THE UNIVERSITY OF ALBERTA

FISHES OF ABRAHAM LAKE (RESERVOIR) AND THE UPPER NORTH SASKATCHEWAN RIVER, ALBERTA

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF ZOOLOGY

EDMONTON, ALBERTA

FALL, 1974

ABSTRACT

The North Saskatchewan River was impounded (August 1972) near its sources, by the Bighorn Dam. The aquatic fauna (primarily the fish) of the reservoir (Abraham Lake) and its tributaries was studied from 1972 to 1974.

Abraham Lake is populated by 11 fish species: 4 salmonids, 3 catostomids, 2 cyprinids, 1 coregonid and 1 cottid. It may also be colonized by another salmonid that presently occurs in the headwaters. One species of catostomid is very rare and may be extirpated by hybridization.

Colonization of the upper North Saskatchewan system, after the Pleistocene epoch, was incomplete. The basin is the most naturally depauperate of Alberta's major watersheds. Several of the large tributaries (Ram River, Mistaya River) and many of the minor ones have no native fish.

The absence of certain invertebrate forms and several species of fish in the study area (which are native to adjacent areas) can be explained by such factors as post-Pleistocene (thermal) isolation, high water velocities or dam construction. The failure of brown trout (*S. trutta*) introductions is probably related to low water temperatures during the spawning season.

The study provided data on a previously undescribed fish hybrid and noted the presence of several other hybrids. These forms pre-date the flooding of the reservoir and are not referable to recent environmental disturbances.

Prior to the creation of the reservoir there was very little habitat in which fish could overwinter. Although Abraham Lake will be extremely oligotrophic, it does provide a wintering area. It seems probable that there will be an increase in the system's fish biomass and in the maximum size attained by individuals.

ACKNOWLEDGEMENTS

I wish to express my thanks to my supervisor, Dr. J. S. Nelson, for his help in planning and organizing this study. I am also grateful for the critical reviews of the manuscript that he provided and the pungent comments of Drs. G. Ball and W. Mackay.

I am indebted to many people for local information and assistance; when pertinent they were quoted. Field assistance was provided by D. Kellough, L. Priest, J. Dickinson, O. Zalitach, D. Ramer, J. Hordern ("Batus Boys") and D. Hyatt (his "quests").

I express appreciation to the Alberta Forest Service, Mr. F. Sutherland, Superintendent, Rocky Clearwater Forest, for the use of facilities during 1972. The many kindnesses, assistance and good companionship of Mr. R. Dubak, Forest Ranger at Nordegg, make pleasant memories. The good company, facilities and assistance of "the Browns and kin" during 1973 will be long remembered.

Dr. S. B. Smith, and Messrs. J. Reid, D. Harrington and R. Laforge of the Alberta Department of the Environment provided both technical assistance and guidance for the study.

Dr. M. J. Paetz, Messrs. M. Kraft, J. Allen and R. Forsyth of the Fish and Wildlife Division, Department of Lands and Forests, provided technical advice, assistance and valuable comments.

For technical assistance and advice in preparing the maps and figures I am eternally indebted to my kinsman, Mr. A. B. Scott.

Financial support for the field work was primarily provided by the Alberta Department of the Environment. The Department of Lands and Forests assisted with both facilities and equipment. Dr. J. S. Nelson provided financial assistance through his N.R.C. grant during 1974.

I express my appreciation to Sonia Volman for her help with the rough drafts and to Diana Zaiffdeen for typing the final draft.

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INTRODUCTION

This study was a pre-impoundment and early impoundment survey of a hydroelectric reservoir, Abraham Lake, located on the North Saskatchewan River approximately 230 km (145 mi) southwest of Edmonton, Alberta. Flooding of the reservoir began on 8 August 1972, with the closure of the Bighorn Dam (52° 18' N, 116° 19' W).

The purpose of the project was to study the life histories and distributions of the fish species above the damsite. The population of the reservoir, at impoundment, was to be evaluated. This thesis and a separately submitted summary report will provide the Alberta Government with background information for use in the management of the reservoir.

The heavy demand for aquatic recreation areas is placing a strain on some natural lakes in Alberta and is increasing public awareness of artificial lakes. Detailed biological studies on other Alberta reservoirs will be required to obtain the maximum possible benefits from them. It seems unlikely that the public's interest, in restricting or reducing adverse ecological and environmental changes, will abate.

Field work, confined largely to the fishes, was undertaken from 8 June to 23 November 1972, on 8 March 1973, from 8 May to 30 October 1973 and on 15 April and 11 May 1974.

The collected material is in the Museum of the Department of Zoology, The University of Alberta, Edmonton, Alberta.

DESCRIPTION OF THE STUDY AREA

LOCATION

The study area (Figure 1) is the drainage basin of Abraham Lake (Figure 2) in west-central Alberta. Access to the region is by Highways 11 from Red Deer and 93, the Banff-Jasper Highway (Figure 3).

GEOGRAPHY

Land

The physiography of the study area is rugged mountains, with many of the peaks over 3000 m (9841 ft) above sea level; Mts. Athabasca (3491 m/11452 ft) and Forbes (3628 m/11902 ft) are among the more outstanding peaks in the district. The region was extensively glaciated during the Pleistocene epoch and contains a wide variety of glacial landforms (McPherson 1970). With a few minor exceptions, such as the Kootenay Plains, the soil is shallow and rocky (Pettapiece 1971).

The steep slopes (Figure 4) combined with the short but intense melting period makes the watercourses subject to flash floods. Much of the North Saskatchewan River valley consists of glacial debris, reworked by the river and its tributaries into a complex of fans, side channels and temporary flood canals.

Rivers and Lakes

The North Saskatchewan River starts as meltwater from the Saskatchewan Glacier, a tongue of the Columbia Icefield, on the east slope of the Rocky Mountains (52° 08' N, 117° 12' W). The present terminus of the glacier is at an elevation of 1950 m (6400 ft). The major tributaries to the North Saskatchewan, within the study area, are all glacial in origin.

At its full supply level (f.s.l.) Abraham Lake (Figure 5) will have a surface area of 5550 ha (13700 a) and a total drainage basin of approximately 3700 km^2 (1430 mi^2). Since the "lake" is a hydroelectric reservoir it will be subject to fluctuations in water level, both daily and seasonally. Present plans indicate that the surface level will vary from 1282 m (4206 ft) to 1321 m (4335 ft).

VEGETATION

Aquatic

The fluctuating nature of the North Saskatchewan River precludes any large area of rooted aquatic plants. The large annual drawdown of Abraham Lake (39 m/129 ft) should prevent any littoral zone with rooted aquatics being established in the reservoir itself. However, springs and sloughs within the drainage basin have rooted aquatic plants; it is not the lack of a seed source but rather the lack of suitable habitat that has prevented and will subsequently prevent rooted aquatic plants from being widely distributed in the area.

It would appear that the silty glacial water will prevent the reservoir from having a significant phytoplankton population.

Terrestrial

The reservoir area was cleared of all standing timber (Photographic Plate 1) and when the flooding commenced some of the second growth (*Populus* spp.) had reached a height of 3 m (10 ft). However, much of the land flooded was covered in a mixture of grass, herbs and low shrubs of less than 1 m (3 ft) in height. This vegetation will not survive the flooding and will rapidly erode or decompose.

The tree cover of the study area is a montane boreal forest. Rowe (1972) delineates the area as subalpine (S A.1) and upper foothills (B.19c) components of the boreal forest. However, the forest cover is not uniform and lower areas have patches of grassland and superficially resemble the aspen parkland zone.

Only a limited degree of commercial logging has been carried out in the basin; the operation failed, due largely to high transportation costs and the low quality of the timber (R. Dubak pers. comm.). It seems doubtful that any logging operations will be attempted in the study area in the future (R. Dubak pers. comm.).

Timberline is normally between 2000 and 2300 m (6600-7500 ft), depending on local factors (slope, etc.). The area above timberline is largely alpine tundra and bare rocks; about 1% of the total drainage basin is glacier ice (Henoch 1971).

PHYSICAL AND CHEMICAL

Climate

The climate of the area is a severe mid-continental type. Winter is cold and long while the transition to or from a summer is rapid. No month is sure to be frost free and the area is subject to sudden outbreaks of cold weather in summer and warm weather (chinooks) in winter. The closest long-term weather station is at Nordegg (Appendix I), which is considered to be somewhat more humid, and warmer than the study area. In any event, the mountain topography causes intense localization of the weather patterns and no station would be definitive for the area. The Kootenay Plains are noted for being an arid patch (precipitation of about 20 cm per year) of only a few square kilometers, which are surrounded by areas of heavier precipitation (Pettapiece 1971).

Breakup and Freezeup

Since Abraham Lake is such a new body of water and has not yet been filled, no averages are available. In 1972, it was reported (A. Kobza pers. comm.) to have frozen over on the night of 6 December 1972. Breakup occurred about 7 May 1973. If these dates prove to be reasonably typical,* the reservoir will have an ice cover period of about 150 days. However, the mountains are generally areas of considerable groundwater movement and many of the rivers and creeks in the watershed remain open throughout the winter. Thus, patches of open water and a variable breakup pattern may be expected. Several large springs have been flooded over and these will contribute to a sporadic breakup regime.

Water Temperatures

Abraham Lake is fed by rivers and streams that originate from glaciers and snowfields, and the water is cold. The maximum surface water temperature observed for the main body was 17 C. A few of the

*Freezeup: 29 November 1973 (J. Reid pers. comm.).
Breakup: Gradual 2-6 May 1974 (J. Reid, pers. comm.).

sheltered bays reach 20-21 C after several days with air temperatures in the 25-27 C range.

No data are available on the reservoir's winter thermal regime. Stream conditions in the area varied widely, some formed anchor ice in late October and were completely frozen by mid-November, while others remained open and running all winter.

Water Chemistry

The area is alkaline and pH readings normally range between 8.0 and 8.3. Results from the water analyzed are provided in Appendix II.

Water Color

No discussion of the system would be complete without commenting on the color of the water. The rock flour from the glaciers gives Abraham Lake a light putty or pasty grey-green color by mid-June. This color remains until mid-August when gradual clearing begins; by mid-October the water is quite blue and clearing continues until freezeup. When the ice breaks up in spring, the water is extremely blue and gradually turns through green to grey. The suspended material that provides the coloring also affects the clarity as shown by the Secchi values (Table 1). Ford (1971:252) considers the waters being fed by the Saskatchewan glacier to be "as turbid as any seen in the Rocky Mountains."

PAST STUDIES

HISTORICAL DATA

David Thompson was the first literate man to enter the study area (1801) but he and other early explorers (Appendix III) left no known notes on the fishes of the area.

Some of the earliest comments on fish in the study area are those in the Tom Wilson papers (1916, see Appendix III). From this material it can be inferred that no fish occurred in the upper Mistaya system and that fishing in the North Saskatchewan River was poor. Other scattered notes occur from then on to the present, mostly dealing with sport fish, or commenting on the (apparent) absence of fish.

BIOLOGICAL DATA

Limited investigations have been carried out in the study area in previous years. Much of it is in the form of unpublished notes (J. C. Ward pers. comm.) and only the limited work of Miller and Paetz (1953) is published.

A search of the historical literature yielded some information on sport fishing during the 1880-1920 period. Discussions and correspondence with various "old-timers" of the area provided some interesting and useful notes concerning the past distributions of the area's fishes. This material will be quoted where pertinent and will not be repeated here.

PLEISTOCENE EVENTS

Pleistocene and post-Pleistocene glaciation and deglaciation is not a primary part of this thesis, but a few remarks regarding deglaciation of the area are worthwhile. An understanding of the sequence of post-glacial events aids in the understanding of the aquatic fauna in the system, and partially explains its relatively impoverished nature.

Reeves (1973) noted that southern Alberta was probably ice free by about 15000 B.P., and discussed the nature of the contact between the Cordilleran and Laurentide ice sheets. St. Onge (1972) provided data on the glacial lakes that formed along the retreating (melting) ice front and made connections between river systems that are now separate. McPherson (1970) provides information on the glacial history of part of the study area, the nature and probable timing of its deglaciation.

Although some parts of the region were unglaciated and while glaciation may not have been uniform (in time) at all points, it seems probable that there were no refugia that would have supported an aquatic fauna through the Wisconsin epoch. Nimmo (1971) shows similar data and establishes that the bulk of the tricopteran fauna is of southern origin.

The pattern of deglaciation in the main valley is outlined by McPherson (1970). Aspects of the surficial geology of the tributary streams suggest that the smaller side valleys may have been ice free even earlier. Many of these tributaries have waterfalls, or enter a bedrock canyon, a short distance above their junction with the main river (Figure 2). These are the characteristics of "hanging tributary valleys" (Flint 1971:130) and it can be inferred that ice action and downcutting occurred later in the main valley. More detailed geological work is required to confirm or refute this hypothesis, but the fact remains that many of the tributary streams have no known native fish populations in their upper reaches (Tebby 1974a). That they are capable of supporting fish is shown by the success of introductions. This information suggests that access from the main valley to the upper parts of the tributaries has not been possible from the time of deglaciation.

The geological and geographical data therefore indicate that no direct surface water exchange has occurred between the upper North Saskatchewan and adjoining major systems (Athabasca, Bow, Columbia) within the mountains. Minor changes in the drainage pattern of tributary streams within the North Saskatchewan system appear to have taken place, probably quite recently. Aspects of the structure of Malma Creek indicate that part of its upper reaches were "captured" from the North Ram River system. However, the North Ram system has no native fish, the present cutthroat trout (*Salmo clarki*) stock results from 1955 introductions (Paetz and Nelson 1970). An exchange or connection between Shunda Creek and Goldeye Lake (near Nordegg) apparently has occurred and this has enabled some cyprinids and brook stickleback (*Culaea inconstans*) to reach parts of the main river immediately downstream of the study area. Both the North Ram River and Shunda Creek are tributaries of the North Saskatchewan, entering it just outside of the foothills.

Thus, insofar as surface water movements are concerned, the fish fauna of the North Saskatchewan River has been derived from the post-glacial connections between the river systems in areas east of the mountains. Subterranean connections between the various systems (within the mountains) are possible as the area is noted for its karst topography (Ford 1971). However, it seems unlikely that this has been a method of fish transfer.

MATERIALS AND METHODS

Water and air temperatures were taken with a Bistabil-Eterna thermometer (Cat. No. 8385 01). Water samples were frozen and analyzed in the water laboratory of the Department of Zoology, University of Alberta (details later). Light penetration readings were made with a 20 cm secchi disk.

All measurements were taken in metric units or converted to metric units. All existing land survey data (maps) are in the English system and this has not been converted except when specific points are mentioned.

Fish were weighed on a variety of scales and balances, all of which had been checked for accuracy by the use of test weights. All fish lengths are fork lengths.

Plankton samples were obtained by use of Wisconsin-type plankton net of No. 25 mesh. Samples were preserved in 70% ethyl alcohol.

Bottom sampling with an Ekman dredge was attempted but failed to yield any suitable material (details later).

Multistrand nylon gill nets (John Leckie Ltd. "Tanglefin") were used in the quantitative sampling of the reservoir (details later).

Non-quantitative samples were taken by a variety of methods, primarily seines, dipnets and rotenone.

Fish were aged by the scale method, using either a Bausch and Lomb Tri-Simplex Microprojector or a microscope.

AQUATIC INVERTEBRATES

Invertebrates were not examined in any detail for this thesis. However, some knowledge of the deficiencies of the reservoir's aquatic invertebrate fauna was required in order to suggest fisheries management practices. The apparent absence of some organisms is probably a result of the deglaciation pattern.

BENTHIC FAUNA

Ekman dredging and the stomach contents of fish indicate that a chironomid fauna was well established by July 1973. The work of Fillion (1963, 1967) suggests that the chironomid population will fluctuate in species composition for several years.

Extensive examinations of the rivers, tributary streams, springs and various bodies of standing water failed to yield any pelecypods, although Clarke (1973) lists various species that should occur in the study area. Examination of 10-12 km of riverbed between Nordegg and the damsite (after closure and dewatering) failed to yield any specimens. If present, the large *Anodonta* spp. which are in the river at Edmonton should have been observed.

Mysis oculata var. *relicta* (Loven) is not known to be present in any lakes that are tributary to Abraham Lake (J. C. Ward pers. comm.). Ricker (1959) discusses the distribution of *Mysis* in relation to the Pleistocene era and its absence from the study area is in agreement with his views.

Oligochaetes were not common in 1973. Chironomids had become a major term in the diet of several species of fish by July 1973. The work of Fillion (1963, 1967) suggests that they will be an important component of the benthos.

PLANKTONIC FAUNA

Plankton hauls were made over the length of Abraham Lake during August 1973. Only the following species of zooplankton could be identified* from the samples.

Daphnia pulex Leydig emend. Richard

Chydorus sphaericus (Müller)

Cyclops bicuspidatus thomasi Forbes

Diaptomus sicilis Forbes

Nursall (1952:397) noted that a planktonic fauna was rapidly established in Barrier Reservoir, but did not comment on the origin of the organisms.

In the case of Abraham Lake an important source would seem to be in the large flocks of migrating aquatic birds that used the reservoir during the fall of 1972 (Appendix IV). When effective test netting began in July, 1973, the zooplankton population was dense enough to have become a major item in the diet of several species of fish (details later).

Quantitative samples taken were subsequently lost during a boat mishap.

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*By Dr. D. N. Gallup and P. Mitchell, Department of Zoology, University of Alberta.

FISH BIOLOGY AND DISTRIBUTION

FISH CULTURE

Earlier records (pre-1950) are of questionable accuracy and unrecorded introductions are possible (earlier dates). In pre-1950 introductions the condition of the fish planted may have been poor (transportation difficulties) with no survival after stocking. The dates for the first releases of the different forms introduced in the study area are:

Form	Year
Cutthroat trout	1929
Rainbow trout	1934
Brook trout	1941
Brown trout	1948
"Splake"	1954

More detailed comments are made in the section dealing with the biology of each form.

Some water bodies above the reservoir were poisoned in order to remove non-sport species prior to the stocking of trout for angling purposes. In the case of the Warden lakes (Banff National Park), T. MacAuley (pers. comm.) informed me that the lakes had "suckers and minnows" when first discovered (1939). This comment and examination of the outlet stream suggest to me that at least occasional contact occurs with the North Saskatchewan River. However, the lakes are officially considered to be "landlocked," and introductions into them are made with the assumption that they will remain isolated.

ABRAHAM LAKE DRAINAGE SPECIES

Mountain Whitefish, *Prosopium williamsoni* (Girard)

This species is native to and common in the main river system, but does not normally occur in the smaller tributaries (Figure 6). Waterfalls and rapids have prevented whitefish from ascending the Siffleur, Mistaya and Cline rivers to reach the lakes that appear to be suitable habitat for them.

