PROPOSED SOCKEYE SALMON DEVELOPMENT PROGRAM FOR BABINE LAKE

This report has been prepared jointly by the staffs of the Fisheries Research Board and the Department of Fisheries for submission to the Skeena River Salmon Management Committee.

Submitted to the Skeena River Salmon Management Committee, April, 1965

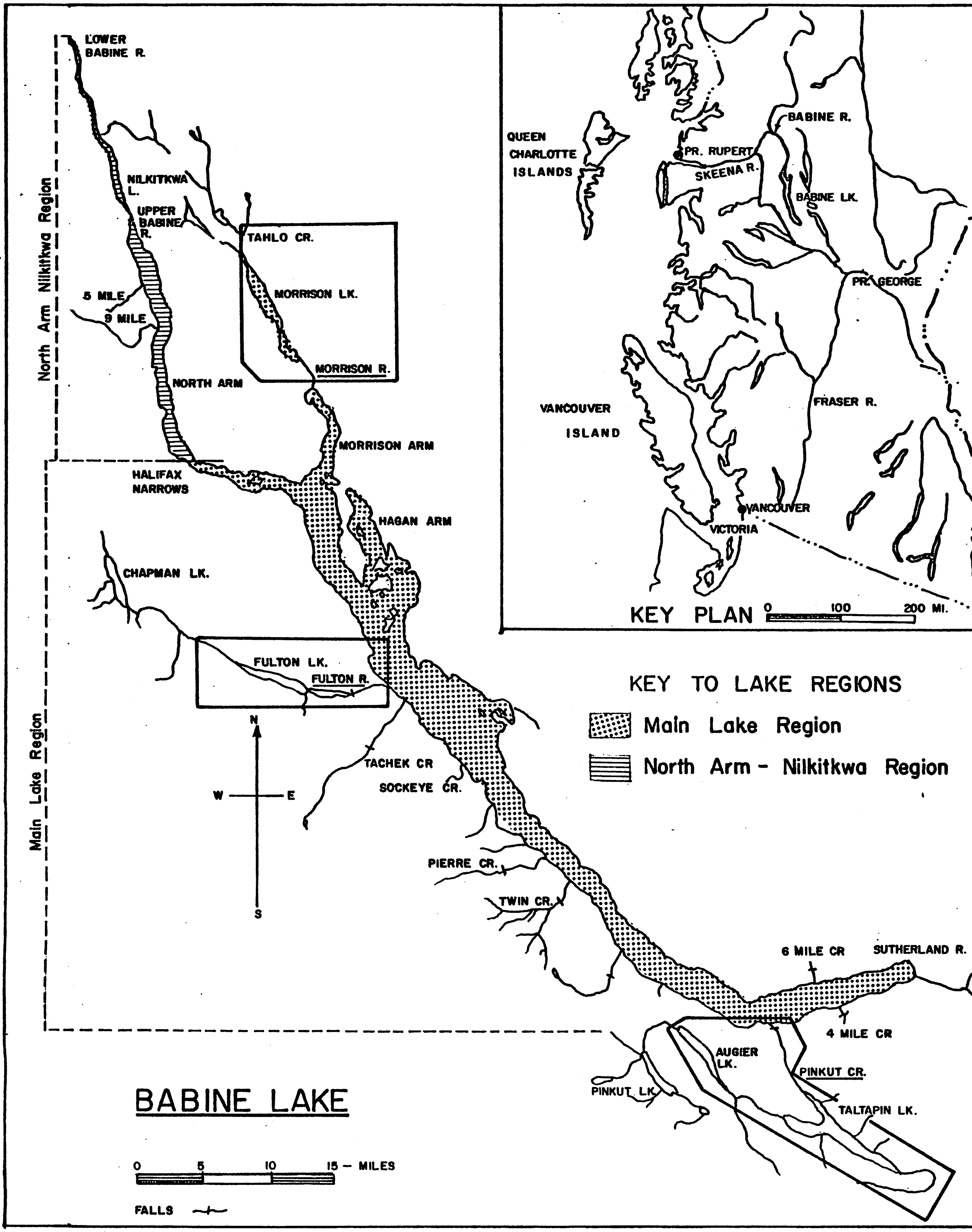

BABINE LAKE
0 5 10 15 - MILES
FALLS
LOWER BABINE R.
NILKITKWA L.
UPPER BABINE R.
5 MILE
9 MILE
NORTH ARM
TAHLO CR.
MORRISON LK.
MORRISON R.
MORRISON ARM
HALIFAX NARROWS
HAGAN ARM
CHAPMAN LK.
FULTON LK.
FULTON R.
TACHEK CR
SOCKEYE CR.
PIERRE CR.
TWIN CR.
6 MILE CR
SUTHERLAND R.
4 MILE CR
AUGIER LK.
PINKUT CR.
PINKUT LK.
TALTAPIN LK.
N
S
W
E
North Arm Nilkitkwa Region
Main Lake Region
KEY TO LAKE REGIONS
Main Lake Region
North Arm - Nilkitkwa Region
KEY PLAN
0 100 200 MI.
QUEEN CHARLOTTE ISLANDS
PR. RUPERT
SKEENA R.
BABINE R.
BABINE LK.
PR. GEORGE
VANCOUVER ISLAND
FRASER R.
VANCOUVER
VICTORIA

Figure 1

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PROPOSED SOCKEYE SALMON DEVELOPMENT PROGRAM FOR BABINE LAKE

1.0 INTRODUCTION

The Skeena River sockeye salmon fishery, which depends heavily upon the native runs to the Babine River system, is one of the largest in British Columbia. The average annual catch of sockeye from 1950 to 1963 in the Skeena fishery has been valued at $1,100,000 to the fishermen and approximately $2,200,000 as a processed product. The historical production records indicate that catches have been two-thirds higher than those of recent years, and since there is every reason to believe that catches of this magnitude will be resumed in future, the Skeena River sockeye fishery represents a proven potential annual value of approximately $2,000,000 to the fishermen and $4,000,000 as a processed product.

Studies undertaken by the Fisheries Research Board of Canada have indicated that Babine Lake could sustain a fry input many times greater than that which now occurs. In addition the studies indicated that larger fry inputs to the lake would result in corresponding increases in smolt and adult production. It is estimated that the lake nursery area could support in the order of 350 million fry over and above that which can be produced from the natural spawning areas. Accordingly, the Fish Culture Development Branch and the Fisheries Research Board, with the guidance of the Skeena River Management Committee, initiated studies to determine the most effective means by which the full potential of the Babine Lake system might be realized.

2.0 PRESENT UTILIZATION AND POTENTIAL OF BABINE LAKE AS A SOCKEYE PRODUCER

2.1 The lake and associated spawning grounds

Babine Lake (Figure 1) is long (about 100 miles) and narrow (maximum width of about 5 miles) and has a surface area of approximately 120,000 acres. Shoreline configuration divides the lake into a number of basins contained in two general lake regions: 1. The area lying north of Halifax Narrows which will be called the North Arm - Nilkitkwa Region, and 2. The area south of Halifax Narrows (including the tributary Morrison Lake system) which will be called the Main Lake Region. The North Arm - Nilkitkwa Region contains about 12 percent of the total lake surface area while the remaining 88 percent is contained in the Main Lake Region.

Most spawning at Babine occurs in the outlet Upper and Lower Babine Rivers adjacent to the North Arm - Nilkitkwa Region and in the tributaries to the Main Lake Region (principally in the Fulton River). A lesser amount of spawning occurs along the beaches of the Main Lake. The Upper and Lower Babine Rivers provide roughly 60 percent of the total stream spawning area in the entire system and virtually all of the stream spawning area of the North Arm - Nilkitkwa Region. The main lake tributaries provide 40 percent of the available stream spawning area, with the Fulton River providing about half of this. The remaining portion of the main lake stream spawning area is divided principally among three moderate-sized streams and nine small streams.

2.2 Abundance and distribution of spawners

Since 1946, fence counts have been made of the number of adult sockeye entering the Babine system. In addition, estimates have been made annually of the number of spawners utilizing the various streams (Table I). In most years the estimated number of spawners has been substantially less than the fence count. This discrepancy varied from 12,000 in 1957, to 215,000 in 1958. Recent studies have shown that some spawning occurs along the beaches of the Main Lake Region where it is difficult to detect and as yet impossible to estimate numbers. A substantial part of the observed discrepancy may therefore be attributed to such lake spawning.

Considering only stream spawners, sockeye are distributed roughly in proportion to the amounts of spawning gravel provided in each stream spawning area. Since 1949, the greatest average number of spawners (198,000) and the largest proportion (53 percent) of the stream spawners have spawned in the extensive grounds of the Upper and Lower Babine Rivers. The number of spawners in the Fulton River, by far the largest of the main lake tributaries, has averaged 76,000 or 21 percent of the Babine total. The smaller main lake tributaries together have supported an average of 98,000 spawners or 26 percent of the total stream spawners in the system.

Babine streams may vary considerably from year to year in their capacity to accommodate spawners and in the conditions prevailing for spawning success and egg survival. This is

Table 1. Babine sockeye escapements[1] in thousands of fish: 1949-1963.

Year	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1949-1963 Sums	1949-1963 Means
Babine fence count	461	364	141	349	687	494	71	355	433	812	783	263	942	548	588	7291	486.1
Indian catch	29	27	19	34	27	22	10	31	20	39	17	17	32	18	20	362	24.1
Potential spawning stock (count less catch)	432	337	122	315	660	472	61	324	413	773	766	246	910	530	568	6929	461.9
NORTH ARM - NILKITKWA REGION																	
Upper Babine River	216.0	65.0	13.3	78.2	147.0	136.7	9.7	66.5	117.8	156.8	156.7	36.9	196.0	192.0	119.3	1707.9	113.9
Lower Babine River	135.0	116.0	10.8	69.0	127.4	100.0	9.0	52.3	66.5	107.8	123.5	54.0	171.5	61.0	34.5	1238.3	82.6
9 Mile Creek	0.9	1.0	0.4	0.1	2.5	1.0	0.1	0	4.0	0	2.4	1.8	2.5	0.5	1.0	18.2	1.2
5 Mile Creek	0	0.1	0.1	0	0.3	0.3	0.1	0	0.2	0	0.6	0	0.5	0.1	0	2.3	0.1
Total spawners	351.9	182.1	24.6	147.3	277.2	238.0	18.9	118.8	188.5	264.6	283.2	92.7	370.5	253.6	154.8	2966.7	197.8
Percent of potential spawners	81.5	54.0	20.2	46.8	42.0	50.4	31.0	36.7	45.6	34.2	37.0	37.7	40.7	47.8	27.3	632.9	42.0
MAIN LAKE REGION																	
Morrison System	1.6	5.9	4.1	1.2	24.7	24.0	1.8	27.0	28.9	18.0	35.9	9.9	23.6	12.5	41.8	260.9	17.4
Fulton River	33.9	42.0	15.2	31.5	134.4	105.6	16.7	81.0	108.0	76.0	114.0	36.0	169.8	77.8	99.2	1141.1	76.1
15 Mile Creek	10.5	12.0	4.9	7.5	23.5	25.0	3.2	22.8	29.1	44.0	77.6	27.0	44.1	20.8	40.0	392.0	26.1
Pierre Creek	4.2	17.9	11.5	3.3	19.2	17.0	3.2	18.0	21.2	29.4	33.0	9.9	24.5	4.1	28.4	244.8	16.3
Grizzly Creek	1.5	2.7	2.1	3.5	6.0	3.1	0.5	4.8	7.0	30.0	14.0	10.8	23.5	4.6	11.4	125.5	8.4
Twin Creek	2.3	7.6	4.8	0.4	9.8	14.0	2.4	4.5	5.4	12.0	9.0	5.4	6.9	1.3	11.4	97.2	6.5
4 Mile Creek	1.6	4.2	0.9	0.2	2.0	2.2	0.4	0.4	2.5	6.0	5.4	1.8	1.0	2.8	2.8	34.2	2.3
Tachek Creek	2.6	2.6	2.5	0	2.4	1.9	0.3	0	6.4	1.8	6.0	1.8	0	0.6	1.6	30.5	2.0
Sockeye Creek	0.2	0.9	0.8	0	0.6	0.9	0.5	0	2.5	1.5	4.0	1.8	0	1.0	2.4	17.1	1.1
6 Mile Creek	0.4	1.2	0	0	2.6	1.8	0.1	0.1	0.6	2.3	3.5	0.9	0	0.9	1.4	15.8	1.1
Pendleton Creek	1.1	1.2	0	0	1.4	1.1	0	0	0.3	0	2.5	0	0	0.2	0	7.8	0.5
Others[2]	0	0	20.0	74.4	1.0	0	0	0	0.2	72.5	3.9	0.3	51.8	6.2	6.2	236.5	15.8
Total spawners	59.9	98.2	66.8	122.0	227.6	196.6	29.1	158.6	212.1	293.5	308.8	105.6	345.2	132.8	246.6	2603.4	173.6
Percent of potential spawners	13.9	29.1	54.8	38.7	34.5	41.7	47.7	49.0	51.4	38.0	40.3	42.9	37.9	25.1	43.4	588.4	39.2
Total spawners accounted for	411.8	280.3	91.4	269.3	504.8	434.6	48.0	277.4	400.6	558.1	592.0	198.3	715.7	386.4	401.4	5570.1	371.3
Percent accounted for	95.3	83.2	74.9	85.5	76.5	92.1	78.7	85.6	97.0	72.2	77.3	80.6	78.6	72.9	70.7	1221.1	81.4
Potential spawners not accounted for	20.2	56.7	30.6	95.7	155.2	37.4	13.0	46.6	12.4	214.9	174.0	47.7	194.3	143.6	166.6	1358.9	90.6
Percent not accounted for	4.7	16.8	25.1	14.5	23.5	7.9	21.3	14.4	3.0	27.8	22.7	19.4	21.4	27.1	29.3	278.9	18.6

[1] Jack sockeye not included.

[2] Includes fish dead without spawning from all tributaries.

particularly true of most main lake tributaries which show extremes in discharge due to limited drainage areas and lake storage basins. Thus during low water periods the area of spawning ground available to spawners may be drastically curtailed. Spawning grounds located in the Upper and Lower Babine Rivers, on the other hand, benefit from the stabilizing effect of the whole of the Babine drainage and lake reservoir.

Escapements utilizing the outlet Upper and Lower Babine Rivers do not appear to have exceeded the capacity of these grounds. The largest escapement observed (367,500 in 1961) represents an average spawning density of about one fish per square yard of gravel. Salmon were observed to spawn satisfactorily at this density.

In the main lake streams, however, the capacity of the grounds appears to have been approached in some years and even exceeded in the case of particular streams. The relatively large 1958 and 1961 escapements encountered below average stream flows and associated high water temperatures. Spawning densities of up to five fish per square yard were observed and substantial pre-spawning mortality occurred in some streams.

2.3 The abundance, distribution, and growth of young sockeye

Each spring, sockeye fry resulting from the spawning of the previous fall, leave the stream to take up lake residence until their seaward migration as smolts one year later. Shortly after entering the lake and throughout the summer and fall these fish can be captured in tow-nets. The catches from standardized tow-netting have been used to estimate the abundance of young sockeye throughout the lake, their density (number per acre of lake surface), and the size attained by the fall of the year. Estimates of the abundance of subsequent emigrant smolt populations and the size of smolts have been provided by marking, recovery and sampling procedures at the lake outlet.

In Table II, the estimated annual number of young sockeye present in August and mean values for the years 1956 to 1963 are shown by lake basin and for the two lake regions. Calculated densities of August fingerlings are given in Table III.

A wide range in the density of young sockeye has been observed over the years in individual lake basins and in the two lake regions. Fingerlings have been consistently most dense in the North Arm - Nilkitkwa Region (overall average of 2,750 per acre with annual average values of from 130 to 5,785 per acre) and particularly in the basins adjoining the outlet spawning grounds (as high as 56,000 per acre). In the Main Lake region on the other hand, the greatest density observed in any one basin was 2,400 per acre while the annual average density for this lake region ranged from 105 to 1,015 per acre with an average for all years of 549 per acre. Thus, since 1956, when estimates of the abundance of August fingerlings were first made, the overall average density in the North Arm - Nilkitkwa Region (2,750 per acre) has been five times that observed in the Main Lake Region (549 per acre).

