The Hon. J.W. (Jack) Cookson
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

Sir:

Enclosed is the report "Aquatic Biophysical Inventory of Major Tributaries in the AOSERP Study Area. Volume I: Summary Report."

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Water System, under the Canada-Alberta Agreement of February 1975 (amended September 1977).

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

AQUATIC BIOPHYSICAL INVENTORY OF MAJOR TRIBUTARIES IN THE AOSERP STUDY AREA

VOLUME I

SUMMARY REPORT

by

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for

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

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ABSTRACT

This report summarizes and compares the physical characteristics of nine streams within five watersheds (Firebag, Muskeg, Steepbank, MacKay, and Ells) in the AOSERP study area. The distributions and relative abundances of fish in each stream and watershed are also described and related to the physical characteristics that tend to promote or limit sport fish production. The system of reach classification and biophysical measurements developed by Chamberlin and Humphries (1977) was used throughout the present study. The detailed results of this study are presented in the accompanying atlas that forms Volume II of this report (Walder et al. 1980).

From 16 to 24 species of fish were found in each watershed. Forage fish (lake chub, pearl dace, longnose dace, trout-perch, brook stickleback, slimy sculpin) and white and longnose suckers were the most abundant fish in every stream or river studied. The most important and widespread sport fish present were (in order of decreasing abundance) arctic grayling, northern pike, and walleye. Other species of sport fish (burbot, lake whitefish, mountain whitefish, yellow perch, Dolly Varden, and goldeye) were found in small numbers, and were almost always confined to the lower reaches of the rivers in proximity to the Athabasca River. A good correlation was found between physical characteristics of streams and the distributions and abundances of fish.

Present information suggests that the following general ratings for sport fish potential can be applied to the five watersheds that were studied: Firebag River watershed, excellent; Muskeg River watershed, poor to moderate; Steepbank River, moderate; MacKay River watershed, poor to possibly moderate; and Ells River, excellent. These ratings are based only on comparisons among the studied watersheds; they do not consider productivity of other watersheds within or beyond the boundaries of the AOSERP study area.

ACKNOWLEDGEMENTS

These acknowledgements are for both the present report and the accompanying Volume II (Walder et al. 1980). We would like to thank R. Seidner, formerly with AOSERP, who made many helpful suggestions as to project design and operation; J. Kristensen, who participated in the 1979 field program and preparation of the biophysical atlas (under the direction of G.L. Walder); B.W. Harvie, who participated in the 1979 and 1978 field programs; M.M. Psutka who directed the 1978 field program and analyzed the 1978 data; W.E. Griffiths, who supervised the 1978 program; B.K. Herbert and D. Kurylowicz, who assisted in the preparation of the atlas; C.E. Tull, who edited the two volumes and assisted in their production; D.A. Birdsall, who provided administrative assistance; and D. Whitford, who prepared the typescript.

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1. INTRODUCTION

Development in the Athabasca Oil Sands area will undoubtedly cause some disturbance to the aquatic resources of the area as a result of mining and related activities (e.g., Seidner 1980). Stream diversions, land clearing, and muskeg drainage will have substantial local effects and may affect water quality over a larger area. Water quality may also be affected by seepages from tailings ponds and by discharges of saline mine depressurization water. Aquatic habitats may be altered, and in some areas lost altogether; these changes will have an impact on the fish resources of the area.

In order to provide information that may be used to limit the adverse effects of development on fish populations in the area, the Alberta Oil Sands Environmental Research Program (AOSERP) has undertaken an extensive series of studies of the aquatic resources of the AOSERP study area (Figure 1). Some of these studies have been concerned with biophysical descriptions of aquatic habitats (e.g., Brown et al. 1978; Wrangler and Seidner 1979). In 1978, Renewable Resources Consulting Services Ltd. (RRCS) was awarded a contract to conduct a physical habitat inventory and survey of fish populations of four tributaries of the Athabasca River (the Firebag, Marguerite, Ells, and Steepbank rivers). Field work was conducted by RRCS in 1978; after that company ceased operation, LGL Limited took over the project and continued the aquatic habitat studies in 1979.

The objectives of the 1979 study were the following:

1. To conduct a field program in 1979 to survey the biophysical features of the MacKay, Dover, Dunkirk, and Muskeg rivers, and Hartley Creek;
2. To present the biophysical inventory information available for the Firebag, Marguerite, Steepbank, Ells, MacKay, Dover, Dunkirk, and Muskeg rivers, and Hartley Creek in the format of an aerial photographic atlas;

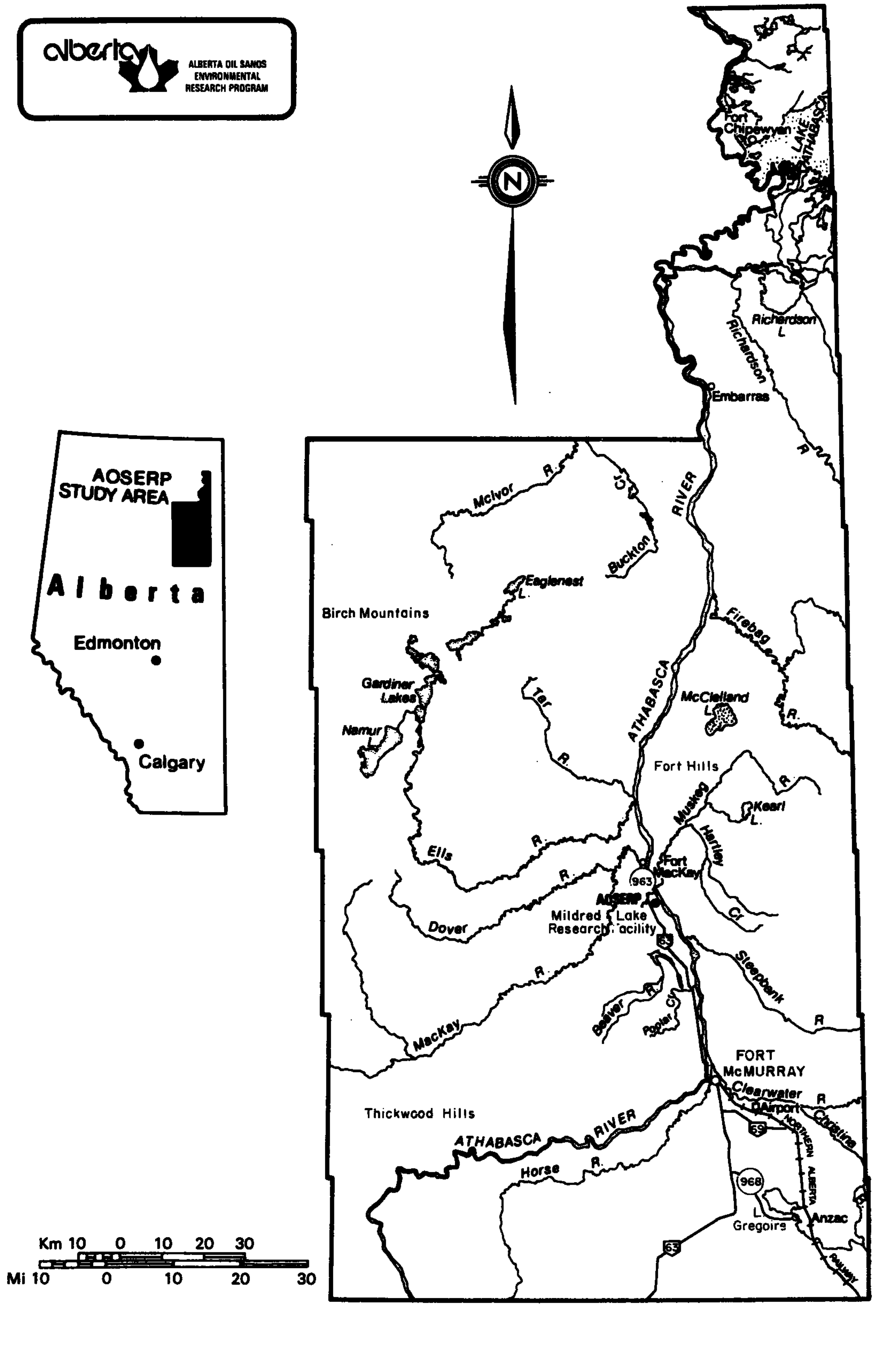


Figure 1. The AOSERP study area.

3. To incorporate into the atlas information compiled from other AOSERP studies on fish resources, autotrophic production, water quality, and hydrology; and
4. To prepare a summary report that contains the methods and a description of reach characteristics and utilization by fish of each watershed surveyed.

The biophysical inventory data have been presented in atlas form as Volume II of this report (Walder et al. 1980). The present volume contains methods used for the field surveys, general physical descriptions of each watershed, and summaries of fish utilization of each watershed. The watersheds studied are shown in Figure 2.

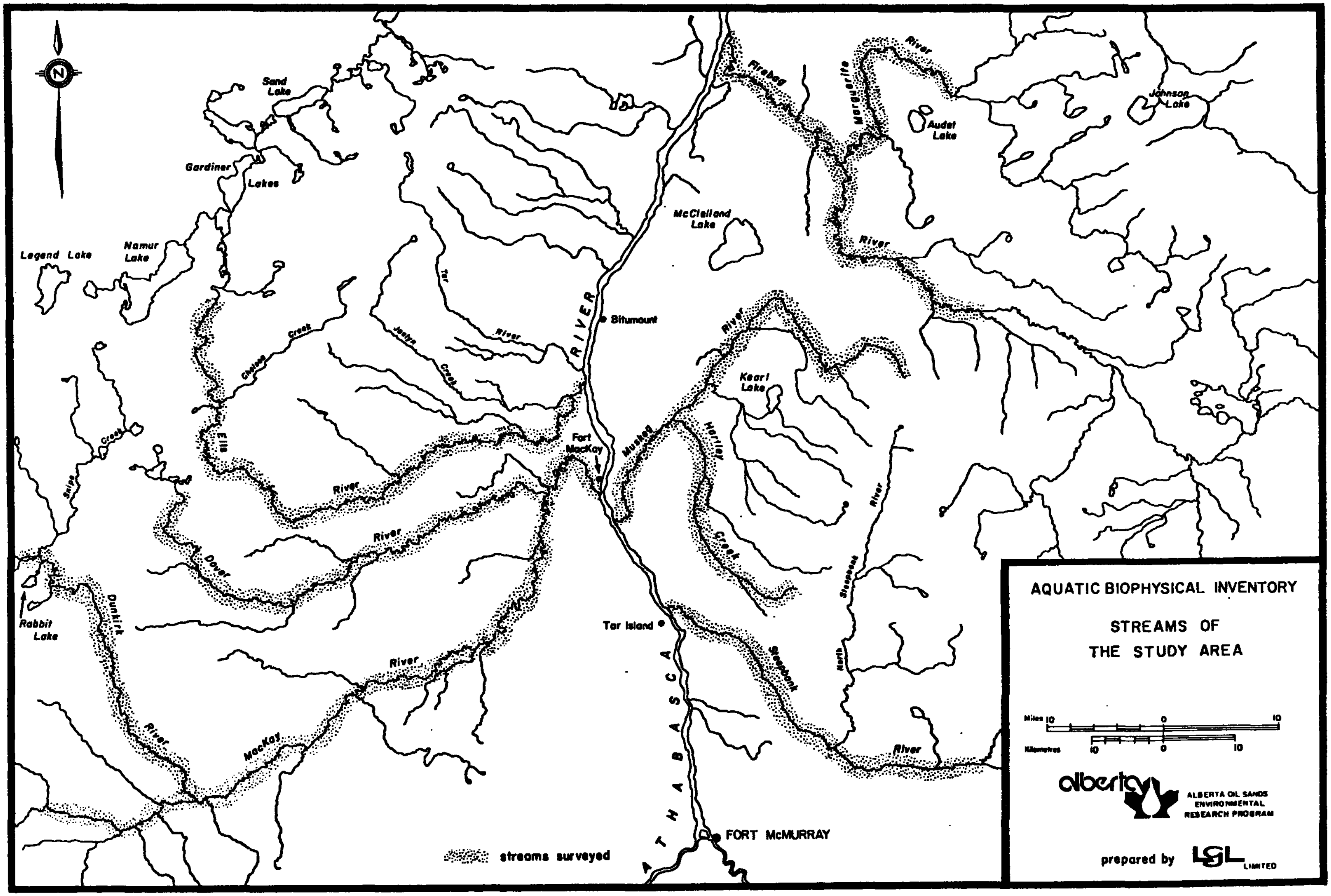


Figure 2. Streams surveyed in the AOSERP study area in 1978 and 1979.

2. A SURVEY OF THE LITERATURE

A number of previous reports contain information from the five watersheds (Firebag, Muskeg, Steepbank, MacKay, Ells) that are the subject of the present study. Few studies of streams in the AOSERP study area had been conducted prior to the 1976 initiation by AOSERP of an extensive program of studies of the aquatic resources of the area. Griffiths (1973) conducted a preliminary fisheries survey and assessment for sport fishery capability of many streams in the AOSERP study area. Other early studies have been reviewed and summarized in a fishery resource inventory and analysis carried out by RRCS (1975). Some hydrographic aspects of many river basins in northeastern Alberta were described by Northwest Hydraulic Consultants Ltd. (1975a).

A variety of studies have since been conducted under the auspices of AOSERP. Intensive studies of fish fauna have been conducted in the watersheds of the Steepbank River (Machniak and Bond 1979), Muskeg River (Bond and Machniak 1979), and MacKay River (Machniak et al. 1980). Barton and Wallace (1980) conducted ecological studies of aquatic invertebrates in the Muskeg River and Steepbank River watersheds, and Hartland-Rowe et al. (1979) studied benthic invertebrate communities in Hartley Creek. Population studies of bacteria and algae have been conducted in the Muskeg and Steepbank rivers and Hartley Creek (Lock and Wallace 1979a, b). Primary productivity of benthic algae has been studied by Hickman et al. (1979) in the Muskeg, Steepbank, MacKay, Ells, and Hangingstone rivers.

The stream gauging data available for streams in the AOSERP study area have been compiled by Loeppky and Spitzer (1977), Warner and Spitzer (1979), and Warner (1979). Schwartz (1979) reported on the hydro-geology of the Muskeg River watershed and Neill and Evans (1979) provided an overview of surface water hydrology of the AOSERP study area. An intensive study of surface water quality in the Muskeg River watershed was conducted by Akena (1979). Seidner (1980) prepared an overview of water quality in the AOSERP study area.

3. MATERIALS AND METHODS

3.1 FIELD SURVEYS

Biophysical inventory surveys were conducted following the techniques developed by the Resource Analysis Branch, B.C. Ministry of the Environment. The procedures followed are described in detail by Chamberlin and Humphries (1977) and in several sets of unpublished notes and instructions that were obtained from the Resource Analysis Branch. The procedures and techniques of the method are summarized in the following sections.

Surveys of the Firebag, Marguerite, Steepbank, and Ells rivers were conducted in the spring and fall of 1978 by RRCS. Helicopter reconnaissance flights and float trips by inflatable raft were employed for these surveys. In September 1979, LGL Limited conducted surveys, entirely by helicopter, of the MacKay, Dover, Dunkirk, and Muskeg rivers, and Hartley Creek.

3.1.1 Reach Definition and Description

A reach is considered to be a section of stream within which physical characteristics of the stream channel are relatively homogeneous and distinct from those in adjacent sections of the stream. The features used in defining reaches include size, gradient, flow character and velocity, pool-to-riffle ratio, substrate, and channel pattern. Many of these features are directly related to the stream gradient.

Prior to conducting the field surveys, preliminary reach divisions were established based on examination of topographical maps and aerial photographs. Final decisions on reach boundaries were made after considering observations made during aerial and ground surveys.

Descriptive information for each reach was recorded on a reach tally card (Figure 3). Most of the parameters recorded on these cards are estimated averages for the reach; a few are measured. Reach length was measured (following the meanders of the stream) on 1:50 0000 scale topographical maps or 1:63 360 scale forest cover maps using the point-line method described by Herrington and Tocher (1967).

REACH TALLY

ABBREVIATIONS	
FLOW CHARACTER	
P	PLACID
S	SWIRLING
R	ROLLING
B	BROKEN
T	TUMBLING
FISH USE	
S	SPAWN
R	REAR/RES.
M	MIG.
OBSTRUCTION TYPE	
R	ROCK
L	LOG
B	BLOCK
D	MAN
F	FALLS
CROSS SECTION	
c	CONFINED
b	BOUNDED
u	UNCONFINED
FORM	
S	STRAIGHT
I	IRREGULAR
M	MEANDER

TOTAL POOL %		
POOL CONTROL %	GRAVEL	
	ROCK	
	LOG/DEBRIS	
	BEAVER	
	OTHER	
FLOW CHARACT.	P S R B T	
CHANNEL	S M	
CROSS SECTION	c b u	
ENTRENCH	L M H	
SUB STABILITY	Brd. Bar. Is.	
FORM	S I M	
FLOOD/SIDE	Nil L M H	
BED %	F	G R
BANK		
% SLOPING		
TEXTURE		
% UNSTABLE		
DEBRIS	L M H	
STABILITY	U S	

BANK VEGETATION %		
CONIFEROUS		
DECIDUOUS		
SHRUB		
GRASSES		
BARREN		
CROWN CLOSURE %		
OVERHANG CLOSURE %		
FISH		
SPECIES	USE	MAP

If same as downstream reach, enter no.____

SYSTEM ____
SYSTEM NO
REACH NO SEQUENCE NO.
REACH LENGTH (Km) ____
CHANNEL WIDTH (m) ____
TALLY COMPLETION DATE

OBSTRUCTIONS			SLUMPS	
LENGTH	HEIGHT (m)	TYPE	LENGTH	MATERIAL
			TOTAL %	

COMMENTS
(FISH HABITAT SUITABILITY, STABILITY, SWIMMING, ETC.)

REACH

Reach No. ____
System Name ____
No. ____
Survey Date yr mo day Compiling Agency ____ Field Obs. ____
Access Weather ____
Field Photo Init. Photo Nos. ____
Photo Interp. Init. NTS Sheets ____
Air Photo. Yr. ____ Scale 1: ____

c	ACTIVE VALLEY WALL PROC.	Loc	
	Avalanche		Nil L M H
	Debris flow/torrent		Nil L M H
	Slump		Nil L M H
	Slide		Nil L M H
	Gully		Nil L M H
	Periglacial		Nil L M H
	BAR PRESENCE		
	Side/Point		Nil L M H
	Mid Channel		Nil L M H
	Transverse		Nil L M H
	Junction		Nil L M H
	Diamond/Braiding		Nil L M H
	Lee		Nil L M H
	Dunes		Nil L M H
	Islands		Nil L M H
	LATERAL CHANNEL MOVEMENT		
	Apparently Stable		Yes No
	Bar Veg. Progressions		Nil L M H
	Cut-Offs/Ox Bows		Nil L M H
	Meander Scars		Nil L M H
	Avulsions	Yes No	*
	Terraces	Yes No	*
	Constrictions	Yes No	*
	Unstable Banks (%)		

	TOTAL POOLS (%)		
	Bedrock control (%)		
	BED MATERIAL (%)		
	Fines	clay silt sand	
	Gravel (2-64 mm)		
	Large (64 mm+)		
	Bedrock		
	CHANNEL COVER		
	Level	% Area	Distr.
	Crown		
	Overhang		
	RIPARIAN VEG.		
	Storey	Sp	Distr.
	Coniferous		
	Deciduous		
	Understorey		
	Ground		
	CHAN. WIDTH (m)		
	Stage	Dry L M H Fld	
	Flow Char.	P S R B T	
	Valley:Chan	0-2 2-5 5-10 10+ N/A	
	Confinement	Ent Conf Fr Oc Un N/A	
	Pattern	St Sin Ir Im Rm Tm	
	Vert. Stab.	Deg ? Agr N/A	
	Side Chan	Nil L M H	

FISH SUMMARY					STREAM FEATURE			
C	Species	Use	Ref	Map	F	Type Code	Ht (m)	Length (m)

	Channel Debris	Nil L M H		Stable Debris (%)	
	Floodplain Debris	Nil L M H		Turbidity	Nil L M H

(Fish)

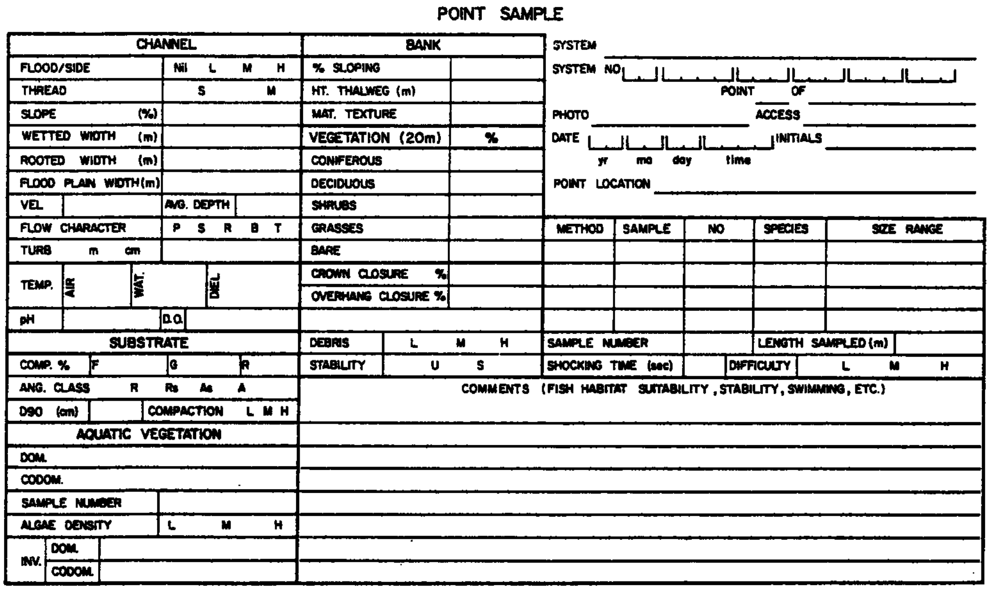
(Width) (Vall:Chan) (Slope) (Bed Material)

Figure 3. Reach tally cards. (The upper form was used for 1978 surveys, the lower form for 1979 surveys.)

Stream gradients were determined from 1:50 000 scale topographical maps or, when they were not available, from 1:250 000 scale maps. Channel width, percentage of pools, and percentage of unstable banks were estimated by visual observation during aerial surveys. Substrate composition was estimated from aerial survey observations and from information collected at point samples. Riparian vegetation coverage (expressed as the percentage of the bank covered by each type of vegetation) and the percentage of the stream channel covered by vegetation were estimated by visual observation during aerial surveys.

3.1.2 Point Samples

At a number of sites along each stream surveyed, detailed descriptive information was collected by completing a point sample card (Figure 4). The location of the point sample was recorded as the distance (in km) upstream from the mouth of the stream. Stream widths were estimated visually during the 1978 surveys, and were measured using range finders during the 1979 surveys. Depths less than 1 m were measured with a metre stick, but those greater than 1 m were estimated. Velocity was usually determined with a pygmy Gurley current meter at three points across the stream channel; the mean of the three measurements was recorded as the velocity for the point sample. When the water was too deep or the flow was too slow for use of the current meter, water velocity was determined by timing a floating wood chip over a known distance. Substrate composition was estimated visually. Bank heights less than 2 or 3 m were measured with a metre stick; those that were higher were estimated. Bank texture was determined by visual examination and touch. Bank vegetation (expressed as the percentage of the bank covered by each vegetation type) was estimated visually. No water quality parameters were measured during the 1978 field surveys. During the 1979 surveys, water temperature was measured with a pocket thermometer, dissolved oxygen was measured with a Hach oxygen kit, and conductivity and pH were measured with portable field meters.



POINT SAMPLE

CHANNEL
FLOOD/SIDE | Nil L M H
THREAD | S M
SLOPE (%)
WETTED WIDTH (m)
ROOTED WIDTH (m)
FLOOD PLAIN WIDTH (m)
VEL | AVG. DEPTH
FLOW CHARACTER | P S R B T
TURB m cm
TEMP. AIR WAT. DIEL
pH | D.O.

SUBSTRATE
COMP. % F G R
ANG. CLASS R Rs As A
D90 (cm) | COMPACTION L M H

AQUATIC VEGETATION
DOM.
CODOM.
SAMPLE NUMBER
ALGAE DENSITY L M H
INV. DOM. CODOM.