The data to date (Figure 7) illustrate that immature mountain whitefish have had accelerated growth rates in Abraham Lake since its impoundment. The samples were taken from a variety of sites and indicate that growth rates were highly variable prior to impoundment. This was probably due to environmental variability (microhabitat) and secondarily a result of different spawning and hatching dates. The 1973 observations suggest that the reservoir will eventually provide a much more uniform habitat and (during its early years) more accelerated growth rates. This is similar to the data of Nelson (1962:64); however, there is no suitable background information which would enable predictions on the probability of these accelerated rates persisting. The data available on the older age classes (Figure 8) illustrate the extreme variability in the range of lengths encountered, presumably due to microhabitat variability.

Abraham Lake mountain whitefish mature at approximately the same rate as those from other Alberta reservoirs (Nelson 1962). In October

1973, all young of the year and yearling (1+) fish were immature, approximately 50% of the 2+ males were ripe or ripening and all 3+ males were ripe. Female whitefish have slightly slower rates of maturation, all 2+ fish were immature, 70% of the 3+ were mature and all 4+ were ripe by October. However, it may be that the first maturity of the individual fish is not an effective maturity since some (10-20%) September fish appeared to be ripening too slowly for October spawning.

Mountain whitefish are known to eat a variety of organisms, in many different areas (Carlander 1969, Pontius and Parker 1973). The young-of-the-year fish taken in Abraham Lake (July-September 1973) were feeding on immature zooplankton and chironomids. Individual selectivity was noted within schools of fry. For example, of 81 fish caught on 28 July 1973, 13% (11/81) were utilizing only zooplankton, 30% (24/81) only chironomids and the balance had varying mixtures of both items.. Larger whitefish utilized a wide variety of organisms, including many terrestrial forms (ants, beetle larvae and grasshoppers) not normally available to them. Whitefish netted offshore normally had been feeding on *Daphnia pulex* while those taken by beach seining tended to have been exclusively utilizing the drowned terrestrial material. No whitefish stomachs contained mollusc or fish remains.

Lake Trout, *Salvelinus namaycush* (Walbaum)

This species is considered to be native to the North Saskatchewan system with relict populations in the headwaters area and Swan Lake (Paterson 1968). J. C. Ward (pers. comm.) reports the species from Glacier Lake and the Alexandra River. It is also reported (several sources) from parts of the North Saskatchewan below its junction with the Alexandra. J. Rimmer (pers. comm.) reports the species from Outram Lake (Howse system) and has photographs of angled specimens. Anglers reported to the writer that in past years they had caught "lake trout" at the junction of the Cline River with the North Saskatchewan River. Until specimens are available the report is a hypothetical record. There are no records of any stockings within the study area.

The precise downstream movement limits of the species have not been determined and it is possible that lake trout will naturally colonize the reservoir.

Dolly Varden, *Salvelinus malma* (Walbaum)

Dolly Varden are indigenous to the study area and have the widest natural distribution of any native fish within it (Figure 9). Some of these populations (upper Cline system, upper Malma Creek) possibly are now genetically distinct from the populations in the main river.

Insufficient specimens were obtained to provide detailed information on all aspects of the species biology. Young fish (probably up to 3 years) are found in small tributaries during the summer months. Since some of these tributaries are dry by September it would seem that they were not the natal waters and the fish were summer immigrants. During late August gravid fish were caught by anglers fishing on the Cline, Siffleur and Mistaya rivers near their junction with the Saskatchewan. Attempts at locating fish on spawning beds in these systems were futile. Ripe fish were taken from the mouths of several small creeks but no fish were observed on redds in them. On 25 October 1973, J. Dickinson angled a 3265 g (7 lb 3 oz) spent male from a pool on the North Saskatchewan about 10 km above the reservoir. This may indicate that some fish (especially large ones) utilize the main river for spawning. In a southeastern British Columbia study the spawning migration lasted from 23 July to 26 September 1968, with the peak occurring during August (Leggett 1969).

Dolly Varden are normally four or more years of age when they first spawn (Carlander 1969). The fish from the North Saskatchewan River and Abraham Lake showed considerable variation in their size for reaching maturity. The smallest ripening fish noted were a 31.2 cm (320 g) male and a 31.5 cm (290 g) female. A 46.5 cm (1000 g) male taken on 8 October 1973 was immature. This fish had gonads that did not appear to have ever ripened. Other large fish (500+ g) of both sexes, in a similar condition, were often noted. The data suggest that one of the following situations exists: (a) several subpopulations occur, with different sizes (and age?) at maturity; (b) one population exists, with considerable individual variation as to size (and age?) at maturity. It also seems plausible that some fish (possibly all fish or all large fish) do not spawn every year after reaching maturity. Additional studies are required to resolve the problem.

Dolly Varden in the North Saskatchewan apparently did not exceed 3.6 kg (8 lb) in previous years. Several former residents of the area reported that "8 lb" was the largest they knew of from the river; Pinto Lake fish were reported to reach 5 kg (11 lb). It should be noted that these weights are estimates. An isolated population (upper Malma Creek) is apparently stunted; no fish that were thought to be larger than 30 cm were observed. These fish are kept separate by a recent (probably less than 10 years) rockslide that has blocked the creek. The fish below the rockslide probably rarely interbreed with the population in the main river since the creek only occasionally (during spring or summer floods) connects with it. A similar situation apparently occurs on several other small creeks.

The stomach contents of Dolly Varden from Abraham Lake suggest that they are generalists, feeding upon a wide variety of organisms (Table 2). The data to date are from fish caught in the open water season; presumably during the period of ice cover the diet would be restricted to zooplankton and fish. Immature fish "summering" in small tributary streams are limited mainly to an invertebrate diet but what they utilize during the winter months is not known. The stunted and isolated populations, previously referred to, probably utilize aquatic invertebrates during this period. It would seem (especially in Pinto Lake) that the larger fish are essentially cannibals and the population (numbers and biomass) is limited by the simple food chain.

The netting data (details later) show that Dolly Varden are the dominant "trout" in Abraham Lake, in both size and numbers. This is in contrast to the data of Nelson (1962) and it will be interesting if this situation persists. Montana studies (Huston 1970) state that the Dolly Varden population of Hungry Horse Reservoir had not reached a stabilized age structure after 16 years of impoundment.

Brook Trout, *Salvelinus fontinalis* (Mitchill)

Brook trout were brought into Banff, Alberta, in 1904 (Department of the Interior 1906) from Ontario. The first record of introduction into the study area was in 1941 (B. Smiley pers. comm.).

Stocking data

Some Stocking Records for the Study Area

Year	Watershed stocked	Agency
1941	Warden Lakes--tributary to the North Saskatchewan River	Banff National Park
1942	Norman Lake--tributary to the North Saskatchewan River	Banff National Park
1945-present	Various waters in the study area	Banff National Park and Alberta Government

They are now widely distributed within the study area (Figure 10) and quite common in Abraham Lake. At the present time the species is absent only from the upper Cline and Siffleur river systems and some of the minor tributaries. In these cases the absence is due to natural barriers for fish moving up from the North Saskatchewan River, not necessarily because of unsuitable habitat. The wide distribution of the species, in many areas that are unlikely to have been stocked, suggests that extensive movements have taken place, either by the stocked fish or dispersing offspring.

Field data suggest that normally brook trout avoid the main rivers during the June-August flood season; seining and spot-poisoning during the 1972-73 seasons yielded only two specimens. During this period the species normally occupies springs, small creeks and bordering marsh areas. Apparently the fish return to the main river during the September-May period since anglers were catching them during September, and October from areas that previously had yielded no brook trout.

Whitegoat Creek is a major spawning stream for Abraham Lake and Fontinalis Creek probably was a major spawning area until the reservoir overran the beds. Field observations indicate that the species is primarily an October spawner within the study area; the run in Whitegoat Creek appeared to have peaked on 19 October 1973 with approximately 50 pairs of fish.

Field data indicate that "stunted" populations occur throughout the study area. Two fish from one population, a small unnamed creek now totally submerged by the reservoir, had attained a length of 17.5 cm and a weight of 78.5 g at 4 years (preserved fish). This feature has been reported from other areas (Rabe 1970). However, not all brook trout in the area have such poor growth rates; specimens up to 641 g were obtained and fish thought to weigh 1 kg were observed. The largest fish collected (641 g) was aged at 5+ years by reading a scale sample.

The brook trout stomach contents taken during this study suggest that the fish are largely invertebrate predators. The largest specimen obtained had been feeding on corixids, mayflies, chironomids, spiders, ants and grasshoppers. Fish netted offshore had been utilizing zooplankters (largely *Diaptomus sicilis*). The most noticeable aspect of the diet of brook trout in this study was the complete absence of fish remains in the specimens examined (62 fish).

<u>Cutthroat Trout, *Salmo clarki* Richardson</u>

Although now fairly widespread and established in the upper North Saskatchewan system, this species is not native. It is native to the adjoining South Saskatchewan (Bow) system. The fish identified as "cutthroat" were those that conformed to the key in Paetz and Nelson (1970:59).

Stocking data

Some Stocking Records for the Study Area

Year	Watershed stocked	Agency
1929	Upper Mistaya River	Banff National Park
1936	Upper Mistaya River	Banff National Park
1949	Upper Mistaya River	Banff National Park
1956	Upper Castleguard River	Banff National Park
1956	Upper North Saskatchewan River	Banff National Park
1970	Lakes on the upper Cline River	Alberta Government

Cutthroat trout were taken in the test gill netting program. Specimens were also obtained from the mouth of Allstones Creek, Loudon Creek headwaters (1973) and from a "lag pond" by Abraham Lake* (1973). J. Dickinson caught a 754 g (43.8 cm) female in the North Saskatchewan River about 10 km above Abraham Lake on 21 October 1973. J. Rimmer (pers. comm.) reports that anglers have caught fish up to about 2 kg in parts of the Mistaya system. M. Kraft (pers. comm.) reports that the fish stocked in Lake of the Falls (Cline System, 1970) have not yet spawned (1973) and are apparently stunted. The species is not common in either Abraham Lake or the main river system. Insufficient data and

*As water levels are lowered the water left behind is a "lag pond."

specimens were obtained for precise statements about the biology of cutthroat in the study area. Data obtained on the streams in the area suggest that very few suitable spawning grounds are available to this species, largely because of severe spring flooding.

Rainbow trout, *Salmo gairdneri* Richardson

This species is not indigenous to any part of the Saskatchewan system. Rainbow trout are native to sections of the adjoining Athabasca system but the forms introduced into the Saskatchewan drainage are of hatchery origin. The fish identified as "rainbow" were those that conformed to the key in Paetz and Nelson (1970:59).

Stocking data

Some Stocking Records for the Study Area

Year	Watershed stocked	Agency
1934	Upper Mistaya River	Banff National Park
1959	Upper Siffleur River	Banff National Park
1964	Upper Howse River	Banff National Park
1972	North Saskatchewan River at Saskatchewan Crossing	Banff National Park From Jasper Hatchery

A single specimen of this species was obtained from a lag pond beside Abraham Lake (1973). No fish were taken during the test gill netting program. Anglers on the Waterfowl Lakes (Mistaya system) were observed with specimens during June 1973. J. Rimmer (pers. comm.) reports that the fish in Isabella Lake (Siffleur system) are long and thin (poor condition) and R. Fink (pers. comm.) reported catching a rainbow trout from the junction of the Siffleur River and Escarpment River.

Rainbow trout are now well established in the upper Mistaya and upper Siffleur river systems. The population in the upper Siffleur may be still expanding its range and presumably some fish will reach Abraham Lake. However, the species seems to be less well suited for glacial systems than the cutthroat trout.

<u>Longnose Dace, *Rhinichthys cataractae* (Valenciennes)</u>

This endemic cyprinid was collected from a variety of locations along the main river and its side channels (Figure 11). No specimens were obtained from any of the tributaries.

The comparative seine haul data (Table 3) may underestimate the relative abundance of the species. Large schools of fish thought to be dace were observed in unseinable rocky areas. Nelson (1965) noted it to be common in the Upper and Lower Kananaskis Reservoirs but to be generally absent from the Kananaskis River.

Chironomids were the main food item of longnose dace in Abraham Lake during August, 1973. However, 20% (5/25) of the fish had utilized some terrestrial material (ants). Detailed stomach analyses were not done as much of the material was unidentifiable to me. Gerald (1966) provides a very detailed study of the species diet.

<u>Lake Chub, *Couesius plumbeus* (Agassiz)</u>

McPhail and Lindsey (1970:245) note that "the lake chub tolerates a wide variety of environments." Specimens of this native minnow were collected throughout the flood area of Abraham Lake and were noted in a large number of locations (Figure 11). However, no lake chub were collected in any of the tributary rivers or creeks.

The spawning season for this species could not be determined during this study. It is reported (Paetz and Nelson 1970) to be "from late June to mid-August." Fry collected on 27 August 1972 were between 15 and 27 mm in fork length (preserved fish). Such a wide range suggests a long spawning and hatching season.

Lake chub were commonly seen and often taken during beach seining operations (Table 3); however, its relative abundance in relation to the longnose dace is difficult to assess due to habitat differences. The lake chub has done well in other reservoirs (Nelson 1965) and can be expected to maintain a high population in Abraham Lake.

Longnose Sucker, *Catostomus catostomus* (Forster)

This sucker is ubiquitous in the main river and its side channels, and comprises a substantial proportion of the reservoir's fish biomass. Of those species gill netted, 41.3% of the catch (by weight) was longnose sucker.

The precise dates for this species spawning could not be determined. Fish taken from the North Saskatchewan River side channels at Windy Point were thought to be spawning on 2 July 1972. However, some fish were spent, some were extruding sex products and others were green. Occasional fish that were running sex products were noted as late as mid-September, in 1972 and 1973. The published data for this species (Scott and Crossman 1973) do not refer to spawning at seasons other than spring. Some of the late maturing fish noted in this study were from areas that were 15 km above the reservoir. Therefore it seems probable that the event was not related to environmental disturbance. However, the late maturing fish may not spawn or if they do the offspring may not survive.

The longnose sucker has declined and the white sucker increased in some other Alberta reservoirs (Nelson 1965) but it seems unlikely that this situation will occur in Abraham Lake.

Longnose suckers were rarely noted in the tributary streams; they did occur in the lower reaches of the Cline River and Tershishner Creek but these localities are now submerged (Figure 12).

White Sucker, *Catostomus commersoni* (Lacépède)

This species is very rare in the study area. Three large (100+ g) fish were obtained, by seining during 1972, from localities that are now within Abraham Lake. All identifiable fry and juvenile catostomids obtained during the study were either longnose or mountain suckers. Specimens of the hybrid (*C. catostomus* x *C. commersoni*) were also obtained and are referred to in the section on fish hybrids.

Collecting in the riverbed between Nordegg and the damsite, after closure and dewatering, yielded no white suckers. However, the species is quite common in Shunda Creek near Nordegg, where it comprises about 35% of the catostomid population (M. Kraft pers. comm.).

McPhail and Lindsey (1970:283) suggest that the white sucker is somewhat less tolerant of cold water than the longnose sucker.

Mountain Sucker, *Catostomus platyrhynchus* (Cope)

Although nowhere abundant, mountain suckers were found in all habitats thought to be suitable for the species. They were collected in 1972 from side channels of the river within what is now Abraham Lake. Collecting in 1973 yielded only two specimens from within Abraham Lake (by seining). Smith (1966) suggests that this species normally avoids lakes and lake-like conditions. Presumably this is the reason for its apparent scarcity in the reservoir; however, it should be noted that collecting was limited to the May-October period.

Ripe fish of both sexes were seined from a side channel of the North Saskatchewan River on 19 June 1972. Spawning fish (10-12 pairs) were noted in the lower reaches of Whiterabbit Creek on 10 July 1972. Each pair was utilizing a riffle above a small pool, one pair to a pool-riffle. The locality is subject to flooding by the reservoir.

The largest specimen of this species recorded to date for Alberta is a ripe 19.6 cm female seined from Abraham Lake on 28 July 1973.

Spoonhead Sculpin, *Cottus ricei* (Nelson)

This is the only species of cottid known from the study area. Although not often taken by seining, field observations suggest that the species is not uncommon in suitable habitat. The fish appear to be restricted to the main river, its side channels and the lower reaches of the larger tributaries (Figure 13). Sculpins were frequently noted in Dolly Varden stomachs and appear to be heavily utilized by them.

The length frequency data (Figure 14) indicate a maximum age of four years. The data also suggest a mid- to late-summer spawning season, which is in agreement with Scott and Crossman (1973:841). Young-of-the-year fish were readily obtained from desiccated river side channels above Abraham Lake in late October, 1973.

SPECIES KNOWN FROM ADJACENT WATERS

Lake Sturgeon, *Acipenser fulvescens* Rafinesque

Lake sturgeon have been observed in the North Saskatchewan River at Rocky Mountain House (several informants) but no specimens have been secured. The species occurs in the Brazeau River and is known from the North Saskatchewan at Edmonton (Paetz and Nelson 1970).

L. Camilli (pers. comm.) reported observing a large specimen at Whirlpool Point in October 1944. Until specimens are secured the species occurrence is hypothetical for areas upstream of the Brazeau.

Brown Trout, *Salmo trutta* Linnaeus

This species was introduced into Tershishner Creek in 1948 (E. Stenton pers. comm.) and apparently it occurred in beaver ponds near Whitegoat Creek in the 1960-65 period (R. Dubak pers. comm.). None have been noted in the study area in recent years and none were taken during this study. Brown trout are common in Shunda Creek and some other creeks near Nordegg (M. Kraft pers. comm.). It seems probable that water temperatures in the study area are too cold for this species (MacCrimmon and Marshall 1968).

Golden Trout, *Salmo aquabonita* Jordan

An introduction into Gap Lake near Nordegg in 1963 failed, probably due to winterkill (M. Paetz pers. comm.).

Northern Pike, *Esox lucius* Linnaeus

Known to be in the North Saskatchewan at Rocky Mountain House, pike are not known to be in the river near Nordegg (A. Kobza pers. comm.) --nor in Shunda Creek (M. Kraft pers. comm.).

Goldeye, *Hiodon alosoides* (Rafinesque)

This species is known from the river at Edmonton (Paetz and Nelson 1970) and until August 1972 had not been known to occur at Rocky Mountain House (various sources). Anglers reported catching "goldeye" in late August 1972 and occasionally during the summer of 1973, near Rocky Mountain House. Since no specimens were obtained and it is now known that mooneye (*H. tergisus*) occur in the river at Edmonton (Roberts 1974) the identification is questionable until specimens are secured.

Pearl Dace, *Semotilus margarita* (Cope)

This species occurs in lakes near Nordegg, and is especially common in Fish Lake, part of the Shunda Creek system.

