zinc (Zn)		ICP	0.002	mg/L					
Group 8a - Target PAHs									
Naphthalene		GC/MS	0.02	ppb	4 L	G - amber	in the dark at 4 °C	7days	
Acenaphthylene		GC/MS	0.02	ppb					
Acenaphthene		GC/MS	0.02	ppb					
Fluorene		GC/MS	0.02	ppb					
Dibenzothiophene		GC/MS	0.02	ppb					
Phenanthrene		GC/MS	0.02	ppb					
Anthracene		GC/MS	0.02	ppb					
Fluoranthene		GC/MS	0.02	ppb					
Pyrene		GC/MS	0.02	ppb					
Benzo(a)Anthracene/Chrysene		GC/MS	0.02	ppb					
Benzo(b&k)fluoranthene		GC/MS	0.02	ppb					
Benzo(a)pyrene		GC/MS	0.02	ppb					
Indeno(c,d-123)pyrene		GC/MS	0.02	ppb					
Dibenzo(a,h)anthracene		GC/MS	0.02	ppb					
Benzo(g,h,i)perylene		GC/MS	0.02	ppb					
Group 8b - Alkylated PAHs									
Methyl naphthalenes		GC/MS	0.02	ppb	contained in above sample				
C2 Substituted naphthalenes		GC/MS	0.04	ppb					
C3 Subst'd naphthalenes		GC/MS	0.04	ppb					
C4 Subst'd naphthalenes		GC/MS	0.04	ppb					
Biphenyl		GC/MS	0.04	ppb					
Methyl biphenyl		GC/MS	0.04	ppb					
C2 Substituted biphenyl		GC/MS	0.04	ppb					
Methyl acenaphthene		GC/MS	0.04	ppb					
Methyl fluorene		GC/MS	0.04	ppb					
C2 Substituted fluorene		GC/MS	0.04	ppb					
Methyl phenanthrene/anthracene		GC/MS	0.04	ppb					
C2 Subst'd phenanthrene/anthracene		GC/MS	0.04	ppb					
C3 Subst'd phenanthrene/anthracene		GC/MS	0.04	ppb					
C4 Subst'd phenanthrene/anthracene		GC/MS	0.04	ppb					

LABORATORY ANALYTICAL METHODS

(G = glass, P = plastic)

PARAMETER	ETL CODE	METHOD	DETECTION LIMIT	UNITS	REQUIRED VOLUME	CONTAINER TYPE	SAMPLE PRESERVATION	HOLDING TIME	COMMENTS
1-Methyl-7-isopropyl-phenanthrene (Retene)		GC/MS	0.04	ppb					
Methyl dibenzothiophene		GC/MS	0.04	ppb					
C2 Substituted dibenzothiophene		GC/MS	0.04	ppb					
C3 Subst'd dibenzothiophene		GC/MS	0.04	ppb					
C4 Subst'd dibenzothiophene		GC/MS	0.04	ppb					
Methyl fluoranthene/pyrene		GC/MS	0.04	ppb					
Methyl benzo(a)anthracene/chrysene		GC/MS	0.04	ppb					
C2 Subst'd benzo(a)anthracene/chrysene		GC/MS	0.04	ppb					
Methyl benzo(b or k) fluoranthene/methyl benzo(a		GC/MS	0.04	ppb					
C2 Subst'd benzo(b or k) fluoranthene/benzo(a)py		GC/MS	0.04	ppb					
SEDIMENT QUALITY PARAMETERS									
Total Metals									
Aluminum (Al)	PMSALT	ICP/MS	0.005	mg/L	500 ml	G	NO_3 < pH 2	6 months	
Antimony (Sb)	PMSSBT	AA	0.0004	mg/L					
Arsenic (As)	PMSAST	AA	0.0004	mg/L					
Barium (Ba)	PMSBAT	ICP/MS	0.0002	mg/L					
Beryllium (Be)	PMSBET	ICP/MS	0.001	mg/L					
Boron (B)	PMSBT	ICP/MS	0.002	mg/L					
Cadmium (Cd)	PMSCDT	ICP/MS	0.0002	mg/L					
Calcium (Ca)	PMSCAT	ICP/MS	0.05	mg/L					
Chromium (Cr)	PMSCRT	ICP/MS	0.0004	mg/L					
Cobalt (Co)	PMSCOT	ICP/MS	0.0005	mg/L					
Copper (Cu)	PMSCUT	ICP/MS	0.0004	mg/L					
Iron (Fe)	PMSFET	ICP/MS	0.01	mg/L					
Lead (Pb)	PMSPBT	ICP/MS	0.0001	mg/L					
Lithium (Li)	PMSLIT	ICP/MS	0.003	mg/L					
Magnesium (Mg)	PMSMGT	ICP/MS	0.01	mg/L					
Manganese (Mn)	PMSMNT	ICP/MS	0.0001	mg/L					
Mercury (Hg)	PMSHGT	AA	0.0002	mg/L	125 ml	G	2 ml NO_3	30 days	
Molybdenum (Mo)	PMSMOT	ICP/MS	0.0001	mg/L	500 ml	G	NO_3 < pH 2	6months	
Nickel (Ni)	PMSNIT	ICP/MS	0.0004	mg/L					
Phosphorus (P)		ICP/MS		mg/L					
Potassium (K)	PMSKT	ICP/MS	0.01	mg/L					
Selenium (Se)	PMSSET	AA	0.0004	mg/L					
Silicon (Si)	PMSSIT	ICP/MS	0.007	mg/L					
Silver (Ag)	PMSAGT	ICP/MS	0.001	mg/L					
Sodium (Na)	PMSNAT	ICP/MS	0.1	mg/L					
Strontium (Sr)	PMSSTR	ICP/MS	0.0001	mg/L					
Sulphur (S)	ICPST	ICP	0.5	mg/L					
Titanium (Ti)	PMSTIT	ICP/MS	0.0004	mg/L					
Uranium (U)	PMSUT	ICP/MS	0.0001	mg/L					
Vanadium (V)	PMSVT	ICP/MS	0.0002	mg/L					
Zinc (Zn)	PMSZNT	ICP/MS	0.002	mg/L					
Target PAHs									
Naphthalene	PAH7S	GC/MS	0.01	ppm	125 ml	G	in the dark at 4 °C	14 days	

LABORATORY ANALYTICAL METHODS

(G = glass, P = plastic)

PARAMETER	ETL CODE	METHOD	DETECTION LIMIT	UNITS	REQUIRED VOLUME	CONTAINER TYPE	SAMPLE PRESERVATION	HOLDING TIME	COMMENTS
Acenaphthylene	PAH7S	GC/MS	0.01	ppm					
Acenaphthene	PAH7S	GC/MS	0.01	ppm					
Fluorene	PAH7S	GC/MS	0.01	ppm					
Dibenzothiophene	PAH7S	GC/MS	0.01	ppm					
Phenanthrene	PAH7S	GC/MS	0.01	ppm					
Anthracene	PAH7S	GC/MS	0.01	ppm					
Fluoranthene	PAH7S	GC/MS	0.01	ppm					
Pyrene	PAH7S	GC/MS	0.01	ppm					
Benzo(a)Anthracene/Chrysene	PAH7S	GC/MS	0.01	ppm					
Benzo(b&k)fluoranthene	PAH7S	GC/MS	0.01	ppm					
Benzo(a)pyrene	PAH7S	GC/MS	0.01	ppm					
Indeno(c,d-123)pyrene	PAH7S	GC/MS	0.01	ppm					
Dibenzo(a,h)anthracene	PAH7S	GC/MS	0.01	ppm					
Benzo(g,h,i)perylene	PAH7S	GC/MS	0.01	ppm					
Alkylated PAHs									
Methyl naphthalenes	PAH7S	GC/MS	0.01	ppm			contained in above sample		
C2 Substituted naphthalenes	PAH7S	GC/MS	0.02	ppm					
C3 Subst'd naphthalenes	PAH7S	GC/MS	0.02	ppm					
C4 Subst'd naphthalenes	PAH7S	GC/MS	0.02	ppm					
Biphenyl	PAH7S	GC/MS	0.02	ppm					
Methyl biphenyl	PAH7S	GC/MS	0.02	ppm					
C2 Substituted biphenyl	PAH7S	GC/MS	0.02	ppm					
Methyl acenaphthene	PAH7S	GC/MS	0.02	ppm					
Methyl fluorene	PAH7S	GC/MS	0.02	ppm					
C2 Substituted fluorene	PAH7S	GC/MS	0.02	ppm					
Methyl phenanthrene/anthracene	PAH7S	GC/MS	0.02	ppm					
C2 Subst'd phenanthrene/anthracen	PAH7S	GC/MS	0.02	ppm					
C3 Subst'd phenanthrene/anthracen	PAH7S	GC/MS	0.02	ppm					
C4 Subst'd phenanthrene/anthracen	PAH7S	GC/MS	0.02	ppm					
Methyl dibenzothiophene	PAH7S	GC/MS	0.02	ppm					
C2 Substituted dibenzothiophene	PAH7S	GC/MS	0.02	ppm					
C3 Subst'd dibenzothiophene	PAH7S	GC/MS	0.02	ppm					
C4 Subst'd dibenzothiophene	PAH7S	GC/MS	0.02	ppm					
Methyl fluoranthene/pyrene	PAH7S	GC/MS	0.02	ppm					
Methyl benzo(a)anthracene/chrysen	PAH7S	GC/MS	0.02	ppm					
C2 Subst'd benzo(a)anthracene/chry	PAH7S	GC/MS	0.02	ppm					
Methyl benzo(b or k) fluoranthene/m	PAH7S	GC/MS	0.02	ppm					
C2 Subst'd benzo(b or k) fluoranthe	PAH7S	GC/MS	0.02	ppm					
Others									
Recoverable Hydrocarbons	HOG1S	Gravimetric	100	ppm	125 ml	G			
Volatile Organics	VOC 1S1	GC/MS	*		125 ml	G		14 days	
Texture	PSA1S	Hydrometer			125 ml	bag			
Total Organic Carbon	COM1S	Dichromate	0.10%		125 ml	G			

LABORATORY ANALYTICAL METHODS

(G = glass, P = plastic)

PARAMETER	ETL CODE	METHOD	DETECTION LIMIT	UNITS	REQUIRED VOLUME	CONTAINER TYPE	SAMPLE PRESERVATION	HOLDING TIME	COMMENTS
*Varies from 10 ppb to 2000 ppb, depending on compound									
APHA -American Public Health Association									
FTIR - Fourier Transformed Infrared Spectrometer									
EPA - Environmental Protection Agency									
ICP - Inductively Coupled Plasma									
AA - Atomic Absorption									
CVAA - Cold Vapour Atomic Absorption									
GC/MS - Gas Chromatography/Mass Spectroscopy									

APPENDIX III

SEDIMENT SAMPLING (TP 8.2-2)

1. PURPOSE

This technical procedure describes the methods to be used for sampling bottom sediment (referred to below as sediment) for analysis of physical, chemical or toxicological characteristics. It does not apply to collection of sediment for benthic community analysis, which is covered in TP8.6 (Benthic Invertebrate Sampling).

2. APPLICABILITY

This technical procedure is applicable to any persons involved in the collection of sediment and is not restricted to any geographic area.

3. DEFINITIONS

3.1 Analytical Request Form

Standard form provided by analytical laboratories. This form is filled out by the person collecting samples and is used to indicate how each sample is to be analyzed. This form is often combined with the Chain-of-Custody Form in a single document.

3.2 Chain-of-Custody Form

Standard form used to track the movement of sample containers from the time they leave the field until they arrive at the specified laboratory. The Chain-of-Custody form provides a clear record of sample transport and handling, thereby reducing the risk of sample loss during transport. This form may be combined with the Analytical Request Form in a single document. Golder Associates' combined form is attached as Appendix 1.

3.3 Chemical Analysis

Analytical procedure used to measure the *amount* of a certain compound, or group of compounds, present in a sample.

3.4 Quality Assurance/Quality Control (QA/QC)

Quality Assurance refers to a detailed protocol used to produce high quality products, while Quality Control refers to the process by which this protocol is tested to ensure that final products are of the specified quality. With reference to sediment sampling, QA protocol includes the use trained personnel, proper sampling methods, clean containers and equipment, proper sample preservation and transportation and detailed documentation of the entire process; field, travel and other test blanks are used for Quality Control testing.

3.5 Sample Types

3.5.1 Grab Samples

Sample containing sediment collected during a single sampling event (i.e., sediment taken from a given place at a given time).

3.5.2 Composite Samples

Sample containing a mixture of sediment collected from multiple locations or from different times at the same location.

3.5.3 Replicate Samples

Replicate samples are used to evaluate within-site variation. Replicate samples are collected by filling multiple containers at a single site. They are labelled and preserved individually and are submitted separately to the analytical laboratory. Check the SWI for the number of replicate samples required per sampling site.

3.5.4 Split Samples

Split samples are used to check analytical variation. A single sample (e.g. grab) is collected and is split into two sample containers. These are labelled and preserved individually and are submitted separately to the analytical laboratory.

3.6 Sediment

Loose material on the bottom of waterbodies, including organic material (live plants or decaying plant material) and inorganic material of varying particle size.

3.7 Specific Work Instructions (SWI)

Detailed instructions in a standardized format provided to field personnel. The SWI describe all aspects of the work to be conducted, including personnel allocation, procedures to be used, time allocation and any additional information deemed necessary by the project or task manager.

3.8 Toxicity Analysis

Analytical procedure specifically designed to examine how the health of living organisms may be affected by exposure to a given substance or sample. Toxicity tests can be based on either: acute exposures (short-term exposures lasting only a small portion of the animals life cycle, e.g. 96 hours for

rainbow trout); or, chronic exposures (longer-term exposures meant to represent a significant portion of the animal's life cycle, or a particularly sensitive portion of the animal's life cycle, e.g. 28 days for *Daphnia magna*). Responses measured in toxicity tests can be lethal (e.g. mortality), or sublethal (e.g., reduced growth or reproduction). Unlike other procedures, toxicity testing evaluates the sample as a whole, rather than describing its chemical make-up.

4. REFERENCES AND SUGGESTED READING

Clesceri, L.S., A.E. Greenberg and R.R. Trussell. 1989. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C., U.S.A.

Environment Canada. 1993. Quality Assurance in Water Quality Monitoring. Ecosystem Sciences and Evaluation Directorate Conservation and Protection. Ottawa, Ontario.

5. DISCUSSION

5.1 General Safety

Refer to Golder Associates Ltd. Health and Safety Manual.

5.2 Methods

5.2.1 Sampling Site Selection and Identification

General sampling locations are described in SWI. However, field crews will have a certain degree of freedom in choosing the exact locations from which to take the samples. When selecting these sites, personnel should consider the layout of the local environment, project objectives and personal safety. They should then choose areas that are both easily accessible and representative of the target waterbody or waterbodies.

Once sampling sites have been identified, they must be accurately described relative to permanent landmarks, such as groundwater wells, outfalls or distinctive landscape features; measuring the distance from permanent landmarks to each site with an appropriate compass heading is recommended. Ideally, one should try to use the Global Positioning System (GPS), but locations can also be recorded as the perpendicular distance from the shoreline and the distance upstream or downstream of a permanent landmark.

5.2.2 Sampling Methods

To ensure the contaminant-free collection of representative sediment samples, consider the following points:

- collect as representative a sample as possible based on the local sediment conditions and safety;
- avoid obvious sources of contamination when collecting samples, unless those sources represent the impact being investigated;
- use an appropriate sampling device, cleaned consistently with the specific requirements of the sampling program (consult SWI);
- sampling equipment should be cleaned between sites as specified in the SWI; and
- only pre-cleaned sample containers provided by the analytical laboratory or those approved by the laboratory should be used.

Grab Samples (Ekman, Ponar, Peterson)

1. Label sample container with indelible ink marker.

2. Grab sampler should be rinsed twice with ambient water prior to sampling to ensure no sediment or other material are attached. This should be done with the jaws open. Be sure to check that sediments have not dried on to the sampler. If so, remove dry material to prevent contamination and rinse sampler again. Additional cleaning may be required, as specified in the SWI.

3. Using a graduated line attached to the top of the sampler, lower it **slowly** until it touches the bottom. If using the Ekman grab, be sure to retain the messenger (small weight used to trigger sampler) at the surface. Be careful not to touch the bottom too abruptly as surface sediments could be disturbed by the mouth of the sampler which would result in an inaccurate sample.

4. Making sure the graduated line is as vertical as possible, release the messenger. Maintain some tension of the line to ensure that the messenger falls freely (Note: when using the Ponar or Peterson grabs, which do not have a messenger, use the appropriate method to trigger the sampler).

5. Once you feel the messenger trigger the sampler, begin to slowly raise it off the bottom. It is important to raise the grab slowly otherwise fine sediments may be lost.

6. Once the grab reaches the surface, the spring loaded jaws should be pried open and the sample put into a flat bottomed pan or similar container. The entire sample, or the top layer of the sample can then be scooped into containers. Sample containers (bottles or bags) should be stored appropriately, as instructed by the analytical laboratory.

Core Samples

Sediment cores are used more frequently for metals analyses than the grab samplers. Any part of core samplers that comes into contact with the sample material must be made of plastic to avoid metal contamination of samples from the sampler itself. For metals analysis, clean the sampler using laboratory soap and rinse it with ambient water prior to sampling and between samples. Cleaning requirements may vary depending on the analyses and should be determined prior to sampling (consult SWI).

1. Label sample container with indelible ink marker.

2. For the 5-cm mouth metal core sampler, insert the plastic sleeve and an 'eggshell' stopper into the mouth of the sampler and screw on the plastic nose cone until tight.

3. If sampling from a boat, slowly lower the sampler using a graduated line until it gently touches but does not penetrate the sediment. If sampling by hand, place and hold the core sampler at the desired location on the bottom.

4. For lake sampling, raise the sampler 1-1.5 metres above the sediment and drop it vertically to collect a sample. Maintain some tension on the line to ensure the sampler falls vertically.

5. Slowly raise the sampler until it reaches the boat. Before lifting the sampler from the water, plug the bottom opening with a rubber stopper to prevent loss of fine sediments.

6. Unscrew the bottom cone and remove the plastic tube containing the sample, while holding the corer in a vertical position. Decant the entire sample, or its desired portion, into an appropriate, pre-labelled container. Sample containers (bottles or bags) should be stored appropriately, as instructed by the analytical laboratory.

5.2.3 Sample Documentation

The importance of proper sample documentation cannot be overemphasized. Lack of careful documentation can lead to misunderstandings and questionable test results. Components of proper documentation of field activities are described below.

Field Notebooks

Field notebooks must be kept, describing all field activities. Format of field notes and information to be recorded should follow Golder Associates' specific guidelines. During the field survey, field notes must be maintained in a permanent, safe location at the field site where samples are collected. If possible, new entries in the field note book should be photocopied at the end of each field day and copies should be stored in a safe place.

Sample Labels

Sample labels must contain the following information:

- Sample identifier (name of site or sample code);
- Date (written as day/month/year; month abbreviated as three letters) and time (24 hour clock) of collection;
- Initials of collector; and
- Analysis requested (this is usually done by the analytical laboratory in the form of a code on the sample bottle).

Fill out labels at the time of collection using waterproof ink and affix a label to each sample container. Plastic bottles may be labelled by writing directly on the bottle using a waterproof marker; however, this approach is not recommended if samples are transported over long distances (friction may rub label off) or if bags of ice are used to keep the samples cool (water may damage label information).

Custody Seals

If required for a project, numbered seals should be used to detect unauthorized tampering with samples in transit. Attach the seal in a way that it is necessary to break it to open the cooler containing the samples. The number on the custody seal should be recorded in the field note book and on the Chain-of-Custody and Analytical Request forms

Chain-of-Custody Forms and Analytical Request Forms

Chain-of-Custody and Analytical Request forms must accompany all samples submitted for analysis. These forms are usually combined as a single document. An example of Golder Associates' combined Chain-of-Custody and Analytical Request Form is provided in Appendix 1.

The combined form must be filled out completely and the white and yellow copies should be sent along with the samples being submitted. Field personnel should retain the pink copy after it is signed by the shipper. Depending on the shipping container, these forms can either be enclosed inside the sealed container or attached firmly to the outside of the container. In either case, it is advisable to enclose the forms within a waterproof plastic bag to guard against damage. It is important that each person having custody or control of the samples identify themselves on this form. This means that the person collecting the sample, any intermediate persons involved in packaging, storing or transporting the sample and the person accepting the sample on behalf of the analytical lab must all be identified.

5.2.4 Sample Handling

Samples need to be treated or preserved according to their specific handling protocols as prescribed by the laboratory. Storage and shipping times are very important and must be considered, as many analytical parameters require that the sample needs to be in the laboratory for analysis within a specific time frame to ensure sample integrity. Refer to SWIs for specific project requirements or check with the analytical laboratory. Contact the laboratory in advance to secure recommended sample storage and transportation times specific to the analytical parameters. Crew leader is to confirm shipment arrival at the laboratory and to explain analysis requests if needed.

6. EQUIPMENT

6.1 Sampling Equipment

The following is a list of the equipment recommended for sediment sampling:

- precleaned sample containers from analytical laboratory

- sampling equipment
- metal tray
- coolers and ice

6.2 Field Location Equipment and Logs

The following is recommended for the complete documentation of sediment samples:

- field record sheets
- maps of area for site locations
- indelible ink pens and felt tip markers and pencils
- 50 metre long tape measure
- survey flagging tape
- GPS unit
- survey lathe
- Analytical Request forms
- Chain-of-Custody forms

6.3 Health and Safety Equipment

- waders and waterproof gloves
- suitable clothing for prolonged water work: heavy socks, warm pants, rain gear, etc.
- first aid kit
- approved personal floatation device

APPENDIX I

SAMPLE CHAIN OF CUSTODY AND ANALYSIS REQUEST FORMS

GOLDER ASSOCIATES LTD.
CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Page ___ of ___

Field Sampler: (Signature) _____

Phone No. _____

Shipment Date: _____

Carrier: _____

Waybill No.: _____

Ship To:

Send Results To:

Project Name: _____

Project No. _____

P.O. No.: _____

Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Relinquished from lab by: (Signature)	Received by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): _____ Standard Turnaround Time: _____

PLEASE RETURN WHITE COPY TO GOLDER ASSOCIATES LTD.

GOLDER ASSOCIATES LTD.
CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Field Sampler: (Signature) _____

Phone No._____

Shipment Date:_____

Carrier: _____

Waybill No.: _____

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): _____

Standard Turnaround Time: _____

PLEASE RETURN WHITE COPY TO GOLDER ASSOCIATES LTD.

APPENDIX IV

BENTHIC INVERTEBRATE SAMPLING (TP 8.6-1)

1. PURPOSE

This technical procedure describes the methods to be used for sampling benthic invertebrates for community structure analysis and tissue analysis. Detailed sampling procedures are provided for the use of the Neill cylinder, Hess sampler, Surber sampler, the Ekman and Ponar grabs, kicknet for community sampling and the hand-held net for tissue sampling.

2. APPLICABILITY

This technical procedure is applicable to any persons involved in the collection of benthic invertebrates from streams, rivers and lakes. Since it contains a variety of sampling techniques that are appropriate for a range of benthic habitats, it is not restricted to a given geographic area.

3. DEFINITIONS

3.1 Benthic Invertebrates (benthic macroinvertebrates, benthos, zoobenthos)

Non-vertebrate animals, such as insects, crustaceans, worms and mollusks, that inhabit the bottoms of waterbodies. Macroinvertebrates are visible to the unaided eye and are frequently defined as those animals that are larger than 0.5 mm. Benthic invertebrates may live on the surface of the substratum, between particles, or burrowed into the substratum to various depths, or on aquatic plants.

3.2 Benthic Habitat

The physical and biological environment which provides a place for benthic (bottom-dwelling) animals to live. Invertebrate habitat may be broadly characterized as run, riffle, backwater, pool, erosional and depositional (see below). More detailed habitat characterization is required during invertebrate surveys, as outlined in Section 5.4.

3.3 Chain-of-Custody Form

Standardized form used as a means of keeping close track of samples that are taken in the field and are subsequently transported to laboratories for chemical or taxonomic analysis. Whenever the samples are transported from one location to the next, the custody is relinquished from the delivery person to the receiver by signing the forms and indicating date and time. These forms substantially decrease the risk of losing samples because they provide a clear record of the chain of transport of the samples.

3.4 Depositional Habitat

Standing water or slow moving areas in streams and rivers where bottom sediments are soft, consisting of sand and smaller particles.

3.5 Erosional Habitat

Wave-washed areas of lakes and areas of streams and rivers with moderate to fast currents and hard bottoms consisting of a variety of particle sizes, but usually dominated by gravel and larger particles.

3.6 Exposure Area

Part of the study area that is exposed to the effluent or disturbance being monitored. Data collected from the reference area (see below) are compared with data from the exposure area to evaluate the presence and severity of environmental effects.

3.7 Littoral Zone

The near-shore area of lakes, where light penetration is sufficient to allow the growth of rooted aquatic plants (macrophytes) or plant-like (macrophytic) algae. The littoral zone is usually the most productive area of lakes and forms a belt of varying width around the periphery of lakes. The size and maximum depth of the littoral zone largely depends on water clarity, bottom sediment characteristics, wave exposure and the extent of water level fluctuation.

3.8 Profundal Zone

The deep area of lakes, where light penetration is low, characterized by exposed fine sediments free of vegetation.

3.9 Reference (Control) Area

Part of the study area that is not exposed to the effluent or disturbance being monitored, representing the baseline condition in the river or lake monitored. Data collected from the reference area are compared with data from the exposure area to evaluate the presence and severity of environmental effects.

3.10 Replicate Sample

Replicate samples are additional samples collected from a sampling site. The number of replicate samples is specific to the project and should be included in the Specific Work Instructions (SWI).

3.11 Specific Work Instructions (SWI)

Detailed instructions in a standardized format provided to field personnel. The SWI describe all aspects of the work to be conducted, including personnel allocation, procedures to be used, time allocation and any additional information deemed necessary by the project manager.

3.12 Substratum

The bottom of waterbodies, usually consisting of varying proportions of organic detritus, clay, silt, sand, gravel, cobble and bedrock.

3.13 Tracer

A chemical or variable such as conductivity that can be used as an indicator of the presence and approximate dilution of a discharge from a point source. Field measurements of a tracer can aid in the selection of sampling sites.

4. REFERENCES AND SUGGESTED READING

Alberta Environment. 1990. Selected methods for the monitoring of benthic invertebrates in Alberta rivers. Environmental Quality Monitoring Branch, Environmental Assessment Division, Edmonton, AB. 41 pp.

Environment Canada. 1993. Guidelines for monitoring benthos in freshwater environments. Prepared by EVS Consultants for Environment Canada, North Vancouver, BC. 81 pp.

Klemm, D.J., P.A. Lewis, F. Fulk and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. Environmental Monitoring Systems Laboratory, Cincinnati, U.S. Environmental Protection Agency, EPA/600/4-90/030, 256 pp.

Rosenberg, D.M. and V.H. Resh (Eds.). 1993. Freshwater biomonitoring and benthic macroinvertebrates. Chapman & Hall, New York, 488 pp.

5. DISCUSSION

5.1 General Safety

Refer to Golder Associates Ltd. Safety Manual. Transportation of Dangerous Goods (TDG) and Workplace Hazardous Materials Information System (WHMIS) regulations must be followed when handling, transporting and storing samples.

5.2 Site Selection

Approximate site locations should be identified prior to the field survey and should be selected according to the SWI. Exact sampling sites should be selected in the field to ensure that sites within a habitat type (i.e., erosional or depositional) are as similar in terms of physical characteristics (especially current velocity, depth and substratum composition) as possible.

When sampling lakes, one's ability to assess the composition of the substratum is limited. Therefore, test grabs should be collected to ascertain that bottom sediments are suitable for grab sampling and comparable to those of other sampling locations. Special care should be taken to minimize the variation in depth among sampling sites (unless the objectives of the study indicate otherwise), since depth is one of the most important factors affecting benthic invertebrate community structure in lakes. It may also be useful to estimate the depth of the littoral zone prior to sampling, since benthic communities within the littoral zone (shallow water) are usually considerably different from those in the profundal zone (deep water).

When sampling erosional sites in rivers or streams, site selection should focus on minimizing variation in terms of current velocity and substratum composition, since most sampling devices useful in such areas can only be operated within a limited depth range. In depositional areas, minimizing variation in depth and substratum composition should be the major consideration. An initial visual survey of the study reach is highly recommended to select the habitat types that are available in all sampling areas. This is especially important during studies of effects of wastewater discharges, because benthic habitat in the exposure area may be limited to a few types, and reference sites must be as closely matched to sites sampled in the exposure area as possible.

One additional consideration when selecting sampling sites during monitoring studies is exposure to the effluent or disturbance being monitored. When monitoring the effect of a specific discharge, it is advisable to select a simple tracer of the effluent that can be measured in the field, which will allow the evaluation of the relative exposure of each site during sampling. A frequently used tracer is conductivity, since the majority of effluents have typically high conductivity compared with ambient values. Measurement of conductivity along a river transect at 1 m intervals will usually be adequate to locate the area of greatest exposure and provide an idea of the width of the plume.

Sampling sites must be accurately located relative to permanent landmarks, such as man-made structures or distinctive landscape features. If possible, measurements with long tape measure and electronic distance measuring devices should be used, in addition to coordinates obtained using a Global Positioning System (GPS) unit. Regardless of the method used for this purpose, detailed notes regarding site locations should be made in the field logbook or on the field data sheets, site locations should be marked on a topographic map and a photograph of the sampling site and relevant landmarks should be taken.

5.3 Sampling Methods

5.3.1 Neill Cylinder or Hess Sampler (erosional habitat)

The following steps should be followed to collect samples using these devices:

1. Select sampling site (Section 5.2). The area to be sampled should be undisturbed, at most 60 cm deep, in run or riffle habitat with moderate to high current velocity and gravel/cobble substratum.

2. Label sample bottle (1-L, wide mouth, plastic bottle) and attach it to the sampler net. An additional label, written with pencil on waterproof paper, should also be placed inside the sample bottle. (Shoulder-length gloves should be worn following this step to protect hands.)

3. Starting near the downstream limit of the sampling site, drive the bottom of the cylinder into the substratum and hold it there for the duration of sampling, with the sample net and attached bottle pointing downstream. Ensure that the seal at the bottom of the cylinder is adequate to prevent animals from escaping during sampling. Water should be flowing through the cylinder, entering through the circular hole at the front and exiting through the sampling net.

4. Reach into the cylinder and agitate the substratum manually to dislodge invertebrates, which will be transported into the downstream net. Gently rub the surfaces of all large rocks within the water enclosed by the cylinder and remove them until only smaller-sized particles (gravel and smaller) are left inside the cylinder. Using your hands, a small shovel, or a heavy-duty garden trowel, stir up the bottom to 5-10 cm depth. This entire step should take approximately 1 minute.

5. Allow suspended material to be transported into the net or to settle. Lift the cylinder with the net pointing down and dip it into the water a few times to transport all invertebrates clinging to the inside of the sampling net into the sample bottle.

6. Place the sampler on the shore or on a convenient surface and fold the net sampler over the mouth of the sample bottle. Pour out as much of the water as possible. When done, spray a small amount of water on the folded-over net to back-wash clinging organisms into the bottle.

7. Remove the bottle and add preservative. The 1-L sample bottle should be at most 1/2 full prior to adding preservative. Add 95% ethanol to obtain approximately 70-80% dilution, or buffered formalin to obtain approximately 10% dilution. Cap bottle, gently agitate it to distribute preservative evenly, double-check label and place it in a container for transport.

8. Rinse the cylinder and net in river water thoroughly to remove any clinging invertebrates and plant material.

Additional replicate samples should be collected using the same methods, from an undisturbed area upstream or adjacent the location of the previous replicate sample. Number of replicate samples should be specified in the SWI. Because differences in sample composition may occur due to slight differences in sampling technique among individuals, it is recommended that all samples for a study should be collected by the same person.

5.3.2 Surber Sampler (erosional habitat)

The operation of the Surber sampler is very similar to that of the Neill cylinder. It delineates the same area of the river bottom (0.1 m^2), but does not fully enclose it, which makes it prone to loss of some of the sample around the net. If given the choice of either sampler, a cylinder-type sampler (Neill cylinder or Hess sampler) should be used because it is a more quantitative sampling device. However, equipment availability, and logistic considerations (the Neill cylinder is heavy and unwieldy to carry) may

necessitate using the Surber sampler. Since Golder Associates owns a number of Surber samplers with different mesh sizes, it is important to select the right one. Mesh sizes >500 μm should not be used for benthic invertebrate sampling. Preferably, mesh size should be between 200 to 250 μm for benthic invertebrate sampling, but 500 μm mesh is sometimes acceptable. If in doubt, check SWI or verify the required mesh size with the project manager or a benthic invertebrate biologist.

The following steps should be followed to collect samples using this device:

1. Select sampling site (Section 5.2). The area to be sampled should be undisturbed, shallow enough for reaching the bottom with one's hands, in run or riffle habitat with moderate to high current velocity and gravel/cobble substratum.

2. Unfold the sampler, label a sample bottle and attach it to the sampler net. An additional label, written with pencil on waterproof paper, should also be placed inside the sample bottle. (Shoulder-length gloves should be worn following this step to protect hands.)

3. Starting near the downstream limit of the sampling site, place the bottom of the sampler on the substratum and hold it there for the duration of sampling, with the sample net and attached bottle pointing downstream. Ensure that the sampler is securely held on the bottom and that there is no space under its downstream side, which would allow invertebrates to bypass the net.

4. Reach into the enclosed area and agitate the substratum manually to dislodge invertebrates, which will be transported into the net. Gently rub the surfaces of all large rocks and remove them until only smaller-sized particles (gravel and smaller) are left in the sample area. Using your hand, a small shovel, or a heavy-duty garden trowel, stir up the bottom to a 5-10 cm depth. This entire step should take approximately 1 minute.

5. Allow suspended material to be transported into the net or to settle. Lift the sampler with the net pointing downstream and if necessary, spray the net with stream water a few times to transport all invertebrates into the sample bottle.

6. Fold the net over the mouth of the sample bottle. Pour out as much of the water as possible. When done, spray a small amount of water on the folded-over net to back-wash clinging organisms into the bottle.

7. Remove the bottle and add preservative. The 1 L sample bottle should be at most 1/2 full prior to adding preservative. Add 95% ethanol to obtain approximately 70-80% dilution, or buffered formalin to obtain approximately 10% dilution. Cap bottle, gently agitate it to distribute preservative evenly, double-check label and place it in a container for transport.

8. Rinse the sampler and net in river water thoroughly to remove any clinging invertebrates and plant material.

Additional replicate samples should be collected using the same methods, from an undisturbed area upstream or adjacent the location of the previous replicate sample. Because differences in sample composition may occur due to slight differences in sampling technique among individuals, it is recommended that all samples for a study should be collected by the same person.

5.3.3 Ekman and Ponar Grabs (standing water and depositional habitat)

Note that these samplers, especially the Ekman grab, require periodic maintenance even during sampling. Bolts frequently become loose during sampling and parts such as the springs and the messenger assembly (Ekman), or the hinge pin and the spring-loaded release pin (Ponar) may fall off, rendering the grab useless. For this reason, it is advisable to have a set of spare parts on the boat whenever these devices are used. The ropes attached to the grabs should also be checked periodically for wear.

The following steps should be followed to collect samples using these devices:

1. Select sampling site (Section 5.2). The area to be sampled should be undisturbed, with slow moving or standing water and soft sediments.

2. Label sample bottle. (Work gloves should be worn from this step to protect hands.)

3. Open grab and set triggering mechanism.

4. Slowly lower sampler to the bottom, at the approximate rate of 0.5 m/s, until it stops. Allowing the sampler to free-fall will generate a shock wave which invertebrates can sense and mobile animals will evacuate the area quickly. In addition, the Ponar grab is susceptible to closing before it reaches the bottom if lowered too quickly. It is advisable to determine water depth using a sonar device or a graduated sounding line before lowering the grab.

5. Send the messenger down (Ekman), or press button on top of pole (pole-mounted Ekman), or give the rope one quick, but gentle pull (Ponar) to close jaws. Pull sampler to the surface. As it comes out of the water check to see if the jaws were completely closed. If any leakage occurs, hold a sieve or sieve bucket of appropriate mesh size (200 to 500 μm, to be determined prior to sampling) below the grab as it is lifted from the water. If plant material or rocks caught in the jaws prevent complete closing, discard sample. Otherwise, continue with the next step.

6. Pour water out of the sampler through its top opening, into the sieve or sieve bucket (the sample material collected in the sieve or sieve bucket should be retained, because it is part of the sample). Set sampler down into a metal or plastic tray. Open jaws and lift sampler to remove the enclosed sediment. Examine the sample. If the grab was >60% full, with an undisturbed top layer, retain it for analysis; otherwise discard it and repeat procedure.

7. Use a spoon to scoop sample into the sieve or sieve bucket (which already contains the material that was poured from the grab after it was lifted from the water). Lower the sieve bucket into ambient water several times using "washing machine"-like circular motion or pour water into the sieve from

the top to wash out silt and clay. If there is a large amount of material, it may be necessary to sieve small amounts at a time. Adding a drop of dish-washing detergent and mixing may help if surface tension is preventing draining of the sieve. It may be more practical to do this step near the shore, after all replicates have been collected from a site, in which case the entire sample can be temporarily stored in a large, labelled Ziploc® bag prior to sieving. If this step proves to be very time-consuming or impractical, it may be skipped, but the amount of preservative and the number of sample jars may have to be increased to accommodate the larger sample amount.

8. Pour or spoon the sample into a pre-labelled sample jar and preserve. An additional label, written with pencil on waterproof paper, should also be placed inside the sample bottle. The 1 L sample bottle should be at most half full. Add 95% ethanol to fill the jar, or buffered formalin to obtain approximately 10% dilution. It may be necessary to use more than one jar per sample; if this is the case label jars as "1 of 2", "2 of 2" etc. If there is a large amount of organic material in the sample, increase the amount of preservative. Cap bottle, gently agitate it to distribute preservative evenly, double-check label and place in container for transport.

9. Rinse the sampler and tray in ambient water thoroughly to remove any sediment or clinging invertebrates.

Additional replicate samples should be collected using the same methods, from an undisturbed area.

5.3.4 Kicknet (erosional habitat)

Kicknet sampling may be used to collect quantitative samples that can be used to calculate densities of invertebrates, or qualitative samples that represent all species inhabiting an area but are not useful to determine densities. Use of this sampling device is different for each of these objectives. There are a variety of methods to collect samples using a kicknet and differences in sample composition due to differences between the techniques of different individuals have been commonly reported. For this reason, the quantitative procedure below is only a guideline and may be adjusted to suit individuals, but it is recommended that all samples for a study should be collected by the same person. If this is not possible, a number of sites (minimum of three) should be sampled by each individual and results should be compared to allow adjustments for potential biases.

Procedure for Quantitative Kicknet Sampling

Prior to collecting samples to be retained for analysis, it is necessary to determine the length of area to be sampled (usually between 3 and 5 metres) and the amount of time allocated per sample (usually between 15 seconds and 1 minute). In a productive river, both of these will have to be lower than in unproductive rivers to arrive at a sample size that is reasonable. As a general guideline, if a sample collected using the initially-chosen distance and time contains mostly organic material (detritus, algae), aim for an amount of sample material that is no more than a third of a 1-L sample jar. If it consists mostly of sand and gravel up to half of a jar may be appropriate. Once the length of area and amount of time are determined, all samples will have to be collected according to those numbers.

1. Select sampling site (Section 5.2). The area to be sampled should be undisturbed, shallow enough for safe foot-hold, in run or riffle habitat with moderate to high current velocity and gravel/cobble substratum.

2. Label a sample bottle and leave in on the shore. An additional label, written with pencil on waterproof paper, should also be placed inside the sample bottle.

3. Starting near the upstream limit of the sampling site (facing downstream), place the kicknet in your path (pointing downstream) and slowly move downstream, while kicking the substratum vigorously. Adjust distance and speed to the pre-determined values. Hold the net at the bottom to minimize escape of animals under the net.

4. Lift the net and quickly run it through river water to concentrate the sample material in its tip. Turn the net inside out and transfer sample into the sample jar.

5. Add preservative. The 1 L sample bottle should be at most 1/2 full prior to adding preservative. Add 95% ethanol to obtain approximately 70-80% dilution or buffered formalin to obtain approximately 10% dilution. Cap bottle, gently agitate it to distribute preservative evenly, double-check label and place it in a container for transport.

6. Rinse the net in river water thoroughly to remove any clinging invertebrates and plant material.

7. Collect additional replicate samples as required.

Procedure for Qualitative Kicknet Sampling

Since the aim of this type of sampling is to collect all species present in an area, site selection should be aimed at locating an area with a wide variety of habitats (pools, riffles, backwaters, vegetation, snags, etc.) or to spread out sampling effort in a relatively large area to ensure adequate coverage. The individual sampling should visit all potential habitats, disturb the bottom or vegetation, and sweep the net in the water to collect dislodged material. Depending on the amount of material being collected, it is simplest to restrict the sampling effort per site according to the amount of time spent sampling. Replicate samples are usually not collected when using this method. Sample preservation and labelling should follow methods provided for other devices.

5.3.5 Hand-held Net for Tissue sampling (erosional habitat)

The purpose of sampling for tissues is to collect as much invertebrate material (i.e. as many animals) as possible for chemical analysis. The required sample amount usually varies between 5 and 10 g, wet weight, though certain analyses may require more or less sample amount. Always verify the amount of sample needed prior to sampling (refer to SWI). Also find out whether there is a need for extra sample material in the form of replicate samples, or for spiking (a laboratory quality control technique), which usually increases the required sample amount considerably.

To collect sufficient sample material, it is necessary to select areas of potentially high abundance of large invertebrates such as larvae of net-spinning caddisflies and nymphs of stoneflies and dragonflies. Shallow, fast riffles with low to moderate growths of benthic algae on cobble/gravel substratum are usually the most promising areas for sampling. Note that in some cases, especially in areas with gross metal contamination, even riffles may be devoid of invertebrates, preventing tissue collection altogether.

Sampling equipment and decontamination methods must be matched to the analytes. For organic chemical analysis, all equipment (sampling net, tweezers) and anything that may come into contact with the sample must be made of metal and must be pre-rinsed with appropriate solvents to remove contaminants. Insect repellents contain organic chemicals and should be avoided. For metals analysis, only plastic materials should be used and the sample container should be appropriately cleaned. Always verify sampling equipment and decontamination requirements prior to sampling (refer to SWI).

Use the following procedure to collect samples:

1. Select sampling site as above. The area to be sampled should be undisturbed and shallow enough for safe foot-hold.

2. Label a sample bottle on the outside only, pre-weigh it on a field balance to the nearest gram and leave in on the shore with the cap on.

3. Starting near the downstream limit of the sampling site, one person should hold a large (e.g. 50 x 100 cm) net in the water facing upstream. The net should be resting on the bottom to minimize the number of animals escaping under it. One or two additional persons should vigorously kick the substratum just upstream from the net for approximately a minute.

4. Remove the net and place it on the shore on a convenient surface, being careful not to allow the invertebrates on the net to come into contact with other materials. Using a net mounted on a rigid frame works well for this step. Using tweezers, remove large invertebrates and place them in the sample bottle. Weigh the sample jar periodically to keep track of sample amount. The sample bottle should be stored on dry ice if sampling is interrupted for more than 15 minutes and should be capped immediately after adding invertebrates.

5. Once all large invertebrates have been picked off, rinse the net in ambient water.

6. Repeat procedure until the desired sample amount is obtained.

Samples should be stored and shipped frozen, on dry ice. To allow taxonomic identification of the animals constituting the samples, collect representative specimens and record their approximate relative abundances in the tissue samples. Preserve these animals in 70% ethanol or 10 % buffered formalin for subsequent taxonomic identification.

5.4 Field Measurements and Observations

Benthic invertebrate samples should be accompanied by appropriate physical measurements and field observations to allow detailed data analysis. At minimum, habitat type, current velocity, substratum composition, depth and the presence and amount of algae and plant material should be recorded at each site. However, if time and equipment are available, it is preferable to collect or record the following information:

- habitat (run/riffle/etc.) at the site;
- stream width;
- riparian vegetation, degree of shading;
- current velocity and depth at each replicate sample location;
- sampler fullness (if grab sampler used);
- substratum composition in the general area of the site as percent cover by each major particle size, using standard size categories (see field data sheet);
- a sediment sample for analysis of texture and organic content (depositional habitat) or weights of at least three size fractions of bottom material (erosional habitat);
- relative amount of benthic algae on the substratum, or a composite sample of benthic algae for analysis of chlorophyll *a* content;
- type and percent cover of aquatic macrophytes at the site;
- general water quality measurements: conductivity, pH, dissolved oxygen, water temperature, turbidity;
- any pertinent observations, such as the presence of visible pollution, disturbance by animals or humans, weather conditions, etc.; and,
- photograph of the sampling site, showing nearby landmarks.

5.5 Sample Labelling and Handling

Chain-of-Custody forms should be used to track samples. Sample labels should include:

- project number;
- sampling date;
- site location or site code;
- replicate number (separated by a hyphen from the site code); and,
- jar number (if applicable).

Preserved benthic invertebrate samples do not require special handling and holding time is indefinite at room temperature. However, if ethanol is used as the preservative and there is a large amount of organic material in the samples, the preservative should be replaced within one day of sampling with fresh 70% ethanol to prevent sample degradation. Transportation of Dangerous Goods (TDG) and Workplace Hazardous Materials Information System (WHMIS) regulations must be followed when handling, transporting and storing samples.

5.6 Field Records and Logbook

For proper interpretation of field survey results, thorough documentation of all field sample collection and processing activities is required. All logbooks should be waterproof, field data forms should be preprinted on waterproof paper, and only indelible ink and pencil (if form or paper is wet) should be used.

All pertinent information on field activities and sampling efforts must be recorded in the logbook. The field crew leader is responsible for ensuring that sufficient detail is provided. The logbook must be complete enough to enable someone unfamiliar with the project to completely reconstruct field activity without relying on the memory of the field crew. All entries must be made in indelible ink, with each page numbered, signed and dated by the author, and a line drawn through the remainder of any partly used page. All corrections should be made by a single-line cross-out of the error, entering the correct information, dating and initialing the change. Upon return to the office, all field notes must be photocopied and placed in the appropriate project files.

Entries in the field logbook should include:

- purpose of proposed sampling effort;
- date and time (24 hour clock) of sampling and related activities (travel, set-up, equipment calibration, etc.);
- names of field crew leader and team members;
- details of sampling method and effort;

- equipment calibration;
- location and description of each sampling site, including information on any photographs that may be taken;
- field observations;
- sample shipping information;
- any additional information on sample collection activities;
- hydrologic conditions;
- boat or equipment operation; and,
- any unusual activities observed or problems encountered that would be useful to the project biologist when evaluating the quality of the data.

If some of the above information is recorded on the field data sheets, it need not be repeated in the field logbook. Specific information pertaining to each sample should be recorded on the field data sheets (one per site). An example of the field data sheet is provided in Exhibit "A" of this technical procedure.

6. EQUIPMENT

The following is a list of the equipment recommended for benthic invertebrate sampling. It should only be used as a guideline, since the specifics of a study should dictate exact equipment requirements.

Sampling for Community Composition

- container for sample jars (plastic tub or cooler)
- extra sampler net and other parts that are failure-prone
- fine mesh net piece (for pouring water out of sample jar)
- garden trowel or small shovel (for Neill cylinder and Hess sampler)
- indelible ink felt tip markers
- metal or plastic tray
- preservative
- rope for grab samplers
- sample containers (1-L plastic jars recommended)
- sample jar labels (or waterproof tape)
- sampling device
- scoops or spoons
- sieve or sieve bucket of appropriate mesh size

Sampling for Tissues

- cooler with dry ice
- decontamination equipment (tarp, soap, brushes, containers, trays, pipettes and bulbs, distilled water, solvents, waste bottles, aluminum foil, etc.)
- field balance
- indelible ink felt tip markers
- large sample net mounted on a frame (metal or fiberglass window screening may be used)
- sample jars and labels
- tweezers (metal or plastic depending on analytes of interest)

Record-keeping and Site Locating/Marking

- camera and film
- Chain-of-Custody forms
- field data sheets on water-proof paper and clipboard
- indelible ink pens and pencils
- long tape measure, electronic distance measuring device, GPS unit
- maps of area for site locations
- survey flagging tape
- water-proof field logbook

Physical Measurements

- calibration solutions and buffers
- conductivity meter
- current velocity meter and wading rod
- dissolved oxygen meter
- pH meter
- Winkler kit (dissolved oxygen calibration)

Health and Safety Equipment

- approved personal floatation device for working in deep, fast water
- cellular telephone
- first aid kit

Personal Gear and Miscellaneous Equipment

- appropriate clothing (plus one extra set)
- drinking water
- knife
- rain gear
- sun protection
- waders (chest or hip)

- waterproof gloves (shoulder length for Neill cylinder and Hess sampler)
- work gloves

Boat and Associated Equipment (if required)

- air pump (if inflatable boat used)
- anchor
- approved personal floatation devices
- fire extinguisher
- fuel
- paddles
- rope
- spare keys
- spare parts
- tool box
- two-stroke oil
- water (bilge) pump

EXHIBIT "A"

FIELD DATA SHEET FOR
BENTHIC INVERTEBRATE SAMPLING

GOLDER ASSOCIATES LTD.

940 Sixth Ave. S.W. Calgary, Alberta. T2P 3T1. Phone: 299-5600

BENTHIC INVERTEBRATE SAMPLE COLLECTION

FIELD DATA SHEET

PROJECT:	SITE:
RIVER/LAKE:	DATE:
PERSONNEL:	TIME:
FIELD NOTES BY:	

WEATHER WIND: AIR TEMP.: PRECIPITATION: CLOUD COVER:

SITE DESCRIPTION (MAP):

MEASUREMENTS / OBSERVATIONS			**SUBSTRATUM (% coverage)**	
Diss. Oxygen (mg/L):	Conductivity (µS/cm):	Benthic Algae (N/L/M/H):	Silt/Clay (<0.06 mm)	
			Sand (0.06-2 mm)	
pH:	Water temp. (°C):	Macrophytes (species, % cover):	Small gravel (2-16 mm)	
			Large gravel (16-64 mm)	
HABITAT DESCRIPTION:			Small Cobble (64-128 mm)	
			Large Cobble (128-256 mm)	
			Boulder (>256 mm)	
			Bedrock	

BENTHIC SAMPLES SAMPLING DEVICE: PERSON SAMPLING:

MESH SIZE: PRESERVATIVE:

SAMPLE LABEL	**DISTANCE FROM ___ BANK (m)**	**DEPTH (m)**	**CURRENT VELOCITY (m/s)**	**SAMPLER FULLNESS (%)**	**NUMBER OF JARS**	**NOTES**

OTHER SAMPLES / MEASUREMENTS / OBSERVATIONS

NOTES: N = none; L = low; M = moderate; H = high

APPENDIX V

FISH INVENTORY METHODS (TP 8.1-3)

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1. PURPOSE

This technical procedure presents the techniques and methodologies used for standard fisheries sampling during fish inventory studies for the purposes of determining species presence, distribution, relative abundance, basic population characteristics and for conducting population estimates. Decisions regarding the type of sampling gear to use, the specific techniques to be employed and the timing of sampling will be determined prior to the commencement of the field study by the project team or project manager. However, due to the nature of fisheries work, some decisions regarding sampling specifics will depend upon conditions in the field. The methods for general fisheries inventory work are covered in this technical procedure. Other technical procedures are required in addition to this one in order to conduct fish sampling for specific tasks such as biomarking/fish health studies. This technical procedure does not detail the Quality Assurance/Quality Control requirements for components of field programs, such as note taking/data recording, as they are included in other documents.

2. APPLICABILITY

This technical procedure is applicable to all personnel involved in fisheries surveys for lakes and streams, including all sizes and orders of streams. It covers sampling equipment and techniques currently owned/used by Golder. Additional techniques are available which may be the most suitable method for specific circumstances or project requirements. If this is the case, the project manager must authorize the use of any new technique or the purchase of additional equipment.

3. DEFINITIONS AND METHODS

3.1 Abundance, Relative

The proportional representation of a species in a sample or a community. In fisheries inventories, relative abundance is typically used to describe the relative number of fish captured for each different species at a sampling site. Relative abundance can also be determined for the same species at different sites or in different seasons. It can also be determined for different life stages of the same species.

In some limited cases, the number of fish captured can be used to describe relative abundance. This is suitable for a single effort in a single sampling area where relative abundance is simply the relative number of fish captured. For example, if 20 fish of one species and 10 fish of another species were captured in 100 seconds of electrofishing at a site, species one is determined to have a relative abundance twice that of species two.

For any sampling situation which is more complicated, Catch-Per-Unit-Effort (CPUE) values must be calculated to determine relative abundance. CPUE values take into account the sampling effort required to catch the fish as well as the number of fish captured. For example, if 20 fish of one species were captured in 100 seconds of electrofishing at one site, and 20 fish of the same species were captured in 200 seconds of electrofishing at a second site, CPUE data shows that this species has a relative abundance at the first site which is twice that of the second site. In this example, twice the effort was required to capture the same number of fish at site two. This example also shows why it would be unsuitable to derive conclusions about relative abundance based solely on the numbers of fish captured.

In order to be able to determine relative abundance, you must record all sampling efforts in a manner suitable for calculating CPUE data.

3.2 Ageing Structures

Ageing structures are bony parts of the fish which are taken for ageing analyses. In fish from temperate zones, these structures contain annual bands (annuli) which delineate seasonal variation in growth which can be counted to determine the fishes' age. Primary examples of these structures are scales, fin rays, saggital otoliths, cleithra and opercula. The appropriate ageing structures to collect vary according to fish species and life stage and include lethal and non-lethal sampling measures. Consult the table of "**Recommended Fish Ageing Structures**" (available in the aquatics reference file) for the appropriate structure and collection method for each species. With respect to fish ageing, all procedures used by Golder (i.e., the ageing structures which are collected and the methods used to determine age) conform to the manual of Fish Ageing Methods for Alberta (Mackay et al. 1990).