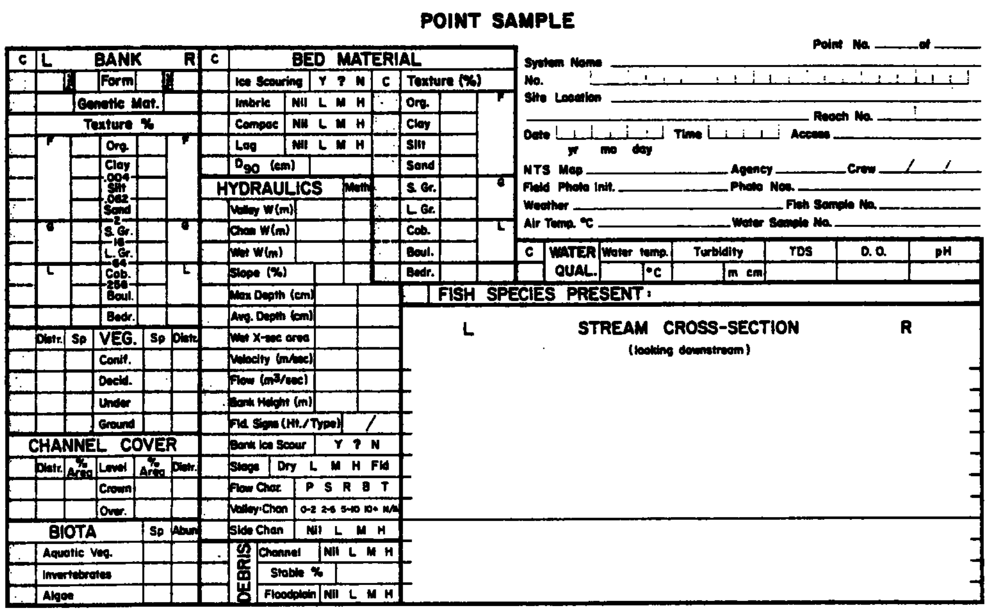
BANK
% SLOPING
HT. THALWEG (m)
MAT. TEXTURE
VEGETATION (20m) %
CONIFEROUS
DECIDUOUS
SHRUBS
GRASSES
BARE
CROWN CLOSURE %
OVERHANG CLOSURE %
DEBRIS L M H
STABILITY U S

SYSTEM
SYSTEM NO. POINT OF
PHOTO ACCESS
DATE yr mo day time INITIALS
POINT LOCATION

METHOD | SAMPLE | NO | SPECIES | SIZE RANGE

SAMPLE NUMBER | LENGTH SAMPLED (m)
SHOCKING TIME (sec) | DIFFICULTY L M H

COMMENTS (FISH HABITAT SUITABILITY, STABILITY, SWIMMING, ETC.)



POINT SAMPLE

Point No. ___ of ___

C | L BANK R
Form
Genetic Mat.
Texture %
F Org. F
Clay
.004
Silt
.062
Sand
2
G S. Gr. G
16
L. Gr.
64
L Cob. L
256
Boul.
Bedr.
Distr. | Sp | VEG. | Sp | Distr.
Conif.
Decid.
Under
Ground
CHANNEL COVER
Distr. | % Area | Level | % Area | Distr.
Crown
Over.
BIOTA | Sp | Abun.
Aquatic Veg.
Invertebrates
Algae

C | BED MATERIAL
Ice Scouring | Y ? N
Imbric | Nil L M H
Compac | Nil L M H
Lag | Nil L M H
D_{90} (cm)
C | Texture (%)
Org. F
Clay
Silt
Sand
S. Gr. G
L. Gr.
Cob. L
Boul.
Bedr.

HYDRAULICS | Meth.
Valley W(m)
Chan W(m)
Wet W(m)
Slope (%)
Max Depth (cm)
Avg. Depth (cm)
Wet X-sec area
Velocity (m/sec)
Flow (m^3/sec)
Bank Height (m)
Fld. Signs (Ht./Type) /
Bank Ice Scour | Y ? N
Stage | Dry L M H Fld
Flow Char. | P S R B T
Valley:Chan | 0-2 2-5 5-10 10+ N/A
Side Chan | Nil L M H
DEBRIS
Channel | Nil L M H
Stable %
Floodplain | Nil L M H

System Name
No.
Site Location
Reach No.
Date yr mo day | Time | Access
NTS Map | Agency | Crew / /
Field Photo Init. | Photo Nos.
Weather | Fish Sample No.
Air Temp. °C | Water Sample No.

C | WATER QUAL. | Water temp. °C | Turbidity m cm | TDS | D.O. | pH

FISH SPECIES PRESENT:

L STREAM CROSS-SECTION R
(looking downstream)

Figure 4. Point sample cards. (The upper form was used for 1978 surveys, the lower form for 1979 surveys.)

3.1.3 Fish Collections

A variety of techniques (gill netting, seining, electrofishing, angling, and dip netting) were used to collect fish during the course of this study. The techniques varied according to the nature of the reach being sampled. Fishing efforts were conducted at each point sample location, and occasionally at other sites.

Most fish were collected by seining, which was conducted in a non-quantitative manner. Seines were either a 3 m fine-meshed minnow seine or a 9 m beach seine. Electrofishing was done with Smith-Root Type VII or Type VIII electrofishers.

During the 1978 surveys, gill nets were set in deep pools, backwaters, and side sloughs. Monofilament test gangs were used; they were 30 m in length and contained panels of 2.5, 3.8, 6.4, 8.9, 11.4, and 14.0 cm stretch mesh. Nets were set for periods of 12 to 24 h. No gill netting was conducted during the 1979 surveys.

Fish collected were identified, counted, and measured. Assessment of whether an individual was a juvenile or an adult was generally based on its length. Some fish collected during the 1978 surveys were dissected to determine sex and maturity.

It should be noted that because of the brief sampling efforts, the fish species present were probably not all captured at many sampling locations. The data are also insufficient to demonstrate seasonal fish use of streams or portions of streams.

3.1.4 Benthic Invertebrate Collections

Samples of benthic invertebrates were collected at each point sample location. Collections were made by disturbing the substrate while holding a dip net immediately downstream. Because only one sample was collected at each site and because the sampling was not done in a quantitative manner, the observations of the benthic community are only qualitative. Samples were preserved in 10% formalin and were later identified to genus when possible, using standard taxonomic references (Ward and Whipple 1959; Merrit and Cummins 1978; Pennak 1978).

3.2 DATA SOURCES

Data for the biophysical atlas (Volume II, Walder et al. 1980) were obtained from the results of the present study and from other pertinent published sources (reviewed previously). Documented fish presence is indicated on the aerial photographs of the streams; this information was compiled from the present study and from Machniak and Bond (1979), Bond and Machniak (1979), and Machniak et al. (1980). The tabular fish data (i.e., numbers caught) presented in the atlas and the lists of benthic invertebrates given for each reach were compiled only from information collected during the present study. Data on benthic algal productivity were taken from Hickman et al. (1979). Stream gauging information was taken from Loeppky and Spitzer (1977), Warner and Spitzer (1979), and Warner (1979). Water quality data were obtained from the National Water Quality Data Bank (NAQUADAT) through the Data Processing and Publications Section, Inland Waters Branch, Ottawa.

3.3 AERIAL PHOTOGRAPHS

The aerial photographs used in preparation of the biophysical atlas were obtained from the National Air Photo Library, Ottawa. All of the photographs were taken in 1974 at a scale of 1:50 000 on panchromatic film. The prints used in the atlas are precise double-size enlargements, so the scale of aerial photographs in the atlas is 1:25 000.

3.4 ELEVATION PROFILES

In preparing the elevation profiles of streams, elevations above sea level were taken from topographical maps at points where contour lines crossed the streams. When available, maps at a scale of 1:50 000 were used. It was necessary, however, to use 1:250 000 scale maps for many of the measurements because much of the study area has not been mapped at a scale of 1:50 000. Distances along the meanders of streams were measured using the point-line method described by Herrington and Tocher (1967).

3.5 TERMINOLOGY

Wrangler and Seidner (1979) provide a glossary of the terminology used in aquatic inventories that follow the techniques of the B.C. Resource Analysis Branch. This terminology has been used in the present report and in Walder et al. (1980).

4. RESULTS AND DISCUSSION

The results of field surveys conducted during the present study, and additional information incorporated from various other AOSERP reports are presented in Volume II of this report (Walder et al. 1980). This section includes general descriptions of each watershed and summaries of the current knowledge of the fish populations of each watershed.

4.1 FIREBAG RIVER WATERSHED

4.1.1 General Description

The Firebag River watershed is located north of Fort McMurray (Figure 2) and drains into the Athabasca River from the east. It is almost circular in shape with gentle relief, a maximum elevation relief of 418 m, a drainage area of 6138 km^2, and 45 lakes over 40 ha in area (Northwest Hydraulic Consultants Ltd. 1975a). The uppermost tributaries of the watershed are located in Saskatchewan. A low ridge that extends westward from the Alberta-Saskatchewan border divides the watershed into two major regions. The Marguerite River, the only major tributary to the Firebag River, lies to the north and drains an area of 1746 km^2 (28% of the Firebag River watershed). It joins the Firebag River approximately 45 km upstream from the confluence of the Firebag and Athabasca rivers.

The Firebag River and the Marguerite River both flow through two distinct physiographic regions--the Firebag Plain forms the headwater plateau region, and the Clearwater Lowland is a gradually sloping region to the west (Government and University of Alberta 1969). Located along the Alberta-Saskatchewan border, the Firebag Plain is a flat heterogeneous area of well-drained outwash sands and gravels of glaciofluvial origin that are mixed with poorly-drained bogs, swampy depressions, and treed muskeg. In well-drained areas, the dominant vegetation is jack pine. Within this headwater region, the mainstems of both rivers and their tributary streams have a high percentage of pools that have slow moving water.

These pools generally have a mud-silt substrate; they are often formed by beaver dams or accumulations of debris. Headwater streams also drain a large number of small eutrophic lakes. Due to its distance from the AOSERP study area, the sections of the rivers within the Firebag Plain were not studied.

The Clearwater Lowland consists of a moderate gradient section of the watershed and a low gradient section that includes the Athabasca River floodplain. Surficial deposits in the area of moderate gradient are a combination of silts and clays of glaciolacustrine origin and outwash sands and gravels of glaciofluvial origin (Research Council of Alberta 1972, cited by Northwest Hydraulic Consultants Ltd. 1975a). Riparian vegetation is primarily jack pine, white spruce, and black spruce along the Firebag River, and poplar, birch, alder, and white and black spruce along the Marguerite River. In the moderate gradient area, both rivers flow through and expose bitumen deposits of the McMurray Oil Sands Formation, Devonian limestone, and Cretaceous sandstones and shales (Research Council of Alberta 1972, cited by Northwest Hydraulic Consultants Ltd. 1975a). In addition, the Marguerite River is deflected around an igneous intrusion near Johnson Lake. The substrate in the Firebag River consists primarily of boulders, rubble, and large gravels in riffle areas, and boulders and sand in pools; the substrate in the Marguerite River varies from limestone bedrock and boulders to sand-silt.

The low gradient section of the watershed within the Clearwater Lowland extends from the Athabasca River floodplain to the confluence of the Marguerite River. Surficial deposits of glaciolacustrine silts and clays overlay the Devonian limestone and Cretaceous sandstones and shales in this area. Vegetation is primarily jack pine and white spruce mixed with deciduous trees and shrubs. Shrubs are dominant along the banks of the Firebag River. The low gradient and the consequent low water velocity have resulted in a bottom substrate with a high proportion (75 to 100%) of fines.

Although a water gauge was installed in the Firebag River 30 km above its mouth in 1971, few uninterrupted measurements are available for entire years (Loeppky and Spitzer 1977; Warner 1979; Warner and Spitzer 1979). Mean annual discharge was 34 m^3/s in 1975, 22 m^3/s in 1977, and 30 m^3/s in 1978. Maximum discharge tends to occur in April or May (maximum mean monthly discharges in April-May of 42.5 m^3/s in 1976, 37.4 m^3/s in 1977, and 56.9 m^3/s in 1978), but much higher monthly flows are sometimes produced by summer storms (e.g., mean monthly flow in August 1973 was 97 m^3/s). Minimum flow occurs in late winter, generally in March, and appears to be very constant. In 1972, and from 1975 to 1978, minimum mean monthly flows were all between 7.1 and 9.4 m^3/s. Details of the flow characteristics of the Marguerite River are unknown; but because of its proximity to the Firebag River, its flow is expected to follow a pattern similar to that of the Firebag River. Northwest Hydraulic Consultants Ltd. (1975b) reported a discharge of 3.2 m^3/s on 20 February 1974 that is probably near the winter minimum discharge rate. Winter flows are thought to be augmented by considerable ground water inflow to the Firebag River watershed through sand and gravel deposits and by inflow from the large number of lakes. Inflow from these sources also moderates water temperatures during summer (Northwest Hydraulic Consultants Ltd. 1975b, c). Water temperatures in the mainstem of the rivers reach 20°C in the summer and the channels are normally ice-free from about late April to late October.

Waters of the Firebag and Marguerite rivers are usually clear with a slight brown organic stain; the stain is derived from leachates of organic matter that originate primarily from muskeg areas within the watershed.

4.1.2 Reaches of the Firebag River

The Firebag River was divided into six reaches (Figure 5). As shown in Figure 6, reaches generally correspond to stream gradient. There is also a good correlation between low gradients and a

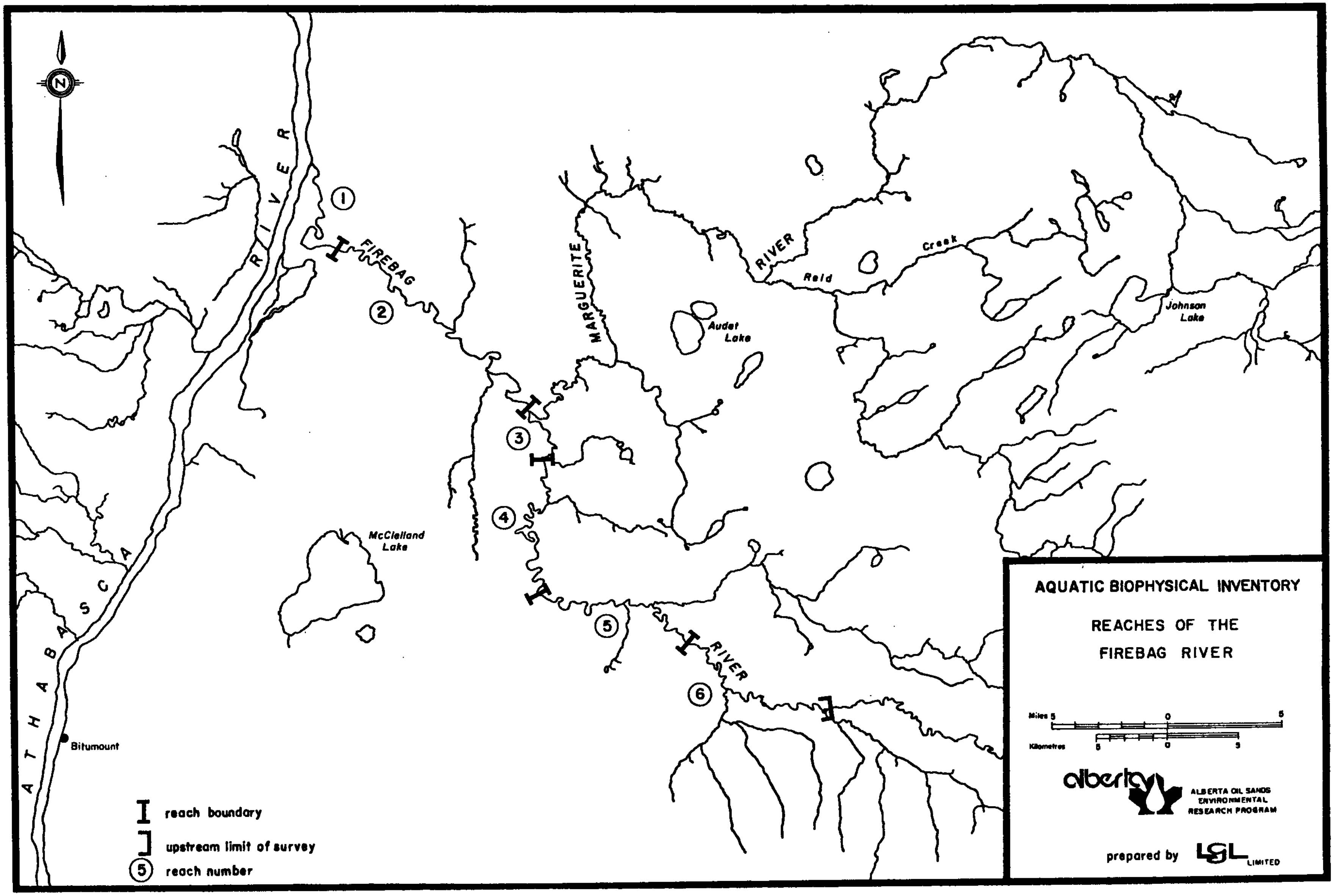


Figure 5. Reaches of the Firebag River.

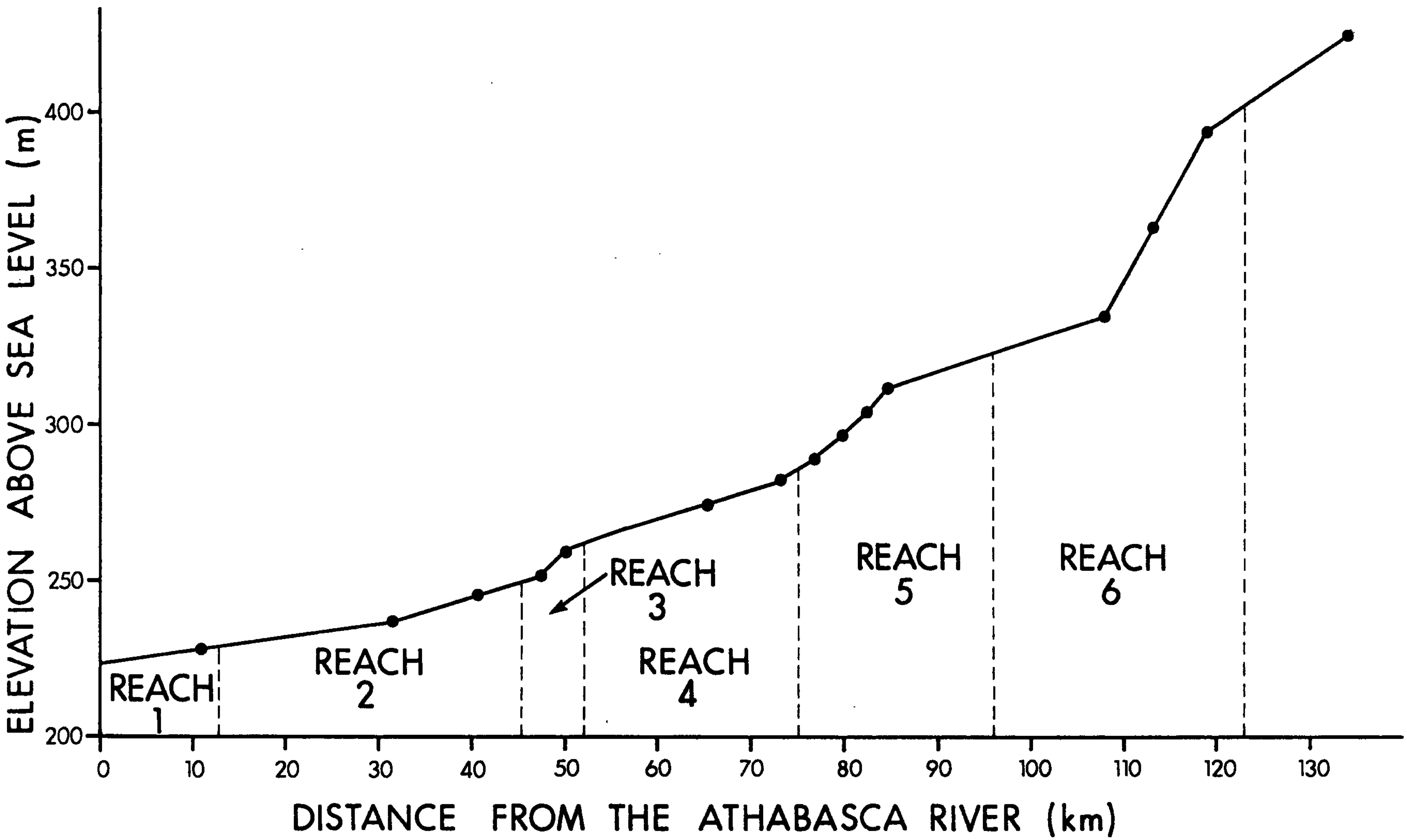


Figure 6. Elevation profile of the Firebag River.

high percentage of pools (Table 1). Physical characteristics of the river change substantially when reaches are considered in succession. Substrate composition changes dramatically from a predominance of fines in the two lowermost reaches to primarily gravels and larges in upstream reaches. Bank instability ranges from 20 to 40% in all areas except in Reach 6, where only 5% of the banks show signs of erosion. The Firebag River is largely unconfined by high banks in Reach 1, where it crosses the Athabasca River floodplain, and in Reach 6. In all other reaches, moderately high banks confine the river, and in Reaches 2 and 3, unstable cutbanks up to 40 m high are found.

4.1.3 Fish Utilization of the Firebag River

Known fish species and their distributions in the Firebag River are shown in Table 2. Because fishing efforts and methods were rarely equal in the various reaches, data are biased and must be interpreted with caution. Reach 1 is deep, for example, and there are few locations where seines can be employed with effectiveness. Most fishing efforts in this region were performed with gill nets; consequently, adult specimens of the larger species were likely to be caught. In all liklihood, however, the presence of small fishes is not adequately shown in Table 2. Despite these limitations, it is evident that burbot, flathead chub, brook stickleback, and emerald shiner are rare in the studied portion of the Firebag River and that ninespine stickleback are relatively uncommon. The most common and widely distributed fish in the river are lake chub, white sucker, northern pike, and arctic grayling. Lake whitefish appear to be common, but restricted to the lowermost portions of the Firebag River. Walleye were found in four of the six reaches, and probably occur in relatively small numbers throughout the river.

With the exception of Reach 1, and to a lesser extent Reach 2, the Firebag River has a diversity of excellent fish habitats (e.g., spawning, feeding, resting) that largely accounts for the relatively large number of fish species present and their widespread

Table 1. Reach characteristics of the Firebag River[a].

	Reach					
	1	2	3	4	5	6
Reach length (km)	13	32.5	6.5	23	21	27
Channel Width (m)	95	80	45	55	50	30
Channel area (ha)	123.5	260	29.3	126.5	105	81
Gradient (m/km)	0.3	0.6	1.9	1.0	1.7	3.3
Flow character[b]	s, r	s, r, b	r	s	s, b	r, b
Total pools (%)	90	90	50	85	25	30
Pattern[c]	im	im	im	im	im	im
Confinement[d]	uc	c	fc	fc	fc	uc
Unstable banks (%)	40	25	20	40	30	5
Substrate composition (%)						
fines (<2 mm)	95	70	10	15	10	10
gravels (2-64 mm)	5	25	25	35	40	30
larges (>64 mm)	0	3	60	40	50	60
bedrock and/or oil sand	0	2	5	10	0	0
Debris[e]	l	l	l	m	l	l

[a]From Walder et al. (1980).

[b]Flow character: b = broken; p = placid; r = rolling; s = swirling; t = tumbling.

[c]Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d]Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e]Debris: h = high; l = low; m = moderate.

Table 2. Known distribution of fish in the Firebag River.

	Presence in Reach[a]						Total Catch All Reaches[b]	
	1	2	3	4	5	6	No.	%
Burbot		p[c]						
Walleye	p	p		p		p	11	<1
Arctic grayling		p	p	p	p	p	100	6
Lake whitefish	p	p					26	2
Northern pike	p		p	p	p	p	36	2
Longnose sucker	p	p	p	p	p	p	105	6
White sucker	p	p	p	p	p	p	388	24
Sucker spp.			p	p	p	p	66	4
Lake chub	p	p	p	p	p	p	702	43
Flathead chub					p		1	<1
Pearl dace		p	p	p			34	2
Longnose dace		p	p	p	p	p	109	7
Emerald shiner			p					
Trout-perch		p	p	p	p	p	17	1
Brook stickleback		p					1	<1
Ninespine stickleback				p		p	4	<1
Slimy sculpin		p	p	p	p	p	26	2

[a]From Griffiths (1973) and Walder et al. (1980).

[b]From Walder et al. (1980).

[c]p = present.

distributions. The lowermost reaches are probably important overwintering areas for all types of fish. (The constant nature of winter flow in the river suggests that upstream reaches could also be utilized in the winter.) Spawning may be limited in the lowermost portion of the river due to the predominance of unstable substrates but important spring migrations to upstream spawning areas undoubtedly occur through this region.