TABLE II ABUNDANCE OF AUGUST FINGERLINGS

ESTIMATED AUGUST FINGERLING POPULATIONS (MILLIONS)

	1956	1957	1958	1959	1960	1961	1962	1963	Mean
	0.8	3.1	1.9	7.9	2.3	3.4	8.3	3.4	3.9
	0.8	3.7	8.5	21.4	5.1	8.2	34.0	10.8	11.6
	0.3	14.9	20.6	35.7	17.9	9.4	8.0	17.6	15.6
	0.0	6.8	4.4	16.9	10.7	1.6	1.0	9.3	6.3
	0.0	1.2	6.8	1.4	1.2	0.2	0.2	6.4	2.2
North Arm - Nilkitkwa Region totals	1.9	29.7	42.2	83.3	37.2	22.8	51.5	47.5	39.6
			0.6	0.7	1.1	0.4			0.7
	0.0	3.9	4.5	5.8	10.5	3.6	1.3	2.2	4.7
			0.4	1.1		0.2			0.6
	5.3	23.8	20.4	22.3	16.3	6.5	23.5	8.3	15.8
	1.7	7.9	6.7	8.2	12.5	6.7	3.6	4.4	7.1
	2.2	19.4	24.4	44.3	10.9	13.6	5.0	16.4	17.0
	1.7	15.1	10.4	23.2	6.6	7.8	4.0	20.8	11.2
Main Lake Region totals	10.9	70.1	67.4	105.6	57.9	38.8	37.4	52.1	57.1

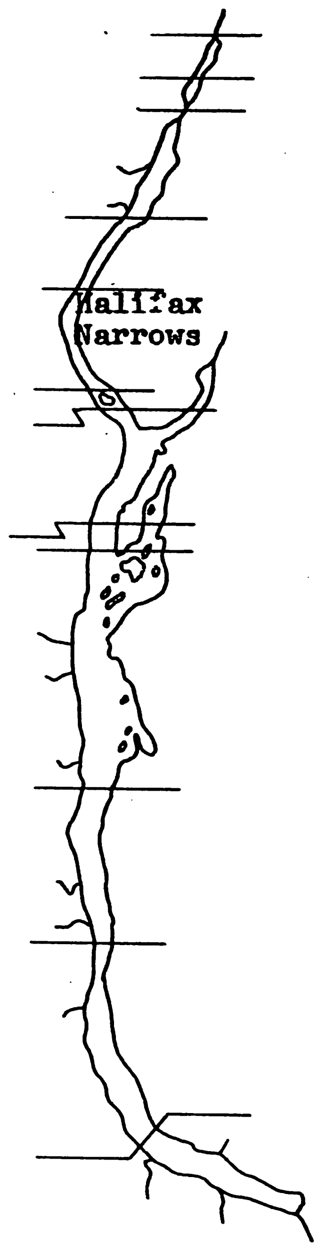
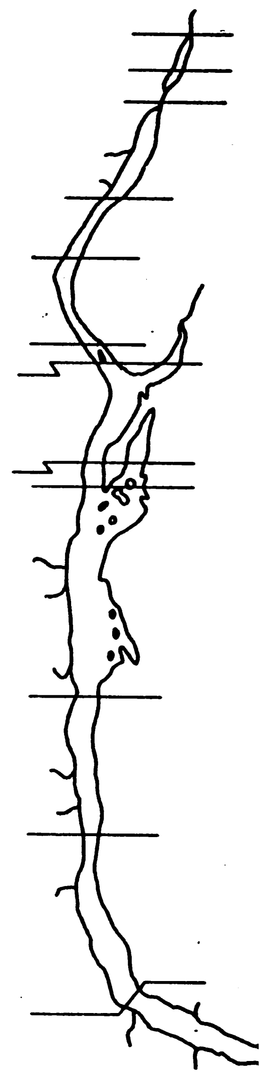


TABLE III AUGUST FINGERLING DENSITIES.

ESTIMATED NUMBER AUGUST FINGERLINGS PER ACRE OF LAKE SURFACE

	1956	1957	1958	1959	1960	1961	1962	1963	Mean
	1,350	5,130	3,160	13,200	3,890	5,750	13,800	5,750	6,504
	1,350	6,030	14,100	35,500	8,500	13,500	56,200	17,800	19,123
	50	2,750	3,800	6,600	3,310	1,740	1,480	3,240	2,871
	0	2,040	1,320	5,130	3,240	480	300	2,820	1,916
	0	260	1,510	310	280	50	50	1,450	489
North Arm - Nilkitkwa Lake Region Means	132	2,063	2,931	5,785	2,583	1,583	4,576	3,299	2,750
	..	..	130	160	245	90	..	..	156
	0	300	350	450	810	280	100	170	308
	..	..	120	300	..	70	..	..	163
	140	630	540	590	430	170	620	220	418
	140	630	540	660	1,000	540	290	350	519
	120	1,050	1,320	2,400	590	740	270	890	923
	120	1,050	720	1,620	460	540	280	1,450	780
Main Lake Region Means	105	674	648	1,015	557	373	360	501	549



In general, young sockeye have been most abundant and most dense in the lake basins adjacent to extensive spawning areas - suggesting that young sockeye do not disperse uniformly throughout the lake system but tend to remain in the general vicinity of their natal stream. This is particularly evident in the North Arm - Nilkitkwa Region where the outlet spawning grounds lie at one end of a series of narrow basins. Distribution was more uniform in the Main Lake Region where basins are less discrete and spawning areas more dispersed.

Differences in the growth rate of sockeye and the amount of food available have been associated with differences in fingerling density. Pertinent data are provided in Tables IV and V.

In the North Arm - Nilkitkwa Region where young sockeye were relatively dense and food supply was relatively low, the mean annual weight of fingerlings by mid-October ranged from 2.3 to 4.0 grams while their mean weight in all years was 2.9 grams. Fingerlings in the Main Lake Region where plankton was relatively abundant were substantially larger. Mean annual weights ranged from 2.8 to 4.0 grams and the mean for all years was 3.6 grams.

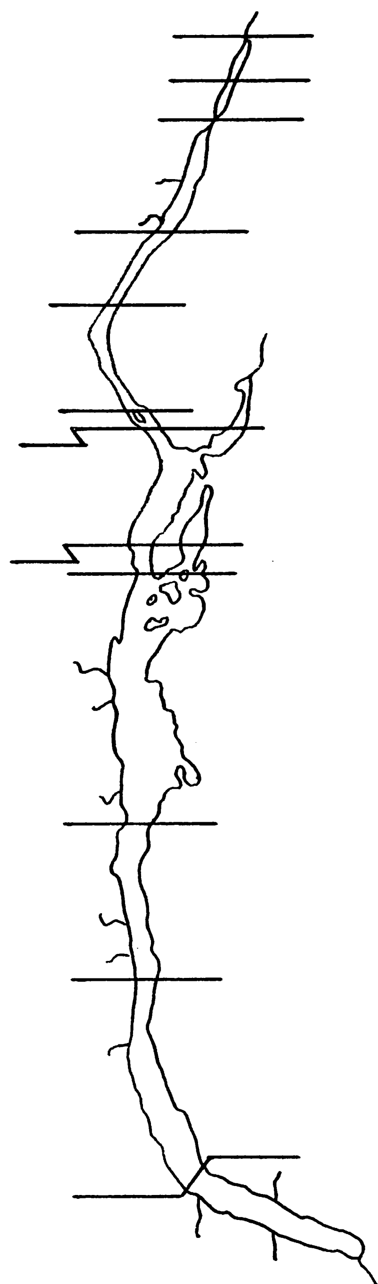
Similar differences in size between the fish reared in the two lake regions occurred at the smolt stage. Since 1956, the average weight of smolts produced in the North Arm - Nilkitkwa Region has been consistently less than that of smolts produced in the Main Lake Region. Over the long term (6 years), the average weight of smolts from the

TABLE IV. ESTIMATED MEAN VALUES OF AUGUST FINGERLING DENSITY, AND RESULTANT SIZE AT FINGERLING AND SMOLT STAGES

Lake region	Year in the Lake	Number of fingerlings per acre	Weight (gms) of fingerlings (mid-October)	Weight (gms) of resultant smolts
North Arm - Nilkitkwa Region	1956	132	4.0	..
	1957	2,063	3.4	4.95
	1958	2,931	2.3	4.08
	1959	5,785	2.6	4.51
	1960	2,583	2.9	3.98
	1961	1,583	2.8	5.62
	1962	3,580	2.3	4.35
	1963	3,299	2.6	..
	Means	2,750	2.9	4.58
Main Lake Region	1956	105	4.0	6.05
	1957	674	4.0	5.74
	1958	648	3.7	5.11
	1959	1,015	3.5	5.87
	1960	557	3.6	5.15
	1961	373	3.4	5.73
	1962	360	3.7	5.42
	1963	501	2.8	..
	Means	549	3.6	5.58

TABLE V RELATIVE AMOUNTS OF ZOOPLANKTON FOOD BY LAKE BASINS.

MEAN STANDING CROP OF ZOOPLANKTON 0-5 M. DEPTH MID-JUNE TO MID-OCT. mg/m^3 (DRY WT.)
9.5
11.1
39.4
55.6
64.2
96.2
67.5
101.1
78.5
90.1
82.4



North Arm - Nilkitkwa Region (4.58 grams) has been only four-fifths the average size of Main Lake Region smolts (5.58 grams).

2.4 Current sockeye production levels at Babine Lake

Studies elsewhere (Foerster, 1954; Ricker, 1962),[1] have shown a positive relationship between the size of sockeye smolts and subsequent survival to maturity. Should a similar kind of relationship hold for Babine sockeye during the freshwater and marine stages of their life history, the relatively high density and associated small size of sockeye observed in the North Arm - Nilkitkwa Region of Babine Lake as compared to those in the Main Lake Region may be associated with relatively low rates of survival and production. In order to examine this possibility, estimates of the survival rates from fingerling to smolt and smolt to returning adult for the two lake regions are compared below.

2.4.1 Survival from fingerling to smolt

Estimates of the survival from August fingerling to smolt are available from six brood years (1956 to 1961) in the North Arm - Nilkitkwa Region and from seven brood years (1955 to 1961) in the Main Lake Region (Table VI). In the North Arm - Nilkitkwa Region survival has ranged from 14.6

[1]Foerster, R.E. 1954. On the relation of adult sockeye salmon returns to known smolt seaward migrations. J. Fish. Res. Bd. Canada, 11: 339-350.
Ricker, W.E. 1962. Comparison of ocean growth and mortality of sockeye salmon during their last two years. J. Fish. Res. Bd. Canada, 19: 531-560.

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percent to 48.5 percent and averaged 25.9 percent while in the Main Lake Region the range was 12.0 to 47.7 percent and the average was 26.4 percent. In view of these very similar values, it must be concluded that the large lake population density in the North Arm - Nilkitkwa Region and the associated small size of the young sockeye has not reduced the rate of smolt production below the level occurring in the less densely populated Main Lake Region.

TABLE VI ESTIMATED SURVIVAL FROM AUGUST FINGERLING TO SMOLT BY LAKE REGIONS.

	North Arm - Nilkitkwa Region			Main Lake Region		
Brood years	Number fingerlings (millions)	Number smolts (millions)	Percent survival	Number fingerlings (millions)	Number smolts (millions)	Percent survival
1955	1.9	..	..	10.9	5.2	47.7
1956	29.7	14.4	48.5	70.1	8.4	12.0
1957	42.2	9.0	21.3	67.4	24.9	36.9
1958	83.2	26.0	31.2	105.6	31.1	29.5
1959	37.2	7.5	20.2	57.9	13.3	23.0
1960	22.8	4.7	20.6	38.8	12.4	32.0
1961	51.5	7.5	14.6	37.4	6.8	18.2
Means	44.4	11.5	25.9	55.4	14.6	26.4

2.4.2 Survival from smolt to returning adult

Past marking and recovery programs at Babine Lake have provided substantial evidence to show that in general, adult sockeye return to the part of this lake system in which they were reared to the smolt stage (i.e., homing is sufficiently developed to return them not only to the Babine system but at least to one of the two lake regions). In view of this evidence it is possible to calculate survival from smolt to adult for each lake region by comparing known smolt outputs to total adult returns.

Estimates of smolt runs from which adult returns are complete, are available for the years 1958 to 1961. Essentially all the adults returned as four- and five-year-old fish from 1960 through to 1964. The number of returning adults has been estimated on the basis of the abundance and age composition of the escapements in the return years and the rate of exploitation by the commercial fishery. Figure 2 shows the seasonal time of migration of adult fish bound for the North Arm - Nilkitkwa and Main Lake Regions (from tagging data) and rates of exploitation which applied throughout the seasons from 1956 to 1963. From these data the mean rate of exploitation on the two major segments of the Babine run has been computed. These calculations reveal that fish bound for the two lake regions were subjected to exploitation rates of the same order. The calculated rates of exploitation on fish bound for the North Arm - Nilkitkwa and Main Lake Regions were

37 and 31 percent respectively. Applying these rates to escapement figures provides approximations of the total return to each lake region from the smolt runs of 1958 to 1961.

It was pointed out earlier that usually a substantial number of the sockeye counted into the system could not be accounted for on the streams. Some of these fish are known to spawn along beaches in the Main Lake Region and it is assumed that these fish represent returns from smolts produced in this region. The survival of smolts from the Main Lake Region has therefore been calculated in two ways: 1. on the basis of the return of stream spawners only, and 2. on the basis of the return of stream spawners plus the unaccounted-for fish (this assumes that all the unaccounted-for fish spawned in this region). The actual survival from smolt to returning adult in the Main Lake Region probably lies between the two values obtained.

The number of adults estimated to have returned from the smolt runs of 1958 to 1961 indicate a smolt-to-adult survival of between 1.9 and 3.1 percent (mid-point 2.5 percent) for the Main Lake Region as compared to 2.9 percent for the North Arm - Nilkitkwa Region (Table VII). Although these are only approximations, they do suggest that there is no substantial difference in the survival rates of smolts produced from the two lake regions. Thus, the high lake population densities observed in the North Arm - Nilkitkwa Region and the smaller smolts produced do not appear to have resulted in a detectable decrease in survival from that occurring in the less densely populated Main Lake Region.

2.5 The estimated potential of the lake nursery areas

From the foregoing, it is readily apparent that the two lake regions of Babine differ markedly in the way in which they are utilized by sockeye. The North Arm - Nilkitkwa Region is characterized by having a small lake nursery area in relation to the large capacity of the associated outlet Babine River spawning grounds. The opposite condition prevails in the Main Lake Region where a relatively large nursery area is associated with spawning grounds of more limited capacity.

When data from the two regions are compared it is evident that since 1955 average or larger escapements to the North Arm - Nilkitkwa Region have been followed by relatively high fingerling densities, relatively small amounts of available food, and relatively slow growth to the fingerling and smolt stages. Escapements to the Main Lake Region, on the other hand - regardless of abundance - have been followed by low fingerling densities, large amounts of available food, and by fingerlings and smolts of relatively large size.

In terms of the average number of fingerlings being reared per unit surface area, the North Arm - Nilkitkwa Region has been utilized at a level about five times that of the Main Lake Region. This greater level of utilization of the North Arm - Nilkitkwa Region does not appear to have affected

TABLE VII ESTIMATED SURVIVAL RATES OF SMOLTS PRODUCED FROM THE BROOD YEARS 1956 THROUGH TO 1959

Lake Region	Number of smolts (millions)	Escapement in return years (thousands)		Rate of exploitation (%)	Calculated adult return (thousands)		Calculated survival smolt to adult (%)	
		1	2		1	2	1	2
North Arm - Nilkitkwa Region	56.9	1,041.0	..	37.0	1,650.00	..	2.9	..
Main Lake Region	77.7	1,040.0	1,649.0	31.0	1,510.0	2,390.0	1.9	3.1

1. on basis of number of stream spawners observed.
2. on basis of stream spawners plus maximum number beach spawners possible in Main Lake Region.

production adversely: both August fingerling-to-smolt survival and smolt-to-adult survival appear similar for the two lake regions.

Data at hand provide substantial evidence that the North Arm - Nilkitkwa Region of Babine Lake has effectively supported lake populations averaging 2,750 August fingerlings per acre. It is reasonable to assume that an equal density of young sockeye could be supported by nursery areas in the adjoining Main Lake Region.

The ultimate capacity of both regions may be higher. Each region contains a number of basins with more or less discrete sockeye populations. Treating the data on young sockeye from each of these basins separately, and reviewing all the sockeye data available from studies elsewhere, Johnson (1965, in press)[1] presents evidence which suggests that the maximum production of Babine sockeye would be achieved with an August fingerling lake population density of about 3,650 per acre. For present purposes, however, it is sufficient to assume the more conservative figure of 2,750 per acre as the density which may be achieved without decreasing production rates.

To achieve this density in the Main Lake Region would require almost 300 million August fingerlings or nearly three times the maximum number observed in any past year, and

[1]Johnson, W.E. (in press). On mechanisms of self-regulation of population abundance in Oncorhynchus nerka. Verh. int. Ver. Limnol. Special communication.

five times the average number. Fry output would have to be increased at least proportionately. Fry-to-August-fingerling survival at Babine is believed to approximate 50 percent. On this basis, an additional output in excess of 350 million fry would be required to produce an August fingerling density of 2,750 per acre in the Main Lake Region. Even a modest increase in fry output appears to be beyond the present capacity of the spawning grounds associated with this lake region. Any substantial increase in fry abundance must be looked for by supplementing present natural production.

3.0 METHODS BY WHICH FRY PRODUCTION HAS BEEN INCREASED

Three methods have been used to increase fry production from a given number of adults. All of these depend on increasing the survival from the egg-to-fry stage. The three methods are: hatcheries, flow control, and artificial spawning channels.

In the case of hatcheries and artificial spawning channels there is ample evidence to show that a high survival to the fry stage is normally achieved. Over the years hatchery methods have generally resulted in an egg-to-fry survival of about 80 percent. Artificial spawning channels where natural spawning has occurred have been constructed at Jones Creek, Robertson Creek, Qualicum River, Seton Creek in British Columbia and at several sites in the United States. These channels have produced pink, chum, coho and chinook salmon at rates varying in most cases from 30 to 60 percent. It is reasonable to expect that these rates would be achieved by sockeye in spawning channels.

The increase in fry survival possible from flow control is indicated by recent results from the Big Qualicum River Fisheries Development Project. Here an increase was recorded in survival for chum salmon to the fry stage from an average of 10 percent (range 5 to 18 percent) under natural conditions to 25 percent in the first year of controlled flow.

Information to assess production in terms of adult returns by the use of these three methods is sparse. For hatcheries, in the few cases where production to the adult stage has been assessed, survival from fry to adult has been substantially lower than the survival of natural fry. Unpublished results from the three experimental salmon hatcheries in B.C. (Scully Creek, Nanika River and Pitt River) show that hatchery produced sockeye fry were smaller than the fry produced in the natural environment from the same parent stock. Studies at the Pitt River and Sweltzer Creek experimental station have led the International Pacific Salmon Fisheries Commission to claim that reduced swimming speed, swimming endurance, glycogen content, carbohydrate content and protein content of hatchery raised sockeye fry can be attributed to the artificiality of hatchery environment.[1] Because of this apparent lack of viability of sockeye hatchery fry and the fact that hatcheries are expensive to construct, operate and

[1]Proposed Artificial Spawning Channel for Weaver Creek sockeye salmon. M.S. International Pacific Salmon Fisheries Commission, 1964.

maintain, this method of fry production has not been given detailed consideration in this report.

Because of the near natural conditions provided by flow control and artificial spawning channels it is believed that fry comparable in viability to natural fry can be produced. There is some evidence to support this view. In the Pitt River and Sweltzer Creek studies cited above the Commission reported that the fry incubated in artificial spawning channels showed the same characteristics as fry incubated in natural spawning areas. Evidence of good adult returns from fry produced in artificial spawning areas comes from both Jones Creek and Baker Lake. Analysis of the three cycles of Jones Creek pinks that have used the spawning channel reveal that 2.5 times as many adults were produced from the spawn of one adult in Jones Creek as compared to one adult in the Fraser River. At Baker Lake, Washington, the first year's use of the artificial spawning area coincided with improvements in transportation facilities and together they are credited with a fourfold increase in the sockeye adult return. This return was the largest spawning run since the construction of the Baker River dam in 1926.