Following removal from the fish, ageing structures should then be placed in a "scale envelope", which consists of a small envelope which has been stamped with fields for recording the following information:

- date
- fish number
- species
- fork length
- weight
- life history stage
- sex
- state-of-maturity
- sampling gear
- sampling location
- ageing structure collected
- project number

Blank envelopes are ordered in batches of 1000 and must be stamped prior to use. If your project includes the collection of ageing structures, it may be necessary to order the required envelopes and stamp them before heading out into the field.

The scale envelopes should be allowed to dry overnight before being stored. Upon returning from the field, the envelopes should be stored frozen in a one of Golder's freezers.

3.3 Anaesthetic

An anaesthetic is used in situations requiring live fish to be removed from the water and handled for extended periods, such as during surgery to implant radio transmitters, or to quiet fish for measurements. The anaesthetic commonly used by Golder is MS-222, known as tricaine methanesulfonate. The concentration of anaesthetic to be used depends on the required level of sedation. For surgery, which requires the fish to remain sedated for a period of 5-10 minutes, a concentration of 100 mg/L is used (i.e. 4 g of MS-222 in 40 L of water). The fish is placed in the anaesthetic bath for 2-4 minutes until the desired level of sedation is reached. Care must be taken as overdoses lead to direct mortality. When monitoring the fish in the anaesthetic solution, watch for loss of coordination (when the fish no longer keeps itself upright) and respiration rate. Towards the end of the anaesthetization period, the fish will begin to "Cough".

Use of anaesthetic for quieting fish for measurements is not typically recommended unless the fish is difficult to handle or may injure itself. Fish anaesthetized with MS-222 are not recommended for consumption by anglers for a period of 2-4 weeks following exposure to the anaesthetic. Therefore, use only on fish which will not be captured and consumed or with permission of Alberta Fisheries Management Division.

3.4 Biomass

Biomass is the total mass (weight) of fish, or of fish of a given species, within a study area. It is a component of population estimates, as an estimate of the total number of fish in the study area is required to calculate biomass. Using either total removal data or a mark/recapture population estimate for the study site, the total biomass is calculated by multiplying the total population of fish by the average weight of the fish captured. Results can be expressed as units of weight over study area dimensions (e.g. kg/m of stream, kg/m^2 of lake).

3.5 Capture/Sampling Techniques

The following sampling techniques are used to capture fish. Some techniques are very specific to one life stage while others are more general. All sampling techniques have some degree of sampling bias associated with them with respect to fish size selectivity and sampling efficiencies based on environmental parameters such as water depth, conductivity, stream size etc. It is important to understand these biases when designing or implementing a study plan and when interpreting the data and drawing conclusions from the results.

3.5.1 Airlifting

Airlift sampling is used to collect fish eggs from the substrate for species which are broadcast spawners (i.e. do not bury their eggs). It can be used simply to determine if incubating eggs are present or to determine the relative density of eggs at each spawning site. The airlift sampler consists of a gas powered generator and compressor unit, a length of hose, an airlift head and couplers to connect the hose to the compressor and airlift head. The airlift head is attached to a long pole and consists of a 4" or 6" diameter hollow tube with a 90° bend at the upper end. The lower end of the airlift head has an internal tube which runs around the internal circumference and which is perforated. With the lower end of the airlift head held against the substrate, air is pumped from the compressor through a hose and into the perforated tube. Air rising inside the airlift head creates a vacuum effect which lifts loose particles up from the substrate. A removable collection bag placed over the upper end of the airlift head collects the particles. The sample is dumped into a sampling tray and examined for the presence of eggs.

This technique is employed when sampling water too deep to kick sample or when a quantitative sample is required. Since the area (cm^2) of the airlift head is known, simply count the number of times the head is touched to the substrate for each sample in order to determine the number of eggs/cm^2 in the sample. Quantitative sampling can be used to determine the relative use of the spawning areas sampled, as determined by egg density. Remember to record the size of the airlift head used.

3.5.2 Angling

Angling refers to the use of angling gear, such as rod and reel, to sample for fish. Angling is an active technique using lures, bait or flies. Leaving a static, baited line in one place is referred to as a Set Line and is not an angling technique. On the other hand, jigging with a baited line would be an angling technique.

Sampling effort should be recorded as both the number of hours angled and the number of angling tools used. It would be recorded as angler-hours, or as rod-hours or some equivalent if more than one piece of angling gear is used per angler. The types of hooks, size of hooks, and number of hooks should also be recorded. In addition, notes on the types of habitats fished and the length of shore line covered if trolling is conducted should be recorded.

3.5.3 Drift Net

Drift net is a passive sampling technique for use in flowing water for the capture of life stages which are moving or drifting downstream. A drift net consists of a long, tapering net with an open mouth at the upstream end and a detachable sample bottle at the downstream end. Drift nets are anchored in place in the stream and filter the water passing through them, collecting materials from the water column. They can be placed to sample the bottom, middle or top of the water column or can be stacked to sample the entire water column. At regular intervals, the nets are removed and cleaned by dumping the collection jars into a sampling tray and examining the sample for the presence of fish. Typically the drift nets are checked and cleaned twice per day, once first thing in the morning and once again in the evening. Record the catch separately for each period in order to be able to determine diurnal patterns.

Sampling effort is usually recorded as the number of hours between net cleanings to determine catch/hour. If more detail is required, it is also possible to estimate the volume of water sampled by the net during the period between net cleanings to determine the catch/m^3. To do this, measure the velocity of the water at the sampling site before setting the drift net and again after lifting the net for cleaning to determine the average water velocity through the net. Multiply the average velocity (m/s) by the area of the net mouth (m^2) to get the volume sampled per unit time (m^3/s) (remember to record the size of the drift net mouth). Multiply this value by the time the net was in place to calculate the total volume sampled. For this calculation, the drift net mouth must be completed submerged.

3.5.4 Electrofishing

Electrofishing refers to the use of electricity to stun and capture fish. An electrical current is passed between electrodes placed in the water and the resulting electrical field attracts passing fish (galvanotaxis) toward the positive electrode (anode). As fish pass close to the anode they encounter an increasingly stronger current gradient which acts as a narcotic and stuns the fish (galvanonarcosis), allowing them to be easily dip-netted from the water. Once captured, the fish may be identified, weighed, measured, tagged and then returned to the water. Fish taken by electrofishing revive quickly when returned to the water. Effort is automatically recorded by the electrofishing unit as the number of seconds of active electrofishing (i.e. the time current is applied to the water). **Record the effort (seconds) immediately after completion of sampling and reset the timer to zero.** Electrofishing techniques require experienced operators in order to reduce injury to the fish and to eliminate potential

injury to the personnel involved. Safety training or working with experienced personnel is required for operating electrofishing equipment.

Backpack Electrofishing

Backpack electrofishing is a sampling technique for small, wadable streams. A backpack electrofisher consists of a portable electrofishing unit and a power source (12v battery or mini generator) attached to a pack frame. It is equipped with a hand held, button-operated anode pole and a cathode plate which is left trailing in the water. The operator wears the pack unit and uses the button switch to activate the anode in order to stun fish while wading instream. One or more assistants wading next to the operator use dip nets to capture the stunned fish. The assistant also adjusts the electrofisher settings for the operator and monitors the electrical output. Sampling is normally conducted while moving upstream so that fish are not disturbed, prior to being sampled, by disturbances to the stream bed and material moving downstream with the flow.

Boat Electrofishing

Boat electrofishing is an extremely effective sampling technique for moderately shallow water and is used for intermediate streams, large rivers and shallow littoral areas in lakes. Two types of boat electrofisher are available, both of which consist of an electrofishing control box which is powered by a 5,000 watt generator. The ***portable boat electrofisher*** has a free control box and generator which can be loaded into an inflatable boat (Zodiac) and is ideal for small or intermediate sized rivers which cannot be waded and which cannot be effectively sampled by the low current outputs provided by a backpack electrofisher. Two anode configurations are possible, depending on stream size, and include either a hand-held, button operated anode pole or a foot-switch operated portable boom system. In both cases, a floating cathode plate is employed. The boat can be drifted downstream or an outboard jet can be used to provide increased mobility. In comparison, an ***electrofishing boat*** consist of an 18' aluminum river boat with an integral electrofisher control box and generator. It is also equipped with a work platform and flow-through live well for holding fish. It has a foot-switch operated anode boom system and uses the boat hull as the cathode. Boat electrofishers are designed for any intermediate or large river which is deep enough to allow a boat of this size to float and which has a site with a suitable boat launch. This unit has the largest anode/cathode surface area and is capable of generating the largest electrical field and the highest current outputs. Boat electrofishing sampling for both types of units is usually conducted while floating downstream, as this makes fish easier to dipnet and puts less stress on the dipnets and anodes.

3.5.5 Emergent Trap

An emergent trap is a passive sampling technique specifically designed to capture fry as they emerge from the substrate following hatching. A typical emergent trap consists of a square metal frame (0.3m x 0.3m) covered with a small mesh net and collection bottle. The mouth of the trap is placed on top of the substrate at a known or suspected spawning area where incubating eggs are known or thought to be present. It is left in place through the incubation period. Once the fry have hatched and absorbed their yolk sacs they emerge from the substrate. The fry from the eggs which were located under the trap mouth will be captured by the trap.

Emergent traps can be used to verify a suspected spawning area or to check for hatching success at a know spawning site.

3.5.6 Fry Traps

A fry trap is a passive sampling technique used to capture fry which are drifting downstream in flowing water. It is suitable for capturing fry which are larger than post-emergent size but which are not yet strong swimmers. The fry trap is anchored to the stream bed using 2 rebar posts and consists of a large metal frame open at the upstream end and otherwise covered with small mesh metal screening. "Wings" lead from the trap mouth into a low velocity area at the downstream end of the trap where the fry accumulate. The trap is designed so that it will pivot at the anchor point on the stream bed. To check the trap, simply tilt it forward and hold a collection bucket in front of the "top" of the low velocity holding cell. Water and fry from the holding cell will pour into the bucket as the trap is tilted. Typically the traps are checked and cleaned twice per day, once first thing in the morning and once again in the evening. Record the catch separately for each period in order to be able to determine diurnal patterns.

Sampling effort is usually recorded as the number of hours between trap cleanings to determine catch/hour. If more detail is required, it is also possible to estimate the volume of water sampled by the trap during the period between trap cleanings to determine the catch/m^3. To do this, measure the depth and velocity of the water at the sampling site before setting the trap and again after checking the trap to determine the average water depth and velocity through the trap during the sampling period. Multiply the average depth (m) by the average velocity (m/s), then by the width of the trap mouth (m) to get the volume sampled per unit time (m^3/s) (remember to record the width of the trap mouth). Multiply this value by the time the trap was in place to calculate the total volume sampled.

3.5.7 Gill Netting

A method of capturing fish that involves the setting of nets of various mesh sizes anchored in place in a river or lake. A gill net consists of netting suspended between a weighted "lead" line and buoyant "float" line which, when set, forms a vertical wall of netting. The lead line is attached at both ends to heavy weights to hold it in place and keep the net taught. The float line is attached at either end to floats. In Alberta, the floats must each consist of a pole which stands upright at the water surface and extends above the water surface for a minimum of 1.0 m. The top of the poles must have a blaze red or orange flag measuring at least 20 cm x 20 cm and marked with the Fish Collection Licence Number in 20 mm high letters. Typically, we use sandbags filled with rocks or sand from the gill net site for lead line weights. This way, all we have to carry with us to the site is a few empty sandbags. New gill nets need to have a length of sideline attached to either end which extends from the float line to the lead line to take the tension when the net is lifted to ensure that the mesh does not rip.

Gill nets are designed to function by catching on the gill covers of fish as they attempt to swim through. Fish of a size for which the gill net mesh size is designed swim into the net but can only pass partway through the mesh. When the fish struggles the twine slips behind the gill covers (opercula) and the fish becomes "gilled". Therefore, the mesh size of the gill net is important when selecting a net or nets for your sampling activity as gill netting can be a very size selective technique.

Gill net mesh size can be measured as either the stretch measure or square measure of the openings in the mesh. At Golder, we always use the stretch measure to identify our gill nets and when reporting results. The stretch measure is the distance between two opposite corners of the square mesh opening, when the square is stretched flat. Gill net mesh sizes typically range from 1.9 to 14.0 cm (3/4"-5.5"). As most gill nets are sold using imperial units of measure, the following table will help you convert mesh sizes to metric units.

Stretch Mesh Sizes:											
Imperial (inches)	3/4	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
Metric (cm)	1.9	2.5	3.8	5.1	6.3	7.6	8.9	10.2	11.4	12.7	14.0

Gill net meshes are constructed either of monofilament or nylon. Monofilament is sturdier and longer lasting but gill nets made from this material do not compress and take up a much larger volume than a nylon net of the same dimensions. For longer nets, the volume of a monofilament net becomes significant.

Gill nets can be simple or multi-mesh. Simple nets consist of one mesh size only, although different nets may have different lengths and depths. Multi-mesh nets are also called "gang" nets and consist of more than one mesh size. Each mesh size occurs in a discreet section of the net which is called a panel. Gang nets typically have from two to five different mesh sizes or panels. Usually, each panel has the same length, although this is not always the case. An important component of recording sampling effort is to record the dimensions of all gill nets that are set. Record the depth of each net as well as the total length. Also record the number of panels, the mesh size of each panel and the length of each panel. Effort should also be recorded as the number of hours the net is set and CPUE is expressed as either duration (hrs), panel-hours, or meter-hours, depending on the type and variety of nets set.

Since the size of the mesh will have a major role in determining the size of fish (i.e. species or life stages) that will be captured, it is extremely important to record the mesh sizes of any gill net used. It is also important to record the catch for each individual panel or mesh size. The field form used to record the catch has a space for recording the mesh size for each fish captured. When removing fish from the gill net, the fish must be separated by mesh size.

Selecting a gill net or nets to be used for a project will vary depending on your sampling goals. Long gang nets with several different mesh sizes, from small to large mesh, are best for general inventory sampling and have the smallest level of sampling bias. For single mesh nets or nets with few panels, it is generally true that the larger the mesh size used the larger the fish that will be captured. The small 1.9 cm mesh nets will capture fish as small as the larger minnow species and juvenile life stages of larger fish. Mesh sizes in the range of 5.1-7.6 cm are typically used for salmonid species while larger mesh sizes will be employed to capture adult northern pike and burbot. Most gill nets will capture a larger size range of fish than mesh size would dictate as some species will be captured without necessarily being "gilled". For example, suckers may be entangled by their large lips and northern pike often bite and roll in the mesh, becoming entangled in mesh sizes too small to capture them by gilling. Bullheads on the other hand are often captured in mesh sizes too large to gill them when their pectoral and dorsal spines become entangled in the mesh.

Nets selected for sampling in rivers are generally different from those used in lakes. River gill nets typically have large floats attached to the float line for added buoyancy. Shorter nets are used as they must be set in low velocity pockets such as backwaters or pools and heavy weights are used to anchor the net so that it will remain in position in flowing water. Caution should be taken when setting nets in a river at high stage if floating debris is moving downstream which could damage or move the net. In lakes, much longer nets can be used if required and, since lakes typically have greater depths than rivers, nets can be set at a variety of depths. Lake nets can be set so that they float near the surface, are set along the lake bed or are positioned in mid column. For floating sets, nets with large floats attached to the float line can be used and long leads are tied to the weights to allow the net to remain at the surface. For sinking sets, nets without additional floats or with small floats are used. For bottom sets, the weights are tied tight to the lead line and long leads are tied to the floats so that the net will sit on the bottom and the floats will remain at the surface. For mid column sets, leads are attached to both the weights and floats so the net will be positioned between the bottom and the surface.

Gill netting is a sampling technique that can be used in the winter as nets can be set under the ice. In lakes where there is no current a jigger is used to run a length of sideline under the ice. A large hole is opened in the ice and the jigger is placed under the ice. The sideline is tied to the jigger and the lever arm is manipulated to send the jigger moving away from the hole. Once the jigger has moved far enough it must be relocated, either by sight if the ice is clear or by sound as the jigger is equipped with a "clicker" device. A hole is drilled at the location of the jigger and a hook is used to pull the sideline up the hole. In rivers or in the case of thick lake ice a Murphy stick is used to set the net. A Murphy stick consists of two sections of aluminum pipe hinged together which extends as an under-ice probe. The far end of the probe has an eye-hook at the end and a float a short distance back. A length of sideline a little longer than the gill net is tied to the eye-hook and the far end of the probe is pushed down through one hole in the ice and maneuvered towards a second hole where the attached sideline is hooked and pulled up through the hole. The process is repeated several times to extend the rope as far as desired. Once the sideline has been placed under the ice it is then attached to one end of the gill net and used to pull the net under the ice.

As a sampling technique, gill nets can have a high mortality rate if the fish are left in the net for a prolonged period or if water temperatures are high. If fish mortality is a concern, the nets should be cleaned of fish on a regular basis (e.g. every two hours). If mortality is desirable (i.e. fish are to be sacrificed) or not a concern, nets should be set overnight in order to sample day and night periods of fish movements and to allow capture of fish which may avoid the net if it is visible during daylight hours in low turbidity water.

3.5.8 Hoop Net (Fyke Net)

A hoop net is cylindrical net distended by a series of hoops or frames with one or more internal funnel-shaped throats whose tapered ends are directed inward from the mouth to prevent fish from escaping once they enter the net. A fyke net is a hoop net with two wings or leads of webbing attached to the mouth to guide fish into the enclosure. Our hoop nets have large square hoops at the front of the net and taper to a smaller diameter with smaller ring hoops at the back end. Webbing extends inwards and backwards between the sides of the first square hoop to form a "V" slot at the net mouth and a funnel is attached to the back of the second square hoop. The chamber between the funnel and the rear of the net is termed the "pot". The net is tapered at the rear end and held closed with a draw string which can be opened to permit removal of the trapped fish from the pot, although trapped fish may also be present

between the "V" slot and the funnel. The funnel also has a draw string which allows removal of fish from this chamber. If it is desirable to have a fyke net, use two lengths of webbing tied to the sides of the hoop net mouth to convert the hoop net to a fyke net.

Fyke nets are typically set at a time and location where fish will be moving through the area in a direction that will lead them into the net mouth. They are very effective when set in small tributaries to lakes or larger rivers during a spawning run but can also be used in shallow areas of lakes and larger rivers. The net and wings are anchored in place by tying them to rebar posts embedded in the substrate. The wings of the net should be set at a 45° to the axis of the hoop net.

As the holding chambers in the fyke nets are small, they should be checked and cleaned of fish on a regular basis, particularly during an active spawning run. Try to set the net so that fish in the holding chamber will not be subjected to high water velocities. Sampling effort is usually recorded as the number of hours between net cleanings. Record fyke net dimensions such as mesh size, mouth size, wing lengths and, when used in streams, whether full or partial channel blockage was achieved and whether the net mouth was oriented upstream or downstream.

3.5.9 Kick Sampling

Kick sampling is used to collect fish eggs from the substrate in spawning areas, both for species which are broadcast spawners and for those which bury their eggs (i.e. from trout redds). It can be used to determine if incubating eggs are present but it is generally considered a qualitative (i.e. non-quantitative) sampling technique and, unlike airlifting, is not suitable for determining the relative density of eggs. The kick sampler is attached to a pole and consists of a tapered net attached to a metal frame which forms the mouth of the net. It is generally used in flowing water. To use, grasp the pole and place the kick net against the substrate. Stand upstream of the net mouth and use your feet to disturb the substrate, letting the disturbed materials float into the net. Remove the net from the water and examine the contents of the net for eggs.

Kick sampling can only be conducted in water shallow enough or which is flowing slow enough to allow instream wading. This technique is simpler to use than the airlift sampler and requires considerably less equipment. It is a very efficient and fast technique for identifying spawning areas in wadable streams, particularly over long lengths of stream.

3.5.10 Minnow Trap

Minnow trapping is a passive sampling technique used to sample for the presence of minnow species and small life stages (i.e. fry) of larger species which can be difficult to capture using other techniques such as electrofishing or gill netting. The traps we use are Gee Minnow Traps which consist of two pieces which are clipped together to form a small cylinder slightly tapered at either end. Each end has a funnel which leads into the centre of the trap which allows fish to enter but prevents them from escaping. The traps are generally placed on the substrate in the shallow shoreline areas of lakes and streams with the long axis of the trap parallel to the shoreline. A length of sideline is used to tie the trap to a stake or anchor on shore to keep it in place. The anchor site is usually flagged so that the site can be easily found when returning to check the trap. The traps can be baited or unbaited, depending on if the intent is to trap fish moving through the area or attract fish to the trap.

Sampling effort is recorded as the number of hours that the trap is set.

3.5.11 Observation

Underwater observation involves the use of either snorkeling or SCUBA techniques to observe, count or record the activities of fish. Scuba diving is generally restricted to lake habitats but may also be employed in deeper rivers. It is a fairly intrusive technique and is considered to be more disruptive than snorkeling and requires that the observer have a valid scuba certificate. Snorkeling is commonly employed by Golder to conduct fish observations in stream habitats which have low turbidities. It is less disruptive than SCUBA and logistically simpler. Equipment used for snorkeling includes a diving mask, snorkel, dry suit, diving gloves and an underwater writing slate. A wet suit can be used in place of a dry suit in warm water but a dry suit is preferable as it increases observation time. To date, snorkeling has been used by Golder to study the habitat preferences of some fish species but the technique can also be used to determine fish abundance and distribution.

3.5.12 Post-Emergent Trap

Post-emergent traps are a passive sampling technique for use in flowing water to sample for the presence of post-emergent fry. Unlike emergent traps which capture the fry as they emerge from the substrate, post-emergent traps capture the fry as they drift downstream following emergence. Unlike emergent traps, it is not required that they be set at a spawning site overtop of incubating eggs, there only needs to be a spawning area somewhere upstream of the set location. Post-emergent traps are essentially extremely large drift nets. Each trap consist of a tapered, small-mesh net attached to a metal frame which forms the trap mouth. The trap mouths are 0.9 x 0.9 m in size. Each net is equipped with a removable sample bottle attached at the downstream end of the net. A post-emergent trap is set by anchoring two rebar poles into the substrate and looping the four hoops attached to the trap over the poles and sliding the trap down until the bottom of the trap sits on top of the substrate with the mouth facing upstream.

Post-emergent traps should be checked at a minimum of twice per day, once in the morning and once in the evening. Definite diurnal/nocturnal patterns have been observed using these traps, so be sure to record the catch separately for each sampling period. To check the catch, remove the trap from the stream and wash all materials from the netting into the sample bottle. Dump the contents of the bottle into a sampling tray to look for the fry. Post-emergent fry are extremely small and almost transparent. They are best seen by looking for the large, dark eyes which will be their most obvious feature. They may also be seen to be swimming around in the sampling tray. It is also prudent to check the mesh of the trap for additional fry as they are so small that some become "gilled" on the mesh and do not wash down into the collection bottle. If more than one species may be hatching at the time and location of your study and you are not sure of the identification of fry in the sample, the sample should be preserved in 5% buffered formalin for laboratory identification.

Sampling effort is recorded as either catch/hr or catch/m^3, as described for fry traps (section 3.5.6). Post-emergent traps are used to check for the presence of post-emergent fry in the study area, either as proof of spawning activity in upstream areas or simply to tell if this life stage or a certain species is present. They are also used in entrainment studies, which are conducted to determine if fish are entering man-made structures such as diversion canals or water intakes. In addition, they may be used to

determine the timing of hatching periods and the relationship between hatching and environmental parameters such as discharge or water temperature.

3.5.13 Seine Netting

Seine netting refers to the use of a specifically designed net to catch fish by dragging it through the water. Seine nets consist of netting suspended between a float line and a lead line. The netting is constructed of thicker net material than gill nets so that fish do not become gilled in the mesh. Mesh sizes vary but most nets are constructed of minnow netting which has a small mesh size and is suitable for catching forage fish and small life stages of larger fish species. Larger mesh seine nets are also available for sampling for large fish and are much easier to drag through the water. Two types of seining operations are possible, beach seining and boat seining.

Beach seining is accomplished by two people dragging the net through the water while wading and is used in shallow water areas in lakes and streams. To beach seine, each person grabs one end of the net by placing one foot in the loop at the end of the lead line and holding the loop at the end of the float line in their hands. One person walks out from shore to a suitable depth. Both people then walk parallel to shore dragging the net between them. The lead line is kept in contact with the substrate to prevent fish from escaping under the net by dragging the foot looped to the lead line along the bottom. As they walk through the water, fish are herded in front of the net. The person near shore moves slower than the person further out. When the further person has passed the near shore person they curve back to shore, meeting the near shore person at the waters edge and bringing the two ends of the net together forming a pen holding the captured fish. Both people then drop the float lines and pick up the lead lines and standing side-by-side pull the net up on shore, ensuring that the lead line remains in contact with the substrate at all times. The trapped fish will congregate in the end of the looped net and will be dragged up onto shore.

Boat seining is a specialized technique used in water too deep to wade. It usually involves the use of long, large mesh seine nets for the capture of large fish. It is particularly useful in areas where fish congregate such as spawning areas of lakes or snye areas in rivers. The principle is similar to beach seining except that a boat is used to move the offshore end of the net through the water. A pole is attached to both the lead and float lines, at the boat end of the net, and is used to keep the lead line on the bottom.

Seine netting is a suitable technique only where the bottom is fairly smooth. If large substrate particles, debris, or aquatic vegetation is present which will cause the lead line to lift off the bottom as it passes, the technique will not be very efficient and most or all fish will escape. Seine netting is typically used to sample for the presence and abundance of small fish and life stages which are not effectively sampled for using other inventory techniques.

Sampling effort is recorded as the number of seine hauls made and either the distance (m) or the area (m^2) seined for each haul. Record the dimensions of the seine net used (length/depth/mesh size) and the shoreline distance of each seine haul. If area is required, multiply the length of the seine haul by the length of the seine net used.

3.5.14 Set (Trot) Line

A set line is a series of leaders and baited hooks strung from one central line which is anchored to shore. Set lines are used to catch predatory fish and are usually set out overnight. Golder set lines are 30 m in length, which includes a 10 m lead with no hooks and 20 m of line with a total of 10 leaders/hooks set at 2 m intervals. A large lead weight is attached to the end of the line to keep it in place once it is set. The 10 m lead is used to set the baited hooks well out from shore or can be tied short to keep the hooks near shore, as desired.

Sampling effort is recorded as the number of hours the line is set or the number of hook-hours if set lines of different lengths and number of hooks are used. Record the size of the hooks that are used (e.g. #8 hooks).

3.5.15 Trap/Counting Fence

Fish traps or counting fences are a passive sampling technique used to capture fish as they move past a specific location. They consist of one or more trap boxes with fences (wings) which stretch out in front of the entrances of the boxes to lead fish into the trap. The trap boxes are large holding pens enclosed on four sides as well as on the bottom with metal or plastic mesh. The front of each box has an opening equipped with a funnel which leads into the interior of the trap box. The boxes are also equipped with locking plywood lids to protect the fish as they congregate in the traps. The fences consist of angular aluminum frames with a series of holes into which are fitted round aluminum rods to form a barrier to fish passage. The counting fence is installed by attaching the components to rebar posts driven into the stream bed and by placing sandbags on cradles included in the fence design. The fences or wings are set as close as possible on a 45° angle to the trap box entrance.

Two types of counting fence set-up are possible, the **one-way fence** and the **two-way fence**. The one-way fence has only one trap box and one set of wings and is used to capture fish moving in one direction. The two way fence has two trap boxes facing in opposite directions, each with its own set of wings, to capture fish moving in both directions. Counting fences can be used to sample portions of the shoreline in lakes or large rivers but are typically used in small or medium sized streams to close off the entire channel and capture all fish moving past the trap location. In this case, the box which captures fish moving upstream is called the upstream trap and the box catching fish moving downstream is called the downstream trap. In streams, the trap boxes should be set in a location where the water velocity is not too high so that the fish caught in the trap can rest. If no such site is available, a piece of plywood placed upstream of the trap will provide a velocity shelter

The counting fence should be checked a minimum of twice a day, once first thing in the morning and once again in the evening and the fish removed from the traps using a dipnet. The fence should also be cleaned of debris to keep the water flowing freely through it and to reduce the build up of pressure on the fence. Record the day, time and catch each time the fence is checked. During an active spawning run, the fence may need to be checked more frequently so that the number of fish holding in the trap boxes does not become too large. Record the catch separately for each sampling period. After removing the fish from the trap boxes they should be released in the direction that they were traveling so that they can continue in that direction (i.e. fish from the upstream trap should be released upstream of the counting fence while fish from the downstream trap should be released downstream of the fence).

Counting fences are used to determine the species, relative abundances and timing of movements of fish past the sampling site. They are typically used to capture fish during their spawning runs in the spring or fall or to quantify the movements of fish into and/or out of tributary streams.

3.6 Catch-Per-Unit-Effort (CPUE)

Catch-Per-Unit-Effort is a measure which relates the catch of fish, with a particular type of gear, to the sampling effort expended; it is expressed as: ***number of fish captured/unit of effort***. Results can be given for a particular species or the entire catch. CPUE is used to define species relative abundance and to compare abundances between sites and/or seasons. Effort can be expressed a number of ways depending on the sampling equipment. If CPUE data is required, sampling effort must be recorded. Following are common CPUE calculations for traditional sampling gear:

• electrofishing (boat and backpack)	No. of fish/100 seconds (of active electrofishing)
• gill net	No. of fish/net-hour, or /panel-hour, or/100m of net-hour
• set line (trot line)	No. of fish/hour, or /hook-hour
• angling	No. of fish/hour, or /angler-hour, or /rod-hour
• minnow trap	No. of fish/hour, or /trap-hour
• seining	No. of fish/area seined (m^2), or /length of shoreline seined (m)
• counting fence (fish trap)	No. of fish/hour
• drift net/post-emergent trap	No. of fish/hour, or /volume of water (m^3)

It is important to recognize the components of the effort inherent in the sampling technique being employed so that effort will be recorded properly. Most field forms will have fields specifically designed to record the pertinent information. Record all aspects of your sampling effort (e.g., number of set lines used and number of hooks per line) so that CPUE can be calculated. CPUE values will be used in our own studies to establish relative abundance. Our data may also be used in a more historical context to compare the abundances we record with past or future research, using both similar and different sampling gear, and CPUE values may need to be recalculated to conform to other studies. The more detailed used when recording sampling effort, the easier it will be to accommodate these needs.

3.7 Coldwater Fish

When dealing with the general suitabilities of freshwater habitats for game fish species, temperature regime is often used to describe the habitat potential and the species assemblage which could possibly be present. Although the terms are not definitive or precise, the designations of habitats as "coldwater" or "coolwater" habitats and the associated fish fauna as "coldwater" or "coolwater" species are often used.

Coldwater fish are those which have a preference for summer water temperatures ranging from about 10-18 °C. In Alberta, this encompasses all of the salmonid species including the trouts, whitefishes and Arctic Grayling. Within this group the species will have differing temperature preferences and tolerances (see section 3.50 - Temperature Criteria).

3.8 Condition Factor (Ponderal Index)

Condition factors are used to describe the plumpness and, by inference, the well-being of individual fish. Formulas are used to calculate condition factors using the fish's length and weight and are based on the principle that the weight of a fish will vary with the cube of its length. Any variation in the shape or plumpness will be measured using the formula. Golder primarily uses the coefficient of condition *K*, also called the Fulton condition factor. The formula (**using metric length and weight data**) is as follows:

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

Condition factor is believed to reflect the nutritional state or well-being of an individual fish. The *K* value will be 1.0 for fish whose weight is equal to the cube of its length. Fish which have a *K* value >1.0 are more plump and are thought to have a higher degree of well-being or better nutritional state-of-health, whereas fish with a value <1.0 are considered to be less robust.

Condition factors vary with season, sex, sexual maturity, age and various other factors. Therefore, if sufficient data is available, average condition factors for a species should be calculated separately for each sex and should exclude young-of-the-year fish. Condition factors also vary by species, particularly if they have different shapes, and should not be used to compare well-being between fish species. They can, however, be used to determine differences in the condition of fish of the same species in different years or at different sites. Fulton's condition factor is also limited for comparisons between fish populations in different lakes because of differences in growth parameters. Other formulas for condition factor calculations are available and would be designated by the project manager if they are required.

3.9 Coolwater Fish

Coolwater fish are those which generally prefer summer water temperatures ranging from about 18-26°C. Alberta species generally considered to belong to this group include northern pike, walleye, sauger, yellow perch, goldeye, mooneye and lake sturgeon (see also Section 3.7 - Coldwater Fish).

3.10 Creel Census

The term "creel" refers to the basket a fisherman uses to hold the fish which have been angled and a creel census refers to a survey in which recreational fisherman are censused in order to determine aspects of the recreational fishery. Important survey goals typically include determining angler effort and success (i.e. fishing pressure and harvest) and may include examining the fisherman's catch for tagged fish or to collect ageing structures.

3.11 Dissolved Oxygen Criteria

The dissolved oxygen concentration in the water is an important habitat component. Different fish species have different dissolved oxygen requirements and have different tolerances to low dissolved

oxygen levels. Dissolved oxygen criteria provide minimum dissolved oxygen levels that are necessary to protect various life stages and have been developed for selected game fish species. Golder has prepared a document which list the criteria for selected Alberta species (Taylor and Barton 1992).

3.12 Fecundity

The most common measure of reproductive potential in fish. Female reproductive potential is the total number of eggs (ova) in both ovaries of a gravid female fish. Fecundity normally increases with the size of the female within a given species. For most studies conducted by Golder, fecundity is determined for female fish only. Fecundity is determined by recording the total weight (g) of both ovaries and removing a small sub-sample of known weight from the middle of the ovaries (usually a 1.0 g sample). Count the number of eggs in the sub-sample to determine the number of eggs/g of ovary. Multiply this value by the total ovary weight to calculate the total number of eggs.

3.13 Field Forms

Golder uses a number of specially designed field forms to aid in recording field data. They are not meant to replace the use of a field book or the recording of detailed field notes. They are intended to provide a template showing the type of supporting data that must be recorded for each sampling technique and provide an organized method of recording the sampling results. For each specific or general type of sampling technique there is a ***Catch Record Form*** (e.g. Gill Net Catch Record Form) for recording sampling information such as location, technique, effort and is used to summarize the results. The main form for recording the catch results is the ***Fish Sample Record Form*** which has fields for recording length and weight data and other particulars for each individual fish. On the back of this form you will find a list of all abbreviations to be used when recording data.

A copy of each field form is kept in the aquatics reference file located at Carole Collins desk (Aquatic Ecology Group Secretary). Copy the forms you will require onto waterproof paper and return the originals to the file.

3.14 Fish Collection Licence

Fish collection licences or permits are granted by provincial governments or by DFO and are required for all fisheries sampling activities. Obtaining a license varies from province to province. In Alberta, a Fish Collection Licence is granted to Golder by Alberta Environmental Protection, Fisheries Management Division. Each Licence is specific to the waterbody(s) being sampled and is valid for a specified time period. To obtain a Licence you must forward a letter of request to the F & W District office for the region in which you wish to sample. Include in the letter the reason for sampling, the location(s) to be sampled, the period the permit should be valid for, the capture techniques to be employed, the fate of the fish captured (i.e. will any be sacrificed), and the personnel to conduct the sampling. They will then send a Licence granting permission to carried out the proposed activities. They may impose specific restrictions on the licence (i.e., restricted number of fish allowed to be sacrificed, designation of a certain landfill for fish disposal, or specific reporting requirements) and the permits should be read carefully to ensure all restrictions will be followed. The original permit or licence should be immediately placed in the project file and a copy of the document given to the field personnel. You must be prepared to produce a copy of the permit while conducting any field sampling.

The Fish Collection Licence will also specify a date by which a permit return is to be submitted to the issuer. In Alberta, the permit return is a form which accompanies the Licence. The form requests information regarding the sampling conducted under authority of the Licence, such as sampling locations and results. Fill out the form and send it to the office which issued the Collection Permit following completion of sampling activities and prior to the date specified on the Licence.

3.15 Forage Fish

A general term applied to smaller species of fish that "forage" on small invertebrate animals or plant materials. This includes minnow species and other small fish such as sculpins, stickleback, trout-perch and darters.

3.16 Game (Sport) Fish

Fish used by anglers for recreational fishing or sought after by the commercial fishing industry, e.g., northern pike, walleye, trout, etc.

3.17 Geographical Position

All sampling sites, whether they are point locations (such as a minnow trap site) or sections (such as a section of river that was electrofished), should be recorded on a map of the study area. The standard is to use a 1:50,000 NTS topographical map but other maps or airphotos can be used if they provide greater detail. The geographical position of sampling sites can also be recorded using Universal Transverse Mercator (UTM) grid coordinates or by degrees of latitude/longitude. UTM coordinates are particularly useful in case the map is lost as they can be used to pinpoint the sampling site on a new map.

UTM and latitude/longitude are two different systems of grid coordinates used to establish geographical location. Both systems appear in the margins of 1:50,000 scale National Topographical Service maps. A calibrated ruler is used to calculate coordinates of any point on the mapsheet. Golder always uses UTM coordinates rather than lat/long, unless otherwise specified by the client.

The most accurate way to record the position of the sampling site is to use Geographical Position System (GPS) technology. If possible, use a GPS rover unit to record a position file at the sampling site that can be stored for differential correction. You should also use the GPS unit to record a "real-time" waypoint in the event that the stored file is lost or accidentally deleted. If you do not have a GPS unit capable of differential correction, a simpler unit will allow you to record a waypoint, which will be less accurate.

3.18 Gradient

Gradient refers to the vertical drop in elevation along a watercourse over a horizontal distance. It is recorded as the percent gradient. To determine the gradient over a length of stream, measurements are taken off of a 1:50,000 scale NTS map of the watercourse. Locate a point upstream and downstream of the study area on the map where contour lines cross the stream and determine the difference in elevation

(m) between these two points. Measure the distance (m), following the channel, between the same two points using a map wheel. The gradient is calculated as follows:

gradient (%) = [difference in elevation (m)/distance (m)] x 100

In very flat terrain determining gradient from a map may not be possible. In these situations, gradient may also be measured in the field using a clinometer. With this method one person with a clinometer stands at the upstream end of the section to be measured, a second person moves as far downstream as possible while still visible to the upstream person. Both individuals stand at the very edge of the stream with their feet at the water surface. The upstream person uses the clinometer to measure the angle from his or her eyes to the eyes of the other person. If your clinometer measures in % then this value should be recorded. If the clinometer measures in degrees, then percent can be calculated by taking the tangent of that number and multiplying by 100. This technique may need to be repeated several times and averaged to determine the gradient of a large section of stream.

3.19 Growth

Fish show indeterminate growth in that they continue to grow throughout their lives rather than stop growing once they reach an "adult size". However, growth rate is asymptotic, meaning the growth rate decreases with increasing age approaching some maximum value for the individual or population. As growth rate is a function of time, true growth rates can only be determined when fish length and age is known. Two parameters related to growth rate are: 1) the maximum size which is possible for fish in a given population, and; 2) the rate at which maximum size is achieved. The maximum size value indicates whether the population is "stunted" (i.e. does not have the potential to reach the normal maximum size for the species) and differentiates between populations that are stunted and those which do not achieve their potential maximum due to a short life span. If the maximum size for the population is at the lower end of the normal range for the species, than the population is slow growing rather than stunted. See Mackay et al. (1990) for methods of calculating maximum size and rate.

3.20 Gonads

Organs which are responsible for producing haploid reproductive cells in multicellular animals. In the male, these are the testes and in the female, the ovaries. In fish they are located in the peritoneal cavity, extending between the diaphragm and the cloaca, and running along the dorsal side of the cavity along both sides of the spine. When the fish is gravid, the gonads will fill much of the peritoneal cavity.

3.21 GSI (Gonadal:Somatic Index)

Gonad-Somatic Index is the proportion of reproductive tissue in the body of a fish to total body weight. It is calculated by dividing the total weight (g) of the gonads by the total body weight (before gonad removal) and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth. It is believed to be an indicator of fish health in that a fish with a comparatively low GSI for its species is considered to not have sufficient energy available for proper gonad growth. Fish are seasonal spawners and the size of the gonads changes dramatically as they pass through the various stages of gamete maturation. It is preferable to conduct

GSI measurements for fish just prior to the spawning season when the gonads are fully developed (i.e. gravid).

3.22 Habitat

Fish habitat refers to aspects of the physical environment which provide the requirements of a fish community, species or life stage. Habitat evaluations conducted for fisheries studies generally involve measurements or evaluations of macro- and/or micro-habitat conditions in order to determine the types of fish or life stages an area might support, the quality of available habitats or habitat limitations.

Macro-habitat

Macro-habitat refers to habitat components which are attributable to a general region or section of the study area. They are general conditions related to geographical location, climate, stream order, lake type, etc. For macro-habitat evaluations, we typically measure general water quality parameters (dissolved oxygen, temperature regime, pH, conductivity, turbidity, visibility (secchi depth), stream gradient), as they relate to describing coldwater and coolwater habitats and the types of fish species which may be present. Different fish species have different tolerances for macro-habitat conditions which affect their abundances and distribution.

Micro-habitat

Micro-habitat conditions are the physical conditions at a specific location. For micro-habitat assessments we measure or evaluate water depth, velocity, substrate particle size and condition, and the availability of cover for fish. Cover includes instream cover (i.e. any objects which provide velocity shelters) and overhead cover (i.e. anything which provides visual isolation). Each fish species has a range of micro-habitat conditions which are suitable, ranging from barely useable to optimal. In addition, each species has a series of life stages which may also have different habitat requirements. These life stages include spawning, incubation/embryo, nursery, rearing, feeding (adult summer) and overwintering.

Knowledge of the suitable and preferred habitat conditions for different species and life stages is very useful when conducting fisheries inventories, habitat evaluations and impact assessments. Information concerning these habitat requirements is available in the form of Habitat Suitability Index (HSI) models and Habitat Preference Criteria (HPC). HSI models were developed by the U.S. Fish and Wildlife Service and are species-specific models, with each model containing information for all life stages of one fish species. The models include all the habitat variables (macro- and micro-habitat) that accumulated research has determined to be significant to each species with respect to population abundance. Each habitat variable is provided along with the range of suitable and optimal conditions. HPC are species-specific curves showing suitable and preferred conditions for micro-habitat variables (depth, velocity, substrate and cover). HPC curves are available for a limited number of game fish species and were developed from snorkeling observations of the different species and life stages (developed for the most part by Golder from streams in Alberta).

Measurements of macro- and micro-habitat conditions in lakes and streams are useful in combination with inventory data and existing information to establish habitat potential for a study area. Habitat based assessments are being used more frequently to provide a complete picture of habitat potential, with respect to use by different fish species and life stages, rather than relying on fish inventory data from a specific point in time.

3.23 Length

Refers to the whole body length of a fish. There are three types of length measurements: standard length, fork length, and total length. The measurement most commonly used in Canada and ***required for use by Golder*** is the ***Fork Length*** and is ***always recorded in millimetres (mm)***. Fork length is the distance from the most anterior point on the head to the tip of the median caudal fin rays. The fork length of captured fish is measured on a fork length board, which is a trough or flat board with a ruler attached to the surface and a vertical block at the anterior (zero mm) end. Place the fish on the board with its head flush with the block and spread the caudal fin to show the mm mark under the anterior point of the fork.

Some fish species such as burbot, sculpins and darters do not have a fork in their caudal fins. For these species, the standard measurement is Total Length, which is the distance from the most anterior part of the head to the distal tip of the longest caudal fin ray.

The fish which must be measured for length and weight may vary between projects. You will always be measuring game species but will not necessarily have to measure rough or forage fish. The project manager will be able to tell you what is required. For instances where large numbers of individuals are being captured and the time required to measure length and weight is excessive, it may be possible to measure length only for some fish. A large number of lengths are required to produce a complete length-frequency distribution (see section 3.25) while a lesser number of weight measurements are required to provide an accurate length-weight analysis (see section 3.26). If fish are being preserved, always measure length and weight before preserving.

3.24 Length-at-Age

Length-at-age analysis is used to determine the average length of fish in each age class in the population. This analysis can only be conducted for individuals for which age is known. For each age class (i.e 1 year old fish, 2 year old fish, etc.) calculate the range of lengths, mean length and the standard deviation of the mean. Plot this data graphically showing the range, mean and standard error (error bars) (see section 3.47 standard error and standard deviation) with age as the X-axis.

3.25 Length-Frequency Analysis

Length and weight data provide the statistics that are the cornerstone of fisheries research and management. Rate of change of length in individuals and length-frequency distributions are key attributes of fish populations. Length-frequency analyses provide an important description of population structure and are used to provide information for the interpretation of age and growth, especially for young fish. Length-frequency distributions reflect the interaction of rates of reproduction, growth and mortality of the population. However, when interpreting length-frequency data it is important to evaluate

sampling biases for the capture technique that was used, particularly with respect to size selectivity. The length-frequency distribution of a population is shown graphically by plotting the number of fish in each size class using a histogram chart. Typically, size classes include every 50 mm fork length interval (i.e. 0-50 mm, 51-100 mm, 101-150 mm..... etc.) but may be more frequent if you have a large sample size. When plotting the length-frequency distribution using Microsoft Excel, label the size classes on the X-axis of the graph using the complete label (i.e. 0-50 mm, not 50 mm).

Using the length-frequency analysis to determine fish age and growth rates is called the Peterson method. The plot of the length-frequency analysis is examined for peaks which are believed to represent each of the year classes in the population. The peak closest to the Y-axis would represent zero aged fish (young-of-the-year) and each peak after that should represent another year class. Great care must be exercised when conducting age analysis with this technique. Typically, distinct peaks are only evident for the first few year-classes. Individual fish exhibit different growth rates and as they get older, the overlap in size ranges for each age class becomes too great and the peaks in the length-frequency distribution are lost. In addition, this method requires measurement of a large number of fish which represent an unbiased sample of the population. The size intervals (fork length classes) chosen for plotting these data are particularly important, as size intervals which are too large or too small will obscure the peaks. Other problems with this method include dominant year-classes which may obscure the peaks of weaker year-classes and divergent growth rates of male and female fish complicates the analysis as does the small incremental changes in length which occur in older fish. However, the Peterson method is quite suitable for some forage fish populations where the life-span is short. It is the recommended ageing method for some minnow species which may have life-spans as short as three years.

3.26 Length-Weight Relationships

Length-weight relationships can be used in order to assess the state of well-being of a fish population. These relationships can be used to compare the condition or "fatness" of fish in a population to other populations, or to that in previous years. As a fish population size increases and/or food resources decline, individual fish become thinner and the ratio of weight to length decreases.

The relationship between fish length and body weight is curvilinear, and can normally be represented by the following function:

$$W = aL^b$$

where W = weight, L = length, and 'a' and 'b' are constants which are characteristic of the population being examined. The constant 'b' reflects the rotundness of the fish or the rate at which weight increases for a given increase in length. In general, a value of 'b' less than 3.0 represents fish becoming less rotund as length increases, and 'b' greater than 3.0 indicates a population where fish become more rotund as length increases. If 'b' is equal to 3.0, growth is isometric, meaning shape does not change as fish grow.

The length-weight relationship that we typically use is called length-weight regression analysis. The length-weight relationship can be changed from curvilinear to linear (straight line) using a $\log_{10}$ transformation of both length and weight. The relationship between length and weight becomes:

$$\log W = \log a + b \log L$$

where log a is the 'Y' intercept of the regression line and b is the slope of the line. A regression analysis can be conducted from length and weight measurements of a sub-sample of the fish population. Be sure to measure fish which are representative of the size range in the population, that is an even number of fish should be measured from all size groups in the population, from the smallest to the largest fish. A general rule is that at least 30 fish should be measured to provide a large enough sample size to calculate an accurate regression. The regression analysis plots the log weight versus log length for all the fish measured and then produces the "best fit" straight line that approximates the mathematical relationship between length and weight. The regression analysis can be conducted by entering the length-weight data on a computer spread sheet (Microsoft Excel) and having the program conduct the log transformation of the data. The computer program will provide the regression equation, including the values for 'a' and 'b'. When conducting a regression analysis, you should also record the 'R' value (coefficient of determination) that the computer calculates as this value represents properties of the linear relationship. The higher the 'R' value, the more closely the data conforms to a straight line and the better the regression equations represents the data.

Differences often exist in the body weight to length relationship for males and females in the same population. If possible, length-weight regressions should be calculated separately for the two sexes. The relationship also changes throughout the annual growing season, particularly for females, as gonad size and weight increases, so care should be taken when comparing various sets of data. Prior to conducting a length-weight regression analysis, the length-weight data should be plotted on a scatter diagram in order to spot 'outlying' data points. Points which are well outside the range represented by the other data points should be checked for accuracy to make sure both length and weight were recorded properly.

3.27 Lesion

Lesions are the result of a pathological change in body tissue. External hemorrhagic lesions (bloody sores) may be observed on the body surface of the fish and should be recorded on the Fish Sample Record form. Reddened areas and lesions on the body surface are evidence of systemic (widespread, internal) infections of bacteria or superficial bacterial infections. Skin lesions in wild fish are seen most often in the early spring when rising water temperatures encourage bacterial growth at a time when fish are least resistant to it. An increased prevalence of skin lesions also has been associated with fish from water with a high organic load and bacterial community, such as below a sewage outfall.

3.28 LSI (Liver:Somatic Index)

Liver-Somatic Index is also known as hepato:somatic index. It is the ratio of liver weight (g) versus total body weight, expressed as a percentage of total body weight. The LSI is used as an indicator of fish health. Energy is stored in the liver in the form of glycogen and the relative size of the liver is believed to correlate with nutritional state.

3.29 Marking/Tagging

Identification of individual fish or simply identification of fish which have been captured is required for some projects. Different marking techniques are available, depending on the goals of the study.

3.29.1 Anchor (Floy) Tagging

A practical and inexpensive method of permanently marking individual fish. The tag, shaped like an inverted "T", is most commonly inserted through the fishes' back at the base of the rear portion of the dorsal fin and anchored between the epipleural bones of the dorsal fin using a special tag-gun. The tip of the gun is a hollow needle which is inserted through the skin and muscle. As the handle of the tag-gun is depressed, an injector rod pushes the anchor portion of the tag out the end of the gun through the needle. The tag-gun needle will not pass through fish scales. In order to insert the needle, use the tip of the needle to lift the posterior edge of a scale and slip it in under the scale. Fully insert the needle through the skin by inserting it to the base of the needle and depress the handle. Once the tag-gun handle has been fully depressed, hold it in the depressed position while giving the gun a quarter turn to free the tag from the needle. Still with the handle depressed, remove the tag-gun needle from the fish and the tag will remain anchored in place.

The posterior portion of the Floy tag remains outside the fishes' body and is usually brightly coloured and carries a numeric identification code. This tagging method is used when conducting mark-recapture population estimates and basic fish movement studies. It is also the preferred marking technique when seeking angler return data to aid in establishing fish movements. Tags marked with the researchers address and the phrase "$2 reward" are often used to ensure angler response.

When sampling, always record the recapture of marked fish, even if the tag is not one that was inserted during your present study. It is common to catch fish carrying old Floy tags inserted by other agencies who will provide the date and location the fish was tagged; information which will provide movement data for all of the researchers involved. Older tags will usually have a build up of algae and will need to be scraped clean with a knife in order to read the tag number and other information.

Floy tags will usually carry the name and address of the client/agency that Golder is working for and, therefore, the tags are usually provided by the client. If this is not the case, Floy tags will need to be ordered and discussion with the client may be necessary to decide what writing the tags will carry.

3.29.2 Visual Implant (VI) Tagging

A "micro-tag" method using tags which are inserted under the skin. VI tags are suitable for use when a tagging method is required which has minimal effects on the swimming and feeding efficiency of the fish. Good for tagging smaller fish than is possible with the anchor tag method, such as small fish species or juvenile fish. Each tag consists of a small metal strip with an individual alpha-numeric code (typically three digits) which is inserted using an injector into a clear tissue somewhere on the fishes body (e.g., post-ocular tissue for salmonids). If working with non-salmonids, it will be necessary to determine a suitable implant location for the fish species you are working with. The implant location should have a sufficiently thick layer of clear tissue so that there will be room to insert the flat injector

needle and the tag can be read through the tissue. Record in the field notes the location (including left or right side) of tag insertion for each fish species that you are tagging. To tag a fish, insert the injector needle into the selected tissue, depress the injector and hold it down while removing the needle from the fish.

3.29.3 Batch Marking

A marking method which does not distinguish between individual fish. Common methods are fin clipping or dye marking. Batch marking can be used to distinguish fish from specific sites by varying the location on the fishes' body which is dye marked, the colour of the dye or varying which fin is clipped by sampling site. This method is suitable for simple movement studies and for simple mark-recapture population estimates. This method is also used when extremely large numbers of fish need to be marked, as it is simple and more economical than anchor or VI tagging.

Dye marking is accomplished by injecting a small amount of a coloured dye or liquid plastic sub-cutaneously. It can be used for marking very small fish, such as minnows and other forage fish, since a very small hypodermic needle can be used as the injector. One disadvantage of dye marking forage fish is that it is difficult to avoid using a colour which is readily visible to the researcher without increasing the probability of predation of the marked individuals.

Fin clipping includes removing or distinctively altering a fin in a recognizable manor. Fin removal is usually only conducted for non-essential fins such as the adipose fin on salmonids. For other fins such as the pectoral or pelvic fins, the first two fin rays may be removed. For larger fish, a hole punch can be used to make a distinctive mark on a fin. When clipping a fin, it is important to make straight, regular cuts to distinguish the mark from naturally frayed or eroded fins. Record the fin which is marked for each sampling site.

3.29.4 Radio Tagging

Attachment of a battery powered radio transmitter to a fish in order to follow its movements using a radio telemetry receiver. The transmitter is affixed externally or surgically implanted in the body cavity. To avoid adverse effects on swimming ability, the transmitter should be <2% of the fishes' body weight. Ground, boat or aerial surveys are conducted with the telemetry receiver in order to follow the fishes movements.

3.30 Maturity (State-of-Maturity)

Maturity refers to the state of gonad maturation of an individual fish at the time it is examined. It does not refer to whether or not the fish is "mature" (i.e adult); classification of a fish as juvenile or adult is referred to as life-history stage (see Section 3.46).