The presence of adult, and juvenile or young-of-the-year arctic grayling in all portions of the river except Reach 1 illustrates the widespread distribution of good to excellent grayling habitat. Walleye and northern pike are probably also found throughout the river. The above sport fish were found in fewer numbers than some of the forage and coarse fish, but piscivorous sport fish are normally less abundant than their prey. As Griffiths (1973) suggested, the Firebag River (within the AOSERP study area) should be considered an excellent stream for sport fish production, and its future sport fisheries potential is high.

4.1.4 Reaches of the Marguerite River

The portion of the Marguerite River within the AOSERP study area was divided into five reaches (Figures 7 and 8). As shown in Table 3, the majority of the river (75.3% of 75 linear km) is slow moving water that flows over fine substrates. Pools are generally deep in Reach 2 (e.g., mean water depth was 2.0 m in the spring of 1978) but shallower in Reach 4. These placid regions are interrupted by short sections of riffles and rapids (Reaches 1 and 3), where moderate amounts of bedrock are exposed and substrate is generally boulders and gravels. The uppermost reach studied is also primarily composed of riffles and rapids, but it contains slightly more pools than Reach 1 or Reach 3. Streambanks are relatively stable, especially in Reach 5.

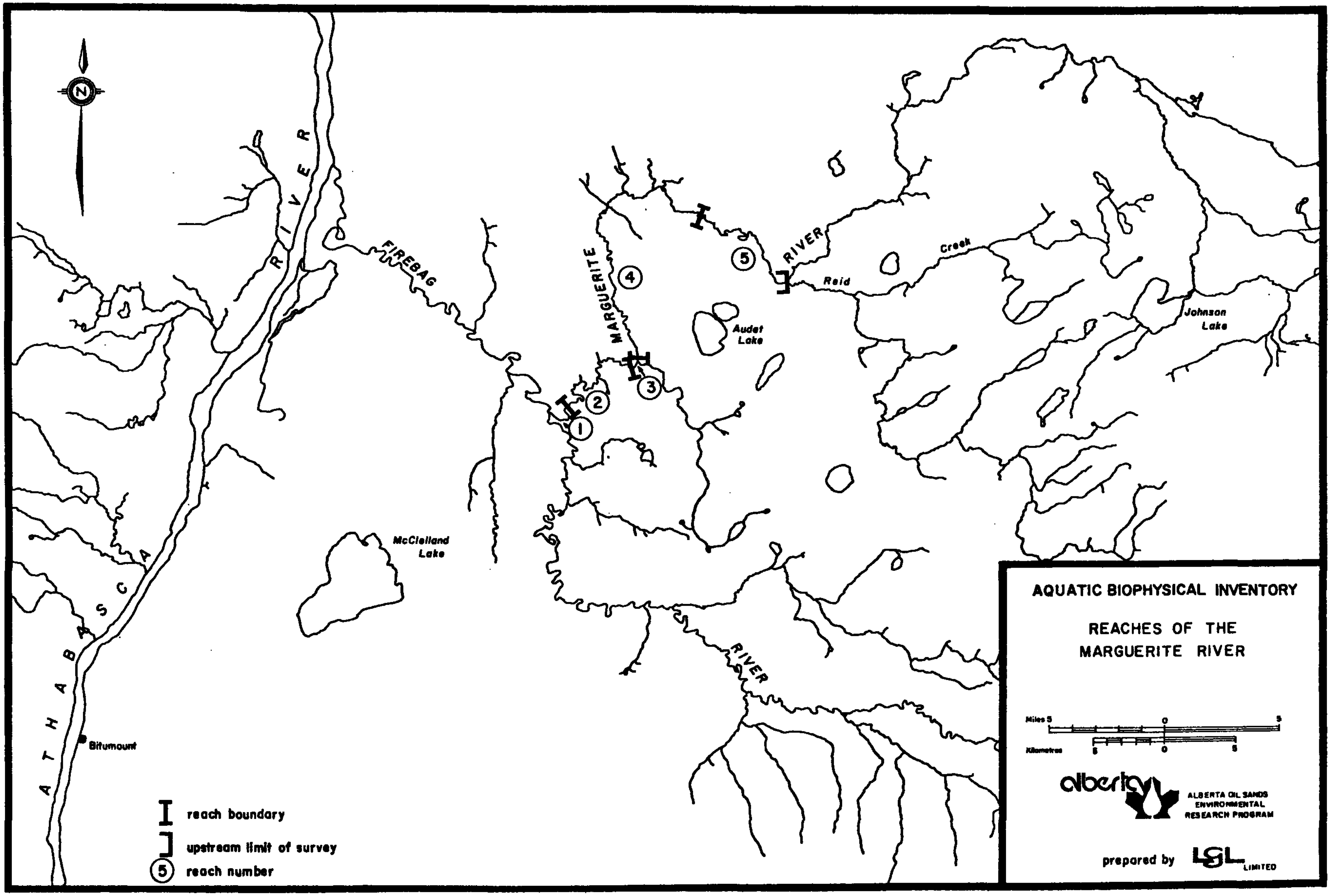


Figure 7. Reaches of the Marguerite River.

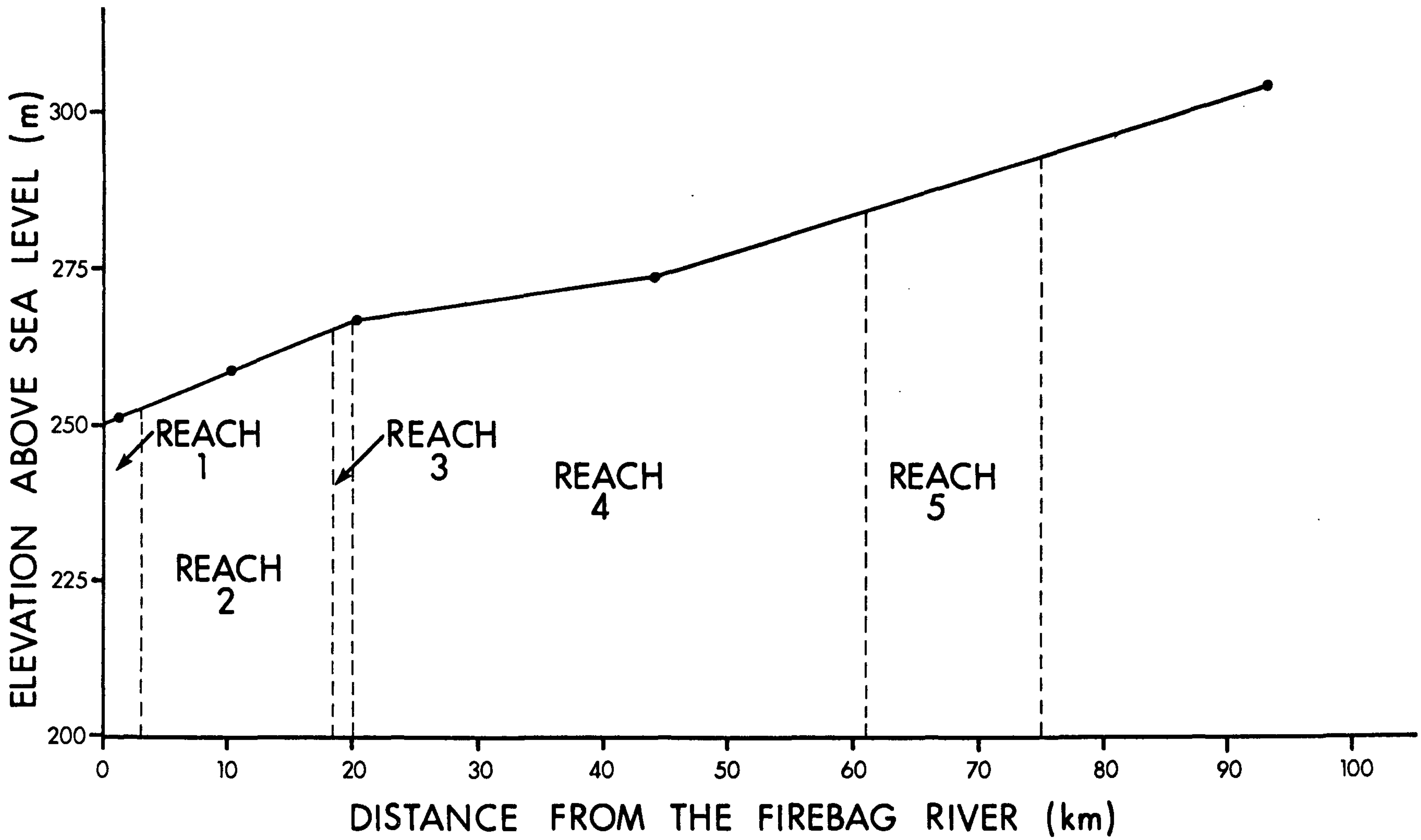


Figure 8. Elevation profile of the Marguerite River.

Table 3. Reach characteristics of the Marguerite River[a].

	Reach				
	1	2	3	4	5
Reach length (km)	3.0	15.5	1.5	41.0	14.0
Channel width (m)	40	30	25	25	20
Channel area (ha)	12.0	46.5	3.8	102.5	28.0
Gradient (m/km)	1.4	0.8	3.0	0.4	0.8
Flow character[b]	b, t	p, s	b, t	p	r, b
Total pools (%)	10	90	10	90	20
Pattern[c]	ir	tm	im	im	im
Confinement[d]	fc	c	c	oc	uc
Unstable banks (%)	10	25	25	20	5
Substrate composition (%)					
fines (<2 mm)	10	70	30	90	20
gravels (2-64 mm)	25	30	15	0	20
larges (>64 mm)	45	0	40	10	40
bedrock and/or oil sand	20	0	15	0	20
Debris[e]	m	l	m	h	h

[a]From Walder et al. (1980).

[b]Flow character: b = broken; p = placid; r = rolling; s = swirling; t = tumbling.

[c]Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d]Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e]Debris: h = high; l = low; m = moderate.

4.1.5 Fish Utilization of the Marguerite River

Thirteen species of fish have been collected from the Marguerite River (Table 4) and fish utilization is high. Burbot, pearl dace, and mountain whitefish appear to be rare or uncommon, whereas arctic grayling, northern pike, longnose and white suckers, trout-perch, lake chub, longnose dace, and slimy sculpin are common and widespread. It should be noted that the apparent absence of many fish species in Reach 5 is likely due, at least in part, to the small amount of fishing effort performed in that area. Adult catches were dominated by arctic grayling, longnose sucker, and slimy sculpin, whereas lake chub, slimy sculpin, and white sucker were the most abundant juvenile fish.

The presence of many young fish in the Marguerite River is attributed to the presence of a variety of suitable spawning habitats--gravel areas in Reaches 1, 2, 3, and 5 for spawning arctic grayling, mountain whitefish, and white and longnose suckers, and shallow backwater regions in Reaches 2 and 4 for northern pike and a number of forage fishes. Catches indicate that young fish become widely dispersed throughout the river, at least below Reach 5.

Information on overwintering of fish in the Marguerite River is lacking, but flow is maintained throughout the winter, and it is thought that overwintering potential is high, especially in Reach 2, which contains many deep pools. Overwintering habitat probably decreases upstream, and may be very limited in Reach 5.

The Marguerite River appears to be somewhat less important in terms of future sport fishery potential than the adjacent Firebag River. Walleye and lake whitefish did not appear to be present; however these species may be seasonal users of the river. The Marguerite River probably harbours substantial numbers of arctic grayling and northern pike, however, and should be considered as a valuable resource.

Table 4. Known distribution of fish in the Marguerite River.

	Presence in Reach[a]					Total Catch All Reaches[b]	
	1	2	3	4	5	No.	%
Burbot[c]							
Arctic grayling	p[d]	p	p	p	p	26	4
Mountain whitefish			p			6	<1
Northern pike	p		p	p		6	<1
Longnose sucker	p	p	p	p		55	9
White sucker	p	p	p	p		63	10
Sucker spp.	p	p	p	p		19	3
Lake chub	p	p	p	p		300	47
Pearl dace				p		4	<1
Longnose dace	p	p	p	p		26	4
Trout-perch	p	p	p	p		34	5
Brook stickleback		p		p		3	<1
Slimy sculpin	p	p	p	p	p	94	15
Spoonhead sculpin		p		p		4	<1

[a]From Griffiths (1973) and Walder et al. (1980).

[b]From Walder et al. (1980).

[c]Burbot were collected in a tributary of the Marguerite River by Griffiths (1973).

[d]p = present.

4.2 MUSKEG RIVER WATERSHED

4.2.1 General Description

The Muskeg River watershed is about 57 km north of Fort McMurray (Figure 2) and drains into the Athabasca River from the east, about 5 km south of Fort MacKay. It encompasses an area of about 1480 km^2 (Northwest Hydraulic Consultants Ltd. 1975a). The main stream (the Muskeg River) is approximately 110 km long. The upper portion of the river generally flows northwest, but the remainder of the stream flows southwest. The major tributary to the Muskeg River is Hartley Creek, which drains an area of 325 km^2 in the southern portion of the watershed. Hartley Creek generally flows northerly, and its confluence is about 33 km upstream from the mouth of the Muskeg River. Only six lakes greater than 40 ha are present in the watershed.

The Muskeg Mountain Upland area lies in the eastern portion of the Muskeg River watershed. Most tributary streams originate in this relatively well-drained, treed area. They flow northwest through thick drift that is composed mainly of till (Northwest Hydraulic Consultants Ltd. 1975a). Bedrock of the area is primarily Cretaceous sandstones and shales. Streams in the Muskeg Mountain Upland area, including the upper mainstem of the Muskeg River, generally have a relatively high gradient, steep channel slopes, and fine substrates. The central and western portions of the Muskeg River watershed are located in the Clearwater Lowland. In this region, the Clearwater Lowland is relatively flat and poorly drained; large areas of muskeg and marsh are present. Surficial deposits are primarily outwash sands. Underlying deposits are Cretaceous sandstones and shales, the McMurray Oil Sands Formation, and Devonian limestone. The Muskeg River exposes areas of the latter two deposits along the lower 16 km of its course. Stream channels in the Clearwater Lowland region are moderately stable and substrates are generally gravel, boulders, and small areas of fines.

Mean annual discharge of the Muskeg River varies considerably; 1974, 1975, and 1978 were years of high mean flows--between 5.9 and 6.3 m^3/s (Loeppky and Spitzer 1977; Warner 1979). In contrast, mean annual flows in 1976 and 1977 were 2.1 and 2.3 m^3/s, respectively (Loeppky and Spitzer 1977; Warner and Spitzer 1979). Maximum flows do not necessarily occur during spring runoff; maximum monthly flows were recorded after summer storms in three of the five years from 1974 to 1978. Minimum monthly flows are fairly constant--from 0.2 to 0.4 m^3/s in late winter.

Waters within the Muskeg River drainage are stained a light brown. A maximum water temperature of 25°C was recorded in 1976 and fluctuations of up to 8°C occurred over a 24-h period (Bond and Machniak 1977). The ice-free season generally lasts from late April to late October.

More detailed information on surface water quality and hydrology of the Muskeg River watershed can be found in Akena (1979) and Schwartz (1979).

4.2.2 Reaches of the Muskeg River

The five lower reaches of the Muskeg River, as defined by Bond and Machniak (1979), correspond to those of Walder et al. (1980). The latter study extended the area of interest to include a sixth reach that covers the extreme headwater portions of the Muskeg River (Figure 9). As shown in Figure 10, the majority (57%) of the Muskeg River is of low gradient and is contained in a single reach, Reach 4. This region corresponds to the flat, poorly-drained portion of the Clearwater Lowland. Characteristics of the river change dramatically in successive upstream reaches (Table 5). Channel width decreases from an average of 24 m in Reach 1 to 8 or 9 m in the two uppermost reaches. Appreciable amounts of hard substrates are found only in the three lowermost reaches of the river, which compose 15% of the river's length. Fine substrates prevail in all other areas. Pools predominate in all portions of the river except Reach 3, where riffles and broken water are most common. Debris is found in all portions of the river, especially in Reaches 5 and 6.

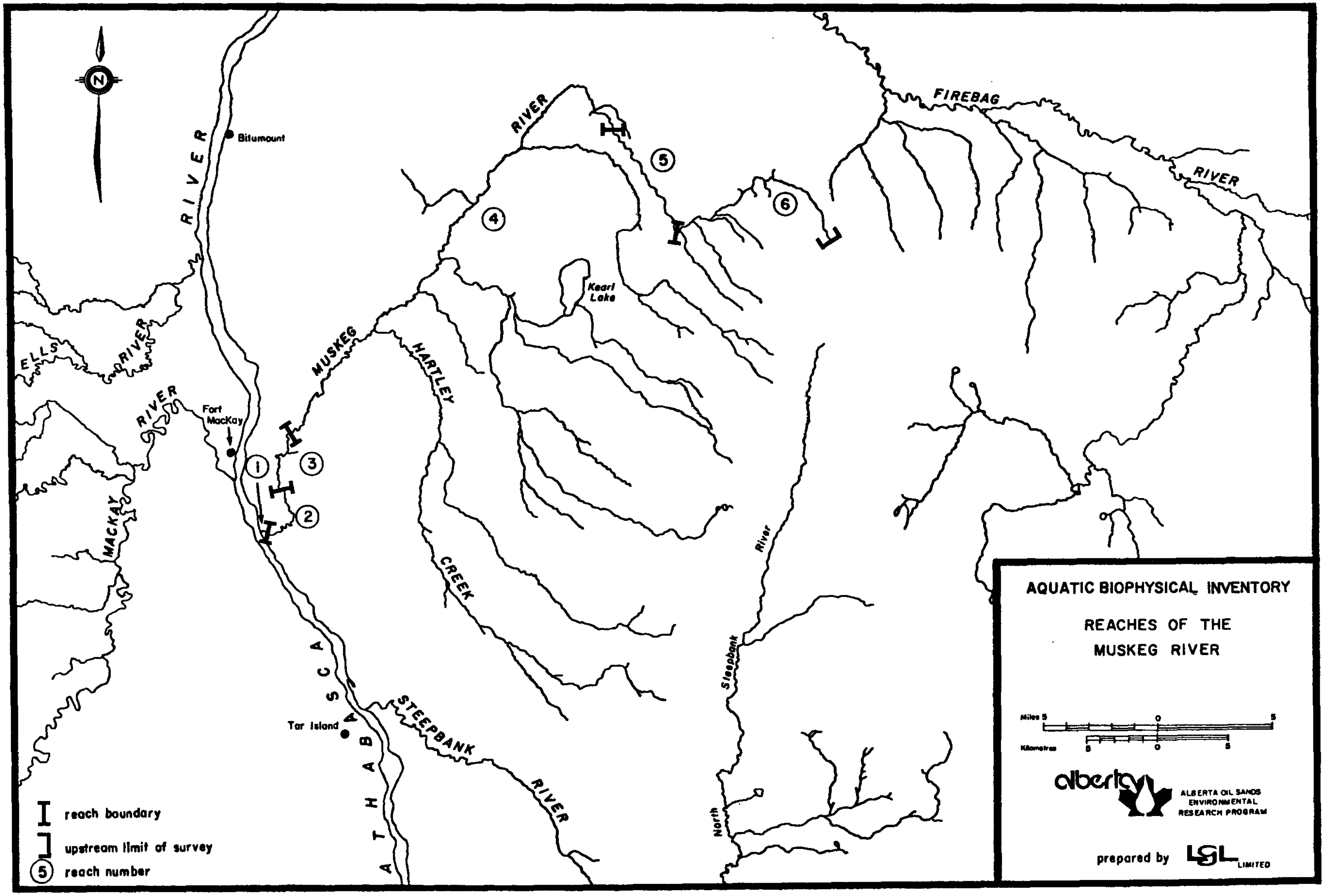


Figure 9. Reaches of the Muskeg River.

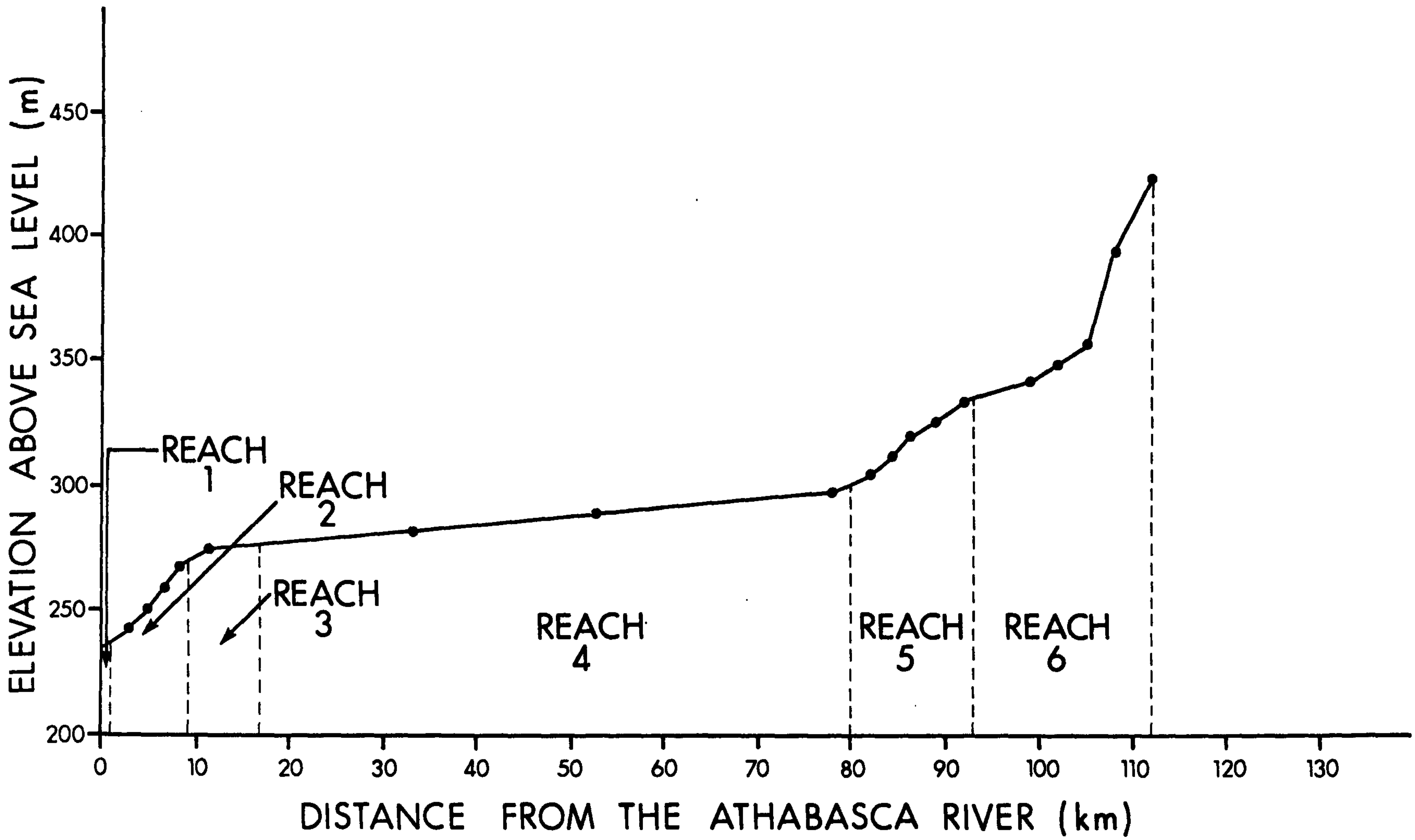


Figure 10. Elevation profile of the Muskeg River.

Table 5. Reach characteristics of the Muskeg River[a].

	Reach					
	1	2	3	4	5	6
Reach length (km)	0.5	8.5	7.5	63.5	13.0	19.0
Channel width (m)	24	15	14	10	9	8
Channel area (ha)	1.2	12.8	10.5	63.5	11.7	15.2
Gradient (m/km)	3.5	3.2	1.0	0.3	2.8	4.2
Flow character[b]	s, r	s, r, b	p, s, r	p	p, s	p
Total pools (%)	65	30	80	95	90	100
Pattern[c]	si	im	im	tm, im	im	im
confinement[d]	uc	en	oc	uc	oc	uc
unstable banks (%)	30	55	10	0	0	0
Substrate composition (%)						
fines (<2 mm)	20	10	30	100	80	100
gravels (2-64 mm)	50	70	50	0	10	0
larges (>64 mm)	30	20	20	0	10	0
bedrock and/or oil sand	0	0	0	0	0	0
Debris[e]	l	m	m	m	h	h

[a]From Walder et al. (1980).

[b]Flow character: b = broken; p = placid; r = rolling; s = swirling; t = tumbling.

[c]Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d]Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e]Debris: h = high; l = low; m = moderate.

