Aquatic Baseline Report for the Athabasca, Steepbank and Muskeg Rivers in the Vicinity of the Steepbank and Aurora Mines

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This report is one of a series of reports prepared for Suncor Inc. Oil Sands Group for the Environmental Impact Assessment for the development and operation of the Steepbank Mine, north of Fort McMurray, Alberta. These reports provided information and analysis in support of Suncor's application to the Alberta Energy Utilities Board and Alberta Environmental Protection to develop and operate the Steepbank Mine, and associated reclamation of the current mine (Lease 86/17) with Consolidated Tailings technology.

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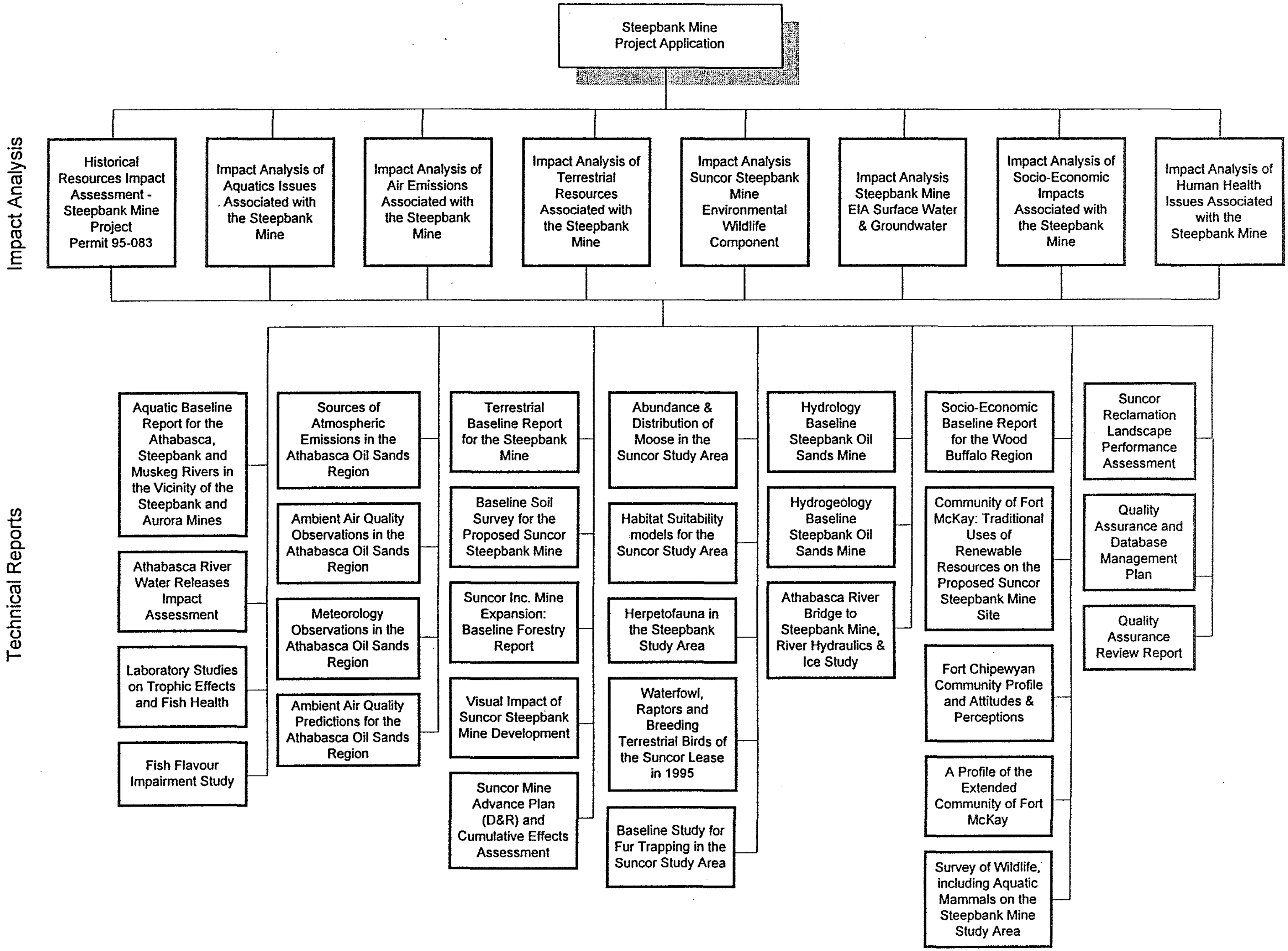

Reports Prepared for the Steepbank Mine Environmental Assessment

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EXECUTIVE SUMMARY

Suncor Inc., Oil Sands Group (Suncor) and Syncrude Canada Ltd. (Syncrude) currently operate oil sands mining facilities on the west side of the Athabasca River, north of Fort McMurray, Alberta. Both companies plan to expand their operations in the near future: Suncor, in the vicinity of the Steepbank and Athabasca Rivers (Steepbank Mine) and Syncrude in the Muskeg River watershed (Aurora Mine). An aquatic study was conducted in 1995 to: 1) describe the current conditions with respect to surface water, parador and sediment quality; benthic invertebrates; fish habitat; fish communities; and fish health; and 2) provide a baseline for comparing future conditions. This study builds on the existing regional database formed by the Other Six Lease Owners (OSLO) and Alberta Oil Sands Environmental Research Program (AOSERP) studies.

Major findings of the 1995 study include:

1) Naturally-occurring hydrocarbons can be found in river sediments and parador; however, no changes in surface water chemistry are associated with Athabasca oil sands deposits or existing oil sands facilities.
2) Benthic invertebrate communities are thriving and show no evidence of negative effects associated with exposure to naturally occurring hydrocarbon deposits or existing oil sands developments.
3) Fish habitat in the Athabasca River within the study area is relatively poor because of the homogeneous habitat and shifting sand bottom. High quality habitat exists in the Steepbank and Muskeg Rivers and in some tributaries to these rivers.
4) There are diverse fish communities in the Athabasca, Steepbank and Muskeg River basins.
5) There is evidence of exposure of fish to naturally-occurring hydrocarbons, although fish general fitness and health indicators suggest that fish populations are healthy.

Study Area

The proposed Steepbank Mine (Suncor) is adjacent to the Athabasca and Steepbank Rivers. The study area for the Steepbank Mine included 25 km of the Steepbank River and 25 km of the Athabasca River as well as sections of a number of small tributaries to the Athabasca River

(McLean, Wood, Leggett and Poplar Creeks). Aquatic resource inventories were conducted in spring, summer and fall of 1995. Fish surveys and water quality (surface water, parador and sediment) sampling took place in all three seasons; detailed fish health data for walleye and goldeye were collected in summer; and benthic invertebrate surveys and habitat mapping took place in fall.

The proposed Aurora Mine (Syncrude) could potentially affect several watercourses in the Muskeg River drainage. The study area for the Aurora Mine included sites on several drainages: Muskeg River, Jackpine Creek, Khahago Creek, Blackfly Creek, Iyinimin Creek, North Muskeg Creek, Muskeg Creek and Kearl Lake. Aquatic resource inventories were conducted in the spring, summer and fall of 1995. A fish fence was operated on the Muskeg River downstream of Jackpine Creek in spring and fall. Fish health data were collected for longnose sucker captured at the fish fence in spring. Stream fish surveys and habitat mapping were conducted in spring and summer; benthic invertebrates were sampled in fall; and water samples and plankton (Kearl Lake only) were collected in all three seasons.

Surface Water, Porewater and Sediment Quality

Surface water quality was monitored in spring, summer and fall of 1995 in the Athabasca, Steepbank and Muskeg Rivers, several small tributaries of the Athabasca and Muskeg Rivers, a small wetland on Lease 25 and Kearl Lake. With the exception of the Athabasca River, none of these water bodies receive wastewater from anthropogenic sources.

River water within the study area was characterized by pHs ranging from 7 to 8, low to moderate dissolved salt concentrations and moderate levels of nutrients. Dissolved organic carbon concentration was elevated in surface waters, indicating the influence of muskeg drainage. Concentrations of metals were non-detectable to low in all water bodies sampled, with the exception of occasionally elevated levels of metals associated with suspended sediments. Surface water samples were not toxic to bacteria, invertebrates, fish or plants. Levels of organic chemicals in surface water were not markedly affected by naturally occurring deposits of oil sands, although total hydrocarbons, PAHs, and naphthenic acids were detected at low concentrations in a few water samples. Water chemistry of Kearl Lake and the Lease 25 wetland did not differ from those of rivers and streams sampled in the study area.

Temporal variation in water quality was low in all water bodies sampled from spring to fall of 1995, with the exception of the Athabasca River. In this large river, high summer flows cause a large increase in suspended sediment load, which results in increased concentrations of associated water quality variables (e.g. nutrients, dissolved organic carbon, some metals).

Surface water quality has not changed in the study area over the last decade. As in previous years, wastewater discharges from Suncor did not have a discernible effect on the water quality of the Athabasca River in 1995.

Bottom sediment chemistry was assessed at four reference sites in the Athabasca and Steepbank Rivers and at one site adjacent to Tar Island Dyke (TID) in the Athabasca River. Athabasca River sediments contained detectable, but low levels of PAHs, as was also reported in a study conducted in 1994.. Hydrocarbon content was elevated at all three sites sampled, indicating the presence of varying amounts of oil sands in the sediments. Levels of metals were typical of large rivers in Alberta. Sediment chemistry was not affected by dyke seepage at the site adjacent to TID. In the Steepbank River, bottom sediments contained variable amounts of naturally-occurring hydrocarbons, and levels of metals were similar to those in the Athabasca River.

Porewater chemistry at reference sites (i.e., sites not affected by anthropogenic activities) in the Athabasca, Steepbank and Muskeg Rivers and Jackpine Creek was variable in terms of concentrations of major ions, dissolved salts, ammonia and PAHs. Naphthenic acid concentrations were low to moderate at all sites, and none of the samples were toxic, as evaluated by the Microtox® test. The results indicate that the chemical composition of river porewater in the study area varies greatly, depending on the amount of oil sands in the substratum.

Benthic Invertebrates

Benthic invertebrate communities were surveyed during the fall of 1995 in the Athabasca, Steepbank and Muskeg Rivers, tributaries of the Muskeg River and in Kearl Lake. Various sampling techniques were used (artificial substrates, Ekman grab, Neill cylinder), depending on habitat characteristics at the sampling sites. Both artificial and natural substrates were sampled in the Athabasca River.

The abundance of benthic invertebrates colonizing artificial substrates in the Athabasca River varied moderately among sites, but was similar at sites above and below Suncor discharge locations. There was a trend of lower numbers of invertebrates on both banks downstream from the Steepbank River. Taxonomic richness (total number of taxa) and the composition of the benthic fauna were generally similar at all sampling sites. Benthic invertebrates colonizing artificial substrates were dominated by stonefly nymphs and chironomid midge larvae. Chironomid dominance was most pronounced at the mouth of Poplar Creek and 5 km below the Steepbank River on the east bank, most likely due to greater amounts of organic detritus deposited from Poplar Creek and reduced current velocity relative to other sites, respectively. The benthic community colonizing artificial substrates was dominated by collector-gatherers and predators at all sampling sites in the Athabasca River.

Community composition and total abundance of benthic invertebrates were more variable on natural substrates in the Athabasca River than on artificial substrates, most likely as a result of greater variation in habitat characteristics. Taxonomic richness varied little among sites. The relative proportions of major functional feeding groups were similar to those on artificial substrates, but also varied more among sites.

Results of the benthic invertebrate survey of the Athabasca River suggest that biological effects were absent at sites exposed to discharges from Suncor. Although not directly comparable to historical data due to differences in sampling locations and, potentially, habitat characteristics, results of this study are generally consistent with those of previous benthic surveys of the Athabasca River.

Benthic communities in the Steepbank River varied moderately among sites, most likely as a result of differences in habitat characteristics. There was a trend of decreasing abundance and taxonomic richness from upstream to downstream stations, as well as a gradual decline in the proportion of chironomid larvae. The relative proportions of different functional feeding groups were similar at all sites. The changes in benthic communities with distance downstream appeared to parallel the variation in current velocity and substratum composition.

Benthic communities in the Muskeg River, its tributaries and Kearl Lake also reflected the habitat types sampled. Depositional sites typically supported invertebrate communities with moderate density and low taxonomic richness, consisting almost exclusively of oligochaete worms, nematode worms and chironomid midge larvae. The benthic community of Kearl Lake was similar, but total abundance was low. Erosional sites tended to support lower total number of invertebrates than depositional sites. A greater variety of invertebrates was found at erosional sites, consisting of the above taxa and various orders of aquatic insects. The structure of benthic communities in terms of relative proportions of functional feeding groups was also consistent with habitat type.

Comparison of the 1995 data with results of previous surveys revealed that benthic communities in the Muskeg River basin have not changed substantially since the 1980s. Differences among years in benthic community composition can be attributed to habitat differences related to the exact location of the sampling sites and normal year-to-year variability.

Results of the bioaccumulation assessment at reference sites in the Athabasca, Steepbank and Muskeg Rivers and Jackpine Creek indicated that concentrations of most metals analyzed were detectable in benthic invertebrate tissues, and were similar at all sites. Concentrations of PAHs and PANHs were non-detectable or near the detection limit at the sites sampled in the Athabasca and Muskeg Rivers and Jackpine Creek. In the Steepbank River, concentrations of several organic chemicals, particularly substituted phenanthrenes/anthracenes and dibenzothiophenes, were elevated relative to the other sites sampled, but levels remained relatively low. These results probably reflect differences in the amount of oil sand present in the substratum in the rivers sampled. No marked differences in tissue concentrations of metals and organics were noted between samples taken from the Athabasca River in August 1994 and October 1995.

Fish Habitat

The Athabasca River has turbid cool-water habitat and dynamic shifting-sand channels. Single channels are the major channel type but near islands and sand bars, multiple channels are present. Islands in the study reach include the Stony/Willow Island complex and Inglis Island. Major habitat features include backwaters and snyes associated with islands and sandbars. The substrate is almost entirely sand with the exception of some rocky shoals along the east bank near Willow Island and McLean Creek. Instream cover is minimal except for that provided by depth and turbidity. River banks are mainly armoured or erosional with some depositional areas and one small area with cliffs.

Habitat in the Steepbank River consists mainly of gravel/cobble/boulder substrate with pool/riffle and run/riffle sequences. River gradient decreases with distance downstream and the length of the riffle areas decreases. The mid-section of the river within the study area has more defined meander bends and the riffles have less boulder and more cobble/gravel substrate. The run/pool areas between the riffles are slower with more fines and less instream cover from boulders. The bottom section of the Steepbank River consists of swift, armoured riffles separated by run sections with the occasional pool occurring on meander bends. Riffles are less common than upstream, constituting 35% of the bottom area compared to 54% at the top of the study reach. Run is the most common type of habitat in this section of the river. Both runs and pools are fairly deep with good cover from boulders and fallen trees providing overhead cover along erosional bank areas.

Habitat in the Muskeg River system consists of low-gradient reaches that flow through muskeg and high-gradient gravel-dominated reaches that flow through well-drained upland areas. The lower reaches of the Muskeg River (8 km) have a fairly high gradient, gravel-dominated substrate and riffle/run complexes. The upper reaches of the Muskeg River (> 60 km) have deep slow runs with tortuous meanders, and a substrate dominated by fines. Beaver activity is common in the upper reaches of the Muskeg River. Stanley Creek, which enters the Muskeg River from the north, is an ephemeral stream that winds through muskeg. The lower reach of Jackpine Creek, which enters the Muskeg River from the south, has a meandering pattern and sand substrate with some cobble. Upstream of this reach, the gradient is higher, gravel substrate is dominant and riffle/run sequences occur. Overhead cover is provided by riparian vegetation. The Muskeg Creek watershed is located east of Jackpine Creek. Muskeg Creek and North Muskeg Creek drain Kearl Lake. These watercourses have mainly run/pool habitat, except for a high gradient section in the middle of Muskeg Creek that contains riffles. Khahago and Blackfly Creeks constitute the southwest drainage into Muskeg Creek. The habitat in Khahago Creek is characterized by deep, slow or flat runs and organic/silt substrate. Blackfly Creek, which discharges into Khahago Creek, has a higher gradient and flows through an area where white spruce provide overhead cover and instream cover from dead snags is abundant. Iyinimin Creek drains the southeast part of the Muskeg Creek watershed into Kearl Lake. The upper reach of this creek has a high gradient and flows through terrain similar to that of Blackfly Creek basin while the lower reach has a low gradient and meanders. Kearl Lake is a shallow mesotrophic to eutrophic lake with organic substrate and abundant aquatic vegetation.

Fish Communities

The Athabasca River fish inventory was carried out in spring, summer and fall using a variety of methods: boat electrofishing, backpack electrofishing, seining, gill netting, set lines, drift nets and minnow traps. Twenty-seven species have been reported historically from the Athabasca River in the area near Suncor. In 1995, 18 species were captured. Longnose sucker, goldeye, lake whitefish and walleye were the most abundant large fish species in the area downstream of Suncor and Syncrude. All of these species are known to overwinter in Lake Athabasca and migrate into the Athabasca River for at least part of the year. Longnose sucker migrate upstream in the spring and move into the tributaries to spawn. Shortly after spawning they move back into the Athabasca River, and remain there to feed for the rest of the open-water season. Immature goldeye are known to migrate to the area near Suncor in the spring to feed. In contrast to previous studies, mature goldeye in spawning condition were found near Suncor in spring 1995. Walleye also move upstream in the spring to spawn. The Athabasca River near Suncor provides important rearing and summer feeding habitat for walleye. Walleye spawning locations have not been located with certainty but there is evidence that they spawn at the rapids upstream of Fort McMurray. Lake whitefish spawn in the rapids upstream of Fort McMurray in the fall, and the Athabasca River near Suncor is an important feeding and resting area for lake whitefish moving upstream to spawn.

Other large fish species captured in the Athabasca River in 1995 include: northern pike, burbot, mountain whitefish, white sucker and yellow perch. The major small fish species in the Athabasca River in 1995 were trout-perch, flathead chub, lake chub, emerald shiner, spottail shiner and slimy sculpin. These results agree with the results of studies from the late 1970s.

Spottail shiner was the only species captured in Leggett Creek. Poplar Creek had a more diverse fish fauna. Flathead minnow and lake chub were the most common species collected in Poplar Creek. Game and domestic fish species from this creek included white sucker, longnose sucker and yellow perch. Arctic grayling and sucker spawning sites were documented in Poplar Creek.

Three sections of the Steepbank River, representing the main habitat types, were surveyed using a portable boat electrofisher and Zodiac in spring, summer and fall. The fish fauna of the Steepbank River is abundant and diverse. Twenty-five species of fish have been recorded from the Steepbank

River, of which ten (Arctic grayling, northern pike, longnose sucker, white sucker, lake chub, pearl dace, longnose dace, trout-perch, brook stickleback and slimy sculpin) are common and widespread. Fish species that use the Steepbank River fall into three main categories: migratory populations that rely on the Steepbank River for an important part of their life cycle; resident fish species; and species that use the lower river reaches for feeding and resting.

In the spring, longnose sucker, white sucker and Arctic grayling move into the Steepbank River to spawn. As well, spring feeding migrations of mountain whitefish are common. In the spring of 1995, mountain whitefish was the most common species, followed by Arctic grayling and longnose sucker. Catch-per-unit-effort (CPUE) for all three of these species was highest in the upper section of the study area where riffle habitat is common and boulders provide excellent instream cover. The white sucker CPUE also followed this pattern, although white sucker were far less abundant. Arctic grayling, longnose sucker and white sucker spawning sites were documented throughout study area on the Steepbank River but they were more common in the top half of the study reach.

The relative abundance of Arctic grayling, longnose sucker, white sucker and mountain whitefish changed throughout the year. Most adult longnose sucker and white sucker left the Steepbank River shortly after spawning while some juveniles remained throughout the open-water season, possibly overwintering in the Steepbank River. Mountain whitefish abundance decreased progressively through summer and fall, indicating that the fish were moving out of the river or to areas further upstream. Both past and present studies indicate that Arctic grayling remain in the Steepbank River until just prior to freeze-up. Young-of-the-year Arctic grayling likely overwinter in the Steepbank River.

Several small fish species (lake chub, pearl dace, longnose dace, slimy sculpin, trout-perch and brook stickleback) are year-round residents of the Steepbank River. In 1995, lake chub, longnose dace, and spoonhead sculpin were the most common small fish species. Several additional species are confined to the lowermost portion of the Steepbank River. In 1995, goldeye, lake whitefish, longnose dace, northern pike, and walleye were captured near the mouth of the river. Post-spawning feeding migrations of northern pike have been reported in the lower reaches of the Steepbank River. Lake whitefish use the mouth of the river as an important staging and resting area on their upstream spawning migration.

There were two main components to the Muskeg River basin fish inventory: a spring fish inventory at selected stream sites and Kearl Lake; and the operation of a fish fence on the Muskeg River in spring and fall. Seventeen fish species have been documented in the Muskeg River drainage basin which, as in the Steepbank River, can be classified into three main groups: resident species; species that use the river basin for part of their life cycle; and, occasional migrants from the Athabasca River.

Species known to use the Muskeg River and its tributaries for part of their life cycle include Arctic grayling, longnose sucker, white sucker, northern pike, lake chub and mountain whitefish. Spawning migrations of Arctic grayling, longnose and white sucker and northern pike into the Muskeg River occurred in the spring of 1995. As well, a few lake chub in spawning condition were documented in the spring. Previous investigators have also reported spawning migrations of these species into the lower reaches of this river, although in the past substantial numbers of fish spawned in Jackpine Creek as well. Fish access to Jackpine Creek is variable due to beaver activity near the creek mouth, which may explain why none of these species spawned in this creek in 1995. Mountain whitefish have also been known to migrate into the Muskeg River for summer feeding, but this activity was not documented in 1995.

Open-water habitat used of the Muskeg River varies depending on the species. Most longnose sucker and white sucker leave the river shortly after spawning, while northern pike and Arctic grayling remain to feed until fall. In the fall of 1995, northern pike and Arctic grayling were captured moving downstream in the Muskeg River, indicating an out-migration. There is little overwintering habitat available for large fish species and, with the possible exception of young-of-the-year, these species do not overwinter in the Muskeg River.

Resident fish species documented in the Muskeg River and its tributaries in 1995 include slimy sculpin, pearl dace, brook stickleback, fathead minnow, longnose and white sucker and northern pike. There is a small isolated population of northern pike in the upper reaches of the Muskeg River that is separate from the spawning population that uses the lower reaches of the Muskeg River. Kearl Lake fish fauna includes white sucker, pearl dace, fathead minnow and brook stickleback.

In 1995, burbot, walleye and trout-perch were recorded in the lower part of the Muskeg River. These three species, as well as lake whitefish and spottail shiner are.known to be only occasional migrants into the lower reaches of the river.

Fish Health

Detailed fish health data were collected for walleye and goldeye captured from the Athabasca River in the summer of 1995. Analyses for body burdens of PAHs and metals showed no elevation in these parameters in the fillets of either species. However, bile contained elevated levels of the PAH metabolites, benzo-a-pyrene (BaP) and naphthalene (NPH) in both species.

The general fitness of these species was assessed by measuring condition factor, mesenteric fat content, liver somatic index (LSI), stomach contents and pathology. Condition factor, mesenteric fat content and stomach contents were similar to those reported by previous studies in the study area and from further upstream. Comparisons with similar studies on other river systems indicates that livers of fish in the study area are similar in size to fish from farther upstream, but may be smaller than in pristine systems. Field-recorded internal pathology indicated parasitism and abnormal spleens and livers in both species; however, histological examination of these tissues revealed no tissue changes related to toxicity or neoplasia (cancer). The only external abnormality of interest was the absence of both pelvic fins and pelvic girdle, without any sign of injury, in a small percentage of goldeye from the Athabasca River.

A number of physiological parameters were also measured in goldeye and walleye: mixed function oxidase activity (MFO), retinol (vitamin A), and blood chemistry. MFO analyses showed elevated levels of the liver enzymes, ethoxyresofurin-O-deethylase (EROD) and aryl (benzo-a-pyrene) hydrocarbon (AHH) activity in both species compared to data from fish captured farther upstream and from other systems. Retinol was measured in liver tissues of goldeye and walleye to provide baseline data for later comparisons; there are no comparable retinol data for either upstream fish or from the pre-development period. Plasma samples for walleye and goldeye were analyzed for lactate, total protein and glucose. Total protein concentration was in the normal range for fish, whereas the glucose level appeared elevated compared to studies in other systems. There are no comparable lactate data.

Reproductive data for goldeye and walleye were limited because these species were sampled in post-spawning condition. Blood hormone levels appeared normal for fish sampled in a non-spawning period when compared to data from other systems.

Detailed fish health data were collected for pre-spawning longnose sucker in the spring of 1995. Composite samples of longnose sucker flesh showed slight elevations in naphthalene levels but no elevation in levels of other PAH compounds or metals. Bile showed elevated levels of BaP and NPH, which indicates exposure to PAH compounds.

Condition factor, mesenteric fat content and stomach contents of longnose sucker were similar to those reported by previous studies in the study area and farther upstream. Comparison with similar studies on other river systems indicates that livers of longnose sucker in the study area are similar in size to fish from farther upstream but may be smaller than in pristine systems. Field-recorded gross pathology indicated no external abnormalities but showed that a number of longnose sucker had pale or discoloured livers. Analyses for MFO activity in longnose sucker showed elevated levels of EROD and AHH in composite liver samples compared to data from fish captured farther upstream and from other systems.

Reproductive parameters recorded for longnose sucker include fecundity and egg diameter, gonad somatic index (GSI) and blood hormone levels. Longnose sucker fecundity was somewhat higher in the present study than previously reported in the study area. The GSIs in pre-spawning longnose sucker appear to be typical of mature fish. As well, sex steroid levels in longnose sucker were similar to those in pre-spawning fish from the Wapiti-Smoky River System and the North Saskatchewan River.

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1.0 INTRODUCTION

Suncor Inc., Oil Sands Group (Suncor) and Syncrude Canada Ltd. (Syncrude) currently operate oil sands mining facilities on the west side of the Athabasca River, north of Fort McMurray, Alberta. Both companies plan to expand their operations in the near future. In anticipation of these expansions, Suncor has acquired Leases 97, 25 and 19 (Steepbank Mine) on the east side of the Athabasca River in the vicinity of the Steepbank River, McLean Creek and Leggett Creek, and Lease 23 on the west side of the Athabasca River near Poplar Creek. Similarly, Syncrude has acquired Leases 10, 12, 13, 31 and 34 (Aurora Mine) on the east side of the Athabasca River located within the Muskeg River drainage. Since these new mines have the potential to impact aquatic resources in a number of watercourse, an aquatic baseline study was conducted in 1995 to ensure that there would be adequate information available to enable an environmental impact assessment. The results of the baseline study and subsequent environmental assessment are required to support both Syncrude and Suncor's applications for mine expansion.

Given that the leases are located in the same region and the new mine developments will have similar potential environmental impacts, Syncrude and Suncor have agreed to produce a joint aquatic baseline report. This will avoid duplication of effort and provide a more comprehensive summary of baseline conditions. Golder Associates Ltd. (Golder) has been retained to produce this report which integrates historical data and the results of current aquatic field studies of the Athabasca River and watercourses on the Suncor and Syncrude leases. Because the new leases are adjacent to leases that, for the most part have been previously studied and developed, the current programs are intended to expand the study areas and build on the extensive database developed from earlier Syncrude and Suncor studies and the more recent Other Six Lease Owners (OSLO) studies.

1.1 Objectives

The study has the following primary objectives:

- To develop a scientifically credible database of the aquatic resources in the local study areas that meets all regulatory requirements and to aid in assessing potential impacts; and
- To develop a database of aquatic resources that is sufficient to serve as a basis for future monitoring.

To satisfying these objectives, a comprehensive study of the aquatic resources in the area was undertaken in the spring, summer and fall of 1995. The following components of the aquatic ecosystem were surveyed:

- Surface water, sediment and porewater quality;
- Benthic invertebrates;
- Fisheries habitat;
- Fish communities; and
- Fish health.

1.2 Study Areas

The location of the study area within Alberta is shown in Figure 1.2-1. The local study areas are depicted in a regional context in Figure 1.2-2. Detailed data collection took place within local study areas (Figures 1.2-3 and 1.2-4). The local study area for the Steepbank Mine included 25 km of the Athabasca River extending from Willow Island to Saline Lake; the lower portion of the Steepbank River within the proposed mine area; Leggett, Poplar, Wood and McLean creeks, an unnamed tributary to the Athabasca River and an unnamed tributary to the Steepbank River (Figure 1.2-3). The local study area for the Aurora Mine focused on the Muskeg River drainage and included sampling on the Muskeg River, Jackpine Creek, Khahago Creek, Blackfly Creek, Iyinimin Creek, North Muskeg Creek, Muskeg Creek and Kearl Lake (Figure 1.2-4).

2.0 VALUED ECOSYSTEM COMPONENT (VEC) SELECTION

It is impossible for an impact assessment to address explicitly all potential effects of a project on all components of the biotic and abiotic environment. Hence, it is necessary that representative ecological indicators (certain species, habitats or physical aspects of the environment) be selected early in the EIA process to focus the assessment. In the present study, the concept of Valued Ecosystem Components (VECs) was used to identify ecological indicators. VECs are defined as "a biological resource that has ecological, social and/or economic significance and which, if affected by a project, would be of concern to scientists, managers, government regulators and the public" (Beanlands and Duiniker 1983). This group of ecological indicators typically represents the most important/critical components of the environment as perceived by scientists, regulators and the public. Components can be selected on the basis of a range of factors, such as their high ecological value (e.g. longnose sucker are ecologically important as they form the base of the food chain for many predators), their high value to the public (e.g., walleye are important from an subsistence and recreational point of view), their sensitivity to disturbance (e.g., spawning habitats), or their rarity (e.g., endangered species).

To identify VECs for the Athabasca River and the Steepbank River, a two dimensional matrix was prepared that listed the fish species that occur within the study areas and important ecological, social and economic attributes. For each of these attributes, scoring criteria were developed (Table 2.0-1). The scoring criteria were adapted from those designed for Environmental Effects Monitoring (EEM) investigations (Environment Canada and Department of Fisheries and Oceans 1993) and from a receptor screening process suggested for ecological risk assessments (Suter 1993). Each fish species was screened against these criteria and a preliminary score was obtained. Of the 14 species screened, goldeye, lake whitefish and walleye received the highest scores.

For the Steepbank Mine, further refinement to the VEC selection process was made during the public consultation process. The initial matrix was presented to the public to provide a basis for discussion of VECs (meeting of April 28, 1995). The stakeholders considered some attributes more important than others. Therefore, a weighting factor was applied to reflect these values. The following factors were considered of primary importance and received a weighting factor of two: residence/abundance; political, commercial, subsistence, and recreational importance; feasibility to study; and the amount of information available. Ecological attributes such as sensitivity to sediment exposure; spawning in study area; benthic food preference; importance as prey; high growth rate and fecundity; and age to maturity were of secondary importance from the stakeholders point of view. The results of the weighting of the VECs for the Steepbank Mine are shown in Tables 2.0-2 and 2.0-3. This process was also used to determine VECs for the Aurora Mine project (Table 2.0-4).

The application of a weighting factor resulted in walleye, lake whitefish, goldeye and longnose sucker scoring highest for the Athabasca River; longnose sucker and trout-perch scoring highest for the Steepbank River; and Arctic grayling and longnose sucker scoring highest for the Muskeg River. Arctic grayling, white sucker, northern pike and mountain whitefish scored high for both the Steepbank and Muskeg Rivers. For the Steepbank Mine the scores were reviewed by individuals from a number of government agencies (Alberta Environmental Protection, Alberta Energy and Utilities Board, Canadian Coastguard, Department of Fisheries and Oceans and Health Canada). Input from government agencies was taken into account in the final VEC selection for both study areas.

To thoroughly evaluate the status of a VEC there are a number of physiological and population parameters that are important to measure. Fish health (biomarker) evaluation in particular has very specific requirements in terms of the type of data, the amount of information and the timing of data collection. Biomarking is done on fairly large fish just prior to spawning and at least 40 fish (20 of each sex) must be sacrificed (for more details on biomarking protocols see Section 3.7). Given that there are a number of possible VECs, only those species that fit the requirements for biomarking analysis were chosen. Of the four species that scored high for the Athabasca River, walleye and longnose sucker are reported to spawn in the area. In contrast, available information indicated that there probably would not be sufficient numbers of lake whitefish and goldeye spawners in the study area. Therefore, walleye and longnose sucker were chosen as VECs for the Athabasca River. Goldeye were added as a VEC when it was found that there were a sufficient number of fish in spawning condition in the study area to enable biomarking collection. In the Steepbank River, longnose sucker were chosen as the VEC with trout-perch being eliminated due to their small size. For the Muskeg River, longnose sucker were chosen as the VEC for biomarker analysis. Arctic grayling were also considered a VEC for the Muskeg River, but detailed fish health analysis was not conducted due to concerns that sacrificing 40 fish might affect Arctic grayling abundance.

While the use of VECs allows a detailed fish health investigation, it does not limit the assessment of baseline conditions to these three species. The fish health investigation was done in addition to a complete fish inventory and fish habitat assessment. Community structure; habitat availability and use; and population parameters were examined for all fish species captured in the study area.

3.0 METHODS

3.1 Historical Data Sources

A considerable amount of information pertaining to aquatic biological resources (fisheries, water quality, benthic invertebrates, plankton) and aquatic habitats in the oil sands region of northern Alberta was reviewed prior to developing the current studies. Most of the aquatic studies associated with the area between Fort McMurray and the Peace-Athabasca Delta date from the late 1970s, during the height of the Alberta Oil Sands Environmental Research Program (AOSERP) research activities. Since the early 1980s, both Suncor and Syncrude have also conducted a number of aquatic studies. More recently, the Northern River Basins Study (NRBS) has added additional data for the area, with surveys done during 1992 to 1995.

Studies on the effects of discharges in the vicinity of Suncor have included investigation of chemical levels in bottom sediments and invertebrates (Beak Associates 1983, 1988), metal levels in fish (Lutz and Henzel 1977), the effect of thermal plumes on fish (Golder 1994a) and the effect of seepage from Tar Island Dyke on aquatic biota, wildlife and human health (Golder 1994b). In addition, benthic invertebrate communities have been monitored in the Athabasca River, upstream and downstream of Tar Island Dyke by Noton (1979) and by Noton and Anderson (1982). Barton and Wallace (1980) surveyed aquatic invertebrates in the Athabasca, Muskeg and Steepbank Rivers.

Areas previously surveyed in the Aurora Mine Study Area (Syncrude) were located primarily in the Muskeg River drainage basin (covering Leases 13, 34 and 31) and included the following: the middle reach of the Muskeg River; Jackpine and East Jackpine Creeks (formerly Hartley Creek); Muskeg and North Muskeg Creeks (formerly Kearl Creek); Iyinimin Creek; Khahago Creek; Green Stocking Creek; Blackfly Creek; Wapasu Creek; Kearl Lake; and, 23 unnamed ponds. The scope of work in the Muskeg River drainage basin that is detailed in this report includes spot-check surveys to verify aquatic biological resource and habitat surveys for Lease 13, 34 and 31 conducted by Beak (1986a, 1986b) and R.L.&L. (1989), and an extension of the database to include Leases 10 and 12.

3.2 Overview of the Study Areas

The local study area for the Steepbank Mine (Suncor) and the sampling sites are presented in Figures 3.2-1 and 3.2-2. The study area included the mainstem Athabasca River and the Steepbank River within the vicinity of Suncor Leases 19, 97, 25, and 86/17 and it is located on the east and west sides of the Athabasca River north of the town of Fort McMurray, Alberta. Also included in the study area, but sampled to a lessor extent, were portions of six small tributary streams. These streams were McLean Creek, Wood Creek, Leggett Creek, Poplar Creek, an unnamed tributary to the Athabasca River (drainage of the Reference Wetland) and an unnamed tributary to the Steepbank River. Table 3.2-1 provides a complete list of all sampling stations within the study area and the type(s) of sampling conducted at each station. The location of each sampling station was recorded with a Geo Explorer Geographic Positioning System (GPS) unit. Map Universal Transverse Mercator (UTM) coordinates and GPS defined UTMs for each site are presented in Appendix I.

In the mainstream Athabasca River, sampling was conducted at selected sites within a section of river approximately 25 km in length, extending from the southernmost boundary of Lease 19 downstream to the northernmost boundary of Lease 25 (Figure 3.2-1). The southern boundary of Lease 19 occurs just upstream of the Stony/Willow Island complex and the northern boundary of Lease 25 is located a few kilometres below the mouth of the Steepbank River.

The study area on the Steepbank River consisted of the lower portion of the river that lies within the Suncor lease area (Figure 3.2.-2). This included about 26 km of the river, with the upstream boundary located just upstream of the border of Lease 19, and the downstream boundary located at the river mouth. Fish surveys, benthic invertebrate and water quality sampling sites were located within three representative sampling areas of the Steepbank River: Section 1, located in the upper portion of the study area (Lease 19 boundary downstream for 3.9 km); Section 2, located in the middle of the study area (a 3.2 km section in the vicinity of Fee Lot 3); and Section 3, located in the lower portion of the study area, starting at the upstream boundary of Fee Lot 1 and ending at the river mouth (a 7.9 km section).

The study area for the Aurora Mine (Syncrude) was within the Muskeg River watershed, which is located north and east (on the opposite side of the river) of the town of Fort MacKay and north of the Suncor Lease Area. The Muskeg River flows southwest draining Wapasu, Stanley, Muskeg and Jackpine Creeks, before it discharges into the Athabasca River. There are a number of ponds and lakes within the watershed; Kearl Lake is the largest.

The sampling sites on the Muskeg River and its tributaries are presented in Figure 3.2-3 and for Kearl Lake in Figure 3.2-4. Investigations in the Aurora Mine study area include spot-check surveys to verify historic aquatic biological resource and habitat surveys for Lease 34 and 13, and an extension of the database to include Lease 12. Note that the sample location numbers correspond to site numbers used in previous studies. However, because there were some new sampling locations, a system of reach/site designation was devised for any new sites that were sampled. Reaches were numbered such that they could be readily distinguished from previously sampled sites. Reach numbers for each main watercourse (shown in Figures 3.2-3 and 3.2-4) are: Muskeg River (Sites 30 - 36); Jackpine Creek and its tributaries (Sites 40 - 43); Muskeg Creek and its tributaries (Sites 50 - 55); Stanley Creek (Site 60); and, Kearl Lake (Site 80). Table 3.2-2 provides a complete list of all sampling stations within the study area and the methods used at each station. Locations referenced with a GPS unit are presented in Appendix I.

The aquatic resources (water quality, fish and benthic communities, aquatic habitat) of the Athabasca River adjacent to the Aurora Mine site have been well documented in previous studies, so no new information for the stretch of river adjacent to Syncrude's leases was collected in 1995. Hence, the description of aquatic resources was based on AOSERP studies of the 1970s, Syncrude's fish inventories from 1989 to 1991, NRBS studies (fish inventory and water quality) and Alberta Environmental Protection (AEP) water quality studies.

3.3 Water Quality

3.3.1 Water Quality Rationale

The water quality surveys developed for the Athabasca, Steepbank and Muskeg Rivers were based on supplementing the limited documentation of natural loadings of trace organic compounds (e.g., Polycyclic Aromatic Hydrocarbons - PAH, Polycyclic Aromatic Nitrogen Heterocycles - PANH and Polycyclic Aromatic Sulphur Heterocycles - PASH) associated with the McMurray Formation deposits. The rationale for the list of water quality parameters that were tested is documented in Appendix II.

3.3.2 Water Quality Sampling Locations

STEEPBANK MINE STUDY AREA

Kilometre posts were used to identify the locations of the sampling sites within the Athabasca and Steepbank River study areas. The kilometre postings on the Athabasca River began at the Lease 19 border and continued downstream for 25 km, whereas the kilometre postings in the Steepbank River began at the river mouth and continued upstream for 25.9 km.

Ten sites were sampled for surface water quality in the mainstream Athabasca River and its tributaries (Figures 3.2-1 and 3.2-2). The mainstream river was sampled at two water quality transect stations which were located as follows; Station AW004 located upstream of the Lease 19 boundary at km -0.71, and Station AW009 located at the Lease 25 boundary at km 25. Surface water quality was measured at the mouths of McLean (AW005), Wood (AW006), Poplar (AW008), and Leggett (AW014) Creeks, as well as at the mouth of the unnamed channel which drains Shipyard Lake (AW007). Surface water quality was also sampled at transect Station AW018 in Saline Lake, which extended from the north to south end of the lake. Two sites were sampled in the Steepbank River for surface water quality and included Station AW010 which was located at the mouth of the Steepbank River at km 0.13, and Station AW001 which was located just upstream of Lease 19 at km 25.9. As well, porewater and river sediments were sampled from the Steepbank River study area. Porewater was sampled at three stations in the Steepbank River: upstream at Station AW001; midstream in the vicinity of Fee Lot 3 at Station AW003 (km 13.94); and, near the river mouth at

Station AW012 (km 0.19). Sampling of river sediments was conducted upstream of Lease 19 at Station AW002 (km 25.9) and near the river mouth at Station AW011 (km 0.13). Quality assurance "blank" samples were taken for both porewater and surface water and consisted of samples prepared using distilled water poured through the sampling equipment following decontamination of the equipment. The distilled water blanks were labelled as Station AW013. Quality Assurance and Quality Control (QA/QC) protocols are outlined in detail in Appendix III.

MUSKEG RIVER

Eleven sites were sampled for surface water quality in the Aurora Mine study area (Figures 3.2.3 and 3.2.4). Water quality sites on the Muskeg River included Site 30 which was located at the mouth and Site 36 just upstream of Stanley Creek confluence. Site 9 was located at North Muskeg Creek at the outlet to Kearl Creek. Water quality was also determined at the mouths of Jackpine (Site 17), Muskeg (Site 50) and Stanley (Site 60) Creeks. Sites 8 and 55 were located at the Syncrude flow gauging stations on Iyinimin and Blackfly Creeks, respectively. In addition, a water quality transect sample was taken at Site 80 in Kearl Lake. As well, porewater was sampled at two sites: Site 30 and Site S-4. Quality Assurance/Quality Control Program samples for surface water included: a duplicate sample from Site 30, referenced as Site 90; and, a field blank sample designated Site 70. Quality assurance for porewater was done in conjunction with sampling for the Steepbank Mine local study area and consisted of samples prepared using distilled water poured through the sampling equipment following decontamination of the equipment.

3.3.3 Water Quality Sampling Methods

STEEPBANK MINE STUDY AREA

Water quality and sediment sampling was conducted during the following periods in 1995: spring, 29 May to 2 June; summer, 4 to 14 August; and fall, 3 to 14 October.

Seasonal surface water quality sampling was conducted during the spring, summer and fall at the following stations: AW001, AW004, AW005, AW006, AW007, AW008, AW010 and AW013 (Figure 3.2-1). Station AW009 was sampled in the spring and summer but due to the similarity in the results between this station and AW004, located further upstream on the Athabasca River, AW009 was not sampled in the fall. Station AW014 was sampled in the summer and fall but was not flowing during the spring survey. Station AW018 was sampled only in the fall.

Porewater and sediment sampling was conducted on the Steepbank River at the selected sites during the spring and fall sampling periods. Porewater sampling was conducted at Stations AW001, AW003, AW012 and AW013. Sediment sampling was conducted at Stations AW002 and AW011.

At all surface water quality stations, field determinations were made for pH, conductivity, dissolved oxygen and water temperature. Field measurements for porewater samples included conductivity and water temperature. In addition, samples for chemical analyses were collected at surface water, porewater and sediment sampling stations (Table 3.3-1). To ensure sample integrity, grab samples for sediments, surface water and porewater were collected following Golder Technical Procedures 8.2-0, 8.3-0 and 8.4-0, respectively (Appendix IV). At Stations AW004 and AW009 in the Athabasca River and Station AW018 in Saline Lake, composite samples were prepared by collecting surface water grab samples at five evenly spaced points across each transect (Figure 3.2-1) then combining the samples to produce a single composite. At each of the five sampling points on the transects, surface water quality field measurements were made and samples were collected for chemical analysis.

At Station AW013, field blank samples were prepared as part of the QA/QC program (Appendix III). The field blank samples were prepared by taking laboratory distilled/deionized water into the field and pouring it into sample containers (surface water blank) and by pumping it up through the mini-piezometer (porewater blank). Additional QA/QC samples consisted of triplicate samples for all parameters except trace organics, where duplicates were done instead. Triplicate samples were collected from the sampling stations at the mouth of the Steepbank River as follows; surface water at Station AW010, porewater at Station AW012, and sediment at Station AW011. During the fall survey, split samples were collected from Stations AW001 and AW010 for analysis of oil and grease, inorganic and organic parameters. Water quality samples were stored and shipped to the laboratories following the procedures set out in Golder Technical Procedures 8.2-0, 8.3-0 and 8.4-0 (Appendix IV).

AURORA MINE STUDY SITE

Water quality samples were collected from Sites 17, 30, 9, 80, and 50 during the spring (4 May and 28 May), summer (8 August and 15 August) and fall (19 September and 26 October) sampling surveys. Two additional sites, 8 and 55, were sampled for water quality only during the summer and fall sampling surveys. To ensure sample integrity, grab samples for surface water were collected following Golder Technical Procedure 8.3-0 (Appendix IV). At Site 80 in Kearl Lake, a composite water sample was collected during the summer and fall surveys, from the euphotic zone at ten sites in the lake (Figure 3.2-4).

In summer and fall, field blank samples (designated Site 70) were prepared by taking laboratory distilled/deionized water into the field and pouring it into sample containers. The field blank samples were sent to Chemex Labs Alberta Inc. (Chemex) for analysis as part of the Quality Assurance/Quality Control program. Duplicate samples were taken in spring, summer and fall at Site 30 and designated Site 90. Duplicate samples were also prepared according to Golder Technical Procedure 8.3-0 for analysis of naphthenic acids, Microtox®, oil and grease, conventional parameters (major ions alkalinity, etc.), Inductively Coupled Plasma (ICP) total metals, dissolved organic carbon, suspended solids, and total phosphorus. Water quality samples were stored and shipped to the laboratories following the procedures set out in Golder Technical Procedures 8.3-0 and 8.4-0 (Appendix IV).

3.3.4 Water Quality Laboratory Methods

Water samples were analyzed by Chemex for conventional parameters, nutrients, Biological Oxygen Demand (BOD), total phenolics, total cyanide, total phosphorus, chlorophyll *a*, suspended solids, and ICP total metals. Enviro-Test Laboratories (Enviro-Test) of Edmonton analyzed the water samples for PAHs, PANHs, volatiles, non-chlorinated phenols and oil and grease. Naphthenic acids and Microtox^R in water samples were analyzed by Syncrude's Research Centre in Edmonton. In addition, split samples collected from the Steepbank River were sent to Analytical Services Laboratories (ASL) in Vancouver for analysis of oil and grease, inorganic and organic parameters. A detailed list of water quality parameters is presented in Table 3.3-1 and a general description of analytical methods used for laboratory analyses is shown in Table 3.3-2. Appendix V contains a detailed description of all laboratory analyses.

3.4 Benthic Invertebrates

3.4.1 Study Design

Benthic invertebrate surveys of the Athabasca, Steepbank and Muskeg Rivers and a number of small streams in the Muskeg River drainage basin were intended to verify the accuracy of the historical data (confirmation sampling) and to extend the spatial coverage of the available data by sampling areas previously not surveyed. Specific objectives and detailed study designs for each river are provided in the following sections.

ATHABASCA RIVER

The baseline assessment monitoring program was designed to:

- Characterize benthic invertebrate communities in the Athabasca River;
- Assess potential impacts of seepage from Tar Island Dyke (TID) on benthic invertebrates in the Athabasca River;
- Assess potential cumulative impacts of other sources of chemical loading from Suncor's mine and operations plant, sewage effluent and mine drainage water on the benthic fauna of the Athabasca River; and
- Determine tissue concentrations of target chemicals in benthic invertebrate tissues.

The field program was completed between September 11 and October 27, 1995. To assess community structure, both artificial and natural substrates were monitored at 12 stations located in depositional areas along the Athabasca River (6 on the east bank and 6 on the west bank; Figure 3.2-1). The availability of depositional areas with similar habitat characteristics for the deployment of artificial substrates was the limiting factor for site selection. Therefore, the design was consistent for both sampling methods and the 12 stations were coincident for both artificial and natural substrates.

Four replicate rock-filled basket samplers were deployed at each station selected for the artificial substrates survey. All were to be retrieved, but only three were randomly selected and submitted for analysis. The fourth sample was archived. For natural substrates, one composite of three replicate samples per station was submitted for analysis.

Monitoring stations were grouped as parallel pairs (i.e., one on each bank of the river) as much as habitat characteristics permitted. Even station numbers were located on the east bank and odd station numbers were located on the west bank as shown in Figure 3.2-1 and as follows:

- Reference: upstream reference (AB001 and AB002);
- Potential exposure: mouth of Poplar Creek (AB003 and AB004);
- Potential reference/exposure: upstream of TID (AB005 and AB006), but downstream of the watershed south of the Steepbank River;
- Potential reference/exposure: immediately downstream of TID (AB007 and AB008), but upstream of wastewater discharges, sewage effluent, mid-plant and north mine drainage from Suncor and upstream of the Steepbank River;
- Potential exposure: downstream of wastewater discharges, mid-plant and north mine drainage and sewage effluent (AB009) and downstream of the Steepbank River (AB010); and
- Reference: far-field downstream reference (AB011 and AB012).

In addition to the benthic community assessment, invertebrate tissue samples were collected at one station (AT003) located on the east bank of the Athabasca River (Figure 3.2-1). Its location was based on the availability of historical data for comparative purposes. Note that this bioaccumulation station was located in an erosional area to increase benthic biomass collected per level of effort.

STEEPBANK RIVER

The baseline assessment monitoring program was designed to characterize benthic communities and to determine tissue concentrations of target chemicals in benthic samples collected in the Steepbank River.

The field program was completed between October 19 and 27, 1995. To assess community structure, natural substrates were monitored at three stations located in erosional areas along the Steepbank River (Figure 3.2-2). Five replicate Hess samples per station were submitted for analysis.

In addition to the benthic community assessment, invertebrate tissue samples were collected at one station (SB002) in the Steepbank River (Figure 3.2-2), to assess the bioaccumulation of metals and organic compounds (PAHs, alkylated PAHs, PANHs and alkylated PANHs).

MUSKEG RIVER BASIN

Benthic invertebrates were sampled for analysis of community structure at the sites selected for confirmation sampling of fish habitat (Figure 3.2-3). The objectives of the baseline study were to characterize benthic communities in the Muskeg River, its tributaries and Kearl Lake and to determine tissue concentrations of target chemicals in benthic invertebrates collected in the Muskeg River basin.

The first objective was addressed by conducting a survey of benthic invertebrate communities at sites sampled during the OSLO Project (R.L. & L. 1989), and comparing the 1995 results with the historical data. In 1995, seven of the 19 sites sampled during the OSLO Project were re-sampled, along with three new sites. Nine stream sites were sampled, including three in the Muskeg River and six in various tributaries (Figure 3.2-3). One mid-lake site was sampled for benthic invertebrates in Kearl Lake (Figure 3.2-4). Zooplankton and phytoplankton were also sampled in Kearl Lake for analysis of abundance and taxonomic composition. Plankton samples were archived for potential future analysis.

Benthic invertebrate tissues were sampled for chemical analysis at two sites (Muskeg River and Jackpine Creek; Figure 3.2-3), to assess the bioaccumulation of metals and organic compounds (PAHs, alkylated PAHs, PANHs and alkylated PANHs).

3.4.2 Sampling Methods

ATHABASCA RIVER

Four artificial substrates were installed at each of 12 stations along the Athabasca River (Figure 3.2-1) between September 11 and 17, 1995. Each substrate consisted of a "barbecue chicken basket" assembled using a method derived from ASTM protocols (ASTM, 1992). Each basket was filled with 2.5 cm diameter sieved crushed aggregate (i.e., rocks ranging from approximately 2.5 to 6 cm) and held closed with both hull clips and cable ties. Steel cable was used to suspend the baskets from 2.75 m iron T-rails, previously pounded about 0.75 m into the river substrate. All baskets were suspended at approximately 0.5 m from the sediment-water interface. Baskets were kept from swinging using a polypropylene rope attached to the basket and looped over the T-rail. Flagging tape and an orange float were tied to the top of the T-rail to mark the sample location. Artificial substrates were generally placed 2-5 m apart and their configuration was either linear or rectangular, depending on the slope of the river bed at any given monitoring station.

Following a four week colonization period, artificial substrates were collected between October 14 and 21, 1995. A 250 µm mesh Nitex® dip net was placed under the artificial substrate as it was raised using a gaff. At the water surface the rope securing the basket in the horizontal was cut and the cables securing the basket in the vertical were released. The artificial substrate was placed in a plastic basin where large pieces of debris (clearly outside of the basket) were removed and the net was rinsed into the sample. A photograph was then taken and the rocks removed from the basket. Each rock was brushed and rinsed by hand and removed from the sample. Once all rocks were removed, the sample was then sieved in a box sieve with a 250 µm mesh. Samples were rinsed in 1-L wide mouth plastic jars and preserved in ~7% solution of formalin. Of the four substrates collected at each station, three were sent for analysis to Aquatic Biology Associates (ABA) and the fourth sample was shipped directly to EVS for archiving.

Although the vicinity of Station AB002 was surveyed several times during the artificial substrate retrieval period, none of the baskets could be located. These baskets were considered lost, presumably dislodged by floating debris. Therefore, only 11 of the 12 monitoring stations could be analyzed for benthos samples collected using artificial substrates.

At the time the artificial substrates were collected in the Athabasca River, a composite of three samples of the natural substrate at each site were collected using a pole-mounted Ekman dredge (15.5 cm x 15.5 cm). Samples were collected between the artificial substrate stakes from each station at a depth ranging between 0.5 and 1.3 m. Samples were composited in the field and sieved over 250 µm metal mesh screen. The invertebrates retained on the sieve were rinsed into 1-L wide mouth plastic jars and preserved in ~7% solution of formalin.

In the area where Station AB002 had been installed, a total of six grab samples were collected. Three of the benthic invertebrate samples were randomly selected and composited for analysis and the other three were archived individually. A total of 12 composite benthos samples (one per station) were shipped to ABA for analysis.

STEEPBANK RIVER

Benthic invertebrate samples from natural substrates along the Steepbank River were collected on October 19, 1995. The three stations were accessed by helicopter and were selected to parallel water quality sample sites. Samples were collected using a Hess sampler (internal diameter of 33 cm). Five individual replicate samples were collected from each station at a depth of <0.5 m. The invertebrates retained in the collecting net of the Hess sampler were rinsed into 1-L plastic jars and preserved with 10% formalin to attain an overall concentration of approximately 7% formalin.

Tissue Samples

Benthic invertebrate tissue samples from one station on the Athabasca River and one station on the Steepbank River were collected for analysis of metals, PAHs, alkylated PAHs, PANHs and alkylated PANHs concentrations. Large rectangular nets (approximately 40 x 80 cm), attached to dowels at each end, were used to collect two types of tissue samples (i.e., for metals and organics analyses). New nets were used at each station to avoid cross contamination. Nets used to collect organisms for metals analysis were made of fibreglass, whereas those used to collect organisms for organics analysis were made of metal window screening. All nets were washed with soap and water, and solvent rinsed to remove any oil residue prior to use. Sample size was approximately 10 g wet weight for metals analysis and 100 g wet weight for organics analysis. The invertebrates were picked from the nets using cleaned tweezers (teflon coated for metals analysis and stainless steel for organics analysis). All large invertebrates were collected and placed into glass jars. Samples were frozen and shipped on dry ice to Chemex Labs (metals analysis) and Enviro-Test Laboratories (organics analysis). Lists of parameters and laboratory methods are provided in Tables 3.3-1 and 3.3-2, respectively. Representative specimens of each taxon collected were preserved in ~7% formalin for taxonomic analysis at ABA.

MUSKEG RIVER BASIN

Benthic invertebrates were sampled for taxonomic identification and chemical analysis during the fall survey, between 19 September and 26 October, 1995. Sampling methods were based on a review of benthic studies in the Muskeg River drainage basin during the OSLO Project (R.L. & L. 1989). Benthic invertebrates were sampled in streams with sand/mud substratum using a Ekman grab of 15.5 cm x 15.5 cm bottom area (Sites 18, 30 and 35 in the Muskeg River; Site 14 in Khahago Creek; Site 9 in North Muskeg Creek, Site 80 in Kearl Lake). At streams with a hard substratum, samples were collected with a Neill cylinder (modified Hess sampler) with a bottom area of 0.093 m^2. These streams included Jackpine Creek (Sites S4 and 17) Blackfly Creek (Site 55) and Iyinimin Creek (Site 8). Three replicate samples were taken at each site, according to protocols set out in Golder Technical Procedure 8.6-0 (Appendix IV). In addition, benthic algae (periphyton) were sampled for measurement of epilithic chlorophyll *a* content by scraping a known surface area (4 cm^2) of five stream cobbles at all sites with hard substratum.

Two additional benthic samples were collected for analysis of metals and organic compounds. Invertebrate tissues were sampled at Site 30 on the Muskeg River and at Site S4 on Jackpine Creek using a technique that yields a large number of organisms in a relatively short time. The substratum was disturbed by kicking, with dislodged animals collected in a large (40 cm x 80 cm), 2 mm mesh size nylon net held downstream. The invertebrates caught on the net were removed using pre-cleaned, stainless steel tweezers and placed in the sample container. Sampling gear used for the collection of tissue samples was rinsed in an acetone bath followed by a hexane bath to minimize contamination of the samples. Samples were stored and transported on dry ice in pre-cleaned containers provided by the analytical laboratories. Representative specimens of each taxon collected were preserved in 5% formalin for taxonomic analysis. Chemical analysis was conducted by Chemex Labs (metals) and Enviro-Test Laboratories (PAHs and alkylated PAHs, PANHs and alkylated PANHs). Lists of parameters and laboratory methods are provided in Tables 3.3-1 and 3.3-2, respectively.

Plankton was sampled in Kearl Lake (Figure 3.2-4) during the spring, summer, and fall surveys following Golder Technical Procedure 8.7-0 (Appendix IV). Two vertical hauls were made at mid-lake from a depth of 1.25 m using a Wisconsin Standard Plankton Net. One sample was preserved with Lugol's solution and was archived for phytoplankton identification while the other was preserved with 5% buffered formalin and archived for zooplankton identification.

3.4.3 Habitat Characterization

STEEPBANK MINE STUDY AREA

Field measurements to characterize monitoring station habitats were completed between October 14 and 22, 1995. Habitat characteristics included substrate composition, current velocity, depth, water temperature, dissolved oxygen content, turbidity, pH, conductivity and redox potential. On the Athabasca River, measurements at each of the 12 stations were made at the most upstream sample location. On the Steepbank River, measurements were made at the five replicate sample locations at each of the three stations.

Each sample location (the farthest upstream location at each station) was positioned in degrees latitude (°N) and longitude (°W) using global positioning system (GPS) technology (Trimble GeoExplorer GPS). At each sample location, the latitude and longitude, elevation, date and time were noted.

Water quality parameters (temperature, pH, dissolved oxygen, conductivity, redox, turbidity) were measured using a calibrated Hydrolab Surveyor 3 Display Logger. As the calibration for turbidity appeared questionable, additional water samples for turbidity were collected and shipped to Chemex Labs for analysis. Turbidity data provided in Section 4.2 are based on the analysis of these additional water samples. Current speed was measured using 1205 Minimeter, while depth was measured with an aluminum telescopic measuring rod.

Sediment samples for particle size analysis were collected using an Ekman grab at Athabasca River stations (depositional areas). Each sample consisted of a composite of three separate grabs. Samples were shipped to EVS Environment Consultants (EVS) for transfer to Pacific Soil Analysis laboratories (PSA) where particle size was determined using the pipette method (Lavkulich, 1977). Substrate samples for grain size determination were not collected at Steepbank River stations (erosional areas) as the substrate was primarily gravel. However, qualitative estimates were made and are presented in the results section.

AURORA MINE STUDY AREA

Field measurements made during benthic invertebrate sampling included current velocity, water depth, water temperature, dissolved oxygen concentration, pH and conductivity. Water temperature, electrical conductivity and dissolved oxygen concentration were measured in the field with calibrated Yellow Springs Instruments (YSI) meters at each site; conductivity was corrected to 25° C. Current velocity was measured at 60% depth with a Price current velocity meter and pH was determined using a calibrated Horiba pH meter. Depth was measured using the wading rod of the current velocity meter. Current velocity and depth measurements were made at each of the three replicate sample points at a site. In addition to these measurements, the presence and abundance of algae and macrophytes and any other pertinent habitat characteristics were recorded at each site. Substratum composition was visually assessed at each site as approximate percentages of particles in standard size categories (as defined in Golder Technical Procedure 8.5-0, Appendix IV).

3.4.4 Laboratory Methods and Quality Assurance/Quality Control (QA/QC)

STEEPBANK MINE STUDY AREA

Sample preparation, subsampling protocols and sorting procedures for this study are outlined in Aquatic Biology Associates (1994). Briefly, the samples were washed directly onto a 250-µm mesh sieve, rinsed gently with cool tap water and transferred into a shallow white pan. Samples were floated from mineral material (e.g., sand, gravel) by decanting organic material and invertebrates from the pan back into the sieve. The elutriation was repeated until no further organic material and invertebrates were seen coming off the mineral residue. The mineral residue was then checked for remaining molluscs and stone-cased caddisflies. The "prepared" sample was transferred back to the original sample jar, preserved with 70% alcohol and labelled.

Subsampling was done using the "prepared" samples. A gridded sorting tray consisting of a shallow, rectangular, 30 x 36 cm, 250-µm mesh sieve, that is gridded into thirty (30), 6 x 6 cm squares was used. This sieve nested in a shallow white pan. Squares of sample material were removed and sorted under a dissecting microscope (6-12X magnification). The squares were randomly selected until a target number of invertebrates was sorted. The target number for this study was 500 organisms per sample.

Planktonic invertebrates were enumerated where encountered, but not included in the data analysis. Invertebrates identified from empty shells or cases were not included in the data sets. Once abundance data for the various fractions had been adjusted to account for the entire sample volume, mean values (±standard deviations) were calculated from the replicate data, and were reported on a square-metre basis. Abundance of major taxonomic groups (Trichoptera, Chironomidae, other Diptera, miscellaneous taxa), and the percent contribution by each taxon, was determined (see Appendix XI for raw data).

The following QA/QC procedures were followed for the benthic invertebrate analyses (ABA, 1994):

- Upon arrival at the laboratory, all benthic samples were reinventoried and checked against chain-of-custody forms.
- Taxonomic identifications were performed by qualified and experienced taxonomists and reference collections were prepared for each taxon recovered.
- Logs were kept by each technician that recorded label data, fraction sorted, hours required to complete sorting, and any comments on sample matrix or problems.
- The standard sorting efficiency required was ≥95% recovery from the matrix. Sorted residues from all sorters were randomly checked. A random subsample of 20% of residues turned in was resorted to ascertain that the ≥95% sorting efficiency had been met. If a sample failed, then all samples from that lot were rechecked. Results of the sorting efficiency test are provided in Appendix VI. Sorting efficiency ranged from 95.5 to 100%, therefore samples satisfied and exceeded the criterion.
- The unsorted fractions and the residues from the sorted samples were re-preserved and archived, in the event that additional analyses were required.

AURORA MINE STUDY AREA

Benthic invertebrate samples were sorted and taxonomic identifications were made by S. Beckett, M.Sc. of Calgary, Alberta, following standard methods based on recommendations of Alberta Environment (1990). First, invertebrates were separated from inorganic material (sand and gravel), by elutriating the sample. All remaining sand and gravel were examined and any remaining stone-cased organisms and mollusks with shells were removed for taxonomic identification. The organic material containing the majority of invertebrates was passed through a 1-mm and a 250 µm sieve. Invertebrates were removed from the resulting coarse and fine size fractions under a dissecting microscope. All remaining material was preserved in 5% buffered formalin for random checks of removal efficiency.

Invertebrates were identified to the same taxonomic levels as done during the OSLO Project (R.L. & L. 1989). Small, early-instar animals were identified to the lowest level possible, generally to family. Identifications were made using recognized taxonomic keys (Edmunds et al. 1976, Wiggins 1977, Merritt and Cummins 1984, Brinkhurst 1986, Stewart and Stark 1988, Pennak 1989, Clifford 1991). All invertebrates removed from the samples were preserved in 5% buffered formalin. Invertebrate abundance was reported as numbers per square metre.

The following QA/QC procedures were followed during the benthic invertebrate analysis:

- Upon arrival at the laboratory, benthic samples were examined for potential degradation, and sample labels were checked against chain-of-custody forms.
- Taxonomic identifications were performed by a qualified and experienced taxonomist.
- The sorting efficiency required was ≥95% recovery from the sample material. Three randomly selected samples, corresponding to 10% of the total number of samples collected, were re-sorted to evaluate invertebrate sorting efficiency. If ≥95% recovery was not obtained, all samples had to be re-sorted until the desired level of efficiency was achieved. Results of quality checks indicate that removal efficiency was >95% from the randomly-selected samples (See Appendix VI for results of quality checks).
- Accuracy of taxonomic identifications was assessed by a second taxonomist who re-identified invertebrates in a subset of samples. Two samples, corresponding to 5% of the total number of samples collected, were re-identified. The required percent similarity between taxonomists was 90%, calculated as (sum of the minima of the two numbers for each taxon / mean total number of animals) x 100. The results of this analysis indicate that the similarity of identifications made by the two taxonomists was acceptable (Appendix VI).
- Invertebrates removed from samples, unsorted fractions and the residues from the sorted samples were preserved and archived.

3.4.5 Data Analysis

The benthic invertebrate data were summarized as the mean densities and relative abundances of common taxa, defined as those constituting >1% of the total number of animals at a site. Non-benthic invertebrates, such as zooplankton and adult insects, were excluded from the analysis. Means and standard deviations of total density and taxonomic richness (total taxa) were calculated for each sampling site, and are presented graphically to facilitate comparisons of these variables among sites. The composition of the benthic invertebrate community is presented graphically, as stacked bar graphs showing percent abundance of major taxonomic groups. Trophic structure of the community is also shown as stacked bar graphs showing percent abundance of major functional feeding groups. Habitat data are summarized as means for each measured or estimated variable at the each sampling site. Tissue chemistry data generated during the bioaccumulation studies are tabulated along with available historical data.

3.5 Fish Habitat

3.5.1 Rationale for Fish Habitat Sampling Areas

The key issues related to the proposed development of both the Steepbank and Aurora Mines, in relation to determining the sampling areas for fish habitat, included:

- The potential for loss of recreational, subsistence or commercial fish production due to direct or indirect toxic effects; and,
- Loss of critical habitats that inhibits or precludes future fish production.

In addition to the above issues, it was necessary to verify habitat information documented during previous surveys.

3.5.2 Fish Habitat Sampling Locations

STEEPBANK MINE STUDY AREA

Habitat mapping was conducted for the entire lengths of the Athabasca and Steepbank Rivers within the Steepbank Mine local study area during the fall survey, between 3 and 15 October 1995 (Figures 3.2-1 and 3.2-2). The physical habitat in the area of the proposed bridge crossing on the Athabasca River was mapped during both the spring (13 May) and fall (3 Oct) surveys. The proposed barge landing area that was subsequently included in the bridge crossing plan was habitat mapped during the fall survey. Table 3.2.1 provides a complete list of the habitat transects for the Athabasca and Steepbank Rivers where measurements of physical habitat conditions were conducted.

AURORA MINE STUDY AREA

A sub-sample of the original 25 stream stations sampled in the 1980s was re-examined using the same habitat assessment criteria as for the OSLO project, as detailed by Beak (1986a, 1986b) and R.L.&L. (1989). The sub-sample consisted of a total of 7 stream sampling stations plus Kearl lake, which represented approximately one-third of the original 25 stations that were examined (Figures 3.2-3 and 3.2-4). As well, new sites at the mouth of the Muskeg River, and at Stanley and Blackfly Creeks were added, making a total of 10 stream sampling sites.

No previous aquatic investigations have been carried out on Lease 12 and examination of the Lease 12 property on 1:50,000 scale NTS maps indicated that the property consisted primarily of bog areas. Further examination of 1:40:000 air photos from 1994 and the results of a helicopter reconnaissance in 1995 confirmed this finding.

Sampling stations were representative of each of the basic aquatic habitat types described in the OSLO studies for different stream reaches (R.L.&L. 1989). The two basic habitat types described previously were:

1. Low gradient, poorly drained sections with run/pool habitats and substrates dominated by fines and organic material; and,
2. Higher gradient, well drained sections with riffle/run/pool habitats and coarser substrate.

To assist in selecting sites for sub-sampling, a matrix was prepared which listed each of the 25 sampling sites along with their reach designation, habitat characteristics, and previous fish inventory and benthos sampling results. Sampling sites were selected to provide an adequate representation of the two main habitat types and to provide sites distributed throughout the upper and lower portions of the drainage basin. Also, sites were selected that had the highest species diversity and abundance, with emphasis on the documented presence of sport species. A complete listing of sampling sites is provided in Table 3.2-2.

3.5.3 Habitat Evaluation Methods

STEEPBANK MINE STUDY AREA

All habitat mapping was conducted following the procedures set out in Golder Technical Procedure (TP) 8.5-0 (Appendix IV) which details the Golder Habitat Mapping and Classification System. The Athabasca River was mapped according to the Large River Habitat Classification System, which is used to map large mainstream rivers that show a limited amount of in-stream heterogeneity. This system consists of three components: channel form, bank habitat types, and special habitat features. The Steepbank River was mapped according to the Stream Habitat Classification and Rating System which provides more detail regarding in-stream habitats and is designed for small to mid-sized streams that exhibit a greater degree of heterogeneity. The stream mapping system is based on individual channel units (i.e. riffle/pool/run) in combination with depth, velocity and substrate characteristics that provide a subjective quality rating for each unit, in relation to the habitat requirements of the various fish life stages (i.e. spawning, rearing, feeding, overwintering). GPS techniques were used to record the location of all significant habitat areas (e.g., spawning sites), locations of significant fish concentrations and all sampling locations (Appendix I).

During habitat mapping procedures, the location and extent of each habitat mapping unit, as defined by the relevant mapping system (TP-8.5-0), was delineated on a habitat base map. The habitat base maps for both the Athabasca and Steepbank Rivers were prepared from aerial photographs of the study area. Transect stations were established at selected locations to provide measurements of physical habitat conditions for representative habitat types. Measurements conducted at the habitat transects on the Athabasca River included water depth (sonar tracing), velocity profile, substrate characteristics and cover availability. For the Steepbank River, transect measurements included channel width, wetted width, water depth, velocity, substrate composition, cover availability, bank stability and bank vegetation.

AURORA MINE STUDY AREA

For the stream sites, in the Muskeg River watershed the habitat evaluation included the same parameters measured in the original studies by Beak (1986a, 1986b) and R.L.&L. (1989). Quantitative biophysical data were collected within a 50-m section of stream centred on the sampling site. Where possible, two transects were completed for each habitat type present in the 50-m stream section. Data from these transects were used to calculate average wetted width; average bank width; maximum and average depth of pools, runs and riffles; and flow characterization. One transect at each site was selected for stream discharge measurements. In addition, each site was photographed and assessed for pool:riffle:run ratios, substrate composition, available in-stream and overhead cover, bankform and stability, riparian vegetation and aquatic macrophyte growth, according to Golder Technical Procedure 8.5-0 (Appendix IV).

The Kearl Lake habitat evaluation included bathymetric and macrophyte mapping following the procedures outlined in R.L.&L. (1989). Existing habitat maps for Kearl Lake were confirmed and updated for depth, area, substrate type, bank form, and aquatic and terrestrial vegetation.

3.5.4 Methods for Habitat Data Summarization

Habitat data were summarized according to Golder Technical Procedure 8.5-0 (Appendix IV). In addition, a stream catalogue containing all habitat information (excluding aquatic vegetation) as well as the UTM coordinates for each site was compiled following the format and terminology of Beak (1986a, 1986b) and R.L.&L. (1989). The catalogue was then compared to the previous stream catalogues prepared by Beak (1986a) and R.L.&L. (1989). Additionally, habitat maps were generated using AUTOCAD software for the Muskeg River, Jackpine Creek and the Muskeg Creek watershed.

3.6 Fish Populations

3.6.1 Rationale for Fish Inventory Approach

Data gaps existed on the use of the lower Athabasca River by fish for spawning, overwintering, summer feeding and rearing. Likewise, there had been no published studies on Athabasca River fish population characteristics since the 1974-75 studies of McCart et al. (1977). It had been previously recorded that Arctic grayling and bull trout spawn in the Steepbank River, however information on fish habitat associations identifying critical habitats during the spring and fall spawning periods was limited. Fish population parameters had previously been documented for Jackpine Creek, the Muskeg River and Kearl Lake in a number of studies (Bond and Machniak 1979; Walder et al. 1980; O'Neil et al. 1982; O'Neil and Jantzie 1987; and, R.L.&L. 1989). Therefore, the fish inventory surveys were developed with the intent of (1) supplementing and confirming existing studies of the area; (2) documenting species presence and abundance in the study areas; and, (3) filling the data gaps that existed with respect to fish population parameters in the Athabasca, Steepbank and Muskeg Rivers. An emphasis was placed on collecting data from the Steepbank Mine local study area to provide sufficient information to assess potential effects of water releases to the Athabasca River and construction of a bridge across the Athabasca River.

3.6.2 Fish Inventory Sampling Areas

STEEPBANK MINE STUDY AREA

Available habitat and fish inventory information from previous studies were utilized in the selection of sampling locations. For game and commercial/domestic fish species, sampling areas were selected that were representative of the habitats available within the study area, as well as special habitat features (e.g., tributary confluences) (Figures 3.2-1 and 3.2-2). Sampling areas for game and commercial/domestic fish included: snye and backwater areas; side channel habitat; and potential spawning, rearing, feeding and overwintering habitats. Sampling areas for forage species were restricted to areas that provided potential habitat for this species assemblage, including channel edge areas, backwaters and sandbar areas that exhibit shallow depths and slow velocities. Sampling stations and methods used at each station listed in Table 3.2.1, with sampling stations shown on Figures 3.2-1 and 3.2-2.

Sampling was conducted on a seasonal basis during the open-water season and included the following periods: spring spawning/migration prior to freshet (between 10 May and 2 June); mid-summer (between 28 July and 15 August); and fall spawning/migration (between 26 September and 16 October). Potential overwintering habitat was defined based on these open-water surveys.

AURORA MINE STUDY AREA

Fish inventory sampling sites were the same as those used for the fish habitat evaluation (Figures 3.2-3 and 3.2-4). Fish inventory was not done at Sites 4, 18 and 60 as these sites were only accessible by helicopter and were too deep to use a backpack electrofisher. A two-way counting fish fence was installed at the mouth of the Muskeg River (Site 30) during the spring (between 4 May and 28 May) and fall (19 September and 28 October) surveys. A complete list of sampling sites and methods used at each site is presented in Table 3.2-2.

3.6.3 Fish Inventory Methods

STEEPBANK MINE STUDY AREA

Fish inventory sampling was conducted following Golder Technical Procedure 8.1-0 (Appendix IV) during the spring, summer and fall surveys. Table 3.2-1 presents a complete list of fish inventory sampling stations, method(s) used at each station, and the season sampled. Sampling for large fish species on the mainstream Athabasca River was conducted primarily with a Smith-Root SR-18 electrofishing boat equipped with a Smith-Root Model 5.0 GPP electrofisher. However, other sampling techniques such as gill nets and set lines were used to sample fish species not susceptible to capture by electrofishing and to sample habitats where electrofishing effectiveness was reduced (i.e. where the water was too deep). Sampling for forage fish in the Athabasca River was conducted by backpack electrofishing, beach seining and through the use of minnow traps. During the spring, drift-traps were used to sample for the presence of post-emergent fry in the Athabasca River. The

Steepbank River was sampled using a Zodiac equipped with a portable Smith-Root Model 5.0 GPP boat electrofishing unit.

For all sampling techniques, catch-per-unit-effort (CPUE) data (number of fish/unit of sampling effort) were calculated to determine the relative density of fish species captured.

All captured fish were identified to species following the coding system recommended by Mackay et al. (1990) and enumerated. Species codes, common and scientific names are presented in Table 3.6-1. For individuals of large fish species, measurements were taken for fork length and weight. The fish were also examined for external pathology according to Golder Technical Procedure 8.1-0. In addition, non-lethal ageing structures were taken according to the recommendations in Mackay et al.(1990). If discernible by external examination, sex and state of maturity of individual fish were also recorded. For forage fish species, a sub-sample from each site was measured for fork length and weight and sampled for ageing materials. Fish population data were recorded in the field logbooks and on catch and sample record forms (Appendix IV).

During the fall survey, two attempts were made to install a two-way counting fence at the mouth of the Steepbank River. The first installation attempt was made with a large fish fence; a second attempt was made after dismantling the large fish fence and using only the essential parts of the fence. However, due to the atypical substrate type (bitumen), which is soft and easily scoured, it was not possible to install or maintain either counting fence.

AURORA MINE STUDY AREA

Fish inventory was conducted during the spring survey, between 4 May and 28 May, 1995, following the protocols set out in Golder Technical Procedure 8.1-0 (Appendix IV). A Smith-Root Type VII backpack electrofisher was used to sample the following sites: 30 (Muskeg River at the mouth); 17 (Jackpine Creek near the mouth); S4 (Jackpine Creek at the bridge); 9 (Kearl Lake outlet); 8 (Iyinimin Creek); and, 55 (Blackfly Creek). At Site 18 (Muskeg River downstream of Jackpine Creek) the water was too deep to use a backpack electrofisher so a zodiac and Smith-Root Model 5.0 GPP portable electrofisher were used.

The Kearl Lake fish inventory was performed on 23 May 1995. Minnow traps and a portable Smith-Root Model 5.0 GPP electrofisher were used to confirm species presence and abundance data collected during studies by Beak (1986b) and R.L.&L (1989). Five baited minnow traps were set in shallow water (< 1m deep) along the shoreline for 5.5 to 7 hours (Figure 3.2-4). In addition, three transects were shocked using a Smith-Root 5.0 Model GPP portable electrofisher and zodiac. For electrofishing runs, the number of seconds and the distance sampled were recorded on catch records.

For all sampling techniques, CPUE values were calculated for each species from each site (number of fish/unit of sampling effort) to determine relative abundances.

All fish captured were identified and enumerated. Codes for fish species follow the system recommended by Mackay et al. (1990. Fish species names and codes are presented in Table 3.6-1. Game and commercial/domestic fish were weighed (g) and measured for fork length (mm), tagged and non-lethal ageing structures were collected. Fork lengths and weights of sucker and lengths of a subset of minnows were recorded. All fish captured were examined for external pathology following the procedures set out in Golder Technical Procedure 8.1-0 (Appendix IV). All abnormal tissues were preserved in 10% buffered formalin and archived until analysis.

In addition to electrofishing and the use of minnow traps, a two-way counting fence was installed on the Muskeg River south of the Canterra Road, downstream of all major tributaries, during the spring (6 May to 26 May) and fall (19 September to 28 October) surveys (Figure 3.2-2). In the spring the fence was composed of five aluminum panels and two trap boxes. In each panel, aluminum dowelling were spaced 2.5 cm apart to prevent passage of large fish through the fence. Note that the fence was not designed to catch forage fish or small juveniles of large fish species. The panels and trap boxes were affixed together so that they extended across the entire width of the stream. The trap boxes were covered with fine mesh on all sides except one, where a funnel net was attached. The boxes faced different directions so that fish travelling upstream could be distinguished from those travelling downstream. The tops of each box were covered with a plywood lid and were locked when the site was unsupervised to avoid theft or harassment of fish. In the fall, a different fish fence but with similar design characteristics was used. Mesh on the fence was 2.5 cm in diameter. During both sampling periods, the fish fence was checked twice a day, except when catches were low (i.e. less than five fish per day) when it was checked once a day.

All game, commercial or domestic fish captured in the fence were identified to species and lifestage, sexed, weighed (g), measured for fork length (mm), tagged and examined for external pathology following the procedures in Golder Technical Procedure 8.1-0 (Appendix IV). Non-lethal ageing structures were also taken. Fish were marked for identification using floy tags for the large game fish (e.g., pike, adult Arctic grayling) and VI tags for the smaller sports fish (e.g., juvenile Arctic grayling). Sucker captured in the fence were identified; the life-stage, sex, weight (g) and fork-length (mm) recorded; and they were examined for external pathology. Ageing structures were taken from the first 300 longnose sucker and first 160 white sucker. Once these numbers were reached, sucker were only identified to species, lifestage and sex. To facilitate the capture of longnose sucker for biomarking, the upstream fence was closed for most of a four day period, between 10 May and 13 May.

In the fall, efforts were made to determine if young-of-the-year Arctic grayling were present by electrofishing with a Smith-Root Type VII backpack electrofisher at Sites S-4 (Jackpine Creek) and Sites 30 and 31 (Muskeg River). Also, kick sampling was done at Sites 30 and 31 to determine if lake whitefish were spawning in the Muskeg River.

Fish population data were recorded in the field logbooks as well as on catch and sample records.

3.6.4 Methods Summarizing Fish Population Data

All fish population data collected during each survey were entered into a database using Microsoft Excel and Microsoft Access software. Data files were checked and verified against the original field data. Statistical analyses, frequencies and regressions were done using Microsoft Excel software.

CPUE values for each capture method (boat electrofishing, backpack electrofishing, gill netting, minnow trapping, set lines and seining) were calculated for each species, from each station or site, to determine relative abundances and compare 1995 catch results to historical surveys.

A sub-sample of fish captured during each survey was aged following the methods outlined in MacKay et al. (1990). Length-frequency-per-unit-effort distributions were prepared for each species in 20, 30 or 50 mm (depending on the size and number of fish). For each interval, ten percent of the fish were randomly selected for ageing.

3.7 Fish Health

3.7.1 Rationale for Fish Health Indicators

Fish health information was collected to address the following issues:

- Lack of tissue chemical data for fish species most abundant in the study area;
- The potential for loss of recreational, subsistence or commercial fish production due to direct or indirect toxic effects;
- Concerns for human health from consumption of fish; and
- Aesthetic concerns in relation to tainting of fish which would limit the use of the resource.

The rationale for the specific fish health parameters that were measured and fish tissues that were collected is presented in Section 4.5.

3.7.2 Fish Health Sampling Methods

Several samples were collected from each fish for fish health analysis. Specifically, fillets were retained for chemical analysis; blood was taken for sex steroid activity and lactate analysis; livers were taken for Mixed Function Oxidase (MFO), and retinols; bile was taken for benzo-a-pyrene (BaP) and naphthalene analysis; and, any abnormal tissues were preserved in 10% buffered formalin for histopathological analysis.

Fillets were sent to Enviro-Test Laboratories in Edmonton for PAH/PANH, ICP metals and hydride metals analysis, as were livers for MFO analysis and bile for benzo-a-pyrene and naphthalene analysis. Blood was sent to Dr. Tracy Marchant at the University of Saskatchewan in Saskatoon, Saskatchewan for sex steroid analysis. HydroQual Laboratories Ltd. (HydroQual) in Calgary received blood for lactate analysis. Retinols in livers were analyzed by Dr. Scott Brown at the Freshwater Institute in Winnipeg, Manitoba. Abnormal tissues were sent to and analyzed by Dr.

Collin Rousseaux of Global Tox International Consultants Inc. in Ottawa, Ontario. Gonad stage was analysed by Dr. Rick Schryer of Golder Associates. Fish tissue samples were stored and shipped to the appropriate laboratories following the detailed storage and shipping procedures set out in Golder Technical Procedure 8.1-0 (Appendix IV). Table 3.3-1 presents the specific parameters analyzed in the fish tissues and Table 3.3-2 presents a general description of laboratory methods used for analyzing the parameters listed in Table 3.3-1. Detailed laboratory methods are provided in Appendix V.

In addition, general biological parameters were measured, collected and recorded for each fish (fork length (mm), weight (g), lethal ageing structures, liver weight (g), gonad weight (g), internal/external pathology, stomach contents, life stage, sex, state-of-maturity). General biological parameters and tissue collection information was recorded for each biomarker fish on internal/external autopsy forms and in the field logbooks.

3.7.3 Fish Health Sampling Areas

The study sampling areas for the collection of fish for biomarker samples are presented in Figures 3.2-1 and 3.2-3.

ATHABASCA RIVER

During the summer survey, 28 July to 15 August, biomarker data were collected from the two sentinel fish species following the detailed protocols set out in Golder Technical Procedure 8.1-0 (Appendix IV), Golder's Fish Inventory and Biomarking Method. Thirty-seven walleye (14 females and 23 males) and 40 goldeye (22 females and 18 males) were captured from the mainstream Athabasca River at Stations AF002, AF003, AF004, AF005, AF006, AF018, AF019, AF020, AF033, AF036, AF041, and AF042 using boat electrofishing techniques. Biological samples were taken from each individual fish for the analysis of PAHs and PASHs, bioaccumulative metals, sex steroids, retinols, lactate, sex steroids and mixed function oxidase (MFO) activity. Figure 3.2-1 and Table 3.2-1 present the stations in the Athabasca River where fish were collected for biomarker analysis.

MUSKEG RIVER

During the spring survey, 4 May to 28 May, biomarker data were collected from the sentinel fish species with adherence to detailed protocols set out in Golder Technical Procedure 8.1-0 (Appendix IV). Forty-one longnose sucker (21 females and 20 males) were captured from the Muskeg River in the vicinity of the fish fence at Site 31 and biological samples were taken from each individual fish for the analysis of PAHs and PASHs, bioaccumulative metals, sex steroids, retinols, and mixed function oxidase (MFO) activity. Some of the fish were captured in the upstream fish trap; however, the majority of fish were captured downstream of the fish fence using dipnets. Figure 3.2-3 presents the sampling station for fish biomarker collections.

3.7.4 Methods for Summarizing Fish Health Data

Fish health data collected during the surveys were entered into a database using Microsoft Excel and Microsoft Access software. Data files were checked and verified against the original field data. Statistical analysis of the data included length-frequency, age-frequency, length-weight regressions and growth curves all of which were executed with Microsoft Excel software

3.8 Quality Assurance/Quality Control

The overall quality assurance objectives for this project were to develop and implement procedures to ensure the collection of representative data of known, acceptable and defensible quality. Therefore, a Quality Assurance Project Plan (QAPP) was prepared for the project and includes sampling and analysis procedures and outlines project-specific data quality objectives (DQOs) that were required for field observations and measurement, physical analyses, laboratory chemical analyses and biological tests (Appendix III). The DQOs were followed throughout the study to ensure the acquisition of reliable data. Furthermore, quality control was integrated throughout the study, beginning with the development of the study design and adhered to throughout the implementation of the sample collections, analysis and data evaluations. This was accomplished through the use of Specific Work Instructions (SWIs) for project employees, detailed Technical Procedures for sampling activities and the QAPP.

4.0 RESULTS

4.1 Water, Sediment and Porewater Quality

4.1.1 Water Quality

Surface water quality was assessed in 1995 in the Athabasca River and two of its major tributaries (Steepbank and Muskeg Rivers), several small streams which drain directly into the Athabasca River or into the Muskeg River, a small wetland and Kearl Lake (Figures 3.2-1 to 3.2-3). With the exception of the Athabasca River, none of these water bodies receive wastewater from anthropogenic sources. Water samples were collected during three seasons in 1995.

Since water quality may also vary among years, it is important to compare the 1995 results, which represent only a snapshot in time, with those of previous surveys. Water quality of the Athabasca River has been monitored in the oils sands area since the 1970s by Alberta Environmental Protection (AEP). Detailed studies of water quality in the oil sands area have been completed under the Alberta Oil Sands Environmental Research Program (AOSERP), Alberta Oil Sands Technology and Research Authority (AOSTRA), the Other Six Leases Operation (OSLO) Project and more recently, as part of the Northern River Basins Study (NRBS) and Environment Canada's Program on Energy Research and Development (PERD).

To assess baseline water quality during this study, only relatively recent data (1980-1995) were used. Historical data collected by AEP were available for the Athabasca, Steepbank and Muskeg Rivers, Poplar Creek and Kearl Lake. These data were obtained from AEP's NAQUADAT database. In addition, water quality data collected during the OSLO Project in the Muskeg River drainage area (R.L. & L. 1989) were used to supplement the historical database.

All available historical and 1995 water quality data were summarized by season and are presented in Appendix VIII. Summary tables showing key water quality variables are presented in the following sections. Seasons were defined as follows:

- **Spring:** March, April, May, June
- **Summer:** July, August
- **Fall:** September, October
- **Winter:** November, December, January, February

Results of a Quality Assurance (QA) review of the analytical data are presented in Appendix VIII. Because of detectable, but low levels of a small number of metals and PAHs in the field blanks, results for some parameters were qualified as non-detectable in the affected samples. However, since the levels measured in the field blanks were frequently higher than in the water quality samples, it is likely that the lab water used for field blanks was contaminated. Therefore, the summary tables include the original results, but the qualifiers are shown in Appendix VIII.

One exception was made to this approach: The presence of acetone in porewater samples was not considered significant, despite high measured levels (Appendix VIII). Because acetone was used to decontaminate sampling equipment between sites, the measured levels most likely reflect incomplete rinsing prior to sampling. This exception was deemed reasonable, since acetone is unlikely to be present in river porewater at the levels measured, especially considering the lack of a source of this compound in the study area.

ATHABASCA RIVER

The Athabasca River has been monitored extensively by AEP for water quality since the 1970s. Detailed studies have been completed as part of AOSERP, AOSTRA and more recently, by NRBS and PERD. The water quality of the river and its major tributaries is well known and was summarized in three reports: Hamilton et al. (1985), Noton and Shaw (1989) and Noton and Saffran (1995).

The study area described in this report is located near the upstream limit of the "downstream reach" of the Athabasca River, as delineated by Hamilton et al. (1985). The changes in water quality along the length of the Athabasca River can be attributed to a combination of point source inputs, tributary inputs and natural changes which typically occur in rivers with distance downstream. The downstream reach of the Athabasca River is characterized by reduced hardness and alkalinity, elevated levels of suspended sediments, colour, iron, manganese, sodium and most particulate and carbon parameters, and a shift in major ion balance relative to upstream. Total nitrogen and phosphorus concentrations are also high, and correlate well with suspended sediment levels, whereas dissolved phosphorus level is typically low. Concentrations of iron, sodium and chloride are greatly increased below the Clearwater River, which enters the Athabasca near Fort McMurray. Because of the high sediment load and shifting depositional substrates in the study reach, algal production is largely in the form of phytoplankton.

Major point source inputs to the river upstream from the study area include five pulp mills in the reach extending from Hinton to just downstream of the town of Athabasca and sewage from five towns. Previous surveys have documented the effects of pulp mill effluents and municipal inputs, and concluded that they 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 Hamilton et al. (1985), Noton and Shaw (1989) and Noton and Saffran (1995).

Within the study area, the river receives treated sewage effluent from Syncrude and, mine drainage, refinery wastewater and treated sewage effluent from Suncor. The effects of these discharges were not discernible during any of the above three large-scale investigations of water quality in the Athabasca River. Smaller-scale surveys conducted by Suncor and Syncrude have documented localized effects on water quality in the immediate vicinity of the Suncor plant, exhibited as increases in the concentrations of dissolved solids, total organic carbon, oil and grease, phenolics, ammonia and odour (McCart 1977, Noton and Anderson 1982). However, these increases were in most cases minor, or restricted to single sites, or were inconsistent among sampling times. Only odour was consistently elevated for some distance downstream.

Recent studies of toxicity and chemistry of Athabasca River surface water documented the presence of detectable but low levels of trace organic compounds (PAHs and chlorophenolic compounds) in river water but found low or no acute or chronic toxicity to a variety of test organisms (PERD studies: Brownlee 1990, Dutka et al. 1990, 1991, McInnis et al. 1992, 1994, Xu et al. 1992, Brownlee et al. 1993).

Since water quality samples were collected only once during each season in 1995, the data are likely to be influenced to a large extent by meteorological conditions and resulting fluctuations in discharge immediately preceding sampling. Discharge during the spring and fall surveys was relatively constant and was similar to average conditions (data from AEP, Surface Water Monitoring Branch). However, during the summer survey, the Athabasca River was sampled immediately following a four-fold increase in discharge (from 760 to 3000 m^3/s), which greatly increased the suspended sediment load of the river. In addition, extensive forest fires within the drainage basin of the Athabasca River may also have affected water quality, but likely to a lesser extent than the increase in discharge.

Comparison of data collected in 1995 with historical data did not reveal any substantial deviation from previously documented water quality in the Athabasca River, with the exception of the high suspended sediment load and associated increases in a number of variables in the summer (Table 4.1-1). The majority of water quality variables measured in 1993 were within their historical ranges (Table IX-1). Total dissolved solids (an indicator of inorganic salt concentration) and pH were slightly lower than the historical medians but were well within their respective historical ranges. The concentration of suspended solids was similar to the historical medians in spring and fall 1995. The high summer value is outside of the historical range from 1985 to 1995, is within the measured range from 1967 to 1972 and is appropriate for the discharge measured on the day sampled (Klohn-Crippen 1995). Concentrations of dissolved organic carbon, aluminum, iron and to a lesser extent, zinc, were also considerably higher during the summer of 1995 than the historical medians. This is a reflection of the high suspended sediment load carried by the river at the time of sampling.

The elevated dissolved organic carbon concentration in river water indicates that the lower Athabasca River receives drainage from muskeg areas. Nutrient levels measured in 1995 were similar to historical values, and are indicative of moderate enrichment from natural sources, and potentially, from upstream point sources. Levels of metals were generally low and similar to the historical medians. Bacterial water quality was not evaluated in 1995. The historical medians suggest that numbers of coliform bacteria are not high enough in the Athabasca River to cause concern.

Concentrations of naturally-occurring hydrocarbons in river water were low, as measured by oil and grease by AEP and recoverable hydrocarbons in 1995. Trace organic compounds and naphthenic acids were not detected in 1995 at any of the sampling sites with one exception: low levels (near the detection limit) of naphthalene and methylnaphthalene were measured during the spring survey below Lease 25. River water was not toxic to bacteria, as shown by no light inhibition during the Microtox® test. This is consistent with the results of previous toxicity assessments of river water, as noted above.

Overall, the data collected in the Athabasca River in 1995 are consistent with the results of previous surveys and did not provide any evidence that the Suncor or Syncrude operations are affecting the water quality of the river.

STEEPBANK RIVER

The historical data available for the Steepbank River are limited to one to two measurements for most variables, in spring and winter of 1980 and 1989 (Table 4.1-2). Comparison of spring historical data with 1995 data revealed that the water quality of the river has changed little since the 1980s, at least during that season. The only notable difference between the two data sets is higher salt concentration in the 1980s near the mouth than in 1995.

The Steepbank River can be characterized as having clear water in all seasons, with occasionally detectable levels of naturally occurring hydrocarbons, low to moderate levels of dissolved salts, moderate levels of nutrients and generally low levels of metals. pH varied from 7.4 to 8.2 and increased slightly in a downstream direction in 1995. Zinc concentration was elevated at the Lease 19 border in spring 1995; however, since only a single measurement is available, its significance cannot be evaluated. The moderately elevated dissolved organic carbon concentration in this river is also indicative of muskeg drainage. An interesting feature of this river is that a visible oil sheen is evident on the water surface. This is a result of natural loading of low levels of hydrocarbons associated with erosion of the McMurray Formation, which is visible along the bank of the Steepbank River. Even so, as noted above, this does not result in measurable hydrocarbons in river water. Naphthenic acids and trace organic compounds were not present at detectable concentrations, with the exception of one low (equal to detection limit) measurement of naphthalene at the mouth of the river during the fall survey. River water was not toxic to Microtox® in 1995.

The data collected in 1995 do not provide evidence of seasonal variation in water quality during the open water season, with the possible exception of lower dissolved salt concentration during the summer in 1995, as may be expected from seasonal flow patterns. Similarly, water quality did not vary between the two sites sampled in 1995, with the possible exceptions of pH and salt concentration, both of which were slightly higher at the mouth than at the Lease 19 border.

ATHABASCA RIVER TRIBUTARIES

Four small tributaries of the Athabasca River were sampled in 1995: Poplar Creek, McLean Creek, Wood Creek and Leggett Creek (Figure 3.2-1). Leggett Creek was completely frozen in May and thus could not be sampled during the spring survey. Historical data were only available for Poplar Creek.

Overall, the four small streams had similar water quality, as indicated by similar concentrations of most variables measured (Tables 4.1-3 and 4.1-4). The streams are characterized by pH near 8.0 with the exception of Leggett Creek (7.4-7.6), moderate dissolved salt and nutrient concentrations, and generally low levels of metals. Dissolved organic carbon concentration was elevated in all streams, as can be expected in areas with substantial muskeg cover. The variation in aluminum, iron, zinc and total phosphorus levels appeared to reflect the variation in suspended sediment load of the streams. This was especially noticeable for Wood Creek in the summer and Leggett Creek in the fall of 1995.

Naturally occurring hydrocarbons were detected in McLean Creek and Wood Creek in summer 1995, but only at low levels. Oil and grease was detectable in all seasons in Poplar Creek from 1980 to 1984, but also at very low concentrations. Naphthenic acids were only detected at the mouth of Poplar Creek in spring 1995 at a relatively low concentration of 6 mg/L. However, analyses for naphthenic acids have only been available since 1995. None of the water samples collected in 1995 were toxic to bacteria in the Microtox® test.

The 1995 data are not indicative of pronounced seasonal variation in stream water quality. The variation in suspended sediment concentration and associated variables most likely reflect the effect of precipitation prior to sampling. The more complete historical data for Poplar Creek (Table 4.1-4) show little variation from spring to fall in most variables, which is consistent with this interpretation.

SHIPYARD LAKE WETLANDS

Shipyard Lake is a wetlands on Lease 25. Water quality of Shipyard Lake (Table 4.1-5) was similar to those of the small tributaries described above (Poplar Creek, McLean Creek, Wood Creek and Leggett Creek), with the following exceptions: pH ranged from 7.5 to 7.8 in the wetland, which is slightly lower than the pH of the streams; levels of nutrients were higher in the wetlands in spring and fall than in the streams; and the concentration of iron was considerably higher in the wetland in all seasons. The positive correlations between the concentrations of suspended sediments, total phosphorus and iron suggest that the seasonal variation in the 1995 data at least partially reflects the inputs of particulate material during rain events prior to sampling. Otherwise, no evidence of seasonal variation can be discerned from the 1995 data.

AURORA MINE STUDY AREA

Historical data for the Muskeg River were available from NAQUADAT (1980-81) and the OSLO Project (R.L. & L. 1989).

The Muskeg River is characterized by clear water in all seasons and moderate dissolved salt and nutrient concentrations (Table 4.1-6). Ammonia and total phosphorus levels were slightly lower in 1995 than historically. The river drains areas with substantial muskeg cover, which is reflected in the elevated dissolved organic carbon levels. pH varied from 6.9 to 8.0 and increased with distance downstream in 1995. Concentrations of metals were similar in all years sampled and were near the detection limits with the exception of iron and zinc. Hydrocarbons were detectable but low in spring 1995 as was oil and grease in the 1980s. Trace organic compounds were not detected at the mouth of the river in 1995 and naphthenic acids were below the detection limit at both sites sampled. River water was not toxic to bacteria. Coliform bacteria are present in the Muskeg River, but only in low numbers. The data collected in 1995 do not provide evidence of seasonal variation in water quality during the open water season.

MUSKEG RIVER TRIBUTARIES

Six tributaries of the Muskeg River were sampled in 1995 (Figure 3.2-3). Historical data from 1988 and 1989 were collected during the OSLO Project (R.L. & L. 1989) for five of the six streams sampled in 1995.

Water quality of the tributaries of the Muskeg River was similar in 1995. Hydrogen ion concentration did not vary greatly among the streams; most pH measurements were within the 7.0 to 7.5 range (Table 4.1-7). The concentration of dissolved salts was slightly lower in North Muskeg Creek, which drains Kearl Lake, than in the other streams in all seasons, but overall was low in all of the streams sampled. Suspended sediment levels were higher in Iyinimin and Blackfly Creeks relative to the other streams during the summer survey, and were accompanied by elevated concentrations of aluminum and iron. These two sites were located in stream reaches with higher gradients than the other sites; thus the higher suspended sediment and metal levels most likely reflect scouring caused by erosion of the stream bottom or precipitation prior to sampling. Dissolved organic carbon was elevated at all sites, reflecting muskeg drainage. This variable was higher in the summer than in other seasons at all sites. The concentration of nutrients was moderate in all streams and did not vary consistently with season. Metal levels were generally low with the exception of aluminum, iron and zinc. As noted above, aluminum and iron concentrations were positively correlated with suspended sediment levels.

Recoverable hydrocarbons were only detected in Blackfly Creek during the summer survey, but at a concentration only slightly above the detection limit. Trace organic compounds were not detected in Jackpine Creek. Similarly, naphthenic acids were not detected in any of the streams sampled and stream water was not toxic to bacteria.

Comparing the 1995 data with the results of the previous surveys for five of the six streams (excluding Stanley Creek; Table 4.1-8) revealed that the stream water quality has changed little since the 1980s. pH was generally lower in 1995 than in previous years, but the absolute differences were small in all streams. Other differences in 1995 relative to the historical data included lower total ammonia in North Muskeg

Creek, higher dissolved salt concentration in Muskeg and Iyinimin creeks and higher concentrations of at least one of aluminum, iron and zinc in Jackpine, Muskeg, Iyinimin and Blackfly creeks. Most of these differences were minor. The elevated levels of metals reflected higher suspended sediment concentrations in 1995 in nearly all cases, most likely resulting from precipitation prior to sampling.

KEARL LAKE

Kearl Lake is a small, shallow lake, with a surface area of 5.3 km^2, mean depth of 1.4 m and a maximum depth of 2.5 m (R.L. & L. 1989). Bottom substratum consists primarily of sand, silt and organic material and is covered with abundant macrophyte growth. The bottom could be seen throughout the lake during the 1995 surveys, indicating that Secchi depth was greater than 2 m.

The historical data for Kearl Lake (NAQUADAT and R.L. & L. 1989) were summarized by season (dissolved oxygen and temperature) or for the entire open water season and winter (water chemistry) for comparisons with the 1995 data (Table 4.1-9). Based on the dissolved oxygen and temperature data, the lake remains generally well-mixed during the open water season. There was a slight decline in dissolved oxygen with depth in summer 1995, but levels remained relatively high throughout the water column. Lake water was anoxic in winter 1989. pH was slightly lower in 1995 than in the 1980s. Concentrations of conventional water quality variables and nutrients were similar in all years sampled. Dissolved salt concentration, suspended sediments and levels of metals were generally low in lake water. Total phosphorus concentration was moderate in all years surveyed, indicating that trophic status of the lake is likely mesotrophic to eutrophic. Hydrocarbons were not detected by any of the surveys and naphthenic acids were below the detection limit in 1995. Lake water was not toxic to Microtox® in 1995.

SUMMARY

The results of 1995 field surveys have shown that the water quality of the Athabasca River, its major tributaries and small streams within the EIA study area have not changed over the last decade. As in previous years, the discharges from Suncor and Syncrude did not have a discernible effect on the water quality of the Athabasca River in 1995. Surface water chemistry in the study area was not affected by naturally occurring deposits of oil sands. Temporal variation in water quality was low in all water bodies sampled from spring to fall of 1995, with the exception of the Athabasca River.

In this large river, summer high flows usually cause a large increase in suspended sediment load which is reflected in the concentrations of associated water quality variables.

4.1.2 Sediment Quality

ATHABASCA RIVER

Bottom sediment chemistry of the Athabasca River in the oil sands area has been reported in a number of studies since the 1970s (Noton 1979, IEC Beak 1983, Beak 1988). More recently, Golder Associates (1994b, 1995) conducted small-scale sampling, as part of bioaccumulation studies examining the potential biological effects of seepage water from Suncor's Tar Island Dyke (TID) on aquatic biota.

The major objective of the 1995 sediment surveys were also to provide relevant data for bioaccumulation studies. The three sites sampled were the same as those sampled by Golder in 1994, and were selected based on the availability of adequate invertebrate biomass for chemical analysis (Figures 3.2-1 and 3.2-2). Analyses were limited to metals and trace organic compounds and variables which serve as indicators of the presence of oil sands (total organic carbon and recoverable hydrocarbons).

Detectable but low levels of PAHs in both years, and high hydrocarbon content at all sites in 1995 indicate the presence of varying amounts of oil sands in the bottom sediments at the sampling sites (Table 4.1-10). Levels of metals were typical of the bottom sediments of large rivers in Alberta (e.g., Shaw et al. 1994). Microtox® tests of sediments in 1994 did not detect toxicity to bacteria at any of the sites sampled.

The 1994 and 1995 results do not show an increase in metals or organic compounds in the vicinity of Suncor. Noton (1979) found minor changes in sediment chemistry in the immediate vicinity of the Great Canadian Oil Sands (now Suncor) operations, exhibited as small increases in the levels of metals and nitrogen compounds at affected sites. An evaluation of historical sediment metals data by IEC Beak (1983) confirmed this interpretation. Similarly, a 1983 study of sediment metal levels by Beak (1988) found no evidence metal accumulation in bottom sediments near Suncor, and concluded that metal levels reflect sediment particle size, rather than effluents from oils sands operations.

STEEPBANK RIVER

Sediment chemistry of the Steepbank River has not been evaluated previously. Bottom sediments at two sites sampled in 1995 (Figure 3.2-2) contained naturally occurring hydrocarbons, as shown by elevated concentrations of recoverable hydrocarbons and total PAHs (Table 4.1-11). The samples from the mouth of the river contained a larger proportion of oil sands than those from farther upstream. Levels of metals in Steepbank River sediments were similar to those in the Athabasca River.

Toxicity of Steepbank River sediments at one site near the mouth was evaluated by Dutka et al. (1995) using a battery of tests. A moderate toxic response was found in two of the ten tests applied (*Spirillum volutans* test and seed root elongation inhibition test).

