A SYNOPSIS OF THE PHYSICAL AND BIOLOGICAL LIMNOLOGY AND FISHERY PROGRAMS WITHIN THE ALBERTA OIL SANDS AREA

by

T. D. (Tim) JANTZIE
RENEWABLE RESOURCES CONSULTING SERVICES LTD.
Edmonton, Alberta

for

AQUATIC FAUNA TECHNICAL RESEARCH COMMITTEE
ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

PROJECT AF 3.1.1

December 1976

ABSTRACT

"A Synopsis of the Physical and Biological Limnology and Fishery Programs within the Alberta Oil Sands Area" forms a background reference document on the limnology of the AOSER Program study area in northeastern Alberta.

Within the report, the following items are discussed and summarized: data on regional water quality, hydrology, physical and chemical limnology, and fisheries resources of the lakes and streams within the Program area.

An extensive bibliography of the pertinent literature for the area is included.

ACKNOWLEDGEMENTS

Grateful appreciation is extended to Dr. J.K. Klaverkamp and Mr. J.S. Loch of Environment Canada, Fisheries and Marine Service, for their constructive comments and technical assistance.

Many people assisted in providing technical information and subreports pertinent to this document. Their assistance is sincerely acknowledged.

I also wish to thank R.B. Murray as well as the entire Aquatic Fauna Technical Committee of the Alberta Oil Sands Environmental Research Program for their critical review of this paper.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

The Alberta Oil Sands Environmental Research Program (AOSERP) was conceived to provide the scientific and technical knowledge required by governments and industry for environmental protection in the Athabasca Oil Sands Region. The program consists of an integrated series of multi-disciplinary and multi-agency research projects in the fields of meteorology, hydrogeology, hydrology, vegetation, terrestrial fauna, aquatic fauna, land use, and human environment.

Prior to the establishment of detailed research programs, the Aquatic Fauna Technical Research Committee recognized a need for documents outlining pertinent background information (published and unpublished) in order to establish program priorities. Pursuant to the requirement, Renewable Resources Consulting Services Ltd. (RRCS) was retained to provide background information on the extent and availability of limnological and fisheries information for the AOSERP study area. This document was requested to be succinct, in order to provide the chairman of the Aquatic Fauna Committee with a synopsis of the status of aquatic research in the AOSERP study area and thus facilitate rapid planning of future studies.

The boundaries of the AOSERP study area (Figure 1) encompass one of the most important industrial and ecological areas in the Province of Alberta. The commercial and industrial potential of the Athabasca Oil

Sands is well known. From a biological standpoint, the area is equally as important. Two large river systems (the Peace River and the Athabasca River) merge within the region to form one of North America's major wetlands, the Peace-Athabasca Delta. The potential for environmental damage within the study area as the result of oil sand mining and extraction, as well as ancillary developments (eg. pipelines, roads, secondary industry), is ever present. This document, "Synopsis of the Physical and Biological Limnology and Fishery Programs Within the Alberta Oil Sands Area", is based to a large extent on information collected by previous investigators, particularly those of the Fish and Wildlife Division of Alberta Recreation, Parks and Wildlife. In addition, knowledge gained by RRCS personnel while conducting other studies in the area was utilized extensively. The time frame for collection and review of information for this document was of necessity short, extending for a period of approximately six weeks prior to the deadline of August 31, 1975.

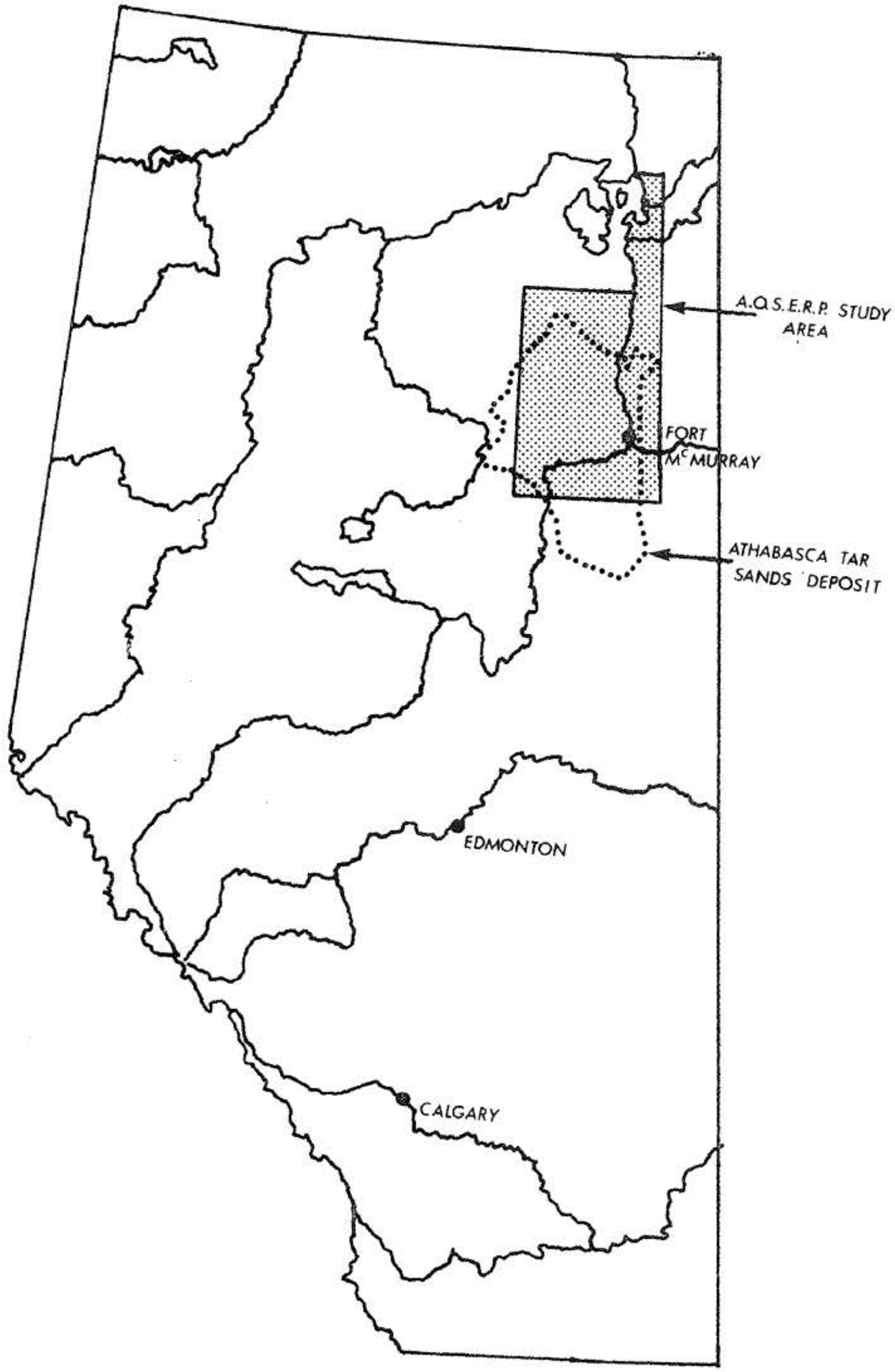

Figure 1. Location of the AOSERP study area.

OBJECTIVES

The major objectives were defined as follows:

1. to review existing data relative to the aquatic resources of the AOSERP region;
2. to indicate the type and level of detail of information available on the physical and chemical limnology of lakes, rivers, and streams in the AOSERP region; and
3. to indicate the type and level of detail of existing information on the biology of fish inhabiting lakes, rivers, and streams in the AOSERP region.

AQUATIC RESOURCES OF THE AOSERP STUDY AREA

General

A description of all lake and stream systems studied within the AOSERP area and vicinity is presented in the Northwest Alberta regional plan project, Fishery resources, Volume II (RRCS, 1975a).

Within this document, lakes of the study area were grouped into the physiographic subregions listed in Appendix II. Although the boundaries of the subregions do not always isolate lakes with similar characteristics, it is convenient to group the lakes of the AOSERP study area into these physiographic subregions, as they provide a useful framework for description and analysis.

For fluvial systems, drainage areas are a more appropriate unit of regional description and analysis, since stream and river systems often flow through several physiographic subregions. These are listed in Appendix III.

Regional Hydrology

Three major river systems, the Athabasca, Slave, and Peace rivers, dominate the drainage patterns of the AOSERP study area and surrounding region. Drainage of the southern two-thirds of the study area is provided by the Athabasca River and its major tributary, the Clearwater River. The valleys of these rivers, which are generally 200 to 300 ft deep, cut across a broad muskeg-covered interior plain. The tributaries of the Athabasca and Clearwater rivers, within the AOSERP study boundaries, originate from three major highland areas. West of the Athabasca River, the Birch Mountains rise to over 2,600 ft elevation. The headwaters of the Birch, McIvor and Ells rivers, and south-flowing tributaries of the MacKay River (eg. Dover, Dunkirk) are located in the Birch Mountains. In addition several smaller systems, such as the Tar and Pierre rivers, and Buckton Creek originate along the Western Birch Mountain slopes. The second highland area, the Muskeg Mountain Uplands, is located east of the Athabasca River and rises gradually to an elevation of 1,900 ft. The Muskeg Mountain Uplands are the source of the Muskeg, Steepbank, and High Hill rivers and southern tributaries of the Firebag River. The Stony Mountain Uplands, the third highland area, are south of Fort McMurray and are situated largely outside of the boundaries of the study area. This upland, which reaches almost 2,500 ft, serves as the headwater of the Christina, Hangingstone and Horse rivers. West of the Athabasca River, between the Stony Mountain Uplands and the Birch Mountains, is located a subdued highland area known as the Thickwood Hills. These hills give rise to the north flowing tributaries of the MacKay River and a few short streams which flow southward to the Athabasca River.

In the northern regions of the study area, the major drainage courses are the Peace and Slave river systems. Both systems exert a tremendous influence on the geographic area contiguous to the northern boundaries of the AOSERP area. The Peace River is a major contributor of surface water to the study area and plays an important role in the water relations of the Peace-Athabasca Delta. The Peace-Athabasca Delta is the focal point of three major river systems and Lake Athabasca. It is the terminus of the Peace and Athabasca rivers and the origin of the Slave River. The Slave River also drains a large portion of the region north of Lake Athabasca (primarily outside the study area) via the Dog and Bocquene rivers, and the LaButte and Ryan creek drainages. This northern region is low lying and generally less than 1,300 ft in elevation.

The hydrologic aspects of basins in northeast Alberta were examined during the Northeast Alberta Regional Planning Study by Northwest Hydraulic Consultants Ltd. (NHCL, 1975a) for Ekistic Design Consultants. The hydrology of the Peace-Athabasca Delta was investigated by the Technical Services Division of Alberta Department of Environment, with assistance from the Water Survey of Canada as part of the Peace-Athabasca Delta Project. The studies on the history of water levels (Bennett and Card, 1972), factors influencing water levels (Card, 1972a and b), sediment investigations (Graham, 1971), groundwater (Nelson, 1972), geology (Bayrock and Root, 1972) and water quality (Reeder and Fee, 1972) conducted during the course of the Project provided background information on this portion of the AOSERP region.

Within the AOSERP study area drainage courses appear to be stable (NHCL, 1975a). Three major types of drainage courses occur in the area. These are:

1. tributary systems where a large number of lakes are present, acting to control runoff and maintain relatively low flood peaks; for example, the Christina River basin south of Fort McMurray; basins north of Lake Athabasca and east of the Slave River; and basins associated with the Birch Mountains;
2. in some basins, large areas of muskeg exist which tend to store precipitation and reduce the runoff rate (eg. Dunkirk, Dover and MacKay rivers). These basins are generally covered by cohesive glacial and lacustrine surficial desposits; and
3. basins of the Richardson, Old Fort and Harrison rivers receive an important groundwater contribution. These basins have a particularly low drainage density especially in their lower reaches. Here, the surficial deposits of the basins are dominated by glacial outwash sands and it appears precipitation rapidly percolates the groundwater zone.

In general, the differences in drainage courses and patterns, rates of surface runoff, retention of soil moisture and groundwater storage potential reflect the past glacial processes and bedrock formations of the area.