Beaver dams are also common in the latter areas and in the upper portion of Reach 4. Stream banks are very stable, with the exception of those in the two lowermost reaches.

4.2.3 Fish Utilization of the Muskeg River

The fish fauna of the Muskeg River is composed of 21 species (Table 6); it is considered to be well known, due to the studies of Griffiths (1973), Bond and Machniak (1977, 1979), and Walder et al. (1980). Although the number of species inhabiting the Muskeg River is relatively large, many species (including burbot, walleye, yellow perch, lake whitefish, mountain whitefish, lake cisco, Dolly Varden, redbelly dace, spottail shiner, fathead minnow, ninespine stickleback, and trout-perch) appear to be confined entirely to the lower three reaches of the river. These reaches comprise only about 15% of the total length of the river. Species diversity quickly decreases in the remaining 85% of the river upstream of Reach 3, where only arctic grayling, northern pike, pearl dace, lake chub, white and longnose suckers, and brook stickleback have been reported. Fish in Reach 6 have not been sampled, but it is suspected that this headwater portion of the Muskeg River would contain only brook stickleback and possibly pearl dace. Much of the diversity in the lower portion of the river can be attributed to its proximity to the Athabasca River.

The most common fish in the river appear to be white and longnose suckers (Bond and Machniak 1979; Table 6); they are distantly followed in abundance by brook stickleback and lake chub. However, relative abundance is thought to change substantially in Reach 5 (and probably 6), where lake chub, longnose dace, pearl dace, and brook stickleback become more common. Large numbers of beaver dams severely restrict fish movement in the upper portion of the Muskeg River, and fish in this area are thought to be year-round residents (Bond and Machniak 1979).

Habitat limitations in the Muskeg River are thought to severely limit sport fish production. Sport fish (e.g., arctic grayling, mountain whitefish, Dolly Varden, walleye) that require

Table 6. Known distribution of fish in the Muskeg River.

	Presence in Reach[a]						Total Catch All Reaches[a]		Upstream Movement[b]	
	1	2	3	4	5	6[c]	No.	%	No.	%
Burbot	p[d]	p					3	<1	1	<1
Walleye	p	p							8	<1
Yellow perch	p	p					33	1		
Arctic grayling	p	p	p	p			75	3	161	3
Lake cisco		p							1	<1
Lake whitefish	p	p	p				16	<1	∿7	<1
Mountain whitefish	p	p					3	<1	∿50	<1
Dolly Varden	p	p							3	<1
Northern pike	p	p	p	p			14	<1	433	8
Longnose sucker	p	p	p	p			7	<1	1641	31
White sucker	p	p	p	p	p		38	1	2970	56
Sucker spp.							1916	73		
Lake chub	p	p	p	p	p		168	6		
Pearl dace	p	p	p	p	p		44	2		
Longnose dace	p	p	p				34	1		
Redbelly dace	p									
Spottail shiner	p						1	<1		
Fathead minnow	p	p					1	<1		
Trout-perch	p	p					8	<1		

continued...

Table 6. Concluded.

	Presence in Reach[a]						Total Catch All Reaches[a]		Upstream Movement[b]	
	1	2	3	4	5	6[c]	No.	%	No.	%
Brook stickleback	p	p	p	p	p		202	8		
Ninespine stickleback	p						1	<1		
Slimy sculpin	p	p	p				49	2		

[a]From small fish collections of Bond and Machniak (1979) and collections of Walder et al. (1980).

[b]From upstream traps of Bond and Machniak (1979).

[c]Fish of Reach 6 are unknown due to absence of fishing effort.

[d]p = present.

gravel or other hard substrates for spawning are limited to the short lower reaches of the river. Spawning of northern pike is probably more widespread, due to the extent of Reach 4 with its many marshy shallow water areas. Water flow in the Muskeg River is low in winter, and many fish apparently leave the system to overwinter in the Athabasca River.

Annual movements of fish to and from the Muskeg River have been studied by Bond and Machniak (1979), who provide life history information and detailed data on timing of movements. Over 85% of the fish that moved upstream in 1976 and 1977 were white and longnose suckers (Table 6). Arctic grayling (167) and northern pike (433) were also captured during upstream movement in 1977. Although these numbers are small in comparison to the numbers of suckers caught (about 4000 in the two years), they do illustrate that the Muskeg River has a limited sport fishery value.

4.2.4 Reaches of Hartley Creek

Hartley Creek is approximately 69 km long and is divided into five reaches (Figure 11). Headwater Reaches 5 and 6 are regions of high gradient--up to 6.6 m/km (Figure 12, Table 7). The remainder of Hartley Creek to its confluence with the Muskeg River is of moderate gradient, and the entire stream is predominantly placid and swirling pools. The stream is largely unconfined, and the banks show no signs of instability. Hard substrates are found only in Reaches 2, 3, and 4, where they occur in small amounts (5 to 10%). Debris is common along the lengths of the stream, especially upstream from Reach 2. Beaver dams are common in Reaches 4 and 5; they contribute large amounts of organic material to the streambed.

4.2.5 Fish Utilization of Hartley Creek

In contrast to the 21 species of fish that have been documented to occur in the mainstem of the Muskeg River, only 10 species are known to occur in Hartley Creek (Table 8); only three of these are sport fish (mountain whitefish, northern pike, and arctic grayling). Much of this lack of diversity of fish species in

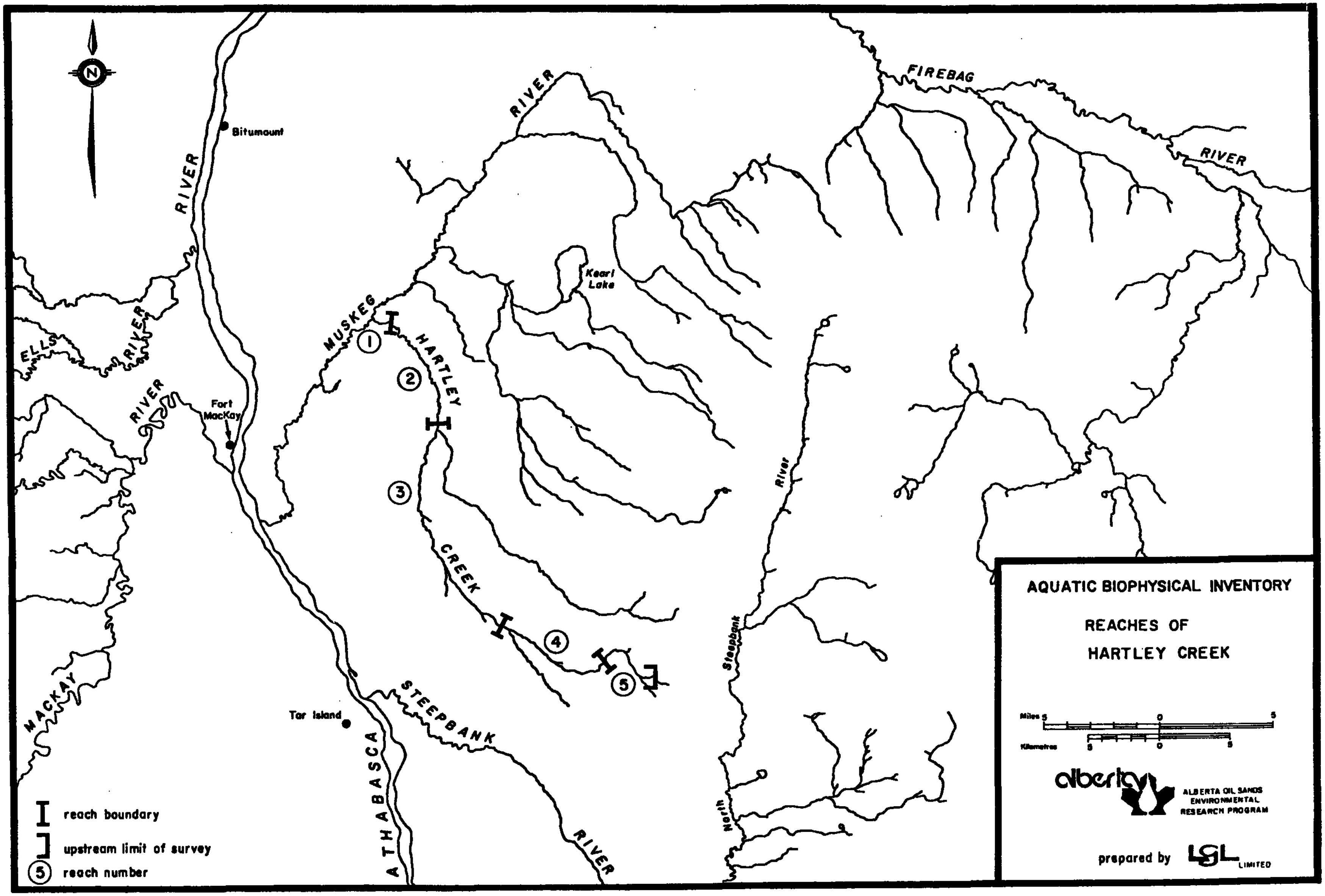


Figure 11. Reaches of Hartley Creek.

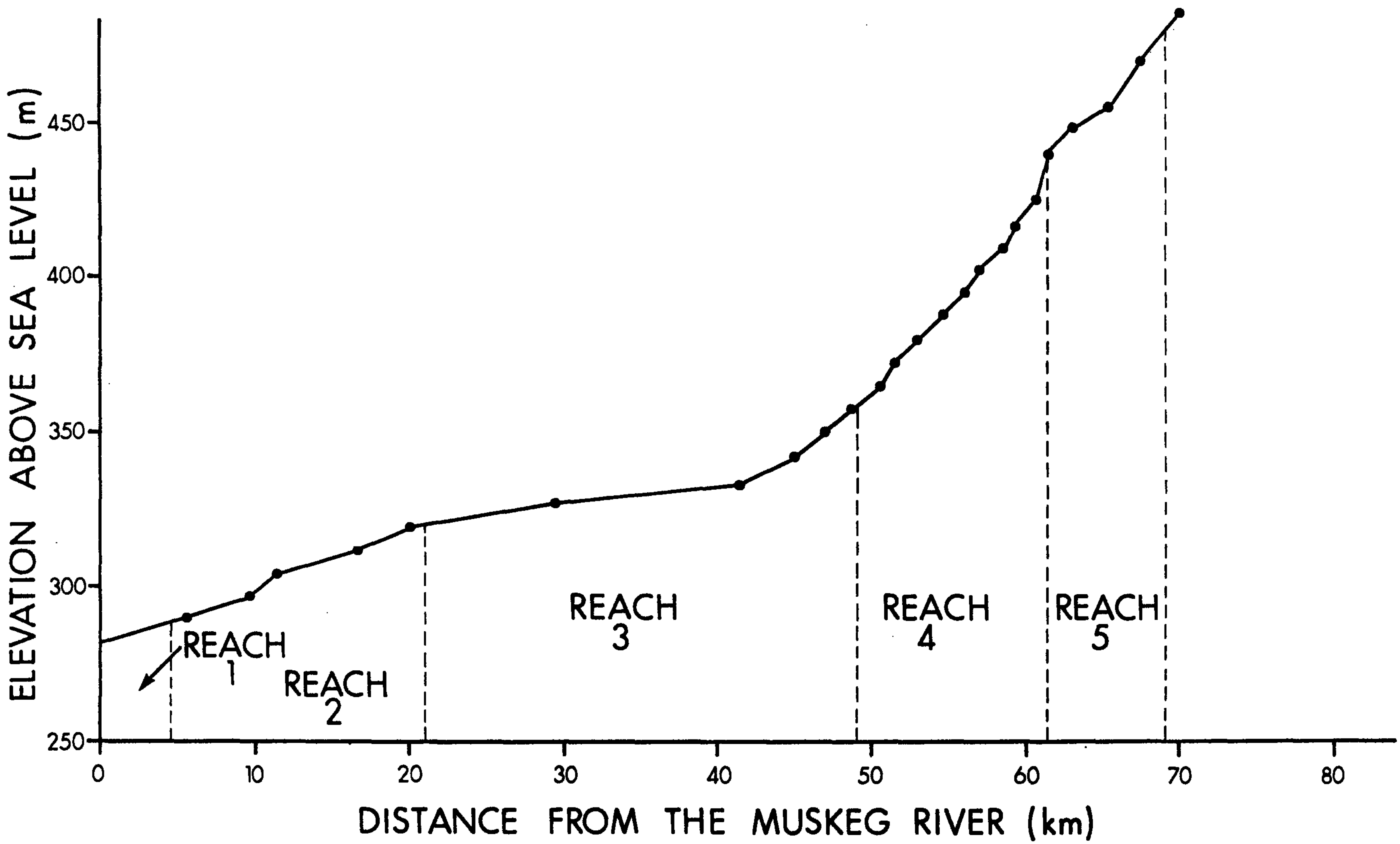


Figure 12. Elevation profile of Hartley Creek.

Table 7. Reach characteristics of Hartley Creek[a].

	Reach				
	1	2	3	4	5
Reach length (km)	4.5	16.5	28.0	12.5	7.5
Channel Width (m)	9	10	7	20	15
Channel area (ha)	4.1	16.5	19.6	25.0	11.3
Gradient (m/km)	1.1	2.1	1.3	6.6	5.2
Flow character[b]	p,s	p, s, r	p, s	p, s, r	p
Total pools (%)	95	70	95	90	100
Pattern[c]	tm	im	tm	im	im
Confinement[d]	uc	oc	uc	oc	uc
Unstable banks (%)	0	0	0	0	0
Substrate composition (%)					
fines (<2 mm)	100	90	90	95	100
gravels (2-64 mm)	0	5	5	5	0
larges (>64 mm)	0	5	5	0	0
bedrock and/or oil sand	0	0	0	0	0
Debris[e]	m	m	h	h	h

[a]From Walder et al. (1980).

[b]Flow character: b = broken; p = placid; r = rolling; s = swirling; t = tumbling.

[c]Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d]Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e]Debris: h = high; l = low; m = moderate.

Table 8. Known distribution of fish in Hartley Creek.

	Presence in Reach[a]					Total Catch All Reaches[a]	
	1	2	3	4	5[b]	No.	%
Arctic grayling	p[d]	p	p	p		3	2
Mountain whitefish[c]							
Northern pike	p						
Longnose sucker	p	p	p			3	2
White sucker	p	p	p	p		45	25
Lake chub	p	p	p	p		36	20
Pearl dace	p		p			6	3
Longnose dace		p	p	p		1	<1
Brook stickleback	p	p	p	p		76	42
Slimy sculpin		p	p	p		10	6

[a]From small fish collections of Bond and Machniak (1979) and collections of Walder et al. (1980).

[b]Fish of reach 5 are unknown due to absence of fishing effort.

[c]Mountain whitefish were reported in Hartley Creek, but location is unknown (Shell Canada Ltd. 1975).

[d]p = present.

Hartley Creek can be attributed both to its distance from the Athabasca River and to its lack of different habitat types. Available data indicate that the commonest fish in the stream are white sucker, lake chub, and brook stickleback, and that these species are distributed fairly uniformly along the length of the stream, at least to Reach 4 (Table 8). Small numbers of arctic grayling are found in Reaches 1 to 4, but northern pike have not been reported beyond Reach 1. Mountain whitefish are considered to be rare in Hartley Creek.

Although ripe arctic grayling, white sucker, and longnose sucker have been captured in Reach 1 (Shell Canada Ltd. 1975), spawning habitat in that portion of the stream is considered to be poor due to lack of gravels and other hard substrates. These specimens were probably moving upstream to areas where small amounts of hard substrates occur--primarily in Reaches 2 and 3 (Bond and Machniak 1979). Upstream fish movement in Hartley Creek is greatly restricted by beaver dams in Reaches 4 and 5. In general, available information suggests that production of sport fish in Hartley Creek is low, and is limited primarily to arctic grayling in the lower reaches of the stream.

4.3 STEEPBANK RIVER WATERSHED

4.3.1 General Description

The Steepbank River watershed encompasses an area of 1425 km^2 and is located about 42 km north of Fort McMurray (Figure 2). The mainstem of the Steepbank River is about 120 km long. The only major tributary to the Steepbank River is the North Steepbank River, which flows south and drains an area of 525 km^2 (37% of the drainage basin). Flow in the mainstem of the river is generally to the northwest. Headwaters of the drainage rise from the Muskeg Mountain Upland; the remainder of the drainage is contained in the Clearwater Lowland. (General physiographic features of these regions have been described in Section 4.2.1.) Only six lakes greater than 40 ha are present in the watershed.

Beaver activity is high in the upper portions of the watershed, and in some areas 90 to 95% of the channel is impounded (Machniak and Bond 1979). Fine substrates prevail in the above areas, but in more downstream portions substrates are usually a mixture of gravels, cobbles, and boulders.

From 1974 to 1978 mean annual flow in the Steepbank River ranged from 3.0 to 10.5 m^3/s (Loeppky and Spitzer 1977; Warner 1979; Warner and Spitzer 1979). In three of the five years, maximum monthly flows occurred in September after heavy rains. A mean flow of 30.3 m^3/s was recorded in September 1975. Mean monthly flows due to spring runoff have varied from a low of 7.2 m^3/s in 1977 to a high of 25.6 m^3/s in 1974. Minimum monthly winter flows are comparatively constant, varying from 0.3 to 0.6 m^3/s.

The Steepbank River water is usually clear with a brown organic stain. Water temperatures reach 20°C in the summer. Breakup usually occurs in late April, and ice begins to form in mid-October.

4.3.2 Reaches of the Steepbank River

The lower 75 km of the Steepbank River contain five reaches (Figure 13). Upper portions of the river and the entire North Steepbank River were not subjected to reach classification. As shown in Figure 14, the Steepbank River descends about 230 m from the upstream boundary of Reach 5 to its confluence with the Athabasca River. Gradient is relatively high in all reaches except Reach 5 (Table 9). As it descends, the river changes from a composition almost entirely of pools with fine substrates in Reach 5 to a mixture of pools, riffles, and broken water areas of primarily hard substrates. A prominent feature of the river is Reach 2, which is essentially a canyon with walls up to 60 m high. The river is confined for most of its length and banks are relatively stable.

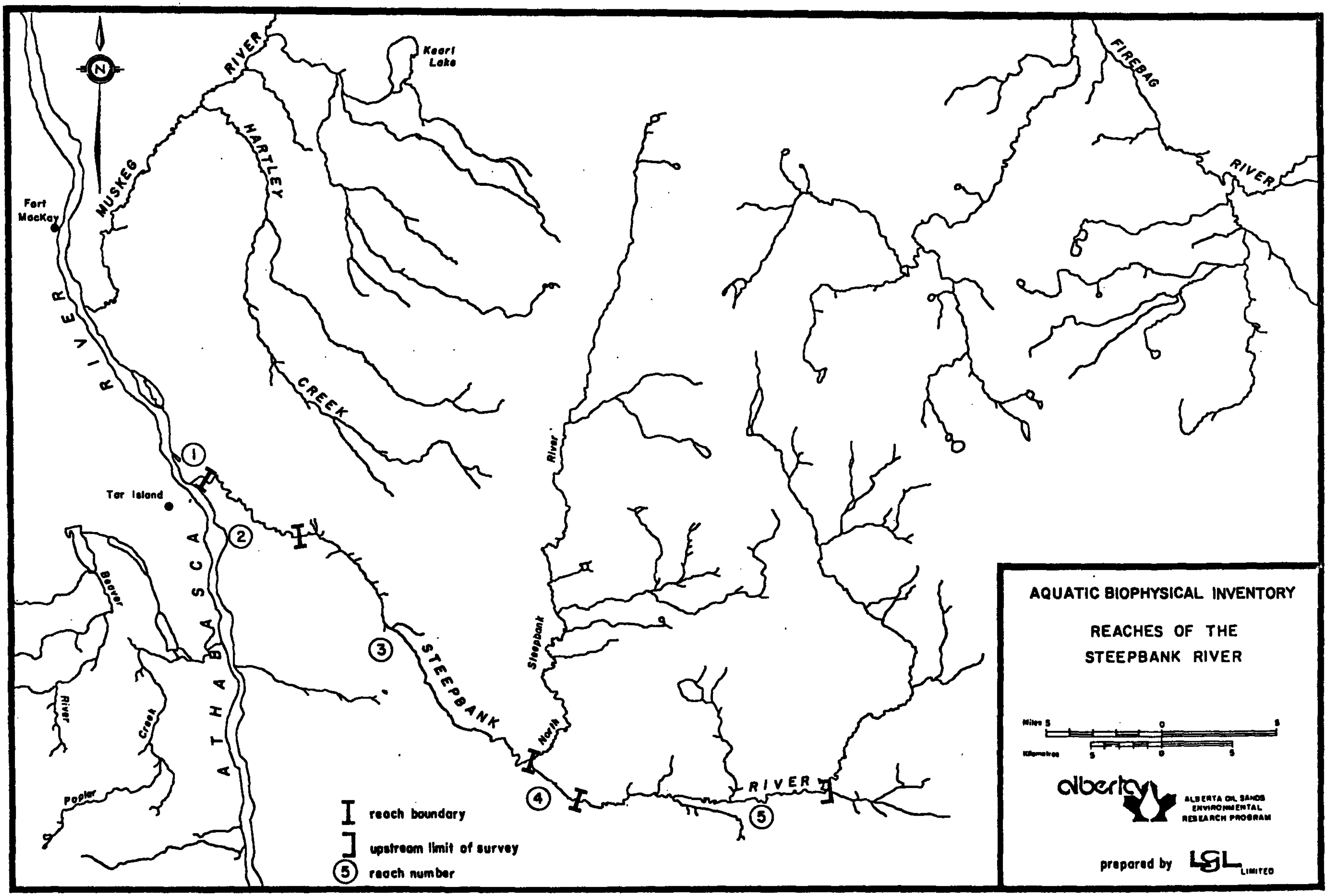


Figure 13. Reaches of the Steepbank River.

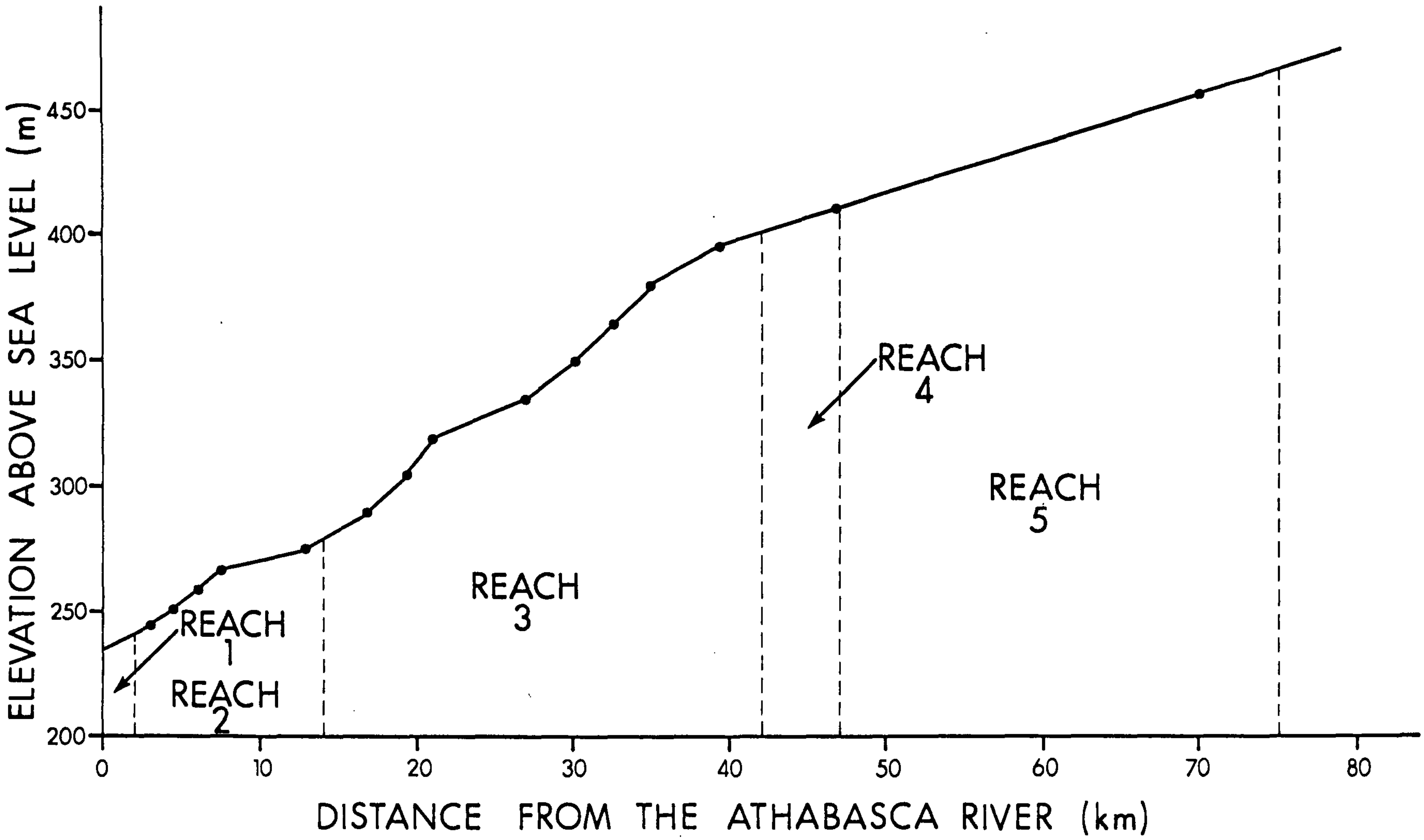


Figure 14. Elevation profile of the Steepbank River.