Northern Redbelly Dace, *Chrosomus eos* Cope

The distribution of this species is the same as for the pearl dace (Paetz and Nelson 1970).

Finescale Dace, *Chrosomus neogaeus* (Cope)

The distribution of this species is the same as that of the pearl dace.

Fathead Minnow, *Pimephales promelas* Rafinesque

The distribution of this species is the same as that of the pearl dace.

Burbot, *Lota lota* (Linnaeus)

The burbot is somewhat enigmatic in its distribution. In previous years it occurred in the North Saskatchewan as far upstream as the Mistaya junction (T. MacAuley pers. comm.). During this study no specimens were obtained from within the Abraham Lake watershed; however the species is quite readily obtained from the North Saskatchewan River near its confluence with the Bighorn River. Set lines in Abraham Lake (906 hook hours) yielded only Dolly Varden while those in the North Saskatchewan River near Nordegg (47 hook hours) yielded 6 burbot and 7 Dolly Varden. Discussions with various people involved in the dam construction indicate that large burbot (reported as ling, marias and catfish) were observed below the damsite when the river was turned into the diversion tunnel. No young burbot were noted in the dewatered river after closure. All catches reported by anglers suggest that the fish noted or caught were fairly large (over 500 g).

The reports to date suggest that the species was not resident in the upper river and that no breeding occurs in the North Saskatchewan River above Nordegg. If this assumption is correct then it appears that the burbot population that occurred in the river above the damsite passed downstream through the diversion tunnel and has been unable to reascend.

Brook Stickleback, *Culaea inconstans* (Kirtland)

This species is common in suitable habitat in the Nordegg area (Shunda Creek system, Shaks and Goldeye lakes). However, it was not found in what would appear to be similar (and suitable) habitat (sloughs, springs, beaver ponds) in the study area. Tebby (1974a) provides a list and the coordinates of the many small waterbodies examined for both stickleback and cyprinids.

HYBRIDS

"Splake"

This form was stocked by the National Parks Service in several small lakes (Warden Lakes and others) in Banff National Park between 1954 and 1957. Apparently no reproduction took place and the introduced fish are now presumed to be deceased. A fish (U.A.M.Z. #3372) obtained from a small creek (Timber, see Tebby 1974a) 5 km downstream from the park boundary has the characteristics of a splake.* This specimen may indicate that some introduced fish escaped and are reproducing, or that an unauthorized stocking was made, or that a mixed group of hatchery fish were released. Until further specimens are secured the status of the splake is enigmatic.

"Brolly"

I "coined" this name for the hybrid between the brook trout and the Dolly Varden. Three specimens, that appeared to be this hybrid, were examined during the study. One was a female (ca. 2.6 kg) caught by D. Brown on 27 September 1973. The gonads of this fish were very rudimentary (ca. 5 cm long) and contained a mixture of roe of all sizes from the almost microscopic to 4 mm in diameter. ~~A scale sample~~ indicates an age of 4+ years. The head was preserved (U.A.M.Z. #3371). A ripening male was taken by angling (U.A.M.Z. #3246) and a fish caught in the test netting program was not retained as it was in a damaged condition from the netting.

Superficially all these fish resembled Dolly Varden in general body shape but had faint bars on the dorsal fin, vermiculations and

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*Dr. J. S. Nelson and W. Roberts, pers. comm.

spots on the dorsal surface, and were more intensely colored than Dolly Varden. The color pattern of the male (U.A.M.Z. #3246) is intermediate in its features (between those of males of the presumed parental types).

The few fish examined do not allow definitive statements on fertility to be made but it is interesting that such large fish (both sexes) have had abnormal appearing or rudimentary gonads during the spawning period. The hybrid has been suspected in Alberta for a number of years (Paetz and Nelson 1970:88).

"Cutbow"

This is the common name for a hybrid between rainbow trout and cutthroat trout. J. C. Ward (pers. comm.) reports that they occur in the Mistaya system and one specimen that was considered to be a "cutbow" was taken in Abraham Lake (U.A.M.Z. #3355).

Cyprinid Hybrids

Nelson (1966, 1973a) reported on the lake chub x longnose dace. No specimens meeting this description have been observed in this study.

Catostomid Hybrids

Hybrids between the longnose sucker and the white sucker were described by Nelson (1973b). Three specimens of this hybrid were obtained during the study; all were large (500+ g) fish. The total number of longnose, white and hybrid suckers examined is unknown but probably is between 2000 and 3000 fish; of these only three were whites and three were hybrids. The data from gill netting give a ratio of 2 hybrids to 126 longnose suckers. In a Colorado reservoir (Middleton 1969) the ratio of hybrid to parental species was much higher (255 white:211

longnose:55 hybrid) than in Abraham Lake.

Middleton (1969) also found hybrids between *C. commersoni* and *C. latipinnis* but found no specimens of the latter. He believed it had been extirpated from within his study area by hybridization and environmental changes. The present situation is possibly analogous and suggests the eventual extirpation of the white sucker by hybridization with the longnose in the Abraham Lake drainage basin.

There were no specimens that appeared to be hybrids between mountain suckers and the other species of sucker.

SPORT FISHING

Although early records (Wilson papers) indicate some interest in sport fishing, the area has never been subject to intensive use by sport anglers. Discussions with various "old-time" residents (Nordegg miners) indicate that the reasons for the lack of fishing pressure are related to the flooding and heavy silt loads of the river during the "prime" months (June-August). Although fully aware that the river had a population of sport fish, several people commented that they fished for "pleasure not just fish." Presumably aspects of safety and aesthetics were involved in decisions not to fish the "muddy" river.

However, various informants knew of "unspecified" individuals who had "flashed" (dynamited) the river for food fish during the depression era. The normal "catch" was reported to be "suckers, trout and whitefish."

During the study period it was noted that anglers did not normally fish in the North Saskatchewan but used the smaller tributaries. After closure of the dam the river became very low and clear near Nordegg and received considerable fishing pressure at the trunk road crossing. Catches noted were largely Dolly Varden and mountain whitefish although small numbers of cutthroat trout, rainbow trout and burbot were taken.

Angler success is determined by many factors, in particular by the anglers' skills and abilities in locating fish and using tackle. Many anglers caught no fish and claimed the waters had no fish. However, good catches have occurred in the Abraham Lake area (Photographic Plate 2).

PARASITES AND DISEASE

The data to date suggest that parasitism is not a major fish management problem within the study area.

"Black spot" occurs within the lake chub (*Couesius plumbeus*) population; the data (Table 4) show that the degree of infection varies both in the locality and in individual specimen. Nelson and Paetz (1970:166) attribute "black spot" to a trematode larva (*Neascus* sp.). The intermediate hosts are reported (Hoffman 1967) to be gastropods and aquatic birds.

Occasionally, specimens of longnose sucker were noted with one or more tapeworms. Nelson and Paetz (1970:188) noted that they are frequently infected with the tapeworm, *Ligula*. Tapeworms were rare in the salmonid fishes; only one heavily infected Dolly Varden was noted during the study.

The levels of tapeworm infestation were low during the study and do not appear to present a management problem at the present time.

No wild fish were noted with any obvious diseases; however, diseases of hatchery origin (Yamamoto 1974) are possible as fish are still being stocked in the system.

ABRAHAM LAKE GILL NET SURVEY

Gill netting in a new hydroelectric reservoir is difficult even when the area being flooded has been very thoroughly cleared.

The first attempt at netting was on 16 September 1972 when a test net was set near Windy Point. The next day the area was covered with driftwood and the nets were missing. It is believed that they had been fouled by one of the driftwood "mats" (Photographic Plate 3) being moved about by the wind.

Test netting resumed on 18 July 1973 when the driftwood problem was deemed to have abated. This, however, did not prove to be a completely valid assumption and further net losses were sustained throughout the survey.

The summarized data (Table 5) should be interpreted with caution since they were obtained from relatively few stations (Figure 15). The fish were all taken in shallow waters and the nets were so frequently fouled by debris (Table 6) that no estimate of fish biomass should be attempted.

SUMMARY DISCUSSION

Pleistocene deglaciation left the upper North Saskatchewan River system depauperate in aquatic fauna. Invertebrates (some molluscs and crustaceans) that lack suitable dispersal techniques are absent from apparently suitable habitat. The native fish population is derived by upstream dispersal from sources outside the mountains, the Mississippi-Missouri refugia being the most plausible source.

Cutthroat trout (*Salmo clarki*) spread northwards only to the adjoining (south) Bow system. Rainbow trout (*S. gairdneri*) are native to the adjacent (north) Athabasca watershed. Thus the North Saskatchewan drainage represents a hiatus in the distribution of *Salmo* on the east slope of the cordillera. This implies that the river very rapidly became ecologically (probably thermally) isolated from the other systems after deglaciation. This implication is strengthened by the establishment of both species after introduction.

The apparent absence of other species of indigenous fish that might be expected to occur in the study area can be related to certain interacting factors. Lake sturgeon lacked a suitable food base for a permanent population, although they may have irregularly visited the area. Burbot probably were regular summer residents. Both species have been unable to return because of the Bighorn Dam. The available data suggest that burbot do not reproduce in the river above Nordegg, possibly because of low winter water levels; they may not reproduce in any part of the river above Rocky Mountain House. Other species of fish, occurring in lakes associated with Shunda Creek, have apparently not been able to move up the North Saskatchewan much above the Shunda Creek junction. The obstacle appears to be the high water velocities of the "Gap," the area where the river exits from the mountains.

Of the various forms of fish introduced into the area only the brook trout has become widely established. Cutthroat and rainbow trout occur but have limited distributions; probably spring flooding is too severe for them to spawn successfully in most areas. Brown trout, although fall spawners, as are brook trout and Dolly Varden, require higher summer water temperatures than the area offers and introductions failed to establish a permanent population.

Several fish hybrids occur in the district; the brook trout x Dolly Varden is newly described but the others are well known. The major factor in the sucker hybridization noted in this study is probably the disproportionate numbers of the parental species, not unnatural occurrence or artificial environmental disturbances as have been reported (Middleton 1969, Nelson 1973b).

Some of the data obtained on the biology of the fishes in the study area do not agree with previously published information (Scott and Crossman 1973). The spawning period for the longnose sucker in the area studied appears to be from spring to mid-September. However, the late spawning (if it occurs) may be a local phenomenon relating to those areas of low water temperatures. If a normal event, it would be of little value to the species because the fry would have low survival. The study provides additional biological background data on the mountain sucker and the spoonhead sculpin.

The data obtained on the Dolly Varden population indicate that it is not homogeneous. Discrete subpopulations with different growth rates (or age at maturity) occur in the area. It appears probable that some fish do not mature until they have reached a length in excess of 50 cm. This late maturity makes the Dolly Varden population very sensitive to fishing pressure. Fish as small as 15 cm were retained by some anglers and if large catches of immature fish take place the fishery will be severely or totally depleted.

Prior to the filling of the reservoir the fish biomass in the area was limited by the low winter water levels and by the lack of deep holes. Abraham Lake will allow a higher biomass to overwinter and this will probably cause population changes (biomass and species ratios) in waters above the reservoir. It also seems probable that the maximum size attained, by individual fish of the various species, will be greater.

The glacial silt in the water during the summer months will prevent the reservoir having any significant phytoplankton population. The annual drawdown will preclude the establishment of rooted aquatics. When the drowned terrestrial matter is exhausted the organisms will largely depend on allochthonous material and the reservoir will have a relatively sparse fish population.

With the completion of the Bighorn Dam and the filling of the reservoir (Abraham Lake) interest in the area's recreational fishery has increased. The data obtained from this study will provide a framework for a fisheries management policy that will enable the people of the province to obtain the maximum benefits from the reservoir.

The author's management suggestions will be submitted as a separate report (Tebby 1974b) and not as part of this thesis.

TABLES

TABLE 1

SELECTED SECCHI VALUES

Date	Secchi value	Location
22 June 1972	22 cm	N. Sask. R., Nordegg
3 July 1972	25 cm	N. Sask. R., Nordegg
28 July 1972	22 cm	N. Sask. R., Nordegg
7 Aug. 1972	12 cm	N. Sask. R., Nordegg
17 Aug. 1972	28 cm	Abraham L. near Allstones Cr.
28 Aug. 1972	32 cm	Abraham L. near Allstones Cr.
28 Aug. 1972	17 cm	Abraham L. above Cline jct.
4 Sept. 1972	38 cm	Abraham L. near Windy Pt.
17 Sept. 1972	45 cm	Abraham L. near Allstones Cr.
8 Oct. 1972	≈2 m	Abraham L. Abraham flats
16 Oct. 1972	45 cm	Abraham L. near Windy Pt.
16 Oct. 1972	≈3 m	N. Sask. R., 1 km above reservoir
24 May 1973	50 cm	N. Sask. R., Sask. Crossing
1 June 1973	75 cm	N. Sask. R., Whirlpool Pt.
13 Aug. 1973	2 cm	N. Sask. R., near Coleman Cr.
21 Aug. 1973	191 cm	Abraham L., Windy Pt.
21 Aug. 1973	170 cm	Abraham L., Fontinalis Bay

TABLE 2

STOMACH CONTENTS OF DOLLY VARDEN

Item	No. of fish
Items that occurred in 66 fish (45-470 g) that were gillnetted	
Daphnia spp.	53
Unidentifiable fish	10
Chironomids	6
Aquatic insects	5
Terrestrial invertebrates	3
Bird (imm.)	2
Cottus sp.	2
Catostomus spp.	1
Rodent	1
Items that occurred in 11 fish (500-1500 g) that were gillnetted	
Unidentifiable fish	7
Rodents	3
Daphnia spp.	2
Cottus sp.	1
Lake chub	1
Mountain whitefish	1

TABLE 3

COMPARATIVE SEINE HAULS

Date	Location	Species (No.)	Total weight/Age
19 June 1972	N. Sask. R. side channel Windy Pt.	Mtn. whitefish	(44) juv.
		Mtn. sucker	(8) juv.
			(7) ripe adults
		Longnose dace	(1) Y.O.Y.
			(10) juv. and adult
		Lake chub	(2) juv.
		Longnose sucker	(1) juv.
2 July 1972	N. Sask. R. near Allstones Cr.	Mtn. whitefish	(2) Y.O.Y.
			(34) juv.
		Longnose dace	(16) juv. and adult
		Longnose sucker	(4) juv.
			(8) adult
		Mtn. sucker	(2) juv.
		Dolly Varden	(1) juv.
		Cutthroat trout	(1) adult
21 July 1972	Side channel N. Sask. R. Windy Pt.	Longnose sucker	(12) 84 g
		Mtn. sucker	(1) 69 g
		Mtn. whitefish	(113) 59 g
		Longnose dace	(81) 55 g
		Lake chub	(5) 6 g
17 Aug. 1972	Tershishner Cr. jct. with the reservoir	Mtn. whitefish	(9) 104 g
27 Aug. 1972	Abraham L. Windy Pt.	Lake chub	(15) juv.
			(9) adult
31 Aug. 1972	Whiterabbit Cr. jct. with the N. Sask.	Longnose sucker	(5) 1395 g (live wt)
		Dolly Varden	(1) 450 g (live wt)
		Mtn. whitefish	(48) 227 g (preserved)

TABLE 3 (Continued)

Date	Location	Species	(No.)	Total weight/Age
19 Sept. 1972	N. Sask. R. side channel 5 km W. Whirlpool Pt.	Mtn. whitefish	(114)	Y.O.Y.
			(10)	juv.
		Longnose sucker	(34)	Y.O.Y.
		Lake chub	(28)	Y.O.Y.
4 July 1973	Abraham L. N. Windy Pt.	Mtn. whitefish	(10)	157 g
		Longnose dace	(10)	10 g
		Lake chub	(3)	9 g
		Longnose sucker	(1)	1 g
4 July 1973	Abraham L. S. Windy Pt.	Mtn. whitefish	(16)	340 g
		Lake chub	(1)	7 g
		Longnose dace	(5)	6 g
4 July 1973	Abraham L. South end	Mtn. whitefish	(26)	276 g
		Dolly Varden	(2)	72 g
		Longnose sucker	(1)	13 g
		Longnose dace	(1)	5 g
28 July 1973	Abraham Lake Abraham Flats	Mtn. whitefish	(92)	Y.O.Y.
			(20)	juv.
		Longnose sucker	(15)	juv.
			(1)	adult
		Longnose dace	(1)	Y.O.Y.
			(8)	adult
		Lake chub	(1)	Y.O.Y.
			(5)	adult
		Mtn. sucker	(2)	adult
		Brook trout	(1)	adult
17 Sept. 1973	Abraham L. Abraham Flats	Mtn. whitefish	(70)	299 g

TABLE 4

BLACK SPOT IN LAKE CHUB

Location	Date	Number of fish (number of spots per fish)
N. Sask. River near Windy Point	20 June 1972	15 (0)
		2 (1)
		1 (2)
		1 (12)
		1 (15)
N. Sask. River near Fontinalis Creek	27 August 1972	9 (0)
N. Sask. River near Tershishner Creek	10 May 1973	40 (0)
		2 (1)
		2 (2)
		1 (5)

TABLE 5

ABBREVIATIONS USED AND SUMMARY OF DATA IN TABLE 6

Gillnets

Net A: Stretched mesh 3.8 cm (1.5 in), 210/2 twine, 45.7 m (50 yd), 60 meshes deep

Net B: Stretched mesh 6.4 cm (2.5 in), 210/2 twine, 45.7 m (50 yd), 60 meshes deep

Net C: Stretched mesh 8.9 cm (3.5 in), 210/3 twine, 45.7 m (50 yd), 36 meshes deep

Net D: Stretched mesh 11.4 cm (4.5 in), 210/3 twine, 45.7 m (50 yd), 24 meshes deep

Net E: Stretched mesh 14.0 cm (5.5 in), 210/3 twine, 45.7 m (50 yd), 16 meshes deep

Fish

MWF = Mountain whitefish	CTT = Cutthroat trout	RBT = Rainbow trout
DVT = Dolly Varden	EBT = Brook trout	HBD = Hybrid "Brolly"
LNS = Longnose sucker	WHS = White sucker	HYS = Hybrid sucker

Total catch from Abraham Lake: all gillnets, wet weight

MWF:	200 fish, 19480 grams	LNS:	126 fish, 50065 grams
DVT:	154 fish, 42840 grams	HYS:	2 fish, 1430 grams
EBT:	35 fish, 6905 grams	WHS:	rare, not netted
HBD:	1 fish, 190 grams	RBT:	rare, not netted
CTT:	2 fish, 205 grams		