The hydrology of the study region will be investigated in detail under the direction of the AOSERP Hydrology Technical Research Committee. To facilitate such programs, the Water Survey of Canada (Inland Waters Directorate, Environment Canada) are presently expanding their stream gauging and lake level recording programs. The stream stations that are expected to be in operation by the end of 1975 are shown in Table 1. Water levels are expected to be recorded on Namur, Gardiner, Gregoire (operational), Richardson, McClelland, Mildred, Eaglenest and Kearl lakes (M. Spitzer, pers. comm.).

The potential hydrologic impacts of oil sands development are discussed in a report by NHCL (1975c). The major impacts expected are: increased soil erosion and associated sedimentation of lakes and watercourses as a result of increased streamflow peaks and more rapid runoff; contamination of surface and groundwater supplies from mining or percolation of contaminants in tailing deposits to the groundwater system; and leakage of tailings through dikes to surface water sources. As well, land use changes imposed by the urban-industrial oil sand complexes are expected to significantly influence the region's hydrologic cycle. Rainfall-runoff relationships will change with clearing, and changes in microclimate are expected as a result of altered surface albedo. The probable effects of several activities associated with open pit mining and industrial development of the oil sands are indicated more specifically in Appendix I. The schedule of proposed diversion of stream courses in the oil sands area is given below:

Table 1. Stream gauging stations in the oil sands area.

Stream	Hydrometric Station Location	Years of Stream Flow	Type of Gauge
Athabasca River	below Fort McMurray	1957-present	R.C.
	below Fort MacKay	1975*	--
	Embarras Airport	1971-present	R.C.
Athabasca Tributaries Upstream of Fort McMurray			
Horse River	near the mouth	1975*	--
Hangingstone River	near the mouth	1965-present	M.C.
Clearwater River	Draper	1957-present	R.C.
	above Christina River	1966-present	R.S.
	below Waterways	1950-1974	M.S.
Athabasca Tributaries West of Athabasca River			
Poplar Creek	near the mouth	1972-present	R.C.
Beaver Creek	near the mouth	1972-present	M.C.
Beaver Creek	above Syncrude Dam	1975*	--
MacKay River	near the mouth	1972-present	R.C.
Dunkirk River	near the mouth	1975*	--
Dover River	near the mouth	1975*	--
Ells River	above Joslyn Creek	1975*	--
Ells River	below Gardiner Lake	1975*	--
Joslyn Creek	near the mouth	1975*	--
Tar River	near the mouth	1975*	--
Calumet River	near the mouth	1975*	--
Pierre River	near the mouth	1975*	--
Asphalt Creek	near the mouth	1975*	--
Unnamed Creek north of Asphalt Creek	near the mouth	1975*	--
Athabasca Tributaries East of the Athabasca River			
Steepbank River	near the mouth	1972-present	R.C.
Muskeg River	near the mouth	1974-present	R.C.
Hartley Creek	above Muskeg River	1975*	--
Stanley Creek	near the mouth	1975*	--
Firebag River	near the mouth	1972-present	R.C.

* - to be installed in 1975, continuous monitoring expected

M - manual gauge

R - recording gauge

C - continuous operation

S - seasonal operation

	Stream	Basin	Construction	Diversion Begins
1.	Beaver Creek	Beaver Creek	1974-1975	fall 1975
2.	Muskeg River	Muskeg River	1990's	late 1990's
3.	Hartley Creek	Muskeg River	late 1970's	1980

Regional Water Quality

In the AOSERP region, only two reports have been published (Reeder, 1971; Reeder and Fee, 1972) dealing specifically with water quality in the Peace-Athabasca Delta. Despite the initiation of water quality sampling programs by Environment Canada, Alberta Environment, Shell Canada Ltd. and Syncrude Canada Ltd., the water quality characteristics of lakes and streams in the study area are poorly known. The location and detail of the programs mentioned previously are discussed later in this report.

In any region, several factors are known to influence the chemical composition of surface water including bedrock and surficial geology, climate, soils and local drainage patterns. In the AOSERP region, the variability of surficial and bedrock material (Cretaceous, Devonian, Precambrian) will undoubtedly play a significant role in the hydrologic dynamics of the region.

A. Lakes

Only limited water quality data are available for a small number of lakes in each physiographic subregion. Specific conductance values are generally less than 250 micromhos/cm indicating low dissolved salt contents. Hardness values range from soft to moderately hard (0 - 150 mg/l as $CaCO_3$). The nutrient data available indicate that productivity may vary considerably. Some lakes show nutrient concentrations which are expected to be high enough to facilitate high production rates (eg. Mildred and Ruth lakes). However, for the majority of lakes, additional water quality data will be required prior to definitive statements with regard to the productivity and possible limiting nutrients. Most study region lakes exhibited relatively low concentrations of major ions. As expected, the lowest levels are generally found in lakes underlain by the Precambrain Shield (subregions 4 and 6).

On the basis of water chemistry alone, statements concerning the classification of lakes by subregional characteristics would be susceptible to error due to the apparent similarities of most lakes and the lack of suitable comparative data.

B. Rivers

The water quality parameters of rivers and streams in the study region show greater ranges than those found in most lakes. Conductance values vary from 27 to 1,050 micromhos/cm in Alice Creek and Christina River, respectively. In all rivers sampled, major dissolved constituents are calcium, sodium, sulphate, and chloride ions. Chloride values are generally low; however, in the Christina River (southeast of Fort McMurray), the level of dissolved sodium chloride was found to be three to four times greater than in any other river. Total hardness values in the rivers range from 16 to 274 mg/1 $CaCO_3$. The phosphorus and nitrogen content of most rivers appears high enough to support good production. The regional water quality of AOSERP rivers appears good with no toxic or harmful effects from any of the parameters measured.

Although very little is known of the seasonal changes in the water quality parameters of specific rivers, significant changes in concentrations of sodium, calcium, magnesium, sulphate, and chloride salts have been noted in the Birch and McIvor rivers during the winter by Reeder and Fee (1972). In the winter, both basins appear to receive significant groundwater contributions from Devonian stratigraphic units. A similar situation may be occurring in the Poplar Creek basin of the Syncrude lease, where chloride values have been observed to rise by an order of magnitude during the winter (RRCS staff, pers. comm.).

Synopsis of Information on Lakes in the AOSERP Region

A. Physical and Chemical Limnology

A large number of lakes are located within the boundaries of the AOSERP region and surrounding geographic area (Appendix II). These lakes are concentrated in the areas north (subregion 4) and south (subregions 3 and 6) of Lake Athabasca. Very few lakes are located in the area of immediate oil sand development (subregions 1 and 7). In comparison with the surrounding geographic area, the AOSERP region contains relatively few lakes.

The majority of the lakes in the study area are small, occupying less than 1,000 acres (404.7 ha) in surface area. In addition to Lake Athabasca and the lakes of the Peace-Athabasca Delta (Claire, Mamawi, Baril, and Richardson), two areas of relatively large lakes can be identified. These are: south of Fort McMurray in subregion 2, the group of Gregoire, Gordon, Birch and Gipsy lakes (2,000 to 19,000 acres, 809.4 to 7,689.2 ha); and the Namur Lake-Gardiner Lake group in subregion 5 (3,000 to 11,000 acres, 1,214.6 to 4,453.5 ha).

Nearly all of the classical lake types (oligotrophic, eutrophic, mesotrophic and dystrophic) are represented in the AOSERP region. The majority of the study area is situated within the "Zone of Forest Lakes" described by Northcote and Larkin (1963). This zone is transitional between the mineral-rich saline lakes of more southern areas and the mineral-poor lakes of northern regions. Lakes of the Forest Zone are characterized by an intermediate range of total dissolved solids and a mineral content of 200 to 500 ppm (Northcote and Larkin, 1963). The predominant lake types of this zone are eutrophic and mesotrophic.

Lakes in the area contiguous with the northern boundary of the AOSERP region (subregions 4 and 6) are located at the southern extreme of Northcote and Larkin's "Zone of Northern Lakes". Lakes in this zone are typically oligotrophic with a mineral content of less than 200 ppm. Dystrophic lakes are also widely distributed in the Northern Zone.

The majority of studied lakes in subregions 1, 2, 5 and 7 are characterized by low mean depths, relatively high levels of nutrients, abundant macrophytic growth, and moderate to high productivities. Lakes such as Ruth Lake (Tp 92-R10-W4) typify the eutrophic condition. Gregoire, Gipsy, Gardiner and Unnamed (Tp 97-R16-W4) lakes are all large lakes with slightly greater mean depths and moderate productivities; they illustrate the mesotrophic condition. Two oligotrophic lakes (Namur; and Unnamed, Tp 100-R15-W4) are found in this area. The maximum depths of these lakes are 92 ft (28.1 m) and 210 ft (64 m) respectively, while the mean depths are 43 ft (13.1 m) and 52 ft (15.8 m). Both are relatively unproductive.

In the region immediately north and east of the study area (subregions 4 and 6), oligotrophic lakes are common and few eutrophic lakes have been indicated. In subregion 4, oligotrophic lakes are most concentrated in the northern and eastern sections while mesotrophic lakes are common in the south and west, particularly in the lower reaches of the Dog River, and LaButte and Ryan creek drainages. The lakes of subregion 3 and 6 appear transitional between the southern lakes of the sedimentary basin (subregions 1, 2, 5, 7) and the northern lakes of the Canadian Shield (subregion 4). In subregions 3 and 6, a wide variety of lake types is encountered in a small geographic area.

1. Extent of Base-line Information

The vast majority of lakes in the AOSERP study area have not been investigated in detail. However, many of these lakes were examined during preliminary biological surveys conducted by Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division. The primary purpose of initial surveys by Turner (1968a, 1968b) and Bradley (1969) was to examine selected northern lakes in order to determine their potential for sport and commercial fishing. These studies concentrated on lakes south of Lake Athabasca and were of short duration (usually less than seven days per lake). Information of varying detail was gathered on morphometry (including contour maps), water chemistry, bottom fauna and fish. The number of samples of plankton, bottom fauna, fish and water chemistry collected was small, since numerous lakes were examined during each survey.

The samples collected during these surveys were analyzed to a level appropriate for preliminary investigations. Common species of phytoplankton were usually identified to the generic level while zooplankton and benthic macroinvertebrates were separated to the level of order. The majority of the water samples were analyzed for pH, conductivity, hardness, alkalinity, and dissolved oxygen. The reports of Turner (1968a, 1968b) and Bradley (1969) formed part of the Alberta Fish and Wildlife Survey Report Series of the late 1960's.

North of Lake Athabasca (subregion 4), the fisheries potential of several lakes was examined in the mid-1960's and a series of manuscript reports were produced (MacDonald 1966a, 1966b, 1966c, 1966d, 1966e; Turner 1966, 1967a, 1967b, 1967c, 1967d, 1967e, 1967f). The objectives of these surveys were similar to those carried out in the other subregions, ie. to determine the fisheries potential of each lake. Information was collected on morphometry, water chemistry, plankton, bottom fauna and fish, and analyzed in a manner similar to that of Turner (1968a, 1968b) and Bradley (1969). In 1974, a second study of Canadian Shield lakes was undertaken (Rhude, in progress). The number of lakes investigated during this latter study was large (approximately 30) and hence the detail of the information collected is expected to be substantially reduced from that of previous surveys.

To date, the most detailed limnological studies in the AOSERP region have been carried out on Ruth Lake (Tp 92-R10-W4) and the Peace-Athabasca Delta. Ruth Lake is under investigation as part of the environmental program of Syncrude Canada Ltd. The results of a preliminary base-line study on the lake have been reported (RRCS, 1974b) and a 1975 field program has been undertaken. Information has been collected on morphometry, water chemistry, phytoplankton, aquatic macrophytes, benthic macroinvertebrates, zooplankton and fish fauna.

In the Ruth Lake study, zooplankton, phytoplankton, benthic invertebrates and aquatic macrophytes were analyzed. Zooplankton and phytoplankton were identified to the lowest taxonomic level possible (usually genera or species for mature individuals) and their abundance enumerated. In addition, the biomass of zooplankton, in terms of wet weight, was calculated. Benthic macroinvertebrates were identified to the generic level except for water mites (Hydracarina), leeches (Hirudinea), and oligochaetes. Within each benthic sample the numeric abundance of all component groups was recorded. Submergent, floating-leaf and emergent aquatic plant species were identified and their abundance calculated.