4.1.3 Porewater Quality

Porewater is defined as the water occupying the void spaces between sediment particles. Since metals and hydrophobic organic chemicals tend to partition to particulate matter, they accumulate in bottom sediments; thus, their concentrations are generally higher in porewater than in the overlying river water. This may result in greater exposure of bottom-dwelling organisms to toxicants. The porewater surveys conducted in 1995 were also intended to provide additional data for the bioaccumulation studies. Therefore, sampling sites generally corresponded with the sediment sampling sites in the Athabasca and Steepbank rivers (Figures 3.1-1 and 3.1-2). Additionally, two sites were sampled in the Muskeg River basin, where invertebrate tissues were also collected (Figure 3.2-3). As in the Athabasca and Steepbank rivers, these sites were also selected based on the availability of adequate invertebrate tissues for chemical analysis.

Porewater chemistry and toxicity were recently surveyed in the Athabasca River by Golder Associates during an investigation of the biological effect of seepage from TID (Golder Associates 1994, 1995). During these studies, the chemical composition and toxicity of river porewater were characterized in areas immediately adjacent to the TID, across from TID and at a reference site upstream from the Suncor plant. The resulting descriptions of the chemistry of "natural" porewater (unaffected by oil sands operations), process-affected porewater (containing chemicals derived from seepage from TID) and water with intermediate chemical characteristics were compared with porewater chemistry data collected during the present study (Table 4.1-12).

The concentrations of dissolved salts varied widely at in Athabasca, Steepbank, Muskeg Rivers and Jackpine Creeks. Dissolved salt concentrations were lowest in the Muskeg River and Jackpine Creek and highest in the Steepbank River. The range in the concentrations of these compounds was greater than in natural or process-affected porewaters. This is most likely due to the presence of varying amounts of oil sands at the baseline study sampling sites, as also suggested by the bottom sediment data. The ranges in levels of naphthenic acids and total ammonia at the baseline study sites corresponded well with that in natural porewater, with the exception of one high measurement of total ammonia in the Steepbank River. Naturally-occurring PAHs were detectable at half of the sites sampled in the Steepbank and Athabasca Rivers, but not in the Muskeg River or Jackpine Creek. The sample from the Steepbank River near Lot 3 contained PAHs at levels higher than previously found in process-affected porewaters adjacent to TID. None of the samples collected during the present study were toxic in the Microtox® test. Overall, examination of the porewater data collected during this study revealed that the chemical composition of naturally occurring river porewaters in the study area can vary greatly, depending on the amount of oil sands in the substratum.

4.2 Benthic Invertebrates

4.2.1 Athabasca River

SUMMARY OF HISTORICAL INFORMATION

Historical data pertaining to benthic community and bioaccumulation assessments were summarized from several studies conducted in the Athabasca River, near the study area, between 1977 and 1994. Note, however, that data from recent surveys conducted in 1992 and 1993 as part of the Northern

River Basins Study (NRBS) have not yet been released publicly and could not therefore be included in the present summary.

McCart et al. (1977) reported the results of a 1975 baseline survey of water quality, periphyton, benthic invertebrates and fisheries in the Athabasca River. The area surveyed included the reach of the river adjacent to TID. Sites upstream and downstream of the dyke were sampled using artificial substrates and Ekman grabs at monthly intervals from June to October, 1975. The lack of detail in the report (invertebrate numbers were pooled at each site for all samples) and the locations of the sampling sites (which were not intended to monitor effects of TID seepage) mean that the presented results are not directly applicable for addressing potential impacts of TID seepage. However, they do provide a general indication of characteristics of benthic communities in this portion of the Athabasca River. The section of the Athabasca River sampled was depositional, and thus was dominated by chironomid midge larvae and oligochaete worms, though nymphs of stoneflies and mayflies were also numerous (most likely on artificial substrates). Total invertebrate densities were generally low, owing to the dominant shifting sand substratum. The authors found no significant difference in community structure between areas with or without bituminous substrates (oil sands), but bituminous substrates tended to support higher proportions of oligochaetes and chironomids.

Benthic invertebrate communities were subsequently monitored in 1978 by Noton (1979). Ekman dredge samples were collected in depositional areas in October and artificial substrates were deployed from late July to mid-October 1978. Ekman samples yielded variable invertebrate densities, with pronounced chironomid midge larval dominance noted at two sites upstream of TID. Samples from the two sites immediately downstream of TID had fewer invertebrates than the upstream sites, because of a substantial reduction in chironomid numbers. The author concluded that this reduction in densities reflected stress caused by dyke filter drainage. These studies were conducted prior to construction of a dyke drainage collector system in the early 1980s, which diverts dyke drainage water back into the tailings ponds. Biological stress was also noted at the sites sampled farther downstream, to a distance of approximately 4 km from TID. However, other effluents (process effluent, sewage) also entered the river immediately downstream of the site sampled below the dyke, implying that dyke seepage alone was likely not responsible for impacts noted farther downstream.

Artificial substrate samples were influenced by the amount of detritus, which may have affected total numbers and diversity (Noton 1979). At the upstream (of TID) control sites, samples were dominated by stonefly nymphs, caddisfly larvae, chironomid midge larvae and water boatmen. At the site sampled immediately below TID, number of taxa and densities of all invertebrate groups except the stoneflies were reduced relative to the control sites. This finding also reflects potential stress caused by dyke drainage water. No evidence of biological stress was noted at the next two downstream sites, located 1-2 km from TID, suggesting the existence of a localized effect.

Most of the sites sampled in 1978 were re-sampled in 1981 using the same methods, with the exception of two control sites, which were each moved approximately 2 km downstream from their previous positions (Noton and Anderson 1982). In contrast to the 1978 study, no changes were detected in invertebrate densities or taxonomic composition below TID in 1981, with the exception of a slight depression in the number of taxa recorded immediately below TID.

Barton and Wallace (1980) conducted ecological studies of aquatic invertebrates in the oil sands area. Qualitative and quantitative information on invertebrates from the Athabasca, Muskeg and Steepbank Rivers are provided from 1976-77. Faunal communities were characterized according to five principal habitats: limestone rubble, glacial till, muskeg reaches, brooks, and oil sands. Three patterns of development were noted: fast seasonal, slow seasonal and non-seasonal. Sites that were upstream of the oil sands had consistently greater numbers of taxa. Tanypodinae and Empididae comprised a larger fraction of the total fauna at the downstream site. The variety and density of invertebrates on oil sands was significantly less than on rubble substrates. Flooding of riffles reduced benthic standing stocks, which recovered rapidly following receding of water. Development of communities was strongly influenced by substrate. For example, changes in texture of sediments, and number and variety of organisms appeared to be directly linked to the life histories of invertebrates, and variations in direction and magnitude of river currents as the discharge fluctuates. Fall sampling showed stocks of microbenthos on bedrock and macrobenthos on the entire range of sediments. The unstable sand which covers most of the Athabasca River's bed may prevent development of large populations of certain organisms such as oligochaetes but does support large numbers of a few specialized chironomids. Oil contamination experiments showed substantial changes in colonization patterns of bare stone surfaces but no great shifts in community structure. The suspended and attached communities of the Muskeg and Steepbank Rivers were found to biodegrade the saturate fraction of synthetic crude oil at 20°C and more slowly at 4°C. The authors investigated several types of material which could be used in reclamation or diversion of streams ranging from tailings sand to large cobbles. Limestone gravel for riffles and overburden for slow reaches appeared to provide for nearly natural biological productivity.

In 1982, Boerger (1983) conducted an extensive survey of 17 sites along an 85 km stretch of the Athabasca River between Fort McMurray and the Ells River. The density of invertebrates downstream from TID was found to be significantly lower (i.e., 31% lower) than at upstream sites. However, the number of taxa and multivariate community ordinations did not reveal markedly different benthic communities at upstream and downstream sites.

Also in 1982, benthic invertebrate communities were monitored using artificial substrates (Beak 1988a). In addition to sites farther downstream than in previous studies, two upstream control sites and one site receiving dyke drainage were sampled using artificial substrates. Invertebrate densities and taxonomic composition were not affected at the site immediately below TID.

In 1983, Beak investigated trace element concentrations in benthic invertebrates and sediments collected near TID (Beak 1988b). Results indicated no significant differences between upstream and downstream sites for most metals except mercury, and no relationships were found between metal concentrations in sediments and those in benthic invertebrates. Mercury level was elevated in invertebrate tissues adjacent to Suncor, with a maximum concentration of 1700 µg/kg. A recent study by Golder (1994; see below) found mercury levels in invertebrate tissues were similar along TID to those reported by Beak (1983), but had declined to 125 µg/kg in the area where high levels were measured in 1983.

IEC Beak (1983) conducted a preliminary assessment aimed at evaluating the potential impact of drainage from the Suncor plant site on fish and invertebrates. Based on data available to July 1993, they concluded there was limited potential for acute and/or chronic toxicity to aquatic organisms immediately below points of entry into the river of surface or subsurface runoff from the reclaimed portion of the Suncor lease.

A survey of benthic communities using both natural (i.e., Hess sampler) and artificial (i.e., floating baskets) substrates was conducted by EVS (1986) to assess any effects in the Athabasca River of sediments dredged from the raw water pond at the Suncor Plant. The study indicated no evidence of effects following dredging operations. Chironomidae were the numerically dominant group and sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera) were typically present at all sites in both the natural and artificial substrates. However, there was a trend for lower taxonomic richness (total number of taxa) and total abundance in natural substrates (11-46 taxa and 7-172 organisms, respectively) compared with artificial substrates (21-50 taxa and 628-1834 organisms, respectively).

Golder (1994) conducted a screening-level benthic invertebrate study in the autumn of 1994 as part of an evaluation of environmental risks associated with TID seepage. Overall, invertebrate densities and taxonomic richness were low, largely due to the seasonal pattern of early summer emergence of adult aquatic insects. The highest densities and taxonomic richness were found at the upstream end of the berm adjacent to TID. At all sites the bulk of invertebrate biomass consisted of dragonfly, mayfly and stonefly nymphs. No apparent difference was noted in taxonomic composition among the sites. Sensitive invertebrates (stoneflies, mayflies, caddisflies) were present in similar numbers at all sites. In addition benthic invertebrates were collected during this study for analysis of PAHs and metal concentrations in tissues. Results were consistent with the benthic community assessment and indicated that there was little or no discernible differences between chemical concentrations measured from sites along TID when compared with reference sites.

HABITAT CHARACTERISTICS

Habitat characteristics at 12 Athabasca River stations (Stations AB001 to AB012; Figure 3.2-1) are provided in Table 4.2-1. Parameters measured included substrate composition, current velocity, depth, water temperature, dissolved oxygen content, turbidity, pH, conductivity and redox potential.

Since relatively uniform depositional areas were selected for deployment of the artificial substrates, large variations in habitat characteristics among stations were not expected. However, spatial trends in benthic communities found in natural substrates may reflect small scale differences in the parameters measured at the stations. Substrate composition ranged primarily from fine to medium grain coarse sand, with the exception of Station AB012 which had higher proportions of silt and clay, and Station AB010 which had higher proportions of fine gravel. Current velocity measurements were quite variable between stations, ranging from 0.009 m/s at Station AB012 to 0.460 m/s at Station AB001. Mean water depth ranged from 82 cm at Station AB010 to 116 cm at Station AB007. Water temperature ranged from 2.4-6.7°C at Stations AB012 and AB002, respectively; dissolved oxygen content ranged from 11.8-12.8 mg/L at Stations AB001 and AB004, respectively; turbidity ranged from 2.1 NTU at Station AB003 to 8.1 NTU at Station AB009; values of pH ranged from 7.16-7.92 at Stations AB012 and AB007, respectively; conductivity ranged from 245-330 µS/cm at Station AB002 and AB003, respectively; and redox ranged from 66 mV at Station AB009 to 120 mV at Station AB002. Note that stations located on the east bank of the river typically had lower water temperature and conductivity than stations located on the west bank. This is possibly due to the inflow of the Clearwater River near Fort McMurray.

BENTHIC COMMUNITY ASSESSMENT

Artificial Substrates (Basket Sampler)

Table 4.2-2 provides a summary of mean total abundance for dominant taxa (i.e., >1% relative abundance) found at each station (raw data are given in Appendix IX). Overall, the most abundant taxon in artificial substrates was the plecopteran, *Isoperla*. This was the most numerous organism at seven of the ten locations surveyed and its relative abundance ranged between 3.9 and 58.2% of total benthic invertebrates collected. The second most numerous taxon was the chironomid, *Micropsectra*. It was the most abundant taxon in samples from Stations AB003, AB005, AB006 and AB012 (33.% to 58.2%), and the second most abundant taxon in samples from Stations AB001, AB004, AB007, AB008 and AB009 (13.3% to 20.5%). However, it was only moderately abundant at Stations AB010 and AB011, accounting for 1.6 and 4.0% of total organisms respectively.

The relative importance of each major taxonomic group is presented in Figure 4.2-1. For all stations, the insects were much more common than non-insects, accounting for 95.8 to 100% of organisms in artificial substrates. Of the insects, Chironomidae and Plecoptera were generally the most abundant. These two taxonomic groups accounted for 57.7 to 86.9% of organisms in the artificial substrates. At most stations, the abundance of chironomids and plecopterans were approximately equal. However, at Stations AB003 and AB012 the mean abundance of Chironomidae (71.8% and 71.6%) greatly exceeded Plecoptera (10.4% and 4.5%), while at stations AB009 and AB011, the abundance of Plecoptera (59.6% and 71.9%) greatly exceeded Chironomidae (35.8% and 12.2%). Of the remaining insect groups, Ephemeroptera and other Diptera were moderately abundant, while Trichoptera had low abundance.

Mean total abundance and mean richness are presented in Figures 4.2-2 and 4.2-3. Mean total abundance was lowest at Station AB006 (425 organisms/basket) and highest at Station AB007 (2908 organisms/basket). With the exception of Station AB006, there was a general trend towards lower abundances at stations located downstream of the Steepbank River. Taxonomic richness was relatively uniform between stations (Figure 4.2-3), with richness being lowest at Station AB012 (17 taxa), and highest at Station AB004 (29 taxa). Note that among all stations monitored, mean total abundance and mean taxonomic richness were 1500 organisms and 23 taxa respectively.

To determine the trophic structure of benthic communities at the Athabasca River stations, organisms were classified in terms of their feeding behaviour (Merritt and Cummins 1984; Peckarsky et al. 1990). Figure 4.2-4 displays the proportion of benthic invertebrates in each of nine feeding groups.

Most of the taxa found in the artificial substrates were either collector-gatherers or predators, with 63.9% to 90.5% of taxa belonging to these two functional feeding groups. With the exception of Stations AB003 and AB012, which were dominated by collector-gatherers, there were no specific trends in trophic structure among stations. Overall, the proportions of benthic invertebrates in the nine trophic categories were as follows: collector-gatherer (45.2%), predator (33.5%), collector-filter (7.2%), omnivore (4.1%), scraper (4.2%), shredder (3.7%), unknown (1.9%) and piercer-herbivore (0.03%).

Natural Substrates (Ekman Grab)

Table 4.2-3 provides a summary of total abundance for dominant taxa (i.e., >1% relative abundance) found at each station. As with the artificial substrate samples, Isoperla (Plecoptera) and *Micropsectra* (Chironomidae) were typically the most abundant taxa in the natural substrates. *Micropsectra* was the most common taxon at Stations AB001, AB004, AB006, AB009 and AB012, and *Isoperla* was the most abundant taxon at Stations AB007, AB008, AB010 and AB011. At the remaining stations, the most common taxa were *Ametropus* (Ephemeroptera), Ceratopogonidae (Diptera), or *Paracladopelma* (Chironomidae).

The relative proportion of invertebrates from each major taxonomic group is shown in Figure 4.2-5. Overall, insects were much more common than non-insects, with insects accounting for 63.2% to 100% of organisms in natural substrates. The greatest number of non-insects was found at Station AB012, where 36.8% of the organisms were Nematoda, Tubificidae, or Sphaeriidae. Of the insects, the Chironomidae were the most abundant group at all locations except Stations AB007 and AB010 where plecopterans were most common. Other dipterans and ephemeropterans were the next most abundant group overall.

Total abundance and richness are presented in Figures 4.2-6 and 4.2-7. The density of benthic invertebrates found in natural substrates varied considerably between stations (Figure 4.2-6). The highest density was noted at Station AB012 (19127 organisms/m^2) downstream of the Steepbank River, and the lowest density was found at station AB002 (101 organisms/m^2) upstream of Poplar Creek. Taxonomic richness for natural substrate samples is shown in Figure 4.2-7. Station AB002 had the lowest richness (4 taxa), and Station AB003 had the highest richness (28 taxa). High taxonomic richness was also observed at Stations AB004 (27 taxa) and AB006 (22 taxa). Note that among all stations monitored, mean total abundance and mean taxonomic richness were 2192 organisms and 15 taxa, respectively.

To determine the trophic structure of benthic communities at the Athabasca River stations, organisms were classified in terms of their feeding behaviour (Merritt and Cummins 1984; Peckarsky et al. 1990). Figure 4.2-8 displays the proportion of benthic invertebrates in each of nine feeding groups.

In general, collector-gatherers and predators were important feeding assemblages. Overall, the proportions of benthic invertebrates in the nine trophic categories were as follows: collector-gatherer (50.8%), predator (26.3%), unknown (14.1%), and omnivore (7.3%), collector-filter (5.6%), scraper (1.5%), shredder (0.9%), parasite (0.7%), and macrophyte-herbivore (0.3%).

BIOACCUMULATION ASSESSMENT

The taxonomic composition of the samples used for chemical analyses is shown in Table 4.2-4. Samples consisted entirely of Odonata and Plecoptera.

Table 4.2-5 summarizes the concentrations of 30 metals in tissue of benthic invertebrates collected from Station AT003 on the Athabasca River. Most of the chemical concentrations were higher than the reported detection limits, with the exception of eight metals (antimony, arsenic, beryllium, boron, cadmium, lead, selenium, and uranium). The highest concentrations were for potassium, followed by phosphorus, and sodium. No marked differences in concentrations were noted between samples taken in August 1994 (Golder 1994) and October 1995 (this study). The concentration of mercury in benthic invertebrate tissues at the east bank reference site sampled in 1995 was similar to the measured level in 1994 (Golder 1994).

Table 4.2-6 provides concentrations of organic chemicals measured in tissue of benthic invertebrates from Station AT003. In both 1994 (Golder 1994) and 1995 (this study), organic chemical concentrations in benthic invertebrate tissues were low. Most of the measurements were below detection limits with the exception of naphthalene, phenanthrene, methyl acenaphthene, and methyl fluorene in 1994, and naphthalene, methyl naphthalene, and substituted naphthalenes in 1995. Concentrations of these organic chemicals were only slightly above detection limits.

SUMMARY

Overall findings were derived from the 1995 baseline community and bioaccumulation assessments conducted on the Athabasca River with consideration to the identification of current spatial trends and their relationship to potential exposure from sources of chemicals and site-specific habitat characteristics, and comparability with available historical data.

Based on these objectives, overall findings are summarized as follows:

1. Artificial substrates were used in this study principally because they permit standardized sampling, reduce habitat-related variability, and are typically colonized by drifting organisms, including sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera) which may not be adequately represented in the natural depositional substrate of the study area. The organisms

that colonize artificial substrates are not in direct contact with the sediment; therefore, artificial substrates are useful for identifying variations in water quality, but not in sediment quality (Gibbons et al. 1993).

- Benthic communities which colonized the artificial substrates over the four week period were relatively similar in composition among monitoring stations. In general, communities were dominated by Plecoptera (stoneflies) and Chironomidae (midges). This suggests that water quality conditions did not differ markedly between reference stations (absence of potential effects; AB001, AB002, AB011, AB012) and exposure stations (presence of current or projected potential effects; AB003, AB004, AB005, AB006, AB007, AB008). Note, however, that Stations AB003 and AB012 were notably dominated by Chironomidae which may be due to a greater abundance of organic debris deposited from Poplar Creek at AB003 and reduced current velocity at AB012 (0.009 m/s; Table 4.2-1). In addition, Stations AB009, located downstream of wastewater discharges and sewage lagoon/ditch runoff, and AB011, a far-field downstream station, were notably dominated by Plecoptera. This group is generally considered among those having low pollution tolerance (Klemm et al. 1990) and, therefore, there is no apparent evidence of organic enrichment at Station AB009.
- There was a trend of decreasing benthic densities in the artificial substrates located downstream of the Steepbank River. There were no distinct changes in habitat characteristics which could account for this observation and taxonomic richness were similar between stations upstream and downstream of the Steepbank River.
- Although not directly comparable due to variations in sampling locations and possibly receiving habitat characteristics, results of this study are generally consistent with data collected over the last two decades.

2. Benthic communities inhabiting natural substrates were monitored in addition to the artificial substrates because they reflect both the depositional nature of river habitat found in the study area (i.e., dominated by fine sediments) and potential variations in sediment and porewater quality.

- As with the artificial substrates, Chironomidae and Plecoptera were typically dominant. Even though habitat characteristics were relatively uniform between stations, there was considerable variation among stations in community composition and total abundance. Taxonomic richness differed little among monitoring stations. Overall, benthic communities in natural substrates did not indicate any specific trends relative to reference and potential exposure stations, which is consistent with data collected over the last two decades.

3. Results of the bioaccumulation assessment indicate that concentrations of most metals were higher than the reported analytical detection limits (with the exception of antimony, arsenic, beryllium, boron, cadmium, lead, selenium, and uranium). No marked differences in tissue concentrations of metals were noted between samples taken in August 1994 (Golder 1994) and October 1995 (this study). Similarly, in both 1994 and 1995, organic chemical concentrations in benthic invertebrate tissues were low. Most of the measurements were below detection limits with the exception of naphthalene, phenanthrene, methyl acenaphthene, and methyl fluorene in 1994, and naphthalene, methyl naphthalene, and substituted naphthalenes in 1995. However, concentrations of these organic chemicals were only slightly above detection limits. Results of the community assessment suggest that the tissue concentrations of metals and organics from the study area did not affect benthic invertebrates.

4.2.2 Steepbank River

SUMMARY OF HISTORICAL INFORMATION

The benthic community of the Steepbank River was surveyed by Barton and Wallace (1980). Results of these surveys were summarized in Section 4.2.1.

HABITAT CHARACTERISTICS

Habitat characteristics at three Steepbank River stations (Stations SB001, SB002, and SB003; Figure 3.2-2) are provided in Table 4.2-7. Parameters measured included current velocity, depth, water temperature, dissolved oxygen content, turbidity, pH, conductivity, and redox potential. Substrate composition was determined qualitatively since representative samples for grain size analysis could not be collected.

Station SB001 located farthest upstream was a riffle of unconsolidated rock varying in size from approximately 1 m to gravel embedded on a hard bed of bituminous substrate. The substrate at Station SB002 located at mid-reach, was similar to the one observed at Station SB001. Station SB003 located near the mouth of the Steepbank River was similar to the other two stations, but was dominated by gravel (approximately 1-3 cm) and small amounts of shifting sand (approximately 1 mm) on top of a hard bed containing bitumen, gravel and sand. The parameter measurements were as follows: mean current velocities increased from Station SB001 (0.420 m/s) to SB002 (0.639 m/s) to SB003 (1.170 m/s); mean water depth ranged from 30-42 cm; mean water temperature ranged from 2.0-2.8°C; mean dissolved oxygen content ranged from 13.4-13.6 mg/L; turbidity was 3.2 NTU at SB001 and SB002, and 2.9 NTU at SB003; mean pH ranged from 7.65-7.97; conductivity ranged from 185-202 µS/cm; and redox potential ranged from 131-141 mV.

BENTHIC COMMUNITY ASSESSMENT

Table 4.2-8 provides a summary of mean total abundance for dominant taxa (i.e., >1% relative abundance) found at each station (raw data is given in Appendix IX). The most abundant taxon found at Station SB001 was *Orthocladium* Complex (Chironomidae). At both Stations SB002 and SB003, the most abundant taxon was *Baetis tricaudatus* (Ephemeroptera). Among other dominant insect taxa at the Steepbank River stations, *Simulium* (Diptera), *Hydroptila* (Trichoptera) and *Rheotanytarsus* (Chironomidae) were the most abundant.

The relative proportion of invertebrates from each major taxonomic group is presented in Figure 4.2-9. Insects represented between 84.6% and 97.1% of the organisms sampled. When abundances were averaged over the three stations, the majority of insects were found to be either chironomids (31.8%), ephemeropterans (30.0%) or other dipterans (17.0%). At Station SB001, the most abundant group was Chironomidae (50.6%); at Station AB002, most of the organisms were ephemeropterans (31.5%) and chironomids (30.7%; and at Station SB003, most of the organisms were ephemeropterans (44.6%) (Figure 4.2-9). There appeared to be a general trend of reduced Chironomidae abundance from upstream to downstream stations, whereas proportions of other Diptera and Ephemeroptera increased from upstream to downstream.

Mean total abundance and mean richness are presented in Figures 4.2-10 and 4.2-11. Mean densities decreased from upstream to downstream stations. Densities decreased from Station SB001 (6846 organisms/m^2), to Station SB002 (3504 organisms/m^2) and Station SB003 (1562 organisms/m^2). Richness also followed the same trend as total abundance (Figure 4.2-11) and decreased from Station SB001 (44 taxa) to Station SB003 (19 taxa). Among all stations monitored, mean total abundance and mean taxonomic richness were 3971 organisms and 33 taxa respectively.

To determine the trophic structure of benthic communities at the Steepbank River stations, organisms were classified in terms of their feeding behaviour (Merritt and Cummins 1984; Peckarsky et al. 1990). Figure 4.2-12 displays the benthic data in terms of feeding assemblage. The proportion of collector-gatherers at the three stations was approximately the same, while the proportion of collector-filters typically increased from upstream to downstream (i.e., Stations SB001 to SB003). Overall, the proportion of organisms in the 10 functional feeding groups were as follows:

collector-gatherer (54.6%), collector-filter (16.8%), predator (8.3%), omnivore (5.6%), parasite (3.9%), piercer-herbivore (3.6%), shredder (2.9%), scraper (2.5%), unknown (1.7%) and macrophyte-herbivore (0.16%).

BIOACCUMMULATION ASSESSMENT

The taxonomic composition of samples used for chemical analyses is shown in Table 4.2-9. Samples for metal and organic analyses both consisted of Odonata, Plecoptera and Trichoptera, with the relative proportions of the three taxa similar in both samples.

Table 4.2-10 provides a summary of tissue concentrations of 30 metals in benthic invertebrates from Station SB002 of the Steepbank River. Chemical concentrations were below detection limits for antimony, total mercury, arsenic, beryllium, cadmium, lead, selenium and uranium. As in Athabasca River samples (Table 4.2-5), potassium, phosphorus and sodium had the highest concentrations. In general, metal concentrations were similar between the Athabasca River and the Steepbank River (compare Tables 4.2-5 and 4.2-10).

Table 4.2-11 provides the tissue concentrations of organic chemicals measured in benthic invertebrates from Station SB002. Concentrations of several organic chemicals were above detection limits, particularly substituted phenanthrenes and substituted dibenzothiophene. Typically, tissue concentrations of organic chemicals were higher in the Steepbank River than the Athabasca River (Table 4.2-6).

SUMMARY

Overall findings were derived from the 1995 baseline community and bioaccumulation assessments conducted on the Steepbank River with consideration to the identification of current spatial trends and their relationship to site-specific habitat characteristics.

Based on these objectives, overall findings are summarized as follows:

1. Benthic communities were monitored in natural erosional substrates (typically dominated by sand and gravel embedded in bituminous substrate) along the Steepbank River. The main environmental factors potentially affecting community structure among the study stations were variations in natural habitat characteristics. Current variations in sediment and porewater quality are related to natural processes, as no mining activities have yet been initiated in the study area.
   - Benthic communities were dominated by Chironomidae at SB001, located in the upper reach of the Steepbank River, and by Ephemeroptera (mayflies) at both stations SB002 and SB003, located at mid-reach and near the mouth of the Steepbank River, respectively. There was a trend of decreasing abundance and taxa from upstream to downstream stations. Differences in habitat characteristics may account for most of the observed variations in benthos composition, abundance and richness. Stations SB002 and SB003 display higher mean current velocity (0.639 m/s at SB002 and 1.170 m/s at SB003; Table 4.2-7) compared with Station AB001 (0.420 m/s; Table 4.2-2). Based on qualitative observations, the substrate at Station AB001 was coarser than at downstream Stations AB002 and AB003. In addition, the layer of substrate material preferred as invertebrate habitat (e.g., fines, sand, gravel) laying on top of the hard bed of bitumen generally decreased from upstream to downstream. Presumably, the finer layer of substrate habitat at downstream stations and the higher current velocity may contribute to reducing both invertebrate abundance and richness. At the upstream station, reduced water flows may contribute to the accumulation of organic matter particles and thus favour taxa such as Chironomidae.

2. Results of the bioaccumulation assessment indicate that concentrations of most metals were higher than the reported analytical detection limits (with the exception of antimony, total mercury, arsenic, beryllium, cadmium, lead, selenium and uranium). Concentrations of several organic chemicals were above detection limits, particularly substituted phenanthrenes and substituted dibenzothiophene. Typically, concentrations of organic chemicals were higher in the Steepbank River than the Athabasca River (Table 4.2-6). These

results may reflect differences in substrate composition. The Steepbank River is mainly embedded with bituminous substrate, whereas the Athabasca River is composed of finer sediments with possibly higher proportions of organic carbon which could reduced bioavailability of chemicals to benthic invertebrates. (See sections 4.1.2 and 4.1.3 for discussion of porewater and sediment quality.)

4.2.3 Muskeg River Basin

SUMMARY OF HISTORICAL INFORMATION

Benthic invertebrate communities at 19 stream sites and in Kearl Lake were characterized most recently in spring, summer and fall, 1988, during the OSLO Project (R.L. & L. 1989). The results of benthic invertebrate studies conducted in 1985 at 14 sites by Beak (1986) were also summarized in the OSLO report. The stream sites sampled during these surveys were classified as pool, riffle or run habitat. Pool sites supported slightly fewer taxa and lower numbers of invertebrates than the other two habitats. All sites were dominated by chironomid midges and other dipterans, followed by non-insect taxa and the aquatic insect groups Ephemeroptera, Trichoptera and Plecoptera. The percentage of insects was slightly higher at riffle sites than at pool or run sites, and the benthic invertebrate community was dominated by detritivores at all sites. Kearl Lake supported a relatively unproductive benthic community, which was also dominated by detritivores.

HABITAT CHARACTERISTICS

Habitat characteristics of all sites sampled in 1995 in the Muskeg River basin are summarized in Table 4.2-12. All sites were classified as run habitat, according to definitions used during habitat mapping. However, depending on current velocity and bottom sediment composition, the sites can be divided into two types: erosional and depositional. Erosional habitat was characterized by substratum consisting of a variety of particle sizes (but with a relatively small proportion of fine sediments), variable current velocity (0.15-0.86 m/s), and depth lower than 0.5 m. The amount of benthic algae, measured as epilithic chlorophyll *a* in algal scrapes, was non-measurable to low, indicating that the streams sampled are relatively unproductive. This was not unexpected, since the smaller streams sampled were shaded, water temperature is low year-round and all running waters in the study area have relatively high colour, which limits light penetration and primary production. Dissolved oxygen concentration was high at all erosional sites. Overall, habitat quality for benthic invertebrates was variable at the erosional sites, as deduced from current velocity, substratum composition and the amount of benthic algae. The Muskeg River (Site 30) appeared to provide the highest quality invertebrate habitat, followed by Sites 17 and S4 in Jackpine Creek.

Depositional habitat was characterized by substratum consisting entirely of fine sediment, no apparent or very low current velocity, greater depth and lower dissolved oxygen concentration than at erosional sites (Table 4.2-12). All depositional sites represented relatively low quality habitat for stream invertebrates, and thus may be expected to support mostly chironomid midge larvae and oligochaete worms.

Due to moderate amounts of fine sediments in the substratum and low current velocity (Table 4.2-12), the sampling sites in Blackfly Creek (Site 55) and Iyinimin Creek (Site 8) were not truly erosional or depositional, but rather represented transitional habitat. Habitat quality at these sites was intermediate between the erosional and depositional sites.

Kearl Lake is shallow, with soft depositional sediments and abundant rooted aquatic macrophyte growth. Based on profiles of temperature and dissolved oxygen (Table 4.1-9), the lake remains well mixed, and thus well-oxygenated, throughout the open-water season. The trophic status of Kearl Lake can be classified as mesotrophic to eutrophic (R.L. & L. 1989 and Section 4.2 of the present study), which suggests that it is likely to support a moderately diverse and productive benthic fauna. However, historical data indicate that the lake may become anoxic in the winter which may affect its benthic invertebrate community, by excluding taxa sensitive to low dissolved oxygen concentration.

BENTHIC COMMUNITY ASSESSMENT

The stream sites supported a relatively unproductive, but moderately diverse benthic fauna. A total of 91 taxa were identified in the samples (see Appendix IX for raw data). Seventy-seven taxa were benthic, whereas the remaining 14 were terrestrial, planktonic or lived in aquatic macrophyte beds. Non-insect taxa were represented by oligochaete worms, leeches, nematode worms, water mites, flatworms, clams, snails and amphipods and with domination by oligochaete and nematode worms and water mites at all sites (Table 4.2-13). All major aquatic insect orders were represented in the samples collected in 1995 (Figure 4.2-13). The insect fauna of erosional sites was generally dominated by chironomid midge larvae, but mayfly nymphs, riffle beetles, caddisfly larvae and stonefly nymphs were also present in low to moderate numbers. At depositional sites, the insects were represented almost exclusively by chironomid midge larvae. The benthic fauna of Kearl Lake was sparse, consisting entirely of oligochaete worms, nematode worms and chironomid midge larvae.

Total density of benthic invertebrates was relatively low at all sites, reflecting the low primary productivity of the streams sampled. Total numbers ranged from 652-5816 animals/m^2 at erosional sites, and from 5038-23481 animals/m^2 at depositional sites (Table 4.2-13). Invertebrate density was also low in Kearl Lake (1277 animals/m^2). Taxonomic richness, defined as the total number of taxa identified, was low to moderate, with means of 12-26 at erosional sites and 13-20 at depositional sites. The site sampled in Kearl Lake supported the lowest mean number of taxa (5) of all sites sampled.

In the following sections, the benthic invertebrate fauna of each waterbody sampled in 1995 is described and the benthos data collected in 1995 are compared with 1985 and 1988 data summarized in the OSLO report (R.L. & L. 1989). Where applicable, the previous name of each stream, as identified in the OSLO report, is shown in parentheses. Functional feeding group definitions of Merritt and Cummins (1984) were used during this study. Functional feeding group designations used by R.L. & L. (1989) were retained when describing historical data, but the equivalent new feeding group names are provided in parentheses to facilitate comparisons among years.

Muskeg River

Three sites, located 10-15 km apart, were sampled in the Muskeg River in 1995 (Figure 3.2-3). One of these sites (Site 18) was also sampled in 1988. Site 30, at the mouth of the river, was classified as erosional habitat during this study and Sites 18 and 35 were depositional.

The benthic invertebrate community at Site 30 was characterized by low density and moderate taxonomic richness (Figures 4.2-14 and 4.2-15). The benthos was dominated by oligochaete and nematode worms (shown as non-insects on Figure 4.2-13). All major aquatic insects groups were also represented, in approximately equal proportions.

The benthic fauna at Site 18, located just downstream from the mouth of Jackpine Creek, was dominated by chironomid midges, oligochaetes and nematodes in 1995 and 1988. Total invertebrate abundance and taxonomic richness were moderate, but variable in 1995 (Figures 4.2-14 and 4.2-15). Mean taxonomic richness was two-fold greater, and mean density was approximately eight-fold greater in 1995 than in 1988. The composition of the single sample from Site 35, located between Stanley Creek and Muskeg Creek, was similar to those from Site 18, though total density was approximately two-fold lower at Site 35 (Figure 3.2-14). Overall, the communities present at these sites were typical of depositional habitats of Alberta rivers.

All sites sampled in the Muskeg River were dominated by collector-gatherers, accounting for 70 to 80% of total invertebrates (Figure 4.2-16). Predators and scrapers accounted for 25% of total numbers at the erosional site (Site 30). Collector-filterers, predators and scrapers constituted a similar proportion of the fauna at the depositional sites (Sites 18 and 35). The results of the functional feeding group analysis on 1995 and 1988 data were similar. The community at Site 18 was dominated by detritivores (collector-gatherers) in 1988, and carnivores (predators) and detritivores/herbivores (piercer-herbivores and shredders) were present in lower numbers.

Jackpine Creek (Hartley Creek)

Two erosional sites were sampled in Jackpine Creek in 1995 (Sites 17 and S4; Figure 3.2-3). One of these sites (Site 17) was also sampled in 1988. This site was classified as pool habitat in 1988.

The density of benthic invertebrates was relatively low at both sites in 1995 (Figure 4.2-14). Mean taxonomic richness at Site 17 was the highest of all sites sampled (Figure 4.2-15). The benthic fauna of Jackpine Creek was dominated by chironomid midges and oligochaete and nematode worms, but other aquatic insect orders were also present at low to moderate densities (Figure 4.2-13). In particular, mayfly nymphs accounted for approximately 10-15% of total invertebrates.

Site 17 was dominated by chironomid larvae in fall, 1988, and mayfly nymphs accounted for 7% of total invertebrates. Total abundance was nearly two-fold greater, whereas taxonomic richness was approximately two-fold lower in 1989 than in 1995. These differences in benthic community composition are the result of sampling different habitat types: pool (depositional) habitat was sampled in 1988 and run (erosional) habitat was sampled in 1995.

Collector-gatherers and predators were present at moderate numbers at the two sites sampled in 1995 (Figure 4.2-16). The proportion of scrapers and collector-filterers was variable. The conspicuously high percentage of predators reflects moderate numbers of water mites (Hydrachnidia) and dance fly larvae (Diptera: Empididae). The trophic structure of the invertebrate community at Site 17 in 1988 also attests to the difference in habitat type between sampling events. Site 17 was dominated by detritivores (collector gatherers; >80%) and carnivores (predators; 15%), which is characteristic of depositional habitats.

Khahago Creek (Unnamed Creek C Mainstem)

Site 14 in Khahago Creek was previously sampled in 1985 and 1988 (Figure 3.2-3). This site was classified as run habitat in 1988 and as run/depositional habitat in 1995.

Total invertebrate abundance was moderate and taxonomic richness was low in 1995 (Figures 4.2-14 and 4.2-15). Both were approximately 30% lower in 1995 than in 1988. In 1995, the benthic community consisted almost exclusively of chironomid larvae and nematode and oligochaete worms (Figure 4.2-13, Table 4.2-13), corresponding to the habitat type sampled. Chironomid dominance was also found in 1985 and 1988, but the percentage of worms was lower. The remainder of the fauna in 1988 consisted of amphipods, mayfly nymphs and fingernail clams (detailed data are not available for 1985). The apparent difference in community composition between the 1988 and 1995 can also be attributed to differences in creek habitat between sampling events.

The community present in 1995 consisted primarily of collector-gatherers, with only small percentages of other feeding groups, as may be expected in depositional habitat (Figure 4.2-16). Trophic structure was similar in 1988, though carnivores (predators) were also present in moderate numbers. According to data presented in the OSLO report (R.L.&L 1989), carnivores (65%) and detritivores (collector-gatherers; 33%) constituted the benthic community in 1985. In the absence of detailed habitat data for the 1985 sampling event, the significance of this difference from 1995 and 1988 results cannot be evaluated.

Blackfly Creek (Unnamed Creek C Tributary)

Blackfy Creek, which was sampled at Site 55 in 1995 (Figure 3.2-3), is located approximately 4 km downstream from Site 12 sampled in 1985 and 1988. Site 55 was classified as transitional habitat in 1995, whereas Site 12 was located in a riffle in 1985 and 1988.

The benthic community of Blackfly Creek was characterized by moderate density and taxonomic richness in 1995 (Figures 4.2-14 and 4.2-15). Total invertebrate density was nearly 13-fold greater and taxonomic richness was two-fold greater in 1995 than in 1988. The benthic fauna was dominated by chironomids, but other aquatic insects were also present in low numbers (Figure 4.2-13). The dominance of chironomids was less pronounced in 1985 and the community was well-balanced (no single dominant group) in 1988. The differences in community composition between 1995 and the 1980s are the result of sampling different habitats.

The benthic community of Blackfly Creek consisted primarily of collector-gatherers and scrapers at Site 55 in 1995 (Figure 4.2-16). Site 12 was dominated by detritivores (collector-gatherers) in 1985 and by detritivores and herbivores in 1988.

Iyinimin Creek (Unnamed Creek B)

Prior to 1995, Site 8 on Iyinimin Creek (Figure 3.2-3) was sampled in 1985 and 1988. During the present study, it was classified as transitional habitat between erosional and depositional habitats (Table 4.2-12). In the 1980s, Site 8 was classified as riffle habitat.

Invertebrate density and taxonomic richness were low at Site 8 in 1995 (Figures 4.2-14 and 4.2-15) and were similar to that reported during the 1988 survey (R.L.&L. 1989). The benthic community was dominated by chironomids in 1995, but stonefly nymphs were also common (Figure 4.2-13). These taxa were also dominant in 1985, but the percentage of stoneflies was greater (37%). Chironomids were a minor taxon in 1988; stonefly nymphs and caddisfly larvae accounted for more than 80% of total invertebrates. The variation in the proportions of these groups among years most likely reflect year-to-year differences in habitat characteristics at the sampling site arising from minor differences in site location.

Despite the low diversity of the invertebrate community at Site 8, Iyinimin Creek supported a well-balanced assemblage of functional feeding groups in 1995 (Figure 4.2-16). Trophic structure was less balanced in the 1980s: detritivores (collector-gatherers) were dominant in 1985 and 1988, accounting for 92 and 73% of total invertebrates, respectively.

Muskeg Creek (Kearl Creek)

Site 9 in Muskeg Creek (Figure 3.2-3) was previously sampled in 1985 (Beak 1986b) and 1988 (R.L.&L. 1989). This site was classified as riffle habitat in 1985 and 1988, and as run/depositional habitat in 1995.

Total invertebrate abundance was moderate but highly variable and mean taxonomic richness was low to moderate in 1995 (Figures 4.2-14 and 4.2-15). The means of these variables were similar in all years sampled. In 1995, the benthic community consisted largely of chironomid larvae and nematode and oligochaete worms, which constituted >90% of total invertebrates. Similarly, chironomids and oligochaete worms dominated this site in 1985 and 1988.

Trophic structure of the benthic community was also similar in all years sampled. Collector-gatherers dominated the assemblage, with lower percentages of predators, scrapers and collector-filterers in 1995 (Figure 4.2-16). Detritivores (collector-gatherers) were also dominant in 1985 and 1988.

Kearl Lake

Kearl Lake was previously sampled in 1985 (Beak 1986b) and in 1988 (R.L.&L. 1989). The habitat sampled can be described as shallow, soft-bottom, lentic habitat with abundant rooted aquatic macrophyte cover.

In 1995, Kearl Lake supported a depauperate benthic community with low total abundance and taxonomic richness (Figures 4.2-14 and 4.2-15). Total invertebrate abundance was approximately seven-fold greater in 1988 than in 1995. Mean taxonomic richness (excluding zooplankton taxa) was two-fold greater in 1988 than in 1995. The benthos consisted exclusively of chironomid midges and nematode and oligochaete worms in 1995 (Table 4.2-13, Figure 4.2-13). Although these taxa were also abundant in 1988, crustaceans, lentic aquatic insects and mollusks were also present at low densities.

BIOACCUMULATION ASSESSMENT

Aquatic insects were collected in the Muskeg River (Site 30) and in Jackpine Creek (Site S4) for analyses of PAHs, alkylated PAHs, PANHs, alkylated PANHs and metals. These locations were selected based on habitat type, to allow collection of large numbers of large-sized invertebrates in a relatively short time.

Taxonomic composition of the samples is provided in Table 4.2-14 and the results of chemical analyses are summarized in Table 4.2-15. Concentrations of metals and trace organic compounds were similar in both samples. Metal concentrations were below the detection limits at both sites for antimony, beryllium, cadmium, mercury, selenium, silver and uranium. Other metals were present at variable, but generally low levels with a few exceptions. Concentrations of the majority of PAHs and PANHs were non-detectable. Concentrations of detectable organic compounds were only slightly above the detection limit.

SUMMARY

Results of the spot-check survey of benthic invertebrate communities conducted in 1995 indicate that benthic communities in the Muskeg River basin are generally characterized by low to moderate density and taxonomic richness. The composition of benthic communities reflected the habitat types at all sampling sites. Depositional sites typically supported invertebrate communities with moderate density and low taxonomic richness, consisting almost exclusively of oligochaete worms, nematode worms and chironomid midge larvae. A greater variety of invertebrates were found at the erosional sites, consisting of the above taxa and aquatic insects of various orders (mayflies, stoneflies, caddisflies and other dipterans). Erosional sites tended to support lower total number of invertebrates than depositional sites. The structure of the benthic communities in terms of functional feeding groups was also similar at all sites within a habitat type. The fauna of depositional sites consisted primarily of collector-gatherers which accounted for approximately 80% of total invertebrate numbers. A greater variety of feeding groups were present at the erosional sites, but collector-gatherers remained dominant. The trophic structure of the benthic communities reflected the type of food source available in the streams sampled. The primary food source for benthic invertebrates is from allochtonous sources (plant detritus) because primary productivity is limited by high water colour, low water temperature year-round and shading of the smaller streams sampled.

Comparison of the 1995 data with results of previous surveys revealed that the benthic communities have not changed substantially since the 1980s. Differences among years in benthic community composition can be attributed to habitat differences related to the exact location of the sampling sites and normal year-to-year variability.

The small-scale assessment of bioaccumulation of metals and trace organic compounds showed that most metals analyzed were present in invertebrate tissues at detectable, but generally low levels. The majority of PAHs and PANHs were non-detectable in invertebrate tissues. Concentrations of all detectable organic compounds were near the detection limit. The samples from the two streams sites had similar levels of metals and trace organic compounds.

4.3 Fish Habitat

The Steepbank and Aurora mine study areas are located in Sub-basin III of the Athabasca River Basin (Fort McMurray to the Peace-Athabasca Delta) (Wallace and McCart 1984). Several tributaries, including the Richardson, Firebag, MacKay, Muskeg and Steepbank Rivers feed into the mainstream Athabasca River. These tributaries flow through a muskeg-dominated plain that is interspersed by four sets of hills: Stony Mountain, Thickwood Hills, the Birch Mountains and Muskeg Mountain (Wallace and McCart 1984). This sub-basin has some of the most diverse fisheries habitat in Alberta (Wallace and McCart 1984). The tributaries have cold brown-water habitat and contain, to varying extents, low-gradient reaches that have organic/sand/silt substrate and high-gradient gravel dominated reaches. In contrast, the mainstem Athabasca River is turbid cool-water habitat and consists of dynamic, shifting-sand channels; water levels fluctuate widely and floods are commonplace. Habitat characteristics of the Athabasca, Steepbank and Muskeg Rivers within the study areas are described in detail below. The habitat classification system and codes that appear on habitat maps are presented in Tables 4.3-1 to 4.3-3.

4.3.1 Athabasca River

Major habitat types, special habitat features, bank types and channel units of the Athabasca River within the study area are defined in Tables 4.3-1, 4.3-2 and 4.3-3 and are illustrated in Figure 4.3-1. Three main channel types occur in this section of the Athabasca River: single channel, multiple island and single island. Single channel was the most common habitat type (47 %), followed by single island (32%) and multiple island (21%). Significant habitat features include backwaters and snyes associated with islands and sandbars.

River banks were mainly armoured (40%) or erosional (38%) with some depositional areas (21%), and only one area with cliffs (1%), just downstream of Stony Island. A detailed breakdown of percent composition of bank types is presented in Table 4.3-4.

Figures 4.3-2a to 4.3-2h depict bathymetry, substrate and cover of representative channel cross-sections. Cross-sections of single channel habitat are shown in Figures 4.3-2b, 4.3-2c, 4.3-2d and 4.3-2e. The profiles of single channel and multiple island transects show similar bathymetry; water depths ranged from 1 to 3 m at the time of sampling and depths vary across the transect. Deeper areas are found in some side-channels along sandbars. Figure 4.3-2e shows a 6 m deep hole in a backwater off a sandbar. Similarly, the east channel off the sandbar at Tar Island Dyke is deep and in contrast to other areas of the study reach, has instream cover in the form of vegetative debris.

There is no instream cover in the main channel with the exception of that provided by depth and turbidity. The substrate of the Athabasca River in this region is almost entirely sand with a few exceptions. The transect across Willow and Stony Islands and the transect upstream of McLean Creek both indicate that the east channel has a predominantly bedrock substrate.

Flow data for the Athabasca River from the Water Survey of Canada flow gauging station upstream of Fort McMurray (Station 07DA001) is presented in Appendix X and Klohn-Crippen (1995).

PROPOSED BRIDGE CROSSING

A habitat transect at the site of the proposed bridge crossing was conducted in the spring and fall. The transect taken in the spring is shown in Appendix XI, as it was taken in an approximate location. A second transect was done in the fall at the exact location of the bridge crossing (Figure 4.3-2h). The bathymetry, substrate and cover are similar to other single channel transects. No spawning habitat for large fish species was documented in the vicinity of the proposed bridge crossing.

McLEAN CREEK

The mouth of McLean Creek was examined in spring 1995. Substrate at the mouth was a mixture of fines and cobble/boulder. Water flow was very low making fish passage into this creek unlikely. Aerial observations of this creek confirmed that this is an intermittent watercourse.

WOOD CREEK

The mouth of Wood Creek had very little flow in the spring. From the air it could be seen that very little water was present in Wood Creek. Water present at the creek mouth was backed up from the Athabasca River. Substrate at the mouth was dominated by fines due to unstable slumping banks.

LEGGETT CREEK

Similar to other small tributaries in the area, the mouth of Leggett Creek showed very little flow in the spring of 1995: water present at the mouth was backed up from the Athabasca River. Substrate at the mouth of Leggett Creek is all fines. Flooding in the summer allowed boat (zodiac) access into the mouth of the creek. Cobble/gravel substrate was present upstream of the mouth of the creek.

Habitat descriptions for the upper reaches of Leggett Creek were made in summer of 1995. A small wetlands (about 200 m long by 50 m wide) occurs at the headwaters of Leggett Creek. Here the channel is poorly defined with substrate comprised of fines and peat. Black spruce and larch dominate the wetlands vegetation.

UNNAMED CREEK

Habitat at the mouth of Unnamed Creek which drains Shipyard Lake wetlands was examined in spring 1995. No water was present in this creek and substrate at the mouth of the creek was dominated by fines. Since no fish habitat was present in Unnamed Creek, Shipyard Lake was not classified as fish habitat.

POPLAR CREEK

Water at the mouth of Poplar Creek is slow and deep but less turbid than the Athabasca River. The substrate was composed of all fines and deadfall is present at the creek mouth. Upstream in Poplar Creek, three reaches were examined (Figure 3.2-1): AF065 (upstream of the spillway); AF066 (at the Highway 63 bridge); and AF067 (halfway between the Highway 63 bridge and the mouth). Upstream of the spillway (AF065), habitat was mainly runs with sand/silt substrate and the occasional riffle and pool. At the confluence of the spillway and Poplar Creek there was a large riffle with cobble/gravel substrate. At the Highway 63 bridge (AF066) there is a long shallow run upstream of the bridge, while downstream there was a series of riffles and pools. The farthest downstream reach (AF067) was entirely a sand/silt substrate. Banks are unstable and deadfall was present throughout this section of the stream.

4.3.2 Steepbank River

The Steepbank River is one of the main tributaries to the Athabasca in the vicinity of Steepbank mine site. Through most of its length it cuts sharply through oil sands-rich hills resulting in the steep banks for which it is named. The 25.8 km of river within the study area have an average channel width of 25m.

Figure 4.3-3 is a habitat map of the Steepbank River showing the location of pools, runs and riffles in the study area. The percent composition of these channel units is shown in Table 4.3-5. Runs are the most common channel type (53%): moderate quality/depth runs are the most common, followed by low and high quality/depth runs. Riffles are also very common, constituting 40% of the habitat in the study area. Pools are infrequent, comprising only 6% of river in the study area. There was one set of rapids in a high gradient area near the top end of the study area.

The Steepbank River within the study area was divided into three reaches on the basis of the habitat characteristics present. A fish inventory site was established in each of these reaches: Section 1 (Station AF017), at the top of the study area; Section 2 (Station AF040), at the meander section in the middle; and Section 3 (Station AF014), the bottom section near the mouth. Figures 4.3-4 to 4.3-6 are detailed habitat maps of the fish inventory reaches. Detailed descriptions of habitats at each inventory site is presented here to facilitate comparisons between fish distribution and abundance data with habitat availability information (Section 4.4.4).

Throughout the top half of the study area, instream habitat consists of pool/riffle and run/riffle sequences (Figures 4.3-3 and 4.3-4). Riffles are the most common habitat type (54%), followed by moderate quality/depth runs (28%) (Table 4.3-6). The riffle areas are armoured with large sized substrate that is dominated by boulders and cobble. Deep run areas with low velocity occur between most of the riffles; pools are infrequent and occur primarily on meander bends. Only second class (moderate quality) pools occur in the top half of the study area. A transect though a second class pool located at Station AF060 (Figure 4.3-3) had an average depth of 1 m, a mean column velocity of 0.16 m/s, and a sand/gravel substrate.

There is a change in general riverine habitat with distance downstream from the top of the study area. The overall river gradient decreases with distance downstream and the length of the riffle areas decreases (Table 4.3-6). The mid-section of the river, located near Fee Lot 3, has more defined meander bends. In this reach of the river, the riffles have less boulder and more cobble/gravel substrate (Figure 4.3-5). Mean column velocities range from 0.75 to 1.25 m/s in the main parts of riffles with areas of low velocity (0.19 to 0.55 m/s) in the downstream shadow of large boulders (transects at Stations AF063 and AF064). The run/pool areas between the riffles are slower with more fines and less instream cover from boulders.

Fish habitat in the bottom section of the Steepbank River consists of swift, armoured riffles separated by run sections with the occasional pool occurring on meander bends (Figure 4.3-6). Riffles are less common than upstream, comprising 35 % of the area compared to 54% at the top of study area. Runs are the most common type of habitat in this reach of the river (Table 4.3-6). Runs and pools are fairly deep with good cover from boulders and fallen trees providing overhead cover along erosional bank areas.

Stream discharges vary seasonally depending on the amount of precipitation and run-off. Data from the Water Survey of Canada (WSC) stream gauging station near the mouth of the Steepbank River (07DA006) is presented in Appendix X and Klohn-Crippen (1995).

4.3.3 Muskeg River System

Detailed habitat mapping of the Muskeg River and its tributaries was performed by Beak (1986a, 1986b) and R.L.&L. (1989) as part of the OSLO study. This information was presented in the form of a stream catalogue (Beak 1986a, R.L.&L. 1989; Appendix E). To assess the applicability of this historical information to current conditions, habitat assessments were repeated on a representative set of the original sites in the spring of 1995. These assessments are summarized in a stream catalogue that has the same format as the OSLO reports (Appendix XII). It includes the location of the site, physical characteristics, stream discharge, riparian vegetation, water quality, biological resources and a photograph. As well, the entire length of the Muskeg River was video taped from a helicopter to document current habitat conditions.

A comparison of present and past habitat conditions for the Muskeg River drainage is presented in the following sections. In previous studies, reaches have been designated for the Muskeg River and its tributaries based on general habitat characteristics. These reaches are shown on Figures 4.3-7 to 4.3-9. Habitat maps of sites that were surveyed in 1995 are inset onto maps of each of the main watercourses in the drainage basin (Figures 4.3-7 to 4.3-9).

MUSKEG RIVER

The Muskeg River flows in a south-east direction to the Athabasca River. It receives discharge from several smaller drainages: Wapasu, Muskeg, Shelley and Jackpine Creeks that flow from the south; Stanley Creek which drains from the north; and a number of smaller, unnamed tributaries. The aquatic habitat of the Muskeg River varies throughout its length. In past studies six distinct reaches have been defined (Walder et al. 1980). In the present study, detailed habitat mapping was done at sites in Reach 1 (Site 30) and Reach 4 (Site 18, Site 4). Reach designations for the Muskeg River and sketch maps of Sites 30, 18 and 4 are shown in Figure 4.3-7.

Reach 1, in the area of the river mouth, is a fairly straight reach that extends for 0.5 km. The next 8.5 km comprise Reach 2, which has irregular meanders. Both reaches have a high gradient (> 3.0 m/km) and are characterized by runs, riffles and pools. Fast low quality/depth runs are predominant at the mouth, with the occasional riffle and pool. Run habitat was on average 0.29 m deep and velocities were fairly high (mean column velocity of 0.47 m/s). Further upstream in Reach 2, pools are more common. Substrate composition in these reaches is mainly gravel and cobble with very little evidence of sedimentation. At Site 30, average substrate composition was as follows: small and medium gravel (35%), pebble[1] (40%), cobble (10%), sand (10%) and silt (5%). In the spring

[1] Beak uses the term pebble to describe substrate that is 32 to 64 mm, while in the Golder classification, this size range is called large gravel. Since the Beak (1986a) classification system was used for mapping the Muskeg River system, pebble will be used in this section in place of large gravel.

of 1995, the average channel width (distance between pre-eminent vegetation on either bank) was 25.6 m, and the wetted width was 12.2 metres. Banks were unstable and eroded. Near the mouth, banks are less than a few metres high, while further upstream in Reach 2, there are cliffs (about 10 to 20 m).

The fish fence was located in Reach 3. Characteristics in this reach are intermediate between Reaches 2 and 4. It has a lower gradient (1 m/km) than Reach 2, but still has gravel substrate and runs interspersed with riffles and pools (R.L.&L. 1989). However, the runs are deep and slow, a characteristic that is representative of Reach 4.

Reach 4 is very long (over 60 km) and represents the most common type of habitat in the Muskeg River. Here the river has slow deep runs and tortuous meanders. Site 18, which is just downstream of the mouth of Jackpine Creek, has mainly high quality/deep run habitat. The average depth is 1.6 m and mean column velocities range from 0.04 to 0.13 m/s. The substrate in the runs is composed mainly of organic debris and silt with a few large boulders. Riffles are uncommon in Reach 4 but there are a few associated with cobble substrate in the vicinity of Site 18. When R.L.&L. (1989) surveyed the site in 1989 they found the pool:run:riffle ratio to be 2:1:2, whereas in 1995 the ratio was 0:5:1. Changes in pool:run:riffle ratio could be due to variations in water levels or beaver activity. The riparian vegetation includes aspen, white spruce and alder. Above the confluence of Jackpine Creek the river winds through muskeg; and alders and willows line the channel. Beaver activity is common and there are many dams causing ponding. Site 4 is just upstream from a large beaver dam. Habitat characteristics at this site are the same as in previous studies (Beak 1986a, R.L.&L 1989). The channel is deep (> 1.5 m) and the water is essentially standing. There is some instream cover in the form of vegetative debris from partial beaver dams.

STANLEY CREEK

Stanley Creek is a small ephemeral tributary that enters Reach 4 of the Muskeg River from the west. There is no well-defined channel at the habitat mapping site (Site 60) at the creek mouth. The creek flows through the muskeg in a system of shallow braided channels. Like the Muskeg River in this area, the substrate is entirely organic debris, sand and silt. Cover is negligible with no overhead cover and only a few sticks to provide instream cover. In the spring the water was standing, but in the summer when water levels were higher, some flow was present.

JACKPINE CREEK

Jackpine Creek has been sub-divided into five reaches based mainly on stream gradient (Bond and Machniak 1979, O'Neil et al. 1982) (Figure 4.3-8). Reach 1, the first 3.4 km, has a low gradient that results in primarily slow runs and tortuous meanders. Previous investigators have noted an abundance of beaver dams in this reach of the river (O'Neil et al. 1982, R.L.&L. 1989). Beaver dams are still common at Site 17 in this reach and habitat characteristics are similar to those documented by R.L.&L. (1989). In the spring of 1995, slow runs (mean column velocity 0.1 m/s) and deep pools created by beaver impoundments were the main habitat features. The primary substrate type is sand and silt but cobble and gravel are present in a few areas. Good overhead cover from riparian vegetation is present.

Reach 2, from km 3.4 to 7.4, has a slightly higher gradient, more habitat diversity and fewer meanders than Reach 1 (O'Neil et al. 1982). Beaver dams are also common in this stretch of river resulting in flat flow characteristics for about half of the reach interspersed by run-riffle-pool sequences. Reach 3 (km 7.4 to 9.4) is a high gradient section (0.51 m/km) (O'Neil et al. 1982). In this stretch, gravel and cobble substrate is common and riffle/run/pool sequences are predominant. Reach 4 (km 9.4 to 14.9) has a moderate gradient, and similar flow characteristics and meander pattern to Reach 2. Site S-4 in Reach 4 was resurveyed in 1995. The main habitat characteristics have not changed since the area was surveyed in 1988. Riffles have boulder/cobble substrate and runs are slow (mean column velocity 0.13 m/s) and shallow. There was a large beaver dam located about 100 m upstream of the habitat site.

MUSKEG CREEK DRAINAGE

Muskeg Creek drains Khahago Creek and Muskeg Creek (Figure 4.3-9). Khahago Creek enters Muskeg Creek from the south. In turn, Khahago Creek drains three smaller tributaries: Pemmican, Green Stockings and Blackfly Creeks. Muskeg Creek drains Wesukemina Creek and Kearl Lake, while Iyinimin Creek discharges into Kearl Lake.

Muskeg Creek

R.L.&L. (1989) describe four reaches for Muskeg Creek (Figure 4.3-9). Reach 1, at the mouth of Muskeg Creek, is part of the Muskeg River floodplain. Reach 2 has a relatively high gradient that results in mainly run habitat with a few pools. When the water is low, riffles develop in areas with gravel/cobble substrate. Deep fast runs are characteristic of Reach 3.

Reach 4, is a low-gradient poorly drained reach. Site 9 in Reach 4 is located about 2 km from the outlet of Kearl Lake. The general habitat type is similar to that described by Beak (1986a) although beaver activity in the vicinity of the site appears to have increased. In 1985, Beak (1986a) noted beaver activity upstream of the site, but the presence of beaver dams did not significantly obstruct flow. Presently, there is little to no flow at the site as a result of presence of two large beaver dams downstream of the site. Changes in flow patterns may have also influenced the substrate characteristics. The stream has a silt/sand bottom with a few areas (10%) of cobble and pebble while in 1985 the substrate consisted of pebble, cobble and gravel with very little sand. Ponding due to beaver activity may have caused increased sedimentation and subsequent changes in the substrate characteristics.

Khahago and Blackfly Creeks

Khahago Creek and Blackfly Creek comprise Reach 1 and 2, respectively, of the south-west drainage into Muskeg Creek. The habitat in Reach 1 (Khahago Creek) is characterized by the features recorded at Site 14. At this site, the creek is meandering with deep slow or flat runs and organic/silt substrate. Water depths are greater than 1.5 m and the channel is about 10 m wide. Cover is provided by depth and by riparian vegetation (willow and alders). Habitat features documented in 1995 are similar to those documented by Beak (1986a, 1986b).

Blackfly Creek, which discharges into Khahago Creek, has a higher gradient, and flows through an area where white spruce provide good overhead cover, and instream cover from dead snags is abundant (Figure 4.3-9). Site 55, which was surveyed in 1995, is a few kilometres upstream of previous OSLO sampling sites 11 and 12 but has similar habitat characteristics. The stream was approximately 10 m wide. The channel type is mainly shallow, swift run with sand substrate. Areas of gravel and cobble substrate are present in riffles.

Iyinimin Creek

Iyinimin Creek drains the south-east part of the Muskeg Creek watershed into Kearl Lake. This creek is divided into two reaches. The first reach is a low gradient section that flows through muskeg into Kearl Lake. It is similar in habitat characteristics to Muskeg Creek. The higher gradient area of Iyinimin Creek (Reach 2) flows through terrain similar to that drained by Blackfly Creek. The sampling station on Iyinimin Creek is located at the stream gauging station about 1 km upstream of the OSLO study site 8. This section of the stream consists mainly of run habitat with sporadic pools and riffles. The 50 m section that was habitat mapped was a fast flowing (0.53 m/s) run with a sand bottom. Gravel, cobble and boulder substrate was also present in riffle areas.

KEARL LAKE

The aquatic habitat of Kearl Lake was mapped by Beak (1986b) and re-surveyed in 1995.

Examination of the bathymetric maps presented in Figures 4.3-10 and 4.3-11 reveals that the location of contour lines in Kearl Lake is similar in 1985 and 1995 with the exception of a deep hole in the south end of the lake that was not noted in 1985. The water level of Kearl Lake in August of 1995 was approximately 0.5 m deeper than it was in October 1985. This difference is likely due to seasonal variation in water levels (i.e. water levels are often lower in the fall).

Aquatic vegetation patterns in the lake are similar to those documented in the OSLO study (Figures 4.3-12 and 4.3-13). The perimeter of the shore is lined with cattails (*Typha latifolia*) and there are a few patches of bullrush (*Scirpus* sp.) along the east side of the lake. Additional species documented near the shoreline in 1995 include: horsetail (*Equisetum* spp.), arrowhead (*Sagittarie cuneata*) and mare's tail (*Hippurus vulgaris*).

Submergent vegetation is common throughout the lake with the exception of the deep area in the centre. In 1985, the most common submergent macrophytes were pondweed (*Potamogeton richardsoni*) and water milfoil (*Myriophyllum exalbescens*). Yellow pond lily (*Nuphar variegatum*), coontail (*Ceratophyllum demersum*) and floating pondweed (*Potamogeton natans*) were present in smaller amounts. Pondweed is still the dominant submergent; however, yellow pond lily is much more common now than it was in October 1985. Duckweed (*Lemna minor*), the only free floating macrophyte is still present is small quantities.

A comparison between historical data and data collected by Golder during the 1995 field season indicates that, although there have been some changes, the OSLO database for Kearl Lake is still valid.

4.4 The Fish Community

The following description of fish communities in the study area includes detailed information from spring, summer and fall of 1995 for the Athabasca and Steepbank Rivers; and from spring and fall 1995 for the Muskeg River and its tributaries. In addition, historical data are presented where available so that current data can be placed in context. The seasonal distribution and abundance of all fish species is presented and discussed in relation to habitat use and availability. Also, population demographics such as length-weight relationships; growth curves; age and size distribution; age to maturity; and migration patterns are presented for the major fish species and other species for which there are available data.

The structure of this chapter is as follows: firstly, fish inventory results for the current investigation are presented for each of the main study areas (Athabasca, Muskeg and Steepbank River systems); and secondly, detailed life histories of the major fish species are described. Note that since detailed analyses of each species are presented in the life history section (Section 4.4.4), the fish inventory sections provide only a general overview of the results.

4.4.1 Athabasca River Fish Inventory

ATHABASCA RIVER

The Athabasca River fish inventory was carried out using a number of methods: boat electrofishing, backpack electrofishing, seine netting, gill netting, set lines, drift nets and minnow traps. The total numbers of each species caught by all methods, by season, are presented in Table 4.4-1. Eighteen species and a total of 5355 fish were caught in the spring, summer and fall fish inventories.

The detailed fisheries studies conducted in the 1970s revealed that 27 fish species occur in the area downstream of Suncor and Syncrude (Bond 1980). Wallace and McCart (1984) reported that the most abundant large fish species in the vicinity of Suncor and Syncrude are: longnose sucker, goldeye, lake whitefish and walleye. The results of the 1995 inventory confirm that these species are indeed still the most common. Other large fish species include: northern pike, burbot, mountain whitefish, white sucker and yellow perch. The major small fish species in the Athabasca River portion of the study area in 1995 were: trout-perch, flathead chub, lake chub, emerald shiner, spottail shiner and slimy sculpin. These results agree with the findings of McCart et al. (1977) from the late 1970s. Brassy minnow, longnose dace, slimy sculpin and spoonhead sculpin which were captured in 1995 have previously been documented to occur in the area but in limited abundance (McCart et al. 1977).

Non-game species that were not captured in 1995 but have been documented to occur in the area include: northern redbelly dace, finescale dace, pearl dace, ninespine stickleback, brook stickleback, fathead minnow and Iowa darter. All of these species are uncommon in the Athabasca River within the study area (Bond 1980), so their absence in the fish inventory is not surprising. The only game species that have previously been documented but were not collected in 1995 are bull trout and Arctic grayling. While bull trout have been documented in this area of the Athabasca River it is the eastern geographical extent of its range (Nelson and Paetz 1992). Arctic grayling are known to use the tributaries extensively for spawning and summer feeding, and consequently their numbers are low in the Athabasca River during the open-water season.

Boat Electrofishing

The main technique for surveying large fish species was boat electrofishing. Due to mechanical problems, less boat electrofishing was done during the spring inventory than in the summer and fall surveys. In total, sixteen species were collected by boat electrofishing (Table 4.4-2). In the spring, the most abundant species was walleye, which comprised 64% of the catch. The next most common species were goldeye (8.4%), longnose sucker (8.4%), white sucker (6.7%) and flathead chub (6.3%). Other species that were captured included northern pike (4.1%), lake whitefish (0.4%), and emerald shiner (0.1%).

Relative abundance of the various species changed in the summer. Trout-perch, a species not captured by electrofishing in the spring, was the most common species captured in the summer (38.8%), followed by flathead chub (23.9%) and goldeye (18.0%). Walleye remained common but constituted only 8.6% of the catch, compared to 64% in spring. The remainder of the catch was made up of lake whitefish (2.5%), northern pike (2.4%), longnose sucker (3.2%), white sucker (0.9%), emerald shiner (0.8%), lake chub (0.1%), burbot (< 0.1%), slimy sculpin (< 0.1%), spoonhead sculpin (< 0.1%), and yellow perch (< 0.1%).

During fall, lake whitefish dominated the catch (76.8%), in contrast to earlier in the season when it was one of the least abundant species (Table 4.4-2). Longnose sucker (6.3%), goldeye (4.4%), walleye (4.5%) and white sucker (2.7%) were the next most common species. Small numbers of trout-perch (1.5%), longnose dace (1%), northern pike (0.6%), flathead chub (0.6%), mountain whitefish (0.4%), emerald shiner (0.1%), and yellow perch (< 0.1%) were also captured in fall.

Gill Nets

Gill netting was done to supplement the boat electrofishing inventory, particularly in deep areas where electrofishing is a less efficient sampling technique. In the spring, as a result of mechanical problems with the boat electrofisher, gill netting was used quite extensively. Gill netting was not done in the summer due to flooding of the Athabasca River. In the fall, gill netting was unnecessary due to the clear water conditions which made boat electrofishing very efficient.

The results of gill netting in the spring are presented in Table 4.4-3. Of the six species captured, goldeye (29%) were the most common, followed by walleye (22%), northern pike (15%), flathead chub (15%), longnose sucker (11%) and lake whitefish (7%). The largest numbers of fish were captured at the mouth of the Steepbank River (AF003) and at the mouth of Unnamed Creek which drains Shipyard Lake wetlands (AF018).

Set Lines

Set lines were used to inventory species such as burbot that are often difficult to catch by electrofishing. Three species were captured with set lines: burbot, northern pike and walleye (Table 4.4-4). Walleye was the most common species captured, constituting 82% of the catch. No burbot were captured in the spring, one in the summer and five in the fall. A single northern pike was caught on a set line.

Post-Emergent Fry Traps

Post-emergent fry traps were used to document the presence or absence of walleye fry in the study area. Hence, they were placed on rocky shores (potential spawning areas) and downstream of the mouths of tributaries. Four species of larval fish were captured with the drift traps: longnose sucker, slimy sculpin, burbot and walleye (Table 4.4-5). Longnose sucker were by far the most common (77%) and they were present at all of the sampling sites. Slimy sculpin fry were also fairly common (20%) and they were found at both of the sites near Willow Island (Stations AF011 and AF012). Walleye and burbot fry were each found at one site. A single burbot fry was collected along the left downstream bank of Willow Island (AF012) and 6 larval walleye were collected along the right downstream bank of Willow Island (AF011). The larval walleye were estimated to be 6 to 10 days old based on key diagnostic characteristics.

Seine Nets

Seining was the main technique used to inventory forage fish species and small juveniles of larger fish species. Due to high water levels during the summer sampling period, seining was only done in spring and fall. Seining took place at four sites: along the left downstream bank of the island upstream of Tar Island Dyke (AF023), the upstream tip of Stony Island (AF035), the east shore of Willow Island (AF037) and the upstream tip of Willow Island (AF038). Ten species were caught by seining (Table 4.4-6). In both spring and fall, trout-perch was the most abundant species, constituting over 75% of the catch in both seasons. Lake chub (13%) and spottail shiner (8%) were common in spring; however, spottail shiner were not present in fall and only a few lake chub were captured. Other species present in small numbers include: emerald shiner, flathead chub, spoonhead sculpin, white sucker, yellow perch and juvenile walleye.

Backpack Electrofishing

Backpack electrofishing was done at three locations on the Athabasca River: a snye at the downstream tip of the island downstream of the Steepbank River (AF052); and, two areas along the right downstream bank of Willow Island. Similar to seining results, trout-perch was the most common species and lake chub and spottail shiner were abundant. More flathead chub were captured by backpack electrofishing than by seining. Other species captured include: northern pike, burbot, emerald shiner, longnose dace, white sucker and yellow perch.

Minnow Traps

Minnow traps were only set once in the Athabasca River, near the mouth of Poplar Creek. Only two brassy minnow were caught and these were the only brassy minnows caught during the inventory studies.

LEGGETT CREEK

Gill nets were set in Leggett Creek and no fish were captured by gill net. The total catch by backpack fishing at Leggett Creek consisted of two spottail shiner (Table 4.4-7). There is also an unsubstantiated claim that Arctic grayling have been captured from Leggett Creek.

POPLAR CREEK

Backpack electrofishing was done in the spring on three sections of Poplar Creek: AF065 (upstream of the reservoir spillway), AF066 (at the Highway 63 bridge) and AF067 (1 km downstream of the Highway 63 bridge). Flathead minnow and lake chub were the most common species at all three sites (Table 4.4-7). One flathead chub was captured at the Highway 63 bridge. Game and domestic fish species captured in Poplar Creek include white sucker, longnose sucker and yellow perch.

A spawning inventory was done at all three electrofishing sites. Sucker (longnose and/or white sucker) and Arctic grayling spawning sites were documented at the confluence of the reservoir spillway and Poplar Creek.

4.4.2 Steepbank River Fish Inventory

The fish inventory on the Steepbank River was done during spring, summer and fall of 1995. Three sections, representing the main habitat types present in the Steepbank River were surveyed using a portable boat electrofisher and a Zodiac (see Section 4.3 for habitat descriptions). With the exception of Section 3, near the river mouth (AF014), the same stretches of river were surveyed in each season. For Section 3 (AF014), in the spring, a boat electrofisher was taken upstream from the mouth as far as possible, whereas in the summer a Zodiac and portable electrofisher were airlifted into the Steepbank, to enable a longer stretch of river to be surveyed (Figure 3.2-2).

The results of the Steepbank River fish inventory are shown in Table 4.4-9. Thirteen species were documented in the 1995 fish inventory. Arctic grayling, lake chub, longnose dace, longnose sucker, mountain whitefish, spoonhead sculpin, trout-perch, walleye and white sucker were found in all three reaches. In contrast, burbot, goldeye, lake whitefish and northern pike were only found in the lower reach of the river, near the mouth.

In the past, 24 species of fish have been recorded from the Steepbank River, of which 10 (Arctic grayling, northern pike, longnose and white sucker, lake chub, pearl and longnose dace, trout-perch, brook stickleback and slimy sculpin) are common and widespread (Sekerak and Walder 1980). Sekerak and Walder (1980) report that although longnose and white sucker outnumber sport fish in the river, substantial numbers of Arctic grayling, walleye, mountain whitefish and northern pike also inhabit the river at least during the open-water season. In 1995 all of these species were documented except for brook stickleback and slimy sculpin (both of which are not easily susceptible to capture by boat electrofisher).

Several additional species are confined to the lowermost portion of the river near the confluence with the Athabasca River. In 1995, goldeye, lake whitefish, longnose dace, mountain whitefish, spoonhead sculpin and walleye were captured near the mouth of the Steepbank. Other species that have previously been documented in the lower reaches of the Steepbank River but were not captured in 1995 include: bull trout, lake cisco, flathead chub, redbelly dace, spottail shiner, brassy minnow and flathead minnow. Of particular interest here is the record of bull trout in this region of the river (Machniak and Bond 1979), as this species is under consideration in several jurisdictions as being considered for special status. The occurrence of bull trout was not documented in 1995.

In the spring of 1995, the following species were the most abundant in the Steepbank River: mountain whitefish (31%), Arctic grayling (29%), and longnose sucker (21%). Spoonhead sculpin (8%) and lake chub (7%) were the most common forage fish species. Other species present in the spring include: white sucker, walleye, trout-perch, northern pike, longnose dace and burbot. In the summer, the abundance pattern was similar except that fewer Arctic grayling were caught and more spoonhead sculpin and longnose dace were caught. Spoonhead sculpin dominated the catch in the fall (43%), followed by mountain whitefish (23%) and Arctic grayling (20%) which remained common. In contrast, longnose sucker were less abundant that during spring and summer.

4.4.3 Muskeg River Fish Inventory

There were two main components to the Muskeg River Basin fish inventory: a spring fish inventory at selected stream sites and Kearl Lake; and a fish fence on the Muskeg River in spring and fall. Twelve fish species and 1860 fish were captured in the Muskeg River and its tributaries in 1995. The total number of fish species and number of fish captured in 1995 is presented in Table 4.4-10.

Seventeen fish species have been documented in the Muskeg River drainage basin (R.L.&L. 1989) that may be classified into three main groups: resident species; species that use the river basin for part of their life cycle; and, occasional migrants from the Athabasca River. Resident fish species documented in the tributaries in 1995 include: slimy sculpin, pearl dace, brook stickleback, fathead minnow, longnose and white sucker and northern pike[1].

Species known to use the Muskeg River and its tributaries for part of their life cycle include: Arctic grayling, longnose sucker, white sucker, northern pike, lake chub and mountain whitefish. Spawning migrations of Arctic grayling, longnose and white sucker and northern pike occurred in the spring of 1995. As well, a few lake chub in spawning condition were documented in the spring. Previous investigators have also reported spawning migrations of these species into the Muskeg River system (O'Neil et al. 1982). Mountain whitefish have also been known to migrate into the

[1]Note that this species is not wide-spread in the Muskeg River basin and is limited to an isolated population in the upper reaches of the Muskeg River and a spawning population that used the lower reaches of the Muskeg River.

Muskeg River for summer feeding (Bond and Machniak 1977) but they were not documented in 1995. None of these species are known to overwinter in the Muskeg River system (Bond 1980).

In 1995, burbot, walleye and trout-perch were recorded in the lower part of the Muskeg River. These three species as well as lake whitefish, and spottail shiner are known to be only occasional migrants into the lower reaches of the Muskeg River (Bond and Machniak 1979).

FISH FENCE RESULTS

The spring fish fence was operated from 6 May until 31 May, 1995. Note that the fence was designed only to catch larger fish (< 2.5 cm in diameter). Thus, most forage fish and small juveniles of larger fish species were not susceptible to capture by this method. The daily totals for each fish species caught in spring are shown in Table 4.4-11, while overall totals and mean catch-per-unit-effort (number of fish/hr) are presented in Table 4.4-12. A total of 748 fish passed through the upstream trap in the spring (Table 4.4-12). Longnose (41%) and white sucker (40%) were the most common species, followed by northern pike (17%) and Arctic grayling (2%), and a single walleye (< 1%). There was very little downstream movement of fish, with the exception of Arctic grayling. Forty-nine grayling (51.6% of the downstream catch) were captured moving downstream between 6 May and 24 May. The next most common species captured in the downstream trap were spent longnose sucker, which comprised 37.0% (n = 36) of the catch. This, however, was a small portion of the longnose sucker that moved upstream early in May. A few lake chub, one trout-perch and one white sucker comprised the remainder of fish caught in the downstream fish trap.

The fall fish fence was operated from 23 September to 26 October 1995 at the same site as the spring fish fence. The daily totals for each fish species caught in fall are shown in Table 4.4-13 and overall totals and mean CPUE (number of fish/hr) are presented in Table 4.4-14. In the downstream trap, 551 fish were captured whereas only two fish passed through the upstream trap. Lake chub was the most abundant species in the downstream trap (45.2%) followed by northern pike (21.2%), white sucker (15.8%), Arctic grayling (13.4%), longnose sucker (3.8%) and trout-perch (0.5%). Two juvenile grayling passed through the upstream trap.

STREAM FISH INVENTORY

The results of the 1995 stream fish inventory are shown in Table 4.4-15 and those for Kearl Lake are shown in Table 4.4-16. These results are presented alongside fish inventory results from 1988 (R.L.&L. 1989) and 1985 (Beak 1986b) for corresponding sites. This was done in order to establish the applicability of the OSLO data which were collected by Beak (1986b) and R.L.&L. (1989).

Note that three sites, 30 (Muskeg River), 31 (Muskeg River) and S-4 (Jackpine Creek) were resurveyed in the fall of 1995, specifically to look for young-of-the-year (YOY) Arctic grayling. No YOY grayling were captured in 1995.

Stanley Creek

Stanley Creek was not previously surveyed as part of the OSLO study. In 1995, electrofishing was not attempted but the water was shallow and clear enough to allow observation of fish. Only one brook stickleback was observed and very little fish habitat was available in Stanley Creek.

Muskeg River

On the Muskeg River, a site in the upper reaches (Site 4) and one downstream of the mouth of Jackpine Creek (Site 18) were selected for resurveying in 1995. At Site 4, no backpack electrofishing could be carried out due to the depth of the water. However, one adult northern pike was observed from shore. R.L.&L. (1989) reported YOY pike in 1988 and Beak (1986b) caught adult northern pike by gill net at this site. It is worth noting that this is the only occurrence of a sports fish species in the upper reaches of the Muskeg River. This population is believed to be isolated, as a result of the large numbers of barriers (i.e., beaver dams) in the upper reaches of the Muskeg River.

Below Jackpine Creek, Site 18 on the Muskeg River was surveyed using a portable boat electrofisher. The presence of adult Arctic grayling, longnose sucker and white sucker was documented at this site. R.L.&L. (1989) also reported longnose and white sucker from this site as well as pearl dace and slimy sculpin.

The lower reaches of the Muskeg River (Sites 30 and 31), were more diverse in terms of species composition. At the fish fence (Site 31), backpack electrofishing revealed the presence of fathead minnow and slimy sculpin in addition to species captured in the fish fence (Arctic grayling, white sucker, longnose sucker, northern pike and lake chub). Trout-perch, slimy sculpin, northern pike, longnose sucker, lake chub, fathead minnow and burbot were collected from the mouth of the Muskeg River by backpack electrofishing (Site 30).

Jackpine Creek

At the mouth of Jackpine Creek (Site 17) backpack electrofishing revealed the presence of juvenile longnose sucker, fathead minnow and slimy sculpin. Further upstream, at the bridge that crosses the creek (Site 17) the same species plus brook stickleback were recorded. This species composition is different than that recorded by R.L.&L. (1989) who found white sucker, pearl dace, longnose sucker and slimy sculpin (Table 4.4-15). However, all six of the aforementioned species are known to occur in Jackpine Creek (R.L.&L. 1989).

Muskeg Creek Drainage

Iyinimin Creek, Muskeg Creek, and Blackfly Creek form part of the Muskeg Creek watershed. On Iyinimin Creek, no fish species were documented in 1995. In the past, brook stickleback and pearl dace (Beak 1986b, R.L.&L. 1989) have been recorded in this creek. Brook stickleback are the only fish species known to inhabit Blackfly and Khahago Creeks (R.L.&L. 1989). In 1995, the presence of brook stickleback was confirmed at Site 55 on Blackfly Creek.

Muskeg Creek drains Kearl Lake. The inventory site on Muskeg Creek was about two kilometres downstream from the lake outlet. Species caught include: brook stickleback, fathead minnow, longnose sucker, pearl dace, and slimy sculpin The species composition differs from the results of the OSLO studies (Table 4.4-15) but all species present have previously been documented in this drainage (R.L.&L. 1989).

Kearl Lake Fish Inventory

Kearl Lake was also surveyed in the spring. Results of the inventory are presented in Table 4.4-16 together with results of the 1985 (Beak 1986b) and 1988 (R.L.&L. 1989) inventories. Note that the previous studies used gill netting for catching large fish species whereas, in 1995 a portable boat electrofisher and Zodiac were used. Thus CPUE data for this aspect of the fish inventory are not directly comparable. Minnow traps were used in both the present and historical investigations, so relative abundance of species caught with minnow traps can be compared.

Four fish species were present in Kearl Lake in the spring of 1995: white sucker, pearl dace, brook stickleback and fathead minnow. This species composition is the same as that found by R.L.&L. (1989) in the spring of 1988 but differs from the inventory done by Beak (1986b) in the fall of 1985 (Table 4.4-16). R.L.&L. (1989) found that species composition varied seasonally. They collected six species during the 1988 field season: white sucker, longnose sucker, pearl dace, brook stickleback, fathead minnow and lake chub.

Fathead minnow, pearl dace and brook stickleback are abundant in Muskeg Creek and in Kearl Lake. These species are often found in small northern lakes, streams and beaver ponds. Large mats of floating and rooted vegetation are present in Kearl Lake in the summer and fall, providing good summer rearing and feeding habitat for these species as well as larger fish species such as longnose and white sucker. Large fish species in Kearl Lake are thought to overwinter and spawn in Muskeg Creek, where habitat is available.

4.4.4 Life History Analyses

Life history analyses are presented for the following species: walleye, goldeye, longnose sucker, white sucker, Arctic grayling, northern pike, lake whitefish, mountain whitefish, and burbot. Where available, current data are compared to historical data. Figure 4.4-1 is a map of the Athabasca River system which shows the study areas of previous investigations referenced in this section. For each species, seasonal abundance, distribution and habitat association data are presented, by the primary watercourse (i.e., Athabasca, Steepbank and Muskeg Rivers). Areas of concentration of each of the main species are mapped by season and life stage and shown in the following figures; Figure 4.4-2 - Athabasca River; Figure 4.4-3 - Steepbank River; and Figure 4.4-4 - Muskeg River system. If enough information was available, length-frequency and age-frequency distributions, length-weight regressions, and length-at-age curves are presented[2]. Note that unless this information differs from historical data, there is no discussion of these data. Migration and movement patterns are also described and the range of each species is shown on a map of the Athabasca River mainstream (Figure 4.4-5).

A summary of the use of the Athabasca River system by major fish species as well as their main ecological characteristics is presented in Table 4.4-17. This table is adapted from Bond (1980; Table 6) and updated with information from the present study.

In addition to the main species described above, all other fish species captured in the study are discussed. The degree of detail presented is based on the amount of information available from the current study. Other species include: flathead chub, lake chub, trout-perch, emerald shiner, longnose dace, slimy sculpin, spoonhead sculpin, spottail shiner, yellow perch, brook stickleback, fathead minnow, lake chub and pearl dace.

[2]The Alberta standards for fish ageing, and length-weight calculations which are recommended by MacKay et al. (1990) are used in this report. This includes using log transformed data for regression calculation.

WALLEYE

Athabasca River

Seasonal Distribution and Abundance - Past and Present

Walleye that are found in the vicinity of Syncrude and Suncor are thought to be part of the population that overwinters in Lake Athabasca (McCart et al. 1977). Walleye are known to spawn near the Delta in Richardson Lake (Bond 1980). As well, upstream spawning migrations have been documented in both past and present studies (McCart et al. 1977, Tripp and Tsui 1980, Bond 1980). Spawning areas have not been documented with certainty, although there is evidence of spawning upstream of the present study area at Cascade Rapids.

Walleye move great distances within the Athabasca River system (Figure 4.4-5). They have been recorded moving as much as 288 km downstream of the Steepbank River within a few weeks of capture and over 400 km upstream within a few months (Machniak and Bond 1979). A walleye captured in the Athabasca River near Syncrude was later recaptured in Lake Athabasca (Syncrude unpublished data). Tripp and Tsui (1978) found CPUEs for this species to be very low upstream of Cascade Rapids and they suggested that these rapids provide a partial barrier to upstream movement of walleye.

Walleye were found in the Athabasca River during spring, summer and fall of 1995 (Figure 4.4-6). Adult and juvenile walleye were very common in the spring, particularly at the mouth of Poplar Creek where as many as 155 walleye were caught in a single sampling effort (Figures 4.4-2 and 4.4-6). A similar pattern of abundance was found by Bond (1980) near Mildred Lake, with peak catches in the spring but continued presence of walleye throughout the open-water season. Further upstream, on the Christina and Gregoire Rivers (tributaries to the Clearwater River near Fort McMurray), peak catches occurred in mid-June with continued presence of walleye throughout the summer. Tripp and McCart (1979) surveyed walleye populations upstream of Fort McMurray during May and June, and did not find a similar peak in walleye concentration although walleye were present throughout their study period.

In the current study, adult and juvenile walleye were most commonly found at the mouths of tributaries, particularly Poplar Creek, and in backwaters (Figure 4.4-2 and Table 4.4-18). Walleye captured in backwaters were found along armoured bank types. This habitat association was also found by R.L.&L. (1994) in the Athabasca River between Fort McMurray and the mouth of the Firebag River (NRBS Reach 9 - see Figure 4.4-1). Syncrude (unpublished data) also found the mouths of tributaries to be important feeding areas for walleye. The continued presence of walleye in the study area throughout the 1995 sampling period indicates that walleye use the Athabasca River near Syncrude and Suncor for summer feeding.

Most (94%) of the adult walleye that were caught in the spring of 1995 were ripe or spent males. Female walleye that were caught were not 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 conditions (Bond and Berry in prep. cited in Tripp and McCart 1979). To date, it has not been established whether walleye spawn in the vicinity of Suncor and Syncrude. Several investigators have hypothesized that walleye spawn in the rapids upstream of Fort McMurray (Machniak and Bond 1979, Tripp and McCart 1979). Tripp and McCart (1979) found YOY near Grand Rapids, Mountain Rapids and the mouth of the Algar River (see Figure 4.4-1 for locations of studies). In the spring of 1995, no walleye spawning areas were confirmed in the study area. Six walleye fry were caught in post-emergent fry traps near Willow Island (Table 4.4-5 and Figure 4.4-2). However, these larval fish were determined to be between 8 and 10 days old and could have easily drifted from the upstream rapids in that time period. R.L.&L. (1994) also documented the presence of walleye fry in the Athabasca River between Fort McMurray and the Firebag River during the spring of 1992.

In the summer and fall of 1995, YOY walleye were found at a number of sites (Table 4.4-18). Locations where three or more individuals were found include: the Suncor water intake (AF002), the mouth of the Steepbank River (AF003), and near McLean Creek (AF006) in the summer; and, the mouth of Leggett Creek (AF020), Stony Island (AF042) and Tar Island Dyke (AF019) in the fall (Figure 4.4-2). In addition, YOY walleye were found in the stomachs of goldeye that were captured in the study area. In past studies, substantial numbers of YOY were found near Mildred Lake (at the downstream end of the present study site) in June and July (Bond 1980). Thus, both past and present studies demonstrate that the Athabasca River, in the vicinity of Suncor and Syncrude provides rearing habitat for YOY walleye.

Size and Age Distribution

The length-frequency distribution for walleye captured in the study area is presented in Figure 4.4-7. This distribution is close to that found in previous investigations on the Athabasca River (McCart et al. 1977, Tripp and McCart 1979, Syncrude unpublished data).

The age-frequency distribution (Figure 4.4-8) shows that walleye caught in the Athabasca River in 1995 range in age from 1 to 16 years and that most fish are 4 or 5 years old.

Age and Growth

Length-weight regressions for male and female walleye captured on the Athabasca River in 1995 are shown in Table 4.4-19. The length-weight relationships for walleye were graphed alongside data from previous studies in northern Alberta (Figure 4.4-9). Figure 4.4-9 indicates that walleye from the present study are smaller (i.e., lower weight-at-length) from those in other populations.

The length-at-age relationship for walleye caught in the Athabasca River in 1995 shows an age range from 1 to 16 years (Figure 4.4-10). This curve was superimposed on a graph prepared by Tripp and McCart (1979) that illustrates growth curves for walleye from various areas in Alberta (Figure 4.4-11). The McCart et al. (1977) study area overlaps the current study area, and thus is the most appropriate graph for a direct comparison. The growth curve for the McCart et al. (1977) study has the highest fork lengths, by age of past Athabasca River studies. However, the growth curve obtained from fish captured in 1995 indicates larger fish in each age category (i.e., faster growth rates) than were found by McCart et al. (1977). Smaller, faster growing fish are typical of an exploited population.

Maturity data for walleye that were aged show that age-at-maturity ranged from 4 to 6 for both sexes.

Steepbank River

Two walleye were caught at the mouth of the Steepbank River in the spring (CPUE 0.07 fish/100 sec) and summer (CPUE 0.03 fish/100 sec). As well, one specimen was caught at each of the two upstream fish inventory sites during the summer, demonstrating that walleye feed in the Steepbank River. In the spring of 1977, Machniak and Bond (1979) documented a substantial upstream migration of walleye in the Steepbank River. Most of the fish moving upstream were spent males, indicating that the migration was a post-spawning event.

Muskeg River

A single walleye was captured in the spring at the Muskeg River fish fence (CPUE 0.005 fish/hr). Previous studies on the Muskeg River indicate that walleye occasionally use the lower reaches of the Muskeg River for summer feeding (Bond and Machniak 1979).

GOLDEYE

The spatial extent of use of the Athabasca River by goldeye is presented in Figure 4.4-5. Large numbers of immature goldeye are known to migrate into the Athabasca River from the Delta (McCart et al. 1977). These fish are thought to be part of the population that spawns in the Delta. While previous studies have not documented goldeye spawning in the vicinity of Suncor and Syncrude, ripe individuals of both sexes were documented in the spring of 1995. Abundance data indicate that goldeye enter the Suncor study area in April and May and largely migrate back to the Delta by the end of October.

The rapids above Fort McMurray provide a partial barrier to goldeye migration (Tripp and Tsui 1980). However, studies upstream of Grand Rapids indicate that goldeye are found as far upstream as the town of Athabasca (Sentar 1992). Also, a recent NRBS spring fisheries survey documented goldeye as far upstream as Reach 4, just downstream from Fort Assiniboine (R.L.&L. 1994).

Athabasca River

Seasonal Distribution and Abundance - Past and Present

CPUE data for goldeye caught on the Athabasca River in 1995 are presented in Figure 4.4-12. This species was found throughout the mainstem sampling area in spring, summer and fall. Goldeye were common during the spring but were most abundant in the summer (Figure 4.4-2 and 4.4-12). CPUE was generally low in the fall and decreased through the fall sampling period. Upstream of Tar Island Dyke, CPUE was 2.34 fish/100 sec on 28 September and was substantially lower (0.68 fish/100 sec) on 16 October. Syncrude (unpublished data) also found goldeye to be common throughout the open-water season with numbers decreasing in the fall as goldeye return to Lake Athabasca to overwinter. Tripp and McCart (1979) and Bond (1980) found the highest abundance in May, in contrast to the peak during summer in 1995. They too noted a decline in abundance in the fall.

The most common areas to find goldeye were backwaters. In the spring and summer, the highest CPUEs (> 2 fish/100 sec) occurred at the pool near Suncor's water intake (AF001) and along the left downstream bank near the water intake (AF002) (Figure 4.4-2). Additional areas of concentration during the summer occurred at backwaters off Willow Island (AF042) and near Syncrude's pumphouse (AF004). The largest catch, 55 goldeye (CPUE > 5 fish/100 sec), occurred near Syncrude's Mildred Lake Site (AF004). In the fall, areas of goldeye concentration included backwaters between McLean Creek and Wood Creek (AF006) and upstream of Tar Island Dyke (AF019).

Adult goldeye were common in the above discussed areas. Juvenile fish were not as common (Table 4.4-20). The only areas of concentrations of juveniles were near the Suncor water intake (AF002) and near Syncrude's pumphouse (AF004) during the summer sampling period (Figure 4.4-2 and Table 4.4-20).

Size and Age Distribution

In 1995, the size range for goldeye extended from 80 to 400 mm with most of the fish within the 280 to 360 mm range (Figure 4.4-13).

Goldeye caught in 1995 ranged from 1 to 9 years of age with most fish falling between 4 to 7 years (Figure 4.4-14). These results are similar to previous studies except that in previous studies no mature fish were found. All fish captured by Tripp and McCart (1979) upstream of Fort McMurray were immature and ranged in age from 5 to 8 years; most fish were 5 years of age. Similarly on the Christina and Horse Rivers, Tripp and Tsui (1980) found no mature fish and an age range of 3 to 6 with 57% of the fish being 4 years of age. Fish caught near Mildred Lake by Bond (1980) ranged in age from 0+ to 9 years but 88% were 4 to 6 years.

Age and Growth

A length-weight regression was calculated for male and female goldeye (Table 4.4-19). A length-at-age distribution for goldeye captured on the Athabasca River in 1995 is shown in Figure 4.4-15. Compared to goldeye collected in previous studies the goldeye captured in 1995 grow faster (Figure 4.4-16). Age-at-maturity ranged from 3 to 6 years for both sexes of goldeye.

Steepbank River

Only three goldeye were caught in the Steepbank River, near the mouth of the river during the summer sampling period when goldeye were most abundant. Goldeye are not normal inhabitants of the Steepbank River, although they have been found in some of the larger tributaries such as the MacKay River (McCart et al. 1977)

Muskeg River

No goldeye were found in the Muskeg River system during the spring or fall of 1995. Past studies have not documented goldeye use of the Muskeg River (R.L.&L. 1989).

LONGNOSE SUCKER

Longnose sucker that overwinter in Lake Athabasca and the Peace-Athabasca Delta undertake extensive seasonal migrations (Figure 4.4-5). Spawning and rearing takes place mainly in the tributaries such as the Steepbank (Machniak and Bond 1979, present study), Muskeg (Bond and Machniak 1977, present study), MacKay (McCart et al. 1977) and Christina Rivers (Tripp and Tsui 1980). The Ells and Firebag Rivers are also likely major spawning grounds (Tripp and McCart 1979). Longnose sucker spawning has also been documented in the rapids of the mainstem, upstream of Fort McMurray (Tripp and McCart 1979). The Cascade Rapids are probably the limit of upstream movements of the longnose sucker population from the Delta; hence, the longnose sucker population upstream of Cascade Rapids is thought to be distinct from the one that overwinters in the Delta.

Evidence from fish fences on Jackpine Creek (Bond and Machniak 1979), the Muskeg River (present study) and the Steepbank River (Machniak and Bond 1977) indicates that the tributaries are important spawning and rearing areas but that most adult fish migrate out of these systems during the summer. Longnose sucker feed during the summer in the tributaries and in the mainstem Athabasca River and return to the Delta and Lake Athabasca in the fall to overwinter (Tripp and McCart 1979, McCart et al. 1977)

Longnose sucker make extensive use of the lower reaches of the Athabasca River ecosystem. Machniak and Bond (1977) found longnose sucker as far downstream as the Delta and Lake Athabasca within a few weeks of spawning in the Steepbank River. One fish was documented to have travelled 218 km in five days. Longnose sucker are known to migrate as far upstream as the Cascade Rapids, which provide at least a partial barrier to movement further upstream (Tripp and McCart 1979).

Athabasca River

<u>Seasonal Distribution and Abundance - Past and Present</u>

CPUE for the Athabasca River is shown in Figure 4.4-17. In the spring and summer, CPUE was generally low (i.e. < 1 fish/100 sec) except in the area near Suncor's water intake (AF002) and Syncrude's pumphouse (AF004), which had a moderate CPUE (1 to 2 fish/100 sec) (Figure 4.4-2). CPUE was much higher in the fall. Areas of fish concentration occurred near Stony Island (AF042), upstream of Tar Island Dyke (AF019) and at the very end of the study reach (AF041).

Most longnose sucker captured in the Athabasca River in 1995 were adults (Table 4.4-21). A few juveniles were caught near Syncrude's pumphouse (AF004) in spring (n = 5), summer (n = 4) and fall (n = 4) and near the mouth of the Steepbank River (n = 5) in summer (Figure 4.4-2). In late spring, fry were captured at several places (Table 4.4-5): left and right downstream banks opposite Willow Island, at the island near Tar Island Dyke, the left downstream bank opposite Inglis Island, 1.5 km downstream of Inglis Island, and 1 km downstream of Wood Creek. Areas of high concentration of fry (i.e., Willow Island, downstream of Inglis Island and downstream of Wood

Creek) are shown on Figure 4.4-2. It is not likely that longnose sucker spawned in this section of the river due to the lack of spawning habitat; these fry may have drifted from the rapids upstream or from tributaries.

Size and Age Distribution

Length-frequency distributions were graphed by season for longnose sucker caught in the Athabasca River (Figure 4.4-18). The age-frequency distribution is presented in Figure 4.4-19.

Age and Growth

There were not enough longnose sucker caught on the Athabasca to determine length-weight relationships for each sex. Therefore, a single length-weight regression equation was determined for all longnose sucker caught in the Athabasca River (Table 4.4-19). A comparison of longnose sucker length-weight relationships is shown in Figure 4.4-20. Longnose sucker collected from the three study areas (Athabasca, Steepbank and Muskeg Rivers) have similar length-weight relationships and they are slightly lower than longnose suckers from other areas.

The length-at-age relationship for longnose sucker is presented in Figure 4.4-21. This curve is also presented in relation to growth curves obtained in previous studies (Figure 4.4-22). Longnose suckers captured in the present study are faster growing than longnose suckers from previous studies on the Athabasca River and its tributaries.

Steepbank River

Seasonal Distribution and Abundance - Past and Present

The seasonal pattern of longnose sucker abundance in the Steepbank River was opposite to the pattern on the Athabasca River. Longnose sucker were common in the spring as they migrated up the tributary to spawn and they were uncommon in the fall. On the Steepbank River, longnose sucker were most abundant in the spring and summer in the upper section of the study area (Figure 4.4-23). They were less common in the mid-section of the river and uncommon near the river mouth. In the spring, adult longnose sucker were present in the deep pool/run areas and in the pool tails upstream of riffles. Juveniles were most abundant in the pool tails and in riffles with large boulders that provided good cover.

Longnose sucker spawning sites were found throughout the study area on the Steepbank River, but were most common in the top half this area (Figure 4.4-24). At a number of sites, longnose sucker spawning activity was observed and at others, eggs were collected. In the spring of 1977, Machniak and Bond (1979) documented an upstream spawning migration of 3811 longnose sucker. Data from the spring of 1995 confirm that the Steepbank River remains an important spawning area for longnose sucker. Also, the Steepbank River provides important rearing (and feeding) habitat for YOY longnose sucker.

No adults were captured in the Steepbank River during the fall, and only a few juveniles were present (Table 4.4-22). Previous studies indicate that most mature longnose sucker start leaving the tributaries shortly after spawning but that a portion generally stay to feed during the summer (Machniak and Bond 1979). There is no evidence that adult longnose sucker overwinter in the Steepbank River; however, the fact that there are some juvenile fish present in the tributaries in mid-October suggests that they may overwinter in pools of the Steepbank River.

Size and Age Distribution

The length-frequency distribution for longnose sucker in the Steepbank River shows that the largest fish were caught in the spring and only juvenile fish were caught in the fall (Figure 4.4-25). Ages of fish caught in the Steepbank River range from 1 to 8 years with the largest number of fish in the 3 and 4 year category (Figure 4.4-26).

Age and Growth

The length-weight regressions for male and female longnose sucker are depicted in Table 4.4-19. The length-weight relationship is compared to previous studies in Figure 4.4-20.

Figure 4.4-27 shows the length-at-age relationship for longnose sucker captured on the Athabasca River in 1995. Length-at-age curves for longnose sucker caught in previous studies show slower growth than those caught in 1995 (Figure 4.4-22).

Of the fish that were aged, all age 3 fish were immature. Mature females were age 4 and older, while mature males were age 5 and older.

Muskeg River

Seasonal Distribution and Abundance - Past and Present

The pattern of longnose sucker abundance in the Muskeg River is similar to that of the Steepbank River. During the spring fish fence operation, over 300 longnose sucker moved upstream on the Muskeg River (CPUE 1.6 fish/hr) to spawn between 8 and 13 May. Between the 17 and 20 of May, some (n = 32) post-spawning longnose sucker passed through the fence downstream trap, whereas during the fall only 21 (CPUE 0.06 fish/hr) passed through, all of these heading downstream (Tables 4.4-23). It is likely that most adult longnose sucker migrated out of the Muskeg River system sometime in the summer.

During spring 1995, longnose sucker were found in the Muskeg River downstream of Jackpine Creek (Sites 30 and 18) and in Jackpine Creek (Sites 17 and S-4) (Figure 4.4-4). No longnose sucker were found at stream sampling sites in the central and eastern portions of the Muskeg River system. Sites where longnose sucker were found in abundance are displayed in Figure 4.4-4.

In Jackpine Creek, spawning habitat (i.e., gravel substrate) is available and previous studies have shown that longnose sucker spawn in the high gradient area between 5.5 and 14.2 km from the mouth (O'Neil et al. 1982). In the spring of 1995, adult longnose sucker were observed in pools near the mouth of the creek (Site 17), but only juvenile longnose sucker were captured at a high-gradient site upstream (Site S-4) and no spawning sites or adult fish were observed. The presence of adult longnose sucker at Site S-4 in the fall indicates that they could be present in Jackpine Creek in the spring.

The documentation of juvenile longnose sucker in the Muskeg River and Jackpine Creek in the spring and the fact that a number of juveniles passed through the downstream fish trap in the fall indicates that these watercourses provide rearing habitat for juvenile longnose sucker.

Size and Age Distribution

The length-frequency distribution for longnose sucker captured in the Muskeg River in spring and fall of 1995 is shown in Figure 4.4-28. The age-frequency distribution presented in Figure 4.4-29 shows that a large proportions of longnose sucker in the Muskeg River are age 3 and 4.

Age and Growth

Length-weight regression equations for male and female longnose sucker from the Muskeg River are shown in Table 4.4-19. Length-weight relationships for longnose suckers from the present and previous studies are shown in Figure 4.4-20. The length-at-age relationship for sucker captured on the Muskeg River is shown in Figure 4.4-30. A comparison of this curve with others obtained in this and previous studies is presented in Figure 4.4-22.

Of the longnose sucker that were aged in this study, all females age 3 and older were mature. There was only one age 2 fish aged, and it was a mature male. All males age 3 and older were mature.