For adult fish, the gonads will typically progress through a series of conditions or phases of maturation each year during the seasonal development cycle. Although juvenile fish have only one possible state-of-maturity, adult fish can be one of several maturities. The state-of-maturity is used to determine the current reproductive status of the individual. For fish populations, state-of-maturity data can be used to

determine the size or age at first spawning, the proportion of the stock that is reproductively active, or to illustrate the nature of the reproductive cycle.

Golder uses a system that includes **9 maturity categories**. The 9 categories, their definitions and abbreviation codes are presented on the back of the Fish Sample Record forms used to record the data. More detailed definitions and descriptions of each maturity category, for both males and females, are provided in Appendix I. Maturity is best determined by conducting an internal examination of the gonads, which requires sacrificing the fish. Maturity can sometimes be determined by external examination of the fish based on fish size and by knowing the typical spawning period for the fish in relation to the capture date or, for some species, by external secondary sexual characteristics which become pronounced during the spawning season (see Section 3.41). The classification system includes an "unknown" category for fish which are examined externally and for which maturity cannot be determined.

For many studies, most or all fish will be released live and only external examinations will be conducted. For other studies, a sub-sample of fish captured will be sacrificed for definitive state-of-maturity data. The following are some hints for establishing state-of maturity from external examination. *Pre-spawning* fish will be found immediately prior to the species spawning season. Fish of a size large enough to be adult or displaying secondary sexual characteristics at this time and with a strongly distended body cavity may be *Pre-spawning*. During the spawning season, gametes (milt or roe) can be extruded from the fish with gentle pressure on the abdomen and it will be obvious that the fish is *Ripe*. *Spent* female fish can be identified by a flaccid, concave abdomen resulting from shedding of the large egg mass and abdominal abrasions obtained during spawning activity. They may extrude a small number of residual eggs in response to pressure on the abdomen. *Spent* males may also have abdominal abrasions and will probably still extrude milt with abdominal pressure, but the milt may appear "watery". Other maturity classifications are very difficult to determine from external examination.

3.31 Milt

Milt is a milky white fluid extruded by male fish during spawning activity and contains the sperm. During spawning season, ripe male fish will extrude milt in response to pressure on the abdomen.

3.32 Necrosis

The death of a tissue due to injury or disease.

3.33 Parasites

Fish are subject to several types of internal and external parasites. A complete parisitological examination requires sacrificing of the subject and microscopic examination of some tissues. For general fisheries inventories, the occurrence of macro-parasites which can be readily observed by the an-aided eye should be recorded on the Fish Sample Record Form. A basic external examination is conducted while measurements of length and weight are conducted. An internal examination is conducted for fish which have been sacrificed. Common external parasites include body lice, gill lice,

leeches and lamprey. Common internal parasites include tapeworms, nematodes and flukes associated with the gastro-intestinal tract and other internal organs.

3.34 Pathology

For fisheries inventory studies, pathology refers to the field examination of captured fish for indications of parasites, disease and abnormalities, without the use of special procedures (e.g. tissue collection) or tools (e.g. microscope). This can include either external pathology or external and internal pathology.

External Pathology

Examination of the body surface , fins, eyes, gills and gill chamber for signs of parasites, disease or abnormalities (deformations). Components of the external examination include body form, body surface, lips and jaws, snout, barbels, opercles, isthmus, eyes, fins, gills, pseudobranch, branchial cavity, anus, and the urogenital opening. A basic external examination can be conducted for most fish while measurements of length and weight are being conducted and the results recorded on the Fish Sample Record Form.

Internal Pathology

Examination of the body cavity and internal organs for signs of parasites, disease and abnormalities. Components of the internal examination include body cavity, mesenteric fat, liver, gall bladder, hind gut, stomach, pyloric caeca, intestines, spleen, gas bladder, kidney, gonads, and muscle. A basic internal examination can be conducted for fish which have been sacrificed.

3.35 Population Estimates

Population estimates are used to determine or approximate the total number of fish, for one species or a number of species, within a study area. Population estimates may be calculated for a portion of a waterbody (e.g. a section of stream - #fish/km) or an entire waterbody (e.g. a lake - #fish/ha). Two basic types of population estimates are used; Removal and Mark-Recapture.

Removal (Reference - Armour et al. 1983)

Removal population estimates involve the isolation of the study area using a physical barrier to block fish movements followed by the removal of fish from the area to provide a population estimate. This technique is restricted to study areas which can be isolated and is typically used in small streams. Small-mesh blocking nets are placed at the upstream and downstream boundaries of the study area to prevent immigration or emigration of fish from the study area. Long minnow seine nets are used as blocking nets and are held in place using rebar posts embedded in the substrate. Care must be taken to ensure the bottom of the net remains in contact with the stream substrate to form an effective barrier.

Electrofishing is used as the capture technique, typically backpack or portable boat electrofishing, depending on stream size and water depth. It is vital that the capture technique be very efficient. If the

stream is too deep or wide for effective sampling by backpack electrofishing, the portable boat electrofisher should be used or use two backpack units working simultaneously. Multiple electrofishing passes are conducted within the study area and the catch (species and length) and sampling effort are recorded for each pass. Captured fish are retained in a holding pen or are released outside the study area. The catch will decline with each pass as the number of fish in the study area is reduced. Ideally, the catch on the final pass will be zero as total removal is achieved, however, total removal is not required. What is required is that the capture efficiency must be high enough that the probability of capture for each individual is high. When this requirement is met, most of the fish in the study area will be captured on the first pass. After two electrofishing passes, the capture probability is calculated (Armour et al. 1983). If the capture probability is 0.8 or greater, the capture efficiency is high enough to provide an accurate population estimate and a sufficient number of passes has been conducted. In practice, capture probabilities as high as 0.8 are uncommon and additional passes must be conducted. Typically, 3 or 4 passes must be conducted to get a good estimate of capture efficiency and to get enough data to calculate a population estimate. If after 4 passes the number of fish being captured has not declined to near zero, the sampling technique is not sufficiently effective and the population estimate will have poor accuracy. A population estimate can be calculated from such data, but the confidence intervals will be very large.

It is very important that the diminishing catch on subsequent passes be due to the reduced number of fish in the study area and not to a reduced amount of sampling effort. It is vital that a similar effort be expended on all passes. The number of seconds of electrofishing and the search pattern in the study area should be similar for all passes. Monitor the electrofishing seconds throughout each pass in order to ensure this requirement is met.

If total removal is achieved, the population estimate for each species is equal to the total number of individuals captured. If total removal is not achieved, formulas are used to calculate the population estimate. Two formulas are available; the first is a simple formula for computations for two removal passes and the second is more complex for computations for more than two removal passes (Armour et al. 1983). Both of these formulas are presented on a Microsoft Excel spreadsheet in the G:\Aquatics directory. Simply type in your data for each species (i.e. number of fish captured on each pass) and the spreadsheet will calculate capture probability, population estimate, standard error and the 95% confidence interval. The lower limit for the 95% confidence interval is sometime lower than the number of fish that was captured. If this is the case, the lower limit should be changed to equal the number of fish captured as this number represents the minimum population size.

Mark-Recapture

Mark-recapture population estimates are used in situations where isolation of the study area is not possible or for situations where removal of a significant portion of the population is not practical. Using this technique, a sub-population of fish is captured, marked and released. These fish are then allowed to mix with the larger unmarked population. A sub-sample of fish is then captured and the number of marked and unmarked fish is used to determine the proportion of the total population represented by the marked sub-population. As the size of the marked sub-population is known, the size of the total population can be calculated. This technique is useful in large and intermediate sized streams and in lakes. Any sampling technique with good sampling efficiency can be used but is typically limited to electrofishing, particularly in flowing waters. The mark-recapture technique assumes a closed population (no immigration/emigration) which is not usually true in many situations. Study design should include aspects to reduce the effects of immigration/emigration of fish. For size selective

sampling techniques such as electrofishing, population estimates should be conducted separately for different size classes.

For most mark-recapture population estimates, it is recommended that multiple sampling passes be conducted to capture and mark fish. This is followed by a few days without sampling to allow mixing of marked fish in the general population. A sampling pass (census) is then conducted to determine the portion of marked to unmarked fish in the census sample. Batch marking (see section 3.29) can be used for this technique. The population estimate is calculated using the Chapman modification of the Peterson method (Ricker 1975) as follows:

$$N = (M+1)(C+1) / R+1$$

where N = population estimate, M = number of marked fish, C = sample taken for census, and R = number of marked fish in the census sample.

At Golder we generally use the ***CAPTURE*** program (Otis et al. 1978) for mark-recapture population estimates. For this method, the fish marking technique must be Floy or VI tagging (see section 3.29) as each individual fish must be identifiable. Multiple sampling events are conducted in order to tag fish and to keep daily counts of the number of tagged and untagged fish that are captured. The results are then arranged in a matrix which has one line for each individual fish that was captured, along with the day or days it was captured/tagged and recaptured. This matrix is used by the CAPTURE software to provide the population estimate. The CAPTURE program is located in the G:\Aquatics directory. The CAPTURE software tracks the capture/recapture history for each individual fish over each pass and calculates the population estimate based on these results. This technique is believed to provide a more accurate result than the single census-pass estimate presented above. This technique does not require a rest period between the marking passes and a census pass and is more suitable for use in open populations where fish movements in or out of the study area may occur.

3.36 Riparian

With respect to fisheries habitat evaluations, riparian areas are terrestrial habitats bordering water bodies (lakes and streams). Riparian areas are not included within the boundaries of the waterbody but are significant in providing habitat features such as overhanging vegetation, inputs of large-woody-debris, sediment stabilization, shading, moderation of surface water run-off, nutrient inputs, etc. Riparian conditions, including species of bank vegetation and floodplain vegetation when possible, are an important part of habitat evaluations.

3.37 Roe

Fully developed, unfertilized eggs produced in the ovaries of adult female fish. During spawning season, ripe female fish will extrude roe in response to pressure on the abdomen.

3.38 Rough Fish

Large fish species (i.e. non-forage fish) which are not included as game fish. Primarily sucker species.

3.39 Sacrifice

Fish which are killed in order to allow internal examination or collection of ageing structures are referred to as sacrificed. For each fish captured, information on whether or not the fish was sacrificed is recorded on the Fish Sample Record Form (i.e. capture code), which helps to identify fish which have been examined internally versus those which were only examined externally. Fish which are sampling mortalities (accidentally killed as a result of capture) are also recorded as sacrificed. Even if intentionally sacrificing fish is not a part of the study design, dead fish should be examined internally for definitive sex and state-of-maturity data, as well as stomach contents and internal pathology when time allows.

3.40 Sampling Bias

Sample inaccuracy caused by bias or imprecision in sampling; e.g., bias towards large fish because of the type of sampling gear. In statistics, a sampling bias may be represented as skewedness or as variance.

3.41 Sex

Sex refers to the sex of the individual fish, usually recorded as either male or female. However, since determination of sex may be difficult from external examination or from internal examination of juvenile fish, sex may also be recorded as unknown.

Sex Determination (Lethal)

To determine the sex of a fish, an incision should be made on the ventral surface of the body from a point immediately anterior of the anus toward the head to a point immediately posterior to the pelvic fins exposing the gonads. If necessary, a second incision may be made on the left side of the fish from the initial point of the first incision toward the dorsal fin. To observe the gonads, fold back the tissue. Ovaries appear whitish to greenish to orange and have a granular texture. The eggs will be readily apparent in developed ovaries. Testes appear creamy white and have a smooth texture.

Sex Determination (Non-Lethal)

Determination of sex from external examination of the fish is generally more difficult. For some species, sex may be determined from external secondary sexual characteristics, observable either during the spawning season or, for some species, at any time of year. For most fish species, sex of adult fish can be determined during the spawning season by forcing extrusion of the sexual product (milt/roe).

Secondary sexual characteristics are external physical characteristics displayed by fish which distinguish sex. Some species do not display secondary sexual characteristics. Other species show secondary sexual characteristics during the spawning season and these characteristics are only useful for distinguishing sex for adult fish during the spawning season. Still other species have morphological differences which allow determination of sex from external examination at any time.

Mountain whitefish develop small tubercles (raised bumps) on the lateral scales prior to spawning. These tubercles are generally more pronounced in males than in females but, alone, tubercles may not be a reliable indicator of sex. Trout may show differences in jaw morphology with females having a rounded jaw and male developing a kype (extended, upwardly hooked lower jaw). This characteristic is not reliable in that the male may not develop a kype, particularly in smaller adults. Males for most sucker species develop obvious tubercles which show as hard nodules in the pelvic, lower caudal and, particularly, the anal fin during the spawning season and which are very reliable for determining sex in adult fish. Many species, such as minnows, suckers and some trout develop distinct body coloration or markings during the spawning season which may aid in separating the sexes. Two species, goldeye and mooneye, show a difference in anal fin structure between mature male and female fish which is a reliable external indication to distinguish sex at any time. In the female, the longest rays of the anal fin are the first four and all of the anal fin rays are slender. The overall shape of the fin is "smoothly concave". The first half of the anal fin of the male has long rays followed by much shorter rays at the back, giving the fin a "lobed" appearance. In the male, the anterior rays are thick near the base. This characteristic is not reliable for juvenile fish.

3.42 Spawning Surveys

Spawning surveys refer to the visual observation of spawning activity or sampling for the presence of incubating eggs and are used to determine if a site has been used as a spawning area, to determine the distribution of spawning sites within a study area, or to collect micro-habitat data (Habitat Preference Criteria) at known spawning areas. Spawning occurs when eggs (roe) and milt (sperm) are extruded by the fish so as to mix and produce fertilized ovum. This is accomplished in a number of ways by different species. Most game fish species for which spawning surveys are typically conducted are either spring or fall spawning species. There are two basic types of spawning surveys (***egg surveys or redd surveys***) depending on the spawning strategy of the species involved.

Egg Surveys

Some species, such as mountain whitefish, lake whitefish, lake trout, walleye and sauger are ***broadcast spawners*** which distribute their eggs over the substrate in areas of suitable depth, velocity and substrate type. The eggs fall into the interstitial spaces (crevices) in the substrate to incubate, although some species will spawn over hard sand if rocky substrates are not available. Spawning surveys for broadcast spawners are conducted using kick sampling and/or airlift sampling techniques (see sections 3.5.1 and 3.5.9). If the study area is small, systematic sampling can be used to examine the entire area for eggs. In large study areas where this type of sampling is impractical, sampling is conducted by examining areas of suitable spawning habitat for the target species. Habitat preference information (see section 3.22) is used to determine the habitat types that should be examined. The section of the stream or portion of lake that is examined during the survey and the location of all spawning sites where incubating eggs are recovered should be identified on maps of the study area. The standard is to use 1:50,000 scale topographical maps but other maps or air photos may be used if they provide greater accuracy. The

number of eggs recovered is also recorded for each spawning site and, depending on the sampling technique, sampling effort may also be recorded at each site.

If incubating eggs are found in a study area where more than one species may be spawning, measure egg diameter for the recovered eggs and use egg size, colour and features such as the presence or absence of oil globules to identify the eggs. Egg diameter can be measured using an egg measuring trough. Place 10 eggs in the trough and measure the total amount of the ruler covered, divide this distance by 10 to get an average egg diameter. Scott and Crossman (1973) provide egg descriptions for most species. If egg identification is still doubtful, collect a sample of eggs, measure the egg diameter, and preserve the sample in 5% buffered formalin.

Some fish species use spawning strategies which are part-way between broadcast spawners and species which construct spawning nests. These species include Arctic grayling and several sucker species such as longnose and white sucker. No actual nest or redd is prepared but spawning occurs close over the substrate while the fish are vigorously vibrating and the fertilized eggs become somewhat covered by the substrate material stirred up during this vibration. In some cases, such as spawning areas used by a large number of suckers, disturbances of the substrate can be visually observed but it is not possible to enumerate the number of spawning acts or the number of fish involved. For species such as Arctic grayling, these disturbances are indistinct. Spawning surveys for these species are conducted using egg surveys, as for broadcast spawners.

Still other species, such as northern pike and yellow perch, attach their incubating eggs to submerged vegetation (aquatic macrophytes or flooded terrestrial vegetation). Spawning surveys for these species are conducted by searching for eggs in areas of submerged vegetation. A kick sampling net or other small mesh net is swept through the vegetation and the net contents are examined for eggs.

Redd Surveys

Most trout species (including brook, brown, bull, cutthroat and rainbow trout) construct excavations in the substrate into which the fertilized eggs are deposited. A similar excavation immediately upstream of the depression is dug and the materials from this excavation are used to cover the incubating eggs. These excavations or spawning "nests" are termed ***redds*** and are typically constructed in flowing water, although areas of ground-water upwellings in lakes may also be used. As the algae and silt covered rocks are turned over during redd construction, the redds can usually be readily observed due to their "clean" nature and distinctive shape (i.e. distinct depression upstream of a mound). Redd surveys are conducted by one or more observers walking or floating through a study area, enumerating the redds observed, and recording the locations of the redds on a 1:50,00 map of the study area. The study area (section of stream or portion of lake) examined should also be recorded on the map. Not all excavations are redds which contain incubating eggs and it may sometimes be difficult to determine if a disturbance of the streambed is truly a redd. Therefore, redds should be enumerated and classified into the following categories: 1) Class A redd - large or distinct, well formed or spawning fish present; 2) Class B redd - less distinct, most likely an active redd; 3) Class C redd - small or indistinct, possible redd but not definite.

If more than one trout species may be spawning in the study area, enumeration of the redds by species may be difficult. If this is the case, species identification for each redd is best facilitated by conducting

the redd survey during the active spawning period so that it is likely that the fish will be present at the redds to aid in identification. Knowing the species and size of the fish in the study area will also help, as some species build larger redds than others. If only one species is expected to be spawning in the study area, the redd survey is usually conducted towards the end of the spawning season when the maximum number of redds will be present.

Repeated redd surveys in the same study area can be used to define the spawning season if required. Surveys are conducted at regular intervals from the start of the spawning season and the number and location of redds on each successive survey is used to determine the length and peak of spawning activity.

3.43 Species Code

Standard abbreviation of fish species names is based on the following rules (MacKay et al. 1990):

a) use a four letter abbreviation
b) for a one word name - use the first four letters
   e.g., GOLD for goldeye
c) two word names - use the first letter in each word plus the next consonant in each word
   e.g., ARGR for Arctic grayling,
   LKWH for lake whitefish, and,
   WHSC for white sucker
   (exception - due to duplication, use BRTR for brook trout and BNTR for brown trout)
d) three word names - use the first letter in the first two words and the first letter and next consonant in the last word
   e.g., NRDC for northern redbelly dace

The species codes for all Alberta species are presented on the back of the Fish Sample Record Form.

3.44 Species Composition

A term that refers to the species found in the sampling area.

3.45 Species Distribution

Where the various species in an ecosystem are found at any given time. Species distribution varies with season and life history stage.

3.46 Stage (Life History Stage)

Stage refers to the life history stage (or life stage) of the individual fish. Three stage categories are used to describe free swimming fish: ***fry, juvenile or adult.*** The incubating egg is also a life stage and is referred to as the embryo stage.

Fry are also called young-of-the-year (YOY) and are fish from their hatching date until the first anniversary of their hatching date. Juvenile fish are fish from one year old until reaching sexual maturity. Adult fish are fish which are sexually mature.

Definitive life history stage is determined for an individual by internal examination of the gonads. Fry and juvenile fish would have undeveloped gonads and would be classified as immature with respect to state-of-maturity. Fry can usually be separated from juvenile fish by their small size (i.e. smallest fish in the population) and, for some species, by secondary characteristics such as parr marks. Adult fish are sexually mature fish which have spawned in the past or will spawn in the upcoming spawning season. Their state-of-maturity can be one of several categories, from maturing to spent.

Determination of stage from external examination is not always possible. Identification of fry is based on their small size. However, it is not always possible to tell large juvenile fish from small adult fish, in which case an ***unknown*** category is provided in addition to the three main categories. Evidence of sexual maturity, such as secondary sexual characteristics or extrusion of milt or roe during the spawning season can be used to identify adult fish.

3.47 Standard Error and Standard Deviation

Standard error (SE) and standard deviation (SD) both express the variability of results around the mean. However, standard error takes the sample size into consideration when calculated. By including sample size, SE gives an indication of how well we've measured the entire population. This is particularly true if you have very different sample sizes for the groups you are comparing; the larger the sample size, the more confidence you have that the data represents the population.

Standard error is calculated as: $SE=SD \div \sqrt{n}$; where n=sample size. Microsoft Excel will calculate SD automatically. In order to calculate SE the formula in Excel would be " =StDev(cells with data)/(sample size)^0.5". The "^.05" denotes square root (by asking excel to calculate to the power of 0.5).

Standard error is now considered to be the appropriate measure to use in any technical presentation of data and should be used in any figures or tables of fish population statistics.

3.48 Stomach Content/Gut Analysis

Stomach content analysis is used to determine the diet and food preferences of fish. The stomach is removed from the sacrificed individual and opened to allow examination of its contents. Record stomach fullness as the percentage of fullness, from 0 to 100%. Record the contents of the stomach as percentage of the material in the stomach, not as percentage of the total stomach volume (e.g. a stomach that was half full, with all the contents being mayflies would be recorded as follows: 50% full, 100% mayfly).

For invertebrates in the stomach contents, record the contents to the lowest taxonomic level possible. Family level is usually required, but Genus should be recorded if known. Unidentifiable, overdigested invertebrates should be recorded as IR (invertebrate remains) and unidentifiable fish remains should be recorded as FR (fish remains).

3.49 Study Site/Sampling Location

A study site or sampling location is the portion of a study area at which sampling is conducted. The site may be a ***point location*** (such as a gill net or set line location) a ***transect*** (cross section of a stream channel or lake) or a ***section*** (such as a section of stream electrofished or an area of a lake which is seined). In any event, the location of the sampling site must be recorded in the field notes. For large studies or studies with multiple sampling locations on the same waterbody, you may wish to number each sampling site. For a single waterbody, sample site may be numbered sequentially (i.e #1, #2, etc.). For multiple waterbodies, you may wish to combine the number with an abbreviation for the waterbody (e.g. BR1 = Bow River Site #1). You may also wish to identify the type of sampling conducted (e.g. GN1 = gill net set #1). All study site abbreviations must be clearly identified in the field notes. At a minimum, all study sites should be recorded on a 1:50,000 scale topographical map. Other maps or air photos may also be used if they provide greater detail than the 1:50,000 map. See section 3.17 for additional methods of recording location.

Study areas on flowing watercourses are often divided into homogeneous sections called reaches. A ***reach*** is a relatively homogenous section of stream having a uniform set of characteristics and habitat types. A reach is relatively uniform with respect to channel morphology, flow volume, gradient and habitat types and is separated from other reaches by changes in these characteristics. Conventionally, reach numbers are assigned in an upstream ascending order starting from the mouth of the stream. Typically, reach lengths are too long to sample in their entirety, in which case representative study sections will be selected in each reach for determining species distribution and abundances.

3.50 Temperature Criteria

Water temperature is a very important habitat component. Different fish species have different temperature requirements and have different tolerances to high water temperatures. Temperature regime in lakes and rivers can affect the presence, distribution and abundance of fish species (see sections 3.7 and 3.9). Temperature criteria provide maximum temperature levels that are tolerable by various life stages and have been developed for selected game fish species. Golder has prepared a document which list the criteria for selected Alberta species (Taylor and Barton 1992).

3.51 Underwater Video

Underwater video equipment includes a remote control underwater camera, light and above surface monitor and video recorder. Underwater video is used to determine fish presence, general abundance and activity. It is not generally useful for recording fish numbers. It is a sampling technique that is effective in both the open water season and for winter sampling under the ice.

3.52 Water Quality

Water quality is a basic aspect of fisheries habitat and can influence fish survival, distribution, abundance and reproductive success. Basic water quality parameters that are measured for fisheries studies include; temperature, dissolved oxygen, pH, conductivity, visibility (secchi depth), turbidity, total suspended solids (TSS) and total dissolved solids (TDS).

3.53 Weight

Weight refers to the total body weight (wet weight) of fish. It is measured for live fish before they are released or for sacrificed fish immediately after they have been killed. Along with length, weight is one of the most basic parameters measured evaluate the key attributes of fish populations.

Weight should be measured **in grams (g)** using a properly calibrated dial scale or electronic scale, depending on fish size. Golder uses dial scales fitted with fork length troughs for measurements of intermediate and large fish. Two types of dial scale are used; small scales which are rated for 0-4 kg in weight are used for most fish species, large scales rated for 0-25 kg are used for large fish species. For forage fish species and fry life stages of large fish species, more sensitive digital electronic scales are used.

3.54 Weight-at-Age

Weight-at-age analysis is used to determine the average weight of fish in each age class in the population. This analysis can only be conducted for individuals for which age is known. For each age class (i.e 1 year old fish, 2 year old fish, etc.) calculate the range of weights, mean weight and the standard deviation of the mean. Plot this data graphically with age as the X-axis, showing the range, mean and standard deviation (error bars). Weight -at-age is usually plotted on the same graph as length-at-age data.

4. REFERENCES AND SUGGESTED READING

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5. DISCUSSION

All basic aspects of each fisheries sampling program should be clear before commencement of field work. The field supervisor and field crew should be appraised by the project manager of all study design details. This will include study objectives, delineation of the study area, sampling techniques, data requirements and budgeting. Conditions at the field site may require alteration of the study design. The field crew should act in coordination with the project manager regarding changes to sampling protocols.

APPENDIX I

MATURITY CODES AND DEFINITIONS

UNKNOWN (UN): This category is used when state-of-maturity cannot be determined. This will most often occur for fish which have only been examined externally, where no examination of the gonads has been conducted. It may also be used following internal examination of the gonads when the observer cannot definitely determine the maturity of the fish. The gonads have been examined but the observer is unsure which maturity category to use, or the conditions of the gonads do not appear to match any of the maturity categories. If this is the case, record a complete description of the gonads and, if possible, collect a sample for microscopic examination.

IMMATURE (IM): This category is for immature fish (fry or juvenile life stages); defined as fish which have never spawned before and will not spawn in the coming spawning season. The gonads will be undeveloped and will be small and largely transparent. They will be string-like organs situated on the dorsal surface of the body cavity (dorsal to other internal organs) and will lie close under the vertebral column. In very young or small fish, determination of sex from examination of the immature gonads may be difficult or impossible.

Male: The testes will typically be smooth in texture and yellow, pink or white in colour. In suckers and percids, immature male testes can be identified by the position of the testicular artery. The artery is usually totally or partially imbedded in the organ.

Female: The ovaries will typically have a granular texture and will be yellow or pink in colour. In suckers and percids, immature female ovaries can be identified by the position of the ovarian artery. The artery is usually completely outside the organ, resting on top of the surface tissue and attached with connective tissue.

MATURING (MA): A maturing fish is a fish which has not spawned before but will spawn in the coming spawning season. This category refers to a fish whose gonads are developing for the first time. Fish in the maturing category are, for the first time, considered adult fish as they are hormonally similar to sexually mature individuals. Since the gonads are developing for the first time, development may not be complete at the time the fish is examined. The gonads may be developed (enlarged and showing sperm or egg development) primarily at the anterior end. The posterior end of the gonad may still be undeveloped and appear thinner (similar to an immature gonad). This category can be difficult to interpret in the field, being difficult to tell from the *Green* category, and examination of the gonads by microscope may be required. In general, the gonads of a maturing fish will be smaller than those for a *Green* fish.

Male: In the field, maturing testes will be smaller and paler than those of fully developed males but considerably larger than immature testes. If unsure, take a sample for histological analysis and designate the fish as *Green* (GN).

Female: In the field, maturing ovaries will be smaller and paler than those of fully developed females but considerably larger than immature ovaries. If unsure, take a sample for histological analysis and designate the fish as *Green* (GN).

SEASONAL DEVELOPMENT (SD): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons and will spawn in the coming spawning season. The gonads are undergoing their seasonal development following the last spawning season. This is the longest of the sexually mature stages as it extends from just after the post-spawning period until the next pre-spawning period, as the fish utilizes its resources to produce new gametes. For spring spawning fish (e.g. walleye, northern pike, longnose sucker, rainbow trout, etc.), this category would last from late May to early April of the next year. For fall spawning fish (e.g. lake whitefish, mountain whitefish, bull trout, brook trout, etc.) this category would last from the end of the fall spawning season one year (September to November) through to the fall of the next year. However, for most fish, gonadal development occurs primarily during the growing season with only limited gonadal development during the winter months.

Male: The testes will vary greatly in size and colour within this category depending on the time of year the fish is examined. Early in development (i.e. after the post-spawning period), the testes will be small and yellow to light orange in colour. By early fall (i.e. after the primary gonad development period in the summer), they will have grown to nearly mature size and be white in colour. At this point, the testes will be large and distinct. Note: Suckers have a black coloured testicular membrane which may mask the white colour of the testes.

Female: The ovaries will vary greatly in size and colour within this category depending on the time of year they are sampled. Early in development (i.e. after the post-spawning period), the ovaries will be small and yellow to light orange in colour. Developing oocytes will be small and dark orange in colour and will give the ovary a granular appearance. By early fall (i.e. after the primary gonad development period in the summer), the ovaries will have grown considerably to nearly mature size and be bright yellow to orange in colour. The individual eggs will be readily apparent.

PRE-SPAWNING (PR): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons and will spawn in the coming spawning season. The *Pre-spawning* category follows right after the *Seasonal Development* category, with respect to both time and stage of gonadal development, and occurs when the gonads have completed their seasonal development prior to the spawning season. This is a short term condition which extends from time the gonads are fully developed until the start of spawning activity.

Male: Externally the abdomen will be slightly distended. Semen can sometimes be extruded with pressure to the abdomen. If this is the case, small amounts of loose semen will be extruded followed by more viscous semen if pressure is re-applied. Internally, the testes will be large and white and will fill much of the body cavity. Pre-spawning condition can also be inferred by the capture location of the male. Males will usually only enter spawning condition once they are on the spawning grounds and around mature females. Thus a male caught away from the spawning grounds as the spawning season approaches is most likely still in pre-spawning condition, even if some sexual products can be extruded. Note: Semen can be extruded from sexually mature males as early as February in spring spawning species.

Female: Externally the abdomen will be noticeably distended. Sometimes a few eggs can be extruded with strong pressure to the abdomen. Care must be taken when applying pressure as the eggs are difficult to extrude and injury to the female can occur. The abdomen will feel tight and hard. Internally, the ovaries will be large and bright yellow to bright orange in colour. The size can be up to 25% of the total body weight and the gonads will fill much of the body cavity. Individual eggs will be large, round and obvious, some eggs will be translucent. Pre-spawning condition can also be inferred by capture location. Females will usually only enter spawning condition once they are on the spawning grounds and around mature males. Thus a female caught away from the spawning grounds as the spawning season approaches is most likely still in pre-spawning condition, even if some sexual products can be extruded.

RIPE (RP): Fish in this category are sexually mature adults. *Ripe* is the term for the spawning condition. The *Ripe* category follows right after the *Pre-spawning* category, with respect to both time and stage of gonadal development, and occurs when the gametes (semen and eggs) have become loose in the gonads. This is a short term condition which extends from start to the end of spawning activity. Externally the fish will appear as they do during the *Pre-spawning* stage but extrusion of the gametes will occur in response to slight pressure on the abdomen.

Male: Externally the abdomen will be slightly distended. Semen can be extruded with light pressure to the abdomen. Large amounts of loose semen will be produced if pressure is applied. Internally, the testes will be large and white.

Female: Externally the abdomen will be greatly distended. Eggs immersed in ovarian fluid can be extruded with light pressure to the abdomen. Large amounts of loose eggs will be produced if pressure is applied. Internally, the ovaries will be large and yellow or orange. The eggs will be large and translucent and some will appear to be loose as the ovarian tissue is weak (i.e. the ovarian sac will be transparent and thin). Eggs will be loose inside the sac and they will be immersed in clear ovarian fluid.

SPENT (SP): Fish in this category are sexually mature adults. *Spent* is the term for the post-spawning condition. The *Spent* category follows right after the *Ripe* category, with respect to both time and stage of gonadal development, and occurs following spawning activity when the gametes (semen and eggs) have been largely extruded during spawning. This length of time a fish will spend in this category depends on how long it takes for the fish to begin the next cycle of seasonal gonadal development, at which time the fish will again be classified as *Green*.

Male: Externally, the abdomen will be slightly flaccid, especially ventrally. Some semen can still be extruded with pressure to the abdomen but it will most likely be watery (i.e. not as intense a white colour as in spawning males). Internally, the testes will be reduced in size and gray to creamy-white in colour. Hemorrhaging and distended blood vessels on the surface of the organ are common. Post-spawning males are known to stay on the spawning grounds for some time (up to 2 weeks) so capture location is not always a reliable indication of whether the fish has finished spawning.

Female: Externally, the abdomen will be noticeably flaccid, especially ventrally. The surface of the abdomen may be red or roughened with abrasions and the urogenital opening may be extended or swollen. Some eggs can still be extruded with pressure but will be few in number and they will be associated with watery ovarian fluid. Internally, the ovaries will be greatly reduced in size and dark orange to brown in colour. Hemorrhaging and distended blood vessels on the surface of the organ as

well as within it are very common and normal. Some residual eggs (from a few up to 25% of the ovary volume) are common. It is not common for post-spawning females to stay on the spawning grounds, most spawn and leave the area immediately. However, capture location is not always reliable indicator.

REABSORBING (RB): Fish in this category are sexually mature fish which have developed to some extent for the coming spawning season but, instead of completing gonadal development or instead of spawning after completing gonadal development, these fish are reabsorbing materials from the gonads back into the body. This category represents arrested gonadal development or interrupted spawning activity. There are several reasons why a fish may terminate gonadal development or decide not to spawn after completing gonadal development. These include the condition of the fish with respect to nutrition and/or health, aspects of population dynamics or environmental cues such as improper water temperatures, poor water quality conditions or adverse water level conditions. Interrupted gonadal development can occur at any stage of development and prior to entering the reabsorbing category the fish may have been *Maturing*, undergoing *Seasonal Development* or in *Pre-spawning* condition.

Male: This condition is *extremely rare in males* and difficult to observe as reabsorption of the semen by the testes is usually a rapid process. Very rarely will a case be observed of a male actually retaining the entire contents of the testes for re-absorption. Should you suspect this condition the testes should be preserved and stage verified by a qualified biologist.

Female: This condition is primarily observed in females. Reabsorption of the eggs by the ovary is usually a lengthy process which can take up to a full year. Some females may retaining the entire contents of the ovaries for re-absorption. Identification of this stage is not always easy. Externally, the female will still have a distended abdomen if caught within a few months of the spawning season. The abdomen will feel unusually hard as compared to normally developing females. Later in the season, it will be impossible to distinguish a normally developing female from a reabsorbing one without an internal examination. Internally, reabsorbing ovaries go through a series of distinct stages. Early in the reabsorption process, the ovary is dark orange to brown in colour. The eggs are dark and flaccid. Heavy amounts of watery ovarian fluid collect at the posterior of the ovary. This fluid most often is ejected readily if the fish is handled. Later, the ovary becomes smaller and hard. The colour becomes darker and the eggs become atritic. Atritic eggs are easily identified as they are small, hard and white. Ovaries in the later stages of eggs reabsorption have few new oocytes. The remnants of the old eggs collect in the middle of the organ. New oocytes production is restricted to the periphery of the ovary. Should you suspect this condition the ovaries should be preserved and stage verified by a qualified biologist. Occasionally, females have been observed which aborted spawning activity after they had became *Ripe*. Functionally speaking, eggs at this stage are no longer connected to the ovaries and cannot be reabsorbed. Instead they remain in the body cavity. Internal examination of a fish in this condition will show the newly developed gonad as well as residual (brown, desiccated) eggs which could not be reabsorbed in the posterior portion of the body cavity.

RESTING (RS): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons but will not spawn in the coming spawning season. These fish are different from *Reabsorbing* fish in that their gonads are either not developing or are developing too slowly to be ready for the upcoming spawning season. This is a common condition for fish which do not spawn every year (alternate year spawners).

Male: This condition is *extremely rare in males*. It can only be used as an alternative to the Green category. A few cases of males in the resting condition have been observed. They are most common in northern latitudes where the growing season is short or in ultra-oligotrophic lakes. Testes will appear flaccid and dirty-white to yellow in colour. They will be larger in size than the testes of immature fish. A good indication is the size of the testicular artery in relation to the organ. In immature fish this artery is very thin whereas in resting males the testicular artery is much larger because of prior testicular development. Should you suspect this condition the testes should be preserved and stage verified by a qualified biologist.

Female: This condition is primarily observed in females but is still relatively infrequent, affecting usually only 0.5 to 1% of the population. This stage can only be used as an alternative to the *Green* category. It is most common in northern latitudes where the growing season is short or in ultra-oligotrophic lakes. The ovaries will appear to have some oocytes but they will be few in number and arrested in their development. The colour of resting ovaries varies greatly with fish species but most often they are a light orange. They will be larger in size than the ovaries of immature fish. A good indication is the size of the ovarian artery in relation to the organ. In immature fish this artery is very thin whereas in resting females the ovarian artery is much larger because of prior egg development. Should you suspect this condition the ovaries should be preserved and stage verified by a qualified biologist.

APPENDIX VI

WATERCOURSE HABITAT MAPPING SYSTEM (TP 8.5-1)

1. PURPOSE

This technical procedure details the classification system and map coding system to be used for habitat mapping a watercourse and provides instructions on habitat mapping procedures and standards. The habitat mapping system consists of two components: 1) The **Large River Habitat Classification System** - a general system for mapping large mainstem rivers; and, 2) The **Stream Habitat Classification and Rating System** - a more detailed system for mapping discrete channels units which is primarily used for intermediate rivers and smaller streams.

2. APPLICABILITY

This technical procedure is applicable to all personnel involved in habitat mapping of all sizes of watercourses in Alberta. The technique was developed primarily in Alberta in consultation with Alberta Fish and Wildlife. With respect to describing aquatic habitats it is applicable to some areas outside of Alberta but may be superseded by local criteria (e.g., B.C. MOE guidelines). This procedure may not be applicable to low gradient streams in the plains areas east of Alberta without some modification. Portions of the stream classification system were developed in relation to salmonid species and would require interpretation in order to be suitable for evaluating habitat conditions for other fish species.

3. DEFINITIONS

Each of the habitat mapping system components includes a set of habitat types or categories, the definitions of which are included in the two different classification systems in Tables 1 and 2. Some more general definitions are presented here.

3.1 Bank

Banks are components of a watercourse. Banks comprise the borders of the stream channel and form the typical boundaries of the channel. The banks are only in contact with the water during high flow or flood events. They typically have rooted vegetation to distinguish them from the normally active channel. Certain bank features can influence the quality of instream fish habitat, particularly with respect to cover for fish.

3.2 Bank Stability

The stability or erodability of the banks is based on factors such as bank slope, bank material, evidence of seepages, undercutting, erosion and slumping. Unstable banks are banks which shed material (bank material or vegetation) into the watercourse. The input of fine sediments into rivers and streams can result in detrimental sedimentation of instream habitats. Alternatively, vegetation and other bank materials which fall in the channel may be beneficial by providing cover for fish or may be detrimental by causing blockages.

3.3 Channel

The channel is the main component of a watercourse. It is the area of the watercourse that typically has flowing water, on at least a seasonal basis, and is usually defined by the area of the stream substrate. The channel is distinguishable from the banks since it has contact with flowing water for at least a portion of each season which usually prevents establishment of permanent vegetation.

3.4 Channel Form

Channel form refers to the cross-sectional shape of the channel as defined by the width:depth ratio of the channel. Channel form will range from deeply incised (low width:depth) to broad (high width:depth).

3.5 Channel Unit (sometimes referred to as habitat type)

Channel units are the hydraulic and morphological features of a stream channel. A channel unit is a section of channel which is homogeneous with respect to water depth, velocity and cover and is separated from other channel units by gradients in these parameters. Channel units are sometimes referred to as habitat types. The most common channel units are **pool**, **riffle** and **run**, although a total of 12 channel units have been defined (Table 2).

The pressure or absence of channel units in a watercourse is the determining factor when choosing which component of the habitat mapping system to employ when working on large rivers. If a river does not show any channel unit differentiation, the *Large River Habitat Classification System* is used. If channel units are present, then the *Stream Habitat Classification and Rating System* is used.

3.6 Channel Width

The horizontal distance along a transect line from stream bank to stream bank (rooted vegetation to rooted vegetation) at the normal high water marks measured at right angles to the direction of flow.

3.7 Cover

Cover is defined as aspects of the physical environment which provide resting places or protection from predators for fish. Cover consists of two categories: 1) **Instream Cover** - any feature which provides a velocity shelter (e.g., large substrate particles, submerged debris, etc.); 2) **Overhead Cover** - any feature which provides visual isolation for the fish (e.g., overhanging vegetation, undercut bank, turbulence, water depth, etc.).

When habitat mapping a watercourse, available cover for fish is evaluated for each section of the channel as it is assigned a classification. For the *Large River Habitat Classification System*, near-shore cover is a part of assigning shoreline habitat types. For the *Stream Habitat Classification and Rating System*, cover is evaluated when assigning a channel unit rating for pool and run channel units.

Cover is assessed by the visual examination and estimation of the quality and quantity of the available features with respect to instream and overhead cover for different fish life stages. Smaller life stages such as fry require smaller cover compared to adult fish. Areas of high quality cover would provide cover for a number of individuals of all life stages. Areas of moderate cover would provide little or no cover for adults but some cover for juveniles and fry. Areas of poor cover would not provide cover for adults and only limited cover for juveniles and fry.

3.8 Discharge

A measurement of the volume of surface water flowing in the stream channel, measured as the volume flowing past a specific point over a given time (i.e., m^3/s). Stream discharge has significant effect on water level and depth in the various habitat types. In order to reduce the effects of variable discharge levels on habitat mapping, it is recommended that habitat mapping be conducted during the late summer low flow period.

3.9 Habitat Associations

Habitat associations are the relationships between habitat categories and fish presence, abundance and use. If the habitat mapping activities are conducted in conjunction with fisheries inventory sampling, the species, numbers and life stages of fish captured should be assessed by habitat type. That is, for each habitat type (either shoreline habitat type or channel unit type and class) the types of fish captured should be recorded. This not done for each individual habitat area but for each general type (e.g., fish captured in all Class 1 Pool channel units, versus Class 2 Pools or each class of run habitat or in riffle channel units).

3.10 Habitat Map

A habitat map is a map of a section of watercourse showing the location and extent (i.e., boundaries) of each habitat type. What constitutes a habitat type depends on which of the two mapping systems is employed. With the *Large River Habitat Classification System*, habitat types are the bank habitat features as described in Table 1. With the *Stream Habitat Classification and Rating System*, the habitat types are the channel units described in Table 2.

3.11 Stream Confinement

Stream confinement refers to the confinement of the watercourse within the boundaries of the floodplain. It is the degree to which the lateral movement of the stream channel is limited by terraces or valley walls.

3.12 Stream Habitat

The physical stream environment which provides a place for aquatic biota (fish, invertebrates, plants, etc.) to live, grow and reproduce. Several types of fish habitat should be considered when habitat mapping and include **spawning habitat, fry nursery habitat, juvenile rearing habitat, adult feeding habitat** and **overwintering habitat.**

3.13 Stream Gradient

The slope of the streambed over which the stream runs. Some channel characteristics are directly related to the gradient. Examples include average velocity, substrate coarseness, and presence and extent of various channel units. Gradient classification: low <2%; medium 2-5%; high >5%.

3.14 Stream Pattern

Channel pattern describes the sinuosity of the channel or the degree to which the channel deviates from straightness. Sinuosity is the channels meander pattern which can range from straight to tortuously meandering.

3.15 Substrate

Stream substrate is the material found on the bottom of the channel portion of the watercourse. It refers to the surficial deposits that can be seen when viewing the streambed. As part of the habitat evaluation process, the substrate is evaluated with respect to particle size composition. Particle size composition refers to the proportions of the substrate particles within each category from a series of size categories. The size categories employed are presented on Table 4. These range from fine sediments (fines are particles <2 mm in size and include clay, silt and sand) through gravels, cobbles, boulders and bedrock. A substrate evaluation is conducted by visual observation. The observer estimates the percentage of the substrate particles, by surface area, in each of the size categories.

3.16 Undercut Bank

An undercut bank has been eroded at the base by flowing water, allowing water to be present underneath a portion of the bank. Although undercutting usually adds to bank instability, it may also provide cover for fish. If the overhanging portion of the bank provides and effective with >9 cm over water with a depth of >0.15 m, it provides a cover feature.

3.17 Watercourse

A natural or artificial waterway which periodically or continuously contains moving water. It has a definite channel, banks which normally confine water and displays evidence of fluvial processes.

3.18 Wetted Width

The width of the water surface measured at right angles to the direction of flow. Multiple channel widths are summed to obtain total wetted width.

4. REFERENCES AND SUGGESTED READING

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5. DISCUSSION

The habitat mapping and classification system is used to provide an ecologically relevant inventory of stream habitats within a designated study area. The mapping procedure is meant to describe the habitats available within the stream and to detail the location and extent of each habitat type/class. The habitat classification system is intended to be ecologically meaningful with respect to describing and cataloguing physical habitats in relation to the requirements of fish species and their various life stages (spawning, incubation, nursery, rearing, summer feeding, holding, overwintering, migration); and also to a lesser extent the relationship between physical habitat and benthic invertebrate productivity, at least with respect to fish food production. Researchers have determined that fish distinguish between the habitat types and sub-classes of habitat types that have been used to map streams. It is intended that this classification system will provide an ecological association of habitat characteristics and fish use/abundance.

Streams are habitat mapped to provide an inventory of the available habitats and to show the locations of habitats that are of importance to fish such as migration routes, spawning habitats and rearing habitats. Habitat maps are used in several applications. A habitat map can be used to show the habitat types that may be impacted by a proposed point disturbance such as a pipeline crossing or bridge construction. A habitat map of a length of stream can also be used to evaluate alternate locations of disturbances in order to minimize the impacts. Habitat maps may be applied to document changes to a stream environment over time, from disturbances or due to habitat rehabilitation or improvement programs. A primary use of the habitat mapping procedure is to provide an inventory of the habitats present in a stream that is subject to a proposed impact in order to ensure compliance with the Federal Regulations stating that "No Net Loss" of productive fish habitat is to occur as a result of a proposed disturbance or alteration of the stream.

The habitat mapping and classification system is composed of two components. The first is a general system called the **"Large River Habitat Classification System"** which is used to map large mainstem rivers such as the Peace or Athabasca rivers where habitat heterogeneity is less than for smaller streams, and use of a more detailed system is not appropriate. The second component is a the more detailed **"Stream Habitat Classification and Rating System"**, which is used for watercourses with a greater degree of channel complexity and which display different types of channel units. Whether the Large River Habitat Classification System (Table 1) is used or the Stream Habitat Classification and Rating System (Table 2) is used will depend on the size of the watercourse and the types of available habitats.

5.1 How to Draw a Habitat Map

It is best to have a **base map** prepared on which to record the habitat map. This is much preferred to drawing a free-hand schematic diagram of the watercourse while in the field. Base maps must usually be prepared in the office before heading out for the field. Air photos provide a good template to prepare basemaps. Air photos can be borrowed from the University Photo Library and photocopied to avoid having to purchase the photos. Topographical maps may also be used to prepare a base map but usually need to be enlarged on a photocopier to provide a map. For small streams which appear on the map as only a single line, it is still best to make an enlargement and then to draw in a second line parallel to the line on the map, approximating the channel. Base maps should be sufficiently large to allow for sufficient detail to be recorded.

Once a map or air photo has been obtained and the enlargement has been made, the watercourse can be traced onto a mylar overlay then traced onto waterproof paper to provide a base map for use in the field. Do not photocopy the mylar tracing onto waterproof paper as you will not be able to erase the lines. You may need to do to redraw portions of the channel if changes have occurred since the photo or map was made. It may be possible to reduce the number of steps here if you can use a light table to trace the map or photo directly to waterproof paper. While producing the base map, be sure to record the scale of the map, particularly if the original map was enlarged to make the base map. If the map used to produce the base map has a scale drawn on it, enlarge this scale along with the map to provide the scale for the base map.

Base maps are very important to provide an accurate representation of the watercourse, to aid in drawing in the boundaries between habitat types, the location of each habitat type and the area and length of each habitat type. This type of accuracy is very difficult with free-hand drawings made onto blank paper. If base maps are not available and this type of accuracy is required, a tape measure or hip chain can be used to measure the lengths for each habitat type. This will help ensure the free-hand drawing is accurate and to scale. Simple free-hand schematic drawings are acceptable if this type of accuracy is not required of a large number of streams are to be mapped making the preparation of a base map for each stream impractical.

The habitat map is produced by **delineating on the base map the location and extent of each of the habitat features**. To do this, the channel is divided into a continuous series of habitat types by drawing on the base map the boundaries of each habitat type and attaching a label to identify the habitat type. The habitat types to be drawn on the map depend on which of the two habitat mapping systems is being employed. For the *Large River Habitat Classification System*, bank habitat types are delineated. For the *Stream Habitat Classification and Rating System*, channel units are delineated. The habitat types to be included, the definitions of these features, and the abbreviations (map symbols) used to label each feature

on the habitat map are detailed in Tables 1 and 2. It is important to draw on the map the boundary of each habitat type so that the length of each habitat type can be measured during the data analysis and interpretation process.

Also to be recorded during on the habitat map are the following: **Project Number/Title**, **Watercourse Name** or some type of identifier if the stream is unnamed, **Location** of the stream or section of stream being mapped, **Date**, and **Personnel (Crew)**. If more than one page is required to complete the habitat map for a given watercourse, record the **page number** on each page (i.e. Page 1 of 2, Page 2 of 2, etc.). If possible, the discharge or relative water level at the time of mapping should be recorded since the water level greatly affects the depths, and potentially the classification of the habitat types. For this reason, **it is preferable to conduct all habitat mapping procedures under late summer base flow conditions**.

Other information to be recorded on the habitat map in order to standardize the maps between projects and observers. The map must show a **North arrow**, an arrow showing the **direction of flow** in the channel, a **scale** or the words 'schematic diagram-not to scale, and a **legend** explaining the abbreviations and symbols used on the map. Before turning the map into drafting for preparation for inclusion in a report, add a **Figure Name** and **Number**.

In addition to habitat types, qualitative descriptions of substrate conditions can be recorded on to the habitat maps the general substrate conditions. Typically, this process would be applied during use of the *Stream Habitat Classification and Rating System* to describe the substrate conditions for specific areas, such as potential spawning habitats, or to describe the substrate type within each individual channel unit. Substrate composition is presented as the percent occurrence (visual estimation) of each substrate size category. Substrate particle sizes are presented on Table 4.

5.2 Large River Habitat Classification System

This is a general system based on gross morphology and habitat types along the river banks and shoreline. It consists of two primary components: 1) "major habitat type", which defines the type of channel present; and, 2) "bank habitat type", which details the structure of the bank and near shore habitats. "Special habitat features" considered significant to fish distribution/use in these large rivers are also to be included on the map. Table 1 presents the details of the large river habitat classification system.

The Large River Habitat Classification System is to be used on large rivers which do not show any differentiation of channel units; distinct pool, riffle and run habitats are absent. In most large rivers, such as the Peace or Athabasca Rivers, the lower segments of the river are wide with relatively low gradients and large flow volumes. Channels do not contain physical or hydraulic features which create riffle/pool sequences. There is little or no differentiation of habitat types in the channel. It should be realized, however, that at any given point, depths across the width of the channel may vary. Habitat features that fish might use are generally associated with shoreline areas, areas of instream islands and tributary confluences. These features should be identified on the habitat map.

Shoreline habitats change as the structure of the banks change, providing one of the few characteristics that can be mapped. Elements of the bank structure which affect fish habitat include: water depth along

the shoreline, substrate type and cover features to substrate, fallen debris/vegetation, and protrusions from the bank which create low velocity related habitats. Therefore, bank features are the basis of the Large River Habitat Classification System.

To draw a habitat map using the large river system, begin by **dividing the length of the watercourse in the study area into *Major Habitat Types***, depending on the number of permanent/vegetated islands present. This can often be done from the base map or air photo which will normally show all permanent islands. Any islands not on the original base map should be drawn onto the habitat map. Next, the **shorelines should be divided into *Bank Habitat Types*** according to the criteria in Table 1. This should be done for both shorelines as well as the shorelines around all permanent islands. Remember to show the boundaries of each Bank Habitat Type. This is usually done by demarcating the boundaries with a short line drawn at the shoreline, perpendicular to the shoreline, and labeling the area inside the boundaries with the appropriate Bank Habitat Type (e.g. A1, E5, etc.). Bank Habitat Types should be a continuous series along the shorelines without any blank, unlabelled sections. For any tributaries which enter the river within the study area, examine the tributary mouth and **label the tributary confluence according to the categories in Table 1.** To complete the map, **draw in the location and extent, again showing the boundaries, of all *Special Habitat Features***, as defined in Table 1.

5.3 Stream Habitat Classification and Rating System

This is a detailed mapping system based on individual channel units. These units are defined as sections of stream of homogenous with respect to depth, velocity and cover. The extent of each channel unit should be delineated on the map, as should the class rating for each unit (where appropriate). Some of the channel units also have modifiers (types) which should also be recorded. Table 2 presents the details of the stream habitat classification and rating system. This system is employed for mapping all watercourses which have distinct channel units such as pool, riffle and run habitats.

To draw a habitat map using the stream mapping system, the **length of stream in the study area is divided into a continuous series of channel units.** Table 2 presents the definitions for each of the 12 types of channel unit. Lines drawn across the channel are used to delineate the location and extent of each channel unit. The appropriate channel unit symbol (abbreviation) is used to label the channel unit. In addition to the channel unit type, three types of channel units have different sub-classes. **Run, pool and impoundment channel unit types should be further divided into Class 1, Class 2 or Class 3, depending on water depth and available cover for fish**, as described in Table 2. The classification should be included in the label on the habitat map (e.g. a riffle would simply be labeled RF on the map but a pool would be labeled as P1, P2 or P3, depending on the Class). Make sure the entire length of the channel in the study area has been divided into channel units on the map, including boundary lines, and that each unit has a complete label. In order to better define the available habitats in the study area, **record the maximum water depth in each channel unit and include it in the channel unit label** (e.g. a Class 1 pool that has a maximum depth of 4.0m should be labeled P1-4.0m).