The limnology of the Peace-Athabasca Delta was examined during the Peace-Athabasca Delta project (summarized in the Technical Report, Peace-Athabasca Delta Project, 1973). In the study by Gallup *et al.* (1971) crustacean zooplankters received the most detailed investigation. These were identified to species and/or genus and the relative abundance of each group in each sample was noted. Since phytoplankton were found to be generally absent in the delta, they were not examined in detail. The absence of phytoplankton in most of the samples may be a result of the extremely turbid condition of the water or a result of the sampling methods used. For each plankton sample, the settled volume of the zooplankton and phytoplankton was measured. The benthic macroinvertebrates collected by Gallup *et al.* (1971) were identified to the family level and in representative samples, the weight of each taxonomic group was determined.

An extensive analysis of the water quality of the Peace-Athabasca Delta is presented in the report by Reeder and Fee (1972). In addition to routine chemical analysis, this study included analysis for heavy metals and micronutrients. During the course of this study, a winter survey at selected sites was undertaken in 1971. The water quality monitoring stations of Reeder and Fee (1972) are presented in Table 2. Although the Peace-Athabasca Delta has been investigated, extremely little is known of the limnology (physical and biological) of Lake Athabasca itself.

The type and detail of limnological information available for the lakes in the AOSERP study area and immediate vicinity are summarized in Appendix II. For convenience, the lakes have been separated into their respective physiographic subregions.

Table 2. Water quality monitoring stations, Reeder and Fee (1972).

Station Name	Station Location	Latitude	Longitude	Frequency
Lake Claire	northwest	58°39'30"	112°21'	Monthly
Lake Claire	center	58°36'	112°	Monthly
Lake Claire	south	58°25'	112°	Monthly
Lake Athabasca	near Ft. Chipewyan	58°43'30"	111°	Monthly
Lake Athabasca	at Alta.-Sask. border	59°9'0"	110°	Monthly
Lake Athabasca	south of Uranium City	59°14'48"	108°39'36"	Monthly
Lake Athabasca	near Fond du Lac	59°20'	107°10'	Monthly

B. Fisheries Resources

In general, fisheries investigations of lakes in the AOSERP region have been carried out simultaneously with studies of physical and biological limnology during preliminary biological surveys. Of approximately 95 lakes in the study region for which information exists, nearly 94 per cent were examined during the course of biological surveys. Studies in the Peace-Athabasca Delta (Bidgood, 1965, 1966b, 1967, 1971, 1972; Schultz, 1955; Sprules, 1950; Donald and Kooyman, 1973, 1974; Kooyman, 1972; Fernet, 1972) have dealt directly with fishery biology.

At present, the distribution of sport, commercial and domestic fish species is well known. Northern pike, lake whitefish, white sucker and longnose sucker are widely distributed throughout the AOSERP region and occur in all lake types (eutrophic, mesotrophic, oligotrophic, and dystrophic lakes). Walleye are less widely distributed, but are common in mesotrophic lakes such as Gardiner Lake (Tp 98-R16-W4) and Unnamed Lake (Tp 99-R16-W4) in subregion 5 and Gregoire Lake (Tp 86-R8-W4) in subregion 2. Walleye are also common, outside the study area, in the lakes of the Dog River (Myers, McClelland and Leland lakes), Bocquene River (Bocquene Lake), and Ryan Creek (Barrow and Ryan lakes) drainages of subregion 4. Lake trout are not common in the AOSERP region and appear restricted to Namur Lake (Tp 97-R17-W4) and Unnamed Lake (Tp 107-R4-W4). Lake trout are common north of Lake Athabasca in the oligotrophic lakes of the area bounded by Andrew, Colin, Cornwall, Charles and Mercredi lakes.

The regional fisheries resources of northeast Alberta, including the AOSERP region, are discussed in the RRCS report "Fishery Resources, Volume I Regional Assessment" (RRCS, 1975a). The fisheries resources (emphasis on potential fish production, and commercial and sport utilization) of many of the individual lakes are discussed in "Volume II, Technical Appendix I" of the same report. These reports are summaries of the work of other investigators. In the original reports, in addition to information on potential fish production, each lake is described and the fish habitat for major sport fish species evaluated.

With the exception of the goldeye and walleye in the Peace-Athabasca Delta, very little is known of the life history of any fish species in the study region. For some lakes, limited information on age, growth and maturity of certain species is available. In these studies, the ranges (and means) of lengths and weights, the sex ratio, and the maturity of the fish in each age class were generally noted for each species collected. All of the lakes in northeast Alberta for which the age and growth of fish species has been reported are presented in Table 3. Information on other aspects of fish biology such as movements, migrations, and reproduction is generally lacking. As well, the habitat requirements and the location and utilization of critical areas for spawning,

Table 3. Lakes in northeast Alberta for which the age and growth of fish species has been reported.

Lake	Species (sample size)		Reference
Subregion 2: Fort McMurray Plain			
Gregoire Lake (86-8-4)	Northern Pike	(40)	Bradley, 1969
	Walleye	(16)	
	Lake Whitefish	(18)	
	Cisco	(13)	
Gipsy Lake (86-2-4)	Lake Whitefish	(50)	Bradley, 1969
	Northern Pike	(45)	
Subregion 3: Peace-Athabasca Delta			
Unnamed Lake (103-5-4)	Northern Pike	(18)	Turner, 1968a
	Lake Whitefish	(33)	
	White Sucker	(30)	
Pearson Lake (103-8-4)	Walleye	(45)	Bradley, 1969
	Northern Pike	(22)	
	Cisco	(45)	
	Lake Whitefish	(34)	
Barber Lake (105-6-4)	Lake Whitefish	(52)	Turner, 1968a
Larocque Lake (105-5-4)	Lake Whitefish	(57)	Turner, 1968a
	Cisco	(30)	
Unnamed Lakes-Maybelle River (105-5-4) combined sample	Northern Pike	(66)	Turner, 1968a
	Walleye	(20)	
	Lake Whitefish	(32)	
	Cisco	(6)	
	White Sucker	(7)	
	Longnose Sucker	(3)	
Subregion 5: Birch Mountain Upland/Algar Plain			
Legend Lake (97-18-4)	Lake Whitefish	(68)	Turner, 1968b
	Northern Pike	(41)	
	Cisco	(17)	
	White Sucker	(26)	
	Longnose Sucker	(41)	
Namur Lake (97-17-4)	Lake Trout	(42)	Turner, 1968b
	Lake Whitefish	(60)	
	Cisco	(43)	

Table 3. Continued

Lake	Species (sample size)		Reference
Gardiner Lake (98-16-4)	Walleye	(83)	Turner, 1968b
	Northern Pike	(40)	
	Lake Whitefish	(67)	
	Cisco	(43)	
	Longnose Sucker	(2)	
	White Sucker	(2)	
	Yellow Perch	(4)	
Unnamed Lake (99-16-4)	Walleye	(33)	Turner, 1968b
	Northern Pike	(13)	
	Lake Whitefish	(11)	
	Cisco	(31)	
	White Sucker	(3)	
	Yellow Perch	(7)	
Unnamed Lake (100-15-4)	Walleye	(7)	
	Northern Pike	(11)	
	Lake Whitefish	(75)	
	Cisco	(7)	
	Yellow Perch	(9)	
Subregion 6: Athabasca Plain			
Rene Lake (104-1-4)	Northern Pike	(17)	Turner 1968a
	Lake Whitefish	(52)	
Algar Lake (105-1-5)	Northern Pike	(8)	Turner, 1968a
	Lake Whitefish	(60)	
Unnamed Lake (106-3-4)	Northern Pike	(24)	Turner, 1968a
	White Sucker	(24)	
Unnamed Lake (107-4-4)	Northern Pike	(34)	Turner, 1968a
	Lake Trout	(2)	
	Lake Whitefish	(64)	
Unnamed Lakes on Crown Creek (107-3-4) combined sample	Lake Whitefish	(52)	Turner, 1968b
	White Sucker	(15)	
Brander Lake (109-1-4)	Northern Pike	(31)	Turner, 1968b
	Lake Whitefish	(49)	
	Cisco	(11)	
Unnamed Lake (109-1-4)	Northern Pike	(6)	Turner, 1968b
	Lake Whitefish	(35)	

rearing, feeding and wintering are unknown.

The goldeye and walleye in the Peace-Athabasca Delta have been studied in greater detail than other species and than in other areas.

The walleye utilizing the Richardson Lake complex for spawning have been investigated since 1965 (Bidgood, 1965), with fairly intensive studies being conducted in 1967, 1971, 1972 (Bidgood, 1967, 1971, 1972). Bidgood (1972) estimated that the spawning population of walleye in Richardson Lake may range from 500 thousand to one million fish. The migration of adult and young-of-the-year walleye into and out of the Richardson Lake complex during May and June, and the relationship of water levels and water direction to these movements, is known. As well, the age, growth, and maturity of the spawning population has been examined. Some information is available on the post-spawning movements of Richardson Lake walleye within Lake Athabasca. During 1975, the walleye in Richardson Lake were scheduled to receive investigation during the Peace-Athabasca Delta Fisheries Monitoring Project (Canadian Wildlife Service and the Research Secretariat of Alberta Environment[1]).

Goldeye in the Peace-Athabasca Delta have been studied in the Lake Claire-Mamawi Lake area for five years (1971 to 1975 inclusive) by the Canadian Wildlife Service (A.H. Kooyman, pers. comm.). Fairly intensive

[1]Study being conducted by LGL Associates, under direction of the Fisheries Subcommittee of the Peace-Athabasca Delta Monitoring Program (G. Townsend, pers. comm.).

investigations were carried out in 1972, 1973 and 1974 (A.H. Kooyman, pers. comm.). The studies have centered on a spawning population ranging in size from approximately 20,000 in 1975 to in excess of 100,000 individuals in 1971 (A.H. Kooyman, pers. comm.). Certain aspects of the biology of the Lake Claire-Mamawi Lake goldeye are well known; in particular, the seasonal migrations of adult, yearling and young-of-the-year fish. The age, composition, sex ratio, and reproductive biology of the spawning populations have also been investigated. In addition, the food habits and growth of yearling and young-of-the-year goldeye have been examined. Reports on the 1971 and 1972 investigations have been published (Donald and Kooyman, 1973, 1974; Kooyman, 1972). As yet, no results of the studies in 1973, 1974 and 1975 have been published and several papers will be forthcoming. Like the walleye, goldeye will also be studied during 1975 as part of the Peace-Athabasca Delta Fisheries Monitoring Program (G. Townsend, pers. comm.).

C. Importance

Four groups of lakes are noteworthy for their importance and contribution to the aquatic resources of the AOSERP area. The lakes which are known primarily for their fisheries and/or recreational potential are: Lake Athabasca and lakes of the Peace-Athabasca Delta; subregion 4 lakes; the Namur-Gardiner Lake group of subregion 5; and the Gregoire-Gipsy Lake group of subregion 2. In addition to these larger lakes, many small lakes may be important to the aquatic environment of the lower

Athabasca River drainage through their hydrological influence on local river and stream systems. Examples of these latter lakes are those associated with the Maybelle River, Eleanor Creek and the headwaters of the Christina River.

Synopsis of Information Regarding Rivers and Streams

A. Physical and Biological Limnology

The limnology of lotic waters in the AOSERP region is poorly known. The large number of fluvial systems, the inaccessibility within the AOSERP region, and the inherent difficulties in sampling streams and rivers are partially responsible for this lack of knowledge. In addition, previous biological investigations of the region have singularly emphasized the study of fish populations. Limnological information is only beginning to accumulate due to the current interest in the resources of the Athabasca Oil Sands.

A variety of physical river or stream types is found within the AOSERP study area. The general hydrologic and water quality characteristics of this large region have been discussed in a previous section. The known hydrologic characteristics of many of the individual river basins in the area are discussed in the Northeast Alberta Regional Plan Project reports of NHCL (1974, 1975a). A list of the basins discussed by NHCL (1974, 1975a) is presented in Table 4.

Table 4. River basins discussed in the report Hydrologic Aspects of River Basins in the Northeast Alberta Region prepared by Northwest Hydraulic Consultants Ltd. (NHCL, 1975a).