WHITE SUCKER

White sucker make wide use of the Athabasca sub-basin during their life cycle (Figure 4.4-5). Like longnose sucker, white sucker spawn in the tributaries, namely the Muskeg, Steepbank and MacKay Rivers, feed there for a short time and then move back into the Athabasca River. In contrast to longnose sucker, white sucker have not been documented to spawn in the mainstem (Tripp and McCart 1979). These fish are thought to overwinter in Lake Athabasca, the Delta and in the lower part of the Athabasca River (Tripp and Tsui 1980).

Athabasca River

Seasonal Distribution and Abundance - Past and Present

In the Athabasca River, peak CPUE for white sucker was attained at two sites in spring: at the backwater near Syncrude's pumphouse (AF004) and along the right downstream bank across from the pumphouse (AF016) (Figure 4.4-2 and Figure 4.4-37). The catch consisted mainly of adults. Summer catches of white sucker were uniformly low (Figure 4.4-31). CPUE was higher during the fall sampling period. Areas where the CPUE was greater than one include: Syncrude's pumphouse (AF004) and the mouth of Leggett Creek (AF020).

The breakdown of adults and juveniles shows that juvenile white sucker are uncommon in the electrofishing catch and that the only areas they were captured in any abundance were at Syncrude's pumphouse (n = 6) and the mouth of Leggett Creek (n = 4) (Table 4.4-24).

Size and Age Distribution

The length-frequency distribution, by season for white sucker captured on the Athabasca River is shown in Figure 4.4-32. Age-frequencies are depicted in Figure 4.4-33.

Age and Growth

The length-weight regression equation for all white sucker captured on the Athabasca River is presented in Table 4.4-19. The length-at-age curve is shown in Figure 4.4-34.

So few white sucker were captured from the Athabasca River that age-at-maturity could not be determined. Note, however, that all age 4 fish were immature and that one 5 year old spent female was documented.

Steepbank River

Seasonal Distribution and Abundance - Past and Present

The pattern of white sucker abundance in the Steepbank River is similar to that of longnose sucker (Figures 4.4-23 and 4.4-35). However, CPUEs are consistently much lower than for longnose sucker (Figures 4.4-23 and 4.4-35). The distribution of adult and juvenile white sucker by sampling reach is shown in Table 4.4-25.

White sucker use the Steepbank River for spawning but to a lesser extent than longnose sucker. While 3811 longnose sucker migrated upstream in 1977, only 992 white sucker moved into the Steepbank River (Machniak and Bond 1977). As with longnose sucker, some fish move out of the Steepbank immediately after spawning and others remain in the river to feed for part of the summer. In 1995, a few white sucker spawning sites were documented (Figure 4.4-24).

Size and Age Distribution

The length-frequency distribution for white sucker captured in the Steepbank River is shown in Figure 4.4-36. Figure 4.4-37 presents the age-frequency distribution for white sucker.

Age and Growth

The length-weight regression equation for all white sucker collected from the Steepbank River is shown in Table 4.4-19. The length-at-age relationship is presented in Figure 4.4-38.

All white sucker age 5 and older were mature. So few white sucker were captured from the Steepbank River that age-at-maturity can not be reliably determined.

Muskeg River

Seasonal Distribution and Abundance - Past and Present

On the Muskeg River CPUE was very similar for longnose (CPUE = 1.57 fish/hr) and white sucker (1.27 fish/hr). Several hundred white sucker migrated upstream to spawn in the Muskeg River in the spring of 1995. The distribution of white sucker by life stage and location is shown on Figure 4.4-4 and Table 4.4-26.

Size and Age Distribution

Figure 4.4-39 displays the length-frequency distribution for white sucker sampled from the Muskeg River in 1995; the age-frequency distribution is shown in Figure 4.4-40.

Age and Growth

Length-weight regressions were determined separately for male and female white sucker (Table 4.4-19). Figure 4.4-41 shows length-at-age relationships for white sucker from the Muskeg River. Age-at-maturity ranges from 3 to 4 for both sexes of white sucker.

Kearl Lake

White sucker was the only large fish species caught in Kearl Lake. A white sucker population has been documented in Kearl Lake during previous studies and is thought to be separate from the population that migrates into the Muskeg River from the Athabasca River to spawn. This population is thought to spawn at the outlet to Kearl Lake in Muskeg Creek where some spawning habitat is available (R.L.&L. 1989). In a 1988 aerial survey, white sucker were observed spawning in Muskeg Creek at the outlet of the lake and white sucker were captured about 2 km downstream of the outlet (R.L.&L. 1989). White sucker are also thought to overwinter in Muskeg Creek, because overwintering habitat in Kearl Lake is minimal due to low winter oxygen levels (R.L.&L. 1989).

Age and Growth

The length-weight regression for white sucker captured in Kearl Lake is shown in Table 4.4-19. Figure 4.4-42 presents the length-at-age relationship for the Kearl Lake white sucker population.

ARCTIC GRAYLING

Arctic grayling typically migrate up tributaries in spring to spawn (Figure 4.4-5). They are uncommon in the larger tributaries such as the MacKay and Clearwater Rivers (McCart et al. 1977) and seem to favour the smaller tributaries, especially the Muskeg and Steepbank Rivers. Arctic grayling have also been found in some of the smaller tributaries to the Clearwater River (i.e. Surmon, Saline and Spray Creeks, and the Hangingstone River). Spawning movements occur early in the spring, sometimes even under the ice. In the Steepbank River in 1977, the Arctic grayling migration was completed by the end of April (Machniak and Bond 1979). On the Muskeg River in 1995, the Arctic grayling migration was underway by the time the fish fence was installed in early May. Unlike other species that spawn in the tributaries (i.e. longnose and white sucker) most Arctic grayling remain in the tributaries throughout the summer months to feed. While adult grayling leave the tributaries in the fall, likely due to the scarcity of overwintering habitat, YOY are thought to overwinter in both the Steepbank and Muskeg Rivers (Machniak and Bond 1979). Overwintering areas for adults have not been identified; however, Arctic grayling have been shown to move downstream from Fort McMurray in the fall (Tripp and Tsui 1980).

Athabasca River

The migration of Arctic grayling into the tributaries is reflected by the scarcity of this species in the mainstem Athabasca River. No Arctic grayling were captured on the Athabasca River in 1995. However, Arctic grayling are occasionally found in the mainstream Athabasca in late fall when they leave the tributaries (Syncrude unpublished data).

Arctic grayling spawning sites were documented in Poplar Creek at the confluence of the Poplar Creek Reservoir spillway and Poplar Creek.

Steepbank River

<u>Seasonal Distribution and Abundance - Past and Present</u>

Arctic grayling were more abundant in the upstream reach of the Steepbank River than near the mouth (Figure 4.4-43). Although the riffle habitat is similar in both sections, the run habitats in the upstream section are of higher gradient than near the mouth and have abundant instream cover from boulders. All life stages of Arctic grayling were caught in the Steepbank River (Table 4.4-27). All life stages of Arctic grayling were found associated with riffles; primarily in the tails of riffles were the water depths increase and instream cover is abundant. One area with a concentration of Arctic grayling juveniles was a high quality/depth run with abundant instream cover and deep, swift-flow characteristics(Figure 4.4-24).

During the 1995 spring spawning survey, Arctic grayling spawning sites were documented throughout the length of the Steepbank River from the upstream end of the study area to 2.5 km from the mouth (Figure 4.4-24). In most riffles, the substrate is too course for spawning. The spawning sites that were recorded were primarily located along the periphery of the riffles where the velocities were lower and the substrate particles were smaller, or in pockets of smaller substrate situated between boulders in the riffle.

Large numbers of Arctic grayling have been previously documented to use the Steepbank River for spawning and rearing. Over 1400 Arctic grayling migrated upstream to spawn in the spring of 1977 (Machniak and Bond 1979). The upstream spawning migration started prior to fish fence operation which began on April 25 and extended throughout the month of May. However, most fish (75.9%) passed through the fish fence before the beginning of May.

Data from the 1995 study as well as historical fish fence and fish inventory data (Machniak and Bond 1979) indicate that most adult Arctic grayling remain in the river for the summer to feed and exit in the fall prior to freeze-up. However, YOY are thought to overwinter in the system until spring (Machniak and Bond 1979).

Size and Age Distribution

Figure 4.4-44 displays the length-frequency distribution for Arctic grayling caught in 1995. The age-frequency distribution is shown in Figure 4.4-45.

Age and Growth

The length-weight regression for Arctic grayling is depicted in Table 4.4-19. Figure 4.4-46 is the length-at-age relationship for Arctic grayling captured on the Steepbank River in 1995.

Muskeg River

Seasonal Distribution and Abundance - Past and Present

Seasonal patterns of Arctic grayling movement in the Muskeg River system are similar to those of the Steepbank River. In the spring, Arctic grayling in pre-spawning and spawning condition were caught between 6 and 24 May in both the downstream and the upstream traps of the fish fence on the Muskeg River (Table 4.4-11 and 4.4-12). Based on a number of recaptures in the spring, it is likely that some Arctic grayling remained in the area of the fish fence to spawn while others moved further upstream. A breakdown of life stages of Arctic grayling, by site is found in Table 4.4-28.

Only one Arctic grayling was captured upstream of the fish fence, at Site 18 near the mouth of Jackpine Creek. No Arctic grayling were found in Jackpine Creek although suitable spawning, rearing, and summer feeding habitat was present. There was an unsubstantiated claim (local angler) that a 30 cm Arctic grayling was caught in June downstream of the bridge on Jackpine Creek. The presence of a spawning migration of this species into Jackpine Creek was documented by O'Neil et al. (1982). In the spring of 1981, over 900 Arctic grayling passed through their fish fence on Jackpine Creek between 2 May and 18 May. They documented spawning in the higher gradient portions of the stream (between 7.4 to 14.9 km from the mouth), as well as summer feeding and rearing. The apparent decrease in abundance of Arctic grayling since 1981 may be due to over-exploitation (i.e. angling). A similar decrease in abundance of Arctic grayling in the Hangingstone River (a tributary to the Clearwater River) was attributed to angling pressure (Tripp and Tsui 1980).

In the fall of 1995, out-migration of adult Arctic grayling from the Muskeg River system occurred from 25 September (the date the fish fence was operational) to 24 October when it was removed. However, most (85%) fish exited the Muskeg River over a seven-day period that extended from 15 October to 21 October. Overwintering habitat within the Muskeg River system is minimal due to the low flows and the likelihood of some portions freezing completely to the bottom.

Size and Age Distribution

The length-frequency distribution for Arctic grayling from the Muskeg River is shown in Figure 4.4-47, while the age-frequency is presented in Figure 4.4-48.

Age and Growth

Length-weight regressions were computed separately for male and female Arctic grayling (Table 4.4-19). The relationship between age and length is depicted in Figure 4.4-49. Age-at-maturity is 4 years for males and ranges from 2 to 4 years for females.

NORTHERN PIKE

Northern pike use different parts of the Athabasca River system for various aspects of their life history, although they do not travel as far afield as species such as walleye and sucker (Tripp and McCart 1979) (Figure 4.4-5). Significant spawning migrations occur from the mainstem Athabasca River into the Muskeg River and the upper Clearwater River (Tripp and McCart 1979), and possibly the upper Christina River (a tributary to the Clearwater River)(Tripp and Tsui 1979) and Saline Lake (McCart et al. 1977). A limited amount of spawning occurs near Fort McMurray in the mainstem

Athabasca River in areas of flooded vegetation (R.L.&L. 1994). Tagging and recapture data from 1977 indicate that most pike either remain in the tributaries or in the Athabasca River near the mouths of the tributaries throughout the summer (Machniak and Bond 1977). This pattern of abundance was also demonstrated in the summer of 1995. Northern pike are thought to overwinter in the Athabasca River in the vicinity of spawning streams (Tripp and McCart 1979).

Athabasca River

Seasonal Distribution and Abundance- Past and Present

Northern pike were consistently present in the Athabasca River but in fairly low numbers throughout the 1995 inventory. Figure 4.4-50 shows that the high CPUE values were seen in the spring at the mouth of Poplar Creek (AF005), the pool at the Suncor water intake (AF001) and near the Syncrude pumphouse (AF015). In summer, areas the high CPUE values were the Syncrude pumphouse and the mouth of the Steepbank River (AF003). CPUE was uniformly low during fall (Figure 4.4-50).

A breakdown of adult and juvenile fish by site and season is shown in Table 4.4-29. Juvenile northern pike were uncommon, but were present at most sites. Adults were more common than juveniles and were most abundant at the sites described above. The presence of northern pike throughout the study area and through all the seasons indicates that habitats in this area provide summer feeding and rearing areas for northern pike. Most often, northern pike are found in association with tributary mouths and near large backwaters.

There was no evidence of pike spawning in the Athabasca River near Suncor and Syncrude nor was there any suitable spawning habitat present.

Size and Age Distribution

The length-frequency distribution for northern pike from the Athabasca River is shown in Figure 4.4-5; Figure 4.4-52 displays the age-frequency distribution.

Age and Growth

The length-weight regression for northern pike from the Athabasca River is presented in Table 4.4-19, and the length-at-age relationship is shown in Figure 4.4-53.

Steepbank River

Seasonal Distribution and Abundance - Past and Present

Northern pike were only captured near the mouth of the Steepbank River (AF014). In the spring, one adult pike was caught (CPUE = 0.03 fish/100 sec) and in the summer, an adult and a juvenile were found (CPUE = 0.35 fish/100 sec). Past studies indicate that pike generally only use the bottom 5 to 8 km of the Steepbank River (Machniak and Bond 1979). Machniak and Bond (1979) recorded a fairly large migration of northern pike (n = 237) in early May of 1977, consisting mainly of immature males (42%) and mature spent males and females (Machniak and Bond 1979).

Muskeg River

Seasonal Abundance and Distribution - Past and Present

Northern pike were captured in both the spring and fall fish fences on the Muskeg River. In the spring, an upstream spawning migration of 123 northern pike took place between 6 and 18 May (Table 4.4-11). Only 3 northern pike passed through the downstream trap prior to removal of the fish fence on 31 May; all of these fish were post-spawners which had been tagged earlier in May when they passed through the upstream trap (Table 4.4-11). In the fall, 117 northern pike moved through the downstream fish trap; 83 were adults and 34 were juveniles (Table 4.4-30).

In the past, northern pike have been documented to spawn in the lower reaches of Jackpine Creek (O'Neil et al. 1982); however, no pike were recorded in Jackpine Creek in 1995. This was likely due to the presence of impassable beaver dams near the mouth of the creek. Northern pike have also been found in the upper reaches of the Muskeg River in both present and past studies (R.L.&L. 1989). In the spring of 1995, one northern pike was observed at Site 4 in the upper reaches of the Muskeg River. R.L.&L. (1989) speculated that there is an isolated population in this area due to the large number of beaver dams (which would be impassable barriers) downstream of the site where the pike were caught.

Size and Age Distribution

The length-frequency distribution for northern pike captured in the Muskeg River fish fence is shown in Figure 4.4-54. Figure 4.4-55 illustrates the age-frequency distribution of this population.

__Age and Growth__

Length-weight regressions were calculated separately for male and female northern pike (Table 4.4-19). The length-at-age relationship is shown in Figure 4.4-56. Age-at-maturity ranges from 3 to 4 for males and 6 to 7 for females.

LAKE WHITEFISH

The use of the Athabasca River system by lake whitefish is shown in Figure 4.4-5. Lake whitefish are residents of Lake Athabasca and the Peace-Athabasca Delta where they overwinter and spend the summer feeding. Most lake whitefish spawn in lakes, but some populations such as those in the Athabasca Delta migrate upstream to spawn in the Athabasca River and some of its tributaries (McCart et al. 1977). There is no evidence that lake whitefish spawn in the Suncor or Syncrude study areas; either in the mainstem Athabasca River or in the tributaries. Past studies indicate that the fall spawning migration of lake whitefish extends spatially from the Delta to Cascade Rapids which constitute the upstream limit of the migration (Jones et al. 1978). While a few individuals may overwinter in the river, a large percentage return to the Delta and Lake Athabasca at the end of October (Bond 1980). YOY lake whitefish have been found near spawning areas in the spring (Tripp and McCart 1979). YOY drift with the current downstream to the Delta and Lake Athabasca.

Athabasca River

__Seasonal Distribution and Abundance - Past and Present__

In 1995, lake whitefish were captured during all three fish inventory periods, although only three individuals were captured in the spring. In the summer, adult lake whitefish were observed to be congregating at the mouth of the Steepbank River but were uncommon elsewhere in the study area (See Figure 4.4-2 and 4.4-57). Large numbers of lake whitefish were caught in the fall sampling period (Figure 4.4-57). Areas of large concentrations of fish included: the mouths of Poplar Creek (AF005), Leggett Creek (AF020) and the Steepbank River (AF003), the Suncor water intake (AF002), near McLean Creek (AF006), upstream of Tar Island Dyke (AF019) and Shipyard Lake drainage (AF018).

A similar seasonal pattern of abundance and habitat use was found by Bond (1980) in the Mildred Lake area. CPUE for lake whitefish was low until late-August when fish started moving into the area from the Delta. Fish moved upstream from the Delta to spawn with large numbers entering the Mildred Lake area around 20 September. Large congregations of lake whitefish were found in backwaters and at the mouths of tributaries (Bond 1980). Syncrude (unpublished data) also found concentrations of lake whitefish at the mouths of tributaries, such as the Muskeg and Steepbank Rivers. Bond (1980) concluded that tributary mouths and backwaters are important staging and resting areas for lake whitefish during their spawning migration. Data from the fall of 1995 indicate these habitats remain important staging and resting areas for lake whitefish.

Lake whitefish spawning has been documented at the Mountain and Cascade rapids upstream of Fort McMurray (Jones et al. 1978) and in the Clearwater and Christina Rivers (Tripp and McCart 1979). However, past studies have not established whether lake whitefish spawn in the Athabasca River near Suncor (McCart et al. 1977). Therefore, in the fall of 1995, extra electrofishing effort was expended in the fall to establish whether the lake whitefish were spawning in the study area or whether the migration continued upstream. CPUEs for lake whitefish were very high at the beginning of the fall sampling period (27 September) and most fish were adult pre-spawners. Of the fish whose sex was identified, 99% of the females and 66% of the males were gravid, while no females and 32% of the males were ripe. Electrofishing in areas of high abundance of lake whitefish was done later in the fall (mid-October). However, few fish were caught in these later runs. At Shipyard Lake drainage (AF018), the CPUE decreased from 47 fish/100 sec (447 fish) to 1.1 fish/100 sec (12 fish), and at Tar Island Dyke (AF019) the CPUE decreased from 20 fish/100 sec (207 fish) to 1.3 fish/100 sec (15 fish). These data clearly indicate lake whitefish passed through the Suncor study area and that they were not spawning in the Athabasca River near Suncor.

Only a few (n = 4) juvenile fish and no YOY were found in the Athabasca River in the Suncor study area (Table 4.4-31). Past studies indicate that this stretch of the Athabasca River is not an important rearing area for lake whitefish (McCart et al. 1977, Bond 1980, Syncrude unpublished data).

Spring data from 1995 do not suggest that lake whitefish overwinter in the Athabasca near Suncor. However, previous investigations showed a small peak in numbers in early spring, and Bond (1980) suggested that a few lake whitefish overwinter in the Athabasca River.

Size and Age Distribution

The length-frequency distribution for lake whitefish shows that fish length ranged from 290 to 520 mm with a large percentage of fish falling in the 380 to 480 mm category (Figure 4.4-58). The age-frequency distribution is shown in Figure 4.4-59.

Age and Growth

The length-weight regression for lake whitefish is shown in Table 4.4-19. Since the sex of most of the fish was unidentifiable, the regression is for all fish. The length-at-age relationship shown in Figure 4.4-60 indicates that fish ranged from 5 to 13 years of age.

Steepbank River

Only a few lake whitefish (n = 6) were captured in the Steepbank River in 1995, and these were caught near the mouth of the river during the summer sampling period when lake whitefish were congregating at the mouth (Figure 4.4-3). No lake whitefish were captured during the fall, indicating that this species does not use the Steepbank River for spawning. In the past, lake whitefish have been documented mainly in the lower reaches of the river (Machniak and Bond 1979). Thirty-nine lake whitefish passed through a counting fence on the Steepbank River in the spring of 1977. It is possible that lake whitefish occasionally move up tributaries in the spring to feed on sucker and Arctic grayling eggs (Kendel 1975 in Bond and Machniak 1977).

Muskeg River

No lake whitefish were documented in the 1995 Muskeg River system fish inventory, either in the spring and fall fish fences or the spring backpack shocking in the tributaries. As with the Steepbank River, lake whitefish are known to congregate at the mouth of the Muskeg River in summer and fall, and occasionally swim into the lower reaches of the river (Syncrude unpublished data, Bond and Machniak 1979). There is no historical evidence of lake whitefish spawning in the Muskeg River and kick sampling at the mouth of the river and near the fish fence in the fall of 1995 revealed no evidence of lake whitefish eggs.

MOUNTAIN WHITEFISH

Mountain whitefish are uncommon in the lower reaches of the Athabasca River. Mountain whitefish make spring feeding migrations into some of the tributaries. These migrations were documented in the Steepbank River in 1995 and in the past (Machniak and Bond 1979) and in the Muskeg River in the past (Bond and Machniak 1977). Syncrude (unpublished data) also documented mountain whitefish in the MacKay River, and to a lesser extent in the Athabasca River near Syncrude.

Further upstream on the Athabasca River (NRBS Reaches 1 to 5), mountain whitefish are the dominant sports fish species (see Figure 4.4-1 for NRBS reaches) (R.L.&L. 1989). It is possible that some mountain whitefish migrate into the lower reaches of the river from upstream areas where mountain whitefish are common. Another possibility is that the mountain whitefish found in the mainstream near Suncor and Syncrude are migrants from local populations in lakes and streams.

Athabasca River

Mountain whitefish were uncommon in the Athabasca River section of the Suncor study area. When R.L.&L. (1994) surveyed the same region of the river in 1992, they did not catch any mountain whitefish. Syncrude (unpublished data) also found that the abundance of mountain whitefish was low in the Athabasca River mainstream.

Steepbank River

<u>Seasonal Distribution and Abundance - Past and Present</u>

In 1995, mountain whitefish were abundant in the Steepbank River, particularly during the spring (Figure 4.4-61). CPUE was highest in the upstream section of the Steepbank study area, and was progressively lower in the downstream sections. Note that this pattern of higher CPUE in the upstream portion of the study area was also seen for Arctic grayling and longnose sucker. In the summer, CPUE was lower in the upper section of the Steepbank, perhaps indicating that the fish were moving out of the Steepbank River or to other areas of the Steepbank River.

Juvenile and YOY mountain whitefish were found in all three fish inventory sections; whereas adults were found only in the middle and upstream sections. Juveniles were by far the most common life stage of mountain whitefish found in the Steepbank River (Table 4.4-32). Machniak and Bond

(1979) also documented a large spring feeding migration of mountain whitefish. Apparently, the Steepbank River provides feeding habitat for young mountain whitefish throughout the spring and summer. The low CPUE in the fall of 1995 indicates that many of the mountain whitefish may have left the river. Machniak and Bond (1979) did not see mountain whitefish passing downstream in the fall, and inferred that the fish had left the watercourse during the summer.

Mountain whitefish spawning locations are not known within the lower reaches of the Athabasca River. No spawning was documented in the mainstream or the tributaries near Suncor and Syncrude. Young-of-the-year have been found in the Clearwater and High Hills Rivers (Machniak and Bond 1979) and in tributaries upstream of Cascade Rapids (Tripp and McCart 1979); however, spawning locations have not been confirmed.

Size and Age Distribution

Length-frequency distribution of mountain whitefish from the Steepbank River ranges from 80 mm to 460 mm with 80% of the fish within the 160 to 260 mm range (Figure 4.4-62). This distribution differs from that obtained by Machniak and Bond (1979) for mountain whitefish caught moving upstream in the spring of 1977. They found a range of 182 to 461 mm with 68% falling within 250 and 300 mm. The age-frequency distribution in Figure 4.4-63 shows that most fish captured on the Steepbank River were juveniles.

Age and Growth

The length-weight regression for mountain whitefish is presented in Table 4.4-19. The length-at-age distribution for mountain whitefish is shown in Figure 4.4-64.

Muskeg River

No mountain whitefish were collected from the Muskeg River at the spring or fall fish fence operations. Historical sources indicate that occasionally, mountain whitefish enter the lower reaches for spring feeding (Bond and Machniak 1977).

BURBOT

Burbot are present throughout the Athabasca River system but in low numbers. Burbot have been caught in reaches of the Athabasca upstream of Grand Rapids (Sentar 1994, R.L.&L 1994); between Grand Rapids and Cascade Rapids (Tripp and McCart 1979); Cascade Rapids to downstream of Suncor and Syncrude (present study, Syncrude unpublished data, Bond 1980) and the Delta (Bond 1980). Because the abundance of burbot is so low, it is difficult to ascertain their migration patterns. Burbot probably overwinter in Lake Athabasca and move into the mainstream Athabasca River to spawn in January and February (Bond 1980). The presence of YOY burbot in the vicinity of Suncor and Syncrude suggest that burbot spawn in the study area (Bond 1980, present study). Bond (1980) suggested that some burbot migrate into Lake Athabasca for the summer when Athabasca River temperatures exceed optimal temperature (15°C to 18°C) for this species.

Athabasca River

Seven burbot were captured in the Athabasca River fish inventory in 1995 and six of these were taken in the fall. One of these was a juvenile.

Steepbank River

A single burbot was captured near the mouth of the Steepbank River in 1995. Burbot occasionally use the lower reaches of the Steepbank River for feeding (Sekerak and Walder 1980).

Muskeg River

One juvenile burbot was captured at the mouth of the Muskeg River in 1995.

FLATHEAD CHUB

Flathead chub are one of the most common small fish species found in the Athabasca River. They are generally confined to the mainstem and rarely enter the tributaries (McCart et al. 1977, R.L.& L. 1989). In 1995, flathead chub were not captured in fish inventories on either the Steepbank or Muskeg Rivers. They were, however, common in the mainstem Athabasca River with peak abundance in summer and low abundance in fall. Area where flathead chub were common include Willow Island and the left and right banks of the Athabasca River near Tar Island Dyke. Spawning occurs in June and July and it is assumed to occur near Suncor and Syncrude (McCart et al. 1977). Flathead chub are thought to overwinter in the Athabasca River and in Lake Athabasca (Bond 1980).

The length-frequency distribution for flathead chub collected from the Athabasca River in 1995 is shown in Figure 4.4-65.

LAKE CHUB

Lake chub are common in both the mainstream Athabasca River and in the tributaries. In 1995, this species was documented in the Athabasca, Steepbank and Muskeg Rivers. In the Athabasca River, concentrations were found near Willow Island. Bond (1980) suggests that spawning areas are likely in the lower reaches of tributaries in May and June. Ripe lake chub found at the fish fence on the Muskeg River in 1995 confirm this suggestion. Overwintering probably occurs in the tributaries and in the mainstream Athabasca River (Bond 1980).

Length-frequency distributions for lake chub captured in the Athabasca, Steepbank and Muskeg Rivers are shown in Figure 4.4-66. Length-weight regression equations for Lake Chub from the Steepbank and Athabasca Rivers are presented in Table 4.4-19.

TROUT-PERCH

Trout-perch use the area near Suncor and Syncrude extensively for feeding (McCart et al. 1977). This species is abundant and wide-spread in the Athabasca River downstream of Fort McMurray (Bond 1980). Bond (1980) found that numbers of trout-perch peak in late June when YOY occur in the catch. This species was common on the Athabasca River in 1995 with peak catches occurring in the summer in nearshore areas (Table 4.4-2). Spawning is thought to occur in the tributaries and has been documented in the lower reaches of the Steepbank River (Machniak and Bond 1979). Trout-perch likely overwinter in the Athabasca River (Bond 1980).

The length-frequency distribution for trout-perch from the Athabasca River is presented in Figure 4.4-67 and the length-weight regression is shown in Table 4.4-19.

EMERALD SHINER

Emerald shiner migrate from the Athabasca Delta (where they are thought to overwinter) into the Athabasca River where they spawn and spend the summer feeding (Bond 1980). This species is found offshore more than other minnow species and often feeds near the surface. Emerald shiner have been reported in the Athabasca River near Suncor and Syncrude but they rarely go into the tributaries (Bond 1980). Abundance data from the 1995 field study is consistent with this pattern. Emerald shiner were found in low abundance in the Athabasca River (n = 29) during the open-water season but not the Steepbank or Muskeg Rivers.

LONGNOSE DACE

Longnose dace is a bottom feeding minnow (Scott and Crossman 1973) that is often found in tributaries to the Athabasca River but are rarely found in the mainstream. This species has been documented in the tributaries to the Clearwater River (Tripp and Tsui 1980), the Clearwater River (Tripp and McCart 1979), the Steepbank River (Sekerak and Walder 1980) and the Muskeg River (R.L.&L. 1989). Longnose dace were captured at one site on the Athabasca River (n = 25). They were captured at all three fish inventory reaches on the Steepbank River (n = 75); but not at all in the Muskeg River drainage.

SLIMY SCULPIN

Slimy sculpin occur in the Athabasca River downstream of the Cascade Rapids (Tripp and McCart 1979). They are uncommon in the mainstream Athabasca River and tend to be associated with the tributaries where they prefer gravel substrate (Bond 1980). Slimy sculpin fry were caught near Willow Island, on the Athabasca River indicating that spawning occurred nearby (Table 4.4-5). Tripp and Tsui (1980) found that this species was a common inhabitant of the tributaries to the Clearwater River. It is also found in the Muskeg River drainage basin (R.L.&L. 1989, present study).

SPOONHEAD SCULPIN

Spoonhead sculpin are widely dispersed but have a low abundance in the Athabasca River from above the Grand Rapids to below Syncrude (Tripp and McCart 1979). A few (n = 2) individuals were caught in the Suncor study area on the Athabasca in 1995. This species was not seen in the Muskeg River drainage but was abundant in the Steepbank River in 1995 (Table 4.4-9). The length-frequency distribution for spoonhead sculpin from the Steepbank River is presented in Figure 4.4-1 and the length-weight regression equation is shown in Table 4.4-19.

SPOTTAIL SHINER

Spottail shiner is one of the main small fish species found in the Athabasca River in the vicinity of Suncor and Syncrude, but it is not as abundant as other small fish species such as flathead chub or trout-perch. Bond (1980) noted that this species spawns in the area near Mildred Lake. In 1995, this species was captured in all seasons, albeit in low abundance (n = 23).

YELLOW PERCH

Yellow perch is uncommon in the Athabasca River but is known to occur in some of the tributaries. This species has been recorded at the mouth of the Clearwater River and in its tributaries (Tripp and Tsui 1980). In 1995, seven yellow perch were collected from the Athabasca River. Yellow perch captured from Poplar Creek may have moved into this creek through the spillway from Poplar Creek reservoir. This species was not documented in either the Steepbank or Muskeg River.

BROOK STICKLEBACK

Brook stickleback are not common in the mainstem Athabasca River but are common residents of tributary streams. They are found in clear, cool water and are often associated with vegetation. They are known to occur in the Steepbank River (Machniak and Bond 1979), but they were not captured in this watercourse in 1995. This species is widespread throughout the upper reaches of the Muskeg River drainage (R.L.&L. 1989, present study). A total of 140 brook stickleback was collected from the Muskeg River drainage in 199.

FATHEAD MINNOW

Fathead minnow are not common in the Athabasca River but have been reported to occur in a number of places downstream of the Cascade Rapids (Tripp and McCart 1979, Tripp and Tsui 1980, Bond 1980). No fathead minnow were recorded in either the Athabasca River or the Steepbank River study areas in 1995. Fathead minnow have been documented in the Steepbank River but they are not common inhabitants of this watercourse (Bond 1980). In 1995, this species was widely distributed through the Muskeg River drainage, although in past studies it was only documented to occur in Kearl Lake (R.L.&L. 1989).

Figure 4.4-69 shows the length-frequency distribution for fathead minnow from the Muskeg River in 1995.

PEARL DACE

Pearl dace are not a common species in the Athabasca River but are often common in the tributaries such as the Steepbank and Muskeg Rivers and a number of tributaries to the Clearwater River (Machniak and Bond 1979, Tripp and Tsui 1979). In 1995, no pearl dace were collected from the Athabasca or Steepbank Rivers. A few pearl dace (n = 14) were captured in the Muskeg River and its tributaries. Pearl dace have been reported to spawn in the gravel/cobble areas at the outlet to Kearl Lake (R.L.&L. 1989).

BRASSY MINNOW

Brassy minnow have been previously documented in the Athabasca River, downstream of Fort McMurray. In 1995, two brassy minnow were captured at the mouth of Poplar Creek, confirming that this species still occurs in the area.

4.5 Fish Health

The following description of fish health for the Steepbank and Aurora mine study areas includes detailed information for fish VECs. Athabasca River VECs include walleye, goldeye and longnose sucker, while longnose sucker are the VEC for the Steepbank and Muskeg Rivers. Walleye and goldeye data were collected from the Athabasca River in the summer of 1995 and longnose sucker data were collected in the spring of 1995 from the Muskeg River.

Fish health include general fitness, physiological and reproductive parameters, as well as measures of chemical body burdens (accumulation of chemicals in body tissues). All data are presented separately by species and sex and compared to relevant data sets, where possible. Correlation and regression were used to illustrate relationships among selected fish health parameters. All statistical analyses were conducted at the 95% level where $p < 0.05$ was considered significant.

This chapter first provides a historical overview of fish health investigations in the study area and then summarizes the results of the present study.

4.5.1 Historical Overview of Fish Health Studies

Historic information on fish health within the study area is minimal. The Northern River Basins Study (NRBS) projects, currently underway, will provide some information on fish health parameters (biomarkers). However, it appears that the NRBS data will not provide a full suite of chemical and health indicator parameters that are relevant to possible oil sands effects because of an emphasis on chemicals related to pulp mills. Also, the NRBS study will not provide data on species that are most abundant in the area (i.e., longnose sucker, walleye, lake whitefish, goldeye). At the time of writing of this report, projects that were still in progress with respect to fish health include: (1) a basin-wide survey of burbot, walleye, mountain whitefish and longnose suckers for physiological parameters (activity of mixed function oxidase enzymes, sex steroid levels) and whole organism data (size-at-age, gonad weight, liver weight, fecundity, age-to-maturity, condition factor, internal and external pathology, chemical data for burbot); (2) compilation and synthesis of data on fish health and pathology; and (3) oxygen requirements of goldeye and burbot (NRBS 1994).

Several historical studies of the lower Athabasca River fish populations include relevant data for comparison to the present study. NRBS Project Report No. 13 presents steroid hormone and gonad morphology data from Upper Athabasca River fish species (Brown et al. 1993). Species-specific fecundity and stomach content data for fish from the Lower Athabasca River are reported by McCart et al. (1977), Bond and Machniak (1979), Tripp and McCart (1979), Machniak and Bond (1979), Bond (1980), and Tripp and Tsui (1980).

Environmental Effects Monitoring (EEM) studies are also relevant for placing baseline fish health data in context. EEM refers to a set of monitoring requirements that are part of all new effluent regulations issued by the federal government. The pulp and paper industry was the first to have EEM become part of the regulations; pulp mills on the Athabasca River are now conducting EEM studies. As adult fish surveys form part of EEM programs, there will be EEM fisheries data available at the end of the first cycle of pulp and paper studies in April 1996. These data will form part of a basin-wide database on fisheries. Since EEM studies must take place every three years, this database will continue to grow and will become an important part of the overall understanding of fish response to effluent discharge in the Athabasca River basin. Because of this, the present baseline study area incorporates EEM data requirements, since this will allow comparison of fish responses in the study area with responses upstream according to a standardized and recognized methodology.

Applicable historical EEM or EEM-style studies include: Swanson et al. (1993) for the Wapiti/Smoky River system, and Sentar's (1994) baseline report for the Athabasca River from the town of Athabasca to Grand Rapids. EEM studies on the Athabasca River system to be released in April 1996 include: Weldwood of Canada Ltd., Hinton; Alberta Newsprint, Whitecourt; Miller-Western, Whitecourt; Slave Lake Pulp, Slave Lake; Alberta-Pacific Forest Industries, Boyle.

4.5.2 Body Burdens

Chemicals in the environment that are taken up by fish are either stored in tissue or transformed (metabolized) by the liver. In turn, liver metabolites are then either stored or excreted. Hence, the resulting body burdens (concentration of chemicals in fish flesh) are dependant on a number of factors: methods and rates of uptake, chemical metabolism and excretion (Heath 1995). Analyses for polycyclic-aromatic hydrocarbons (PAH), alkylated PAHs, polycyclic aromatic nitrogen heterocycles (PANH), alkylated PANHs, and metals were performed on walleye, goldeye and longnose sucker muscle samples (Appendix XIII). As well, bile which contains excretory products from the liver, was sampled and analyzed for the PAH metabolites benzo-a-pyrene (BaP) and naphthalene (NHP) (Appendix XIII).

PAH/PANH

PAH and PANH are the most harmful constituents to fish in petroleum products (Anderson 1979). Both long-term and brief exposures have significant sub-lethal effects on fish and other biota. Also, PAH metabolites are known to produce carcinogenic and mutagenic effects (Varanasi and Gmur 1981, cited in Melancon et al. 1992).

Fish flesh samples from all three VECs (walleye, goldeye and longnose suckers) were composited by species and sex and analyzed for PAH/PANH and alkylated PAH/PANH. Levels of PAH/PANH and alkylated PAH/PANH in walleye and goldeye composite samples were non-detectable at a detection limit varying between 0.02-0.04 $\mu g/g$ (ppm). Longnose sucker composite samples from the Muskeg River showed detectable naphthalene levels of 0.04 $\mu g/g$ (ppm) and methyl napthalene levels of 0.03 $\mu g/g$ (ppm). Other PAH/PANH and alkylated PAH/PANH parameters were not detectable at limits of 0.02-0.04 $\mu g/g$ (ppm) (Appendix XIII).

TRACE ICP METALS

Metals are required in trace amounts for various cellular functions; however, high concentrations of metals in fish cells cause detrimental physiological effects. The body burden of a metal is related to several factors including the bioavailability of metals in the surrounding water, the ability of the fish to excrete the metal, and its body size (Heath 1995). For example, an inverse relationship has been observed between body size and accumulation of certain metals, such as zinc (Newman and Mitz 1988).

Fish flesh samples from all three VECs (walleye, goldeye and longnose suckers) were composited by species and sex and analyzed for metals by Inductively Coupled Plasma spectrometry (Appendix XIII). The results are listed in Tables 4.5-21 to 4.5-23. There were no elevated levels of metals in fish flesh.

PAH METABOLITES IN FISH BILE

PAH and PANH are not often detected directly in body tissues because they are rapidly metabolized by the liver before bioaccumulation in tissues can occur (Melancon et al. 1992). Petroleum hydrocarbons are converted into metabolites that collect in tissues, sub-cellular macromolecules and bodily fluids, specifically bile. Metabolites resulting from PAH conversion by the MFO system are more toxic than the parent PAH and have been correlated with the occurrence of pathological conditions (ie. hepatic lesions) (Thakker et al. 1985, Krahn et al. 1986, cited in Melancon et al. 1992).

Goldeye bile samples were individually analyzed for the PAH metabolites benzo-a-pyrene(BaP) and naphthalene (NPH) (Table 4.5-25) (Appendix XIII). Analysed walleye bile samples included one individual sample plus three composited samples (Table 4.5-24). Longnose sucker bile samples were composited by sex for a total of two composite samples and analyzed for BaP and NPH (Table 4.5-26). Both BaP and NPH were present in walleye, goldeye and longnose sucker bile.

4.5.3 General Fitness of Fish

The effect of chemical exposure on fish health can be measured through changes in various physiological parameters (Shugart et al. 1992, Adams et al. 1989). Parameters used to indicate general fitness of fish include condition factor, mesenteric fat content, liver somatic index (LSI), stomach contents and pathology.

CONDITION FACTOR

The condition factor is a generalized indicator of overall fitness and can reflect the integrated effect of both nutrition and metabolic costs induced by stress (Adams et al. 1989). Fulton's Condition Factor is calculated according to the formula (Ricker 1975):

$$K=W/L^3 \times 10^5$$

where K= Fulton's Condition Factor

W= weight in grams

L= length in millimetres

10^5= scaling factor

Condition factor often corresponds with Gonad Somatic Index (GSI) and mesenteric fat content. Condition factors for walleye and goldeye from the Athabasca River are listed, by species and sex, in Table 4.5-1. Longnose sucker condition factors are presented together with GSI results (Table 4.5-2) as they were sampled in spring pre-spawning condition. GSI data are not available for walleye and goldeye from the Athabasca River as they were sampled in summer post-spawning condition.

MESTENTERIC FAT

Gross mesenteric fat content is a measure of fat storage and nutrition in fish (Adams et al. 1990). Lipid and mesenteric fat content decreases in fish exposed to some toxic compounds (Rao and Rao 1984, cited in Mayer et al. 1992) and increases in response to others (e.g., pulp mill effluent) (Swanson et al. 1993, Hodson et al. 1992, Gagnon et al. 1993). Fish exposed to chemicals tend to accumulate body fat because they cannot convert the fat into new tissue (Munkittrick et al. 1991). Therefore, mesenteric fat content in the body cavity was observed and recorded as a percent of the caeca covered with fat. Mesenteric fat content is provided for walleye and goldeye (Table 4.5-3) and longnose suckers (Table 4.5-4). Comparison with data from the Wapiti Smoky River system does not indicate any marked increase or decrease in mesenteric fat content (Swanson et al. 1994).

LIVER SOMATIC INDEX

Liver Somatic Index (LSI) is a measure of the liver size relative to the body where:

LSI = liver weight / total body weight x 100

The LSI is species-specific and can provide general insight into the health of a fish (Goede and Barton 1990, cited in Heath 1995). The LSI reflects both short-term nutritional status and metabolic energy demands and is also sensitive to toxicant stress (Adams et al. 1990). Fish exposed to chemicals (petroleum hydrocarbons in particular) tend to have enlarged livers (Everaarts et al. 1993).

The LSIs for Athabasca River walleye and goldeye, and Muskeg River longnose suckers are outlined in Table 4.5-5. For comparison purposes, LSI data are also listed for each species with other general parameters, such as fish length, weight and age (Tables 4.5-6 and 4.5-7). There are no previous LSI data for the study area. Comparison with similar studies on other river systems indicates that livers in the study area are similar in size to fish from farther upstream (Sentar 1994), but may be smaller than in pristine systems (Kloepper-Sams et al. 1994, Swanson et al. in press).

STOMACH CONTENTS

Food ingestion is one of the main pathways in which pollutants enter fish and it plays a role in the bioaccumulation of chemicals in fish muscle and liver (Gobas 1992). Bioaccumulation depends on the concentration of chemicals in the food, the amount of food eaten by the fish, and metabolic rate (Heath 1995). Stomach content information was collected for walleye and goldeye from the Athabasca River, and longnose suckers from the Muskeg River.

Of the 41 longnose suckers that were examined from the Muskeg River, 26 had food in their stomachs. All 26 stomachs contained 100% chyme (mucus). The high percentage of empty stomachs is a common observation in pre-spawning (gravid) longnose suckers (Bond and Machniak

1977, Machniak and Bond 1979). Stomach contents were more variable for Athabasca River walleye and goldeye

Stomach contents from walleye captured in 1995 and from a study by McCart et al. (1977) are presented in Figures 4.5-1 and 4.5-2, respectively. Walleye examined by McCart et al. (1977) showed similarities to walleye examined in the 1995 study, in that there was a high incidence of fish as food items. However, there were some differences in walleye stomach contents between historical and present studies. The main invertebrate species reported by McCart et al. (1977) included Ephemeroptera, Plecoptera and Diptera species, whereas the present study showed three walleye with invertebrates in their stomachs (primarily Odonata species).

Food items observed in goldeye captured in 1995 included walleye fry and mammal remains (shrews and deer mice) (Figure 4.5-3). In a previous study, McCart et al. (1977) reported more invertebrate species diversity in goldeye stomachs than observed in the 1995 study (Figures 4.5-3 and 4.5-4). This may be attributed to the fact that the McCart et al (1977) sampling took place over longer periods of time and over various seasons. McCart et al. (1977) did not report mammal remains in goldeye stomachs.

PATHOLOGY

The incidence of pathological conditions is often related to degradation of the aquatic environment. Fish exposed to chemicals frequently show signs of disease internally in tissue (Heath 1995) as well as externally, often in the form of surface lesions and fin erosion (Hinton et al. 1992). Exposure to PAHs has been linked to the development of liver tumours (Stein et al. 1990). Thus, gross and microscopic pathological surveys were conducted on fish within the study area. Three categories of gross pathology were observed: (1) parasitism; (2) injuries (natural or sampling related); and (3) non-specific abnormalities such as growths, lesions or deformities. Baseline data are presented as percent incidence of both external and internal abnormalities.

External pathology was recorded for all fish species captured from the Athabasca, Steepbank and Muskeg Rivers in 1995. Percent incidence of external pathology for Athabasca and Steepbank River fish is presented in Table 4.5-8 and for the Muskeg River in Table 4.5-9. Incidence of gross pathology was similar to that observed in fish from farther upstream (Sentar 1994). A notable observation in the non-specific category in Table 4.5-8, is a small percentage (1%) of goldeye from the Athabasca River were missing both pelvic fins and pelvic girdle, without any sign of injury.

Internal pathology was recorded for fish sacrificed for biomarking (walleye and goldeye from the Athabasca River, and longnose suckers from the Muskeg River), and incidental mortalities from fish inventory sampling efforts. Field observations of gross internal pathology are presented in Table 4.5-10 by percent incidence. Seven out of 13 lake whitefish mortalities had small white spots (granulomata) covering the surface of the heart. Histological examination of one of these hearts (Sample AF003/T336) showed granulomata, possibly resulting from nematode parasitism on the heart tissue (GlobalTox 1995). A report of this sample and other tissue samples examined histologically is presented in Appendix XIV. This report concluded that "The findings ranged from incidental changes that could be attributed to the method of capture and sampling to chronic parasitism. There were no changes consistent with toxicity, nor were there any neoplasia" (GlobalTox 1995).

4.5.4 Physiological Parameters

Specific enzymes and proteins in select tissues are commonly assayed for biomonitoring purposes. They are used as indicators of stress; however, the causes of stress in fish can include both generalized and chemical factors, and are often indistinguishable (Heath 1995). In this study, several physiological parameters were examined in both fish liver tissue and blood. Liver parameters investigated include mixed function oxidase (MFO) activity and retinol (Vitamin A) levels. Blood was analyzed for reproductive hormones and lactate.

MIXED FUNCTION OXIDASE (MFO) ACTIVITY

MFO refers to the activity of a group of enzymes in the liver, the cytochrome P450 system, that have been shown to increase in response to exposure to specific chemicals, including polyaromatic hydrocarbons (PAHs). Many chemicals induce activity of the liver enzymes ethoxyresorufin-O-deethylase (EROD) and aryl (benzo-a-pyrene) hydrocarbon (AHH) that are catalyzed by the cytochrome P450 protein (Stegeman et al. 1992 cited in Heath 1995). This enzyme activity occurs quickly following exposure (Heath 1995). Livers from fish in the study area were analyzed for percent P450 (to check for sample integrity) as well as EROD and AHH activity (induction) (Appendix XIII).

Mean hepatic EROD and AHH activity is presented in Tables 4.5-11 to 4.5-13. The data indicate elevated levels of activity for both enzymes in comparison to baseline levels from farther upstream (Sentar 1994) and to levels from a pristine site in northwest Saskatchewan (Sentar 1994). NRBS investigated fish liver MFO induction in response to various waters. The first study demonstrated that oil sands operations wastewaters contain potent EROD inducers but that EROD inducers are present in the Athabasca River both upstream and downstream of oil sands operations (Parrott 1996a). A second study showed no differences in MFO responses in fish liver cell cultures between tributaries which flow over naturally-occurring oil sands deposits and oil sands wastewater (Parrott 1996b).

Regression analyses were carried out on enzyme activity versus LSI for each species and sex because increased liver size often accompanies elevated levels of EROD and AHH. There was no relationship between these two parameters (Figures 4.5-3 to 4.5-8).

Enzyme activity versus concentration of benzo-a-pyrene and napthalene metabolites in bile was examined. A relationship between these two measures of exposure would help reduce future monitoring requirements because data for one parameter could be used to predict the other. Thus, measurements of both would be unnecessary. However, no relationship was found.

RETINOL (VITAMIN A)

Retinol and its derivative forms, collectively known as Vitamin A, are essential for vision, maintenance of epithelial tissues, growth, and reproduction (Zile 1992, cited in Palace et al. 1995). Vitamin A stores have been shown to decline in fish exposed to organic chemicals that interact with the Ah receptor (e.g., polychlorinated biphenyls, PAHs, dioxins) (Palace et al. 1995). Retinol (Vitamin A) was analyzed from fish liver tissue to provide a baseline for later comparison. The results of the retinol analyses are presented in Table 4.5-14. There are no other published retinol data from the Athabasca River available for comparison.

BLOOD CHEMISTRY

Plasma chemistry is often used as an indicator of fish health. An increase in plasma enzymes, such as lactate, indicates tissue damage (Versteeg et al. 1985, cited in Mayer et al. 1992). Concentrations of lactate, as well as total protein and glucose, in plasma may also be used as general stress markers (Heath 1995). Plasma samples for walleye and goldeye were analyzed for lactate, total protein and glucose (Table 4.5-15 and Appendix XIII).

Total protein is in the normal range for fish whereas glucose appears elevated (Folmar 1993). Elevated glucose levels are often a response to both organic and inorganic chemicals; however, changes in glucose can also be caused by handling stress and environmental factors such as pH, temperature and water velocity changes (Hille 1980 cited in Folmar 1993).

4.5.5 Reproductive Parameters

An important indicator of the health of a fish is its ability to reproduce. Exposure to chemicals (including petroleum hydrocarbons) may cause significant effects on fish reproduction (Heath 1995). Parameters such as blood hormone levels and relative gonad size are indicators of reproductive fitness, and were examined in fish from the Athabasca and Muskeg Rivers. Fecundity and egg diameter data were measured for longnose suckers from the Muskeg River.

REPRODUCTIVE HORMONES AND GONAD SOMATIC INDEX (GSI)

Levels of reproductive hormones in fish blood serum can show effects of chemical exposure on fish health and reproduction. A fish's capability to spawn, specifically the production of sperm and eggs, is governed by sex steroids. Levels of circulating sex steroids in fish exposed to pulp mill effluents have been shown to decrease in both sexes with a corresponding decrease in gonad size (Munkittrick et al. 1991, Munkittrick et al. 1994). Hence, plasma was analyzed for testosterone in males and 17b-estradiol in females.

Gonad Somatic Index (GSI) is a measure of the size of the gonad relative to body size and is defined as follows:

GSI = gonad weight / total body weight x 100

GSI is an important sign of reproductive health, typically being reduced in chemically exposed fish (Payne et al. 1978, cited in Heath 1995). An inverse relationship has been observed between GSI and condition factor in studies of fish exposed to pulp mill effluents (Munkittrick et al. 1991, Gagnon et al. 1995).

Sex steroid results are presented for all three VECs (Appendix XIII): walleye (Table 4.5-16), goldeye (Table 4.5-17), and longnose suckers (Table 4.5-18). Sex steroid levels in longnose suckers are similar to those found pre-spawning fish from the Wapiti Smoky River system (Schryer et al. 1995) and the North Saskatchewan River (Schryer et al. 1995). Sex steroid levels in goldeye and walleye reflect the time of sampling, which was during the period of early gonadal development during mid-summer in preparation for the following spring.

Longnose sucker GSI data are presented with corresponding condition factors (Table 4.5-2). The GSI in the pre-spawning longnose suckers appear to be typical of mature fish (Schryer et al 1995). GSI for walleye and goldeye were not calculated because these species were sampled in a non-spawning period; therefore, the gonads were in a small developing condition.

FECUNDITY AND EGG DIAMETER

Fecundity in fish is measured as the number of eggs produced by a female. The diameter of mature eggs is another measure of reproductive performance. A reduction in these parameters usually corresponds with depressed estradiol levels. Both fecundity and egg diameter are species-specific and are affected by a variety of factors including chemicals and food availability (Heath 1995).

Walleye and goldeye fecundity and egg diameter data were not collected in this study because these species were sampled in a non-spawning period. However, historical studies report that one walleye from the Christina River had 35,060 eggs (Tripp and Tsui 1980), two walleye from the Athabasca River had fecundities of 76,806 and 94,633 eggs per female (McCart et al. 1977), and six walleye from the Lower Athabasca River had a mean fecundity of 79,970 eggs, ranging from 39,466 to 117,588 eggs per female (Bond 1980). During the present study, longnose suckers from the Muskeg River were sampled for fecundity and egg diameters in spring pre-spawning condition. The results from this study are listed in Table 4.5-19 along with historical data (Table 4.5-20). Fecundity is somewhat higher in the present study than in the historical information.

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6.0 GLOSSARY OF TERMS

Age-to-Maturity

Most often refers to the age at which more than 50% of the individuals of a particular sex within a population reach sexual maturity. Age-to-maturity of individuals within the same population can vary considerably from the population median value. Males most often reach sexual maturity at a younger age than females in fish species.

Ageing Structures

Parts of the fish which are taken for ageing analyses. These structures contain bands for each year of growth or maturity which can be counted. Some examples of these structures are scales, fin rays, otoliths and opercula. Most ageing structures can be taken with minimal effect on the fish and vary according to fish species.

Alkalinity

A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. It is expressed as an equivalent of calcium carbonate. The composition of alkalinity is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.

Anchor (Floy) Tagging

A practical and inexpensive method of permanently marking an individual fish. The tag, shaped like an inverted "T", is most commonly inserted in the epipleural bones of the dorsal spine. The posterior of the tag is usually brightly coloured and carries a numeric identification code. This method is preferred because it has minimal effects on the swimming and feeding efficiency of the fish.

ANOVA	Analysis of Variance. A statistical test of whether 2 or more sample means could have been obtained from populations with the same parametric (true, absolute) mean.
AOSERP	Alberta Oil Sands Environmental Research Program.
ASL	Analytical Services Laboratories.
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.
BaP	Benzo-a-pyrene. A metabolite of PAH that accumulates in body tissues and fluids, specifically bile, following PAH biotransformation. Often metabolite concentration is more easily detected than the parent chemical concentration and serves as a biomarker of exposure to that parent chemical (Melancon et al. 1992).
Benthic Invertebrates	Invertebrate organisms living at, in, or associated with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include several aquatic insect species which spend at least part of their lifestages dwelling on bottom sediments in the river (i.e. caddisfly larvae). These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the open water above or brought in from external sources, and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for small fishes.

Bile	An alkaline secretion of the vertebrate liver, which is temporarily stored in the gall bladder. It is composed of organic salts, excretion products, and bile pigment. It is responsible primarily for emulsifying fats in the small intestine.
Bioaccumulation	A general term, meaning that an organism stores within its body, a higher concentration of a substance than is found in the environment. This is not necessarily harmful. For example, freshwater fish must bioaccumulate common salt in order to survive. Many toxicants, such as arsenic, are not included because they can be handled and excreted by aquatic organisms.
Biological Indicators	Any biological parameter that is used to indicate the response of individuals, populations or ecosystems to environmental stress. For example, growth is a biological indicator.
Biomarker	Biomarker refers to a chemical, physiological or pathological measurement of exposure or effect in an individual organism from the laboratory or the field. Examples include: chemicals in liver enzymes, bile, and sex steroids.
BOD	Biochemical Oxygen Demand. A measure of oxygen-consuming properties of a water.
Bottom Sediments	Substrates which lie at the bottom of a body of water. In this case, they are soft mud, silt, sand, gravel, rock and organic litter, which make up the river bottom.
Bottom-feeding Fish	Fish which feed on the substrates and/or organisms associated with the river bottom.
Caecum (pl. caeca)	A blind sac attached to the digestive tract in fish.

Chemex	Chain of Custody Forms
Chemex Labs Alberta Inc.	Standardized forms which are used as a means of keeping close track of samples which are taken from the field and transported to laboratories for analysis. Whenever the samples are transported from the field, the custody is relinquished from the delivery person to the receiver by signatures on the forms. These forms substantially decrease the risk of losing samples because they provide a clear record of the chain of transport and handling of the samples.
Condition Factor	A measure of the relative "fitness" of an individual or population of fishes by examining the mathematical relationship between length and weight. The values calculated show the relationship between growth in length relative to growth in weight. In populations where increases in length are matched by increases in weight, the growth is said to be isometric. Allometric growth, the most common situation in wild populations, occurs when increases in either length or weight are disporportionate.
CPUE	Catch-Per-Unit-Effort. A measure which relates to the catch of fish, with a particular type of gear, per unit of time (e.g., number of fish/hour). Results can be given for a particular species or the entire catch. The results can reflect both the density and/or the vulnerability of the gear utilized, of a species in a particular system.
Conductivity	A measure of a water's capacity to conduct an electrical current. It is the reciprocal of resistance. This measurement provides the limnologist with an estimation of the total concentration of dissolved ionic matter in the water. It allows for a quick check of the alteration of total water quality due to the addition of pollutants to the water.

Chemical Body Burdens	The total concentration of a chemical found in either whole-body or individual tissue samples.
CWQG	Canadian Water Quality Guidelines. Numerical concentrations or narrative statements recommended to support and maintain a designated water use in Canada. The guidelines contain recommendations for chemical, physical, radiological and biological parameters necessary to protect and enhance designated uses of water.
Detoxification	To decrease the toxicity of a compound. Bacteria decrease the toxicity of resin and fatty acids in mill effluent by metabolizing or breaking down these compounds; enzymes like the EROD or P4501A proteins begin the process of breaking down and metabolizing many "oily" compounds by adding an oxygen atom.
Detritus	A food source for invertebrates consisting mainly of decomposing organic plant material and the organic material's associated microflora, such as bacteria.
DL	Detection Limit. 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.
DQO	Data Quality Objectives.
Ecosystem	An integrated and stable association of lingin and non-living resources functioning within a defined physical location.
Effluent	A waste material discharged into the environment.

Ekman Grab	A spring-loaded dredge which is used for sampling soft mud, silt or sandy river bottoms. The contents of the dredge are emptied into a large tub, water is added to create a slurry and this slurry is sieved through a screen. Mud and sand will pass through the screen, leaving a mixture of debris and benthic organisms on the screen. This mixture is preserved and returned to the laboratory for further separation and benthos analysis.
Electrofishing	The use of electricity to stun and capture fish. It employs a portable generator which supplies current and develops an electric field between positive and negative electrodes suspended from a boat. Pulsed direct current between the electrodes act as a narcotic to fish passing between them and attracts them toward the positive (anode) poles where they are easily netted. Fish taken by electrofishing revive quickly when returned to the water. Thus, fish may be identified, weighed, measured, tagged and then returned to the river unharmed.
Enviro-Test	Enviro-Test Laboratories.
EROD	Ethoxyresorufin-O-deethylase. EROD is a laboratory technique that indirectly measures the presence of catalytical proteins that remove a CH_3CH_2-group from the substrate ethoxyresorufin. This substrate was chosen because the fluorescent product formed is very easy to monitor in the laboratory. In the animal, various hydrophobic compounds can be biotransformed by this enzyme to more polar products, which prepared them for eventual eliminations from the body. Thus, this is a "detoxification" or defense system that reduces the amounts of potentially harmful foreign substances in the body. Cytochrome P4501A is the scientific designation of the dominant protein which carries out this catalytic function in mammals and fish. EROD activity refers to the rate of the deethylation and indirectly reflects the amount of enzyme present.

17 - Estradiol	A C-19 steroid hormone produced mainly in the granulosa layer of developing ovarian follicles. It is the main estrogenic hormone in females and is correlated with the growth of vitellogenic oocytes. It induces production of vitellogenesis and then drop at the time of spawning. Estradiol levels have been correlated to the female gonad-somatic index (GSI).
Fate	In the context of the study of anthropogenic chemical releases, fate refers to the form of a chemical when it enters the environment and the compartment of the ecosystem in which that chemical is primarily concentrated (e.g., water or sediments). Fate also includes transport of the chemical within the ecosystem (via water, air or mobile biota) and the potential for food chain accumulation.
Fecundity	The most common measure of reproductive potential in fishes. It is the number of eggs in the ovary of a female fish. It is most commonly measured in gravid fish. Fecundity increases with the size of the female.
Field Blanks	Samples of chemical-free water, (water that has been distilled and filtered so that it does not contain any detectable chemicals) which are subjected to the same routine in the field as the actual sample. This tests for inadvertent contamination because of sample handling.
Filter-Feeders	Organisms which feed by straining small organisms or organic particles from the water column.
Filterable Residue	Materials in water that pass through a standard-size filter (often 0.45 mm). This is a measure of the "total dissolved solids" (TDS), i.e. chemicals that are dissolved in the water or that are in a particulate form smaller than the filter size. These chemicals are usually salts, such as sodium ions and potassium ions.

Fish Health Parameters	Parameters used to indicate the health of an individual fish. May include, for example, short-term response indicators such as changes in liver mixed function oxidase and the levels of plasma glucose, protein and lactic acid. Longer-term indicators include internal and external examination of exposed fish, changes in organ characteristics, hematocrit and hemoglobin levels. May also include challenge tests such as disease resistance and swimming stamina.
Food Chain Transfer	A set of interactions among organisms, including producers, herbivores and carnivores, through which energy and materials move within a community or ecosystem.
Game Fish	Fish used by anglers for recreational fishing, for example, northern pike and walleye.
Gillnetting	A method of capturing fish that involves the setting of nets of various mesh sizes (usually from about 2 to 10 cm) anchored in place in a river or lake. The nets function by catching on the gills of fish as they attempt to swim through.
GSI	Gonad-Somatic Index. The proportion of reproductive tissue in the body of a fish. It is calculated by dividing the total gonad weight by the total body weight and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth.
Golder	Golder Associates Ltd.
Gonads	Organs which are responsible for producing haploid reproductive cells in multi-cellular animals. In the male, these are the testes and in the female, these are the ovaries.

GPS	Geographic Positioning System.
Habitat	The place where an animal or plant naturally or normally lives and grows, for example, the stream habitat.
Half-life	The period of time required for one-half of a compound to be degraded or metabolized.
Histology/ Histological	The microscopic study of tissues.
Hydrophobic	Term used for those compounds "fearing water" (from latin). Characteristically these compounds are only slightly soluble in water and are more soluble in "oily" solvents like octanol.
ICP (Metals)	Inductively Coupled Plasma (Atomic Emission Spectroscopy). This analytical method is a United States Environmental Protection Agency (USEPA) designated method (Method 6010). The method determines elements including groundwater, aqueous samples, leachates, industrial wastes, soils, sludges, sediments and other solid wastes. Samples require chemical digestion prior to analysis.
Induction	Response to a biologically-active compound - involves new or increased gene expression resulting in enhanced synthesis of a protein. Such induction is commonly determined by measuring increases in protein levels and/or increases in the corresponding enzyme activity. For example, induction of EROD would be determined by measuring increases in cytochrome P4501A protein levels and/or increases in EROD activity.
Lesions	Pathological change in a body tissue.

Lipid	One of a large variety of organic fats or fat-like compounds, including waxes, steroids, phospholipids and carotenes. This term refers to substances that can be extracted from living matter using hydrocarbon solvents. They serve several functions in the body, such as energy storage and transport, cell membrane structure and chemical messengers.
LSI	Liver Somatic Index. Ratio of liver versus total body weight. Expressed as a percentage of total body weight
m^3/s	Cubic metres per second. The standard measure of water flow in rivers; i.e., the volume of water in cubic metres that passes a given point in one second.
Metabolism	Metabolism is the total of all enzymatic reactions occurring in the cell; a highly coordinated activity of interrelated enzyme systems exchanging matter and energy between the cell and the environment. Metabolism involves both the synthesis and breakdown (catabolism) of individual compounds.
Metabolites	Organisms alter or change compounds in many various ways like removing parts of the original or parent compound or in other cases adding new parts. Then, the parent compound has been metabolized and the newly converted compound is called a metabolite.
Microbial	Refers to processes involving micro-organisms such as bacteria.
MFO	Mixed Function Oxidase. A term for reactions catalyzed by the Cytochrome P450 family of enzymes, occurring primarily in the liver. These reactions transform organic chemicals, often altering toxicity of the chemicals.

Necrosis	The death of tissue due to injury or disease.
Non-Filterable Residue	Material in a water sample that does not pass through a standard size filter (often 0.45 mm). This is considered to represent "total suspended solids" (TSS) i.e., particulate matter suspended in the water column.
Non-game Fish	A general term applied to smaller species of fish that "forage" on plant material or small invertebrate animals, for example, minnows.
Non-viable	Unable to develop or survive, such as non-viable eggs cannot develop normally or hatch successfully.
NPH	Naphthalene. A metabolite of PANH that accumulates in body tissues and fluids, specifically bile, following PAH biotransformation. See BaP.
Nutrients	Environmental substances (elements or compounds), such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
OSLO	Other Six Leases Owners.
Overwintering Habitat	Habitat used by fish during the winter as a refuge and for feeding.
Oxygen-Demanding Materials	Materials in water that are subject to decomposition by microbes; this activity consumes oxygen. For example, tiny wood fibres and dead plant material create an "oxygen demand" in the water.

PAH	Polycyclic Aromatic Heterocycles. A chemical by-product of petroleum-related industry. Aromatics are considered to be highly toxic components of petroleum products. PAHs are composed of at least two fused benzene rings, many of which are potential carcinogens. Toxicity increases along with molecular size and degree of alkylation of the aromatic nucleus.
PANH	Polycyclic Aromatic Nitrogen Heterocycles. See PAH.
PASH	Polycyclic Aromatic Sulphur Heterocycle. See PAH.
Partitioning	Chemical compounds distribute or partition between water and lipiphilic solvents on sediments depending on how water soluble the compounds are. Very soluble compounds remain free in water, while insoluble compounds leave water and bind to sediments. Scientists usually calculate a ratio between water and an oily solvent called octanol to estimate partitioning. For example, dioxin's ratio is over 1,000,000 molecules in octanol to one molecule in water. In addition, those compounds which partition to sediments often tend to bioconcentrate in living organisms.
Pathology	The science which deals with the cause and nature of disease or diseased tissues.
Physiological	Related to function in cells, organs or entire organisms, in accordance with natural processes of life.
Priority Pollutants	A list of chemicals devised by government regulatory agencies that are considered to pose the greatest hazard to humans and/or the environment.
QAPP	Quality Assurance Project Plan.

QA/QC	Quality Assurance/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 such things as proper instrument calibration, meticulous glassware cleaning and an accurate sample information system.
Rearing Habitat	Habitat used by young fish for feeding and/or as a refuge from predators.
Regression	The statistical estimation of the relationship between one variable and another in terms of a linear (or more complex) function.
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, which approximates uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.
Sampling Efficiency	The relative success of a sampling method in capturing a representative sample from the natural population; e.g., the success of obtaining a representative sample of all of the fish species present in the area. Sampling efficiency depends on the type of gear and environmental conditions, such as water depth.

Sampling Error	Sample inaccuracy caused by bias or imprecision in sampling; e.g., bias towards large fish because of the type of sampling gear. In statistics, sample error is expressed by the standard deviation, which expresses the variability of results around the mean. For example, several measurements of fish gonad sizes are taken from the population; the mean is calculated and the standard deviation describes how variable all the gonad sizes used to calculate the mean were.
Secondary Sex Characteristics	External physical characteristics displayed by fish, particularly during spawning season. Examples are tubercles on fins or body colouration.
Seine Netting	The use of a fine mesh net to catch smaller fish from shallow areas. The net is dragged along the bottom or through the water column to collect fish by straining them from the water.
Set Lines	A series of hooks strung from one line. Used for fish collection.
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 Composition	A term that refers to the species found in the sampling area.
Species Distribution	Where the various species in an ecosystem are found at any given time. Species distribution varies with season.

Species Diversity	A description of a biological community that includes both the number of different species and their relative abundances. Usually measured by the Shannon-Wiener index of diversity. Provides a measure of the variation in number of species in a region. This variation depends partly on the variety of habitats and the variety of resources within habitats and, in part, on the degree of specialization to particular habitats and resources. This index provides an overall measure of ecological variety in a community.
Standard Deviation	A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.
Statistically Significant	Tests of statistical difference are performed to determine the level of certainty of observed differences. For example, for the purposes of this study, populations of fish were analyzed and tested to see whether they were more different from one another than one would expect from chance variation. All statistically significant values in this study were determined at the 95% level ($p < 0.05$).
Substrate	(1) The foundation to which an organism is attached. (2) A substance acted on by an enzyme.
Suncor	Suncor Inc., Oil Sands Group
Suspended Sediments	Particles of matter suspended in the water. Measured as the oven dry weight of the solids, in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have about 200 mg/L of suspended sediments.
SWI	Specific Work Instructions.

Syncrude	Syncrude Canada Ltd.
Taxonomic Structure	The formally identified organisms present in an environment; i.e. the types and number of species present.
TDS	Total dissolved solids. See filterable residue.
Testosterone	A C-19 steroid hormone produced mainly by the interstitial (Leydig)cells of the testes. In males, it is linked with spermatozoa production and the onset of spermiation. In females, testosterone may be present in large amounts and has been linked to the final stages of vitellogenesis.
TOC	Total Organic Carbon. TOC is composed of both dissolved and particulate forms. TOC is often calculated as the difference between total carbon (TC) and total inorganic carbon (TIC). TOC has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon (CCREM 1987).
Tolerant Species	Organisms which are able to withstand adverse or other environmental conditions for an indefinitely long exposure without dying.
Toxic	A substance, a dose, or a concentration that is harmful to a living organism (Bonsor et al. 1988).
Toxic Threshold	Almost all compounds become toxic at some level with no evident harm or adverse effect below that level. Scientists refer to the level or concentration where they can first see evidence for an adverse effect on an organism as the toxic threshold.

TP	Technical Procedure.
TSS	Total suspended solids. See non-filterable residue.
UTM	Universal Transverse Mercator Grid.
VEC	Valved ecosystem component.
Vitellogenesis	The period of egg development where the yolk is being laid down.
Watershed	The entire basin area drained by a stream or lake.
WSC	Water Survey of Canada.
YOY	Young of the year. Fish at age 0, within the first year after hatching.

TABLE 2.0-1
Scoring Criteria for Fish VECs

1.	**residence and relative abundance:** 1 = uncommon 2 = moderately abundant 3 = common
2.	**provincial importance: (or status, measure of the relative abundance and degree of management concern or aesthetic value)** 0 = species abundant, no concern (green-listed) 1 = species rare, but not threatened or special status (yellow-listed) 2 = threatened or vulnerable species (blue-listed) 3 = endangered species (or red-listed)
3.	**commercial economic importance (importance to guides, outfitters, fisheries)** 0 = no importance 1 = low importance 2 = moderate importance 3 = high importance
4.	**subsistence economic importance: (fish species important for subsistence)** 0 = not fished for food 1 = low 2 = moderate 3 = high
5.	**recreational importance: (fish species important for recreational fishing)** 0 = non-game species 1 = low 2 = moderate 3 = high
6.	**habitat niche/sediment exposure** yes/no
7.	**spawning in study area** yes/no
8.	**benthic food preference:** yes/no
9.	**important as prey:** yes/no
10.	**high fecundity:** 1 = low fecundity 2 = moderate fecundity 3 = high fecundity
11.	**high growth rate:** 1 = low growth rate 2 = high growth rate
12.	**age to maturity:** 1 = long age to maturity 2 = moderate age to maturity 3 = short age to maturity
13.	**feasibility of studying** 0 = none 1 = limited 2 = moderate 3 = abundant
14.	**availability of information: (the amount of information available for each species or species group)** 0 = none 1 = limited 2 = moderate 3 = abundant

Table 2.0-2

Weighted Athabasca River Fish VECs for the Steepbank Mine Project Area

Species	Residence/ Abundance	Political Importance	Commercial Importance	Subsistence Importance	Recreational Importance	Sediment Exposure	Spawning in Study Area	Benthic Food Preference	Important as Prey	High Fecundity	High Growth Rate	Age to Maturity	Feasibility to Study	Information Availability	Total
Weighting Factor	2	2	2	2	2	1	1	1	1	1	1	1	2	2	
Goldeye	6	0	2	6	2	No	No	Yes	Yes	3	2	2	0	2	27
Longnose Sucker	4	0	0	1	0	Yes	Yes	Yes	Yes	2	2	2	6	4	25
Northern Pike	2	0	0	2	4	No	No	No	No	3	2	3	2	4	22
Walleye	6	0	4	4	6	No	Yes	No	No	3	2	2	4	4	36
Lake Whitefish	4	0	6	6	2	No	?	Yes	Yes	2	2	2	4	4	34
White Sucker	2	0	0	0	0	Yes	Yes	Yes	Yes	2	2	3	4	4	21
Flathead Chub	4	0	0	0	0	No	Yes	Yes	Yes	1	2	3	4	4	21
Emerald Shiner	4	0	0	0	0	No	Yes	Yes	Yes	1	?	3	4	4	19
Trout - Perch	6	0	0	0	0	Yes	Yes	Yes	Yes	1	1	3	6	2	23
Lake Chub	4	0	0	0	0	No	?	Yes	Yes	?	?	3	2	2	13
Mountain Whitefish	2	0	0	0	0	No	No	Yes	Yes	2	2	2	0	4	14
Burbot	2	0	0	0	0	Yes	Yes	No	No	2	2	2	0	2	12
Arctic Grayling	4	2	0	0	6	No	No	Yes	No	2	2	2	0	4	23
Bull Trout	2	4	0	0	0	Yes	?	No	No	2	3	2	0	2	16

No = 0

Yes = 1

? = 0

Table 2.0-3

Weighted Steepbank River Fish VECs for the Steepbank Mine Project Area

Species	Residence/ Abundance	Political Importance	Commercial Importance	Subsistence Importance	Recreational Importance	Sediment Exposure	Spawning in Study Area	Benthic Food Preference	Important as Prey	High Fecundity	High Growth Rate	Age to Maturity	Feasibility to Study	Information Availability	Total
Weighting Factor	2	2	2	2	2	1	1	1	1	1	1	1	2	2	
Goldeye	0	0	0	0	0	No	No	Yes	Yes	3	2	2	0	2	11
Longnose Sucker	4	0	0	0	0	Yes	Yes	Yes	Yes	2	2	2	6	4	24
Northern Pike	2	0	0	0	0	No	No	No	No	3	2	3	2	4	16
Walleye	4	0	2	0	0	No	Yes	No	No	3	2	2	4	4	22
Lake Whitefish	4	0	2	0	0	No	?	Yes	Yes	2	2	2	4	4	21
White Sucker	2	0	0	0	0	Yes	Yes	Yes	Yes	2	2	3	4	4	21
Flathead Chub	2	0	0	0	0	No	Yes	Yes	Yes	1	2	3	4	4	19
Emerald Shiner	2	0	0	0	0	No	Yes	Yes	Yes	1	?	3	4	4	17
Trout - Perch	6	0	0	0	0	Yes	Yes	Yes	Yes	1	1	3	6	2	23
Lake Chub	6	0	0	0	0	No	?	Yes	Yes	?	?	3	2	2	15
Mountain Whitefish	2	0	0	0	0	No	No	Yes	Yes	2	2	2	0	4	14
Burbot	2	0	0	0	0	Yes	No	No	No	2	2	2	0	2	11
Arctic Grayling	4	2	0	0	0	No	Yes	Yes	No	2	2	2	0	4	18
Bull Trout	2	4	0	0	0	Yes	?	No	No	2	3	2	0	2	16

No = 0

Yes = 1

? = 0

Table 2.0-4

Weighted Muskeg River Fish VECs for the Aurora Mine Project Area

Species	Residence/ Abundance	Political Importance	Commercial Importance	Subsistence Importance	Recreational Importance	Sediment Exposure	Spawning in Study Area	Benthic Food Preference	Important as Prey	High Fecundity	High Growth Rate	Age to Maturity	Feasibility to Study	Information Availability	Total
Weighting Factor	2	2	2	2	2	1	1	1	1	1	1	1	2	2	
Longnose Sucker	4	0	0	0	0	Yes	Yes	Yes	Yes	2	2	2	6	4	24
Northern Pike	4	0	0	0	4	No	Yes	No	No	3	2	3	2	4	23
Walleye	2	0	2	0	0	No	No	No	No	3	2	2	4	4	20
Lake Whitefish	2	0	2	0	0	No	No	Yes	Yes	2	2	2	4	4	20
White Sucker	4	0	0	0	0	Yes	Yes	Yes	Yes	2	2	3	4	4	23
Trout - Perch	2	0	0	0	0	Yes	Yes	Yes	Yes	1	1	3	6	2	19
Lake Chub	2	0	0	0	0	No	Yes	Yes	Yes	?	?	3	2	2	15
Mountain Whitefish	2	0	0	0	0	No	No	Yes	Yes	2	2	2	0	4	12
Burbot	2	0	0	0	0	Yes	No	No	No	2	2	2	0	2	11
Arctic Grayling	4	2	0	0	6	No	Yes	Yes	No	2	2	2	0	4	24

No = 0
Yes = 1
? = 0

Table 3.2-1

Summary of Stations within Steepbank Mine (Suncor) Study Area

STATION ID	STATION WATERCOURSE	STATION TYPE	STATION KM POST	STATION DESCRIPTION	SEASON SAMPLED	SAMPLING METHOD: BIOMARKER	FISH INVENTORY	BENTHIC INVERTEBRATES	HABITAT MEASUREMENT	SURFACE WATER	POREWATER	SEDIMENT
AF001	ATHABASCA	POINT	16.92	POOL AT SUNCOR WATER INTAKE	P,U	EF	EF					
AF002	ATHABASCA	SECTION	16.92-18.83	LDB D/S OF SUNCOR INTAKE	P,U,F	EF	EF					
AF002-GN1	ATHABASCA	POINT	17.84	LDB D/S OF SUNCOR INTAKE	P		GN					
AF002-SL1	ATHABASCA	POINT	17.17	LDB JUST D/S OF SUNCOR INTAKE	F		SL					
AF002-SL2	ATHABASCA	POINT	17.2	LDB JUST D/S OF SUNCOR INTAKE	F		SL					
AF003	ATHABASCA	SECTION	18.60-19.56	VICINITY OF STEEPBANK R. MOUTH	P,U,F	EF	EF					
AF003-GN1	ATHABASCA	POINT	19.18	RDB JUST D/S OF STEEPBANK R. MOUTH	P		GN					
AF004	ATHABASCA	SECTION	19.25-20.96	LDB U/S OF SYNCRUDE PUMPHOUSE	P,U,F	EF	EF					
AF004-GN1	ATHABASCA	POINT	20.8	LDB D/S OF SYNCRUDE PUMPHOUSE	P		GN					
AF004-SL1	ATHABASCA	POINT	20.37	SYNCRUDE PUMPHOUSE	U		SL					
AF004-SL2	ATHABASCA	POINT	20.4	LDB JUST D/S OF SYNCRUDE PUMPHOUSE	F		SL					
AF005	ATHABASCA	SECTION	5.92-8.8	VICINITY OF POPLAR CREEK MOUTH	P,U,F	EF	EF					
AF005-MT1	ATHABASCA	POINT	6.96	LDB U/S OF POPLAR CREEK MOUTH	P		MT					
AF005-MT2	ATHABASCA	POINT	6.96	LDB U/S OF POPLAR CREEK MOUTH	P		MT					
AF005-MT3	ATHABASCA	POINT	6.96	LDB U/S OF POPLAR CREEK MOUTH	P		MT					
AF005-MT4	ATHABASCA	POINT	7.4	MOUTH OF POPLAR CREEK	P		MT					
AF005-MT5	ATHABASCA	POINT	7.4	MOUTH OF POPLAR CREEK	P		MT					
AF005-MT6	ATHABASCA	POINT	7.4	MOUTH OF POPLAR CREEK	P		MT					
AF006	ATHABASCA	SECTION	3.92-4.98	MCLEAN CREEK TO WOOD CREEK	P,U,F	EF	EF					
AF006-SL1	ATHABASCA	POINT	4.64	LIMESTONE RDB D/S OF MCLEAN CREEK	F		SL					
AF006-SL2	ATHABASCA	POINT	4.7	LIMESTONE RDB D/S OF MCLEAN CREEK	F		SL					
AF007	ATHABASCA	SECTION	0.0-0.2	RDB U/S OF WILLOW ISLAND	P		BP					
AF008	ATHABASCA	POINT	0	RDB AT U/S TIP OF WILLOW ISLAND	P,F		BP					
AF009-GN1	ATHABASCA	POINT	23.76	LDB OPPOSITE UNNAMED ISLAND	P		GN					
AF010-SL1	ATHABASCA	POINT	23.82	20M D/S OF AF009	P		SL					
AF011-PE1	ATHABASCA	POINT	0.5	RDB OPPOSITE WILLOW ISLAND	P		PE					

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AF012-PE1	ATHABASCA	POINT	1	LDB OPPOSITE WILLOW ISLAND	P		PE					
AF013-GN1	ATHABASCA	POINT	2.2	D/S TIP OF STONY ISLAND	P		GN					
AF014	STEEPBANK	SECTION	7.9-0.0	LOWER 8KM OF THE STEEPBANK RIVER	P,U,F		EF					
AF015	ATHABASCA	SECTION	20.6-21.5	LDB D/S OF SYNCRUDE PUMPHOUSE	P,U		EF					
AF016	ATHABASCA	SECTION	21.6-23.5	RDB D/S OF SYNCRUDE PUMPHOUSE	P,U		EF					
AF017	STEEPBANK	SECTION	25.00-22.8	U/S BOUNDARY OF LEASE 19	P,U,F		EF					
AF018	ATHABASCA	SECTION	14.08-16.9	VICINITY OF REF. WETLD. DRAINAGE	U,F	EF	EF					
AF018-GN1	ATHABASCA	POINT	14.7	RDB OPPOSITE TAR ISLAND DYKE	P		GN					
AF018-SL1	ATHABASCA	POINT	15.6	LIMESTONE RDB D/S OF CABIN	F		SL					
AF018-SL2	ATHABASCA	POINT	15.66	LIMESTONE RDB D/S OF CABIN	F		SL					
AF019	ATHABASCA	SECTION	11.0-13.3	U/S OF TAR ISLAND DYKE	U,F	EF	EF					
AF019-GN1	ATHABASCA	POINT	11.5	BACKWATER U/S OF TAR ISL. DYKE	P		GN					
AF019-SL1/2	ATHABASCA	POINT	11.5	BACKWATER U/S OF TAR ISL. DYKE	P,U		SL					
AF019-SL3	ATHABASCA	POINT	12.4	BACKWATER U/S OF TAR ISL. DYKE	U		SL					
AF019-SL4	ATHABASCA	POINT	12.28	BACKWATER U/S OF TAR ISL. DYKE	F		SL					
AF019-SL5	ATHABASCA	POINT	12.35	BACKWATER U/S OF TAR ISL. DYKE	F		SL					
AF020	ATHABASCA	SECTION	7.3-10.9	VICINITY OF LEGGET CREEK MOUTH	U,F	EF	EF					
AF020-PE1	ATHABASCA	POINT	10.42	RDB-1.5 KM D/S OF INGLIS ISLAND	P		PE					
AF021-GN1	ATHABASCA	POINT	10.61	RDB-1.75 KM D/S OF INGLIS ISLAND	P		GN					
AF022-PE1	ATHABASCA	POINT	11.9	LDB OF ISLAND U/S OF TAR ISL. DYKE	P		PE					
AF023-SN1/2	ATHABASCA	POINT	12.03	LDB OF ISLAND U/S OF TAR ISL. DYKE	P,F		SN					
AF024-GN1	ATHABASCA	POINT	12.2	LDB OF ISLAND U/S OF TAR ISL. DYKE	P		GN					
AF025-GN1	ATHABASCA	POINT	5.44	LDB OPPOSITE MOUTH OF WOOD CREEK	P		GN					
AF026-GN1	ATHABASCA	POINT	5.61	RDB 1/4 KM D/S OF WOOD CREEK	P		GN					
AF027-GN1	ATHABASCA	POINT	5.85	RDB 1/2 KM D/S OF WOOD CREEK	P		GN					
AF028-SL1	ATHABASCA	POINT	5.77	LDB 1/3 KM D/S OF WOOD CREEK	P		SL					
AF029-SL1/2/3	ATHABASCA	POINT	4.9	RDB 1/4 KM U/S OF WOOD CREEK	P,U,F		SL					

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AF030-PE1	ATHABASCA	POINT	6.54	LDB 1 KM D/S OF WOOD CREEK	P		PE					
AF031-PE1	ATHABASCA	POINT	7.92	LDB OPPOSITE U/S TIP OF INGLIS ISLAND	P		PE					
AF032-GN1	ATHABASCA	POINT	1.81	D/S TIP OF STONY ISLAND	P		GN					
AF033	ATHABASCA	SECTION	0-2.4	LDB AT STONY ISLAND	U,F	EF	EF					
AF033-SL1	ATHABASCA	POINT	0.25	LDB OPPOSITE WILLOW ISLAND	P		SL					
AF034	ATHABASCA	SECTION	1.31-2.78	WEST SHORE OF STONY ISLAND	U,F		EF					
AF034-SL1	ATHABASCA	POINT	0.64	U/S TIP OF STONEY ISLAND	P		SL					
AF035-SN1/2	ATHABASCA	POINT	0.58	U/S TIP OF STONEY ISLAND	P,F		SN					
AF036	ATHABASCA	SECTION	0.62-2.86	RDB AT STONY ISLAND	U,F	EF	EF					
AF036-SL1	ATHABASCA	POINT	1.48	RDB OPPOSITE STONY ISLAND	P		SL					
AF036-SL2	ATHABASCA	POINT	3.05	D/S OF STONY ISLAND	U		SL					
AF037-SN1	ATHABASCA	POINT	0.2	EAST SHORE OF WILLOW ISLAND	P		SN					
AF038-SN1	ATHABASCA	POINT	0	U/S TIP OF WILLOW ISLAND	P		SN					
AF039-GN1	ATHABASCA	POINT	0.94	EAST SHORE OF STONY ISLAND	P		GN					
AF040	STEEPBANK	SECTION	17.10-13.93	MEANDER BENDS, VICINITY OF FEE LOT 3	P,U,F		EF					
AF041	ATHABASCA	SECTION	22.9-25	LDB AT BOTTOM OF STUDY AREA	U,F	EF	EF					
AF042	ATHABASCA	SECTION	3.41-6.82	LDB D/S OF STONY ISLAND	U,F	EF	EF					
AF043	LEGGETT CK	SECTION	n/a	LOWER 800M OF LEGGETT CREEK	U		BP					
AF044	ATHABASCA	SECTION	11.58-13.5	SIDE CHANNEL AT UNNAMED ISLAND	U		EF					
AF045-SL1	ATHABASCA	POINT	3.28	U/S OF MCLEAN CREEK MOUTH	U		SL					
AF046	LEGGET CREEK	POINT	n/a	UPPER LEGGETT CREEK WETLAND	U		GN					
AF047	ATHABASCA	TRANSECT	0.65	ACROSS U/S TIP OF STONY/WILLOW ISLs.	F				X			
AF048	ATHABASCA	TRANSECT	3.28	U/S OF MCLEAN CREEK CONFLUENCE	F				X			
AF049	ATHABASCA	TRANSECT	7.5	AT POPLAR CREEK CONFLUENCE	F				X			
AF050	ATHABASCA	TRANSECT	8.7	WEST CHANNEL, D/S TIP INGLIS ISLAND	F				X			
AF051	ATHABASCA	TRANSECT	14.2	D/S OF REFERENCE WETLAND DRAINAGE	F				X			
AF052	ATHABASCA	SECTION	22.7-22.9	SNYE AT D/S TIP OF UNNAMED ISLAND	F		BP					

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AF053-MT1/2	SALINE LAKE	POINT	n/a	EAST SHORE OF SOUTHERN BAY	F		MT					
AF054-GN1	SALINE LAKE	POINT	n/a	OFF TIP OF PENNINSULA ON NW SHORE	F		GN					
AF055-GN1	SALINE LAKE	POINT	n/a	MIDDLE OF LAKE IN NORTHERN BAY	F		GN					
AF057	ATHABASCA	TRANSECT	16.9	AT PROPOSED BRIDGE CROSSING	F				X			
AF058	ATHABASCA	TRANSECT	11.4	U/S OF TAR ISLAND DYKE	F				X			
AF059	ATHABASCA	TRANSECT	13.39	SANDBAR AT TID - EAST CHANNEL	F				X			
AF060	STEEPBANK	TRANSECT	19.6	STEEPBANK RIVER - KM 19.6	F				X			
AF061	STEEPBANK	TRANSECT	18.25	STEEPBANK RIVER - KM 18.25	F				X			
AF062	STEEPBANK	TRANSECT	16.76	STEEPBANK RIVER - KM 16.76	F				X			
AF063	STEEPBANK	TRANSECT	12.45	STEEPBANK RIVER - KM 12.45	F				X			
AF064	STEEPBANK	TRANSECT	10.3	STEEPBANK RIVER - KM 10.3	F				X			
AF065	POPULAR CR	TRANSECT	n/a	u/s OF RESERVIOR SPILLWAY	P		BP					
AF066	POPULAR CR	TRANSECT	n/a	AT THE HIGHWAY 63 BRIDGE	P		BP					
AF067	POPULAR CR	TRANSECT	n/a	1.0 KM d/s OF BRIDGE CROSSING	P		BP					
AX001	ATHABASCA	POINT	16.22	LDB AT SUNCOR ICE ROAD ACCESS	P,U,F				X			
SS1	STEEPBANK	POINT	20	SPAWNING SITE	P		KS					
SS2	STEEPBANK	POINT	18.64	SPAWNING SITE	P		KS					
SS3	STEEPBANK	POINT	18.19	SPAWNING SITE	P		KS					
SS4	STEEPBANK	POINT	17.64	SPAWNING SITE	P		KS					
SS5	STEEPBANK	POINT	17.5	SPAWNING SITE	P		KS					
SS6	STEEPBANK	POINT	17.15	SPAWNING SITE	P		KS					
SS7	STEEPBANK	POINT	16.8	SPAWNING SITE	P		KS					
SS8	STEEPBANK	POINT	16.51	SPAWNING SITE	P		KS					
SS9	STEEPBANK	POINT	16.22	SPAWNING SITE	P		KS					
SS10	STEEPBANK	POINT	15.27	SPAWNING SITE	P		KS					
SS11	STEEPBANK	POINT	14.27	SPAWNING SITE	P		KS					
SS12	STEEPBANK	POINT	14.14	SPAWNING SITE	P		KS					

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SS13	STEEPBANK	POINT	13.29	SPAWNING SITE	P		KS					
SS14	STEEPBANK	POINT	12.25	SPAWNING SITE	P		KS					
SS15	STEEPBANK	POINT	7.1	SPAWNING SITE	P		KS					
SS16	STEEPBANK	POINT	5.1	SPAWNING SITE	P		KS					
SS17	STEEPBANK	POINT	25	SPAWNING SITE	P		KS					
SS18	STEEPBANK	POINT	24.75	SPAWNING SITE	P		KS					
SS19	STEEPBANK	POINT	24.6	SPAWNING SITE	P		KS					
SS20	STEEPBANK	POINT	24.35	SPAWNING SITE	P		KS					
SS21	STEEPBANK	POINT	24.13	SPAWNING SITE	P		KS					
SS22	STEEPBANK	POINT	23.06	SPAWNING SITE	P		KS					
SS23	STEEPBANK	POINT	21.54	SPAWNING SITE	P		KS					
AW001	STEEPBANK	POINT	25.8	RIFFLE U/S OF LEASE 19 BOUNDARY	P,U,F					X	X	
AW002	STEEPBANK	POINT	25.9	DEPOSITIONAL AREA U/S OF AW001	P,F							X
AW003	STEEPBANK	POINT	13.94	RIFFLE IN VICINITY OF FEE LOT 3	P,F						X	
AW004	ATHABASCA	TRANSECT	-0.71	U/S OF LEASE 19 BOUNDARY	P,U,F					X		
AW005	MCLEAN CK	POINT	n/a	MOUTH OF MCLEAN CREEK	P,U,F					X		
AW006	WOOD CK	POINT	n/a	MOUTH OF WOOD CREEK	P,U,F					X		
AW007	REF WETL	POINT	n/a	MOUTH OF REFERENCE WETLAND OUTLET	P,U,F					X		
AW008	POPLAR CK	POINT	n/a	MOUTH OF POPLAR CREEK	P,U,F					X		
AW009	ATHABASCA	TRANSECT	25	AT THE LEASE 25 BOUNDARY	P,U					X		
AW010	STEEPBANK	POINT	0.13	VICINITY OF STEEPBANK RIVER MOUTH	P,U,F					X		
AW011	STEEPBANK	POINT	0.13	VICINITY OF STEEPBANK RIVER MOUTH	P,F							X
AW012	STEEPBANK	POINT	0.19	VICINITY OF STEEPBANK RIVER MOUTH	P,F						X	
AW013	FIELD BLANK	POINT	n/a	DISTILLED WATER BLANK SAMPLE	P,U,F					X	X	
AW014	LEGGETT CK	POINT	n/a	MOUTH OF LEGGET CREEK	U,F					X		
AW015	ATHABASCA	POINT	15.22	ACROSS FROM TAR ISLAND DYKE	F						X	
AW016	ATHABASCA	POINT	13.84	SHORELINE OF TAR ISLAND DYKE	F						X	

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AW017	ATHABASCA	POINT	12.35	U/S OF TAR ISLAND DYKE	F						X	
AW018	SALINE LAKE	TRANSECT	n/a	NORTH TO SOUTH END OF LAKE	F					X		
AB001	ATHABASCA	POINT	n/a	U/S WILLOW ISLAND ON LDB	F			AS, EG				
AB002	ATHABASCA	POINT	n/a	ADJACENT TO WILLOW ISL. ON RDB OF MAIN CHANNEL, WITHIN AF034	F			EG				
AB003	ATHABASCA	POINT	n/a	MOUTH OF POPLAR CREEK AT AW008	F			AS, EG				
AB004	ATHABASCA	POINT	n/a	ACCROSS FROM MOUTH OF POPLAR CREEK	F			AS, EG				
AB005	ATHABASCA	POINT	n/a	300 M U/S TAR ISLAND DYKE, ON LDB	F			AS, EG				
AB006	ATHABASCA	POINT	12.2	D/S ISLAND, LOCATED U/S OF TAR ISLAND DYKE, ON RDB AT AF024-GN1	F			AS, EG				
AB007	ATHABASCA	POINT	n/a	ADJACENT TO D/S PART OF TAR ISLAND DYKE, ON LDB	F			AS, EG				
AB008	ATHABASCA	POINT	n/a	ADJACENT TO D/S PART OF TAR ISLAND DYKE, ON RDB	F			AS, EG				
AB009	ATHABASCA	POINT	n/a	1.8 KM D/S MOUTH OF STEEPBANK R., ON LDB, WITHIN AF015	F			AS, EG				
AB010	ATHABASCA	POINT	n/a	2 KM D/S MOUTH OF STEEPBANK R., ON RDB	F			AS, EG				
AB011	ATHABASCA	POINT	n/a	5.5 KM D/S MOUTH OF STEEPBANK R., ON LDB	F			AS, EG				
AB012	ATHABASCA	POINT	n/a	5.5 KM D/S MOUTH OF STEEPBANK R., ON RDB	F			AS, EG				

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AT003	ATHABASCA	POINT	15.66	LIMESTONE ON RDB D/S OF CABIN, AT AF018-SL2	F			KS				
SB001	STEEPBANK	POINT	25.9	RIFFLE AREA U/S OF AW001	F			NC				
SB002	STEEPBANK	POINT	13.94	RIFFLE IN VICINITY OF FEE LOT 3	F			NC, KS				
SB003	STEEPBANK	POINT	0.13	RIFFLE IN THE VICINITY OF STEEPBANK RIVER MOUTH	F			NC				

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Table 3.2-2

Summary of Stations within the Aurora Mine (Syncrude) Study Area

				METHOD			SEASON SAMPLED					
STATION ID	WATERCOURSE	REACH	STATION DESCRIPTION	BIOMARKERS	FISH INVENTORY	BENTHIC	BIOMARKERS	FISH INVENTORY	BENTHIC	HABITAT	SURFACE WATER	POREWATER
30	MUSKEG RIVER	30	MOUTH OF THE MUSKEG RIVER		BP, KS	NC, KS		P, F	F	P	P, U, F	F
90	MUSKEG RIVER	30	DUPLICATE AT SITE 30								P, U, F	
31	MUSKEG RIVER	31	MUSKEG RIVER AT THE FISH FENCE	FF, DN	FF, BP, KS		P	P,F				
18	MUSKEG RIVER	33	DOWNSTREAM FROM MOUTH OF JACKPINE CREEK		EF	EG		P	F	P	P, U, F	
4	MUSKEG RIVER	34	DOWNSTREAM FROM MOUTH OF MUSKEG CREEK							P		
35	MUSKEG RIVER	35	DOWNSTREAM FROM STANLEY CREEK			EG			F			
36	MUSKEG RIVER	36	UPSTREAM OF STANLEY CREEK								P, U, F	
17	JACKPINE CREEK	40	MOUTH OF JACKPINE CREEK		BP	NC		P	F	P	P, U, F	
S-4	JACKPINE CREEK	41	AT THE CANTERRA ROAD BRIDGE CROSSING		BP	NC, KS		P, F	F	P	P, U, F	F
50	MUSKEG CREEK	50	MOUTH OF MUSKEG CREEK								U, F	

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SEASON
P = Spring
U = Summer
F = Fall

FISH CAPTURE METHODS
BP = Backpack Electrofisher
DN - Dip Net
EF = Boat Electrofisher
FF - Fish Fence
KS = Kick Sampling
MT = Minnow Trap

BENTHIC SAMPLING METHODS
NC - Neill cylinder
EG - Ekman Grab
KS - Kicknet Sample (for tissue analysis)

Table 3.2-2 Page 2 of 2

				METHOD			SEASON SAMPLED					
STATION ID	WATERCOURSE	REACH	STATION DESCRIPTION	BIOMARKERS	FISH INVENTORY	BENTHIC	BIOMARKERS	FISH INVENTORY	BENTHIC	HABITAT	SURFACE WATER	POREWATER
9	NORTH MUSKEG CREEK	50	DOWNSTREAM FROM THE OUTLET OF KEARL LAKE		BP	EG		P	F	P	P, U, F	
80	KEARL LAKE		KEARL LAKE		EF	EG		P	F	U	P, U, F	
8	IYINIMIN CREEK	56	UPPER PORTION OF IYINIMIN CREEK		BP	NC		U	F	U	U, F	
14	KHAHAGO CREEK	53	UPPER PORTION OF KHAHAGO CREEK			EG			F	P	P, U, F	
55	BLACKFLY CREEK	55	LOWER PORTION OF BLACKFLY CREEK		BP	NC		U	F	U	U, F	

KEY

SEASON
P = Spring
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BP = Backpack Electrofisher
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BENTHIC SAMPLING METHODS
NC - Neil cylinder
EG - Ekman Grab
KS - Kicknet Sample (for tissue analysis)

Table 3.3-1

Parameters Analysed in Surface Water, Porewater, Sediment and Invertebrate and Fish Tissue Samples Collected in the Suncor and Syncrude Study Areas

✓ = Suncor/Syncrude ● = Suncor ■ = Syncrude

ANALYSIS	PARAMETER	SURFACE WATER	POREWATER	SEDIMENT	INVERTEBRATE TISSUE	FISH TISSUE
PAH & Alkylated PAH	1-Methyl-7-isopropyl-phenanthrene	✓	✓	●	✓	✓
	Acenaphthene	✓	✓	●	✓	✓
	Acenaphthylene	✓	✓	●	✓	✓
	Anthracene	✓	✓	●	✓	✓
	Benzo(a)anthracene/Chrysene	✓	✓	●	✓	✓
	Benzo(a)pyrene	✓	✓	●	✓	✓
	Benzo(b&k)fluoranthene	✓	✓	●	✓	✓
	Benzo(g,h,i)perylene	✓	✓	●	✓	✓
	Biphenyl	✓	✓	●	✓	✓
	C2 substituted benzo(a)anthracene/chrysene	✓	✓	●	✓	✓
	C2 substituted benzo(b&k)florathene/benzo(a)pyrene	✓	✓	●	✓	✓
	C2 substitutedd biphenyl	✓	✓	●	✓	✓
	C2 substituted dibenzothiophene	✓	✓	●	✓	✓
	C2 substituted fluorene	✓	✓	●	✓	✓
	C2 substituted naphthalene	✓	✓	●	✓	✓
	C2 substituted phenanthrene/anthracene	✓	✓	●	✓	✓
	C3 substituted dibenzothiophene	✓	✓	●	✓	✓
	C3 substituted naphthalenes	✓	✓	●	✓	✓
	C3 substituted phenanthrene/anthracene	✓	✓	●	✓	✓
	C4 substituted dibenzothiophene	✓	✓	●	✓	✓
	C4 substituted naphthalenes	✓	✓	●	✓	✓
	C4 substituted phenanthrene/anthracene	✓	✓	●	✓	✓
	Dibenzo(a,h)anthracene	✓	✓	●	✓	✓
	Dibenzothiophene	✓	✓	●	✓	✓
	Fluoranthene	✓	✓	●	✓	✓
	Fluorene	✓	✓	●	✓	✓
	Indeno(c,d-123)pyrene	✓	✓	●	✓	✓
	Methyl acenaphthene	✓	✓	●	✓	✓

Table 3.3-1

Parameters Analysed in Surface Water, Porewater, Sediment and Invertebrate and Fish Tissue Samples Collected in the Suncor and Syncrude Study Areas

✓ = Suncor/Syncrude ● = Suncor ■ = Syncrude

	Methyl benzo(a)anthracene/chrysene	✓	✓	●	✓	✓
	Methyl benzo(b&k)fluoranthene/methyl benzo(a)pyren	✓	✓	●	✓	✓
	Methyl biphenyl	✓	✓	●	✓	✓
	Methyl dibenzothiophene	✓	✓	●	✓	✓
	Methyl fluoranthene/pyrene	✓	✓	●	✓	✓
	Methyl fluorene	✓	✓	●	✓	✓
	Methyl naphthalene	✓	✓	●	✓	✓
	Methyl phenanthrene/anthracene	✓	✓	●	✓	✓
	Naphthalene	✓	✓	●	✓	✓
	Phenanthrene	✓	✓	●	✓	✓
	Pyrene	✓	✓	●	✓	✓
PANH & Alkylated PANH	7-Methyl quinoline	✓	✓	●	✓	✓
	Acridine	✓	✓	●	✓	✓
	C2 Alkyl substituted carbazoles	✓	✓	●	✓	✓
	C2 Alkyl substituted quinolines	✓	✓	●	✓	✓
	C3 Alkyl substituted quinolines	✓	✓	●	✓	✓
	Carbazole	✓	✓	●	✓	✓
	Methyl acridine	✓	✓	●	✓	✓
	Methyl carbazoles	✓	✓	●	✓	✓
	Phenanthridine	✓	✓	●	✓	✓
	Quinoline	✓	✓	●	✓	✓
Hydrocarbons	Recoverable Hydrocarbons	✓	✓	✓		
Phenolic Compounds	Phenol	✓	✓			
	o-Cresol	✓	✓			
	m-Cresol	✓	✓			
	p-Cresol	✓	✓			
	2,4-Dimethylphenol	✓	✓			
	2-Nitrophenol	✓	✓			
	4-Nitrophenol	✓	✓			
	2,4-Dinitrophenol	✓	✓			
	4,6-Dinitro-2-methyl phenol	✓	✓			
Volatile Organics	1,1,1-Trichloroethane	✓	✓			
	1,1,2,2-Tetrachloroethane	✓	✓			
	1,1,2-Trichloroethane	✓	✓			
	1,1-Dichloroethane	✓	✓			
	1,1-Dichloroethene	✓	✓			

Table 3.3-1

Parameters Analysed in Surface Water, Porewater, Sediment and Invertebrate and Fish Tissue Samples Collected in the Suncor and Syncrude Study Areas

✓ = Suncor/Syncrude ● = Suncor ■ = Syncrude

	1,2,3-Trichloropropane	✓	✓			
	1,2-Dichlorobenzene	✓	✓			
	1,2-Dichloroethane	✓	✓			
	1,2-Dichloropropane	✓	✓			
	1,3-Dichlorobenzene	✓	✓			
	1,4-Dichlorobenzene	✓	✓			
	2-Butanone (MEK)	✓	✓			
	2-Chloroethyl vinyl ether	✓	✓			
	2-Hexanone	✓	✓			
	4-Methyl-2-pentanone (MIBK)	✓	✓			
	Acetone	✓	✓			
	Acrolein	✓	✓			
	Acrylonitrile	✓	✓			
	Benzene	✓	✓			
	Bromodichloromethane	✓	✓			
	Bromoform	✓	✓			
	Bromomethane	✓	✓			
	Carbon disulfide	✓	✓			
	Carbon tetrachloride	✓	✓			
	Chlorobenzene	✓	✓			
	Chloroethane	✓	✓			
	Chloroform	✓	✓			
	Chloromethane	✓	✓			
	cis-1,3-Dichloropropene	✓	✓			
	cis-1,4-Dichloro-2-butene	✓	✓			
	Dibromochloromethane	✓	✓			
	Dibromomethane	✓	✓			
	Dichlorodifluoromethane	✓	✓			
	Ethanol	✓	✓			
	Ethyl methacrylate	✓	✓			
	Ethylbenzene	✓	✓			
	Ethylene dibromide	✓	✓			
	Iodomethane	✓	✓			
	Methylene chloride	✓	✓			
	Styrene	✓	✓			
	Tetrachloroethylene	✓	✓			

Table 3.3-1

Parameters Analysed in Surface Water, Porewater, Sediment and Invertebrate and Fish Tissue Samples Collected in the Suncor and Syncrude Study Areas