As artificial spawning channels are usually constructed adjacent to natural spawning areas, it is usually necessary to include a measure of flow control in conjunction with spawning channel projects. This combination provides the greatest benefits because: 1. production is usually greater in channels,

2. channels augment natural spawning areas and 3. some measure of flow control is usually desirable to prevent depletion of natural spawning areas by diversion of water to channels.

4.0 POSSIBLE PROJECTS FOR INCREASING FRY PRODUCTION

4.1 Description of Proposed Development Areas and their spawning populations.

Preliminary surveys and studies were started in 1961 on all sockeye salmon spawning streams tributary to the main basin of Babine Lake (Figure 1). Subsequently three streams: Fulton River, Pinkut Creek and Morrison River were selected for detailed studies of possible fisheries development projects for the following reasons:

(1) These three streams have native stocks of salmon of such a magnitude as to make possible an increase of fry in the required range.

(2) These streams are lake fed which would provide storage for flow control.

(3) The average discharges are adequate to provide the amount of water required for an installation of the size required to produce large numbers of fry.

4.1.1 Fulton River

An assessment of the Fulton River sockeye population was commenced in 1961 in connection with a proposed hydroelectric power project. The power project was subsequently dropped by the British Columbia Hydro and Power Authority. The biological assessment, however, was continued with the objective being fisheries development.

Description of area

The Fulton River, with a drainage area of 532 square miles, rises on the northern side of the Babine mountain range and flows in an easterly direction through Chapman Lake (2.7 sq. mi.) and through Fulton Lake (3.5 sq. mi.) and empties into Babine Lake at Topley Landing. The elevation of Fulton Lake is approximately 190 feet higher than that of Babine Lake. The Fulton River passes over a 40-foot falls immediately downstream of Fulton Lake, then passes through a mile of rock canyon, and approximately three miles of narrow valley to enter Babine Lake. Salmon spawn in the four miles of river downstream of the base of the impassable falls.

Characteristics of the spawning population

Population abundance: Fulton River is the principal spawning stream entering the main basin of Babine Lake. The spawning populations (excluding jacks) have ranged from 15.2 to 169.8 thousand, with an average of 76.1 thousand in the period 1949 to 1963. This average figure accounts for one-half of the observed spawners in the main lake tributaries. The optimum spawning capacity in terms of the best rate of production per spawner is estimated to be 120,000 fish (60,000 females). This was established on the basis of 0.8 females per square yard of gravel. The number of spawners which can most productively utilize a unit area of gravel varies with the physical characteristics of the gravel. It is believed that in productive areas such as Babine a density of 0.8 females per square yard of gravel is not excessive and therefore this density is used tentatively as an optimum figure.

Timing of migration: The main run of sockeye enters the river between August 20 and September 25 with the peak of migration occurring in the first week of September. The fish remain in the river pools for up to three weeks and spawning peaks in late September and early October. "A sub-race" of only a few hundred fish enter the river in early August and complete spawning by August 31 at the same time as a kokanee population.

The emergent fry migration begins in late April or early May and peaks one month later, i.e., late May or early June. The fry migration is virtually completed by the end of the third week of June.

Egg-to-fry survival: Egg deposition has been determined for three years from data collected on population abundance, sex ratio, size composition, fecundity and success of spawning (Table VIII). An estimate of the adult escapement was measured by a tagging program in 1961 and by tower counts in 1962 and 1963. The fry output has been estimated from samples taken throughout the downstream migration period by a vertical sampler. The sampler was operated at several locations in a cross-sectional area of the stream. The egg-to-fry survivals were 11.0 and 30.4 percent from their 1961 and 1962 brood years. An estimate of fry survival for the 1963 brood year was not obtained because of unusually high discharges.

TABLE VIII. SOCKEYE PRODUCTION, FULTON RIVER 1961 - 1963

BROOD YEAR	1961	1962	1963
Number of spawners (Jacks included)	189,000	86,000	154,000
Sex ratio - females	45.2%	52.0%	35.2%
- males	44.6%)	48.0%	29.2%
- jacks	10.2%)		35.6%
Number of females	85,478	44,936	54,200
Average number of eggs per female	2,887	3,272	3,013
Success of spawning	96.3%	93.3%	90.6%
Potential deposition (millions of eggs)	237.7	137.2	148.0
Migration of fry (millions)	26.5	41.7	-
Survival	11.0%	30.4%	-

Spawning distribution: Figure 3 illustrates the locations classified as to relative degrees of spawning utilization. It is estimated that 55 percent of the total number of spawners are to be found in the heavy density areas and 10 percent in the light density areas. Thus 35 percent of the spawning stock utilizes the remaining stream area to a moderate degree. Spawning density is associated with gradient and streambed composition. The higher spawning densities occur where the gradient is relatively low and the streambed contains a large amount of gravel. In low density areas, the gradient is relatively high, and the streambed consists of boulders and bedrock outcroppings. The total river area from lower to upper spawning boundaries is estimated to be 156,000 square yards. Approximately 50 percent of this area is utilized to a significant degree by spawning sockeye.

Discharge

Discharge records (Figure 4) are available from July, 1960 to the present with the exception of a seven-month period between October, 1963 and April, 1964. These flows are illustrated in Figure 5 with relation to the timing of spawning, incubation and migration phases of the salmon. It is noted that yearly maxima are recorded in late May and early June with a considerably smaller peak in the fall.

It should be pointed out that in the two years of complete records the value of stable flows is indicated. In the 1962 brood year, spawning took place in flows ranging from 150 cfs to 70 cfs while the minimum March-April flows were in the order of 70 cfs, and therefore did not fall below the minimum spawning flows. The egg-to-fry survival was 30.4 percent. In the 1961 brood year however, peak spawning occurred at discharge levels fluctuating between 100 to 150 cfs and March-April incubation flows were down to 25 cfs or one-quarter of the minimum spawning flows. The egg-to-fry survival for this year was 11.0 percent, presumably because of flow conditions.

Further evidence of the damage caused by flow fluctuations was recorded during the downstream migration of fry. Peak runoff coincides with the peak of migration. Observations during peak flows in 1962 show a significant increase in the proportion of yolk-sac fry in the catch samples. It is generally accepted that these under-developed fry are less likely to survive.

Temperature

The daily minimum temperatures were measured only during adult migration, spawning and fry migration and are presented in Figure 5.

The optimum temperature range for maturation and spawning of Fulton River sockeye appears to be between 55° and 45°F (daily minima). In 1963, temperatures falling between 65° and 55°F appeared to delay the spawning considerably. These higher temperatures were associated with an abbreviated spawning period, a crowding of adults on the spawning grounds, and an increase in the rate of egg retention.

It would appear that the rate of migration of fry observed in 1963 and 1964 (Figure 5) was stimulated by the rate of discharge; however, rising water temperatures may have also exerted a stimulus to increase the rate of migration.

A study of the thermal characteristics of Fulton Lake as well as additional studies of stream temperatures were implemented to predict possible temperature changes which might occur as a result of providing storage.

4.1.2 Pinkut Creek

Description of area

Pinkut Creek discharges into Babine Lake in the southeast part of the main basin (Figure 1). The Pinkut Creek watershed area is approximately 320 square miles and includes three lakes, Taltapin Lake (8.6 sq. mi.), Augier Lake (3.7 sq. mi.) and Pinkut Lake (2.1 sq. mi.), (Figure 10). Pinkut Creek drains Taltapin to Babine Lake. It is approximately 5 miles in length and flows in a northerly direction. Access to salmon is limited to the lower 1200 yards by an impassable falls. Taltapin Lake is approximately 500 feet in elevation above Babine Lake.

Characteristics of the spawning population

Population abundance: Pinkut Creek is second in importance as a spawning stream tributary to the main lake basin with sockeye salmon populations ranging from 3.2 to 77.6 thousand and a 1949-63 average of 26.1 thousand. This latter figure is nearly double the estimated optimum capacity of 14,400 fish, suggesting that full or over-utilization occurs in the majority of the years.

Timing of migration: The timing of the life stages of the Pinkut Creek sockeye run is similar to that of the Fulton River, namely, the adult migration occurs in the latter part of August and first half of September and spawning takes place two to three weeks later. Fry migration occurs principally in the latter half of May and early June.

Egg-to-fry survival: Virtually no information on the egg-to-fry survival for Pinkut Creek sockeye exists. An assessment of the survival to the pre-emergent stage was carried out during a five-day period from April 28 to May 3, 1964. This was done by randomly sampling approximately 0.5 percent of the heavily spawned area of the stream with a hydraulic pump. It should be pointed out that this is a new method and only one year's tests were carried out. The results suggested that egg-to-fry survival was at least as high as that measured on the Fulton River. Consequently the same survival rates were used for estimating benefit-cost ratios at Pinkut Creek.

Figure 11 outlines the main spawning areas in Pinkut Creek. The major spawning area is approximately 1000 feet long, 72 feet wide or 8000 square yards and consists of coarse to fine gravel with a fairly high proportion of fines at the lower end. The estimated optimum capacity of this area would be 6400 females or a total of 12,800 spawners (based on 0.8 females per square yard).*

The remaining 2000 feet of accessible river is confined in a canyon area with cascades and pools, having limited areas for spawning. The bottom is mostly bedrock and boulders with some gravel pockets existing amongst boulders and in crevices. The estimated spawning area of this section is 1000 square yards and the capacity is 800 females or 1600 spawners. The total estimated capacity of the system is therefore 7200

* In 4 out of 6 years since 1958, when the commercial fishery was regulated to provide more sockeye in the Babine Lake stream spawning grounds, there have been seasonal densities of two or more females per square yard.

females or 14,400 fish.

Discharge

Flows in Pinkut Creek have been recorded since September 1, 1961. The minimum and maximum flows recorded during this period were 7.4 cfs and 2240 cfs respectively. A hydrograph of Pinkut flows is given in Figure 12.

The runoff pattern in Pinkut Creek is similar to that of the Fulton River with relatively low even flows occurring in the winter and early spring months and the peak discharges occurring in late spring and early summer. The recorded discharge is such that severe mortality may occur during the spawning as well as the incubation stages in Pinkut Creek. For example, the extremely low flows of 7.4 to 23 cfs which occurred during September and early October in 1961 are reported to have reduced the effective spawning area to one-third of the normal streambed or 3000 square yards. The spawning population in this year was estimated at 44.0 thousand which is much greater than the optimum for an area of this size. Losses from superimposition could be excessive in this situation. Mortality to eggs and alevins during the incubation period could occur in all years from reduced water levels. The low water levels combined with the absence of snow cover would expose the incubating eggs and fry to cold temperatures and cause mortality by freezing. Stable flow would reduce losses from both these causes.

Temperature

Stream temperature data are available for a part of the sockeye salmon spawning stage for three years commencing in 1961. In addition, temperatures were taken during the spring of 1964. The data suggest that the range of water temperatures at Pinkut Creek are comparable to those observed at Fulton River.

Fall minimum daily water temperatures at Pinkut Creek drop to 55°F at the peak of spawning, a week or ten days earlier than at Fulton River. This temperature is considered to be optimum for spawning. Water temperatures in 1964 during fry migration ranged from 33° to 35°F.

4.1.3 Morrison River

Description of area

Morrison River has a drainage area of approximately 183 square miles, rises on low rolling mountains, sub-alpine swamp and meadowland and drains in a southerly course through broad valleys to Morrison Arm, Babine Lake. The Morrison watershed (Figure 14) consists of three streams and two lakes. Upper Tahlo River (Upper Salmon River) drains 12-14 miles to Tahlo Lake (0.8 sq. mi.). From Tahlo Lake, Tahlo River (Salmon River) drains approximately five miles to Morrison Lake (5.6 sq. mi.). The outflow, Morrison River, drains three and one-half miles through sharp to moderate gradient to Babine Lake.

Characteristics of the spawning population

Population abundance: The Morrison River sockeye spawning population has ranged from 0.6 to 22.8 thousand with an average of 10.2 thousand fish. It is fourth in order of sockeye escapement, being exceeded by Fulton River, Pinkut and Pierre Creeks. Transient populations migrating to Morrison Lake and upper tributary stocks averaged 7.2 thousand sockeye for the period 1949-1963 inclusive.

Timing: Tagging and migration studies conducted by the Fisheries Research Board and spawning surveys made by the Protection Branch indicate a timing similar to the Fulton and Pinkut populations for the salmon migrating to the Morrison River. However, the transient salmon destined for the upper part of the system appear in the Morrison River as early as the first week in August. There is no information on the time of fry migration.

Survivals: No data available.

Spawning distribution: Information on spawning distribution was obtained from a preliminary survey made in September, 1961. The first mile of river from the outlet of Morrison Lake is described as having a steep gradient, high velocity flow and a bottom of large boulders. No spawning was observed. The next two miles were of moderate gradient with good gravel. Heavy spawning was found in those areas not obstructed or flooded by beaver dams. The lower one-half mile of stream contains moderate gradient with boulders and some gravel. Spawning was light.

The total spawning area was estimated at 30,000 square yards; at a density of 0.8 females, the optimum spawning population would be 48.0 thousand.

Discharge

Periodic measurements by the Department indicate spawning flows in the range of 25-150 cfs.

Temperature

No records available

Summary

The Morrison River system was assigned a lower priority for field surveys and preliminary development studies than the Fulton and Pinkut due to its relatively inaccessible location, substantially smaller spawning population and the presence of a transient race migrating to the Tahlo River. Therefore, development proposals for the Morrison River are not yet available. It is expected by the end of the present field season sufficient data will be available to provide preliminary proposals for development projects for this system.

4.2 Criteria used in determining benefits of possible projects

The following criteria have been used in determining the expected benefits of development projects on Babine Lake.

(1) Average spawning escapement (1949-63) - Fulton = 76,100, Pinkut = 26,100.

(2) Average egg deposition per sockeye spawner (including jacks) - 1250.

(3) Optimum spawning density - 0.8 females/sq. yd.

(4) Average natural rate of return per spawner (1946-1964) - 2.5.

(5) Assumed range of egg-to-fry survival - 11 to 30 percent with most probable average value of 20 percent.

(6) Increase in percentage survival by increasing natural low flows during the spawning and incubation periods - 5 percent.

(7) Increase in percent survival by partial flow control through spawning, incubation and emergence - 10 percent.

(8) Egg-to-fry survival in artificial spawning channel - 40 percent.

(9) Artificial spawning channel used to optimum capacity.

(10) Spawning escapement to natural spawning grounds would be equal to the average escapement which occurred during the period 1949-63.

It will be noted that the benefits for each of the schemes have been calculated primarily for comparative purposes. Allowances have not been made for interest charges on the capital expenditure over the four-year period before benefits from the returning adult salmon are realized, nor has any allowance been made for the loss to the fishery for the extra escapement required to seed the artificial spawning channels during the first years of operation.

The above costs could be offset to some extent through higher actual survival rates than those assumed since the criteria used in calculating the benefits are considered to be conservative. In addition the optimum capacity of the Fulton River spawning grounds is considerably higher than the average escapement which has been used in the calculations. Additional benefits therefore could be realized with improved management leading to better utilization of the existing spawning grounds.

The following example, based on scheme 3, shows the method used to calculate benefit-cost ratios of a partial flow control project.

Under natural conditions, the average spawning population of 76,100 adults produce fry in the order of 10.5 million to 28.5 million with an average of 19.5 million corresponding to the observed natural fry survivals of 11 percent to 30 percent and an average of 20 percent. The adult yield, based on the average rate of return of 2.5 per spawner, is 190,000 or 114,000 for the fishery and 76,000 for the spawning escapement.

With partial flow control, the increase in egg-to-fry survivals is estimated to be 10 percent. The increased adult yield from this increase in egg-to-fry survival, based on an average natural survival of 20 percent, would be

$$76,100 \times 2.5 \times \frac{30-20}{20} = 95,000.$$

The probable range of increased yield, corresponding to the natural range of egg-to-fry survivals stated above, would be 172,000 to 64,000 adults.

Benefits in terms of adult production from artificial channels have been calculated on the basis of the increased rate of fry production over that occurring in the natural stream. For the purpose of these calculations the natural egg-to-fry survivals observed in the Fulton River have been used (range 11 to 30 percent, mid-point 20 percent). The egg-to-fry survival in the channel is estimated to be 40 percent.

With the addition of a spawning channel with an area of 85,000 sq yds, a capacity of 136,000 sockeye and an egg-to-fry survival of 40 percent, the adult yield if the natural fry survival is 11 percent would be 136,000 x 2.5 x 40/11 = 1,240,000. Similarly, the adult yield if the natural fry survival is 30 percent would be 136,000 x 2.5 x 40/30 = 453,000. The most probable yield when natural fry survival is 20 percent would be 136,000 x 2.5 x 40/20 = 680,000. Allowing 136,000 to seed the channel the net gain in catch would range from 1,104,000 adults to 317,000 with a probable net gain in catch of 544,000 adults. The expected total increase in catch resulting from partial flow control and the addition of an artificial spawning channel could, therefore, range from 1,276,000 to 381,000 adults corresponding to the observed egg-to-fry survival range of 11 to 30 percent.

At a landed value to the commercial fishery of $2.00 per fish, the net gain in value of fish could range from $2,552,000 to $762,000. The indicated value based on an average survival of 20 percent would be $1,278,000.

There would be little additional cost involved in catching these extra fish in an existing fishery, therefore the full value obtained may be applied as benefit. Based on a total equivalent annual cost of 10 percent, covering interest, depreciation, operation and maintenance, a capital investment of $12,780,000 would be repaid with an equal value of fish.

If the estimated cost of the project is $3,600,000, then the benefit-cost ratio, based on the average value of benefits is $\frac{12,780,000}{3,600,000} = 3.6$.