Table 9. Reach characteristics of the Steepbank River[a].

	Reach				
	1	2	3	4	5
Reach length (km)	2.0	12.0	28.0	5.0	28.0
Channel width (m)	20	12	12	10	12
Channel area (ha)	4.0	14.4	33.6	5.0	33.6
Gradient (m/km)	2.7	3.1	4.4	2.0	1.3
Flow character[b]	s, r	r, b	s, r, b	s, r, b	p
Total pools (%)	50	50	40	50	90
Pattern[c]	ir	im	si	si	im
Confinement[d]	oc	en	c	c	oc
Unstable banks (%)	10	20	10	5	5
Substrate composition (%)					
fines (<2 mm)	15	15	15	20	90
gravels (2-64 mm)	50	30	45	20	10
larges (>64 mm)	35	40	40	60	0
bedrock and/or oil sand	0	15	0	0	0
Debris[e]	l	l	l	l	h

[a] From Walder et al. (1980).

[b] Flow character: b = broken; p = placid; r = rolling; s = swirling; t = tumbling.

[c] Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d] Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e] Debris: h = high; l = low; m = moderate.

4.3.3 Fish Utilization of the Steepbank River

Twenty-four species of fish are known to occur in the Steepbank River (Table 10); however, only 10 species (arctic grayling, northern pike, longnose sucker, white sucker, lake chub, pearl dace, longnose dace, trout-perch, brook stickleback, and slimy sculpin) are common and widespread. Species such as goldeye, lake cisco, Dolly Varden, flathead chub, redbelly dace, spottail shiner, brassy minnow, fathead minnow, and spoonhead sculpin are rare, and are confined to the lowermost portion of the Steepbank River near its confluence with the Athabasca River. Although longnose and white suckers outnumber sport fish in the river, substantial numbers of arctic grayling, walleye, mountain whitefish, and northern pike also inhabit the river at least during the open water season. With the exception of arctic grayling and northern pike, all sport fish appear to be restricted to the lower three reaches (42 km) of the river.

As previously described, fish habitat upstream from Reach 4 changes substantially, due to the predominance of fine substrates and the scarcity of riffle areas. Northern pike spawning habitat is present, but it is doubtful that other sport fish spawn in the area. Reaches 1 to 4 contain a variety of excellent fish habitats (e.g., spawning gravels, feeding and resting areas, shelter), and this diversity appears to be partly responsible for the relatively large numbers of species present in that region of the river.

Machniak and Bond (1979) documented large spawning runs of longnose sucker and white sucker in the Steepbank River, with smaller numbers of arctic grayling, walleye, mountain whitefish, and northern pike entering the river in spring to spawn or feed (Table 10). Although the Steepbank River does not appear to be heavily utilized for overwintering by sport fish, it does provide valuable spawning grounds and/or summer feeding areas for a number of sport fish. Young-of-the-year arctic grayling may overwinter in the river (Machniak and Bond 1979), and it is thought that the northern pike that were found in Reach 4 may also overwinter in that area. Resident forage fish of the Steepbank River include lake

Table 10. Known distribution of fish in the Steepbank River.

	Presence in Reach[a]					Total Catch All Reaches[b]		Upstream Movement Catch[c]	
	1	2	3	4	5	No.	%	No.	%
Burbot	p[d]		p			6	<1	2	<1
Walleye	p		p			2	<1	222	3
Yellow perch	p					101	3		
Arctic grayling	p	p	p		p	52	1	1447	20
Lake cisco	p							1	<1
Lake whitefish	p					1	<1	39	<1
Mountain whitefish	p					5	<1	503	7
Dolly Varden	p							4	<1
Goldeye	p							7	<1
Northern pike	p			p				237	3
Longnose sucker	p	p	p	p	p	283	8	3811	52
White sucker	p	p	p		p	147	4	992	14
Sucker spp.	p	p		p	p	1467	42		
Lake chub	p	p	p	p	p	307	9		
Flathead chub	p							2	<1
Pearl dace	p	p	p	p	p	456	13		
Longnose dace	p	p	p	p		226	7		
Redbelly dace	p					1	<1		
Spottail shiner	p					17	<1		

continued...

Table 10. Concluded.

	Presence in Reach[a]					Total Catch All Reaches[b]		Upstream Movement Catch[c]	
	1	2	3	4	5	No.	%	No.	%
Brassy minnow	p					2	<1		
Fathead minnow	p					1	<1		
Trout-perch	p	p	p		p	115	3		
Brook stickleback	p			p	p	5	<1		
Slimy sculpin	p	p	p	p	p	271	8		
Spoonhead sculpin	p					2	<1		

[a]From Griffiths (1973), Machniak and Bond (1979), and Walder et al. (1980).

[b]From small fish collections of Machniak and Bond (1979) and collections of Walder et al. (1980).

[c]From upstream traps of Machniak and Bond (1979).

[d]p = present.

chub, pearl dace, longnose dace, trout-perch, brook stickleback, and slimy sculpin.

In summary, present information indicates that the Steepbank River is of moderate to high importance to several sport fish, especially arctic grayling, and to a lesser degree northern pike, walleye, and mountain whitefish. Little is known about the river upstream from Reach 5, but available data suggest that fish habitat is poor in headwater areas.

4.4 MACKAY RIVER WATERSHED

4.4.1 General Description

Of the five watersheds considered in the present report, the MacKay River watershed is the second largest--5517 km^2 in area (Figure 2). The watershed is located to the west of the Athabasca River, about 56 km northwest of Fort McMurray. Three major sub-basins are present. The mainstem of the MacKay River flows northeast for approximately 200 km and directly drains an area of 2350 km^2. The Dunkirk River generally flows southeast and drains 2183 km^2. The smaller Dover River, which generally flows to the northeast, drains approximately 984 km^2. Mouths of the Dover and Dunkirk rivers are 16 km and 89 km, respectively, upstream from the mouth of the MacKay River. Twenty-four lakes over 40 ha in area are present in the entire watershed; most are located in the headwaters of the Dunkirk River.

Headwaters of the Dunkirk and Dover rivers rise from the southern slopes of the Birch Mountains Upland; however, most of the watershed is within the Algar Plain. The lowermost few kilometres of the MacKay River flow across the Clearwater Lowland. In this region, Devonian limestone, Cretaceous sandstones and shales, and the McMurray Oil Sands Formation are sometimes exposed. Till, lacustrine clay, and silt are the predominant surficial materials in the upper and middle portions of the watershed (Northwest Hydraulic Consultants Ltd. 1975a). Vegetation in the watershed is primarily mixed spruce and muskeg, and most of the region is poorly drained, with the exception of lower portions adjacent to the mainstem of the MacKay River. Fine substrates prevail in the upper portions of all rivers, where banks are generally very stable. Hard substrates are more common in the middle and lower MacKay River, where bank instability is also more common.

Flow in the MacKay River fluctuates widely (Loeppky and Spitzer 1977; Warner 1979; Warner and Spitzer 1979). Minimum monthly winter flows (1973 to 1978) varied from 0.1 to 9.3 m^3/s. The maximum monthly flow recorded was 157 m^3/s in June 1973. Such maxima are more frequently caused by summer storms than by spring snowmelt. Mean annual discharge is somewhat more constant; it ranged from 6 to 27 m^3/s.

River water is normally slightly discoloured due to dissolved organics, but suspended sediment is generally low, except during periods of extreme floods.

4.4.2 Reaches of the MacKay River

The MacKay River was divided into two short reaches and five relatively long (25.5 to 46 km) reaches (Figure 15). Reaches 6 and 7 in the upper portion of the mainstem are of low gradient (Figure 16). In these areas, substrates are generally fines, pools are very common, and banks are stable (Table 11). These reaches, which account for slightly less than 50% of the MacKay River, are generally considered to provide moderate or poor sport fish habitat (Griffiths 1973). Habitat in the MacKay River improves considerably downstream from Reach 6, where the stream gradient is moderate, pools are interrupted by numerous riffle areas (especially in Reaches 3, 4, and 5), and a variety of substrate types is present (Table 11).

Stream banks become progressively more unstable in downstream reaches, especially in Reaches 1, 2, and 3. The latter two reaches of the MacKay River flow through a canyon where valley walls are 40 to 50 m high. Large areas of oil sands are exposed in the canyon and oil sands form a major part of the substrate. Reach 1 is contained in the Athabasca River floodplain, where undercut banks are common.

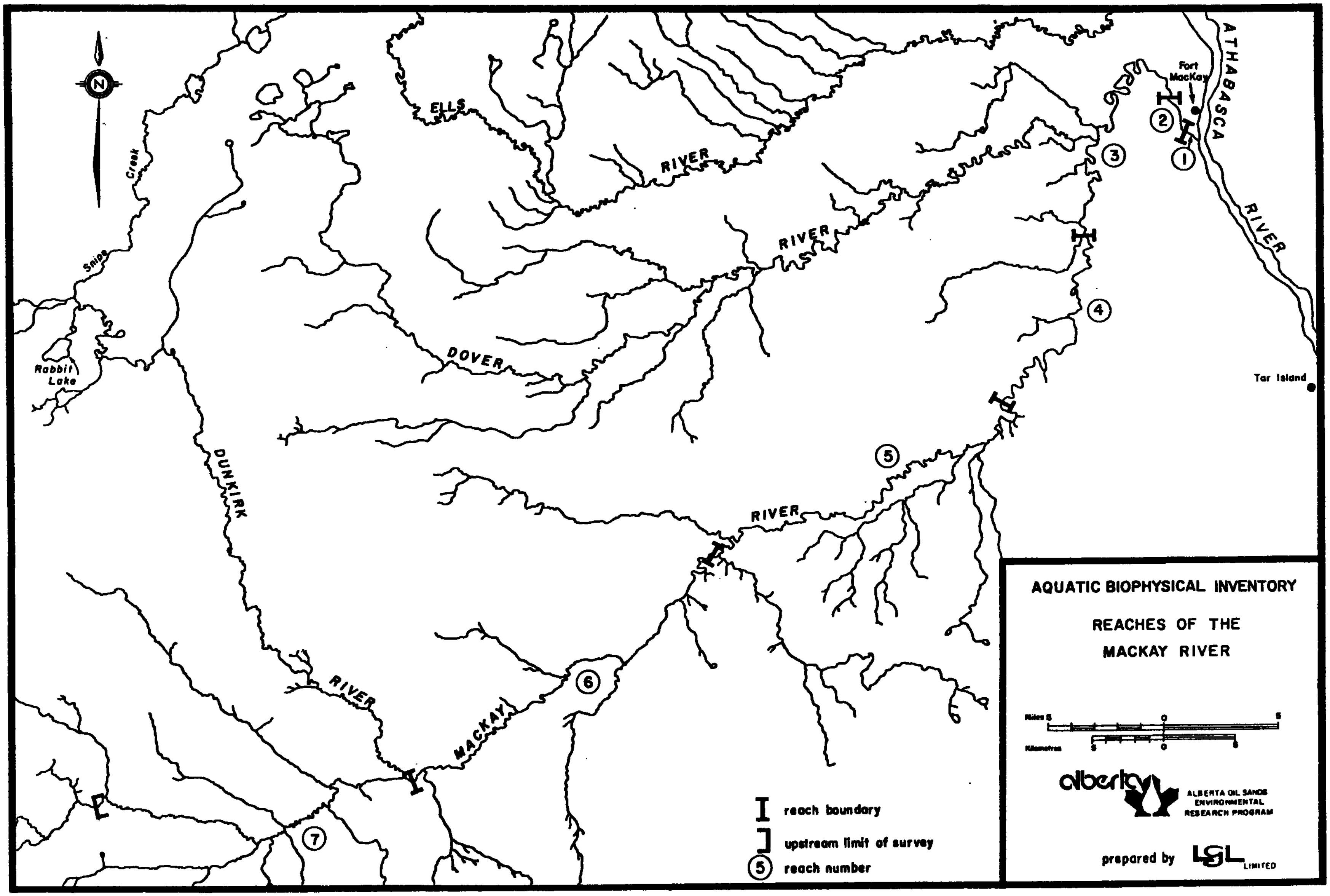


Figure 15. Reaches of the MacKay River.

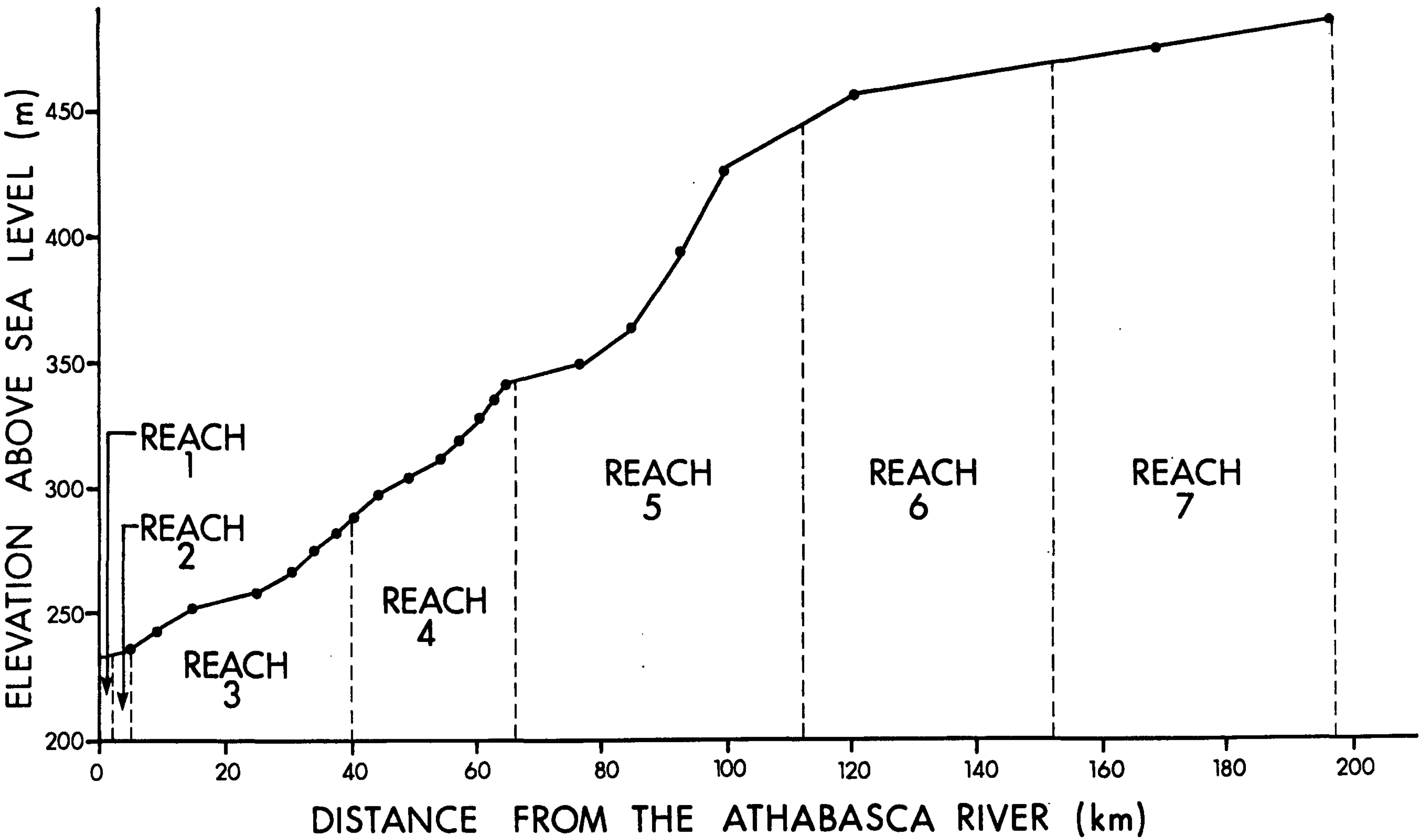


Figure 16. Elevation profile of the MacKay River.

Table 11. Reach characteristics of the MacKay River[a].

	Reach						
	1	2	3	4	5	6	7
Reach length (km)	1.4	3.1	35.5	25.5	46.0	40.0	45.5
Channel width (m)	70	31	28	50	45	38	10
Channel area (ha)	9.8	9.6	99.4	127.5	207.0	152.0	45.5
Gradient (m/km)	1.4	1.5	1.3	2.2	2.4	0.7	0.5
Flow character[b]	s	s	s, r, b	s, r	s, r, b	p, s, r	p
Total pools (%)	90	95	75	60	40	90	100
Pattern[c]	st	si	tm	im	im	im	tm
Confinement[d]	c	en	en	c	fc	oc	uc
Unstable banks (%)	45	25	60	15	10	2	0
Substrate composition (%)							
fines (<2 mm)	25	35	10	20	10	50	100
gravels (2-64 mm)	45	60	30	40	50	35	0
larges (>64 mm)	15	0	20	40	40	15	0
bedrock and/or oil sand	15	5	40	0	0	0	0
Debris[e]	l	l	l	l	l	h	h

[a]From Walder et al. (1980).

[b]Flow character: b = broken; p = placid; r = rolling; s = swirling; t = tumbling.

[c]Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d]Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e]Debris: h = high; l = low; m = moderate.

4.4.3 Fish Utilization of the MacKay River

The MacKay River is known to provide habitat for 21 species of fish. Known distributions of fish in the various reaches are shown in Table 12. Reaches 2 and 7 have received lesser amounts of fishing effort than other portions of the drainage. Additional efforts in Reach 7 would likely reveal the presence of a few more species of forage fish and possibly northern pike and longnose sucker. The large number of species reported in Reach 3 is due primarily to the fishing efforts of Machniak et al. (1980), who operated a counting fence and performed other intensive fishing efforts in Reach 3 in the spring of 1979. It is believed that virtually all fish species reported in Reach 3 are also found in Reach 2.

Species such as lake whitefish, goldeye, yellow perch, emerald shiner, and spottail shiner are thought to originate from the Athabasca River. They are present in very small numbers and utilize only the lowermost portions of the MacKay River. Large numbers of white and longnose suckers migrate upstream to spawning grounds in the spring. These species comprised 90% of the total number of fish moving upstream in 1979 (Machniak et al. 1980).

Available data suggest that sport fish are relatively uncommon in the MacKay River. Northern pike are most widespread; they likely occur in small numbers, and possibly spawn throughout the river. Arctic grayling, burbot, and mountain whitefish appear to be rare, and only small numbers of walleye occur--primarily in the lower three reaches of the river. Walleye accounted for 6% of the total catch of upstream migrants at the counting fence in 1979, but formed less than 1% of the catch in those collections in which small fish are prone to be captured (Table 12). The majority of the migrant walleye were spent males (Machniak et al. 1980), and the MacKay River appears to have little value as a spawning area for that species.

The combination of low winter flows, large amounts of fine substrate (especially in the upper portion of the river), and some extensive areas of bedrock in the lower reaches is not conducive to

Table 12. Known distribution of fish in the MacKay River.

	Presence in Reach[a]							Total Catch All Reaches[b]		Upstream Movement Catch[c]	
	1	2	3	4	5	6	7	No.	%	No.	%
Burbot	p[d]		p					3	<1	5	<1
Walleye	p	p	p			p		19	<1	364	6
Yellow perch	p							62	<1		
Arctic grayling	p		p		p			2	<1	49	<1
Lake whitefish	p		p							5	<1
Mountain whitefish	p		p					2	<1		
Goldeye	p		p					1	<1	21	<1
Northern pike	p		p	p		p		32	<1	90	2
Longnose sucker	p		p	p	p	p		2167	14	1236	21
White sucker	p	p	p	p	p	p	p	1750	11	3961	69
Lake chub	p		p	p	p	p	p	7420	48		
Flathead chub	p		p					4	<1	43	<1
Finescale dace			p	p	p	p		113	<1		
Pearl dace	p	p	p	p	p	p		724	5		
Longnose dace	p		p	p	p	p		132	<1		
Emerald shiner	p										
Spottail shiner	p		p					11	<1		
Trout-perch	p	p	p	p	p			2978	19	1	<1
Brook stickleback	p		p	p	p		p	10	<1		

continued...

Table 12. Concluded.

	Presence in Reach[a]							Total Catch All Reaches[b]		Upstream Movement Catch[c]	
	1	2	3	4	5	6	7	No.	%	No.	%
Slimy sculpin	p		p	p	p			174	1		
Spoonhead sculpin	p		p					2	<1		

[a]From Griffiths (1973), Machniak et al. (1980), and Walder et al. (1980).

[b]From small fish collections of Machniak et al. (1980) and collections of Walder et al. (1980).

[c]From upstream traps of Machniak et al. (1980).

[d]p = present.

overwintering and spawning of most sport fish. Griffiths (1973) indicated the presence of severe limiting factors to fish production in the upper MacKay River, and slight to moderate limitations in middle and lower portions of the mainstem. Studies since 1973 support Griffiths' evaluation and suggest that the MacKay River has importance as a summer feeding area for small numbers of walleye and as a year-round habitat for moderate to small numbers of northern pike.

4.4.4 Reaches of the Dover River

The Dover River consists of six reaches (Figures 17 and 18). The five upper reaches of the river (about 92% of its length) are almost entirely pools. Although the gradient is relatively high in some areas, large numbers of beaver dams throughout the river impede the flow and promote the accumulation of debris and soft substrates (Table 13). Gravel is nearly absent in Reaches 3, 5, and 6. Substantial amounts of gravel are present in the other reaches (which account for only 37% of the length of the river). The Dover River is largely unconfined and the banks are stable above Reach 2.

4.4.5 Fish Utilization of the Dover River

Although two juvenile yellow perch were collected in Reach 4 and one juvenile northern pike was obtained in Reach 3, the Dover River apparently has extremely little direct importance to sport fish (Table 14). Forage fish (primarily lake chub and pearl dace) and white sucker are the most abundant species in the Dover River; brook stickleback are probably the most widespread. Substantially more species of fish have been reported in Reaches 1 and 4 due to the fishing efforts of Machniak et al. (1980). Additional fishing efforts, especially in Reach 2, would undoubtedly reveal other species; however, only brook stickleback and perhaps pearl dace and lake chub likely occur in the headwaters of the Dover River.