✓ = Suncor/Syncrude ● = Suncor ■ = Syncrude

	Toluene	✓	✓			
	trans-1,2-Dichloroethene	✓	✓			
	trans-1,3-Dichloropropene	✓	✓			
	trans-1,4-Dichloro-2-butene	✓	✓			
	Trichloroethene	✓	✓			
	Trichlorofluoromethane	✓	✓			
	Vinyl acetate	✓	✓			
	Vinyl chloride	✓	✓			
	Xylenes	✓	✓			
Trace Elements - ICP	Aluminum	✓	✓	✓	✓	✓
	Arsenic	✓	✓	✓	✓	✓
	Barium	✓	✓	✓	✓	✓
	Beryllium	✓	✓	✓	✓	✓
	Boron	✓	✓	✓	✓	✓
	Cadmium	✓	✓	✓	✓	✓
	Chromium	✓	✓	✓	✓	✓
	Cobalt	✓	✓	✓	✓	✓
	Copper	✓	✓	✓	✓	✓
	Iron	✓	✓	✓	✓	✓
	Lead	✓	✓	✓	✓	✓
	Manganese	✓	✓	✓	✓	✓
	Molybdenum	✓	✓	✓	✓	✓
	Nickel	✓	✓	✓	✓	✓
	Selenium	✓	✓	✓	✓	✓
	Silver	✓	✓	✓	✓	✓
	Strontium	✓	✓	✓	✓	✓
	Vanadium	✓	✓	✓	✓	✓
	Zinc	✓	✓	✓	✓	✓
	Calcium	✓	✓	✓	✓	✓
	Magnesium	✓	✓	✓	✓	✓
	Sodium	✓	✓	✓	✓	✓
	Potassium	✓	✓	✓	✓	✓
	Silicon	✓	✓	✓	✓	✓
	Lithium	✓	✓	✓	✓	✓
	Uranium	✓	✓	✓	✓	✓
	Phosphorus	✓	✓	✓	✓	✓

Table 3.3-1

Parameters Analysed in Surface Water, Porewater, Sediment and Invertebrate and Fish Tissue Samples Collected in the Suncor and Syncrude Study Areas

✓ = Suncor/Syncrude ● = Suncor ■ = Syncrude

	Titanium	✓	✓	✓	✓	✓
	Sulphur	✓	✓	✓	✓	✓
	Available Sulphur			✓		
Trace Elements - CV	Mercury	✓	✓	✓	✓	✓
Hydride Metals - AA	Antimony	✓	✓	✓	✓	✓
	Arsenic	✓	✓	✓	✓	✓
	Selenium	✓	✓	✓	✓	✓
Conventional Parameters	Total Alkalinity	✓	✓			
	Bicarbonate	✓	✓			
	Carbonate	✓	✓			
	PP Alkalinity	✓	✓			
	Hydroxide	✓	✓			
	Chloride	✓	✓			
	Sulphate	✓	✓			
	pH	✓	✓			
	Total Hardness	✓	✓			
	Specific Conductance	✓	✓			
	Total Dissolved Solids	✓	✓			
	Nitrate + Nitrite as Nitrogen	✓	✓			
	Total Ammonia as Nitrogen	✓	✓			
	Total Cyanide	✓	✓			
	Phenols	✓	✓			
	Total Organic Carbon/Dissolved Organic Carbon	✓	✓			
	Total Organic Carbon/Organic Matter			✓		
	Non-Filterable Residue	✓	✓			
	Chlorophyll *a*	■	■			
	Biochemical Oxygen Demand	■	■			
	Total Phosphorous as Phosphorus	✓	✓			
Blood Serum	Testosterone					✓
	17b-estradiol					✓
	17a, 20b-dihydroxyprogesterone					■
	Glucose					●
	Protein					●
	Lactate					●
Bile	Benzo-a-pyrene					✓
	Napthalene					✓

Table 3.3-1

Parameters Analysed in Surface Water, Porewater, Sediment and Invertebrate and Fish Tissue Samples Collected in the Suncor and Syncrude Study Areas

✓ = Suncor/Syncrude ● = Suncor ■ = Syncrude

Liver	Ethoxyresorufin-O-deethylase (EROD)					✓
	AHH					✓
	P450					✓
	Retinols					●

Table 3.3-2

General Description of Analytical Methods for All Laboratory Analyses

PARAMETER	METHOD
PAH/Alkylated PAH , PANH/Alkylated PANH, Phenolic Compounds (water)	Base/neutral and acid liquid/liquid extraction, gas chromatography/mass selective detection (GC/MSD), modified EPA methods 3540, 3510, 8720
PAH/Alkylated PAH, PANH/Alkylated PANH (sediment)	16 hour soxhlet extraction, solvent partitioned using base/neutral and acid liquid/liquid extraction, GC/MSD, modified EPA methods 3540, 3510, 8720
PAH/Alkylated PAH, PANH/Alkylated PANH (invertebrates)	Air dried, pulverized to fine powder, analysis same as for sediment
PAH/Alkylated PAH, PANH/Alkylated PANH (fish tissue)	Homogenized with dry ice to form fine powder, analysis same as for sediment
PAH Metabolism (bile)	Method ETL MSOP# 66.00
Recoverable Hydrocarbons (water, sediment)	Separatory funnel, gravimetric analysis, H/C ENVIRODAT method 6579, APHA method 5520F
Volatile Organics (water, sediment)	Automated headspace, gas chromatography/mass selective detection, EPA methods 3810, 8240
Trace Elements - ICP (water)	Inductively coupled plasma, EPA (1979) method 200.7
Trace Elements - ICP (sediment)	Digested, EPA method 3050, inductively coupled plasma, EPA (1979) method 200.7
Trace Elements - ICP (invertebrates)	Air dried, pulverized to fine powder, analysis same as for sediment
Trace Elements - ICP (fish tissue)	Homogenized with dry ice to form fine powder, analysis same as for sediment
Mercury (water)	Cold vapour: Digested, air sparged, absorbance of Hg vapour in absorption cell measured spectrophotometrically, EPA (1979) method 245.2, APHA (1985) method 303F
Mercury (sediment)	Digested, reduced, measured spectrophotometrically, APHA (1985) method 303F
Mercury (invertebrates)	Air dried, pulverized to fine powder, analysis same as for sediment

General Description of Analytical Methods for All Laboratory Analyses

Mercury (fish tissue)	Homogenized with dry ice to form fine powder, analysis same as for sediment
Hydride Metals - AA (water, sediment)	Digested, reduced to hydrides (automated), atomic absorption spectrophotometer, APHA (1985) method 303E, EPA (1979) method 206.5
Hydride Metals - AA (invertebrates)	Air dried, pulverized to fine powder, analysis same as for sediment
Hydride Metals - AA (fish tissue)	Homogenized with dry ice to form fine powder, analysis same as for sediment
Alkalinity (water)	PP (Phenolphthalein) and Total Alkalininty determined by potentiometric titration system (automated) and pH meter; carbonate, bicarbonate and hydroxide calculated from PP and Total Alkalinity, APHA (1985) method 2320B, EPA (1979) method 310.1
Chloride (water)	Technicon, APHA (1985) method 407D, EPA 1979 method 235.2
Sulfate (water)	Technicon, EPA (1979) method 375.2
pH (water)	Potentiometrically (pH meter), APHA (1985) method 4500-H
pH (sediment)	Potentiometrically (pH meter), on saturated paste or specified water to soil ratio, Cdn. Soc. Soil Sci., 2 ed., (1978)
Total Hardness (water)	Calculated from results of separate determinations of calcium and magnesium, APHA (1992) method 2340B
Specific Conductance (water)	Specific conductivity meter, APHA (1985) method 403, EPA (1979) method 310.1
Total Dissolved Solids (water)	Gravimetric, (180°C dried), APHA (1985) method 209B, EPA (1979) method 160.1
Nitrate + Nitrite as Nitrogen (water)	Azo dye intensity measured spectrophotometrically, EPA (1979) method 353.2
Total Ammonia as Nitrogen (water)	Berthelot Reaction on autoanalyzer, APHA (1985) method 417C
Total Cyanide (water)	Prepared by automated system, measured spectrophotometrically, EPA (1979) method 335.2, APHA (1989) method 4500-CN E

General Description of Analytical Methods for All Laboratory Analyses

Phenol (water)	Prepared by automated system, measured spectrophotometrically, EPA (1979) method 420.2
Total Organic Carbon/ Dissolved Organic Carbon (water)	Prepared by automated system, passed through UV coil, measured by IR analyzer; TOC taken from shaken sample, DOC taken from unshaken sample, APHA (1985) method 505A, EPA (1979) method 415.1
Total Organic Carbon/ Organic Matter Modified (sediment)	Mebus Method, Potassium Dichromante Oxydation, For. Can.(1991), Amer. Soc. Agronomy, Inc. (1982), Cdn. Soc. Soil Sci. (1978)
Non-filterable Residue (TSS) (water)	Gravimetric, (105°C dried), EPA (1979) method 160.2, APHA (1989) method 2540D&E
Chlorophyll A (water)	Filtered, pigments extracted, measured spectrophotometrically, APHA (1989) method 10200H
Biochemical Oxygen Demand (water)	Incubation, EPA (1979) method 405.1, APHA (1989) method 5210B
Total Phosphorous as Phosphorous (water)	Autoclaved, prepared by automated system, measured spectrophotometrically, EPA (1979) method 365.1, Technicon Instruments Corp. (1966)
Testosterone, 17b-estradiol, (blood serum)	Incubation, cooling, vortexing, centrifuging, scintillation 17a, 20b-dihydroxyprogesteroneand counting, Van Der Kraak method, Univ. of Guelph
White/Red blood cell counts (whole blood)	Blood smear, manual count
Total hemoglobin (whole blood)	Milton Roy Spectronic Model 21 spectrophotometer, Sigma Diagnostics, Procedure No. 525.
Glucose (blood plasma)	Enzymatic assay, incubation, Milton Roy Spectronic Model 21 spectrophotometer, Sigma Diagnostic Procedure No. 315
Protein (blood plasma)	Milton Roy Spectronic Model 21 spectrophotometer, Sigma Diagnostic Procedure No. 610
Lactate (blood plasma)	Enzymatic assay, Milton Roy Spectronic Model 21 spectrophotometer, Sigma Diagnostic Procedure No. 735

Table 3.3-2

General Description of Analytical Methods for All Laboratory Analyses

Benzo-a-pyrene (bile)	Homogenizing, Zeiss PMQ-3 spectrofluorometer, (Ralitsch *et al.*, 1993)
Naphthalene (bile)	Homogenizing, Zeiss PMQ-3 spectrofluorometer, (Ralitsch *et al.*, 1993)
Ethhoxyresorufin-O-deethylase (liver)	Centrifuging, incubation, filtration, fluorometer, Addison and Payne method (1986)
AHH (liver)	Vortexing, incubation, processing, vortexing, fluorometer, Addison and Payne method (1986)
P450 (liver)	Dilution, bubbling (CO), spectrophotometer, Stegeman, Binder and Orren method (1979)

Table 3.6-1

Fish Species Names and Codes

SPECIES COMMON NAME	SCIENTIFIC NAME	CODE
Arctic Grayling	*Thymallus arcticus*	ARGR
Brassy Minnow	*Hybognathus hankinsoni*	BRMN
Brook Stickleback	*Culaea inconstans*	BRST
Bull Trout	*Salvelinus confluentus*	BLTR
Burbot	*Lota lota*	BURB
Cisco	*Coregonus artedi*	CISC
Emerald Shiner	*Notropis atherinoides*	EMSH
Fathead Minnow	*Pimephales promelas*	FTMN
Finescale Dace	*Phoxinus neogaeus*	FNDC
Flathead Chub	*Platygobio gracilis*	FLCH
Goldeye	*Hiodon alosoides*	GOLD
Iowa Darter	*Etheostoma exile*	IWDR
Lake Chub	*Couesius plumbeus*	LKCH
Lake Whitefish	*Coregonus clupeaformis*	LKWH
Longnose Dace	*Rhinichthys cataractae*	LNDC
Longnose Sucker	*Catostomus catostomus*	LNSC
Mountain Whitefish	*Prosopium williamsoni*	MNWH
Ninespine Stickleback	*Pungitius pungitius*	NNST
Northern Pike	*Esox lucius*	NRPK
Northern Redbelly Dace	*Phoxinus eos*	NRDC
Pearl Dace	*Semotilus margarita*	PRDC
Slimy Sculpin	*Cottus cognatus*	SLSC
Spoonhead Sculpin	*Cottus ricei*	SPSC
Spottail Shiner	*Notropis hudsonius*	SPSH
Trout Perch	*Percopsis omiscomaycus*	TRPR
Walleye	*Stizostedion vitreum*	WALL
White Sucker	*Catostomus commersoni*	WHSC
Yellow Perch	*Perca flavescens*	YLPR
Unidentified		UNID

TABLE 4.1-1

Water Quality of the Athabasca River

Parameter	Units	Above Ft.McMurray (1985-1995)*				Above Lease 19 (1995)			Below Lease 25 (1995)	
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Spring	Summer
Conventional Parameters and Nutrients										
pH		8.0	8.1	8.1	7.9	7.8	7.6	7.8	7.9	7.6
Total Dissolved Solids	mg/L	223	127	181	251	141	120	146	145	123
Non-Filterable Residue	mg/L	14	55	6	2	19	624	4	23	676
Dissolved Organic Carbon	mg/L	7.6	3.9	5.2	7.3	7.1	16.7	9.2	7.6	16.1
Hydrocarbons, Recoverable	mg/L	--	--	--	--	<1	1	<1	<1	<1
Oil and Grease	mg/L	0.3	0.2	0.2	0.2	--	--	--	--	--
Total Ammonia	mg/L	0.02	<0.01	0.01	0.04	<0.01	0.04	<0.01	<0.01	0.04
Total Phosphorus	mg/L	0.064	0.045	0.016	0.019	0.048	0.390	0.028	0.040	0.440
Metals (Total)										
Aluminum	mg/L	0.02	0.60	0.08	0.03	0.17	8.64	0.11	0.15	10.10
Arsenic	mg/L	0.0004	0.0008	0.0008	0.0005	0.0006	0.0070	0.0005	0.0008	0.0070
Cadmium	mg/L	<0.001	0.001	<0.001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003
Iron	mg/L	0.23	1.89	0.78	0.2	0.43	17.90	0.91	0.43	19.40
Mercury	µg/L	<0.1	0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	0.002	0.001	0.002	0.001	<0.003	<0.003	<0.003	0.004	<0.003
Vanadium	mg/L	0.003	0.004	0.003	0.002	<0.002	0.009	0.003	0.004	0.015
Zinc	mg/L	0.005	0.008	0.009	0.010	0.019	0.085	0.017	0.019	0.095
Organics										
Total PAHs	µg/L	--	--	--	--	ND	ND	ND	0.05	ND
Naphthenic Acids	mg/L	--	--	--	--	<1	<1	<1	<1	<1
Bacteria										
Total Coliforms	#/100 mL	68	24	44	28	--	--	--	--	--
Fecal Coliforms	#/100 mL	<4	10	14	4	--	--	--	--	--
Toxicity										
Microtox IC50	%	--	--	--	--	>100	>100	>100	>100	>100

NOTES:

* Median values; Data from NAQUADAT

ND = Not detected

-- = Not analyzed

TABLE 4.1-2

Water Quality of the Steepbank River

Parameter	Units	Near Mouth (1980-1989)*		At Mouth (1995)**			At Lease 19 Border (1995)		
		Spring	Winter	Spring	Summer	Fall	Spring	Summer	Fall
Conventional Parameters and Nutrients									
pH		8.2	7.8	7.9	7.9	7.8	7.4	7.7	7.7
Total Dissolved Solids	mg/L	342	355	134	100	127	111	87	115
Non-Filterable Residue	mg/L	--	5	<0.4-11	3	<0.4-1	<0.4	4	<0.4
Dissolved Organic Carbon	mg/L	12.6	12.5	16.3	23.1	23.4	15.7	23.3	22.6
Oil and Grease	mg/L	--	0.4	--	--	--	--	--	--
Hydrocarbons, Recoverable	mg/L	--	--	<1-1	<1	<1	1	2	<1
Total Ammonia	mg/L	0.06	0.06	<0.01-0.01	0.08	<0.01-0.02	0.02	0.07	0.03
Total Phosphorus	mg/L	0.059	0.074	0.038	0.030	0.043	0.057	0.041	0.038
Metals (Total)									
Aluminum	mg/L	0.01	0.07	<0.01	0.03	0.05	<0.01	0.05	0.02
Arsenic	mg/L	0.0006	--	0.0003	0.0004	<0.0002-0.0002	0.0004	0.0004	<0.0002
Cadmium	mg/L	0.002	--	<0.003-0.003	<0.003-0.003	<0.003	<0.003	0.005	<0.003
Iron	mg/L	0.83	0.81	0.43	0.65	0.71	0.81	0.74	0.57
Mercury	μg/L	<0.0001	<0.0001	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	0.003	--	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Vanadium	mg/L	0.005	<0.001	<0.002-0.003	0.004	<0.002-0.003	0.004	0.004	<0.002
Zinc	mg/L	0.012	0.010	0.042	0.038	0.015	0.162	0.029	0.012
Organics									
Naphthenic Acids	mg/L	--	--	<1	<1	<1	<1	<1	<1
Total PAHs	μg/L	--	--	ND	ND	0.02	--	--	--
Bacteria									
Total Coliforms	#/100 mL	--	0	--	--	--	--	--	--
Fecal Coliforms	#/100 mL	--	6	--	--	--	--	--	--
Toxicity									
Micrototx IC50	%	--	--	>100	>100	>100	>100	>100	>100

NOTES:
ND = Not detected
-- = Not analyzed
* Median values; Data from NAQUADAT
** Mean of three measurements; range shown if at least one value was below the detection limit

Table 4.1-3

Water Quality at the Mouths of Athabasca River Tributaries in 1995

Parameter	Units	McLean Cr. at Mouth			Wood Cr. at Mouth			Leggett Cr. at Mouth	
		Spring	Summer	Fall	Spring	Summer	Fall	Summer	Fall
Conventional Parameters and Major Ions									
pH		7.73	8.15	7.96	7.86	8.18	8.08	7.6	7.4
Total Dissolved Solids	mg/L	339	156	167	328	191	207	167	188
Non-Filterable Residue (TSS)	mg/L	46	17	1	9	87	5	10	211
Dissolved Organic Carbon	mg/L	12	21.9	21.4	12.3	27.5	23	25.7	26.2
Hydrocarbons, Recoverable	mg/L	<1	<1	<1	<1	9	<1	<1	<1
Total Ammonia Nitrogen	mg/L	0.03	0.05	<0.01	0.01	<0.01	<0.01	0.03	0.03
Total Phosphorus	mg/L	0.048	0.033	0.014	0.037	0.049	0.021	0.019	0.196
Metals (Total)									
Aluminum	mg/L	0.29	0.28	0.06	0.06	1.12	0.09	0.14	1.89
Arsenic	mg/L	0.0002	0.0003	0.0008	0.0003	0.0015	0.0003	0.0005	0.0012
Cadmium	mg/L	<0.003	0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Iron	mg/L	0.89	0.77	0.41	0.64	2.22	0.38	0.76	4.81
Mercury	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/L	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	0.004
Vanadium	mg/L	<0.002	0.007	<0.002	<0.002	<0.002	<0.002	0.006	0.008
Zinc	mg/L	0.023	0.066	0.024	0.032	0.043	0.023	0.038	0.035
Organics									
Naphthenic Acids	mg/L	<1	<1	<1	<1	<1	<1	<1	<1
Toxicity									
Microtox IC50	%	>100	>100	>100	>100	>100	>100	>100	>100

TABLE 4.1-4

Water Quality of Poplar Creek

Parameter	Units	Near Mouth (1980-84)*				At Mouth (1995)		
		Spring	Summer	Fall	Winter	Spring	Summer	Fall
Conventional Parameters and Nutrients								
pH		7.8	8.1	8.0	8.0	7.9	8.3	8
Total Dissolved Solids	mg/L	270	253	259	471	273	203	206
Non-Filterable Residue	mg/L	9	6	6	8	2	4	117
Dissolved Organic Carbon	mg/L	20.9	26.6	27.4	26.8	21.9	22.5	25.3
Oil and Grease	mg/L	0.4	0.4	0.6	1.3	--	--	--
Hydrocarbons, Recoverabl	mg/L	--	--	--	--	<1	<1	<1
Total Ammonia	mg/L	0.05	0.05	0.05	0.17	0.02	0.07	0.02
Total Phosphorus	mg/L	0.051	0.040	0.041	0.040	0.031	0.023	0.043
Metals (Total)								
Aluminum	mg/L	0.07	0.16	0.05	0.27	0.03	0.1	0.31
Arsenic	mg/L	0.0010	0.0018	0.0007	--	0.0005	0.0005	0.0005
Cadmium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.003	<0.003	0.003
Iron	mg/L	0.66	0.71	0.96	0.72	0.42	0.71	1.10
Mercury	µg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.05	<0.05	<0.05
Molybdenum	mg/L	<0.001	<0.001	<0.001	--	<0.003	<0.003	<0.003
Vanadium	mg/L	0.001	0.001	0.001	<0.001	<0.002	<0.002	0.004
Zinc	mg/L	0.004	0.003	0.009	0.006	0.012	0.080	0.038
Organics								
Naphthenic Acids	mg/L	--	--	--	--	6	<1	<1
Toxicity								
Microtox IC50	%	--	--	--	--	>100	>100	>100

NOTE:
* Median values; Data from NAQUADAT
-- = Not analyzed

TABLE 4.1-5

Water Quality of Shipyard Lake in 1995

Parameter	Units	Outlet of Shipyard Lake		
		Spring	Summer	Fall
Conventional Parameters and Nutrients				
pH		7.6	7.8	7.6
Total Dissolved Solids	mg/L	268	190	196
Non-Filterable Residue	mg/L	30	2	79
Dissolved Organic Carbon	mg/L	25.5	25.4	25.6
Hydrocarbons, Recoverabl	mg/L	<1	<1	<1
Total Ammonia	mg/L	0.06	0.06	0.03
Total Phosphorus	mg/L	0.075	0.030	0.102
Metals (Total)				
Aluminum	mg/L	0.30	0.03	1.09
Arsenic	mg/L	0.0018	0.0008	0.001
Cadmium	mg/L	0.003	<0.003	<0.003
Iron	mg/L	3.28	1.16	3.29
Mercury	µg/L	<0.05	<0.05	<0.05
Molybdenum	mg/L	0.003	<0.003	<0.003
Vanadium	mg/L	0.002	0.002	<0.002
Zinc	mg/L	0.047	0.051	0.039
Organics				
Naphthenic Acids	mg/L	<1	<1	<1
Toxicity				
Microtox IC50	%	>100	>100	>100

TABLE 4.1-6

Water Quality of the Muskeg River

Parameter	Units	At Mouth (1995)*			Above Stanley Creek					
					1995		1980-89**			
		Spring	Summer	Fall	Spring	Summer	Spring	Summe	Fall	Winter
Conventional Parameters and Nutrients										
pH		8.0	8.0	7.9	6.9	7.4	7.4	7.5	7.6	7.7
Total Dissolved Solids	mg/L	167	151	169	187	147	163	211	167	300
Non-Filterable Residue	mg/L	<0.4	<0.4-6	2	2	1	4	5	4	16
Dissolved Organic Carbo	mg/L	15.9	25.0	24.1	16.8	23.3	18.0	24.5	24.8	23.0
Oil and Grease	mg/L	--	--	--	--	--	0.8	1.1	0.5	0.75
Hydrocarbons, Recovera	mg/L	3	<1	<1	<1	<1	--	--	--	--
Total Ammonia	mg/L	<0.01	<0.01	0.04	--	--	0.07	0.14	0.07	0.44
Total Phosphorus	mg/L	0.034	0.027	0.022	0.034	0.095	0.054	0.058	0.036	0.100
Metals (Total)										
Aluminum	mg/L	<0.01-0.01	0.09	0.08	<0.01	0.1	0.04	0.05	0.01	0.03
Arsenic	mg/L	0.0002	0.0002	0.0002	--	--	0.0005	<0.0002	0.0005	0.0004
Cadmium	mg/L	<0.003	<0.003	0.003-0.00	<0.003	<0.003	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.53	0.84	1.14	1.95	0.91	1.48	1.44	1.05	3.23
Mercury	µg/L	<0.05	<0.05	<0.05	--	--	<0.1	<0.1	<0.1	<0.1
Molybdenum	mg/L	<0.003-0.004	<0.003	0.003-0.00	0.004	<0.003	--	--	--	--
Vanadium	mg/L	<0.002	<0.002-0.00	0.002-0.00	0.003	<0.002	<0.001	<0.001	<0.001	0.001
Zinc	mg/L	0.007	0.048	0.021	0.054	0.025	0.004	0.003	0.007	0.003
Organics										
Naphthenic Acids	mg/L	<1	<1	<1	<1	<1	--	--	--	--
Total PAHs	µg/L	ND	ND	ND	--	--	--	--	--	--
Bacteria										
Total Coliforms	#/100mL	--	--	--	--	--	38	33	4	11
Fecal Coliforms	#/100mL	--	--	--	--	--	1	9	2	0
Toxicity										
Microtox IC50	%	>100	>100	>100	>100	>100	--	--	--	--

NOTES:

ND = Not detected

-- = Not analyzed

* Mean of two measuements; both numbers shown if one was below the detection limit

** Median values; Data from NAQUADAT and R.L. & L. (1989)

TABLE 4.1-7

Water Quality of Tributaries of the Muskeg River in 1995

Parameter	Units	North Muskeg Cr.			Jackpine Cr. at Mouth			Muskeg Cr. at Mouth			Stanley Cr. at Mouth		Iyinimin Cr.		Blackfly Cr.	
		Spring	Summe	Fall	Spring	Summer	Fall	Spprin	Summe	Fall	Spring	Summer	Summe	Fall	Summer	Fall
Conventional Parameters and Nutrients																
pH		6.9	7.0	7.1	7.2	7.6	7.6	7.1	7.4	7.5	6.8	7.0	7.3	7.6	7.7	7.6
Total Dissolved Solids	mg/L	97	84	96	116	109	127	124	169	166	125	143	69	102	108	135
Non-Filterable Residue	mg/L	<0.4	6	<0.4	<0.4	24	<0.4	1	15	3	<0.4	2	171	<0.4	77	2
Dissolved Organic Carb	mg/L	19.8	23.8	22.6	17.8	28.1	26.7	19.9	26.9	24.0	10.6	23.5	35.4	26.8	33.2	29.6
Hydrocarbons, Recover	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2	<1
Total Ammonia	mg/L	<0.01	--	--	0.01	<0.01	0.01	--	--	--	--	--	--	--	--	--
Total Phosphorus	mg/L	0.030	0.022	0.02	0.051	0.034	0.010	0.025	0.024	0.04	0.033	0.215	0.042	0.040	0.033	0.04
Metals (Total)																
Aluminum	mg/L	0.05	0.09	<0.01	0.05	0.20	0.04	0.04	0.07	0.04	0.02	0.06	1.13	0.07	1.20	0.10
Arsenic	mg/L	--	--	--	0.0008	0.0004	0.0002	--	--	--	--	--	--	--	--	--
Cadmium	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0
Iron	mg/L	0.35	0.21	0.13	0.77	0.87	0.58	0.72	0.70	1.74	0.56	1.43	2.69	0.91	2.45	0.76
Mercury	µg/L	--	--	--	<0.05	<0.05	<0.05	--	--	--	--	--	--	--	--	--
Molybdenum	mg/L	0	<0.003	<0.00	0.006	<0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.01	<0.003	0.01
Vanadium	mg/L	0.01	0.003	<0.00	0.011	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0	0.007	0
Zinc	mg/L	0.02	0.100	0.02	0.009	0.433	0.186	0.025	0.015	0.01	0.127	0.030	0.031	0.03	0.039	0.02
Organics																
Naphthenic Acids	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PAH	µg/L	--	--	--	ND	ND	ND	--	--	--	--	--	--	--	--	--
Toxicity																
Microtox IC50	%	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100

NOTES:

-- = Not analyzed

ND = Not detected

TABLE 4.1-8

Water Quality of Tributaries of the Muskeg River in 1985-89*

Parameter	Units	North Muskeg Cr.				Jackpine Cr. at Mouth			Muskeg Cr. at Mouth			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Spring	Summe	Fall	Winter
Conventional Parameters and Nutrients												
pH		7.5	8.0	7.4	7.6	7.8	8.0	7.8	7.7	8.1	7.7	7.9
Total Dissolved Soli	mg/L	127.5	91	95.5	135	91	147	122	87	122	114	160
Non-Filterable Resid	mg/L	1.5	2.5	1.3	3.6	<0.4	0.5	1.2	2.0	3.5	0.9	4.4
Oil and Grease	mg/L	<0.1-0.7	0.4	<0.1-1.0	0.6	<0.1	<0.1	0.4	<0.1	0.1	<0.1-0.7	1.1
Total Ammonia	mg/L	0.52	0.08	0.04	0.74	0.03	0.05	0.03	0.08	0.05	0.04	0.36
Total Phosphorus	mg/L	0.024	0.028	0.028	0.030	0.017	0.029	0.022	0.022	0.037	0.028	0.051
Metals (Total)												
Aluminum	mg/L	<0.01-0.04	0.01	<0.01	0.02	0.02	0.02	<0.01	<0.01	0.02	0.02	0.03
Arsenic	mg/L	0.0003	<0.0002	0.0003	0.0005	0.0004	0.0003	0.0002	0.0003	0.0002	0.0003	0.0004
Cadmium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	4.68	0.28	0.27	0.65	0.35	0.93	0.57	0.59	0.6	0.34	1.2
Mercury	µg/L	<0.05	<0.05	<0.05-<0.1	<0.1	<0.05	<0.05	<0.05	<0.05	0.1	<0.05-<0.1	<0.1
Vanadium	mg/L	<0.001	<0.001	<0.001	0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.009	<0.001	0.012	0.004	0.001	0.001	0.002	0.002	<0.001	0.014	0.005

NOTE: Median values; Data from R.L. & L. (1989)

TABLE 4.1-8 (Continued)

Parameter	Units	Iyinimin Creek				Blackfly Creek			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Conventional Parameters and Nutrients									
pH		8.0	8.1	7.8	8.3	7.9	7.2	7.9	8.0
Total Dissolved Soli	mg/L	102	190	124.5	400	95	152	125	260
Non-Filterable Resid	mg/L	5.2	7.6	4.9	29.0	4.0	4.5	3.9	8.8
Oil and Grease	mg/L	<0.1	0.5	<0.1-1.0	0.6	<0.1	0.1	<0.1-0.5	0.6
Total Ammonia	mg/L	0.05	0.07	0.04	0.14	0.04	0.05	0.04	0.13
Total Phosphorus	mg/L	0.020	0.044	0.029	0.135	0.021	0.026	0.031	0.063
Metals (Total)									
Aluminum	mg/L	0.04	0.08	0.05	0.13	0.02	0.02	0.02	0.05
Arsenic	mg/L	0.0007	0.0100	0.0008	0.0015	0.0006	0.0009	0.0006	0.0015
Cadmium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.52	1.44	0.80	3.20	0.53	0.84	0.52	3.29
Mercury	µg/L	<0.05	<0.05	<0.05-<0.1	<0.1	<0.05	<0.05	<0.05-<0.	<0.1
Vanadium	mg/L	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.003	0.066	0.006	0.004	0.002	<0.001	0.007	0.006

TABLE 4.1-9

Water Quality of Kearl Lake

Dissolved Oxygen and Temperature Profile Data

Parameter	1995			1988-89*			
	Spring	Summer	Fall	Spring	Summer	Fall	Winter
Dissolved Oxygen (mg/L)							
Surface	8.8	10.7	12.4	11.7	10.2	14.1	0.0
0.5 m		10.5	12.4	11.7	10.2	14.2	
1.0 m		10.1	12.4	11.6	10.0	14.0	
1.5 m		9.3	12.4	11.6	10.0	14.0	
2.0 m		8.1	12.2				
Temperature (°C)							
Surface	13.0	17.3	12.5	16.0	20.5	6.5	0.0
0.5 m		16.9		16.0	20.0	6.0	
1.0 m		16.6		16.0	19.7	5.5	
1.5 m		15.8		16.2	19.0	5.5	
2.0 m		15.0					

Water Chemistry

Parameter	Units	1995		1983-1989**	
		Summer	Fall	Open Water Season	Winter
Conventional Parameters and Nutrients					
pH		7.9	7.6	8.3	7.2
Total Dissolved Solids	mg/L	93	98	95	172
Non-Filterable Residue	mg/L	1	1	2.8	0.5
Dissolved Organic Carbon	mg/L	21.2	23.1	28.6	--
Oil and Grease	mg/L	--	--	<0.1	27.9
Hydrocarbons, Recoverab	mg/L	<1	<1	--	--
Total Phosphorus	mg/L	0.016	0.030	0.024	0.036
Metals (Total)					
Aluminum	mg/L	<0.01	<0.01	<0.02	<0.01
Arsenic	mg/L	--	--	<0.0002	0.0002
Cadmium	mg/L	<0.003	<0.003	<0.001	<0.001
Iron	mg/L	0.08	0.11	0.11	2.40
Mercury	μg/L	--	--	<0.1	<0.05
Molybdenum	mg/L	<0.003	0.003	<0.001	--
Vanadium	mg/L	<0.002	<0.002	<0.002	<0.001
Zinc	mg/L	0.016	0.011	0.005	0.046
Organics					
Naphthenic Acids	mg/L	<1	<1	--	--
Toxicity					
Microtox IC50	%	>100	>100	--	--

NOTES:
-- = Not analyzed
* Data from R.L. & L. (1989)
**Median values, Data from NAQUADAT and R.L. & L. (1989)

TABLE 4.1-10

Sediment Quality of the Athabasca River in 1994 and 1995

Parameter	Units	1994*			1995		
		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
Total Organic Carbon	Weight %	1.07	1.31	0.49-1.61	1.39	0.49	1.02
Hydrocarbons, Recoverable	mg/kg	--	--	--	2160	450	703
Total PAHs	mg/g	0.09	0.14	ND-0.13	0.66	0.07	0.13
Metals							
Aluminum	mg/g	6420	7670	4250-7740	3910	3730	4890
Arsenic	mg/g	1.7	2.1	1.3-2	0.6	0.9	1
Cadmium	mg/g	<0.3	<0.3	<0.3	<0.3	0.6	0.5
Iron	mg/g	13600	16400	10200-14800	11000	9820	13100
Mercury	µg/kg	23	25	<20-27	25	36	30
Molybdenum	mg/g	1	1.2	0.9-1.4	<0.3	0.4	0.5
Vanadium	mg/g	18.8	19.4	14-19.8	14.7	12.8	14.5
Zinc	mg/g	35.6	43.6	26.3-46.1	29.9	27.6	39.6
Toxicity							
Microtox Screen	% Control	73-99	118	91-120	--	--	--

NOTES:
* Golder Associates (1994)
** Tar Island Dyke, Suncor
-- = Not analyzed
ND = Not detected

TABLE 4.1-11

Sediment Quality of the Steepbank River in 1995

Parameter	Units	At Lease 19 Border		At Mouth	
		Spring	Fall	Spring	Fall
Total Organic Carbon	Weight %	1.36	2.17	2.12	3.51
Hydrocarbons, Recoverable	mg/kg	154	247	5720	17833
Total PAHs	mg/g	--	--	0.73-1.65	37.76-76.81
Metals					
Aluminum	mg/g	3950	4990	3333	2330
Arsenic	mg/g	1.1	1.7	1.0	1.2
Cadmium	mg/g	<0.3	<0.3	0.3	<0.3
Iron	mg/g	10400	12600	10237	7280
Mercury	μg/kg	<20	28	<20	<20
Molybdenum	mg/g	<0.3	1	<0.3	0.9
Vanadium	mg/g	13.0	15.4	13.0	12.1
Zinc	mg/g	22.8	30.5	24.2	15.7

NOTE:
-- = Not analyzed

TABLE 4.1-12

Porewater Chemistry and Toxicity in the Athabasca, Steepbank and Muskeg Rivers and Jackpine Creek Compared with Natural and Process-Affected Porewater

Site or Water Type	Sodium (mg/L)	Total Dissolved Solids (mg/L)	Naphthenic Acids (mg/L)	Total Ammonia (mg/L)	Total PAHs (µg/L)	Microtox Screen (% Control)	Microtox IC50 (%)
Athabasca R. 1 km above TID*, West Bank	1210	3220	17	0.78	0.04	--	>100
Athabasca River at TID, West Bank	12.8	259	<1	0.58	ND	--	>100
Athabasca River at TID, East Bank	423	1730	<1	0.59	ND	--	>100
Steepbank River at Lease 19 Border	11.5-26.1	125-228	<1-5	0.03-0.06	ND-0.03	--	>100
Steepbank River near Lot 3	380-5120	1370-14500	3-16	0.5-3.01	1.21-33.75	--	>100
Steepbank River at Mouth	12.6-26.5	240-374	2-4	0.47-0.62	ND-0.84	--	>100
Muskeg River at Mouth	11	130	<1	<0.01	ND	--	>100
Jackpine Creek	10.5	168	<1	0.01	ND	--	>100
Natural Porewater**	11.6-148	192-954	<1-13	0.01-0.72	ND-1	100	--
Intermediate Porewater**	62.1-306	234-1422	7-34	0.07-1.70	0.13-3	100	--
Process-affected Porewater**	100-336	309-948	19-68	0.44-4.51	ND-9.12	29-100	--

NOTES:
* Tar Island Dyke, Suncor
** Data from Golder Associates (1995)
-- = Not analyzed
ND = Not Detected

TABLE 4.2-1

PHYSICAL CHARACTERISTICS AND HABITAT ATTRIBUTES OF THE SAMPLING SITES IN THE ATHABASCA RIVER

Station	Substratum composition (%)[1]						Current velocity (m/s)	Mean depth[2] (cm)	Water temp. (°C)	Dissolved oxygen (mg/L)	Turbidity[3] (NTU)	pH	Conductivity (mS/cm, 25°C)	Redox (mV)
	S/C	FS/VFS	CS/MS	VCS	FG	CG								
AB001	22	75	3	0	0	0	0.460	94	6.4	11.8	6.0	7.54	324	113
AB002	4	36	60	1	0	0	0.038	-	2.9	12.8	7.0	7.53	245	120
AB003	33	66	1	0	0	0	0.416	84	6.7	12.2	2.1	7.87	330	117
AB004	20	65	15	0	0	0	0.371	87	2.9	12.8	6.6	7.67	255	118
AB005	10	40	43	4	3	0	0.207	85	3.8	12.5	7.2	7.92	309	92
AB006	8	14	79	0	0	0	0.162	84	3.3	12.7	6.6	7.75	262	95
AB007	5	92	2	0	0	0	0.336	106	4.3	12.6	6.0	7.93	307	67
AB008	3	5	91	2	1	0	0.227	97	4.0	12.6	7.6	7.79	269	95
AB009	25	71	4	0	0	0	0.048	116	4.2	12.5	8.1	7.84	308	66
AB010	1	9	30	7	54	0	0.361	82	2.8	12.8	6.6	7.69	256	77
AB011	12	87	1	0	0	0	0.282	109	4.0	12.5	6.9	7.72	306	68
AB012	54	45	2	0	0	0	0.009	96	2.4	12.5	6.5	7.16	282	96

[1] S/C = silt/clay; FS/VFS = fine sand/very fine sand; CS/MS = coarse sand/medium sand; VCS = very coarse sand; FG = fine gravel; CG = coars

[2] Average depth of 4 replicates at each Station, except Station AB002 which was not found.

[3] Turbidity measurements are based on analysis of additional water samples (see Methods).

TABLE 4.2-2

MEAN TOTAL ABUNDANCE (no./basket) AND RELATIVE ABUNDANCE OF DOMINANT BENTHIC INVERTEBRATE TAXA COLLECTED IN THE ATHABASCA RIVER USING ARTIFICIAL SUBSTRATES

Station AB001			
Taxon	**Mean**	**St. Dev.**	**%**
Isoperla	308.8	450.4	30.9
Micropsectra	152.9	145.6	15.3
Tvetenia	102.8	160.8	10.3
Simulium	101.5	121.5	10.2
Ephemerella inermis/infrequens	61.3	92.1	6.1
Baetis tricaudatus	61.2	81.5	6.1
Capniidae-early instar	57.6	70.6	5.8
Taenionema	45.3	50.5	4.5
Hydropsyche	19.3	28.1	1.9
Heptagenia	14.7	7.3	1.5
Rhithrogena	13.6	14.4	1.4
Heptageniidae-early instar	10.2	13.7	1.0
Total Density (no. per basket)	949.1	1236.5	95.0
Total Taxa	21.7	2.3	

Station AB003			
Taxon	**Mean**	**St. Dev.**	**%**
Micropsectra	1452.0	1062.7	49.9
Tvetenia	390.3	513.0	13.4
Simulium	257.3	350.4	8.8
Isoperla	232.3	210.4	8.0
Baetis tricaudatus	80.0	89.9	2.8
Parametriocnemus	59.0	41.5	2.0
Heptagenia	57.3	58.6	2.0
Thienemannimyia	55.0	49.7	1.9
Ephemerella inermis/infrequens	43.7	57.9	1.5
Taenionema	40.3	69.0	1.4
Orthocladiinae-early instar	29.7	12.5	1.0
Total Density (no. per basket)	2697.0	2515.5	92.7
Total Taxa	23.0	2.6	

Station AB004			
Taxon	**Mean**	**St. Dev.**	**%**
Isoperla	610.6	583.9	29.3
Micropsectra	373.9	299.0	17.9
Tvetenia	198.4	226.1	9.5
Capniidae-early instar	90.6	74.1	4.3
Ephemerella inermis/infrequens	87.4	71.6	4.2
Rheotanytarsus	86.0	71.0	4.1
Heptagenia	82.8	60.1	4.0
Taeniopteryx	82.1	72.1	3.9
Simulium	70.9	94.9	3.4
Baetis tricaudatus	66.6	68.3	3.2
Hydropsyche	58.9	66.1	2.8
Orthocladius Complex	39.6	51.6	1.9
Taenionema	32.9	30.0	1.6
Thienemannimyia	30.7	45.0	1.5
Leptophlebia	27.9	12.0	1.3
Orthocladiinae-early instar	25.0	21.0	1.2
Pentaneurini-early instar	21.7	33.3	1.0
Total Density (no. per basket)	1986.1	1879.9	95.1
Total Taxa	28.7	2.9	

Station AB005			
Taxon	**Mean**	**St. Dev.**	**%**
Micropsectra	647.2	553.8	33.1
Isoperla	537.8	301.7	27.5
Tvetenia	142.8	105.3	7.3
Capniidae-early instar	110.7	81.6	5.7
Taenionema	70.3	40.4	3.6
Orthocladius Complex	66.5	47.3	3.4
Ephemerella inermis/infrequens	62.0	41.1	3.2
Heptagenia	57.7	48.5	2.9
Baetis tricaudatus	49.7	36.5	2.5
Orthocladiinae-early instar	43.2	47.2	2.2
Simulium	38.7	28.7	2.0
Tanytarsini-early instar	25.7	30.4	1.3
Total Density (no. per basket)	1852.2	1362.7	94.7
Total Taxa	23.0	1.7	

Station AB006			
Taxon	**Mean**	**St. Dev.**	**%**
Micropsectra	147.6	88.7	34.8
Isoperla	84.1	42.7	19.8
Heptagenia	44.9	18.6	10.6
Taenionema	28.7	12.1	6.8
Tvetenia	24.3	0.6	5.7
Baetis tricaudatus	12.9	2.4	3.0
Taeniopteryx	10.6	10.7	2.5
Ephemerella inermis/infrequens	10.1	9.4	2.4
Capniidae-early instar	9.7	3.2	2.3
Simulium	9.7	12.7	2.3
Orthocladiinae-early instar	9.1	11.1	2.2
Leptophlebia	5.9	1.8	1.4
Orthocladius Complex	5.5	2.8	1.3
Total Density (no. per basket)	403.2	216.8	95.0
Total Taxa	19.7	3.1	

Station AB007			
Taxon	**Mean**	**St. Dev.**	**%**
Isoperla	1134.5	217.1	36.3
Micropsectra	530.5	131.3	17.0
Tvetenia	344.0	211.0	11.0
Ephemerella inermis/infrequens	255.5	54.8	8.2
Capniidae-early instar	155.5	37.7	5.0
Simulium	114.5	47.3	3.7
Taenionema	75.5	36.5	2.4
Baetis tricaudatus	72.5	33.3	2.3
Heptagenia	72.5	39.2	2.3
Hydropsyche	47.0	24.4	1.5
Isogenoides	41.5	15.3	1.3
Thienemannimyia	38.0	21.1	1.2
Orthocladiinae-early instar	37.0	26.2	1.2
Total Density (no. per basket)	2918.5	895.3	93.4
Total Taxa	27.0	3.0	

TABLE 4.2-2 (Page 2 of 2)

Station AB008			
Taxon	Mean	St. Dev.	%
Isoperla	1002.0	528.0	42.4
Micropsectra	313.0	307.0	13.3
Tvetenia	259.0	353.9	11.0
Ephemerella inermis/infrequens	225.0	148.1	9.5
Baetis tricaudatus	71.0	47.8	3.0
Rheotanytarsus	63.0	70.5	2.7
Heptagenia	57.0	27.5	2.4
Simulium	52.0	19.5	2.2
Capniidae-early instar	45.0	55.1	1.9
Hydropsyche	44.0	25.0	1.9
Taenionema	39.0	10.4	1.7
Pentaneurini-early instar	33.0	57.2	1.4
Orthocladiinae-early instar	28.0	45.9	1.2
Total Density (no. per basket)	2231.0	1696.0	94.5
Total Taxa	23.0	1.7	

Station AB009			
Taxon	Mean	St. Dev.	%
Isoperla	323.5	60.9	52.2
Micropsectra	126.8	49.7	20.5
Paracladopelma	52.9	46.3	8.5
Capniidae-early instar	38.9	6.9	6.3
Pentaneurini-early instar	9.9	3.6	1.6
Orthocladiinae-early instar	9.5	14.3	1.5
Heptagenia	8.7	1.9	1.4
Total Density (no. per basket)	570.1	183.7	92.1
Total Taxa	25.3	3.1	

Station AB010			
Taxon	Mean	St. Dev.	%
Isoperla	202.9	161.1	30.9
Simulium	84.9	66.4	12.9
Ephemerella inermis/infrequens	83.6	68.4	12.7
Tvetenia	72.5	60.7	11.0
Hydropsyche	38.2	50.6	5.8
Heptagenia	26.5	17.6	4.0
Taenionema	26.3	10.9	4.0
Baetis tricaudatus	25.2	18.9	3.8
Taeniopteryx	21.1	17.8	3.2
Capniidae-early instar	15.7	20.7	2.4
Micropsectra	10.7	9.3	1.6
Rheotanytarsus	7.9	7.1	1.2
Total Density (no. per basket)	615.5	509.5	93.8
Total Taxa	20.3	6.0	

Station AB011			
Taxon	Mean	St. Dev.	%
Isoperla	566.4	360.8	63.5
Ephemerella inermis/infrequens	40.4	21.3	4.5
Capniidae-early instar	39.6	21.5	4.4
Micropsectra	35.8	19.4	4.0
Thienemannimyia	31.5	25.6	3.5
Simulium	31.4	9.0	3.5
Taenionema	30.5	3.9	3.4
Baetis tricaudatus	20.9	17.5	2.3
Tvetenia	11.1	6.8	1.2
Heptagenia	11.0	1.8	1.2
Orthocladius Complex	8.9	5.5	1.0
Total Density (no. per basket)	827.7	493.0	92.8
Total Taxa	26.7	0.6	

Station AB012			
Taxon	Mean	St. Dev.	%
Micropsectra	277.0	67.5	58.2
Leptophlebia	59.0	32.8	12.4
Heptagenia	27.0	19.0	5.7
Heterotrissocladius	19.3	15.4	4.0
Isoperla	18.5	13.3	3.9
Thienemannimyia	16.8	21.1	3.5
Tubificidae	8.0	10.6	1.7
Sphaeriidae	8.0	11.4	1.7
Chironomini-early instar	5.2	7.3	1.1
Paracladopelma	5.0	4.4	1.1
Total Density (no. per basket)	443.8	202.7	93.2
Total Taxa	17.3	2.5	

TABLE 4.2-3

TOTAL ABUNDANCE (number/m^2) AND RELATIVE ABUNDANCE OF DOMINANT BENTHIC INVERTEBRATE TAXA COLLECTED IN THE ATHABASCA RIVER USING AN EKMAN GRAB

Station AB001			Station AB002		
Taxon	**Abundance**	**%**	**Taxon**	**Abundance**	**%**
Micropsectra	849.6	48.8	*Ametropus*	28.8	28.6
Isoperla	316.8	18.2	*Micropsectra*	28.8	28.6
Tubificidae	144.0	8.3	*Paracladopelma*	28.8	28.6
Simulium	100.8	5.8	Tubificidae	14.4	14.3
Polypedilum	72.0	4.1			
Capniidae-early instar	57.6	3.3			
Taenionema	43.2	2.5			
Paracladopelma	43.2	2.5			
Total Density (no./m^2)	1627.2	93.4	Total Density (no./m^2)	100.8	100.0
Total Taxa	16		Total Taxa	4	
Station AB003			**Station AB004**		
Taxon	**Abundance**	**%**	**Taxon**	**Abundance**	**%**
Ceratopogoninae	345.6	18.3	*Micropsectra*	1238.4	30.3
Tubificidae	158.4	8.4	*Polypedilum*	748.8	18.3
Polypedilum	158.4	8.4	*Isoperla*	720.0	17.6
Stempellina	144.0	7.6	*Paracladopelma*	187.2	4.6
Nematoda	100.8	5.3	*Ophiogomphus*	144.0	3.5
Acari	100.8	5.3	*Ephemerella inermis/infrequens*	144.0	3.5
Ophiogomphus	100.8	5.3	Ceratopogoninae	129.6	3.2
Dicrotendipes	86.4	4.6	Tubificidae	115.2	2.8
Dubiraphia	72.0	3.8	*Thienemannimyia*	86.4	2.1
Hemerodromia	72.0	3.8	*Taeniopteryx*	72.0	1.8
Caenis	57.6	3.1	*Hemerodromia*	72.0	1.8
Dicranota	57.6	3.1	Nematoda	43.2	1.1
Thienemannimyia	57.6	3.1	Capniidae-early instar	43.2	1.1
Cryptochironomus	43.2	2.3	Chironomini-early instar	43.2	1.1
Stempellinella	43.2	2.3	*Phaenopsectra*	43.2	1.1
Aeshna	28.8	1.5			
Brachycentrus occidentalis	28.8	1.5			
Haliplus	28.8	1.5			
Orthocladiinae-early instar	28.8	1.5			
Parametriocnemus	28.8	1.5			
Potthastia Longimana Gr.	28.8	1.5			
Tanytarsini-early instar	28.8	1.5			
Total Density (no./m^2)	1800.0	95.4	Total Density (no./m^2)	3830.4	93.7
Total Taxa	28		Total Taxa	27	
Station AB005			**Station AB006**		
Taxon	**Abundance**	**%**	**Taxon**	**Abundance**	**%**
Paracladopelma	302.4	39.6	*Micropsectra*	4464.0	65.5
Isoperla	144.0	18.9	Ceratopogoninae	633.6	9.3
Micropsectra	129.6	17.0	*Procladius*	504.0	7.4
Chernovskiia	72.0	9.4	*Chironomus*	446.4	6.6
Heptagenia	28.8	3.8	Ostracoda	129.6	1.9
Nematoda	14.4	1.9	*Cryptochironomus*	115.2	1.7
Baetis tricaudatus	14.4	1.9	Chironomidae-pupae	100.8	1.5
Taenionema	14.4	1.9	*Paracladopelma*	86.4	1.3
Chironomus	14.4	1.9			
Polypedilum	14.4	1.9			
Stempellina	14.4	1.9			
Total Density (no./m^2)	763.2	100.0	Total Density (no./m^2)	6480.0	95.1
Total Taxa	11		Total Taxa	22	

TABLE 4.2-3 (Page 2 of 2)

Station AB007

Taxon	Abundance	%
Isoperla	417.6	61.7
Baetis tricaudatus	57.6	8.5
Ephemerella inermis/infrequens	57.6	8.5
Brachycentrus occidentalis	28.8	4.3
Hydropsyche	28.8	4.3
Cryptochironomus	28.8	4.3
Tubificidae	14.4	2.1
Heptagenia	14.4	2.1
Isogenoides	14.4	2.1
Simulium	14.4	2.1
Total Density (no./m^2)	676.8	100.0
Total Taxa	10	

Station AB008

Taxon	Abundance	%
Isoperla	187.2	25.0
Micropsectra	187.2	25.0
Ceratopogoninae	115.2	15.4
Chironomus	86.4	11.5
Ephemerella inermis/infrequens	43.2	5.8
Heptagenia	28.8	3.8
Paracladopelma	28.8	3.8
Sphaeriidae	14.4	1.9
Ametropus	14.4	1.9
Chironomini-early instar	14.4	1.9
Lopescladius	14.4	1.9
Polypedilum	14.4	1.9
Total Density (no./m^2)	748.8	100.0
Total Taxa	12	

Station AB009

Taxon	Abundance	%
Micropsectra	576.0	19.8
Tubificidae	532.8	18.3
Polypedilum	432.0	14.9
Paracladopelma	374.4	12.9
Procladius	360.0	12.4
Ceratopogoninae	187.2	6.4
Monodiamesa	129.6	4.5
Isoperla	115.2	4.0
Cryptochironomus	57.6	2.0
Cryptotendipes	57.6	2.0
Chironomus	43.2	1.5
Total Density (no./m^2)	2865.6	98.5
Total Taxa	14	

Station AB010

Taxon	Abundance	%
Isoperla	100.8	23.3
Ephemerella inermis/infrequens	86.4	20.0
Hydropsyche	57.6	13.3
Ametropus	28.8	6.7
Micropsectra	28.8	6.7
Rheotanytarsus	28.8	6.7
Isogenoides	14.4	3.3
Taenionema	14.4	3.3
Cheumatopsyche	14.4	3.3
Ceratopogoninae	14.4	3.3
Hemerodromia	14.4	3.3
Simulium	14.4	3.3
Polypedilum	14.4	3.3
Total Density (no./m^2)	432.0	100.0
Total Taxa	13	

Station AB011

Taxon	Abundance	%
Isoperla	216.0	37.5
Micropsectra	144.0	25.0
Paracladopelma	86.4	15.0
Lopescladius	43.2	7.5
Ametropus	28.8	5.0
Orthocladiinae-early instar	28.8	5.0
Tubificidae	14.4	2.5
Ophiogomphus	14.4	2.5
Total Density (no./m^2)	576.0	100.0
Total Taxa	8	

Station AB012

Taxon	Abundance	%
Micropsectra	10382.4	54.3
Tubificidae	5160.3	27.0
Sphaeriidae	1823.1	9.5
Procladius	710.7	3.7
Ceratopogoninae	401.7	2.1
Cryptochironomus	309.0	1.6
Total Density (no./m^2)	18787.2	98.2
Total Taxa	10	

TABLE 4.2-4

TAXONOMIC COMPOSITION OF BENTHIC INVERTEBRATE TISSUE SAMPLES COLLECTED FROM THE ATHABASCA RIVER IN OCTOBER, 1995

Organism	Station AT003			
	Metals		Organics	
	Weight (g)	%	Weight (g)	%
Odonata	6.5	57	96.5	78
Plecoptera	5.0	43	27.0	22
Total	11.5	100	123.5	100

TABLE 4.2-5

CONCENTRATIONS OF METALS IN BENTHIC INVERTEBRATE TISSUE SAMPLES FROM THE ATHABASCA RIVER, SAMPLED IN AUGUST, 1994 AND IN OCTOBER, 1995

Parameter	Units	August 1994[1]	October 1995 Station AT003
Antimony	µg/g	-	<0.2
Aluminum	µg/g	1330	1070
Arsenic	µg/g	0.9	<20
Barium	µg/g	24	29
Beryllium	µg/g	0.1	<0.1
Boron	µg/g	12	<1
Cadmium	µg/g	<0.3	<0.3
Calcium	µg/g	5110	3030
Chromium	µg/g	64.6	10.5
Cobalt	µg/g	3.3	1.4
Copper	µg/g	15.9	45
Iron	µg/g	3170	2400
Lead	µg/g	<2	<2
Lithium	µg/g	1.8	1.3
Magnesium	µg/g	1530	1530
Manganese	µg/g	166	314
Mercury	µg/kg	78	55
Molybdenum	µg/g	6.2	0.9
Nickel	µg/g	41	8.8
Phosphorus	µg/g	5640	5620
Potassium	µg/g	6610	6640
Selenium	µg/g	<0.2	<4
Silicon	µg/g	359	546
Silver	µg/g	2.4	0.4
Sodium	µg/g	7000	5140
Strontium	µg/g	15.4	16.4
Titanium	µg/g	22	16.4
Uranium	µg/g	<50	<50
Vanadium	µg/g	4.6	3.6
Zinc	µg/g	103	133

[1] Data from Golder (1994)

TABLE 4.2-6

CONCENTRATIONS OF ORGANIC CHEMICALS IN BENTHIC INVERTEBRATE TISSUE SAMPLES FROM THE ATHABASCA RIVER, SAMPLED IN AUGUST, 1994 AND IN OCTOBER, 1995

Parameter	Units	August 1994[1]	October 1995 Station AT003
Naphthalene	µg/g	0.04	0.08
Acenaphthylene	µg/g	<0.02	<0.02
Acenaphthene	µg/g	<0.02	<0.02
Fluorene	µg/g	<0.02	<0.02
Dibenzothiophene	µg/g	<0.02	<0.02
Phenanthrene	µg/g	0.03	<0.02
Anthracene	µg/g	<0.02	<0.02
Fluoranthene	µg/g	<0.02	<0.02
Pyrene	µg/g	<0.02	<0.02
Benzo(a)anthracene/Chryse	µg/g	<0.02	<0.02
Benzo(b&k)fluoranthene	µg/g	<0.02	<0.02
Benzo(a)pyrene	µg/g	<0.02	<0.02
Indeno(c,d-123)pyrene	µg/g	<0.02	<0.02
Dibenzo(a,h)anthracene	µg/g	<0.02	<0.02
Benzo(ghi)perylene	µg/g	<0.02	<0.02
Methyl naphthalene	µg/g	<0.04	0.08
C2 sub'd naphthalene	µg/g	<0.04	0.07
C3 sub'd naphthalene	µg/g	<0.04	0.07
C4 sub'd naphthalene	µg/g	<0.04	<0.04
Biphenyl	µg/g	<0.04	<0.04
Methyl biphenyl	µg/g	<0.04	<0.04
C2 sub'd biphenyl	µg/g	0.07	<0.04
Methyl acenaphthene	µg/g	<0.04	<0.04
Methyl fluorene	µg/g	0.08	<0.04
C2 sub'd fluorene	µg/g	<0.04	<0.04
Methyl phenanthrene/anthra	µg/g	<0.04	<0.04
C2 sub'd phenanthrene/anth.	µg/g	<0.04	<0.04
C3 sub'd phenanthrene/anth.	µg/g	<0.04	<0.04
C4 sub'd phenanthrene/anth.	µg/g	<0.04	<0.04
1-Methyl-7-isopropylphenant	µg/g	<0.04	<0.04
Methyl dibenzothiophene	µg/g	<0.04	<0.04
C2 sub'd dibenzothiophene	µg/g	<0.04	<0.04
C3 sub'd dibenzothiophene	µg/g	<0.04	<0.04
C4 sub'd dibenzothiophene	µg/g	<0.04	<0.04
Methyl fluoranthene/pyrene	µg/g	<0.04	<0.04
Methyl B(a)A/chrysene	µg/g	<0.04	<0.04
C2 sub'd B(a)A/chrysene	µg/g	<0.04	<0.04
Methyl B(b&k)F/B(a)P	µg/g	<0.04	<0.04
C2 sub'd B(b&k)F/B(a)P	µg/g	<0.04	<0.04
Quinoline	µg/g	-	<0.02
7-Methyl quinoline	µg/g	-	<0.02
C2 Alkyl subst'd quinolines	µg/g	-	<0.02
C3 Alkyl subst'd quinolines	µg/g	-	<0.02
Acridine	µg/g	-	<0.02
Methyl acridine	µg/g	-	<0.02
Phenanthridine	µg/g	-	<0.02
Carbazole	µg/g	-	<0.02
Methyl carbazoles	µg/g	-	<0.02
C2 Alkyl subst'd carbazoles	µg/g	-	<0.02

[1] Data from Golder (1994)

TABLE 4.2-7

PHYSICAL CHARACTERISTICS AND HABITAT ATTRIBUTES OF THE SAMPLING SITES IN THE STEEPBANK RIVER

Station	Sample	Current velocity (m/s)	Mean depth (cm)	Water temp. (°C)	Dissolved oxygen (mg/L)	Turbidity[1] (NTU)	pH	Conductivity (mS/cm, 25°C)	Redox (mV)
SB001	B11	0.207	23	1.9	13.7		7.30	186	140
	B21	0.182	30	2.0	13.3		7.64	184	132
	B31	0.252	26	2.0	13.4		7.75	186	139
	B41	0.892	39	2.0	13.3		7.79	185	145
	B51	0.569	41	2.0	13.3		7.80	186	148
	Mean	0.420	32	2.0	13.4	3.2	7.66	185	141
SB002	B11	0.530	34	2.0	13.5		7.84	193	122
	B21	0.693	43	2.0	13.5		7.88	193	134
	B31	0.942	44	2.1	13.5		7.91	193	142
	B41	0.495	43	2.1	13.6		7.91	193	146
	B51	0.535	45	2.2	13.5		7.93	193	146
	Mean	0.639	42	2.1	13.5	3.2	7.89	193	138
SB003	B11	1.100	23	2.7	13.5		7.86	202	102
	B21	1.175	35	2.8	13.6		8.00	203	133
	B31	0.986	35	2.8	13.6		8.02	202	138
	B41	1.200	28	2.8	13.6		8.01	203	140
	B51	1.388	31	2.8	13.7		7.95	201	142
	Mean	1.170	30	2.8	13.6	2.9	7.97	202	131

[1] Turbidity measurements are based on analysis of additional water samples (see Methods).

TABLE 4.2-8

MEAN TOTAL ABUNDANCE (number/m^2) AND RELATIVE ABUNDANCE OF DOMINANT BENTHIC INVERTEBRATE TAXA COLLECTED IN THE STEEPBANK RIVER USING A HESS SAMPLER

Station SB001			
Taxon	Mean	St. Dev.	%
Orthocladius Complex	784	499.5	11.5
Acari	530	470.5	7.7
Rheotanytarsus	514	250.3	7.5
Baetis tricaudatus	504	605.0	7.4
Micropsectra	380	228.3	5.6
Brachycentrus occidentalis	360	327.1	5.3
Ephemerella inermis/infrquens	304	121.2	4.4
Hemerodromia	254	147.9	3.7
Chironomini-early instar	244	227.7	3.6
Lopescladius	230	208.2	3.4
Lepidostoma-sand case larvae	222	98.6	3.2
Parametriocnemus	200	152.0	2.9
Synorthocladius	200	179.9	2.9
Hydroptila	192	120.7	2.8
Orthocladiinae-early instar	170	80.6	2.5
Tvetenia	158	162.8	2.3
Eukiefferiella	152	55.4	2.2
Tanytarsini-early instar	124	98.4	1.8
Chloroperlidae	120	54.8	1.8
Naididae	112	74.6	1.6
Hydropsyche	90	96.7	1.3
Atherix	88	60.2	1.3
Cladotanytarsus	78	89.0	1.1
Total Density (no./m^2)	6010	4409.3	87.8
Total Taxa	44.0	4.9	

Station SB002			
Taxon	Mean	St. Dev.	%
Baetis tricaudatus	776	812.7	22.1
Hydroptila	228	187.5	6.5
Hemerodromia	226	65.4	6.4
Ephemerella inermis/infrequens	210	120.2	6.0
Rheotanytarsus	210	131.1	6.0
Enchytraeidae	172	124.2	4.9
Eukiefferiella	148	143.2	4.2
Tubificidae	142	134.2	4.1
Micropsectra	136	90.2	3.9
Acari	130	105.4	3.7
Orthocladius Complex	96	55.5	2.7
Simulium	84	171.3	2.4
Chironomini-early instar	76	45.6	2.2
Tanytarsini-early instar	76	59.4	2.2
Naididae	74	26.1	2.1
Tvetenia	72	53.1	2.1
Orthocladiinae-early instar	62	40.2	1.8
Rhithrogena	56	54.1	1.6
Lepidostoma-sand case larvae	50	30.0	1.4
Heptagenia	44	49.8	1.3
Parametriocnemus	36	43.4	1.0
Total Density (no./m^2)	3104	2542.7	88.6
Total Taxa	36.2	2.6	

Station SB003			
Taxon	Mean	St. Dev.	%
Baetis tricaudatus	622	283.3	39.8
Simulium	498	334.1	31.9
Tvetenia	86	40.4	5.5
Ephemerella inermis/infrequens	40	25.5	2.6
Capniidae-early instar	34	30.5	2.2
Isoperla	32	21.7	2.0
Micropsectra	30	20.0	1.9
Heptageniidae-early instar	22	14.8	1.4
Chironomini-early instar	22	27.7	1.4
Tubificidae	20	44.7	1.3
Thienemannimyia	16	15.2	1.0
Total Density (no./m^2)	1422	857.9	91.0
Total Taxa	19.0	4.2	

TABLE 4.2-9

TAXONOMIC COMPOSITION OF BENTHIC INVERTEBRATE TISSUE SAMPLES COLLECTED FROM THE STEEPBANK RIVER IN OCTOBER, 1995

Organism	Station SB002			
	Metals		Organics	
	Weight (g)	%	Weight (g)	%
Odonata	5.0	23	19.0	15
Plecoptera	12.5	57	87.5	68
Tricoptera	4.5	21	22.5	17
Total	22.0	100	129.0	100

TABLE 4.2-10

CONCENTRATIONS OF METALS IN BENTHIC INVERTEBRATE TISSUES FROM THE STEEPBANK RIVER, SAMPLED IN OCTOBER, 1995

Parameter	Units	October 1995 Station SB002
Antimony	µg/g	<0.2
Aluminum	µg/g	1040
Arsenic	µg/g	<20
Barium	µg/g	46
Beryllium	µg/g	<0.1
Boron	µg/g	1
Cadmium	µg/g	<0.3
Calcium	µg/g	3650
Chromium	µg/g	9.9
Cobalt	µg/g	1.1
Copper	µg/g	48.8
Iron	µg/g	3200
Lead	µg/g	<2
Lithium	µg/g	1.6
Magnesium	µg/g	1910
Manganese	µg/g	431
Mercury	µg/kg	<20
Molybdenum	µg/g	0.9
Nickel	µg/g	8.5
Phosphorus	µg/g	6260
Potassium	µg/g	7360
Selenium	µg/g	<4
Silicon	µg/g	481
Silver	µg/g	0.3
Sodium	µg/g	5720
Strontium	µg/g	17.9
Titanium	µg/g	18.6
Uranium	µg/g	<50
Vanadium	µg/g	3.8
Zinc	µg/g	174

TABLE 4.2-11

CONCENTRATIONS OF ORGANIC CHEMICALS IN BENTHIC INVERTEBRATE TISSUES FROM THE STEEPBANK RIVER, SAMPLED IN OCTOBER, 1995

Parameter	Units	October 1995 Station SB002
Naphthalene	µg/g	0.08
Acenaphthylene	µg/g	<0.02
Acenaphthene	µg/g	<0.02
Fluorene	µg/g	<0.02
Dibenzothiophene	µg/g	<0.02
Phenanthrene	µg/g	0.07
Anthracene	µg/g	<0.02
Fluoranthene	µg/g	0.02
Pyrene	µg/g	0.06
Benzo(a)anthracene/Chrysene	µg/g	<0.02
Benzo(b&k)fluoranthene	µg/g	<0.02
Benzo(a)pyrene	µg/g	<0.02
Indeno(c,d-123)pyrene	µg/g	0.02
Dibenzo(a,h)anthracene	µg/g	<0.02
Benzo(ghi)perylene	µg/g	0.02
Methyl naphthalene	µg/g	0.08
C2 sub'd naphthalene	µg/g	0.08
C3 sub'd naphthalene	µg/g	0.11
C4 sub'd naphthalene	µg/g	0.25
Biphenyl	µg/g	<0.04
Methyl biphenyl	µg/g	<0.04
C2 sub'd biphenyl	µg/g	<0.04
Methyl acenaphthene	µg/g	<0.04
Methyl fluorene	µg/g	0.10
C2 sub'd fluorene	µg/g	0.14
Methyl phenanthrene/anthracen	µg/g	0.14
C2 sub'd phenanthrene/anth.	µg/g	0.89
C3 sub'd phenanthrene/anth.	µg/g	1.1
C4 sub'd phenanthrene/anth.	µg/g	0.83
1-Methyl-7-isopropylphenanth.	µg/g	<0.04
Methyl dibenzothiophene	µg/g	0.13
C2 sub'd dibenzothiophene	µg/g	0.38
C3 sub'd dibenzothiophene	µg/g	1.2
C4 sub'd dibenzothiophene	µg/g	0.95
Methyl fluoranthene/pyrene	µg/g	0.16
Methyl B(a)A/chrysene	µg/g	0.19
C2 sub'd B(a)A/chrysene	µg/g	0.34
Methyl B(b&k)F/B(a)P	µg/g	0.13
C2 sub'd B(b&k)F/B(a)P	µg/g	0.07
Quinoline	µg/g	<0.02
7-Methyl quinoline	µg/g	<0.02
C2 Alkyl subst'd quinolines	µg/g	<0.02
C3 Alkyl subst'd quinolines	µg/g	<0.02
Acridine	µg/g	<0.02
Methyl acridine	µg/g	<0.02
Phenanthridine	µg/g	<0.02
Carbazole	µg/g	<0.02
Methyl carbazoles	µg/g	<0.02
C2 Alkyl subst'd carbazoles	µg/g	<0.02

TABLE 4.2-12

PHYSICAL CHARACTERISTICS OF BENTHIC INVERTEBRATE SAMPLING SITES
IN THE MUSKEG RIVER BASIN IN FALL, 1995

Site Number	Description	Habitat	Substratum Composition					Current Velocity*	Depth*	Water Temp.	Dissolved Oxygen	pH	Conductivity	Epilithic Chlorophyll a**
			S/S/C (%)	FG (%)	CG (%)	SC (%)	LC (%)	(m/s)	(m)	(°C)	(mg/L)		(mS/cm, 25°C)	(mg/m²)
30	Muskeg R.	Run/Erosional	0	10	75	15	0	0.860	0.45	8.8	13.4	7.80	287	3.0
17	Jackpine Cr.	Run/Erosional	0	0	40	60	0	0.153	0.42	--	--	7.16	215	1.5
S4	Jackpine Cr.	Run/Erosional	0	35	65	0	0	0.447	0.27	3.4	11.5	6.57	209	23.5
55	Blackfly Cr.	Run/Transitional	40	30	20	10	0	0.327	0.18	8.5	13.4	7.47	231	<0.5
8	Iyinimin Cr.	Run/Transitional	50	0	0	25	25	0.178	0.35	8.5	12.6	7.25	192	<0.5
18	Muskeg R.	Run/Depositional	100	0	0	0	0	0.028	0.70	7.0	10.6	7.50	280	--
35	Muskeg R.	Run/Depositional	100	0	0	0	0	0.000	>2.00	5.4	6.6	7.14	297	--
14	Khahoga Cr.	Run/Depositional	100	0	0	0	0	0.023	1.33	5.4	6.6	7.14	297	--
9	N. Muskeg Cr.	Run/Depositional	95	5	0	0	0	0.101	0.46	11.0	10.8	7.25	119	--
80	Kearl Lake	--	100	0	0	0	0	--	1.93	12.5	12.4	7.30	125	--

NOTES:

* Mean of three measurements

** Composite algal scrape from five cobbles

-- = Not measured or not applicable

S/S/C = sand/silt/clay; FG = fine gravel; CG = coarse gravel; SC = small cobble; LC = large cobble; B = boulder

TABLE 4.2-13

DENSITIES (number/m^2) OF COMMON BENTHIC INVERTEBRATES AT SITES SAMPLED IN THE MUSKEG RIVER BASIN

Muskeg R. (Site 30; Erosional)			
Taxon	**Mean**	**St. Dev.**	**%**
Tubificidae	341	185	26.8
Nematoda	147	103	11.5
Naididae	129	22	10.2
Baetis	115	33	9.0
Hydrachnidia	111	31	8.7
Enchytraeidae	64	47	5.1
Hemerodromia	50	41	4.0
Chioroperlidae	50	13	4.0
Chironomini	43	39	3.4
Corynoneura	36	16	2.8
Callicorixa	22	18	1.7
Orthocladiinae	18	6	1.4
Heptagenia	18	12	1.4
Plecoptera	18	22	1.4
Optioservus	15	6	1.2
Total Invertebrates	1273	184	92.5
Total Taxa	23	2	

Muskeg R. (Site 18, Depositional)			
Taxon	**Mean**	**St. Dev.**	**%**
Chironomini	7378	7173	43.1
Tubificidae	2297	2117	13.4
Corynoneura	1392	1766	8.1
Bezzia	1163	1052	6.8
Nematoda	1019	1289	5.9
Tanypodinae	1005	1558	5.9
Orthocladiinae	459	318	2.7
Hydrachnidia	445	503	2.6
Pisidium	416	456	2.4
Diamesinae	402	329	2.3
Tanytarsini	273	436	1.6
Total Invertebrate	17136	16101	94.8
Total Taxa	20	10	

Muskeg R. (Site 35; Depositional; n=1)		
Taxon	**Number**	**%**
Chironomini	1550	30.8
Corynoneura	775	15.4
Tanytarsini	646	12.8
Tubificidae	474	9.4
Naididae	474	9.4
Tanypodinae	388	7.7
Orthocladiinae	344	6.8
Isotomus	86	1.7
Helisoma	86	1.7
Nematoda	86	1.7
Lasmigona complan	86	1.7
Total Invertebrates	5038	99.1
Total Taxa	19	

Jackpine Cr. (Site 17; Erosional)			
Taxon	**Mean**	**St. Dev.**	**%**
Tanytarsini	484	331	18.2
Chironomini	459	236	17.2
Hydrachnidia	395	144	14.8
Hemerodromia	240	66	9.0
Tanypodinae	219	13	8.2
Baetis pygmaeus	144	54	5.4
Orthocladiinae	118	112	4.4
Naididae	104	118	3.9
Corynoneura	72	106	2.7
Nematoda	72	16	2.7
Heptagenia	47	72	1.8
Baetis	40	25	1.5
Heptageniidae	32	29	1.2
Pisidium	29	41	1.1
Hexatoma	25	6	1.0
Total Invertebrate	2666	464	93.0
Total Taxa	26	3	

TABLE 4.2-13 (Page 2 of 3)

Jackpine Cr. (Site S4; Erosional)				Khahoga Cr. (Site 14; Depositional)			
Taxon	**Mean**	**St. Dev.**	**%**	**Taxon**	**Mean**	**St. Dev.**	**%**
Hydrachnidia	276	221	14.5	Chironomini	3861	3488	42.8
Baetis	272	190	14.3	*Corynoneura*	1694	2085	18.8
Orthocladiinae	233	200	12.2	Orthocladiinae	746	635	8.3
Chironomini	186	125	9.8	Tanypodinae	632	711	7.0
Nematoda	179	178	9.4	Tubificidae	588	741	6.5
Naididae	104	102	5.5	Nematoda	517	156	5.7
Tubificidae	90	78	4.7	Tanytarsini	344	345	3.8
Corynoneura	79	33	4.1	Naididae	172	172	1.9
Optioservus	75	65	3.9	*Lepidostoma*	115	199	1.3
Anagapetus	72	45	3.8	*Thienemanniella*	86	114	1.0
Hemerodromia	68	50	3.6				
Plecoptera	61	59	3.2				
Tanypodinae	32	29	1.7				
Enchytraeidae	29	33	1.5				
Total Invertebrat	1908	1312	92.2	Total Invertebrat	9013	6195	97.1
Total Taxa	21	10		Total Taxa	13	4	
Blackfly Cr. (Site 55; Erosional)				**Iyinimin Cr. (Site 8; Erosional)**			
Taxon	**Mean**	**St. Dev.**	**%**	**Taxon**	**Mean**	**St. Dev.**	**%**
Orthocladiinae	2783	1487	47.9	Orthocladiinae	294	109	45.2
Chironomini	983	1250	16.9	Capniidae	101	43	15.4
Optioservus	395	27	6.8	Chironomini	54	29	8.2
Tubificidae	345	291	5.9	Hydrachnidia	43	38	6.6
Hydrachnidia	258	76	4.4	Tanytarsini	43	43	6.6
Nematoda	212	124	3.6	*Chelifera*	25	25	3.9
Chelifera	125	43	2.2	Naididae	14	16	2.2
Brachycentrus	122	33	2.1	Tubificidae	11	11	1.7
Tanytarsini	101	54	1.7	Nemouridae	11	11	1.7
Baetis	93	54	1.6	Tanypodinae	7	6	1.1
Diamesinae	86	74	1.5	*Parameletus*	7	6	1.1
Parameletus	68	51	1.2	*Nemoura*	7	13	1.1
				Baetis pygmaeu	7	13	1.1
				Nematoda	7	13	1.1
Total Invertebrat	5816	3214	95.8	Total Invertebrat	652	232	97.2
Total Taxa	21	2		Total Taxa	12	1	

TABLE 4.2-13 (Page 3 of 3)

North Muskeg Cr. (Site 9; Depositional)				Kearl Lake (Site 80)			
Taxon	Mean	St. Dev.	%	Taxon	Mean	St. Dev.	%
Orthocladiinae	6129	4479	26.1	Chironomini	918	1293	71.9
Corynoneura	5497	8099	23.4	Orthocladiinae	115	199	9.0
Chironomini	4794	4963	20.4	Naididae	100	138	7.9
Nematoda	2942	1250	12.5	Tubificidae	57	25	4.5
Tubificidae	1349	814	5.7	Nematoda	43	43	3.4
Diamesinae	833	850	3.5	Diamesinae	29	25	2.2
Pisidium	416	574	1.8	Tanypodinae	14	25	1.1
Hydrachnidia	359	366	1.5				
Tanytarsini	316	293	1.3				
Bezzia	287	423	1.2				
Lasmigona complan	244	386	1.0				
Total Invertebrates	23481	20018	98.7	Total Invertebrat	1277	1727	100.0
Total Taxa	15	2		Total Taxa	5	2	

TABLE 4.2-14

TAXONOMIC COMPOSITION OF BENTHIC INVERTEBRATE TISSUE SAMPLES FROM THE MUSKEG RIVER AND JACKPINE CREEK IN FALL, 1995

Taxon	Muskeg River Site 30 (% by number)	Jackpine Creek Site S4 (% by number)
Ephemeroptera (mayfly nymphs)	20	30
Odonata (dragonfly nymphs	10	10
Plecoptera (stonefly nymphs)	35	45
Trichoptera (caddisfly larvae)	35	15

TABLE 4.2-15

CONCENTRATIONS OF METALS AND ORGANIC COMPOUNDS IN AQUATIC INSECTS FROM THE MUSKEG RIVER BASIN IN FALL, 1995

Parameter	Units	Muskeg River Site 30	Jackpine Creek Site S4
Metals			
Aluminum	mg/g	737	345
Antimony	mg/g	<0.2	<0.2
Arsenic	mg/g	1.6	1.4
Barium	mg/g	39	32
Beryllium	mg/g	<0.1	<0.1
Boron	mg/g	7	6
Cadmium	mg/g	<0.3	<0.3
Calcium	mg/g	9300	4610
Chromium	mg/g	9.4	6.5
Cobalt	mg/g	1.1	2
Copper	mg/g	58	48.2
Iron	mg/g	4220	2310
Lead	mg/g	3	<2
Lithium	mg/g	0.9	<0.5
Magnesium	mg/g	2390	2240
Manganese	mg/g	776	856
Mercury	mg/kg	<20	<20
Molybdenum	mg/g	0.3	<0.3
Nickel	mg/g	15.5	14
Phosphorus	mg/g	6660	6860
Potassium	mg/g	7270	6690
Selenium	mg/g	<0.2	<0.2
Silicon	mg/g	373	252
Silver	mg/g	<0.2	<0.2
Sodium	mg/g	4330	4100
Strontium	mg/g	21.7	21.5
Titanium	mg/g	24.5	12.5
Uranium	mg/g	<50	<50
Vanadium	mg/g	3.1	10.8
Zinc	mg/g	161	144
Detectable Trace Organic Compounds*			
Naphthalene	mg/g	0.06	0.08
Phenanthrene	mg/g	0.02	0.02
Methyl naphthalene	mg/g	0.07	0.05
C2 sub'd naphthalene	mg/g	0.07	0.11
C3 sub'd naphthalene	mg/g	0.11	0.17
C2 sub'd phenanthrene/anth.	mg/g	0.04	0.04
C3 sub'd phenanthrene/anth.	mg/g	0.05	0.05
C3 sub'd dibenzothiophene	mg/g	0.05	0.06
C4 sub'd dibenzothiophene	mg/g	0.06	0.05

NOTE:

* Samples were analyzed for PAHs, alkylated PAHs, PANHs and alkylated PAN

TABLE 4.3-1

Large River Habitat Classification System
(From R.L.&L. 1992 - General Habitat Inventory for the NRBS)

MAJOR HABITAT TYPES

Type	Abbreviation	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

SPECIAL HABITAT FEATURES

Type	Abbreviation	Description
Tributary confluences [sub-classified according to tributary flow and wetted width at mouth at the time of the survey)	TC	confluence area of tributary entering mainstem
	TC1	intermittent flow, ephemeral stream
	TC2	flowing, width <5m
	TC3	flowing width 5-15 m
	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

BANK HABITAT TYPES

Type	Abbreviation	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	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

TABLE 4.3-2

Stream Habitat Classification and Rating System
(Adapted from R.L.&L. 1992 - General Habitat Inventory for the NRBS)

Channel Unit	Type	Class	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/gradient relative to run habitat; surface broken; relatively shallow; coarse substrate; limited instream or overhead cover
Run				moderate to high velocity; surface largely unbroken; deeper than RF; substrate size dependent on hydraulics
	Depth/Velocity Type			run habitat is differentiated into 4 types; deep/slow, deep/fast, shallow/slow, shallow/fast
		Class 1	R1	highest quality/deepest run habitat; generally deep/slow type; coarse substrate; high instream cover from substrate/depth
		Class 2	R2	moderate quality/depth;

Channel Unit	Type	Class	Symbol	Description
				high instream cover except at low flow; generally deep/fast or moderately deep/slow type
		Class 3	R3	lowest quality/depth; generally shallow/slow or shallow/fast type; low instream cover in all but high flows
Flat			FL	area characterized by low velocity and near-laminar flow; differentiated from pool habitat by high channel uniformity; more depositional than RU3 habitat
Pool				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
		Class 2	P2	moderate quality; shallower than P1 with high instream cover except during low flow conditions
		Class 3	P3	low quality pool habitat; shallow and/or small; low instream cover at all but high flow events
	Pool Type			several types of pool are specified, depending on the hydraulic factors which formed them, they include; eddy, trench, lateral, mid-channel, plunge and convergence
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

Channel Unit	Type	Class	Symbol	Description
				Class 1, 2 or 3 as for scour pools
	Dam Type			four types of impoundments have been identified based on dam type; debris, beaver, landslide and abandoned channel
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 (eg. R1/BG)

ADDITIONAL HABITAT MAPPING SYMBOLS

Feature	Symbol	Description
Ledge	LE	area of bedrock intrusion into the channel; often associated with chute or plunge pool habitat
Overhead Cover	OC	area of extensive or high quality overhead cover
Instream Cover	IC	area of high quality instream cover (velocity shelter) for all life stages
Undercut Bank	UB	area of extensive/high quality undercut bank providing overhead cover
Unstable Bank	US	area of unstable bank with potential to collapse instream, affecting instream habitat or producing sedimentation
Overhanging Veg.	OV	area of high quality overhanging vegetation providing overhead cover and stream shading
Inundated Veg.	IV	area of inundated vegetation; either submergent macrophytes or flooded terrestrial

Debris Pile	DP	debris pile which influences instream habitat; include effect on cover and fish passage
Root Wad	RW	fallen terrestrial vegetation large enough to provide cover for fish
Log Jam	LJ	instream log pile; include effect on cover and fish passage
Beaver Dam	BD	include effect on fish passage
Stream Blockage	XX	include effect on fish passage
Large Organic Debris	LOD	area of high quanity of vegetation debris

TABLE 4.3-3

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	-	-

TABLE 4.3-4

Percent Composition of Bank Types for the Portion of the Athabasca River in the Suncor Study Area

Bank Type	Bank Code	Length (km)	Percent Composition
Armoured/Stable	A1	8	32
	A2	1	4
	A4	1	4
Canyon	C2	0.25	1
Depositional	D1	4.75	19
	D2	0.75	3
Erosional	E1	1.5	6
	E2	0.5	2
	E3	< 0.25	< 1
	E5	7.5	30
	E6	< 0.25	<1
TOTAL		25.0 km	100

TABLE 4.3-5

Percent Composition of Channel Types for the Portion of the Steepbank River in the Suncor Study Area, Fall, 1995

Channel Type	Channel Code	Length (km)	Percent Composition
Riffle	RF	10.3	40
Run	R1	2.8	11
	R2	8.2	32
	R3	2.8	11
Backwater	BW	0.2	1
Pool	P1	0.5	2
	P2	1	4
Rapids	RA	< 0.2	< 1
TOTAL		25.8	100

TABLE 4.3-6

Percent Composition of Channel Types for Fish Inventory Sections on the Steepbank River, Fall 1995

Channel Type	Channel Code	Percent Compostion Section 1 (AF017)	Section 2 (AF040)	Section 3 (AF014)
Riffle	RF	54	48	35
Run	R1	10	4	9
	R2	28	35	28
	R3	1	8	21
Backwater	BW	1	1	1
Pool	P1	0	4	1
	P2	3	0	5
Rapids	RA	3	0	0
TOTAL		100	100	100

Table 4.4-1

Total Number of each Species Captured from the Steepbank Mine Local Study Area, 1995

SPECIES	ATHABASCA RIVER			Steepbank River			Leggett Creek			Saline Lake			Poplar Creek		
	SPRING	SUMMER	FALL	SPRING	SUMMER	FALL	SPRING	SUMMER	FALL	SPRING	SUMMER	FALL	SPRING	SUMMER	FALL
ARTIC GRAYLING	-	-	-	104	33	93	-	-	-	-	-	-	-	-	-
BRASSY MINNOW	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BROOK STICKLEBACK	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
BURBOT	1	2	6	1	-	-	-	-	-	-	-	-	-	-	-
EMERALD SHINER	16	12	3	-	-	-	-	-	-	-	-	-	-	-	-
FLATHEAD CHUB	80	347	16	-	-	-	-	-	-	-	-	-	1	-	-
FATHEAD MINNOW	-	-	-	-	-	-	-	-	-	-	-	-	78	-	-
GOLDEYE	67	282	93	-	3	-	-	-	-	-	-	-	-	-	-
LAKE CHUB	25	2	21	25	13	5	-	-	-	-	-	-	60	-	-
LAKE WHITEFISH	5	37	1643	-	6	-	-	-	-	-	-	-	-	-	-
LONGNOSE DACE	2	-	23	4	35	36	-	-	-	-	-	-	-	-	-
LONGNOSE SUCKER	292	50	134	73	110	21	-	-	-	-	-	-	6	-	-
MOUNTAIN WHITEFISH	-	4	9	110	83	104	-	-	-	-	-	-	-	-	-
NORTHERN PIKE	33	37	15	1	3	-	-	-	-	-	-	-	-	-	-
PEARL DACE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SLIMY SCULPIN	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SPOONHEAD SCULPIN	1	1	-	28	73	197	-	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	13	1	9	-	-	-	-	2	-	-	2	-	-	-	-
TROUT-PERCH	144	606	160	2	1	-	-	-	-	-	-	-	-	-	-
UNIDENTIFIED	210	5	6	-	-	-	-	-	-	-	-	1	-	-	-
WALLEYE	473	136	120	2	4	-	-	-	-	-	-	-	-	-	-
WHITE SUCKER	53	15	76	5	5	5	-	-	-	-	-	-	4	-	-
YELLOW PERCH	-	1	6	-	-	-	-	-	-	-	-	-	4	-	-
TOTAL	1477	1538	2340	355	369	461	0	2	0	0	2	5	153	0	0
GRAND TOTALS	Athabasca R.		5355	Steepbank R.		1185	Leggett Cr.		2	Saline Lk.		7	Poplar Cr.		153

Table 4.4-2

Total Catch and Catch-Per-Unit-Effort for Fish taken by Electrofishing, Athabasca River, 1995

STATION	SEASON	TIME SAMPLED	BURB	EMSH	FLCH	GOLD	LKCH	LKWH	LNDC	LNSC	MNWH	NRPK	SPSC	SPSH	TRPR	UNID	WALL	WHSC	YLPR	TOTAL
AF001	SPRING	370	-	-	-	5 (1.351)	-	-	-	2 (0.541)	-	2 (0.541)	-	-	-	-	2 (0.541)	-	-	11
	SPRING	244	-	-	-	1 (0.410)	-	1 (0.410)	-	-	-	-	-	-	-	-	1 (0.410)	-	-	3
	SUMMER	na	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF002	SPRING	833	-	-	-	5 (0.600)	-	1 (0.120)	-	2 (0.240)	-	-	-	-	-	-	9 (1.080)	-	-	17
	SPRING	734	-	-	-	3 (0.409)	-	-	-	1 (0.136)	-	-	-	-	-	-	8 (1.090)	-	-	12
	SPRING	1840	-	-	12 (0.652)	12 (0.652)	-	1 (0.054)	-	21 (1.141)	-	4 (0.217)	-	-	-	-	33 (1.793)	2 (0.109)	-	85
	SPRING	430	-	-	-	10 (2.326)	-	-	-	-	-	1 (0.233)	-	-	-	-	4 (0.930)	-	-	15
	SPRING	561	-	-	3 (0.535)	2 (0.357)	-	-	-	1 (0.178)	-	1 (0.178)	-	-	-	2 (0.357)	6 (1.070)	1 (0.178)	-	16
	SUMMER	731	-	2 (0.273)	25 (3.420)	7 (0.958)	-	-	-	1 (0.137)	-	1 (0.137)	-	-	-	-	5 (0.684)	-	-	41
	SUMMER	309	-	-	4 (1.294)	10 (3.236)	-	-	-	-	-	1 (0.324)	-	-	-	-	-	-	-	15
	SUMMER	774	-	-	10 (1.291)	8 (1.034)	-	-	-	-	-	1 (0.129)	-	-	1 (0.129)	-	5 (0.646)	-	-	25
	SUMMER	238	1 (0.420)	-	3 (1.260)	7 (2.941)	-	-	-	-	-	-	-	-	3 (1.261)	-	-	-	-	14
	FALL	831	-	-	3 (0.361)	1 (0.120)	-	70 (8.424)	-	2 (0.241)	-	1 (0.120)	-	-	-	-	12 (1.444)	6 (0.722)	-	95
AF003	SPRING	438	-	-	-	-	-	-	-	3 (0.685)	-	-	-	-	-	-	-	-	-	3
	SUMMER	845	-	-	11 (1.302)	7 (1.215)	-	-	-	2 (0.237)	-	-	-	-	301 (35.62	1 (0.174)	6 (0.710)	-	-	328
	SUMMER	413	-	-	1 (0.242)	-	-	9 (2.179)	-	-	-	1 (0.242)	-	-	-	-	5 (1.210)	-	-	16
	SUMMER	640	-	-	-	-	-	4 (0.625)	-	1 (0.156)	-	4 (0.625)	-	-	2 (0.313)	-	2 (0.313)	1 (0.156)	-	14
	SUMMER	713	-	-	8 (1.122)	11 (1.543)	1 (0.140)	19 (2.665)	-	2 (0.281)	-	3 (0.421)	-	-	1 (0.140)	-	3 (0.421)	2 (0.281)	-	50
	FALL	1137	-	-	-	2 (0.176)	-	65 (5.717)	-	2 (0.176)	1 (0.088)	4 (0.352)	-	-	5 (0.440)	-	-	6 (0.528)	-	85
AF004	SPRING	403	-	-	-	4 (0.993)	-	-	-	1 (0.248)	-	-	-	-	-	-	10 (2.481)	2 (0.496)	-	17
	SPRING	490	-	-	-	-	-	-	-	1 (0.204)	-	2 (0.408)	-	-	-	3 (0.612)	1 (0.204)	2 (0.408)	-	9
	SPRING	880	-	-	7 (0.795)	4 (0.455)	-	-	-	16 (1.818)	-	2 (0.227)	-	-	-	-	21 (2.386)	4 (0.455)	-	54
	SPRING	604	-	-	6 (0.993)	5 (0.828)	-	-	-	1 (0.166)	-	-	-	-	-	-	6 (0.993)	11 (1.821)	-	29
	SUMMER	551	-	-	34 (6.171)	9 (1.633)	-	-	-	2 (0.363)	-	1 (0.181)	-	-	12 (2.178)	-	13 (2.359)	-	-	71
	SUMMER	549	-	-	13 (2.368)	9 (1.639)	-	-	-	2 (0.364)	-	2 (0.364)	-	-	13 (2.368)	-	6 (1.093)	-	-	45
	SUMMER	499	-	-	5 (1.002)	5 (1.002)	-	-	-	1 (0.200)	-	1 (0.200)	-	-	-	-	5 (1.002)	-	-	17
	SUMMER	431	-	-	2 (0.469)	11 (2.552)	-	-	-	-	-	-	-	-	-	-	1 (0.232)	1 (0.232)	-	15
	SUMMER	1079	-	-	-	55 (5.097)	-	-	-	3 (0.278)	-	1 (0.093)	-	1 (0.093)	-	-	5 (0.463)	2 (0.185)	-	67
	SUMMER	1120	-	2 (0.179)	4 (0.357)	31 (2.768)	-	1 (0.089)	-	8 (0.714)	-	2 (0.179)	-	-	-	-	6 (0.536)	1 (0.089)	-	55
	FALL	1156	-	-	2 (0.173)	11 (0.952)	-	26 (2.249)	-	10 (0.865)	-	2 (0.173)	-	-	-	3 (0.260)	23 (1.990)	20 (1.730)	-	97
AF005	SPRING	953	-	-	-	3 (0.315)	-	-	-	5 (0.524)	-	1 (0.105)	-	-	-	-	130 (13.64	-	-	139
	SPRING	958	-	-	-	-	-	-	-	-	-	7 (0.731)	-	-	-	-	155 (16.18	-	-	162
	SPRING	403	-	-	-	-	-	-	-	2 (0.496)	-	4 (0.993)	-	-	-	-	52 (12.903	-	-	58
	SUMMER	1047	-	-	10 (0.955)	4 (0.382)	-	-	-	2 (0.191)	-	4 (0.382)	-	-	-	-	6 (0.573)	-	-	26
	SUMMER	505	-	-	3 (0.594)	1 (0.198)	-	-	-	-	-	3 (0.594)	-	-	-	-	3 (0.594)	-	-	10
	FALL	906	-	-	-	-	-	182 (20.08)	-	19 (2.097)	-	-	-	-	1 (0.110)		11 (1.214)	1 (0.110)	1 (0.110)	215
AF006	SPRING	676	-	-	7 (1.035)	3 (0.444)	-	-	-	2 (0.296)	-	-	-	-	-	-	11 (1.627)	2 (0.296)	-	25
	SUMMER	1037	-	-	15 (1.446)	4 (0.386)	-	-	-	-	-	-	1 (0.096)	-	21 (2.025)	-	8 (0.771)	-	1 (0.096)	50
	FALL	515	-	-	-	18 (3.495)	-	106 (20.58)	-	9 (1.748)	-	1 (0.194)	-	-	-	-	-	2 (0.388)	-	136
AF014	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	1097	-	-	10 (0.912)	6 (0.547)	-	-	-	2 (0.182)	-	4 (0.365)	-	-	-	-	4 (0.365)	-	-	26
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.4-2 con't

STATION	SEASON	TIME SAMPLED	BURB	EMSH	FLCH	GOLD	LKCH	LKWH	LNDC	LNSC	MNWH	NRPK	SPSC	SPSH	TRPR	UNID	WALL	WHSC	YLPR	TOTAL
AF015	SPRING	546	-	1 (0.183)	3 (0.549)	2 (0.366)	-	-	-	-	-	4 (0.734)	-	-	-	2 (0.366)	-	4 (0.733)	-	16
	SUMMER	459	-	-	2 (0.435)	-	-	-	-	-	-	-	-	-	-	-	1 (0.218)	-	-	3
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF016	SPRING	697	-	-	6 (0.861)	-	-	-	-	-	-	1 (0.144)	-	-	-	3 (0.430)	1 (0.143)	19 (2.726)	-	30
	SUMMER	459	-	-	14 (3.050)	-	-	-	-	1 (0.218)	-	1 (0.218)	-	-	3 (0.654)	-	2 (0.436)	-	-	21
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF018	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	1119	-	3 (0.268)	14 (1.251)	2 (0.179)	-	-	-	2 (0.179)	1 (0.089)	1 (0.089)	-	-	3 (0.268)	-	2 (0.179)	-	-	28
	FALL	1122	-	-	3 (0.267)	-	-	12 (1.070)	-	3 (0.267)	1 (0.089)	2 (0.178)	-	-	-	-	8 (0.713)	1 (0.089)	-	30
	FALL	949	-	2 (0.211)	-	-	-	447 (47.10)	-	4 (0.421)	1 (0.105)	-	-	-	2 (0.210)	-	6 (0.632)	7 (0.737)	-	469
AF019	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	1727	-	1 (0.057)	11 (0.637)	4 (0.232)	-	-	-	-	-	-	-	-	3 (0.174)	-	10 (0.579)	-	-	29
	SUMMER	1313	-	1 (0.076)	8 (0.609)	5 (0.381)	1 (0.076)	-	-	-	1 (0.076)	2 (0.152)	-	-	10 (0.762)	-	4 (0.305)	-	-	32
	FALL	1180	-	-	2 (0.169)	8 (0.678)	-	15 (1.271)	-	38 (3.220)	-	1 (0.085)	-	-	-	-	7 (0.593)	2 (0.169)	-	73
	FALL	1025	-	1 (0.098)	2 (0.195)	24 (2.341)	-	207 (20.20)	-	9 (0.878)	-		-	-	-	-	4 (0.390)	2 (0.195)	-	249
AF020	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	1246	-	1 (0.080)	8 (0.642)	4 (0.321)	-	-	-	-	1 (0.080)	1 (0.080)	-	-	54 (4.334)	2 (0.161)	-	-	-	71
	FALL	1502	-	-	1 (0.067)	5 (0.333)	-	218 (14.51)	-	2 (0.133)	1 (0.067)		-	-	13 (0.866)	-	6 (0.399)	16 (1.065)	-	262
AF034	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	884	-	-	14 (1.584)	1 (0.113)	-	-	-	2 (0.226)	-	1 (0.113)	-	-	1 (0.113)	2 (0.226)	2 (0.226)	2 (0.226)	-	25
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF033	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	336	-	-	32 (9.523)	2 (0.595)	-	-	-	2 (0.595)	-	-	-	-	12 (3.571)	-	5 (1.488)	-	-	53
	SUMMER	1314	-	-	5 (0.381)	15 (1.142)	-	3 (0.228)	-	8 (0.609)	-	-	-	-	53 (4.033)	-	3 (0.228)	2 (0.152)	-	89
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF036	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	1420	-	1 (0.070)	11 (0.775)	5 (0.352)	-	-	-	1 (0.070)	-	-	-	-	-	-	4 (0.282)	-	-	22
	SUMMER	619	-	-	1 (0.162)	9 (1.454)	-	-	-	-	-	-	-	-	-	-	2 (0.323)	-	-	12
	SUMMER	1374	-	-	11 (0.800)	4 (0.291)	-	-	-	1 (0.073)	-	-	-	-	-	-	2 (0.146)	1 (0.073)	-	19
	FALL	1296	-	-	-	15 (1.157)	-	115 (8.873)		1 (0.077)	-	1 (0.077)	-	-	-	-	3 (0.321)	10 (0.772)	-	145
AF038	SPRING	na	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	1065	-	-	81 (7.606)	15 (1.408)	-	-	-	4 (0.376)	-	1 (0.094)	-	-	02 (9.577	-	10 (0.938)	-	-	213
	FALL	na	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF041	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FALL	618	-	-	-	9 (1.456)	-	127 (20.55)	23 (3.722)	2 (0.324)	4 (0.647)	-	-	-	-	-	-	-	-	165
AF042	SPRING	na	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	272	-	-	1 (0.368)	6 (2.206)	-	1 (0.368)	-	-	-	-	-	-	10 (3.676)	-	3 (1.103)	-	-	21
	SUMMER	1305	-	-	2 (0.153)	19 (1.456)	-	-	-	2 (0.153)	1 (0.077)	1 (0.077)	-	-	-	-	2 (0.153)	3 (0.230)	-	30
	FALL	708	-	-	-	-	-	53 (7.486)	-	33 (4.661)	1 (0.141)	-	-	-	12 (1.695)	-	17 (2.401)	2 (0.282)	-	118
AF044	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	902	-	1 (0.111)	1 (0.111)	6 (0.665)	-	-	-	1 (0.111)	-	-	-	-	1 (0.111)	-	-	-	-	10
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	SPRING	12060	-	1	44	59	-	3	-	58	-	29	-	-	-	10	450	47	-	701
	SUMMER	28392	1	12	374	282	2	37	-	50	4	37	1	1	606	5	135	15	1	1563
	FALL	12945	-	3	13	93	-	1643	23	134	9	12	-	-	33	3	97	75	1	2139
GRAND TOTAL		53397	1	16	431	434	2	1683	23	242	13	78	1	1	639	18	682	137	2	4403

Species Codes

BURB	Burbot	NRPK	Northern Pike
EMSH	Emerald Shiner	SPSC	Spoonhead Sculpin
FLCH	Flathead Chub	SPSH	Spottail Shiner
GOLD	Goldeye	TRPR	Trout-perch
LKCH	Lake Chub	UNID	Unidentified
LKWH	Lake Whitefish	WALL	Walleye
LNDC	Longnose Dace	WHSC	White Sucker
LNSC	Longnose Sucker	YLPR	Yellow perch
MNWH	Mountain Whitefish		

Table 4.4-3

Total Catch and Catch-Per-Unit-Effort for Fish taken by Gill Nets, Athabasca River and Leggett Creek, 1995

STATION	SEASON	TIME SAMPLED	FLCH	GOLD	LKWH	LNSC	NRPK	WALL	TOTAL
AF002	SPRING	19.35	2 (0.103)	-	-	-	-	-	2
	SUMMER	na	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
AF003	SPRING	21.08	-	5 (0.237)	1 (0.047)	2 (0.095)	1 (0.047)	1 (0.047)	10
	SUMMER	na	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
AF004	SPRING	18.47	-	-	-	-	-	1 (0.054)	1
	SUMMER	na	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
AF009	SPRING	7.73	1 (0.129)	-	-	-	-	-	1
	SUMMER	na	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
AF018	SPRING	7.50	-	1 (0.133)	1 (0.133)	-	3 (0.400)	4 (0.533)	9
	SUMMER	na	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
AF019	SPRING	0.16	-	2 (12.5)	-	-	-	-	2
	SUMMER	na	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
AF026	SPRING	19.83	-	-	-	1 (0.050)	-	-	1
	SUMMER	na	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
AF039	SPRING	18.17	1 (0.055)	-	-	-	-	-	1
	SUMMER	na	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
AF046 LEGGETT CREEK	SPRING	na	-	-	-	-	-	-	-
	SUMMER	21.75	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
TOTAL	SPRING	112.29	4	8	2	3	4	6	27
	SUMMER	21.75	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-
GRAND TOTAL		134.04	4	8	2	3	4	6	27

Species Codes

FLCH	Flathead Chub	LNSC	Longnose Sucker
GOLD	Goldeye	NRPK	Northern Pike
LKWH	Lake Whitefish	WALL	Walleye

Table 4.4-4

Total Catch and Catch-Per-Unit-Effort for Fish taken by Set Lines, Athabasca River, 1995

STATION	SEASON	TIME SAMPLED	BURB	NRPK	UNID	WALL	TOTAL
AF002	SPRING	na	-	-	-	-	-
	SUMMER	na	-	-	-	-	-
	FALL	19.93	-	-	-	4 (0.200)	4
	FALL	19.93	1 (0.050)	-	-	1 (0.050)	2
AF004	SPRING	na	-	-	-	-	-
	SUMMER	19.80	-	-	-	1 (0.051)	1
	FALL	19.80	-	1 (0.051)	-	-	1
AF006	SPRING	na	-	-	-	-	-
	SUMMER	na	-	-	-	-	-
	FALL	15.78	-	-	-	1 (0.063)	1
	FALL	15.63	1 (0.064)	-	-	3 (0.192)	4
AF010	SPRING	21.42	-	-	-	1 (0.047)	1
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF018	SPRING	na	-	-	-	-	-
	SUMMER	na	-	-	-	-	-
	FALL	15.80	-	-	-	1 (0.064)	1
	FALL	15.80	1 (0.063)	-	-	2 (0.127)	3
AF019	SPRING	14.75	-	-	-	1 (0.068)	1
	SUMMER	na	-	-	-	-	-
	FALL	19.62	-	-	1 (0.051)	-	1
	FALL	19.33	-	-	1 (0.052)	-	1
	FALL	17.20	-	-	-	3 (0.174)	3
	FALL	17.20	2 (0.116)	-	-	3 (0.174)	5
AF028	SPRING	19.50	-	-	-	2 (0.103)	2
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF029	SPRING	19.25	-	-	-	3 (0.156)	3
	SUMMER	20.00	1 (0.050	-	-	-	1
	FALL	16.28	-	-	-	3 (0.184)	3
AF033	SPRING	22.12	-	-	-	1 (0.045)	1
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF034	SPRING	22.00	-	-	-	2 (0.045)	2
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF036	SPRING	19.75	-	-	1 (0.051)	-	1
	SUMMER	na	-	-	-	-	-
	FALL	17.95	-	-	1 (0.056)	-	1
AF045	SPRING	na	-	-	-	-	-
	SUMMER	na	-	-	-	-	-
	FALL	15.63	-	-	1 (0.064)	-	-
TOTAL	SPRING	138.79	-	-	1	10	11
	SUMMER	39.80	1	-	-	1	2
	FALL	245.88	5	1	4	21	31
GRAND TOTAL		424.47	6	1	5	32	44