Dividing the run, pool and impoundment units into subclasses is based on water depth and the quality of available cover for fish. Some general water depth guidelines are included in Table 2 to assist in classifying these channel units. However, these depths are not the only criteria. The classification of each channel unit is also based on its potential use by different life stages of fish (Table 1). For example, if a run channel unit is slightly shallower than the minimum depth for a Class 1 (Table 3), but high quality cover for adult fish is present, it would be classified as Class 1. Conversely, a run channel unit

that is deeper than the minimum depth for a Class 1 run but with very poor cover would be classified as a Class 2 run.

The use of the channel unit and class categories are meant to relate instream habitats to the potential utilization by fish species and life stages. Much of the criteria used to establish the classifications are based on the habitat requirements of salmonid species. In Alberta, this includes non-anadromous trout and whitefish. Table 5 provides the fish utilization expected for each of the habitat types. The overall goal of the Stream Habitat Classification and Rating System is to provide habitat classifications that relate to fish utilization. Therefore, the associations within Table 5 should be kept in mind when assigning classifications.

TABLE 5

CHANNEL UNIT CLASSIFICATION AND HABITAT ASSOCIATIONS FOR SALMONIDS

Spawning		Nursery/Rearing	Adult Feeding	Overwintering
Trout (gravel sub.)	Whitefish (cobble sub.)			
RF	R2	RF	R1	P1
RF/BG	R2/BG	RF/BG	R2	R1
R3	RF	R1	R2/BG	R2
R3/BG		R2	P1	R2/BG
		R2/BG		
		R3/BG		

From Table 5 it can be seen that the potential utilization of some channel units, particularly those suitable for spawning, depends on substrate particle size. Therefore, a quick assessment of substrate size should be made for each channel unit. **For each channel unit record the dominant and co-dominant substrate size classes** and include this information with the channel unit label. For some projects, substrate particle sizes should be recorded in full detail as presented on Table 4. However, for most projects general substrate sizes could be used such as fines, gravel, cobble and boulder, without further dividing the substrate particles. For example, a Class 2 run channel unit with a maximum depth of 0.8 m and a cobble dominant and gravel co-dominant substrate would be labeled *R2-0.8m, cobble/gravel.*

Table 3 presents additional habitat features along with their symbols and abbreviations. These features include structures that would occur at specific points rather than for sections of the channel such as beaver dams or ledges. Other relevant features in Table 4 include aspects of cover such as areas of undercut or unstable banks, overhanging vegetation, inundated vegetation, debris piles or root wads. **Draw the appropriate symbol on the map to show the location of these features.**

5.4 Habitat Map Interpretation

Once the habitat map is completed, it is analyzed to determine the relative proportion of each habitat type in the study area. Measure the overall length of watercourse in the study area (i.e. section of watercourse habitat mapped) and the length of each habitat type; either bank habitat type (if using the large river system) or channel unit type (stream system). Sum the lengths of stream in each habitat type and calculate the percent composition, by length, of each habitat type for the study area as a whole. For the large river mapping system, the results will be presented as the percent composition of each bank type: e.g. 60% E5, 30% A1, and 10% D1. For the stream mapping system, the results are presented for each type and class of channel unit; e.g. 40% RF, 5% R1, 10% R2, 20% R3, 5% P1, 15% P2 and 5% P3.

If a coincidental fisheries inventory was conducted during the classification of fish habitat associations, observed fish use for each habitat type along with the proportion of each type should be included for a more accurate assessment of fish use in the study area. Otherwise, Table 5 can be compared to the habitat composition of the stream to evaluate the potential fish use in the study area.

TABLE 1: LARGE RIVER HABITAT CLASSIFICATION SYSTEM

MAJOR HABITAT TYPES

Type	Symbol	Description
Unobstructed channel	U	single main channel, no permanent islands, side bars occasionally present, limited development of exposed mid-channel bars at low flow
Singular island	S	two channels around single, permanent island, side and mid-channel bars often present at low flow
Multiple island	M	more than two channels and permanent islands, generally extensive side and mid-channel bars at low flow

BANK HABITAT TYPES

Type	Symbol	Description
Armoured/Stable	A1	largely stable and at repose; cobble/s.boulder/gravel predominant; uniform shoreline configuration; bank velocities low-moderate; instream/overhead cover limited to substrate and turbidity
	A2	cobble/s.-l.boulder predominant; irregular shoreline due to cob/boulder outcrops producing BW habitats; bank velocity low (BW)-mod; instream/overhead cover from depth, substrate and turbidity
	A3	similar to A2 with more l.boulder/bedrock; very irregular shoreline; bank velocities mod-high with low velocity BW/eddy pools providing instream cover; overhead cover from depth/turbidity
	A4	artificial rip-rap substrates consisting of angular boulder sized fill; often associated with high velocity areas; shoreline usually regular; instream cover from substrate; overhead cover from depth/turbulence
Canyon	C1	banks formed by valley walls; l.cobble/boulder bedrock; stable at bank-water interface; typically deep/high velocity water offshore; abundant velocity cover from substrate/bank irregularities
	C2	steep, stable bedrock banks; regular shoreline; mod-deep/mod-fast water offshore; occasional velocity cover from bedrock fractures
	C3	banks formed by valley walls, primarily fines with some gravel/cobble at base; moderately eroded at bank-water interface; mod-high velocities; no instream cover
Depositional	D1	low relief, gently sloping bank; shallow/slow offshore; primarily fines; instream cover absent or consisting of shallow depressions or embedded cobble/boulder; generally associated with bars
	D2	similar to D1 with gravel/cobble substrate; some areas of higher velocities producing riffles; instream/overhead cover provided by substrate/turbulence; often associated with bars/shoals
	D3	similar to D2 with coarser substrates (cobble/boulder); boulders often imbedded; mod-high velocities offshore; instream cover abundant from substrate; overhead cover from turbulence
Erosional	E1	high, steep eroded banks with terraced profile; unstable; fines; mod-high offshore velocity; deep immediately offshore; instream/overhead cover from submerged bank materials/vegetation/depth
	E2	similar to E1 without the large amount of instream vegetative debris; offshore depths shallower
	E3	high, steep eroding banks; loose till deposits (gravel/cobble/sand); mod-high velocities and depths; instream cover limited to substrate roughness; overhead cover provided by turbidity
	E4	steep, eroding/slumping highwall bank; primarily fines; mod-high depths/velocities; instream cover limited to occasional BW formed by bank irregularities; overhead cover from depth/turbidity
	E5	low, steep banks, often terraced; fines; low velocity; shallow-moderate; no instream cover; overhead cover from turbidity
	E6	low slumping/eroding bank; substrate either cobble/gravel or silt with cobble/gravel patches; moderate depths; mod- high velocities; instream cover from abundant debris/boulder; overhead cover from depth/turbidity/overhanging vegetation

SPECIAL HABITAT FEATURES

Type	Symbol	Description
Tributary confluences	TC	confluence area of tributary entering mainstem
[sub-classified according	TC1	intermittent flow, ephemeral stream
to tributary flow and	TC2	flowing, width <5m
wetted width at mouth at	TC3	flowing, width 5-15m
the time of the survey]	TC4	flowing, width 16-30m
	TC5	flowing, width 31-60m
	TC6	flowing, width >60m
Shoal	SH	shallow (<1m deep), submerged areas in mid-channel or associated with depositional areas around islands/side bars
	SHC	submerged area of coarse substrates
	SHF	submerged area of fine substrates
Backwater	BW	discrete, localized area exhibiting reverse flow direction and, generally, lower velocity than main current; substrate similar to adjacent channel with more fines
Rapid	RA	area with turbulent flow, broken surface (standing waves, chutes etc.), high velocity (>1 m/s), armoured substrate (large boulder/bedrock) with low fines
Snye	SN	discrete section of non-flowing water connected to a flowing channel only at its downstream end, generally formed in a side channel or behind a peninsula (bar)
Slough	SL	non-flowing water body isolated from flowing waters except during flood events; oxbows
Log Jam	LJ	accumulation of woody debris; generally located on island tips, heads of sidechannels, stream meanders; provide excellent instream cover

TABLE 2: STREAM HABITAT CLASSIFICATION AND RATING SYSTEM

(Adapted from R.L.&L. 1992 & Hawkins et. al 1993)

Channel Unit	Type	Class	Map Symbol	Description
Falls			FA	Highest water velocity; involves water falling over a vertical drop; impassable to fish
Cascade			CA	Extremely high gradient and velocity; extremely turbulent with entire water surface broken; may have short vertical sections, but overall is passable to fish; armoured substrate; may be assoc. with chute (RA/CH)
Chute			CH	Area of channel constriction, usually due to bedrock intrusions; associated with channel deepening and increased velocity
Rapids			RA	Extremely high velocity; deeper than riffle; substrate extremely coarse (l.cobble/boulder);instream cover in pocket eddies and associated with substrate
Riffle			RF	High velocity/gradientrelative to run habitat; surface broken due to submerged or exposed bed material; shallow relative to other channel units; coarse substrate; usually limited instream or overhead cover for juvenile or adult fish (generally ≤0.5m deep)
Run (glide)			R	Moderate to high velocity; surface largely unbroken; usually deeper than RF; substrate size dependent on hydraulics
	Depth/Velocity Type			Run habitat can be differentiated into one of 4 types: deep/slow, deep/fast shallow/slow, or shallow/fast
		Class 1	R1	Highest quality/deepestrun habitat; generally deep/slow type; coarse substrate; high instream cover from substrate and/or depth (generally >1.0 m deep)
		Class 2	R2	Moderate quality/depth; high-mod instream cover except at low flow; generally deep/fast or moderately deep/slow type (generally 0.75-1.0m deep)
		Class 3	R3	Lowest quality/depth; generally shallow/slow or shallow/fast type; low instream cover in all but high flows (generally 0.5-0.75m deep)
Flat			FL	Area characterized by low velocity and near-laminar flow; differentiated from pool habitat by high channel uniformity; more depositional than R3 habitat
Pool			P	Discrete portion of channel featuring increased depth and reduced velocity relative to riffle/run habitats; formed by channel scour
		Class 1	P1	Highest quality pool habitat based on size and depth; high instream cover due to instream features and depth; suitable holding water for adults and for overwintering (generally >1.5m deep)
		Class 2	P2	Moderate quality; shallower than P1 with high-mod instream cover except during low flow conditions, not suitable for overwintering
		Class 3	P3	Low quality pool habitat; shallow and/or small; low instream cover at all but high flow events
Impoundment		Class 1-3	IP (1-3)	Includes pools which are formed behind dams; tend to accumulate sediment/organic debris more than scour pools; may have cover associated with damming structure; identify as Class 1, 2 or 3 as for scour pools
	Dam Type			Three types of impoundments have been identified based on dam type; debris, beaver and landslide
Backwater			BW	Discrete, localized area of variable size exhibiting reverse flow direction; generally produced by bank irregularities; velocities variable but generally lower than main flow; substrate similar to adjacent channel with higher percentage of fines
Snye			SN	Discrete section of non-flowing water connected to a flowing channel only at its downstream end; generally formed in a side-channel or behind a peninsula
Boulder Garden			BG	Significant occurrence of large boulders providing significant instream cover; always in association with an overall channel unit such as a riffle (RF/BG) or run (e.g. R1/BG)

TABLE 3

ADDITIONAL HABITAT MAPPING SYMBOLS

Feature	Abbr.	Symbol	Description
Ledge	LE		Area of bedrock intrusion into the channel; often associated with chute or plunge pool habitat, may have a vertical drop affecting fish passage
Overhead Cover	OHC		Area of extensive or high quality overhead cover
Instream Cover	ISC		Area of high quality instream cover (velocity shelter) for all life stages
Undercut Bank	UCB		Area of extensive/high quality undercut bank providing overhead cover
Unstable Bank	USB		Area of unstable bank with potential to collapse instream, affecting instream habitat or producing sedimentation
Overhanging Veg.	OHV		Area of high quality overhanging vegetation providing overhead cover and stream shading
Inundated Veg.	INV		Area of inundated vegetation; either submergent macrophytes or flooded terrestrial
Debris Pile	DP		Debris pile (e.g. log jam) which influences instream habitat; include effect on cover
Root Wad	RW		Fallen terrestrial vegetation large enough to provide cover for fish
Beaver Dam	BD	XX	Include effect on fish passage

Considerations

Overhead cover includes overhanging vegetation, undercut bank or debris which has an effective width >9 cm over water with a depth > 0.15 m.

Instream cover is provided by aquatic vegetation or by substrate particles as large or larger than small cobbles when associated with water depths >0.15 m.

Deep water may provide cover if depth is >0.5 m.

Vertical drops >0.8 m are potentially impassable for resident trout species.

Generally, suitable spawning sites for trout occur in pool tail-outs, riffles and the transition areas from runs to riffles where the dominant substrate sizes range from small gravel to small cobble, fines (particles <2 mm) comprise <30% of the substrate, minimum water depths exceed 0.15 m, and velocities range from 0.3 to 1.0 m/s. Individual patches of gravel must be 1-2 m^2 to be considered as spawning habitat.

TABLE 4

SUBSTRATE CRITERIA

SUBSTRATE DEFINITIONS, CODES AND SIZE-RANGE CATEGORIES

CLASS NAME	SIZE RANGE	
	MM	INCHES
Clay/Silt	<0.06	<0.0024
Sand	0.06-2.0	0.0024-0.08
Small Gravel	2-8	0.08-0.3
Medium Gravel	8-32	0.3-1.3
Large Gravel	32-64	1.3-2.5
Small Cobble	64-128	2.5-5
Large Cobble	128-256	5-10
Small Boulder	256-762	10-30
Large Boulder	>762	>30
Bedrock	-	-

APPENDIX VII

WATER AND SEDIMENT QUALITY DATA

Table VII-1 Water Quality of the Athabasca River Upstream from Fort McMurray (1976-1995)

Parameter	Units	Winter				Spring				Summer				Fall			
		median	min.	max.	n	median	min.	max.	n	median	min.	max.	n	median	min.	max.	n
Field Parameters																	
Temperature	°C	0.02	-0.4	1.5	31	11.9	0	18.3	10	18.5	14	26	31	7.7	-0.04	17	21
Dissolved Oxygen	mg/L	12.3	10.8	15.1	25	10.3	9.5	11.6	6	9.3	4.3	13	27	10.4	8.2	14.4	19
Conventional Parameters and Major Ions																	
pH	-	7.88	7.35	8.53	43	8.01	7.46	8.4	14	7.98	7.44	8.50	41	7.90	7.28	8.40	25
Conductivity	µS/cm	398	267	530	42	246	176	350	13	221	155	278	40	249	150	345	24
Colour	T.C.U.	20	<5	80	37	44	18.9	80	11	34	<5	76	25	33	5	190	17
Total Alkalinity	mg/L	169	127	231	43	102	80	125	14	98	78	118	43	110	64	158	26
Total Dissolved Solids	mg/L	243	183	355	34	159	51	496	14	144	102	398	37	158	109	214	23
Total Suspended Solids	mg/L	2.45	0.4	92.3	46	82	3	1090	15	126.5	11	1490	44	19.2	1	344	27
Total Hardness	mg/L	190	142	271	30	114	90	134	7	105	85	126	24	124	93	162	14
Calcium	mg/L	50	39	74	42	32	26	37	13	30	23	40	43	33	19	42	25
Magnesium	mg/L	13.9	10.6	21.0	42	7.8	6.2	11.0	13	7.4	5.8	9.1	43	8.7	5.4	11.6	25
Potassium	mg/L	1.8	0.1	2.7	42	1.6	1.2	3.7	12	0.9	0.1	2.1	38	0.9	0.1	1.4	26
Sodium	mg/L	16.1	11.5	24.6	43	9.0	6.7	20.5	14	5.4	3.5	11.0	44	6.9	4.0	15.2	26
Chloride	mg/L	5.2	2.7	14.0	43	3.0	1.4	19.0	14	1.5	0.5	4.6	44	2.1	<1	7.2	26
Sulphate	mg/L	39.7	27.0	58.0	43	22.2	16.1	30.0	14	17.1	11.8	36.9	41	22.0	13.0	38.1	25
Nutrients																	
Total Kjeldahl Nitrogen	mg/L	0.54	0.16	1.46	29	0.87	0.63	1.50	8	0.81	0.24	3.19	26	0.62	0.20	1.90	17
Nitrate + Nitrite	mg/L	0.16	0.13	0.19	2	-	-	-	-	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05	1
Total Ammonia	mg/L	0.03	<0.01	0.08	17	0.02	<0.01	0.06	4	0.01	<0.01	0.02	9	0.01	<0.01	0.02	6
Total Phosphorus	mg/L	0.022	<0.003	0.179	42	0.110	0.034	2.500	13	0.128	0.025	1.300	40	0.033	0.009	0.350	24
Dissolved Phosphorus	mg/L	0.012	<0.003	0.035	19	0.013	0.006	0.026	6	0.013	<0.003	0.042	8	0.007	<0.003	0.012	6
General Organics																	
Biochemical Oxygen Demand	mg/L	0.6	<0.1	3.0	20	0.9	0.6	1.2	2	-	-	-	-	-	-	-	-
Chlorophyll *a*	µg/L	0.3	0.2	1.1	19	4.2	2	13.7	5	2.8	<1	19.0	18	1.7	<1	5.0	13
Dissolved Organic Carbon	mg/L	8.0	5.3	20.0	43	10.0	7.3	19.0	13	8.0	1.0	23.5	32	8.0	2.5	25.0	21
Total Organic Carbon	mg/L	8.5	5.7	21.0	35	13.1	7.0	22.5	10	9.5	2.0	29.5	32	9.0	3.1	26.0	19
Total Phenolics	mg/L	0.003	0.001	0.008	25	0.003	<0.001	0.006	7	0.002	<0.001	0.007	13	0.002	<0.001	0.009	9
Metals (Total)																	
Aluminum (Al)	mg/L	0.055	<0.005	0.35	36	0.844	0.2	6.9	11	0.908	0.13	11.4	31	0.23	<0.005	2.5	19
Arsenic (As)	mg/L	0.0004	0.0002	0.0007	14	0.0012	0.0008	0.0019	4	0.0012	0.0004	0.0125	13	0.001	0.0003	<0.005	9
Barium (Ba)	mg/L	0.086	0.079	0.122	13	0.0705	0.055	0.121	4	0.0705	0.059	0.15	10	0.068	0.057	0.08	5
Beryllium (Be)	mg/L	<0.001	<0.001	<0.001	3	<0.0006	<0.0002	<0.001	2	0.001	0.001	0.003	3	<0.001	<0.001	<0.001	1
Boron (B)	mg/L	0.03	0.01	0.05	2	-	-	-	-	0.04	0.04	0.04	1	0.04	0.04	0.04	1
Cadmium (Cd)	mg/L	0.001	<0.001	0.003	13	0.001	<0.001	0.002	4	<0.001	<0.0002	<0.001	12	<0.001	<0.001	<0.001	7
Chromium (Cr)	mg/L	0.003	0.001	0.006	18	0.0045	0.002	0.009	4	0.004	0.003	0.032	12	0.0025	<0.001	0.007	8
Cobalt (Co)	mg/L	0.001	<0.001	0.004	13	0.001	<0.001	0.005	4	0.002	<0.001	0.009	12	0.001	<0.001	0.003	7
Copper (Cu)	mg/L	0.001	<0.001	0.007	22	0.004	<0.001	0.009	6	0.005	0.002	0.018	16	0.0015	<0.001	0.004	10
Iron (Fe)	mg/L	0.174	0.101	0.25	11	3.21	2.7	7.51	3	3.115	2.3	10.7	6	0.352	0.254	2.42	3
Lithium (Li)	mg/L	0.0125	<0.005	0.02	2	<0.005	<0.005	<0.005	1	0.014	0.014	0.014	1	0.017	0.017	0.017	1
Mercury (Hg)	mg/L	0.0001	<0.00004	0.0005	41	0.0001	<0.00005	0.001	13	<0.0001	<0.00004	<0.0002	38	<0.0001	<0.00004	<0.0002	26
Selenium (Se)	mg/L	<0.0001	<0.0001	<0.0002	14	0.0002	<0.0002	0.0003	4	0.0002	<0.0001	0.0004	10	0.0002	<0.0001	0.0004	7
Silver (Ag)	mg/L	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1
Strontium (Sr)	mg/L	0.34	0.32	0.36	2	0.18	0.18	0.18	1	0.22	0.22	0.22	1	0.22	0.22	0.22	1
Titanium (Ti)	mg/L	<0.05	<0.05	<0.05	2	-	-	-	-	<0.01	<0.01	<0.01	1	<0.05	<0.05	<0.05	2
Vanadium (V)	mg/L	<0.002	<0.002	<0.002	1	0.002	0.002	0.002	1	0.0045	0.004	0.005	2	-	-	-	-
Zinc (Zn)	mg/L	0.007	0.001	0.034	23	0.0145	0.002	0.025	7	0.013	0.005	0.059	15	0.007	<0.001	0.03	9
Metals (Dissolved)																	
Aluminum (Al)	mg/L	0.01	<0.01	0.02	3	0.0675	0.045	0.09	2	0.011	<0.002	0.02	2	0.02	0.02	0.02	1
Arsenic (As)	mg/L	0.0005	0.0002	0.0015	23	0.0009	<0.0005	0.0054	8	0.0009	0.0003	0.021	24	0.0006	0.0003	0.01	14
Barium (Ba)	mg/L	-	-	-	-	0.059	0.059	0.059	1	-	-	-	-	-	-	-	-
Beryllium (Be)	mg/L	<0.001	<0.001	<0.005	11	<0.001	<0.001	<0.005	3	<0.001	<0.001	<0.005	8	<0.001	<0.001	<0.001	4
Boron (B)	mg/L	0.05	<0.01	0.14	22	0.04	0.03	0.07	5	0.06	<0.01	0.12	15	0.06	0.02	0.17	11
Cadmium (Cd)	mg/L	<0.001	<0.001	<0.001	1	0.0035	<0.001	0.006	2	<0.001	<0.001	<0.001	1	-	-	-	-
Chromium (Cr)	mg/L	0.003	0.003	0.005	17	0.003	<0.003	0.004	6	0.003	0.003	0.008	23	0.003	<0.003	0.01	14
Cobalt (Co)	mg/L	0.002	0.002	0.002	1	0.003	<0.002	0.004	2	<0.002	<0.002	<0.002	1	-	-	-	-
Copper (Cu)	mg/L	<0.001	<0.001	<0.001	1	0.002	<0.001	0.003	2	0.002	0.002	0.002	1	-	-	-	-
Iron (Fe)	mg/L	0.11	0.1	0.17	5	0.1	0.06	0.136	3	0.07	0.05	0.09	3	0.12	0.12	0.12	1
Selenium (Se)	mg/L	<0.0002	<0.0002	<0.0005	20	<0.0003	<0.0002	<0.0005	6	0.0002	0.0002	0.0018	16	0.0002	<0.0002	0.0011	11
Vanadium (V)	mg/L	<0.001	<0.001	<0.001	1	<0.0015	<0.001	<0.002	2	<0.001	<0.001	<0.001	1	-	-	-	-
Zinc (Zn)	mg/L	0.002	0.002	0.002	1	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	1	-	-	-	-

NOTES: - = No data

Table VII-2 Water Quality of the Athabasca River in the Oil Sands Area (1984-1997)

Parameter	Units	Near Donald Creek									Below Existing Oil Sands Operations										Below Fort Creek											
		Spring			Summer			Fall			Spring			Summer			Fall				Winter				Spring				Summer				Fall			
		min.	max.	n		n	min.	max.	n		min.	max.	n	min.	max.	n		n	median	min.	max.	n	median	min.	max.	n	median	min.	max.	n	median	min.	max.	n
Field Parameters																																			
Temperature	°C	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	0	-0.3	0.3	10	12.2	-	-	1	18.6	18.2	21	3	11	2.2	14.2	3
Dissolved Oxygen	mg/L	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	12.05	11.5	13.01	10	10.3	-	-	1	8.9	8	9.3	3	9.3	9.2	12.4	3
Conventional Parameters and Major Ions																																			
Bicarbonate	mg/L	93	119	2	108	1	113	116	2		127	127	2	110	115	2	-	-	-	-	-	-	88	-	-	1	-	-	-	-	109	-	-	1
Calcium	mg/L	<0.5	30.7	2	32.5	1	27	28	2		33.6	33.6	2	28.5	33.5	2	-	-	42	37	51	10	28	20.8	32	3	27	23	32	5	31.5	25.5	37	6
Chloride	mg/L	<0.5	9.6	2	3.1	1	2.3	14.8	2		7.1	7.1	2	2	2.6	2	-	-	30.1	18.6	49	12	8	1.3	13	3	6	3	17	6	8.5	4.8	21	6
Colour	T.C.U.	90	90	2	-	-	60	-	1		-	-	-	150	150	2	-	-	23.13	19	32	12	-	62	90	2	58.4	35	105.6	6	54.4	23.6	80	6
Conductance	µS/cm	186	253	2	200	1	236	268	2		249	249	2	205	224	2	-	-	439	385	544	10	251	175	302	3	223	202	256	6	258.5	227	343	6
Dissolved Organic Carbon	mg/L	7.1	11	2	16.7	1	9.0	9.2	2		7.6	7.6	2	13	16.1	2	-	-	6.8	6	7.6	12	11	7.1	12.2	3	12.7	8.2	16.2	6	8.75	5.9	12	6
Hardness	mg/L	<1	111	2	114	1	100	104	2		121	121	2	101	118	2	-	-	158	136	193	11	103	75	113	3	92	78	118	6	108	95	129	6
Magnesium	mg/L	<0.1	8.4	2	8	1	7.9	8.2	2		8.9	8.9	2	7.2	8.2	2	-	-	12.5	11	16	10	8	5.5	8	3	7	5	8	5	7.75	6	9	6
pH		7.81	8.1	2	7.63	1	7.82	8	2		7.94	7.94	2	7.63	8	2	-	-	7.92	7.45	8.1	11	8.2	7.6	8.2	3	7.95	7.45	8.3	6	8.25	7.9	8.4	6
Potassium	mg/L	<0.1	1.2	2	0.9	1	1.2	1.4	2		1.2	1.2	2	0.7	1	2	-	-	1.5	1.2	2	11	1.5	1.3	2.3	3	0.95	0.8	1.2	6	1	0.8	1.1	6
Sodium	mg/L	<1	13.6	2	8.6	1	9.0	16.6	2		11.5	11.5	2	6	8.3	2	-	-	32.5	23	43	12	8	8	16	3	8.15	7	10	6	11.5	9	19	6
Sulphate	mg/L	<0.5	18.3	2	13.1	1	20.3	23.1	2		19.2	19.2	2	14.2	15.9	2	-	-	36	26	44	12	19	12.8	20	3	20.5	12	22.1	6	19	16	24	6
Sulphide	mg/L	<0.002	<0.002	2	-	-	<0.002	<0.002	1		-	-	-	<0.002	<0.002	2	-	-	-	-	-	-	<0.002	-	-	1	-	-	-	-	0.005	-	-	1
Total Alkalinity	mg/L	76	97	2	88	1	92	95	2		104	104	2	90	94	2	-	-	144	138	168	11	99	72	117	3	90	83	98	6	104	89	119	6
Total Dissolved Solids	mg/L	140	141	2	120	1	146	200	2		146	240	2	123	158	2	-	-					46	30	146	3	182	182	182	1	150	140	160	2
Total Organic Carbon	mg/L	16	16	2	-	-	14	14	1		-	-	-	14	14	2	-	-	-	6.1	7.7	2	17	-	-	1	16.3	-	-	1	13	-	-	1
Total Suspended Solids	mg/L	19.0	181.0	2	624.0	1	4.0	57.0	2		30.0	190.0	3	624.0	676.0	2	-	-	2.5	0.4	6.4	12	-	190.0	240.0	2	265.5	38.0	521.0	6	36.0	6.0	59.2	5
Nutrients																																			
Nitrate + Nitrite	mg/L	0.015	<0.05	2	0.110	1	0.007	0.050	2		0.003	0.003	2	0.060	0.100	2	-	-	0.200	-	-	1	0.060	-	-	1	-	-	-	-	<0.05	-	-	1
Total Ammonia	mg/L	<0.01	<0.05	2	0.04	1	<0.01	<0.05	2		<0.01	<0.01	2	0.04	<0.05	2	-	-	0.06	0.05	0.13	6	0.05	-	-	1	0.03	-	-	1	<0.05	-	-	1
Total Kjeldahl Nitrogen	mg/L	1.20	1.20	2	-	-	<0.2	<0.2	1		-	-	-	<0.2	<0.2	2	-	-	0.33	0.30	0.48	3	1.20	-	-	1	1.01	-	-	1	0.50	-	-	1
Total Phosphorus	mg/L	0.140	0.144	2	0.390	1	0.084	0.087	2		0.120	0.120	2	0.298	0.440	2	0.080	1	0.029	0.025	0.050	8	0.082	0.034	0.180	3	0.290	0.055	0.900	6	0.058	0.023	0.074	6
Dissolved Phosphorus	mg/L	0.020	0.020	2	-	-	0.022	0.022	1		-	-	-	0.019	0.019	2	<0.01	1	0.020	0.01	0.027	6	0.015	0.010	0.020	3	0.018	0.018	0.028	3	0.013	0.008	0.019	3
General Organics and Toxicity																																			
Biochemical Oxygen Demand	mg/L	3	3	2	-	-	8	8	1		-	-	-	3	3	2	-	-	0.5	0.2	1.4	9	-	<1	2	2	2.3	-	-	1	2	-	-	1
Chlorophyll *a*	µ/L	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	0.3	0.3	0.5	3	-	6.7	9.5	2	6.3	6	8.2	5	4.4	2.6	7	5
Microtox IC50	%	100	100	2	100	1	100	100	1		91	100	2	100	100	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microtox IC25	%	100	100	2	100	1	100	100	1		91	100	2	100	100	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naphthenic Acids	mg/L	<1	2	2	<1	1	<1	<1	1		<1	<1	2	<1	<1	2	1	1	-	-	-	-	1	-	-	1	-	-	-	-	<1	-	-	1
Total Phenolics	mg/L	0.001	0.001	2	0.001	1	<0.001	<0.001	1		<0.001	0.002	2	<0.001	<0.001	2	<0.01	1	0.004	<0.001	0.008	12	-	0.003	0.007	2	0.004	<0.001	0.008	6	0.0045	<0.001	0.007	5
Recoverable Hydrocarbons	mg/L	<0.5	<1	2	1	1	0.6	<1	1		<0.5	<1	2	<0.5	<1	2	1	1	-	-	-	-	<0.5	-	-	1	-	-	-	-	0.6	-	-	1
Metals (Total)																																			
Aluminum (Al)	mg/L	0.17	5.18	2	8.64	1	0.11	2.23	2		0.15	4.05	2	10.1	14.1	2	3.89	1	0.0155	<0.005	0.04	8	3.66	-	-	1	6.13	-	-	1	2.38	-	-	1
Antimony (Sb)	mg/L	<0.0002	0.0007	2	0.0002	1	<0.0002	0.0012	2		<0.0002	<0.0004	2	0.0003	0.0006	2	0.0005	1	-	-	-	-	<0.0004	-	-	1	-	-	-	-	0.001	-	-	1
Arsenic (As)	mg/L	0.0006	0.002	2	0.007	1	0.0005	0.0013	2		0.0008	0.0017	2	0.0057	0.007	2	0.0015	1	0.0004	0.0003	0.0006	9	0.0011	0.001	0.0017	3	0.0045	0.0006	0.0085	6	0.0008	0.0005	0.0013	6
Barium (Ba)	mg/L	0.05	0.0976	2	0.2	1	0.04	0.067	2		0.06	0.0896	2	0.21	0.232	2	0.0758	1	0.065	0.06	0.081	10	-	0.06	0.0892	2	0.0685	0.063	0.2	4	0.0584	0.055	0.063	4
Beryllium (Be)	mg/L	<0.001	<0.001	2	0.004	1	<0.001	<0.001	2		<0.001	<0.001	2	<0.001	0.004	2	<0.001	1	<0.001	-	-	1	<0.001	-	-	1	0.002	-	-	1	<0.001	-	-	1
Boron (B)	mg/L	0.043	0.05	2	0.05	1	0.03	0.09	2		0.03	0.031	2	0.033	0.05	2	0.033	1	-	-	-	-	0.035	-	-	1	-	-	-	-	0.24	-	-	1
Cadmium (Cd)	mg/L	<0.0002	<0.003	2	<0.003	1	<0.002	<0.003	2		<0.0002	<0.003	2	0.0002	<0.003	2	<0.0002	1	0.001	<0.001	0.002	10	<0.001	-	-	3	0.001	<0.001	0.002	5	0.001	<0.002	0.002	6
Chromium (Cr)	mg/L	<0.002	0.0051	2	0.003	1	<0.002	0.0026	2		<0.002	0.0051	2	<0.002	0.0197	2	0.0043	1	0.0025	<0.001	0.004	10	0.005	0.0037	0.007	3	0.00995	0.002	0.018	6	0.003	0.0019	0.006	6
Cobalt (Co)	mg/L	0.0021	<0.003	2	<0.003	1	0.0009	<0.003	1		0.0018	0.006	2	0.005	0.0068	2	0.0012	1	0.001	<0.001	0.003	10	0.001	<0.001	0.0021	3	0.005	<0.001	0.01	5	0.001	0.0009	0.004	6
Copper (Cu)	mg/L	<0.001	0.007	2	-	-	0.049	0.049	1		0.004	0.0061	2	0.0181	0.0181	2	0.0041	1	0.0015	<0.001	0.004	10	0.002	<0.001	0.007	3	0.008	0.002	0.014	5	0.002	<0.001	0.004	6
Iron (Fe)	mg/L	0.43	5.24	2	17.9	1	0.91	2.19	2		0.43	3.76	2	17.6	19.4	2	2.98	1	0.4625	0.36	0.502	8	5.04	-	-	1	16.1	-	-	1	2.41	-	-	1
Lead (Pb)	mg/L	0.0038	<0.02	2	<0.02	1	0.0013	<0.02	2		0.0024	<0.02	2	0.0108	<0.02	2	0.0016	1	-	-	-	-	0.0031	-	-	1	-	-	-	-	0.0013	-	-	1
Lithium (Li)	mg/L	0.006	0.011	2	0.014	1	0.006	0.008	2		0.006	0.01	2	0.018	0.019	2	0.011	1	-	-	-	-	0.011	-	-	1	-	-	-	-	0.009	-	-	1
Manganese (Mn)	mg/L	0.04	0.106	2	0.509	1	0.033	0.0709	2		0.044	0.101	2	0.408	0.534	2	0.0739	1	-	-	-	-	0.12	-	-	1	-	-	-	-	0.0752	-	-	1
Mercury (Hg)	mg/L	<0.0002	<0.05	2	<0.05	1	<0.0001	<0.05	2		<0.0002	<0.05	2	<0.0001	<0.05	2	<0.0001	1	0.0001	-	-	8	<0.0001	-	-	3	<0.0001	-	-	6	<0.0001	-	-	6
Molybdenum (Mo)	mg/L	0.0026	<0.003	2	<0.003	1	0.0008	<0.003	2		0.0007	0.004	2	0.0018	<0.003	2	0.0009	1	-	-	-	-	0.0005	-	-	1	-	-	-	-	0.0007	-	-	1
Nickel (Ni)	mg/L	0.005	0.0051	2	<0.005	1	0.003	<0.005	2		<0.005	0.014	2	0.009	0.0211	2	0.0071	1	-	-	-	-	0.0046	-	-	1	-	-	-	-	0.003	-	-	1
Selenium (Se)	mg/L	<0.0002	<0.0004	2	<0.0002	1	<0.0002	0.0007	2		<0.0002	<0.0004	2	<0.0002	0.0007	2	<0.0004	1	<0.0001	-	-	9	<0.0002	-	-	3	0.0002	<0.0002	0.0007	4	0.0002	<0.0002	0.0007	5
Silicon (Si)	mg/L	2.12	12.6	2	-	-	-	-	-		1.85	9.52	2	26.2	26.2	2	2.09	1	-	-	-	-	9.77	-	-	1	-	-	-	-	-	-	-	-
Silver (Ag)	mg/L	<0.001	<0.002	2	<0.002	1	<0.0001	<0.002	2		<0.001	<0.002	2	0.0006	<0.002	2	<0.0001	1	-	-	-	-	<0.001	-	-	1	<0.0001	-	-	1	<0.0001	-	-	1
Strontium (Sr)	mg/L	0.153	0.19	2	0.229	1	0.171	0.2	2		0.168	0.21	2	0.24	0.248	2	0.192	1	-	-	-	-	0.142	-	-	1	-	-	-	-	0.172	-	-	1
Sulphur (S)	mg/L	6.6	6.6	2	-	-	-	-	-		7.3	7.3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Titanium (Ti)	mg/L	0.004	0.0539	2	0.085	1	0.007	0.0254	2		0.005	0.0515	2	0.056	0.151	2	0.0386	1	-	-	-	-	0.0454	-	-	1	-	-	-	-	0.0276	-	-	1
Uranium (U)	mg/L	0.0007	<0.5	2	-	-	0.0004	0.0004	1		0.0006	<0.5	2	0.0012	0.0012	2	0.0004	1	-	-	-	-	0.0007	-	-	1	-	-	-	-	0.0004	-	-	1
Vanadium (V)	mg/L	<0.002	0.0125	2	0.009	1	<0.0001	<0.0001	1		0.004	0.0113	2	0.015	0.0379	2	0.0097	1	<0.002	-	-	1	0.009	-	-	1	0.023	-	-	1	0.0061	-	-	1
Zinc (Zn)	mg/L	0.019	0.812	2	0.085	1	0.14	0.14	1		0.019	0.036	2	0.064	0.095	2	0.034	1	0.004	<0.001	0.081	11	0.003	<0.001	0.039	3	0.0285	0.006	0.074	6	0.005	0.002	0.008	5
Metals (Dissolved)																																			
Aluminum (Al)	mg/L	0.241	0.241	1	0.0159	1	0.0443	0.0443	1		0.0572	0.0572	1	0.0499	0.0499	1	0.0729	1	-	-	-	-	0.415	-	-	1	0.026	-	-	1	0.0363	-	-	1
Antimony (Sb)	mg/L	<0.0004	<0.0004	1	<0.0004	1	0.0006	0.0006	1		<0.0004	<0.0004	1	0.0005	0.0005	1	0.0006	1	-	-	-	-	<0.0004	-	-	1	0.006	-	-	1	0.0012	-	-	1
Arsenic (As)	mg/L	0.001	0.001	1	<0.0004	1	0.0005	0.0005	1		0.0006	0.0006	1	0.0006	0.0006	1	0.0006	1	-	-	-	-	0.0012	-	-	1	0.0005	-	-	1	0.0005	-	-	1
Barium (Ba)	mg/L	0.0578	0.0578	1	0.0382	1	0.0418	0.0418	1		0.043	0.043	1	0.0506	0.0506	1	0.0396	1	-	-	-	-	0.0612	-	-	1	0.0245	-	-	1	0.0365	-	-	1
Beryllium (Be)	mg/L	<0.0005	<0.0005	1	<0.0005	1	<0.0005	<0.0005	1		<0.0005	<0.0005	1	<0.0005	<0.0005	1	<0.0005	1	<0.001	-	-	9	-	<0.0005	<0.001	2	<0.001	-	-	4	<0.001	-	-	4
Boron (B)	mg/L	0.024	0.024	1	0.022	1	0.022	0.022	1		0.025	0.025	1	0.018	0.018	1	0.026	1	-	-	-	-	0.026	-	-	1	0.065	-	-	1	0.025	-	-	1
Cadmium (Cd)	mg/L	<0.0001	<0.0001	1	0.0028	1	0.0001	0.0001	1		<0.0001	<0.0001	1	0.0002	0.0002	1	0.0001	1	-	-	-	-	0.0001	-	-	1	0.0002	-	-	1	0.0001	-	-	1
Chromium (Cr)	mg/L	<0.0004	<0.0004	1	<0.0004	1	<0.0004	<0.0004	1		<0.0004	<0.0004	1	<0.0004	<0.0004	1	<0.0004	1	-	-	-	-	0.0007	-	-	1	<0.0004	-	-	1	<0.0004	-	-	1
Cobalt (Co)	mg/L	0.001	0.001	1	0.0002	1	0.0003	0.0003	1		0.0003	0.0003	1	0.0002	0.0002	1	0.0003	1	-	-	-	-	0.0013	-	-	1	0.0002	-	-	1	0.0003	-	-	1
Copper (Cu)	mg/L	0.0043	0.0043	1	0.0022	1	0.0022	0.0022	1		0.0024	0.0024	1	0.006	0.006	1	0.0042	1	-	-	-	-	0.0049	-	-	1	0.003	-	-	1	0.002	-	-	1
Iron (Fe)	mg/L	1.14	1.14	1	0.1	1	0.14	0.14	1		0.32	0.32	1	0.08	0.08	1	<0.01	1	-	-	-	-	1.93	-	-	1	0.43	-	-	1	0.14	-	-	1
Lead (Pb)	mg/L	0.00148	0.00148	1	0.0113	1	0.00052	0.00052	1		0.00038	0.00038	1	0.00101	0.00101	1	0.00147	1	-	-	-	-	0.00198	-	-	1	0.0017	-	-	1	0.00067	-	-	1
Lithium (Li)	mg/L	0.007	0.007	1	0.007	1	-	-	-		0.007	0.007	1	0.005	0.005	1	0.007	1	-	-	-	-	0.007	-	-	1	0.009	-	-	1	0.007	-	-	1
Manganese (Mn)	mg/L	0.0744	0.0744	1	0.0034	1	0.0114	0.0114	1		0.024	0.024	1	0.0098	0.0098	1	0.0102	1	-	-	-	-	0.0916	-	-	1	0.0253	-	-	1	0.0132	-	-	1
Mercury (Hg)	mg/L	<0.0002	<0.0002	1	<0.0002	1	<0.0002	<0.0002	-		<0.0002	<0.0002	1	<0.0002	<0.0002	1	<0.0002	1	-	-	-	-	<0.0002	-	-	1	<0.0002	-	-	1	<0.0002	-	-	1
Molybdenum (Mo)	mg/L	0.00038	0.00038	1	0.00046	1	0.00064	0.00064	1		0.00054	0.00054	1	0.0009	0.0009	1	0.00075	1	-	-	-	-	0.00028	-	-	1	0.00023	-	-	1	0.00061	-	-	1
Nickel (Ni)	mg/L	0.0061	0.0061	1	0.002	1	0.0016	0.0016	1		0.0012	0.0012	1	0.0047	0.0047	1	0.0023	1	-	-	-	-	0.0056	-	-	1	0.0018	-	-	1	0.0016	-	-	1
Selenium (Se)	mg/L	<0.0004	<0.0004	1	<0.0004	1	<0.0004	<0.0004	1		<0.0004	<0.0004	1	<0.0004	<0.0004	1	<0.0004	1	-	-	-	-	<0.0004	-	-	1	<0.0004	-	-	1	<0.0004	-	-	1
Silicon (Si)	mg/L	2.53	2.53	1	1.99	1	2.3	2.3	1		2.2	2.2	1	2.09	2.09	1	-	1	-	-	-	-	2.72	-	-	1	2.29	-	-	1	2.4	-	-	1
Silver (Ag)	mg/L	<0.0002	<0.0002	1	<0.0002	1	<0.0002	<0.0002	-		<0.0002	<0.0002	1	<0.0002	<0.0002	1	<0.0002	1	-	-	-	-	<0.0002	-	-	1	<0.0002	-	-	1	<0.0002	-	-	1
Strontium (Sr)	mg/L	0.127	0.127	1	0.129	1	0.179	0.179	1		0.143	0.143	1	0.163	0.163	1	0.175	1	-	-	-	-	0.12	-	-	1	0.0893	-	-	1	0.168	-	-	1
Titanium (Ti)	mg/L	0.0023	0.0023	1	0.0003	1	0.0009	0.0009	1		0.0007	0.0007	1	0.0009	0.0009	1	0.0004	1	-	-	-	-	0.0025	-	-	1	0.0006	-	-	1	0.0007	-	-	1
Uranium (U)	mg/L	0.00045	0.00045	1	0.00021	1	0.00029	0.00029	1		0.00027	0.00027	1	0.00041	0.00041	1	0.00029	1	-	-	-	-	0.00045	-	-	1	<0.00005	-	-	1	0.00027	-	-	1
Vanadium (V)	mg/L	0.0012	0.0012	1	<0.0001	1	<0.0001	<0.0001	1		0.0002	0.0002	1	<0.0001	<0.0001	1	0.0002	1	-	-	-	-	0.002	-	-	1	0.0001	-	-	1	<0.0001	-	-	1
Zinc (Zn)	mg/L	-	-	1	0.038	1	0.014	0.014	1		0.006	0.006	1	0.027	0.027	1	0.023	1	-	-	-	-	0.015	-	-	1	0.016	-	-	1	0.019	-	-	1
Trace Organics																																			
PAHs and Alkylated PAHs	µg/L	ND	ND	2	ND	2	ND	ND	1		ND	0.03	2	ND	ND	2	ND	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PANHs	µg/L	ND	ND	2	ND	2	ND	ND	1		ND	ND	2	ND	ND	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenolics	µg/L	ND	ND	2	ND	2	-	-	-		ND	ND	2	ND	ND	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Volatile Organics	µg/L	ND	ND	2	-	-	-	-	-		ND	ND	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

NOTES: - = No data; ND = Not detected; PAHs = Polycyclic Aromatic Hydrocarbons; PANHs = Polycyclic Aromatic Nitrogen Heterocycles

Table VII-3 Water Quality of the Muskeg River (1972-1997)

At Mouth

Parameter	Units	Winter median	Winter min.	Winter max.	Winter n	Spring median	Spring min.	Spring max.	Spring n	Summer median	Summer min.	Summer max.	Summer n	Fall median	Fall min.	Fall max.	Fall n
Field Parameters																	
pH	-	-	-	-	-	7.8	7.8	7.9	3	8.1	7.7	8.3	3	-	8	9.2	2
Specific Conductance	µS/cm	-	-	-	-	196	-	-	1	316	-	-	1	-	-	-	-
Temperature	°C	0	-0.1	2	12	11	10	13.5	3	16	12	22	5	-	-	-	-
Dissolved Oxygen	mg/L	7.285	1.9	11.5	12	10.8	-	-	1	-	8	9	2	-	-	-	-
Conventional Parameters and Major Ions																	
Bicarbonate	mg/L	350	-	-	1	137	93	185	6	187	172	207	6	183	128	310	5
Calcium	mg/L	73.1	39.9	160	13	30.15	20.2	44.4	6	43.4	24	59	13	41.7	25.5	75.3	8
Chloride	mg/L	5.4	3.4	20.2	17	3.65	1.6	4.2	6	3.5	<1	13.5	16	4.35	1.8	18.1	8
Colour	T.C.U.	62.5	50	96	8	-	60	80	2	90	80	100	3	120	-	-	1
Conductance	uS/cm	495	259	1360	12	209	157	300	5	279	216	450	15	310	205	444	8
Dissolved Organic Carbon	mg/L	21.4	9	61	14	15.8	11	15.9	3	24	18	25.3	5	24	17	27	5
Hardness	mg/L	253	137	638	14	111	72	151	6	153	108	203	14	148	97	232	8
Magnesium	mg/L	17	9.1	58	13	8.6	5.3	9.6	6	9.9	3	13.5	15	9.55	7	10.7	8
pH	-	7.5	7.2	8.3	16	7.7	7.4	8.09	5	8.01	7.2	8.5	15	7.84	7.5	8.3	8
Potassium	mg/L	1.5	0.9	6	13	1.45	0.95	1.8	6	0.5	0.03	1.4	16	1	0.5	1.5	8
Sodium	mg/L	15.65	9	50	14	9.05	5	11.5	6	11.8	6	14.9	16	13.3	8	26.5	8
Sulphate	mg/L	4.3	2.3	10.9	15	4.9	2.4	6.6	6	4.8	0.5	31	16	3.8	0.5	10.4	8
Sulphide	mg/L	0.01	0.01	0.01	3	0.003	-	-	1	0.004	-	-	1	0.003	-	-	1
Total Alkalinity	mg/L	257	136	790	13	113	76	152	6	148	66	224	16	153	105	254	8
Total Dissolved Solids	mg/L	331	181	844	7	143	108	167	6	202	151	248	10	184	123	316	7
Total Organic Carbon	mg/L	21.7	10	63	8	-	16	20.8	2	23.75	18	29.4	6	24	19	29	3
Total Suspended Solids	mg/L	4.0	<0.4	20.4	17	1.0	<0.4	4.0	6	3.0	0.0	9.2	10	5.6	1.0	70.0	7
Nutrients																	
Nitrate + Nitrite	mg/L	0.185	0.020	0.300	4	<0.0095	-	-	6	0.050	0.013	0.055	13	0.015	<0.002	0.100	6
Total Ammonia	mg/L	0.23	0.15	1.63	7	<0.025	-	-	4	0.04	<0.01	0.05	4	0.05	0.04	0.06	2
Total Kjeldahl Nitrogen	mg/L	1.11	0.86	3.94	6	-	0.60	0.76	2	1.05	0.60	2.89	6	0.70	0.55	0.70	3
Total Phosphorus	mg/L	0.027	0.020	0.070	10	0.034	0.025	0.040	4	0.029	<0.005	0.600	11	0.045	0.016	0.600	6
Dissolved Phosphorus	mg/L	0.008	0.006	0.013	5	<0.02	-	-	1	0.015	-	-	1	0.014	-	-	1
General Organics and Toxicity																	
Biochemical Oxygen Demand	mg/L	0.7	0.5	4	9	3	0.8	17	3	0.5	0.4	3	3	2.3	0.6	4	2
Chlorophyll *a*	µg/L	<1	-	-	1	-	-	-	-	-	<1	<5	2	<1	-	-	4
Microtox IC50	%	-	-	-	-	>100	91	100	3	>100	100	100	3	>100	91	100	3
Microtox IC25	%	-	-	-	-	>100	91	100	3	-	100	100	2	>100	91	100	3
Naphthenic Acids	mg/L	-	-	-	-	1	<1	4	3	<1	-	-	3	<1	-	-	3
Total Phenolics	mg/L	0.007	<0.001	0.01	11	-	-	-	-	0.001	<0.001	0.011	7	0.001	<0.001	0.002	3
Recoverable Hydrocarbons	mg/L	-	-	-	-	0.5	<0.1	3	3	<0.75	<0.1	1	4	<1	-	-	3
Metals (Total)																	
Aluminum (Al)	mg/L	0.01	<0.002	0.06	12	0.01	<0.01	0.231	4	0.05	0.02	0.11	8	0.06	0.03	1.2	5
Antimony (Sb)	mg/L	-	-	-	-	-	<0.0002	<0.0004	2	-	<0.0002	0.0005	2	0.00035	<0.0002	0.0005	2
Arsenic (As)	mg/L	0.0002	0.0001	0.0006	8	0.0003	0.0002	0.0003	3	<0.0004	-	-	5	0.001	0.0002	0.014	4
Barium (Ba)	mg/L	0.052	0.048	0.072	8	0.03	0.0254	0.03	3	0.03	0.03	0.0333	4	-	0.03	0.03	3
Beryllium (Be)	mg/L	<0.001	-	-	1	<0.001	-	-	3	0.001	<0.001	0.002	4	<0.001	-	-	2
Boron (B)	mg/L	-	-	-	-	0.055	0.045	0.06	4	0.052	<0.04	0.13	5	0.04	0.034	0.16	3
Cadmium (Cd)	mg/L	0.001	0.001	0.002	8	<0.002	-	-	4	<0.001	-	-	7	0.003	<0.002	0.004	4
Chromium (Cr)	mg/L	0.003	<0.001	0.01	8	0.002	<0.0004	0.005	4	0.002	<0.0004	0.017	8	0.006	0.0007	0.008	4
Cobalt (Co)	mg/L	0.001	0.001	0.001	7	<0.003	-	-	3	0.002	<0.0005	0.007	6	0.005	0.0008	0.006	4
Copper (Cu)	mg/L	0.001	<0.001	0.003	7	0.001	0.0008	0.001	4	0.004	<0.001	0.022	5	0.001	0.001	0.004	4
Iron (Fe)	mg/L	1.374	0.88	2.9	11	0.56	0.52	0.79	4	0.84	0.59	1.3	8	1.14	0.8	1.81	4
Lead (Pb)	mg/L	0.007	-	-	1	0.011	-	-	4	0.011	0.0008	0.002	4	<0.02	0.0021	<0.02	3
Lithium (Li)	mg/L	-	-	-	-	0.007	0.006	0.008	3	0.008	0.007	0.011	3	0.008	0.007	0.008	3
Manganese (Mn)	mg/L	0.66	-	-	1	0.034	0.031	0.0393	4	0.0355	0.029	0.0403	4	0.053	0.048	0.115	3
Mercury (Hg)	mg/L	0.0001	<0.00004	0.0011	12	<0.0002	-	-	3	<0.0002	-	-	10	<0.05	-	-	5
Molybdenum (Mo)	mg/L	-	-	-	-	0.003	0.0002	0.004	3	0.003	0.0002	0.003	3	0.003	<0.0001	0.005	3
Nickel (Ni)	mg/L	-	-	-	-	<0.003	-	-	4	0.0033	0.001	0.016	4	0.005	0.0016	0.015	3
Selenium (Se)	mg/L	<0.0001	-	-	8	0.0002	-	-	3	<0.0002	-	-	4	<0.0004	-	-	2
Silicon (Si)	mg/L	-	-	-	-	1.69	1.64	2.2	3	4.23	-	-	1	4.07	3.49	4.31	3
Silver (Ag)	mg/L	-	-	-	-	<0.002	-	-	3	<0.00105	-	-	4	0.002	<0.0001	0.003	2
Strontium (Sr)	mg/L	-	-	-	-	0.091	0.0594	0.093	3	0.098	0.095	0.113	3	0.097	0.086	0.097	3
Titanium (Ti)	mg/L	<0.01	-	-	1	0.003	<0.003	0.0036	3	0.003	0.0014	0.005	3	0.006	0.006	0.0167	3
Uranium (U)	mg/L	-	-	-	-	<0.5	-	-	3	<0.0001	-	-	1	<0.5	-	-	3
Vanadium (V)	mg/L	<0.002	-	-	1	0.0015	-	-	4	0.002	0.0003	0.006	5	0.002	0.002	0.003	3
Zinc (Zn)	mg/L	0.003	<0.001	0.025	9	0.0065	0.003	0.011	4	0.015	0.008	0.115	8	0.0205	0.008	0.033	4
Metals (Dissolved)																	
Aluminum (Al)	mg/L	-	-	-	-	0.0315	-	-	1	0.0094	-	-	1	0.0269	-	-	1
Antimony (Sb)	mg/L	-	-	-	-	<0.0004	-	-	1	0.0008	-	-	1	-	-	-	-
Arsenic (As)	mg/L	<0.00075	-	-	4	<0.0004	-	-	1	-	<0.0004	<0.0005	2	<0.001	-	-	2
Barium (Ba)	mg/L	-	-	-	-	0.019	-	-	1	0.0291	-	-	1	0.024	-	-	1
Beryllium (Be)	mg/L	<0.001	-	-	7	<0.0005	-	-	1	-	<0.0005	<0.005	2	<0.0005	-	-	1
Boron (B)	mg/L	0.135	0.06	0.36	4	0.039	-	-	1	0.0715	0.01	0.16	4	0.033	0.01	0.16	3
Cadmium (Cd)	mg/L	<0.001	-	-	1	<0.0001	-	-	1	-	0.0001	<0.001	2	<0.0001	-	-	-
Chromium (Cr)	mg/L	0.004	<0.003	0.013	3	<0.0004	-	-	1	<0.003	-	-	3	0.003	<0.0004	0.004	3
Cobalt (Co)	mg/L	<0.002	-	-	1	0.0002	-	-	1	-	0.0002	<0.002	2	0.0002	-	-	1
Copper (Cu)	mg/L	0.001	-	-	1	0.0013	-	-	1	-	0.0009	<0.001	2	0.0011	-	-	1
Iron (Fe)	mg/L	0.48	-	-	1	1.03	-	-	1	-	0.12	0.41	2	0.25	-	-	1
Lead (Pb)	mg/L	-	-	-	-	0.00037	-	-	1	0.00381	-	-	1	0.0003	-	-	1
Lithium (Li)	mg/L	-	-	-	-	0.005	-	-	1	0.01	-	-	1	0.007	-	-	1
Manganese (Mn)	mg/L	-	-	-	-	0.0363	-	-	1	0.0199	-	-	1	0.03	-	-	1
Mercury (Hg)	mg/L	-	-	-	-	<0.0002	-	-	1	<0.0002	-	-	1	0.0002	-	-	1
Molybdenum (Mo)	mg/L	-	-	-	-	0.00013	-	-	1	0.00009	-	-	1	0.00008	-	-	1
Nickel (Ni)	mg/L	-	-	-	-	0.001	-	-	1	0.0008	-	-	1	0.0004	-	-	1
Selenium (Se)	mg/L	<0.0005	-	-	4	<0.0004	-	-	1	-	<0.0004	<0.0005	2	<0.0005	-	-	2
Silicon (Si)	mg/L	-	-	-	-	1.36	-	-	1	3.66	-	-	1	4.07	-	-	1
Silver (Ag)	mg/L	-	-	-	-	<0.0002	-	-	1	<0.0002	-	-	1	<0.0002	-	-	1
Strontium (Sr)	mg/L	-	-	-	-	0.0529	-	-	1	0.101	-	-	1	0.074	-	-	1
Titanium (Ti)	mg/L	-	-	-	-	0.0008	-	-	1	0.0004	-	-	1	0.0006	-	-	1
Uranium (U)	mg/L	-	-	-	-	<0.00005	-	-	1	<0.00005	-	-	1	-	-	-	-
Vanadium (V)	mg/L	<0.001	-	-	1	0.0001	-	-	1	-	<0.0001	<0.001	2	-	-	-	-
Zinc (Zn)	mg/L	<0.001	-	-	1	0.008	-	-	1	-	0.001	0.017	2	-	-	-	-
Trace Organics																	
PAHs and Alkylated PAHs	µg/L	-	-	-	-	-	-	-	-	ND	-	-	1	ND	-	-	1
PANHs	µg/L	-	-	-	-	ND	-	-	1	ND	-	-	1	ND	-	-	1
Phenolics	µg/L	-	-	-	-	ND	-	-	1	ND	-	-	1	ND	-	-	1
Volatile Organics	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Lower Muskeg River