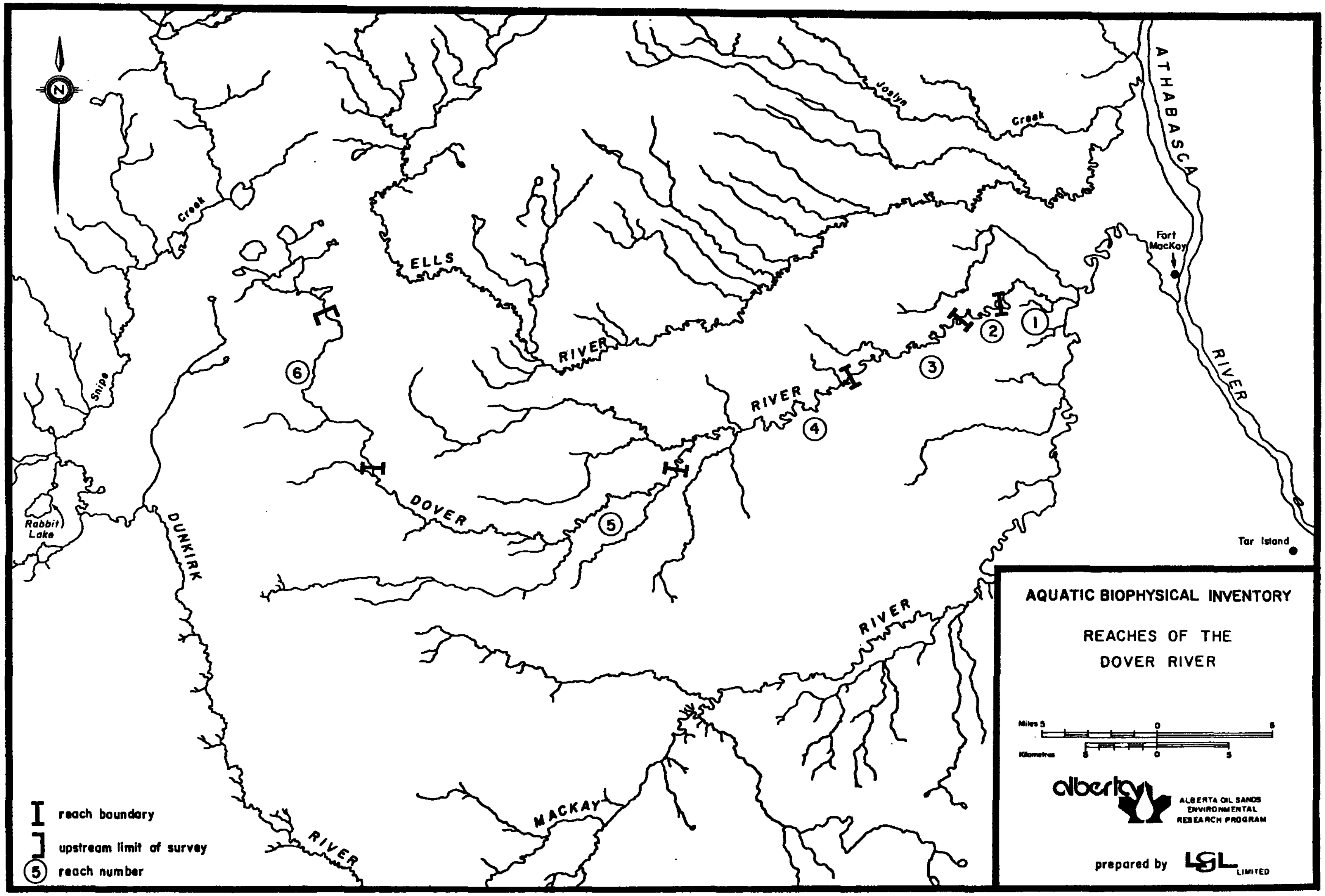


Figure 17. Reaches of the Dover River.

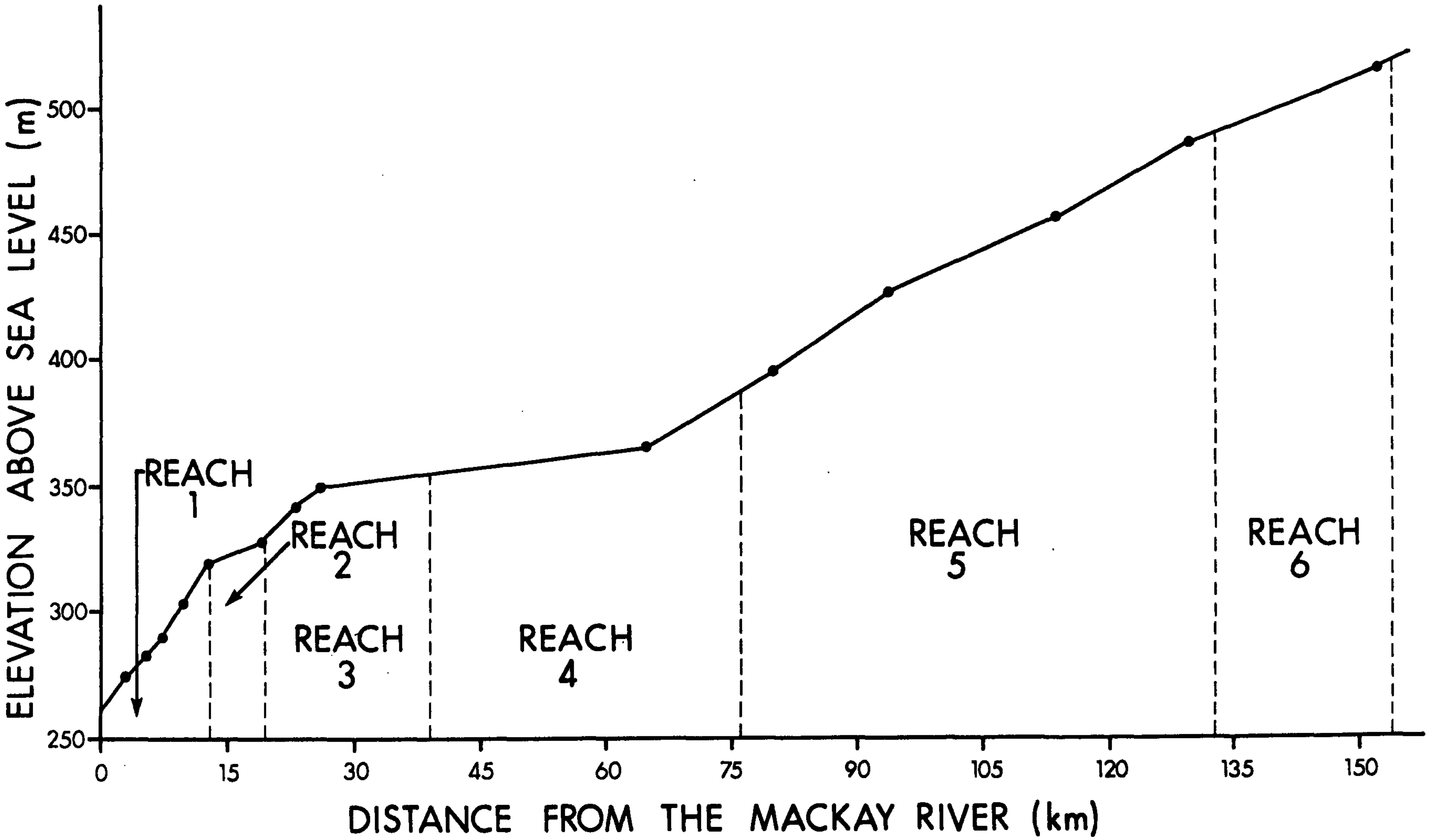


Figure 18. Elevation profile of the Dover River.

Table 13. Reach characteristics of the Dover River[a].

	Reach					
	1	2	3	4	5	6
Reach length (km)	12.5	7.0	19.7	36.8	56.5	21.5
Channel width (m)	10	15	20	14	7	75
Channel area (ha)	12.5	10.5	39.4	51.5	39.6	161.3
Gradient (m/km)	4.1	2.2	0.9	1.0	1.6	1.8
Flow character[b]	s, r, b	p, s	p	p, s	p, s	p
Total pools (%)	70	95	100	100	100	100
Pattern[c]	im	im	im	tm	tm	ir
Confinement[d]	c	fc	oc	uc	oc	uc
Unstable banks (%)	40	15	5	5	2	0
Substrate composition (%)						
fines (<2 mm)	20	40	95	60	95	95
gravels (2-64 mm)	40	35	5	40	5	5
larges (>64 mm)	35	20	0	0	0	0
bedrock and/or oil sand	5	5	0	0	0	0
Debris[e]	m	m	m	h	h	m

[a]From Walder et al. (1980).

[b]Flow character: b = broken; p = placed; r = rolling; s = swirling; t = tumbling.

[c]Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d]Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e]Debris: h = high; l = low; m = moderate.

Table 14. Known distribution of fish in the Dover River.

	Presence in Reach[a]						Total Catch All Reaches[b]	
	1	2	3	4	5	6	No.	%
Yellow perch				p[c]			2	<1
Northern pike			p				1	<1
Longnose sucker	p		p	p	p	p	55	5
White sucker	p	p	p	p	p		295	26
Lake chub	p			p	p		538	47
Finescale dace	p						18	2
Pearl dace	p			p	p		137	12
Longnose dace	p						21	2
Trout-perch	p		p	p	p		22	2
Brook stickleback					p	p	30	3
Slimy sculpin	p	p		p	p		21	2

[a]From Griffiths (1973), Machniak et al. (1980), and Walder et al. (1980).

[b]From small fish collections of Machniak et al. (1980) and collections of Walder et al. (1980).

[c]p = present.

In general, fish habitat is poor in the Dover River and catches indicate that it is rarely utilized by sport fish. Overwintering potential of the river appears to be low, little spawning habitat is available except for northern pike, and the large numbers of beaver dams would seriously impede any upstream fish movement.

4.4.6 Reaches of the Dunkirk River

Although it is over 80 km in length, the Dunkirk River is rather uniform in its physical characteristics and only three reaches were identified (Figure 19). Gradient is low throughout the river (Figure 20) and riffle areas are found only in Reach 2. Substrates in riffle areas are gravels and boulders, but the remainder of the river bottom is composed of fines (Table 15). Beaver dams are common in Reach 2. Most of the river is not confined by valley walls, banks are generally stable, and aquatic vegetation and debris are abundant.

4.4.7 Fish Utilization of the Dunkirk River

Only nine species of fish are known to occur in the Dunkirk River (Table 16). Lake chub appear to be most common; they are followed in abundance by white sucker, pearl dace, and trout-perch. Most species are found throughout the three reaches of the river, perhaps due to its rather uniform physical characteristics. Arctic grayling are rare, but available data indicate that northern pike, whose spawning habitat is widespread, are found in moderate or low numbers throughout the Dunkirk River.

In general, production of sport fish in the Dunkirk River appears to be low (except for northern pike), and the stream was considered to have severe limitations by Griffiths (1973). Although food is abundant for piscivorous fish, beaver dams restrict upstream fish movement, overwintering potential for large fish appears to be low or moderate, and spawning gravels are restricted.

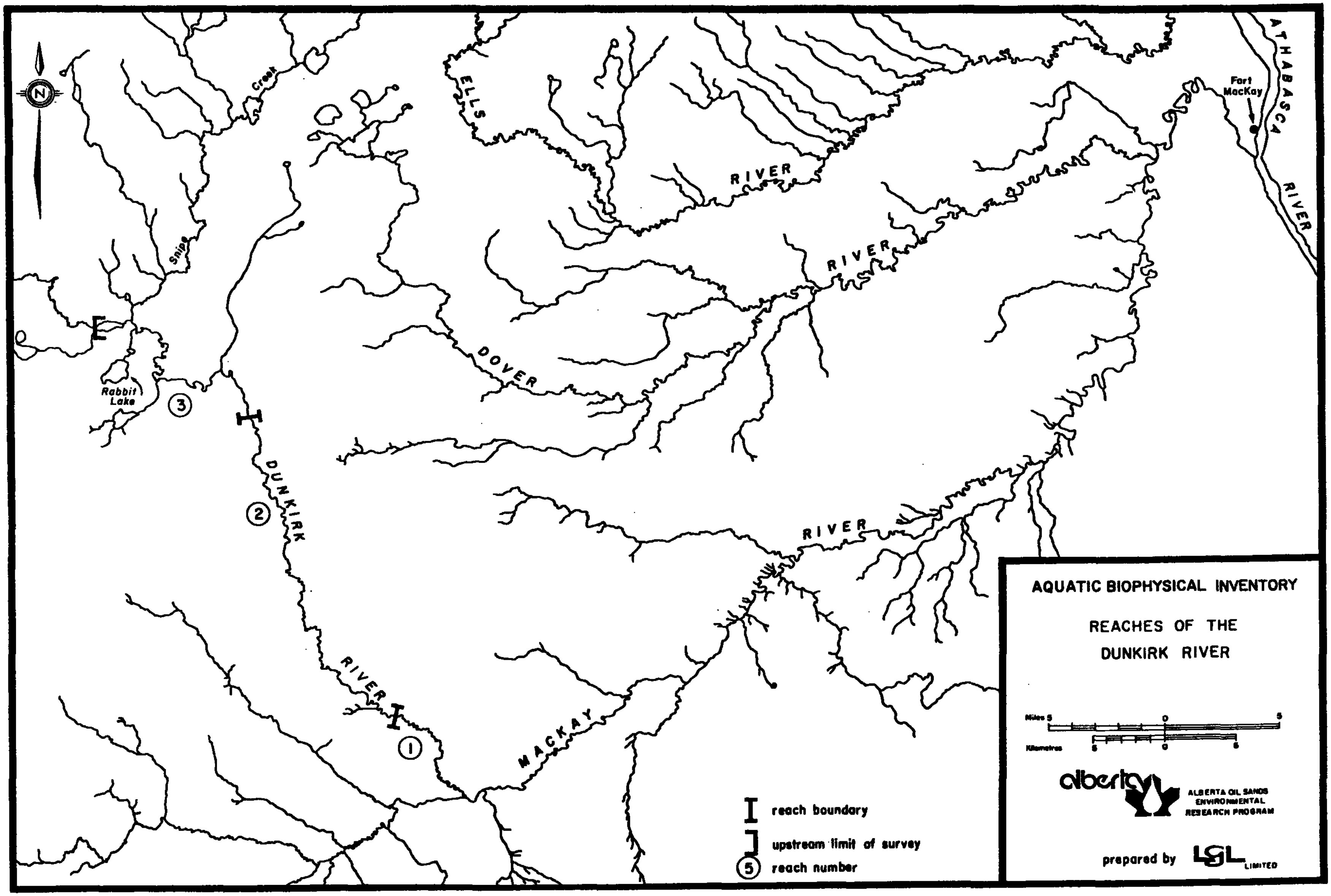


Figure 19. Reaches of the Dunkirk River.

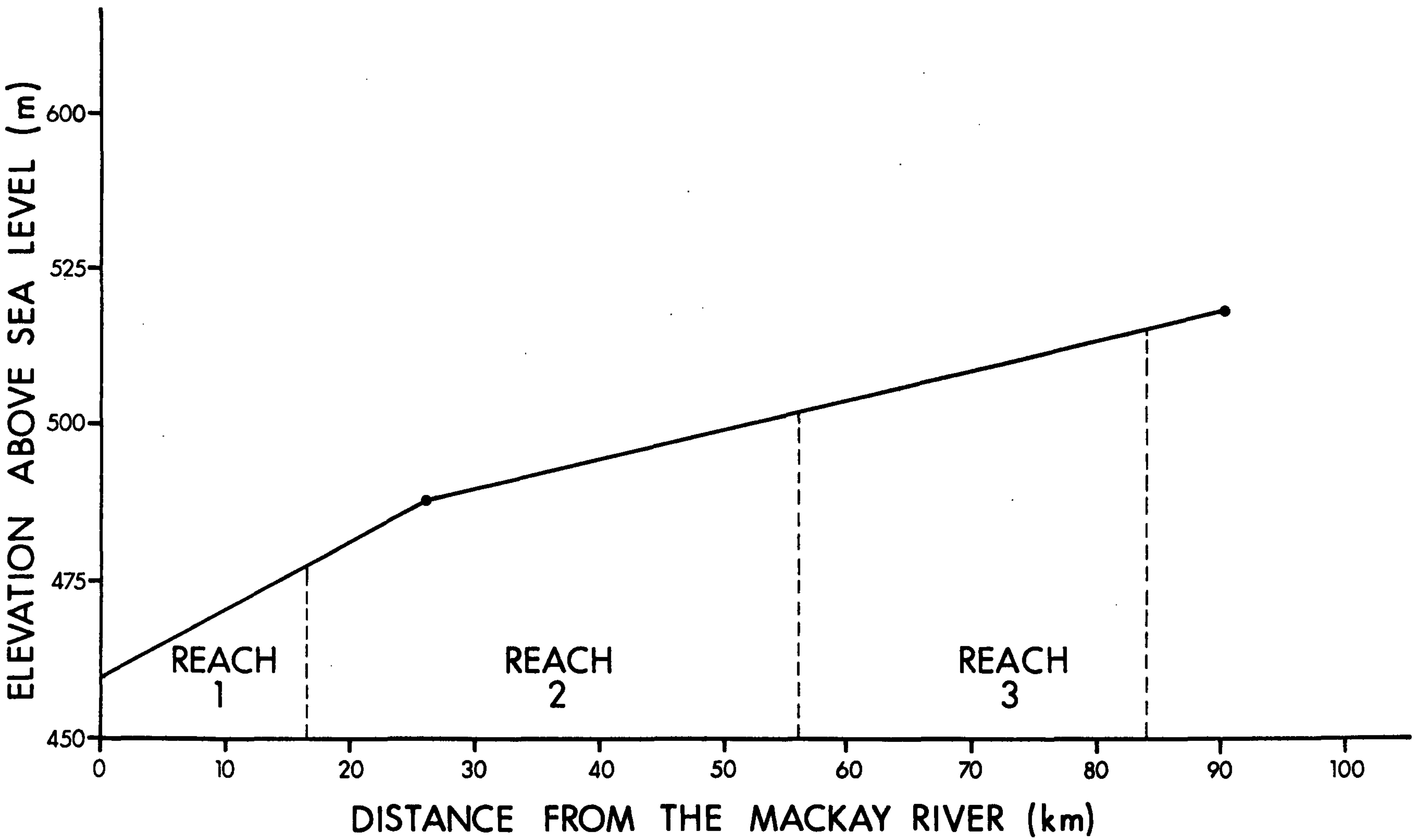


Figure 20. Elevation profile of the Dunkirk River.

Table 15. Reach characteristics of the Dunkirk River.

	Reach		
	1	2	3
Reach length (km)	16.5	39.7	27.8
Channel width (m)	17	22	13
Channel area (ha)	28.1	87.3	36.3
Gradient (m/km)	0.4	0.9	0.2
Flow character[b]	p	p, s, r	p
Total pools (%)	100	90	100
Pattern[c]	tm	im	im
Confinement[d]	uc	oc	uc
Unstable banks (%)	0	5	2
Substrate composition (%)			
fines (<2 mm)	100	50	100
gravels (2-64 mm)	0	30	0
larges (>64 mm)	0	20	0
bedrock and/or oil sand	0	0	0
Debris[e]	h	h	m

[a]From Walder et al. (1980).

[b]Flow character: b = broken; p = placid; r = rolling; s = swirling; t = tumbling.

[c]Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d]Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e]Debris: h = high; l = low; m = moderate.

Table 16. Known distribution of fish in the Dunkirk River.

	Presence in Reach[a]			Total Catch All Reaches[a]	
	1	2	3	No.	%
Arctic grayling			p[b]	2	<1
Northern pike	p	p	p	11	2
Longnose sucker		p		35	6
White sucker	p	p	p	132	23
Lake chub	p	p	p	232	40
Pearl dace	p	p	p	70	12
Trout-perch	p	p	p	65	11
Brook stickleback	p	p	p	16	3
Slimy sculpin	p	p		11	2

[a]From small fish collections of Machniak et al. (1980) and collections of Walder et al. (1980).
[b]p = present.

4.5 ELLS RIVER WATERSHED

4.5.1 General Description

The Ells River watershed is located about 64 km northwest of Fort McMurray, on the west side of the Athabasca River (Figure 2). It drains a total area of 2707 km^2 (Northwest Hydraulic Consultants Ltd. 1975a). Flow in the headwater region is to the south, but middle and lower sections of the river flow to the southeast and east, respectively, and the lowermost portion of the river flows northeast into the Athabasca River. Numerous small tributaries enter the mainstem of the Ells River from the north and northeast. The two largest tributaries to the Ells River, Joslyn Creek and Chelsea Creek, are both relatively small; they drain areas of about 264 km^2 and 202 km^2, respectively. Forty-four lakes over 40 ha in area are present in the watershed; most are located in the Gardiner Lakes area in the headwaters of the drainage.

The Ells River watershed has three distinct physiographic regions--a headwater area (Birch Mountains Upland), a gradually sloping midstream region (Algar Plain), and a downstream region (Clearwater Lowland) of variable gradients (Government and University of Alberta 1969).

The Birch Mountains Upland is a well-drained region with numerous lakes and streams. The surficial deposits in this region consist of glacial till over a bedrock of Cretaceous shales and sandstones (Research Council of Alberta 1972, cited by Northwest Hydraulic Consultants Ltd. 1975a). As the river gradually descends the south slope of the Birch Mountains Upland, it forms a narrow confined valley.

Once within the Algar Plain, the Ells River is no longer confined by valley walls. It flows through a variety of surficial deposits (muskeg, till, sands, and gravels) and occasional bedrock, which in this region is Cretaceous shales and sandstones.

In the Clearwater Lowland, the Ells River has many convoluted meanders that are entrenched within the bedrock of Cretaceous sandstones and shales (primarily the McMurray Tar Sands Formation) and Devonian limestone and dolomite. Surficial deposits in the Clearwater Lowland consist of sands, gravels, and till of glaciolacustrine origin.

Two gauging stations are established on the Ells River. The upper station is located about 8 km below the Gardiner Lakes, and the lower station is approximately 8 km above the mouth of the river. Mean annual flows from 1976 to 1978 varied from 3.4 to 6.4 m^3/s at the upper station and from 4.3 to 10.3 m^3/s at the lower station (Loeppky and Spitzer 1977; Warner 1979; Warner and Spitzer 1979). Minimum monthly flows at the upper and lower stations were 0.2 and 0.6 m^3/s, respectively, in March 1977. Minimum monthly flows in 1976 and 1978 were 1.4 and 0.9 m^3/s, respectively, at both the upstream and the downstream stations. The equivalence of upstream and downstream flows indicates that there is a minimum of groundwater entering the Ells River between the Birch Mountains and the Athabasca River during the winter months, and that the Gardiner Lakes system is important in maintaining winter flow. Maximum monthly flows tend to occur in the spring; a high of 27.8 m^3/s was recorded at the lower station in May 1978.

The Ells River water is usually stained light brown from decomposed organic matter. Suspended sediment concentrations are low, except during periods of high runoff. Water temperatures in the mainstem of the river probably reach 20°C in the summer, and the river channel is normally ice-free from late April to late October.

4.5.2 Reaches of the Ells River

The studied portion of the Ells River consists of eight reaches (Figure 21). Stream gradient is extremely varied over the length of the river (Figure 22) and a wide variety of habitats are present (Table 17). Descent of the river from the Birch Mountains Upland area is reflected in the very high gradient of Reaches 7 and 8.

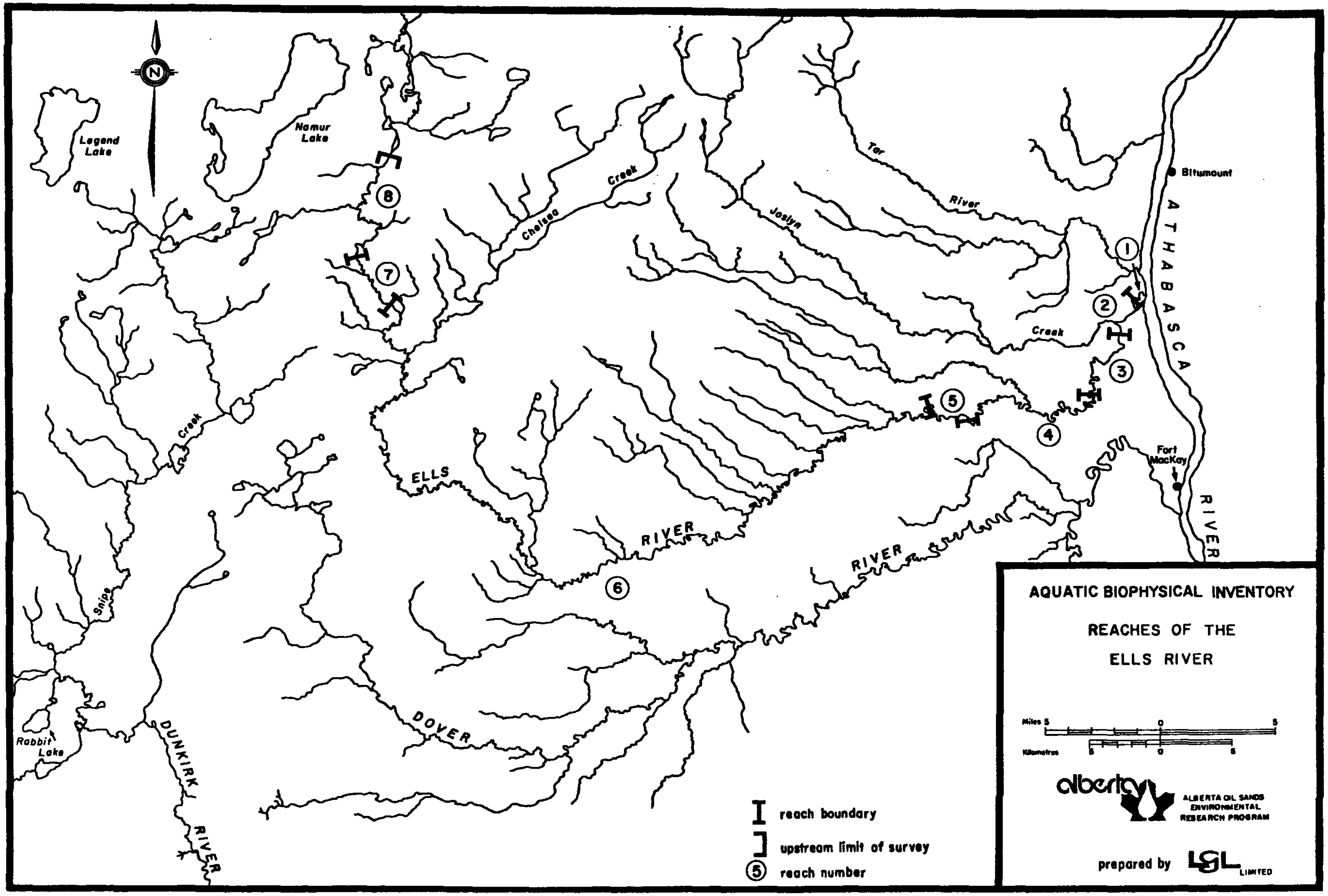


Figure 21. Reaches of the Ells River.