Athabasca River	Algar River
Beaver River	Birch River
Buffalo Creek	Christina River
Gregoire River	Georges Creek
Gordon River	Clearwater River
Edwin Creek	Eleanor Creek
Ells River*	Firebag River*
Florence Lake & Winefred Lake	Grayling Creek
Hangingstone River	Saline Creek
Harrison River	High Hill River
Horse River	Keane Creek
MacKay River*	Maybelle River
Muskeg River*	Rattlepan Creek
Richardson River	Slave River
Steepbank River	Wylie Lake-Bryant Lake Basin
Basins north of Lake Athabasca (Dog River, Bocquene River, LaButte River, Ryan Creek)	
Basins west of Athabasca River (Tar River, Calumet River, Pierre River, Unnamed Creek, Eymundson Creek)*	

*Also discussed in NHCL (1974).

The discharge of selected fluvial systems in the study region has been monitored by the Water Survey of Canada (Inland Waters Directorate of Environment Canada). In 1975, this program was expanded to include thirteen additional locations. The locations of stream gauging stations in the study area are presented in Table 1. Most of these stations will be monitored the year around. At present, winter discharge records for many of the small systems in the AOSERP region are lacking. However, the winter discharge of several streams in northeast Alberta (see Table 5) was investigated by NHCL (1975b).

To date, no single agency has been responsible for the collection of water quality information in the AOSERP region. Several groups have been involved including: the Inland Waters Directorate of Environment Canada; the Pollution Control Division (Water Quality Control Branch) of the Alberta Department of Environment; Syncrude Canada Ltd.; and Shell Canada Ltd. The locations sampled by each of the preceding groups are given in Table 6. Both Syncrude Canada Ltd. and Shell Canada Ltd. have initiated surface water quality monitoring as part of their respective environmental programs. The monitoring programs appear to operate at monthly sampling frequencies during the summer and at two month or three month intervals during the winter. The Beaver River (Beaver Creek) and Poplar Creek are sampled by Syncrude, while Shell surveyed the Muskeg River and Hartley Creek. Both Shell and Syncrude analyze water from the Athabasca River. The Alberta Department of Environment has investigated

Table 5. Streams and rivers for which winter flows have been investigated (NHCL, 1975b).

Eymundson Creek	Tar River
MacKay River	Dover River
Dunkirk River	Ells River
Namur River	Beaver River
Firebag River	Marguerite River
Muskeg River	Hartley Creek
Steepbank River	North Steepbank River

Table 6. Water quality sampling locations in northeast Alberta.

Inland Water Directorate, Environment Canada

Clearwater River at Draper
Athabasca River below Fort McMurray
Peace River at Peace Point
Birch River below Alice Creek
Slave River at Fitzgerald
Bench Mark Creek near Fort Smith

Pollution Control Division, Alberta Department of Environment

Alice Creek (1 sample)
Birch River (1 sample)
McIvor River (1 sample)
Dover River (5 samples)
Eymundson Creek (1 sample)
Horse Creek (3 samples)
Hangingstone River (4 samples)
Prairie Creek (1 sample)
Saline Creek (1 sample)
Saprae Creek (1 sample)
Gregoire River (1 sample)
Surmont Creek (1 sample)
High Hill River (2 samples)
Christina River (4 samples)
Clearwater River (5 samples)
Athabasca River (5 samples)
MacKay River (6 samples)
Ells River (7 samples)
Muskeg River (5 samples)
Steepbank River (6 samples)
Firebag River (3 samples)

Syncrude Canada Ltd.

Beaver Creek
Poplar Creek

Shell Canada Ltd.

Muskeg River
Hartley Creek

(since 1972) the largest number of fluvial systems (21): however, the number of samples per system is low (one to six). The program is operational only during the open water season and no sampling routine was established. The water quality program of the Inland Waters Directorate has only four permanent stations (year-round operation) but collects the greatest number of samples per station (approximately 60). All water quality programs have been similar in that dissolved solids and salts received the bulk of analyses while heavy metals were not investigated routinely. The result is that background levels of heavy metals in AOSERP streams and rivers are poorly understood.

The water quality (including heavy metals) of the Peace-Athabasca Delta was investigated during the Peace-Athabasca studies and is discussed by Reeder and Fee (1972). This study also included a winter water quality survey. The stream and river monitoring stations of Reeder and Fee (1972) are presented in Table 7. Additional water quality information is available for selected AOSERP streams and rivers in the reports of RRCS (1975a, Appendix IV), Griffiths (1973) and Bidgood (1966a).

In the study of Griffiths (1973), 38 fluvial systems were investigated. However, only 10 streams or rivers received chemical analysis at two or more locations. The streams and rivers in the AOSERP region (all studies combined) on which at least one analysis of water chemistry has been carried out are presented in Appendix III.

Table 7. Water quality monitoring stations, Reeder and Fee (1972).

Station Name	Station Location	Latitude	Longitude	Frequency
Peace River	at Peace Point	59°07'20"	112°27'20"	Monthly
Athabasca	at Embarras Airport	58°11'98"	111°23'12"	"
Birch River	near mouth	58°32'18"	112°15'6"	"
Richardson River	near mouth	58°25'	11°23'12"	"
Riviere des Roches	at outlet Athabasca Lake	58°49'36"	11°16'48"	"
McFarlane River	at outlet Davy Lake	58°58'24"	108°10'30"	"
Fond du Lac River	at outlet Black Lake	59°10'	105°	"
McIvor River	near mouth	58°18'6"	112°1'48"	"
Old Fort River	near mouth	58°36'18"	110°28'24"	"
Harrison River	near mouth	58°41'	110°20'24"	"
William River	near mouth	59°6'54"	109°16'54"	"
Crown Creek	at mouth	58°36'18"	110°29'30"	Periodic
Clarence Creek	at mouth	58°42'42"	110°17'36"	"
Quatre Fourches	north of jnt. of Forks	58°39'42"	111°18'54"	Monthly
Dunville Creek	near mouth	58°59'18"	109°5'42"	Periodic
Maybelle River	near mouth	58°22'54"	110°57'36"	Monthly
Keane Creek	near mouth	58°26'6"	110°52'12"	Periodic
Serwatka	near mouth	58°59'18"	109°4'6"	"

The biological aspects of stream limnology, like the physical aspects, have received relatively little investigation. The bulk of the biological information on rivers and streams in the AOSERP area was obtained during the preliminary biological surveys of Griffiths (1973) and Turner (1968a) under the sponsorship of the Alberta Fish and Wildlife Division. These studies concentrated on systems in the southern half of the study area (south of Tp 101) and were primarily designed to assess the fishery potential of the region. Samples of benthic invertebrates and water chemistry were collected at least once during the investigation of the majority of rivers and streams. The limnology of the Peace-Athabasca Delta has been discussed in the section on lakes. Limnological information is lacking on systems north of Lake Athabasca, the Athabasca, Peace and Slave rivers.

Of the 41 streams and rivers examined (38 by Griffiths, 1973, and three by Turner, 1968b), only 14 were sampled at more than one location, only three at more than three locations, and none were sampled at more than five locations. For only six streams, information is available on more than a single benthic sample. In these cases, samples from two different sites are reported. Benthic samples were generally identified to the lowest convenient taxonomic unit (eg. genus or family for Plecoptera, Epheroptera and Tricoptera; and family for Diptera). No indication of the relative abundance or distribution of the major faunal components was reported. Since the aforementioned preliminary biological surveys dealt almost exclusively with the main channel of the selected river or creek, very little information is available on their tributary systems.

The invertebrates of the Muskeg River and Hartley Creek have been investigated during studies of the base-line environmental conditions of Shell Oil Sands Lease #13 and Home Lease #30 (M. Raisbeck, pers. comm.). However, none of these studies has been released and they are expected to be only preliminary in content.

To date, only two studies have dealt with biological limnology specifically. These studies were carried out on Poplar Creek (RRCS, 1974b) and Beaver Creek (RRCS, 1974a) under the environmental program of Syncrude Canada Ltd. The Poplar Creek study was initiated to establish base-line aquatic conditions, whereas in Beaver Creek, the effects of pumping saline groundwater into the creek were examined. Both studies included routine sampling (surber sampler) of benthic invertebrates throughout the year. Organisms were sorted to the lowest convenient taxonomic unit (usually family or genus) and the abundance and density of major groups discussed. In addition, the species diversity at each sample station was calculated and compared with that found at other stations. In 1975, the study on Poplar Creek was continued and expanded to include drift sam plingof invertebrates.

A summary of the type and detail of limnological information available on streams and rivers in the AOSERP region and immediate vicinity is presented in Appendix III.

B. Fisheries Resources

Information on the life history, and general biology of streams and river fish populations residing within the AOSERP study area is generally lacking. This lack of data is partially a function of the large numbers of fluvial systems in the region and the preliminary nature of the fisheries studies carried out to date. In addition, the problems associated with sampling stream or river dwelling species particularly during certain critical life history periods (eg. spawning during spring break-up) and the fact that populations tend to be extremely mobile makes identification of critical areas as well as the establishment of habitat utilization patterns extremely difficult without a considerable expenditure of effort (time, money, personnel and equipment). The sport fisheries potential of 13 major and two minor watersheds (38 rivers and streams) has been investigated by Griffiths (1973). In addition, Griffiths extracted pertinent information from the reports by Bradley (1969), Turner (1968a, 1968b) and Bidgood (1966b). An extremely short study period (August, 1972), a large study area (approximately 11,340 sq mi) and a lack of previous fishery information imposed certain limitations on the study by Griffiths (1973). As a result tributaries or small watersheds were rarely studied in any detail. Major systems were rarely sampled at more than three locations regardless of the length of the river or stream. On 12 rivers (or streams) fish were sampled at more than one location; six were sampled at three or more sites. The watersheds surveyed by Griffiths (1973) are presented in Appendix IV.

The classification system (Table 8) used by Griffiths to establish the sport fish potential or habitat capability of a stream or river involved a rigid point method, with equal weight for all physical factors. The system was derived primarily for use on a stream or river with an overwintering fish population. It does not take into account the different habitat requirements for different fish species. In addition, the potential for seasonal utilization of a stream for spawning, rearing, or feeding functions is not adequately considered. Griffith's (1973) classification was useful in identifying streams of high importance but ineffective in identifying medium and low quality streams. In spite of the many limitations of his study, Griffiths (1973) was able to identify four high quality watersheds in the AOSERP region. These watersheds are: Clearwater, Firebag, Ells and Steepbank rivers.

In the early 1970's interest in the oil sands prompted the Alberta Fish and Wildlife Division to examine the fisheries potential of the Beaver River (Robertson, 1970). Syncrude Canada Ltd. subsequently investigated the same river (RRCS, 1971b). More recently, studies initiated by Syncrude Canada Ltd. (in particular RRCS, 1973a, 1974a, 1974b; Aquatic Environments, 1975) and Shell Canada Ltd. (Lombard North Group, 1973; RRCS, 1973a, 1974b, 1974c) have involved investigations of the biology of fish populations in Beaver Creek (Beaver River), Poplar Creek, Muskeg River, Hartley Creek and the Athabasca River. The Athabasca River is under investigation only in the vicinity of the Syncrude lease. With the excep-

Table 8. Score sheet for stream classification.[1]

Factor	Unit	Score
Flow (minimum winter)	Good	5
	Shallow riffle	3
	Intermittent	1
Summer temperature	3 months over 15°C	5
	3 months over 12°C	3
	3 months less than 12°C	1
Depths of pools	Greater than 3'	5
	1'-3'	3
	Less than 1'	1
Frequency of pools	45 - 60%	5
	60 - 80% or 30 - 45%	3
	Greater than 80% or less than 30%	1
Refugia (banks, logs, deep still pools)	Good	5
	Fair	3
	Poor	1
Nutrients	Good	5
	Fair	3
	Poor	1
Bank cover (amount of shading and bank stability)	Good	5
	Fair	3
	Poor	1
Substrate type of riffle	Gravel, rubble	5
	Sand	3
	Silt, mud or large boulders	1
Land utilization which will or has adversely affected the stream for 5 to 10 years	Grazing Logging Pollution Mineral exporation	-1 to -5

CLASSES

Class 1	Score 35-40	Class 3	Score 21-27
Class 2	Score 28-34	Class 4	Score 1-20

[1]Griffiths (1973).

tion of studies on the goldeye and walleye in the Peace-Athabasca Delta, little is known of the fish resources of lotic systems north of Township 101. The type and detail of fisheries information available from the studies of Griffiths (1973), Robertson (1970), and RRCS (1971, 1973a, 1973b, 1974a, 1974b, 1974c) are shown in Table 9.