Parameter	Units	Winter median	Winter min.	Winter max.	Winter n	Spring median	Spring min.	Spring max.	Spring n	Summer median	Summer min.	Summer max.	Summer n	Fall median	Fall min.	Fall max.	Fall n
Field Parameters																	
pH	-	7.68	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Specific Conductance	µS/cm	470	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	°C	0	0	0.5	18	4.25	0	13	8	16	13	21	19	7.5	0	12	13
Dissolved Oxygen	mg/L	6.75	1.8	10.4	8	8.7	6.2	11.8	6	8.8	5.2	11.8	20	9.3	5	13.6	13
Conventional Parameters and Major Ions																	
Bicarbonate	mg/L	-	313	350	2	93	-	-	1	-	-	-	-	-	-	-	-
Calcium	mg/L	71.5	18	90	25	27.1	15.5	66	10	45.5	27.8	67.2	21	36	26.5	80.6	15
Chloride	mg/L	5.6	0.5	13	27	1.7	1.6	5.5	10	4.2	1.6	14.4	21	2.6	1.7	29.7	15
Colour	T.C.U.	47.5	25	100	14	60	40	80	5	95	30	130	14	100	30	140	10
Conductance	uS/cm	478	120	596	24	187	115	450	10	320	170	442	21	260	160	504	15
Dissolved Organic Carbon	mg/L	20	9.5	37	23	17.25	8	34	10	22.5	6	53	20	25.25	7	29	12
Hardness	mg/L	253	134	281	12	74	60	229	5	156	108	196	10	141	133	170	5
Magnesium	mg/L	17.2	5.3	21	25	7.25	4	16.9	10	10.8	7.5	13.7	21	9.4	7.7	16.9	15
pH	-	7.4	7.2	8.62	27	7.5	7.4	8.2	10	7.8	7.3	8.29	21	7.72	7.3	8.1	15
Potassium	mg/L	1.4	0.45	1.9	23	1.45	1.2	2.6	10	0.55	0.3	0.9	21	0.61	0.25	1.5	15
Sodium	mg/L	14.75	2.9	21.5	24	6.15	4.1	14.5	10	11.5	6.7	22	21	11.6	7.4	38.5	15
Sulphate	mg/L	5.1	1	42.5	25	3.9	2.8	6	10	4.9	0.5	9.1	21	4.4	0.1	11.5	15
Sulphide	mg/L	0.01	<0.002	0.01	4	0.003	-	-	1	-	-	-	-	-	-	-	-
Total Alkalinity	mg/L	259	61	333	24	101	56	254	10	170	100	232	21	136	105	267	15
Total Dissolved Solids	mg/L	303	79	476	27	138	72	297	10	195	112	276	21	162	121	319	15
Total Organic Carbon	mg/L	22	10	38	25	17.5	8	35	10	24	6	53	21	25.5	19.9	31	15
Total Suspended Solids	mg/L	6.0	1.6	72.0	27	5.2	3.6	36.0	10	2.5	0.4	6.0	21	2.8	<0.4	5.2	15
Nutrients																	
Nitrate + Nitrite	mg/L	-	<0.05	0.300	2	<0.05	-	-	1	-	-	-	-	-	-	-	-
Total Ammonia	mg/L	-	0.59	1.63	2	<0.05	-	-	1	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	1.30	0.40	3.00	23	0.86	0.04	2.10	10	1.04	0.48	1.66	21	0.90	0.35	1.75	13
Total Phosphorus	mg/L	0.038	0.022	0.190	24	0.031	<0.02	0.090	10	0.025	<0.005	0.053	21	0.028	0.017	0.070	15
Dissolved Phosphorus	mg/L	<0.02	-	-	1	0.600	-	-	1	-	-	-	-	-	-	-	-
General Organics and Toxicity																	
Biochemical Oxygen Demand	mg/L	-	2	4	2	3	-	-	1	-	-	-	-	-	-	-	-
Chlorophyll *a*	µg/L	1	<1	6	9	-	<1	4	2	1	<1	8	6	1	1	10	7
Microtox IC50	%	>99	-	-	1	>91	-	-	1	-	-	-	-	-	-	-	-
Microtox IC25	%	-	-	-	-	>91	-	-	1	-	-	-	-	-	-	-	-
Naphthenic Acids	mg/L	<1	-	-	1	4	-	-	1	-	-	-	-	-	-	-	-
Total Phenolics	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Recoverable Hydrocarbons	mg/L	2	-	-	1	<0.5	-	-	1	-	-	-	-	-	-	-	-
Metals (Total)																	
Aluminum (Al)	mg/L	0.04	<0.01	0.58	23	0.07	0.03	0.231	10	0.05	<0.01	0.42	21	0.04	<0.01	0.32	13
Antimony (Sb)	mg/L	<0.0004	-	-	1	<0.0004	-	-	1	-	-	-	-	-	-	-	-
Arsenic (As)	mg/L	<0.0004	-	-	1	<0.0004	-	-	1	<0.005	-	-	1	-	0.001	<0.005	2
Barium (Ba)	mg/L	0.0712	-	-	1	0.0254	-	-	1	-	-	-	-	-	-	-	-
Beryllium (Be)	mg/L	<0.001	-	-	1	<0.001	-	-	1	-	-	-	-	-	-	-	-
Boron (B)	mg/L	0.058	-	-	1	0.045	-	-	1	-	-	-	-	-	-	-	-
Cadmium (Cd)	mg/L	-	<0.0002	0.001	2	<0.0002	-	-	1	-	-	-	-	-	-	-	-
Chromium (Cr)	mg/L	-	<0.0004	0.01	2	<0.0004	-	-	1	-	-	-	-	-	-	-	-
Cobalt (Co)	mg/L	0.0005	-	-	1	<0.0005	-	-	1	-	-	-	-	-	-	-	-
Copper (Cu)	mg/L	0.002	-	-	1	0.0008	-	-	1	-	-	-	-	-	-	-	-
Iron (Fe)	mg/L	2.42	1.9	2.9	4	0.79	-	-	1	-	-	-	-	-	-	-	-
Lead (Pb)	mg/L	-	0.0005	0.007	2	0.0004	-	-	1	-	-	-	-	-	-	-	-
Lithium (Li)	mg/L	0.012	-	-	1	0.006	-	-	1	-	-	-	-	-	-	-	-
Manganese (Mn)	mg/L	-	0.43	0.66	2	0.0393	-	-	1	-	-	-	-	-	-	-	-
Mercury (Hg)	mg/L	0.0001	<0.0001	0.0005	25	0.0001	<0.0001	0.0003	10	<0.0001	-	-	21	0.0001	<0.0001	0.0004	15
Molybdenum (Mo)	mg/L	<0.0001	-	-	1	0.0002	-	-	1	-	-	-	-	-	-	-	-
Nickel (Ni)	mg/L	0.0013	-	-	1	<0.0004	-	-	1	-	-	-	-	-	-	-	-
Selenium (Se)	mg/L	<0.0004	-	-	1	<0.0004	-	-	1	-	-	-	-	-	-	-	-
Silicon (Si)	mg/L	6.54	-	-	1	2.2	-	-	1	-	-	-	-	-	-	-	-
Silver (Ag)	mg/L	<0.001	-	-	1	<0.001	-	-	1	-	-	-	-	-	-	-	-
Strontium (Sr)	mg/L	0.178	-	-	1	0.0594	-	-	1	-	-	-	-	-	-	-	-
Titanium (Ti)	mg/L	0.05	-	-	6	0.01	0.0036	0.01	3	-	<0.05	<0.05	2	-	<0.05	<0.05	2
Uranium (U)	mg/L	<0.0001	-	-	1	<0.0001	-	-	1	-	-	-	-	-	-	-	-
Vanadium (V)	mg/L	0.0005	-	-	1	0.0004	-	-	1	-	-	-	-	-	-	-	-
Zinc (Zn)	mg/L	-	0.013	0.03	2	0.011	-	-	1	-	-	-	-	-	-	-	-
Metals (Dissolved)																	
Aluminum (Al)	mg/L	-	-	-	-	0.0315	-	-	1	-	-	-	-	-	-	-	-
Antimony (Sb)	mg/L	-	-	-	-	<0.0004	-	-	1	-	-	-	-	-	-	-	-
Arsenic (As)	mg/L	0.0004	<0.0002	0.02	23	0.0005	0.0002	0.0006	10	0.00035	<0.0002	0.005	20	0.0004	<0.0002	0.012	13
Barium (Ba)	mg/L	-	-	-	-	0.019	-	-	1	-	-	-	-	-	-	-	-
Beryllium (Be)	mg/L	-	-	-	-	<0.0005	-	-	1	-	-	-	-	-	-	-	-
Boron (B)	mg/L	0.115	0.03	0.26	14	0.11	0.039	0.2	7	0.1	0.01	0.18	9	0.135	<0.05	0.22	8
Cadmium (Cd)	mg/L	-	-	-	-	<0.0001	-	-	1	-	-	-	-	-	-	-	-
Chromium (Cr)	mg/L	0.003	<0.003	0.007	22	0.003	<0.0004	0.006	10	0.003	<0.003	0.016	21	0.003	0.003	0.007	13
Cobalt (Co)	mg/L	-	-	-	-	0.0002	-	-	1	-	-	-	-	-	-	-	-
Copper (Cu)	mg/L	-	-	-	-	0.0013	-	-	1	-	-	-	-	-	-	-	-
Iron (Fe)	mg/L	-	-	-	-	1.03	-	-	1	-	-	-	-	-	-	-	-
Lead (Pb)	mg/L	-	-	-	-	0.00037	-	-	1	-	-	-	-	-	-	-	-
Lithium (Li)	mg/L	-	-	-	-	0.005	-	-	1	-	-	-	-	-	-	-	-
Manganese (Mn)	mg/L	-	-	-	-	0.0363	-	-	1	-	-	-	-	-	-	-	-
Mercury (Hg)	mg/L	-	-	-	-	<0.0002	-	-	1	-	-	-	-	-	-	-	-
Molybdenum (Mo)	mg/L	-	-	-	-	0.00013	-	-	1	-	-	-	-	-	-	-	-
Nickel (Ni)	mg/L	-	-	-	-	0.001	-	-	1	-	-	-	-	-	-	-	-
Selenium (Se)	mg/L	0.0002	<0.0002	0.0009	22	<0.0002	-	-	10	0.0002	0.0002	0.0008	20	<0.0002	-	-	11
Silicon (Si)	mg/L	-	-	-	-	1.36	-	-	1	-	-	-	-	-	-	-	-
Silver (Ag)	mg/L	-	-	-	-	<0.0002	-	-	1	-	-	-	-	-	-	-	-
Strontium (Sr)	mg/L	-	-	-	-	0.0529	-	-	1	-	-	-	-	-	-	-	-
Titanium (Ti)	mg/L	-	-	-	-	0.0008	-	-	1	-	-	-	-	-	-	-	-
Uranium (U)	mg/L	-	-	-	-	<0.00005	-	-	1	-	-	-	-	-	-	-	-
Vanadium (V)	mg/L	-	-	-	-	0.0001	-	-	1	-	-	-	-	-	-	-	-
Zinc (Zn)	mg/L	-	-	-	-	0.008	-	-	1	-	-	-	-	-	-	-	-
Trace Organics																	
PAHs and Alkylated PAHs	µg/L	ND	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
PANHs	µg/L	ND	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Phenolics	µg/L	ND	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Volatile Organics	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Upper Muskeg River

Parameter	Units	Winter median	Winter min.	Winter max.	Winter n	Spring median	Spring min.	Spring max.	Spring n	Summer median	Summer min	Summer max.	Summer n	Fall median	Fall min.	Fall max.	Fall n
Field Parameters																	
pH	-	8.195	7.2	8.38	4	7.4	7.4	7.6	3	7.3	7.2	7.5	3	7.655	7.4	7.87	6
Specific Conductance	µS/cm	560	550	581	4	243	235	245	3	382	365	390	3	358	294	430	6
Temperature	°C	0	0	0.75	14	9	4.5	14	7	15	10.75	17	9	5	0.4	10.5	9
Dissolved Oxygen	mg/L	2.7	0.8	4.6	5	8.4	4	10	7	6.2	0	7.3	9	9.05	3.9	10.6	8
Conventional Parameters and Major Ions																	
Bicarbonate	mg/L	363	349	388	4	161	152	221	4	247	178	257	4	226	198	255	6
Calcium	mg/L	81.6	38	88	15	32.8	19	50.3	8	55.5	38	75.3	11	45.7	31	62	10
Chloride	mg/L	2.4	1.3	6	15	1.25	0.8	1.8	8	1.5	0.5	2.7	11	1.4	1.1	2.4	10
Colour	T.C.U.	100	50	200	7	70	25	80	4	85	55	100	6	100	70	150	7
Conductance	uS/cm	530	305	610	11	197	120	333	5	338	277	479	8	277	248	420	4
Dissolved Organic Carbon	mg/L	21.5	9.5	44	11	16.8	11	28	5	24.5	21.5	26	7	24.5	23	24.5	3
Hardness	mg/L	291	162	328	12	125	75	178	7	177	147	222	8	168	146	221	9
Magnesium	mg/L	22	13.8	26.8	15	9.65	6.6	12.7	8	14.4	11.5	18.2	11	13.5	11.5	16	10
pH	-	7.43	7.1	7.67	11	7.5	6.93	8.2	5	7.62	7.36	7.9	8	7.65	7.3	7.95	4
Potassium	mg/L	1.3	0.66	2.6	15	1.2	0.92	2.1	8	0.7	0.3	1.7	11	0.925	0.3	1.23	10
Sodium	mg/L	9.5	5	12.9	15	4.35	2.6	6.8	8	5.6	4.5	7.7	11	6	4.5	7	10
Sulphate	mg/L	3.5	1	5	15	3.2	1	7.6	8	4.2	0.5	9.2	11	0.55	0.1	5.4	10
Sulphide	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Alkalinity	mg/L	301	162	327	15	128	76	181	8	196	146	266	11	171	127	216	10
Total Dissolved Solids	mg/L	327	198	385	15	135	79	187	8	211	147	311	11	23	20	27	10
Total Organic Carbon	mg/L	21.7	10	45	15	18	12	29	7	25	17.5	27	10	23	20.4	26.5	10
Total Suspended Solids	mg/L	10.0	0.4	78.4	15	2.8	1.2	5.6	8	4.0	1.0	7.2	11	-	-	-	-
Nutrients																	
Nitrate + Nitrite	mg/L	0.014	<0.003	0.045	4	0.003	<0.003	0.010	4	0.063	0.029	0.113	4	0.027	0.009	0.036	6
Total Ammonia	mg/L	0.82	0.58	1.04	4	0.05	0.04	0.05	3	0.14	0.13	0.16	3	0.07	0.04	0.08	6
Total Kjeldahl Nitrogen	mg/L	1.50	0.50	3.40	15	0.81	0.68	0.95	7	1.04	0.99	1.31	10	0.85	0.59	5.50	10
Total Phosphorus	mg/L	0.099	0.020	0.250	15	0.031	0.024	0.090	8	0.055	0.038	0.095	11	0.037	0.025	0.080	10
Dissolved Phosphorus	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General Organics and Toxicity																	
Biochemical Oxygen Demand	mg/L	1.45	0.6	4.6	4	0.6	0.6	1	3	0.5	0.04	0.5	3	1.55	0.8	1.9	6
Chlorophyll *a*	µg/L	<1	-	-	3	-	-	-	-	-	-	-	-	-	<1	<1	2
Microtox IC50	%	-	-	-	-	>100	-	-	1	>100	-	-	1	-	-	-	-
Microtox IC25	%	-	-	-	-	>100	-	-	1	>100	-	-	1	-	-	-	-
Naphthenic Acids	mg/L	-	-	-	-	<1	-	-	1	<1	-	-	1	-	-	-	-
Total Phenolics	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Recoverable Hydrocarbons	mg/L	0.4	0.3	0.6	4	<0.1	-	-	4	0.15	0.1	0.2	4	0.25	<0.1	0.5	6
Metals (Total)																	
Aluminum (Al)	mg/L	0.03	<0.01	0.14	15	0.03	<0.01	0.22	7	0.035	0.01	0.1	8	0.02	0.01	0.12	10
Antimony (Sb)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic (As)	mg/L	0.0004	<0.0002	0.0004	4	0.0004	0.0004	0.0005	3	0.0002	<0.0002	0.005	4	0.00045	0.0003	0.009	8
Barium (Ba)	mg/L	-	-	-	-	0.05	-	-	1	0.04	-	-	1	-	-	-	-
Beryllium (Be)	mg/L	-	-	-	-	<0.001	-	-	1	<0.001	-	-	1	-	-	-	-
Boron (B)	mg/L	0.06	0.05	0.06	4	0.02	<0.01	0.06	4	0.025	0.02	0.04	4	0.035	0.01	0.05	6
Cadmium (Cd)	mg/L	<0.001	-	-	4	<0.001	-	-	4	<0.001	-	-	4	<0.001	-	-	6
Chromium (Cr)	mg/L	<0.001	-	-	4	0.001	<0.001	0.008	4	0.001	<0.001	0.014	4	0.001	<0.001	0.008	6
Cobalt (Co)	mg/L	-	-	-	-	<0.003	-	-	1	0.005	-	-	1	-	-	-	-
Copper (Cu)	mg/L	<0.001	-	-	4	<0.001	-	-	4	<0.001	-	-	3	<0.001	-	-	6
Iron (Fe)	mg/L	6.2	-	-	1	1.055	0.89	1.95	4	2.71	0.91	3.02	4	1.17	1.05	1.5	3
Lead (Pb)	mg/L	0.002	0.002	0.002	4	<0.002	-	-	4	<0.002	-	-	4	<0.002	-	-	6
Lithium (Li)	mg/L	-	-	-	-	0.007	-	-	1	0.006	-	-	1	-	-	-	-
Manganese (Mn)	mg/L	1.15	0.561	1.5	4	0.027	0.023	0.072	4	0.135	0.032	0.16	4	0.066	0.058	0.084	6
Mercury (Hg)	mg/L	0.0001	<0.00005	0.0002	15	0.0001	<0.00005	0.0002	7	<0.0001	-	-	10	0.0001	<0.00005	0.0043	10
Molybdenum (Mo)	mg/L	-	-	-	-	0.004	-	-	1	<0.003	-	-	1	-	-	-	-
Nickel (Ni)	mg/L	<0.001	-	-	4	0.002	0.001	0.003	4	0.001	<0.001	0.006	4	<0.001	-	-	6
Selenium (Se)	mg/L	0.00055	<0.0002	0.0009	4	0.0004	0.0003	0.0004	3	<0.0002	-	-	3	0.0004	0.0002	0.0009	6
Silicon (Si)	mg/L	-	-	-	-	2.93	-	-	1	-	-	-	-	-	-	-	-
Silver (Ag)	mg/L	-	-	-	-	<0.002	-	-	1	<0.002	-	-	1	-	-	-	-
Strontium (Sr)	mg/L	-	-	-	-	0.108	-	-	1	0.094	-	-	1	-	-	-	-
Titanium (Ti)	mg/L	<0.05	-	-	3	-	<0.003	<0.01	2	-	0.009	<0.05	2	<0.05	-	-	1
Uranium (U)	mg/L	-	-	-	-	<0.5	-	-	1	-	-	-	-	-	-	-	-
Vanadium (V)	mg/L	<0.001	-	-	4	0.001	0.001	0.003	4	<0.001	-	-	4	0.001	<0.001	0.002	6
Zinc (Zn)	mg/L	0.0055	0.002	0.024	4	0.0015	0.001	0.054	4	0.001	<0.001	0.025	4	0.011	0.002	0.02	6
Metals (Dissolved)																	
Aluminum (Al)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antimony (Sb)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic (As)	mg/L	0.0005	<0.0002	0.005	11	0.0005	0.0003	0.0007	4	0.00025	0.0002	0.0006	6	-	<0.0002	0.0003	2
Barium (Ba)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Beryllium (Be)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boron (B)	mg/L	0.105	0.04	0.23	10	0.13	0.1	0.14	3	0.07	0.02	0.09	4	0.075	0.03	0.11	4
Cadmium (Cd)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromium (Cr)	mg/L	0.003	<0.003	0.005	11	0.005	<0.003	0.008	3	0.003	0.003	0.006	4	<0.003	-	-	4
Cobalt (Co)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copper (Cu)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron (Fe)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lead (Pb)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lithium (Li)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese (Mn)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury (Hg)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Molybdenum (Mo)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel (Ni)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium (Se)	mg/L	0.0002	<0.0002	0.0007	11	0.00035	<0.0002	0.0009	4	0.0002	<0.0002	0.0005	6	-	<0.0002	<0.0002	2
Silicon (Si)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver (Ag)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium (Sr)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Titanium (Ti)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uranium (U)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vanadium (V)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zinc (Zn)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trace Organics																	
PAHs and Alkylated PAHs	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PANHs	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenolics	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Volatile Organics	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

NOTES: - = No data; ND = Not detected; PAHs = Polycyclic Aromatic Hydrocarbons; PANHs = Polycyclic Aromatic Nitrogen Heterocycles

Table VII-4 Water Quality of the Steepbank River (1972-1997)

Parameter	Units	At Mouth																Lower Steepbank River																Upper Steepbank River					
		Winter				Spring				Summer				Fall				Winter				Spring				Summer				Fall				Spring		Summer		Fall	
		median	min.	max.	n	median	min.	max.	n	median	min.	max.	n	median	min.	max.	n	median	min.	max.	n	median	min.	max.	n	median	min.	max.	n	median	min.	max.	n		n		n		n
Field Parameters																																							
pH		8.37	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific Conductance	µS/cm	548	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	°C	0.3	-0.2	0.5	3	-	-	-	-	14	-	-	1	-	-	-	-	0	0	0.5	13	2	0.9	14	8	15.5	11	23.5	10	7.5	1.2	12	6	-	-	-	-	-	-	-	-
Dissolved Oxygen	mg/L	13.7	12.9	13.8	3	-	-	-	-	-	-	-	-	-	-	-	-	17.5	-	-	1	9.9	2.2	16	6	8.4	6.9	9.1	6	10	9.3	10.4	3	-	-	-	-	-	-	-	-
Conventional Parameters and Major Ions																																							
Bicarbonate	mg/L	371	370	374	3	105.5	65	146	6	109	109	110	3	105	77	134	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	120	1	97.2	1	129	1
Calcium	mg/L	61.5	60	62.4	4	20	13.3	28.8	6	25.9	22	44	6	25.9	17.1	34	7	64.5	32	76	19	17.15	11	62.5	8	21.4	15.8	33.8	10	22.5	17	32	8	22.3	1	22.5	1	18.5	1
Chloride	mg/L	7.5	6.5	7.8	6	2.95	0.6	3.1	6	1	0.8	7	9	1.2	<1	1.9	7	6.5	3	7.8	19	1.8	1.5	6.7	8	2.15	1	4.6	10	1.75	1.2	2.6	8	3.7	1	< 0.5	1	0.8	1
Colour	T.C.U.	35	20	95	6	100	90	105	3	100	-	-	1	120	120	120	3	32.5	15	110	6	120	-	-	1	-	70	120	2	-	140	180	2	-	-	-	-	-	-
Conductance	µS/cm	588	586	610	4	169	107	234	6	178	143	360	9	178	141	227	6	567	256	704	19	140	89	560	8	169.5	114	291	10	169	100	250	8	200	1	159	1	201	1
Dissolved Organic Carbon	mg/L	10.1	9	13.1	6	14.05	12	16.5	6	22.9	19.9	23.5	4	19.65	16	23.5	6	14.75	6.5	25	20	17	9	23	8	21.5	15.5	28	9	22	14.5	28	8	15.7	1	23.3	1	22.6	1
Hardness	mg/L	236	227	265	5	76.5	51	108	6	95.4	66.8	158	7	99.7	65	112	7	245.9	125.2	272.8	11	75.5	49.8	259	7	90.8	69.7	132	7	97.05	83.4	121.1	4	83.3	1	82.6	1	75.1	1
Magnesium	mg/L	19.05	18.7	22	4	6.45	4.2	8.7	6	7.2	5	9	8	6	5.3	8.8	7	20	11	24	19	5.45	3.4	25	8	6.7	4.9	11.5	10	6.6	5.3	10	8	6.7	1	6.4	1	7	1
pH	-	7.9	7.8	8.2	5	7.825	7.7	7.88	6	8	7.4	8.3	9	7.8	7.6	8.3	7	7.8	7.3	8.7	19	7.51	7	7.9	8	7.76	7.2	8.3	10	7.515	7.22	8.12	8	7.42	1	7.69	1	7.67	1
Potassium	mg/L	2	2	2.1	5	1.05	0.8	1.1	6	0.5	0.4	1.3	9	0.5	0.3	0.8	7	1.9	0.9	2.4	19	1.49	0.8	2.4	8	0.53	0.3	0.7	10	0.3	0.2	0.95	8	1.5	1	0.63	1	1.1	1
Sodium	mg/L	41.5	40	46	6	10	5	15.1	6	9	5	23	9	6	4	13.1	7	40	17.5	57.5	19	6.75	4.4	50	8	8.05	5.1	21.3	10	8.3	4.9	16.5	8	12.6	1	7.5	1	13	1
Sulphate	mg/L	12.7	10	14.2	6	4.45	4.2	8.3	6	4.2	2.1	31	9	5.3	5	10.1	7	12	6.8	16	19	5.9	3.6	14	8	6.1	3.8	9.4	10	4.85	1.9	7	8	4.8	1	1.6	1	9.5	1
Sulphide	mg/L	< 0.002	-	-	3	0.002	< 0.002	0.003	3	-	-	-	-	0.006	0.005	0.008	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Alkalinity	mg/L	306	303	330	5	86.5	53	120	6	89.6	65.7	189	9	109	63	126	7	314.4	148	362	19	68.45	43.8	337.6	8	85.4	59.9	163.8	10	89.4	62.4	142.4	8	98	1	79.7	1	106	1
Total Dissolved Solids	mg/L	350	330	360	3	125	70	135	6	99.8	99.5	118	4	126	100	140	6	353	0.38	436	18	88	56	379	8	114	84	191	10	104.5	74	165	8	111	1	87	1	115	1
Total Organic Carbon	mg/L	13	11	15	4	20	20	20	3	20.6	-	-	1	25	25	25	3	15	6.5	27	20	18	9.5	27	8	23	18.5	33	10	23	18	30.5	8	-	-	-	-	-	-
Total Suspended Solids	mg/L	3	<0.4	4	6	39	< 0.4	70	6	3	3	166	5	15.5	< 0.4	45	6	4.8	2	36	19	50.1	5.2	161	8	10	4	171	10	8.8	1.2	42.8	8	< 0.4	1	4	1	< 0.4	1
Nutrients																																							
Nitrate + Nitrite	mg/L	0.34	0.32	0.45	4	0.0275	< 0.003	0.07	6	0.1	< 0.03	0.16	8	0.05	0.003	0.034	7	-	-	-	-	-	-	-	-	1.29	-	-	1	-	-	-	-	0.003	1	< 0.03	1	0.004	1
Total Ammonia	mg/L	0.05	0.03	0.06	6	0.03	0.01	0.04	6	0.07	0.02	0.11	4	< 0.035	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	1	0.07	1	0.03	1
Total Kjeldahl Nitrogen	mg/L	0.75	0.34	0.9	6	1.1	1	1.1	3	-	0.62	1	2	0.2	0.015	0.5	3	0.765	0.54	1.64	18	0.95	0.42	1.22	7	0.96	0.36	2.1	9	1.1	0.56	2.28	8	-	-	-	-	-	-
Total Phosphorus	mg/L	0.05	0.04	0.05	3	0.0975	0.08	0.129	6	0.093	0.072	1.2	7	0.117	0.038	0.3	7	0.06	0.024	0.21	19	0.048	0.029	0.17	8	0.042	0.016	0.23	10	0.046	0.024	0.22	8	0.171	1	0.123	1	0.114	1
Dissolved Phosphorus	mg/L	< 0.02	-	-	3	0.03	0.02	0.03	3	0.02	0.02	0.03	3	0.019	0.018	0.5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General Organics and Toxicity																																							
Biochemical Oxygen Demand	mg/L	1	0.2	1	5	5	2	5	3	0.04	-	-	1	7	7	8	3	< 1	-	-	3	-	-	-	-	-	-	-	-	-	7	7	2	-	-	-	-	-	-
Chlorophyll *a*	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>100	1	>100	1	>100	1
Microtox IC50	%	>91	91	91	3	>100	91	100	4	99.5	95	100	6	>100	100	100	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>100	1	>100	1	>100	1
Microtox IC25	%	>91	91	91	3	>100	91	100	4	>100	100	100	3	>100	100	100	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>100	1	>100	1	>100	1
Naphthenic acids	mg/L	2	1	2	3	1.5	< 1	3	6	< 1	-	-	3	< 1	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 1	1	< 1	1	< 1	1
Total Phenolics	mg/L	0.004	<0.001	0.005	3	-	0.003	0.004	2	0.001	< 0.001	0.0012	7	0.001	0.001	0.002	7	0.01	-	-	1	<0.00 5	-	-	1	0.001	-	-	1	-	-	-	-	-	-	0.003	1	< 0.001	1
Recoverable Hydrocarbons	mg/L	< 1	-	-	3	< 0.75	-	-	6	< 1	-	-	3	< 0.85	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	1	< 1	1
Metals (Total)																																							
Aluminum (Al)	mg/L	0.12	0.013	0.143	5	0.67	< 0.01	1.8	6	0.04	0.02	0.029	4	0.4375	0.05	1.03	6	0.03	0.01	0.3	19	0.53	0.09	5.6	7	0.1	0.04	0.48	9	0.13	0.04	0.3	7	< 0.01	1	0.05	1	0.02	1
Antimony (Sb)	mg/L	0.0004	< 0.0004	0.0005	3	< 0.0003	-	-	6	< 0.0002	-	-	3	0.0004	< 0.0002	0.001	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.0002	1	0.0002	1	< 0.0002	1
Arsenic (As)	mg/L	0.0004	<0.0002	0.0006	5	0.0005	0.0003	0.001	6	0.0004	0.0004	0.0004	4	0.0007	0.0002	0.012	7	-	-	-	-	-	-	-	-	< 0.005	-	-	1	-	0.004	0.004	2	0.0004	1	0.0004	1	< 0.0002	1
Barium (Ba)	mg/L	0.0768	0.073	0.08	5	0.0371	0.0314	0.04	6	0.03	0.03	0.03	4	0.02845	0.023	0.03	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	1	0.03	1	0.02	1
Beryllium (Be)	mg/L	< 0.001	-	-	3	< 0.001	-	-	6	0.001	0.001	0.002	4	< 0.001	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.001	1	0.003	1	< 0.001	1
Boron (B)	mg/L	0.284	0.282	0.284	3	0.076	0.041	0.14	6	0.08	0.07	0.08	3	0.0575	0.024	0.1	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14	1	0.07	1	0.07	1
Cadmium (Cd)	mg/L	0.0002	< 0.0002	0.002	4	< 0.0016	-	-	6	0.002	<0.001	0.003	3	0.003	< 0.0002	0.004	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.003	1	0.005	1	< 0.003	1
Chromium (Cr)	mg/L	<0.0027	< 0.0004	0.005	4	0.0018	0.001	0.002	6	0.004	< 0.002	0.02	7	0.003	< 0.0004	0.014	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.002	1	0.005	1	0.003	1
Cobalt (Co)	mg/L	0.0005	< 0.0005	0.001	4	0.00195	0.0008	0.0009	6	< 0.002	-	-	6	0.003	0.0005	0.004	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.003	1	< 0.003	1	< 0.003	1
Copper (Cu)	mg/L	0.0017	0.0012	0.002	4	0.00215	< 0.001	0.0036	6	0.007	0.005	0.011	3	0.00135	0.0005	0.004	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.001	1	-	-	-	-
Iron (Fe)	mg/L	1.07	0.61	1.2	5	1.3	0.42	2.55	6	0.67	0.5	2.2	7	0.74	0.5	1.5	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.81	1	0.74	1	0.57	1
Lead (Pb)	mg/L	0.0033	0.0009	0.0103	3	0.01075	0.0012	0.0015	6	< 0.02	-	-	3	0.01055	0.0005	0.0011	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.02	1	< 0.02	1	< 0.02	1
Lithium (Li)	mg/L	0.027	0.027	0.028	3	0.0085	0.007	0.011	6	0.007	0.006	0.007	3	0.0075	0.006	0.009	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.006	1	0.006	1	0.009	1
Manganese (Mn)	mg/L	0.021	0.0209	0.0213	3	0.05065	0.034	0.0693	6	0.032	0.031	0.033	3	0.033	0.014	0.0567	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.028	1	0.046	1	0.014	1
Mercury (Hg)	mg/L	< 0.0002	-	-	5	< 0.0251	-	-	6	< 0.0012	-	-	7	< 0.001	-	-	7	0.0001	< 0.0001	0.0004	18	< 0.0001	-	-	5	0.0001	< 0.0001	0.0003	9	0.0001	< 0.0001	0.0006	8	< 0.05	1	< 0.05	1	< 0.05	1
Molybdenum (Mo)	mg/L	0.0006	0.0005	0.0006	3	0.0016	0.0002	0.002	6	< 0.003	-	-	3	0.0016	0.0002	0.0002	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.003	1	< 0.003	1	< 0.003	1
Nickel (Ni)	mg/L	0.0015	0.0014	0.0017	3	0.00285	0.0006	0.005	6	< 0.005	-	-	3	0.0035	0.0012	0.01	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.005	1	< 0.005	1	< 0.005	1
Selenium (Se)	mg/L	< 0.0004	-	-	5	< 0.0003	-	-	6	< 0.0002	-	-	4	0.00035	< 0.0002	0.0007	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.0002	1	0.0002	1	< 0.0002	1
Silicon (Si)	mg/L	6.14	6.04	6.15	3	2.73	1.13	5.04	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.29	1	-	-	-	-
Silver (Ag)	mg/L	< 0.001	-	-	3	< 0.0015	-	-	6	0.002	< 0.0001	0.003	4	< 0.00105	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.002	1	< 0.002	1	< 0.002	1
Strontium (Sr)	mg/L	0.291	0.286	0.293	3	0.0867	0.0623	0.11	6	0.089	0.089	0.09	3	0.078	0.0635	0.096	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.094	1	0.083	1	0.073	1
Sulphur (S)	mg/L	6.6	6.2	7.4	3	2.1	2.1	2.1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	1	-	-	-	-
Titanium (Ti)	mg/L	0.0053	0.0051	0.0054	3	0.00925	< 0.003	0.0205	6	< 0.003	-	-	3	0.0085	0.006	0.0144	6	< 0.05	-	-	3	< 0.01	-	-	4	-	-	-	-	-	< 0.05	< 0.05	2	< 0.003	1	< 0.003	1	0.005	1
Uranium (U)	mg/L	0.0002	0.0002	0.0002	3	0.25005	0.0001	0.0001	6	-	-	-	-	< 0.0001	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.5	1	-	-	-	-
Vanadium (V)	mg/L	0.0006	0.0005	<0.002	4	0.003	< 0.002	0.004	6	0.005	0.002	0.006	4	0.002	0.0017	0.003	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.004	1	0.004	1	< 0.002	1
Zinc (Zn)	mg/L	0.067	0.012	1.53	5	0.0195	0.013	0.092	6	0.025	0.006	0.07	7	0.016	0.008	0.025	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.162	1	0.029	1	0.012	1
Metals (Dissolved)																																							
Aluminum (Al)	mg/L	0.0058	0.0058	0.015	3	0.16	0.018	0.177	3	0.0188	0.0167	0.0232	3	0.0591	0.0413	0.0987	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antimony (Sb)	mg/L	0.0004	< 0.0004	0.0005	3	< 0.0004	-	-	3	0.0005	0.0005	0.0008	3	0.0007	0.0005	0.0007	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic (As)	mg/L	< 0.0004	-	-	3	0.0005	< 0.0004	0.0006	3	0.0005	0.0004	0.0005	3	0.0004	0.0004	0.0004	3	0.0006	< 0.0002	0.7	15	0.0005	< 0.0002	0.0024	8	0.0004	< 0.0002	0.0007	6	0.0005	< 0.0002	0.0021	4	-	-	-	-	-	-
Barium (Ba)	mg/L	0.0697	0.0696	0.0701	3	0.0227	0.0156	0.0232	3	0.0245	0.0236	0.047	3	0.0163	0.0163	0.0167	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Beryllium (Be)	mg/L	< 0.0005	-	-	4	< 0.0005	-	-	3	< 0.0005	-	-	3	< 0.0005	-	-	3	-	-	-	-	< 0.001	-	-	1	< 0.005	-	-	1	-	-	-	-	-	-	-	-	-	-
Boron (B)	mg/L	0.265	0.25	0.268	3	0.035	0.034	0.035	3	0.06	0.022	0.062	3	0.023	0.023	0.024	3	0.41	0.06	0.48	10	0.17	0.12	0.39	7	0.12	0.08	0.2	5	0.11	0.08	0.18	5	-	-	-	-	-	-
Cadmium (Cd)	mg/L	< 0.0001	-	-	3	< 0.0001	-	-	3	0.0007	0.0002	0.0012	3	0.0001	0.0001	0.0002	3	-	-	-	-	< 0.001	-	-	1	< 0.001	-	-	1	-	-	-	-	-	-	-	-	-	-
Chromium (Cr)	mg/L	< 0.0004	-	-	3	< 0.0004	-	-	3	< 0.0004	-	-	3	< 0.0004	-	-	3	0.003	< 0.003	0.007	16	0.003	< 0.003	0.01	7	0.003	< 0.003	0.009	6	0.003	< 0.003	0.007	7	-	-	-	-	-	-
Cobalt (Co)	mg/L	0.0001	0.0001	0.0001	3	0.0005	0.0003	0.0005	3	0.0004	0.0002	0.0008	3	0.0002	0.0002	0.0002	3	-	-	-	-	0.002	-	-	1	< 0.002	-	-	1	-	-	-	-	-	-	-	-	-	-
Copper (Cu)	mg/L	0.0008	0.0008	0.0011	3	0.002	0.0018	0.0046	3	0.0012	0.001	0.005	3	0.0009	0.0009	0.0013	3	-	-	-	-	0.003	-	-	1	0.001	-	-	1	-	-	-	-	-	-	-	-	-	-
Iron (Fe)	mg/L	< 0.01	-	-	3	1.08	0.38	1.12	3	0.39	0.1	0.42	3	0.29	0.28	0.29	3	-	-	-	-	0.33	-	-	1	0.34	-	-	1	-	-	-	-	-	-	-	-	-	-
Lead (Pb)	mg/L	0.00017	0.00008	0.0002	3	0.00076	0.00035	0.00102	3	0.00606	0.00213	0.0104	3	0.00059	0.00049	0.00209	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lithium (Li)	mg/L	0.024	0.022	0.024	3	0.005	0.004	0.005	3	0.009	0.007	0.009	3	0.005	0.005	0.005	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese (Mn)	mg/L	0.0003	0.0003	0.0008	3	0.0531	0.0127	0.0534	3	0.0241	0.0032	0.025	3	0.0179	0.0157	0.0181	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury (Hg)	mg/L	< 0.0002	-	-	3	< 0.0002	-	-	3	< 0.0002	-	-	3	< 0.0002	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Molybdenum (Mo)	mg/L	0.00051	0.00047	0.00054	3	0.00016	0.00013	0.00019	3	0.0002	0.00019	0.00068	3	0.00022	0.00021	0.00027	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel (Ni)	mg/L	0.0006	0.0006	0.0006	3	0.0015	0.001	0.002	3	0.0017	0.0006	0.0044	3	0.0008	0.0007	0.0015	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium (Se)	mg/L	< 0.0004	-	-	3	< 0.0004	-	-	3	< 0.0004	-	-	3	< 0.0004	-	-	3	0.0002	< 0.0002	0.0014	16	< 0.0002	-	-	8	0.0002	0.0002	0.002	6	< 0.0002	-	-	4	-	-	-	-	-	-
Silicon (Si)	mg/L	5.07	4.91	5.11	3	1.49	1.28	1.5	3	2.2	2.14	2.3	3	2.7	2.4	2.8	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver (Ag)	mg/L	< 0.0002	-	-	3	< 0.0002	-	-	3	< 0.0002	-	-	3	< 0.0002	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium (Sr)	mg/L	0.239	0.239	0.239	3	0.0543	0.0522	0.0547	3	0.0887	0.0866	0.148	3	0.0589	0.0584	0.0589	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Titanium (Ti)	mg/L	0.0004	0.0004	0.0005	3	0.0017	< 0.0003	0.002	3	0.0005	0.0004	0.0005	3	0.0007	< 0.0003	0.0008	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uranium (U)	mg/L	0.00023	0.00022	0.00024	3	0.00007	< 0.00005	0.00008	3	0.00007	< 0.00005	0.0003	3	< 0.00005	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vanadium (V)	mg/L	< 0.0001	-	-	3	0.0007	0.0001	0.0008	3	0.0001	< 0.0001	0.0002	3	< 0.0001	-	-	3	-	-	-	-	< 0.001	-	-	1	< 0.001	-	-	1	-	-	-	-	-	-	-	-	-	-
Zinc (Zn)	mg/L	0.006	0.004	0.008	3	0.009	0.008	0.015	3	0.028	0.018	0.03	3	0.013	0.007	0.014	3	-	-	-	-	< 0.001	-	-	1	< 0.001	-	-	1	-	-	-	-	-	-	-	-	-	-
Trace Organics																																							
PAHs and Alkylated PAHs	µg/L	ND	-	-	3	ND	-	-	2	ND	-	-	2	ND	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PANHs	µg/L	ND	-	-	3	ND	-	-	2	ND	-	-	2	ND	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenolics	µg/L	ND	-	-	3	ND	-	-	2	ND	-	-	2	ND	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Volatile organics	µg/L	-	-	-	-	ND	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

NOTES: - = No data; ND = Not Detected; PAHs = Polycyclic Aromatic Hydrocarbons

Table VII-5 Sediment Quality in the Athabasca, Muskeg, Steepbank and MacKay Rivers, and in Jackpine and Poplar Creeks (1997)

Parameter	Units	Athabasca River at Donald Creek	Athabasca River at Fort Creek (Replicate 1)	Athabasca River at Fort Creek (Replicate 2)	Muskeg River at Mouth	Muskeg River upstream Jackpine Creek	Steepbank River at Mouth	MacKay River at Mouth	Jackpine Creek at Mouth	Poplar Creek at Mouth
Total Organic Carbon	%	0.67	2.98	1.67	2.98	4.5	0.86	1.37	2.0	1.82
Recoverable Hydrocarbons	mg/kg	423	1080	1300	3440	3690	10100	4180	5660	6670
Metals										
Aluminum (Al)	mg/kg	10700	8160	7420	2970	5820	2070	5650	3060	5330
Barium (Ba)	mg/kg	168	147	142	40.1	118	27.1	70.0	34.4	76.2
Beryllium (Be)	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium (Cd)	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium (Ca)	mg/kg	17500	18400	18700	50600	5650	2590	7690	2380	9210
Chromium (Cr)	mg/kg	19.0	22.9	17.4	6.9	12.3	5.5	12.9	7.8	12.7
Cobalt (Co)	mg/kg	7	7	7	3	4	3	5	2	5
Copper (Cu)	mg/kg	15	15	15	7	10	7	11	7	11
Iron (Fe)	mg/kg	15000	15500	15500	11200	23000	6800	14400	5430	10200
Lead (Pb)	mg/kg	9	8	8	<5	<5	<5	6	<5	6
Magnesium (Mg)	mg/kg	5680	6340	6390	3240	1390	1410	4270	855	3110
Manganese (Mn)	mg/kg	381	380	384	373	620	102	302	124	210
Molybdenum (Mo)	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nickel (Ni)	mg/kg	16	21	17	6	9	7	12	6	13
Potassium (K)	mg/kg	1990	1470	1320	741	744	454	1380	520	1140
Silver (Ag)	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sodium (Na)	mg/kg	244	140	134	<100	121	<100	119	<100	119
Strontium (Sr)	mg/kg	52	53	53	75	27	11	34	16	33
Sulphur (S)	mg/kg	1540	1930	1970	2530	2780	1030	1750	1080	1440
Thallium (Tl)	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tin (Sn)	mg/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5
Titanium (Ti)	mg/kg	54	20	16	17	19	11	15	18	10
Vanadium (V)	mg/kg	28	19	18	9	16	7	16	11	13
Zinc (Zn)	mg/kg	53.0	58.0	56.8	26.4	37.9	22.0	44.3	22.2	36.2
Antimony (Sb)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (As)	mg/kg	5.6	5.1	5.1	1.0	2.4	2.1	4.5	1.2	3.1
Mercury (Hg)	mg/kg	0.05	0.05	0.06	0.04	0.04	0.03	0.05	0.03	0.05
Selenium (Se)	mg/kg	0.8	0.5	0.5	<0.1	0.6	0.1	0.3	0.1	0.3
PAHs and Alkylated PAHs										
Naphthalene	µg/g	<0.01	0.005	0.006	<0.003	0.003	<0.003	0.008	<0.003	0.006
Acenaphthylene	µg/g	<0.01	<0.003	<0.003	<0.003	0.004	0.008	0.004	<0.003	<0.003
Acenaphthene	µg/g	<0.01	<0.003	<0.003	<0.003	<0.003	0.012	0.016	<0.003	<0.003
Fluorene	µg/g	<0.01	<0.003	0.004	<0.003	<0.003	0.005	0.011	<0.003	<0.003
Dibenzothiophene	µg/g	<0.01	<0.003	0.19	<0.003	0.005	0.020	0.022	0.005	0.006
Phenanthrene	µg/g	0.01	0.012	0.012	0.007	0.009	0.020	0.080	<0.003	0.015
Anthracene	µg/g	<0.01	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003
Fluoranthene	µg/g	<0.01	0.006	0.005	0.003	0.006	0.023	0.022	0.004	0.005
Pyrene	µg/g	<0.01	0.011	0.008	0.012	0.015	0.072	0.047	0.006	0.010
Benzo(a)anthracene/Chrysene	µg/g	0.02	0.027	0.023	0.035	0.057	0.17	0.11	0.034	0.025
Benzo(b&k)fluoranthene	µg/g	0.01	0.018	0.018	0.014	0.034	0.076	0.053	0.023	0.023
Benzo(a)pyrene	µg/g	<0.01	0.006	0.006	0.013	0.016	0.097	0.023	0.015	0.007
Indeno(c,d-123)pyrene	µg/g	<0.01	0.006	0.005	0.006	0.009	0.008	0.010	<0.003	0.010
Dibenzo(a,h)anthracene	µg/g	<0.01	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Benzo(ghi)perylene	µg/g	<0.01	0.007	0.006	0.012	0.010	0.017	0.017	0.010	0.012
Methyl naphthalene	µg/g	<0.02	0.015	0.015	<0.003	<0.003	<0.003	0.006	<0.003	0.019
C2 sub'd naphthalene	µg/g	0.02	0.03	0.04	<0.02	0.03	0.02	0.06	0.02	0.05
C3 sub'd naphthalene	µg/g	0.03	0.06	0.05	0.04	0.03	0.19	0.42	0.04	0.05
C4 sub'd naphthalene	µg/g	<0.02	0.06	0.05	0.06	0.16	0.66	0.75	0.09	0.05
Biphenyl	µg/g	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Methyl biphenyl	µg/g	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
C2 sub'd biphenyl	µg/g	<0.02	<0.02	<0.02	<0.02	<0.02	0.09	<0.02	<0.02	0.02
Methyl acenaphthene	µg/g	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	0.04	<0.02	<0.02
Methyl fluorene	µg/g	<0.02	<0.02	<0.02	<0.02	0.02	0.04	0.08	0.02	<0.02
C2 sub'd fluorene	µg/g	<0.02	0.04	0.05	0.06	0.15	0.33	0.43	0.08	0.06
Methyl phenanthrene/anthracene	µg/g	<0.02	0.03	0.02	0.04	0.09	0.15	0.28	0.08	0.02
C2 sub'd phenanthrene/anth.	µg/g	0.03	0.12	0.12	0.10	0.26	1.4	1.3	0.19	0.13
C3 sub'd phenanthrene/anth.	µg/g	0.04	0.14	0.13	0.18	0.60	1.8	1.2	0.21	0.16
C4 sub'd phenanthrene/anth.	µg/g	0.04	0.05	0.09	0.11	0.21	1.3	0.82	0.10	0.08
Methyl dibenzothiophene	µg/g	<0.02	0.03	0.02	<0.02	0.03	0.19	0.31	0.03	0.03
C2 sub'd dibenzothiophene	µg/g	0.02	0.10	0.09	0.11	0.30	1.2	1.2	0.15	0.11
C3 sub'd dibenzothiophene	µg/g	0.04	0.20	0.20	0.21	0.58	2.0	1.4	0.25	0.20
C4 sub'd dibenzothiophene	µg/g	0.05	<0.02	<0.02	0.24	0.56	2.5	1.8	0.28	0.29
Methyl fluoranthene/pyrene	µg/g	0.03	0.05	0.04	0.07	0.07	0.35	0.25	0.03	0.05
Methyl B(a)A/chrysene	µg/g	0.03	0.03	0.04	0.07	0.12	0.38	0.25	0.05	0.05
C2 sub'd B(a)A/chrysene	µg/g	0.05	0.09	0.08	0.13	0.20	0.68	0.40	0.09	0.09
Methyl B(b&k)F/B(a)P	µg/g	0.03	0.03	0.04	0.09	0.12	0.24	0.15	0.12	0.02
C2 sub'd B(b&k)F/B(a)P	µg/g	0.03	0.03	0.04	0.10	0.19	0.26	0.11	0.10	0.06