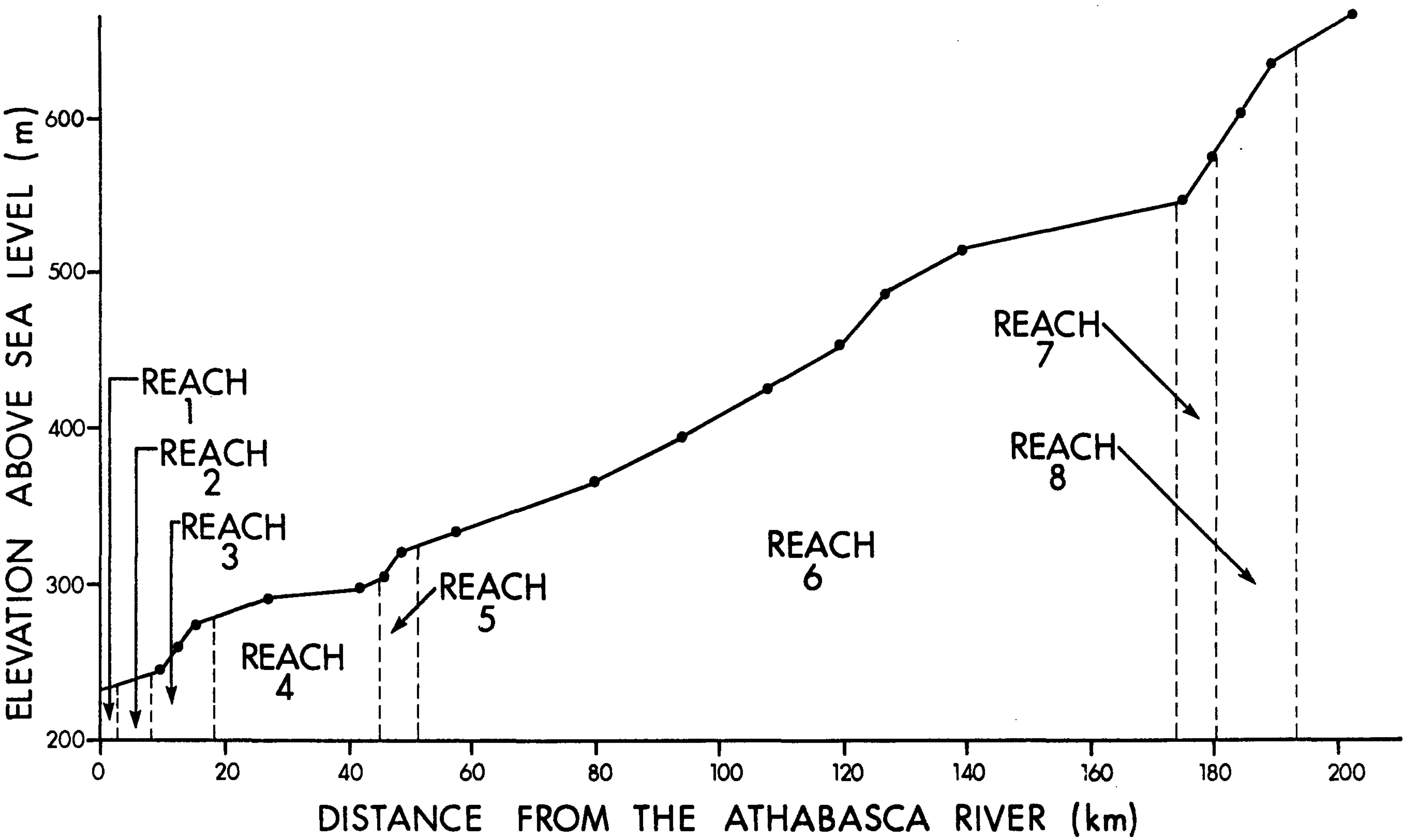


Figure 22. Elevation profile of the Ells River.

Table 17. Reach characteristics of the Ells River[a].

	Reach							
	1	2	3	4	5	6	7	8
Reach length (km)	2.5	5.5	10.0	27.0	6.0	123.0	6.0	13.0
Channel width (m)	35	35	30	30	25	30	20	30
Channel area (ha)	8.8	19.3	30.0	81.0	15.0	369.0	12.0	39.0
Gradient (m/km)	1.7	1.6	3.8	0.9	4.1	1.9	7.2	5.0
Flow character[b]	p, s	p, s	s, r, b	s, r	r, b	s, r, b	r, b	s, r, b
Total pools (%)	100	100	75	80	25	60	20	50
Pattern[c]	tm	im	im	tm	im	tm	im	im
Confinement[d]	oc	c	en	c	c	fc	c	c
Unstable banks (%)	20	40	35	40	20	35	10	5
Substrate composition (%)								
fines (<2 mm)	100	90	25	15	20	30	15	15
gravels (2-64 mm)	0	10	25	30	30	30	40	25
larges (>64 mm)	0	0	40	50	45	40	40	60
bedrock and/or oil sand	0	0	10	5	5	0	5	0
Debris[e]	l	m	l	l	m	m	m	m

[a]From Walder et al. (1980).

[b]Flow character: b = broken; p = placid; r = rolling; s = swirling; t = tumbling.

[c]Pattern: im = irregularly meandering; ir = irregular; si = sinuous; st = straight; tm = tortuously meandering.

[d]Confinement: c = confined; en = entrenched; fc = frequently confined; oc = occasionally confined; uc = unconfined.

[e]Debris: h = high; l = low; m = moderate.

The gradient is moderate within the Algar Plain (Reach 6), but is more severe in Reaches 5 to 1, as the river crosses the Clearwater Lowland and enters the Athabasca River.

Substrates in the lower two reaches, which constitute only about 3% of the length of the river, are almost entirely fines; substrates in the remaining 97% of the river are a mixture of fines, gravels, and larges, with small amounts of bedrock in some areas. Reaches 1 and 2 are entirely pools, whereas most other portions of the river have good pool-to-riffle ratios and contain some backwater areas. The river is almost entirely confined within moderately unstable banks. Deciduous trees and shrubs are most common along the Ells River. Scattered stands of conifers are present in most areas, especially in the upper reaches of the river.

4.5.3 Fish Utilization of the Ells River

Because intensive fisheries investigations have not been conducted on the Ells River, its fisheries resources are poorly known in comparison to those of the Steepbank, Muskeg, and MacKay rivers. However, 19 species have been reported from the mainstem of the Ells River; eight of these species are sport fish (Table 18). Although fishing efforts to date have not documented their presence in all reaches, arctic grayling, northern pike, and walleye probably occur throughout the river. Burbot, yellow perch, lake whitefish, mountain whitefish, and goldeye are likely to be confined to the lower two or three reaches of the river. As is commonly the case, forage fish (primarily lake chub, pearl dace, longnose dace, and trout-perch) and suckers are the most abundant fish in the Ells River. These species comprised 93% of the total catch, and are likely to be found throughout the river.

Griffiths (1973) considered the Ells River to have few limitations in relation to fish production, and Walder et al. (1980) found good to high quality fish habitat in nearly all sections of the river. A variety of spawning habitats, resting areas, feeding areas, and nursery areas are found in all but the lower two reaches of the river; 97% of the river thus provides high quality fish

Table 18. Known distribution of fish in the Ells River.

	Presence in Reach[a]								Total Catch All Reaches[b]	
	1	2	3	4	5	6	7	8	No.	%
Burbot	p[c]								1	<1
Walleye	p	p				p		p	12	<1
Yellow perch	p									
Arctic grayling					p	p	p	p	42	1
Lake whitefish	p								6	<1
Mountain whitefish	p	p							2	<1
Goldeye	p		p						16	<1
Northern pike	p	p		p	p	p		p	13	<1
Longnose sucker	p	p	p	p	p	p	p	p	313	10
White sucker	p	p	p	p		p	p	p	420	13
Sucker spp.		p		p	p	p		p	53	2
Lake chub		p	p	p	p	p	p	p	1698	52
Flathead chub	p								2	<1
Pearl dace				p	p	p			118	4
Longnose dace		p	p	p	p	p	p	p	273	8
Spottail shiner	p									
Trout-perch	p	p	p	p	p	p			208	6
Brook stickleback		p							3	<1
Slimy sculpin	p	p				p	p	p	83	3
Spoonhead sculpin	p					p			1	<1

[a]From Griffiths (1973) and Walder et al. (1980).

[b]From Walder et al. (1980).

[c]p = present.

habitat. In addition, winter flow from headwater regions to the mouth of the Ells River is relatively constant and most of the river could provide overwintering habitat. The Ells River is therefore regarded as having a high sport fishery potential.

It should be noted that the Gardiner-Namur lakes region, in the headwaters of the Ells River watershed, has long been recognized as an excellent producer of sport fish. Namur Lake and the Gardiner Lakes have the highest fisheries potential in the Fort McMurray region (Griffiths 1973). Fish species reported in this area include northern pike, grayling, lake whitefish, burbot, longnose and white sucker, slimy sculpin, lake cisco, yellow perch, walleye, and lake trout of trophy size.

5. CONCLUSIONS

Tables 19, 20, and 21 summarize present fisheries information on the nine streams within the five watersheds that were considered in the present study. Catches listed in Tables 19 and 20 should be interpreted with caution, because a variety of fishing techniques were used with unequal total efforts for the various rivers, and because local conditions at the times of sampling often determined the success of fishing efforts. In general, it is thought that, because most fishing was conducted with seines and electrofishers, numbers of large fish (i.e., most sport fish) were underestimated. The use of gill nets and angling was limited in 1978, and no gill netting was conducted in 1979 surveys. Collections by Bond and Machniak (1979), Machniak and Bond (1979), and Machniak et al. (1980) were obtained primarily with small mesh seines. The seasonal fish use of many of the streams is also ill-defined, because sampling was conducted only during brief periods.

Despite the above limitations, it is obvious that some tributary streams, such as the Dover River and the Dunkirk River, harbour few sport fish (Table 20). Northern pike is probably the commonest sport fish in these placid soft-bottomed streams, and numbers of pike present do not appear to be large. Much of the Muskeg and MacKay rivers are filled with fine sediment, and have a sluggish flow except in their lowermost portions; these rivers are also thought to have a very limited sport fish potential. It is thought that the data in Tables 19 and 20 are biased in favor of sport fish in the Muskeg River, because the majority of the fish were captured in the lower three reaches, which account for only a minor proportion of the total length of the river. Northern pike and arctic grayling are the primary sport fish in the Muskeg and MacKay rivers and their numbers appear to be low.

In contrast, the Ells, Marguerite, and Firebag rivers, and to a lesser extent the Steepbank River, are thought to have a high sport fish potential. Good fish habitat is generally widespread in these streams, and catches of sport fish are generally high in comparison to those in the above streams. A relatively large

Table 19. Total catches from all reaches of each river.

	Firebag River Watershed[a]				Muskeg River Watershed[b]						MacKay River Watershed[d]							
	Firebag River		Marguerite River		Muskeg River		Hartley Creek		Steepbank River[c]		MacKay River		Dover River		Dunkirk River		Ells River[a]	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Burbot	p[e]		p		3	<1			6	<1	3	<1					1	<1
Walleye	11	<1			p				2	<1	19	<1					12	<1
Yellow perch					33	1			101	3	62	<1	2	<1			p	
Arctic grayling	100	6	26	4	75	3	3	2	52	1	2	<1			2	<1	42	1
Lake cisco					p				p									
Lake whitefish	26	2			16	<1			1	<1	p						6	<1
Mountain whitefish			6	<1	3	<1	p		5	<1	2	<1					2	<1
Dolly Varden					p				p									
Goldeye									p		1	<1					16	<1
Northern pike	36	2	6	<1	14	<1	p		p		32	<1	1	<1	11	2	13	<1
Longnose sucker	105	6	55	9	7	<1	3	2	283	8	2167	14	55	5	35	6	313	10
White sucker	388	24	63	10	38	1	45	25	147	4	1750	11	295	26	132	23	420	13
Sucker spp.	66	4	19	3	1916	73			1467	42							53	2
Lake chub	702	43	300	47	168	6	36	20	307	9	7420	48	538	47	232	40	1698	52
Flathead chub	1	<1							p		4	<1					2	<1
Finescale dace											113	<1	18	2				
Pearl dace	34	2	4	<1	44	2	6	3	456	13	724	5	137	12	70	12	118	4
Longnose dace	109	7	26	4	34	1	1	<1	226	7	132	<1	21	2			273	8
Redbelly dace					p				1	<1								
Emerald shiner	p										p							
Spottail shiner					1	<1			17	<1	11	<1					p	
Brassy minnow									2	<1								
Fathead minnow					1	<1			1	<1								
Trout-perch	17	1	34	5	8	<1			115	3	2978	19	22	2	65	11	208	6
Brook stickleback	1	<1	3	<1	202	8	76	42	5	<1	10	<1	30	3	16	3	3	<1
Ninespine stickleback	4	<1			1	<1												
Slimy sculpin	26	2	94	15	49	2	10	6	271	8	174	1	21	2	11	2	83	3
Spoonhead sculpin			4	<1					2	<1	2	<1					1	<1

[a]From Walder et al. (1980).

[b]From small fish collections of Bond and Machniak (1979) and collections of Walder et al. (1980).

[c]From small fish collections of Machniak and Bond (1979) and collections of Walder et al. (1980).

[d]From small fish collections of Machniak et al. (1980) and collections of Walder et al. (1980).

[e]p=present.

Table 20. Contributions of sport fish to total fish catches in each river and watershed.

	Total Catch	No. of Sport Fish	% Sport Fish
Firebag River watershed[a]	2 266	211	9.3
Firebag River	1 626	173	10.6
Marguerite River	640	38	5.9
Muskeg River watershed[b]	2 793	147	5.3
Muskeg River	2 613	144	5.5
Hartley Creek	180	3	1.7
Steepbank River[c]	3 467	167	4.8
MacKay River watershed[d]	17 320	137	0.8
MacKay River	15 606	121	0.8
Dover River	1 140	3	0.3
Dunkirk River	574	13	2.3
Ells River[a]	3 264	92	2.8

[a]From Walder et al. (1980).

[b]From small fish collections of Bond and Machniak (1979) and collections of Walder et al. (1980).

[c]From small fish collections of Machniak and Bond (1979) and collections of Walder et al. (1980).

[d]From small fish collections of Machniak et al. (1980) and collections of Walder et al. (1980).

Table 2.1. Upstream movements of fish.

	Muskeg River[a]		Steepbank River[b]		MacKay River[c]	
	No.	%	No.	%	No.	%
Burbot	1	<1	2	<1	5	<1
Walleye	8	<1	222	3	364	6
Arctic grayling	161	3	1447	20	49	<1
Lake cisco	1	<1	1	<1		
Lake whitefish	∿7	<1	39	<1	5	<1
Mountain whitefish	∿50	<1	503	7		
Dolly Varden	3	<1	4	<1		
Goldeye			7	<1	21	<1
Northern pike	433	8	237	3	90	2
Longnose sucker	1641	31	3811	52	1236	21
White sucker	2970	56	992	14	3961	69
Flathead chub			2	<1	43	<1
Trout-perch					1	<1

[a]From upstream traps of Bond and Machniak (1979).

[b]From upstream traps of Machniak and Bond (1979).

[c]From upstream traps of Machniak et al. (1980).

(possibly atypical) catch of yellow perch near the mouth of the Steepbank River contributed heavily to the total catch of sport fish in that stream; sport fish may thus have been overestimated in the Steepbank River. The widespread distributions of walleye, northern pike, and arctic grayling account for the high percentage of sport fish in the Firebag River (Table 19) and its excellent potential as a sport fishery. Substantial numbers of the latter two species are also found in the Marguerite River, and the Firebag River watershed as a whole is highly rated (Table 20). It is believed that walleye, arctic grayling, and northern pike are also widely distributed throughout the Ells River. The Steepbank River also appears to be moderately productive; arctic grayling are likely found throughout the river, but northern pike and walleye appear to be more restricted in their distributions.

The lowermost portions of the streams that were studied harbour a far greater diversity of fish than the upstream areas. Most of these fish probably originate from the Athabasca River. Sport fish in this category include yellow perch, lake whitefish, mountain whitefish, Dolly Varden, goldeye, burbot, and possibly lake cisco. (Burbot are also endemic in some streams). In general, such areas have a substantially higher sport fish potential than do the middle or upper portions of the rivers.

The lower portions of the rivers also serve as migration routes for walleye, arctic grayling, northern pike, mountain whitefish, and very large numbers of white and longnose suckers. (Table 21). A large run of arctic grayling occurs in the Steepbank River, and substantial numbers of mountain whitefish, walleye, and northern pike also migrate upstream in the spring. Moderate numbers of walleye and arctic grayling migrate up the MacKay River and the Muskeg River, respectively. It should be noted that because the two most productive watersheds (the Firebag and the Ells) have not been intensively studied, larger runs of sport fish could occur in these rivers. The importance of the lowermost reaches of the streams in the study area is emphasized; if necessary, special measures to protect such areas should be taken.

In consideration of the present information on the aquatic habitat and the distribution and relative abundance of fish, the following general evaluation is offered of the five watersheds that were studied (based on comparisons among the five watersheds):

Watershed	Sport Fish Potential
Firebag River	excellent
Muskeg River	poor to moderate
Steepbank River	moderate
MacKay River	poor to possibly moderate
Ells River	excellent

6. REFERENCES CITED

Akena, A.M. 1979. An intensive surface water quality study of the Muskeg River watershed. Vol. I, water chemistry. Prep. for Alberta Oil Sands Environmental Research Program by Alberta Environment. AOSERP Report 85. 187 pp.

Barton, D.R., and R.R. Wallace. 1980. Ecological studies of the aquatic invertebrates of the Alberta Oil Sands Environmental Research Program study area of northeastern Alberta. Prep. for Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute. AOSERP Report 88. 215 pp.

Bond, W.A., and K. Machniak. 1977. Interim report on an intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Prep. for Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute. AOSERP Report 26. 137 pp.

Bond, W.A., and K. Machniak. 1979. An intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Prep. for Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute. AOSERP Report 76. 180 pp.

Brown, A., M.J. Kent, J.O. Park, and R.D. Robarts. 1978. Preliminary recommendations for mapping of aquatic habitat parameters for the AOSERP study area. Prep. for Alberta Oil Sands Environmental Research Program by Schultz International Ltd. AOSERP Project AF 4.4.1. 113 pp.

Chamberlin, T., and D. Humphries, editors. 1977. Aquatic system inventory and analysis: an interim methodological summary prepared for a workshop, March 23 and 24, 1977. Resource Analysis Branch, B.C. Ministry of Environment. 51 pp.

Government and University of Alberta. 1969. Atlas of Alberta. Univ. Alberta Press, Edmonton. 162 pp.

Griffiths, W.E. 1973. Preliminary fisheries survey of the Fort McMurray tar sands area. Alberta Dep. Lands and Forests, Fish and Wildlife Div. 622 pp.

Hartland-Rowe, R.C.B., R.W. Davies, M. McElhone, and R. Crowther. 1979. The ecology of macrobenthic invertebrate communities in Hartley Creek, northeastern Alberta. Prep. for Alberta Oil Sands Environmental Research Program by Dep. Biology, Univ. Calgary. AOSERP Report 49. 144 pp.

Herrington, R.B., and S.R. Tocher. 1967. Aerial photo techniques for a recreation inventory of mountain lakes and streams. U.S. Forest Serv. Res. Pap. INT-37. Inter-mountain Forest and Range Exp. Sta., Ogden, Utah. 21 pp.

Hickman, M., S.E.D. Charlton, and C.G. Jenkerson. 1979. Interim report on a comparative study of benthic algal primary productivity in the AOSERP study area. Prep. for Alberta Oil Sands Environmental Research Program by Dep. Botany, Univ. Alberta. AOSERP Report 75. 107 pp.

Lock, M.A., and R.R. Wallace. 1979a. Interim report on ecological studies on the lower trophic levels of muskeg rivers within the Alberta Oil Sands Environmental Research Program study area. Prep. for Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute. AOSERP Report 58. 105 pp.

Lock, M.A., and R.R. Wallace. 1979b. Aquatic biological investigations of the Muskeg River watershed. Prep. for Alberta Oil Sands Environmental Research Program by Environment Canada, Freshwater Institute. AOSERP Report 67. 29 pp.

Loeppky, K.D., and M.O. Spitzer. 1977. Interim compilation of stream gauging data to December 1976 for the Alberta Oil Sands Environmental Research Program by Environment Canada, Water Survey. AOSERP Project HY 1.1. 257 pp.

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

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

Merrit, R.W., and K.W. Cummins, editors. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Co., Dubuque, Iowa. 441 pp.

Neill, C.R., and B.J. Evans. 1979. Synthesis of surface water hydrology. Prep. for Alberta Oil Sands Environmental Research Program by Northwest Hydraulic Consultants Ltd. AOSERP Report 60. 84 pp.

Northwest Hydraulic Consultants Ltd. 1975a. Hydrological aspects of river basins in the northeast Alberta region. Prep. for Ekistic Design Consultants Ltd.

Northwest Hydraulic Consultants Ltd. 1975b. A preliminary investigation of minimum flows of selected rivers in the northeast Alberta region. Prep. for Ekistic Design Consultants Ltd.

Northwest Hydraulic Consultants Ltd. 1975c. Recreational aspects of river basins in the northeast Alberta region. Prep. for Ekistic Design Consultants Ltd.

Pennak, R.W., editor. 1978. Fresh-water invertebrates of the United States. Second Edition. John Wiley & Sons, Inc., New York. 803 pp.

Renewable Resources Consulting Services Ltd. (RRCS). 1975. Northwest Alberta regional plan project: fishery resources. Vol. 1, regional assessment. Vol. 2, technical appendices. Prep. for Ekistic Design Consultants Ltd. Vol. 1, 84 pp. Vol. 2, 389 pp.

Research Council of Alberta. 1972. Hydraulic and geomorphic characteristics of rivers in Alberta. (Cited in Northwest Hydraulic Consultants Ltd., 1975a.)

Schwartz, F.W. 1979. Interim report on a hydrogeological investigation of the Muskeg River basin, Alberta. Prep. for Alberta Oil Sands Environmental Research Program by Dep. Geology, Univ. Alberta. AOSERP Report 48. 104 pp.

Seidner, R.T. 1980. Regional water quality of the Alberta Oil Sands Environmental Research Program study area. Volume II: Discussion of 1976 and 1977 data. Prep. for Alberta Oil Sands Environmental Research Program by Alberta Environment. AOSERP Project HY 2.8.1. 245 pp.

Shell Canada Ltd. 1975. Environmental impact assessment, Lease 13 mining project, Alberta oil sands. Prep. for Alberta Environment. 257 pp.

Walder, G.L., P.L. Strankman, E.B. Watton, and K.A. Bruce. 1980. Aquatic biophysical inventory of major tributaries in the AOSERP study area. Volume II; Atlas. Prep. for Alberta Oil Sands Environmental Research Program by LGL Limited. AOSERP Project WS 3.4. 166 pp.

Ward, H.B., and G.C. Whipple. 1959. Fresh-water biology. Second Edition. W.T. Edmondson, editor. John Wiley & Sons Inc., New York. 1248 pp.

Warner, L.A. 1979. Interim compilation of stream gauging data, 1978. Prep. for Alberta Oil Sands Environmental Research Program by Environment Canada, Water Survey. AOSERP Project WS 1.1. 68 pp.

Warner, L.A., and M.O. Spitzer. 1979. Interim compilation of stream gauging data, 1977. Prep. for Alberta Oil Sands Environmental Research Program by Environment Canada, Water Survey. AOSERP Project HY 1.1. 99 pp.

Wrangler, E.M., and R.T. Seidner, compilers and editors. 1979. Aquatic system workshop, 20 and 21 September 1978. Prep. for Alberta Oil Sands Environmental Research Program. AOSERP Project WS 3.4. 148 pp.