It has been shown in the preceding calculations that a large variance may occur in the total or net increase in catch depending on the natural egg-to-fry survival. Actual egg-to-fry survivals in a large system such as Babine Lake may vary considerably between spawning areas within the system. Since the data available on egg-to-fry survivals in the Babine Lake system is limited, assuming an average value for egg-to-fry survival for calculating the expected benefits of the various projects may unduly favour one stream over another. For this reason, a range of increased catches has been calculated, as illustrated, based on the range of egg-to-fry survivals obtained on the Fulton River.

The benefit-to-cost ratios of the various schemes described in this report have been determined on the basis of an average egg-to-fry survival of 20 percent.

4.3 Description of possible development proposals

4.3.1 Fulton River

4.3.1.1 Scheme 1

The development of spawning channels adjacent to the main river channel using natural flows constitutes Scheme 1.

The design of channels under this scheme would be limited by the minimum flow of approximately 20 cfs. This proposal would also limit the choice of sites for developing channels to those adjacent to relatively light natural spawning areas in the river, inasmuch as the entire flow during the minimum stages would be diverted into the artificial channels. The maximum potential spawning area that could be developed under this proposal would be 330,000 square feet (36,700 square yards).

Areas adjacent to the Fulton River considered suitable for developing spawning channels are shown in Figure 6. Areas 1 to 6 inclusive could be developed under this proposal. A spawning channel layout for area 5 is shown in Figure 7. The estimated cost of developing artificial spawning channels in areas 1 to 6 is $990,000 (330,000 square feet at $3.00 per sq. ft. = $990,000).

It is estimated that the net gain in fry production from these areas would be 25.6 million which in turn would yield an additional 214,000 adult sockeye to the fishery. Based on a landed value to the commercial fishery of $2.00 per adult sockeye, the annual value of these additional fish is $428,000. A summary of benefits and costs for this scheme is contained in Table IX.

4.3.1.2 Scheme 2

The development of spawning channels adjacent to the main river and provision of storage to increase low flows constitutes Scheme 2.

Under this proposal, storage would be provided in Fulton Lake to maintain a minimum flow of 150 cfs. This would provide sufficient flow to operate a series of spawning channels adjacent to the river or a large single area indicated by area 11 in Figure 6. The storage reservoir would not, however, be sufficient to control the fall freshets. A general plan of the Fulton River area showing the reservoir area is contained in Figure 8.

Storage requirements to maintain a minimum flow of 150 cfs could be satisfied with the construction of a 17-foot high dam at the outlet of Fulton Lake or by construction of a tunnel and control works to draw down Fulton Lake by approximately 20 feet to elevation 2500.

This proposal would also permit a channel design incorporating optimum spawning velocities and depths in addition to providing a greater selection of areas for artificial spawning channels. The maximum potential area that could be developed under this proposal would be 76,000 square yards (areas 1-9 in Figure 6).

The estimated project cost for Scheme 2 is 2.7 million dollars (Table IX). The net gain in fry production from both the natural channel, due to increased egg-to-fry survival resulting from increased spawning and incubation flows, and from the 76,000 square yards of artificial spawning channels is 65.5 million fry which could yield an additional 534,000 adults to the fishery. The annual landed value to the commercial fishery of these additional adults is $1,068,000. Table X contains a summary of the estimated benefits and cost of Scheme 2.

TABLE IX - ITEMIZED COST SUMMARY OF POSSIBLE FULTON RIVER PROJECTS

Scheme	1	2	3	4
1. Dam c/w control works	$ -	$ 250,000	$ 500,000	$ 500,000
2. Reservoir clearing	-	330,000	880,000	880,000
3. Flood channel	-	-	-	5,000,000
4. Access and relocation of works	-	65,000	65,000	65,000
5. Spawning channel	990,000	2,055,000	2,155,000	2,100,000
6. Stream improvement	-	-	-	1,055,000
Total cost	$ 990,000	$2,700,000	$3,600,000	$9,600,000

4.3.1.3 Scheme 3

The development of spawning channels plus partial flow control constitutes Scheme 3.

This scheme would provide controlled flows in the main river during spawning and incubation periods and control of all flooding with the exception of the spring floods in conjunction with the development of spawning channels. One of several possible partial flow control proposals would require a 40-foot dam creating a reservoir with a capacity of 63,000 cfs-days and would enable a regulation of flows as indicated in Figure 9. The same regulation of flows could be realized with a 32-foot dam and by drawing down Fulton Lake to elevation 2500. Several other flow regulation schemes are shown in Figure 9. Figure 9 also depicts the maximum floods for various dam heights that would occur during the period April 1 to June 30. Flows during the period September 1 to April 1 would be in the 200 to 360 cfs. range.

Under this proposal the minimum flow would be sufficient to develop a combination of the smaller spawning channel sites shown in Figure 5 or to develop a large single area, as indicated by area 11, or a combination of both. The first alternative would require a series of intake structures along the river to divert the required water into the channel, while the second alternative would require a single diversion structure located in the canyon area plus a pipeline or tunnel to the spawning channel. A definite advantage in choosing a single area, preferably removed from the immediate vicinity of the river is realized in the reduction in flood protection requirements.

The project outlined under this scheme using either the spawning channel adjacent to the river or a single larger area would cost an estimated 3.6 million dollars (Table IX) and would yield 9.5 million additional fry from the natural channel due to increased survivals resulting from partial flow control and an additional 68 million fry from the artificial spawning channel. The estimated increase in adults to the fishery would be 639,000 with an annual value of $1,278,000 (Table X).

4.3.1.4 Scheme 4

The development of spawning channels and complete flow control constitutes Scheme 4.

Complete flow control would make possible full stream improvement of approximately 120,000 square yards in the main channel. In addition, any number of the potential spawning channel sites illustrated in Figure 6 could also be developed. Complete flow control would reduce costs of developing many of the potential areas by reducing or eliminating the requirements for flood protection.

Complete flow control is possible either by:

(1) creating a reservoir to control all inflows and permit a safe, regulated discharge. A 68-foot dam with spillway at elevation 2588 could control the

TABLE X SUMMARY OF BENEFITS AND COSTS FOR POSSIBLE FULTON RIVER PROJECTS

Scheme		1	2	3	4
1. Flows		Natural	150 cfs min	200 cfs-min and partial flow control	200 cfs-min and full flow control
2. Dam height for flow regulation		N/A	17 ft.	40 ft.	40 ft. and flood channel
3. Additional spawning areas (Artificial spawning channel) sq. yds.		36,700	76,000	85,000	85,000
4. Increased fry output in millions -Natural channel	Maximum				85.5
	Average	-	4.75	9.5	77.0
	Minimum				67.5
-Spawning channel		29.4	60.8	68.0	68.0
5. Increase in adults to fishery in thousands	Maximum	424	1070	1276	2548
	Average	185	534	639	1198
	Minimum	86	315	381	671
6. Value of annual benefits based on the average increase in adults to fishery		$ 370,000	$1,068,000	$1,278,000	$2,396,000
7. Project cost		$ 990,000	$2,700,000	$3,600,000	$9,600,000
8. Equivalent annual cost		$ 99,000	$ 270,000	$ 360,000	$ 960,000
9. Ratio benefit to cost		3.7	4.0	3.6	2.5

theoretical wet year with a maximum release of 800 cfs.

(2) creating a reservoir to provide sufficient storage to maintain a desired minimum flow for the main channel plus the required spawning channel flows and passing all surplus water down a flood channel to Babine Lake. A 40-foot dam would provide a minimum of 150 cfs for the main channel plus 75 cfs for spawning channel development. Investigations are underway to determine if a flood channel with a capacity of 20,000 cfs (the 50-year theoretical design flood) is economically feasible.

Complete flow control and full stream improvement with the development of 85,000 square yards of artificial spawning channel would yield a total increased fry output of 145 million fry and a net increase in adults to the fishery of 1,198,000 with an annual value of $2,396,000. This scheme would cost $9,600,000.

Table IX contains a comparison of costs for the various schemes. A summary of benefits and costs is shown in Table X.

4.3.2. Pinkut Creek

4.3.2.1 Scheme 5

A proposal to provide a minimum flow of 70 cfs during the period August 15 through May 20 would require a reservoir with a minimum storage capacity of approximately 28,000 acre-feet. A general plan of Pinkut Creek showing possible development areas is shown in Figure 10. A number of alternatives using either Taltapin or Augier Lakes or both to provide this storage are possible. The final choice could be made after detailed studies involving costs of relocation of existing roads and facilities, construction of dam and clearing of reservoir area, if required. The estimated cost of this project is $200,000 and the benefits to be derived from increased egg-to-fry survivals are valued at $34,600 annually, based on a net gain to the fishery of 17,300 adults being produced from 1.6 million additional fry.

4.3.2.2 Scheme 6

A proposed spawning channel layout is illustrated in Figure 13 utilizing a section of low-lying land on the right bank at the mouth of Pinkut Creek. The proposed channel would provide a maximum addition of 74,000 square yards of spawning gravel and would utilize the minimum flows provided under section 4.3.2.1. A dam would divert the required water in the canyon area through a tunnel to a diffusion chamber and channel intake structure. The scheme provides for all waters circulated through the spawning channel to be directed back into Pinkut Creek upstream of the main spawning grounds. The estimated cost of this project is $1,500,000. The net gain in fry production is 60.6 million, which yields an additional 489,000 adults to the fishery. The landed value to the commercial fishery of this additional yield is $978,000.

A summary of costs and benefits is shown in Table XI.

TABLE XI SUMMARY OF BENEFITS AND COSTS FOR POSSIBLE PINKUT CREEK PROJECTS

Scheme		5	6
1. Flows		70 cfs.	70 cfs.
2. Dam height at Taltapin Lake to provide 70 cfs.		5 feet	5 feet
3. Additional spawning area (sq.yds.) (Artificial spawning channel)		Nil	74,000
4. Increased fry output in millions			
- Natural channel		1.6	1.6
- Spawning channel		-	59.0
5. Increase in adults to fishery in thousands	Maximum	30	987
	Average	17	489
	Minimum	11	286
6. Value of annual benefits, based on the average increase in adults to fishery		$ 34,000	$ 978,000
7. Project cost		$200,000	$1,500,000
8. Equivalent annual cost		$ 20,000	$ 150,000
9. Ratio benefit to cost		1.7	6.5

5.0 IMPLEMENTATION OF INITIAL PROGRAM

The investigations of an initial development program for Babine Lake have been directed to providing an additional 100 million fry in the main lake basin. It is considered that this size of project is necessary in order to make a substantial contribution to the production of the system and at the same time meet the requirements for biological assessment. The results of the investigation conducted to this date show that both the Fulton River and Pinkut Creek projects should be considered in the initial development program. The objective of providing an additional 100 million fry can be only partly achieved by proceeding with Scheme 3 on the Fulton River alone or Scheme 6 on Pinkut Creek alone, but could be wholly achieved by a combination of projects on both systems. The best selection of projects will, of course, be possible when more detailed engineering studies are completed.

It is considered that a satisfactory initial development program to produce 100 million fry could be phased over a period of five years. The maximum expenditure in any one year would be about $1.0 million. Following completion of the construction program and the period of assessment, consideration could then be given to the implementation of any remaining development proposals which would have the ultimate objective of utilizing as much of the total rearing capacity of Babine Lake as proved economically feasible.

6.0 OPERATION AND MAINTENANCE

The planning of the project could be carried out with existing Departmental engineering staff combined with the services of consulting engineers. Preliminary biological work can be carried out with existing personnel. Following commencement of any part of the initial project an increase in permanent staff for operation and maintenance of the facilities would be required consisting of two technicians.

The annual operating and maintenance costs would be approximately two percent of the capital cost of the initial five-year development program.

7.0 EVALUATION

Evidence at hand has indicated that a potential for increased sockeye production exists at Babine Lake and that this potential may be exploited by increasing the fry output into the Main Lake Region by the use of artificial aids.

Although further studies would assist in anticipating the results of the development schemes outlined in this report, in the end, only by proceeding with one or more of the proposed schemes can the extent of the potential and the effectiveness of the means used to exploit it be determined. Evaluation of development projects is necessary not only to measure the success of the projects but also to reveal the causes of success or failure. It is only in this way, that full exploitation of the lake's potential can be achieved.

An adequate evaluation program would include these areas of study:

1. Measurements of the effectiveness of the fish cultural

methods (spawning channels, water flow and temperature control and spawning ground improvement generally) to produce additional fry.

2. A comparative study of the "survival potential" of fry produced with artificial aids and fry produced naturally.
3. Measurements of the growth and survival of both types of fry as lake populations are increased in size.
4. Measurement of the overall gain in adult production related to costs.

A specific evaluation program cannot be formulated until the exact nature and scope of the initial development project is known. In addition, the amount of effort required will depend to a considerable extent on methods developed particularly in regard to assessment of growth and survival during lake residence. It is our present belief, however, that a minimal evaluation program would require, in addition to the present effort now expended at Babine by the Department of Fisheries and the Research Board, the full-time services of three biologists and the technical assistance and funds necessary for their support.

It is anticipated that an intensive program will be required for a period of about five years following commencement of development with good assessment of adult returns for another five years.

8.0 SUMMARY

1. The purpose of this report is to review evidence bearing on the potential of Babine Lake as a sockeye producer and to examine means by which the potential may be exploited.
2. A comparative study of sockeye salmon production in the two major lake regions has indicated that the large Main Lake Region is currently under-utilized as a sockeye nursery area. Here, August lake population densities of young sockeye have averaged 549 per acre or only about one-fifth the average density of 2750 per acre observed in the North Arm - Nilkitkwa Region. It appears that the Main Lake Region is equally capable of supporting young sockeye and that lake population densities of 2750 per acre could be realized without exceeding the capacity of rearing area.
3. To achieve an August density of 2750 young sockeye per acre in the Main Lake Basin would require a fry output estimated to be 350 million greater than the number currently produced by spawning grounds in this region.
4. Any substantial increase in the output of fry into the Main Lake Region appears to be beyond the capacity of the spawning grounds under present conditions. Past spawning runs which are believed to have used the spawning ground to capacity have resulted in lake populations no more than about one-third the size which could be supported. Increased fry output is considered possible only by increasing natural survival from egg

to fry and/or by providing additional spawning grounds.

5. Fish cultural techniques currently used to increase salmon fry survival and subsequently adult returns have been examined. The most promising techniques are those involving spawning ground improvement through water control combined with extension of spawning area by the construction of artificial spawning channels.

   These techniques have been shown to produce pink, chum, and spring salmon fry at a rate substantially higher than that observed under natural conditions. There is every reason to believe that a high rate of sockeye fry survival can be achieved and that these fry will provide good adult returns.

6. Six possible development proposals are described in this report to depict the range and scope of possible development projects, on streams tributary to the Main Lake Region, to increase the fry production from the present native stocks.

   The four schemes described in section 4.3.1 illustrate the relative potential of different projects on the Fulton River combining flow control, stream improvement and artificial spawning channels. The increased fry output resulting from these schemes ranges from 25 million to 145 million. The corresponding estimated project costs and benefit-cost ratios range from $990,000 to $9.6 million and 4.0 to 2.5 respectively.

Two schemes are described in section 4.3.2 to illustrate the potential of projects combining flow control and artificial spawning channels on Pinkut Creek. The net increase in fry production attributed to these projects could range to a maximum of 60 million, with corresponding project costs and benefit-cost ratios ranging from $200,000 to $1.5 million and 1.7 to 7.0 respectively.

The Morrison River system is considered to have potential for a similar development project, but the results of preliminary studies suggest that the priority would be lower than either the Fulton River or Pinkut Creek, because of its location and the low level of present escapements.

7. A comprehensive evaluation program is considered essential to measure the results in terms of increased sockeye production from development projects which may proceed. The information resulting from this program is also essential if full development of Babine Lake potential is to be achieved.

8. It is considered that the initial project should be large enough to provide an additional 100 million fry to the main basin of the lake in order to make a substantial contribution to production and to enable a proper evaluation of the project. This could be achieved

by a combination of projects on the Fulton and Pinkut systems at a cost of $4 to $5 million and could be phased over a five-year period.

PHOTOGRAPHS

FULTON RIVER

No.1. Falls at outlet of Fulton Lake.

No.2. Possible dam site immediately above falls shown in Photo No.1.

No.3. Natural channel adjacent to site No.5-possible entrance to proposed spawning channel indicated by arrow.

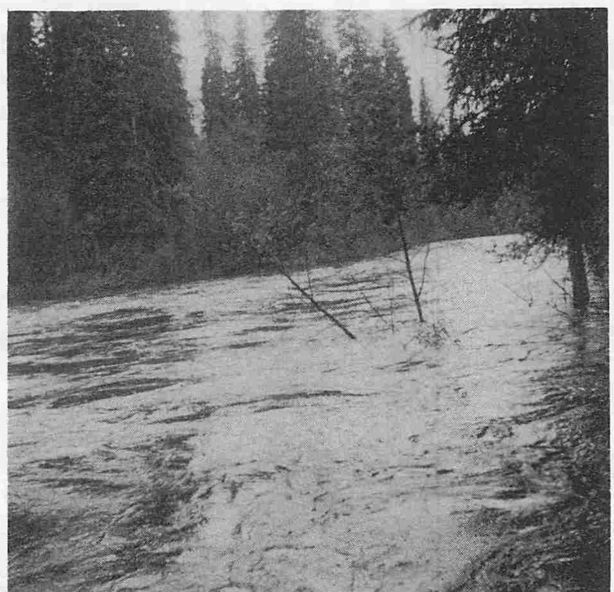
No.4. Natural channel adjacent to site No.5 - stream bed visible in foreground is typical of light spawning areas.

PHOTOGRAPHS

FULTON RIVER

No. 5. Site No. 11, Potential spawning channel development area adjacent to Fulton River.