Species Codes

BURB	Burbot	UNID	Unidentified
NRPK	Northern Pike	WALL	Walleye

Table 4.4-5

Total Catch and Catch-Per-Unit-Effort for Fish Captured by Post-Emergent Fry Drift Traps, Athabasca River, 1995

STATION	SEASON	TIME SAMPLED	BURB	LNSC	SLSC	WALL	TOTAL
AF011	SPRING	6.82	-	-	10 (1.466)	-	10
	SPRING	16.93	-	9 (0.532)	43 (2.540)	6 (0.354)	58
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF012	SPRING	6.93	-	2 (0.289)	2 (0.289)	-	4
	SPRING	17.43	1 (0.057)	36 (2.065)	5 (0.287)	-	42
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF020	SPRING	20.92	-	146 (6.979)	-	-	146
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF022	SPRING	19.17	-	1 (0.052)	-	-	1
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF030	SPRING	19.25	-	30 (1.558)	-	-	30
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
AF031	SPRING	19.50	-	7 (0.359)	-	-	7
	SUMMER	na	-	-	-	-	-
	FALL	na	-	-	-	-	-
TOTAL	SPRING	126.95	1	231	60	6	298
	SUMMER	na	-	-	-	-	0
	FALL	na	-	-	-	-	0
GRAND TOTAL		126.95	1	231	60	6	298

Species Codes

BURB	Burbot	SLSC	Slimy Sculpin
LNSC	Longnose Sucker	WALL	Walleye

TABLE 4.4-6

Total Catch and Catch-Per-Unit-Effort for Fish taken by Seine Nets, Athabasca River, 1995

STATION	SEASON	AREA SAMPLED (m2)	EMSH	FLCH	LKCH	LNSC	SPSC	SPSH	TRPR	WALL	WHSC	YLPR	TOTAL
AF023	SPRING	192	-	-	-	-	-	-	41 (0.214)	1 (0.005)	3 (0.016)	-	45
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-
	FALL	3709.44	-	-	-	1 (0.0002)	-	-	8 (0.002)	-	-	-	9
AF035	SPRING	960	-	4 (0.004)	-	-	-	-	3 (0.003)	-	-	-	7
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-
	FALL	999.36	-	3 (0.003)	3 (0.003)	1(0.001)	-	-	02 (0.102	2 (0.002)	-	4 (0.004)	115
AF037	SPRING	480	-	1 (0.002)	2 (0.004)	-	1 (0.002)	-	93 (0.194)	-	-	-	97
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-	-	-	-	-
AF038	SPRING	480	2 (0.004)	1 (0.002)	23 (0.048)	-	-	10 (0.021)	7 (0.015)	-	-	-	43
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-
	FALL	na	-	-		-	-	-	-	-	-	-	-
TOTAL	SPRING	1632	2	6	25	-	1	10	144	1	3	-	192
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-
	FALL	4708.8	-	3	3	2	-	-	110	2	-	4	124
GRAND TOTAL		6340.8	2	9	28	2	1	10	254	3	3	4	316

Species Codes

EMSH	Emerald Shiner	SPSH	Spottail Shiner
FLCH	Flathead Chub	TRPR	Trout-perch
LKCH	Lake Chub	WALL	Walleye
LNSC	Longnose Sucker	WHSC	White Sucker
SPSC	Spoonhead Sculpin	YLPR	Yellow perch

Table 4.4-7

Total Catch and Catch-Per-Unit-Effort for Fish taken by Backpack Electrofishing, Athabasca River and Tributaries, 1995

STATION	SEASON	TIME SAMPLED	BURB	EMSH	FLCH	FTMN	LKCH	LNDC	LNSC	NRPK	SPSH	TRPR	UNID	WHSC	YLPR	TOTAL
AF007 Athabasca R.	SPRING	1385	-	1 (0.072)	1 (0.072)	-	-	2 (0.0144)	-	-	-	-	-	-	-	4
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF008 Athabasca R.	SPRING	302	-	12 (3.974)	25 (8.278)	-	-	-	-	-	3 (0.993)	-	200 (66.22)	-	-	240
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FALL	805	-	-	-	-	1 (0.124)	-	-	-	2 (0.248)	13 (1.615)	-	-	1 (0.124)	17
AF052 Athabasca R.	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FALL	1442	1 (0.069)	-	-	-	17 (1.179)	-	-	2 (0.139)	7 (0.485)	4 (0.277)	3 (0.208)	1 (0.069)	-	35
AF043 Leggett Cr.	SPRING	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SUMMER	1637	-	-	-	-	-	-	-	-	2 (0.122)	-	-	-	-	2
	FALL	na	-	-	-	-	-	-	-		-	-	-	-	-	-
AF065 Popular Cr.	SPRING	1557	-	-	-	38 (0.024)	40 (0.026)	-	1 (0.001)	-	-	-	-	3 (0.002)	-	82
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF066 Popular Cr.	SPRING	1288	-	-	1 (0.001)	32 (0.026)	18 (0.014)	-	5 (0.004)	-	-	-	-	-	3 (0.002)	60
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AF067 Popular Cr.	SPRING	1468	-	-	-	8 (0.005)	1 (0.001)	-	-	-	-	-	-	1 (0.001)	1 (0.001)	11
	SUMMER	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FALL	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	SPRING	6000	-	13	27	78	60	2	6	-	3	-	200	4	4	397
	SUMMER	1637	-	-	-	-	-	-	-	-	2	-	-	-	-	2
	FALL	2247	1	-	-	-	18	-	-	2	9	17	3	1	1	52
GRAND TOTAL		9884	1	13	27	78	78	2	6	2	14	17	203	5	5	451

Species Codes

BURB	Burbot	NRPK	Northern Pike
EMSH	Emerald Shiner	SPSH	Spottail Shiner
FLCH	Flathead Chub	TRPR	Trout-perch
FTMN	Fathead Minnow	UNID	Unidentified
LKCH	Lake Chub	WHSC	White Sucker
LNDC	Longnose Dace	YLPR	Yellow perch
LNSC	Longnose Sucker		

TABLE 4.4-8

Total Catch and Catch-Per-Unit-Effort for Fish Captured by Minnow Traps, Athabasca River, 1995

STATION	SEASON	TIME SAMPLED	BRMN	BRST	UNID	TOTAL
AF005 Athabasca R.	SPRING	19.45	2 (0.103)	-	-	2
	SUMMER	na	-	-	-	-
	FALL	na	-	-	-	-
AF046 Leggett Cr.	SPRING	na	-	-	-	-
	SUMMER	21.75	-	-	-	0
	FALL	na	-	-	-	-
TOTAL	SPRING	19.45	2	-	-	2
	SUMMER	21.75	-	-	-	0
	FALL	na	-	-	-	0
GRAND TOTAL		41.2	2	0	0	2

Species Codes

BRMN	Brassy Minnow	UNID	Unidentified
BRST	Brook Stickleback		

TABLE 4.4-9

Total Catch and Catch-Per-Unit-Effort for Fish taken by Electrofishing, Steepbank River, 1995

STATION	SEASON	TIME SAMPLED	ARGR	BURB	GOLD	LKCH	LKWH	LNDC	LNSC	MNWH	NRPK	SPSC	TRPR	WALL	WHSC	TOTAL
AF014	SPRING	3019	1 (0.033)	1 (0.033)	-	8 (0.265)	-	1 (0.033)	5 (0.166)	33 (1.09)	1 (0.033)	4 (0.132)	1 (0.033)	2 (0.066)	2 (0.066)	59
	SUMMER	6500	-	-	-	8 (0.123)	3 (0.046)	16 (0.246)	14 (0.215)	5 (0.077)	1 (0.015)	15 (0.230)	-	2 (0.031)	-	64
	SUMMER	578	-	-	3 (0.519)	-	3 (0.519)				2 (0.346)					8
	FALL	6873	35 (0.509)	-	-	3 (0.044)	-	12 (0.175)	6 (0.087)	26 (0.378)	-	44 (0.640)	-	-	3 (0.044)	129
AF017	SPRING	2553	64 (2.506)	-	-	2 (0.078)	-	2 (0.078)	29 (0.136)	24 (0.940)	-	7 (0.274)	-	-	1 (0.039)	129
	SPRING	229	17 (7.423)	-	-	1 (0.437)		1 (0.437)	5 (2.183)	9 (3.930)		1 (0.437)			1 (0.437)	35
	SUMMER	3436	26 (0.757)	-	-	4 (0.116)	-	13 (0.378)	67 (1.950)	47 (1.368)	-	26 (0.757)	1 (0.029)	1 (0.029)	5 (0.146)	190
	FALL	4479	31 (0.692)	-	-	-	-	14 (0.313)	8 (0.179)	37 (0.826)	-	82 (1.830)	-	-	-	172
AF040	SPRING	3155	22 (0.697)	-	-	14 (0.444)	-	-	34 (1.078)	44 (1.395)	-	16 (0.507)	1 (0.032)	-	1 (0.032)	132
	SUMMER	7120	7 (0.098)	-	-	1 (0.014)	-	6 (0.084)	29 (0.408)	31 (0.436)	-	32 (0.451)	-	1 (0.014)	-	107
	FALL	2921	27 (0.924)	-	-	2 (0.068)	-	10 (0.342)	7 (0.240)	41 (1.404)	-	71 (2.431)	-	-	2 (0.068)	160
TOTAL	SPRING	8956	104	1	-	25	-	4	73	110	1	28	2	2	5	355
	SUMMER	17634	33	-	3	13	6	35	110	83	3	73	1	4	5	369
	FALL	14273	93	-	-	5	-	36	21	104	-	197	-	-	5	461
GRAND TOTAL		40863	230	1	3	43	6	75	204	297	4	298	3	6	15	1185

<u>Species Codes</u>

ARGR	Arctic Grayling	MNWH	Mountain Whitefish
BURB	Burbot	NRPK	Northern Pike
GOLD	Goldeye	SPSC	Spoonhead Sculpin
LKCH	Lake Chub	TRPR	Trout-perch
LKWH	Lake Whitefish	WALL	Walleye
LNDC	Longnose Dace	WHSC	White Sucker
LNSC	Longnose Sucker		

Table 4.4-10

Total Number of each Species Captured on the Muskeg River and its Tributaries, 1995

SPECIES	MUSKEG RIVER SYSTEM			TOTAL	PERCENT
	SPRING	SUMMER	FALL		
Arctic Grayling	64	-	76	140	7.5
Brook Stickleback	122	18	-	140	7.5
Burbot	1	-	-	1	< 0.1
Fathead Minnow	97	-	-	97	5.2
Lake Chub	5	-	249	254	13.7
Longnose Sucker	399	-	33	432	23.2
Northern Pike	129	-	117	246	13.2
Pearled Dace	14	-	-	14	0.7
Slimy Sculpin	78	-	48	126	6.8
Trout-Perch	1	-	8	9	0.5
Walleye	1	-	-	1	< 0.1
White Sucker	311	-	89	400	21.5
Total	1222	18	620	1860	99.8

Table 4.4-11

Daily Total by Species for Fish Fence, Muskeg River, Spring 1995

	Downstream Trap							Upstream Trap					
Date	Arctic Grayling	Lake Chub	Longnose sucker	Northern Pike	Trout-perch	White Sucker	Daily Totals	Arctic Grayling	Longnose Sucker	Northern Pike	Walleye	White Sucker	Daily Totals
6-May	14	0	0	0	0	0	**14**	0	0	1	0	0	**1**
7-May	6	0	0	0	0	0	**6**	0	0	24	0	0	**24**
8-May	4	0	0	0	0	0	**4**	3	3	52	0	0	**58**
9-May	0	0	0	0	0	0	**0**	6	199	21	0	86	**312**
10-May	1	0	0	0	0	0	**1**	0	0	0	0	0	**0**
11-May	4	1	2	0	0	0	**7**	0	1	12	0	9	**22**
12-May	6	2	1	0	0	0	**9**	0	9	3	0	2	**14**
13-May	1	2	1	0	0	0	**4**	0	3	0	0	0	**3**
14-May	2	0	0	0	0	0	**2**	1	92	8	0	202	**303**
15-May	0	0	0	0	0	0	**0**	1	0	5	0	0	**6**
16-May	0	0	0	0	0	0	**0**	1	0	0	0	0	**1**
17-May	1	0	2	0	0	1	**4**	0	0	0	0	0	**0**
18-May	3	0	4	0	0	0	**7**	0	0	0	0	0	**0**
19-May	0	0	4	0	0	0	**4**	0	0	0	0	0	**0**
20-May	1	0	22	1	1	0	**25**	2	0	0	1	0	**3**
21-May	2	0	0	0	0	0	**2**	0	0	0	0	0	**0**
22-May	1	0	0	0	0	0	**1**	0	1	0	0	0	**1**
23-May	2	0	0	0	0	0	**2**	0	0	0	0	0	**0**
24-May	1	0	0	2	0	0	**3**	0	0	0	0	0	**0**
25-May	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**
26-May	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**
27-May	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**
28-May	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**
29-May	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**
30-May	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**
31-May	0	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Totals	**49**	**5**	**36**	**3**	**1**	**1**	95	**14**	**308**	**126**	**1**	**299**	748
%	51.6	5.3	37.9	3.2	1.1	1.1		1.9	41.2	16.8	0.1	40.0	

Table 4.4-12

Total Numbers and Mean Catch-Per-Unit-Effort at Fish Fence, Muskeg River, Spring 1995

Species	Downstream Trap		Upstream Trap	
	Totals	CPUE (#/hr)	Totals	CPUE (#/hr)
Arctic Grayling	49	0.204	14	0.243
Lake Chub	5	0.011	0	0.000
Longnose Sucker	36	0.057	308	1.569
Northern Pike	3	0.004	126	1.269
Trout-perch	1	0.002	0	0.000
Walleye	0	0.000	1	0.005
White Sucker	1	0.012	299	2.301
Total	95	0.289	748	5.388

Table 4.4-13

Daily Total by Species for Fish Fence, Muskeg River, 1995

	Downstream Trap							Upstream Trap						
Date	Arctic Grayling	Lake Chub	Longnose Sucker	Northern Pike	Trout-perch	White Sucker	Daily Totals	Arctic Grayling	Lake Chub	Longnose Sucker	Northern Pike	Trout-perch	White Sucker	Daily Totals
23-Sep	0	0	0	1	0	0	**1**	0	0	0	0	0	0	**0**
24-Sep	0	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
25-Sep	0	3	0	4	0	1	**8**	0	0	0	0	0	0	**0**
26-Sep	1	2	0	4	0	0	**7**	0	0	0	0	0	0	**0**
27-Sep	2	20	0	4	0	0	**26**	2	0	0	0	0	0	**2**
28-Sep	0	23	0	0	0	0	**23**	0	0	0	0	0	0	**0**
29-Sep	0	33	0	0	0	0	**33**	0	0	0	0	0	0	**0**
30-Sep	0	14	0	0	0	0	**14**	0	0	0	0	0	0	**0**
1-Oct	0	7	0	1	0	0	**8**	0	0	0	0	0	0	**0**
2-Oct	0	14	0	2	0	4	**20**	0	0	0	0	0	0	**0**
3-Oct	0	7	0	1	0	0	**8**	0	0	0	0	0	0	**0**
4-Oct	1	39	0	0	0	0	**40**	0	0	0	0	0	0	**0**
5-Oct	0	13	0	1	1	3	**18**	0	0	0	0	0	0	**0**
6-Oct	0	14	0	1	0	0	**15**	0	0	0	0	0	0	**0**
7-Oct	0	36	0	4	1	0	**41**	0	0	0	0	0	0	**0**
8-Oct	0	16	0	1	0	0	**17**	0	0	0	0	0	0	**0**
9-Oct	0	3	0	0	0	0	**3**	0	0	0	0	0	0	**0**
10-Oct	0	5	0	8	0	1	**14**	0	0	0	0	0	0	**0**
11-Oct	1	0	0	6	1	1	**9**	0	0	0	0	0	0	**0**
12-Oct	0	0	0	3	0	0	**3**	0	0	0	0	0	0	**0**
13-Oct	0	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
14-Oct	0	0	0	1	0	0	**1**	0	0	0	0	0	0	**0**
15-Oct	10	0	0	4	0	1	**15**	0	0	0	0	0	0	**0**
16-Oct	0	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
17-Oct	0	0	0	0	0	0	**0**	0	0	0	0	0	0	**0**
18-Oct	2	0	0	0	0	0	**2**	0	0	0	0	0	0	**0**
19-Oct	7	0	0	3	0	3	**13**	0	0	0	0	0	0	**0**
20-Oct	17	0	6	6	0	27	**56**	0	0	0	0	0	0	**0**
21-Oct	17	0	4	10	0	10	**41**	0	0	0	0	0	0	**0**
22-Oct	10	0	6	15	0	18	**49**	0	0	0	0	0	0	**0**
23-Oct	4	0	1	31	0	12	**48**	0	0	0	0	0	0	**0**
24-Oct	1	0	4	3	0	7	**15**	0	0	0	0	0	0	**0**
25-Oct	0	0	0	3	0	1	**4**	0	0	0	0	0	0	**0**
26-Oct	1	0	0	0	0	0	**1**	0	0	0	0	0	0	**0**
Totals	**74**	**249**	**21**	**117**	**3**	**89**	**553**	**2**	**0**	**0**	**0**	**0**	**0**	**2**
%	13.4	45.0	3.8	21.2	0.5	16.1		100.0	0.0	0.0	0.0	0.0	0.0	

Table 4.4-14

Total Numbers and Mean Catch-Per-Unit-Effort at Fish Fence, Muskeg River, Fall 1995

Species	Downstream Trap		Upstream Trap	
	Totals	CPUE (#/hr)	Totals	CPUE (#/hr)
Arctic Grayling	76	0.575	2	0
Lake Chub	249	1.035	0	0
Longnose Sucker	21	0.234	0	0
Northern Pike	117	0.356	0	0
Trout-perch	3	0.086	0	0
White Sucker	89	0.628	0	0
Total	555	0.486	2	0

Table 4.4-15

Totals and Catch-Per-Unit-Effort for Fish caught by Backpack Electrofishing at Selected Sites on the Muskeg River and its Tributaries in 1995, 1988 (RL&L 1989), AND 1985 (BEAK 1986B)

SITE	YEAR	SPECIES AND NUMBER													CPUE (#/m2x100)
		ARGR	BRST	BURB	FTMN	LKCH	LNSC	NRPK	PRDC	SLSC	TRPR	WALL	WHSC	TOTAL	
Iyinimin Cr. 8	1995	-	-	-	-	-	-	-	-	-	-	-	-	-	NA
	1988	-	31	-	-	-	-	-	3	-	-	-	-	34	11.9
	1985	-	40	-	-	-	-	-	-	-	-	-	-	40	2.5
North Muskeg Cr. 9	1995	-	122	-	45	-	6	-	14	34	-	-	-	221	3.7
	1988	-	143	-	-	-	-	-	244	-	-	-	210	597	91.7
	1985	-	54	-	-	-	-	-	3	-	-	-	4	61	4.4
Jackpine Cr. 17	1995	-	-	-	3	-	2	-	-	1	-	-		6	0.9
	1988	-	7	-	-	-	-	-	3	-	-	-	1	11	10.7
S4	1995 Spring	-	-	-	41	-	4	-	-	34	-	-	-	79	0.8
	1995 Fall	-	4	-	25	-	9	-	-	44	-	-	-	53	
	1988	-	-	-	-	-	1	-	16	70	-	-	27	114	12.2
Muskeg R. 4	1995[d]	-	-	-	-	-	-	1[c]	-	-	-	-	-	-	NA
	1988	-	3	-	-	-	-	1	1	-	-	-	-	5	1.5
	1985	-		-	-	-	-	6 (0.21)[b]	-	-	-	-	-	6	0
18	1995	1	-	-	-	-	6	-	-	-	-	-	11	18	1.26
	1988	-	-	-	-	-	8	-	16	16	-	-	3	43	7.1
30	1995 Spring	-	-	1	8	-	2	-	-	5	-	-	-	16	0.13
	1995 Fall	-	-	-	17	14	2	1	-	1	5	-	-	40	3.2
31 (Fish Fence)	1995 Spring	63	-	-	-	5	379[a]	129	-	2	1	1	300	501	NA
	1995 Fall	76	-	-	-	249	21	117	-	-	3	-	89	555	NA
31 (BP)	1995 Spring	-	-	-	-	-	-	-	-	2	-	-		2	0.04
	1995 Fall	-	-	-	-	2	1	1	-	3	-	-		7	0.13
Khahoga Cr.	1995[d]	-	-	-	-	-	-	-	-	-	-	-	-	0	
	1988	-	22	-	2	-	-	-	9	-	-	-	-	33	23
	1985	-	61	-	-	-	-	-	1	-	-	-	-	62	2.9
Stanley Cr.	1995[d]	-	1[c]	-	-	-	-	-	-	-	-	-	-	0	NA
Blackfly Cr. 55	1995	-	18	-	-	-	-	-	-	-	-	-	-	18	2.5

[a]this number included 344 fish caught in the fish fence and 35 fish caught by dipnet in front of the fish fence
[b]these fish caught by gill net
[c]fish which were observed form shore but not captured
[d]not electrofished in 1995 due to water conditions

Species Codes

ARGR	Arctic Grayling	NRPK	Northern Pike
BRST	Brook Stickleback	PRDC	Pearl Dace
BURB	Burbot	SLSC	Slimy Sculpin
FTMN	Fathead Minnow	TRPR	Trout-perch
LKCH	Lake Chub	WALL	Walleye
LNSC	Longnose Sucker	WHSC	White Sucker

Table 4.4-16

Fish Inventory Results for Kearl Lake from 1995, 1988 (RL&L 1989) and 1985 (Beak 1986b)

Sample Period	Number of Fish (CPUE)					
	BRST[a]	FTMN[a]	LKCH[a]	LNSC	PRDC[a]	WHSC
1995 Spring[b]	117 (3.9)	380 (12.6)	0	0	38 (1.26)	11(0.28)
1988 Spring[c]	122(0.66)	2(0.01)	0	0	9(0.05)	198(2.08)
1988 Summer[c]	44 (0.30)	0	2 (0.06)	10 (2.08)	0	145 (4.12)
1988 Fall[c]	16 (0.09)	1 (0.01)	0	3 (0.07)	1 (0.01)	44 (0.98)
1985 Fall[c]	52(0.37)	0	0	0	1(0.01)	35(0.43)

[a] these species collected by minnow traps - CPUE fish/hr

[b] 1995 white suckers collected by electrofishing - CPUE fish/100 sec

[c] 1985 and 1988 suckers collected by gillnet - CPUE fish/hr

Table 4.4-17

Summary of Important Results Relative to the Major Fish Species on the Athabasca River (Adapted from Bond 1980)

Species	*Migrations*	*Spawning*	*Overwintering*	*Principal Foods*	*Predators*	*Competitors*	*Sensitive Locations and Times*	*Use by Man Within AOSERP Area*
Goldeye	Feeding migration into Athabasca River occurs in early spring (April) under ice. All immature fish except in 1995: mature (ripe) fish of both sexes	N/A - As adults, these fish will probably spawn in Peace-Athabasca Delta.	Suspected in Lake Athabasca or the Peace River.	Benthic and surface insects.	Pikes, Walleye, Burbot.	Few, because of varied diet.	Entire Athabasca River up to (and probably beyond) Fort McMurray serves as summer feeding area from April to October.	Commercial, Domestic, Sport.
Lake Whitefish	Spawning migration September to October. Post-spawing downstream movement begins immediately after spawning. Downstream fry migration probably April to June.	Mid-October in Athabasca River, upstream of Fort McMurray (Cascade and Mountain Rapids).	Most likely in Lake Athabasca. Some overwintering suspected in Mildred Lake study area.	Benthic Invertebrates.	Pike, Walleye, Burbot.	Bottom feeders, White Suckers, Longnose Suckers.	Tributary mouths serve as resting areas during spawning migration. Egg incubation November to March.	Domestic.
Longnose Sucker	Spawining migration begins under ice in late April to early May. Post-spawning, downstream movement begins in mid-May. Fry emerge late May to early June. Fry migration June to August. Some non-spawners remain in tributaries until freeze-up.	Over gravel in tributaries during first half of May. Muskeg River, Steepbank River, MacKay River are known spawning streams. Also spawn in Athabasca River upstream of Fort McMurray.	Probably Lake Athabasca. Some young-of-year overwinter in spawning streams.	Benthic Invertebrates, but feed little during spawning migration.	Pike, Walleye, Burbot, Grayling. Flathead Chub.	Bottom feeders, Lake Whitefish, White Suckers.	Athabasca River during migration of adults and fry (April to August). Spawning and nursery areas in tributaries (May to July). Mouth areas of tributaries are important nursery areas.	Domestic (dog food).
Walleye	Spawning migration begins under ice in late April. Post-spawning downstream movement in May and June. Fry hatch in May to June and migrate downstream during June and July.	Sites unknown but probably in Athabasca River upstream of Fort McMurray in late April and early May.	Suspected in Lake Athabasca.	Mainly fish of several species. Some aquatic insects.	Pike, Burbot, Walleye.	Pike, Burbot.	Athabasca River during migration of adults and fry. Tributary mouths serve as resting areas for adults and as nursery areas.	Commercial, Domestic, Sport.
Northern Pike	Spawning movements in April and early May. Upstream migration noted in some tributaries in May consist of ripe, spent and immature fish. Frequent lower reaches and mouth areas of tributaries during summer.	Probably late April and early May in marshy areas adjacent to Athabasca River and in some tributaries.	Probably Athabasca River in Mildred Lake area. Those in Delta may over-winter in the Athabasca River, upstream of Delta or in Lake Athabasca.	Mainly fish of several species. Some immature insects.	Pike, Burbot, Walleye.	Walleye, Burbot.	Marshy areas in late April and early May. Lower reaches of tributaries important feeding areas in summer.	Sport, Domestic.
White Sucker	Spawning migration begins under ice in late April to early May. Downstream movement of spawners begins in mid-May. Fry emerge late May and early June. Fry migration June to August. Some non-spawners remain in tributaries until freeze-up.	Over gravel in tributaries during first half of May. Muskeg River, Steepbank River, MacKay River are known spawning streams.	Probably Lake Athabasca. Some young-of-year overwinter in spawning streams.	Benthic Invertebrates, but feed little during spawning period.	Pike, Burbot, Grayling, Flathead Chub.	Bottom feeders, Lake Whitefish, Longnose Suckers.	Athabasca River during migration of adults and fry. Spawning and nursery areas in tributaries (May to July). Mouth areas of tributaries are important nursery areas.	Domestic (dog food).
Flathead Chub	May be resident in Athabasca River. Mature fish more common in Mildred than in Delta study area. Decrease in abundance after June suggests movement but extent unknown. Seldom enter tributaries. Young-of-year appear in July. Nursery areas suspected in Delta or Lake Athabasca.	Areas unknown but assumed in Athabasca River within or upstream of Mildred Lake area during June and July.	Unknown; suspected within Athabasca River and Lake Athabasca.	Varied, mainly mature and immature insects, both aquatic and terrestrial.	Pike, Walleye, Goldeye, Burbot.	Few, because of varied diet.	Spawning and egg incubation probably in Athabasca River from mid-June to mid-August.	None, but sometimes taken by anglers.

Table 4.4-17

Summary of Important Results Relative to the Major Fish Species on the Athabasca River (Adapted from Bond 1980)

Species	*Migrations*	*Spawning*	*Overwintering*	*Principal Foods*	*Predators*	*Competitors*	*Sensitive Locations and Times*	*Use by Man Within AOSERP Area*
Emerald Shiner	Spawning migration into Mildred Study area assumed in May and June. Seldom enter tributaries. Most spawners age 2. Large post-spawning mortality suspected. Fry migrate down-stream during summer and remain in Delta and/or Lake Athabasca until age 2.	Areas unknown but assumed in Athabasca River within or upstream of Mildred Lake area. Probably spawn in June and July.	Suspected in Delta and/or Lake Athabasca.	Benthic Invertebrates (mostly insects).	Walleye, Pike, Goldeye, Burbot.		Spawning and egg incubation in Athabasca River during June and July.	None.
Trout-Perch	Probably resident in Athabasca River. Enter tributaries in May to spawn during late May or early June. Severe post-spawning mortality suspected. Fry emerge in early June and migrate out of tributaries to Athabasca River during June and July.	Tributaries in late May and early June. Possibly Athabasca River also.	Probably Athabasca River.	Benthic Invertebrates (mostly insects).	Walleye, Pike, Goldeye, Burbot.		Spawning and egg incubation in tributaries from May to July.	None.
Lake Chub	Seldom found in Delta but common in Mildred Lake study area and tributaries. Fry appear in Athabasca River in July. Few matures captured.	Locations unknown. Probably spawn in lower reaches of tributaries or along edge of Athabasca River in Mildred Lake area during May or June.	Athabasca River or tributaries in Mildred Lake study area.	Benthic Invertebrates (mostly insects).	Walleye, Pike, Goldeye, Burbot.		Probably spawn in May or June.	None.
Spottail Shiner	Occur throughout study area but more common in Delta study area. Fry appear mid-July but not abundant until mid-August. Seldom enter tributaries.	Unknown, but probably Athabasca River or lower reaches of some tributaries in late June or early July.	Probably Athabasca River and Lake Athabasca.	Benthic Invertebrates (mostly insects).	Walleye, Pike, Goldeye, Burbot.		Spawning and egg incubation in late June or early July.	None.
Arctic Grayling	Migrate into tributary streams of Mildred Lake in late April and early May. Seldom found in Athabasca River during summer. Never taken in Delta. Migrate out of tributaries just prior to freeze-up in October. Tributaries provide summer feeding for adults and nursery areas for fry.	Late April and early May. Muskeg River and Steepbank River are known spawning streams.	Young-of-year may overwinter in spawning streams. Age 1+ and older fish overwinter in Athabasca River, probably in the upper Mildred Lake area or above Fort McMurray.	Mature and immature stages of aquatic and terrestrial insects.	Walleye, Pike, but probably little predation while in tributaries.	Few, because of varied diet.	Spawning, feeding and nursery areas in tributaries. Over-wintering areas for young in tributaries. Susceptable to over-harvest by anglers.	Sport.
Burbot	A spawning migration into Mildred Lake area is suspected during the winter. Burbot leave Mildred Lake area by Mid-June. Young-of-year appear in early June.	Spawning for this species usually occurs from January to March under ice.	Probably Lake Athabasca.	Fish of many species.	Walleye, Pike.	Walleye, Pike, Goldeye.	Spawning and egg incubation in or upstream of Mildred Lake area January to June.	Domestic, Sport.

Table 4.4-18

Life Stage and Sex of Walleye by Sampling Station and Season, Athabasca River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF001	SPRING	1	0	0	1	0	0	0	0	0	0	1
AF002	SPRING	44	43	1	0	11	0	0	11	0	1	56
AF002	SUMMER	0	0	0	0	5	1	0	4	4	1	10
AF002	FALL	2	0	0	2	5	0	0	5	2	1	10
AF002 SL1	FALL	1	0	0	1	0	0	0	0	0	0	1
AF002 SL2	FALL	2	0	0	2	2	0	0	2	0	0	4
AF003	SPRING	1	0	1	0	0	0	0	0	0	0	1
AF003	SUMMER	4	3	1	0	8	0	0	8	3	1	16
AF004	SPRING	26	25	1	0	4	0	0	4	0	1	31
AF004	SUMMER	11	5	6	0	19	3	0	13	1	1	32
AF004	FALL	9	0	0	9	9	0	0	9	0	2	20
AF005	SPRING	41	38	3	0	24	0	0	24	0	2	67
AF005	SUMMER	1	0	1	0	7	1	1	5	1	0	9
AF005	FALL	3	0	0	3	4	0	0	4	0	1	8
AF006	SPRING	5	4	1	0	0	0	0	0	0	0	5
AF006	SUMMER	2	2	0	0	3	0	0	3	3	0	8
AF006-SL1	FALL	2	1	1	0	0	0	0	0	0	1	3
AF006-SL2	FALL	0	0	0	0	0	0	0	0	0	1	1
AF010	SPRING	1	1	0	0	0	0	0	0	0	0	1
AF016	SUMMER	0	0	0	0	0	0	0	0	1	0	1
AF018	SUMMER	0	0	0	0	2	0	0	2	0	0	2
AF018	FALL	4	0	0	4	6	0	0	6	1	2	13
AF018-GN1	SPRING	4	1	0	3	0	0	0	0	0	0	4
AF018-SL1	FALL	2	1	0	1	0	0	0	0	0	0	2

Table 4.4-18 con't

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF018-SL2	FALL	1	0	1	0	0	0	0	0	0	0	1
AF019-SL1	SPRING	0	0	0	0	1	0	1	0	0	0	1
AF019	SUMMER	1	1	0	0	7	1	0	6	1	0	9
AF019	FALL	1	0	0	1	5	0	0	5	3	0	9
AF019-SL4	FALL	2	1	0	1	0	0	0	0	0	1	3
AF019-SL5	FALL	1	0	1	0	2	0	0	2	0	0	3
AF020	FALL	0	0	0	0	1	0	0	1	5	0	6
AF023-SN1	SPRING	0	0	0	0	1	0	0	1	0	0	1
AF028-SL1	SPRING	2	1	0	1	0	0	0	0	0	0	2
AF029-SL1	SPRING	2	2	0	0	0	0	0	0	0	1	3
AF029-SL1	FALL	1	0	0	1	1	0	0	1	0	0	2
AF033-SL1	SPRING	1	0	0	1	0	0	0	0	0	0	1
AF034-SL1	SPRING	2	2	0	0	0	0	0	0	0	0	2
AF033	SUMMER	6	1	5	0	7	1	0	6	0	0	13
AF034	SUMMER	0	0	0	0	0	0	0	0	0	2	2
AF035-SN2	FALL	0	0	0	0	0	0	0	0	1	1	2
AF036	SUMMER	2	2	0	0	2	0	0	2	2	0	6
AF036	FALL	0	0	0	0	2	0	0	2	0	0	2
AF041	SUMMER	1	1	0	0	3	0	0	3	0	0	4
AF041	FALL	0	0	0	0	1	0	0	1	0	0	1
AF042	SUMMER	2	0	2	0	0	0	0	0	0	0	2
AF042	FALL	2	0	0	2	2	0	0	2	4	2	10

Table 4.4-19

Length-Weight Regression Equations for Fish Collected from the Athabasca, Steepbank and Muskeg River Systems, 1995

SPECIES	WATERCOURSE	MALE EQUATION	MALE R^2	MALE n	FEMALE EQUATION	FEMALE R^2	FEMALE n	BOTH SEXES EQUATION	BOTH SEXES R^2	BOTH SEXES n
Walleye	Athabasca	$Log_{10}W = 2.95Log_{10}L-4.85$	0.91	142	$Log_{10}W = 2.64Log_{10}L-4.02$	0.99	38	-	-	-
Goldeye	Athabasca	$Log_{10}W = 2.90Log_{10}L-4.69$	0.88	100	$Log_{10}W =3.14Log_{10}L-5.30$	0.97	125	$Log_{10}W = 3.16Log_{10}L-5.34$	0.98	276
Longnose Sucker	Athabasca	-	-	-	-	-	-	$Log_{10}W = 3.08Log_{10}L-5.10$	0.98	185
Longnose Sucker	Steepbank	$Log_{10}W = 2.68Log_{10}L-4.05$	0.82	23	$Log_{10}W = 2.40Log_{10}L-3.29$	0.94	24	-	-	-
Longnose Sucker	Muskeg	$Log_{10}W = 2.59Log_{10}L-3.84$	0.71	199	$Log_{10}W = 2.62Log_{10}L-3.89$	0.73	178	-	-	-
White Sucker	Athabasca	-	-	-	-	-	-	$Log_{10}W = 3.20Log_{10}L-5.33$	0.99	97
White Sucker	Steepbank	-	-	-	-	-	-	$Log_{10}W = 3.15Log_{10}L-5.26$	0.98	14
White Sucker	Muskeg	$Log_{10}W = 2.98Log_{10}L-4.79$	0.91	112	$Log_{10}W =3.14Log_{10}L-5.20$	0.85	119	-	-	-
White Sucker	Kearl Lake	-	-	-	-	-	-	$Log_{10}W = 2.96Log_{10}L4.78$	0.95	10
Arctic Grayling	Steepbank	-	-	-	-	-	-	$Log_{10}W = 3.14Log_{10}L-5.24$	0.99	164
Arctic Grayling	Muskeg	$Log_{10}W = 2.19Log_{10}L-2.91$	0.59	39	$Log_{10}W = 2.74Log_{10}L-4.26$	0.84	51	-	-	-
Northern Pike	Athabasca	-	-	-	-	-	-	$Log_{10}W = 2.94Log_{10}L-5.00$	0.96	46
Northern Pike	Muskeg	$Log_{10}W = 2.36Log_{10}L-3.39$	0.84	81	$Log_{10}W = 3.13Log_{10}L-5.47$	0.96	52	-	-	-
Lake Whitefish	Athabasca	-	-	-	-	-	-	$Log_{10}W = 3.09Log_{10}L-5.03$	0.85	616
Mountain Whitefish	Steepbank	-	-	-	-	-	-	$Log_{10}W = 3.24Log_{10}L-5.45$	0.99	210
Flathead Chub	Athabasca	-	-	-	-	-	-	$Log_{10}W = 3.08Log_{10}L-5.13$	0.93	211
Lake Chub	Athabasca	-	-	-	-	-	-	$Log_{10}W = 2.46Log_{10}L-3.99$	0.85	28
Lake Chub	Steepbank	-	-	-	-	-	-	$Log_{10}W = 3.16Log_{10}L-5.27$	0.71	31
Trout Perch	Athabasca	-	-	-	-	-	-	$Log_{10}W = 2.61Log_{10}L-4.23$	0.80	212
Spoonhead Sculpin	Steepbank	-	-	-	-	-	-	$Log_{10}W = 3.44Log_{10}L-5.81$	0.74	177

Note: all data is log_{10} transformed as recommended by MacKay et al. (1990)

Table 4.4-20

Life Stage and Sex of Goldeye by Sampling Station and Season, Athabasca River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF001	SPRING	1	1	0	0	0	0	0	0	0	3	4
AF002	SPRING	15	2	12	1	8	2	5	1	0	6	29
AF002	SUMMER	11	5	6	0	13	0	2	11	1	3	28
AF002	FALL	0	0	0	0	0	0	0	0	0	1	1
AF003	SPRING	4	2	2	0	1	1	0	0	0	0	5
AF003	SUMMER	5	3	2	0	2	0	1	1	0	0	7
AF003	FALL	2	0	2	0	0	0	0	0	0	0	2
AF004	SPRING	2	1	1	0	1	0	0	1	0	8	11
AF004	SUMMER	27	18	9	0	13	0	9	4	0	24	64
AF004	FALL	5	5	0	0	2	0	2	0	0	0	7
AF005	SPRING	0	0	0	0	2	0	2	0	0	1	3
AF005	SUMMER	0	0	0	0	2	0	2	0	0	1	3
AF006	SPRING	0	0	0	0	2	1	0	1	0	1	3
AF006	SUMMER	2	1	1	0	2	1	1	0	0	0	4
AF006	FALL	9	4	5	0	0	0	0	0	0	1	10
AF018-GN1	SPRING	1	1	0	0	0	0	0	0	0	0	1
AF018	SUMMER	1	0	1	0	0	0	0	0	0	0	1
AF019-GN1	SPRING	2	0	2	0	0	0	0	0	0	0	2
AF019	SUMMER	2	0	2	0	3	2	0	1	0	0	5
AF019	FALL	19	10	9	0	0	0	0	0	0	1	20
AF020	SUMMER	2	0	2	0	0	0	0	0	0	0	2
AF020	FALL	4	1	2	1	0	0	0	0	0	0	4
AF033	SUMMER	11	4	4	3	2	0	0	2	0	6	19
AF034	SUMMER	0	0	0	0	1	1	0	0	0	0	1
AF036	SUMMER	6	1	5	0	4	1	2	1	0	2	12
AF036	FALL	10	3	6	1	0	0	0	0	0	0	10

Table 4.4-20 con't

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF041	SUMMER	1	0	1	0	4	2	2	0	0	1	6
AF041	FALL	3	1	2	0	0	0	0	0	0	0	3
AF042	SUMMER	2	2	0	0	1	0	1	0	0	4	7
AF044	SUMMER	2	1	1	0	0	0	0	0	0	0	2

Table 4.4-21

Life Stage and Sex of Longnose Sucker by Sampling Station and Season, Athabasca River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF001	SPRING	1	1	0	0	0	0	0	0	0	0	1
AF002	SPRING	21	8	13	0	3	0	0	3	0	0	24
AF002	SUMMER	0	0	0	0	1	0	0	1	0	0	1
AF002	FALL	0	0	0	0	1	0	0	1	1	0	2
AF003	SPRING	4	4	0	0	0	0	0	0	0	0	4
AF003	SUMMER	0	0	0	0	5	0	0	5	0	0	5
AF003	FALL	1	0	0	1	0	0	0	0	0	0	1
AF004	SPRING	8	2	6	0	5	0	0	5	0	1	14
AF004	SUMMER	5	0	0	5	4	0	0	4	0	0	9
AF004	FALL	2	1	0	1	4	0	0	4	0	1	7
AF005	SPRING	2	0	2	0	0	0	0	0	0	3	5
AF005	SUMMER	0	0	0	0	2	0	0	2	0	0	2
AF005	FALL	12	9	0	3	1	0	0	1	0	1	14
AF006	FALL	6	1	0	5	1	0	0	1	0	0	7
AF018	SUMMER	0	0	0	0	2	0	0	2	0	0	2
AF018	FALL	3	2	1	0	0	0	0	0	1	0	4
AF019	FALL	15	6	2	7	0	0	0	0	0	0	15
AF020	FALL	1	0	0	1	1	0	0	1	0	0	2
AF023	FALL	0	0	0	0	0	0	0	0	1	0	1
AF026	SPRING	1	0	1	0	0	0	0	0	0	0	1
AF033	SUMMER	4	0	0	4	5	0	0	5	0	1	10
AF034	SUMMER	1	0	0	1	1	0	0	1	0	0	2
AF035	FALL	0	0	0	0	0	0	0	0	1	0	1
AF036	SUMMER	0	0	0	0	1	0	0	1	0	0	1
AF036	FALL	1	0	0	1	0	0	0	0	0	0	1
AF041	SUMMER	0	0	0	0	2	0	0	2	0	0	2
AF041	FALL	17	7	3	7	0	0	0	0	0	0	17

Table 4.4-21 con't

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF042	SUMMER	2	1	0	1	0	0	0	0	0	0	2
AF042	FALL	24	0	0	24	2	0	0	2	1	1	28

Table 4.4-24

Life Stage and Sex of White Sucker by Sampling Station and Season, Athabasca River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF002	SPRING	2	0	2	0	0	0	0	0	0	0	2
AF002	FALL	5	1	2	2	1	0	0	1	0	0	6
AF003	SUMMER	1	0	0	1	2	0	0	2	0	0	3
AF003	FALL	2	0	0	2	2	0	0	2	0	0	4
AF004	SPRING	2	0	1	1	2	0	0	2	0	0	4
AF004	SUMMER	3	0	0	3	0	0	0	0	0	1	4
AF004	FALL	12	3	1	8	4	0	0	4	0	3	19
AF005	FALL	1	0	0	1	0	0	0	0	0	0	1
AF006	FALL	2	0	0	2	0	0	0	0	0	0	2
AF015	SPRING	2	1	1	0	0	0	0	0	0	0	2
AF016	SPRING	2	0	2	0	0	0	0	0	0	0	2
AF018	FALL	7	3	0	4	1	0	0	1	0	0	8
AF019	FALL	1	0	0	1	1	0	0	1	0	0	2
AF020	FALL	10	3	0	7	4	0	0	4	0	0	14
AF023 SN1	SUMMER	0	0	0	0	3	0	0	3	0	0	3
AF033	SUMMER	1	0	0	1	0	0	0	0	0	1	2
AF034	SUMMER	0	0	0	0	2	0	0	2	0	0	2
AF036	FALL	6	1	0	5	1	0	0	1	0	0	7
AF041	FALL	3	1	0	2	1	0	0	1	0	0	4
AF042	SUMMER	2	1	0	1	0	0	0	0	0	1	3
AF042	FALL	1	0	0	1	0	0	0	0	0	1	2
AF052	FALL	0	0	0	0	0	0	0	0	0	1	1

Table 4.4-25

Life Stage and Sex of White Sucker by Sampling Station and Season, Steepbank River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF014	SPRING	2	1	1	0	0	0	0	0	0	0	2
AF014	FALL	0	0	0	0	3	0	0	3	0	0	3
AF017	SPRING	0	0	0	0	0	0	0	0	0	2	2
AF017	SUMMER	2	0	0	2	1	0	0	1	0	1	4
AF040	SPRING	1	0	1	0	0	0	0	0	0	0	1
AF040	SPRING	0	0	0	0	2	0	0	2	0	0	2

Table 4.4-26

Life Stage and Sex of White Sucker by Sampling Station and Season, Muskeg River System, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
18	SPRING	11	1	10	0	0	0	0	0	0	0	11
18	FALL	0	0	0	0	0	0	0	0	0	0	0
31	SPRING	298	109	189	0	1	0	0	1	0	1	300
31	FALL	62	2	3	57	27	0	0	27	0	0	89

Table 4.4-27

Life Stage and Sex of Arctic Grayling by Sampling Station and Season, Steepbank River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF014	SPRING	1	0	0	1	0	0	0	0	0	0	1
AF014	FALL	28	10	4	14	0	0	0	0	1	4	33
AF017	SPRING	4	0	0	4	16	0	0	16	0	27	47
AF017	SUMMER	2	0	0	2	10	0	0	10	2	3	17
AF017	FALL	12	0	0	12	9	0	0	9	0	3	24
AF040	SPRING	4	1	0	3	9	0	0	9	0	0	13
AF040	SUMMER	0	0	0	0	5	0	0	5	0	0	5
AF040	FALL	14	0	0	14	6	0	0	6	0	3	23

Table 4.4-28

Life Stage and Sex of Arctic Grayling by Sampling Station and Season, Muskeg River System, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
18	SPRING	1	0	0	1	0	0	0	0	0	0	1
18	FALL	0	0	0	0	0	0	0	0	0	0	0
31	SPRING	49	24	17	8	1	0	0	1	0	10	60
31	FALL	43	14	28	1	33	0	0	33	0	0	76

Table 4.4-29

Life Stage and Sex of Northern Pike by Sampling Station and Season, Athabasca River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF001	SPRING	1	1	0	0	0	0	0	0	0	1	2
AF002	SPRING	3	1	0	2	0	0	0	0	0	1	4
AF002	SUMMER	0	0	0	0	1	0	0	1	0	1	2
AF002	FALL	0	0	0	0	1	0	0	1	0	0	1
AF003	SPRING	0	0	0	0	0	0	0	0	0	1	1
AF003	SUMMER	7	0	0	7	0	0	0	0	0	0	7
AF003	FALL	1	0	0	1	1	0	0	1	0	0	2
AF004	SPRING	2	0	2	0	0	0	0	0	0	0	2
AF004	SUMMER	1	0	0	1	1	0	0	1	0	1	3
AF004-SL2	FALL	0	0	0	0	0	0	0	0	0	1	1
AF005	SPRING	2	0	0	2	0	0	0	0	0	0	2
AF005	SUMMER	3	0	0	3	1	0	0	1	0	0	4
AF006	FALL	1	0	0	1	0	0	0	0	0	0	1
AF015	SPRING	1	0	0	1	0	0	0	0	0	0	1
AF016	SUMMER	1	0	0	1	0	0	0	0	0	0	1
AF018-GN1	SPRING	3	3	0	0	0	0	0	0	0	0	3
AF018	FALL	1	0	0	1	0	0	0	0	0	0	1
AF019	SUMMER	0	0	0	0	1	0	0	1	0	0	1
AF019	FALL	1	0	0	1	0	0	0	0	0	0	1
AF020	SUMMER	1	0	0	1	0	0	0	0	0	0	1
AF033	SUMMER	0	0	0	0	0	0	0	0	0	1	1
AF036	FALL	0	0	0	0	1	0	0	1	0	0	1
AF041	SUMMER	3	0	0	3	0	0	0	0	0	0	3

Table 4.4-29 con't

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF052	FALL	2	0	2	0	0	0	0	0	0	0	2

Table 4.4-30

Life Stage and Sex of Northern Pike by Sampling Station and Season, Muskeg River , 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMAL	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
30	SPRING	0	0	0	0	0	0	0	0	0	0	0
30	FALL	0	0	0	0	1	0	0	1	0	0	1
31	SPRING	127	72	49	6	1	0	0	1	0	0	128
31	FALL	83	4	9	70	34	0	0	34	0	0	117
S4	FALL	0	0	0	0	0	0	0	0	1	0	1

Table 4.4-31

Life Stage and Sex of Lake Whitefish by Sampling Station and Season, Athabasca River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF001	SPRING	1	0	0	1	0	0	0	0	0	0	1
AF002	SPRING	2	0	0	2	0	0	0	0	0	0	2
AF002	FALL	40	17	9	14	1	0	0	1	0	5	46
AF003	SPRING	0	0	0	0	1	0	0	1	0	0	1
AF003	SUMMER	13	2	3	8	0	0	0	0	0	1	14
AF003	FALL	36	20	15	1	1	0	0	1	0	2	39
AF004	SUMMER	1	0	0	1	0	0	0	0	0	0	1
AF004	FALL	11	7	2	2	0	0	0	0	0	0	11
AF005	FALL	72	36	21	15	0	0	0	0	0	0	72
AF006	FALL	43	21	3	19	0	0	0	0	0	0	43
AF018-GN1	SPRING	1	1	0	0	0	0	0	0	0	0	1
AF018	FALL	59	23	32	4	1	0	0	1	0	0	60
AF019	FALL	47	19	21	7	0	0	0	0	0	0	47
AF020	FALL	129	5	3	121	0	0	0	0	0	0	129
AF033	SUMMER	1	0	0	1	0	0	0	0	0	0	1
AF036	FALL	70	17	2	51	0	0	0	0	0	0	79
AF041	FALL	47	18	23	6	0	0	0	0	0	0	47
AF042	SUMMER	1	0	0	1	0	0	0	0	0	0	1
AF042	FALL	31	0	0	31	0	0	0	0	0	0	31

Table 4.4-32

Life Stage and Sex of Mountain Whitefish by Sampling Station and Season, Steepbank River, 1995

		ADULT				JUVENILE						
STATION	SEASON	TOTAL	MALE	FEMALE	UNKNOWN	TOTAL	MALE	FEMALE	UNKNOWN	FRY	UNKNOWN	TOTAL FISH
AF014	SPRING	5	1	0	4	10	0	0	10	0	10	25
AF014	SUMMER	2	0	0	2	1	0	0	1	0	1	4
AF014	FALL	0	0	0	0	17	0	0	17	3	0	20
AF017	SPRING	2	0	0	2	4	1	2	1	0	15	21
AF017	SUMMER	7	0	0	7	17	0	0	17	6	1	31
AF017	FALL	0	0	0	0	21	0	0	21	6	3	30
AF040	SPRING	0	0	0	0	11	5	1	5	0	16	27
AF040	SUMMER	0	0	0	0	13	1	1	11	2	0	15
AF040	FALL	0	0	0	0	22	0	0	22	6	0	28

Table 4.5-1

Mean Condition Factor with Standard Deviation (SD) for Female and Male Walleye from the Athabasca River, 1995

Species	Sex	n	Condition Factor Mean ± SD
Walleye	Female	38	1.1 ± 0.3
	Male	142	1.1 ± 0.1
Goldeye	Female	138	1.2 ± 0.1
	Male	103	1.2 ± 0.1

Table 4.5-2

Mean Condition Factor and Mean Gonad Somatic Index (GSI) with Standard Deviation (SD) for Female and Male Longnose Sucker from the Muskeg River, 1995

Sex	n	Condition Factor Mean ± SD	GSI Mean ± SD
Female	21	1.3 ± 0.1	11.2 ± 2.4
Male	20	1.3 ± 0.2	4.9 ± 0.9

Table 4.5-3

Mesenteric Fat Content (Percent Incidence) in Fillets, for Female and Male Walleye and Goldeye from the Athabasca River, Summer 1995

Species/Sex	n	Mesenteric Fat Content (% Incidence) No Coverage	<50% Coverage	50% Coverage	>50% Coverage	Complete Coverage
Walleye Female	14	-	28.6	21.4	42.9	7.1
Walleye Male	23	8.7	47.8	13	21.7	4.3
Goldeye Female	22	9.1	50	13.6	18.2	4.5
Goldeye Male	18	-	61.1	16.7	22.2	-

Table 4.5-4

Mesenteric Fat Content (Percent Incidence) in Fillets, for Female and Male Longnose Sucker from the Muskeg River, Spring 1995

Species/Sex	n	Mesenteric Fat Content (% Incidence) No Coverage	<50% Coverage	50% Coverage	>50% Coverage	Complete Coverage
Longnose Suckers Female	21	9.5	57.1	14.3	4.8	14.3
Longnose Suckers Male	17	-	47	23.5	11.8	17.6

Table 4.5-5

Mean Liver Somatic Index (LSI) with Standard Deviation for Female and Male Walleye, Goldeye and Longnose Sucker from the Athabasca and Muskeg Rivers, Spring and Summer 1995

Season/Year	Sex	Index	Mean ± Standard Deviation Walleye Athabasca River	 Goldeye Athabasca River	 Longnose Sucker Muskeg River
Spring 1995	Female	n	-	-	21
		LSI	-	-	1.6 ± 0.3
	Male	n	-	-	20
		LSI	-	-	1.5 ± 0.3
Summer 1995	Female	n	14	22	-
		LSI	0.8 ± 0.2	0.9 ± 0.2	-
	Male	n	23	18	-
		LSI	0.9 ± 0.4	0.9 ± 0.2	-

Table 4.5-6

Mean (± Standard Deviation), Minimum and Maximum Length (mm), Weight (g), LSI and Age of Female and Male Walleye and Goldeye from the Athabasca River, Summer 1995

Species/Sex	Index	Length (mm)	Weight (g)	LSI	Age
Walleye Female	n	14	14	14	14
	Mean ± SD	476.5 ± 58.8	1194.6 ± 531.4	0.8 ± 0.2	6.1 ± 2.0
	Minimum	395	640	0.52	4
	Maximum	624	2523	1.16	11
Walleye Male	n	23	23	23	23
	Mean ± SD	426.0 ± 33.8	860.4 ± 226.5	0.9 ± 0.4	5.0 ± 1.1
	Minimum	379	520	0.48	4
	Maximum	489	1241	2.38	8
Goldeye Female	n	22	22	22	22
	Mean ± SD	356.1 ± 25.2	521.2 ± 112.3	0.9 ± 0.2	5.3 ± 1.5
	Minimum	318	370	0.59	3
	Maximum	401	730	1.29	9
Goldeye Male	n	18	18	18	18
	Mean ± SD	335.6 ± 15.6	438.2 ± 55.5	0.9 ± 0.2	5.4 ± 1.6
	Minimum	313	357	0.59	3
	Maximum	363	545	1.2	9

Table 4.5-7

Mean (± Standard Deviation), Minimum and Maximum Length (mm), Weight (g), LSI and Age of Female and Male Longnose Sucker from the Muskeg River, Spring 1995

Sex	Index	Length (mm)	Weight (g)	LSI	Age
Female	n	21	21	21	20
	Mean ± SD	415.9 ± 25.1	965.2 ± 172.0	1.6 ± 0.3	6.6 ± 0.8
	Minimum	382	770	1.05	5
	Maximum	475	1400	2.07	8
Male	n	20	20	20	20
	Mean ± SD	384.6 ± 21.1	741.8 ± 130.6	1.5 ±0.3	5.6 ± 0.7
	Minimum	350	590	0.92	5
	Maximum	430	1055	2	7

Table 4.5-8

Percent Incidence of External Pathology in Various Fish Species from the Athabasca and Steepbank Rivers, 1995

Species/River	n	External Pathology		
		%Parasites	% Injuries	% Other[a]
Arctic Grayling Steepbank River	230	0.0	0.9	3.0
Flathead Chub Athabasca River	443	0.5	0.9	0.7
Goldeye Athabasca River	442	0.0	4.5	18.6
Lake Chub Athabasca River	48	0.0	2.1	0.0
Lake Chub Steepbank River	43	0.0	0.0	2.3
Lake Whitefish Athabasca River	1685	5.9	22.7	33.5
Longnose Sucker Athabasca River	476	5.7	8.8	7.6
Longnose Sucker Steepbank River	204	3.4	6.4	3.4
Northern Pike Athabasca River	85	0.0	8.2	5.9
Mountain Whitefish Athabasca River	13	0.0	7.7	23.1
Mountain Whitefish Steepbank River	297	0.0	4.0	5.1
Spottail Shiner Athabasca River	23	0.0	4.4	0.0
Trout Perch Athabasca River	910	0.0	0.2	0.0
Walleye Athabasca River	729	0.3	3.4	1.2
White Sucker Athabasca River	144	9.0	29.2	40.3
White Sucker Steepbank River	15	6.7	6.7	26.7

a. Includes emaciated, raised/missing scales, missing/damaged eyes, gill damage, inflammation of urogenital/anal openings, lesions/growths, hemorrhagic body surface/fins, and unusual features (i.e. deformities)

Table 4.5-9

Percent Incidence of Field-Recorded Gross External Pathology in Various Fish Species from the Muskeg River, 1995

Species	n	Gross External Pathology		
		%Parasites	% Injuries	% Other[a]
Arctic Grayling	140	0.0	0.7	0.7
Brook Stickleback	140	0.0	0.8	0.0
Lake Chub	254	0.0	0.4	0.0
Longnose Sucker	432	0.0	1.9	2.4
Northern Pike	246	0.0	8.5	13.2
White Sucker	400	0.0	2.8	1.8

a. Includes emaciated, raised/missing scales, missing/damaged eyes, gill damage, inflammation of urogenital/anal openings, lesions/growths, hemorrhagic body surface/fins, and unusual features (i.e. deformities)

Table 4.5-10

Percent Incidence of Field-Recorded Gross Internal Pathology in Walleye and Goldeye from the Athabasca River, and Longnose Sucker from the Muskeg River, Spring and Summer 1995

Species/River	Season	n	Gross Internal Pathology			
			% Parasites[a]	% Liver Anomalies[b]	% Spleen Anomalies[c]	% Other[d]
Walleye						
Athabasca River	Summer 1995	37	59.5	54.1	2.7	2.7
Goldeye						
Athabasca River	Summer 1995	40	75.0	5.0	40.0	2.5
Longnose Sucker						
Muskeg River	Spring 1995	41	0.0	17.1	0.0	2.4

a. Includes parasites observed in the intestine and pyloric caecae
b. Includes growths, and discoloured or pale liver tissue
c. Includes granular, nodular and discoloured spleen tissue
d. Includes body cavity adhesions, and inflammation of the hindgut

Table 4.5-11

Hepatic EROD and AHH Specific Activity in Female and Male Walleye from the Athabasca River, Summer 1995

Sex	Index	Hepatic EROD Specific Activity (pmol/min/mg)	Hepatic AHH Specific Activity (pmol/min/mg)
Female	n	9	9
	Mean ± SD	181.7 ± 84.4	49.0 ± 25.6
	Minimum	38.0	8.9
	Maximum	309.0	79.0
Male	n	14	14
	Mean ± SD	200.6 ± 142.8	58.7 ± 43.4
	Minimum	57.0	17.0
	Maximum	631.0	183.0

Table 4.5-12

Hepatic EROD and AHH Specific Activity in Female and Male Goldeye from the Athabasca River, Summer 1995

Sex	Index	Hepatic EROD Specific Activity (pmol/min/mg)	Hepatic AHH Specific Activity (pmol/min/mg)
Female	n	21	21
	Mean ± SD	213.4 ± 151.1	59.4 ± 48.3
	Minimum	8.0	3.3
	Maximum	491.0	156.0
Male	n	17	17
	Mean ± SD	324.9 ± 129.3	90.2 ± 45.2
	Minimum	159.0	31.0
	Maximum	593.0	215.0

Table 4.5-13

Hepatic EROD and AHH Specific Activity in Female and Male Longnose Sucker from the Muskeg River, Spring 1995

Sex	Index	Hepatic EROD Specific Activity (pmol/mg/min)	Hepatic AHH Specific Activity (pmol/mg/min)
Female	n	1	1
	Mean +/- SD	70	27
	Minimum		
	Maximum		
Male	n	1	1
	Mean +/- SD	320	70
	Minimum		
	Maximum		

Table 4.5-14

Mean Retinol (Vitamin A) with Standard Deviation in Female and Male Walleye and Goldeye from the Athabasca River, Summer 1995

	Walleye		Goldeye	
Parameter	**Female (n=4) Mean ± SD**	**Male (n=5) Mean ± SD**	**Female (n=3) Mean ± SD**	**Male (n=4) Mean ± SD**
Retinol	0.12±0.09	0.16±0.18	0.83±0.59	0.90±0.35

Table 4.5-15

Mean Blood Serum Parameters with Standard Deviation in Female and Male Walleye and Goldeye from the Athabasca River, Summer 1995

	Walleye		Goldeye	
Parameter	**Female (n=2) Mean± SD**	**Male (n=6) Mean ± SD**	**Female (n=3) Mean± SD**	**Male (n=3) Mean ± SD**
Lactate (mg/dL)	61.0 ± 17.0	71.7 ± 7.5	118.7 ± 22.2	128.3 ± 24.6
Glucose (mg/dL)	122.5 ± 26.2	248.5 ± 88.1	94.3 ± 5.5	121.3 ± 24.8
Protein (g/dL)	4.3 ± 0.2	3.5 ± 0.7	3.3 ± 1.3	3.4 ± 0.1

Table 4.5-16

Mean Sex Steroid Concentrations (pg/ml) and GSI (+/- Standard Deviation), with Minimum and Maximum for Female and Male Walleye from the Athabasca River, Summer 1995

Sex	Index	Sex Steroid Concentrations (pg/ml)	
		Testosterone	Estradiol
Female	n	5	13
	Mean ± SD	279.4 ± 85.1	1274.1 ± 1574.5
	Minimum	209.0	126.0
	Maximum	416.0	5824.0
Male	n	6	17
	Mean ± SD	281.2 ± 59.9	170.8 ± 39.4
	Minimum	230.0	100.0
	Maximum	396.0	259.0

Table 4.5-17

Mean Sex Steroid Concentrations (pg/ml) and GSI (+/- Standard Deviation), with Minimum and Maximum for Female and Male Goldeye from the Athabasca River, Summer 1995

Sex	Index	Sex Steroid Concentrations (pg/ml)	
		Testosterone	Estradiol
Female	n	10	12
	Mean ± SD	595±287	137±31
	Minimum	270	83
	Maximum	1132	178
Male	n	11	3
	Mean ± SD	844±236	95±8
	Minimum	604	87
	Maximum	1300	102

Table 4.5-18

Mean Sex Steroid Concentrations (pg/mL) and GSI (± Standard Deviation), with Minimum and Maximum for Female and Male Longnose Sucker from the Muskeg River, Spring 1995

Sex	Index	GSI	Sex Steroid Concentrations (pg/ml)	
			Testosterone	Estradiol
Female	n	21	21	21
	Mean ± SD	11.2 ± 2.4	9224.3 ± 8057.4	2230.0 ± 1543.7
	Minimum	7.6	1610.0	252.0
	Maximum	16.0	29900.0	6220.0
Male	n	20	20	-
	Mean ± SD	4.9 ± 0.9	5161.0 ± 2219.9	-
	Minimum	3.1	1670.0	-
	Maximum	6.3	9660.0	-

Table 4.5-19

Mean Reproductive Indices with Standard Deviation for Female Longnose Sucker from the Muskeg River, Spring 1995

Parameter	n	Mean ± SD	Minimum	Maximum
Total Fecundity (eggs per female)	21	30511.6 ± 9676.9	15262.8	49912.2
Egg Diameters (mm)	19	2.0 ± 0.1	1.7	2.2
Mean Age of Mature Fish	20	6.6 ± 0.8	5	8

Table 4.5-20

Fecundity Data for Longnose Sucker from the Athabasca River Region, 1979 - Present

Waterbody	Mean Fecundity (±SD) (eggs per female)	n	Source
Muskeg River	30,512 ± 9,677	21	Present study
Lower Athabasca River	34,597 ±12,251	14	McCart et al. 1977
Muskeg River	23,639	-	Bond and Machniak 1979
Lower Athabasca River	21,843	30	Tripp and McCart, 1979
Steepbank River	29,502	14	Machniak and Bond 1979
Lower Athabasca River	29,203	12	Bond 1980
Christina and Gregoire Rivers	16,180 ± 5,605	15	Tripp and Tsui 1980

Note: Standard deviation and number of fish was not available for all studies listed

Table 4.5-21

ICP Metals (mg/kg) in Walleye Fillets from the Athabasca River, Summer 1995

ICP METALS	Male[1]	Whole Fish
SILVER	<0.2	<0.2
ALUMINUM	3	<2
ARSENIC	<0.5	<0.5
BARIUM	<0.5	<0.5
BERYLLIUM	<0.5	<0.5
BORON	<5	<5
CALCIUM	662	277
CADMIUM	<0.5	<0.5
COBALT	<0.5	<0.5
CHROMIUM	<0.5	<0.5
COPPER	1	<1
IRON	7	12
POTASSIUM	4880	4640
MAGNESIUM	307	321
MANGANESE	<0.5	1.2
MOLYBDENUM	<1	<1
SODIUM	228	440
NICKEL	<1	<1
LEAD	<2	<2
PHOSPHORUS	2880	2800
SELENIUM	<0.5	<0.5
SILICON	4	4
TIN	<2	<2
STRONTIUM	0.6	<0.5
THALLIUM	<1	<1
VANADIUM	<1	<1
ZINC	6	9

[1]Composite male samples (SUN95UWALLCOMP4), whole fish (SUN95UWALLAF868T001)

Table 4.5-22

ICP Metals (mg/kg) in Goldeye Fillets from the Athabasca River, Summer 1995

ICP METALS	Males[1]	Females
SILVER	<0.2	<0.2
ALUMINUM	<2	2
ARSENIC	<0.5	<0.5
BARIUM	<0.5	<0.5
BERYLLIUM	<0.5	<0.5
BORON	<5	<5
CALCIUM	627	342
CADMIUM	<0.5	<0.5
COBALT	<0.5	<0.5
CHROMIUM	<0.5	<0.5
COPPER	<1	2
IRON	12	8
POTASSIUM	4380	3950
MAGNESIUM	315	377
MANGANESE	<0.5	<0.5
MOLYBDENUM	<1	<1
SODIUM	360	357
NICKEL	<1	2
LEAD	<2	<2
PHOSPHORUS	2590	2140
SELENIUM	<0.5	<0.5
SILICON	5	7
TIN	<2	<2
STRONTIUM	<0.5	<0.5
THALLIUM	<1	<1
VANADIUM	<1	<1
ZINC	6	6

[1]Composite samples males (SUN95UGOLDCOMP1), females (SUN95UGOLDCOMP2)

Table 4.5-23

ICP Metals (mg/kg) in Longnose Sucker Fillets From the Muskeg River, Spring 1995

ICP METALS	Males[1]	Females
SILVER	<0.2	<0.2
ALUMINUM	10	11
ARSENIC	<0.5	<0.5
BARIUM	<0.5	<0.5
BERYLLIUM	<0.5	<0.5
BORON	<5	<5
CALCIUM	246	880
CADMIUM	<0.5	<0.5
COBALT	<0.5	<0.5
CHROMIUM	<0.5	<0.5
COPPER	<1	<1
IRON	15	16
POTASSIUM	5190	5120
MAGNESIUM	328	661
MANGANESE	<0.5	0.9
MOLYBDENUM	<1	<1
SODIUM	352	409
NICKEL	<1	<1
LEAD	<2	<2
PHOSPHORUS	2760	2960
SELENIUM	0.3	0.3
SILICON	12	9
TIN	<2	<2
STRONTIUM	<0.5	0.9
THALLIUM	<1	<1
VANADIUM	<1	<1
ZINC	5	6

[1]Composite samples male (SRD95LNSCCOMP03); females (SRD95LNSCCOMP04)

Table 4.5-24

Bile PAH/ PANH Metabolites (Benzo-a-pyrene, Naphthalene) in Walleye from the Athabasca River, Summer 1995

Fish Sample #	PAH/PANH Metabolites in Bile	
	Benzo-a-pyrene (BaP) (µg/g)	Naphthalene (NPH) (µg/g)
SUN95UWALLAF004T011	26	660
SUN95UWALLCOMP1	3.1	490
SUN95UWALLCOMP2	6.7	890
SUN95UWALLCOMP3	10	620

Table 4.5-25

Bile PAH/ PANH Metabolites (Benzo-a-pyrene, Naphthalene) in Goldeye from the Athabasca River, Summer 1995

Fish Sample #	PAH/PANH Metabolites in Bile	
	Benzo-a-pyrene (BaP) (µg/g)	Naphthalene (NPH) (µg/g)
SUN95UGOLDAF002T031	1.9	390
SUN95UGOLDAF003T007	3.8	810
SUN95UGOLDAF003T009	9.3	1100
SUN95UGOLDAF004T015	5.4	1000
SUN95UGOLDAF004T016	6.1	120
SUN95UGOLDAF004T019	4.3	640
SUN95UGOLDAF004T021	3	560
SUN95UGOLDAF036T004	1.8	350

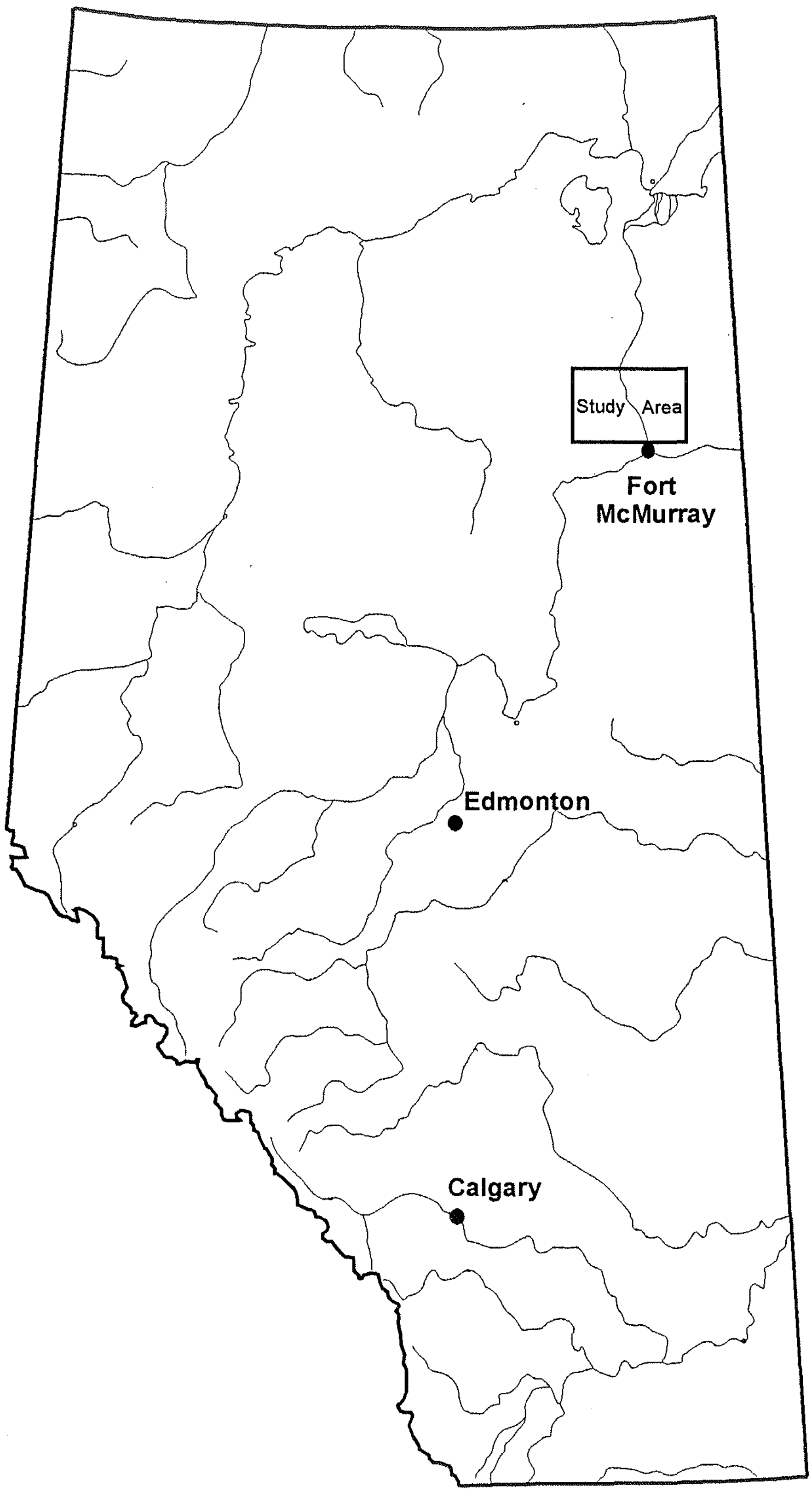
Table 4.5-26

Bile PAH/ PANH Metabolites (Benzo-a-pyrene, Naphthalene) in Longnose Sucker from the Muskeg River, Spring 1995

Fish Sample #	PAH/PANH Metabolites in Bile	
	Benzo-a-pyrene (BaP) (µg/g)	Naphthalene (NPH) (µg/g)
SRD95PLNSCCOMP07	3.8	550
SRD95PLNSCCOMP08	2.3	420

Location of the Study Area Within Alberta

Figure 1.2-1



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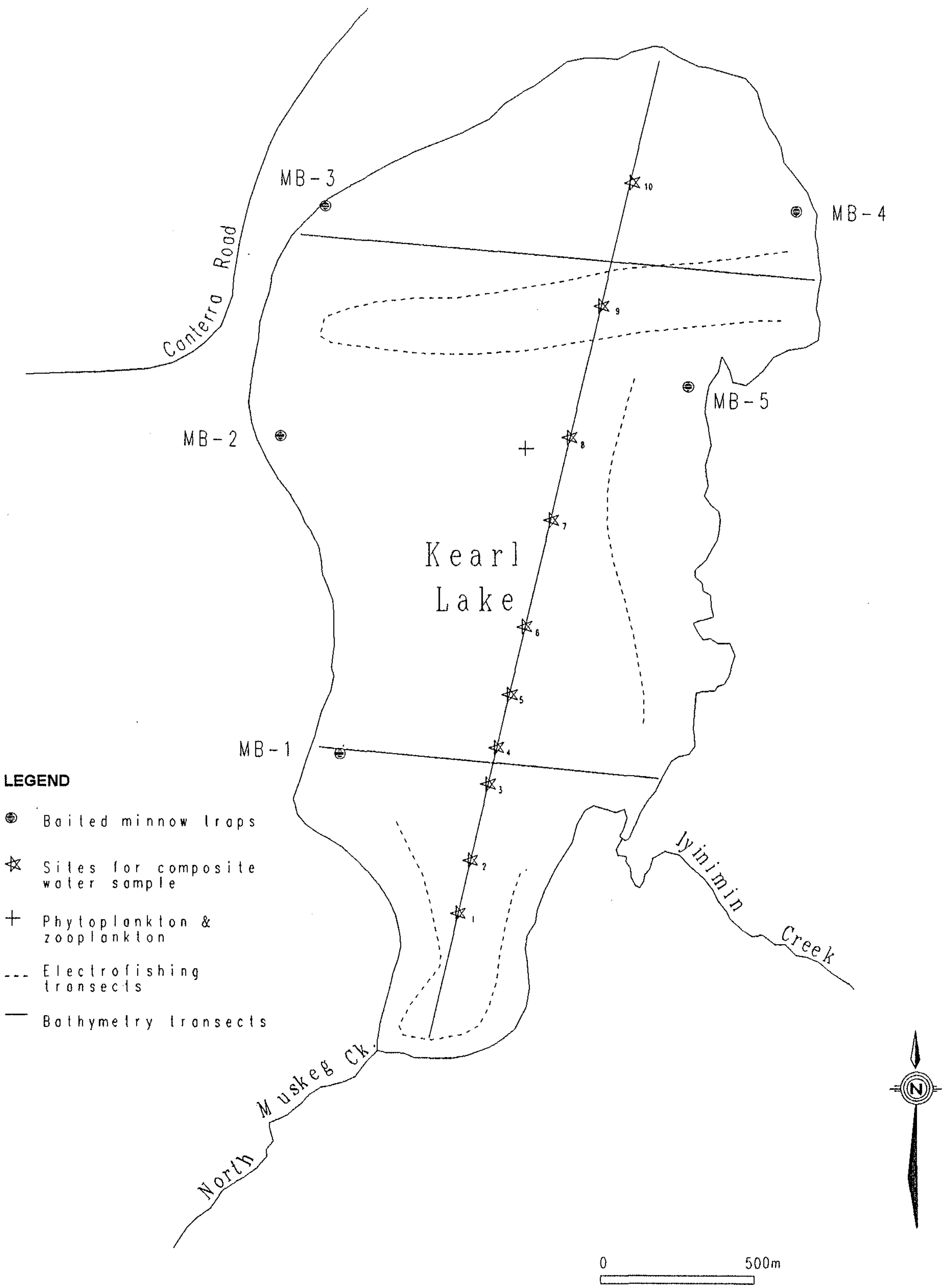
Kearl Lake Sampling Sites for Fish Inventory, Bathymetry, Plankton and Water

Figure 3.2-4



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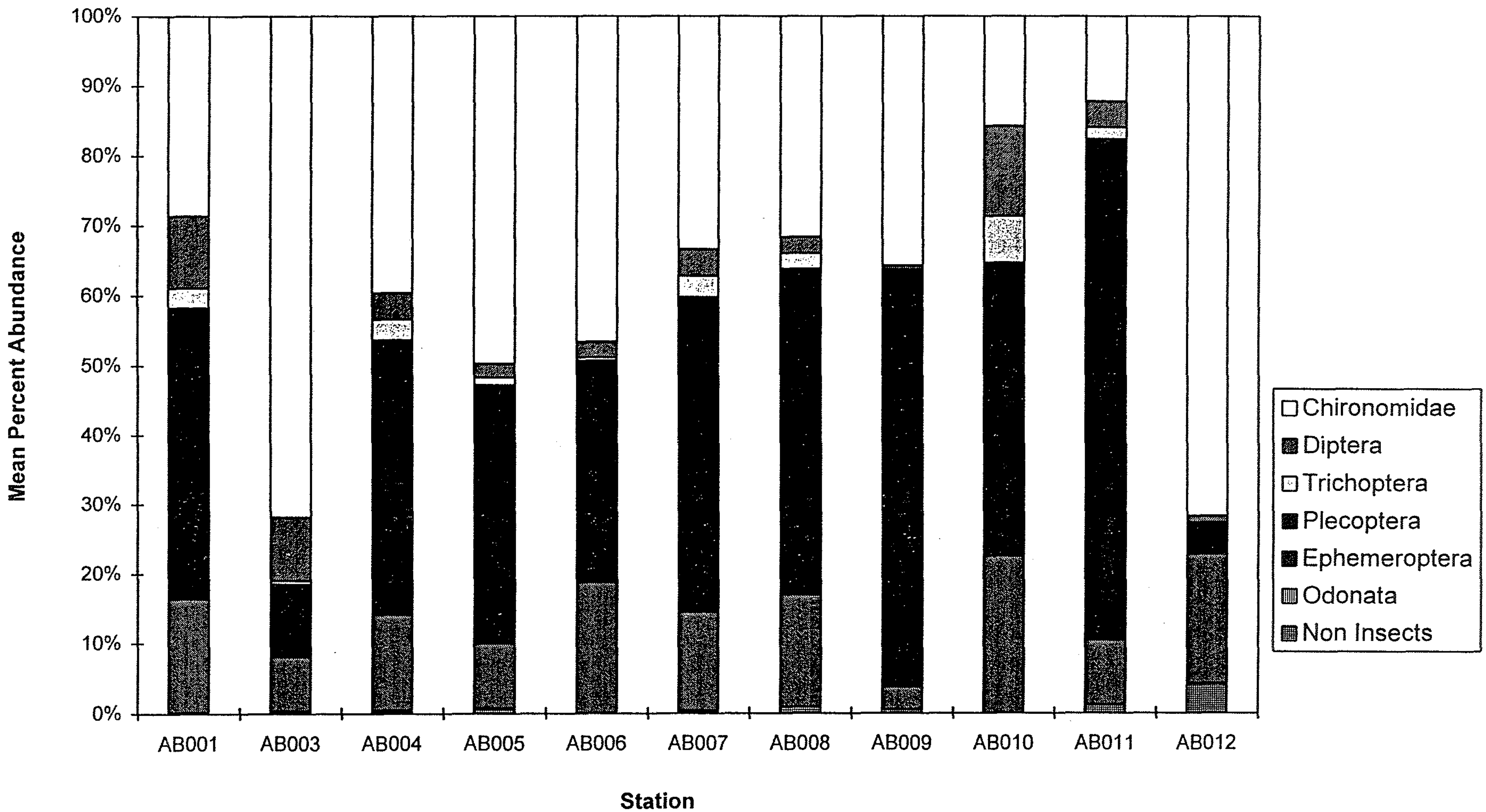


Figure 4.2-1 Percent Abundance of Major Taxonomic Groups Collected in the Athabasca River Using Artificial Substrates

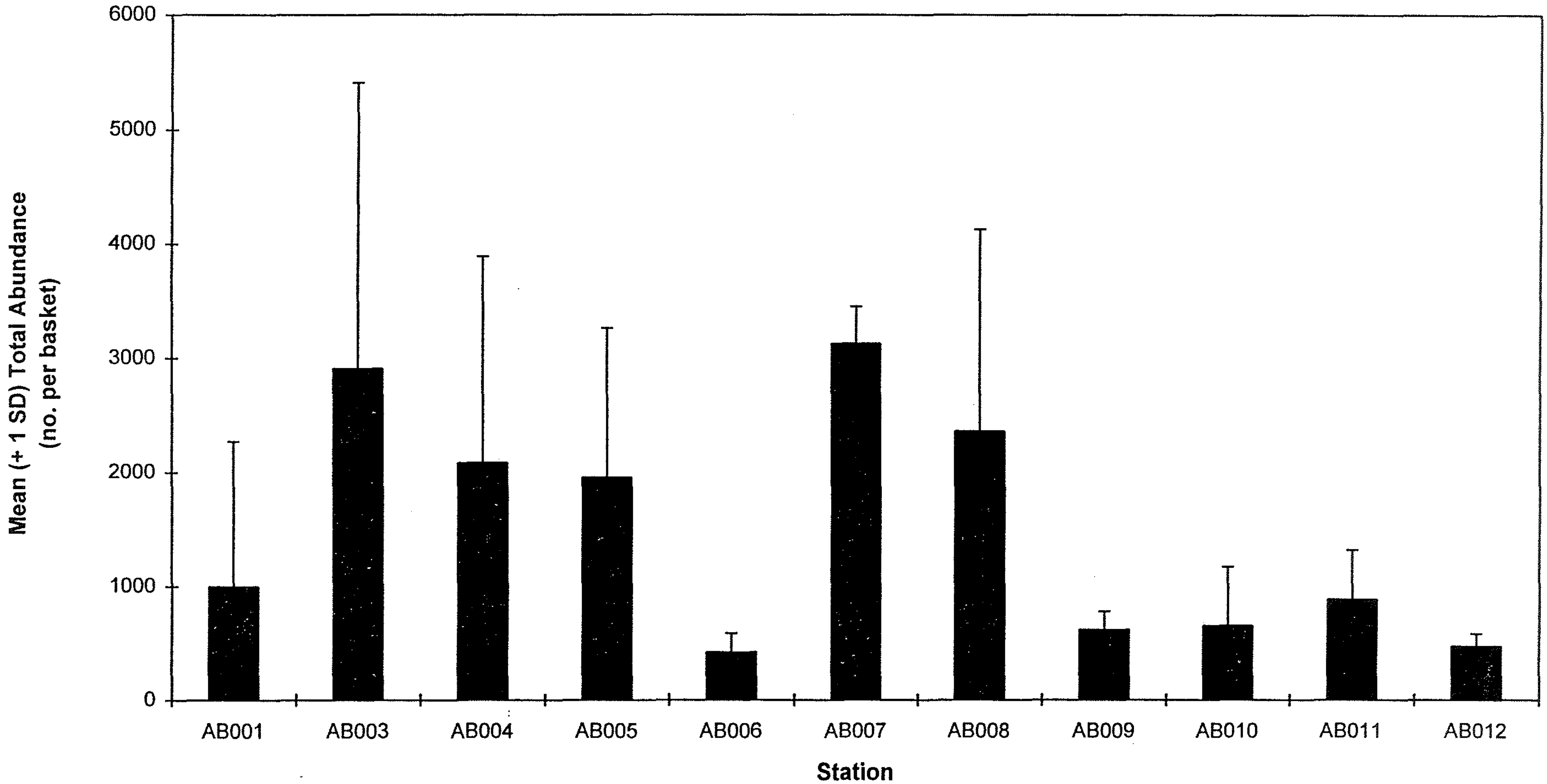


Figure 4.2-2 Mean Total Abundance of Benthic Invertebrates Collected in the Athabasca River Using Artificial Substrates (SD = standard deviation)

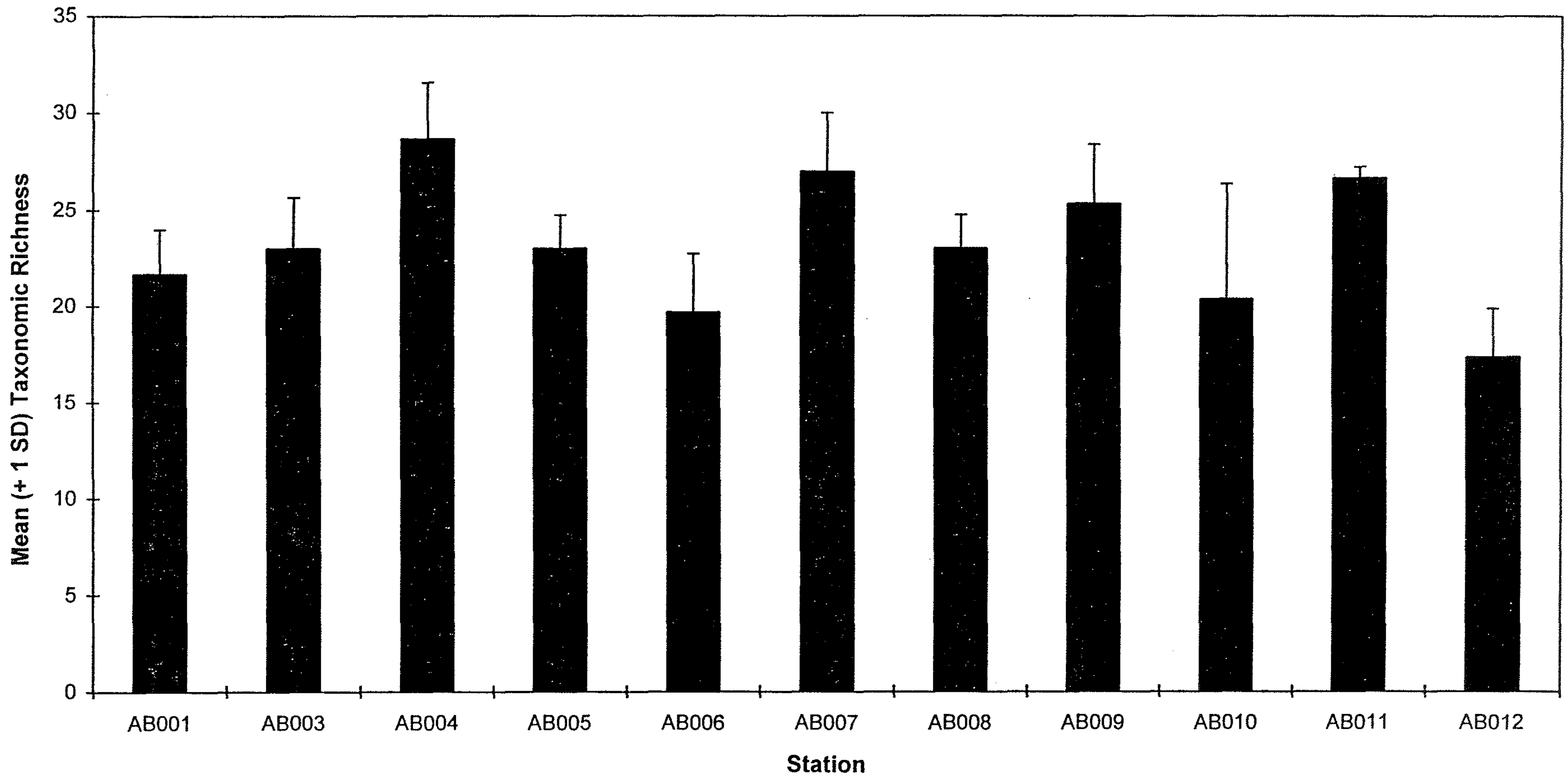


Figure 4.2-3 Mean Taxonomic Richness of Benthic Invertebrates Collected in the Athabasca River Using Artificial Substrates (SD = standard deviation)

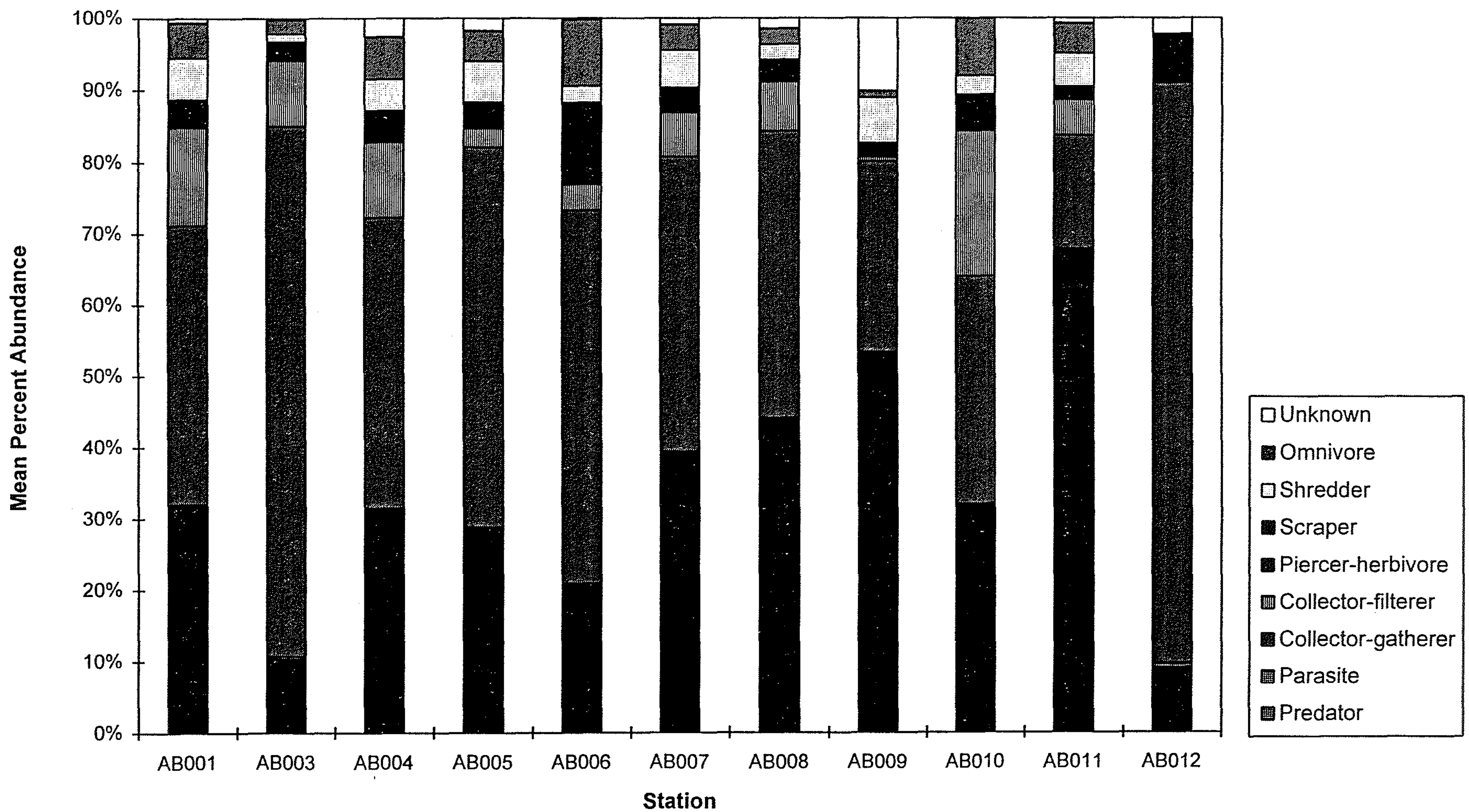


Figure 4.2-4 Major Functional Feeding Groups of Benthic Invertebrates Collected in the Athabasca River Using Artificial Substrates

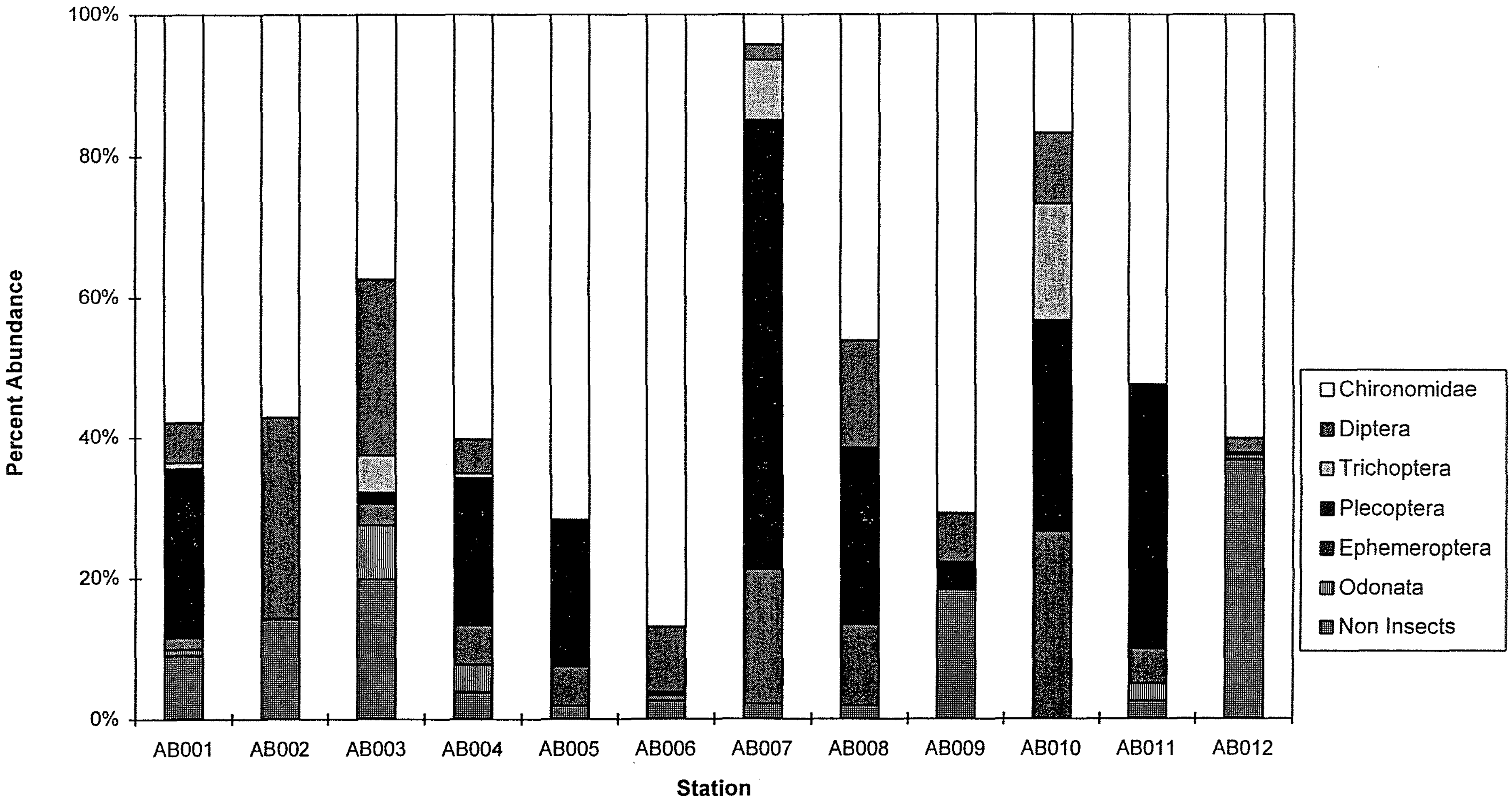


Figure 4.2-5 Percent Abundance of Major Taxonomic Groups Collected in the Athabasca River Using an Ekman Grab

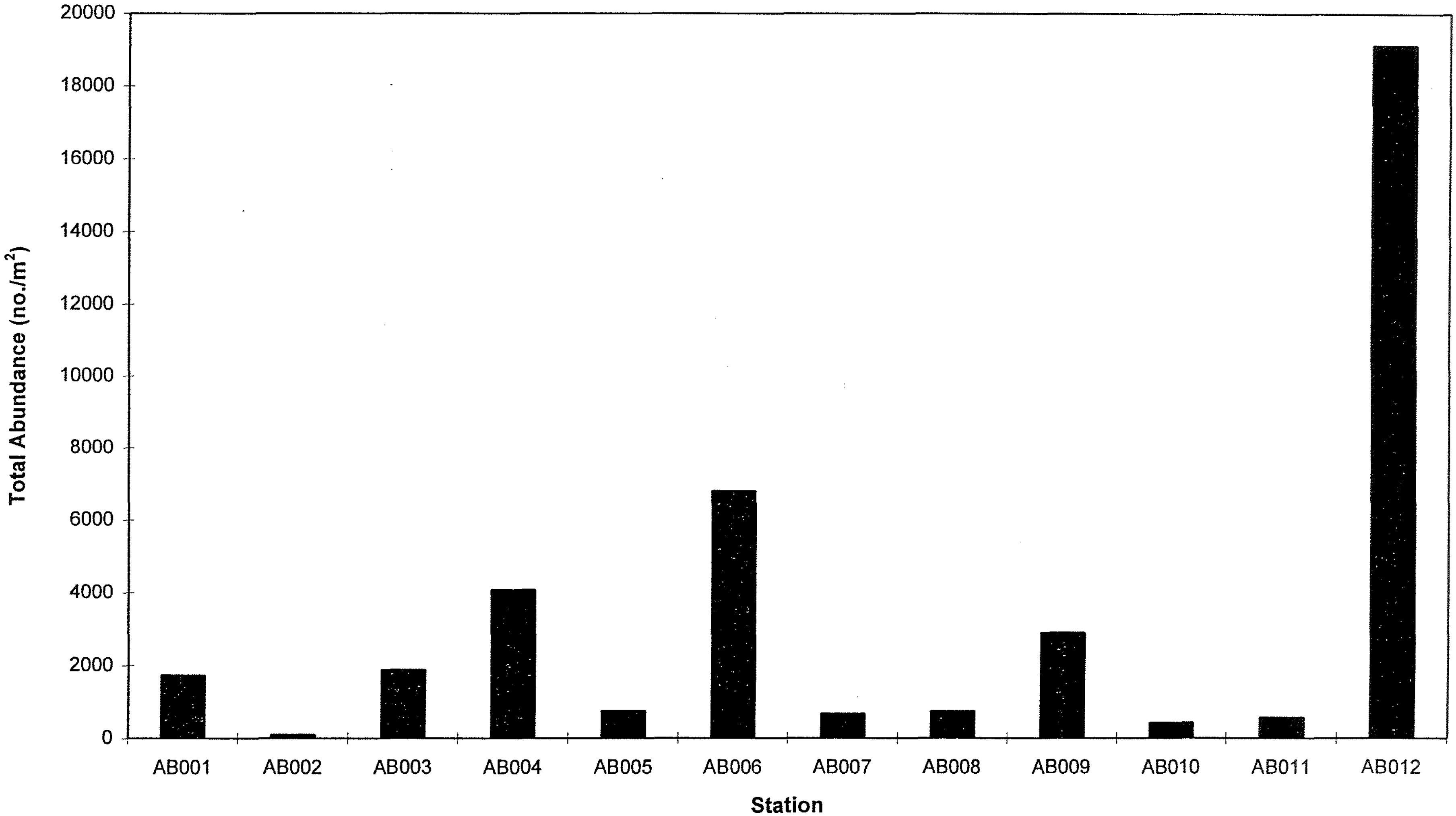


Figure 4.2-6 Total Abundance of Benthic Invertebrates Collected in the Athabasca River Using an Ekman Grab

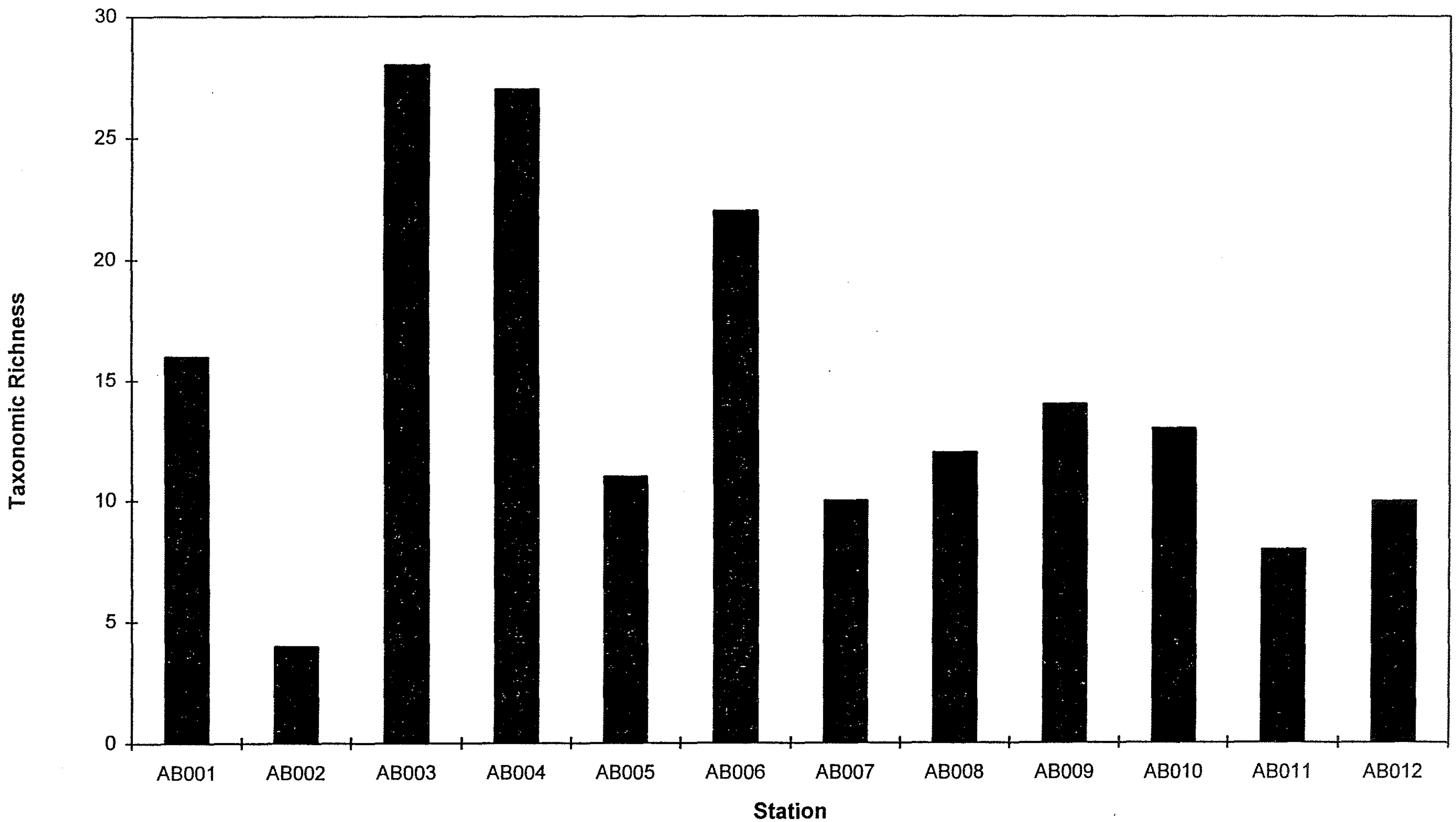


Figure 4.2-7 Taxonomic Richness of Benthic Invertebrates Collected in the Athabasca River Using an Ekman Grab