Generally, the distribution of large fish species (particularly sport fish) within the ASOERP region is known but information on aspects of the life history, behavior or general biology of any species is lacking. Northern pike, Arctic grayling, white suckers and longnose suckers appear to be widely distributed in both large and small lotic systems. Large numbers of white suckers and longnose suckers have been located spawning in Beaver Creek (RRCS, 1973a) and in the Muskeg River (RRCS, 1974c). During the summer of 1974 white suckers tagged in Beaver Creek (1973) and the Muskeg River (1974) were recaptured in Lake Athabasca (RRCS, 1974c). Yellow walleye are also widely distributed in the AOSERP region but appear to be restricted to the lower reaches of the larger systems such as the Christina, MacKay, Ells and Firebag rivers. Walleye are also found in the Athabasca; and the mainstem Clearwater rivers. In addition, walleye have been collected in the confluences of the Athabasca River with the MacKay and Muskeg rivers, and Beaver Creek. During certain periods of the year goldeye are common in the channels of the Peace-Athabasca Delta (Kooyman, 1972; Donald and Kooyman, 1973) and have been documented in the Birch and McIvor rivers (both of which are tributaries to Lake Claire). Nothing is known of the distribution of stream fish populations north of Lake Athabasca.

Table 9. Fishery studies in northeast Alberta: detail of information collected.

Study→ Information Available↓	Griffiths 1973	Robertson 1970	RRCS 1971	RRCS 1973a, 1973b	RRCS 1974a	RRCS 1974b	RRCS 1974c
Species Composition	+	+	+	+	+	+	+
Species Abundance	–	–	+	+	–	–	+
Habitat							
General Description	+	+	+	+	+	+	+
Description of Specific Sites	–	–	–	+	–	–	+
Life History Information							
Age	+[1]	–	–	–	–	–	+[3]
Length-Weight Relationships	+[1]	–	–	+[2]	–	–	+[3]
Maturity	–	–	–	–	–	–	+[3]
Reproduction	–	–	–	+[2]	–	–	+[3]
Movements and Migrations	–	–	–	+[2]	–	–	+[3]
Utilization of Athabasca River	–	–	–	+[2]	–	–	+[3]
Critical Areas Identified							
Spawning	–	–	–	+	–	–	+
Rearing	–	–	–	–	–	–	–
Feeding	–	–	–	–	–	–	–
Wintering	–	–	–	–	–	–	–
Fish Production							
General	+	+	+	+	–	–	+
Commercial	–	–	–	–	–	–	–
Sport	–	–	–	–	–	–	–

\+ - data present
+[1] - data present only on Arctic grayling in the High Hill River, Ells River and Namur River.
+[2] - species discussed: yellow walleye, northern pike, longnose sucker, white sucker, and Arctic grayling
+[3] - species discussed: yellow walleye, northern pike, longnose sucker, white sucker Arctic grayling, and mountain whitefish.
\- - indicates no data collected.

During the Northeast Alberta Regional Plan Project, the fishery resources of the majority of the streams and rivers in the AOSERP study area were assessed by RRCS (1975a). This assessment was based largely on existing fisheries information. A regional assessment was presented in Volume I, "Northeast Alberta Regional Plan Project Fishery Resources, Regional Assessment" while data on individual rivers and streams were presented in Volume II, "Northeast Alberta Regional Plan Project Fishery Resources, Technical Appendices". In each drainage basin discussed in Volume II (see Appendix V), the longitudinal gradient profile of each major river or stream was constructed. Where sufficient information existed, tentative gradient zones were established. The physical features of the zone as well as fish species present and their distribution were indicated. Where possible the important features of a system, their significance and value were outlined. The rivers rated with exceptionally high importance to the region were: the Athabasca, Clearwater, Firebag, Ells, Steepbank, MacKay, and Birch rivers.

The gradient classification system of RRCS (1975a) should be regarded as "preliminary" since proposed field studies which were designed to establish the validity and confidence limits of the system were not approved. It was recognized that as research fills in the current gaps in fishery knowledge in northeast Alberta, modifications and revisions to the classification will be required.

BIBLIOGRAPHY

Alberta Department of the Environment. 1975. Athabasca oil sands Fort McMurray Alberta area: socio-economic and environmental studies. (Biblio.).

Aquatic Environments Limited. 1975. This report will deal with aquatic investigations of the Athabasca River and Beaver Creek, prepared for Syncrude Canada Ltd. (In progress).

Bayrock, L. and J.D. Root. 1972. Geology of the Peace-Athabasca Delta. *In*: The Peace-Athabasca delta project, Technical Appendices. Volume I, Hydrologic Investigations, Peace-Athabasca Delta Project Study Group. 47 pp.

Bennett, R.M. and J.R. Card. 1972. History of water levels. *In*: The Peace-Athabasca delta project, Technical Appendices. Volume I, Hydrologic Investigations, Peace-Athabasca Delta Project Study Group. 21 pp.

Bidgood, Bryant F. 1965. Spring movement of walleyes into Richardson Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

________________. 1966a. Water quality study-Athabasca River. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep. 13 pp.

________________. 1966b. Richardson Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep. 6 pp.

________________. 1967. Ecology of walleye in Richardson Lake-Lake Athabasca complex. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 21 pp.

________________. 1971. Ecology of walleye (*Stizostedion vitreum vitreum*) in the Richardson Lake-Lake Athabasca complex. *In*: R.E. Reinelt *et al.* (eds.), Proceedings of the Peace-Athabasca Delta Symposium. Univ. Alberta, Edmonton. pp. 187-203.

________________. 1972. Walleye and water levels in Lake Athabasca. *In*: The Peace-Athabasca delta project, Technical Appendices. Volume II, Ecological Investigations, Peace-Athabasca Delta Project Study Group. 20 pp.

Bradley, G.M. 1969. Preliminary biological survey of six lakes in northern Alberta. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 110 pp.

Card, J.R.. 1972a. Factors influencing water levels. In: The Peace-Athabasca delta project, Technical Appendices. Volume I, Hydrological Investigations, Peace-Athabasca Delta Project Study Group. 16 pp.

________. 1972b. Peace River flows and their effect. *In*: The Peace-Athabasca delta project, Technical Appendices. Volume I. Hydrological Investigations, Peace-Athabasca Delta Project Study Group. 16 pp.

Donald, D.B. and A.H. Kooyman. 1973. Status of the goldeye (*Hiodon alosoides*). Populations in the Peace-Athabasca Delta, 1971-1972. Can. Wildl. Serv. Manuscr. Rep. 72 pp.

________________________. 1974. Status of the goldeye (*Hiodon alosoides*). Populations in Peace-Athabasca Delta of Wood Buffalo National Park (1971-1973). Can. Wildl. Serv. Rep. prepared for Parks Canada.

Fernet, D.A. 1972. Lake Claire goldeye study: young of year sampling program July and August 1971. Manuscr. Rep., Can. Wildl. Serv.

Gallup, D.N., P. Van der Giessen and H. Boerger. 1971. A survey of plankton and bottom invertebrates of the Peace-Athabasca Delta Region. *In*: Peace Athabasca delta project. Technical Appendices. Volume II. Ecological Investigations, Peace-Athabasca Delta Project Study Group. 36 pp.

Graham, D. 1971. Sediment investigations. *In*: The Peace-Athabasca delta project, Technical Appendices. Volume I. Hydrologic Investigations, Peace-Athabasca Delta Project Study Group. 19 pp.

Griffiths, W.E. 1973. Preliminary fisheries survey of the Fort McMurray Tar sand area. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 618 pp.

Home Oil Ltd. ____. Unpublished reports and data pertaining to the environment of Tar-Sand Lease No. 30.

Kooyman, A.H. 1972. Status of goldeye, (*Hiodon alosoides*). Populations of the Peace-Athabasca Delta. *In*: The Peace-Athabasca delta project, Technical Appendices. Volume II, Ecological Investigations, Peace-Athabasca Delta Project Study Group. 26 pp.

Lombard North Group Ltd. 1973. Supplementary ecological base-line measurements of tar sands Lease C-13. Report prepared for Shell Canada Ltd.

McDonald, D.G. 1966a. Bocquene Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1966b. North Leland Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1966c. Tulip Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Ablerta. Manuscr. Rep.

__________. 1966d. Myers Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1966e. Wylie Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Ablerta. Manuscr. Rep.

Nielson, G. 1972. Groundwater investigations. *In*: The Peace-Athabasca delta project, Technical Appendices. Volume I, Hydrologic Investigations, Peace-Athabasca Delta Project Study Group. 29 pp.

Northcote, T.G. and P.A. Larkin. 1963. Western Canada. *In*: D.G. Frey, Limnology in North America. Univ. Wisconsin Press, Madison, Wisconsin:451-485.

Northwest Hydraulic Consultants Ltd. 1974. Northeast Alberta regional plan, water resources study, sector I. Report prepared for Ekistic Design Consultants Ltd. 27 pp. + appendices.

__________________________. 1975a. Northeast Alberta regional plan, basins in the northeast Alberta region. Report prepared for Ekistic Design Consultants Ltd. 16 pp. + appendices.

__________________________. 1975b. Preliminary investigations of minimum flows of selected rivers in section I in the northeast Alberta region. Report prepared for Ekistic Design Consultants Ltd. 10 pp. + tables + appendices.

__________________________. 1975c. Working paper on probable hydrological impact of oil sands development. Report prepared for Ekistic Design Consultants Ltd. 26 pp.

Peace-Athabasca Delta Project. 1973. Technical report. A report on low water levels in Lake Athabasca and their effect on the Peace-Athabasca Delta. Peace-Athabasca Delta Project Group. 176 pp.

Reeder, S. 1971. Interim water quality report. Peace-Athabasca Delta Study, Winter 1971. Environment Canada, Inland Water Branch, Calgary, Alberta. Manuscr. Rep.

Reeder, S. and P. Fee. 1972. Water quality of the Peace-Athabasca Delta. *In*: The Peace-Athabasca delta project, Technical Appendices. Volume I. Hydrological Investigations. Peace-Athabasca Delta Project Study Group.

Renewable Resources Consulting Services. 1971. A fisheries survey of the Beaver River. Prepared for Syncrude Canada Ltd. 45 pp.

____. 1973a. An investigation of the spring spawning migrations in Beaver Creek, Alberta. Prepared for Syncrude Canada Ltd. 42 pp.

____. 1973b. Ecological base-line report: Athabasca Tar Sands Lease No. 17. Prepared for Syncrude Canada Ltd. Various pagings + Appendices.

____. 1974a. An investigation of saline effluent effects on the biota of Beaver Creek. Prepared for Syncrude Canada Ltd. 46 pp.

____. 1974b. Base-line environmental studies of Ruth Lake and Poplar Creek. Prepared for Syncrude Canada Ltd. 148 pp.

____. 1974c. Fisheries investigation of the Muskeg River and Hartley Creek. Prepared for Shell Oil Ltd. and Home Oil Ltd. 127 pp.

____. 1975a. Northwest Alberta regional plan project. Fishery Resources, Volume II. Technical Appendices: Appendix II (Summaries of streams in northeast Alberta) and Appendix IV (Results of aquatic field investigations, September 1974). Prepared for Ekistic Design Consultants Ltd. 389 pp.

____. 1975b. Base-line environmental studies of Ruth Lake and Poplar Creek. Prepared for Syncrude Canada Ltd. Ongoing study.

Rhude, L. 1975. Preliminary limnological and biological survey of some shield lakes in Alberta. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. (In progress).

Robertson, Michael R. 1970. A survey of the Beaver River with respect to fisheries potential. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 24 pp.

Shell Canada Resources Ltd. Results of base-line environmental studies. Unpub. rep. and data on the aquatic fauna and/or water quality of the Muskeg River, Hartley Creek, and the Athabasca River.