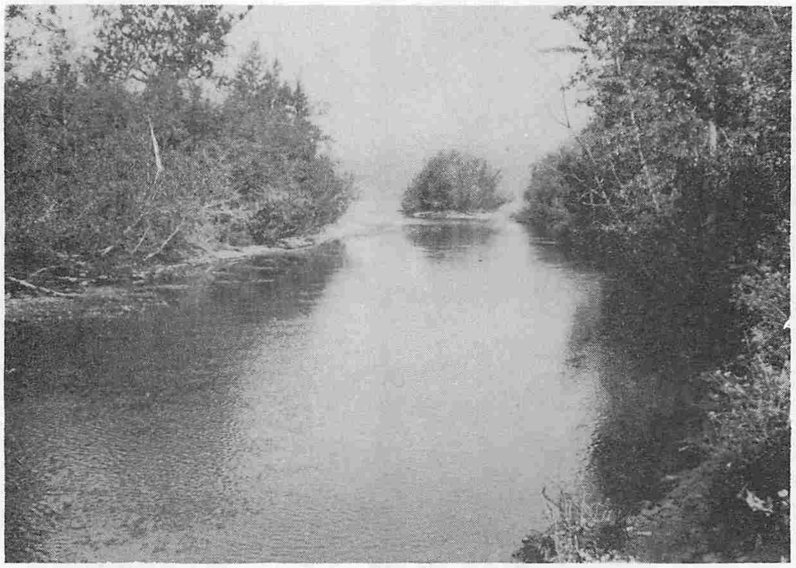
No.6. Area where heavy spawning occurs. Discharge approx.400 cfs.



No.7. Same area as in photo No.6 at discharge of 6000 cfs.

PHOTOGRAPHS

PINKUT CREEK



No.8. Spawning grounds at discharge of approx. 100 cfs. Babine Lake in center background.

No.9. Delta Area site of proposed Pinkut Creek spawning channel. Tree covered area in background is typical of the stage 1 development area shown in Fig.12. The swamp-grass area in the foreground is typical of the stage 2 development area.

PHOTOGRAPHS

PINKUT CREEK

No.10. Delta Area at mouth of Pinkut Creek. Low area in foreground is included in the stage 2 development plan.

No.11. Pinkut Creek at outlet of Taltapin Lake as seen from the left bank. A storage dam is proposed in this area.

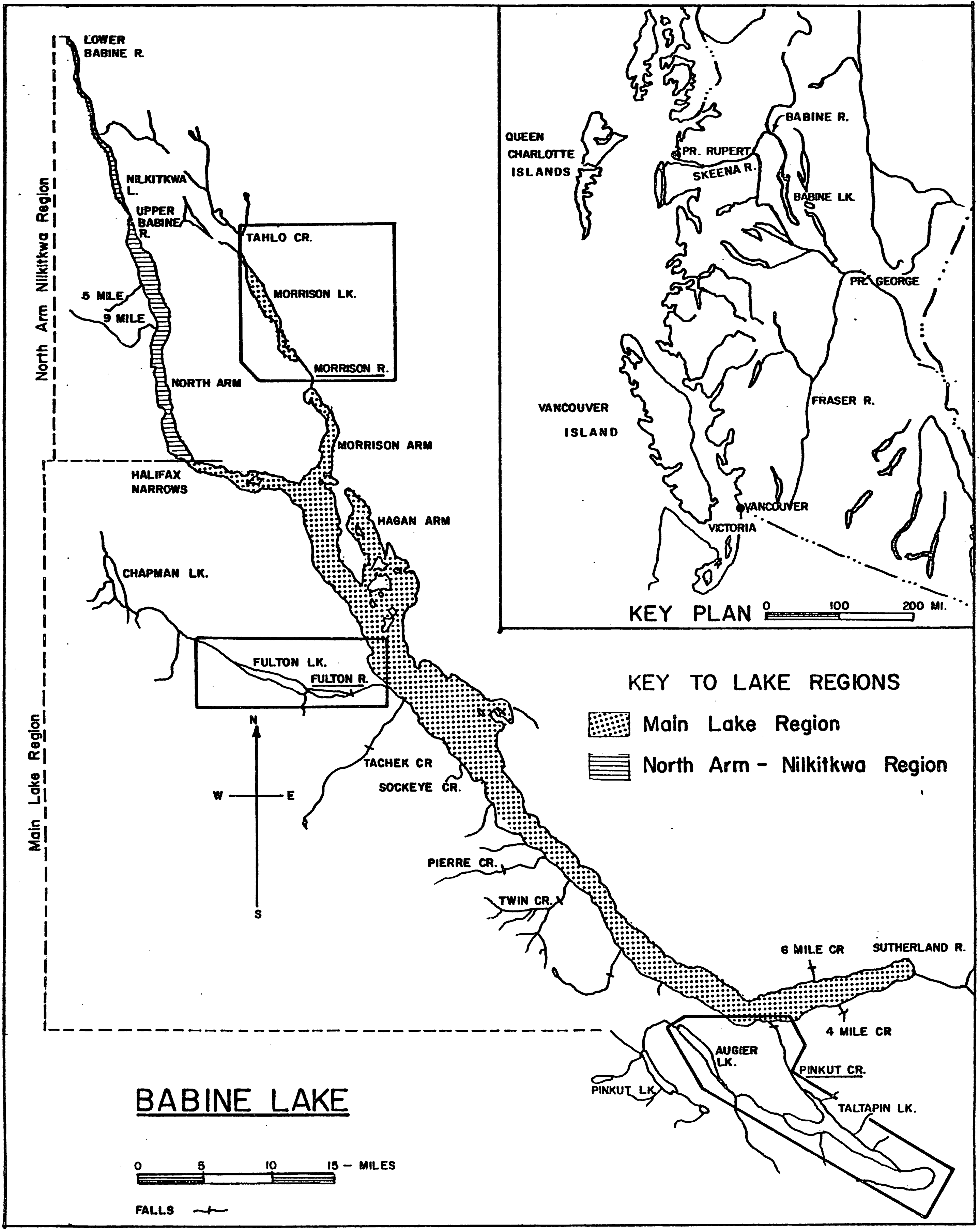
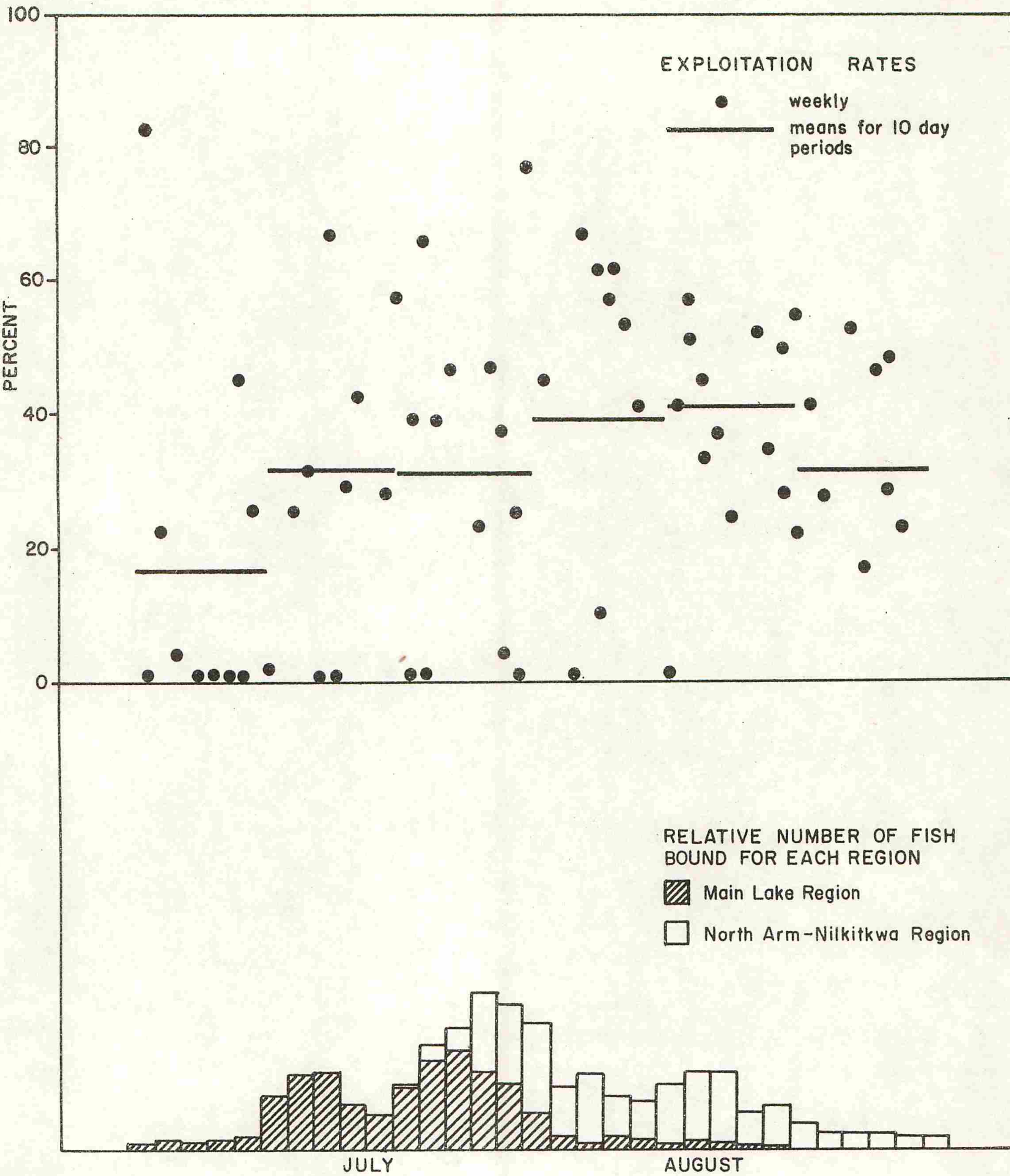

LOWER BABINE R.
NILKITKWA L.
UPPER BABINE R.
5 MILE
9 MILE
NORTH ARM
TAHLO CR.
MORRISON LK.
MORRISON R.
MORRISON ARM
HALIFAX NARROWS
HAGAN ARM
CHAPMAN LK.
FULTON LK.
FULTON R.
TACHEK CR
SOCKEYE CR.
PIERRE CR.
TWIN CR.
6 MILE CR
SUTHERLAND R.
4 MILE CR
AUGIER LK.
PINKUT CR.
PINKUT LK.
TALTAPIN LK.
North Arm Nilkitkwa Region
Main Lake Region
N
W
E
S
QUEEN CHARLOTTE ISLANDS
BABINE R.
PR. RUPERT
SKEENA R.
BABINE LK.
PR. GEORGE
VANCOUVER ISLAND
FRASER R.
VANCOUVER
VICTORIA
KEY PLAN
0 100 200 MI.
KEY TO LAKE REGIONS
Main Lake Region
North Arm - Nilkitkwa Region
BABINE LAKE
0 5 10 15 — MILES
FALLS

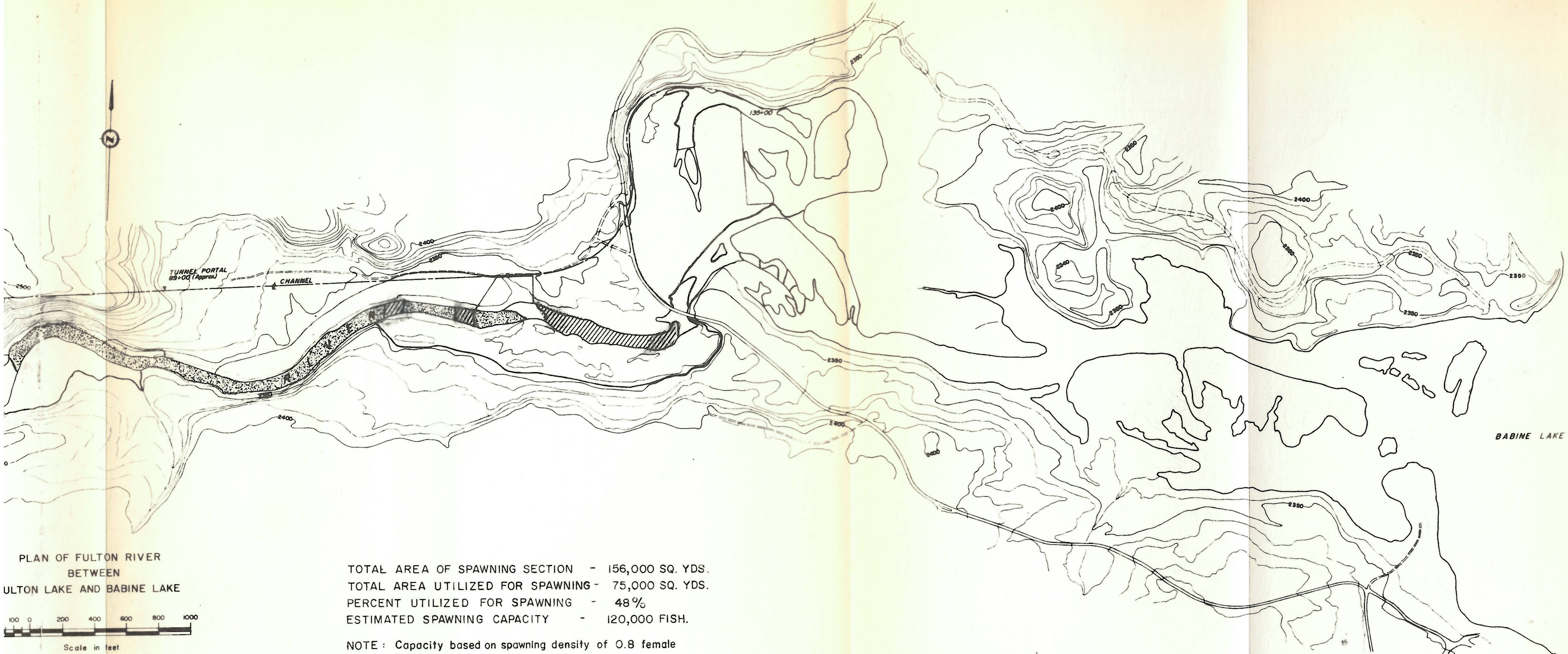
Figure 1



ESTIMATED EXPLOITATION RATES AND MIGRATION TIME OF BABINE SOCKEYE.

Figure 2


FULTON LAKE
W.L. 2523
June 15, 1961.
0+00
PLAN OF FULTON
BETWEEN
FULTON LAKE AND B
200 100 0 200 400
Scale in fee



TOTAL AREA OF SPAWNING SECTION - 156,000 SQ. YDS.
TOTAL AREA UTILIZED FOR SPAWNING - 75,000 SQ. YDS.
PERCENT UTILIZED FOR SPAWNING - 48%
ESTIMATED SPAWNING CAPACITY - 120,000 FISH.

NOTE : Capacity based on spawning density of 0.8 female per square yard.
Data primarily based on survey of Oct. 9 & 10 1963, when river discharge during spawning ranged between 150 - 230 CFS (high flow).