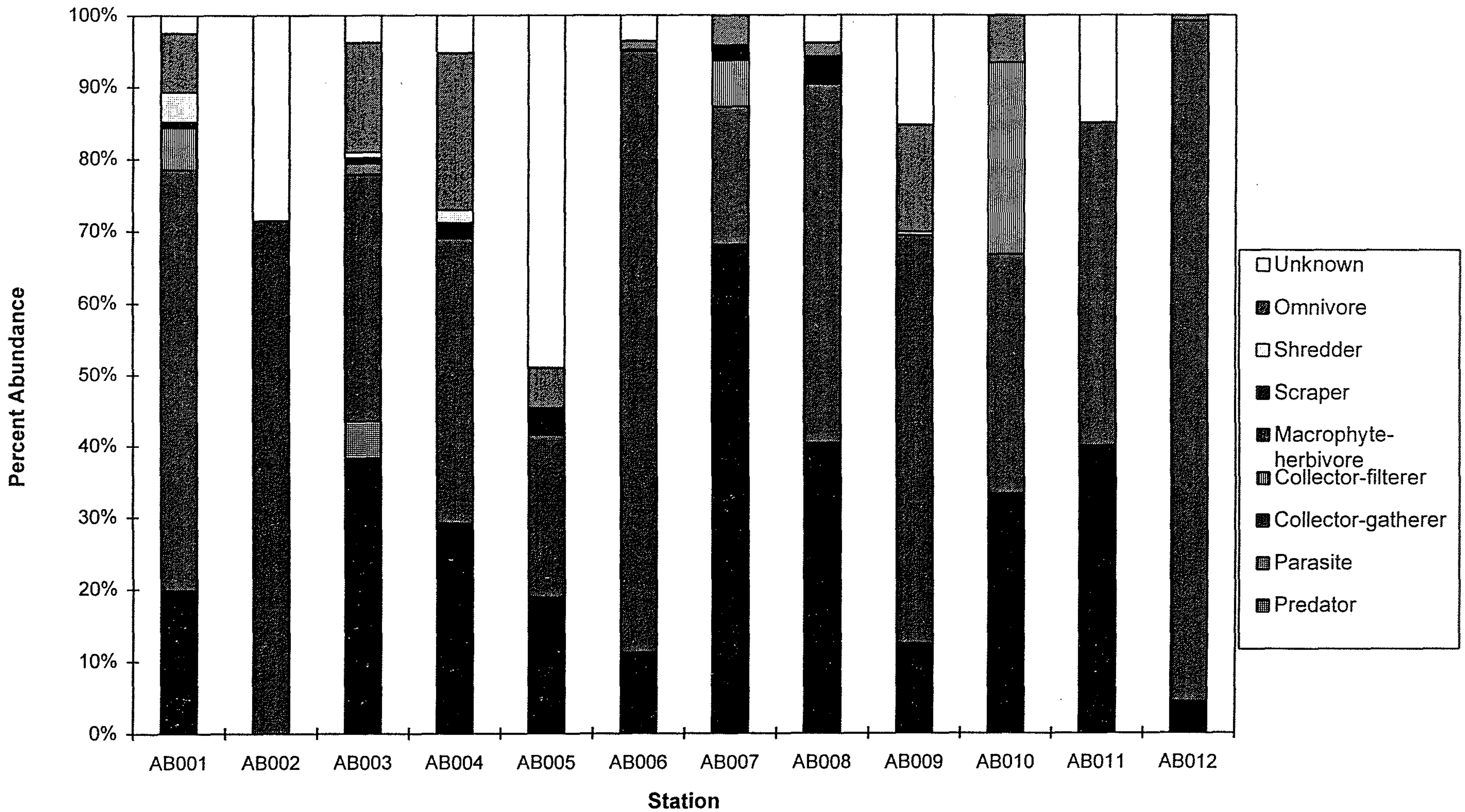


Figure 4.2-8 Major Functional Feeding Groups of Benthic Invertebrates Collected in the Athabasca River Using an Ekman Grab

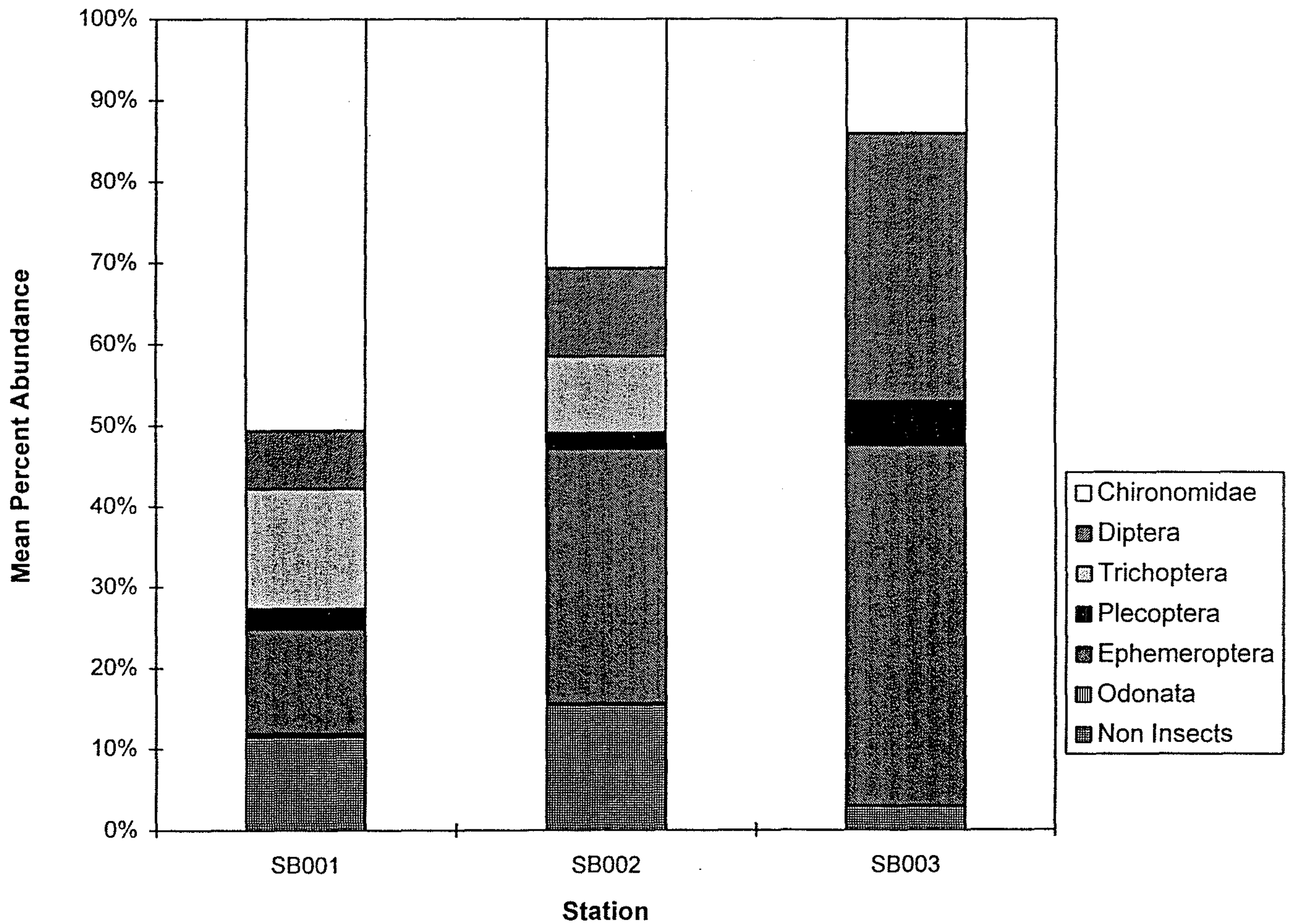


Figure 4.2-9 Percent Abundance of Major Taxonomic Groups Collected in the Steepbank River Using a Hess Sampler

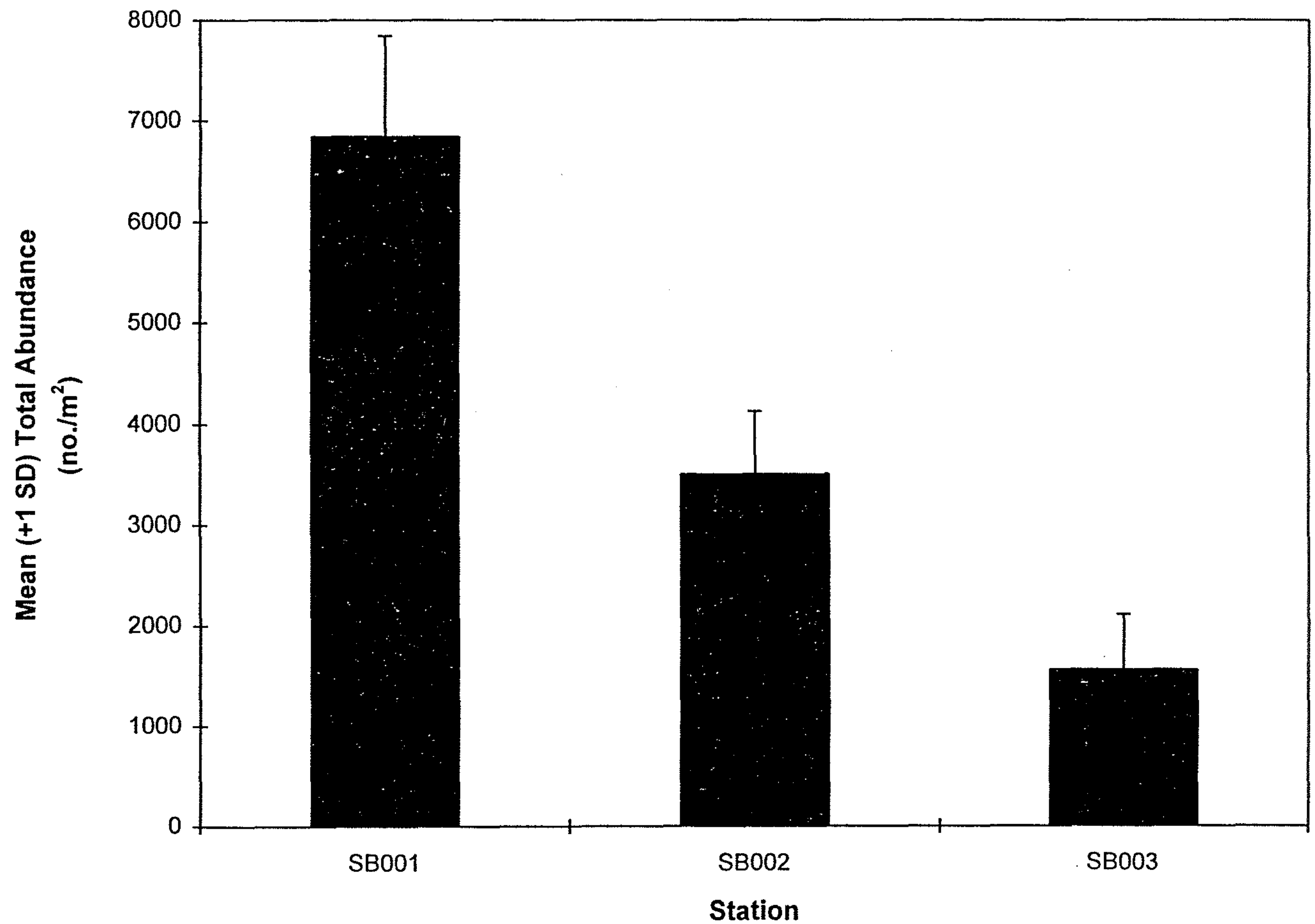


Figure 4.2-10 Mean Total Abundance of Benthic Invertebrates Collected in the Steepbank River Using a Hess Sampler (SD = standard deviation)

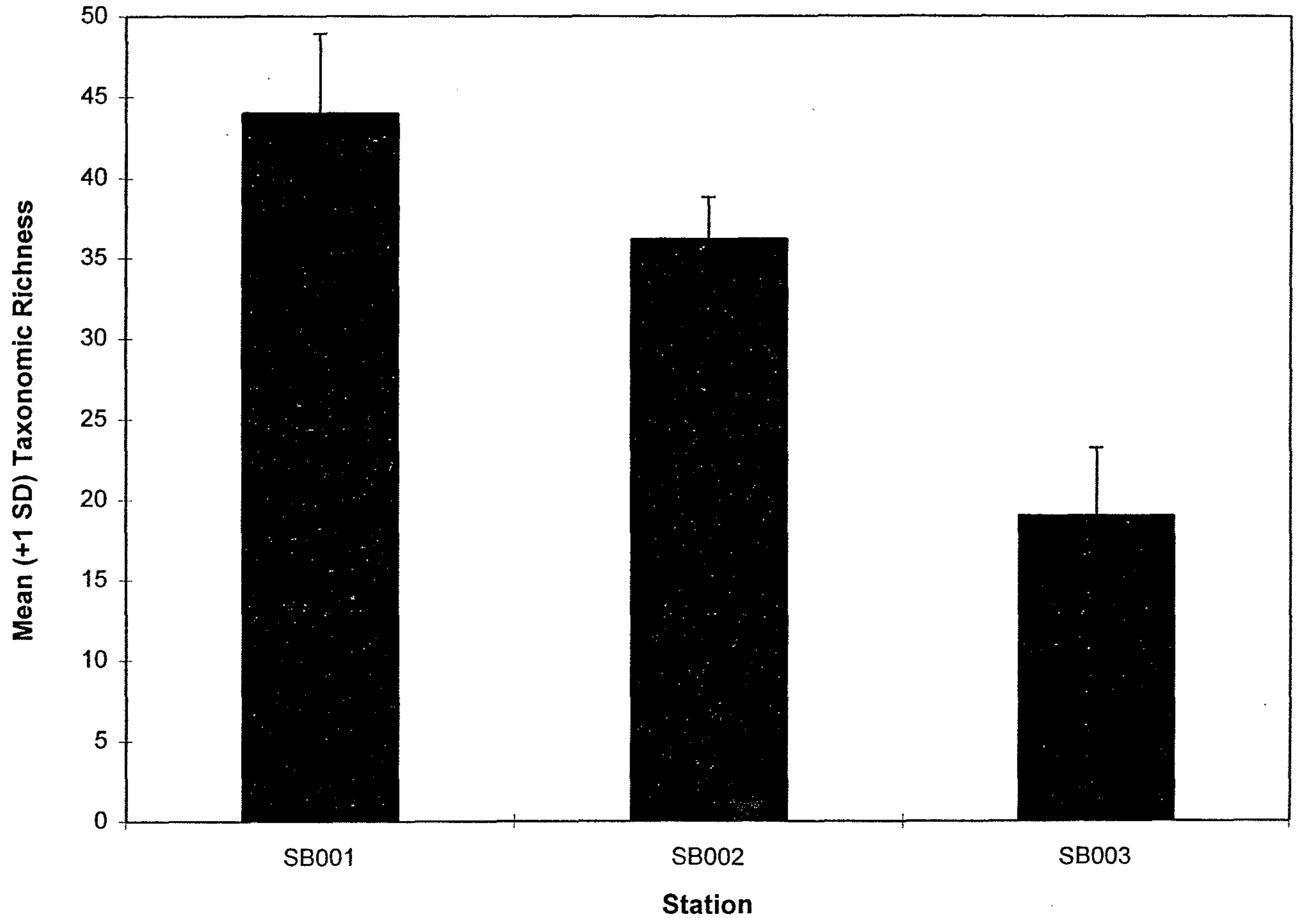


Figure 4.2-11 Mean Taxonomic Richness of Benthic Invertebrates Collected in the Steepbank River Using a Hess Sampler (SD = standard deviation)

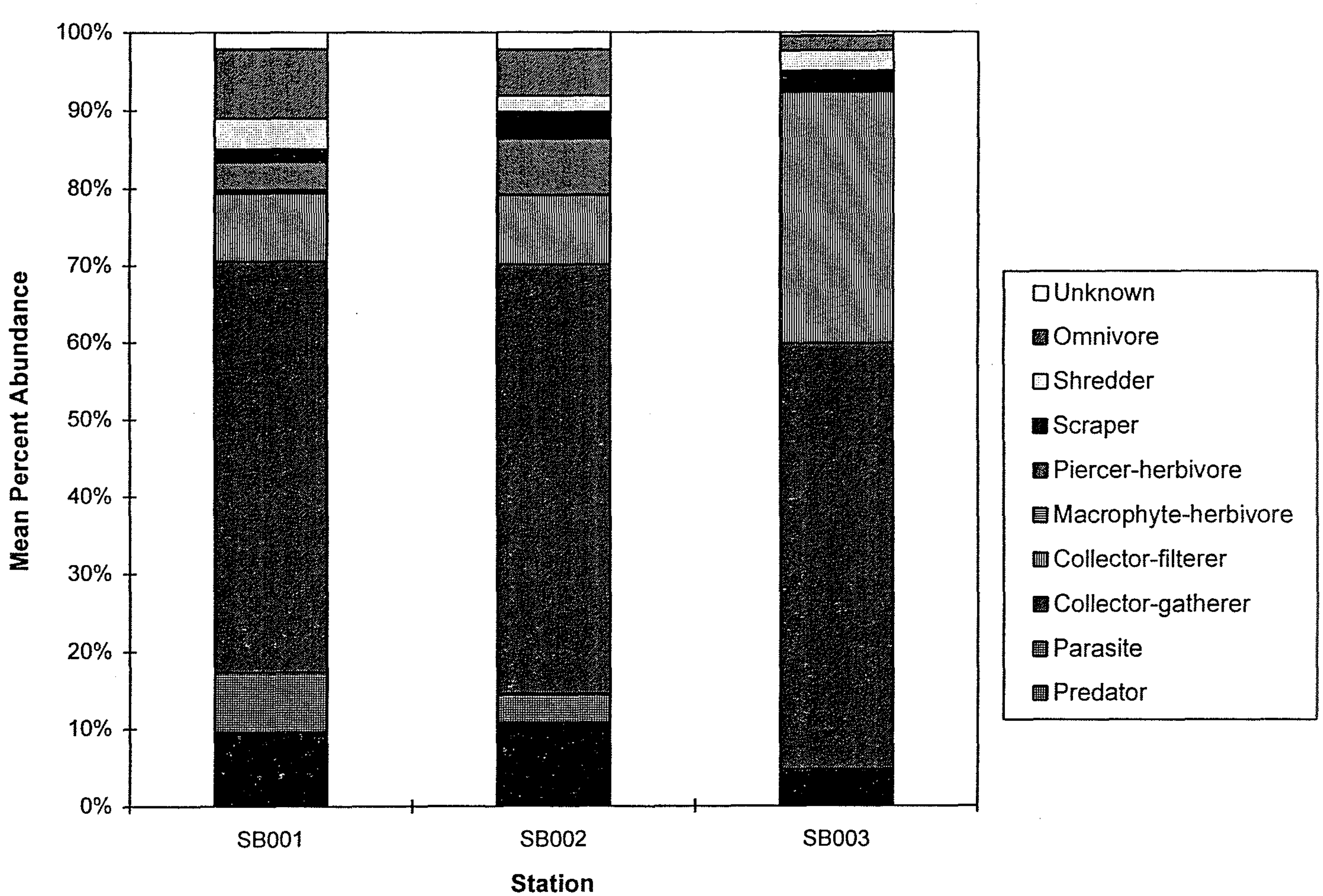


Figure 4.2-12 Major Functional Feeding Groups of Benthic Invertebrates Collected in the Steepbank River Using a Hess Sampler

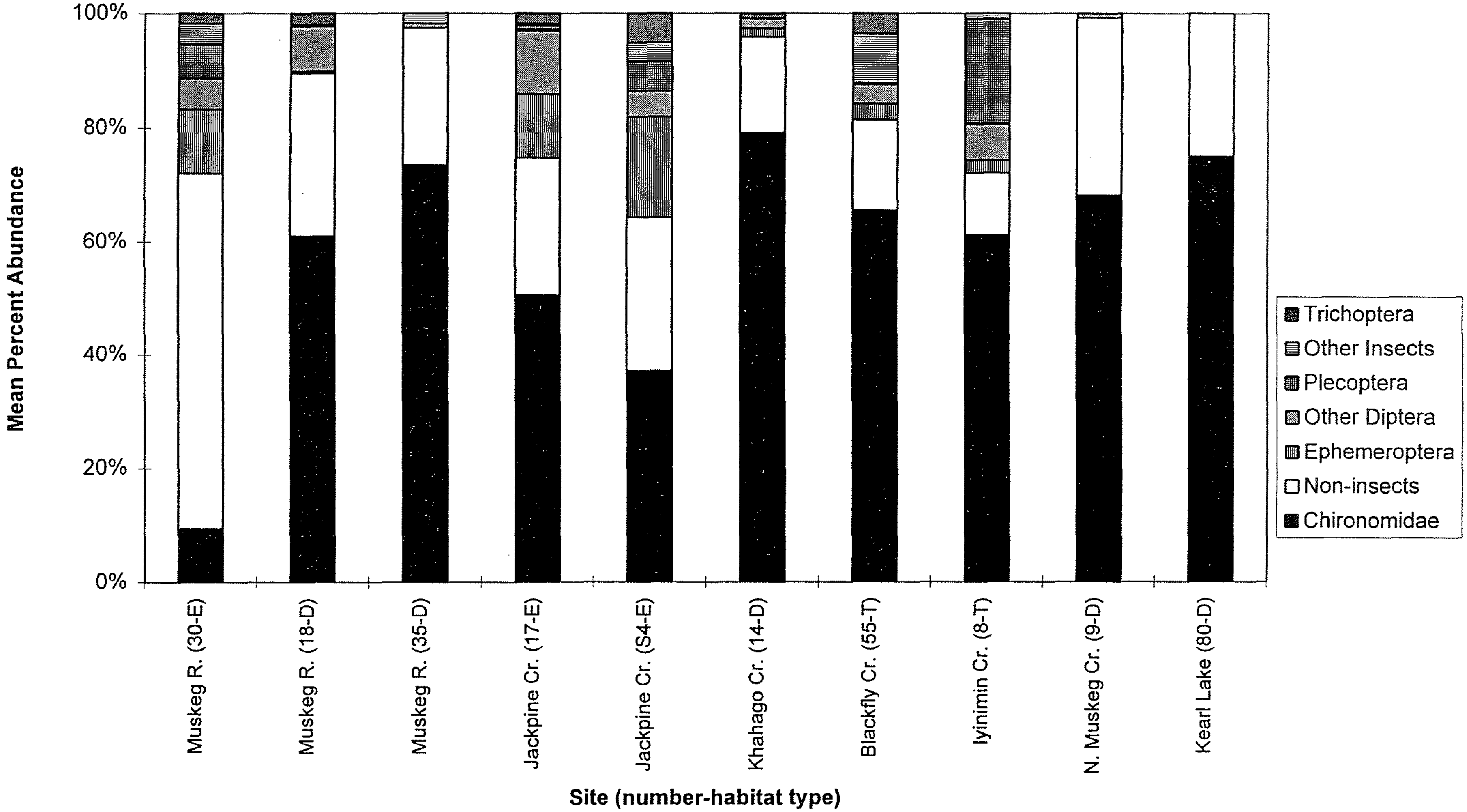


Figure 4.2-13 Percent Abundance of Major Taxonomic Groups in the Muskeg River Basin in Fall, 1995 (E = erosional; D = depositional; T = Transitional)

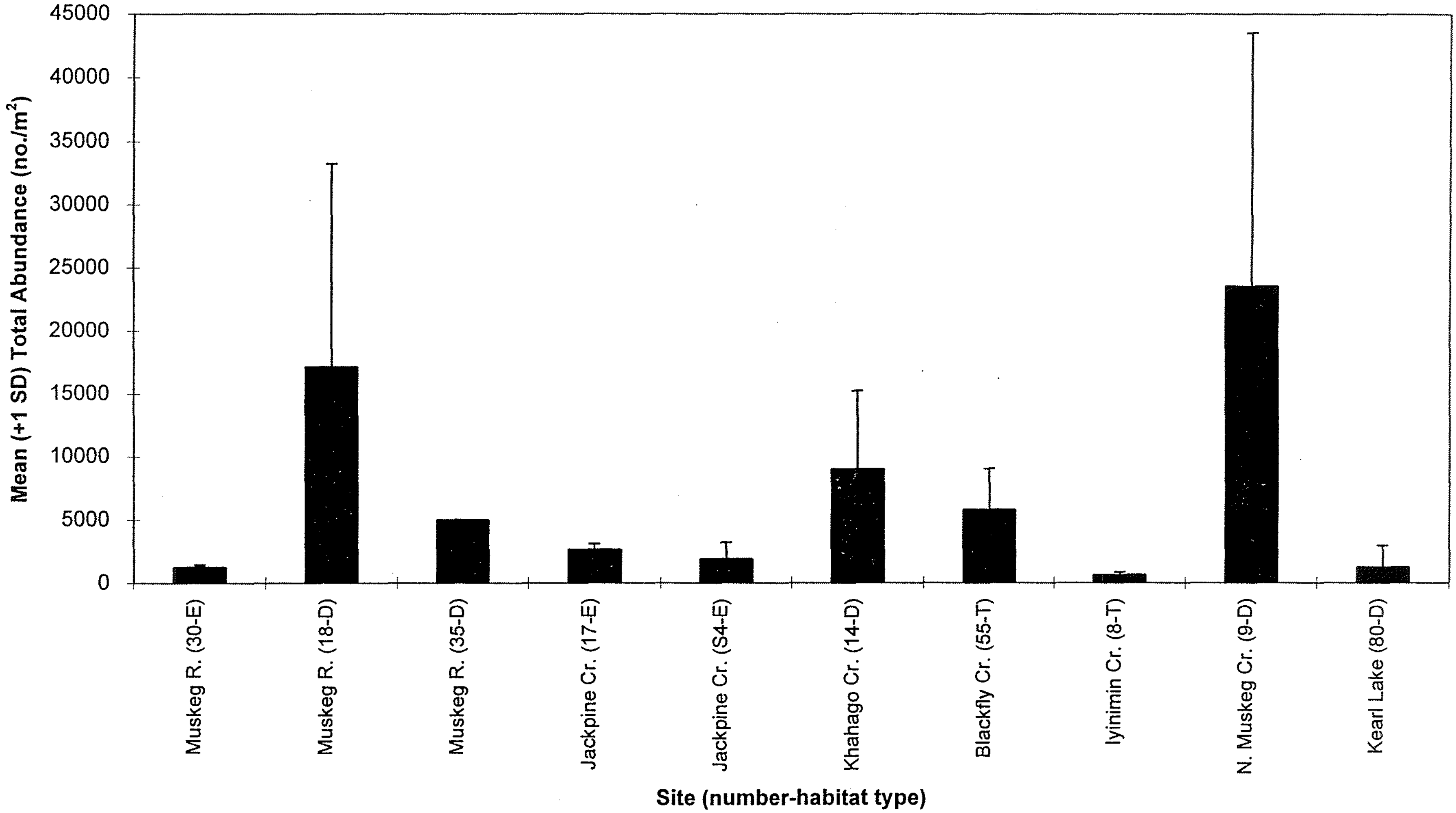


Figure 4.2-14 Mean Total Abundance of Benthic Invertebrates in the Muskeg River Basin in Fall, 1995 (E = erosional; D = depositional; T = transitional; SD = standard deviation)

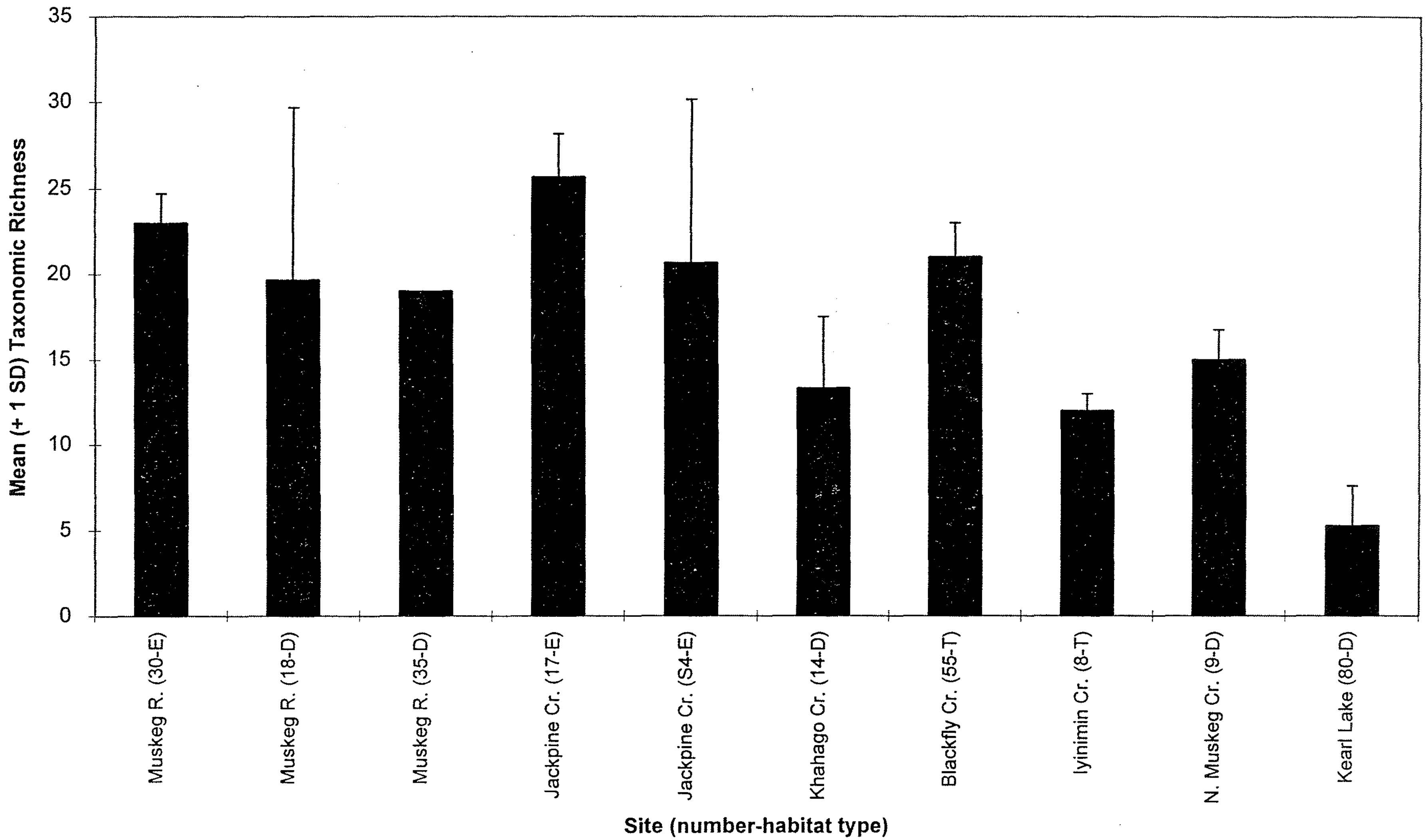


Figure 4.2-15 Mean Taxonomic Richness of Benthic Invertebrates in the Muskeg River Basin in Fall, 1995 (E = erosional; D = depositional; T = transitional; SD = standard deviation)

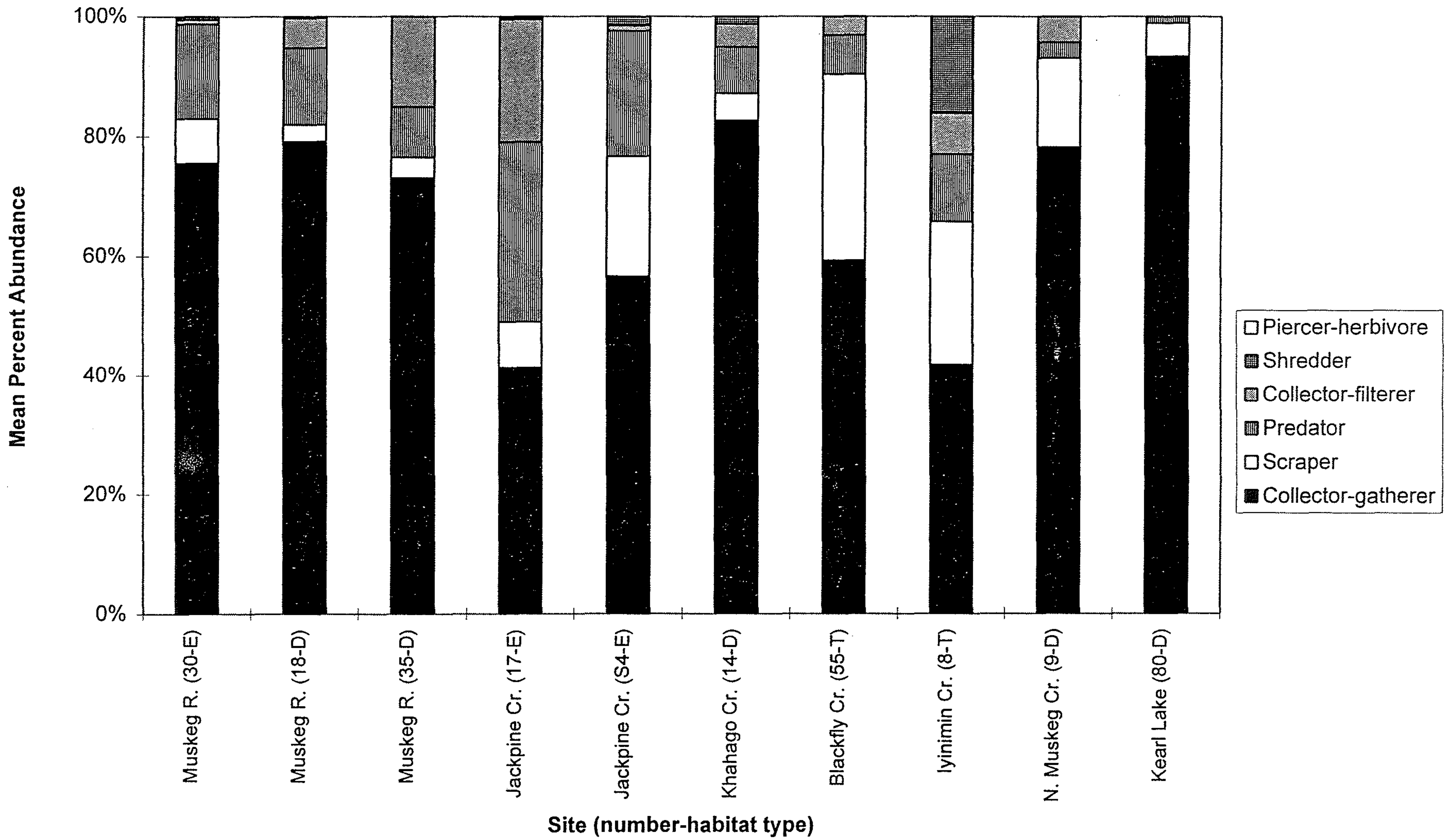
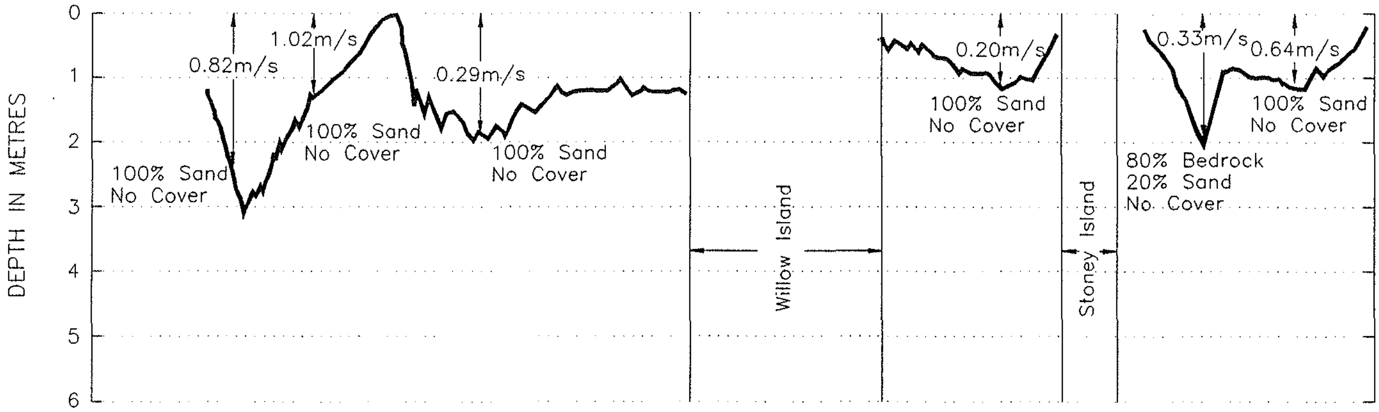


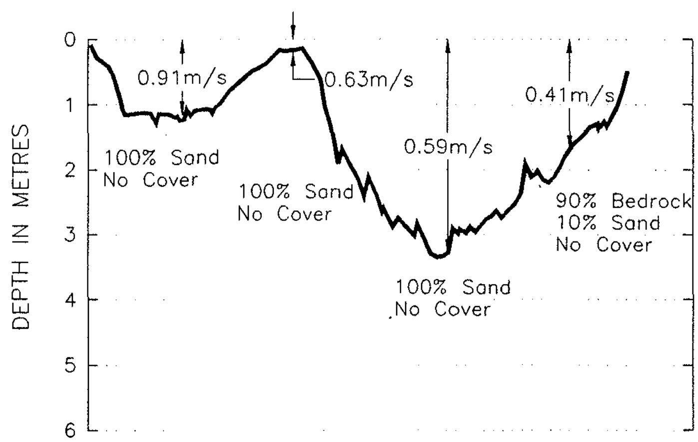
Figure 4.2-16 Distribution of Benthic Invertebrates in Functional Feeding Groups in the Muskeg River Basin in Fall, 1995
(E = erosional; D = depositional; T = transitional)

Habitat Transects of Representative Habitats of the Athabasca River, Fall 1995

Figures 4.3-2 a+b



a) HABITAT TRANSECT ACROSS THE UPSTREAM TIP OF STONEY ISLAND (REACH 1, STATION AF047)

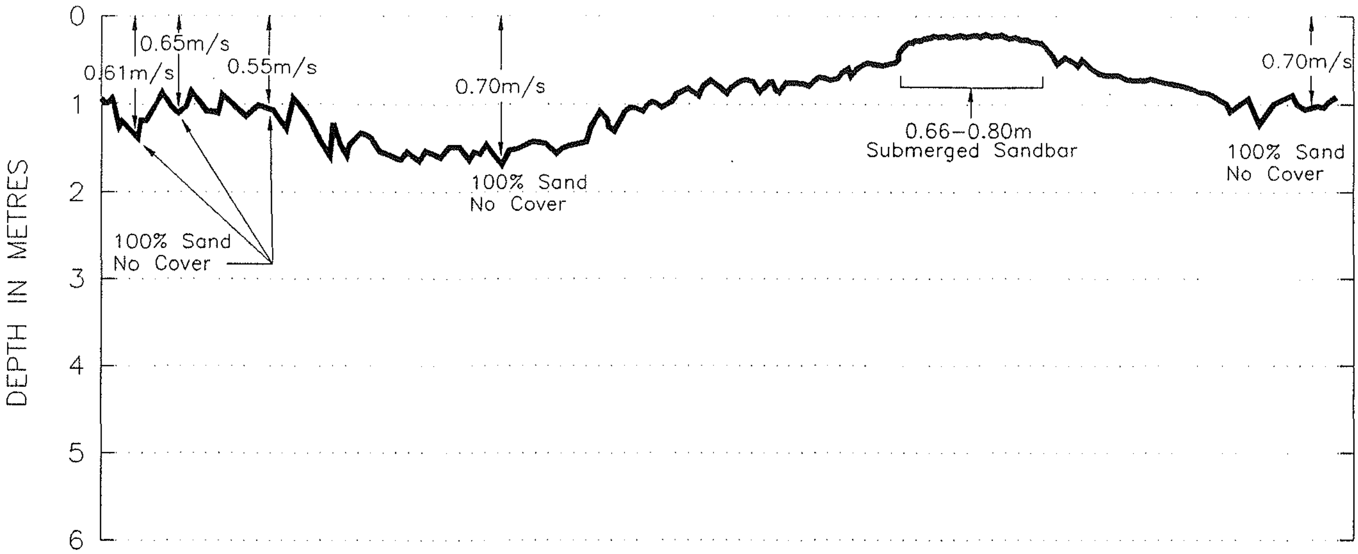


b) HABITAT TRANSECT UPSTREAM OF McLEAN CREEK (REACH 1, STATION AF048)

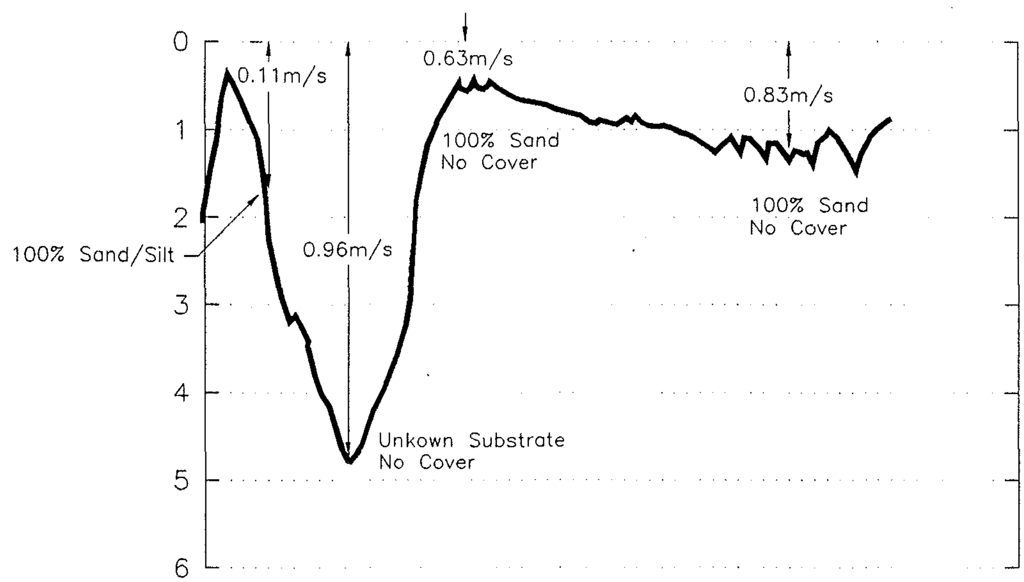
PROJECT 952-2308.7150 DRAWN MOH REVIEWED DATE 21 DEC 95 2308\FISH\43-2ab

Habitat Transects of Representative Habitats of the Athabasca River, Fall 1995

Figures 4.3-2 c+d



c) HABITAT TRANSECT DOWNSTREAM OF POPLAR CREEK (REACH 2, STATION AF049)

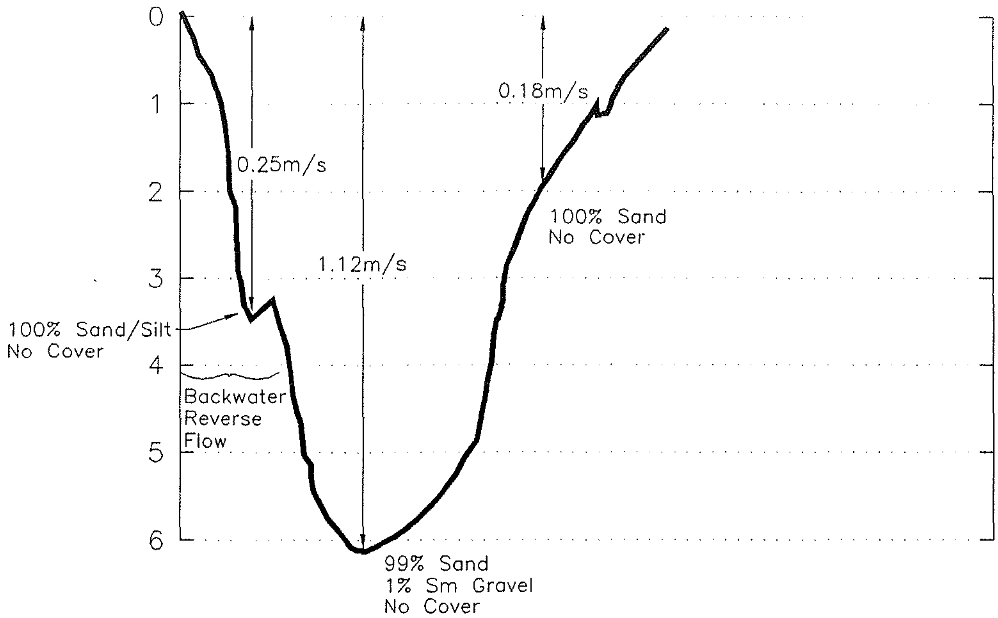


d) HABITAT TRANSECT AT DOWNSTREAM TIP OF INGLIS ISLAND, WEST CHANNEL (REACH 2, STATION AF050)

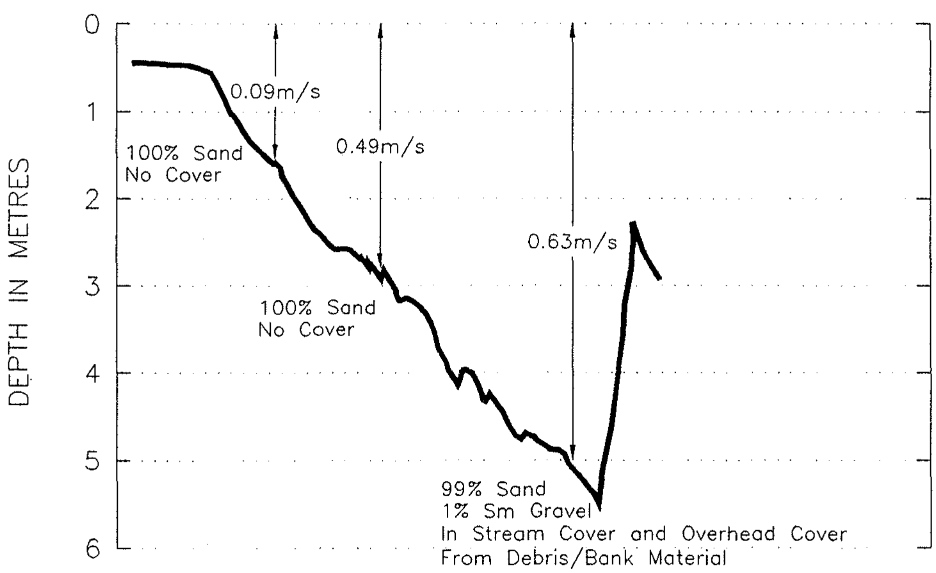
PROJECT 952-2308 DRAWN MOH REVIEWED DATE 21 DEC 95 \2308\FISH\43-2cd

Habitat Transects of Representative Habitats of the Athabasca River, Fall 1995

Figures 4.3-2 e+f



e) HABITAT TRANSECT IN BACKWATER AREA OF STATION AF019 (REACH 3, STATION AF058)

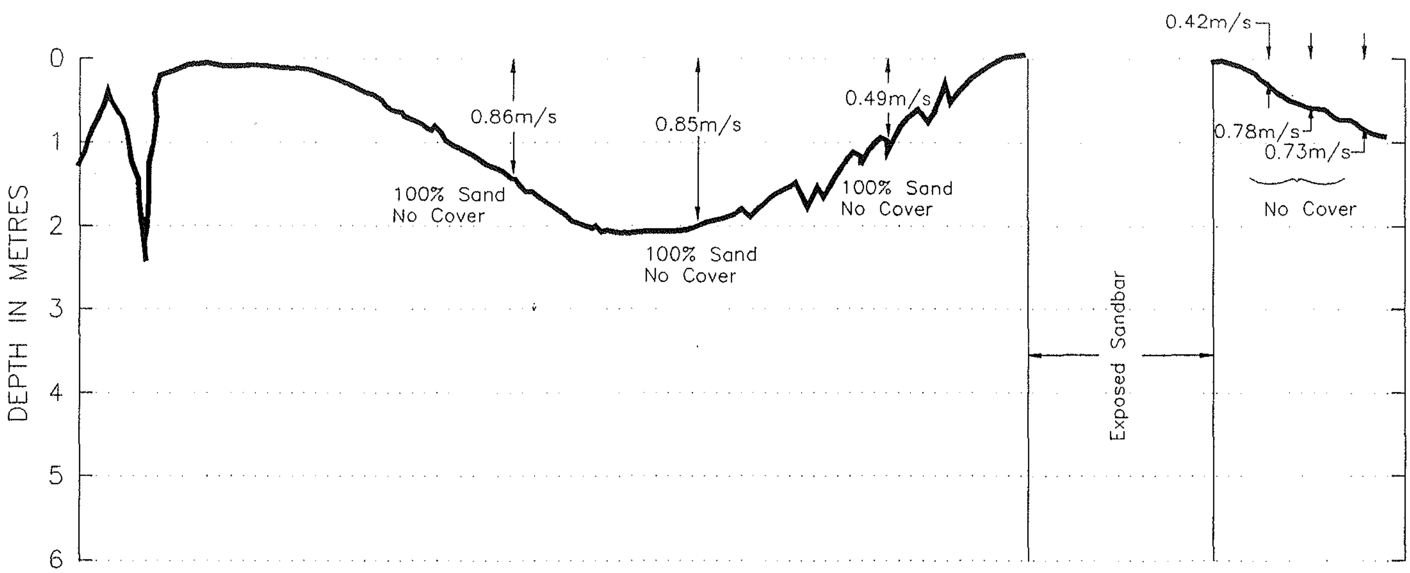


f) HABITAT TRANSECT OF EAST CHANNEL OFF SANDBAR AT TAR ISLAND DYKE (REACH 3, STATION AF059)

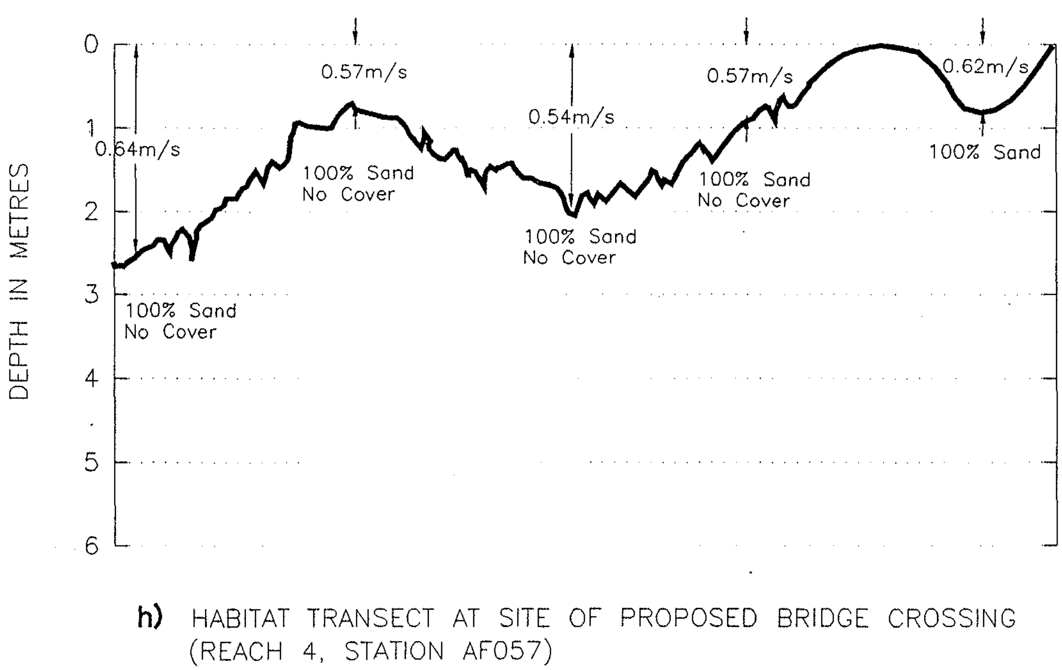
PROJECT 952-2308 DRAWN MOH REVIEWED DATE 11 NOV 95 2308\FISH\43-2ef

Habitat Transects of Representative Habitats of the Athabasca River, Fall 1995

Figures 4.3-2 g+h



g) HABITAT TRANSECT DOWNSTREAM OF REFERENCE WETLAND DRAINAGE (REACH 3, STATION AF051)

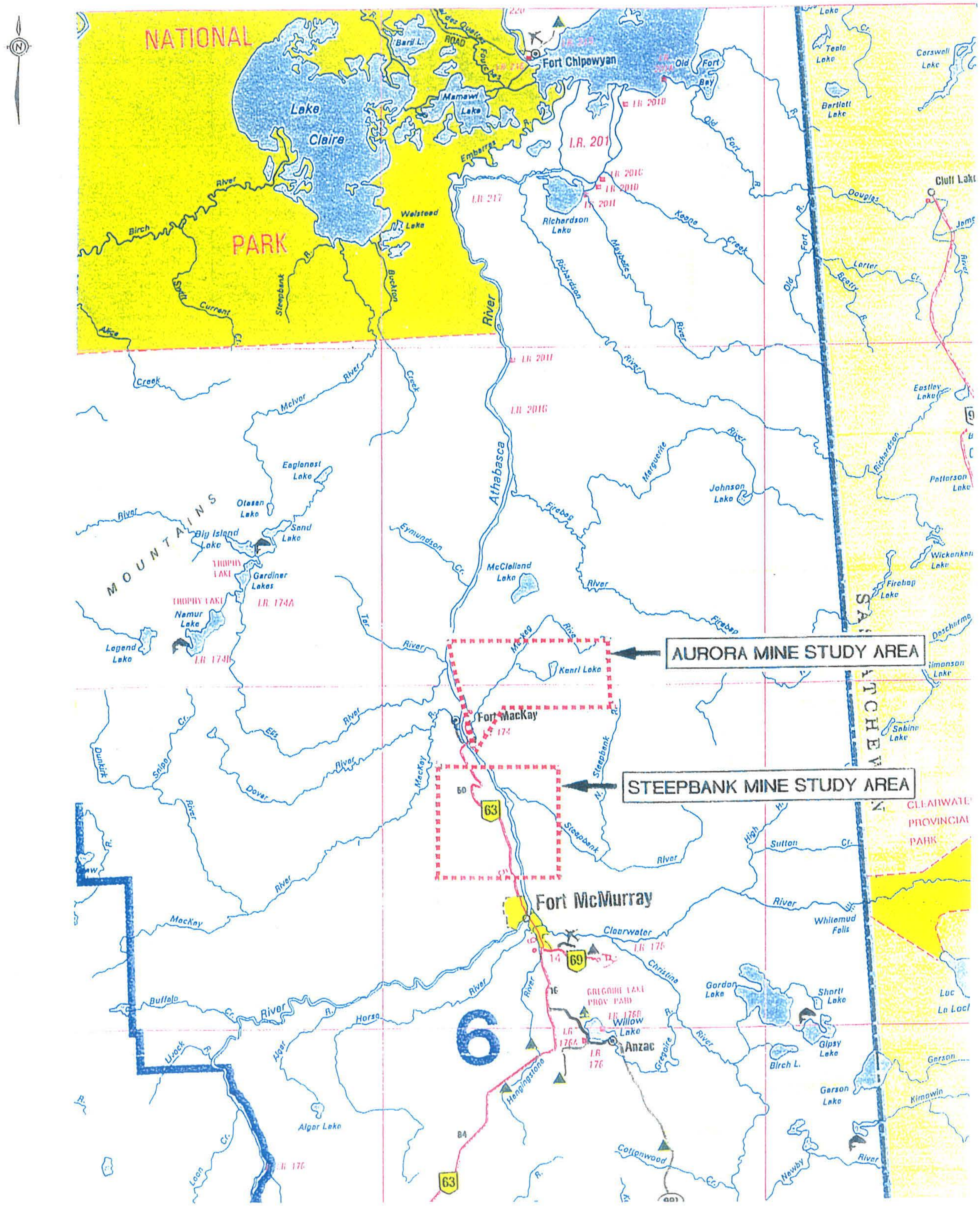


h) HABITAT TRANSECT AT SITE OF PROPOSED BRIDGE CROSSING (REACH 4, STATION AF057)

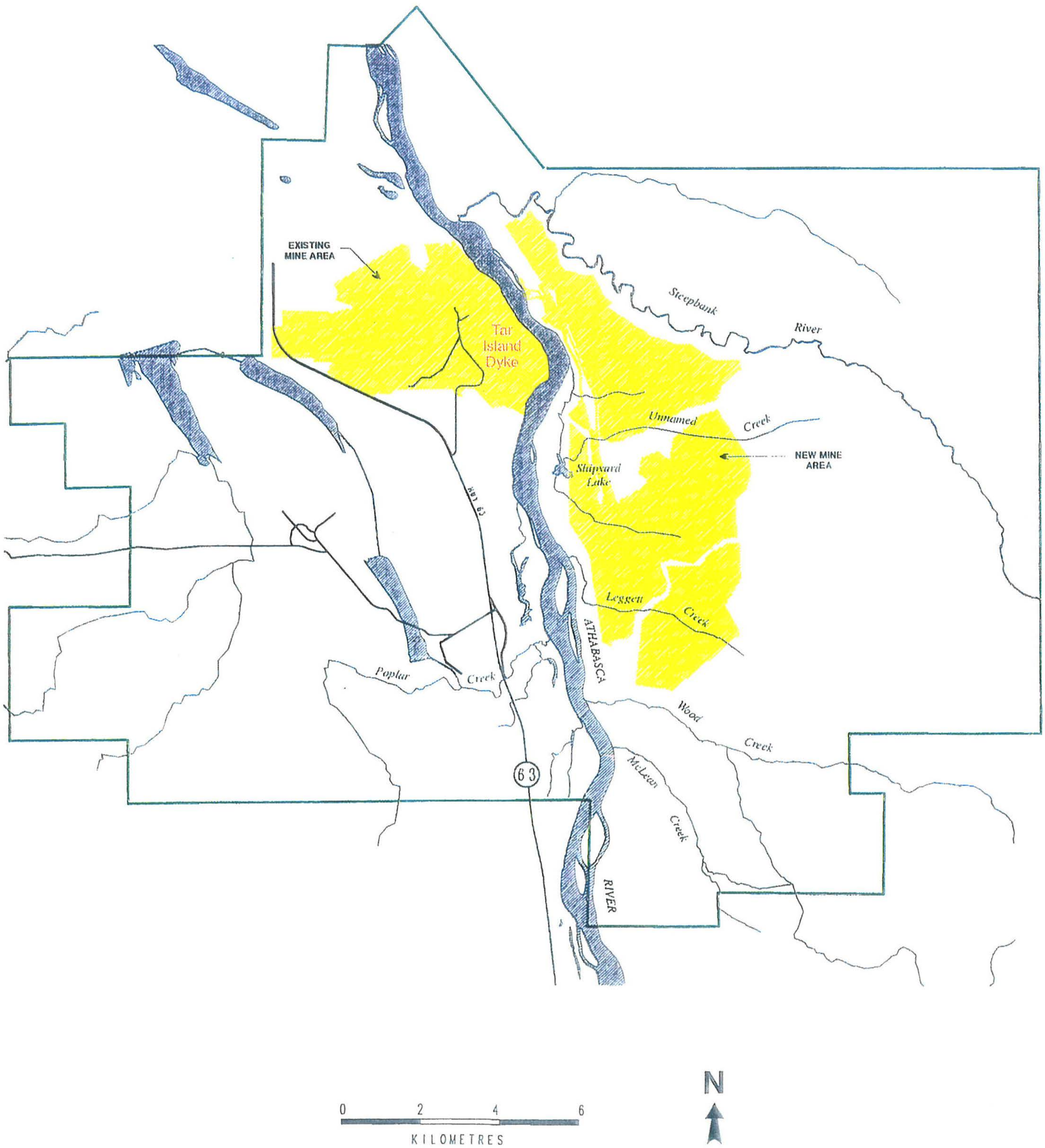
PROJECT 952-2307 DRAWN MOH REVIEWED DATE 12 DEC 95 2308\FISH\43-2gh

Suncor (Steepbank Mine) and Syncrude (Aurora Mine) Local Study Areas in a Regional Content

Figure 1.2-2



Local Study Area for the Steepbank Mine Environmental Baseline Program	Figure 1.2-3



PROJECT 952-2308.7150 DRAWN RP REVIEWED DATE 4 April 1996

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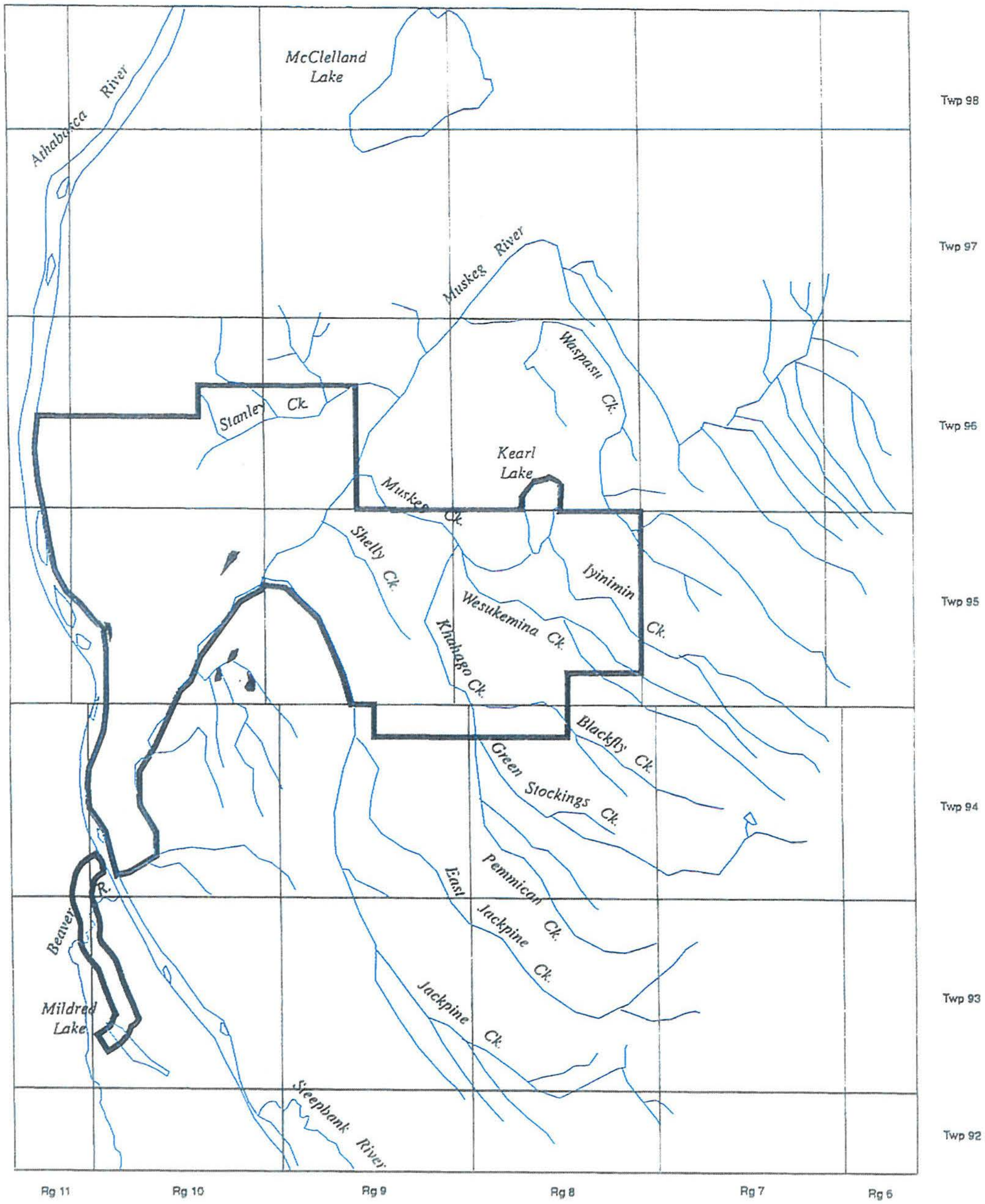

Figure 1.2-4
Local Study Area for the Aurora Mine Environmental Baseline Program

LEGEND

Syncrude boundary

N

0 5 10 15

KILOMETRES

Project No. 952-2308 7150 4 April 1996

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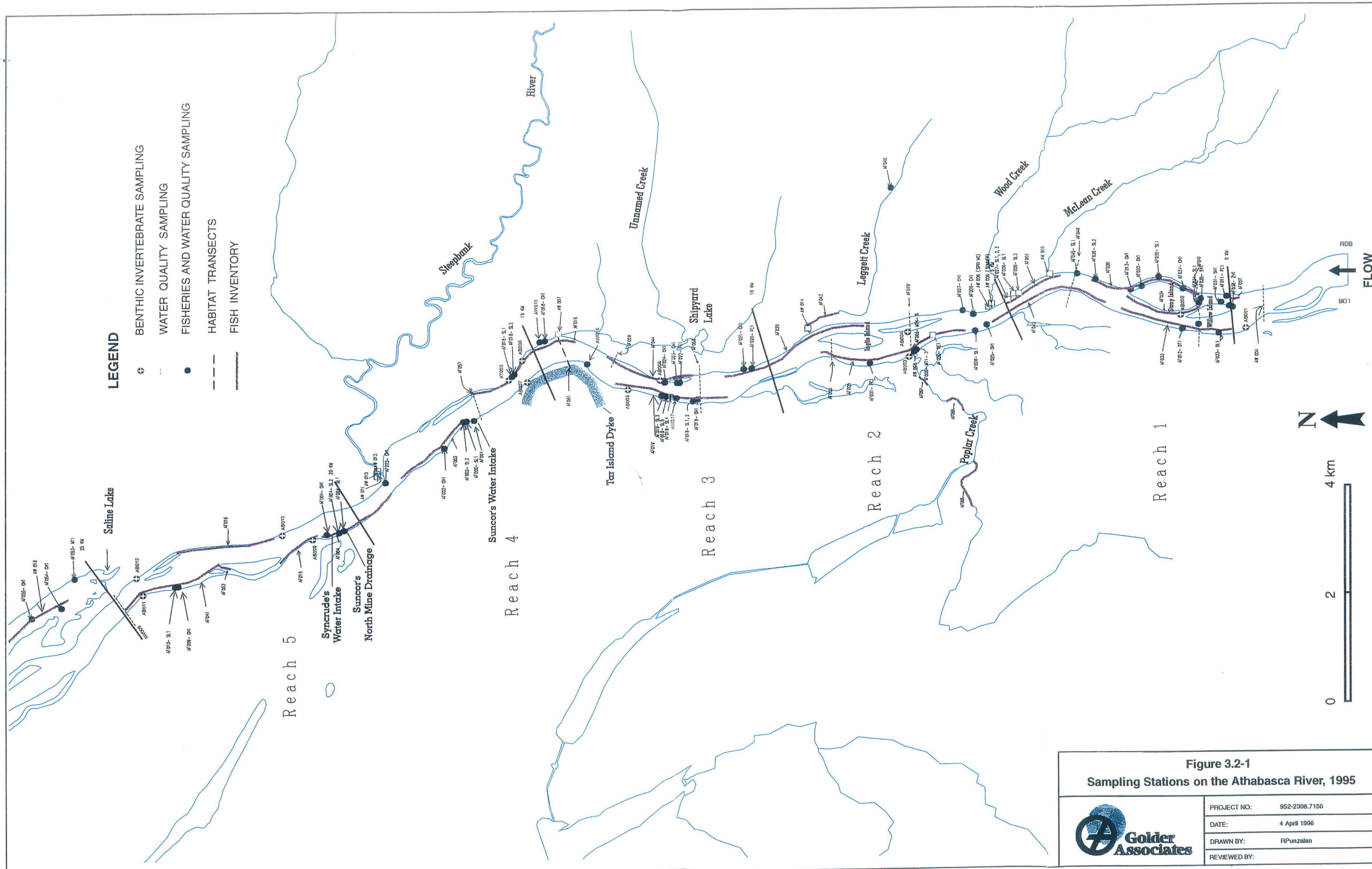


Figure 3.2-1
Sampling Stations on the Athabasca River, 1995

PROJECT NO:	952-2308.7150
DATE:	4 April 1996
DRAWN BY:	RPunzalan
REVIEWED BY:	

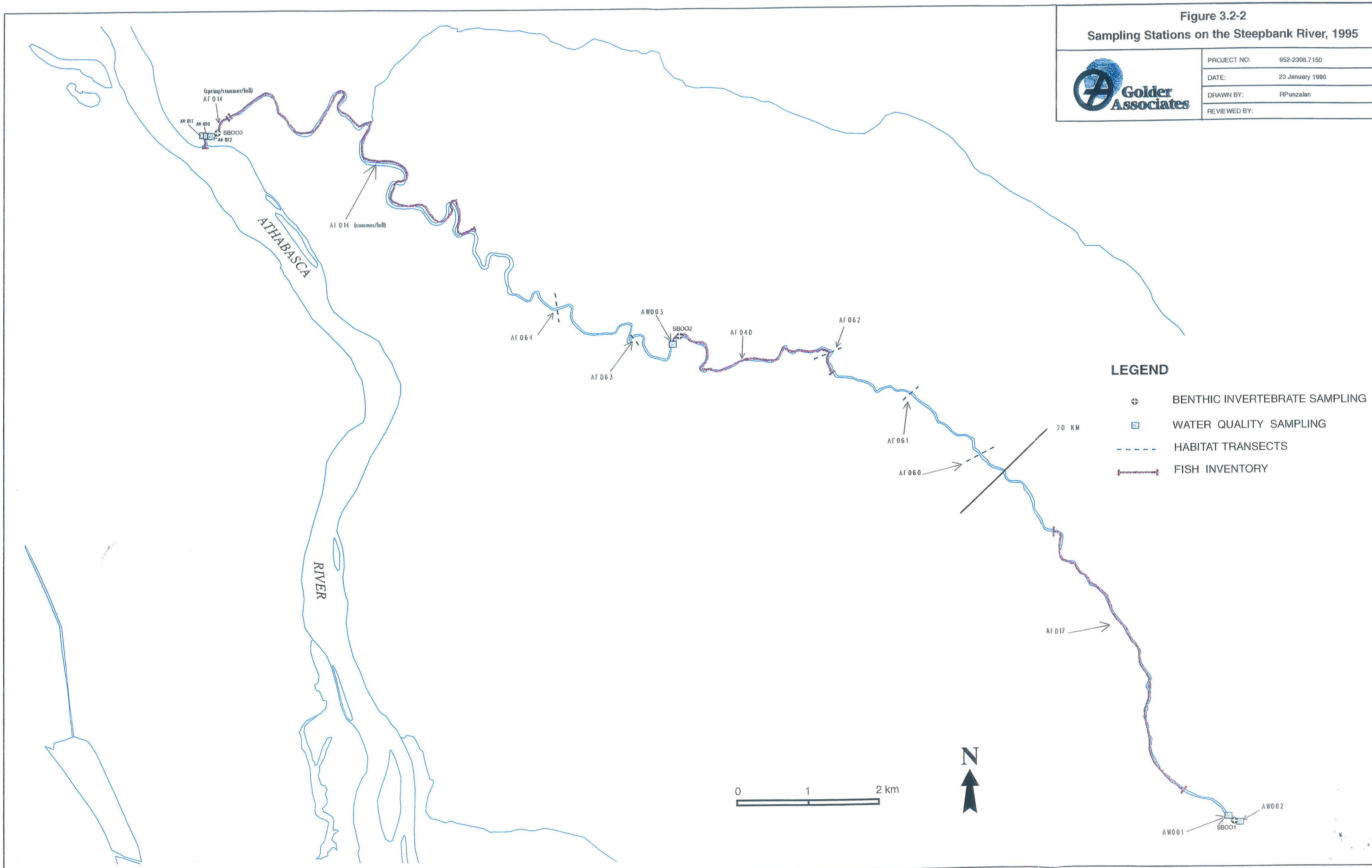
Golder Associates

Figure 3.2-2

Sampling Stations on the Steepbank River, 1995

PROJECT NO:	952-2308.7150
DATE:	23 January 1996
DRAWN BY:	RPunzalan
REVIEWED BY:	

Golder Associates



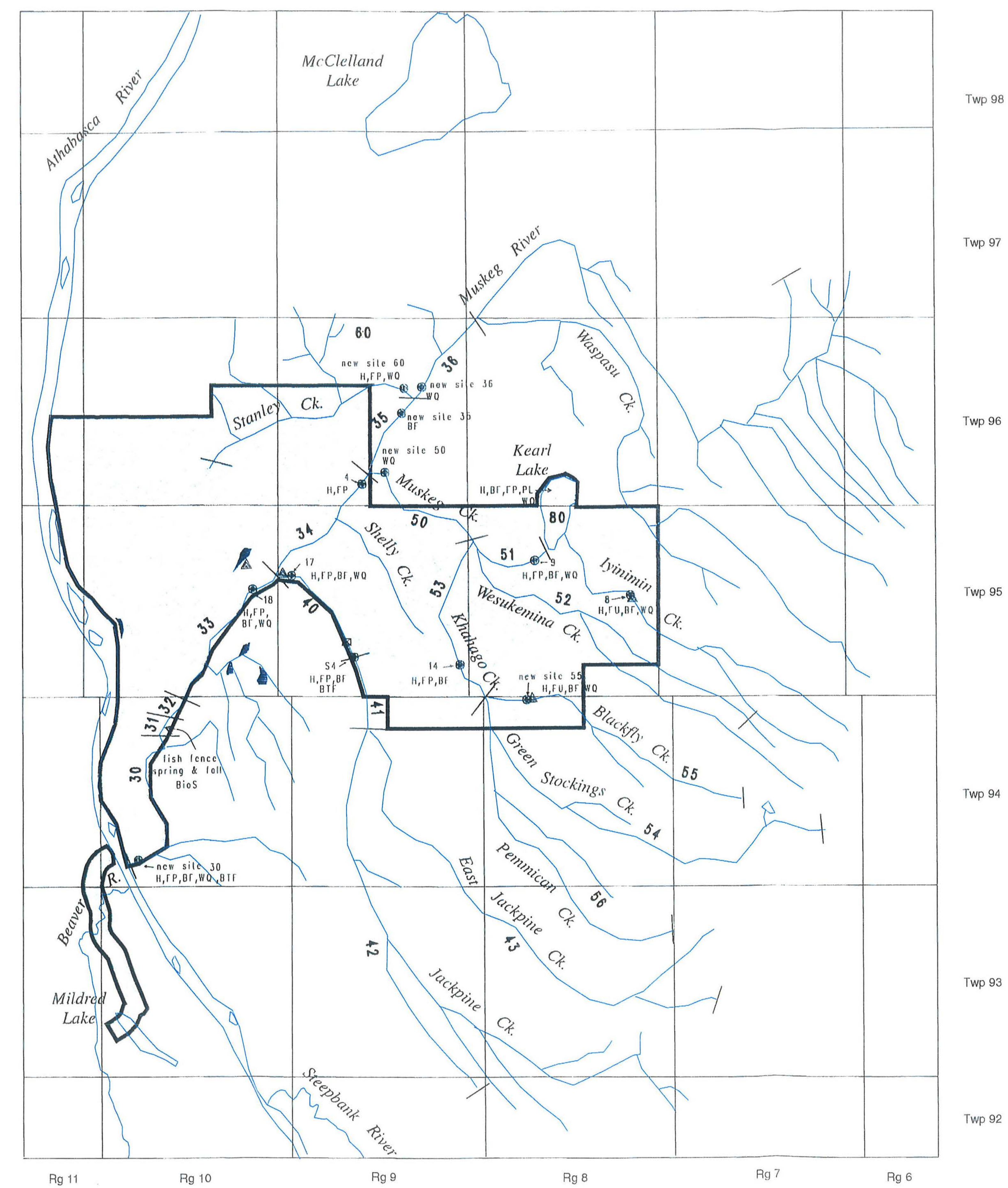


Figure 3.2-3
Sampling Sites on the Muskeg River and its Tributaries, 1995

LEGEND

- Syncrude boundary
- Selected Stream Sampling Station
- Stream Gauging Station
- Climate Station

H	Habitat Assessment
FP	Fisheries Assessment - Spring
FU	Fisheries Assessment - Summer
FF	Fisheries Assessment - Fall
BF	Benthos - Fall
PL	Plankton (quarterly)
WQ	Water Quality (quarterly)
BioS	Biomarking - Spring
BTF	Benthos Tissue - Fall

N

Scale = 1 : 250,000

0 5 10 15

KILOMETRES

Project No. 952-2308.7150 4 April 1996

Golder Associates

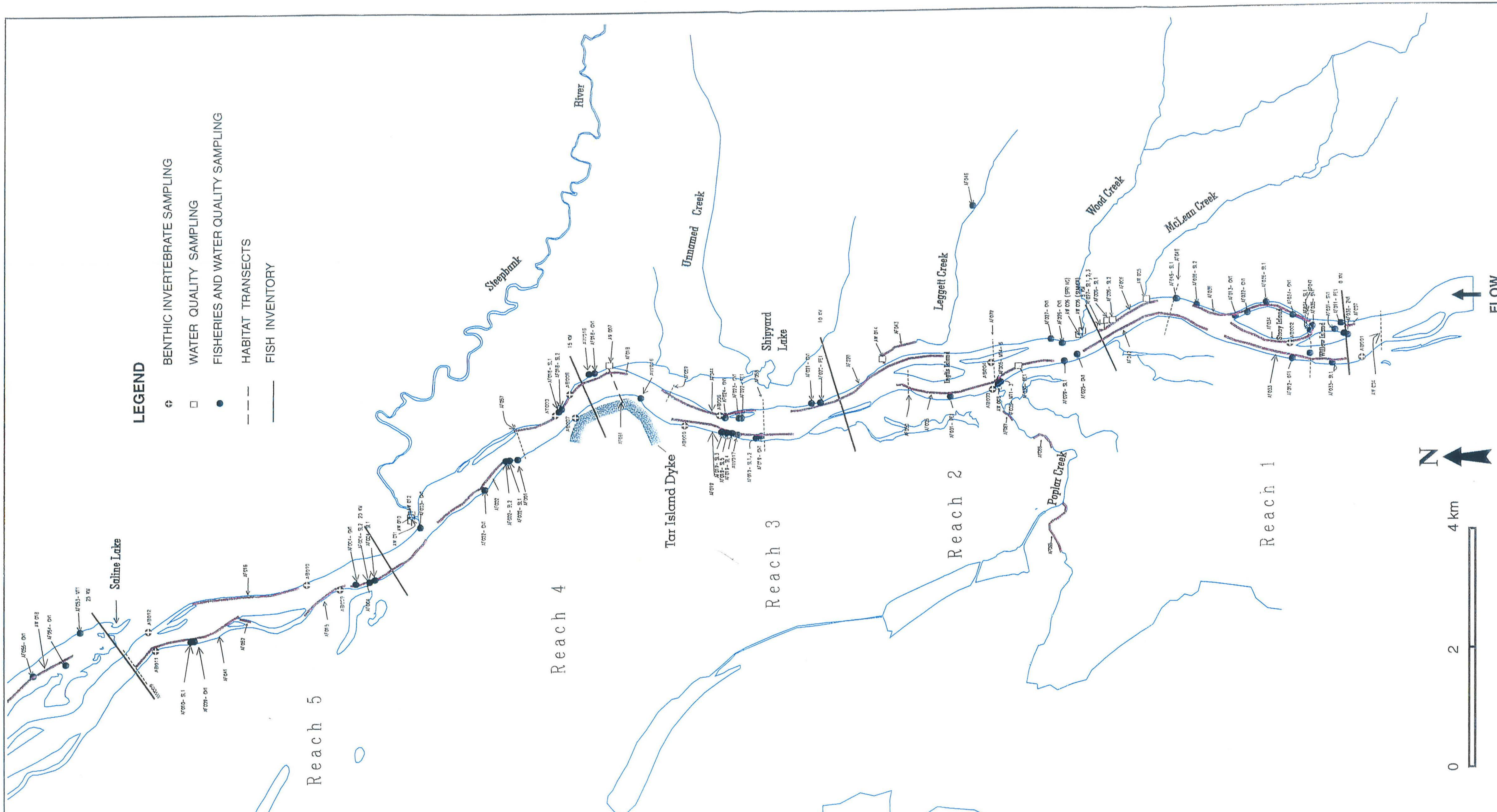


Figure 4.3-1
Sampling Stations on the Athabasca River, 1995

PROJECT NO:	952-2307.5270
DATE:	20 March 1996
DRAWN BY:	RPunzalan
REVIEWED BY:	

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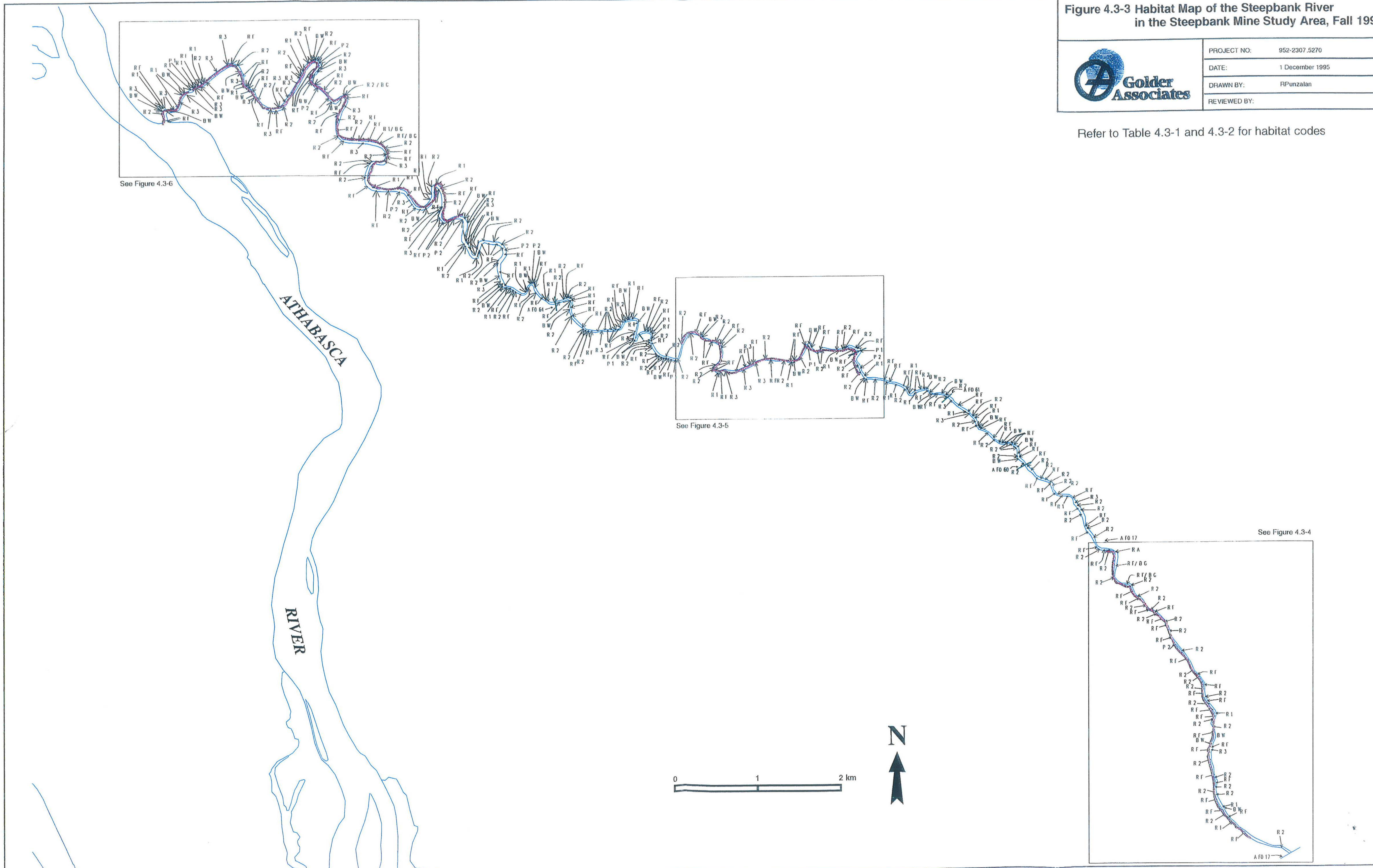
Figure 4.3-3 Habitat Map of the Steepbank River in the Steepbank Mine Study Area, Fall 1995

Golder Associates

PROJECT NO:	952-2307.5270
DATE:	1 December 1995
DRAWN BY:	RPunzalan
REVIEWED BY:	



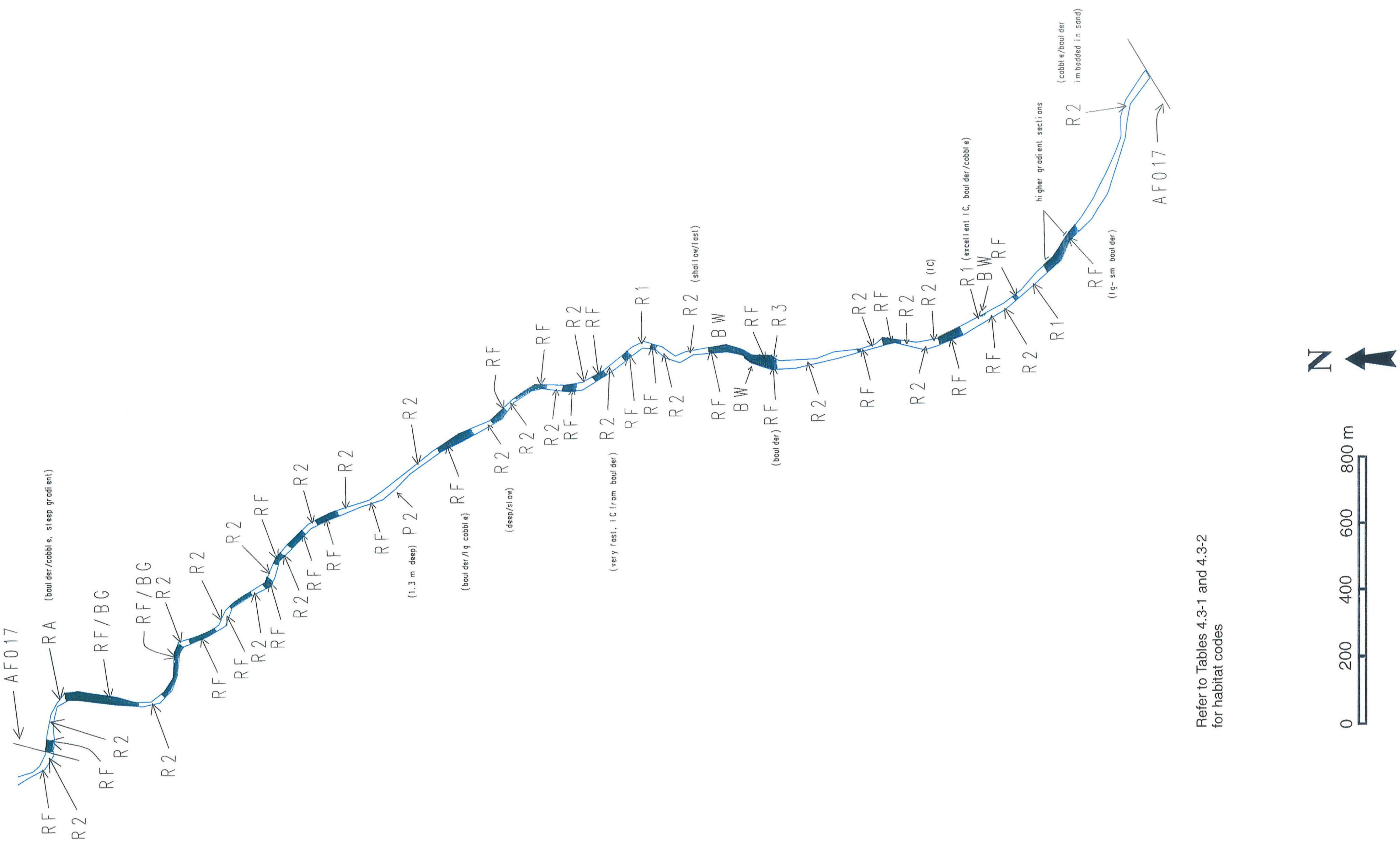
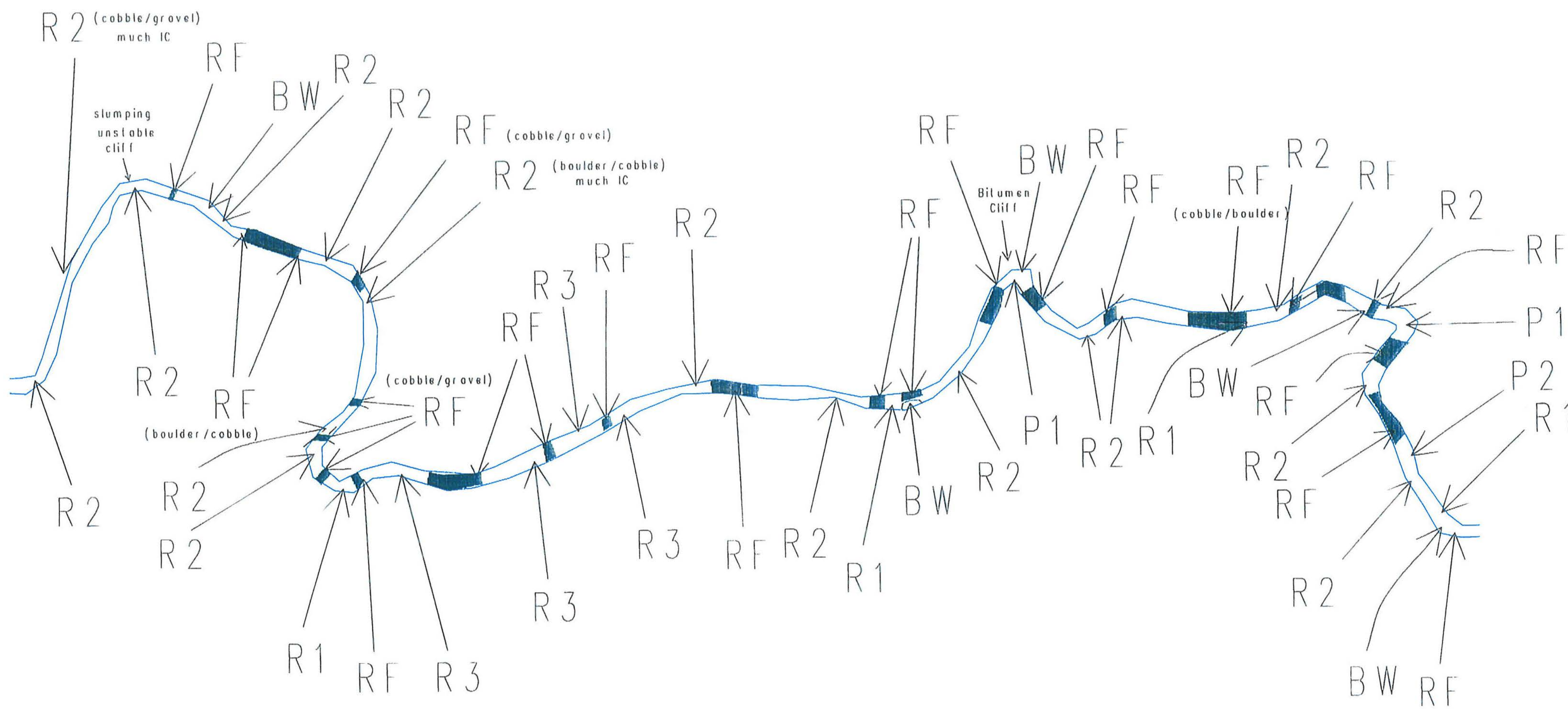


Figure 4.3-4 **Habitat Map of Fish Inventory Section 1 (AF017) on the Steepbank River, Fall 1995**

Golder Associates

PROJECT NO:	952-2307.5270
DATE:	1 December 1995
DRAWN BY:	RPunzalan
REVIEWED BY:	



0 200 400 m

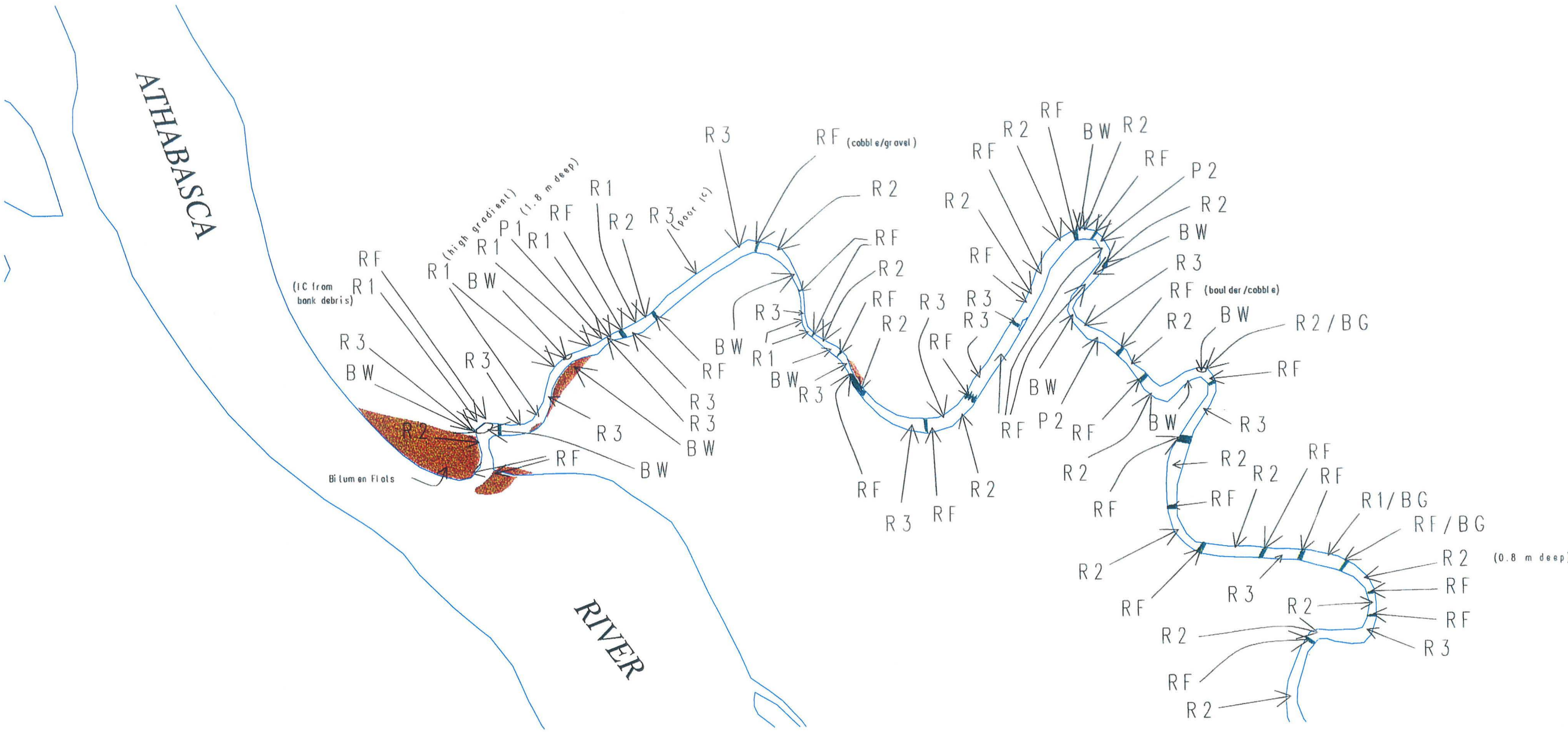
N

Refer to Tables 4.3-1 and 4.3-2 for habitat codes

Figure 4.3-5 **Habitat Map of Fish Inventory Section 2 (AF040) on the Steepbank River, Fall 1995**

Golder Associates

PROJECT NO:	952-2307.5270
DATE:	1 December 1995
DRAWN BY:	RPunzalan
REVIEWED BY:	



0 200 400 600 800 m

N

Refer to Tables 4.3-1 and 4.3-2 for habitat codes

Figure 4.3-6 Habitat Map of Fish Inventory Section 3 (AF014) on the Steepbank River, Fall 1995

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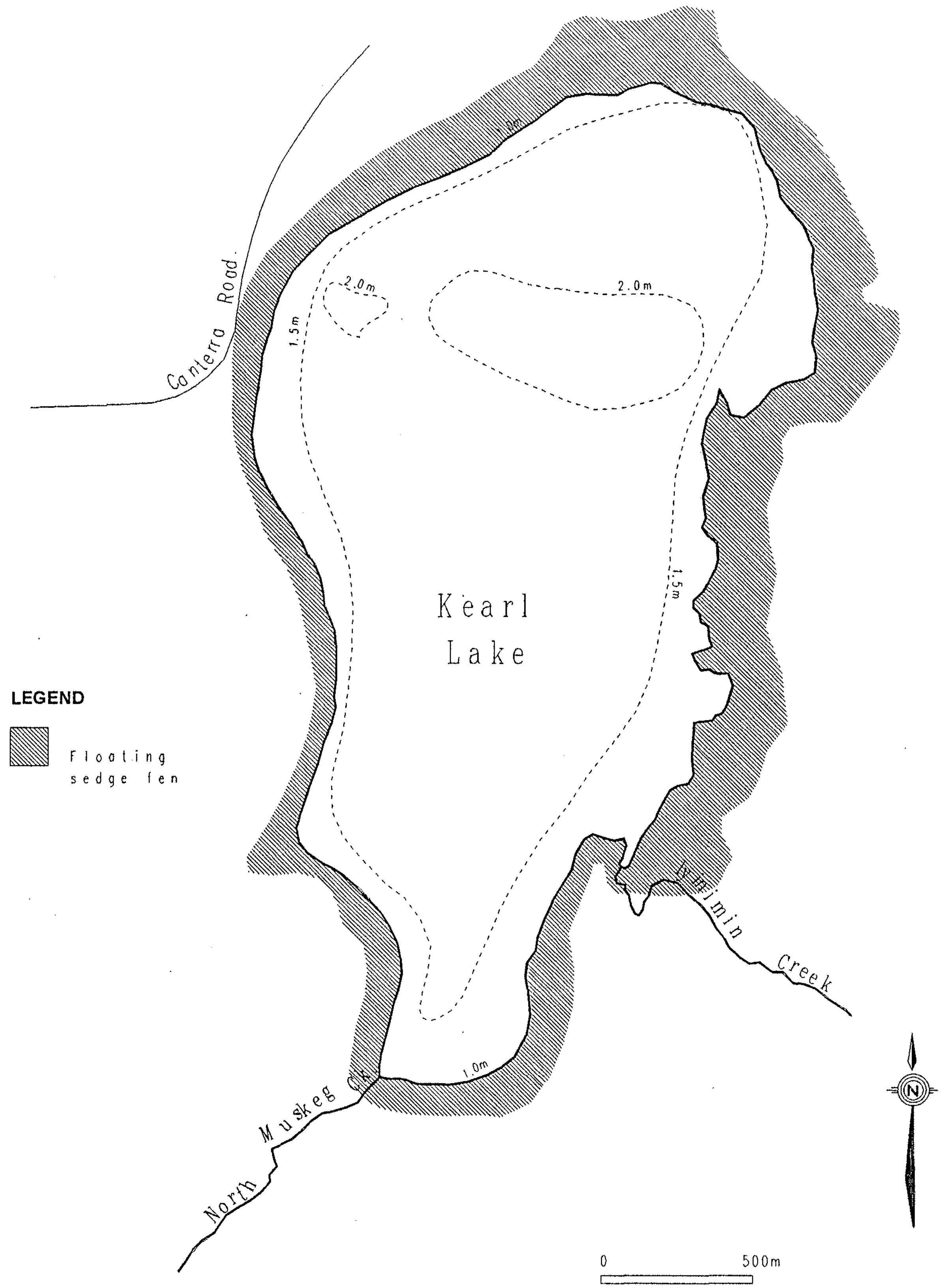
PROJECT NO:	952-2307.5270
DATE:	1 December 1995
DRAWN BY:	RPunzalan
REVIEWED BY:	

Bathymetric Map of Kearl Lake, October 1985 (from Beak 1986b)(Contour Interval = 0.5m)

Figure 4.3-10



PROJECT NO. 952-2308.7150 DRAWN RP REVIEWED DATE 4 April 1996

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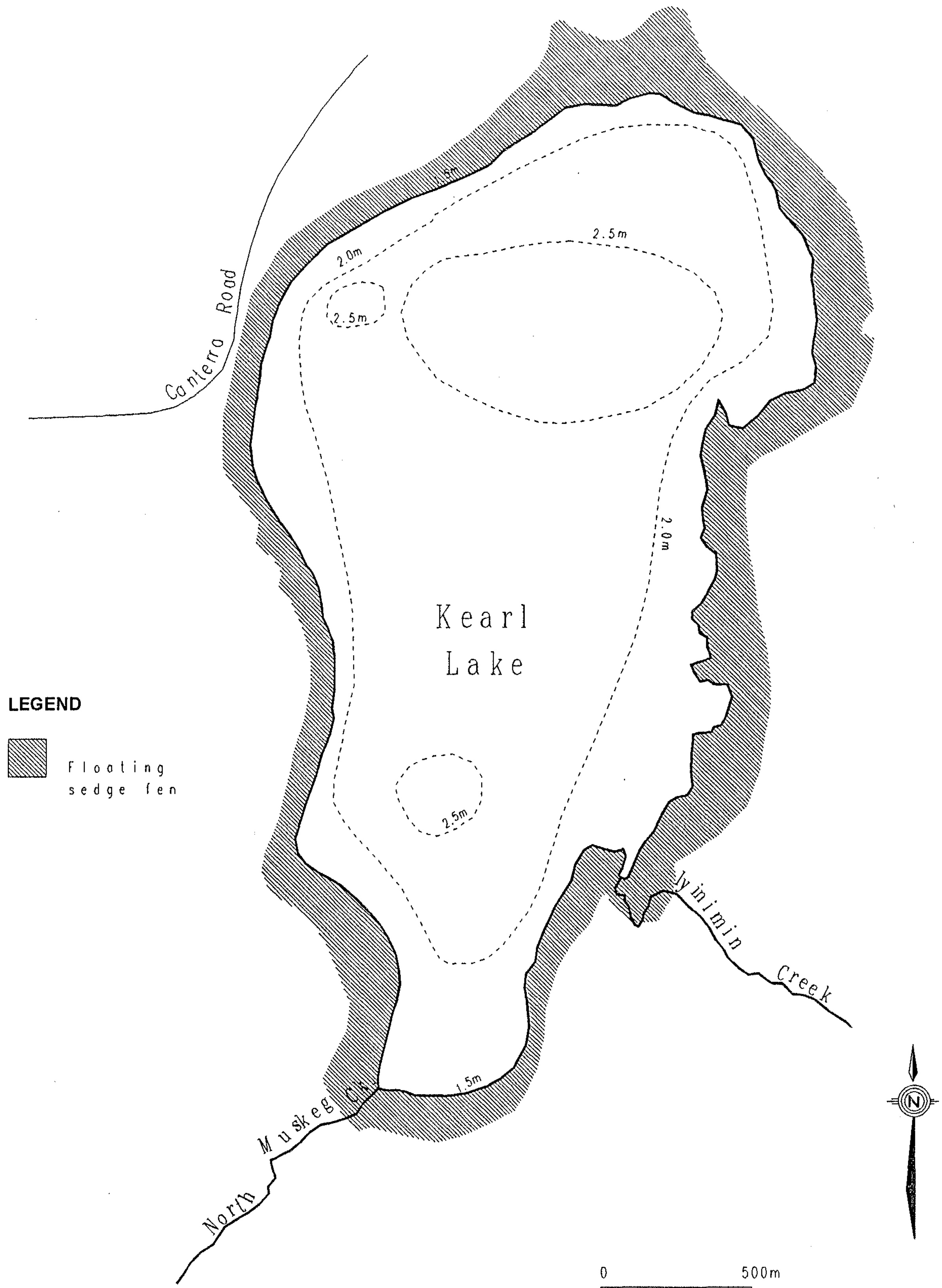
Bathymetric Map of Kearl Lake, August 1985
(Contour Interval = 0.5m)

Figure 4.3-11



PROJECT NO. 952-2308.7150 DRAWN RP REVIEWED DATE 4 April 1996

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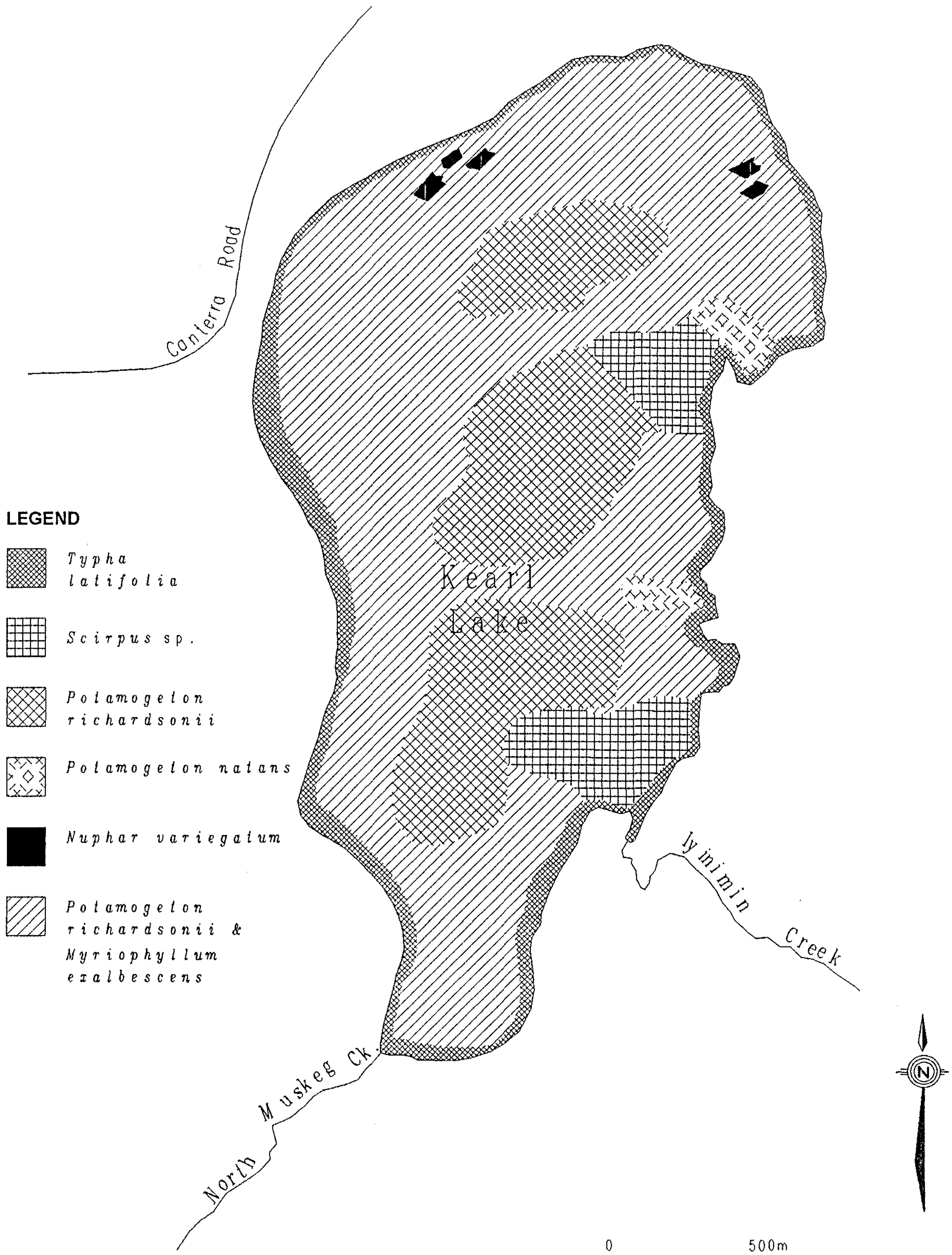
Aquatic Vegetation Map of Kearl Lake, October 1995 (from Beak 1986b)