____________________. 1975. Environmental impact assessment. Submitted to Alberta Government, Summer 1975.

Shultz, G.H. 1955. A report of investigations of the 1954 goldeye fishery in Lake Claire, Wood Buffalo National Park, Alberta. Can. Wildl. Serv. Manuscr. Rep. 17 pp.

Sprules, W.M. 1950. A report of the Lake Claire goldeye fishery for 1949. Fish. Res. Bd. Can. Manuscr. Rep. No. 470. 14 pp.

Syncrude Canada Ltd. 1973. The habitat of Syncrude tar sands lease No. 17. Syncrude Environmental Research Monograph 1973-1. 40 pp.

__________. 1973. Environmental impact assessment. Volume I: Overview. Volume II: Consideration of resources development alternatives. Volume III: Base-line information. Volume IV: Supporting studies.

__________. ____. Unpublished water quality data on the Athabasca River, Poplar Creek, and the Beaver River (Beaver Creek).

Turner, W.R. 1966. Hooker Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1967a. Barrow Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1967b. Darwin Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1967c. Cockscomb Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Ablerta. Manuscrp. Rep.

__________. 1967d. Colin Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1967e. Andrew Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1967f. Charles Lake. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Manuscr. Rep.

__________. 1968a. A preliminary biological survey of waters in the Maybelle River, Keane Creek, Crown Creek, Old Fort River, and Richardson River drainages. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 158 pp.

__________. 1968b. A preliminary biological survey of waters in the Birch Mountains, Alberta. Alberta Dept. of Lands Forests, Fish and Wildl. Div., Edmonton, Ablerta. 138 pp.

PERSONAL COMMUNICATIONS

Kooyman, A.H. 1975. Canadian Wildlife Service, Environment Canada, Winnipeg, Manitoba.

Raisbeck, M. 1975. Tar Sands Department, Home Oil Limited. Calgary, Alberta.

Spitzer, M. 1975. Water Survey of Canada, Inland Waters Directorate, Envrionment Canada. Calgary, Alberta.

Townsend, G. 1975. Environment Canada, Peace-Athabasca Delta Monitoring Program. Edmonton, Alberta.

APPENDICES

Appendix Ia. Expected Hydrologic Impact of Open Pit Mining.[1]

Associated Subactivity	Probable Effect on the Hydrological Regime	Scale of Effect
Diversion Channels	Rerouting a watercourse would likely produce a diversion channel which is not in regime. Results could be lateral and/or vertical instability, hence higher sediment loads and more delta formation.	Local or regional depending upon size of channel and degree it is from being in regime.
Overburden removal	It is likely that infiltration amounts would be lessened, resulting in more surface runoff, high sediment loads, etc.	Local
Pit Excavation	Pit would act as catch basin for precipitation and groundwater. Would require continuous 'pump out' operations.	Local; unless major subsurface flow path intercepted, then it could be basin-wide.
Tailings deposits	Source of supply for contaminants, which by deep percolation of infiltration water would reach the groundwater regime, or by surface erosion would reach watercourses and lakes.	Local; could be regional depending upon amount and nature of contaminants.
Settling ponds	Leakage of contaminants to surface and subsurface water. Excessive thermal energy could cause adverse microclimatic problems (ie. ice fog in winter).	Local

[1] from NHCL (1975c)

Appendix Ia. Continued

Associated Subactivity	Probable Effect on the Hydrological Regime	Scale of Effect
Road construction	Disruption of surface drainage patterns resulting in faster runoff, higher peak flows, increased surface erosion, unstable channels, higher sediment loads in water courses.	Local, could be regional if on a basin wide scale.
Surface drainage	Vegetation would likely die, more water would get to watercourses, the lag time between precipitation events and subsequent high runoff would be lessened.	Local (but could affect small basin greatly).
Subsurface drainage	Dewatering operations would draw down watertable, resulting in groundwater flow into the area increasing. Lower hydrostatic pressures may allow saline groundwater to enter freshwater aquifer in aquifer compaction and possibly land surface subsidence.	Local, but could be regional if permeabilities encountered were high and the network of dewatering wells basin widespread.
Vegetation removal	Lower retention capability of area would result in earlier response, faster rates of runoff, higher volumes of runoff and higher peak flows in watercourses. Combined effect would be unstable channels, increased soil erosion, higher sediment loads in watercourses and more delta formation.	Local or regional depending upon areas involved, natural revegetation, etc.
Water waste disposal	Act as a pollutant to surface or groundwater systems to lower the quality of the water.	Local or regional depending upon the nature of the effluent and the dilution attainable.

Appendix Ib. Expected Hydrologic Impacts of Industrial Development Associated with Oil Sand Developments.[1]

Associated Subactivity	Probable Effect on the Hydrological Regime	Scale of Effect
Vegetation removal	Lower retention capability of area would result in earlier response, faster rates of runoff, higher volumes of runoff and higher peak flows in watercourses. Combined effect would be unstable channels, increased soil erosion, higher sediment loads in watercourses and more delta formation.	Local or regional depending upon areas involved and form of replacement.
Road and parking lot construction	Areas are impermeable, no infiltration is allowed, very rapid response from precipitation results.	Local; could affect small basin if large industrial center involved.
Industrial water use	Not anticipated to be a problem for area as a whole. However, streamflow from small basins could be overtaxed and the water balance upset.	Local.
Effluent disposal	Would act as a pollutant to surface and groundwater systems, thus lowering water quality.	Local or regional depending upon the nature of the pollution and the dilution attainable.
Alteration of micro climate	Changes to surface albedo, air quality, etc. are not expected to significantly affect the hydrological cycle.	Insignificant.

[1]NHCL (1975c)

APPENDIX II

Sources of Limnological Information for Lakes in the AOSERP Region

Legend:

A, B, C, . . . indicates the source of data for each parameter

L - data limited in scope

R - data present, restricted distribution

S - spot soundings of lake depths only, no contours determined

I - incomplete

G - invertebrates identified to generic level

O - invertebrates identified to order

F - invertebrates identified to family

Information Sources:

A. Renewable Resources Consulting Services Ltd. 1975a. Northwest Alberta regional plan project. Fishery Resources, Volume II. Technical Appendices: Appendix II (Summaries of streams in northeast Alberta) and Appendix IV (Results of aquatic field investigations, September 1974). Prepared for Ekistic Design Consultants Ltd. 389 pp.

B. Renewable Resources Consulting Services Ltd. 1973b. Ecological base-line report: Athabasca Tar Sands Lease No. 17. Prepared for Syncrude Canada Ltd. Various pagings + Appendices.

C. Syncrude Canada Ltd. 1973. The habitat of Syncrude tar sands lease No. 17. Syncrude Environmental Research Monograph 1973-1. 40 pp.

D. Alberta Department of Environment. 1975. Pollution Control Division, Edmonton. Unpublished water quality analysis.

E. Northwest Hydraulic Consultants Ltd. 1974. Northeast Alberta regional plan, water resources study sector I. Report prepared for Ekistic Design Consultants Ltd. 27 pp. + appendices.

F. Northwest Hydraulic Consultants Ltd. 1975a. Hydrological aspects of river basins in the Northeast Alberta region for Ekistic Design Consultants Ltd. 16 pp. + appendices.

G. Bradley, G.M. 1969. Preliminary biological survey of six lakes in northern Alberta. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 110 pp.

H. Renewable Resources Consulting Services. 1974b. Base-line environmental studies of Ruth Lake and Poplar Creek. Prepared for Syncrude Canada Ltd. 148 pp.

I. Syncrude Canada Ltd. ____. Unpublished water quality data.

J. Turner, W.R. 1968a. A preliminary biological survey of waters in the Maybelle River, Keane Creek, Crown Creek, Old Fort River, and Richardson River drainages. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 158 pp.

K. Gallup, D.N., P. Van der Giessen and H. Boerger. 1971. A survey of plankton and bottom invertebrates of the Peace-Athabasca Delta Region. *In*: Peace-Athabasca Delta Project. Technical Appendices. Volume II. Ecological Investigations, Peace-Athabasca Delta Project Study Group. 19 pp.

L. Reeder, S. and P. Fee. 1972. Water quality of the Peace-Athabasca Delta. *In*: Peace-Athabasca Delta Project, Technical Appendices. Volume I. Hydrological Investigations. 122 pp.

M. Bennett, R.M. and J.R. Card. 1972. History of water levels. *In*: The Peace-Athabasca Delta Project, Technical Appendices. Volume I. Hydrologic Investigations, Peace-Athabasca Delta Project Study Group. 21 pp.

N. Turner, W.R. 1968b. A preliminary biological survey of waters in the Birch Mountains, Alberta. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 138 pp.

Subregion 1: Athabasca Lowland

Lake → Parameter ↓	Mildred 93-10-4	Unnamed[1] 93-10-4	Saline 93-10-4	Kearl 95-3-4	Calumet 97-11-4	McClelland 98-9-4	Audet 100-6-4
Morphometry			Source of Information ↓				
Surface Area	ABC	ABC	--	AE	AE	AE	A
Depth Distribution	A^L	--	--	E^L	E^L	A^2E	AG
Mean Depth Calculated	--	--	--	--	--	--	--
Contour Map	--	--	--	E^S	E^S	E^S	--
Discussion of Drainage Patterns	A	ABC	A	AE	AE	AE	A
Physical & Chemical Characteristics							
Thermal Stratification Investigated	--	--	--	--	--	--	--
Secchi Disc Measurements	--	--	--	--	--	A^2	--
Dissolved Oxygen Profiles	--	--	--	--	--	--	--
Chemical Water Analysis	D	--	--	--	--	A^2D	--
Phytoplankton							
Species Composition	--	--	--	--	--	--	--
Relative Abundance	--	--	--	--	--	--	--
Biomass	--	--	--	--	--	--	--
Density	--	--	--	--	--	--	--
Zooplankton							
Species Composition	--	--	--	--	--	--	--
Relative Abundance	--	--	--	--	--	--	--
Density	--	--	--	--	--	--	--
Biomass	--	--	--	--	--	--	--
Benthic Macroinvertebrates							
Species Composition	B^LC^L	--	--	--	--	--	--
Diversity	--	--	--	--	--	--	--
Density	--	--	--	--	--	--	--
Biomass	--	--	--	--	--	--	--
Distribution	--	--	--	--	--	--	--
Substrate Type	--	--	--	--	--	--	--
Aquatic Macrophytes							
Species Composition	B^LC^L	B^LC^L	--	--	--	--	--
Relative Abundance	B^LC^L	--	--	--	--	--	--
Distribution	B^LC^L	B^LC^L	--	--	--	--	--
Primary Investigator(s)	B	B	A	AE	AE	AE	--

[1]Unnamed Lake (93-10-4) Known Locally as Horseshoe Lake
[2]Data in Appendix IV of RRCS (1975)

Subregion 2: Fort McMurray Plain

Lake → Parameter ↓	Algar 84-15-4	Gregoire 86-8-4	Georges 84-5-4	Formby 84-1-4	Birch 85-3-4	Gipsy 86-2-4	Shortt 86-2-4	Gordon 86-3-4	Ruth 92-10-4
Morphometry			Source of Information ↓						
Surface Area	A	AG	A	A	A	AG	A	A	AH
Depth Distribution	--	G	--	--	--	G	--	--	H
Mean Depth Calculated	--	AG	--	--	--	AG	--	--	AH
Contour Map	--	G	--	--	--	G	--	--	H
Discussion of Drainage Patterns	A	AG	A	A	A	AG	A	A	A
Physical & Chemical Characteristics									
Thermal Stratification Investigated	--	G	--	--	--	G	--	--	H
Secchi Disc Measurements	--	G	--	--	--	G	--	--	H
Dissolved Oxygen Profiles	--	G	--	--	--	G	--	--	H
Chemical Water Analysis	--	GD	--	--	--	G	--	--	DHS[R]
Phytoplankton									
Species Composition		G[G]	--	--	--	G[G]	--	--	H
Relative Abundance	--	G	--	--	--	G	--	--	H
Biomass	--	--	--	--	--	--	--	--	--
Density	--	--	--	--	--	--	--	--	H
Zooplankton									
Species Composition	--	G[O]	--	--	--	G[O]	--	--	H
Relative Abundance	--	G	--	--	--	G	--	--	H
Density	--	--	--	--	--	--	--	--	H
Biomass	--	--	--	--	--	--	--	--	H
Benthic Macroinvertebrates									
Species Composition	--	G[O]	--	--	--	G[O]	--	--	H[G]
Diversity	--	--	--	--	--	--	--	--	H
Density	--	G	--	--	--	G	--	--	H
Biomass	--	G	--	--	--	--	--	--	--
Distribution	--	--	--	--	--	--	--	--	--
Substrate Type	--	--	--	--	--	--	--	--	--
Aquatic Macrophytes									
Species Composition	--	--	--	--	--	--	--	--	H
Relative Abundance	--	--	--	--	--	--	--	--	H
Distribution	--	--	--	--	--	--	--	--	H
Primary Investigator(s)	G[3]	G	G[3]	G[3]	G[3]	G	G[3]	G[3]	H

[3]Lake did not merit a detailed survey.