NOTE: PAHs = Polycyclic Aromatic Hydrocarbons

APPENDIX VIII

BENTHIC INVERTEBRATE DATA

PLANT SPECIES LIST

Plant Species List

Common Name	Latin Name
tickle grass	*Agrostis scabra*
slender wheat grass	*Agropyron trachycaulum*
broad-leaved water plantain	*Alisma plantago-aquatica*
river alder	*Alnus rugosa*
arum-leaved arrowhead	*Sagittaria cuneata*
bearberry, kinnickinnick	*Arctostaphylos uva-ursi*
flat-leaved bladderwort	*Utricularia intermedia*
common bladderwort	*Utricularia vulgaris*
blueberry	*Vaccinium myrtilloides*
blue joint, marsh reed grass	*calamagrostis candensis*
sedge	*Carex Spp.*
chickweed, starwort	*Stellaria spp.*
mouse-eared chickweed	*Cerastium spp.*
coontail, hornwort	*Ceratophyllum demersum*
cow parsnip	*Heracleum lanatum*
common duckweed	*Lemnaceae minor*
purple-leaved willowherb	*Epilobium glandulosum*
common scouring rush	*Equisetum hyemale*
northern bedstraw	*Galium boreale*
high bush cranberry, pembina	*Viburnum trilobum*
wire rush	*Juncus balticus*
rush	*Juncus spp.*
Labrador tea	*Ledum groenlandicum*
leather leaf	*Chamaedaphne calyculata*
low bush cranberry, mooseberry	*Viburnum edule*
marsh cinquefoil	*Potentilla palustris*
marsh skullcap	*Scutellaria galericulata*
spiked water-milfoil	*Myriophyllum spicatum var. exalbescens*
small yellow pond lily	*Nuphur variegatum*
showy yellow pond lily	*Nuphur polysepalum*
rat root, sweet flag	*Acorus calamus*
beaked willow, Bebb's willow	*Salix bebbiana*
long-spiked smartweed	*Polygonum coccineum*
pale persicaria, dockweed smartweed	*Polygonum lapathifolium*
narrow leaved bur-weed	*Sparganium angusfolium*
giant bur-reed	*Sparganium eurycarpum*
tamarack	*Larix laricina*
tufted loosestrife	*Lysimachia thyrsiflora*
twin flower	*Linnaea borealis*
common cattail	*Typha latifolia*
white water-crowfoot	*Ranunculus aquatilis var. capillaceus*
yellow water-crowfoot	*Ranunculus gmelinii*
water arum	*Calla palustris*
water-hemlock	*Cicuta maculata ver. angustifolia*
water parsnip	*Sium suave*
white water-lily	*Nymphaea tetragona*
wild mint	*Mentha arvensis*
yellow water-crowfoot	*Ranunculus gmelinii*
small yellow pond lily	*Nuphur variegatum*
clasping-leaf pondweed	*Potamogeton perfoliatus*
Richardson's pondweed	*Potamogeton perfoliatus var. richardsonii*
various leaved pondweed, grass leaved pondweed	*Potamogeton gramineus*

Table VIII-1 Benthic Invertebrate Data (numbers reported on the basis of the bottom area of the Ekman grab [0.023 m^2]) (Page 1 of 2)

Major Taxon	Family	Subfamily/Tribe	Genus/Species	B3-1	B3-2	B3-5	B3-6	B3-7	B3-8	B1-2,3, 4,6,8,9	B2-1,2, 3,4,6,8	B4-1,2, 3,4,7,8	B5-4,5, 6,7,8,9	B6-1,2, 3,4,6,9	A1-1	A1-2	A1-3	A1-5	A1-6	A1-9	A2-2,3, 4,5,7,8
Nematoda	-	-	-	4	5	3	16	8	0	57	6	18	8	0	49	34	40	38	88	81	72
Oligochaeta	Enchytraeidae	-	-	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Naididae	-	-	0	0	0	2	4	0	5	3	16	4	0	0	16	0	16	8	16	20
	Tubificidae	-	-	3	5	6	0	1	7	3	8	2	4	0	0	14	0	3	3	9	12
Pelecypoda	Sphaeriidae	-	*Pisidium*	1	1	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Hydracarina	-	-	-	0	0	1	0	0	0	0	0	0	0	0	0	0	8	0	0	0	8
Cladocera	-	-	-	0	0	0	0	0	0	0	0	0	0	0	4	32	4	24	12	12	24
Copepoda	-	-	-	0	0	0	0	0	0	1	0	30	28	0	9	0	0	8	0	16	0
Ostracoda	-	-	-	12	4	0	0	0	0	6	0	8	12	1	4	8	0	8	0	10	0
Ephemeroptera	-	-	(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ephemeridae	-	*Hexagenia limbata*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Ephemerellidae	-	*Ephemerella*	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ametropodidae	-	*Ametropus neavei*	0	1	1	0	1	1	1	0	0	0	0	1	0	4	0	18	2	0
	Heptageniidae	-	(d)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Plecoptera	Pteronarcydae	-	*Pteronarcys*	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Perlodidae	-	*Isoperla*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Capniidae	-	(d)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Perlodidae	-	(d)	0	0	0	1	0	0	0	0	0	16	0	0	0	0	3	0	0	4
Trichoptera	Hydroptilidae	-	(p)	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Brachycentridae	-	*Brachycentrus*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Hydropsychidae	-	*Hydropsyche*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Limnephilidae	Limnephilini	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anisoptera	Gomphidae	-	*Gomphus*	0	0	0	1	1	1	1	1	0	0	0	1	0	0	2	0	1	0
		-	*Ophiogomphus*	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Corduliidae	-	*Epitheca*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemiptera	Corixidae	-	*Callicorixa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Diptera	-	-	(t)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-	-	(d)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ceratopogonidae	-	*Dasyhelea*	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
		Ceratopogoninae	-	0	0	0	1	0	0	0	0	2	0	0	2	0	0	6	0	2	8
	Dolichopodidae	-	*Rhaphium*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Empididae	-	*Hemerodromia*	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	Chironomidae	-	(p)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Prodiamesinae	*Monodiamesa*	1	1	0	2	0	0	9	1	8	15	0	1	1	0	1	0	5	4
		Diamesinae	*Potthastia*	0	0	0	0	0	0	0	0	0	0	0	0	4	0	8	0	0	0
		Tanypodinae	*Ablabesmyia*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4	0	2	0
			Procladius	0	0	0	2	0	0	0	0	4	0	0	5	30	3	22	6	7	8
		Chironomini	(d)	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
			Chironomus	0	0	0	1	0	0	0	0	36	3	0	0	6	0	0	0	2	0
			Cryptochironomus	0	3	0	2	1	0	0	2	0	1	0	1	0	0	0	1	0	0
			Demicryptochironomus	0	2	0	1	0	0	1	0	2	0	0	0	0	0	0	1	0	0
			Harnischia complex*	0	28	1	13	0	0	20	12	58	121	3	15	102	20	49	48	62	64
			Paratendipes	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
			Paralauterborniella	0	0	0	6	0	0	6	8	18	20	0	55	80	56	80	31	44	32
			Phaenopsectra	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
			Polypedilum	670	757	141	573	214	314	120	222	294	257	1	212	514	150	556	304	153	696
			Stenochironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
			Stictochironomus	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		Tanytarsini	*Micropsectra*	0	1	0	1	0	0	0	0	18	4	0	1	8	0	13	0	9	8
			Rheotanytarsus	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	2	0
			Stempellinella	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Orthocladiinae	(d)	0	0	0	0	0	0	0	0	0	0	0	1	6	0	1	5	4	0
			Rheosmittia	0	0	0	0	0	0	0	0	0	4	416	0	0	0	0	0	0	0
			Brillia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total				694	810	155	625	231	328	241	269	514	499	426	370	856	285	845	525	439	960

Table VIII-1 Benthic Invertebrate Data (numbers reported on the basis of the bottom area of the Ekman grab [0.023 m^2]) (Page 2 of 2)

Major Taxon	Family	Subfamily/Tribe	Genus/Species	A3-2,4, 6,7,8,9	A4-3,4, 5,6,8,9	A5-1,3, 5,6,7,8	A6-3,4, 5,7,8,9
Nematoda	-	-	-	4	2	8	6
Oligochaeta	Enchytraeidae	-	-	0	0	0	0
	Naididae	-	-	6	6	24	4
	Tubificidae	-	-	74	14	10	8
Pelecypoda	Sphaeriidae	-	*Pisidium*	0	0	0	0
Hydracarina	-	-	-	6	0	0	0
Cladocera	-	-	-	10	2	0	0
Copepoda	-	-	-	2	0	0	0
Ostracoda	-	-	-	0	0	2	0
Ephemeroptera	-	-	(d)	0	0	0	0
	Ephemeridae	-	*Hexagenia limbata*	0	0	0	0
	Ephemerellidae	-	*Ephemerella*	0	0	2	0
	Ametropodidae	-	*Ametropus neavei*	0	0	2	0
	Heptageniidae	-	(d)	0	0	0	0
Plecoptera	Pteronarcydae	-	*Pteronarcys*	0	2	0	0
	Perlodidae	-	*Isoperla*	0	0	0	0
	Capniidae	-	(d)	0	0	0	0
	Perlodidae	-	(d)	0	0	0	4
Trichoptera	Hydroptilidae	-	(p)	0	0	0	0
	Brachycentridae	-	*Brachycentrus*	0	0	0	0
	Hydropsychidae	-	*Hydropsyche*	0	0	2	0
	Limnephilidae	Limnephilini	-	0	0	0	2
Anisoptera	Gomphidae	-	*Gomphus*	0	0	0	2
		-	*Ophiogomphus*	0	0	2	2
	Corduliidae	-	*Epitheca*	0	0	0	2
Hemiptera	Corixidae	-	*Callicorixa*	0	4	2	16
Diptera	-	-	(t)	0	0	0	0
	-	-	(d)	0	0	0	0
	Ceratopogonidae	-	*Dasyhelea*	0	0	0	0
		Ceratopogoninae	-	0	4	16	6
	Dolichopodidae	-	*Rhaphium*	0	0	0	0
	Empididae	-	*Hemerodromia*	0	0	0	0
	Chironomidae	-	(p)	0	0	0	0
		Prodiamesinae	*Monodiamesa*	2	0	0	0
		Diamesinae	*Potthastia*	0	0	0	0
		Tanypodinae	*Ablabesmyia*	2	0	0	2
			Procladius	0	0	4	0
		Chironomini	(d)	0	0	0	0
			Chironomus	0	0	0	0
			Cryptochironomus	0	0	0	0
			Demicryptochironomus	0	0	0	0
			Harnischia complex*	14	0	10	4
			Paratendipes	0	0	0	0
			Paralauterborniella	4	8	14	8
			Phaenopsectra	0	0	0	0
			Polypedilum	102	28	34	4
			Stenochironomus	0	0	0	0
			Stictochironomus	0	0	0	0
		Tanytarsini	*Micropsectra*	0	0	0	0
			Rheotanytarsus	0	0	0	0
			Stempellinella	0	0	0	0
		Orthocladiinae	(d)	0	0	0	0
			Rheosmittia	28	0	0	2
			Brillia	0	0	0	0
Total				254	70	132	72

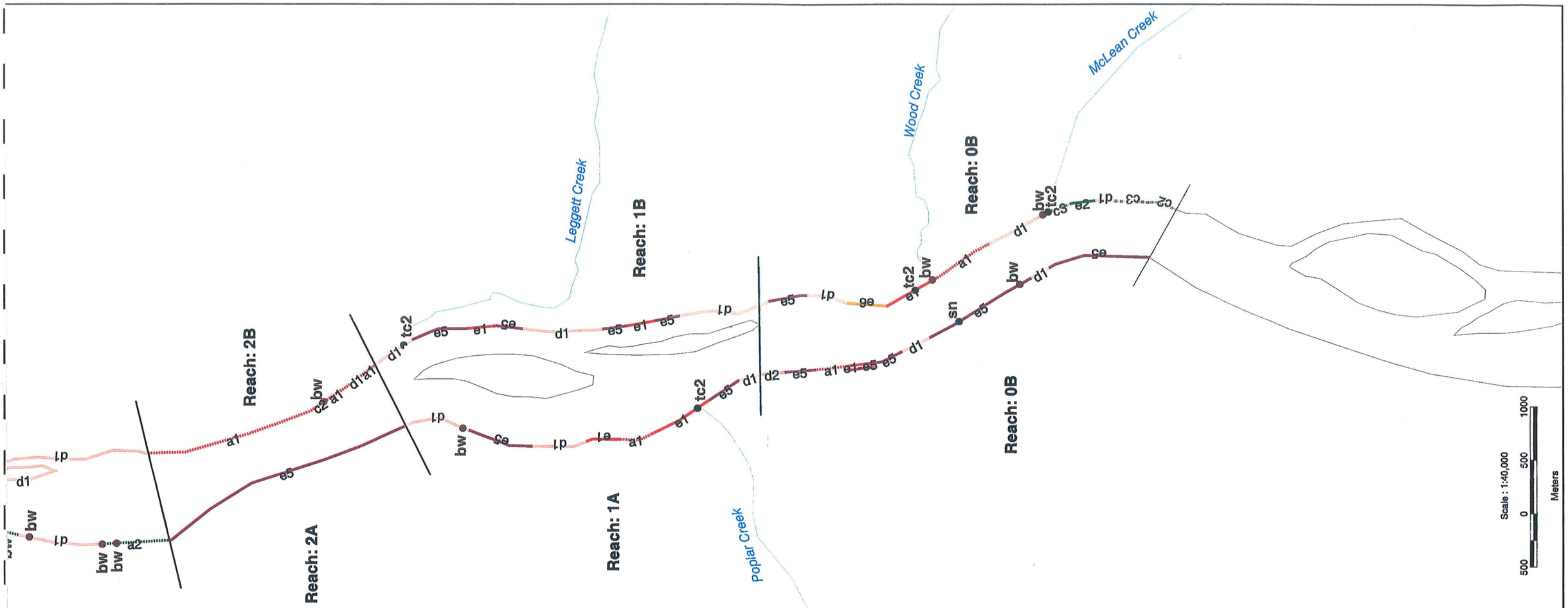
Table VIII-2 QA/QC results for re-sorted benthic invertebrate samples

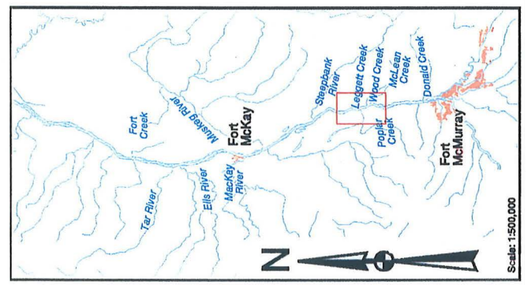
Major Taxon	Family	Subfamily/Tribe	B3-5		A1-9		A2-2,3,4,5,7,8
			Coarse	Fine	Coarse	Fine	Coarse+Fine
Nematoda	-	-	0	1	0	1	1
Oligochaeta	Naididae	-	0	0	0	0	1
Hydracarina	-	-	0	0	0	1	0
Diptera	Chironomidae	(damaged)	0	0	1	0	0
		Tanypodinae	0	0	1	0	0
		Chironomini	1	5	0	2	1
		Tanytarsini	0	0	0	0	0
		Orthocladiinae	0	0	0	0	0
Total recovered			1	6	2	4	3
Total in sample			155		439		960
% recovered			4.3		3.9		7.0
Sorting efficiency (%)			95.7		96.1		93.0

NOTE: Numbers of recovered organisms were multiplied by the subsampling factor to calculate % recovered

APPENDIX IX

ATHABASCA RIVER HABITAT MAPS, 1997





- 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
- sn snye
- bw backwater area

Reaches: 0,1,4,5,6,10, 11,12,16,17
Last update: 1997

Reaches: 2,8,9,13,14,15
Last update: 1996

Reaches: 3,7
Last update: 1995

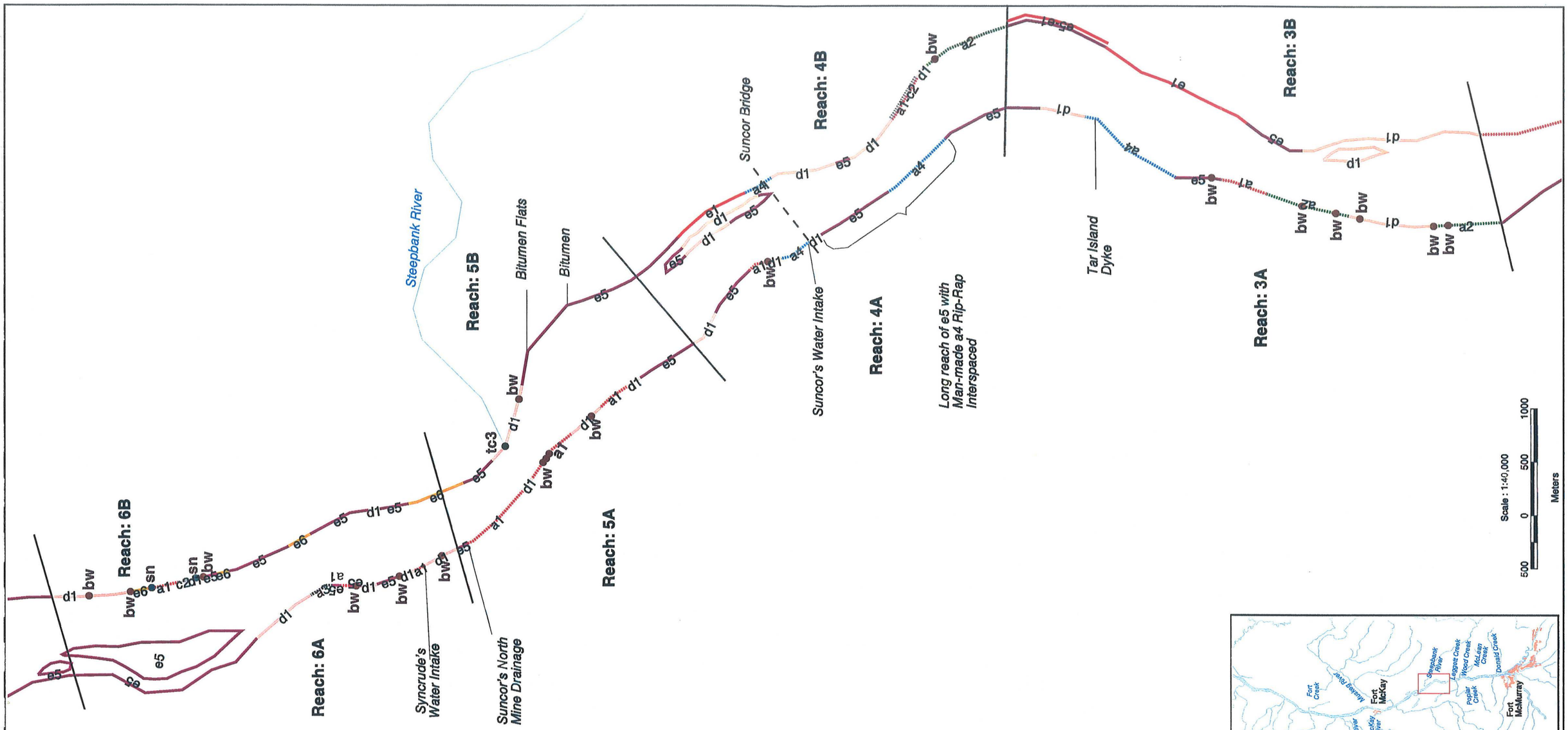
Source: Golder 1996a, 1996b, Present Report

Map Projection: UTM 12
Datum: NAD 83

Golder Associates

ATHABASCA RIVER RAMP HABITAT MAP

26 Jan. 1998	Figure IX-1	Produced by: R.P/K.Q. 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

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

Reaches: 0,1,4,5,6,10, 11,12,16,17
Last update: 1997

Reaches: 2,8,9,13,14,15
Last update: 1996

Reaches: 3,7
Last update: 1995

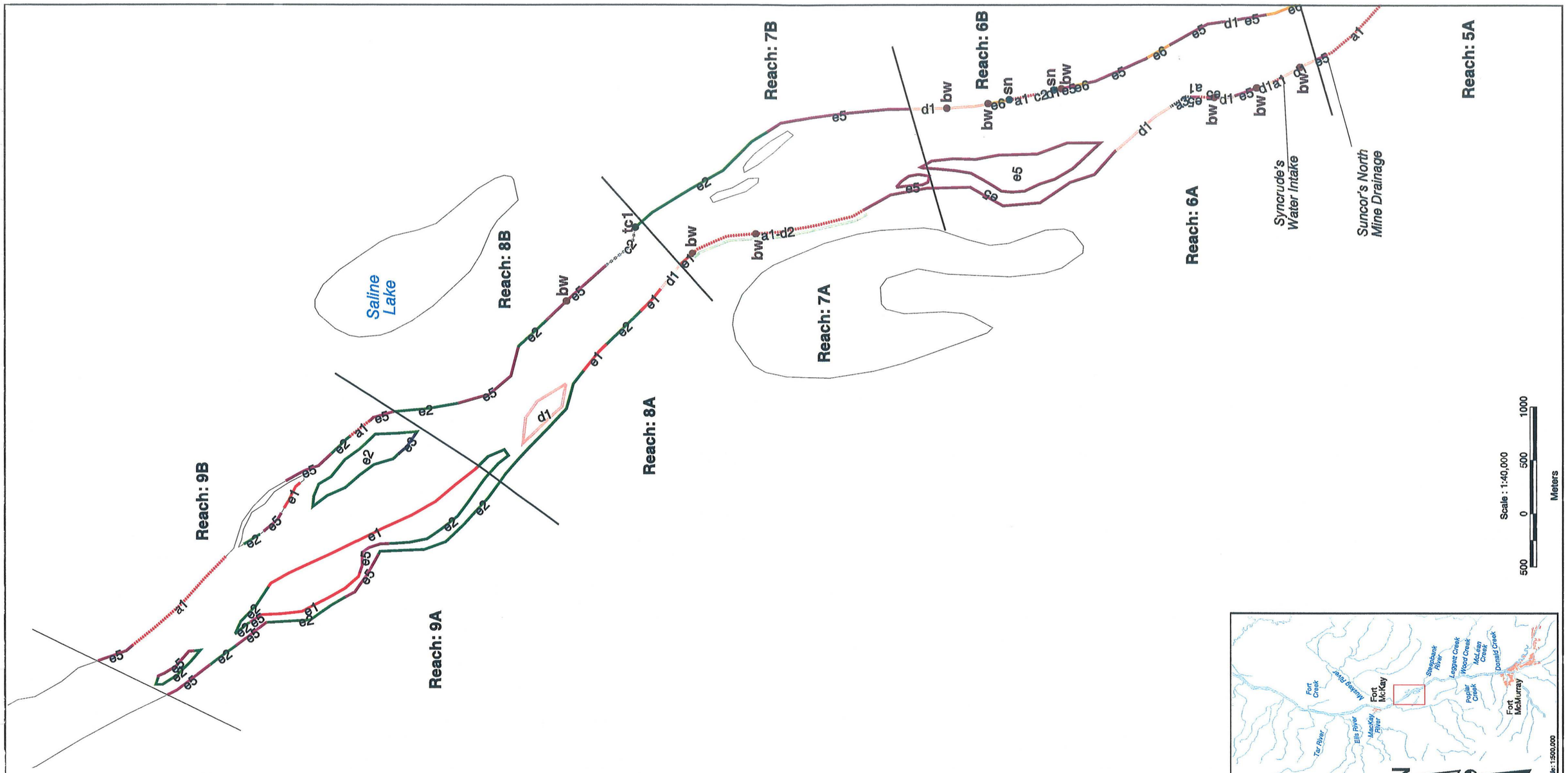
Source: Golder 1996a, 1996b, Present Report

Map Projection: UTM 12
Datum: NAD 83

Golder Associates

ATHABASCA RIVER RAMP HABITAT MAP

26 Jan. 1998	Figure IX-2	Produced by: R.P/K.Q. 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

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

Reaches: 0,1,4,5,6,10, 11,12,16,17
Last update: 1997

Reaches: 2,8,9,13,14,15
Last update: 1996

Reaches: 3,7
Last update: 1995

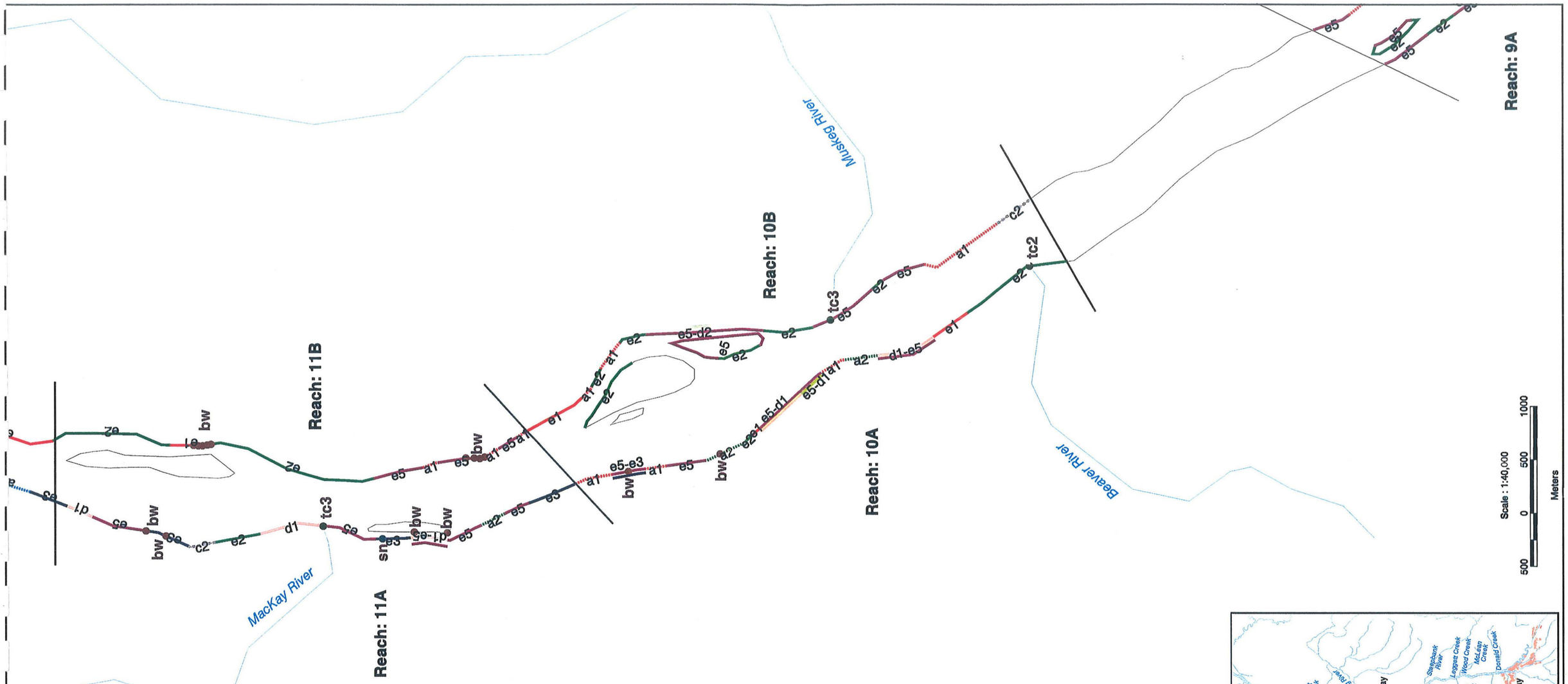
Source: Golder 1996a, 1996b, Present Report

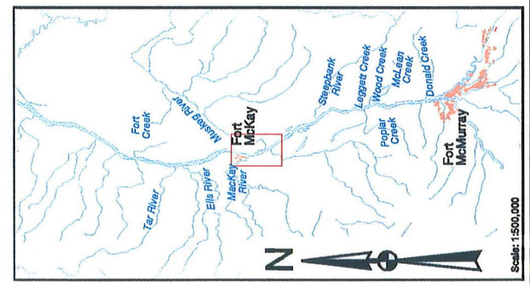
Map Projection: UTM 12
Datum: NAD 83

Golder Associates

ATHABASCA RIVER RAMP HABITAT MAP

26 Jan. 1998	Figure IX-3	Produced by: R.P/K.Q. 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

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

Reaches: 0,1,4,5,6,10, 11,12,16,17
Last update: 1997

Reaches: 2,8,9,13,14,15
Last update: 1996

Reaches: 3,7
Last update: 1995

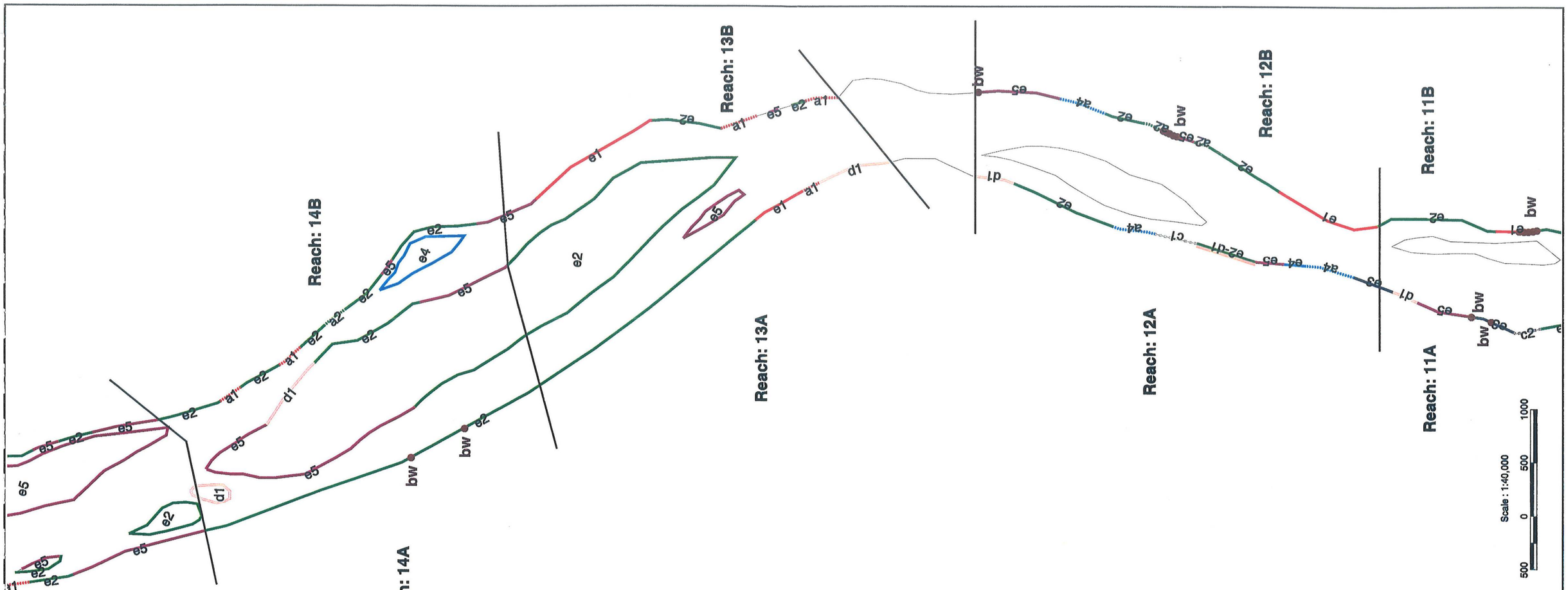
Source: Golder 1996a, 1996b, Present Report

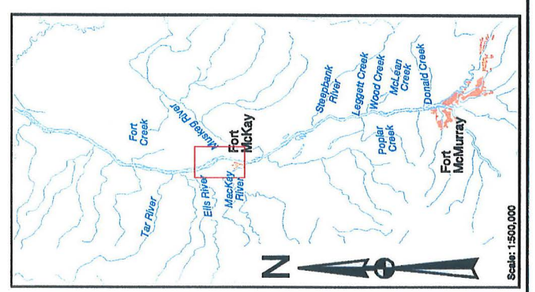
Map Projection: UTM 12
Datum: NAD 83

Golder Associates

ATHABASCA RIVER RAMP HABITAT MAP

26 Jan. 1998	Figure IX-4	Produced by: R.P/K.Q. 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

- tc confluence area of tributary
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  - tc2 - flowing, width < 5m
  - tc3 - flowing, width 5-15m
- sn snye
- bw backwater area

Reaches: 0,1,4,5,6,10, 11,12,16,17
Last update: 1997

Reaches: 2,8,9,13,14,15
Last update: 1996

Reaches: 3,7
Last update: 1995

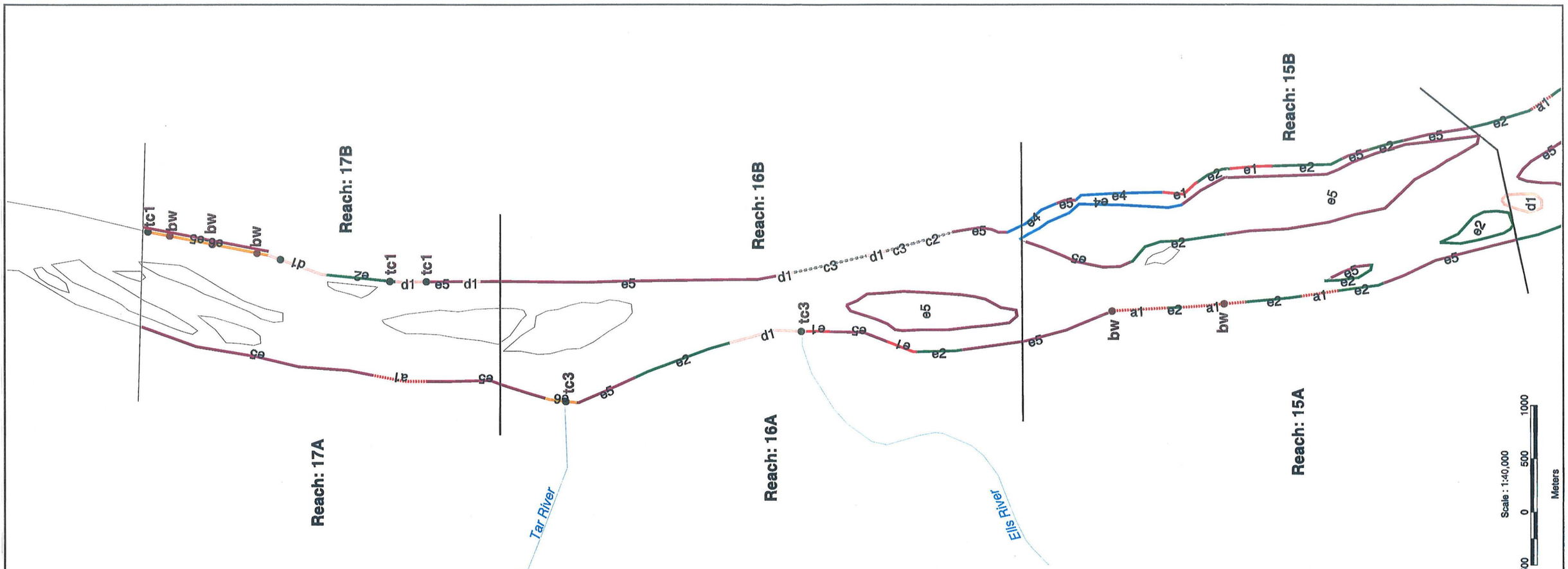
Source: Golder 1996a, 1996b, Present Report

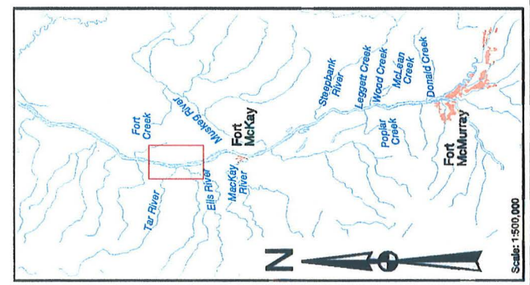
Map Projection: UTM 12
Datum: NAD 83

Golder Associates

ATHABASCA RIVER RAMP HABITAT MAP

26 Jan. 1998	Figure IX-5	Produced by: R.P/K.Q. 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
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- tc confluence area of tributary
  - tc1 - intermittent flow
  - tc2 - flowing, width < 5m
  - tc3 - flowing, width 5-15m
- sn snye
- bw backwater area

Reaches: 0,1,4,5,6,10, 11,12,16,17
Last update: 1997

Reaches: 2,8,9,13,14,15
Last update: 1996

Reaches: 3,7
Last update: 1995

Source: Golder 1996a, 1996b, Present Report

Map Projection: UTM 12
Datum: NAD 83

Golder Associates

ATHABASCA RIVER RAMP HABITAT MAP

26 Jan. 1998	Figure IX-6	Produced by: R.P/K.Q. Reviewed by:

APPENDIX X

INDIVIDUAL WALLEYE AND LAKE WHITEFISH RADIOTELEMETRY LOCATIONS, ATHABASCA RIVER, 1997

J:\1997\2320\6050\WALLEY10.dwg

LEGEND

Frequency (MHz): 150.104
Tagged and Released: October 3/97
Fork Length(mm): 468
Weight(g): 1070
Stage:UN
Reconnaissance Results:
R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

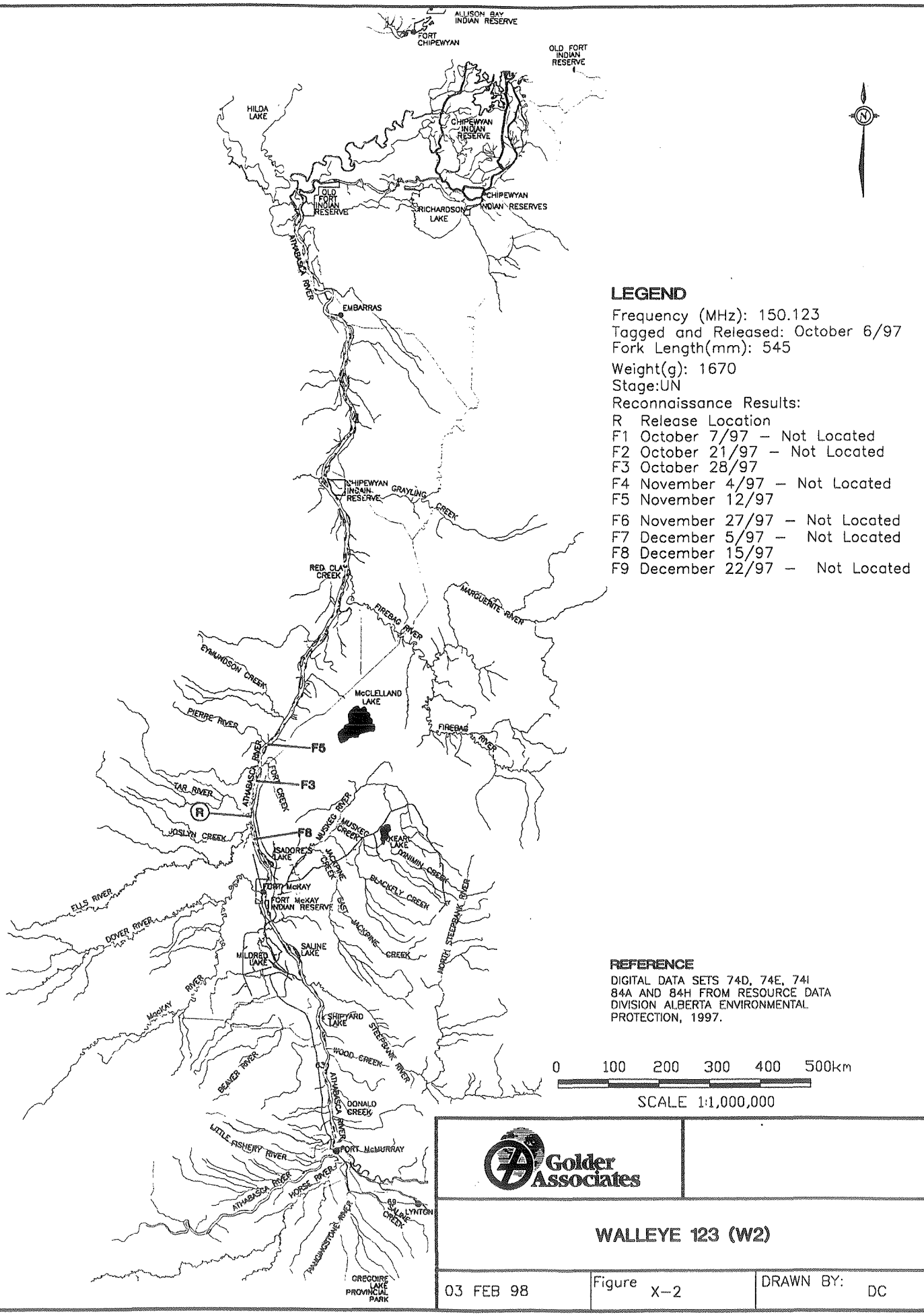
SCALE 1:1,000,000

Golder Associates

WALLEYE 104 (W1)

03 FEB 98	Figure X–1	DRAWN BY: DC

J:\1997\2320\6050\WALLEY12.dwg



LEGEND

Frequency (MHz): 150.123
Tagged and Released: October 6/97
Fork Length(mm): 545
Weight(g): 1670
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

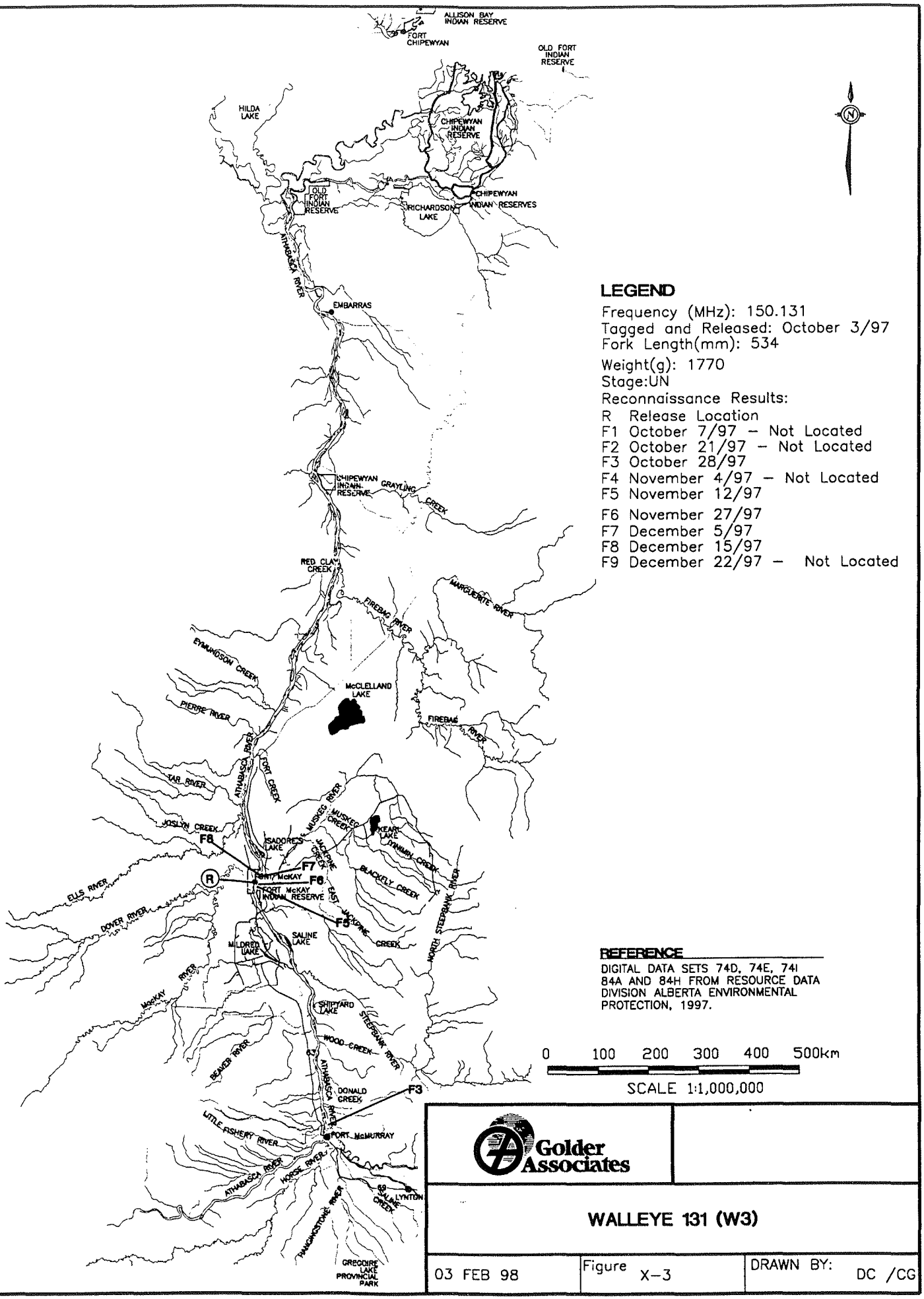
SCALE 1:1,000,000

Golder Associates

WALLEYE 123 (W2)

03 FEB 98	Figure X–2	DRAWN BY: DC

J:\1997\2320\6050\WALLEY13.dwg



LEGEND

Frequency (MHz): 150.131
Tagged and Released: October 3/97
Fork Length(mm): 534
Weight(g): 1770
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97
F7 December 5/97
F8 December 15/97
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

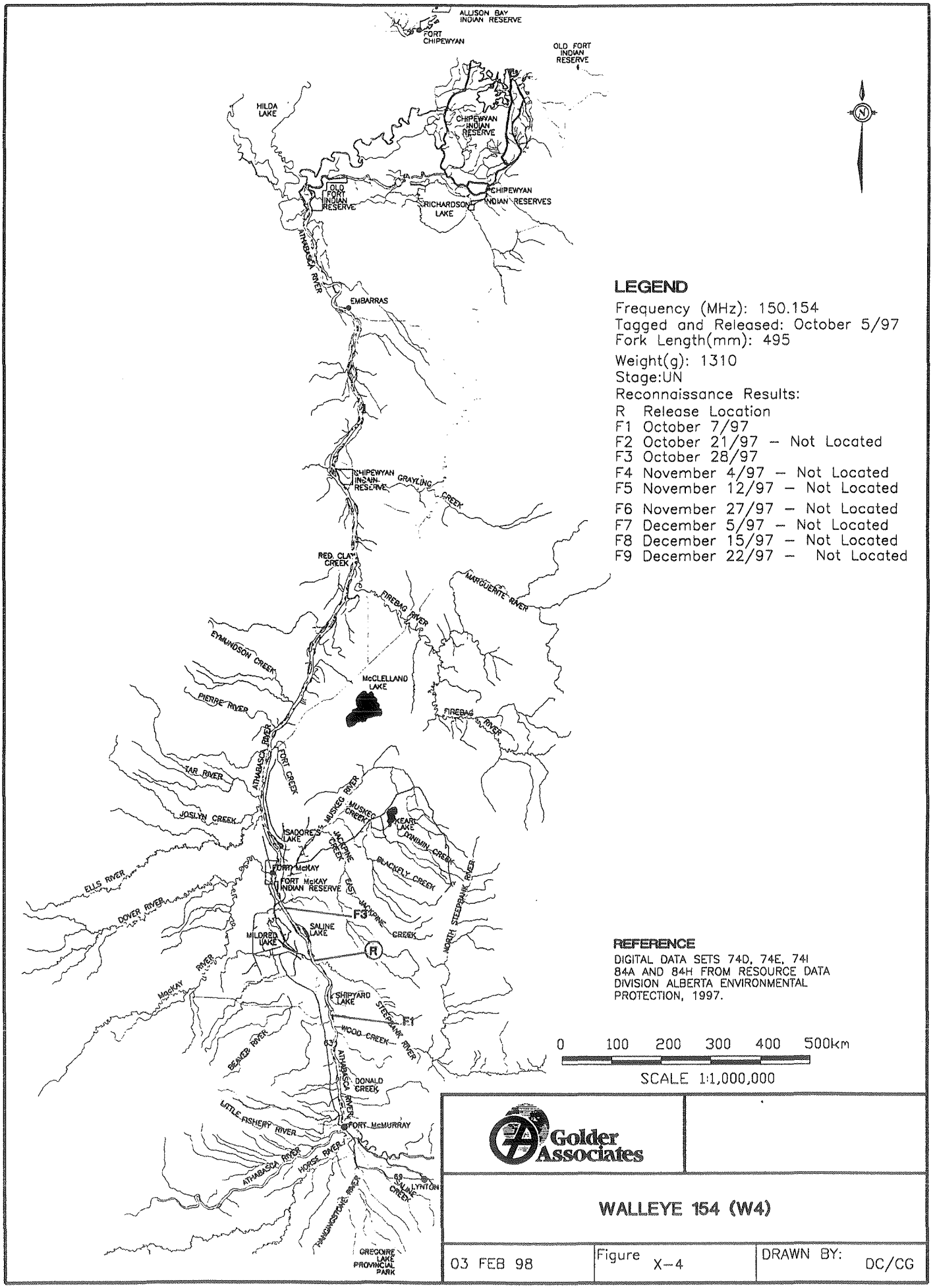
SCALE 1:1,000,000

Golder Associates

WALLEYE 131 (W3)

03 FEB 98	Figure X-3	DRAWN BY: DC /CG

J:\1997\2320\6050\WALLEY15.dwg



LEGEND

Frequency (MHz): 150.154
Tagged and Released: October 5/97
Fork Length(mm): 495
Weight(g): 1310
Stage:UN
Reconnaissance Results:
R Release Location
F1 October 7/97
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

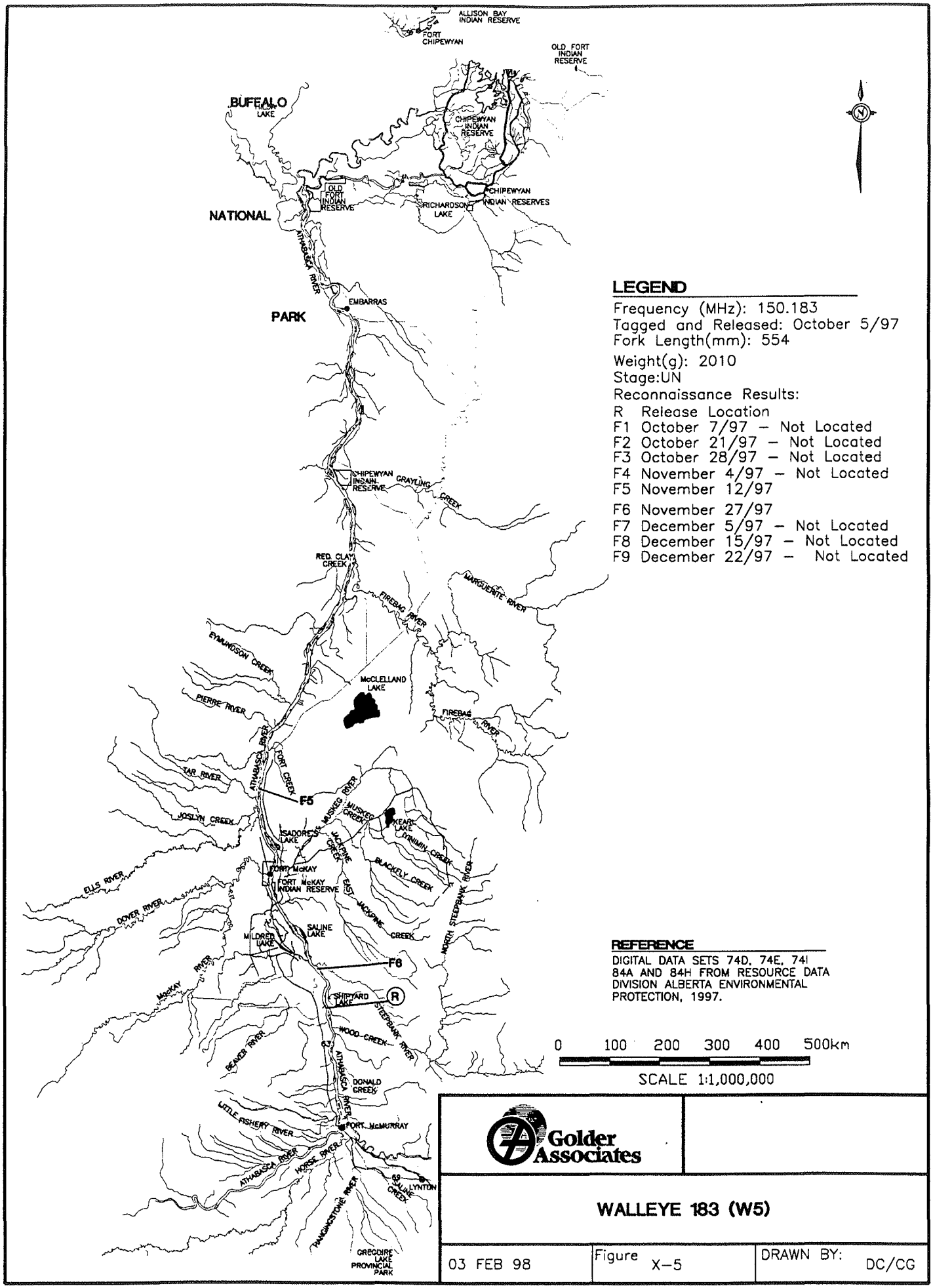
SCALE 1:1,000,000

Golder Associates

WALLEYE 154 (W4)

03 FEB 98	Figure X-4	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY18.dwg



LEGEND

Frequency (MHz): 150.183
Tagged and Released: October 5/97
Fork Length(mm): 554
Weight(g): 2010
Stage:UN
Reconnaissance Results:
R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97 – Not Located
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

SCALE 1:1,000,000

Golder Associates

WALLEYE 183 (W5)

03 FEB 98	Figure X-5	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY22.dwg

LEGEND

Frequency (MHz): 150.223
Tagged and Released: October 3/97
Fork Length(mm): 411
Weight(g): 770
Stage:UN
Reconnaissance Results:
R Release Location
F1 October 7/97
F2 October 21/97 – Not Located
F3 October 28/97 – Not Located
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