TABLE 6

ABRAHAM LAKE GILL NET SURVEY, 1973

Location	Date/Time	Depth	Results	Comments
		NET A		
Abraham Flats	18 July: 1500 19 July: 1100	2- 3	MWF-(10)-1060 DVT-(4)- 570 EBT-(3)- 310	Badly fouled with driftwood
	19 July: 1200 20 July: 1200	2- 3	MWF-(5)- 260 DVT-(1)- 170 EBT-(1)- 60 CTT-(1)- 60	As above
	20 July: 1200 21 July: 1000	2- 3	MWF-(6)- 330	Not on bottom in all places
	21 July: 1000 22 July: 1530	2- 3	MWF-(7)- 420 DVT-(1)- 30 EBT-(2)- 370	Some driftwood in nets
	22 July: 1200 22 July: 1930	15-20	~~No fish~~	
Cline Mouth	8 Aug : 1315 8 Aug : 1930	3- 4	MWF-(4)- 300 DVT-(1)- 170 EBT-(2)- 230 LNS-(1)- 550	Partially held off bottom by trees
	8 Aug : 1930 9 Aug : 0800	3- 4	MWF-(6)- 360 DVT-(3)-1460 EBT-(2)- 325 LNS-(7)- 530	
	9 Aug : 0800 9 Aug : 1900	3- 4	MWF-(5)- 340 LNS-(3)-1890	
	9 Aug : 1900 10 Aug : 1830	3- 4	MWF-(10)- 700 DVT-(5)- 940 EBT-(1)- 60 LNS-(4)-1570	
Fontinalis Bay	16 Aug : 1300 17 Aug : 1930	5- 6	MWF-(31)-2180 DVT-(8)- 885 EBT-(1)- 400 LNS-(13)-2635	

TABLE 6 (Continued)

Location	Date/Time	Depth	Results	Comments
Camas Island	21 Aug : 1500 22 Aug : 0745	12-15	MWF-(1)- 75	Caught in the top mesh
Grebe Bay	22 Aug : 1400 23 Aug : 0730	8-10	MWF-(5)- 380 DVT-(2)- 345	
Tershishner Bay	26 Aug : 2030 27 Aug : 0830	4- 7	MWF-(12)- 750 DVT-(7)-1060 LNS-(13)-1565	
	27 Aug : 0900 28 Aug : 1015	5- 7	MWF-(26)-1580 DVT-(7)-1185 LNS-(9)- 710	Strong winds
Cline Mouth	17 Sept: 1500 18 Sept: 1200	6	MWF-(9)- 650 DVT-(5)- 665 LNS-(1)- 100	
North Saskatchewan Junction	25 Sept: 1600 26 Sept: 1330	3- 7	MWF-(13)-1000 DVT-(10)-2355	91.4 m of net (100 yd)
	7 Oct : 1600 8 Oct : 1100	2- 5	MWF-(2)- 150	91.4 m of net (100 yd)
	9 Oct : 1430 10 Oct : 1130	4	MWF-(8)- 745 DVT-(2)- 735	91.4 m of net (100 yd)
		NET B		
Abraham Flats	18 July: 1500 19 July: 1100	2- 3	No fish	Badly fouled with debris
	19 July: 1200 20 July: 1200	2- 3	No fish	Badly fouled
	20 July: 1200 21 July: 1000	2- 3	DVT-(5)-1300	
	21 July: 1000 22 July: 1530	2- 3	No fish	Badly fouled
Cline Mouth	9 Aug : 1200 9 Aug : 1845	3- 4	MWF-(2)- 520 DVT-(6)-2310	

TABLE 6 (Continued)

Location	Date/Time	Depth	Results	Comments
Cline Mouth	9 Aug : 1900 - ? -	3- 4	Lost	Probably lost to debris
	9 Aug : 1845 10 Aug : 0900	3- 4	MWF-(7)-1370 DVT-(11)-3560 EBT-(1)- 370 LNS-(2)- 580	
	10 Aug : 0900 10 Aug : 1915	3- 4	DVT-(1)- 230 EBT-(2)- 490 LNS-(2)- 650	
	10 Aug : 1915 11 Aug : 0900	3- 4	MWF-(3)- 710 DVT-(1)- 440 LNS-(1)- 420	
	11 Aug : 0900 11 Aug : 2115	3- 4	MWF-(2)- 370 DVT-(11)-3520 EBT-(5)-1160 LNS-(1)- 190	
Fontinalis Bay	16 Aug : 1300 17 Aug : 1930	5- 6	No fish	Badly fouled
	21 Aug : 1300 21 Aug : 1800	8-10	MWF-(2)- 540 DVT-(1)- 230 EBT-(2)- 440	
	21 Aug : 1500 22 Aug : 0800	8-10	MWF-(1)- 185 DVT-(3)- 755 EBT-(1)- 135 LNS-(1)- 295 HYS-(1)- 620	Badly fouled fish limited to top 1 m of net (too deep)
Grebe Bay	22 Aug : 1400 23 Aug : 0730	8-10	DVT-(2)- 580 EBT-(3)- 545 LNS-(2)- 445	
Tershishner Bay	26 Aug : 2030 27 Aug : 0830	4- 7	MWF-(1)- 210 DVT-(9)-2325 EBT-(1)- 310 LNS-(20)-6535 HBD-(1)- 190	Stormy
	27 Aug : 0830 27 Aug : 1915	5- 7	MWF-(2)- 375 LNS-(8)-3190	

TABLE 6 (Continued)

Location	Date/Time	Depth	Results	Comments
Cline Mouth	17 Sept: 1500 18 Sept: 1200	6	DVT-(3)- 875 EBT-(3)- 625 LNS-(4)-1680	
North Saskatchewan Junction	25 Sept: 1600 26 Sept: 1330	3- 7	MWF-(1)- 250 DVT-(12)-3500 LNS-(1)- 745	91.4 m of net (100 yd) set - but ½ badly tangled in a tree
	7 Oct : 1600 8 Oct : 1100	2- 5	MWF-(5)- 780 DVT-(15)-5595 EBT-(4)- 785 CTT-(1)- 145	Also 1 Western Grebe 80.5 m of net (88 yd)
	9 Oct : 1430 10 Oct : 1130	4- 5	MWF-(13)-2520 DVT-(8)-3290 EBT-(1)- 290 LNS-(2)-1145	80.5 m of net (88 yd)
		NET C		
Abraham Flats	18 July: 1500 19 July: 1100	2- 3	No fish	Badly fouled
	19 July: 1200 20 July: 1200	2- 3	No fish	Badly fouled
	20 July: 1200 21 July: 1000	2- 3	No fish	Badly fouled
	22 July: 1200 22 July: 1930	15-20	No fish	
Cline Mouth	9 Aug : 1900 - ? -	3- 4	Lost	Probably lost to debris
Fontinalis Bay	16 Aug 1300 17 Aug : 1930	5- 6	No fish	Badly fouled
Cline Mouth	7 Sept: 1630 8 Sept: 0930	6- 9	LNS-(4)-2830 HYS-(1)- 810	
	8 Sept: 1330 9 Sept: 1015	5- 6	DVT-(2)- 525 LNS-(8)-5540	

TABLE 6 (Continued)

Location	Date/Time	Depth	Results	Comments
Cline Mouth	9 Sept: 1015 10 Sept: 1045	4- 6	DVT-(2)- 830 LNS-(12)-8950	
	17 Sept: 1500 18 Sept: 1200	6	LNS-(1)- 790	
North Saskatchewan Junction	7 Oct : 1600 8 Oct : 1100	5	MWF-(1)- 370 DVT-(1)- 670	
	9 Oct : 1430 10 Oct : 1130	5	DVT-(2)-1275	
		NET D		
Abraham Flats	18 July: 1500 19 July: 1100	2- 3	No fish	Badly fouled
	19 July: 1200 20 July: 1200	2- 3	No fish	Badly fouled
	20 July: 1200 21 July: 1000	2- 3	No fish	
	21 July: 1000 22 July: 1530	2- 3	No fish	
Fontinalis Bay	16 Aug : 1300 - ? -	5- 6	Lost	Cause unknown
Cline Mouth	7 Sept: 1630 8 Sept: 0930	6- 9	LNS-(1)- 980	
	8 Sept: 1330 9 Sept: 1015	6	DVT-(2)- 480 LNS-(3)-3280	
	9 Sept: 1015 10 Sept: 1045	5	DVT-(1)- 280 LNS-(2)-2270	
	17 Sept: 1500 18 Sept: 1200	6	No fish	

TABLE 6 (Continued)

Location	Date/Time	Depth	Results	Comments
NET E				
Abraham Flats	18 July: 1500 19 July: 1100	3	No fish	Badly fouled
	19 July: 1200 20 July: 1200	3	No fish	Badly fouled
	22 July: 1200 22 July: 1930	20	No fish	
Cline Mouth	7 Sept: 1630 8 Sept: 0930	9	No fish	
	8 Sept: 1330 9 Sept: 1015	6	No fish	
	9 Sept: 1015 10 Sept: 1045	6	No fish	

Note: See Table 5 for explanation of abbreviations used. Depth values in meters. Number of fish in ( ) followed by weight in grams.

FIGURES

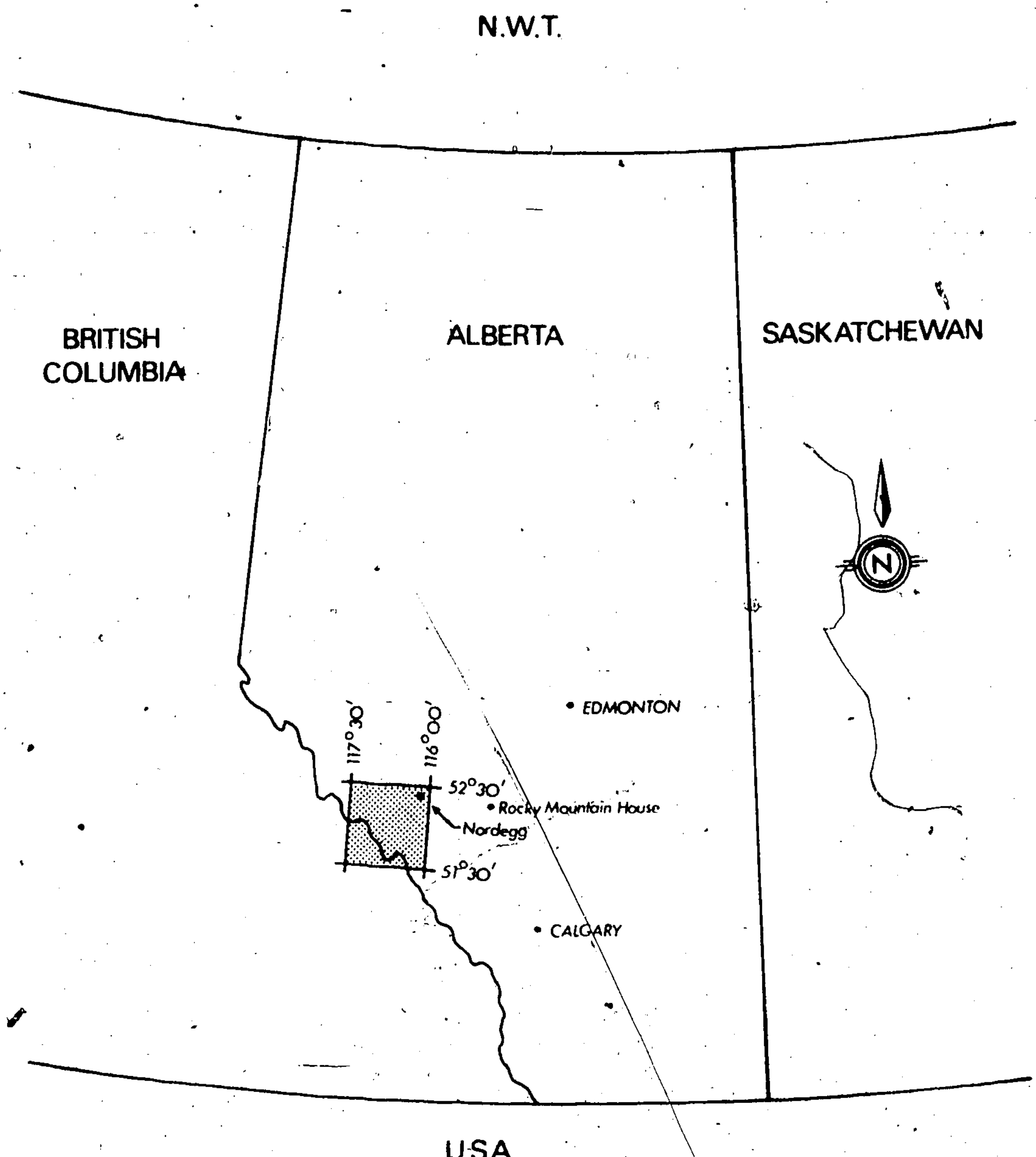
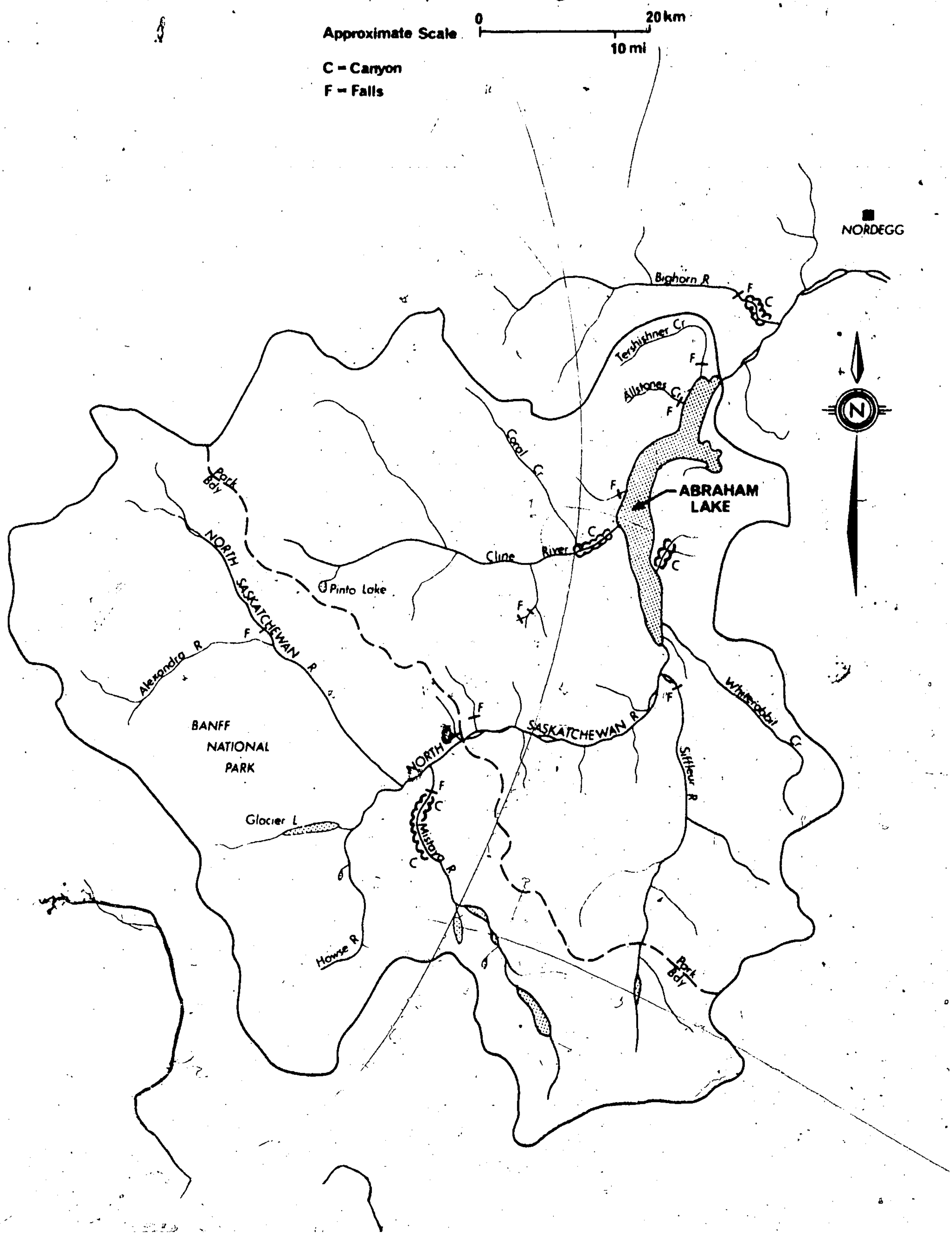
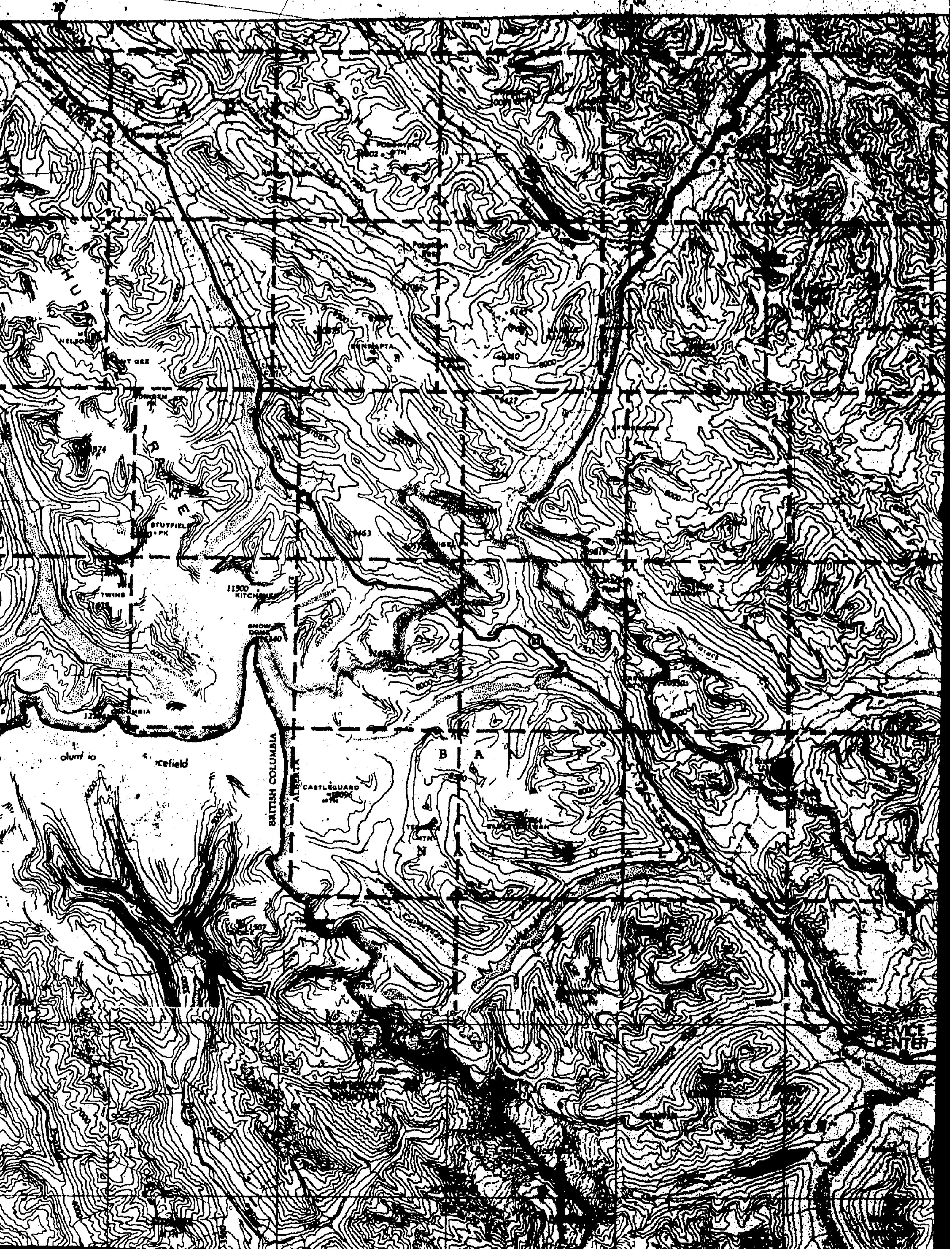