Subregion 3: Peace - Athabasca Delta

Lake → Parameter ↓	Unnamed 103-5-4	Pearson 103-8-4	Barber 105-6-4	Larocque 105-5-4	Unnamed #6 105-5-4	Unnamed #1 105-5-4	Unnamed #5 105-5-4	Unnamed #4 105-5-4	Unnamed #3 105-5-4	Unnamed #2 105-5-4
Morphometry			Source of Information ↓							
Surface Area	AJ	AG	AJ	AJ	AJ	AJ	AJ	AJ	AJ	AJ
Depth Distribution	J	G	J	J	J	--	J	J	--	J
Mean Depth Calculated	AJ	AG	AJ	AJ	AJ	--	AJ	AJ	--	AJ
Contour Map	J	G	J	J	J	--	J	J	--	J
Discussion of Drainage Patterns	AJ	AG	AJ	AJ	AJ	AJ	AJ	AJ	AJ	AJ
Physical & Chemical Characteristics										
Thermal Stratification Investigated	J	G	J	J	--	J	J	--	--	J
Secchi Disc Measurements	J	G	J	J	--	J	J	--	--	J
Dissolved Oxygen Profiles	J	G	J	J	--	J	J	--	--	J
Chemical Water Analysis	J	DG	J	J	--	J	J	--	--	J
Phytoplankton										
Species Composition	J^G	G^G	--	--	--	J^G	J^G	--	--	J^G
Relative Abundance	J	G	--	--	--	J	J	--	--	J
Biomass	--	--	--	--	--	--	--	--	--	--
Density	--	--	--	--	--	--	--	--	--	--
Zooplankton										
Species Composition	J^O	G^O	--	--	--	J^O	J^O	--	--	--
Relative Abundance	J	G	--	--	--	J	J	--	--	--
Density	--	--	--	--	--	--	--	--	--	--
Biomass	--	--	--	--	--	--	--	--	--	--
Benthic Macroinvertebrates										
Species Composition	J^O	G^O	J^O	J^O	J^O	J^O	J^O	J^O	--	J^O
Diversity	--	--	--	--	--	--	--	--	--	--
Density	J	G	J	J	J	J	J	J	--	J
Biomass	J	--	J	J	J	J	J	J	--	J
Distribution	--	--	--	--	--	--	--	--	--	--
Substrate Type	J	--	J	J	J	J	J	J	--	J
Aquatic Macrophytes										
Species Composition	--	--	--	--	--	--	--	--	--	--
Relative Abundance	--	--	--	--	--	--	--	--	--	--
Distribution	--	--	--	--	--	--	--	--	--	--
Investigator	J	G	J	J	J	J	J	J	J	J

Subregion 3: Peace - Athabasca Delta

Lake → Parameter ↓	Claire	Baril	Mamawi	Richardson	Others
Morphometry		Source of Information ↓			
Surface Area	--	M	--	M	--
Depth Distribution	--	--	--	--	--
Mean Depth Calculated	--	--	--	--	--
Contour Map	--	--	--	--	--
Discussion of Drainage Patterns	M	M	M	M	M
Physical & Chemical Characteristics					
Thermal Stratification Investigated	--	--	--	--	--
Secchi Disc Measurements	K^L	--	K^L	K^L	--
Dissolved Oxygen Profiles	--	--	--	--	--
Chemical Water Analysis	K^L	--	K	K	--
Phytoplankton					
Species Composition	K	--	K*	K*	--
Relative Abundance	K	--	K*	K*	--
Biomass	K^+	--	K^+	K^+	--
Density	--	--	--	--	--
Zooplankton					
Species Composition	K	--	K*	K*	--
Relative Abundance	K	--	K*	K*	--
Density	--	--	--	--	--
Biomass	K^+	--	K^+	K^+	--
Benthic Macroinvertebrates					
Species Composition	K^F	--	K^F	K^F	--
Diversity	--	--	--	--	--
Density	--	--	--	--	--
Biomass	K	--	K	K	--
Distribution	--	--	--	--	--
Substrate Type	--	--	--	--	--
Aquatic macrophytes					
Species Composition	--	--	--	--	--
Relative Abundance	--	--	--	--	--
Distribution	--	--	--	--	--
Investigator					

*Results of a single sample, with zooplankton and phytoplankton combined.
+Biomass of zooplankton and phytoplankton combined.

Subregion 5: Birch Mountains Upland/Algar Plain

Lake → Parameter ↓	Legend 97-18-4	Namur 97-17-4	Gardiner 98-16-4	Unnamed 99-16-4	Unnamed 100-15-4
Morphometry		Source of Information ↓			
Surface Area	AN	AN	AN	AN	AN
Depth Distribution	N	N	N	N	N
Mean Depth Calculated	AN	AN	AN	AN	AN
Contour Map	AN	AN	AN	AN	AN
Discussion of Drainage Patterns	AN	AN	AN	AN	AN
Physical & Chemical Characteristics					
Thermal Stratification Investigated	--	N	N	N	N
Secchi Disc Measurements	--	N	N	N	N
Dissolved Oxygen Profiles	--	N	N	N	N
Chemical Water Analysis	N	DN	DN	N	N
Phytoplankton					
Species Composition	--	N^G	N	N	N
Relative Abundance	--	N	N	N	N
Biomass	--	--	--	--	--
Density	--	--	--	--	--
Zooplankton					
Species Composition	--	N^O	N^O	N^O	N^O
Relative Abundance	--	N	N	N	N
Density	--	--	--	--	--
Biomass	--	--	--	--	--
Benthic Macroinvertibrates					
Species Composition	N^O	N^O	N^O	N^O	N^O
Diversity	--	--	--	--	--
Density	N	N	N	N	N
Biomass	N	N	N	N	N
Distribution	--	--	--	--	--
Substrate Type	N	N	N	N	N
Aquatic Macrophytes					
Species Composition	--	--	--	--	--
Relative Abundance	--	--	--	--	--
Distribution	--	--	--	--	--
Investigator	N	N	N	N	N

Subregion 6: Athabasca Plain

Lake → Parameter ↓	Rene 104-1-4	Algar 105-1-4	Unnamed 106-3-4	Unnamed 107-4-4	Unnamed #3 107-3-4	Unnamed #2 107-3-4	Unnamed #1 107-3-4	Unnamed #4 107-3-4	Brander 109-1-4	Unnamed 109-1-4
Morphometry			Source of Information ↓							
Surface Area	AJ	A	AJ	AJ	AJ	AJ	AJ	AJ	AJ	AJ
Depth Distribution	J	--	--	J	J	J	J	J	J	J
Mean Depth Calculated	AJ	--	--	AJ	AJ	AJ	AJ	AJ	AJ	AJ
Contour Map	J	J[I]	--	J	J	J	J	J	J	J
Discussion of Drainage Patterns	AJ	A	AJ	AJ	AJ	AJ	AJ	AJ	AJ	AJ
Physical & Chemical Characteristics										
Thermal Stratification Investigated	J	J	--	J	J	J	J	--	J	J
Secchi Disc Measurements	J	J	--	J	J	J	J	--	J	J
Dissolved Oxygen Profiles	J	J	--	J	J	J	J	--	J	J
Chemical Water Analysis	J	J	--	J	J	J	J	—	J	J
Phytoplankton										
Species Composition	J[G]	J[G]	--	J[G]	J[G]	J[G]	J[G]	--	J[G]	J[G]
Relative Abundance	J	J	--	J	J	J	J	--	J	J
Biomass	--	--	--	--	--	--	--	--	--	--
Density	--	--	--	--	--	--	--	--	--	--
Zooplankton										
Species Composition	J[O]	J[O]	--	J[O]	J[O]	J[O]	J[O]	--	J[O]	J[O]
Relative Abundance	J	J	--	J	J	J	J	--	J	J
Density	--	--	--	--	--	--	--	--	--	--
Biomass	--	--	--	--	--	--	--	--	--	--
Benthic Macroinvertebrates										
Species Composition	J[O]	J[O]	J[O]	J[O]	J[O]	J[O]	J[O]	J[O]	J[O]	J[O]
Diversity	--	--	--	--	--	--	--	--	--	--
Density	J	J	J	J	J	J	J	J	J	J
Biomass	J	J	J	J	J	J	J	J	J	J
Distribution	--	--	--	--	--	--	--	--	--	--
Substrate Type	J	J	J	J	J	J	J	J	J	J
Aquatic Macrophytes										
Species Composition	--	--	--	--	--	--	--	--	--	--
Relative Abundance	--	--	--	--	--	--	--	--	--	--
Distribution	--	--	--	--	--	--	--	--	--	--
Investigator	J	J	J	J	J	J	J	J	J	J

APPENDIX III

Sources of Limnological Information for Rivers in the AOSERP Region

Legend:

A, B, C, . . . indicates the source of data for each parameter

A
- extent of information unavailable

G
- invertebrates identified to the generic level

O
- invertebrates identified to order

Information Sources:

A. Renewable Resources Consulting Services Ltd. 1975a. Northwest Alberta regional plan project. Fishery Resources, Volume II. Technical Appendices: Apendix II (Summaries of streams in northeast Alberta) and Appendix IV (Results of aquatic field investigations, September 1974). Prepared for Ekistic Design Consultants Ltd. 389 pp.

B. Northwest Hydraulic Consultants Ltd. 1975a. Hydrological aspects of river basins in the northeast Alberta region for Ekistic Design Consultants Ltd. 16 pp. + Appendices.

C. Water Survey of Canada. ____. Environment Canada inland waters directorate, Calgary. Unpublished discharge records.

D. Griffiths, W.E. 1973. Preliminary fisheries survey of the Fort McMurray Tar sands area. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 618 pp.

E. Alberta Department of Environment. 1975. Pollution Control Division. Edmonton. Unpublished water quality analysis.

F. Bradley, G.M. 1969. Preliminary biological survey of six lakes in northern Alberta. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. 110 pp.

G. Shell Canada Ltd. ____. Results of base-line environmental studies. Unpub. rep. and data on the aquatic fauna and/or water quality of the Muskeg River, Hartley Creek, and the Athabasca River.

H. Home Oil Ltd. ____. Unpublished reports and data pertaining to the environment of Tar Sand Lease No. 30.

I. Turner, W.R. 1968b. A preliminary biological survey of waters in the Birch Mountains, Alberta. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton, Alberta. Survey report No. 3. 138 pp.

J. Syncrude Canada Ltd. ____. Unpublished water quality data on the Athabasca River, Poplar Creek, and the Beaver River (Beaver Creek).

K. Robertson, M.R. 1970. A survey of the Beaver River with respect to fisheries potential. Alberta Dept. of Lands and Forests, Fish and Wildl. Div., Edmonton. 24 pp.

L. Renewable Resources Consulting Services Ltd. 1971b. A fisheries survey of the Beaver River. Prepared for Syncrude Canada Ltd. 45 pp.

M. Renewable Resources Consulting Services Ltd. 1973a. An investigation of the spring spawning migrations in Beaver Creek, Alberta. Prepared for Syncrude Canada Ltd. 42 pp.

N. Renewable Resources Consulting Services Ltd. 1974b. Base-line environmental studies of Ruth Lake and Poplar Creek. Prepared for Syncrude Canada Ltd. 148 pp.

O. Reeder, S. and P. Fee. 1972. Water quality of the Peace-Athabasca Delta. *In*: The Peace-Athabasca Delta Project, Technical Appendices. Volume I. Hydrological Investigations. Peace-Athabasca Delta Project Study Group.