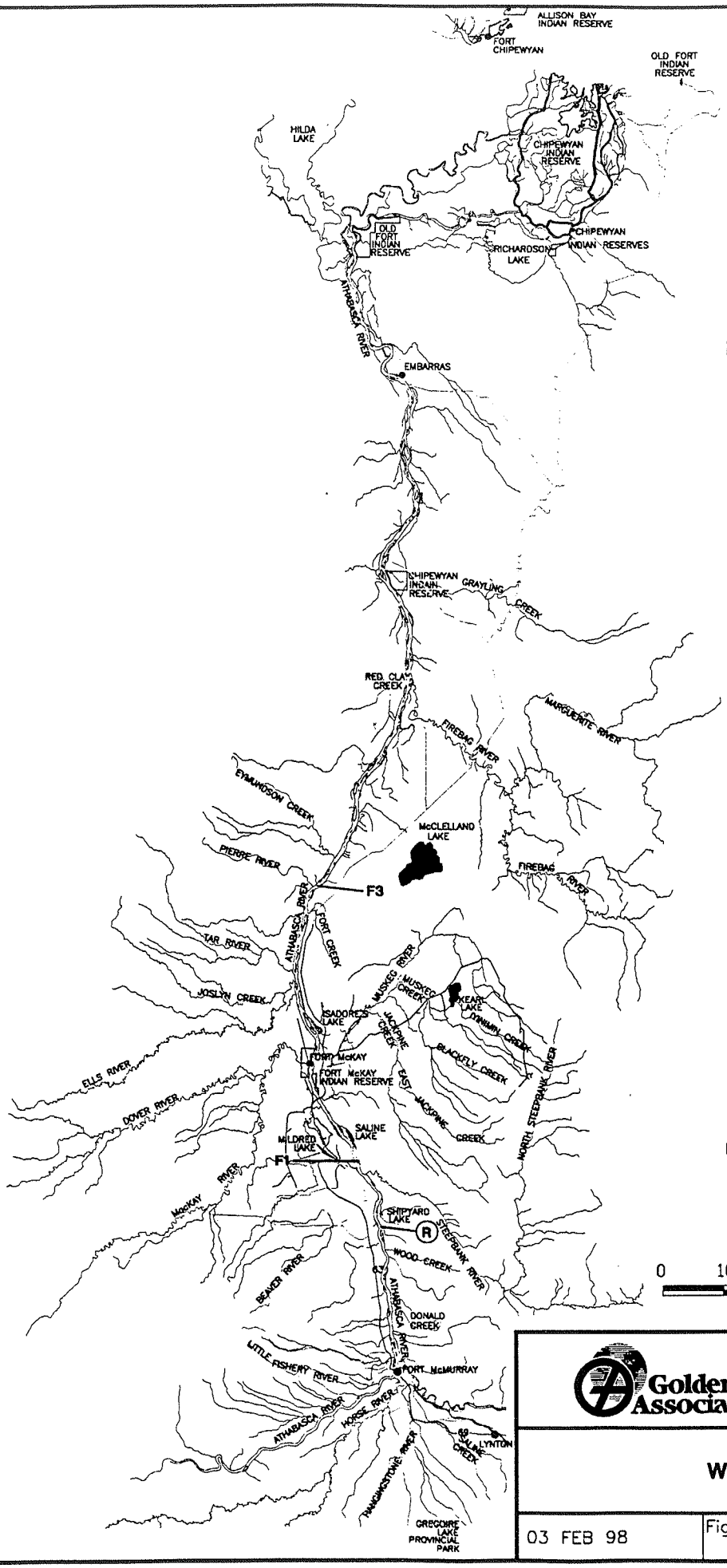
SCALE 1:1,000,000

Golder Associates

WALLEYE 223 (W6)

03 FEB 98	Figure X-6	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY28.dwg



LEGEND

Frequency (MHz): 150.282
Tagged and Released: October 5/97
Fork Length(mm): 451
Weight(g): 930
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

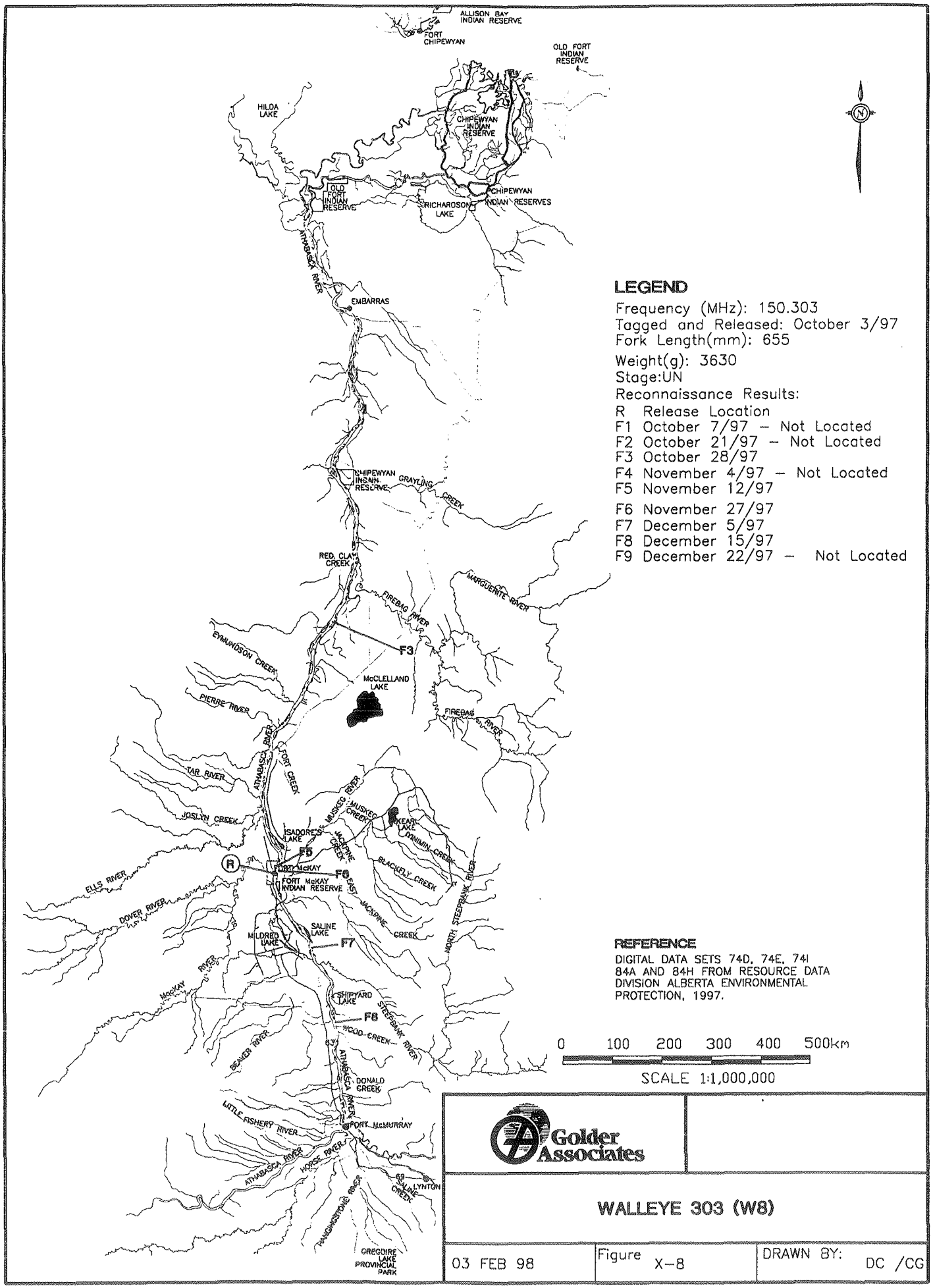
SCALE 1:1,000,000

Golder Associates

WALLEYE 282 (W7)

03 FEB 98	Figure X-7	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY30.dwg



LEGEND

Frequency (MHz): 150.303
Tagged and Released: October 3/97
Fork Length(mm): 655
Weight(g): 3630
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97
F7 December 5/97
F8 December 15/97
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

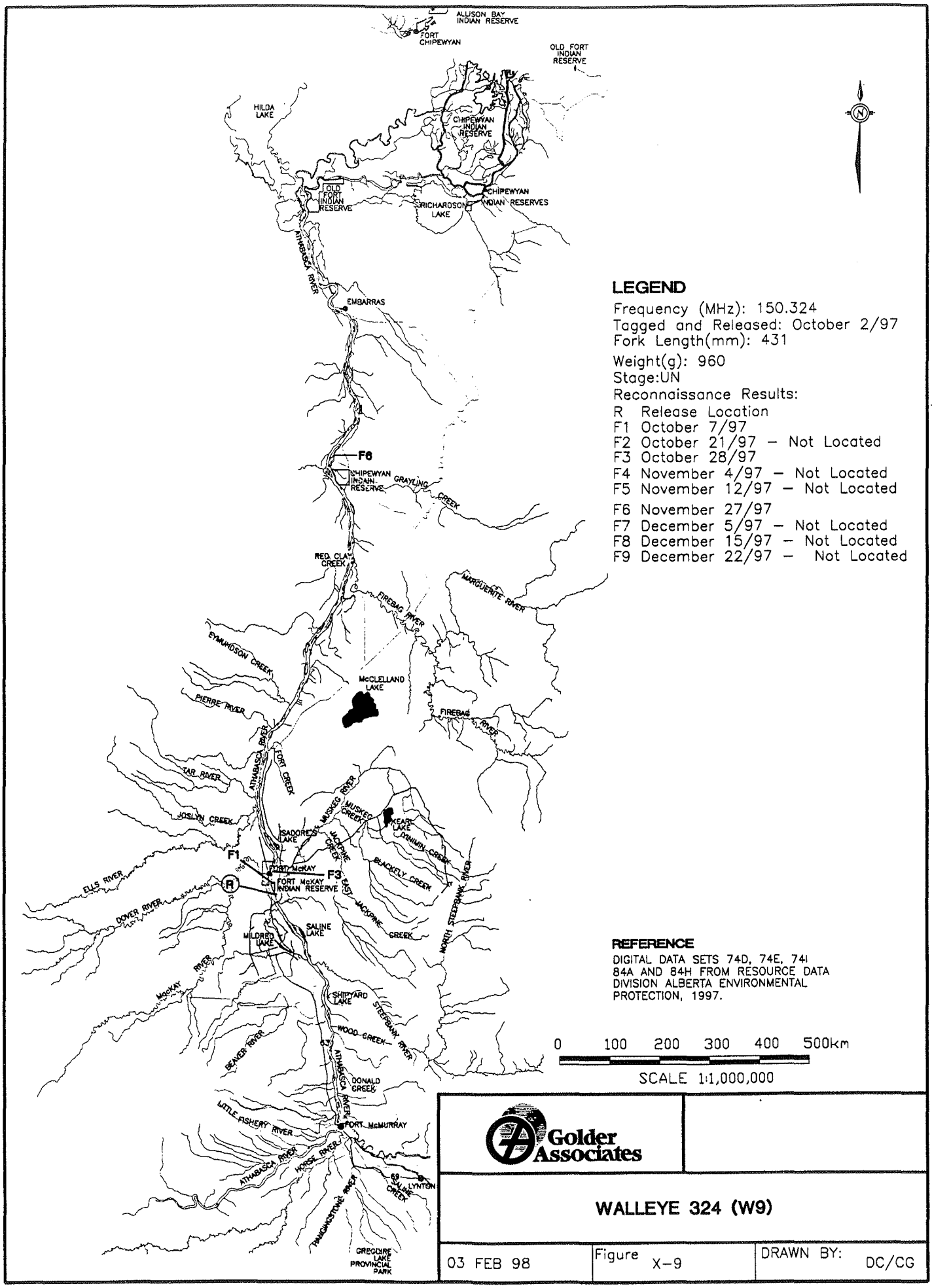
SCALE 1:1,000,000

Golder Associates

WALLEYE 303 (W8)

03 FEB 98	Figure X–8	DRAWN BY: DC /CG

J:\1997\2320\6050\WALLEY32.dwg



LEGEND

Frequency (MHz): 150.324
Tagged and Released: October 2/97
Fork Length(mm): 431
Weight(g): 960
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

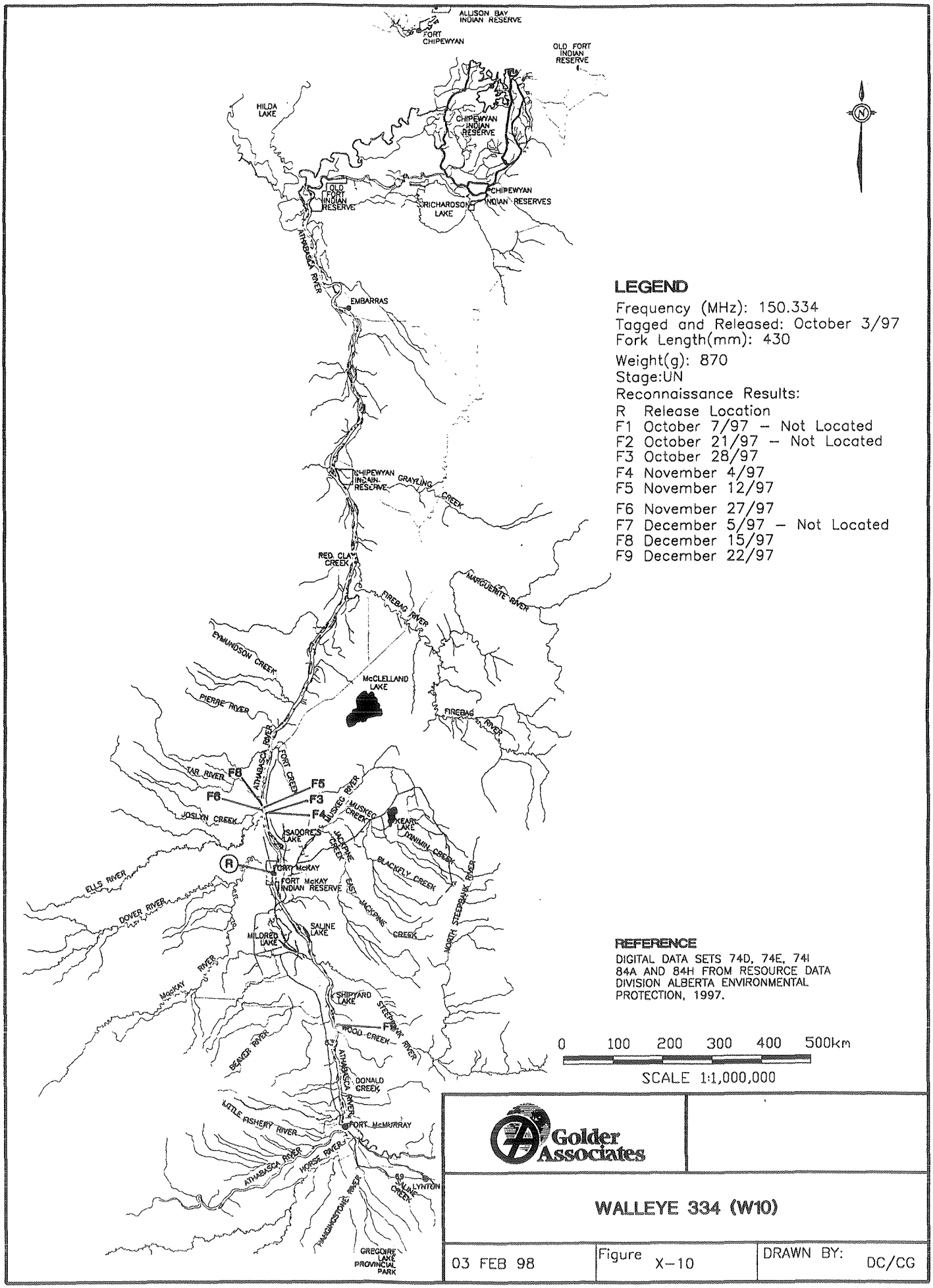
SCALE 1:1,000,000

Golder Associates

WALLEYE 324 (W9)

03 FEB 98	Figure X-9	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY33.dwg



LEGEND

Frequency (MHz): 150.334
Tagged and Released: October 3/97
Fork Length(mm): 430
Weight(g): 870
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97
F5 November 12/97
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97
F9 December 22/97

REFERENCE

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

0 100 200 300 400 500km

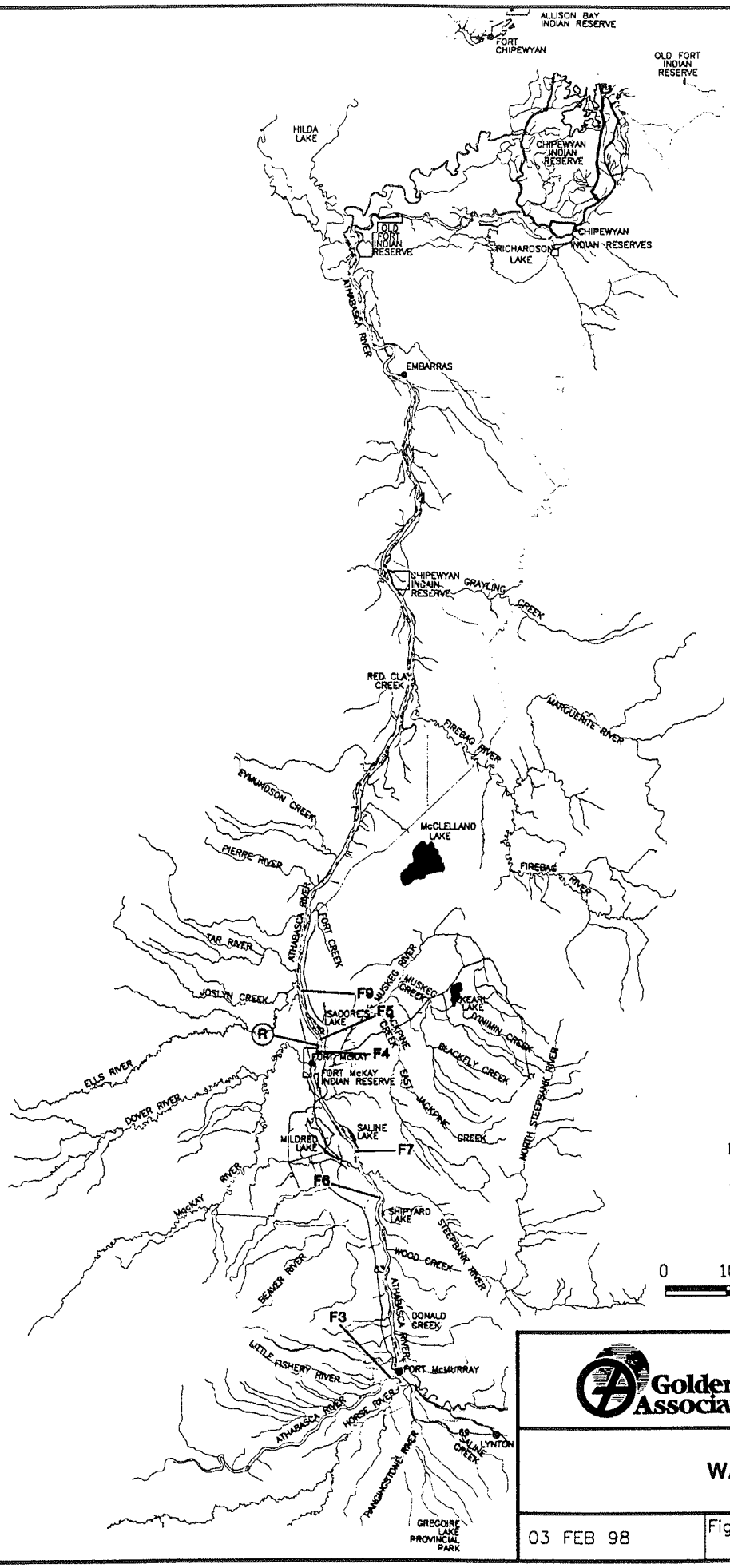
SCALE 1:1,000,000

Golder Associates

WALLEYE 334 (W10)

03 FEB 98	Figure X–10	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY35.dwg



LEGEND

Frequency (MHz): 150.353
Tagged and Released: October 6/97
Fork Length(mm): 605
Weight(g): 2820
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97
F5 November 12/97
F6 November 27/97
F7 December 5/97
F8 December 15/97 – Not Located
F9 December 22/97

REFERENCE

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

0 100 200 300 400 500km

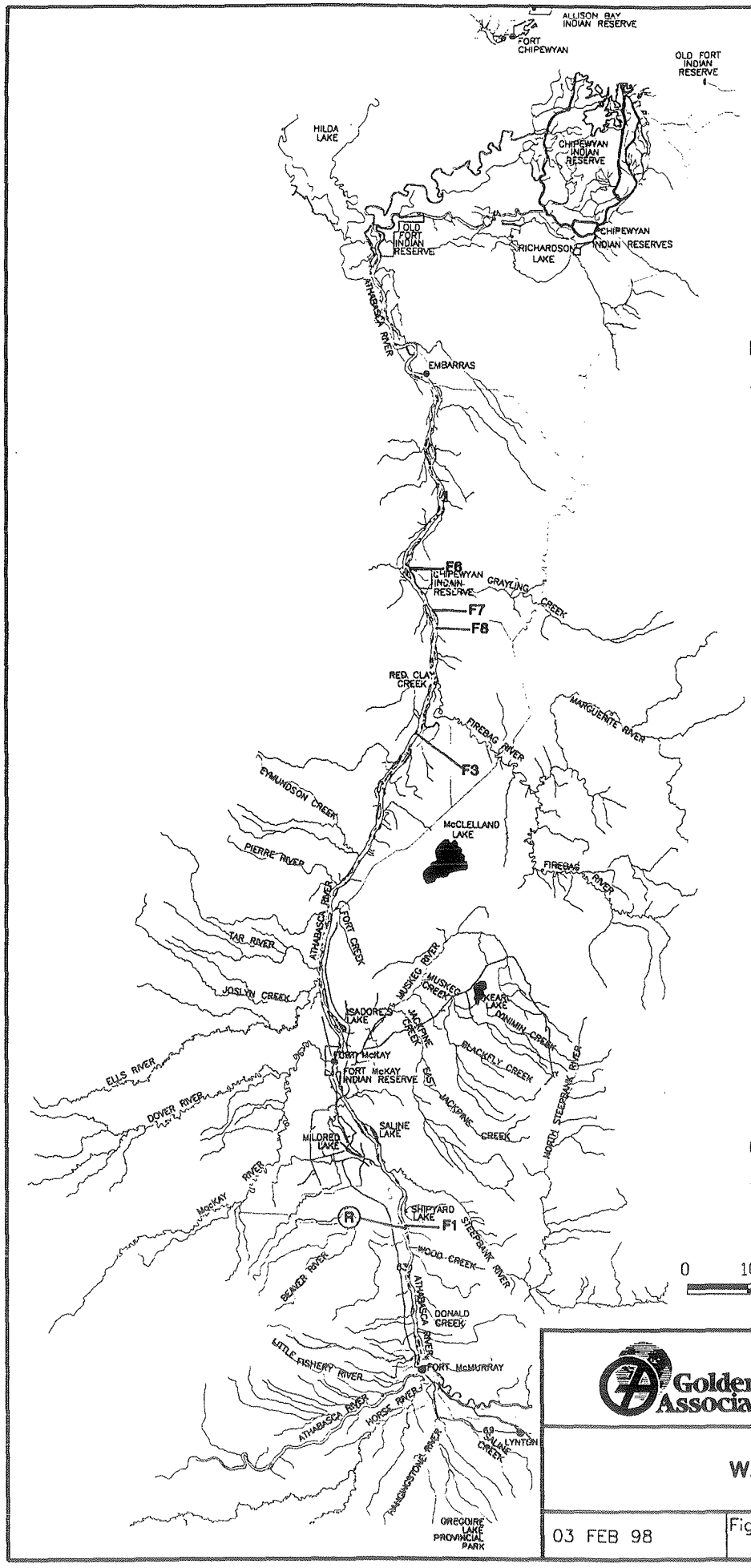
SCALE 1:1,000,000

Golder Associates

WALLEYE 353 (W11)

03 FEB 98	Figure X-11	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY37.dwg



LEGEND

Frequency (MHz): 150.371
Tagged and Released: October 5/97
Fork Length(mm): 503
Weight(g): 1220
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97
F8 December 15/97
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

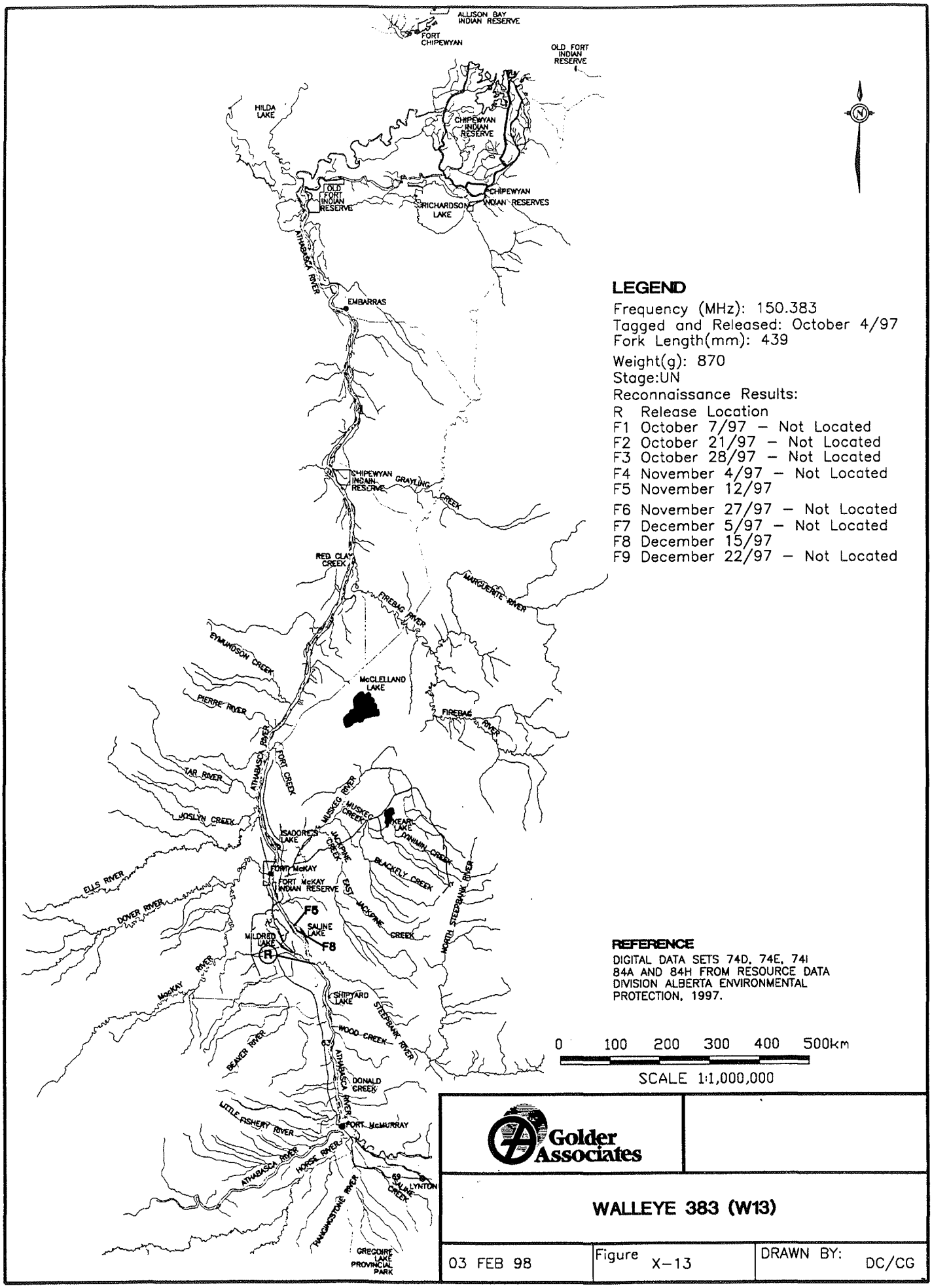
SCALE 1:1,000,000

Golder Associates

WALLEYE 371 (W12)

03 FEB 98	Figure X-12	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY38.dwg

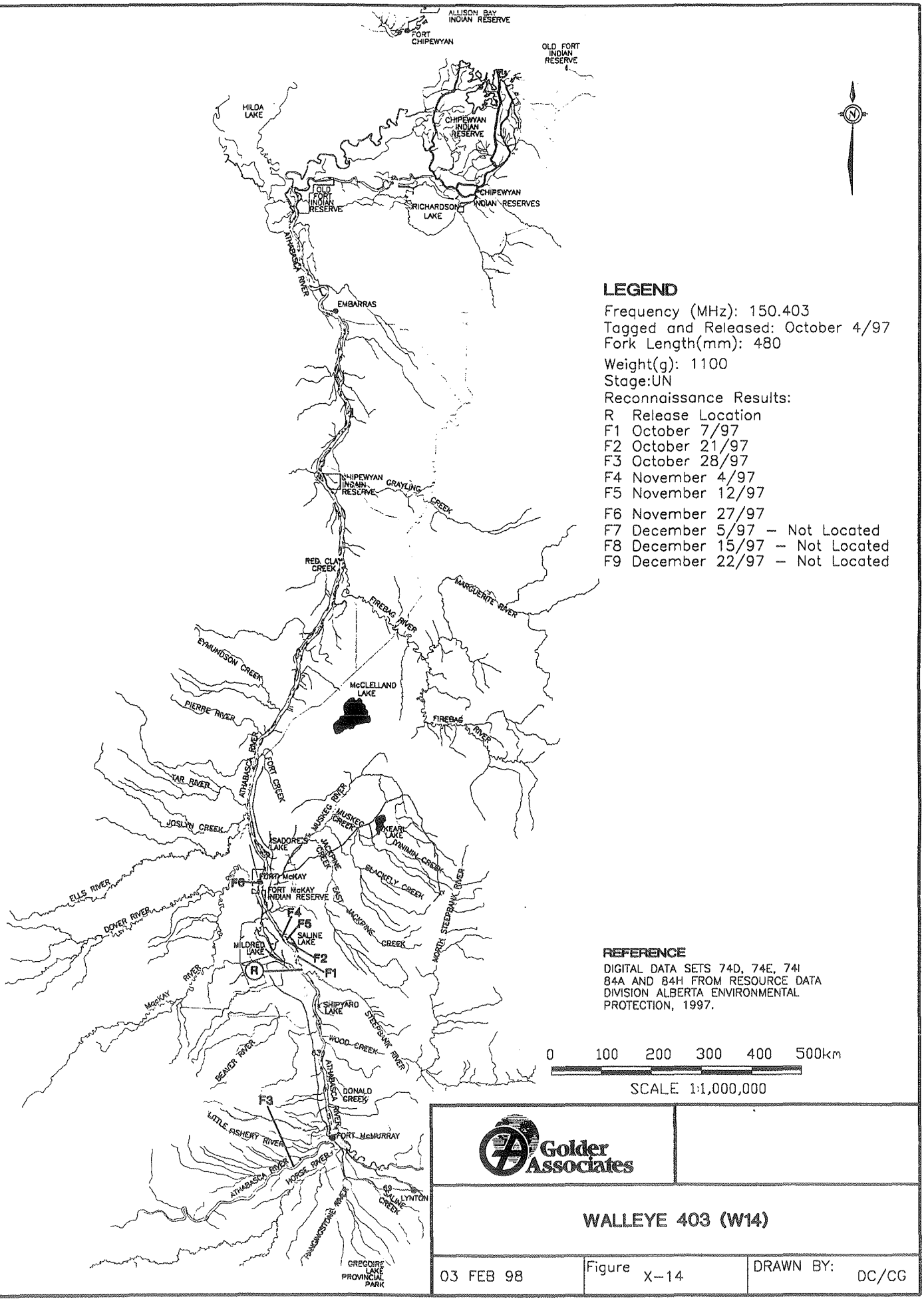


Golder Associates

WALLEYE 383 (W13)

03 FEB 98	Figure X–13	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY40.dwg

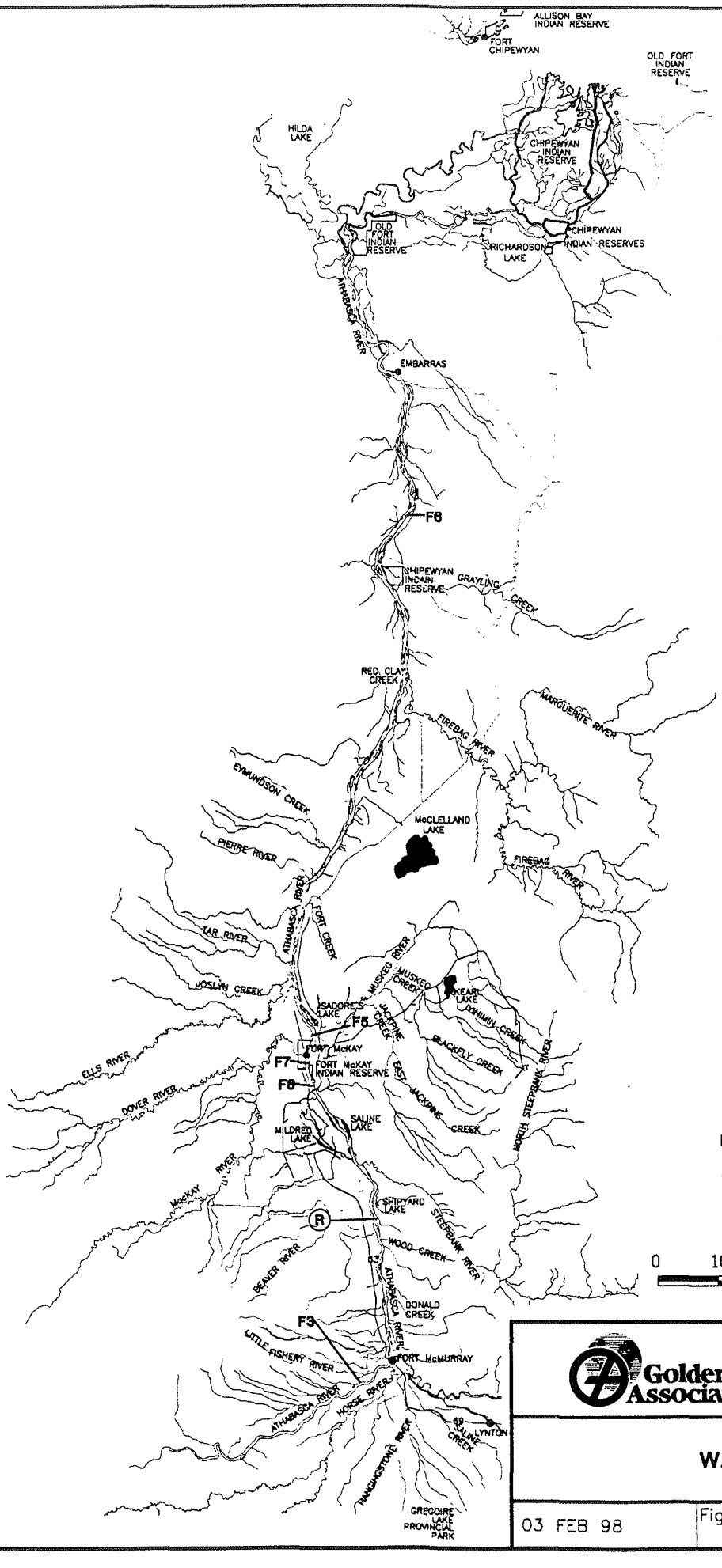


Golder Associates

WALLEYE 403 (W14)

03 FEB 98	Figure X–14	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY41.dwg



LEGEND

Frequency (MHz): 150.412
Tagged and Released: October 5/97
Fork Length(mm): 435
Weight(g): 940
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97
F7 December 5/97
F8 December 15/97
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

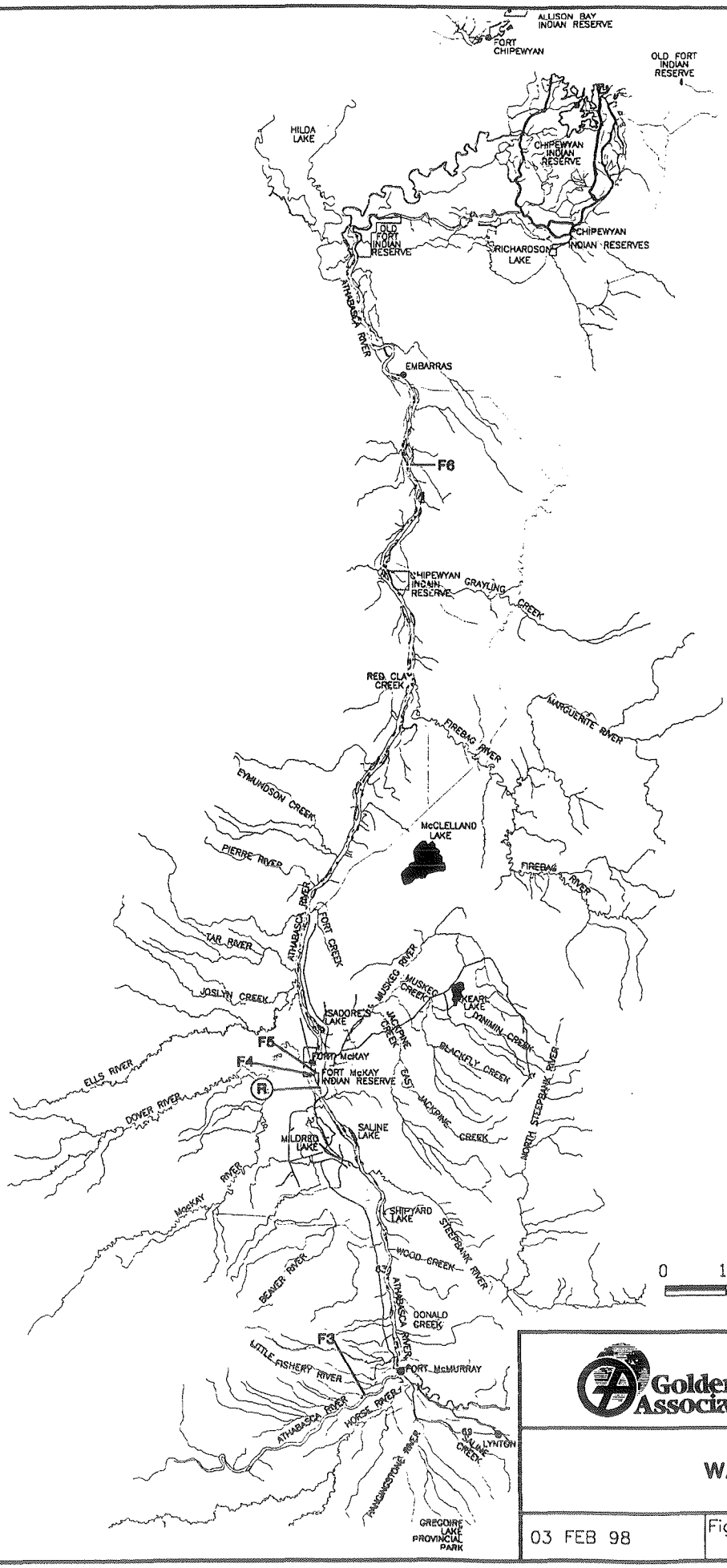
SCALE 1:1,000,000

Golder Associates

WALLEYE 412 (W15)

03 FEB 98	Figure X-15	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY42.dwg



LEGEND

Frequency (MHz): 150.424
Tagged and Released: October 2/97
Fork Length(mm): 440
Weight(g): 900
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97
F5 November 12/97
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

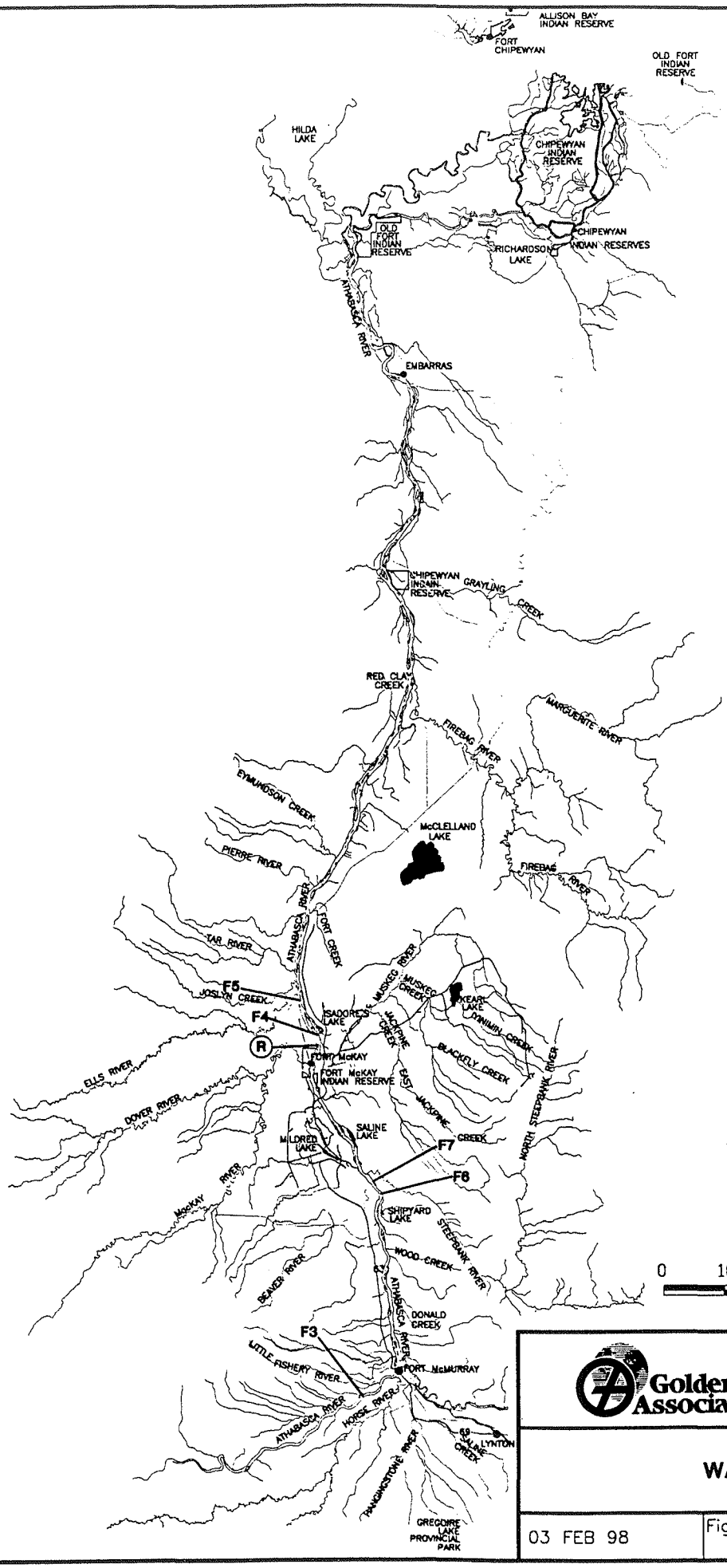
SCALE 1:1,000,000

Golder Associates

WALLEYE 424 (W16)

03 FEB 98	Figure X–16	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY43.dwg



LEGEND

Frequency (MHz): 150.433
Tagged and Released: October 6/97
Fork Length(mm): 475
Weight(g): 1210
Stage:SD
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97
F5 November 12/97
F6 November 27/97
F7 December 5/97
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

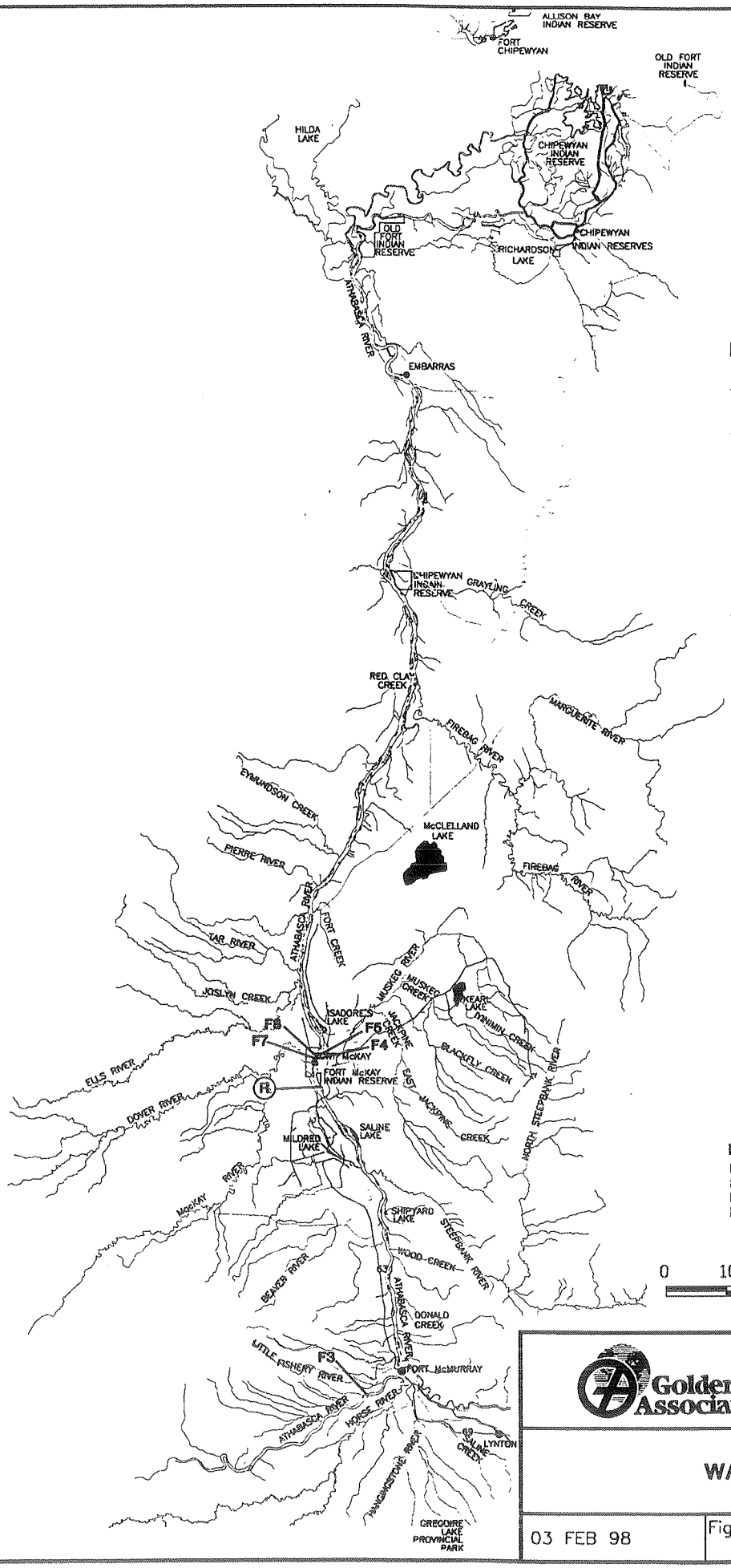
SCALE 1:1,000,000

Golder Associates

WALLEYE 433 (W17)

03 FEB 98	Figure X-17	DRAWN BY: DC/CG

J:\1997\2320\6050\WALLEY45.dwg



LEGEND

Frequency (MHz): 150.454
Tagged and Released: October 2/97
Fork Length(mm): 414
Weight(g): 690
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97
F5 November 12/97
F6 November 27/97 – Not Located
F7 December 5/97
F8 December 15/97
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

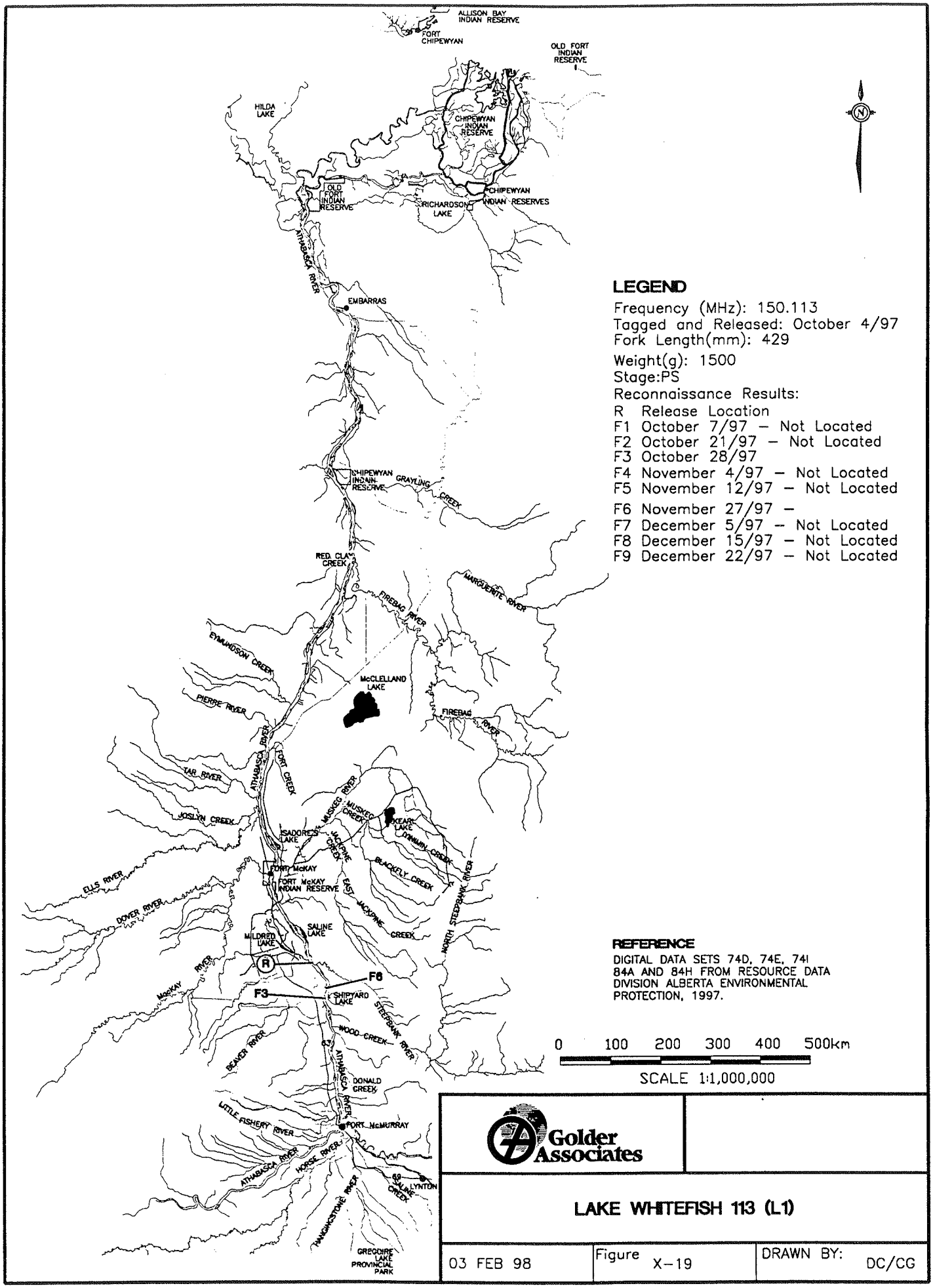
SCALE 1:1,000,000

Golder Associates

WALLEYE 454 (W18)

03 FEB 98	Figure X-18	DRAWN BY: DC/CG

J:\1997\2320\6050\WHITEFIS.dwg



LEGEND

Frequency (MHz): 150.113
Tagged and Released: October 4/97
Fork Length(mm): 429
Weight(g): 1500
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97 –
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 113 (L1)

03 FEB 98	Figure X-19	DRAWN BY: DC/CG

J:\1997\2320\6050\WHITEFI0.dwg

LEGEND

Frequency (MHz): 150.144
Tagged and Released: October 5/97
Fork Length(mm): 390
Weight(g): 1000
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97

REFERENCE

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

0 100 200 300 400 500km

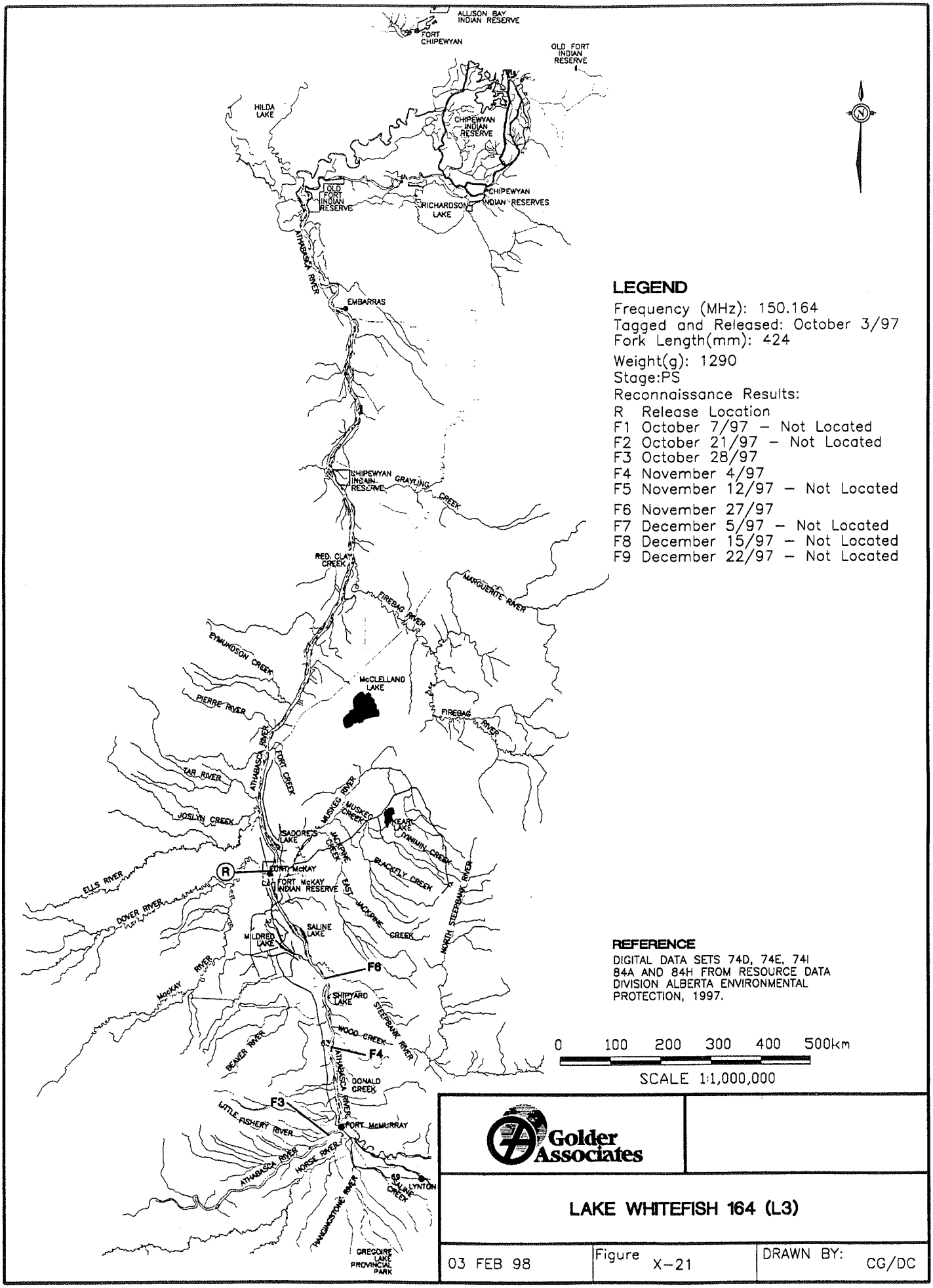
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 144 (L2)