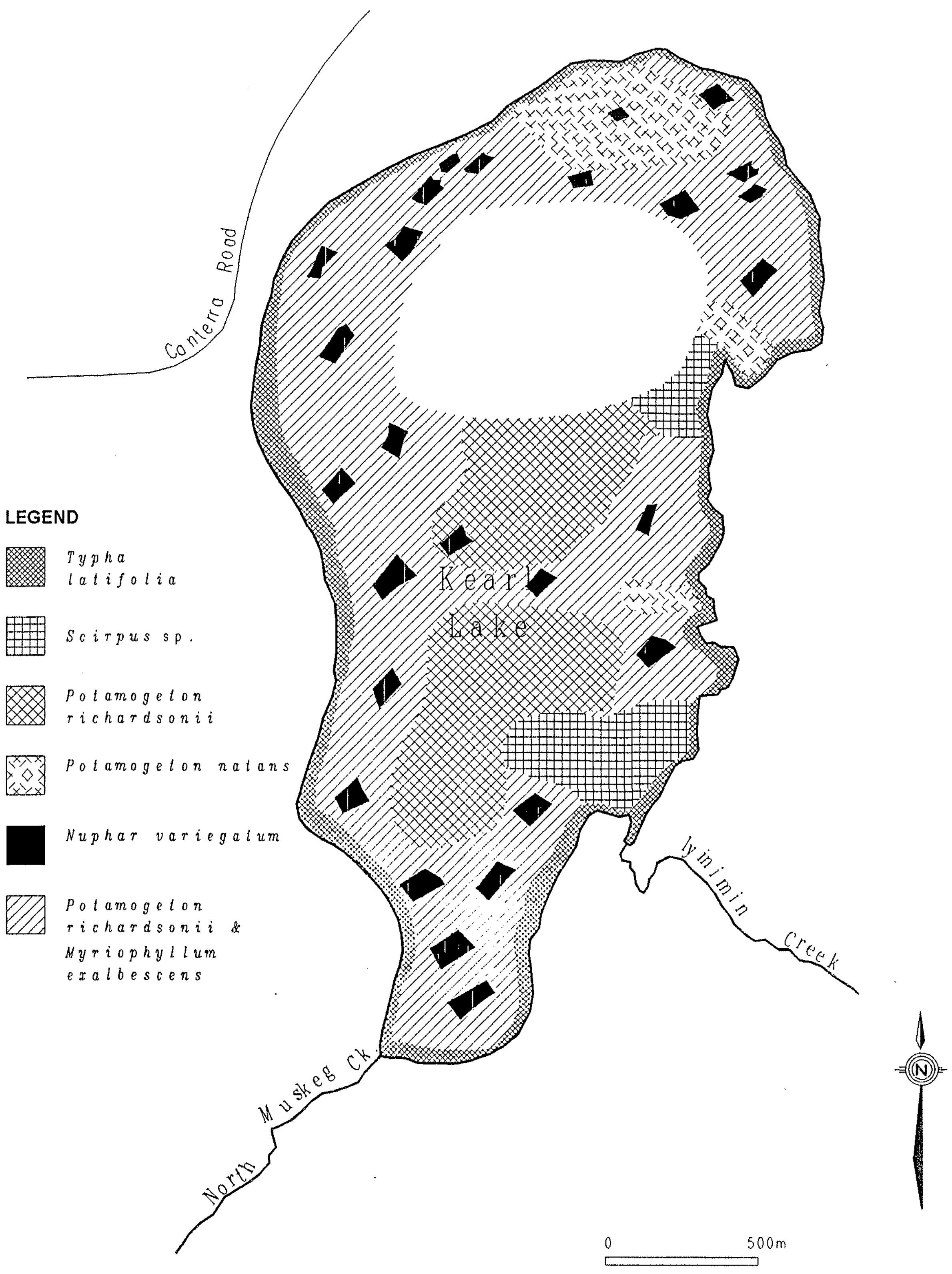
Figure 4.3-12



PROJECT NO. 952-2308.7150 DRAWN RP REVIEWED DATE 4 April 1996

Aquatic Vegetation Map of Kearl Lake, August 1995

Figure 4.3-13



PROJECT NO. 952-2308.7150 DRAWN RP REVIEWED DATE 4 April 1996

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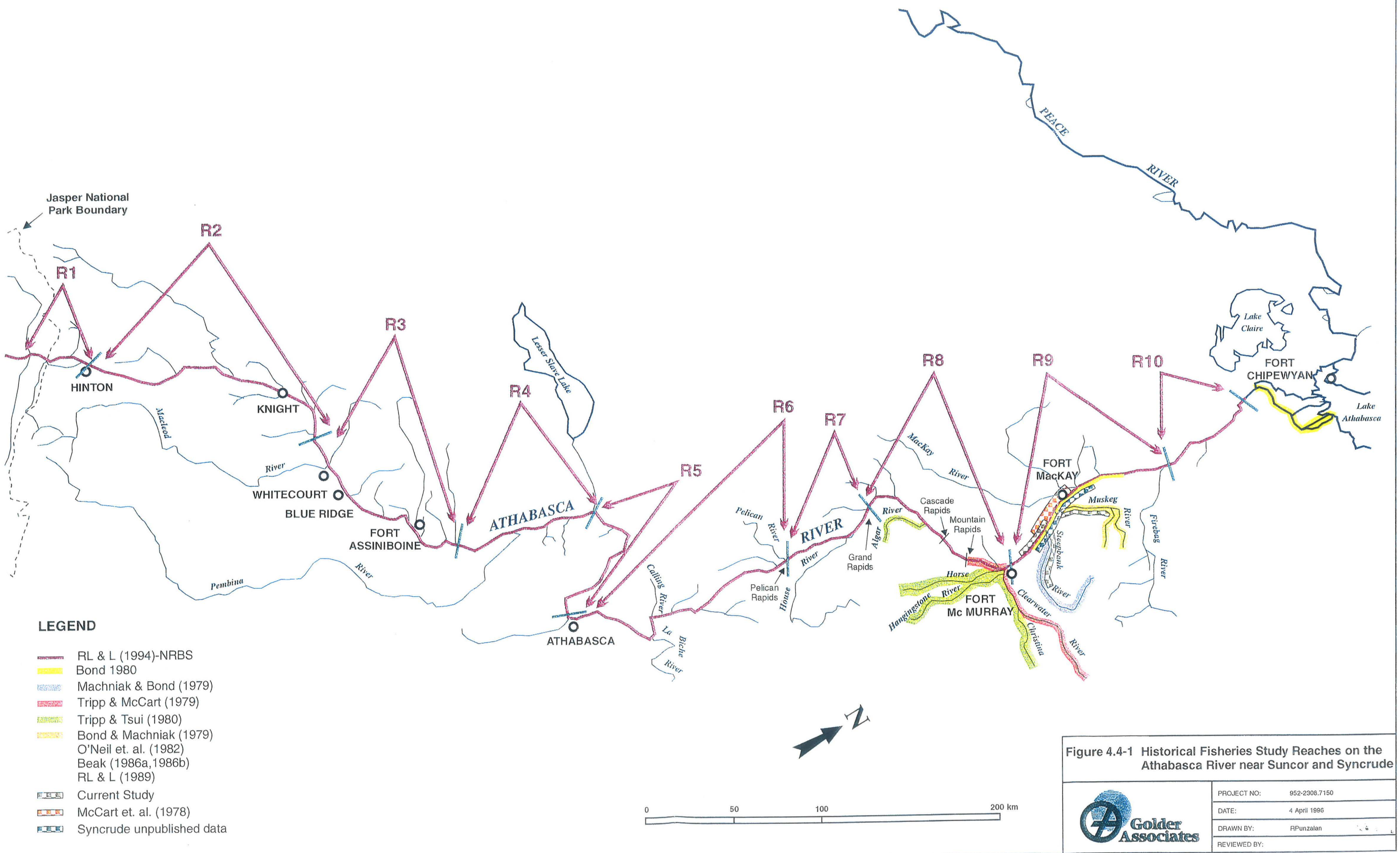

Figure 4.4-1 Historical Fisheries Study Reaches on the Athabasca River near Suncor and Syncrude

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PROJECT NO:	952-2308.7150
DATE:	4 April 1996
DRAWN BY:	RPunzalan
REVIEWED BY:	

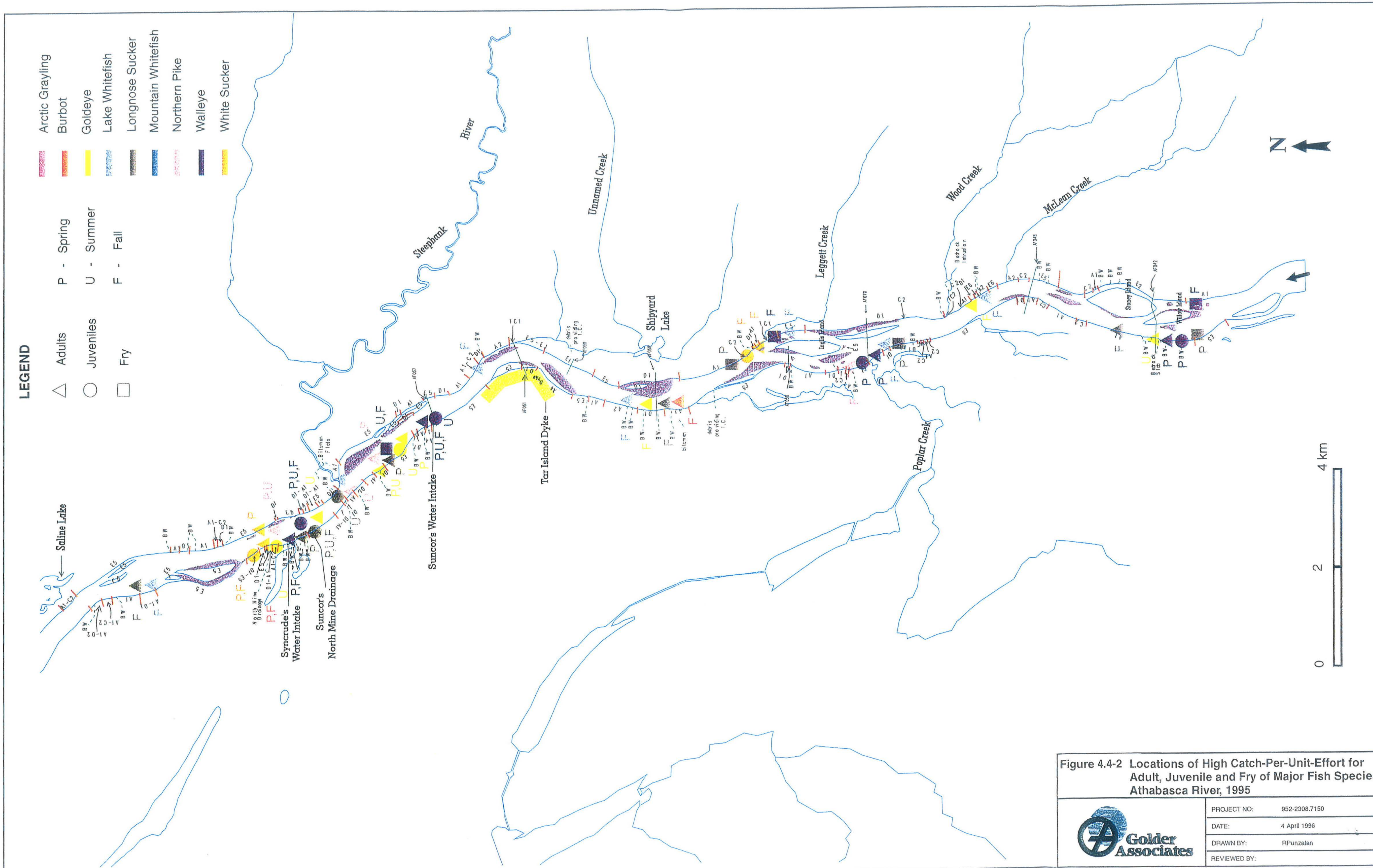


Figure 4.4-2 Locations of High Catch-Per-Unit-Effort for Adult, Juvenile and Fry of Major Fish Species, Athabasca River, 1995

Golder Associates

PROJECT NO:	952-2308.7150
DATE:	4 April 1996
DRAWN BY:	RPunzalan
REVIEWED BY:	

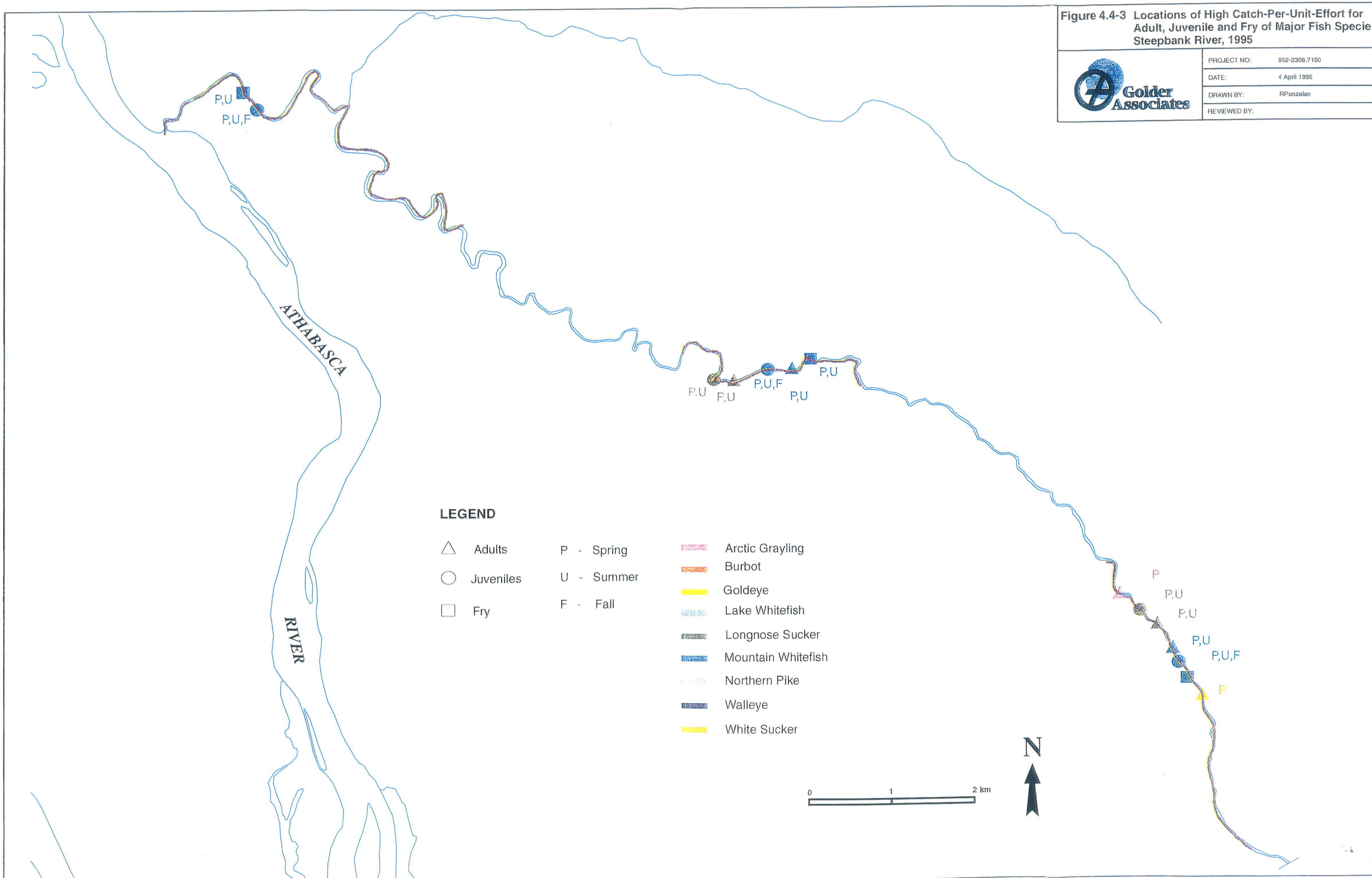
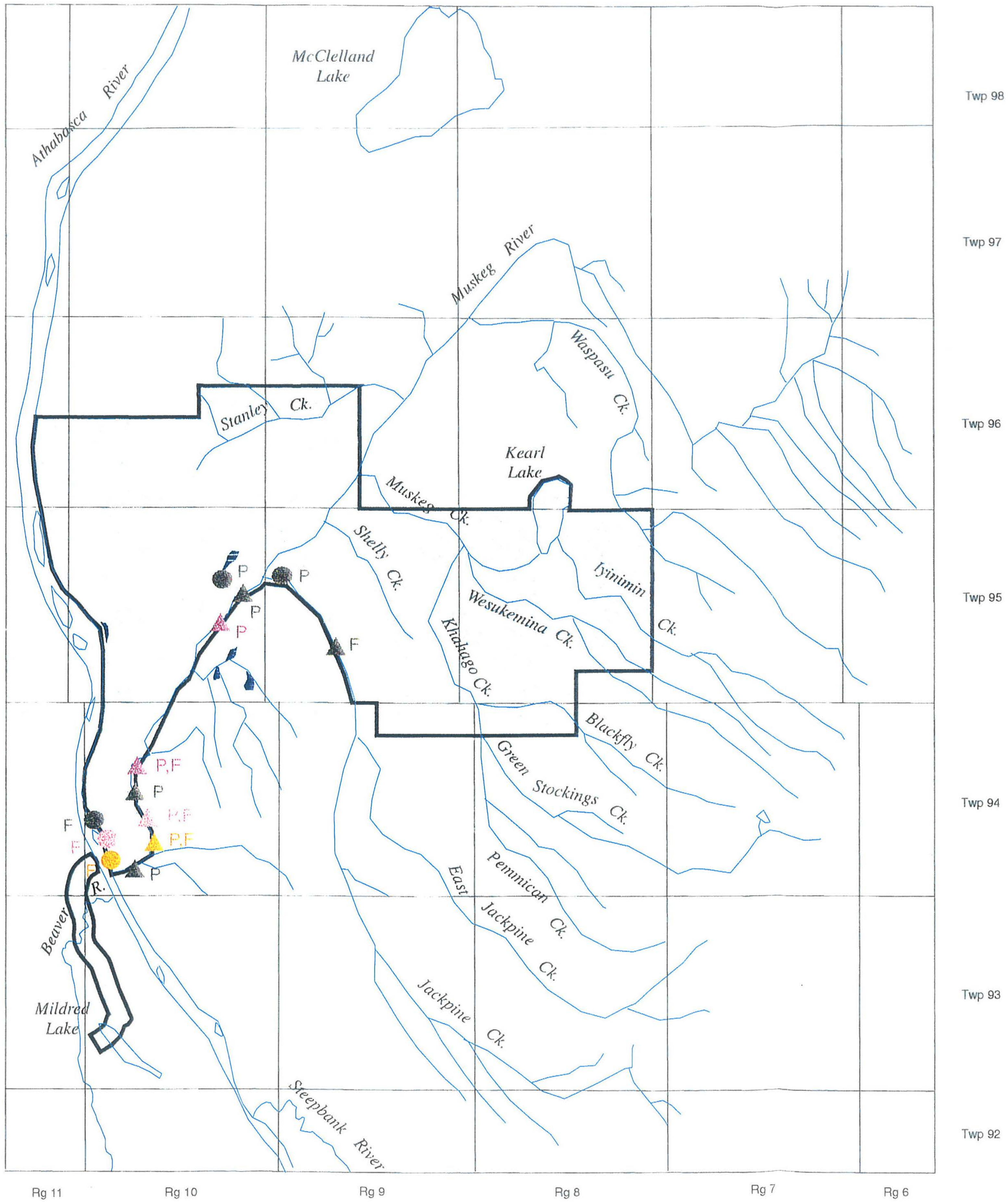


Figure 4.4-3 Locations of High Catch-Per-Unit-Effort for Adult, Juvenile and Fry of Major Fish Species, Steepbank River, 1995
PROJECT NO: 952-2306.7150
DATE: 4 April 1996
DRAWN BY: RPunzalan
REVIEWED BY:
Golder Associates
ATHABASCA
RIVER
P,U
P,U,F
P,U
P,U
P,U,F
P,U
P,U
P
P,U
P,U
P,U
P,U,F
P
LEGEND
Adults
Juveniles
Fry
P - Spring
U - Summer
F - Fall
Arctic Grayling
Burbot
Goldeye
Lake Whitefish
Longnose Sucker
Mountain Whitefish
Northern Pike
Walleye
White Sucker
0
1
2 km
N

Figure 4.4-4
Locations of High Catch-Per-Unit-Effort for Adult, Juvenile and Fry of Major Fish Species, Muskeg River System, 1995



LEGEND

△ Adults	P	- Spring
○ Juveniles	U	- Summer
□ Fry	F	- Fall

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

Scale = 1:250,000

0 5 10 15

KILOMETRES

Project No: 952-2308.7150 4 April 1996

Golder Associates

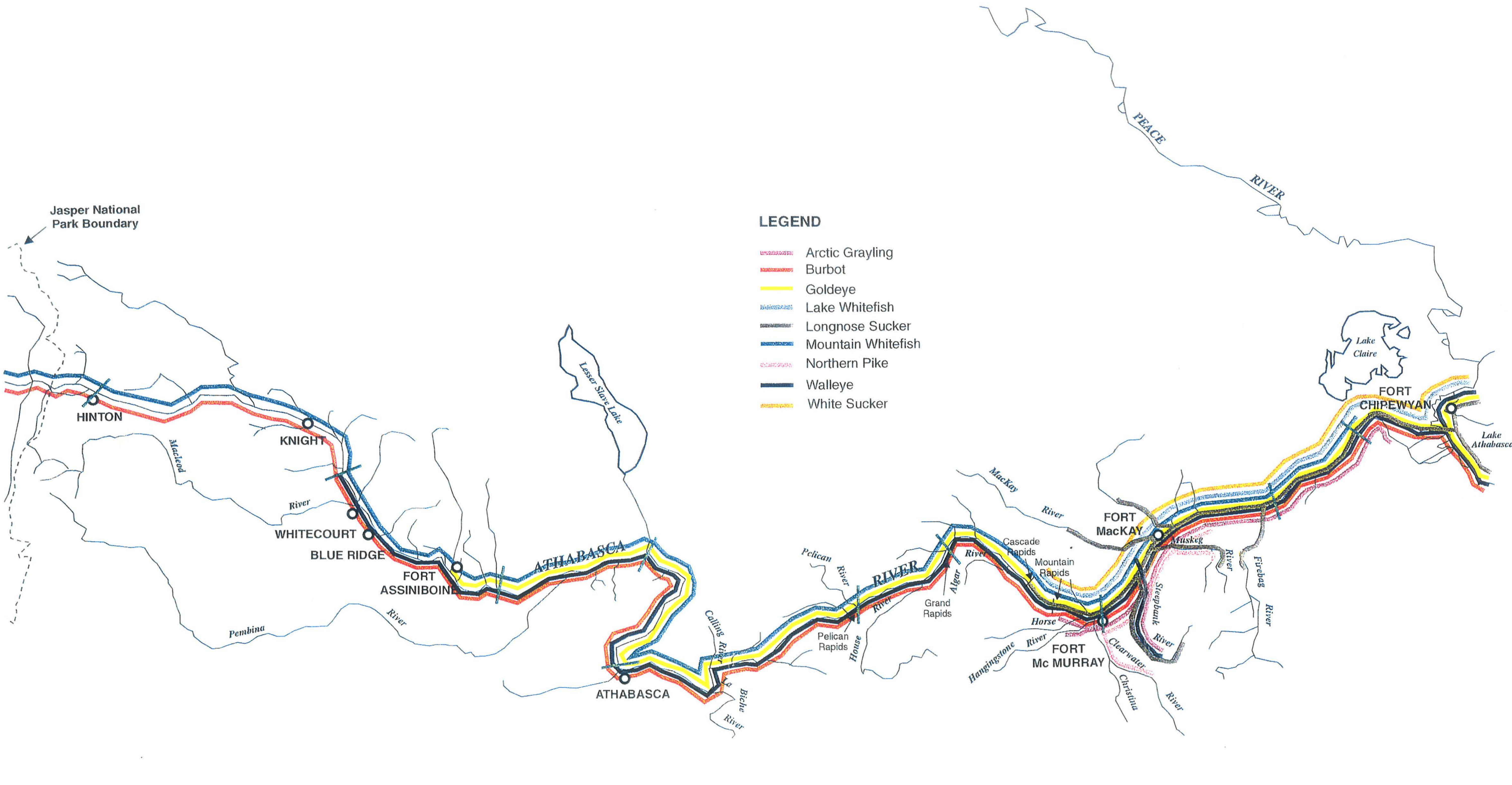


Figure 4.4-5 Spatial Extent of Use of the Athabasca River System by Populations of Major Fish Species Found in the Steepbank and Aurora Mine Study Areas

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PROJECT NO:	952-2307.5270
DATE:	7 December 1995
DRAWN BY:	RPunzalan
REVIEWED BY:	

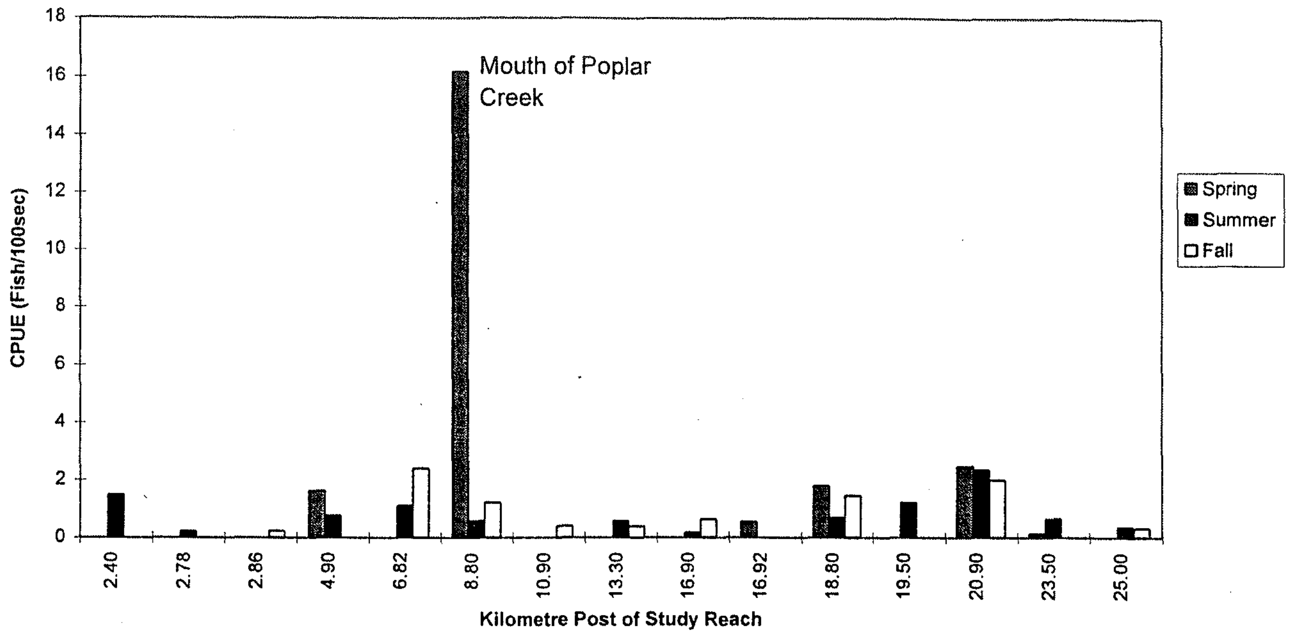


Figure 4.4-6 Catch-Per-Unit-Effort for Walleye from the Athabasca River in Spring, Summer and Fall, 1995

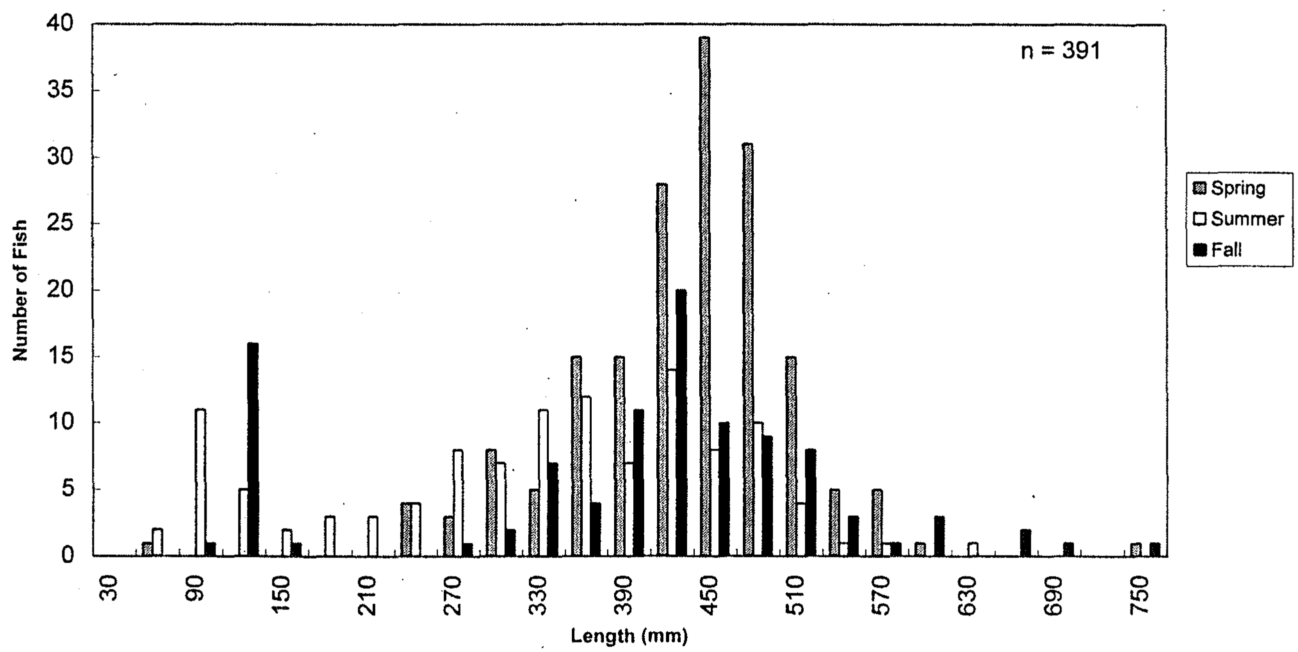


Figure 4.4-7 Length-Frequency Distribution for Walleye from the Athabasca River in Spring, Summer and Fall, 1995

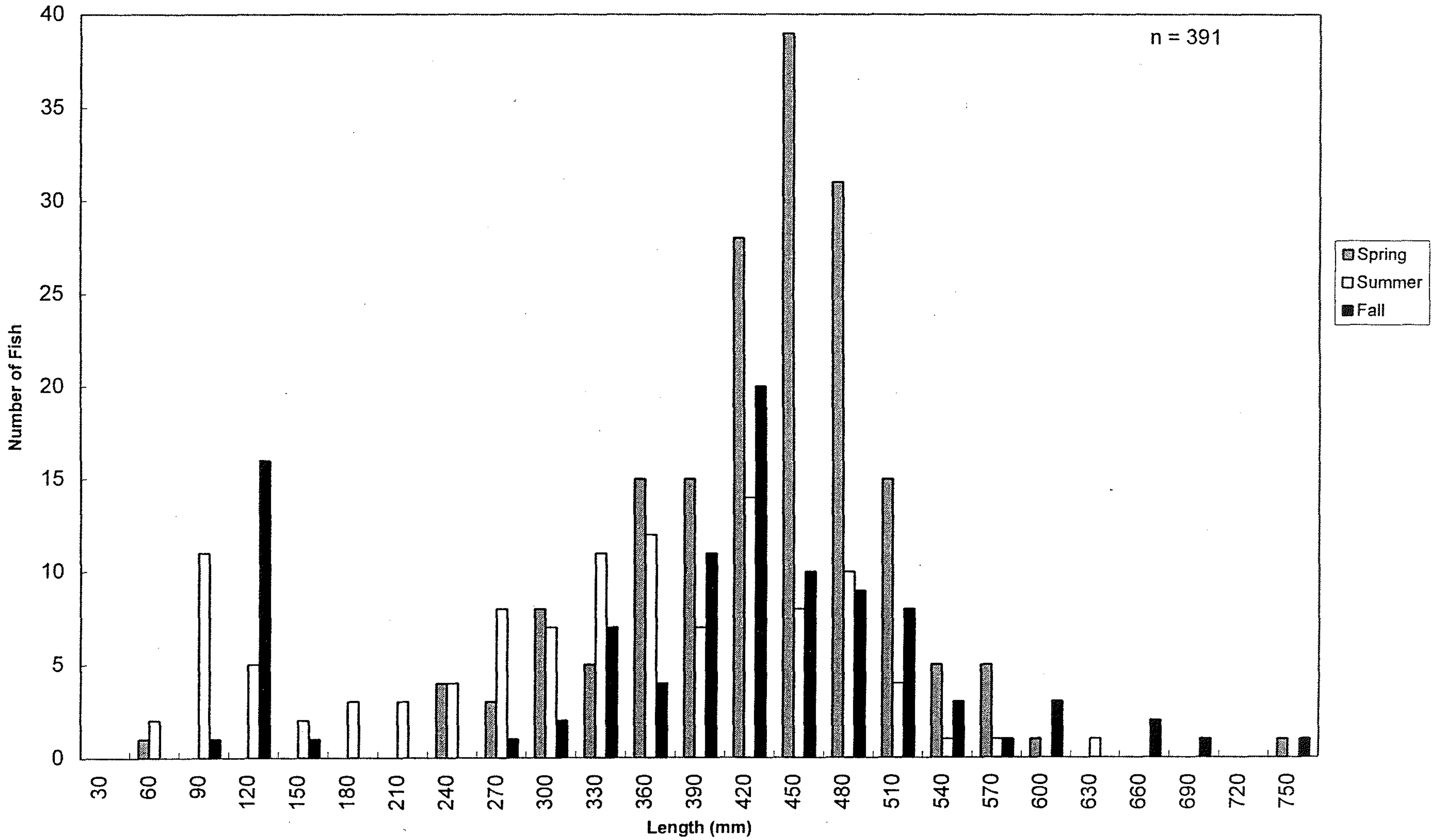
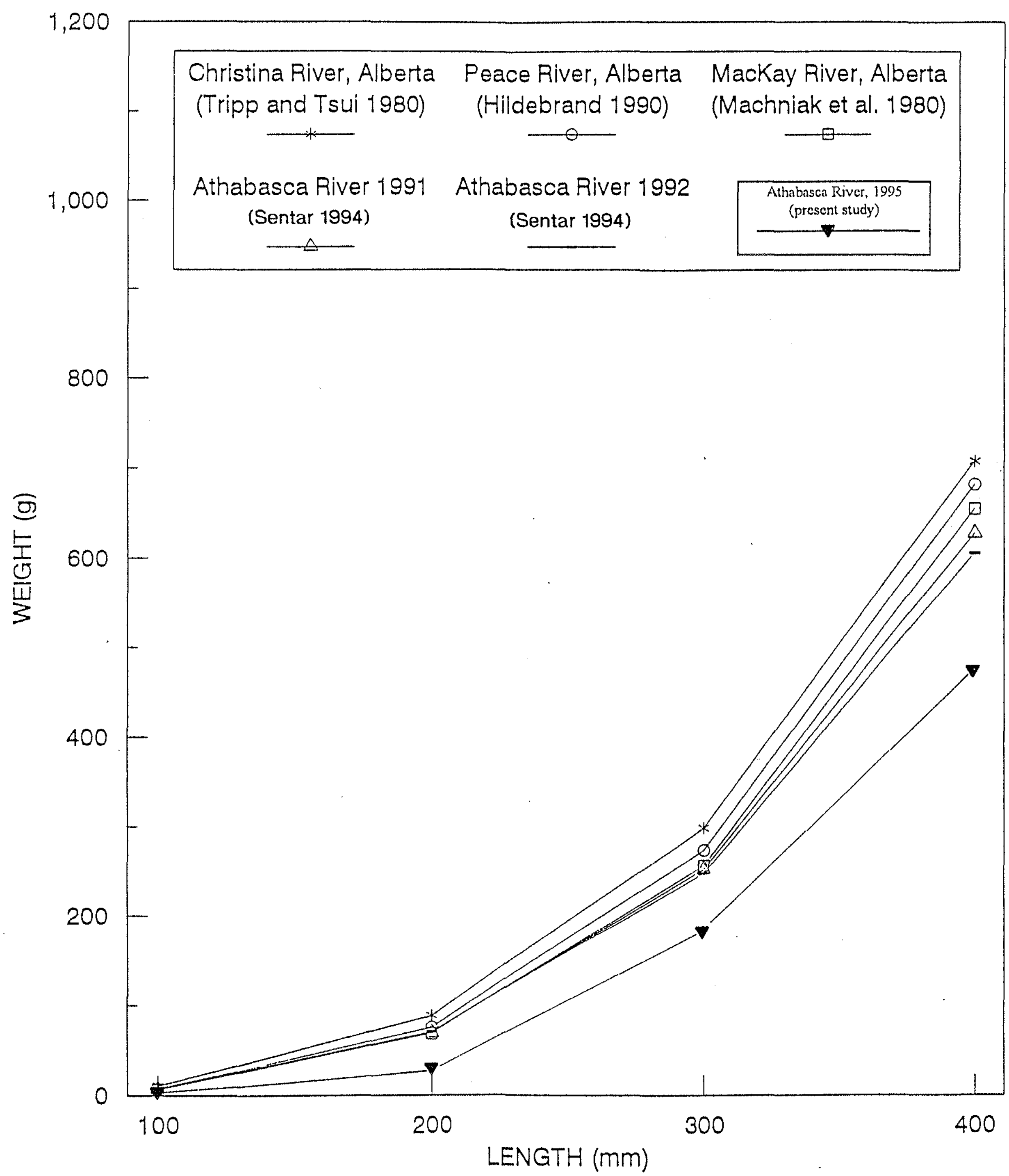


Figure 4.4-8 Length-Frequency Distribution for Walleye from the Athabasca River in Spring, Summer and Fall, 1995

Comparison of Walleye Length-Weight Relationships from Present and Previous Studies (Adapted from Sentar 1994)

Figure 4.4-9



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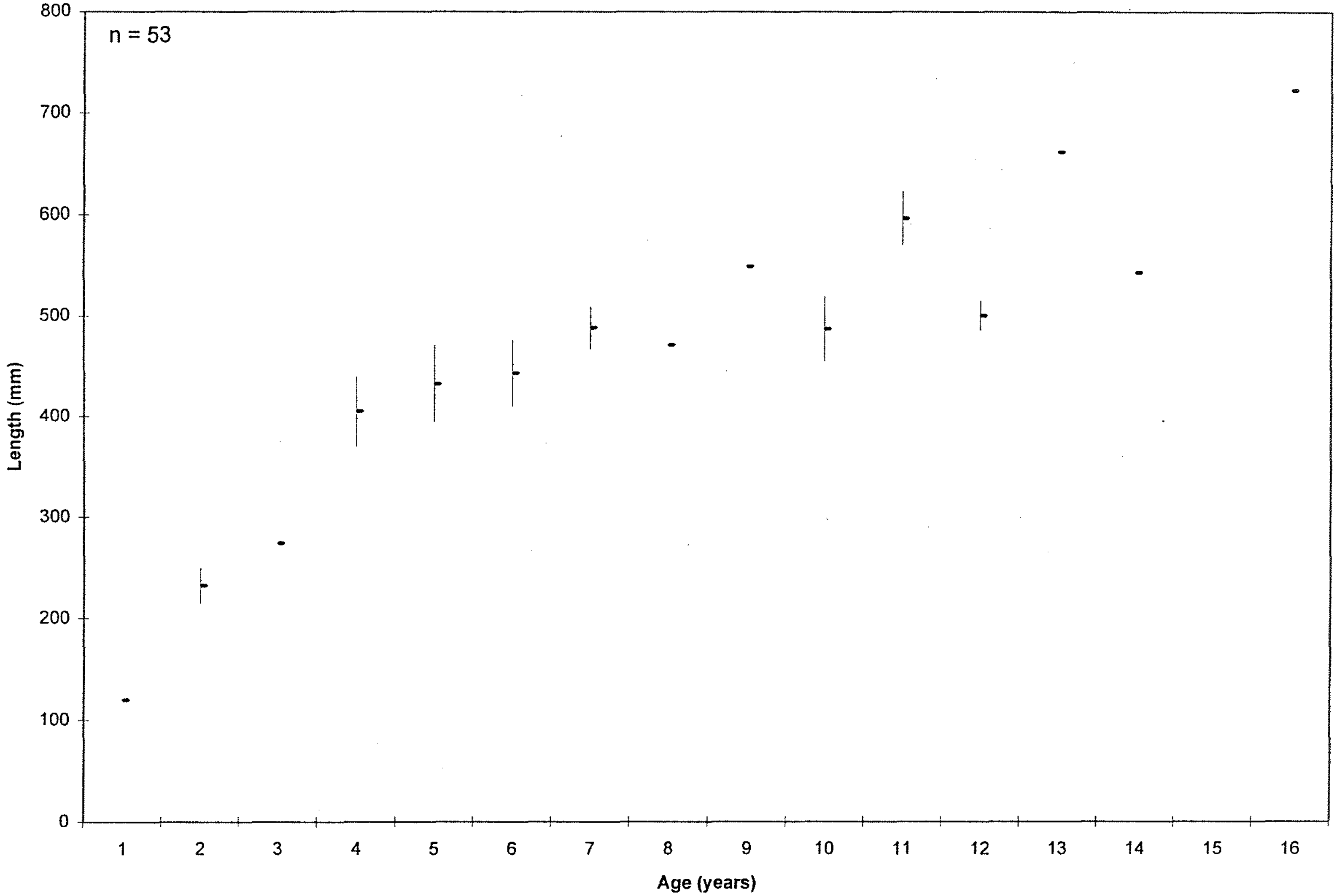
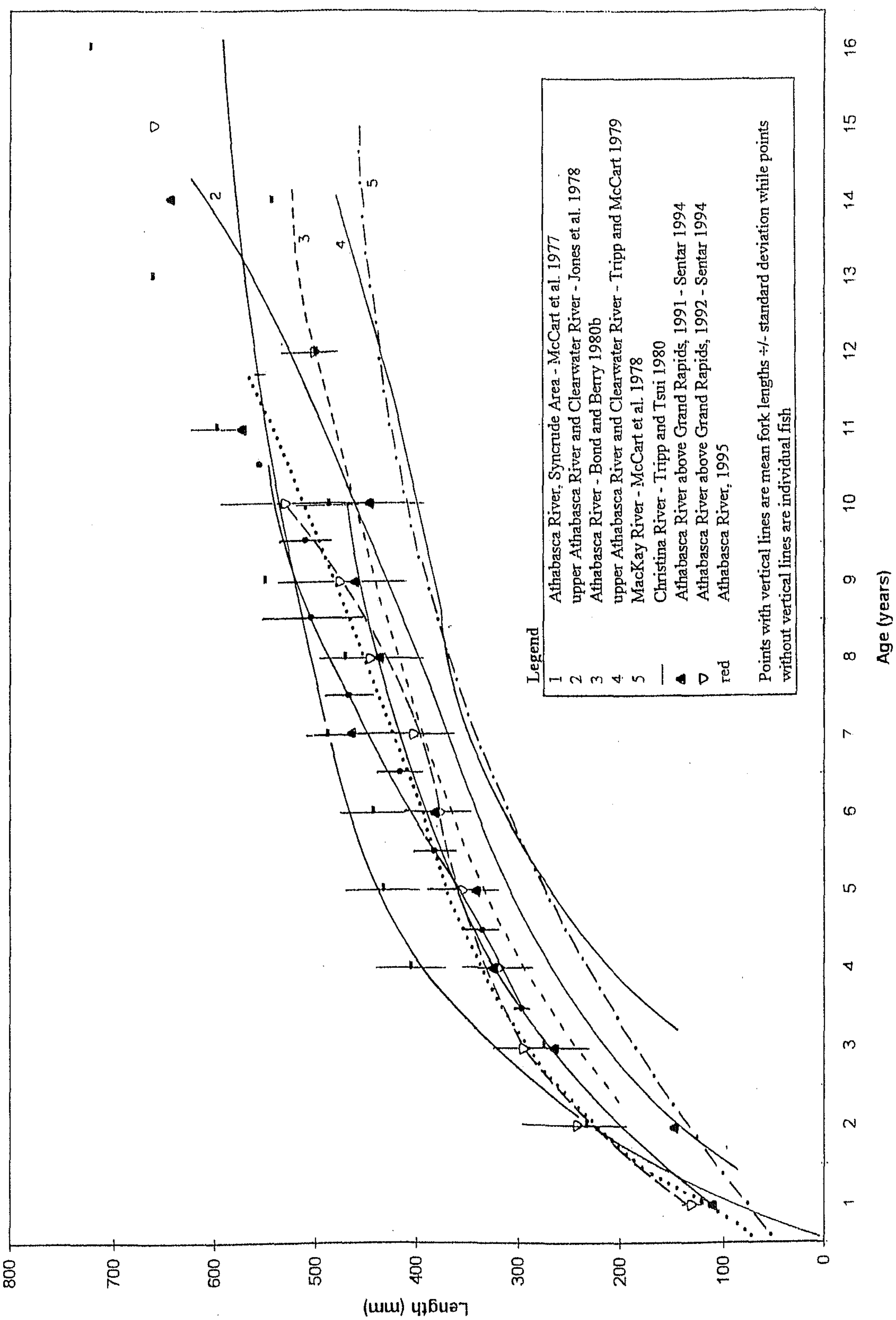


Figure 4.4-10 Length-at-Age with Standard Deviations for Walleye from the Athabasca RIver, 1995

Comparison of Walleye Length-at-age from the Present Study with Previous Studies (Adapted from Tripp and Tsui 1980)

Figure 4.4-11



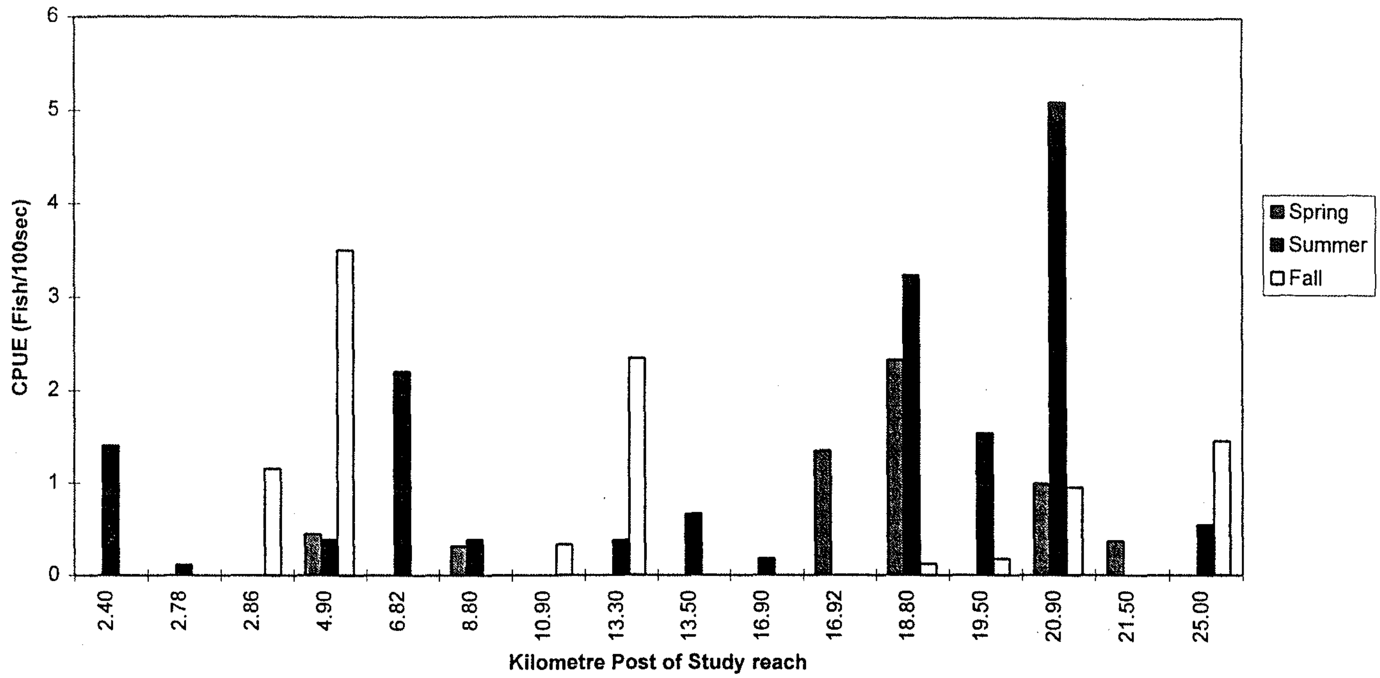


Figure 4.4-12 Catch-Per-Unit-Effort for Goldeye from the Athabasca River in Spring, Summer and Fall, 1995

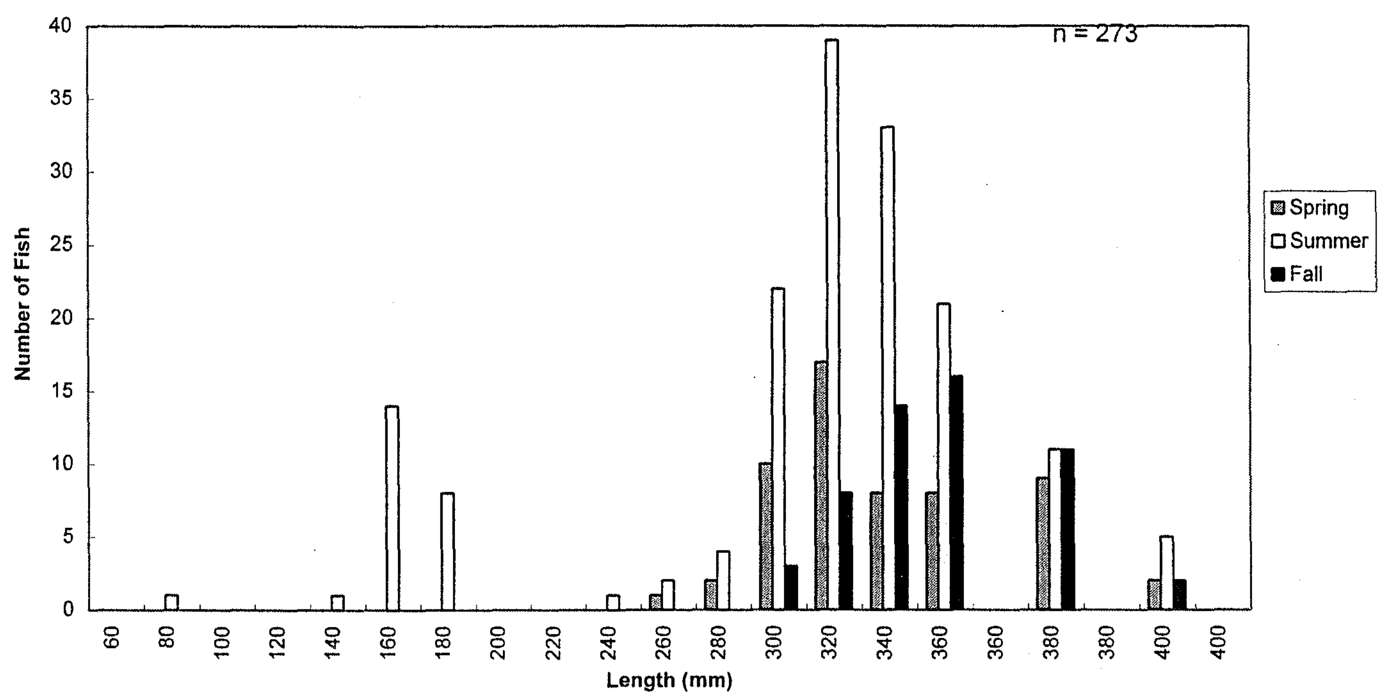


Figure 4.4-13 Length-Frequency Distribution for Goldeye from the Athabasca River in Spring, Summer and Fall, 1995

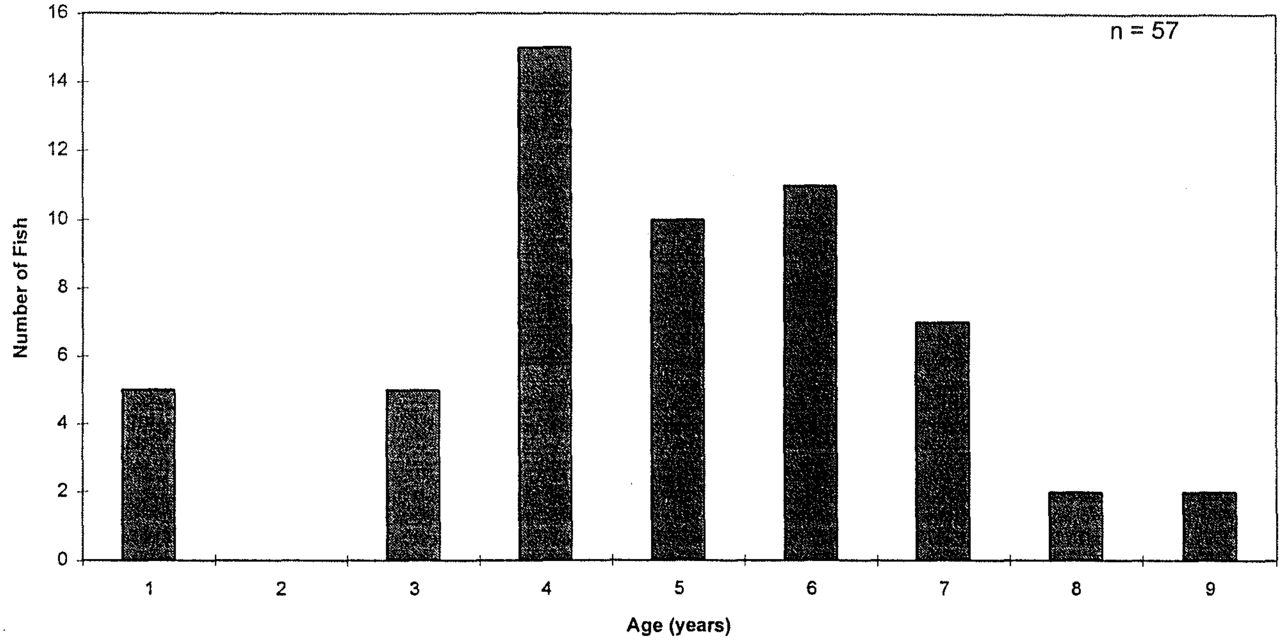


Figure 4.4-14 Age-Frequency Distribution for Goldeye from the Athabasca River, 1995

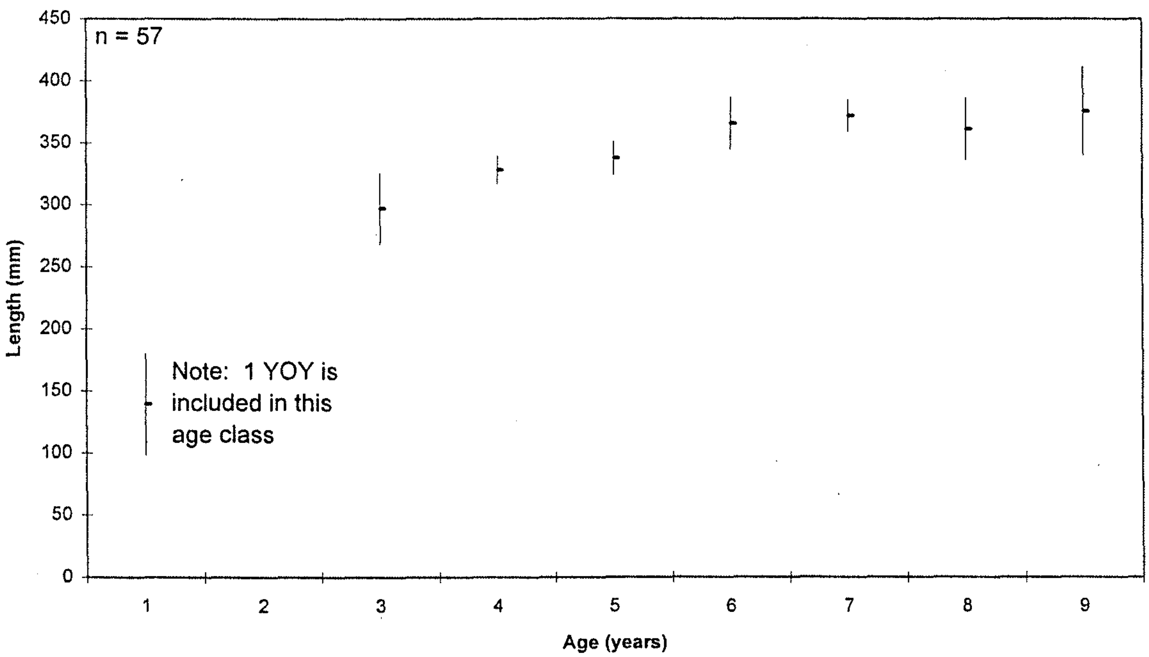


Figure 4.4-15 Length-at-Age with Standard Deviations for Goldeye from the Athabasca River, 1995

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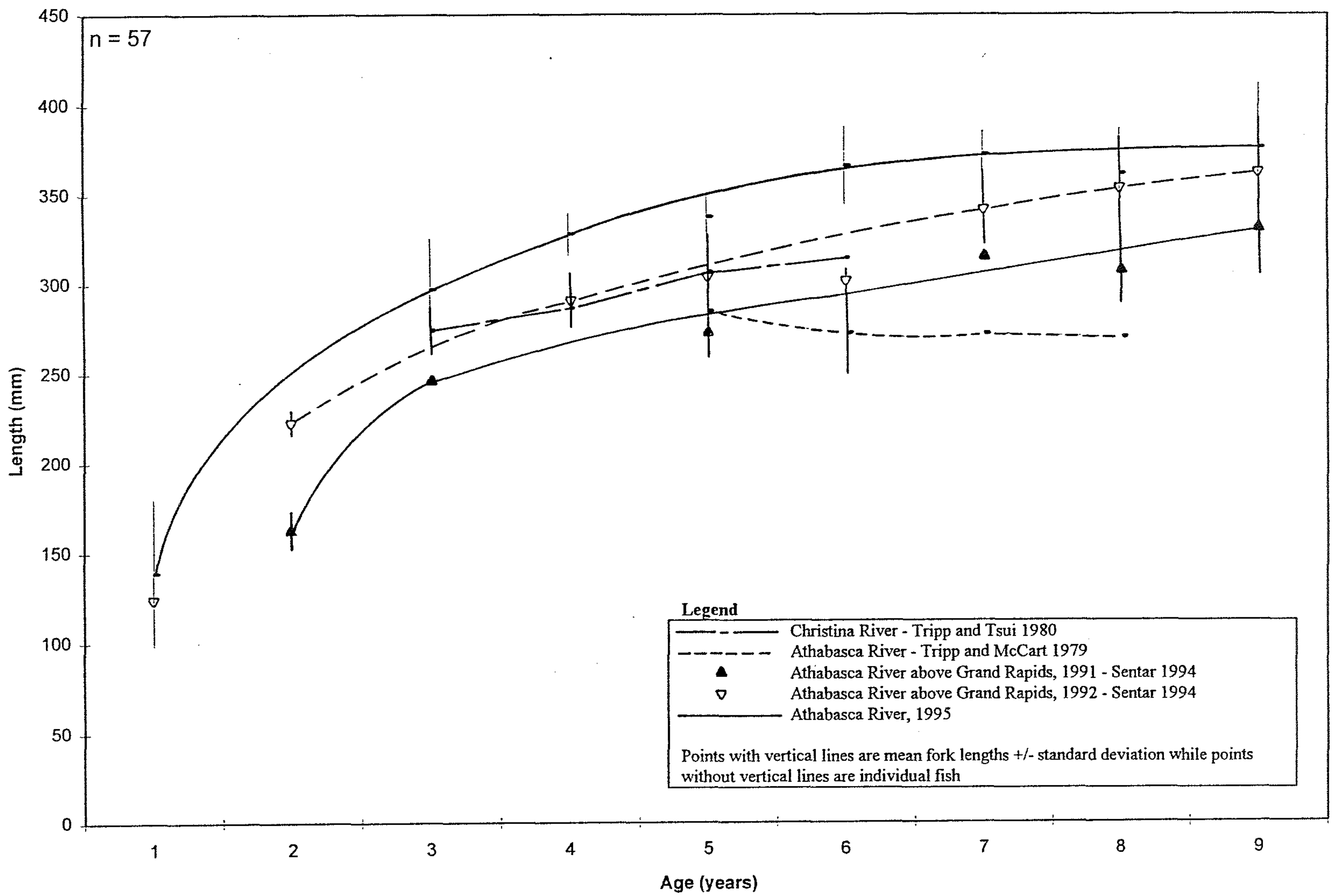

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Comparison of Goldeye Length-at-Age from the Present Study and Previous Studies

Figure 4.4-16

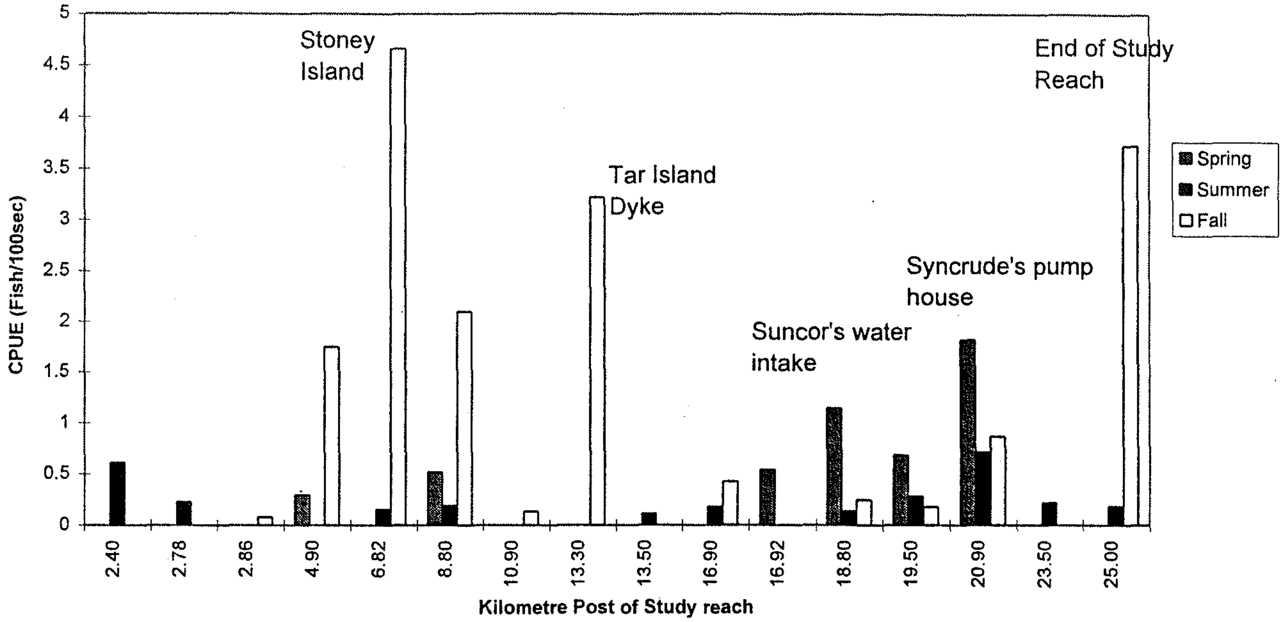


Figure 4.4-17 Catch-Per-Unit-Effort for Longnose Suckers from the Athabasca River in Spring, Summer and Fall, 1995

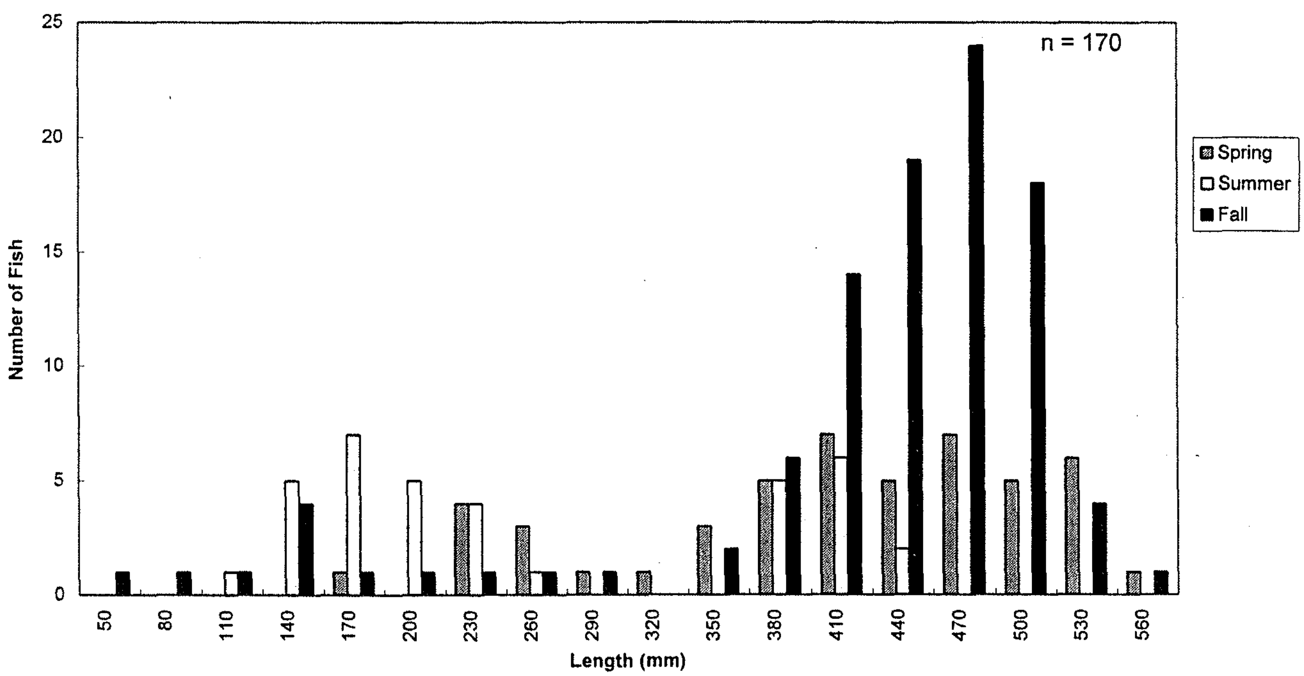


Figure 4.4-18 Length-Frequency Distribution for Longnose Suckers from the Athabasca River in Spring, Summer and Fall, 1995

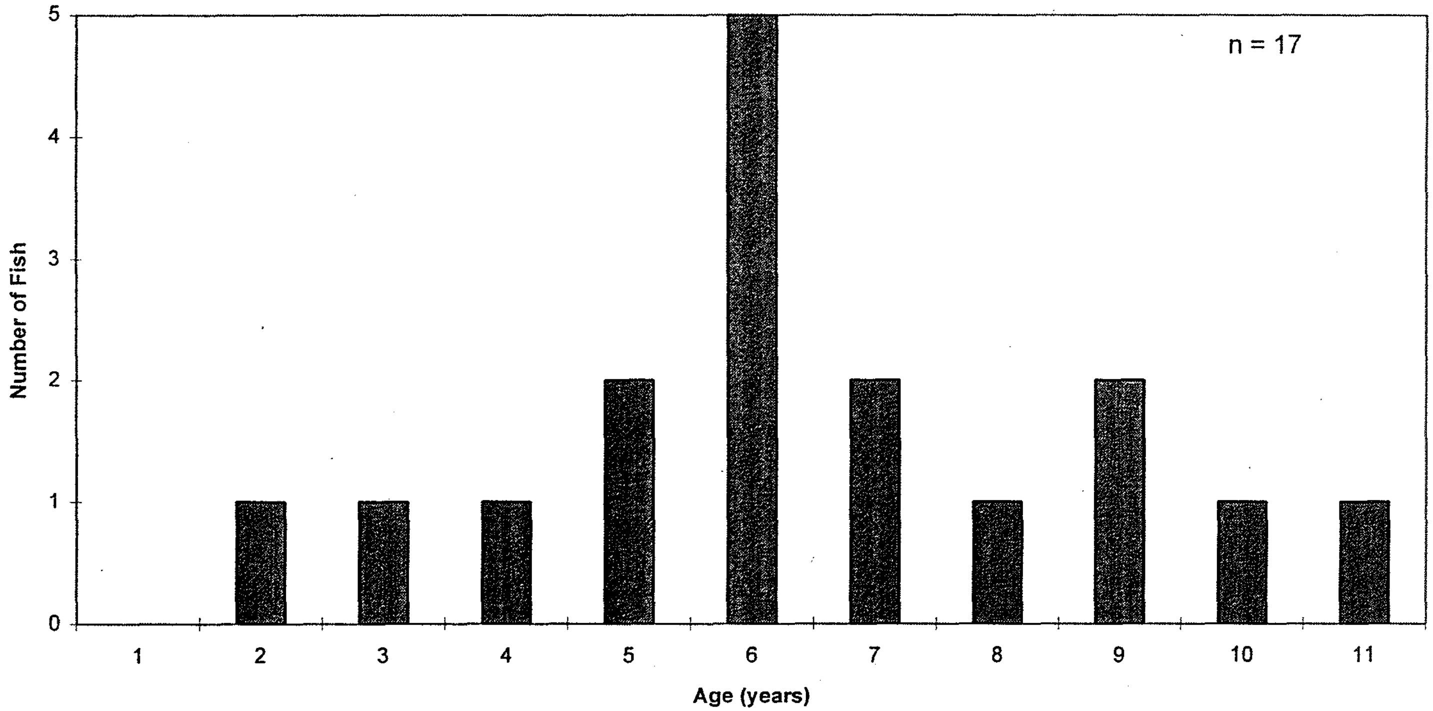
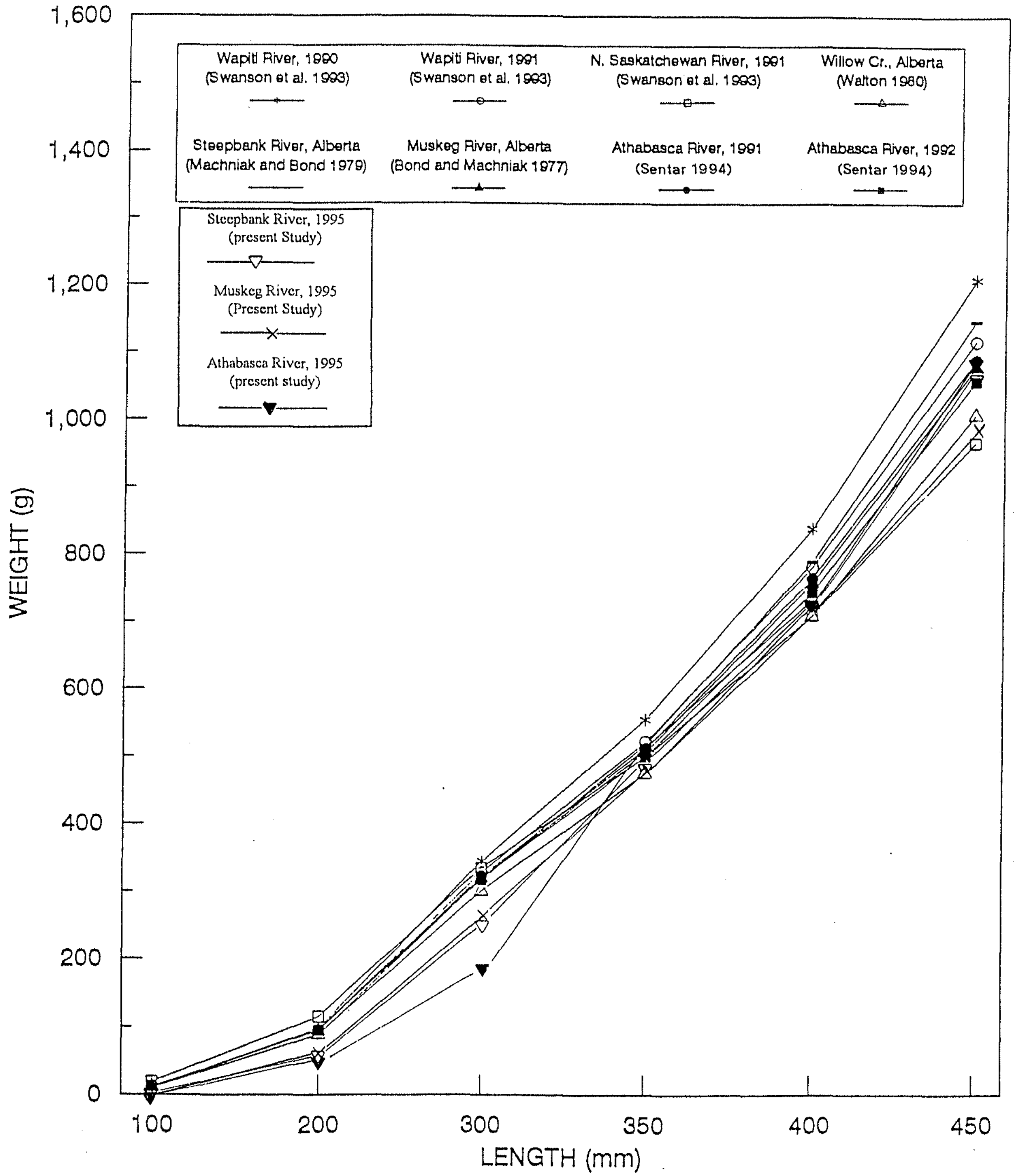


Figure 4.4-19 Age-Frequency Distribution for Longnose Suckers from the Athabasca River, 1995

Comparison of Longnose Sucker Length-Weight Relationships from Present and Previous Studies (Adapted from Sentar 1994)

Figure 4.4-20



PROJECT 952-2308.7150 DRAWN CG REVIEWED ____ DATE 20 DEC 95

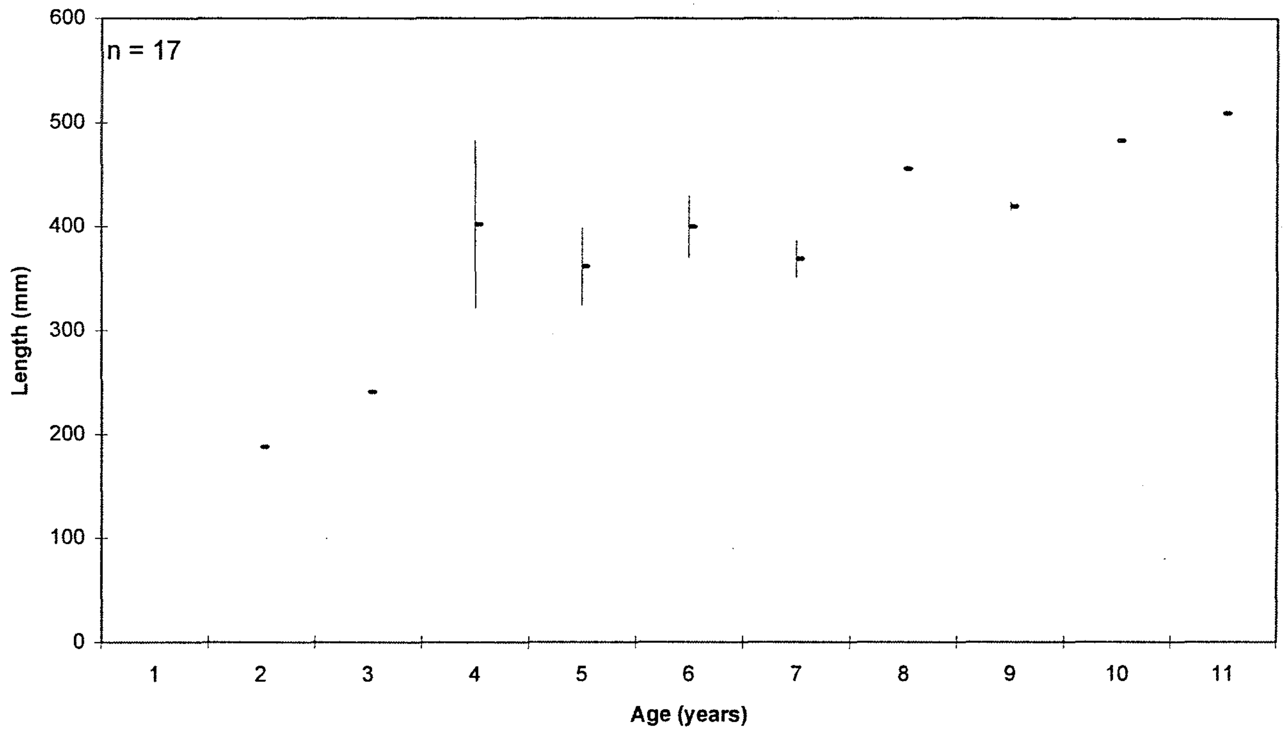


Figure 4.4-21 Length-at-Age with Standard Deviations for Longnose Suckers from the Athabasca RIver, 1995

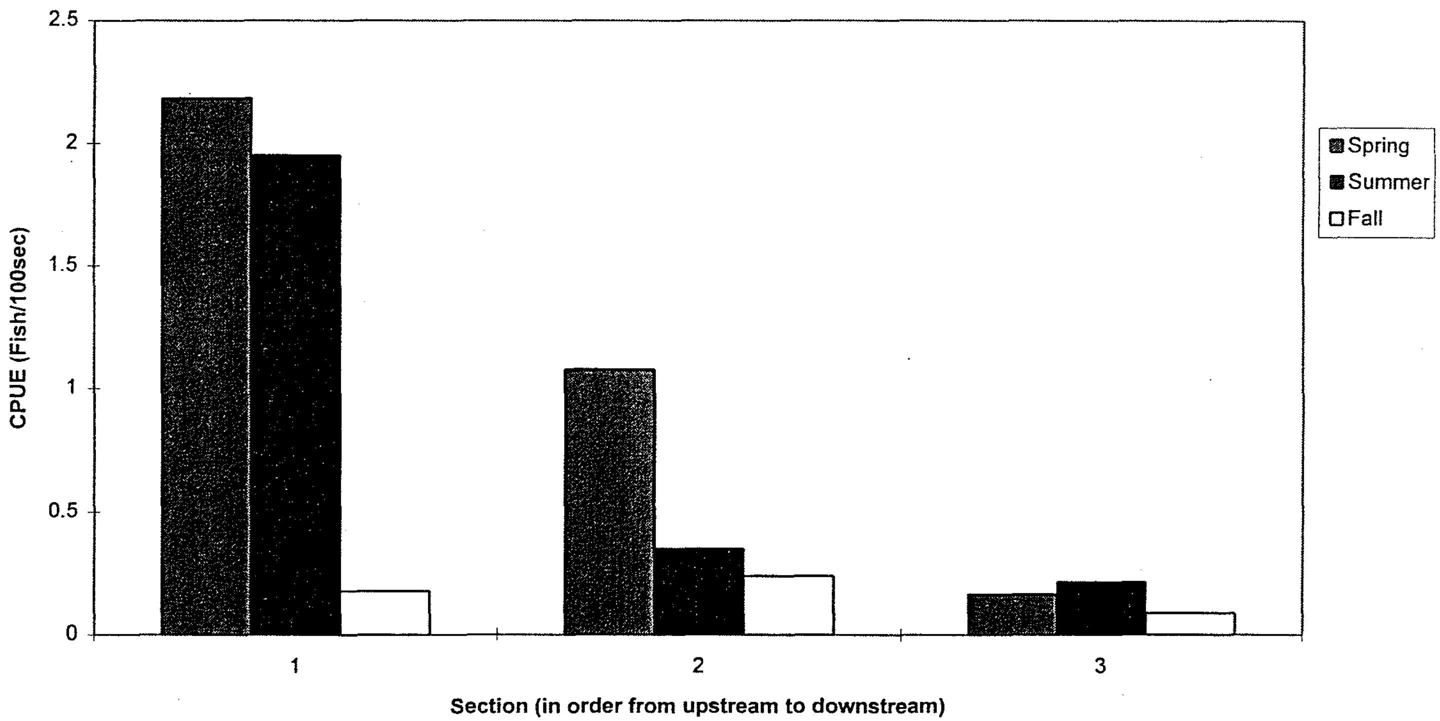


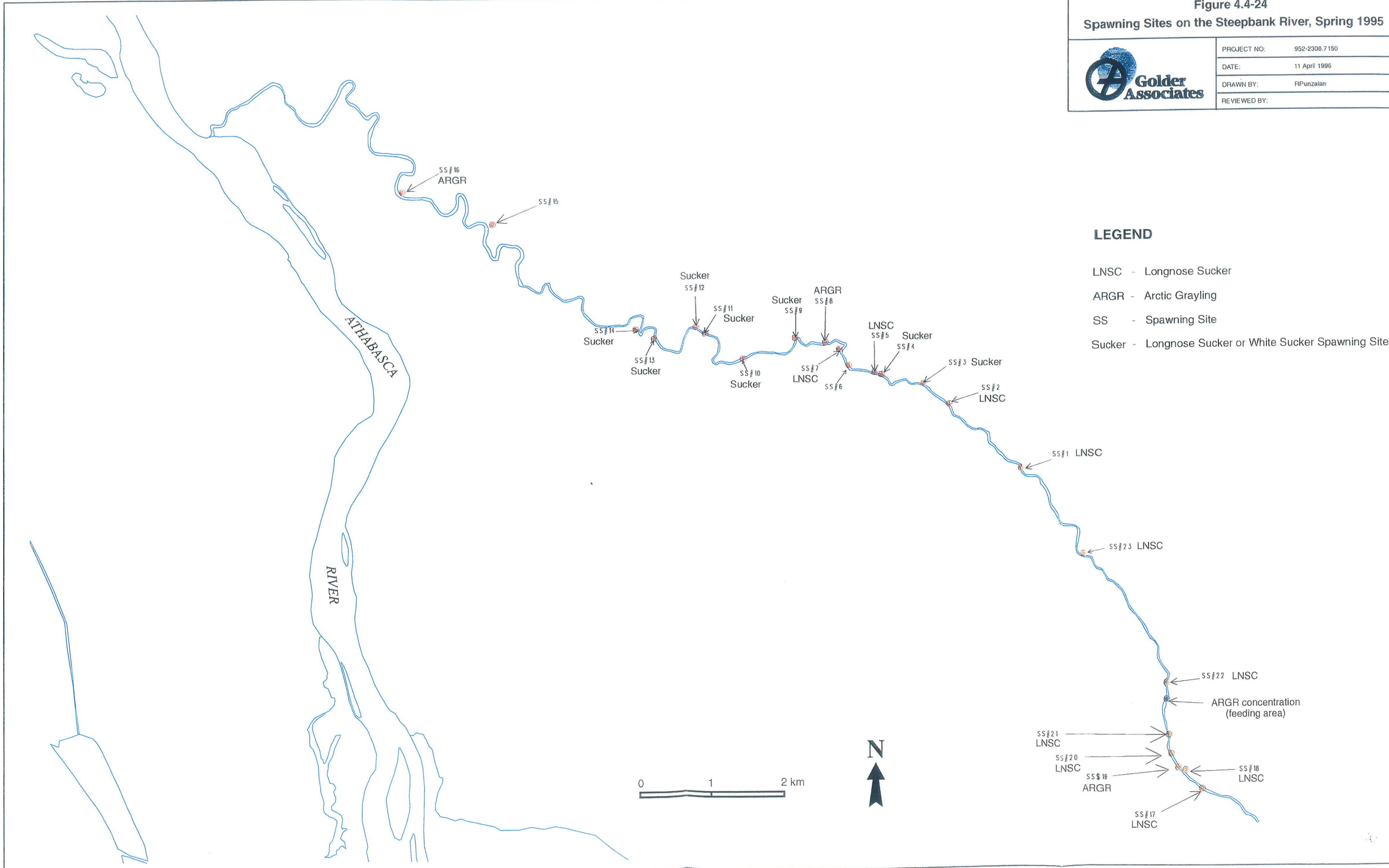
Figure 4.4-23 Catch-Per-Unit-Effort for Longnose Sucker from the Steepbank River in Spring, Summer and Fall, 1995

Figure 4.4-24

Spawning Sites on the Steepbank River, Spring 1995

PROJECT NO:	952-2308.7150
DATE:	11 April 1996
DRAWN BY:	RPunzalan
REVIEWED BY:	

Golder Associates



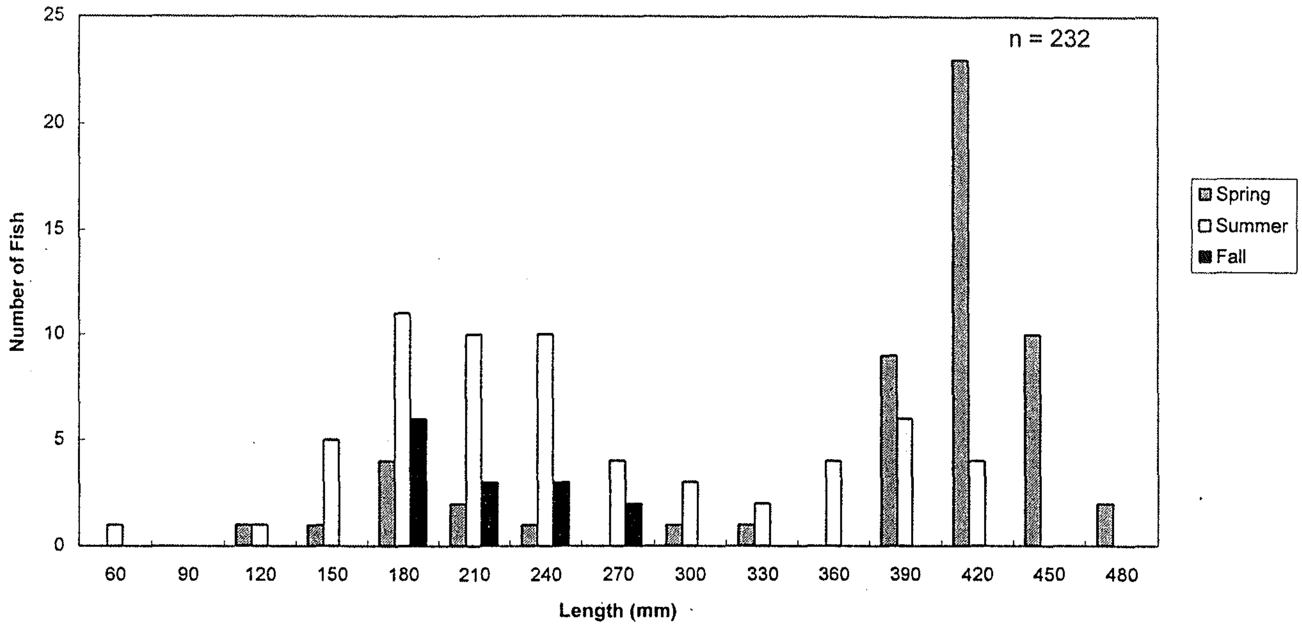


Figure 4.4-25 Length-Frequency Distribution for Longnose Suckers from the Steepbank River in Spring, Summer and Fall, 1995

Figure 4.4-26 Age-Frequency Distribution for Longnose Suckers from the Steepbank River, 1995

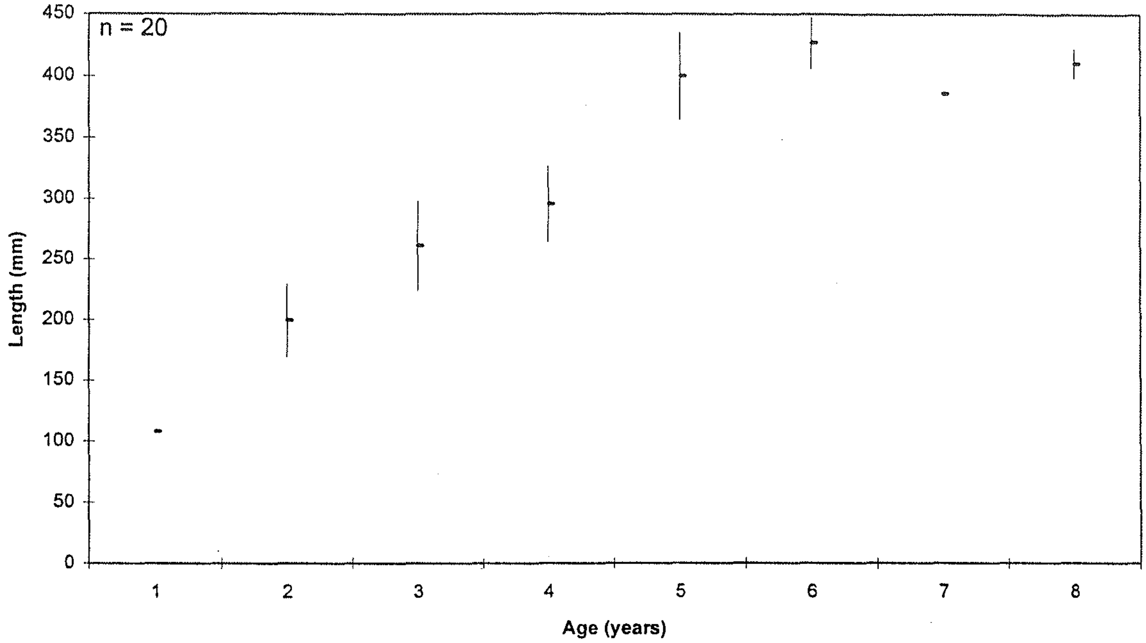


Figure 4.4-27 Length-at-Age with Standard Deviations for Longnose Sucker from the Steepbank River, 1995

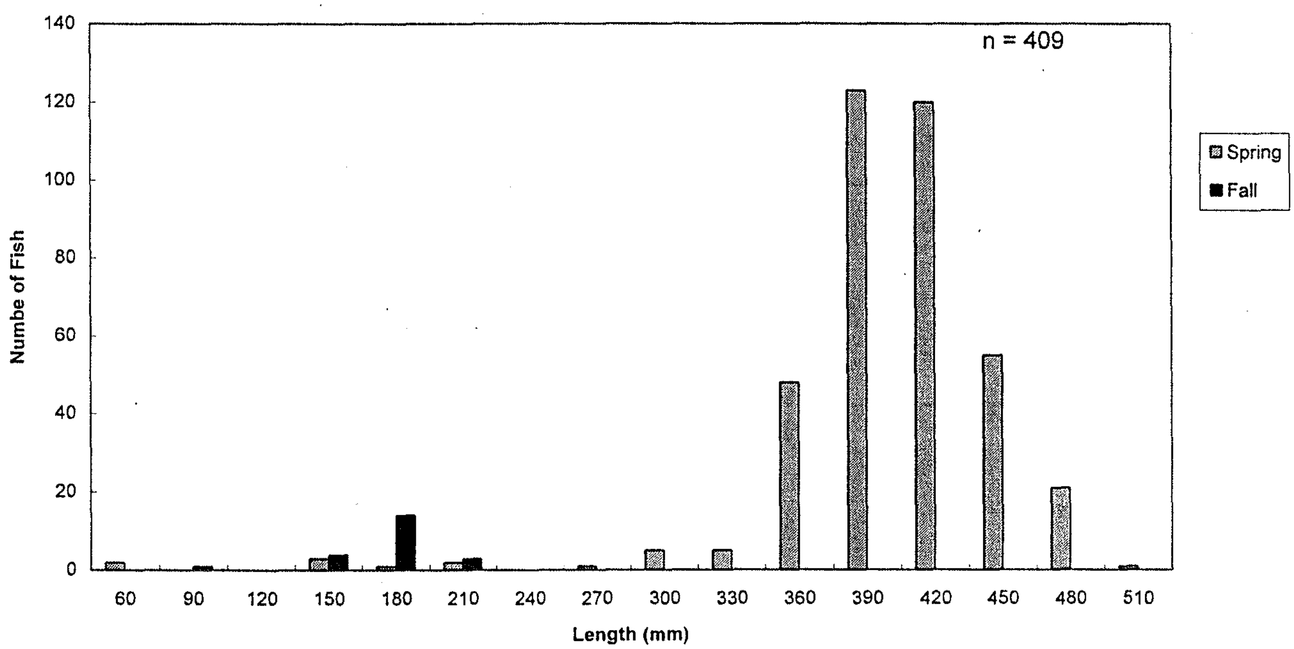


Figure 4.4-28 Length-Frequency Distribution for Longnose Sucker from the Muskeg River in Spring and Fall, 1995

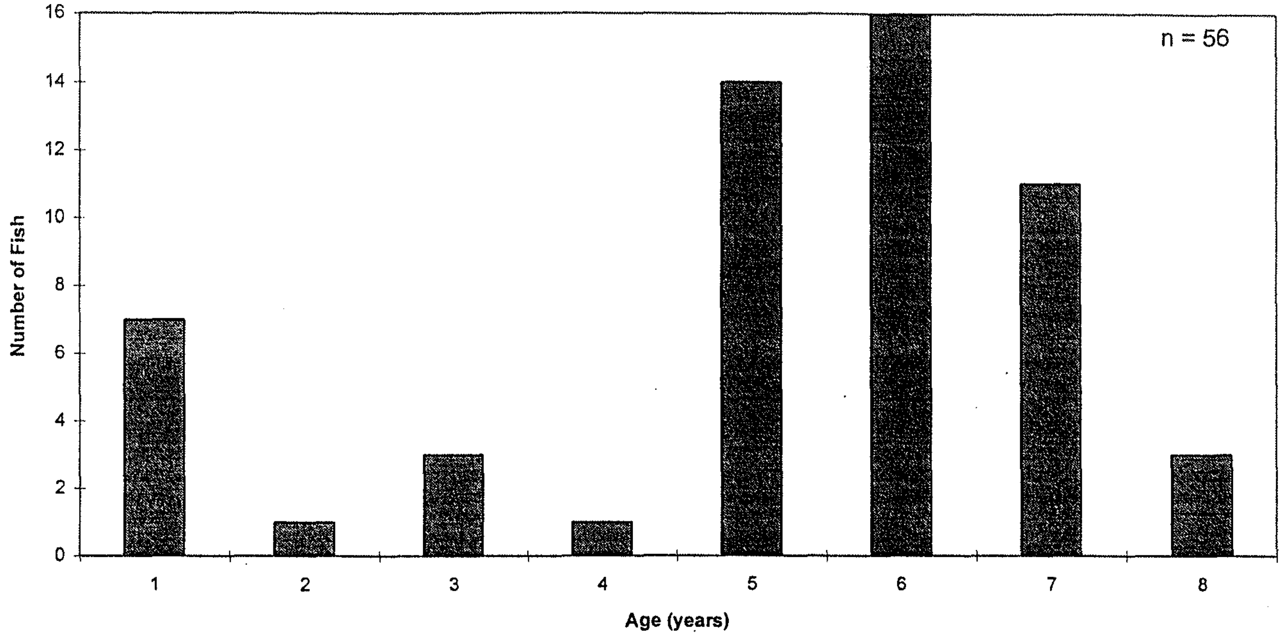


Figure 4.4-29 Age-Frequency Distribution for Longnose Sucker from the Muskeg River, 1995

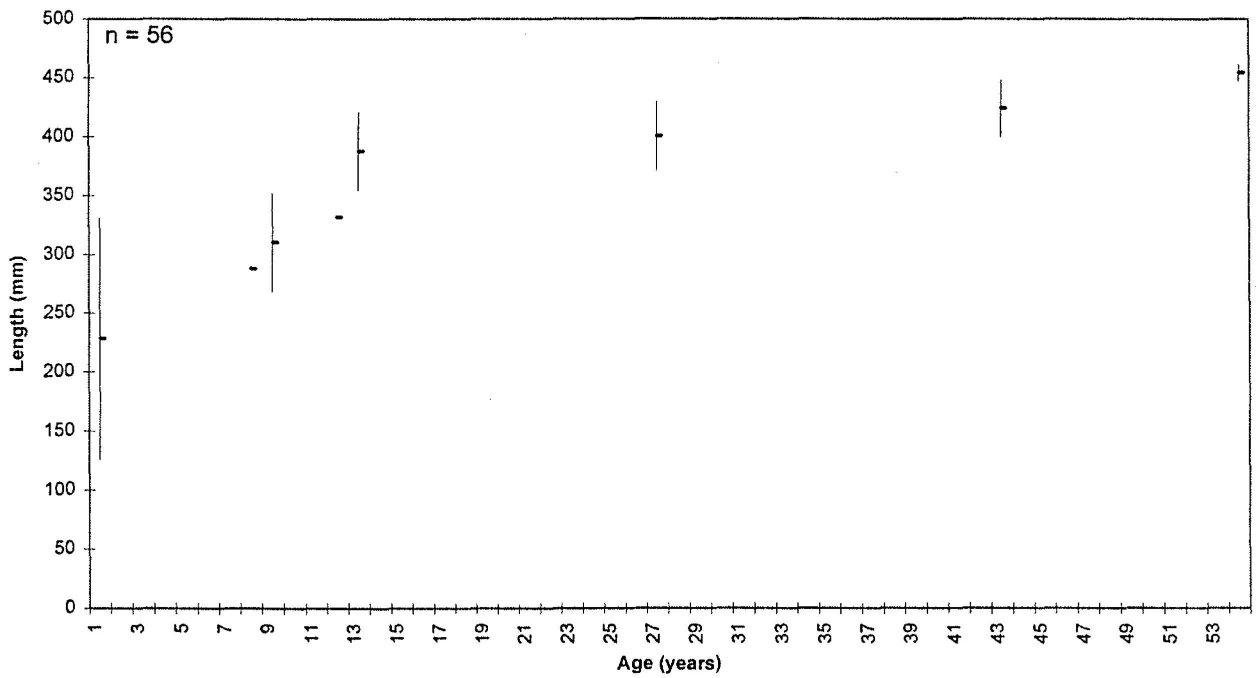


Figure 4.4-30 Length-at-Age with Standard Deviations for Longnose Sucker from the Muskeg RIver, 1995

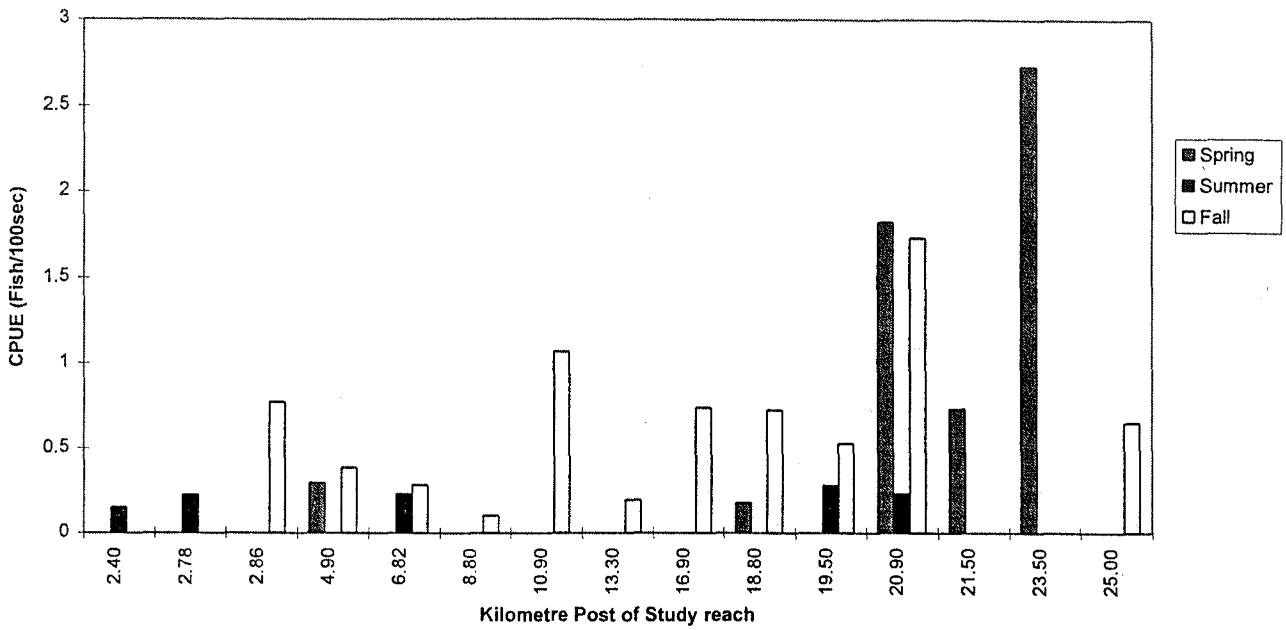


Figure 4.4-31 Catch-Per-Unit-Effort for White Sucker from the Athabasca River in Spring, Summer and Fall, 1995

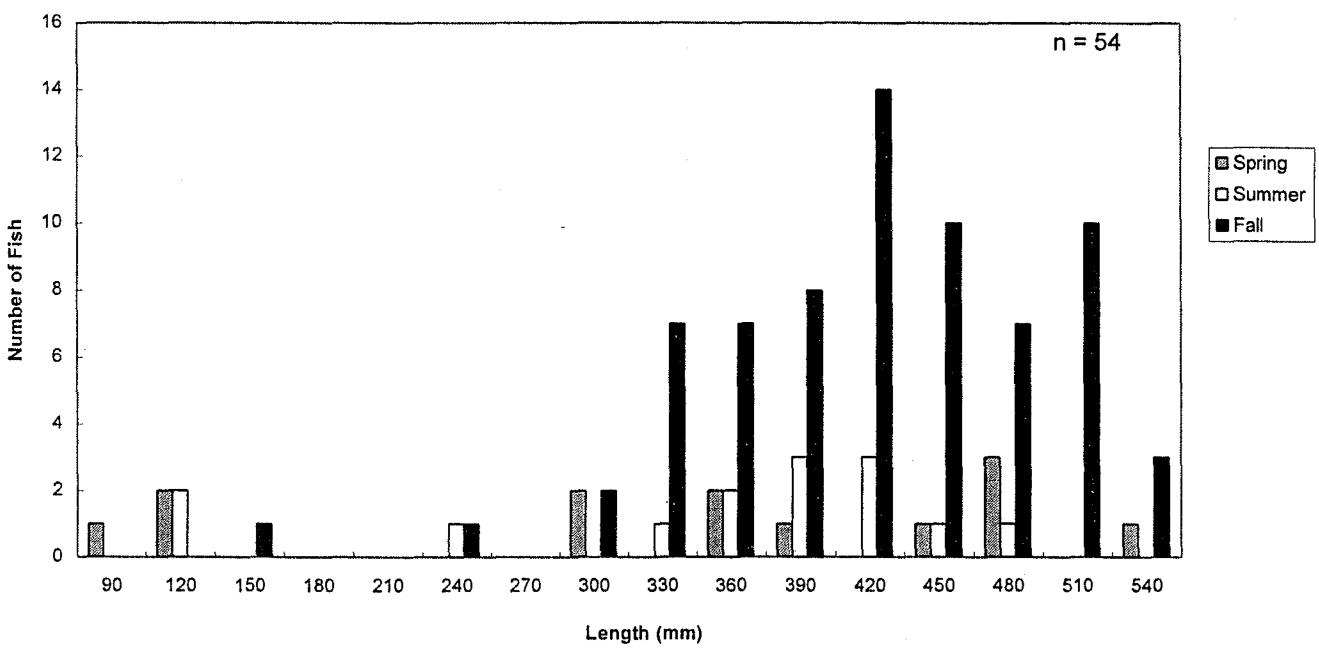


Figure 4.4-32 Length-Frequency Distribution for White Sucker from the Athabasca River in Spring, Summer and Fall, 1995

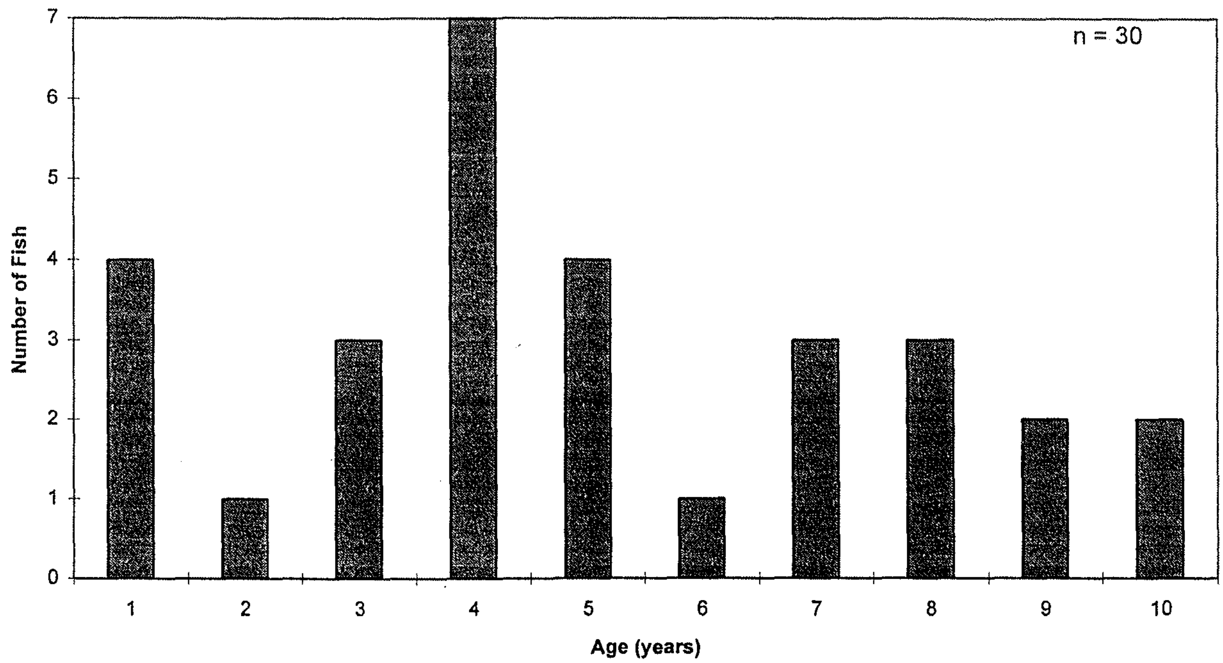


Figure 4.4-33 Age-Frequency Distribution for White Sucker from the Athabasca River, 1995