HEAVY

MEDIUM

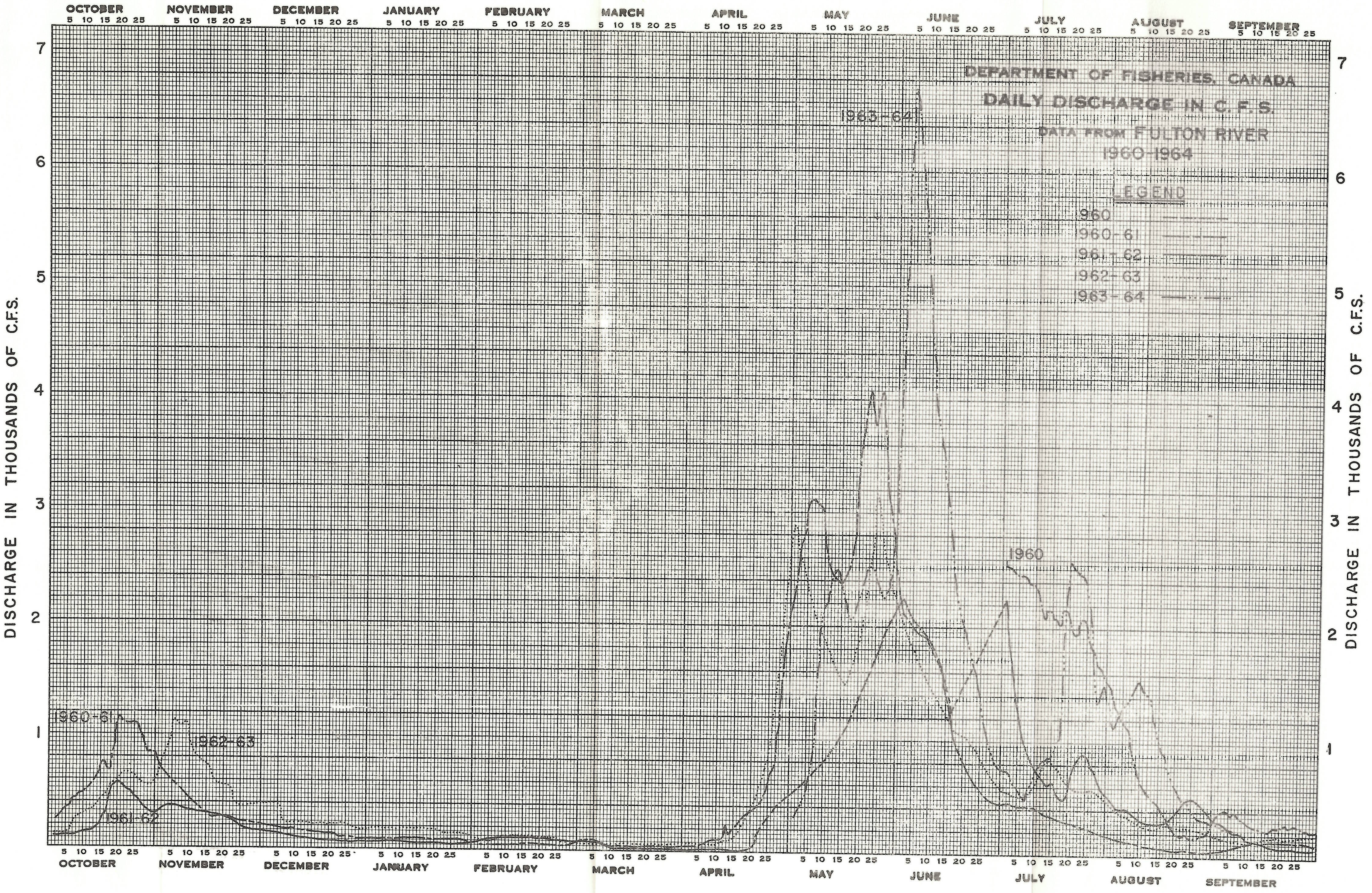
LIGHT

BABINE LAKE REPORT

FULTON RIVER
SOCKEYE SPAWNING AREAS

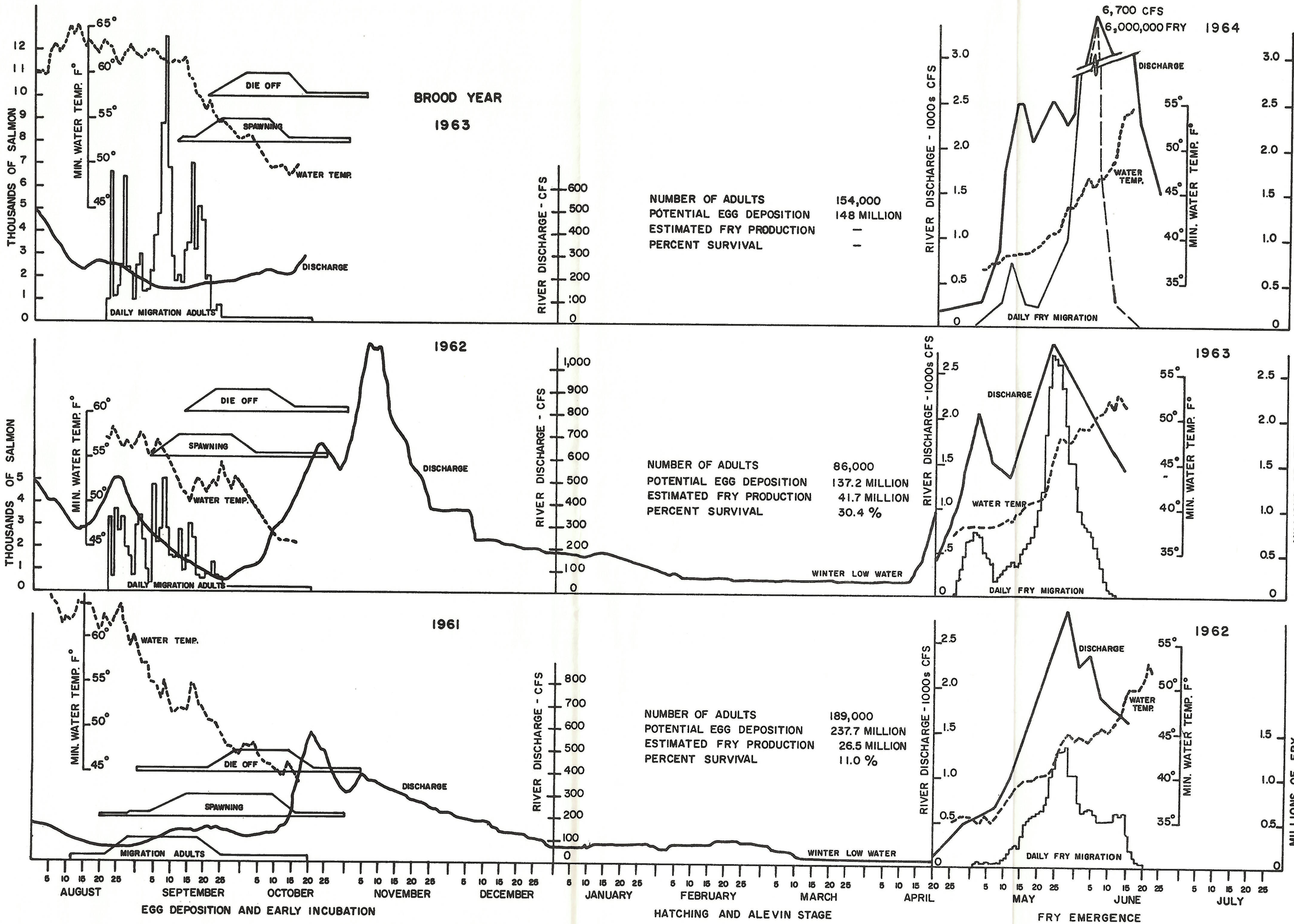
DEPARTMENT OF FISHERIES, CANADA

Figure 3



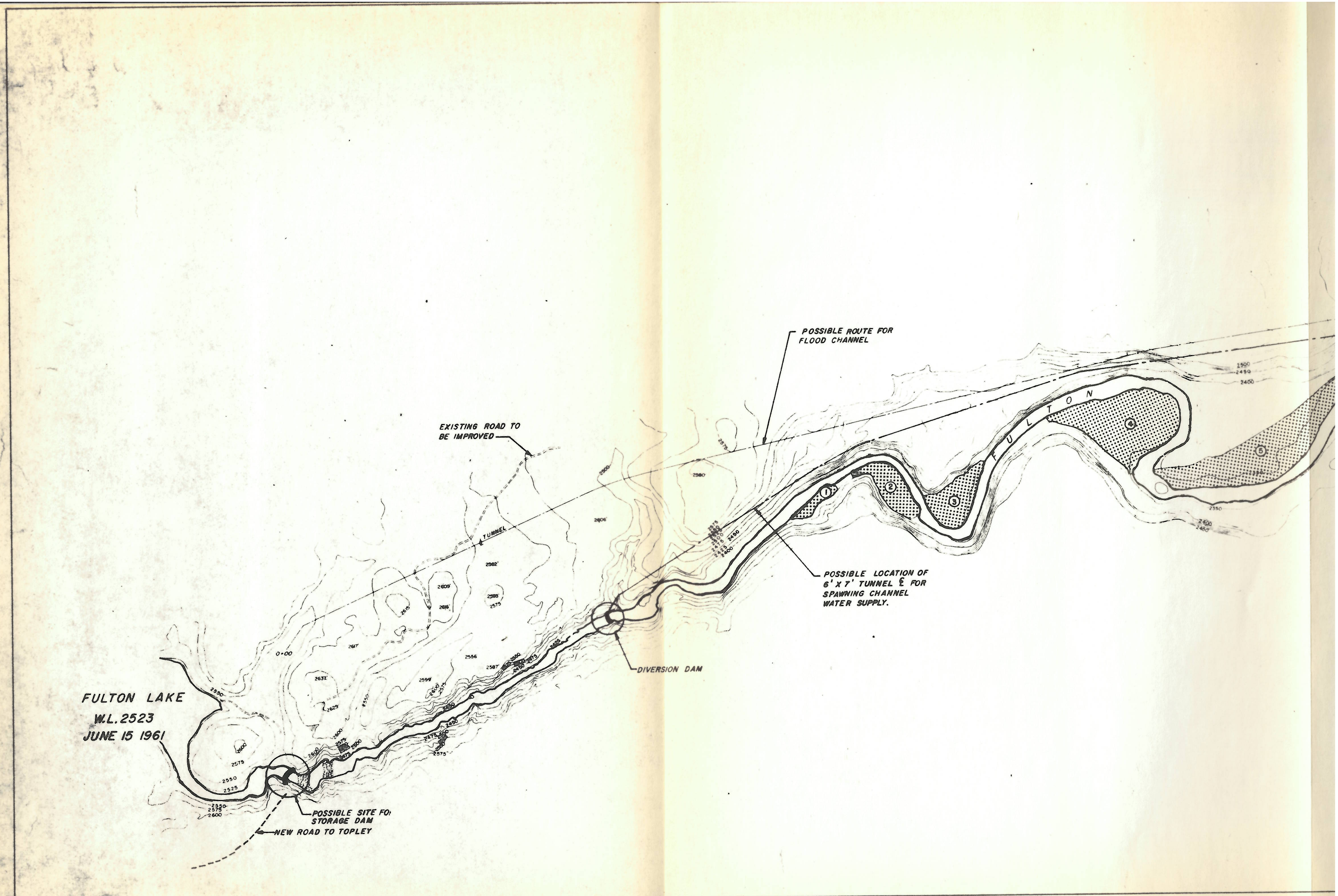
DEPARTMENT OF FISHERIES, CANADA
DAILY DISCHARGE IN C.F.S.
DATA FROM FULTON RIVER
1960-1964
LEGEND
1960
1960-61
1961-62
1962-63
1963-64
DISCHARGE IN THOUSANDS OF C.F.S.
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
1963-64
1960
1960-61
1962-63
1961-62

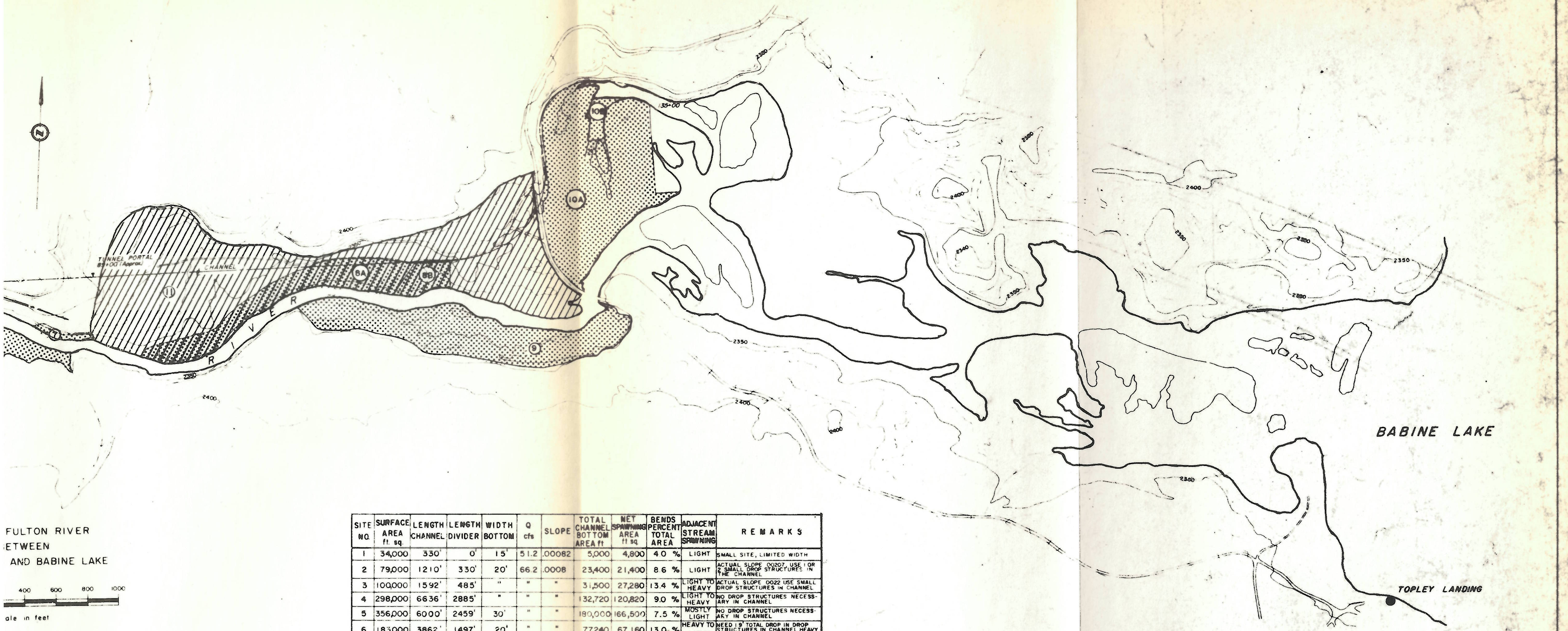
Figure 4



FULTON RIVER SOCKEYE, TIMING, TEMPERATURE AND RIVER DISCHARGE, BROOD YEARS 1961 TO 1963.

Figure 5


POSSIBLE ROUTE FOR
FLOOD CHANNEL
EXISTING ROAD TO
BE IMPROVED
TUNNEL
FULTON
POSSIBLE LOCATION OF
6' X 7' TUNNEL ℄ FOR
SPAWNING CHANNEL
WATER SUPPLY.
DIVERSION DAM
FULTON LAKE
W.L. 2523
JUNE 15 1961
POSSIBLE SITE FOR
STORAGE DAM
NEW ROAD TO TOPLEY



SITE NO.	SURFACE AREA ft. sq.	LENGTH CHANNEL	LENGTH DIVIDER	WIDTH BOTTOM	Q cfs	SLOPE	TOTAL CHANNEL BOTTOM AREA ft	NET SPAWNING AREA ft sq	BENDS PERCENT TOTAL AREA	ADJACENT STREAM SPAWNING	REMARKS
1	34,000	330'	0'	15'	51.2	.00082	5,000	4,800	4.0 %	LIGHT	SMALL SITE, LIMITED WIDTH
2	79,000	1210'	330'	20'	66.2	.0008	23,400	21,400	8.6 %	LIGHT	ACTUAL SLOPE .00207. USE 1 OR 2 SMALL DROP STRUCTURES IN THE CHANNEL
3	100,000	1592'	485'	"	"	"	31,500	27,280	13.4 %	LIGHT TO HEAVY	ACTUAL SLOPE .0022 USE SMALL DROP STRUCTURES IN CHANNEL
4	298,000	6636'	2885'	"	"	"	132,720	120,820	9.0 %	LIGHT TO HEAVY	NO DROP STRUCTURES NECESSARY IN CHANNEL
5	356,000	6000'	2459'	30'	"	"	180,000	166,500	7.5 %	MOSTLY LIGHT	NO DROP STRUCTURES NECESSARY IN CHANNEL
6	183,000	3862'	1497'	20'	"	"	77,240	67,160	13.0 %	HEAVY TO LIGHT	NEED 1.9' TOTAL DROP IN DROP STRUCTURES IN CHANNEL HEAVY STRIPPING REQUIRED
7	18,400	255'	0'	"	"	"	5,100	4,500	11.75%	HEAVY	SMALL SITE, POSSIBLE TEST CHANNEL
8A & 8B	322,000	5557'	2365'	"	"	"	111,140	105,300	5.25%	MOSTLY MEDIUM	HEAVY STRIPPING, DIVERSION STRUCTURE OR 1000' PIPELINE UPSTREAM NECESSARY TO PROVIDE 4' ADDITIONAL HEAD TO MAINTAIN REQUIRED SLOPE.
8B	55,500	1249'	558'	"	"	"	24,980	21,660	13.3 %	MEDIUM	STRUCTURE OR 925' PIPELINE REQUIRED FOR 0.5 ADDITIONAL HEAD
9	477,000	8080'	3300'	"	"	"	161,160	155,340	3.6 %	MOSTLY HEAVY	HEAVY STRIPPING, STRUCTURE OR 1800' PIPELINE REQUIRED FOR 4.5' ADDITIONAL HEAD
10A	678,000	16,533'	7476'	"	"	"	330,660	301,980	8.7 %	MEDIUM	EXTENSIVE FILL REQUIRED, STRUCTURE OR 5200' PIPELINE REQUIRED FOR 13.2' ADDITIONAL HEAD.
10A & 10B	725,000	13,134'	5973'	30'	96.2	.00074	394,020	367,860	6.7 %	MEDIUM	30' CHANNEL INSTEAD OF 20' STRUCTURE OR 3850' PIPELINE REQUIRED FOR 9.8' ADDITIONAL HEAD
11	1,628,000	39,919'	15,900'	20'	66.2	.0008	798,380	731,560	8.4 %	HEAVY	6300' PIPELINE OR TUNNEL AND 25' DIVERSION DAM REQUIRED