FIGURE 1: MAP SHOWING THE GENERAL LOCATION OF STUDY AREA
(See figure 3 for details)

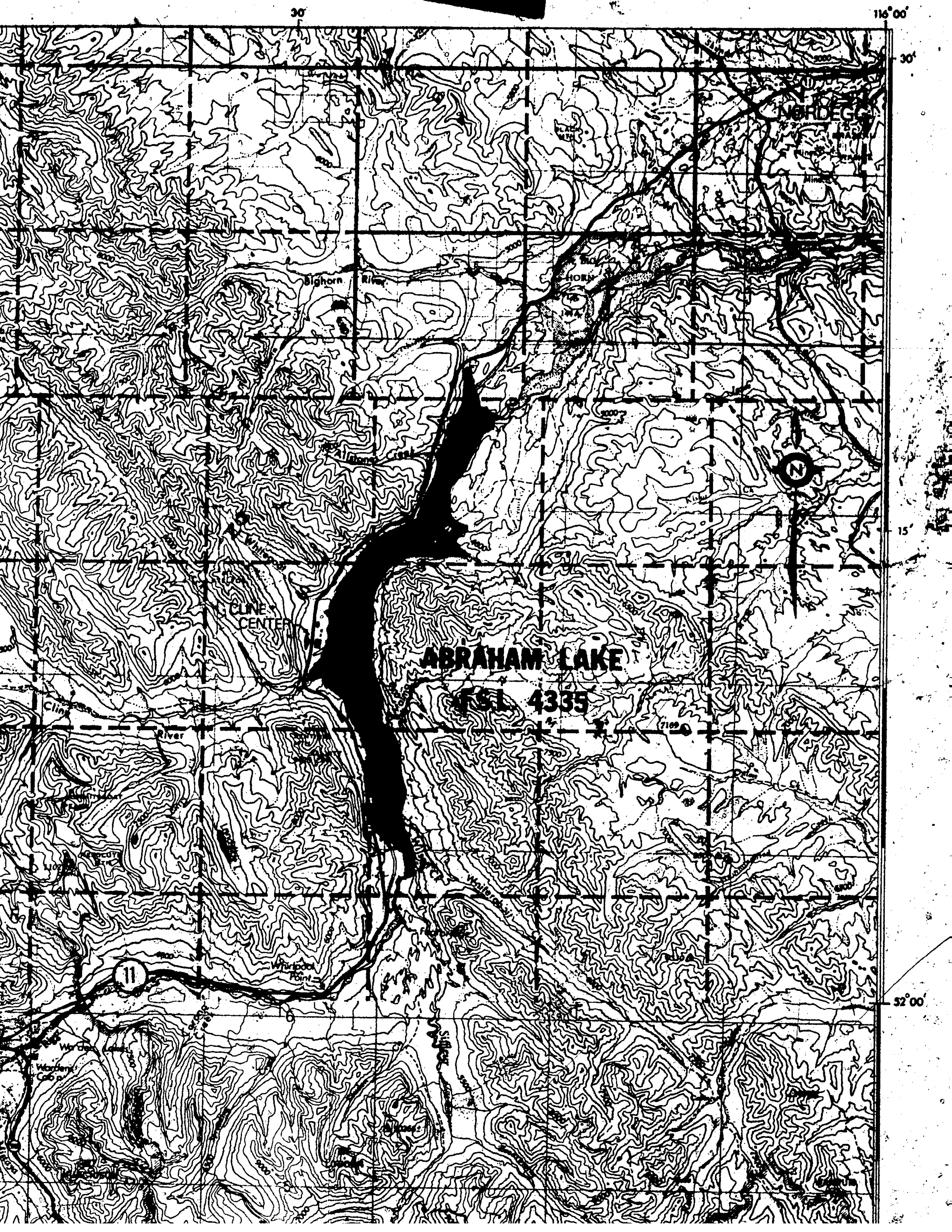
FIGURE 2 DRAINAGE BASIN OF ABRAHAM LAKE

NOTE : Map is Semi-diagrammatic

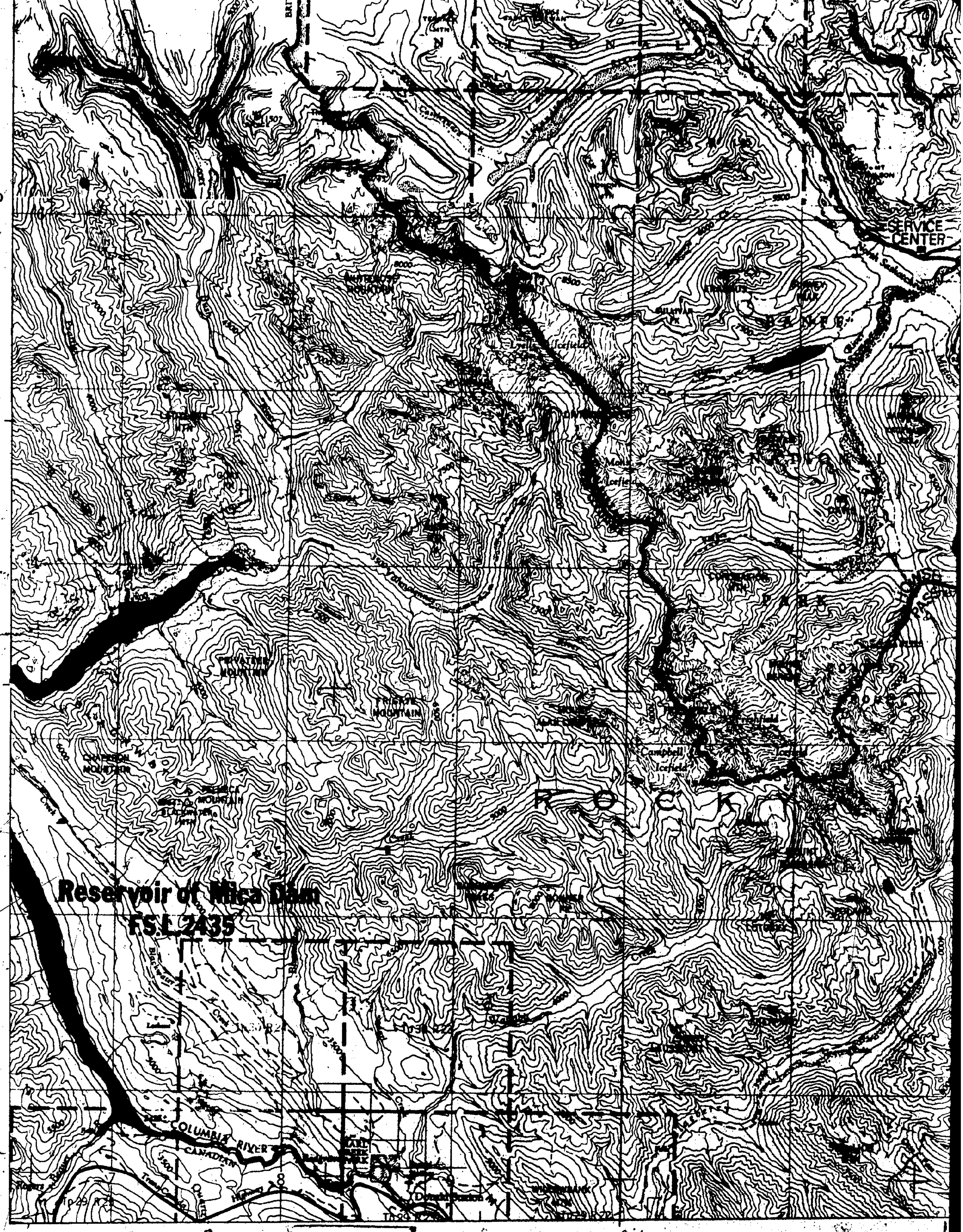




BRITISH COLUMBIA
CASTLEGUARD MTN
STUTFIELD PK
TWINS
11500
KITCHENER
SNOW DOME
B
A
N



30'
116°00'
30'
NORDEGG
Bighorn River
CLINE CENTER
ABRAHAM LAKE
F.S.L. 4335
15'
Cline
River
Whirlpool Point
11
52°00'



SERVICE CENTER
PRIVATEER MOUNTAIN
FRIGATE MOUNTAIN
CHAPERON MOUNTAIN
Reservoir of Mica Dam
F.S.L. 2435
Campbell Icefield
R O C K
COLUMBIA RIVER
117°00'
30'

3 of

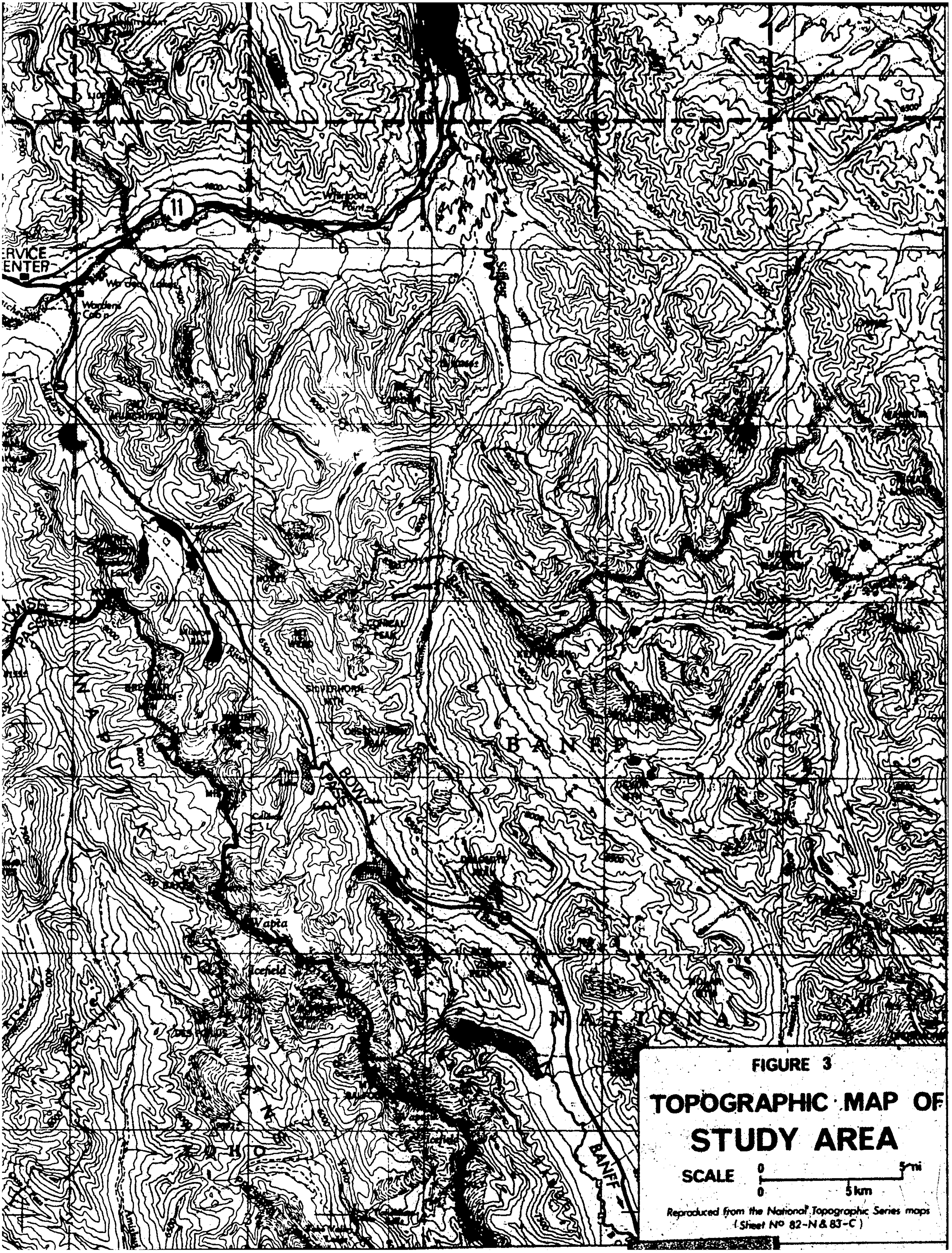


FIGURE 3

TOPOGRAPHIC MAP OF STUDY AREA

SCALE 0 — 5 mi; 0 — 5 km

Reproduced from the National Topographic Series maps (Sheet No 82-N & 83-C)