03 FEB 98	Figure X-20	DRAWN BY: DC/CG

J:\1997\2320\6050\WHITEFI1.dwg



Golder Associates

LAKE WHITEFISH 164 (L3)

03 FEB 98	Figure X-21	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI2.dwg

LEGEND

Frequency (MHz): 150.173
Tagged and Released: October 5/97
Fork Length(mm): 420
Weight(g): 1310
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97
F2 October 21/97
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

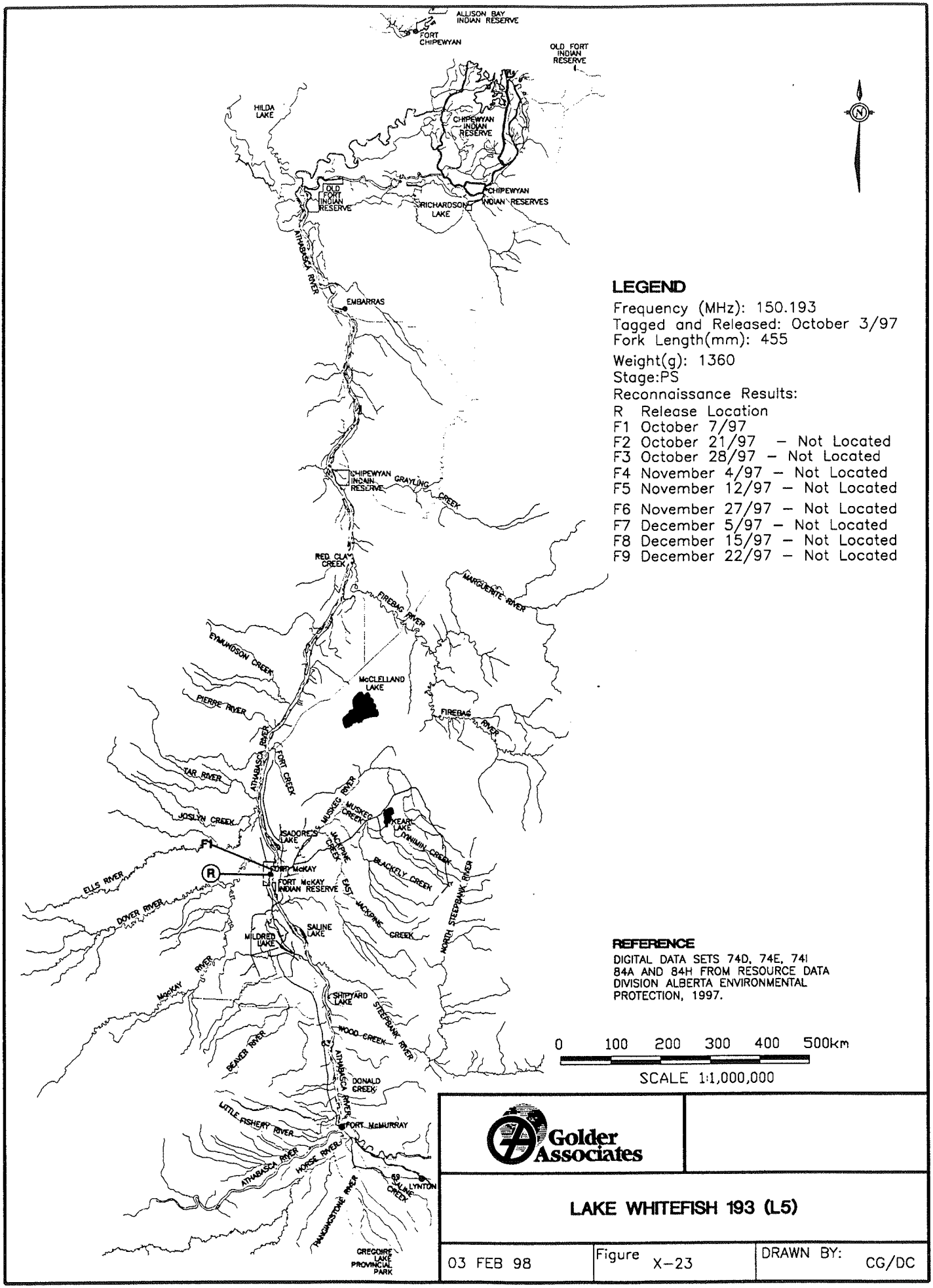
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 173 (L4)

03 FEB 98	Figure X-22	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI3.dwg



LEGEND

Frequency (MHz): 150.193
Tagged and Released: October 3/97
Fork Length(mm): 455
Weight(g): 1360
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97
F2 October 21/97 – Not Located
F3 October 28/97 – Not Located
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

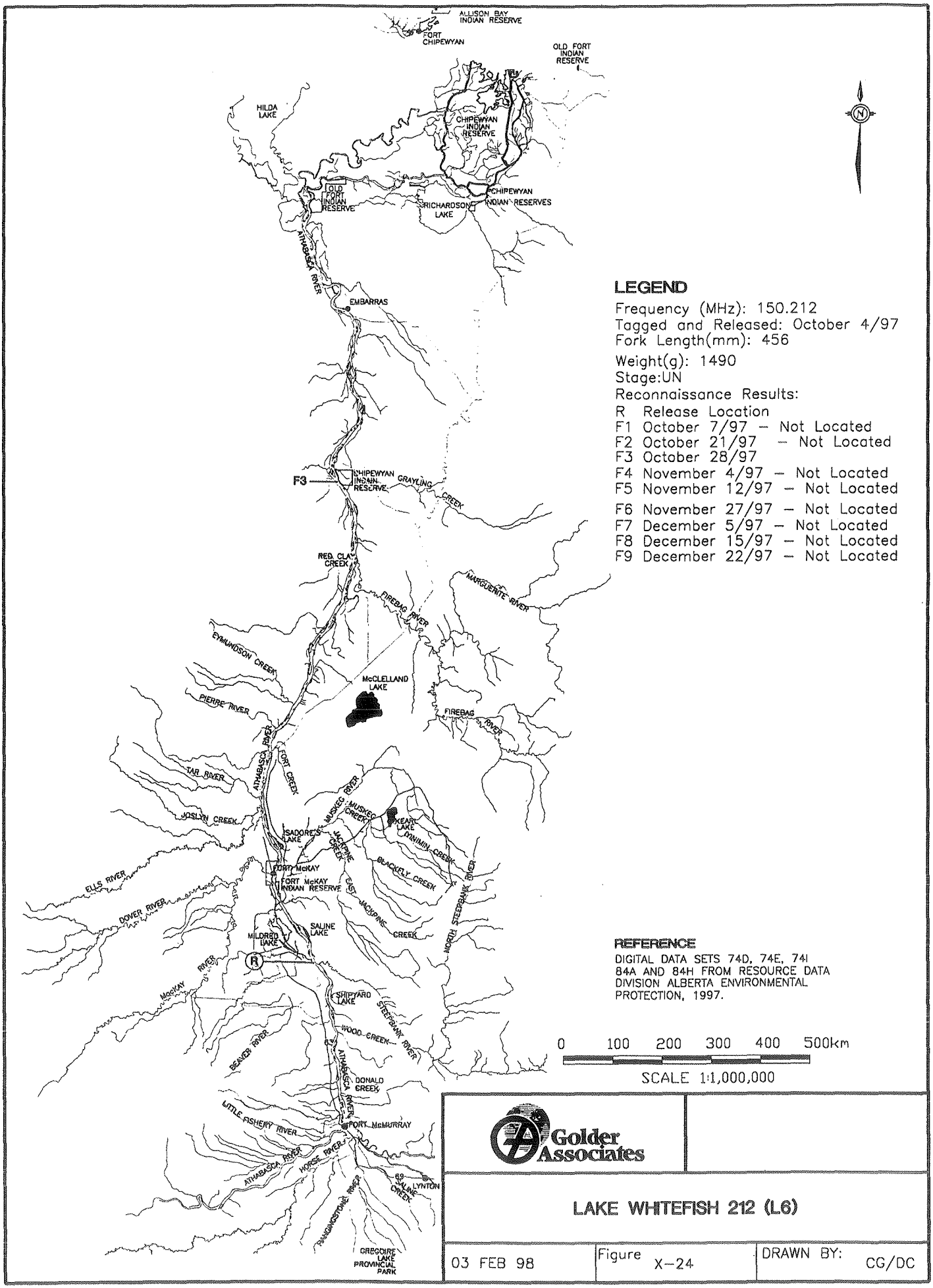
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 193 (L5)

03 FEB 98	Figure X-23	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI4.dwg

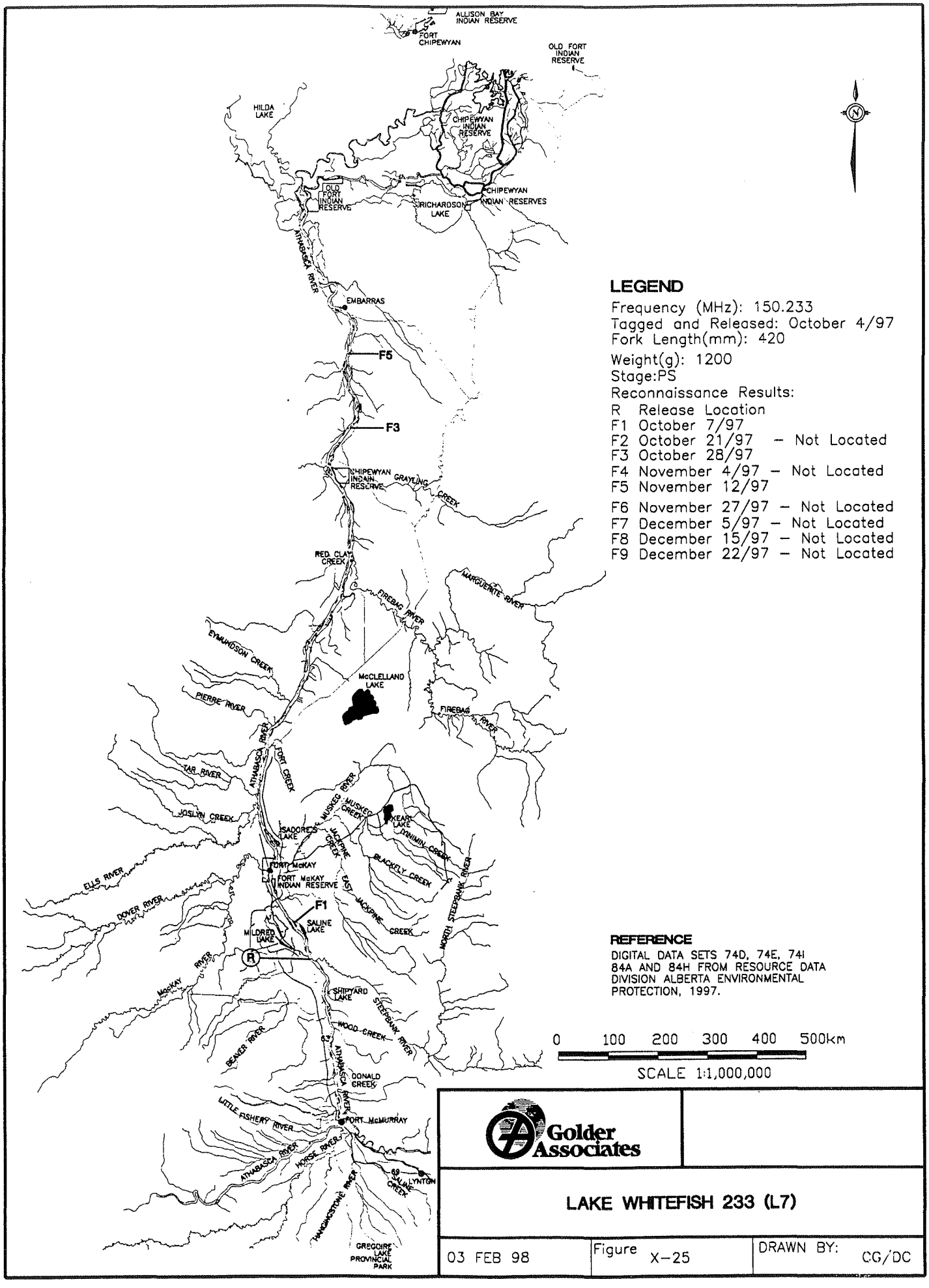


Golder Associates

LAKE WHITEFISH 212 (L6)

03 FEB 98	Figure X–24	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI5.dwg



LEGEND

Frequency (MHz): 150.233
Tagged and Released: October 4/97
Fork Length(mm): 420
Weight(g): 1200
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

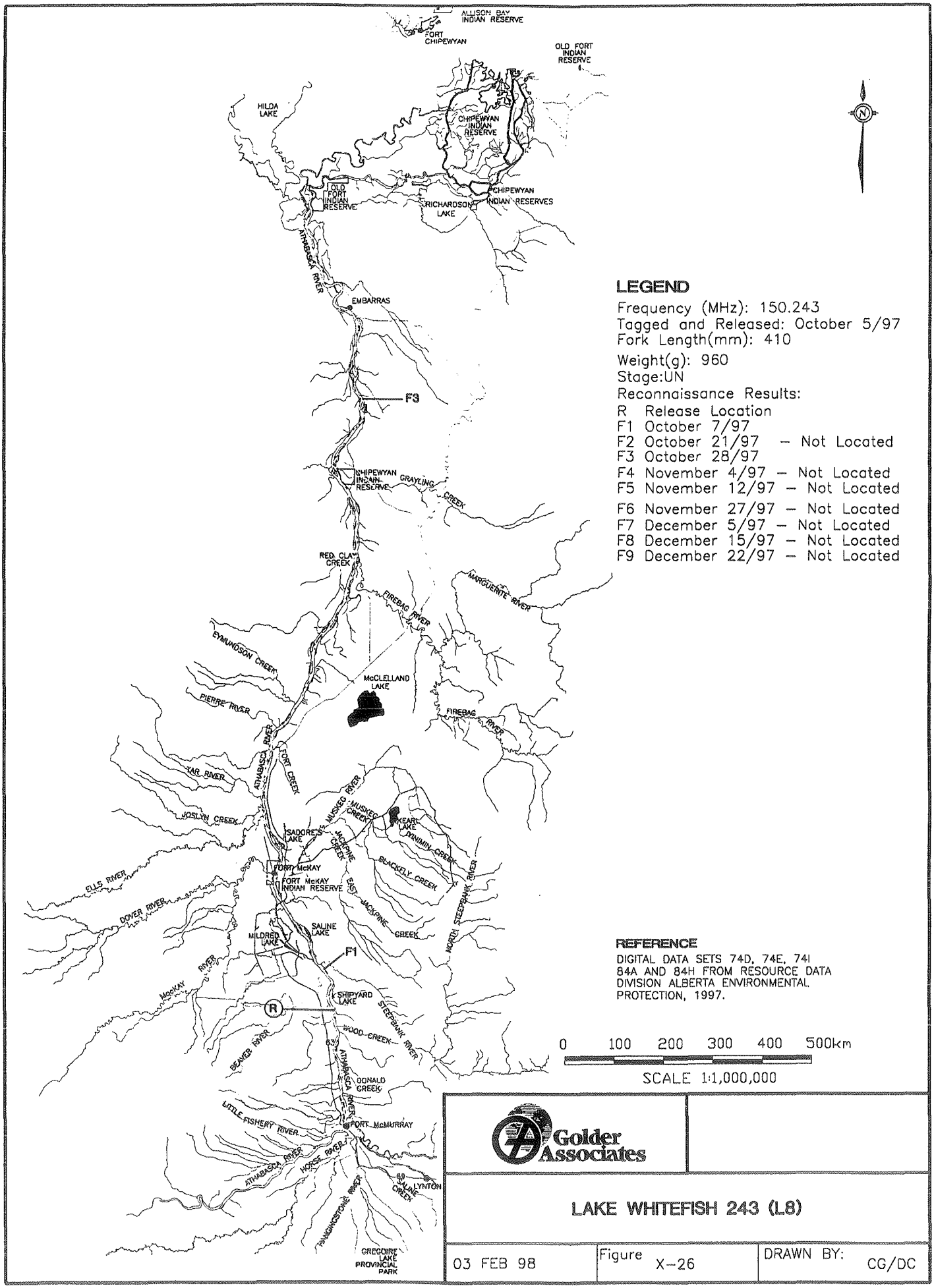
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 233 (L7)

03 FEB 98	Figure X–25	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI6.dwg



LEGEND

Frequency (MHz): 150.243
Tagged and Released: October 5/97
Fork Length(mm): 410
Weight(g): 960
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

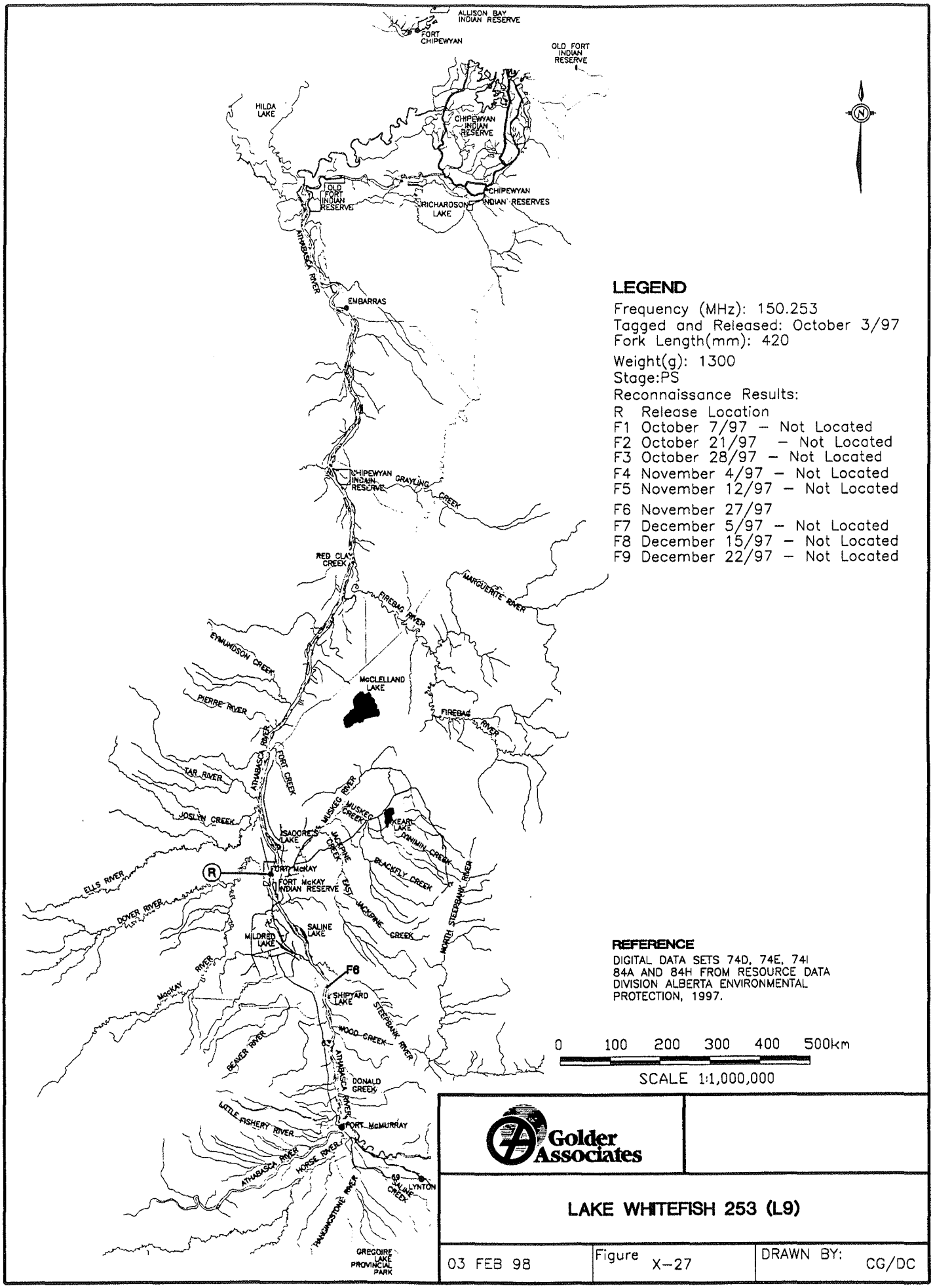
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 243 (L8)

03 FEB 98	Figure X-26	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI7.dwg



LEGEND

Frequency (MHz): 150.253
Tagged and Released: October 3/97
Fork Length(mm): 420
Weight(g): 1300
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97 – Not Located
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

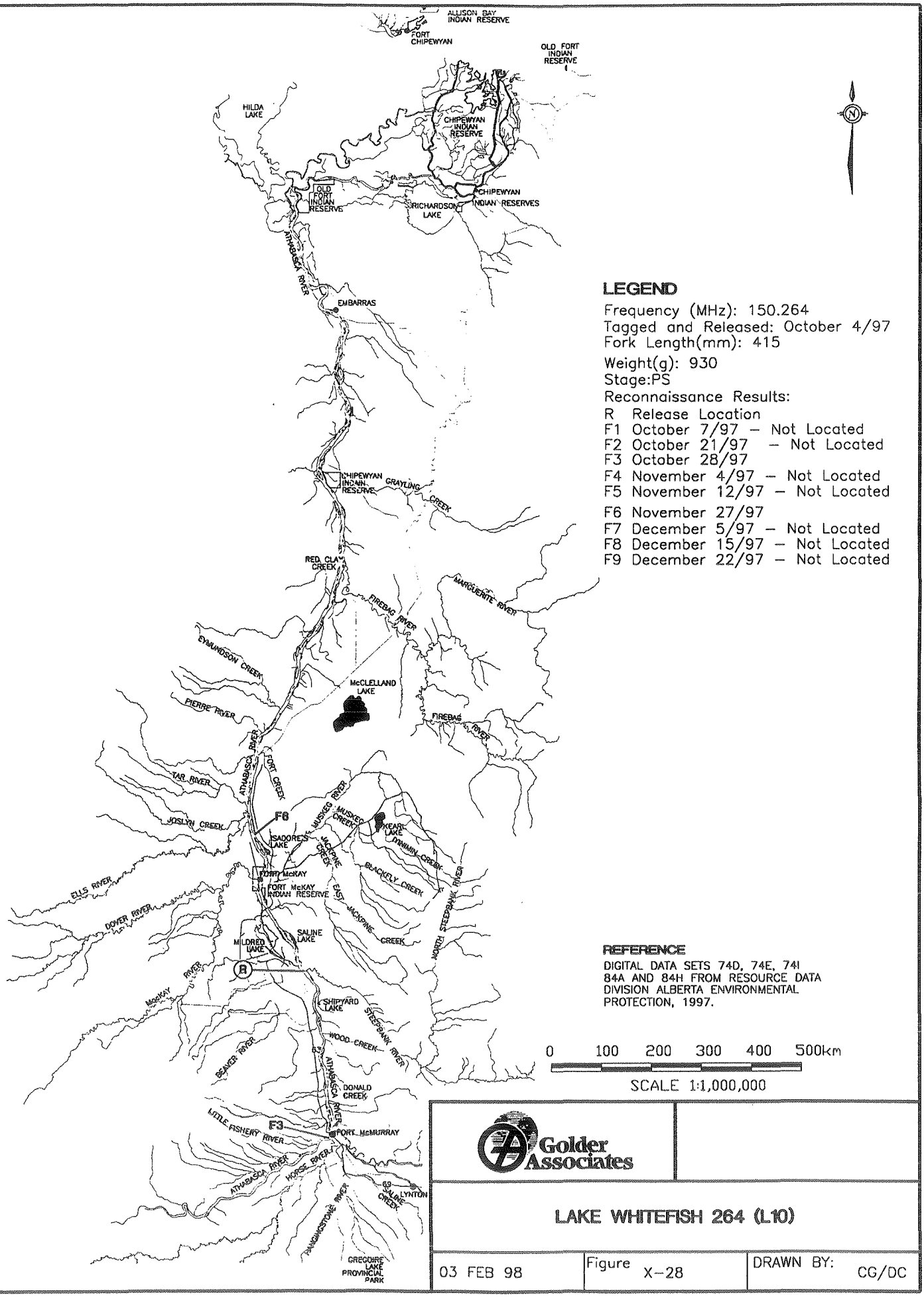
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 253 (L9)

03 FEB 98	Figure X-27	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI8.dwg



LEGEND

Frequency (MHz): 150.264
Tagged and Released: October 4/97
Fork Length(mm): 415
Weight(g): 930
Stage:PS
Reconnaissance Results:
R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

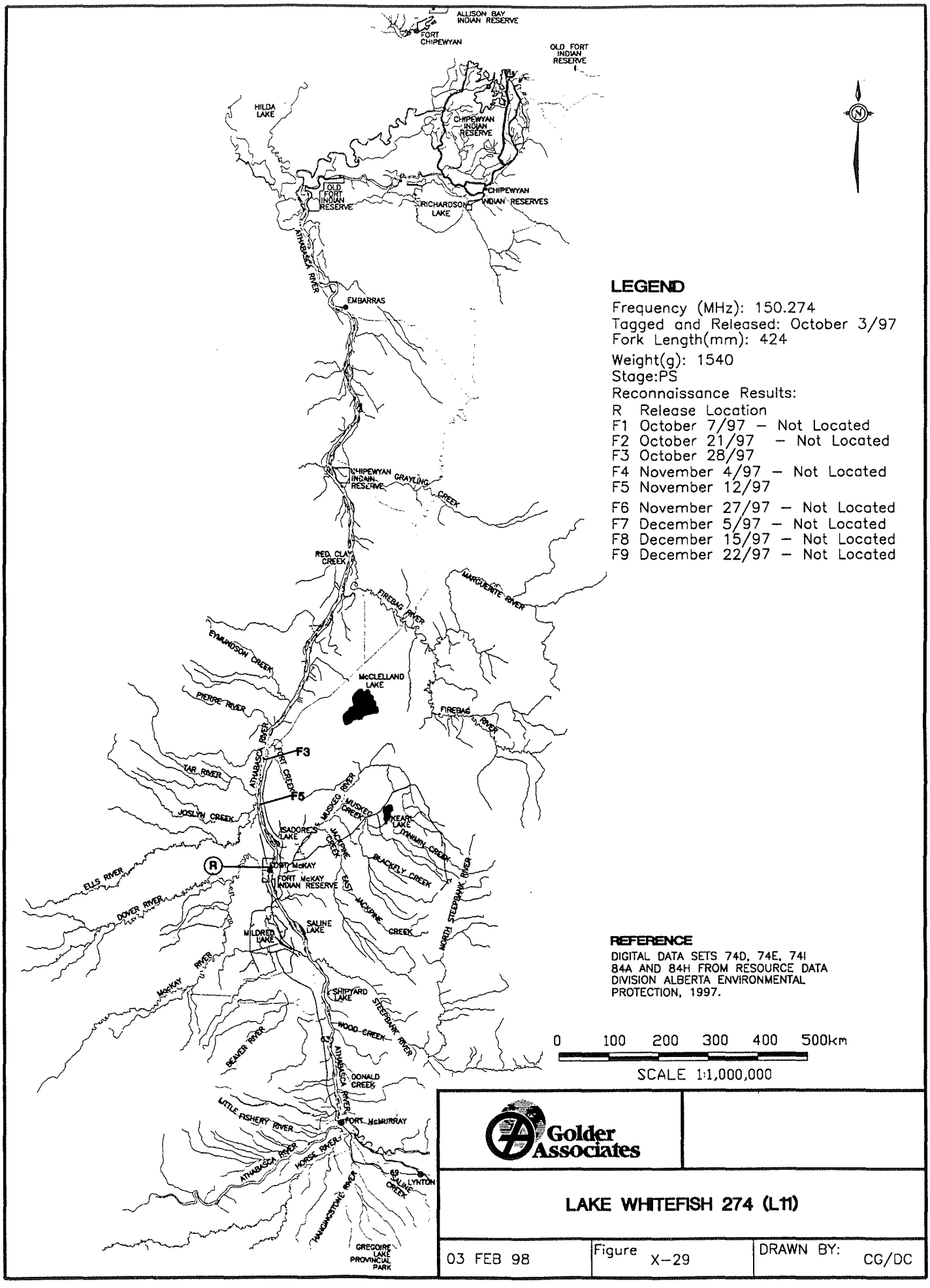
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 264 (L10)

03 FEB 98	Figure X-28	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI9dwg



LEGEND

Frequency (MHz): 150.274
Tagged and Released: October 3/97
Fork Length(mm): 424
Weight(g): 1540
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

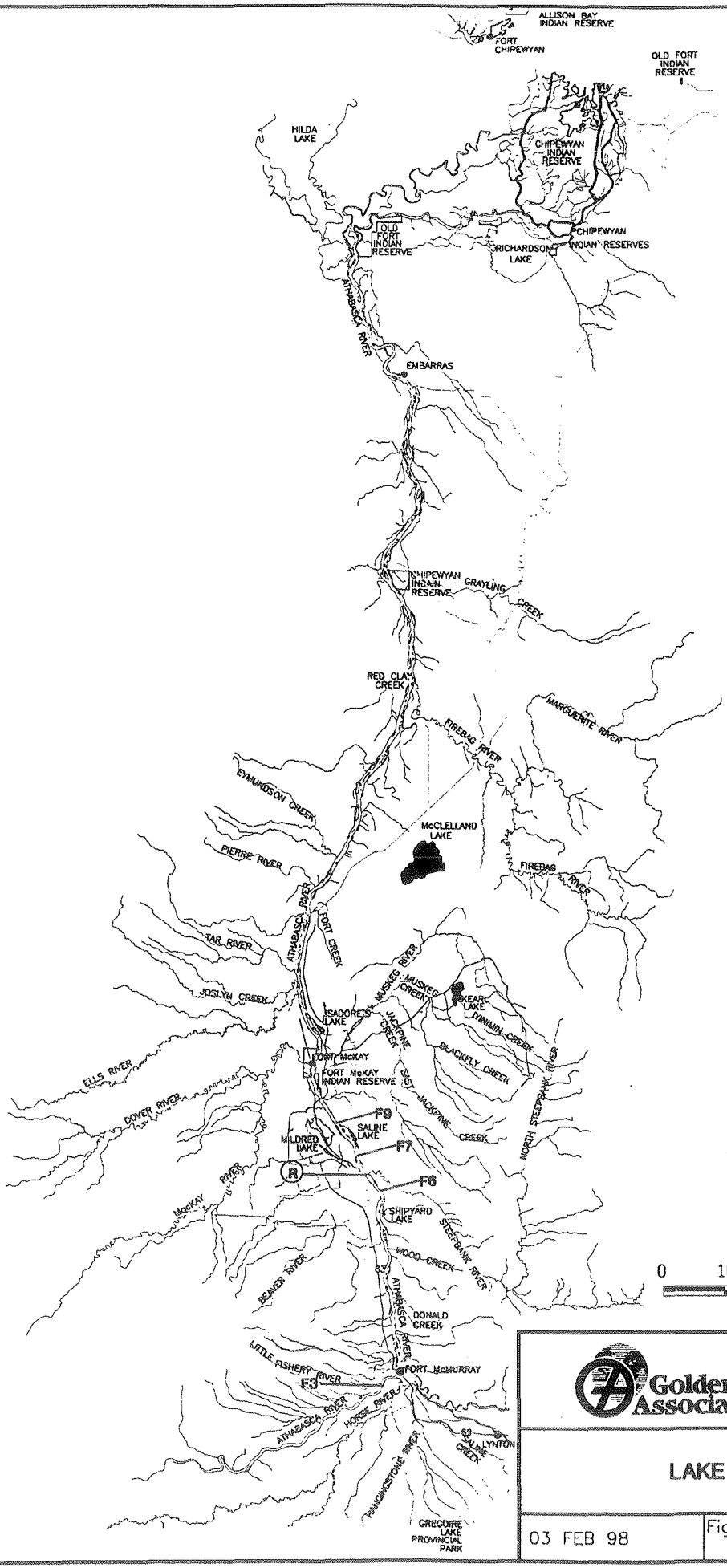
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 274 (L11)

03 FEB 98	Figure X-29	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEF00.dwg



LEGEND

Frequency (MHz): 150.294
Tagged and Released: October 4/97
Fork Length(mm): 475
Weight(g): 1640
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97
F8 December 15/97 – Not Located
F9 December 22/97

REFERENCE

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

0 100 200 300 400 500km

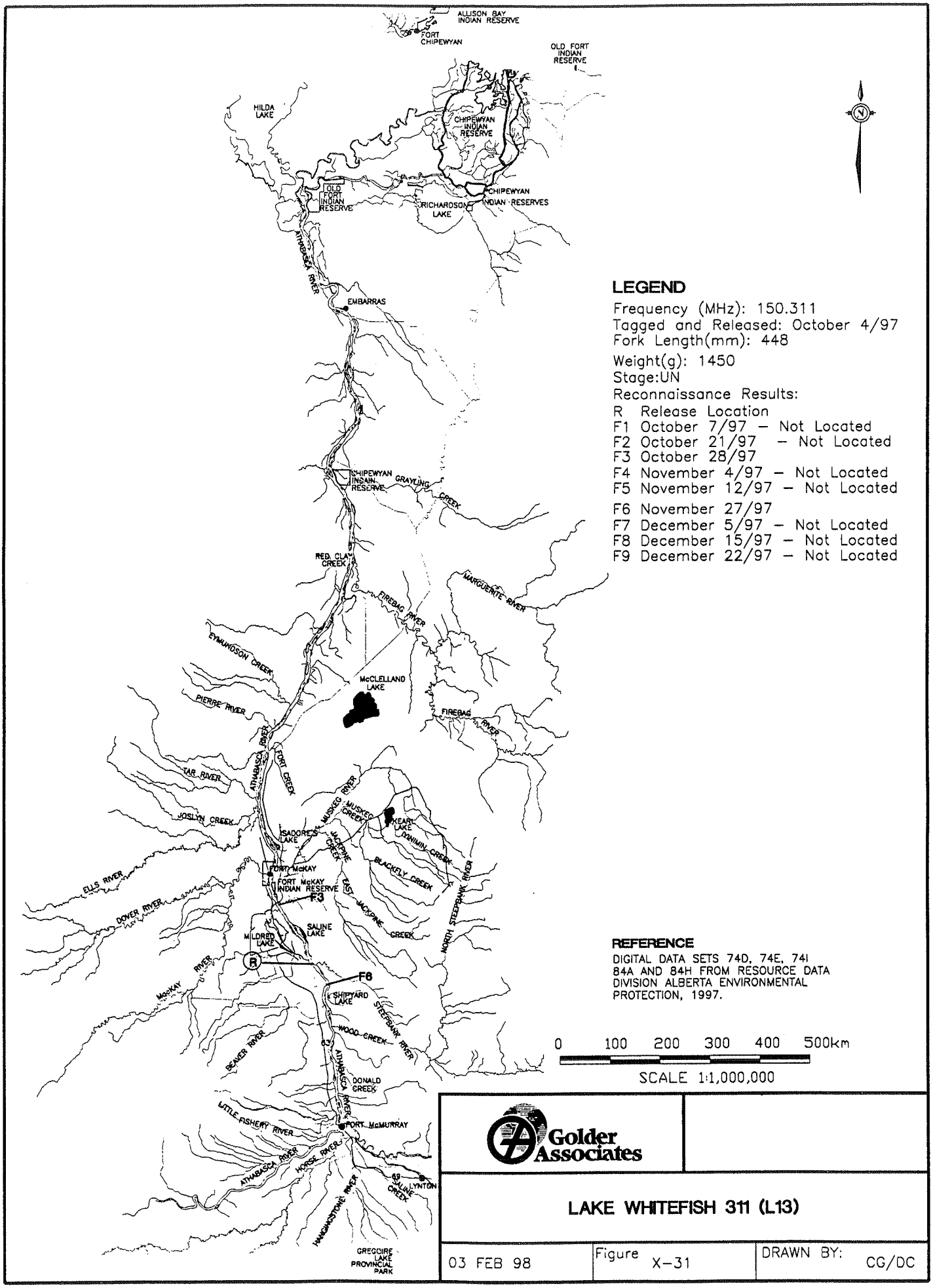
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 294 (L12)

03 FEB 98	Figure X-30	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEF01.dwg



LEGEND

Frequency (MHz): 150.311
Tagged and Released: October 4/97
Fork Length(mm): 448
Weight(g): 1450
Stage:UN
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

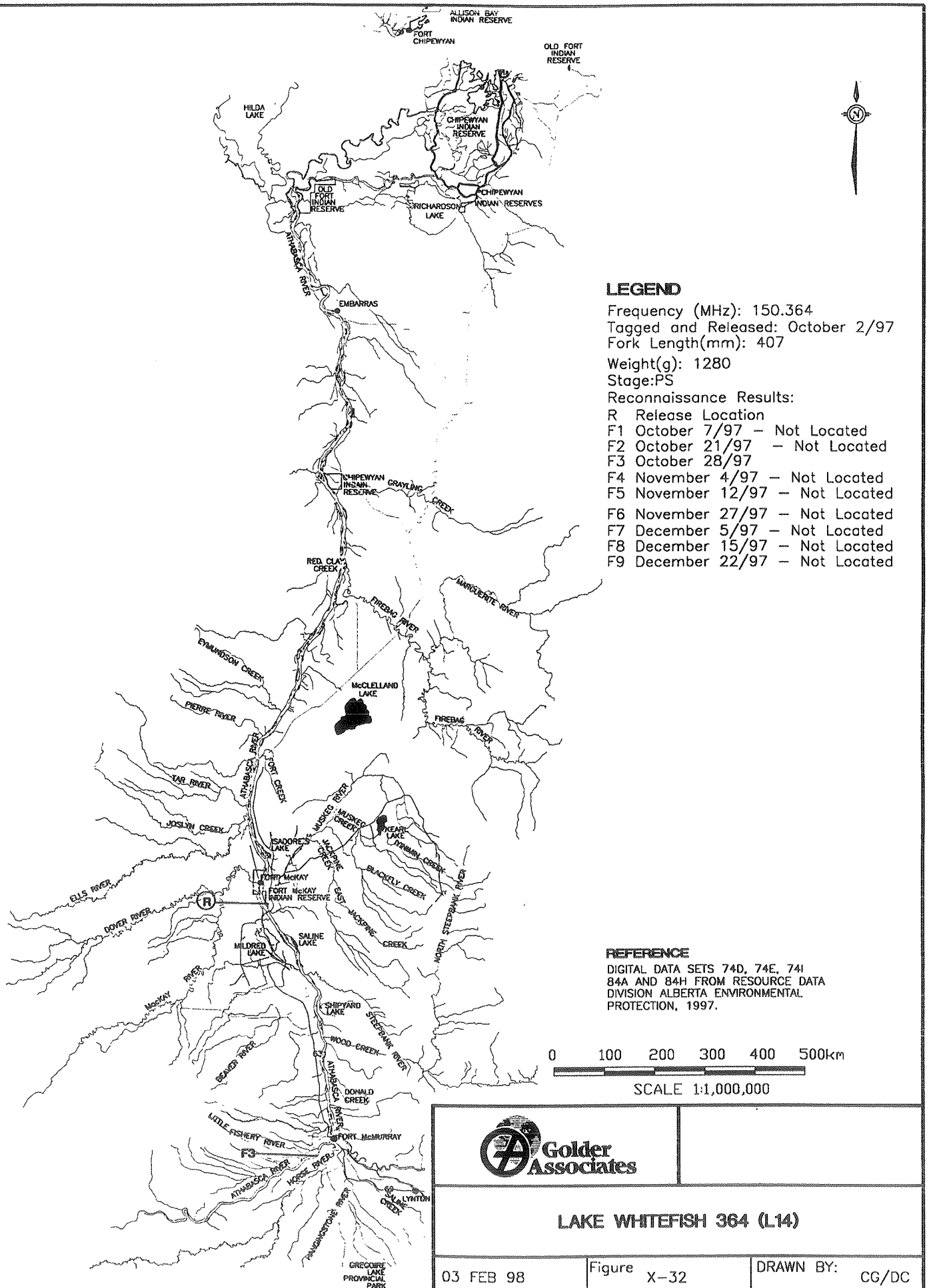
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 311 (L13)

03 FEB 98	Figure X-31	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEFI02.dwg



LEGEND

Frequency (MHz): 150.364
Tagged and Released: October 2/97
Fork Length(mm): 407
Weight(g): 1280
Stage:PS
Reconnaissance Results:
R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97 – Not Located
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

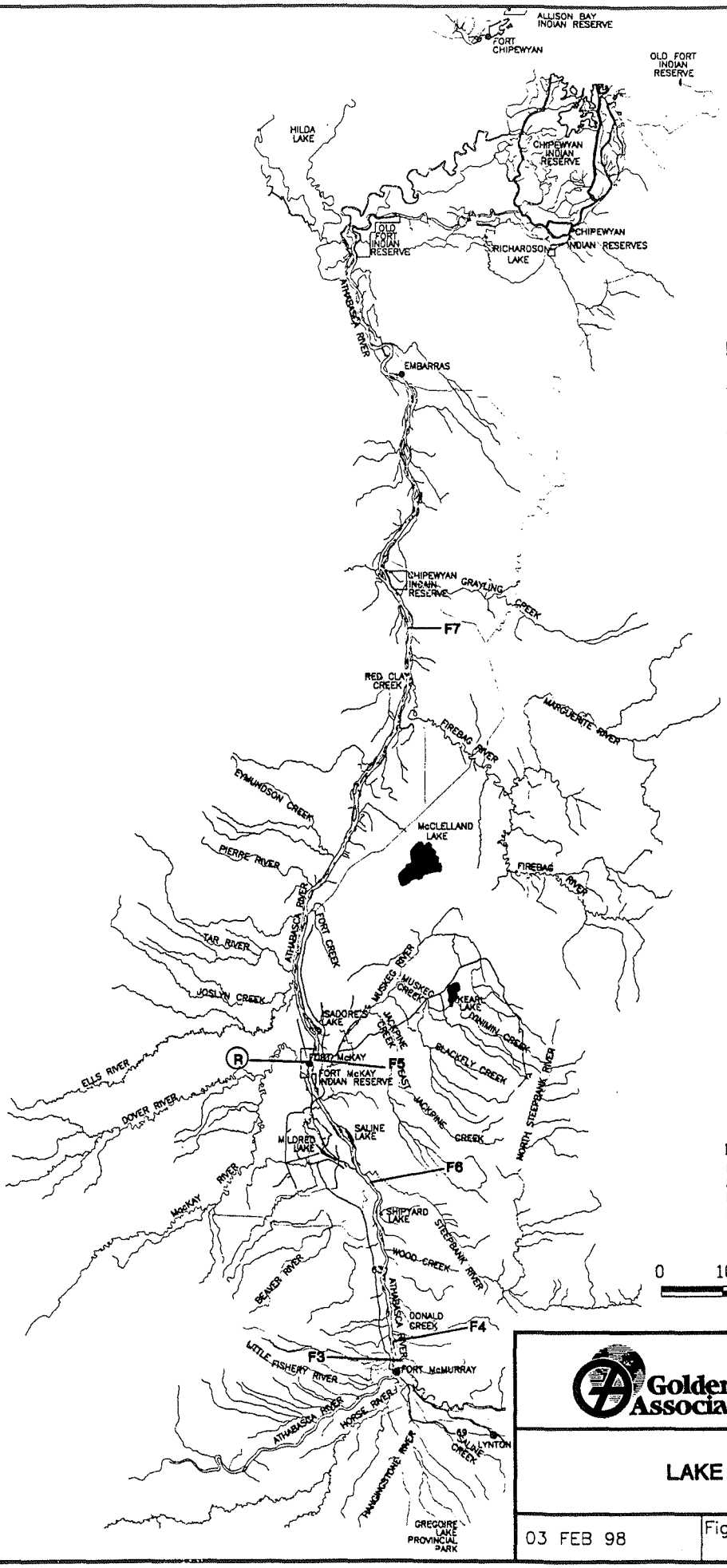
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 364 (L14)

03 FEB 98	Figure X-32	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEF03.dwg



LEGEND

Frequency (MHz): 150.394
Tagged and Released: October 2/97
Fork Length(mm): 482
Weight(g): 1990
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97
F5 November 12/97
F6 November 27/97
F7 December 5/97
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 394 (L15)

03 FEB 98	Figure X-33	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEF04.dwg

LEGEND

Frequency (MHz): 150.443
Tagged and Released: October 4/97
Fork Length(mm): 399
Weight(g): 970
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

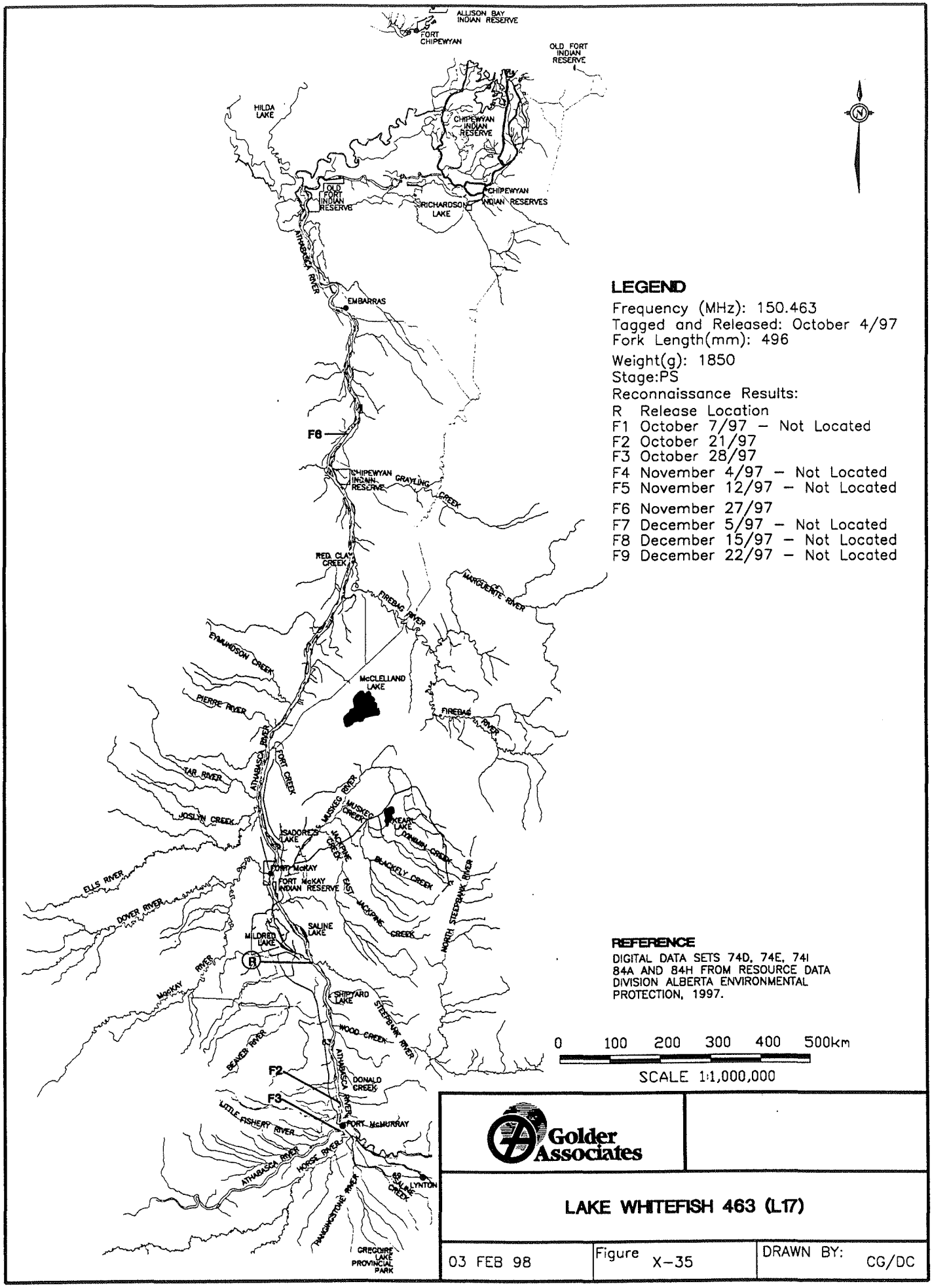
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 443 (L16)

03 FEB 98	Figure X–34	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEF05.dwg



LEGEND

Frequency (MHz): 150.463
Tagged and Released: October 4/97
Fork Length(mm): 496
Weight(g): 1850
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

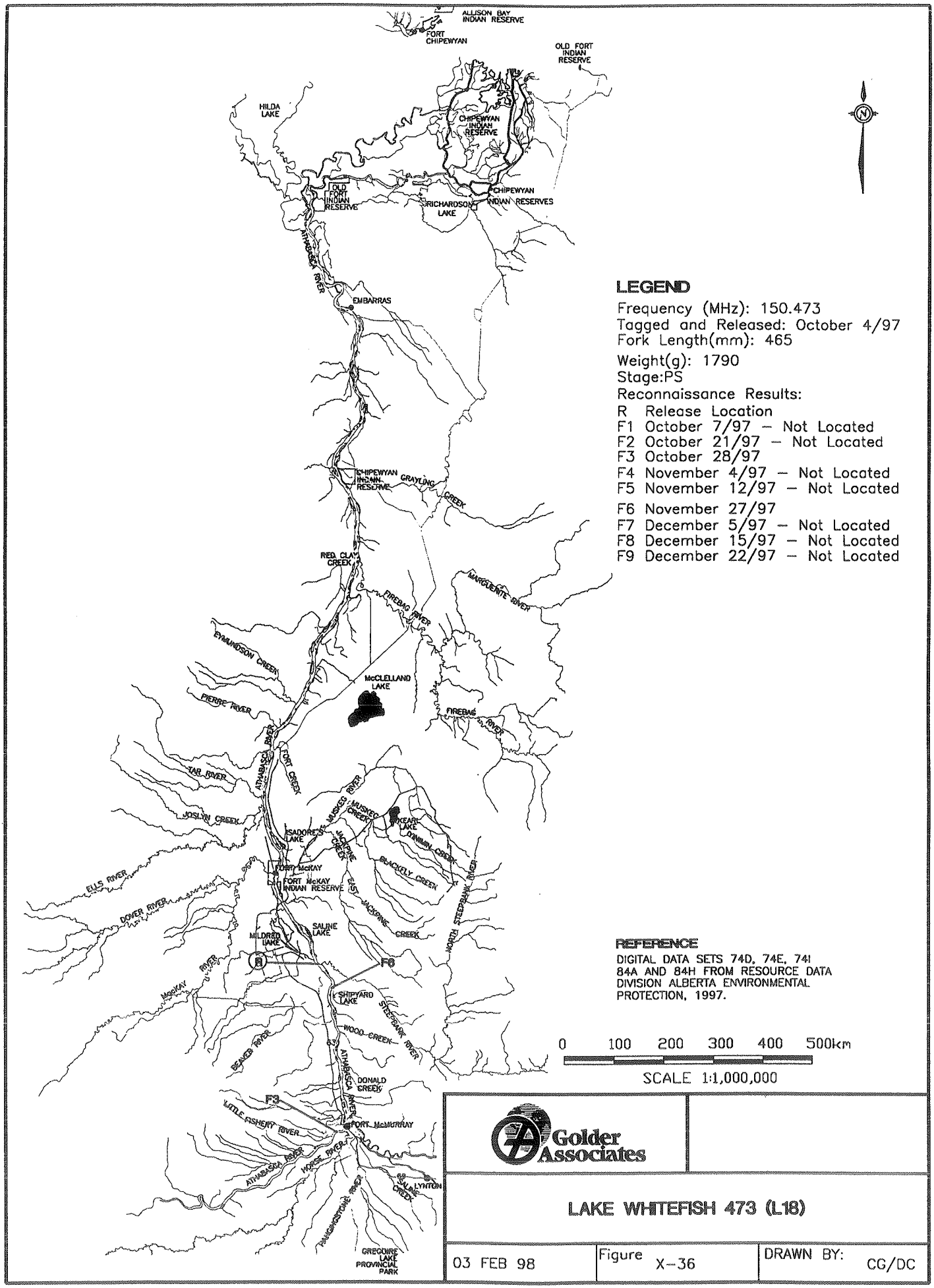
SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 463 (L17)

03 FEB 98	Figure X-35	DRAWN BY: CG/DC

J:\1997\2320\6050\WHITEF06.dwg



LEGEND

Frequency (MHz): 150.473
Tagged and Released: October 4/97
Fork Length(mm): 465
Weight(g): 1790
Stage:PS
Reconnaissance Results:

R Release Location
F1 October 7/97 – Not Located
F2 October 21/97 – Not Located
F3 October 28/97
F4 November 4/97 – Not Located
F5 November 12/97 – Not Located
F6 November 27/97
F7 December 5/97 – Not Located
F8 December 15/97 – Not Located
F9 December 22/97 – Not Located

REFERENCE

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

0 100 200 300 400 500km

SCALE 1:1,000,000

Golder Associates

LAKE WHITEFISH 473 (L18)

03 FEB 98	Figure X-36	DRAWN BY: CG/DC