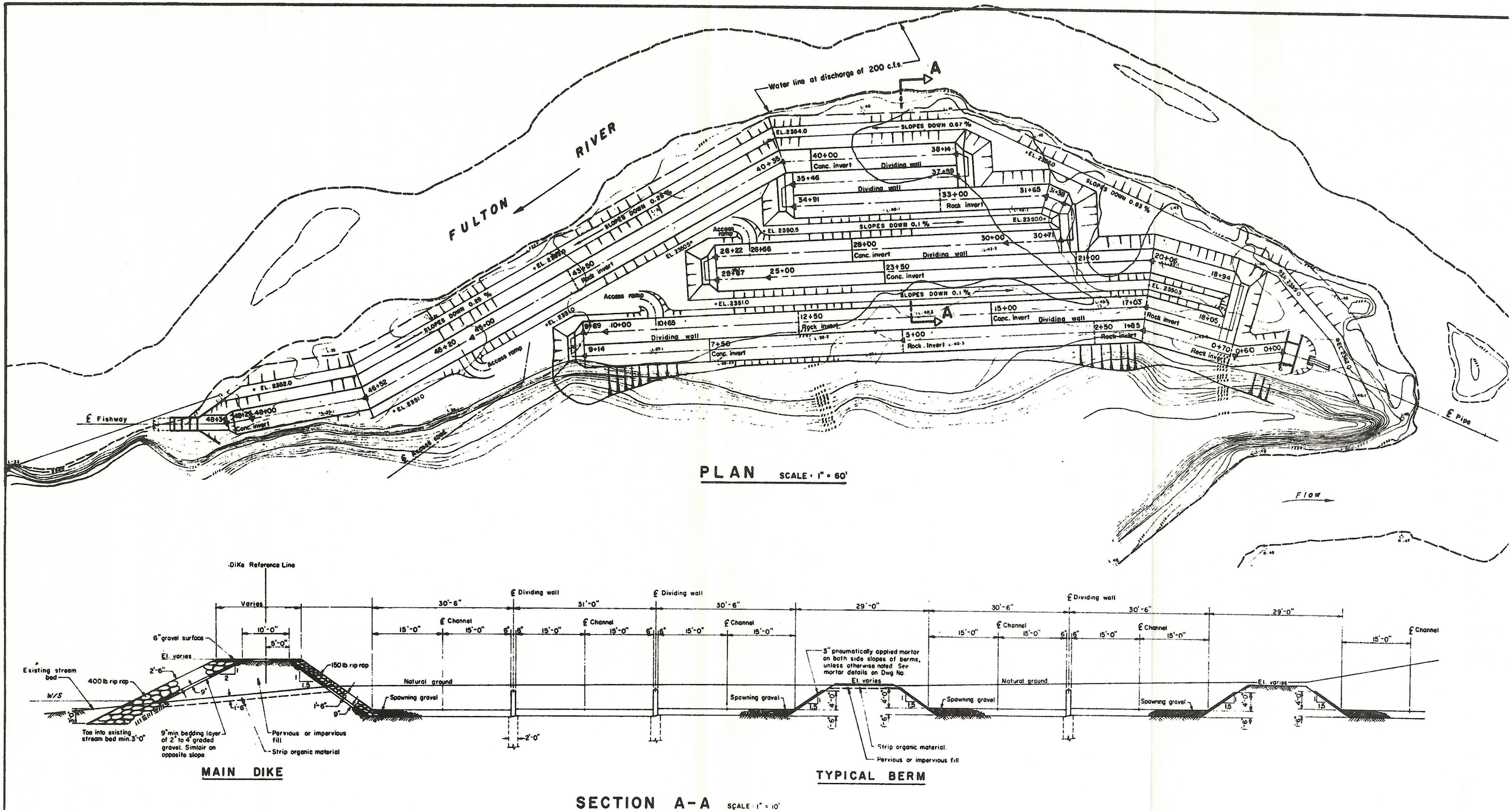
BABINE LAKE REPORT

FULTON RIVER

PLAN OF POSSIBLE SPAWNING CHANNEL SITES

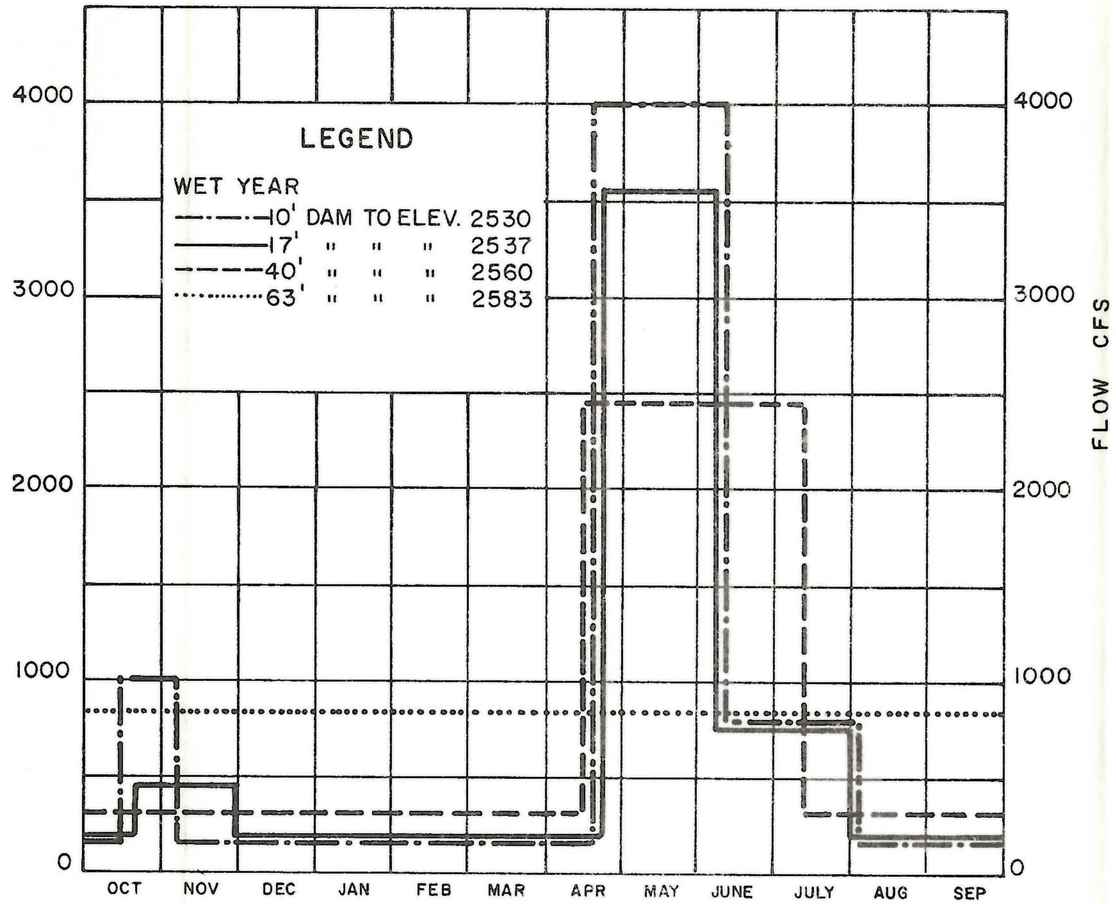
DEPARTMENT OF FISHERIES, CANADA

Figure 6

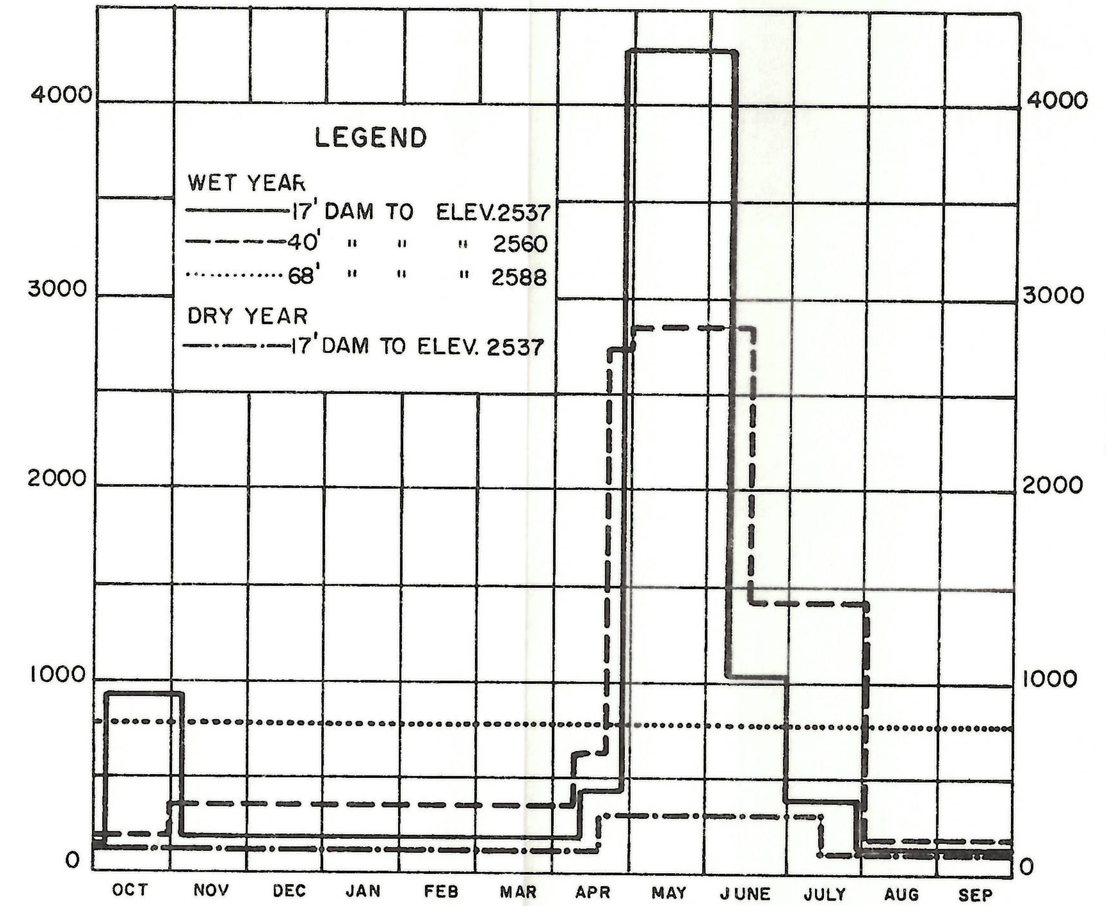


BABINE LAKE REPORT
FULTON RIVER
POSSIBLE SPAWNING CHANN
LAYOUT SITE Nº 5
DEPARTMENT OF FISHERIES, C.

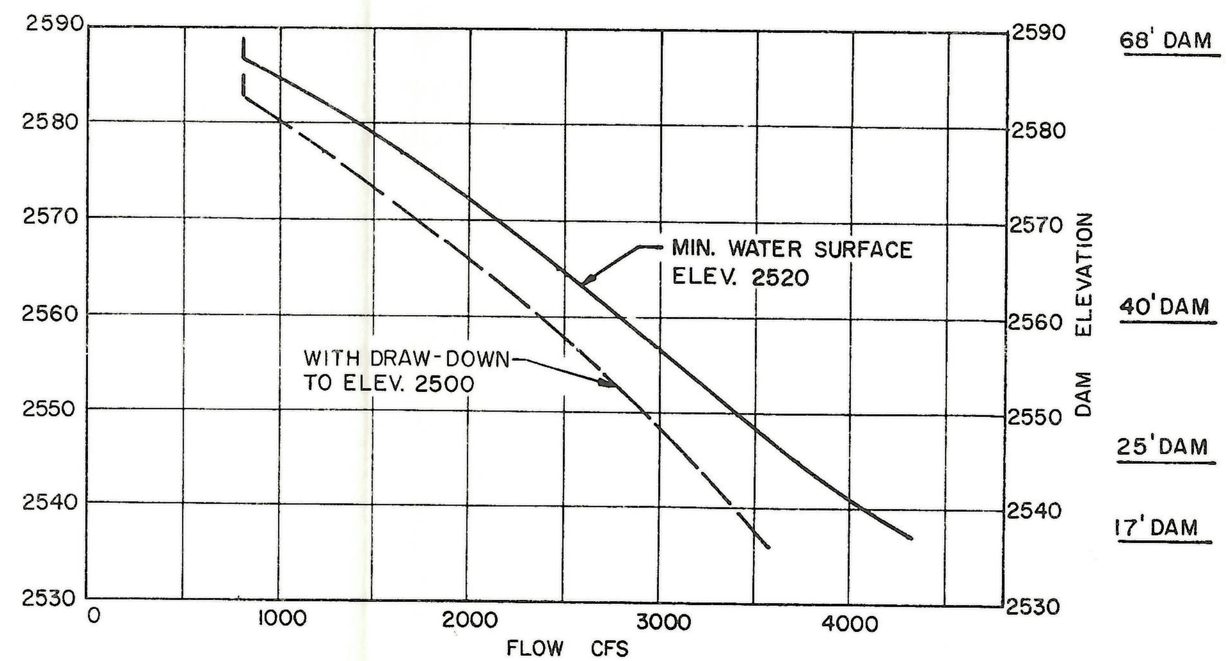
Figure 7



FLOW REGULATION CURVES FOR VARIOUS DAM HEIGHTS WITH DRAW-DOWN.



FLOW REGULATION CURVES FOR VARIOUS DAM HEIGHTS WITHOUT DRAW-DOWN.



MAXIMUM REGULATED FLOWS vs. DAM ELEVATION.

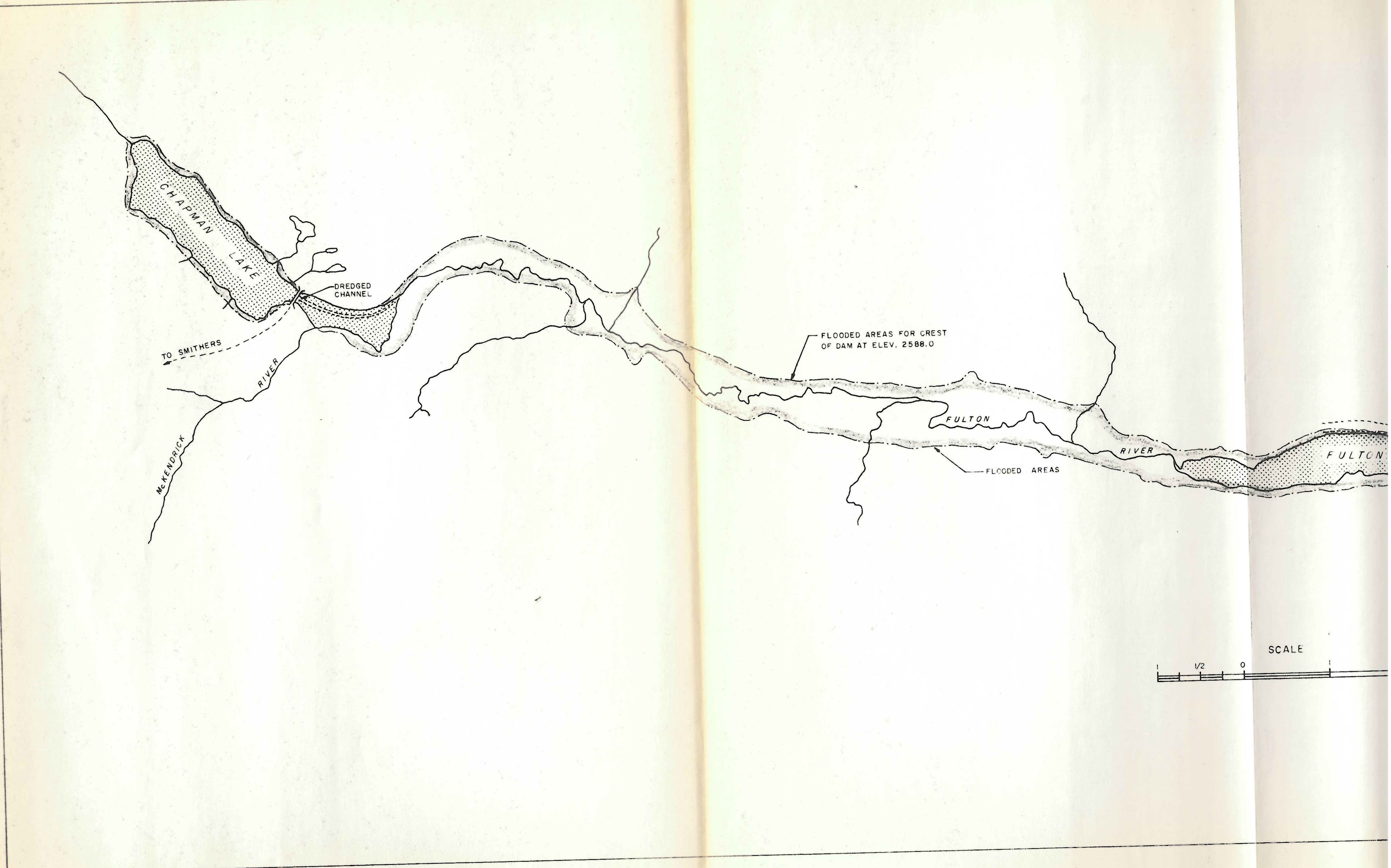
BABINE LAKE REPO

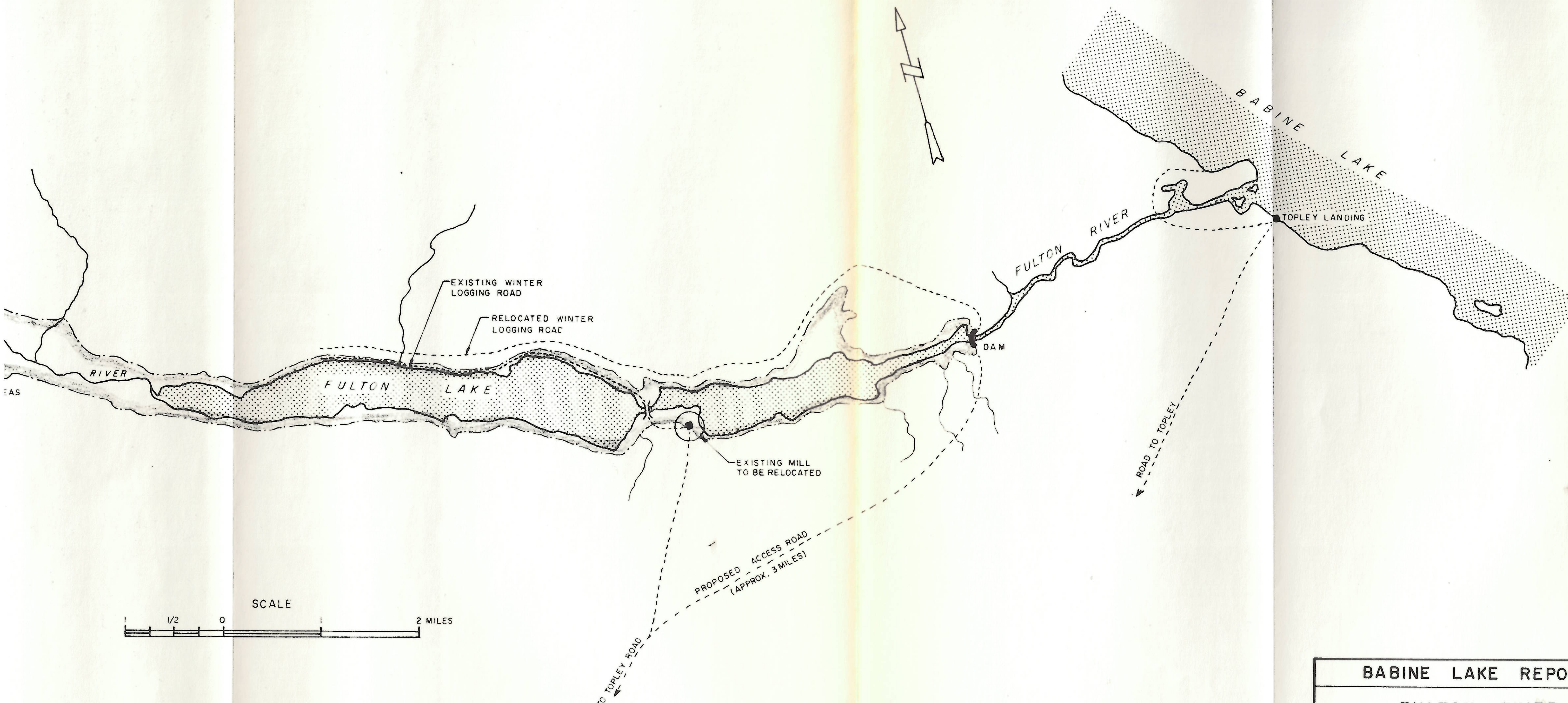
FULTON RIVER

FLOW REGULATION CU

DEPARTMENT OF FISHERIES,

Figure


CHAPMAN LAKE
DREDGED CHANNEL
TO SMITHERS
RIVER
McKENDRICK
FLOODED AREAS FOR CREST OF DAM AT ELEV. 2588.0
FULTON
RIVER
FLOODED AREAS
FULTON
SCALE
1
1/2
0
1