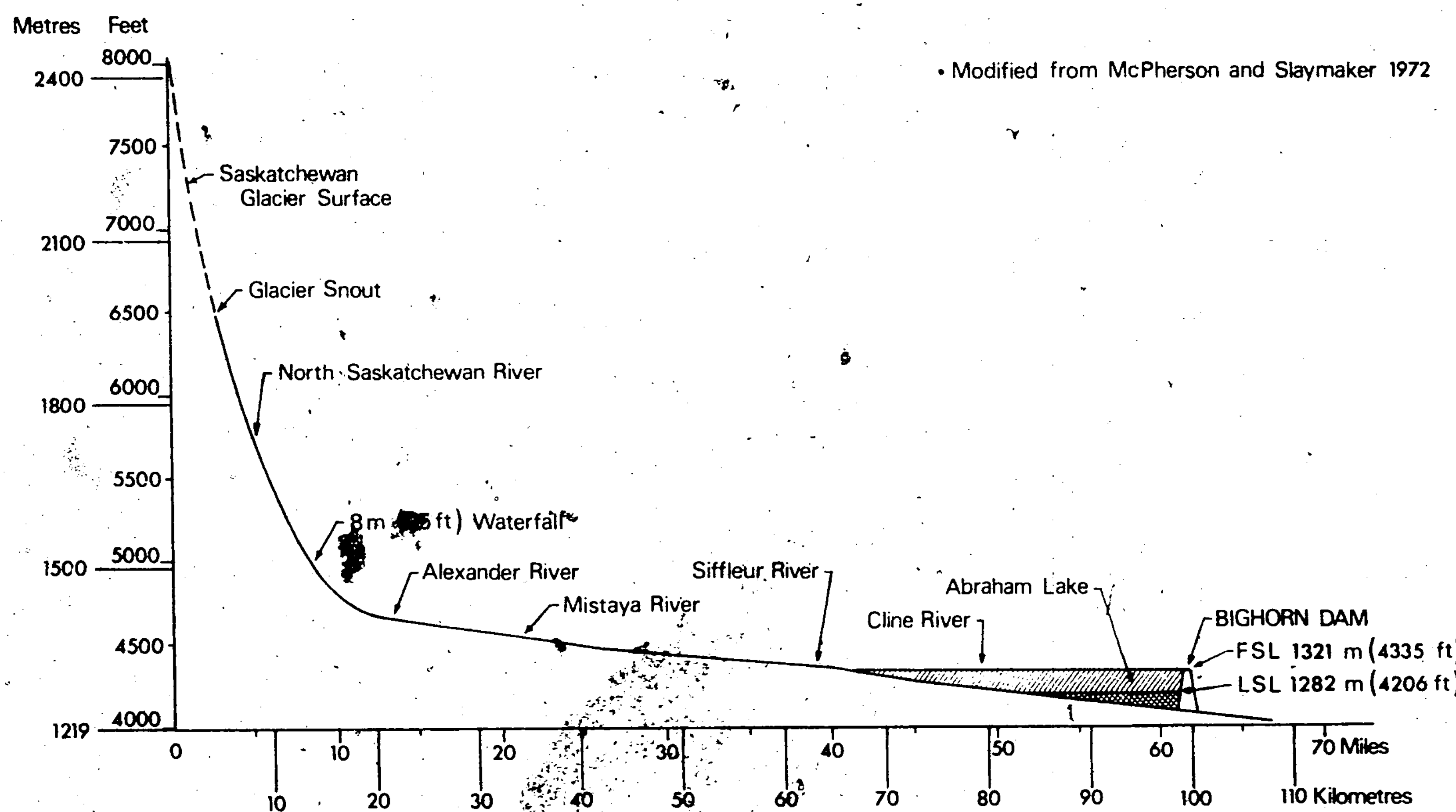


FIGURE 4 LONGITUDINAL PROFILE OF THE UPPER NORTH SASKATCHEWAN RIVER

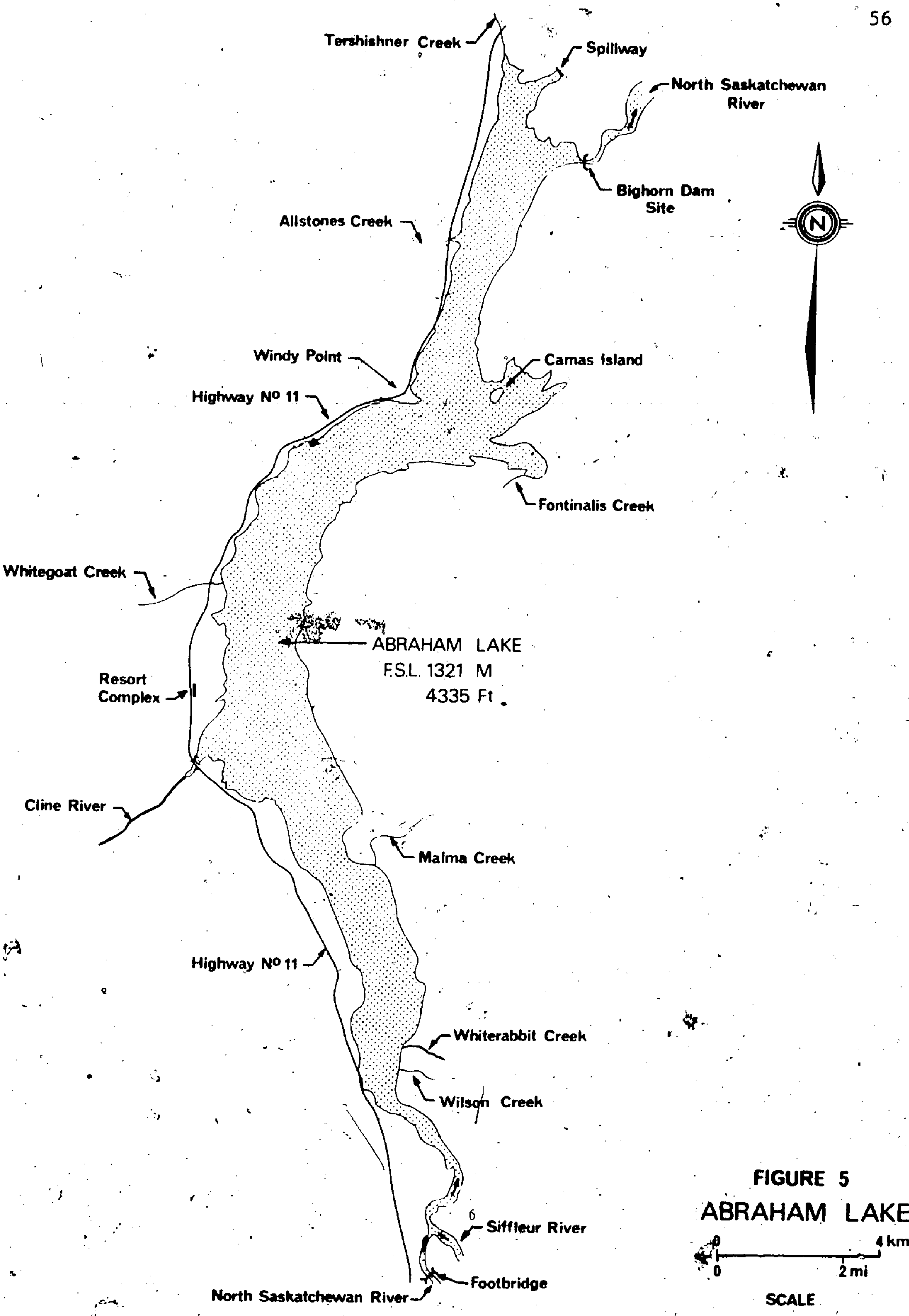
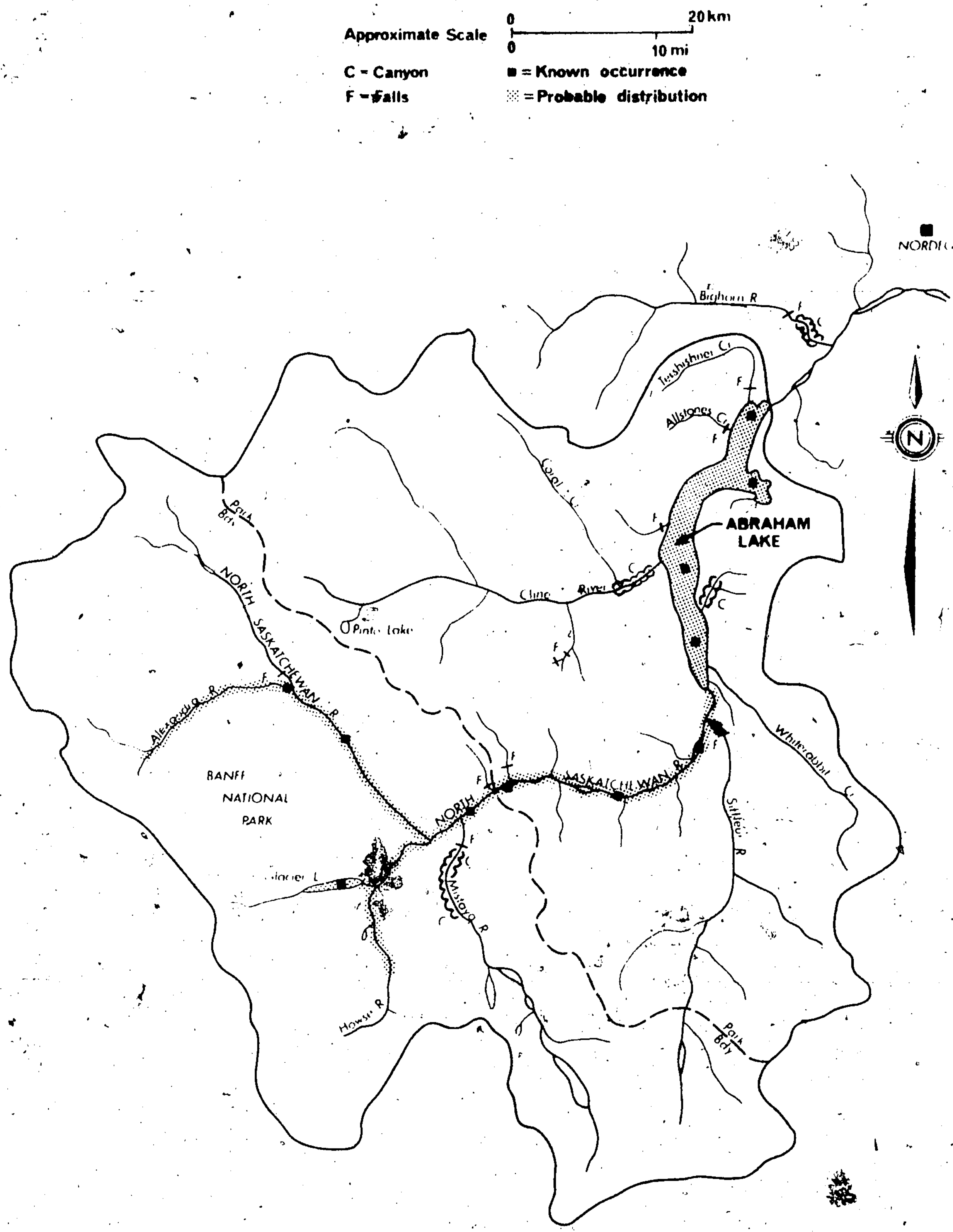