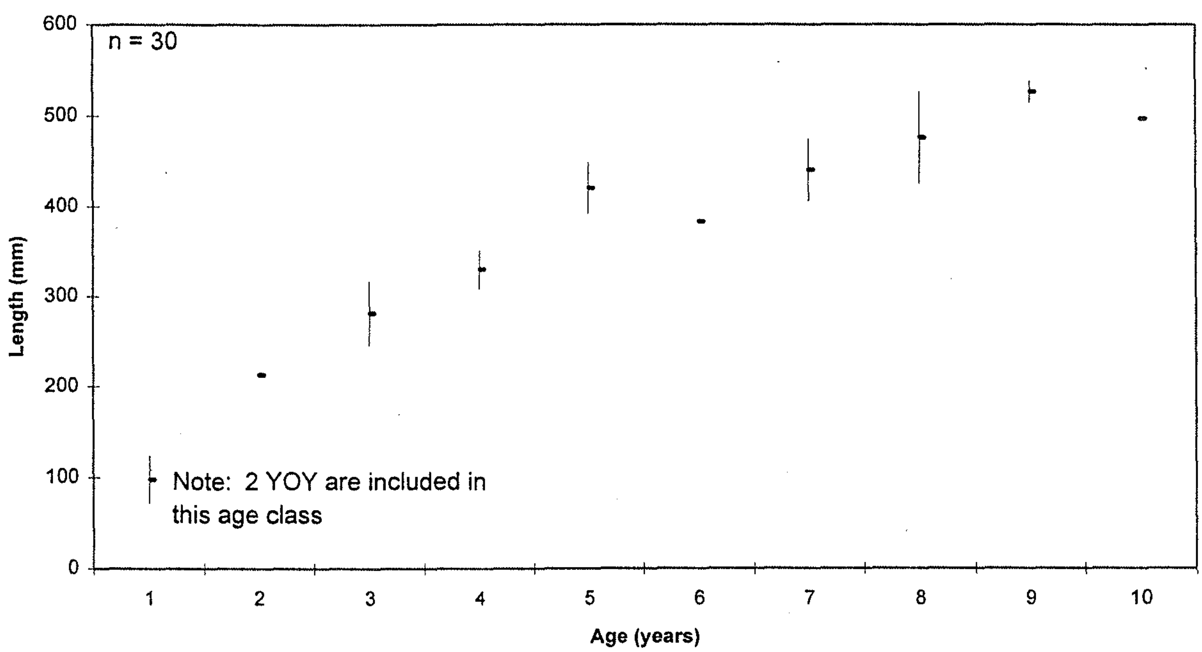


Figure 4.4-34 Length-at-Age with Standard Deviations for White Sucker from the Athabasca River, 1995

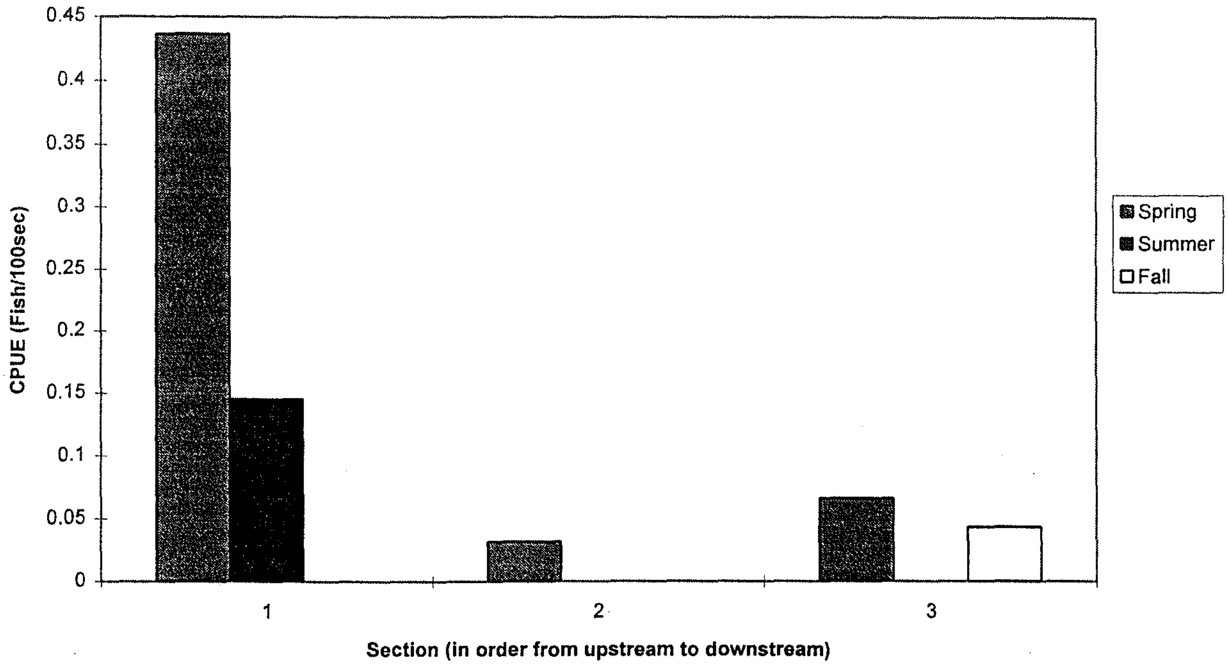


Figure 4.4-35 Catch-Per-Unit-Effort for White Sucker from the Steepbank River in Spring, Summer and Fall, 1995

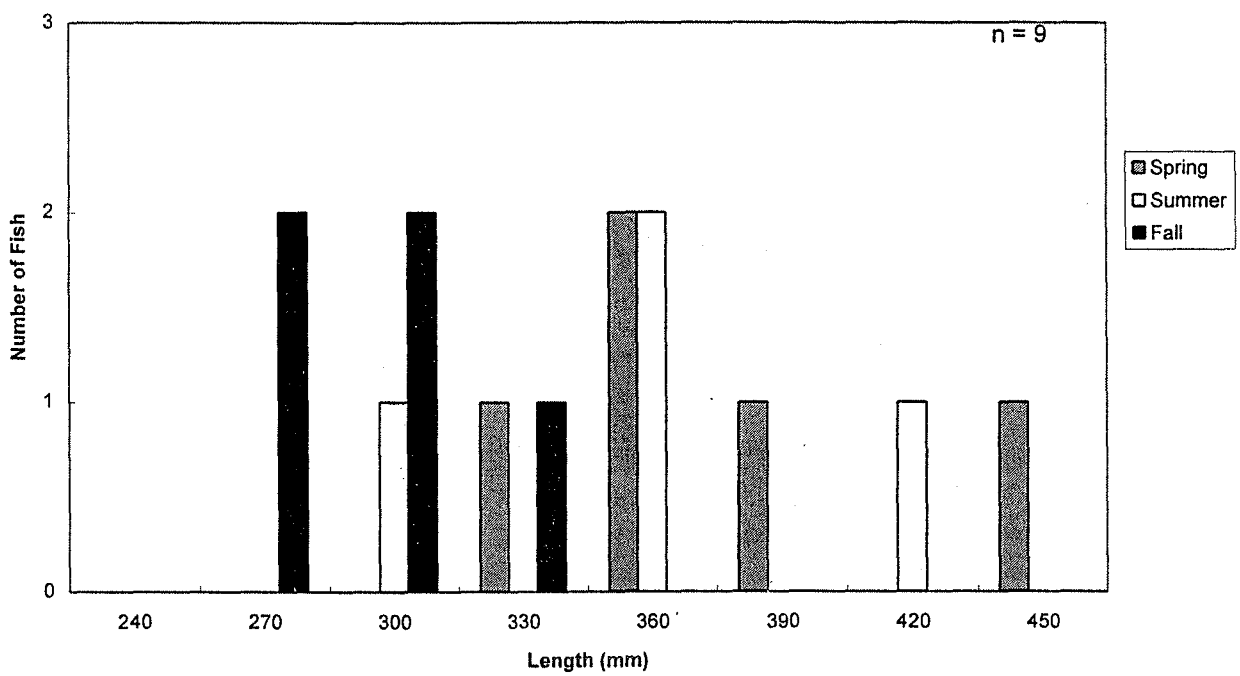


Figure 4.4-36 Length-Frequency Distribution for White Sucker from the Steepbank River in Spring, Summer and Fall, 1995

Figure 4.4-37 Age-Frequency Distribution for White Sucker from the Steepbank River, 1995

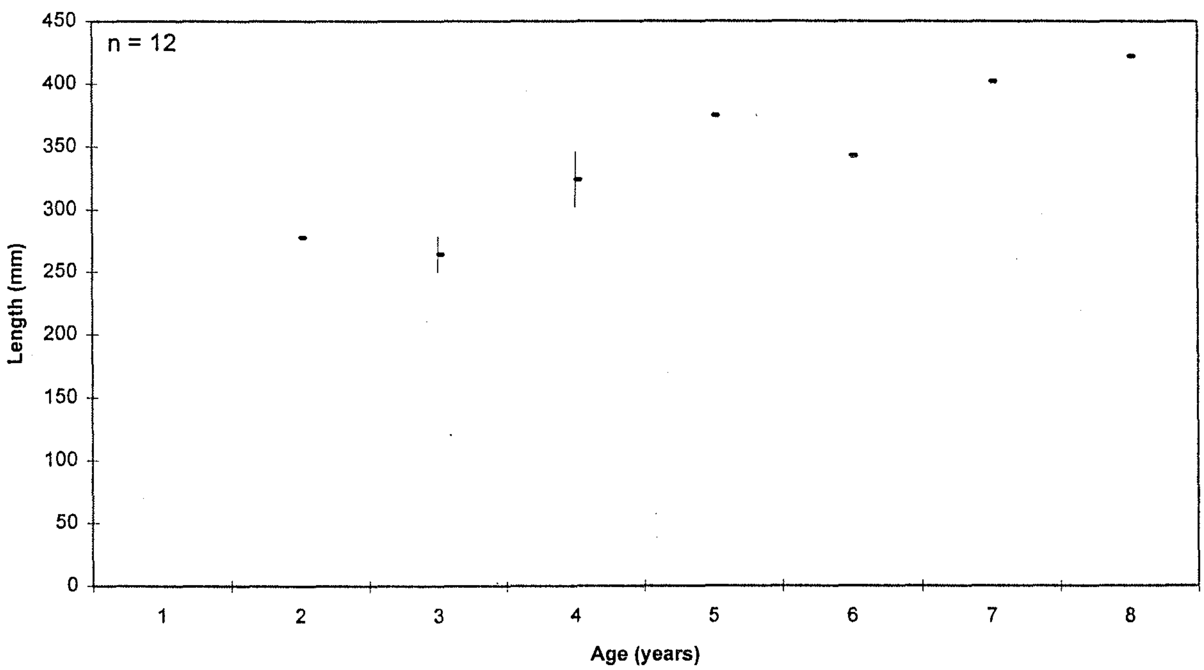


Figure 4.4-38 Length-at-Age with Standard Deviations for White Sucker from the Steepbank River, 1995

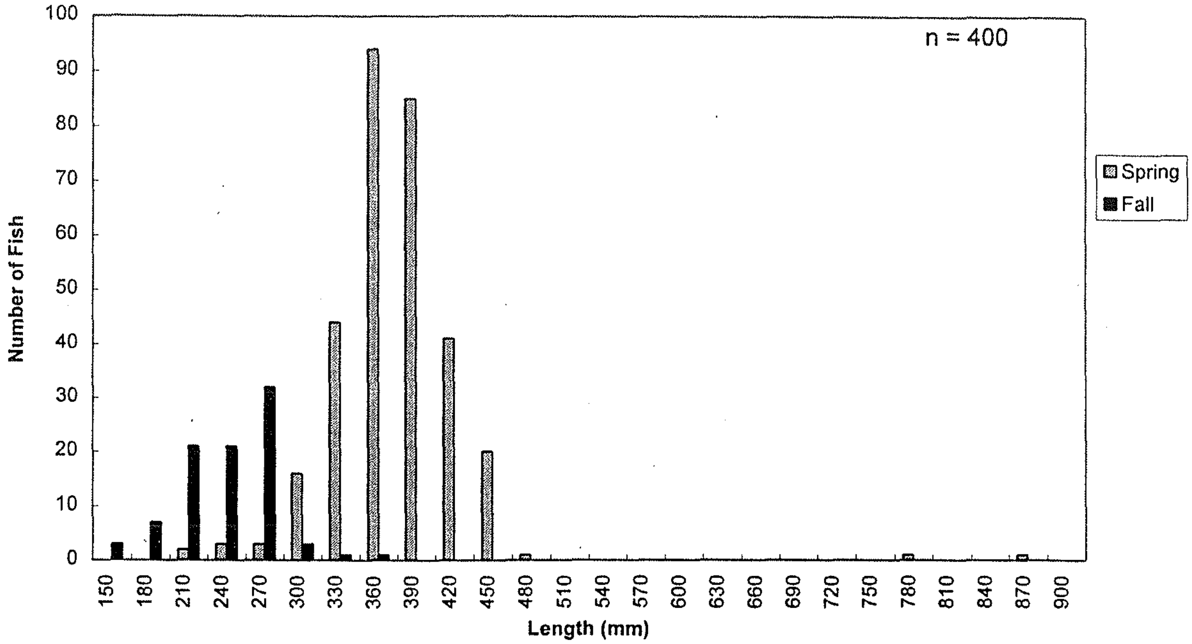


Figure 4.4-39 Length-Frequency Distribution for White Sucker from the Muskeg River in Spring and Fall, 1995

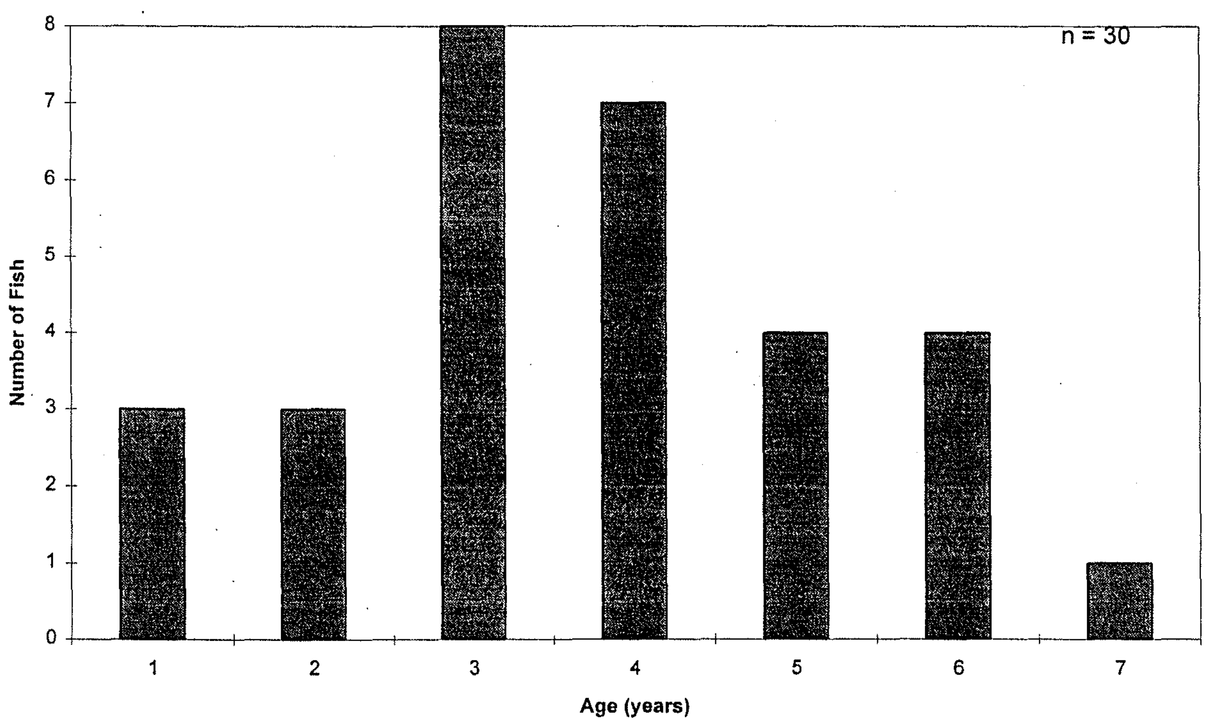


Figure 4.4-40 Age-Frequency Distribution for White Sucker from the Muskeg River, 1995

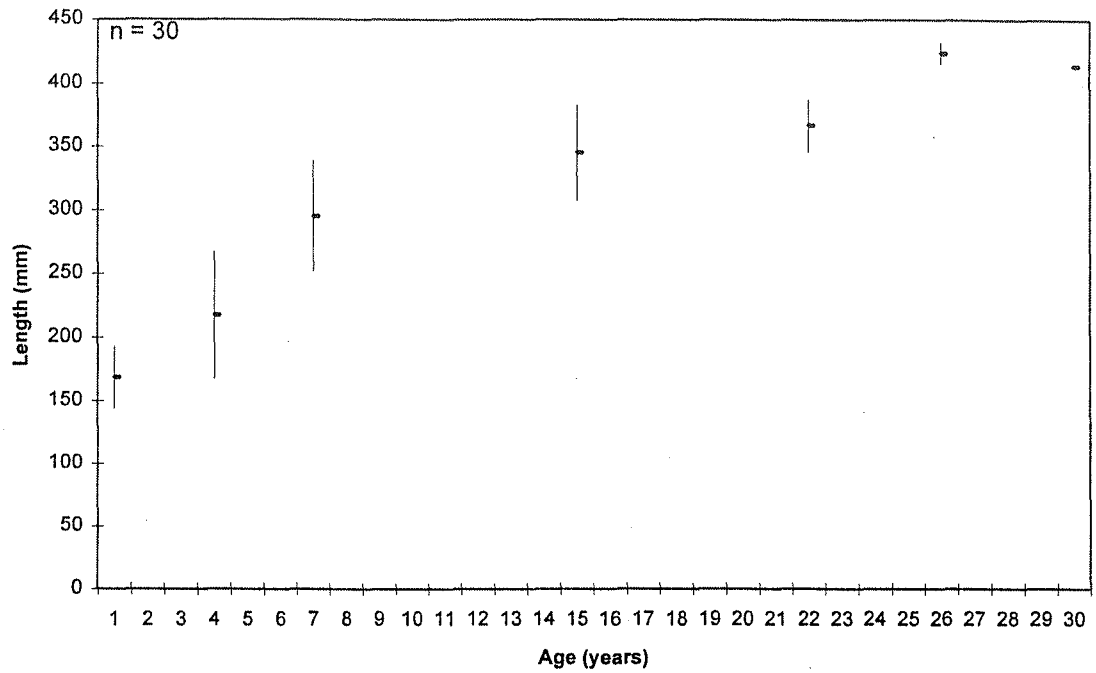


Figure 4.4-41 Length-at-Age with Standard Deviations for White Sucker from the Muskeg River, 1995

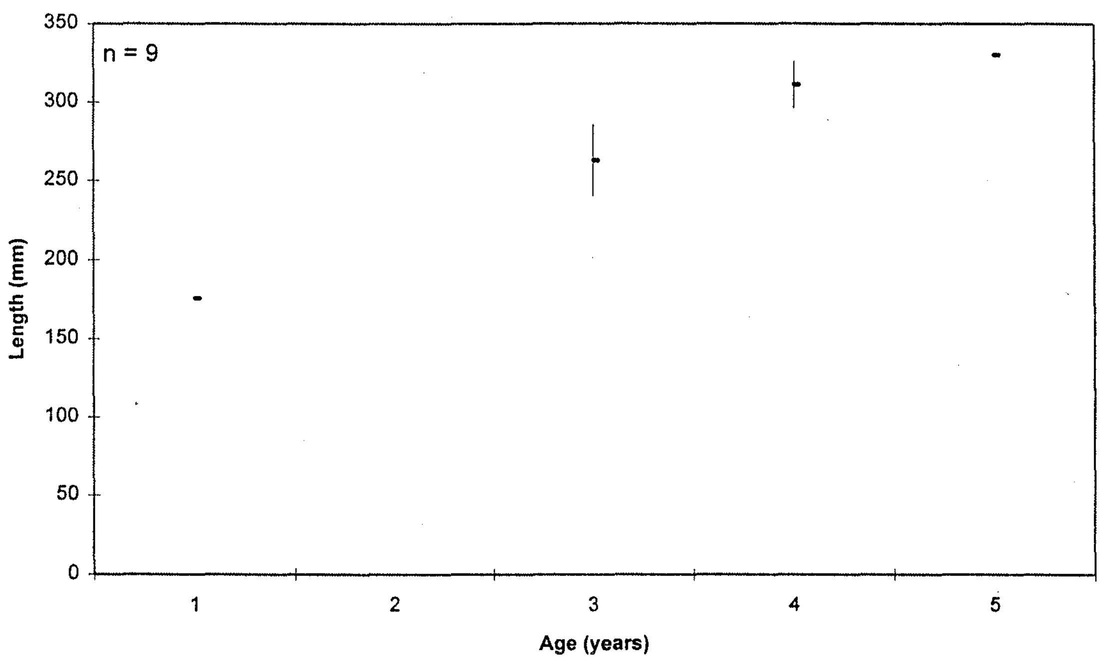


Figure 4.4-42 Length-at-Age with Standard Deviations for White Sucker from Kearl Lake, 1995

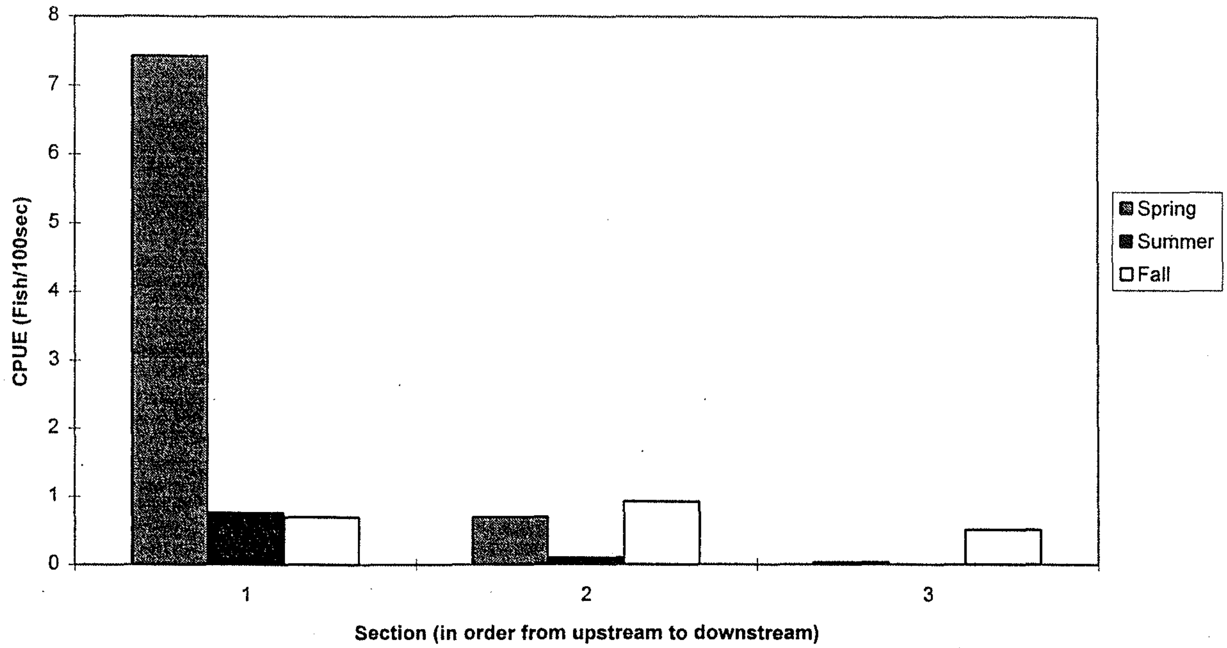


Figure 4.4-43 Catch-Per-Unit-Effort for Arctic Grayling from the Steepbank River in Spring, Summer and Fall, 1995

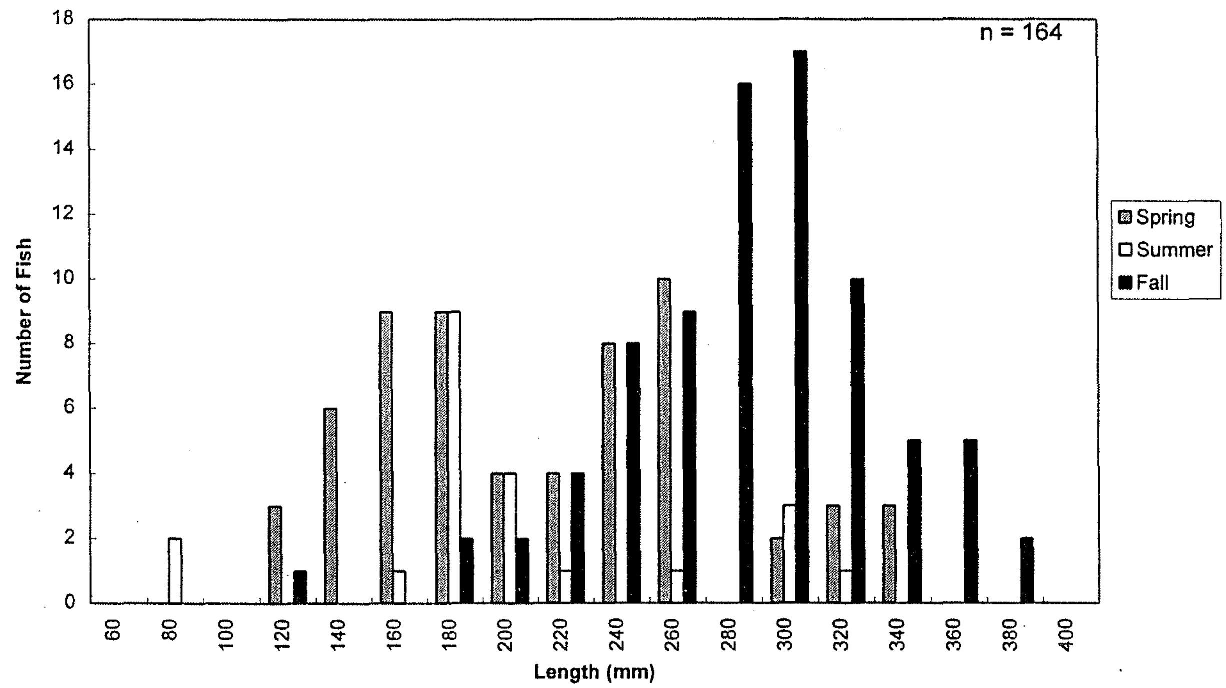


Figure 4.4-44 Length-Frequency Distribution for Arctic Grayling from the Steepbank River in Spring, Summer and Fall, 1995

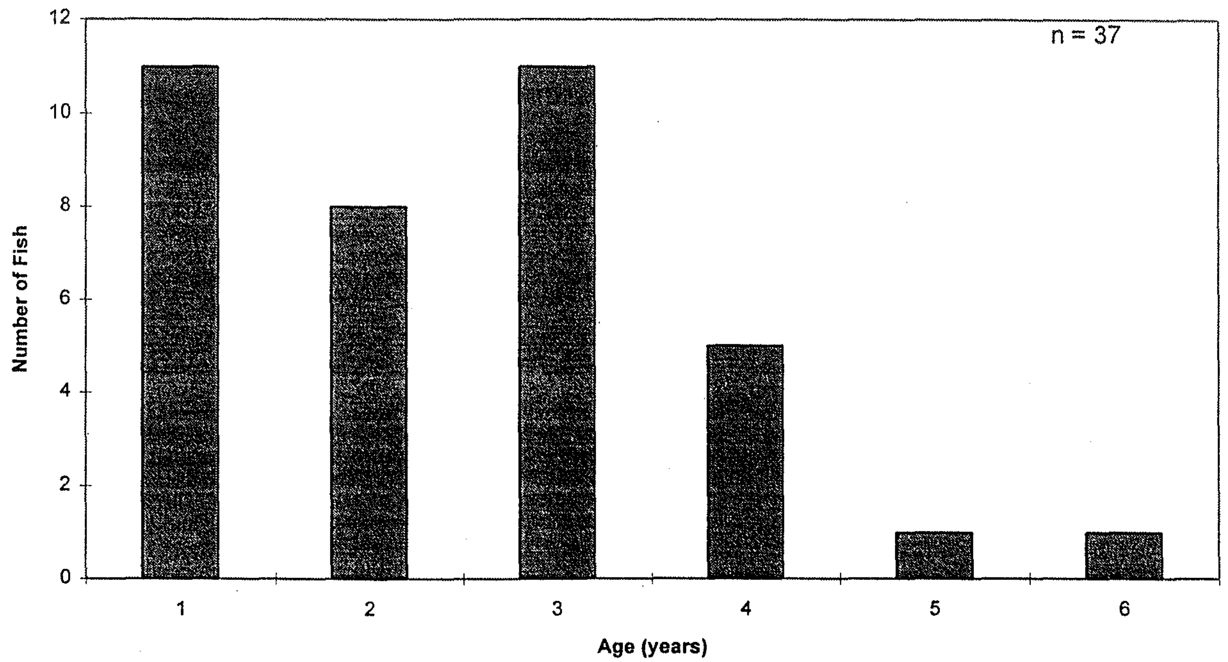


Figure 4.4-45 Age-Frequency Distribution for Arctic Grayling from the Steepbank River, 1995

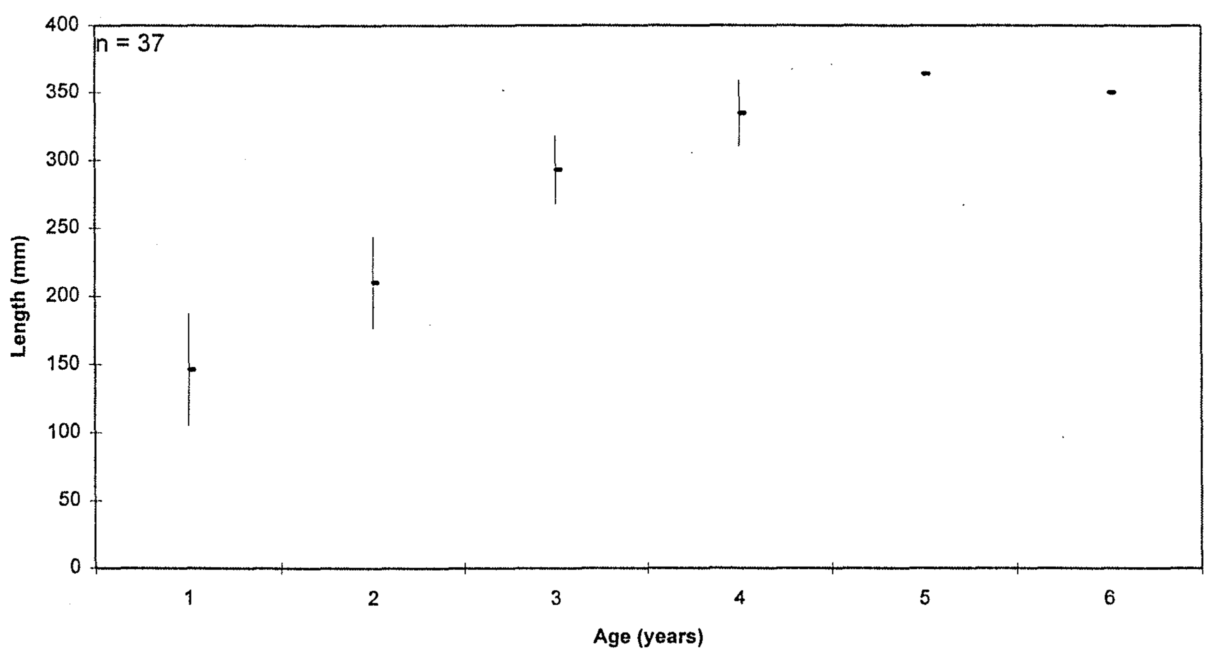


Figure 4.4-46 Length-at-Age with Standard Deviations for Arctic Grayling from the Steepbank River, 1995

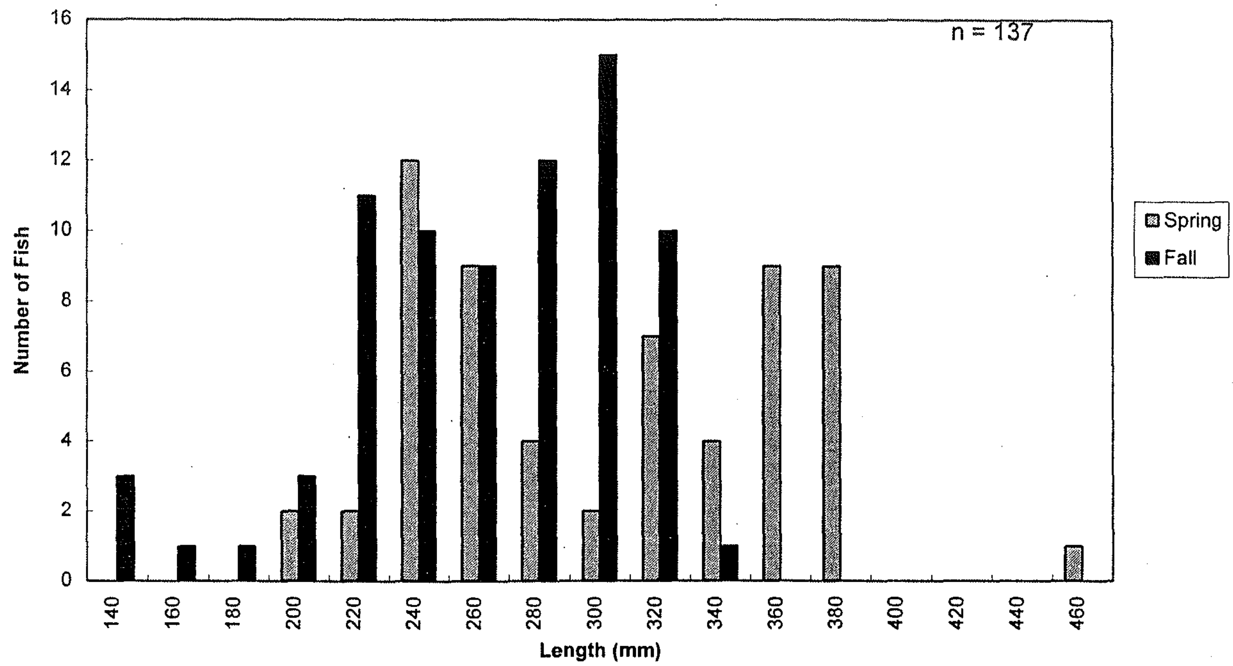


Figure 4.4-47 Length-Frequency Distribution for Arctic Grayling from the Muskeg River in Spring and Fall, 1995

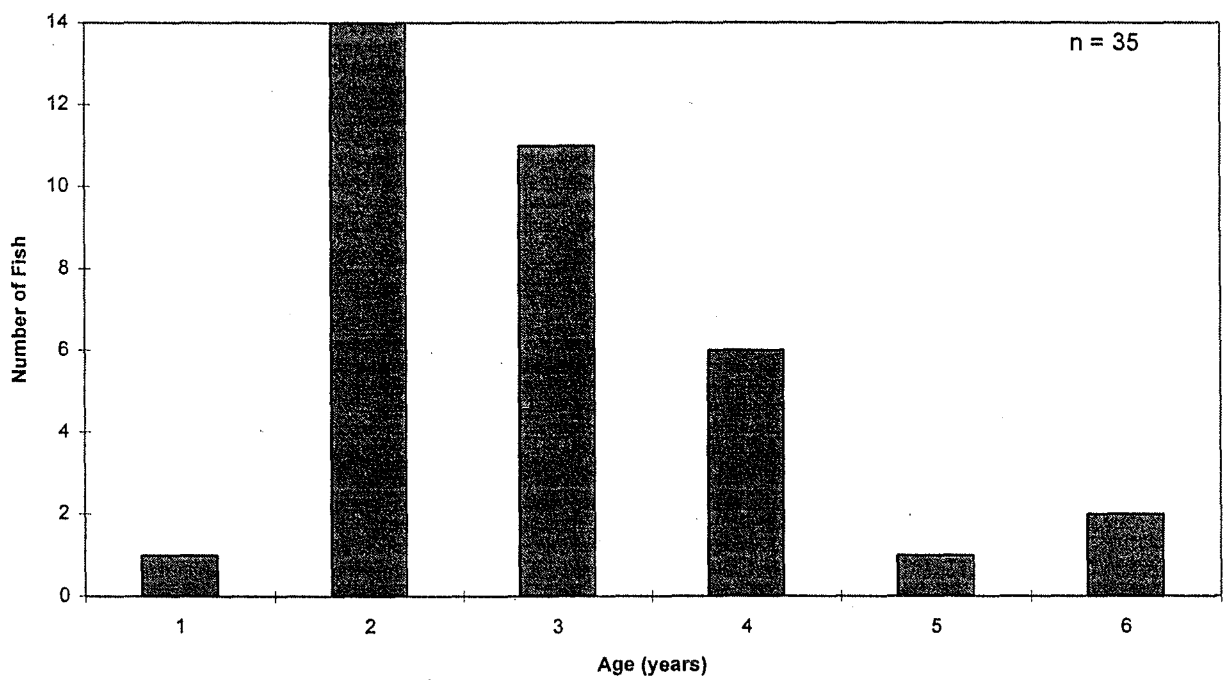


Figure 4.4-48 Age-Frequency Distribution for Arctic Grayling from the Muskeg River, 1995

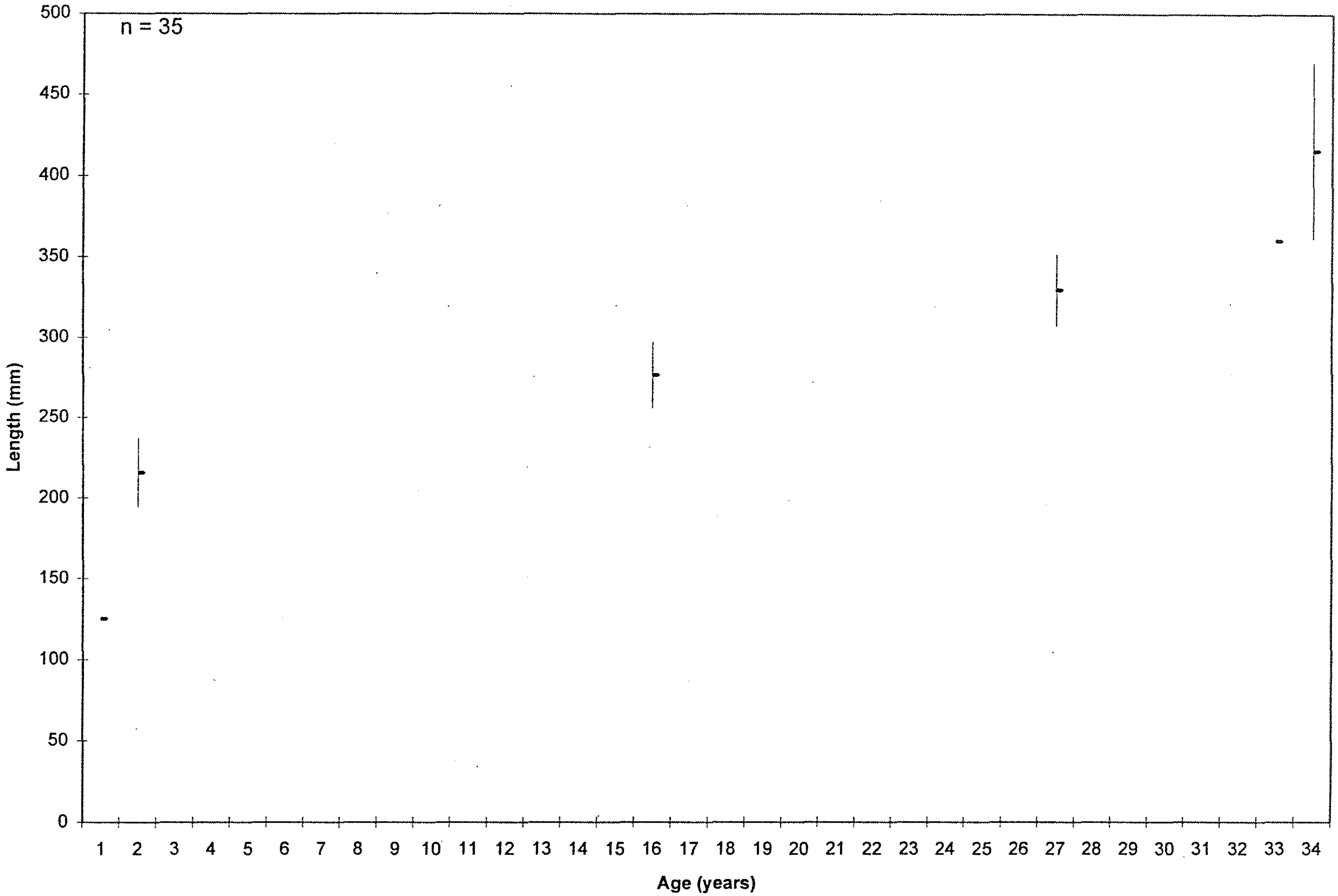


Figure 4.4-49 Length-at-Age with Standard Deviations for Arctic Grayling from the Muskeg River, 1995

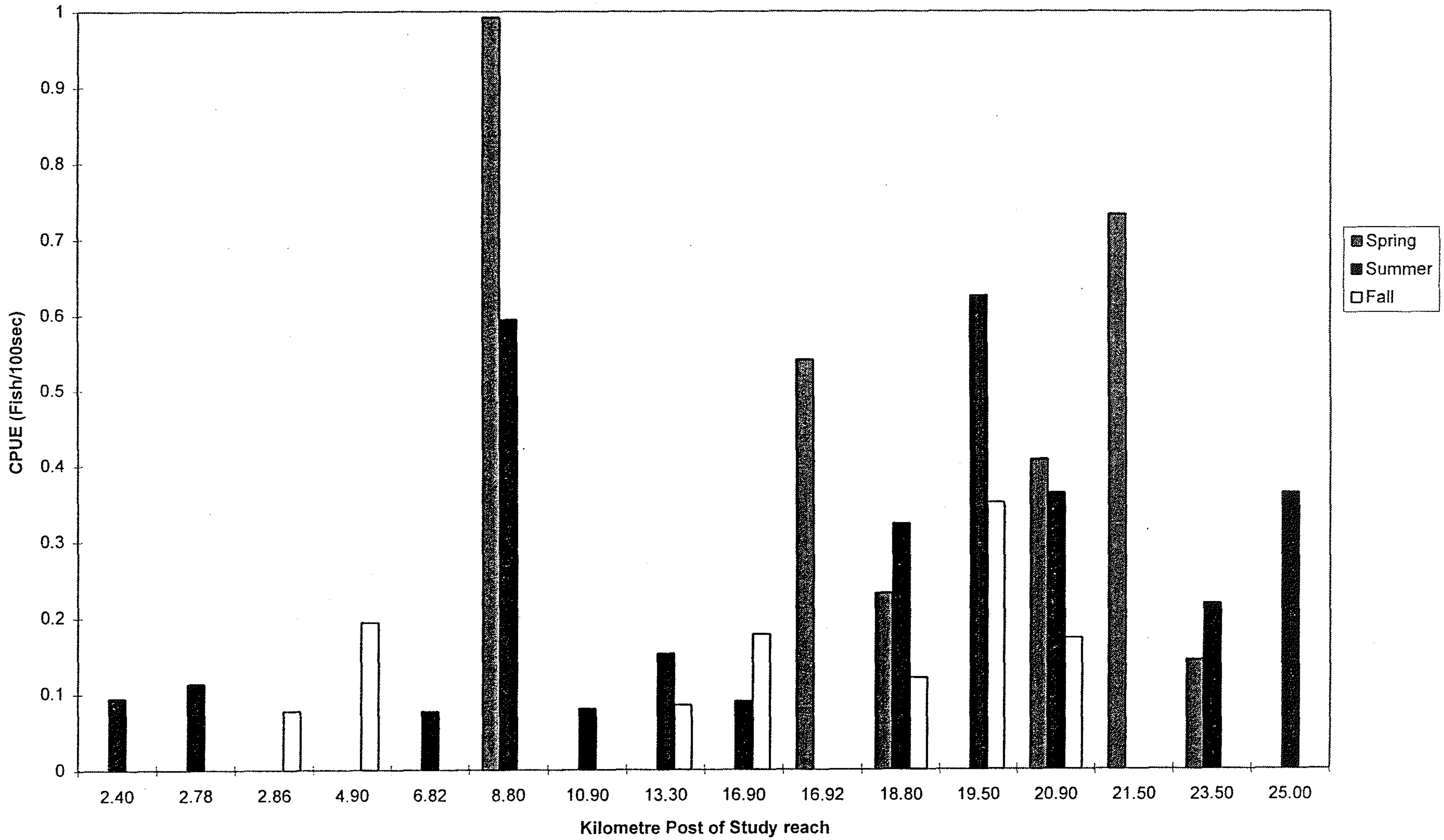


Figure 4.4-50 Catch-Per-Unit-Effort for Northern Pike from the Athabasca River in Spring, Summer and Fall, 1995

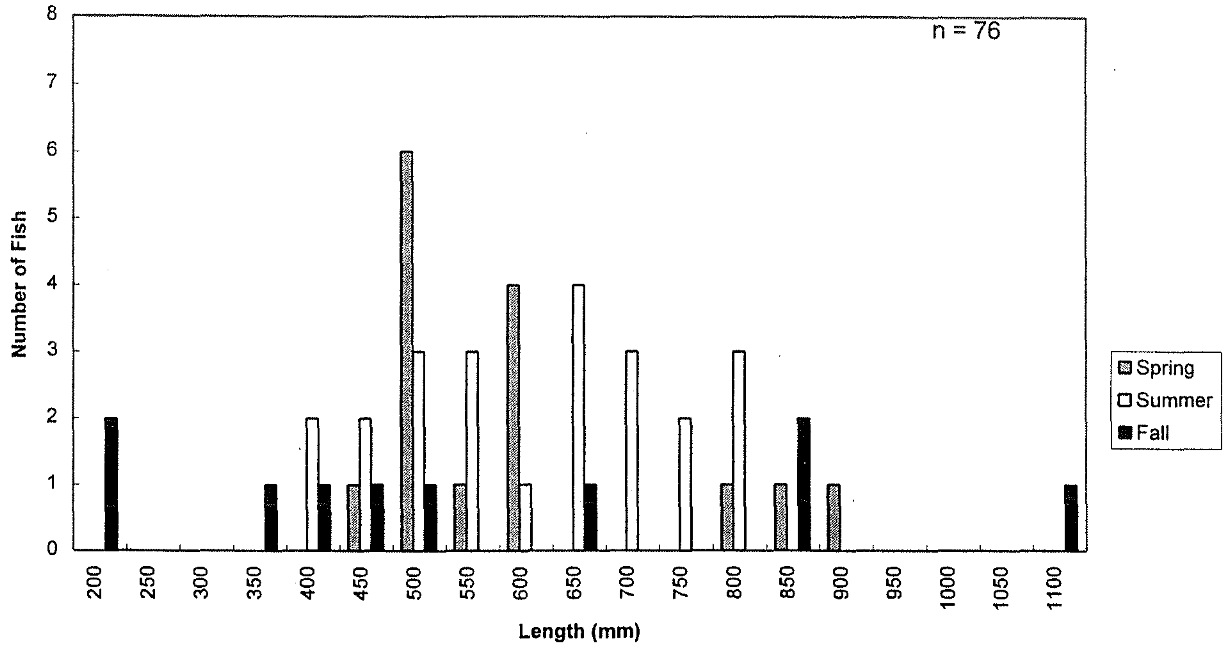


Figure 4.4-51 Length-Frequency Distribution for Northern Pike from the Athabasca River in Spring, Summer and Fall, 1995

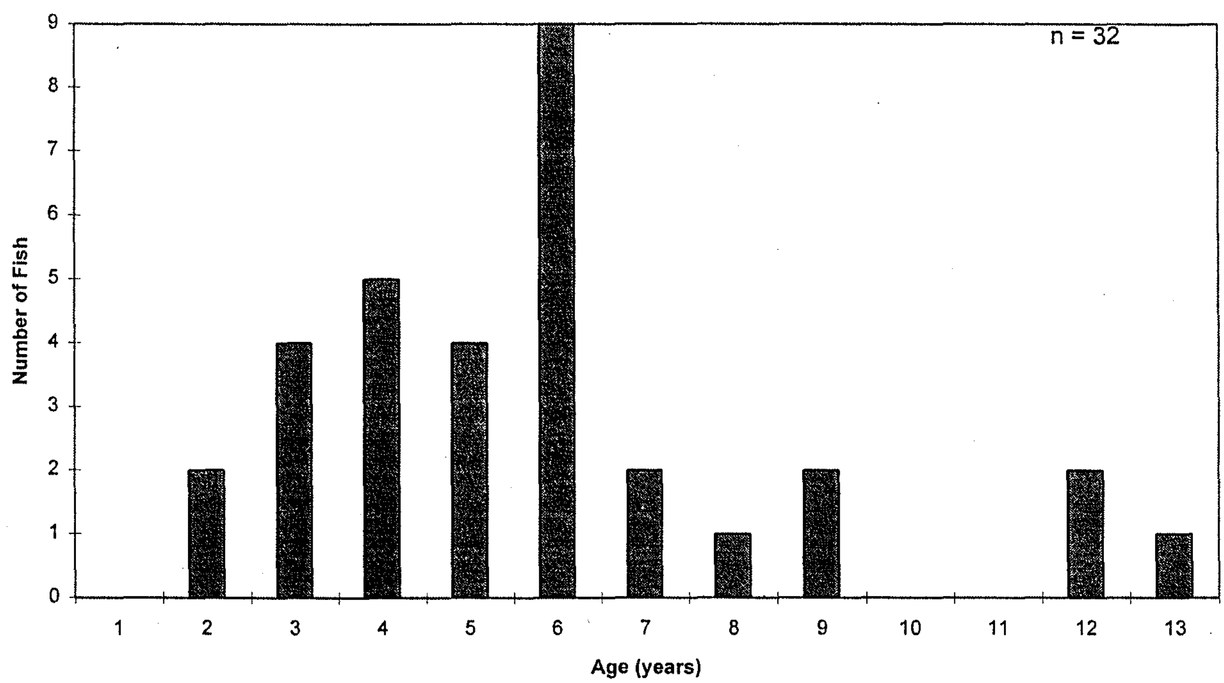


Figure 4.4-52 Age-Frequency Distribution for Northern Pike from the Athabasca River, 1995

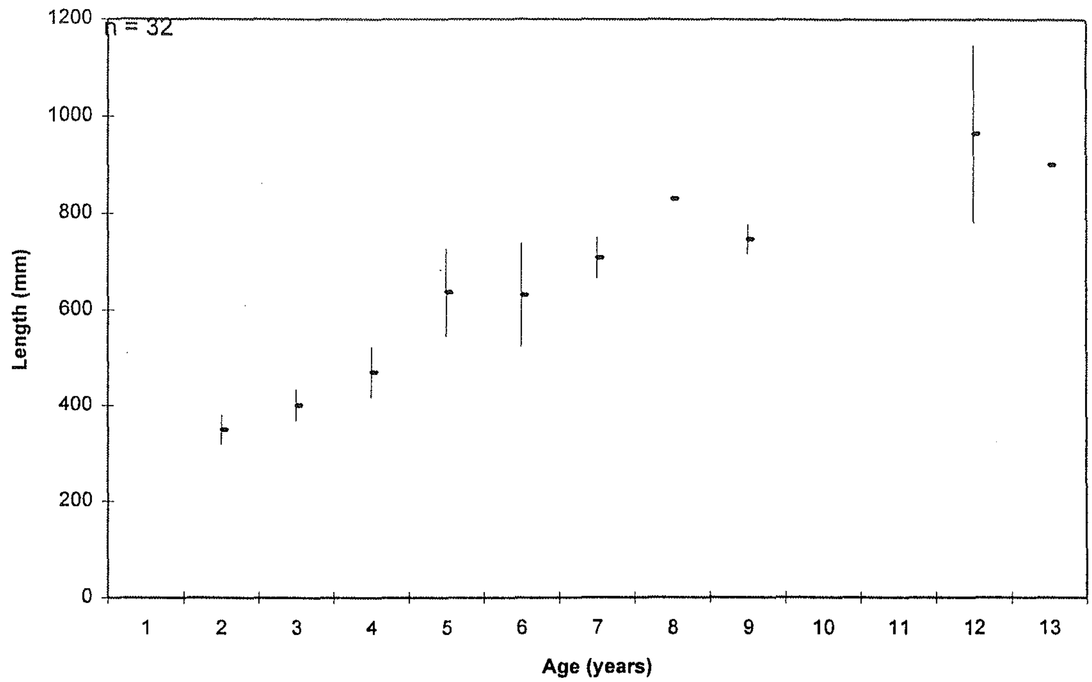


Figure 4.4-53 Length-at-Age with Standard Deviations for Northern Pike from the Athabasca River, 1995

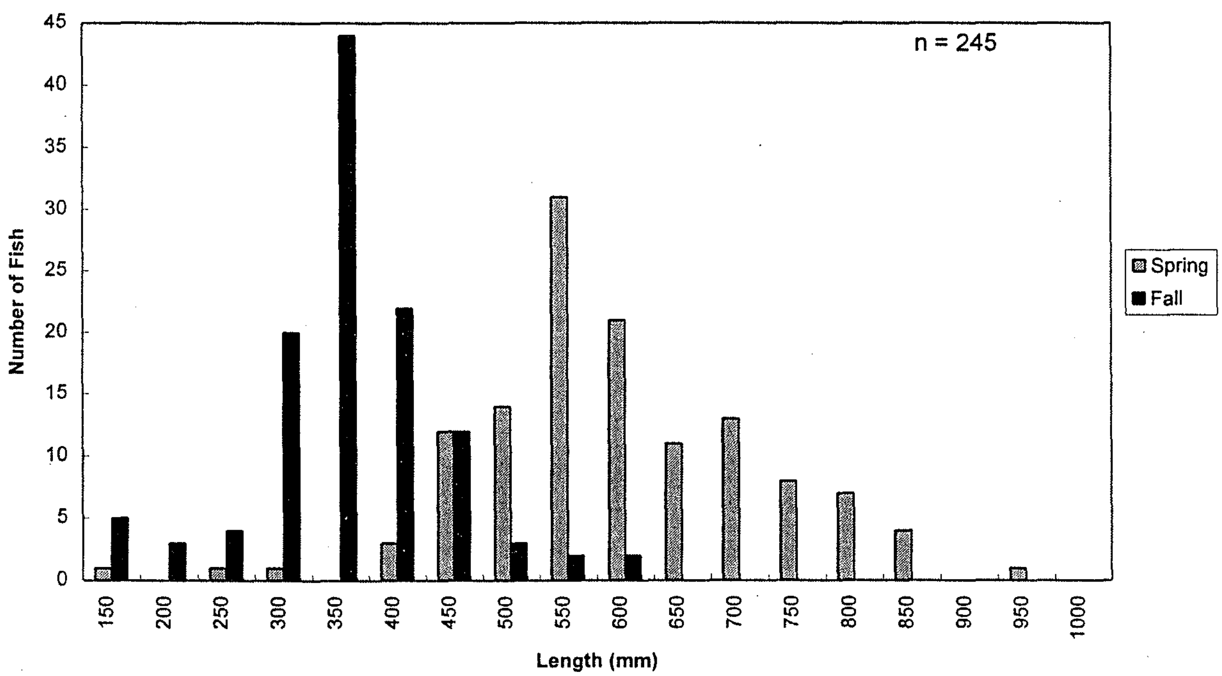


Figure 4.4-54 Length-Frequency Distribution for Northern Pike from the Muskeg River in Spring and Fall, 1995

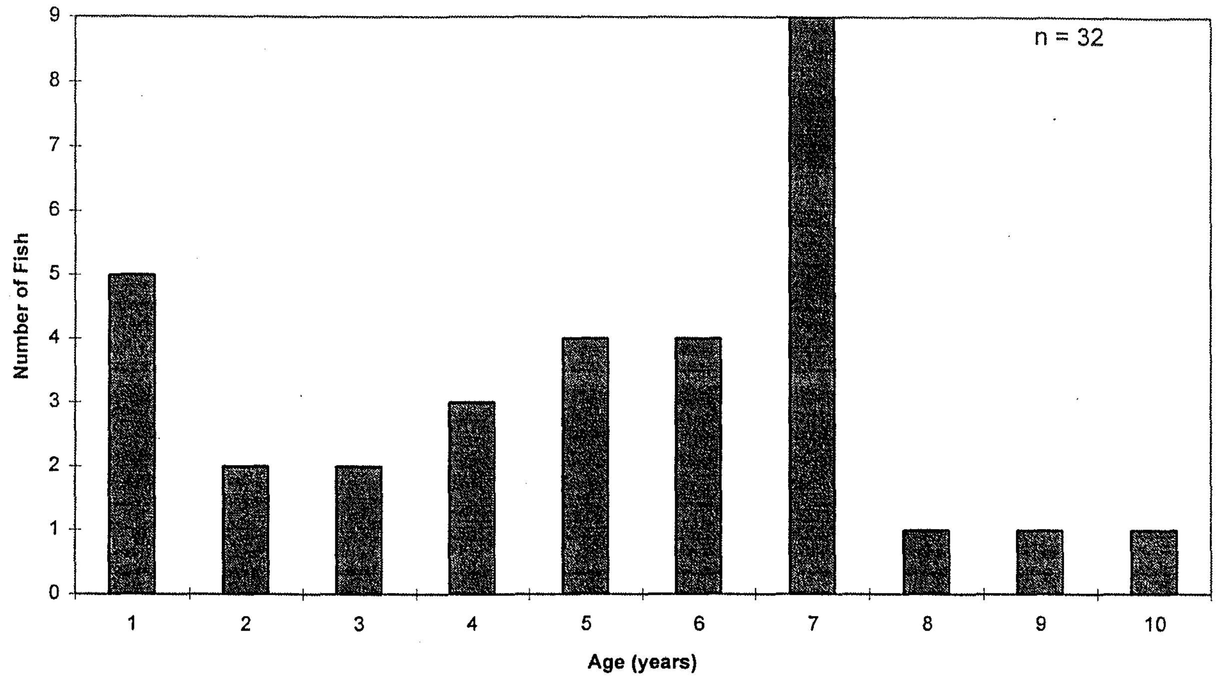


Figure 4.4-55 Age-Frequency Distribution for Northern Pike from the Muskeg River, 1995

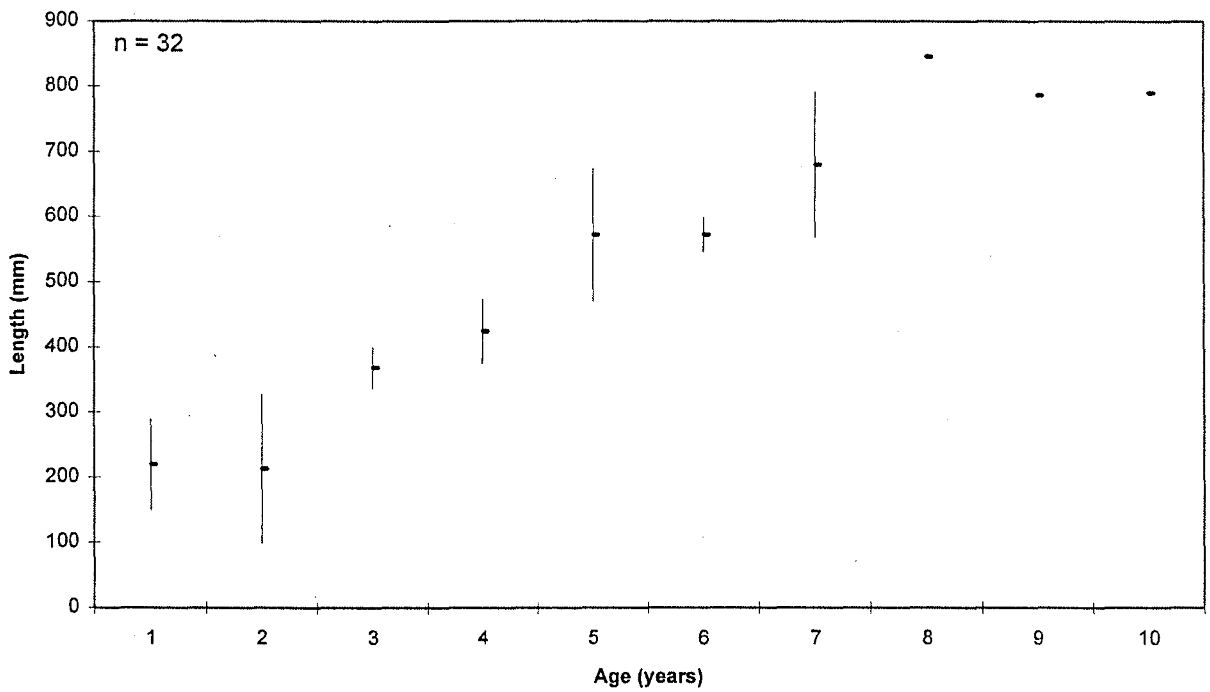


Figure 4.4-56 Length-at-Age with Standard Deviations for Northern Pike from the Muskeg River, 1995

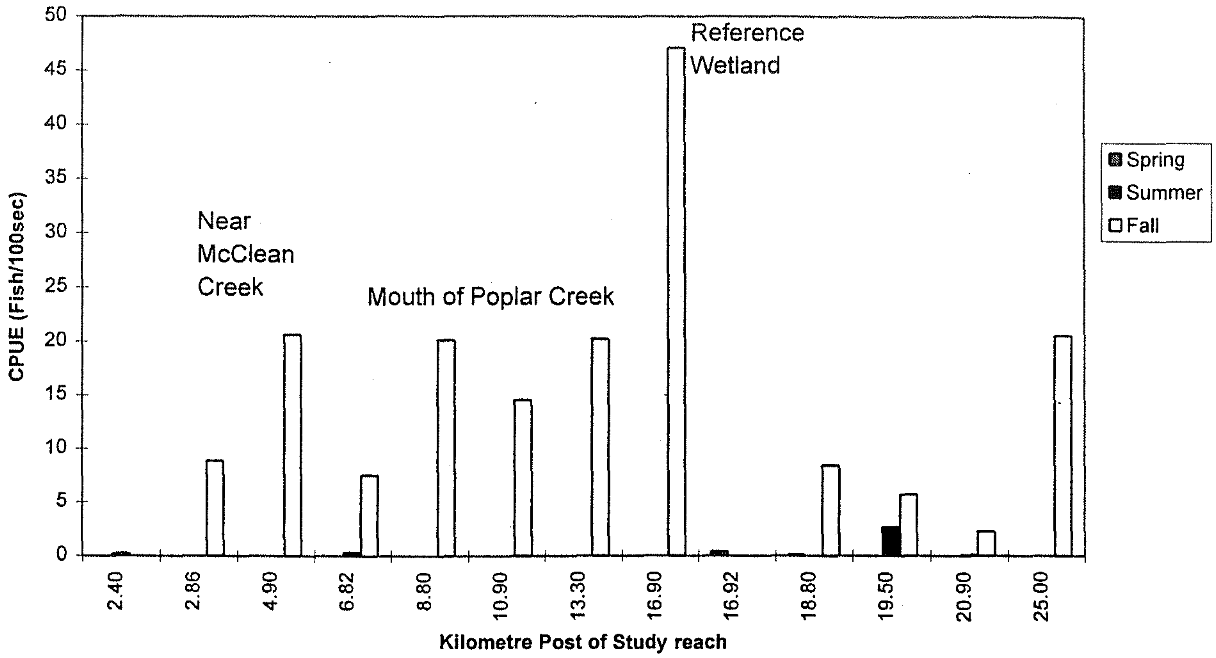


Figure 4.4-57 Catch-Per-Unit-Effort for Lake Whitefish from the Athabasca River in Spring, Summer and Fall, 1995

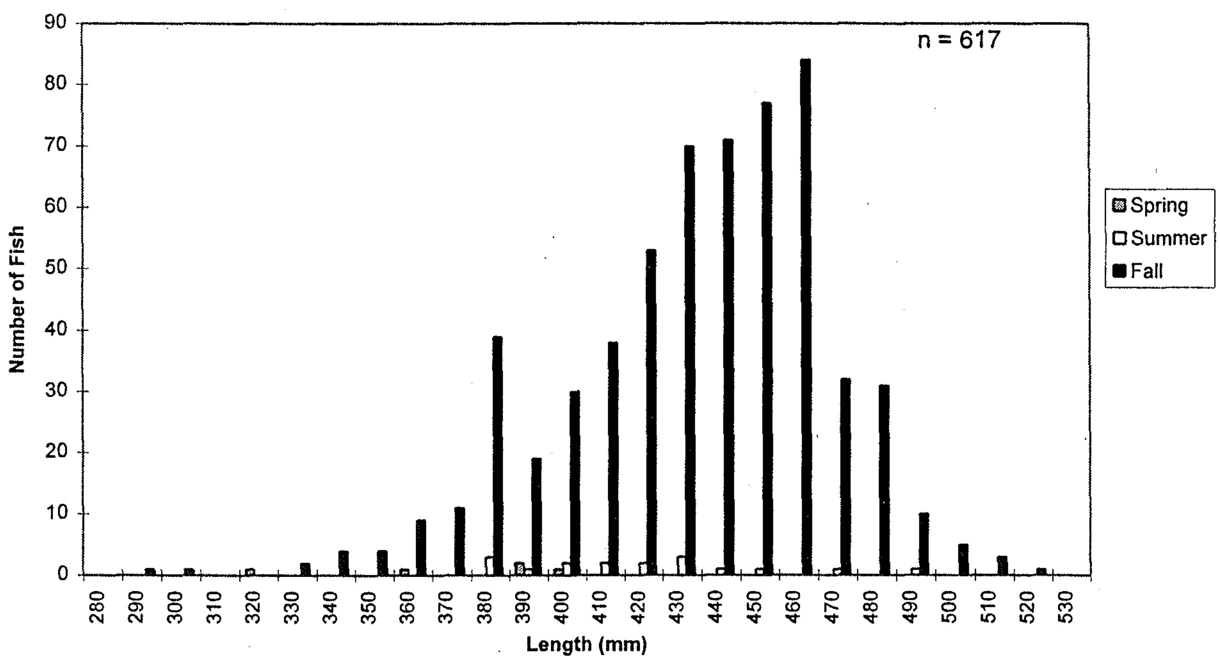


Figure 4.4-58 Length-Frequency Distribution for Lake Whitefish from the Athabasca River in Spring, Summer and Fall, 1995

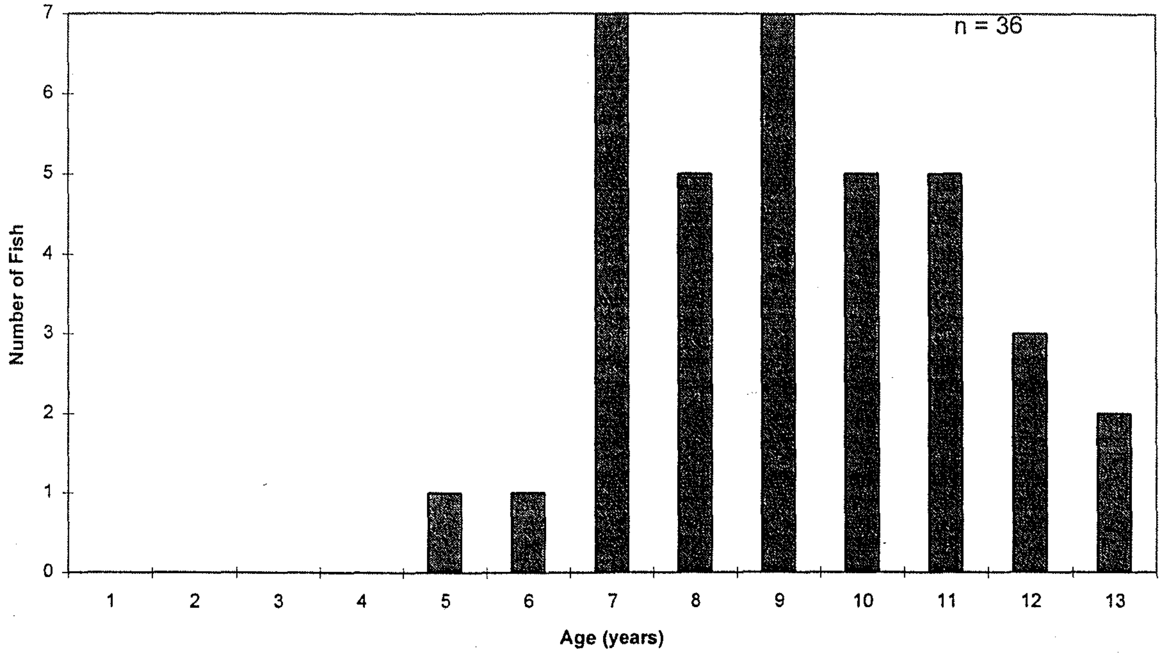


Figure 4.4-59 Age-Frequency Distribution for Lake Whitefish from the Athabasca River, 1995

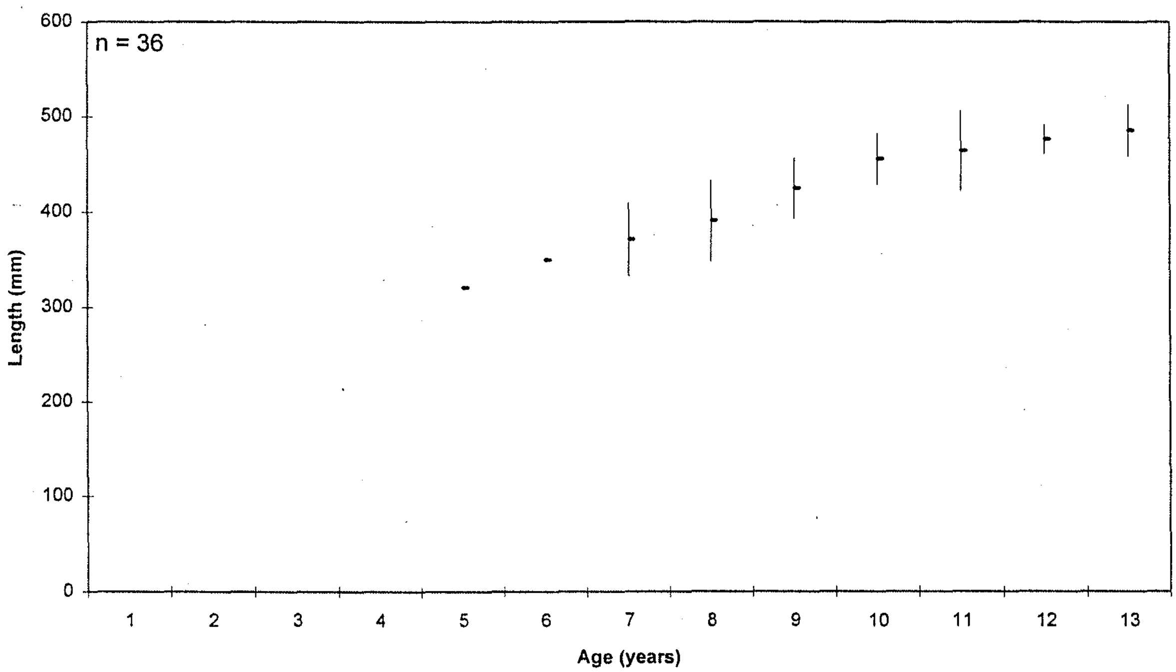


Figure 4.4-60 Length-at-Age with Standard Deviations for Lake Whitefish from the Athabasca River, 1995

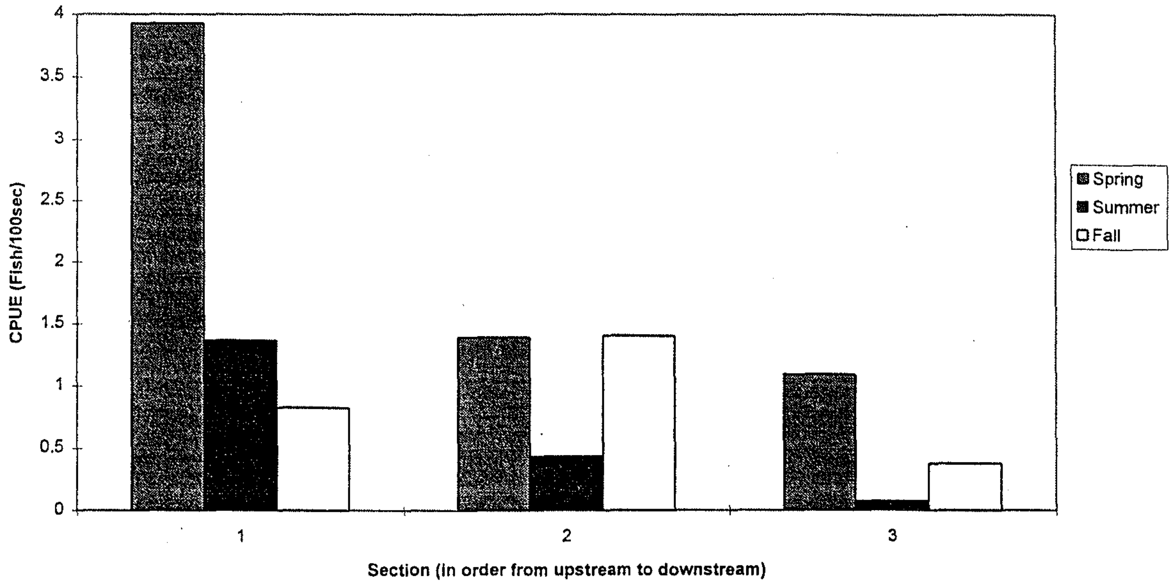


Figure 4.4-61 Catch-Per-Unit-Effort for Mountain Whitefish from the Steepbank River in Spring, Summer and Fall, 1995

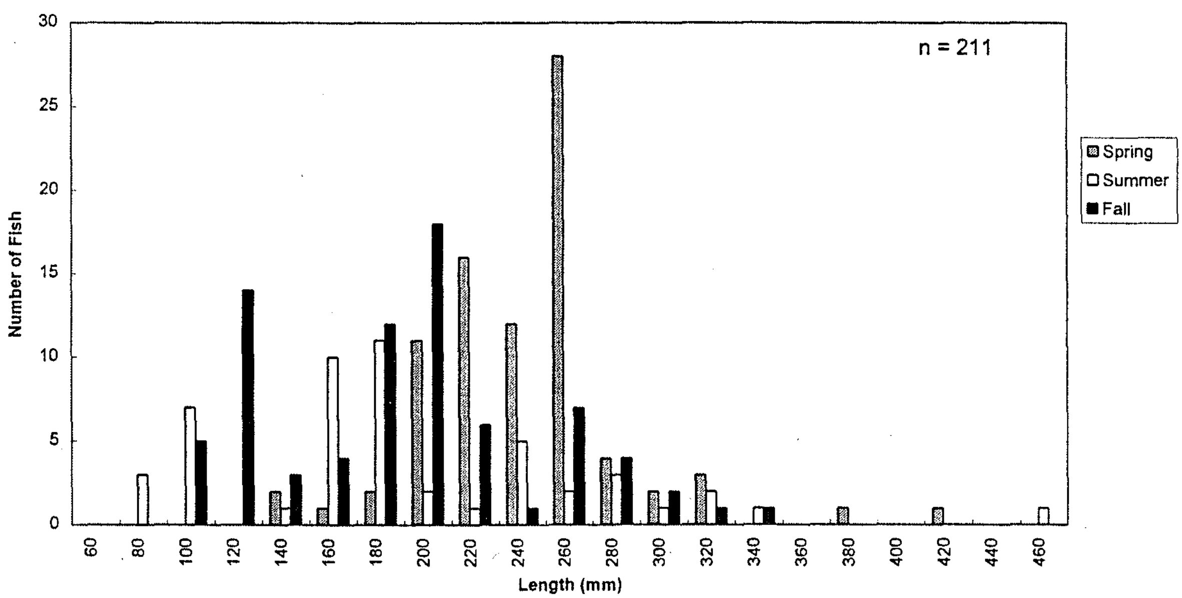


Figure 4.4-62 Length-Frequency Distribution for Mountain Whitefish from the Steepbank River in Spring, Summer and Fall, 1995

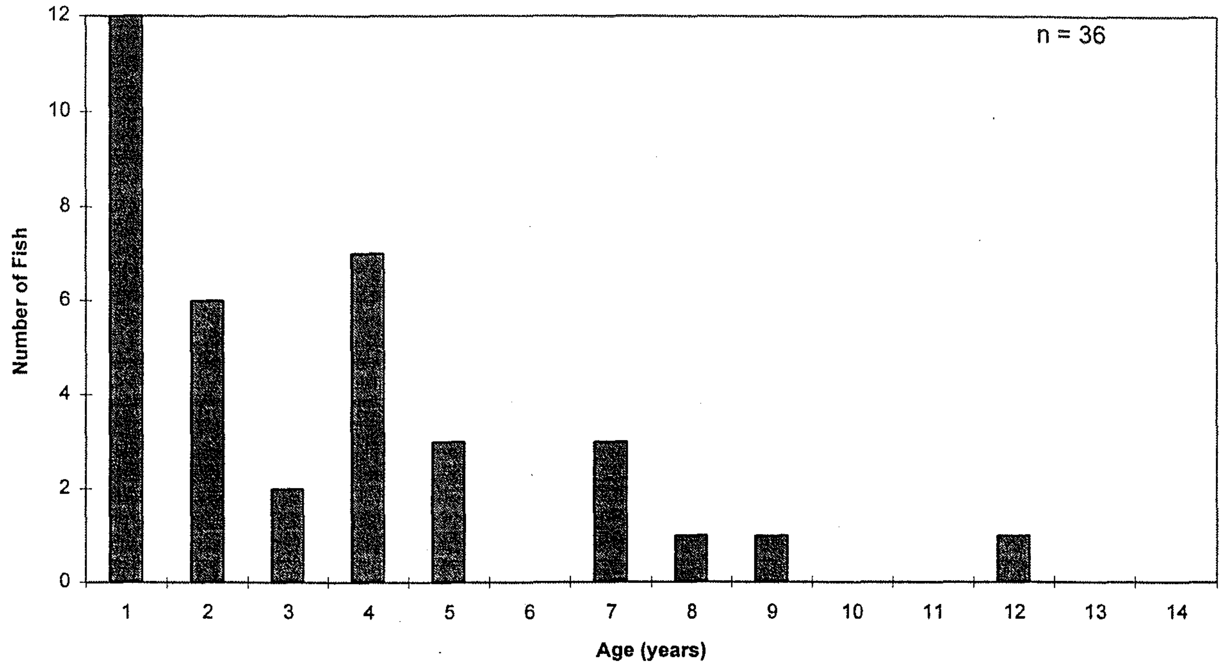


Figure 4.4-63 Age-Frequency Distribution for Mountain Whitefish from the Steepbank River, 1995

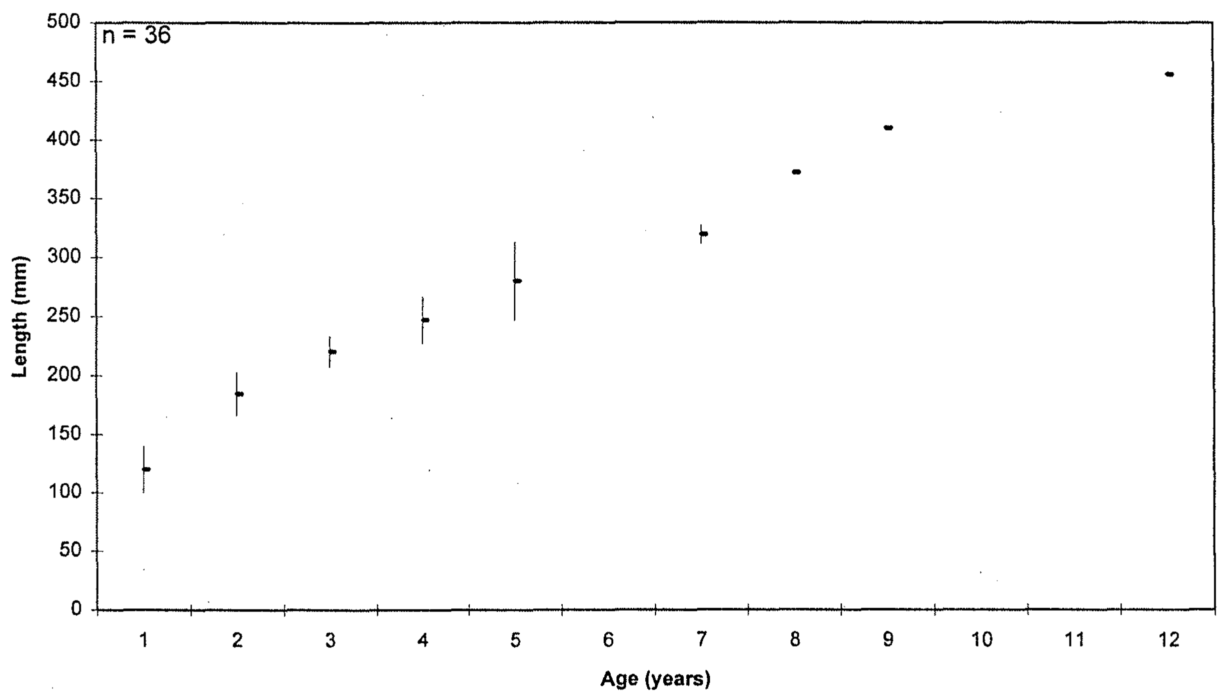


Figure 4.4-64 Length-at-Age with Standard Deviations for Mountain Whitefish from the Steepbank River, 1995

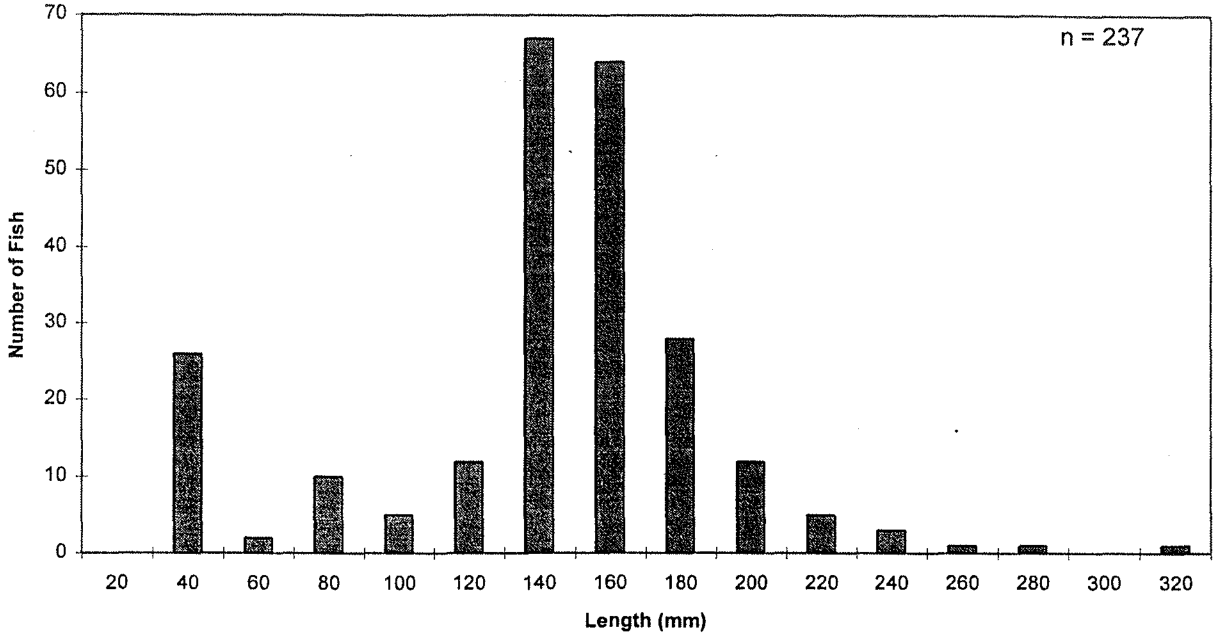


Figure 4.4-65 Length-Frequency Distribution for Flathead Chub from the Athabasca River, 1995

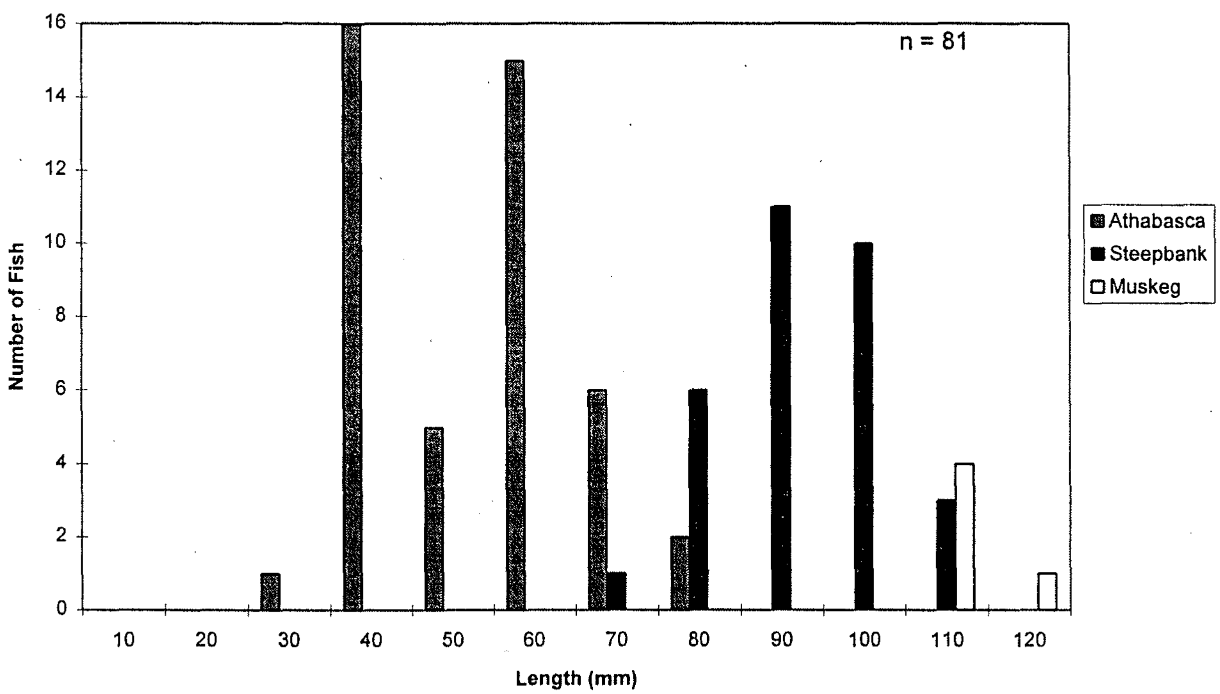


Figure 4.4-66 Length-Frequency Distribution for Lake Chub from the Athabasca, Steepbank and Muskeg Rivers, 1995

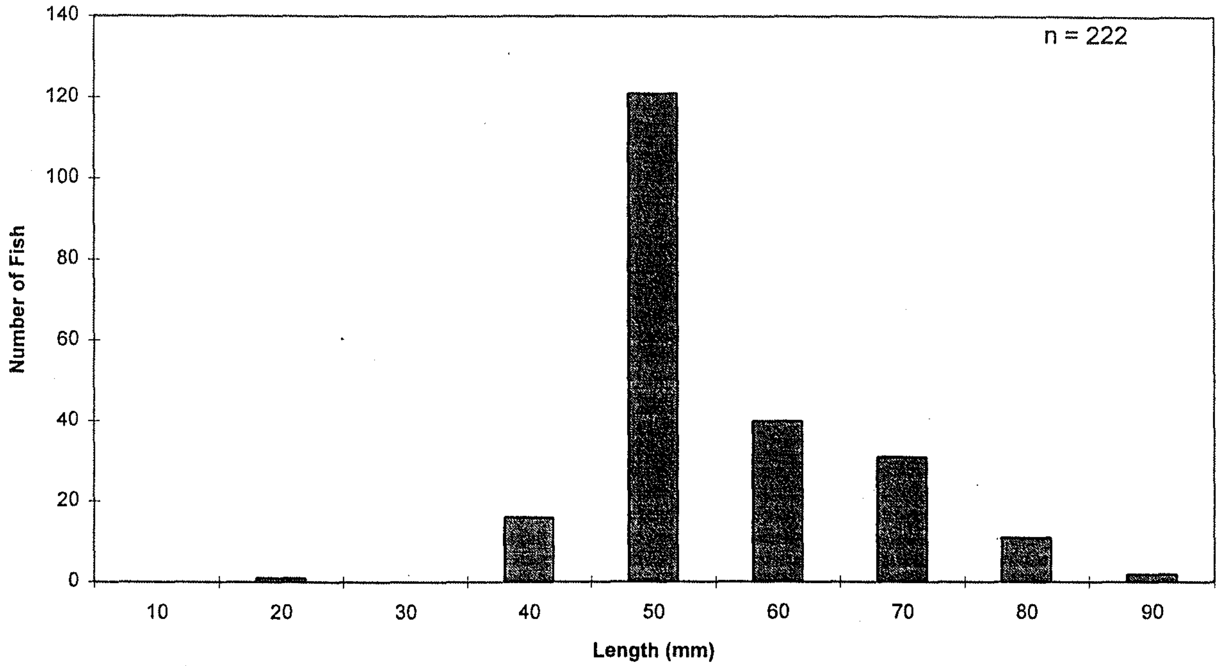


Figure 4.4-67 Length-Frequency Distribution for Trout Perch from the Athabasca River, 1995

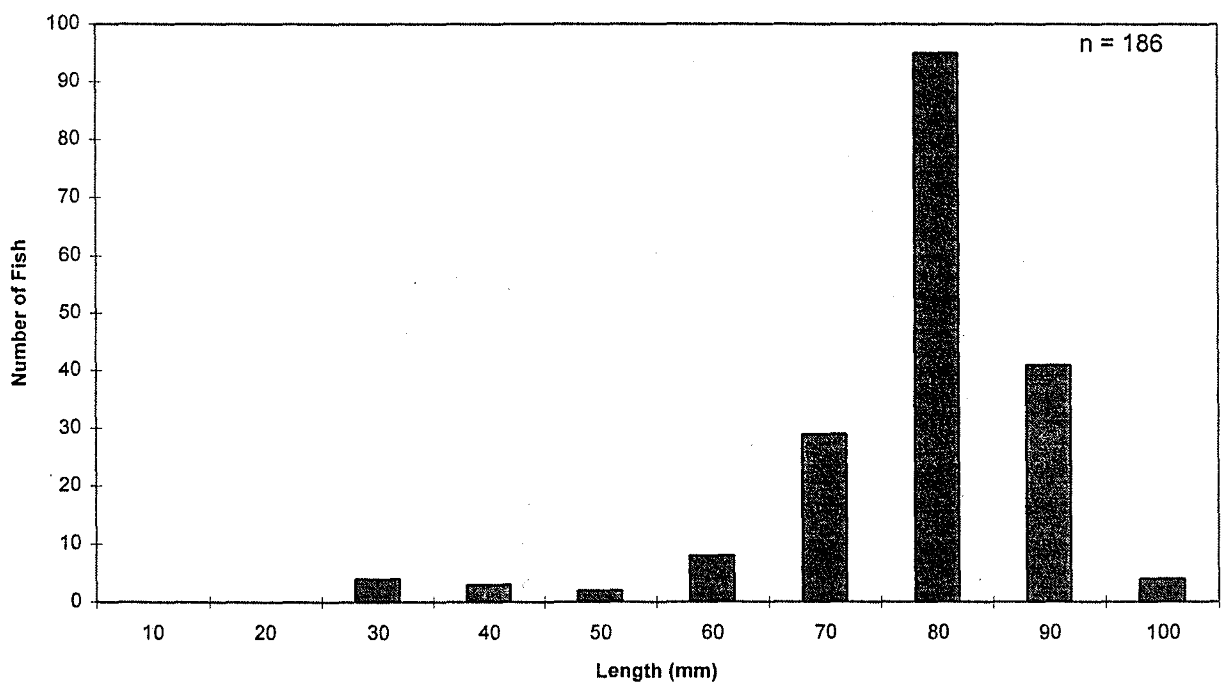


Figure 4.4-68 Length-Frequency Distribution for Spoonhead Sculpins from the Steepbank River, 1995

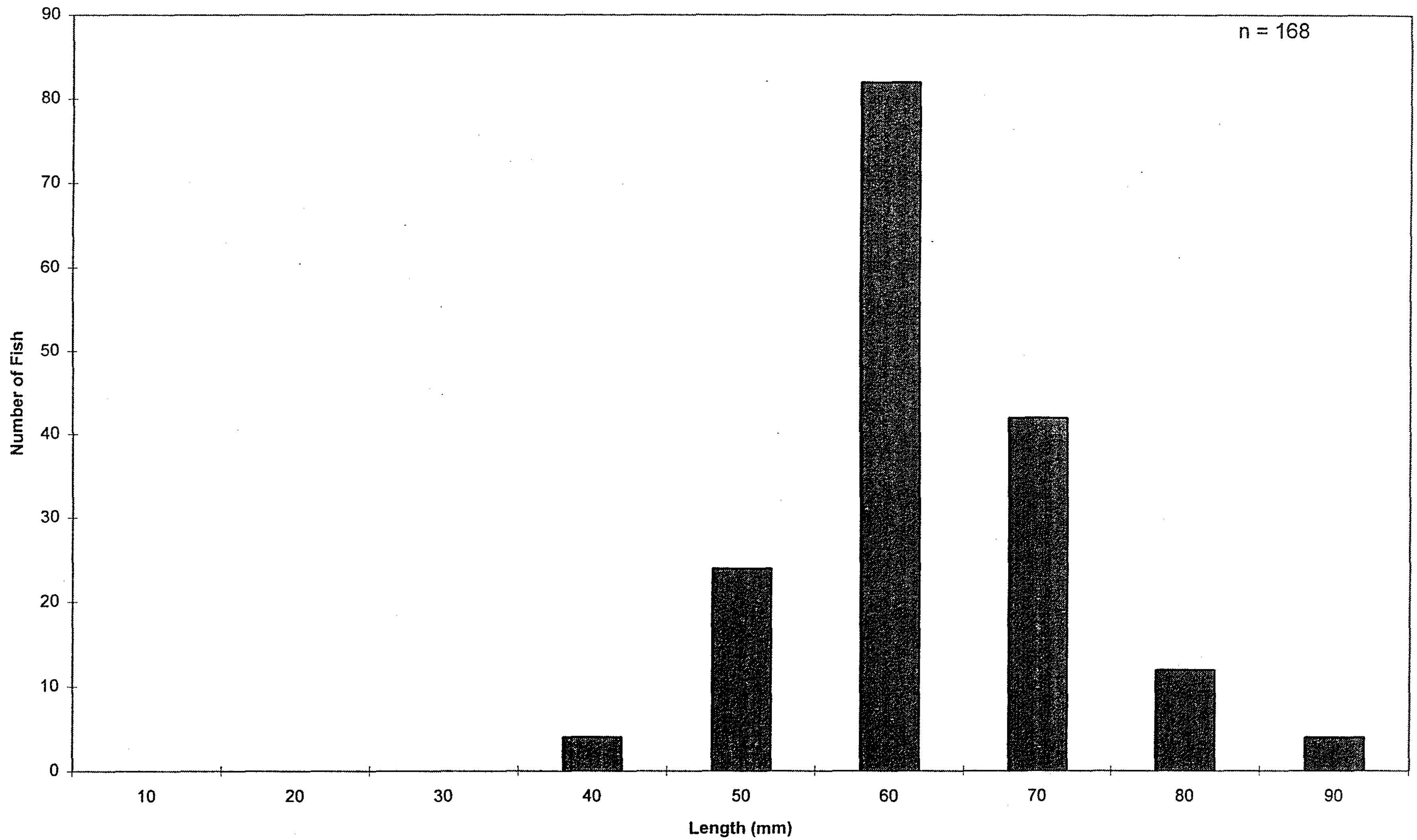


Figure 4.4-69 Length-Frequency Distribution for Fathead Minnows from the Muskeg River, 1995

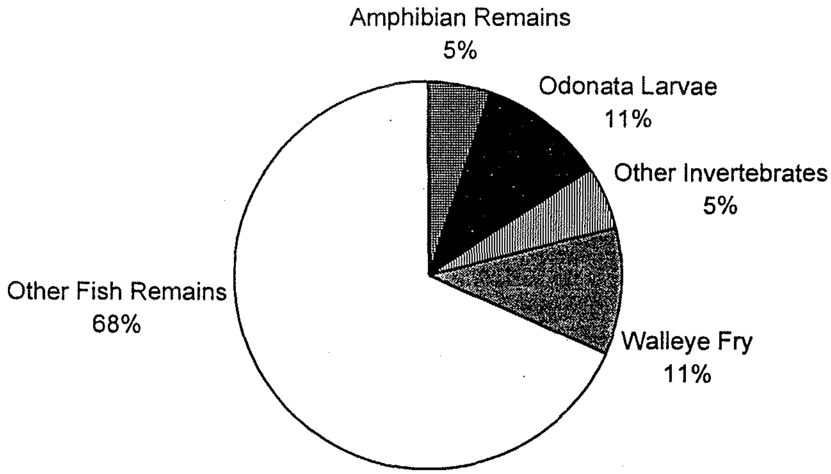


Figure 4.5-1 Stomach Contents of Walleye from the Athabasca River, Summer 1995

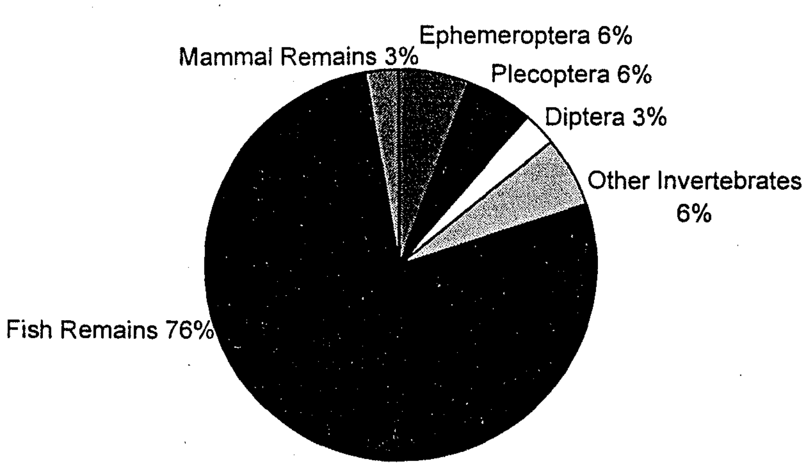


Figure 4.5-2 Stomach Contents of Walleye from the Athabasca River in 1974 and 1975, Adpated from McCart et al. 1977

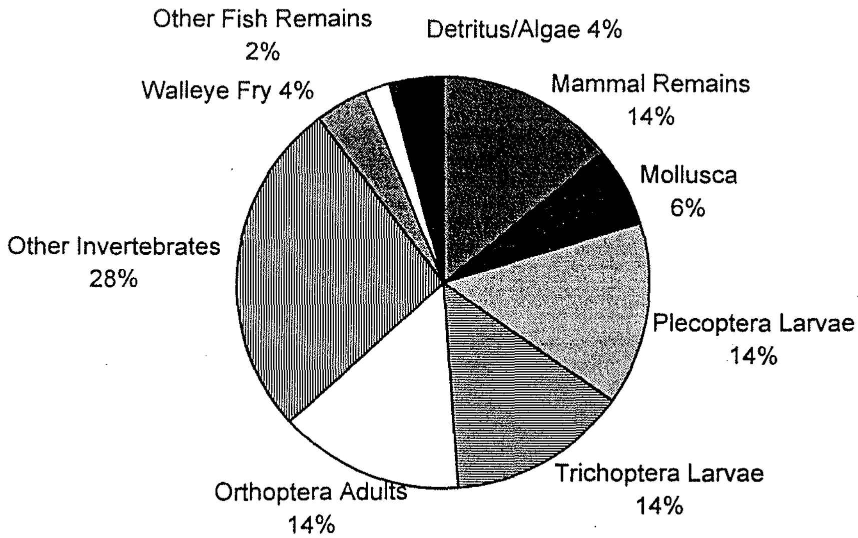


Figure 4.5-3 Stomach Contents of Goldeye from the Athabasca River, Summer 1995

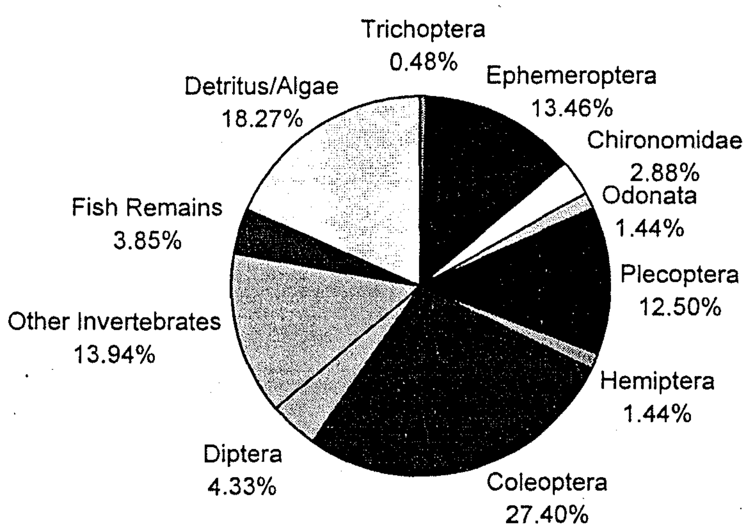


Figure 4.5-4 Stomach Contents of Goldeye from the Athabasca River in 1974 and 1975, Adapted from McCart et al. 1977

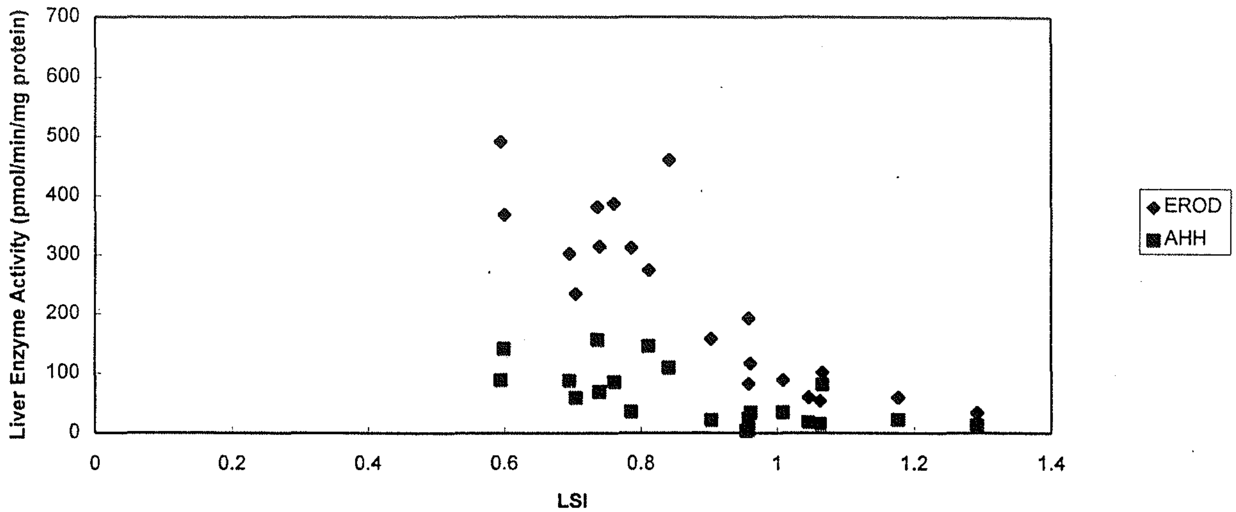


Figure 4.5-7 EROD and AHH Activity Versus Liver Somatic Index in Female Goldeye Livers from the Athabasca River, Summer 1995

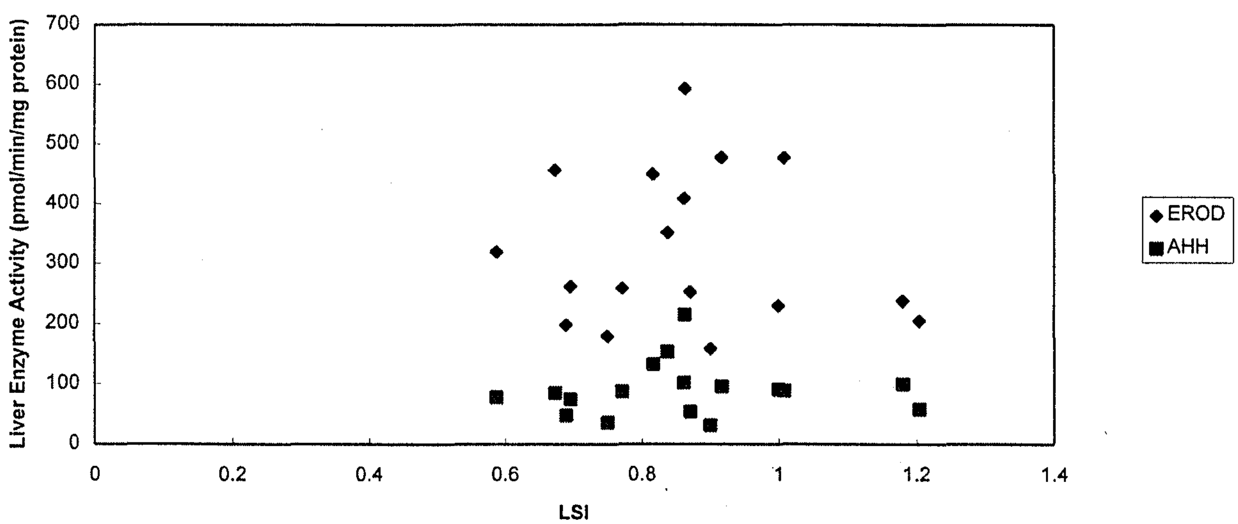


Figure 4.5-8 EROD and AHH Activity Versus Liver Somatic Index in Male Goldeye Livers from the Athabasca River, Summer 1995