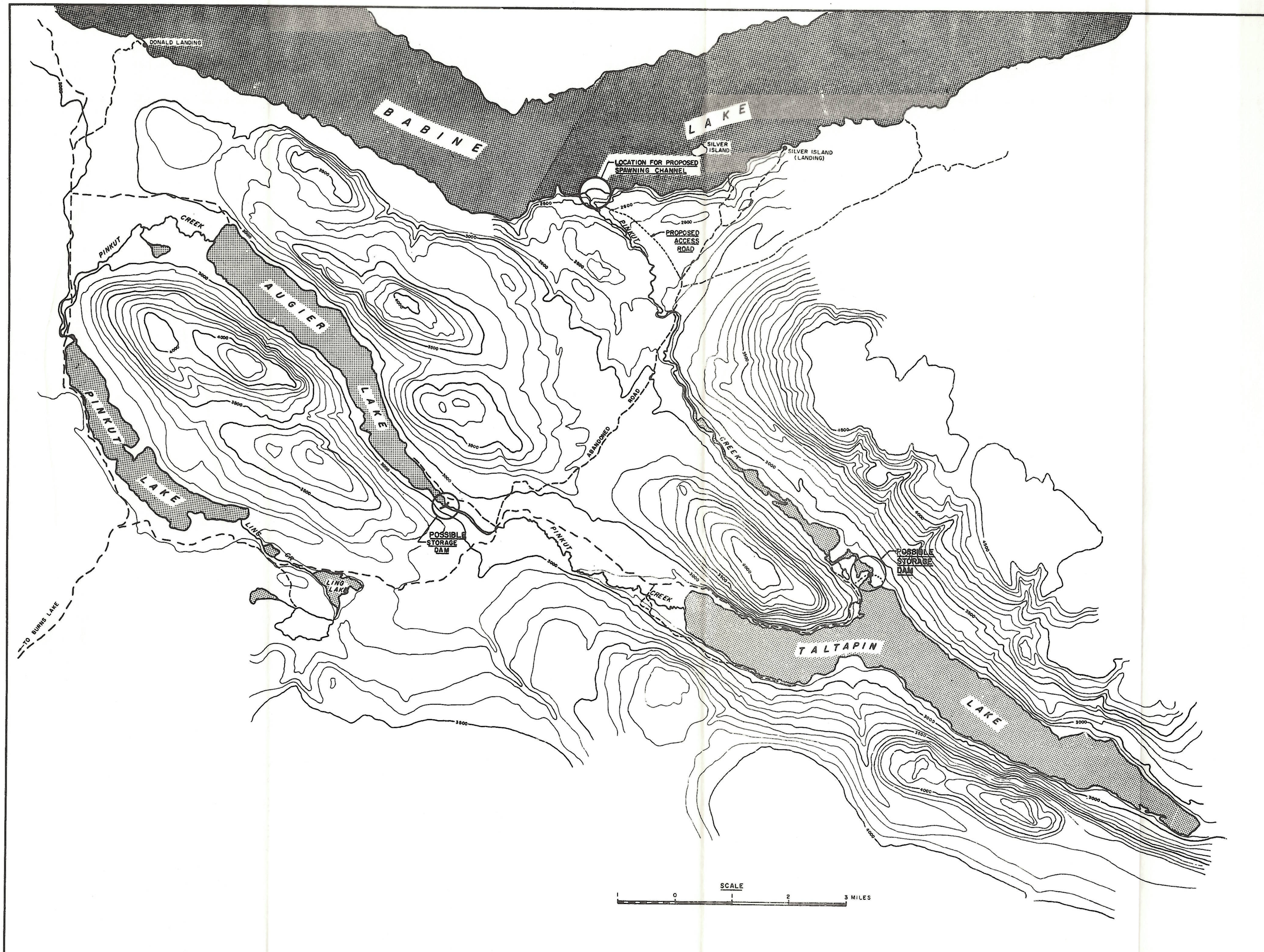


BABINE LAKE REPORT

FULTON RIVER
GENERAL PLAN OF FULTON RIVER AREA SHOWING RESERVOIR FOR 68 FT. DAM

DEPARTMENT OF FISHERIES, CANADA

Figure 8



BABINE LAKE REPOR

PINKUT CREEK

GENERAL PLAN OF PIN
CREEK SHOWING POSSI
DEVELOPMENT AREA

DEPARTMENT OF FISHERIES, C

Figure

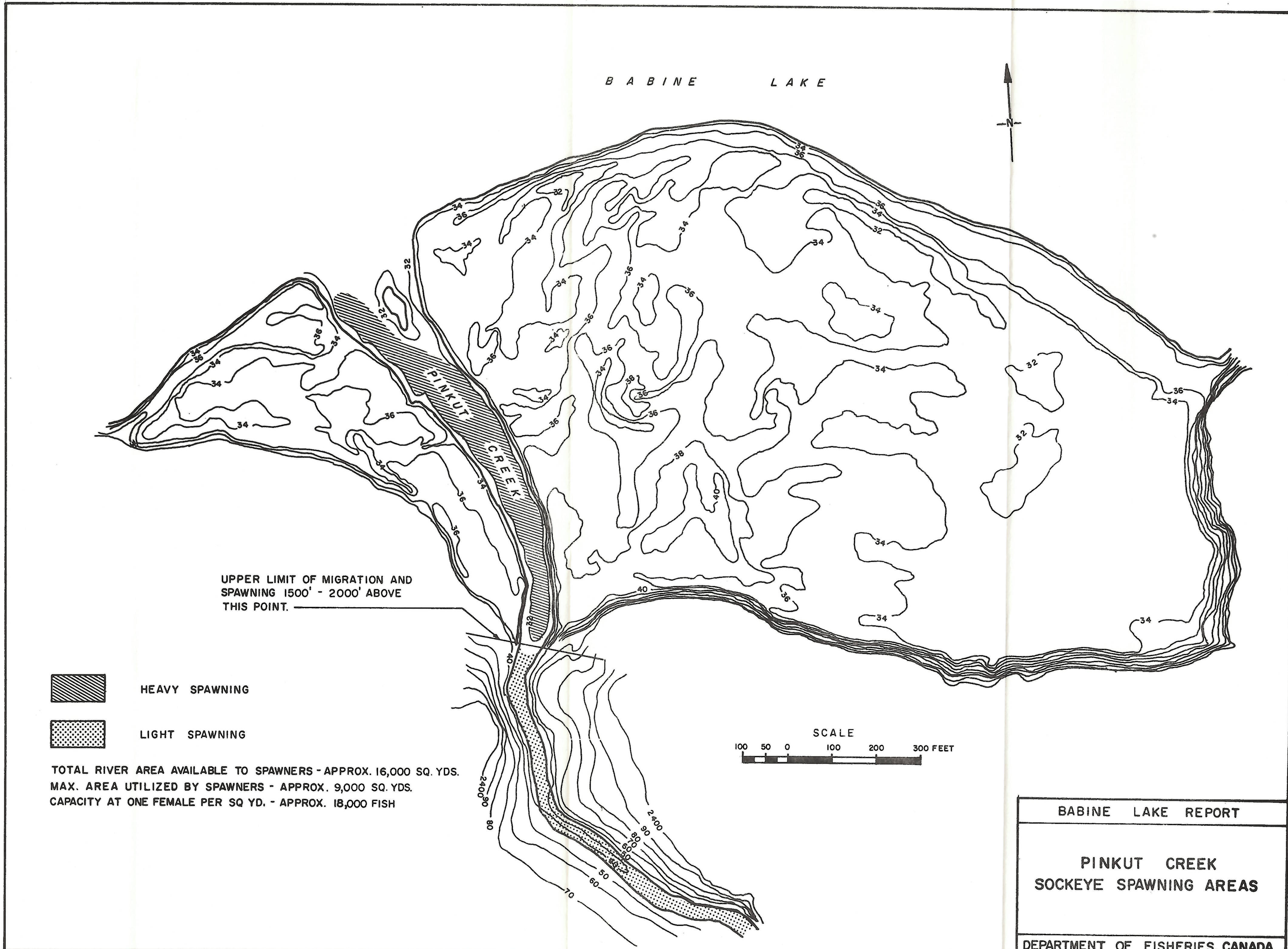

B A B I N E L A K E
N
PINKUT CREEK
UPPER LIMIT OF MIGRATION AND
SPAWNING 1500' - 2000' ABOVE
THIS POINT.
HEAVY SPAWNING
LIGHT SPAWNING
TOTAL RIVER AREA AVAILABLE TO SPAWNERS - APPROX. 16,000 SQ. YDS.
MAX. AREA UTILIZED BY SPAWNERS - APPROX. 9,000 SQ. YDS.
CAPACITY AT ONE FEMALE PER SQ YD. - APPROX. 18,000 FISH
SCALE
100 50 0 100 200 300 FEET
BABINE LAKE REPORT
PINKUT CREEK
SOCKEYE SPAWNING AREAS
DEPARTMENT OF FISHERIES, CANADA

Figure 11

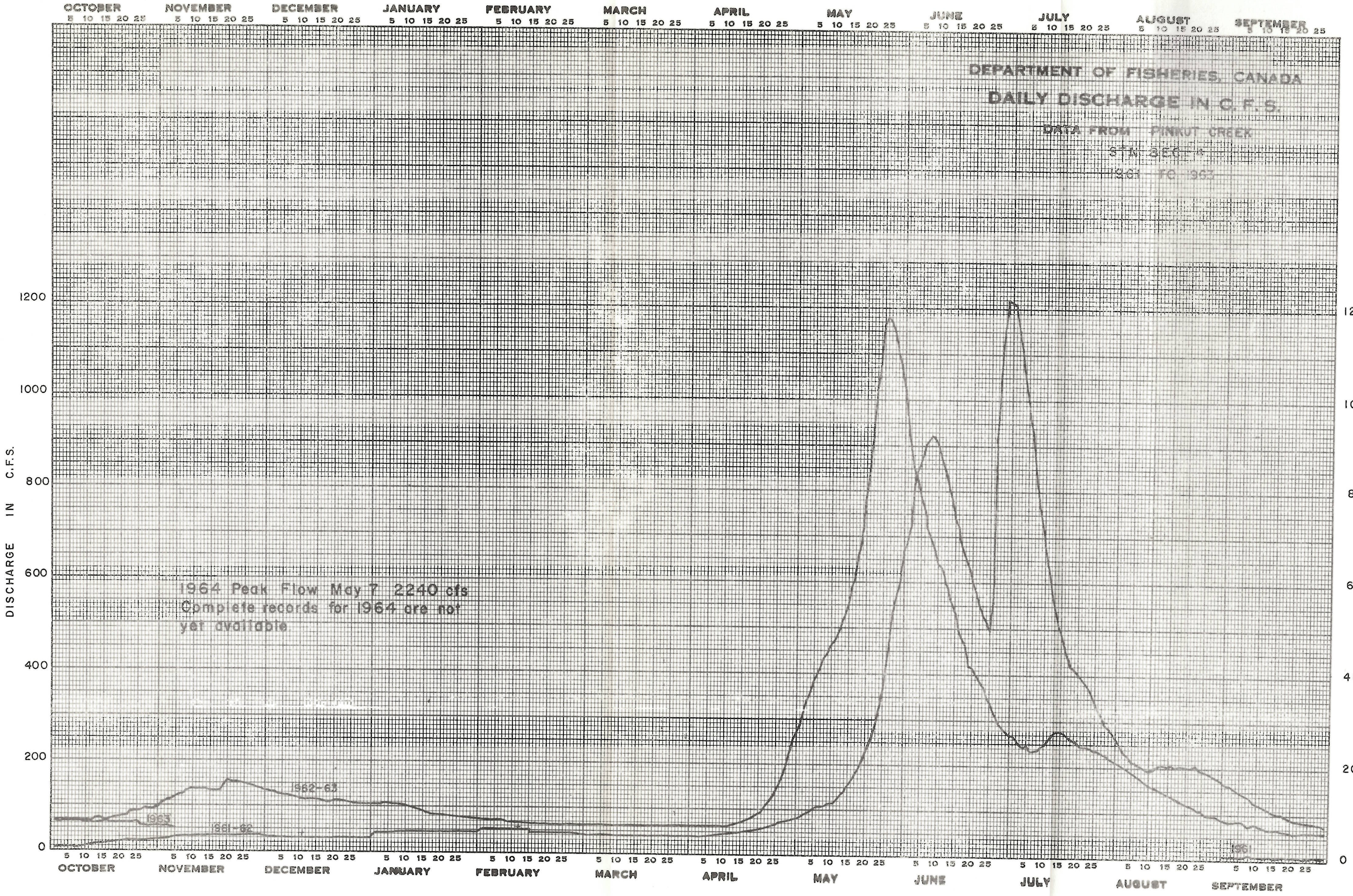

DEPARTMENT OF FISHERIES, CANADA
DAILY DISCHARGE IN C.F.S.
DATA FROM PINKUT CREEK
STN. SEC. 4
1961 TO 1963
1964 Peak Flow May 7 2240 cfs
Complete records for 1964 are not
yet available
1962-63
1963
1961-62
1961
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
DISCHARGE IN C.F.S.
0
200
400
600
800
1000
1200

Figure 12

NOTES,

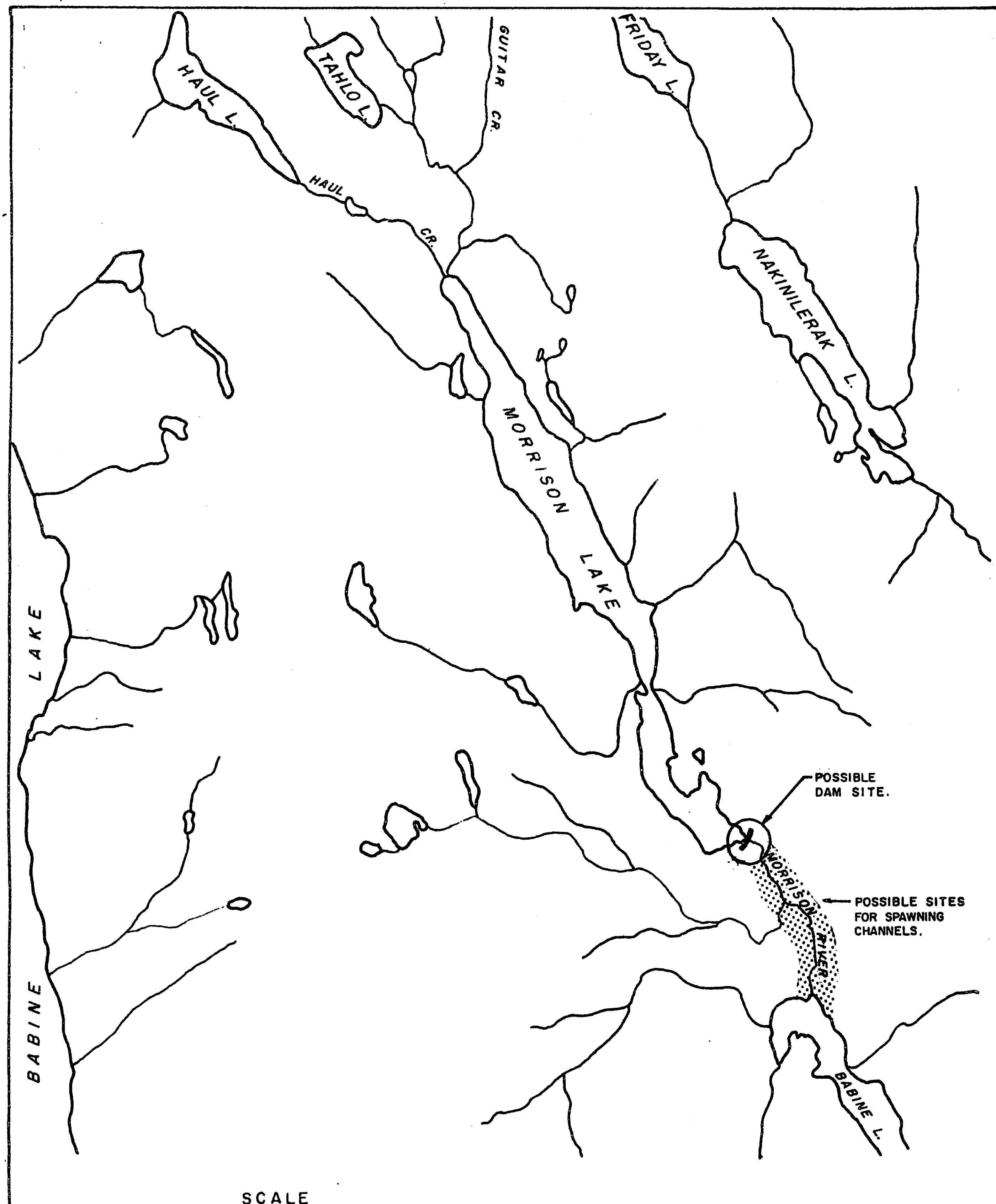
Width of spawning channel = 20 ft.
Depth of spawning gravel = 2 ft.
Slope of channel bed = 5 in 10,000
Length of stage 1 channel = 19,800 ft. (3.75
Length of stage 2 channel = 13,500 ft. (2.35
Spawning area stage 1 = 396,000 sq. ft. (44,
Spawning area stage 2 = 270,000 sq. ft. (30,
Total area = 666,000 sq. ft. (74,

BABINE LAKE REPO

PINKUT CREEK
POSSIBLE SPAWNIN
CHANNEL LAYOUT "A

DEPARTMENT OF FISHERIES,

Figure



BABINE LAKE REPORT

MORRISON LAKE WATERSHED AREA

DEPARTMENT OF FISHERIES, CANADA

Figure 14