FIGURE 5
ABRAHAM LAKE

FIGURE 6 MOUNTAIN WHITEFISH DISTRIBUTION

NOTE : Map is Semi-diagrammatic



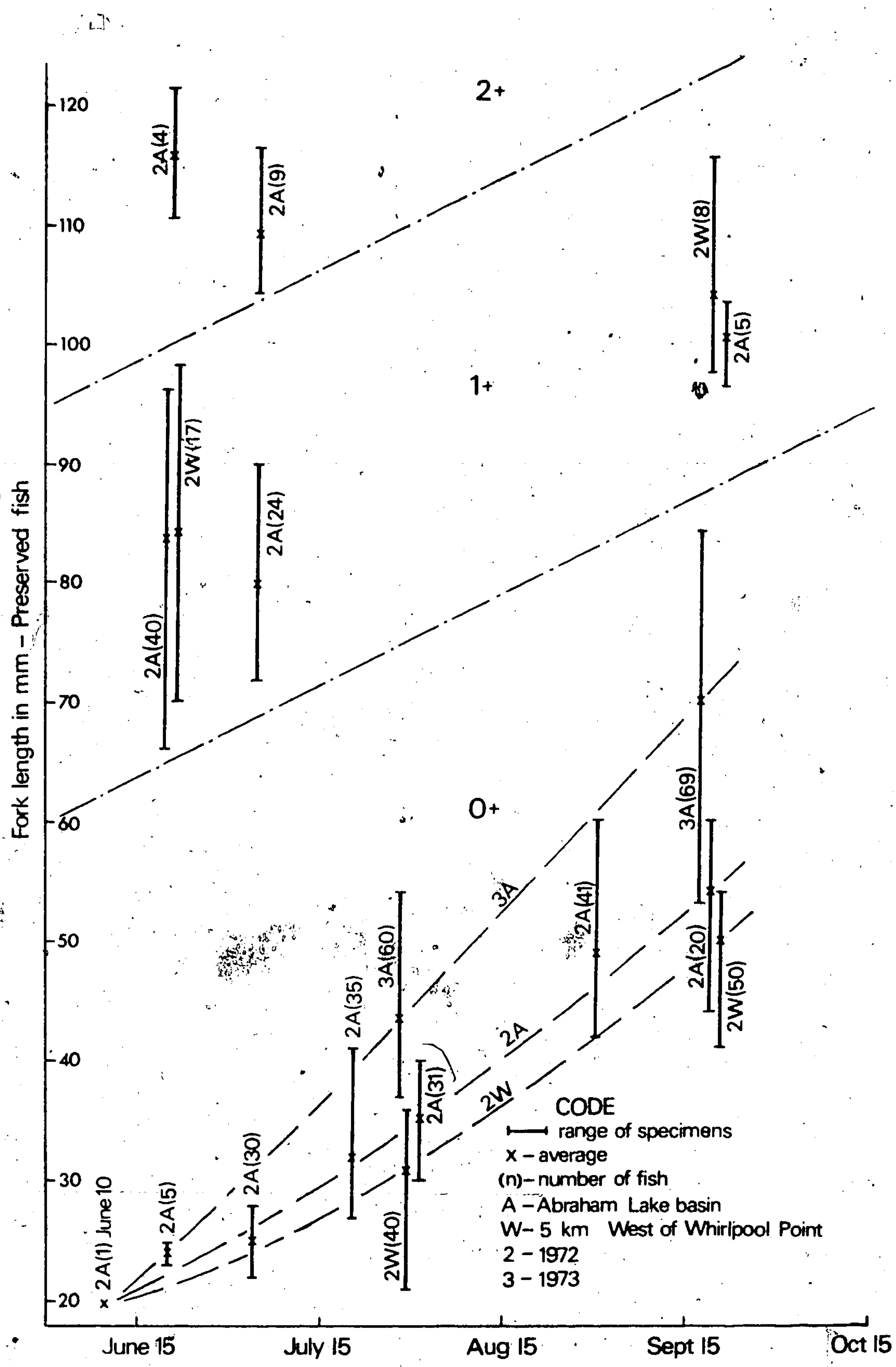


FIGURE 7 SEASONAL CHANGES IN THE LENGTHS OF IMMATURE MOUNTAIN WHITEFISH

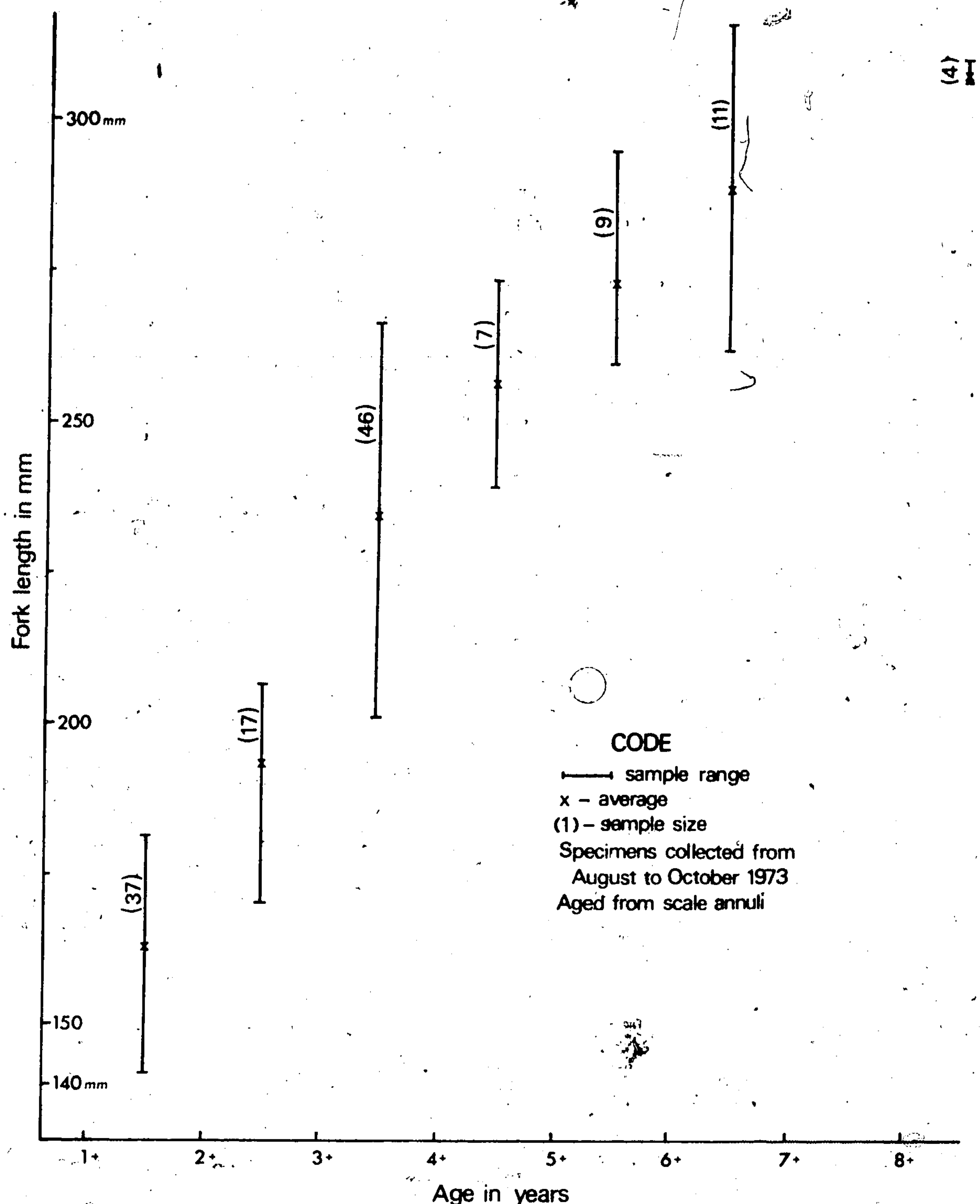


FIGURE 8 AGE-LENGTH RELATIONSHIP OF MOUNTAIN WHITEFISH

FIGURE 9 DOLLY VARDEN DISTRIBUTION

NOTE : Map is Semi-diagrammatic

Approximate Scale 0 — 20 km / 0 — 10 mi

C = Canyon ■ = Known occurrence

F = Falls ░ = Probable distribution

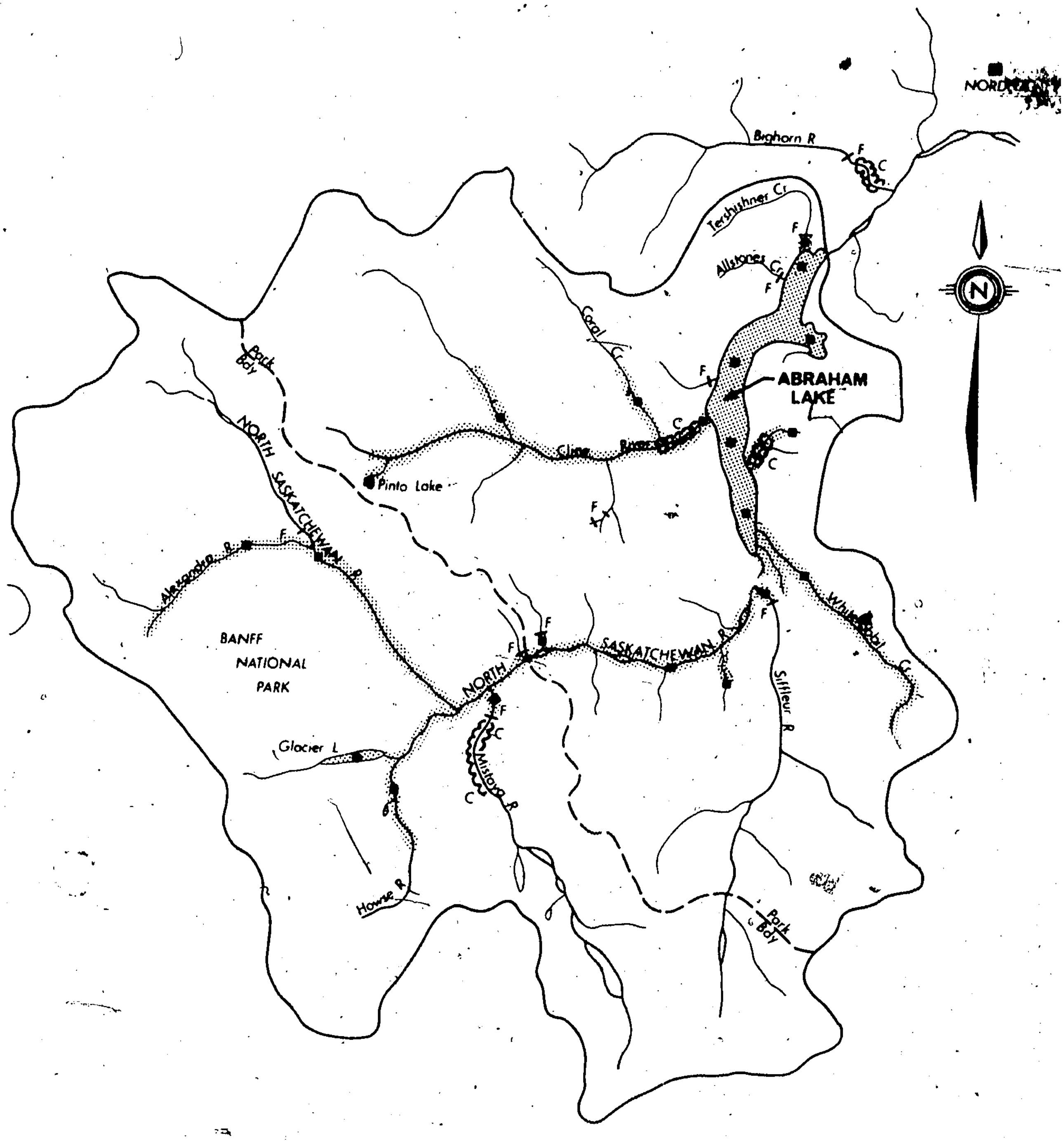


FIGURE 10 BROOK TROUT DISTRIBUTION

NOTE : Map is Semi-diagrammatic

Approximate Scale 0 20 km / 0 10 mi

C = Canyon
F = Falls
■ = Known occurrence
░ = Probable distribution

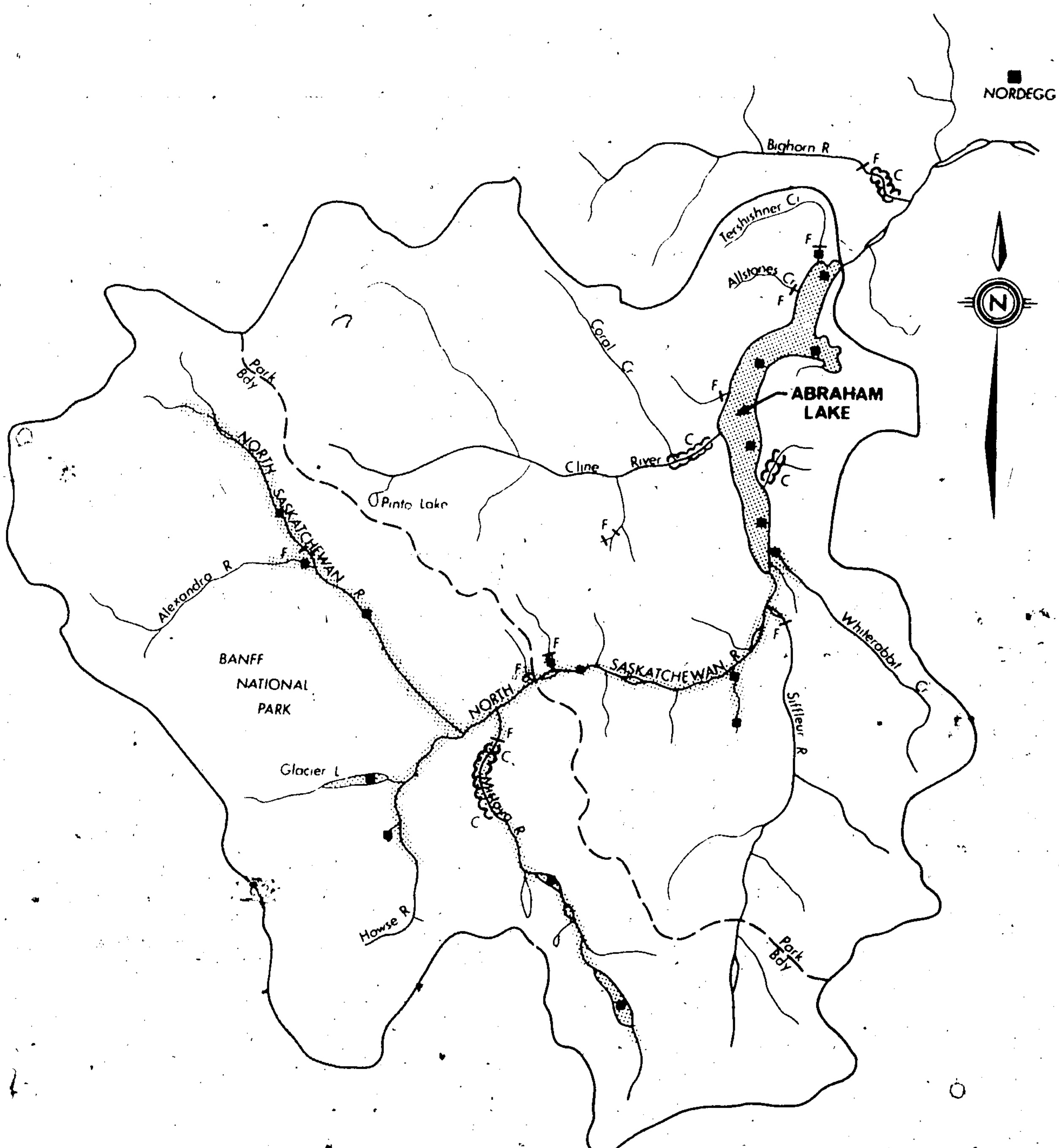


FIGURE 11 LONGNOSE DACE AND LAKE CHUB DISTRIBUTION

NOTE: Map is Semi-diagrammatic

Approximate Scale: 0 – 20 km; 0 – 10 mi

C = Canyon

F = Falls

■ = Known occurrence

░ = Probable distribution

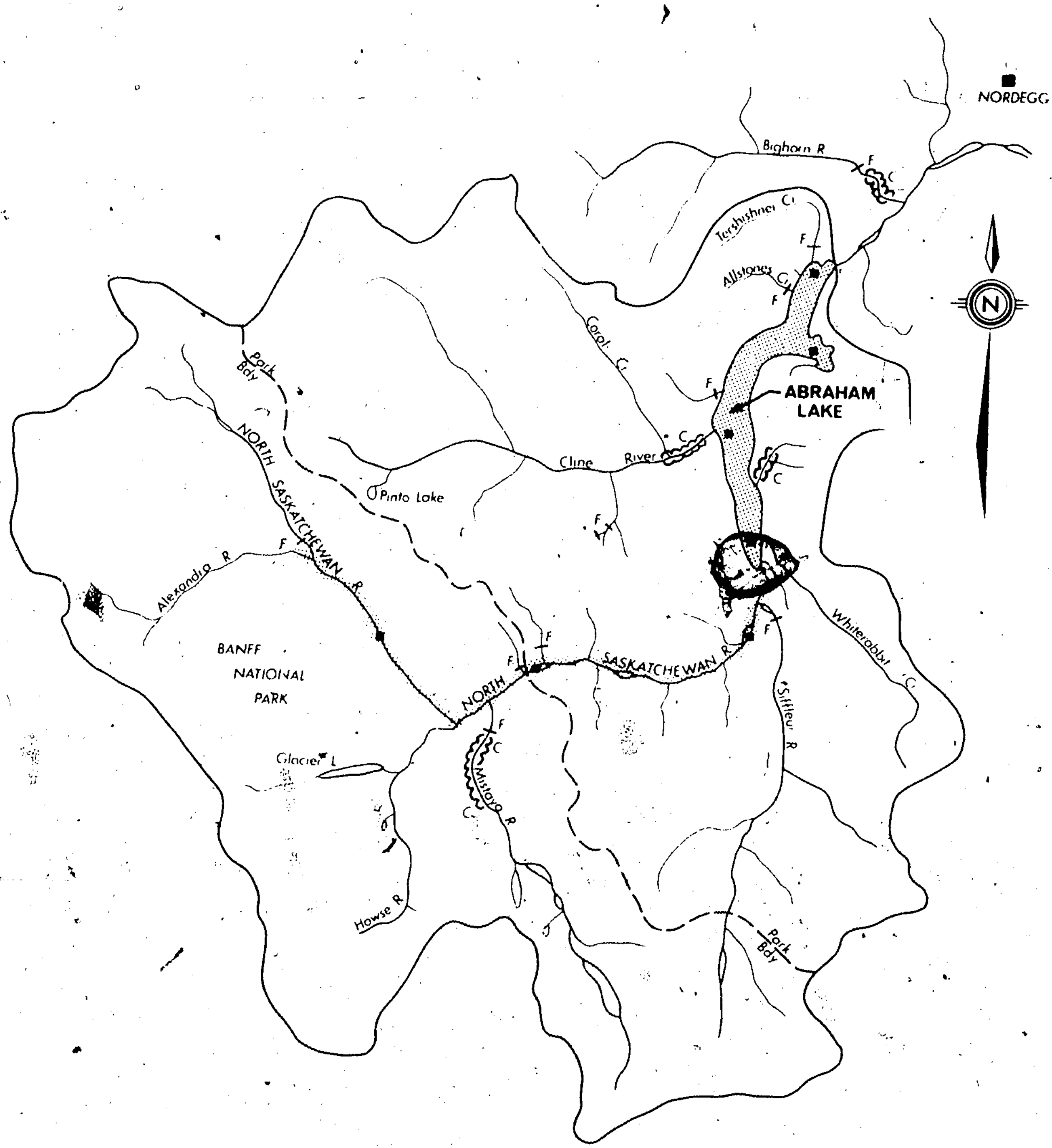


FIGURE 12 LONGNOSE SUCKER DISTRIBUTION

NOTE: Map is Semi-diagrammatic

Approximate Scale: 0 — 20 km; 0 — 10 mi

C = Canyon

F = Falls

■ = Known occurrence

░ = Probable distribution

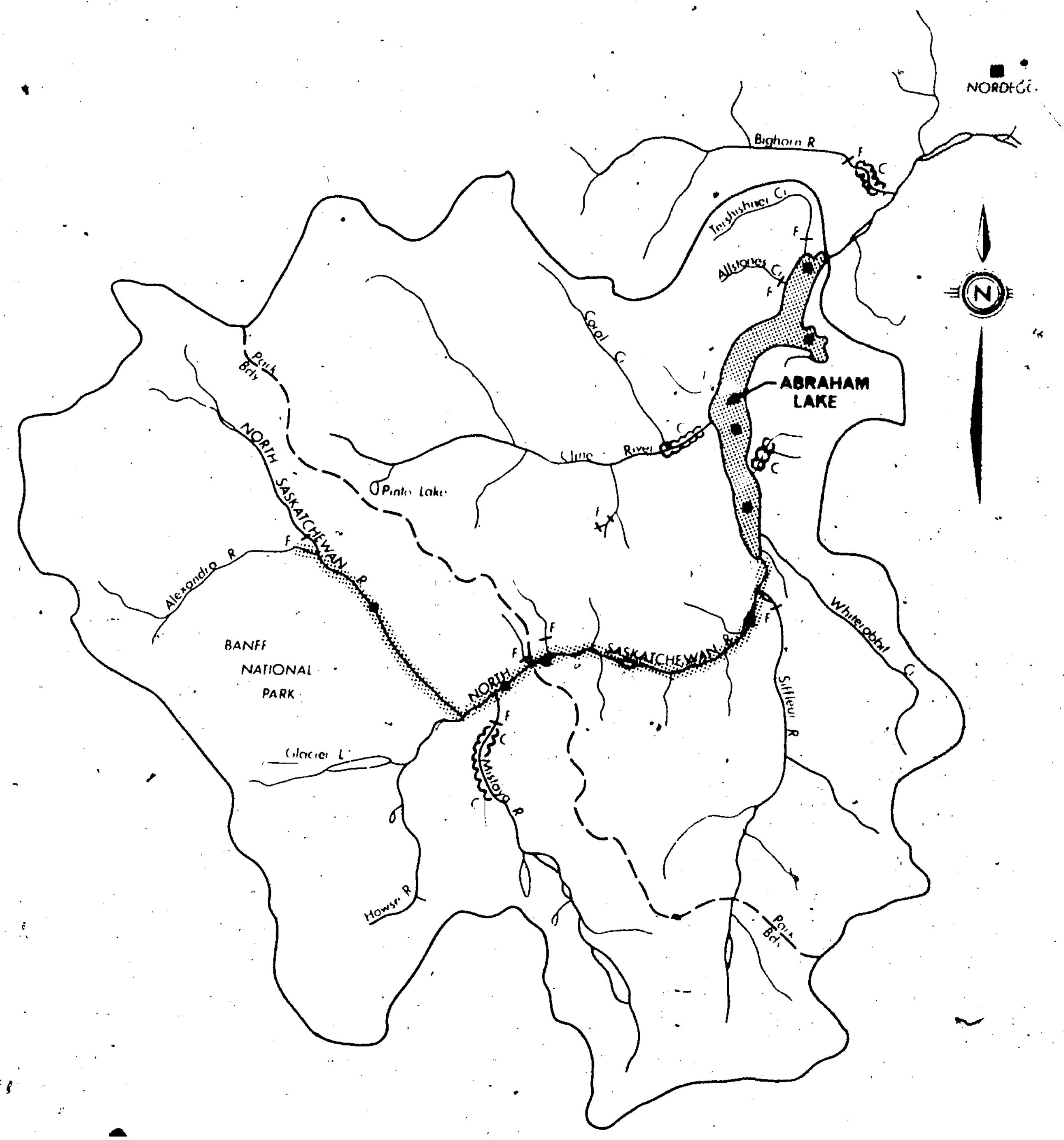
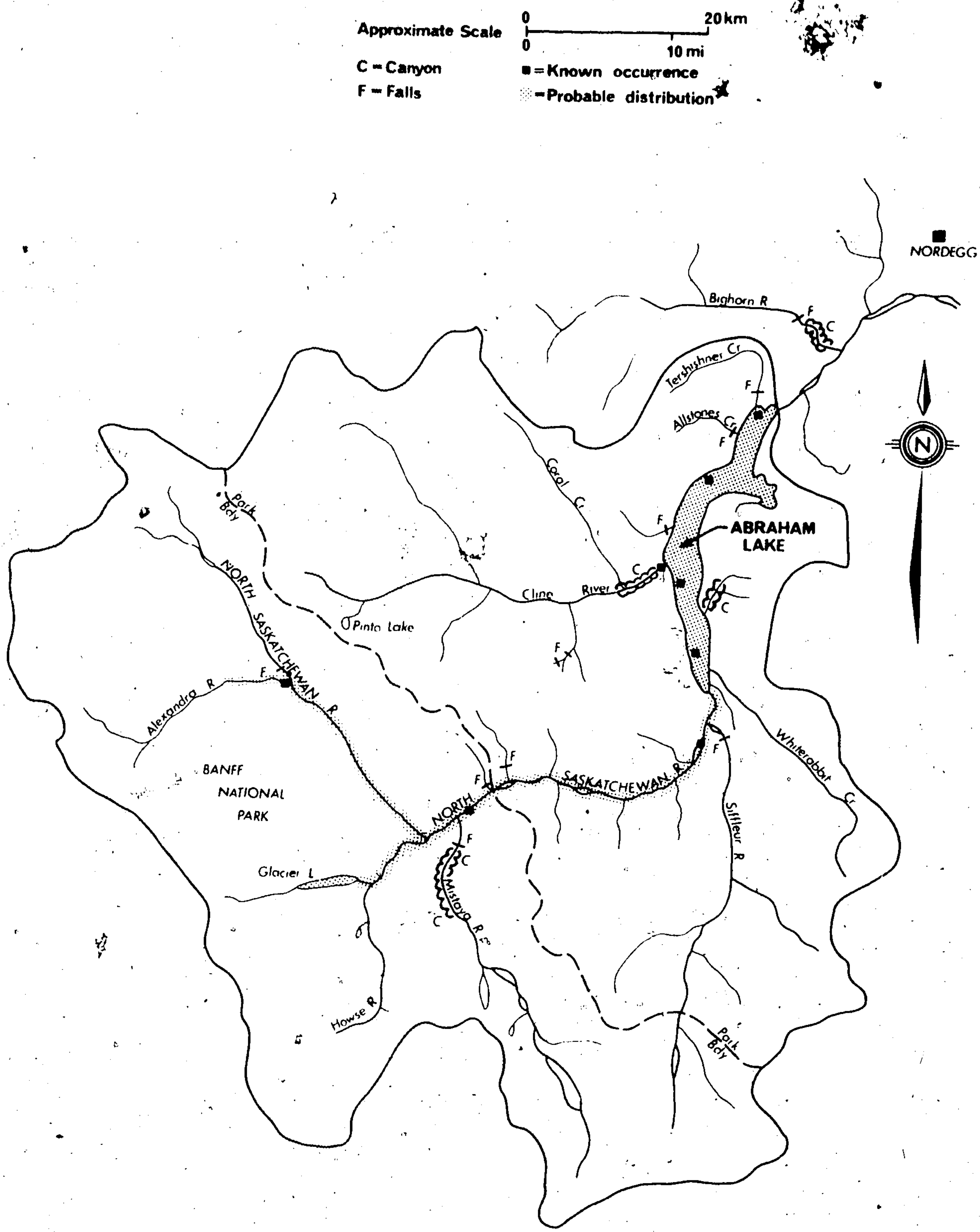
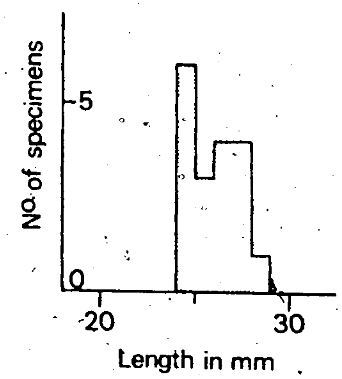


FIGURE 13 SPOONHEAD SCULPIN DISTRIBUTION

NOTE : Map is Semi-diagrammatic





Y-O-Y Collected 24 October 1973 near Loudon Creek

Length frequencies of 212 preserved specimens collected 9 - 26 August 1972, between Nordegg and the Bighorn Dam