P. Northwest Hydraulic Consultants Ltd. 1974. Northeast Alberta regional plan, water resources study, sector I. Report prepared for Ekistic Design Consultants Ltd. 27 pp. + Appendices.

Drainage Area 1: Clearwater River

Stream → Parameter ↓	Clearwater R.	Saprae Ck.	Rattlepan Ck.	Edwin Ck.	Prairie Ck.	Christina R.	Gregoire R.	Surmont Ck.	Georges Ck.	Meadow Ck.	Gordon R.	Gipsy Ck.	Hangingstore R.	Saline Ck.	High Hill R.
Stream Profile	AD	A	A	A	-	AD	A	A	A	A	A	A	AD	A	AD
Calculated Stream Gradients	A	A	A	A	-	A	A	A	A	A	A	A	A	A	A
Description & Outline of															
Drainage Basin	ABD	A	B	AB	-	AB	AB	A	AB	A	AB	AB	AB	AB	AB
Discharge Records	CD	-	-	-	-	-	-	-	-	-	-	-	CD	-	-
Current Velocity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chemical Characteristics	DE	E	-	-	E	DE	DE	DE	-	-	-	-	DE	E	DE
Sediment Data	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dates of Break up & Freeze up	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Drift	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Species Composition	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Relative Abundance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Density	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distribution	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benthic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Species Composition	-	-	-	-	-	D^G	D^G	D^G	-	-	-	-	D^G	-	D^G
Relative Abundance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Density	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distribution - Substrate Type	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Winter Sampling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Drainage Area 2: Athabasca River West

Stream → Parameter ↓	Buffalo Ck.	Poplar Ck.	Beaver Ck.	MacKay R.	Dover R.	Dunkirk R.	Ells R.	Redclay Ck.	Unnamed Ck.	Eymundson Ck.	Pierre R.	Calumet R.	Tar R.	Namur R.
Stream Profile	A	A	ADKL	ADQ	A	A	ADQ	A	AQ	AQ	AQ	AQ	AQ	-
Stream Gradients calculated	A	A	A	A	A	A	A	A	A	A	A	A	A	-
Description & Outline of Drainage Basin	AB	A	ABDK	ABDQ	ABD	ABD	ABDQ	A	ABQ	ABQ	ABQ	ABQ	ABQ	-
Discharge	-	C	CDKM	C	C*	C*	C*	-	C*	-	C*	C*	C*	-
Current Velocity	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	LMN	-	-	-	-	-	-	-	-	-	-	-
Chemical Characteristics	-	-	ADKL[A]N	ADE	DE	-	ADE	-	-	DE	-	AD	AD	D[G]I
Sediment Loading	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Break Up & Freeze Up	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates -	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Drift	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Species Composition	-	O[A]	L[O]	-	-	-	-	-	-	-	-	-	-	-
Relative Abundance	-	O	L	-	-	-	-	-	-	-	-	-	-	-
Biomass	-	-	L	-	-	-	-	-	-	-	-	-	-	-
Density	-	-	L	-	-	-	-	-	-	-	-	-	-	-
Distribution	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benthic	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Species Composition	-	O[G]	L[O]N[G]	D[G]	D[G]	-	D[G]	-	-	-	-	-	D[G]	D[G]I
Relative Abundance	-	O	LN[G]	-	-	-	-	-	-	-	-	-	-	-
Biomass	-	-	L	-	-	-	-	-	-	-	-	-	-	-
Density	-	O	N[G]	-	-	-	-	-	-	-	-	-	-	-
Distribution - Substrate Type	-	O	LN	-	-	-	-	-	-	-	-	-	-	-
Winter Sampling	-	O	N	-	-	-	-	-	-	-	-	-	-	-

*Gauging station to be installed in 1975.

Notes:

1) Namur River data was collected and reported in Report I (Turner, 1968). This data is also reported in D (Griffiths, 1973).

2) Beaver Creek data supplied by the Alberta Fish and Wildlife Division was originally collected and reported in K (Robertson, 1970). The Aquatic macrophytes and diversity of benthic invertebrates in Beaver Creek are discussed in N (RRCS, 1974).

3) The diversity of benthic invertebrates in Poplar Creek is discussed in O (RRCS, 1974).

Drainage Area 3: Athabasca River East

Stream → Parameter ↓	Algar R.	Horse R.	Steepbank R.	North Steepbank R.	Muskeg R.	Hartley Ck.	Firebag R.	Eleanor Ck.	Grayling Ck.	Marguerite R.
Stream Profile	A	AD	AD	A	ADQ	AD	ADQ	A	A	A
Calculated Stream Gradients	A	A	A	A	A	A	A	A	A	A
Description & Outline of Drainage Basin	AB	ADB	ADB	ADB	ADBQ	ADB	ADBQ	AB	AB	ADB
Discharge	-	-	C	-	C	C[1]	C*	-	-	-
Current Velocity	-	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-	-	-
Chemical Characteristics	D	DE	DE	DE	ADEG	G	ADE	F	-	ADE
Sediment Loading	-	-	-	-	-	-	-	-	-	-
Break Up & Freeze Up	-	-	-	-	-	-	-	-	-	-
Invertebrates	-	-	-	-	-	-	-	-	-	-
Drift	-	-	-	-	-	-	-	-	-	-
Species Composition	-	-	-	-	-	-	-	-	-	-
Relative Abundance	-	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-	-
Density	-	-	-	-	-	-	-	-	-	-
Distribution	-	-	-	-	-	-	-	-	-	-
Benthic	-	-	-	-	-	-	-	-	-	-
Species Composition	-	D^G	D^G	D^G	D^GG	-	D^G	-	-	D^GGH
Relative Abundance	-	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-	-
Density	-	-	-	-	-	-	-	-	-	-
Distribution - Substrate Type	-	-	-	-	-	-	-	-	-	-
Winter Sampling	-	-	-	-	-	-	-	-	-	-

[1]Spot recordings only, continuous recording gauge to be installed in 1975.
*Gauging station to be installed in 1975.

Drainage Area 4: Lake Claire - Lake Athabasca

Stream → Parameter ↓	Birch R.	McIvor R.	Buckton Ck.	Richardson R.	Maybelle R.	Keane Ck.	Old Fort R.	Harrison R.	Crown Ck.
Stream Profile	A	A	A	A	A	A	A	A	A
Stream Gradients calculated	A	A	A	A	A	A	A	A	A
Drainage Basin Outlined	ABD	ABD	A	AB	AB	AB	A	AB	A
Discharge	C	C	-	C	-	-	C	-	-
Current Velocity	-	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	-	-	-	-	-
Chemical Characterisics	DEP	PEP	-	P	P	P	P	P	P
Sediment Data	C	C	-	-	-	-	C	-	-
Break Up & Freeze Up	-	-	-	-	-	-	-	-	-
Invertebrates -	-	-	-	-	-	-	-	-	-
Drift	-	-	-	-	-	-	-	-	-
Species Composition	-	-	-	-	-	-	-	-	-
Relative Abundance	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-
Density	-	-	-	-	-	-	-	-	-
Distribution	-	-	-	-	-	-	-	-	-
Benthic	-	-	-	-	-	-	-	-	-
Species Composition	D[G]	D[G]	-	-	-	-	-	-	-
Relative Abundance	-	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-	-
Density	-	-	-	-	-	-	-	-	-
Distribution - Substrate Type	-	-	-	-	-	-	-	-	-
Winter Sampling	-	-	-	-	-	-	-	-	-

Appendix IV. Watersheds Investigated by Griffiths (1973)

Athabasca River	Beaver River
Clearwater River	MacKay River
Steepbank River	Ells River
Muskeg River	Birch River
Firebag River	McIvor River
Richardson River	Buckton Creek
Eleanor Creek	Buffalo Creek
Algar River	Poplar Creek
Clark Creek	Tar River
Grayling Creek	Pierre River
Horse River	Calumet River
	Unnamed Creek

Appendix V. Drainage Basins Discussed by RRCS (1975a)

Drainage Area 1: Clearwater River

Clearwater River; Saprae Creek; Rattlepan Creek; Edwin Creek
Christina River
Gregoire River; Surmont Creek; Georges Creek; Meadow Creek
Gordon River; Gipsy Creek
Winefred River; Newby River
Hangingstone River
High Hill River

Drainage Area 2: Athabasca River West

Buffalo Creek
Poplar Creek
Beaver River
MacKay River; Dover River; Dunkirk River
Ells River
Small northern rivers: Redclay Creek; Unnamed Creek; Eymundson Creek; Pierre River; Calumet River; Tar River

---

Drainage Area 3: Athabasca River East

House River
Algar River
Horse River
Steepbank River
Muskeg River
Firebag River
Eleanor Creek
Grayling Creek

Drainage Area 4: Lake Claire-Lake Athabasca

Birch River
McIvor River
Buckton Creek
Richardson River
Maybelle River
Keane Creek
Old Fort River
Harrison River
Crown Creek

Appendix VI. Comments on Sampling Techniques

<u>Aquatic Sampling of Flowing Water in the AOSERP Region</u>

The development of techniques capable of investigating the fish and benthos of lotic environments has lagged far behind the sampling methodology utilized in the study of standing waters. The difficulties of sampling fish and benthos of streams and rivers are well known and are related to a combination of factors including water discharge, water velocity, water depth, substrate variability, and suspended debris. In addition, each technique is somewhat selective in sampling and is functional over a relatively narrow range of environmental conditions.

A. Benthos

Potentially the following benthic samplers or their modifications could be used in the study region: air lift or suction samplers, core samplers, dredges (Ekman, Peterson), grabs, Surber samplers, Hess samplers, and artificial substrates (basket, multiplate). The techniques available for sampling relatively shallow (less than 2 m) habitats with varying current speeds are well known and will not be discussed in this section. In the study area, the greatest sampling difficulties will be encountered in medium to large-sized rivers with moderate to swift currents and depths in excess of 1 to 2 m. Due to the variability in substrate type, current speed, channel morphometry and narrow substrate suitability of most benthic samplers, several sampling techniques should be tested (at least initially) to determine which (if any) yields satisfactory results.

From these initial tests, suitable modifications or perhaps new sampling techniques could be developed. It is expected that in most situations, sampling from a boat will be required.

Of the aforementioned benthic sampling techniques, the following methods could be tested in the Athabasca River and its tributaries: heavy dredges or grabs operated by winches (preferably power); artificial substrates; and samplers operated or assisted by scuba divers. If dredges or grabs are utilized, they must be heavy to ensure a straight descent and a suitable boat will be required. Ideally this boat would be large, stable, and capable of maintaining itself in a swift current. In slower moving sections with gravel or rubble substrates a modified Hess sampler operated by scuba divers might prove useful.

B. Fish

To capture fish species a variety of collecting techniques could be utilized. These are as follows: electrofishers (both boat-mounted and back-pack models), gill nets, fish traps (weir type), fyke nets, pound nets, seines (hand, beach, purse), trawls, (including meter and half meter mets), fish toxicants, and angling. The early life history stages of species with limnetic fry may require special traps such as those described by Faber (1968), Sameoto and Jaroszynski (1969). The functional limitations of each of the previously mentioned techniques are well known. The methods chosen in the AOSERP area will depend on the scope of study (survey or intensive), life history stages desired (considerably more effort is required to obtain immature individuals than mature ones), area of sampling, size of sampling area, habitat type (eg. pool, riffle), substrate type, and accessibility of sampling location. The method will also depend on whether dead or live capture of fish is required. A combination of several sampling techniques should prove most suitable for the investigation of fish populations in any river system.

In addition to gill nets and hand seines, RRCS has used back-pack and boat-mounted electrofishers and weir type fish traps with success in the oil sands region. Most of these techniques were used during the high water spring runoff period. Weir type fish traps are extremely susceptible to damage by high spring flows. A fish trap was maintained in Beaver Creek in flows of 120 cfs but a similar trap was washed out in the Muskeg River in flows of 800 cfs. Electrofishing (back-pack and boat) and fish traps (weir and hoop) have also been used successfully in studies on the Peace River in northern British Columbia. In order to determine what sampling methods may be most appripriate, it is recommended that a detailed site investigation be undertaken prior to any study.