7. LIST OF AOSERP RESEARCH REPORTS

Report	Project	Reference
1	PM	Alberta Oil Sands Environmental Research Program. 1976. First annual report, 1975. Alberta Oil Sands Environmental Research Program. AOSERP Report 1. 58 pp.
2	AF 4.1.1	Kristensen, J., B.S. Ott, and A.D. Sekerak. 1976. Walleye and goldeye fisheries investigations in the Peace-Athabasca Delta--1975. Prep. for the Alberta Oil Sands Environmental Research Program by LGL Ltd., Environmental Research Associates. AOSERP Report 2. 103 pp.
3	HE 1.1.1	McVey, W.W. 1976. Structure of a traditional baseline data system. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Alberta, Population Research Laboratory. AOSERP Report 3. 26 + 266 pp.
4	VE 2.2	Stringer, P.W. 1976. A preliminary vegetation survey of the Alberta Oil Sands Environmental Research Program study area. Prep. for the Alberta Oil Sands Environmental Research Program by Intraverda Plant Systems Ltd. AOSERP Report 4. 108 pp.
5	HY 3.1	Strosher, M.T., and E. Peake. 1976. The evaluation of waste waters from an oil sand extraction plant. Prep. for the Alberta Oil Sands Environmental Research Program by The University of Calgary, Environmental Sciences Centre (Kananaskis). AOSERP Report 5. 103 pp.
6	PM	Patterson, R., and A.M. Lansdown. 1976. Housing for the north--the stackwall system: construction report, Mildred Lake tank and pump house. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Manitoba, Faculty of Engineering, Northern Housing Committee. AOSERP Report 6. 36 pp.
7	AF 3.1.1	Jantzie, T.D. 1977. A synopsis of the physical and biological limnology and fishery programs within the Alberta oil sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Renewable Resources Consulting Services Ltd. AOSERP Report 7. 73 pp.

8	AF 1.2.1	Machniak, K. 1977. The impact of saline waters upon freshwater biota (a literature review and bibliography). Prep. for the Alberta Oil Sands Environmental Research Program by Aquatic Environments Ltd. AOSERP Report 8. 258 pp.
9	ME 3.3	Croft, B.R., A. Lamb, and R.N. Dawson. 1977. Preliminary investigation into the magnitude of fog occurrence and associated problems in the oil sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Stanley Associates Engineering Ltd. AOSERP Report 9. 87 pp.
10	HE 2.1	Millar, J.F.V. 1977. Development of research design related to archaeological studies in the Athabasca Oil Sands area. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Saskatchewan. AOSERP Report 10. 69 pp.
11	AF 2.2.1	Flannagan, J.F. 1977. Life cycles of some common aquatic insects of the Athabasca River, Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 11. 20 pp.
12	ME 1.7	Mercer, J.M., and R.B. Charlton. 1977. Very high resolution meteorological satellite study of oil sands weather: "a feasibility study". Prep. for the Alberta Oil Sands Environmental Research Program by the University of Alberta, Department of Geography. AOSERP Report 12. 44 pp.
13	ME 2.3.1	Davison, D.S., C.J. Fortems, and K.L. Grandia. 1977. Plume dispersion measurements from an oil sands extraction plant, March 1976. Prep. for the Alberta Oil Sands Environmental Research Program by Intera Environmental Consultants Ltd. AOSERP Report 13. 195 pp.
14		none
15	ME 3.4	Denison, P.J. 1977. A climatology of low-level air trajectories in the Alberta oil sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Acres Consulting Services. AOSERP Report 15. 118 pp.

16	ME 1.6	Barge, B.L., R.G. Humphries, and S.L. Olson. 1977. The feasibility of a weather radar near Fort McMurray, Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Research Council. Atmospheric Sciences Division. AOSERP Report 16. 72 pp.
17	AF 2.1.1	Lutz, A., and M. Hendzel. 1977. A survey of baseline levels of contaminants in aquatic biota of the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 17. 51 pp.
18	HY 1.1	Loeppky, K.D., and M.O. Spitzer. 1977. Interim compilation of stream gauging data to December 1976 for the Alberta Oil Sands Environmental Research Program. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 18. 257 pp.
19	ME 4.1	Walmsley, J.L., and D.L. Bagg. 1977. Calculations of annual averaged sulphur dioxide concentrations at ground level in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Atmospheric Environment Service. AOSERP Report 19. 40 pp.
20	HE 3.1.1	Strosher, M.T., and E. Peake. 1978. Characterization of organic constituents in waters and wastewaters of the Athabasca Oil Sands mining area. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Calgary, Environmental Sciences Centre (Kananaskis). AOSERP Report 20. 70 pp.
21	PM	Alberta Oil Sands Environmental Research Program. 1977. Second Annual Report, 1976-77. Alberta Oil Sands Environmental Research Program. AOSERP Report 21. 62 pp.
22	PM	Smith, S.B. (ed.). 1979. Alberta Oil Sands Environmental Research Program interim report covering the period April 1975 to November 1978. Prep. by A.S. Mann, R.A. Hursey, R.T. Seidner, and B. Kasinska-Banas. Edmonton, Alberta. AOSERP Report 22.

23 AF 1.1.2 Lake, W., and W. Rogers. 1979. Acute lethality of mine depressurization water on trout perch and rainbow trout. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Environment. AOSERP Report 23. 44 pp.

24 ME 1.5.2 ME 3.5.1 Fanaki, F., R. Mickle, M. Lusis, J. Kovalick, J. Markes, F. Froude, J. Arnold, A. Gallant, S. Melnychuk, D. Brymer, A. Gaudenzi, A. Moser, and D. Bagg. 1979. Air system winter field study in the AOSERP study area. February 1977. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Atmospheric Environment Service. AOSERP Report 24. 182 pp.

25 ME 3.5.1 Bottenheim, J.W., and O.P. Strausz. 1977. Review of pollutant transformation processes relevant to the Alberta oil sands area. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Alberta, Hydrocarbon Research Centre. AOSERP Report 25. 166 pp.

26 AF 4.5.1 Bond, W.A., and K. Machniak. 1977. Interim report on an intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Department of Fisheries. AOSERP Report 26. 137 pp.

27 ME 1.5.1 Fanaki, F., compiler. 1978. Meteorology and air quality winter field study in the AOSERP study area, March 1976. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Atmospheric Environment Service. AOSERP Report 27. 249 pp.

28 VE 2.1 Turchenek, L.W., and J.D. Lindsay. 1978. Interim report on a soils inventory in the Athabasca Oil Sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Research Council, Soils Division. AOSERP Report 28. 100 pp.

29 ME 2.2 Shelfentook, W. 1978. An inventory system for atmospheric emissions in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by SNC Tottrup Services Ltd. AOSERP Report 29. 58 pp.

30	ME 2.1	Strosher, M.M. 1978. Ambient air quality in the AOSERP study area, 1977. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Environment. AOSERP Report 30. 74 pp.
31	VE 2.3	Thompson, M.D., M.C. Wride, and M.E. Kirby. 1978. Ecological habitat mapping of the AOSERP study area: Phase I. Prep. for the Alberta Oil Sands Environmental Research Program by Intera Environmental Consultants Ltd. AOSERP Report 31. 176 pp.
32	PM	Alberta Oil Sands Environmental Research Program. 1979. Third Annual Report, 1977-78. Alberta Oil Sands Environmental Research Program. AOSERP Report 32. 128 pp.
33	TF 1.2	Nowlin, R.A. 1979. Relationships between habitats, forages, and carrying capacity of moose range in northern Alberta. Part I: moose preferences for habitat strata and forages. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division. AOSERP Report 33. 63 pp.
34	HY 2.4	Allan, R., and T. Jackson. 1978. Heavy metals in bottom sediments of the mainstem Athabasca River system in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 34. 74 pp.
35	AF 4.9.1	Griffiths, W.H., and B.D. Walton. 1978. The effects of sedimentation on the aquatic biota. Prep. for the Alberta Oil Sands Environmental Research Program by Renewable Resources Consulting Services Ltd. AOSERP Report 35. 86 pp.
36	AF 4.8.1	Jones, M.L., G.J. Mann, and P.J. McCart. 1979. Fall fisheries investigations in the Athabasca and Clearwater rivers upstream of Fort McMurray: Volume 1. Prep. for the Alberta Oil Sands Environmental Research Program by Aquatic Environments Ltd. AOSERP Report 36. 71 pp.
37	HE 2.2.2	Van Dyke, E.W., and C. Loberg. 1979. Community studies: Fort McMurray, Anzac, Fort MacKay. Prep. for the Alberta Oil Sands Environmental Research Program by Applied Research Associates Ltd. AOSERP Report 37. 195 pp.

38 VE 7.1.1 Green, J.E. 1979. Techniques for the control of small mammal damage to plants: a review. Prep. for the Alberta Oil Sands Environmental Research Program by LGL Ltd., Environmental Research Associates. AOSERP Report 38. 111 pp.

39 ME 1.0 Longley, R.W., and B. Janz. 1979. The climatology of the Alberta Oil Sands Environmental Research Program study area. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Atmospheric Environment Service. AOSERP Report 39. 102 pp.

40 WS 3.3 Beltaos, S. 1979. Mixing characteristics of the Athabasca River below Fort McMurray--winter conditions. Prep. for the Alberta Oil Sands Environmental Research Program by Transportation and Surface Water Engineering Division, Alberta Research Council. AOSERP Report 40 110 pp.

41 AF 3.5.1 Sprague, J.B., D.A. Holdway, and D. Stendahl. Acute and chronic toxicity of vanadium to fish. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Guelph. AOSERP Report 41. 92 pp.

42 TF 1.1.4 Todd, A. 1978. Analysis of fur production records for registered traplines in the AOSERP study area, 1970-75. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Recreation, Parks and Wildlife. AOSERP Report 42. 17 pp.

43 TF 6.1 Phillips, W., D. DePape, and L. Ewanyk. 1979. A socioeconomic evaluation of the recreational use of fish and wildlife resources in Alberta, with particular reference to the AOSERP study area. Volume 1: summary and conclusions. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Alberta, Department of Rural Economy. AOSERP Report 43. 116 pp.

44 VE 3.1 Malhotra, S.S., and P.A. Addison. 1979. Interim report on symptomology and threshold levels of air pollutant injury to vegetation, 1975 to 1978. Prep. for the Alberta Oil Sands Environmental Research Program by Canadian Forestry Service, Northern Forest Research Centre. AOSERP Report 44. 13 pp.

45 VE 3.3 Malhotra, S.S. 1979. Interim report on physiology and mechanisms of air-borne pollutant injury to vegetation, 1975 to 1978. Prep. for the Alberta Oil Sands Environmental Research Program by Canadian Foresty Service, Northern Forest Research Centre. AOSERP Report 45. 38 pp.

46 VE 3.4 Addison, P.A., and J. Baker. 1979. Interim report on ecological benchmarking and biomonitoring for detection of air-borne pollutant effects on vegetation and soils, 1975 to 1978. Prep. for the Alberta Oil Sands Environmental Research Program by Canadian Forestry Service, Northern Forest Research Centre. AOSERP Report 46. 40 pp.

47 TF 1.1.1 Cook, R.D., and J.O. Jacobson. 1979. A visibility bias model for aerial surveys of moose on the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by

48 HG 1.1 Schwartz, F.G. 1979. Interim report on hydrogeological investigations of the Muskeg River Basin, Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Alberta, Dept. of Geology. AOSERP Report 48. 101 pp.

49 WS 1.3.3 Hartland-Rowe, R.C.B., R.S. Davies, M. McElhone, and R. Crowther. The ecology of macrobenthic invertebrate communities in Hartley Creek, northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Dept. of Biology, The University of Calgary. AOSERP Report 49. 144 pp.

50 ME 3.6 Denison, P.J., R.A. McMahon, and J.R. Kramer. 1979. Literature review on pollution deposition processes. Prep. for the Alberta Oil Sands Environmental Research Program and Syncrude Canada Ltd. by Acres Consulting Services Limited and Earth Science Consultants Inc. AOSERP Report 50. 264 pp.

51 HY 1.3 Warner, L.A. 1979. Interim compilation of 1976 suspended sediment data for the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Water Survey of Canada, Environment Canada. AOSERP Report 51. 59 pp.

52 ME 2.3.2 Davison, D.S., and K.L. Grandia. 1979. Plume dispersion measurements from an oil sands extraction plant, June 1977. Prep. for the Alberta Oil Sands Environmental Research Program by Intera Environmental Consultants Ltd. Calgary, Alberta. AOSERP Report 52. 209 pp.

53 HY 3.1.2 Strosher, M.T., and E. Peake. 1979. Baseline states of organic constituents in the Athabasca River System upstream of Fort McMurray. Prep. for the Alberta Oil Sands Environmental Research Program by Environmental Sciences Centre (Kananaskis), The University of Calgary. AOSERP Report 53. 71 pp.

54 WS 2.3 Nix, P.G., J.W. Costerton, R. Ventullo, and R.T. Coutts. 1979. A preliminary study of chemical and microbial characteristics in the Athabasca River in the Athabasca Oil Sands area of northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Chemical and Geological Laboratories Ltd., Microbios Ltd., and Xenotox Services Ltd. AOSERP Report 54. 135 pp.

55 HY 2.6 Costerton, J., and G.G. Geesy. 1979. Microbial populations in the Athabasca River. Prep. for the Alberta Oil Sands Environmental Research Program by Dept. of Biology, The University of Calgary. AOSERP Report 55. 66 pp.

56 AF 3.2.1 Giles, M.A., J.F. Klaverkamp, and S.G. Lawrence. 1979. The acute toxicity of saline groundwater and of vanadium to fish and aquatic invertebrates. Prep. for the Alberta Oil Sands Environmental Research Program by Dept. of Fisheries and the Environment, Freshwater Institute. AOSERP Report 56. 216 pp.

57 LS 2.3.1 Thompson, M.D. 1979. Ecological habitat mapping of the AOSERP study area: Phase 1, aquatic macrophytes. Prep. for the Alberta Oil Sands Environmental Research Program by Intera Environmental Consultants Ltd. AOSERP Report 57. 45 pp.

58 AF 2.0.2 Lock, M.A., and Wallace, R.R. 1979. Interim report on ecological studies on the lower trophic levels of Muskeg rivers within the Alberta Oil Sands Environmental Research Program study area. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada. AOSERP Report 58. 104 pp.

59	TF 3.1	Gilbert, F.F., S.A. Brown, and M.E. Stoll. 1979. Semi-aquatic mammals. Annotated bibliography. Prep. for the Alberta Oil Sands Environmental Research Program by Department of Zoology, University of Guelph. AOSERP Report 59. 167 pp.
60	WS 1.1.1	Neill, C.R., and B.J. Evans. 1979. Synthesis of surface water hydrology. Prep. for the Alberta Oil Sands Environmental Research Program by Northwest Hydraulic Consultants Ltd. AOSERP Report 60. 84 pp.
61	AF 4.5.2	Machniak, K., and W.A. Bond. 1979. Intensive study of the fish fauna and aquatic habitat of the Steepbank River watershed of northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Freshwater Institute. AOSERP Report 61. 194 pp.
62	TF 5.1	Roberts, W., V. Lewin, and L. Brusnyk. 1979. Amphibians and reptiles in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by University of Alberta, Museum of Zoology. AOSERP Report 62. 51 pp.
63	ME 3.8.3	Davison, D.S., and E.D. Leavitt. 1979. Analysis of AOSERP plume sigma data. Prep. for the Alberta Oil Sands Environmental Research Program by Intera Environmental Consultants Ltd. AOSERP Report 63. 251 pp.
64	LS 21.6.1	Thomson, D.C., D.M. Ealey, and K.H. McCourt. 1979. A review and assessment of the baseline data relevant to the documentation and evaluation of the impacts of oil sands developments on large mammals in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Renewable Resources Ltd. AOSERP Report 64. 155 pp.
65	LS 21.6.2	Penner, D.F. 1979. A review and assessment of the adequacy of baseline data relevant to the documentation and evaluation of the impacts of oil sands development on black bear in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Renewable Resources Consulting Services Ltd. AOSERP Report 65. 62 pp.

66 AS 4.3.2 Reid, J.D., J.L. Walmsley, L.B. Findleton, and A.D. Christie. 1979. An assessment of the models LIRAQ and ADPIC for application to the Alberta Oil Sands Environmental Research Program by Atmospheric Environment Service. AOSERP Report 66. 95 pp.

67 WS 1.3.2 Lock, M.A., and R.R. Wallace. 1979. Aquatic biological investigations of the Muskeg River watershed. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 67. 29 pp.

68 AS 1.5.3 Fanaki, F. 1979. Air system summer field study in the AOSERP study area, June 1977. Prep. for the Alberta Oil Sands Environmental Research Program by Atmospheric Environment Service. AOSERP Report 68. 248 pp.

69 HS 40.1 Deines, A., C. Littlejohn, and T. Hunt. 1979. Native employment patterns in Alberta's Athabasca Oil Sands region. Prep. for the Alberta Oil Sands Environmental Research Program by Canadian Institute for Research in the Behavioral and Social Sciences. AOSERP Report 69. 216 pp.

70 LS 28.1.12 Ealey, D.M., S. Hannon, and G. J. Hilchie. 1979. An interim report on the insectivorous animals in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by McCourt Management Ltd. AOSERP Report 70. 294 pp.

71 HY 2.2 Hesslein, R.H. 1979. Lake acidification potential in the Alberta Oil Sands Environmental Research Program study area. Prep. for the Alberta Oil Sands Environmental Research Program by the Freshwater Institute, Environment Canada. AOSERP Report 71. 36 pp.

72 LS 7.1.2 Green, J.E. 1979. The ecology of five major species of small mammals in the AOSERP study area: a review. Prep. for the Alberta Oil Sands Environmental Research Program by LGL Limited, Environmental Research Associates. AOSERP Report 72. 103 pp.

73	LS 23.2	Searing, G.F. 1979. Distribution, abundance, and habitat associations of beavers, muskrats, mink, and river otters in the AOSERP study area, northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by LGL Limited, Environmental Research Associates. AOSERP Report 73. 119 pp.
74	AS 4.5	Angle, R.P. 1979. Air quality modelling and user needs. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Environment, Air Quality Control Branch. AOSERP Report 74. 34 pp.
75	WS 1.3.4	Hickman, M., S.E.D. Charlton, and C.G. Jenkerson. 1979. Interim report on a comparative study of benthic algal primary productivity in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Department of Botany, University of Alberta. AOSERP Report 75. 197 pp.
76	AF 4.5.1	Bond, W.A., and K. Machniak. 1979. An intensive study of the fish fauna of the Muskeg River watershed of northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Freshwater Institute. AOSERP Report 76. 180 pp.
77	HS 20.1	Peter C. Nichols and Associates Ltd. 1979. Overview of local economic development in the Athabasca Oil Sands region since 1961. Prep. for the Alberta Oil Sands Environmental Research Program by Peter C. Nichols & Associates Ltd. AOSERP Report 77. 221 pp.
78	LS 22.1.1	Francis, J. and K. Lumbis. 1979. Habitat relationships and management of terrestrial birds in northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Canadian Wildlife Service. AOSERP Report 78. 365 pp.
79	AF 3.6.1	Anderson, P.D., P. Spear, S. D'Apollinia, S. Perry, J. Deluca, and J. Dick. 1979. The multiple toxicity of vanadium, nickel, and phenol to fish. Prep. for the Alberta Oil Sands Environmental Research Program by Department of Biology, Concordia University. AOSERP Report 79. 109 pp.

80	HS 10.2 & HS 10.1	Parker, J.M., and K.W. Tingley. 1980. History of the Athabasca Oil Sands region, 1890 to 1960's. Volume I: socio-economic developments. Volume II: oral history. Prep. for the Alberta Oil Sands Environmental Research Program by Boreal Institute for Northern Studies, The University of Alberta. AOSERP Report 80.
81	LS 22.1.2	Hennan, E., and B. Munson. 1979. Species distribution and habitat relationships of waterfowl in northeastern Alberta. Prep. for Alberta Oil Sands Environmental Research Program by Canadian Wildlife Service. AOSERP Report 81. 115 pp.
82	LS 22.2	Beaver, R., and M. Ballantyne. 1979. Breeding distribution and behaviour of the White Pelican in the Athabasca Oil Sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Canadian Wildlife Service. AOSERP Report 82. 93 pp.
83	LS 22.2	Ealey, D. 1979. The distribution, foraging behaviour, and allied activities of the White Pelican in the Athabasca Oil Sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Canadian Wildlife Service. AOSERP Report 83. 69 pp.
84	WS 1.6.1	Tripp, D.B., and P.J. McCart. 1979. Investigations of the spring spawning fish population in the Athabasca and Clearwater rivers upsteam from Fort McMurray: Volume I. Prep. for the Alberta Oil Sands Environmental Research Program by Aquatic Environments Limited. AOSERP Report 84. 128 pp.
85	HY 2.5	Akena, A.M. 1979. An intensive surface water quality study of the Muskeg River watershed. Volume I: water chemistry. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Environment. AOSERP Report 85. 187 pp.
86	AS 3.7	Murray, W., and T. Low. 1979. An observational study of fog in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Promet Environmental Group Ltd. AOSERP Report 86. 54 pp.

87	WS 2.2	Schwartz, F.W. 1980. Hydrogeological investigation of Muskeg River basin, Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by University of Alberta, Department of Geology. AOSERP Report 87. 97 pp.
88	AF 2.0.1	Barton, D.R., and R.R. Wallace. 1980. Ecological studies of the aquatic invertebrates of the Alberta Oil Sands Environmental Research Program study area of northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 88. 215 pp.
89	AF 4.3.2	Bond, W.A. 1980. Fishery resources of the Athabasca River downstream of Fort McMurray, Alberta. Volume I. Prep. for the Alberta Oil Sands Environmental Research Program by Department of Fisheries and Oceans, Freshwater Institute. AOSERP Report 89. 81 pp.
90	AS 3.2	Barrie, L.A., and J. Kovalick. 1980. A wintertime investigation of the deposition of pollutants around an isolated power plant in northern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Atmospheric Environment Service. AOSERP Report 90. 115 pp.
91	LS 5.2	Kong, K., J.D. Lindsay, and W.B. McGill. 1980. Characterization of stored peat in the Alberta Oil Sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Research Council of Alberta, Soils Division, and Department of Soil Science, University of Alberta. AOSERP Report 91. 116 pp.
92	WS 1.6.2	Tripp, D.B., and P.T.P. Tsui. 1980. Fisheries and habitat investigations of tributary streams in the southern portion of the AOSERP study area. Volume I: summary and conclusions. Prep. for the Alberta Oil Sands Environmental Research Program by Aquatic Environments Limited. AOSERP Report 92. 224 pp.
93	WS 1.3.1	Machniak, K., W.A. Bond, M.R. Orr, D. Rudy, and D. Miller. 1980. Fisheries and aquatic habitat investigations in the MacKay River watershed of northeastern Alberta. Prep. for the Alberta Oil Sands Environmental Research Program and Syncrude Canada Ltd. by Department of Fisheries and Oceans. AOSERP Report 93. 173 pp.

94	WS 1.4.1	Ash, G.R., and L.R. Noton. 1980. A fisheries and water quality survey of ten lakes in the Richardson Tower area, northeastern Alberta. Volume I: methodology, summary, and discussion. Prep. for the Alberta Oil Sands Environmental Research Program by R L & L Environmental Services Ltd. AOSERP Report 94. 187 pp.
95	AS 4.2.6	Venkatram, A. 1980. Evaluation of the effects of convection on plume behaviour in the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program. AOSERP Report 95. 75 pp.
96	HS 20.3	Peter C. Nichols & Associates Ltd. 1980. Service delivery in the Athabasca Oil Sands region since 1961. Prep. for the Alberta Oil Sands Environmental Research Program by Peter C. Nichols & Associates Ltd. AOSERP Report 96. 92 pp.
97	LS 3.4.1	Baker., J. 1980. Differences in the composition of soils under open and canopy conditions at two sites close-in to the Great Canadian Oil Sands Operation, Fort McMurray, Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Northern Forest Research Centre. AOSERP Report 97. 24 pp.
98	LS 3.4.2	Addison, P.A. 1980. Baseline conditions of jack pine biomonitoring plots in the Athabasca Oil Sands area; 1976 and 1977. Prep. for the Alberta Oil Sands Environmental Research Program by Canadian Forestry Service, Environment Canada. AOSERP Report 98. 43 pp.
99	LS 10.2	Eulert, G.K., and H. Hernandez. 1980. Synecology and autecology of boreal forest vegetation in the Alberta Oil Sands Environmental Research Program by Interdisciplinary Systems Ltd. AOSERP Report 99. 184 pp.
100	LS 10.2	Thompson, M.D., and J. Crosby-Diewold. 1980. Baseline inventory of aquatic macrophyte species distributions in the Alberta Oil Sands Environmental Research Program by Intera Environmental Consultants Ltd. and Beak Consultants Ltd. AOSERP Report 100. 73 pp.

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