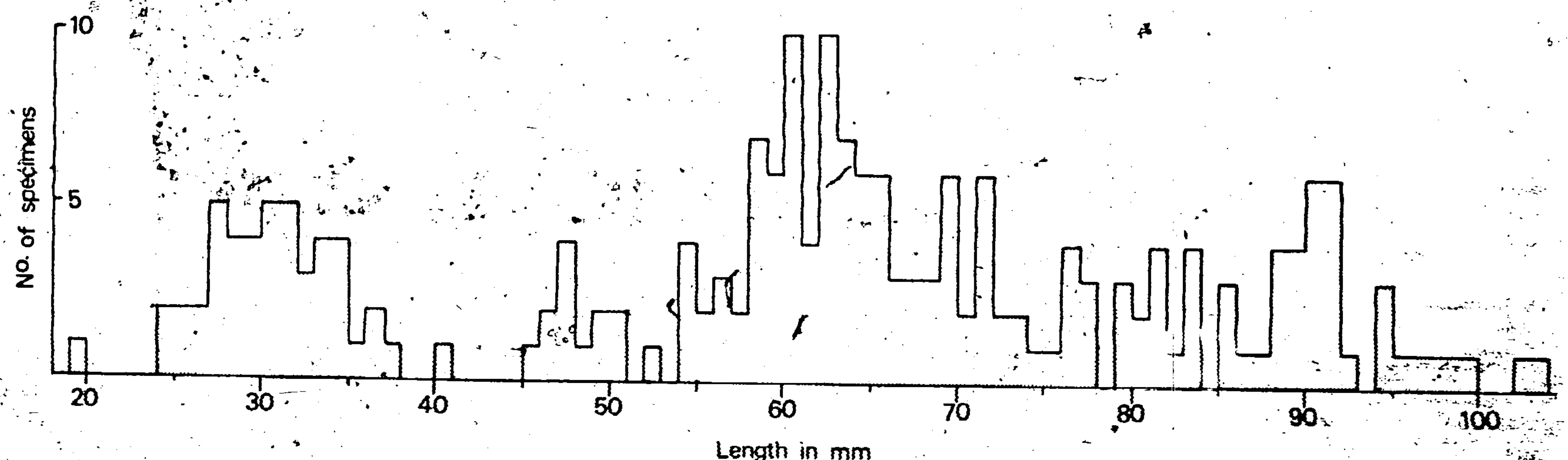


FIGURE 14 LENGTH FREQUENCY OF SPOONHEAD SCULPINS

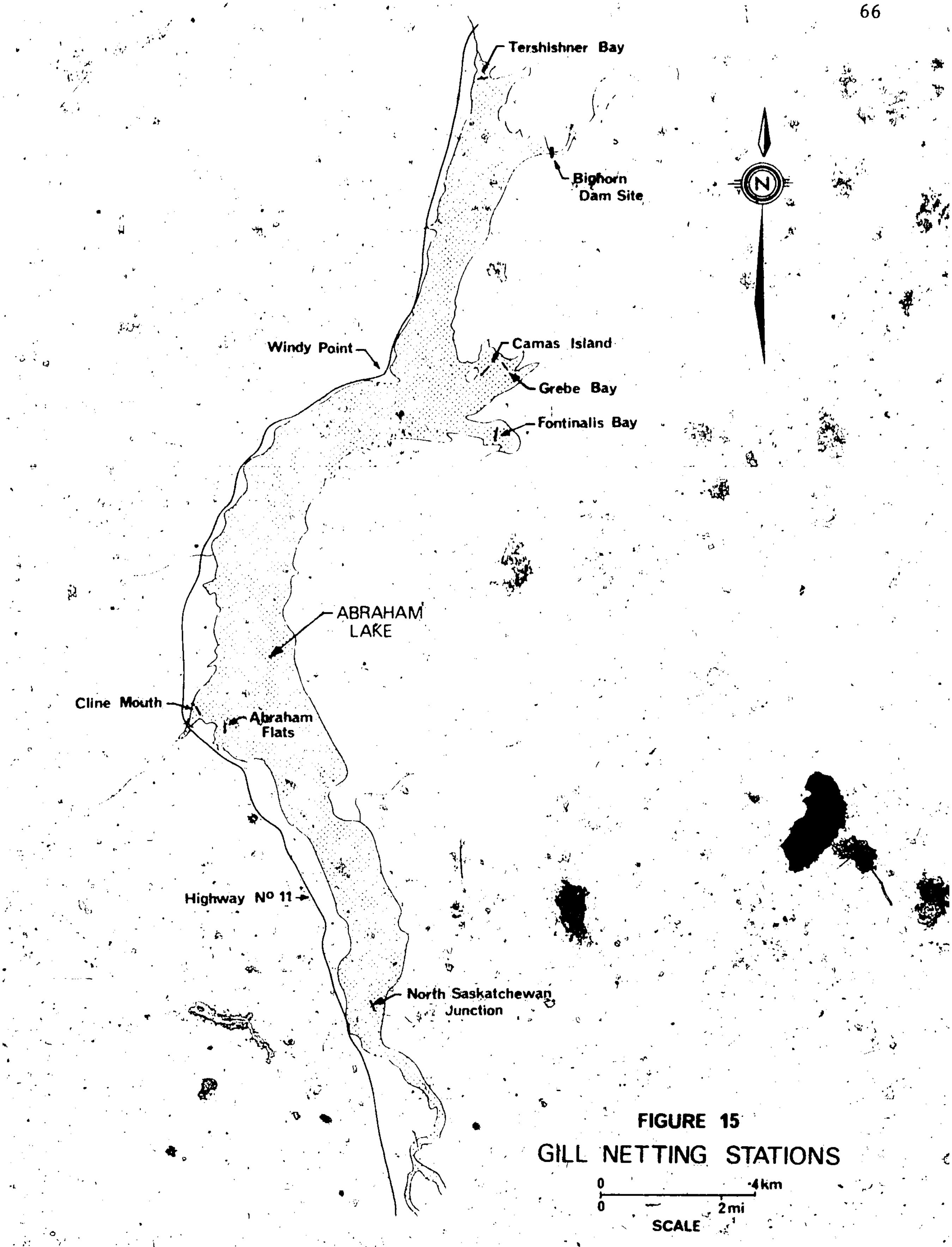


FIGURE 15

GILL NETTING STATIONS

PHOTOGRAPHIC PLATES

PHOTOGRAPHIC PLATE 1

Near Windy Point, June 1968

Alberta Government Photograph

Before clearing

Near Windy Point, 17 June 1972

After clearing

Near Windy Point, 18 March 1973

Flooded and frozen

PHOTOGRAPHIC PLATE 2

J. Horden of "BATUS"

Dolly Varden; 37.5 cm, 480 g - 54.3 cm, 1500 g

7 September 1973, Abraham Lake

J. Dickinson of Edmonton

Dolly Varden; 66.0 cm, 3765 g

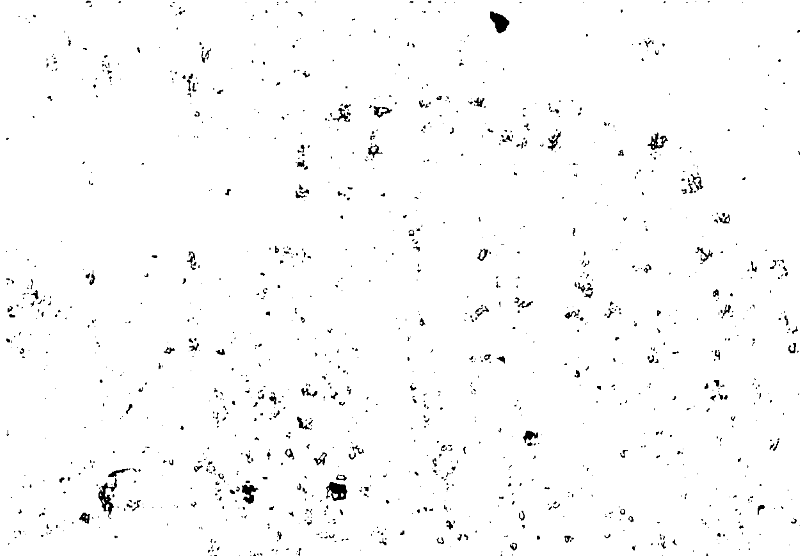
25 October 1973, North Saskatchewan River

10 km above Abraham Lake

PHOTOGRAPHIC PLATE 3

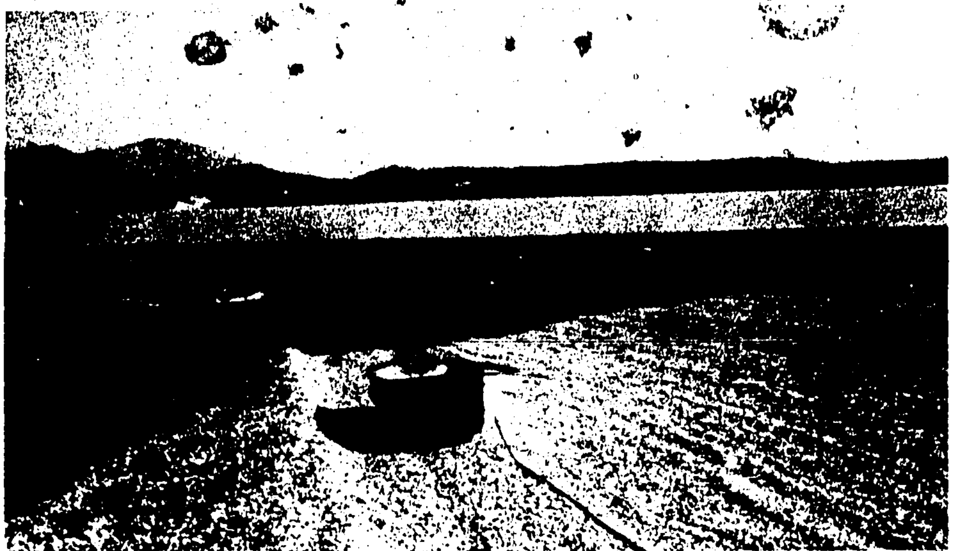
North of Windy Point, 25 August 1972

Net setting problem



North of Windy Point, 15 July 1973

Net retrieving problem



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APPENDIX

APPENDIX I

CLIMATIC DATA: NORDEGG[1, 2] 1962–1970

	Mean daily temp C/F	Extreme max C/F	Extreme min C/F	No. of days with frost	Mean total precip. cm/in	No. of days with precip.
Jan.	-	16.6/62	-42.8/-45	31	-	-
Feb.	-	14.4/58	-33.3/-28	28	-	-
Mar.	-	16.1/61	-33.3/-28	31	-	-
April	0.7/33.3	19.4/67	-23.3/-10	24	-	-
May	6.2/43.2	24.4/76	-12.7/ 9	24	6.3/2.47	12
June	9.6/49.2	30.6/87	- 8.9/ 16	12	10.3/4.05	13
July	12.4/54.6	29.4/85	- 6.6/ 20	4	10.0/3.93	13
Aug.	11.7/53.1	31.1/88	- 6.6/ 20	7	7.7/3.03	11
Sept.	7.2/45.0	28.9/84	-14.4/ 6	18	5.0/1.97	10
Oct.	3.0/37.4	25.0/77	-19.4/-3	27	2.2/0.85	7
Nov.	- 5.2/23.5	18.3/65	-34.4/-30	30	-	-
Dec.	-10.7/12.7	10.0/50	-39.4/-39	31	-	-

[1] 52° 29' N, 116° 05' W, 1326 m (4350 ft) a.s.l.

[2] Source: Atmospheric Environment Service, Environment Canada.

APPENDIX II

WATER ANALYSIS

Unless otherwise specified, the methods used are from "Standard Methods for the Examination of Water and Wastewater," 13th Edition, 1971. American Public Health Association, Washington, U.S.A.

pH - used Fisher Model 22 pH Meter

Alkalinity - phenolphthalein for first end-point and bromcresol green-methyl red for second end-point

Phosphate (Ortho) - Stannous chloride method

Silica - Molybdosilicate method

Nitrate-N - Phenoldisulfonic acid method

Conductivity - used Beckman Model RB3-338 conductivity meter with temperature compensation to 25 C

Total Dissolved Solids - Total Residue method

Iron - Phenanthroline method

Turbidity - read directly from Hach Kit Model DR-EL

Color - Sample was centrifuged for 10 minutes in an International Clinical Centrifuge (Model CL) and the color was read at a wavelength of 420. A standard curve was drawn using platinum cobalt color standards.

Hardness: Total - EDTA Titrimetric method
Calcium - EDTA Titrimetric method

Chloride - Argentometric method

Sulphate - Turbidimetric method

The spectrophotometer used was a Unicam SP 1800 with either 10 mm or 40 mm cells depending on the test requirements.

APPENDIX II (Continued)

Location (Date)	pH in field	pH before Alk.	Phenl Alk. as $CaCO_3$	Total Alk. as $CaCO_3$	Phosphate (Ortho)	Silica	Nitrate-N	Conductance micromhos
N. Sask. River 5 km S. Whirlpool Pt. (18-III-73)	8.2	8.6	5.2	90.0	0.003	2.5	0.07	270
Cline River at hwy. (18-III-73)	8.3	8.6	6.0	109.9	0.003	3.9	0.02	620
Abraham Lake shore - Windy Pt. (18-III-73)	8.1	8.5	3.2	88.0	0.005	2.3	0.05	250
Abraham Lake Abraham Flats (29-VII-73)	-	8.0	0	164.5	0.08	2.00	0.05	160
Abraham Lake Fontinalis Bay (27-IX-73)	-	8.4	2.9	66.1	> 0.05	1.70	0.06	170
Abraham Lake Windy Pt. (27-IX-73)	-	8.25	0	69.8	> 0.05	1.65	0.05	170

APPENDIX II (Continued)

Location (date)	Total dissolved solids	Iron	Color	Turbidity	Hardness as $CaCO_3$ Calcium	Total	Chloride	Sulphate	Remarks
N. Sask. River 5 km S. Whirlpool Pt. (18-III-73)	215.3	0.12	25	8	76	176	0	66	
Cline River at hwy. (18-III-73)	438.1	0.02	16	4	216	308	0	275	(?) coal outcrops
Abraham Lake shore - Windy Pt. (18-III-73)	166.6	0.14	16	9	76	140	0	48	
Abraham Lake Abraham Flats (29-VII-73)	104.0	0.17	12	15	56	148	1.38	24	500 m offshore
Abraham Lake Fontinalis Bay (27-IX-73)	89.9	0.09	16	10	59	96	0.94	26	entrance to bay
Abraham Lake Windy Pt. (27-IX-73)	106.3	0.10	5	30	62	54	0.47	26	at midpoint 500 m offshore

Water samples were taken in plastic bottles, frozen, and analysis was done by G. Hutchinson, Department of Zoology, University of Alberta.

Note: Where appropriate the units are mg/l.

APPENDIX III

SOME HISTORICAL LITERATURE REVIEWED

Palliser, J. 1860. Explorations of British North America. London, H.M.S.O., Vol. 1. 75 p., Vol. 2, Map (1863).

Sisley, E. 1911. Fish of the Eastern slopes of the Rockies. Cdn. Alpine J. 3:113-116.

Southesk, J. C. Earl of. 1875. Saskatchewan and the Rocky Mountains. Edmonston and Douglas, Edinburgh. 448 p.

Thompson, D. 1784-1812. Travels in Western North America. Edited by V. G. Hopwood 1971. Macmillan, Toronto. 341 p.

Additional material (manuscript) may be read in the Glenbow Archives, Calgary. In particular, the Tom Wilson Papers W753 A, File 29.

The Department of the Interior (Canada) Annual Reports frequently contain notes on fish, usually of a negative nature; however the 1902-1906 reports are valuable as they document the first introductions of brook trout.

The Fisheries Branch (Canada) Annual Reports are also worthy of examination for historical data, the 1924 report (p. 51) notes that "Very little angling for trout is carried on in the Red Deer and Saskatchewan rivers and their tributaries as only Dolly Varden trout are found."

APPENDIX IV

SOME AQUATIC BIRDS OBSERVED

This list is not intended to be comprehensive; only those species that are thought to be important in the transfer of aquatic organisms are noted. For further details on the birds of the area, and for the scientific name of the species referred to here, see: Salt, W. F., and A. L. Wilk, 1966. The birds of Alberta (2nd ed. rev.), Queens Printer, Edmonton.

Common loon	- resident, fall migrant; 1972, 1973.
Arctic loon	- one noted, fall migrant; 1973.
Western grebe	- abundant fall migrant; 1972, 1973.
Canada goose	- resident, spring and fall migrant, 1972, 1973.
Mallard	- resident, spring and fall migrant, 1972, 1973.
Pintail	- common spring and fall migrant; 1972, 1973.
Teal (Green and Blue-winged; Cinnamon)	- resident; 1972, 1973.
Shoveler	- rare resident, occasional migrant; 1972, 1973.
Lesser scaup	- common fall migrant; 1972, 1973.
Old squaw	- uncommon spring migrant; 1973.
White-winged scoter	- abundant fall migrant; 1972, 1973.
Surf scoter	- common fall migrant; 1972, 1973.
Coot	- abundant fall migrant; 1972, 1973.
Yellowlegs (Greater and Lesser)	- resident, fall migrant; 1972, 1973.
Sandpipers (*Erolia* spp.)	- abundant fall migrant; 1972, 1973.
Wilson's phalarope	- common fall migrant; 1972, 1973.
Gull (*Larus* spp.)	- many small flocks, fall migrant; 1972, 1973.

APPENDIX V

SUPPLEMENTARY REFERENCES

Davis, D. A. and A. Coulson. 1967. Hydrologic zones in the headwaters of the Saskatchewan River. Tech. Bull. 6. Inland Waters Branch, Dept. of Energy, Mines and Resources, Ottawa. 23 p. + map.

Eastern Rockies Forest Conservation Board. 1969. Conservation Unit Guide, Part II: Upper North Saskatchewan Unit R-6. MS. 41 p. + maps.

Frechette, T. D. 1970. Recreation potential of the Bighorn Dam reservoir and shorelands. Dept. of Lands and Forests, Edmonton. MS. 43 p. + maps and appendices.

Hirst, F. M. 1971. Alluvial fans of the North Saskatchewan River Valley, Alberta, Canada. M.Sc. thesis, Dept. of Geography, Queens Univ., Kingston, Ontario. 242 p.

Nanson, G. C. 1972. Sediment transport in two Rocky Mountain streams. M.Sc. thesis, Dept. of Geography, Univ. of Alberta, Edmonton.

Reid, I. A. and J. O. G. Charbonneau. 1972. Glacier Surveys in Alberta. Report Series No. 22. Inland Waters Directorate, Dept. of the Environment, Ottawa. 17 p. + map.

Samide, G. 1971. Sediment transport measurements. M.Sc. thesis, Dept. of Civil Engineering, Univ. of Alberta, Edmonton. 55 p.

Saskatchewan-Nelson Basin Board. 1972. Water supply for the Saskatchewan-Nelson Basin Report. Canada, Alberta, Saskatchewan and Manitoba governments. Main report + 8 appendices.

Slaymaker, O. and H. J. McPherson (eds.). 1972. Mountain Geomorphology. B.C. Geographical Series, No. 14. Tantalus Research Ltd., Vancouver. 274 p.

Survey of the Athabasca and Saskatchewan Glaciers. 1972. Water Survey of Canada, Dept. of the Environment (Canada), Calgary. 34 p.

The Foothills Resource Allocation Study. Phase 1. Cline-Siffleur Drainage District. 1973. Dept. of Lands and Forests, Alberta. MS. 33 p. + maps.

APPENDIX VI

CHARACTERISTICS OF ABRAHAM LAKE AND ITS DRAINAGE BASIN

Since the reservoir will not fill before late 1974 some of the data are approximate only.

River involved: North Saskatchewan River (main stem)

Location of Bighorn Dam: 52° 18' N, 116° 19' W

Elevation (water surface at full supply): 1321 m (4335 ft), a.s.l.

Basin characteristics: Mountain valley ("U" type, flood plain valley)

Source of river (reservoir) water: 80% snowmelt, 10% glacier, 10% rainfall

Primary purpose of reservoir: hydroelectric (peak load) generation

Depth when full: ca. 100 m (300 ft)

Drawdown (maximum possible): 39 m (129 ft)

Length (maximum): 35.4 km (22 mi)

Width (average): ca. 1.3 km (ca. 4000 ft)

Surface area (maximum): 5544 ha (13700 a)

Shoreline length (maximum): 100 km (60 mi)

Water temperatures (ca.): 0-5 C winter (32-41 F); 15-17 C summer (59-63 F)

Oxygen: probably always over 90% saturation

pH: 8.0-8.3

Ice cover: early December to early May (150 days)

Timber: all forest cover within the basin has been removed

Thermocline: the area is subject to sudden, violent winds. It is thought that the combined action of wind and inflowing river will keep the reservoir well mixed.

Probable operating schedule: low in May, full in September