THE BABINE LAKE DEVELOPMENT PROGRAM FOR SOCKEYE SALMON

by

B. A. Heskin, P. Eng.

Department of Fisheries of Canada,
Vancouver, B. C.

Presented at the
1967 Northeast Fish and Wildlife Conference,
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ABSTRACT

The Babine River system, in north central British Columbia is a leading producer of sockeye salmon. Investigations by the Fisheries Research Board of Canada indicated that the main lake basin of Babine Lake is presently under-utilized as a sockeye salmon nursery area. Studies, carried out by the Department of Fisheries of Canada to determine the most effective means by which the potential of Babine Lake could be more fully realized, revealed that major development projects on two of the large tributaries of Babine Lake would be feasible and would substantially increase the fry production of the system.

Subsequently, a seven-year construction program with an estimated cost of nearly $8 million was initiated in 1965 and includes several projects combining the principals of flow control, stream improvement, and artificial spawning channels for both the Fulton River and Pinkut Creek.

INTRODUCTION

The sockeye salmon is historically the most valuable of the five species of Pacific Salmon and, because of its high oil content and ability to hold its red colour, is used solely for canning. Sockeye spawn in streams having lakes in their watershed and young sockeye spend from one to two years in lake rearing areas before migrating to sea (Figure 1).

The Skeena River sockeye salmon fishery, which is largely dependent upon the native runs to the Babine River system has an annual value of approximately $1,100,000 to fishermen and $2,200,000 as a processed product. Based on the historical production records which show that catches have been two-thirds higher than the present catches, the Skeena historically ranks second to the Fraser River as a sockeye salmon producer.

Babine Lake (Figure 2) is long and narrow, (about 100 miles long with a maximum width of 5 miles) and can geographically be divided into two general lake regions: 1. the North Arm - Nilkitkwa Region; and 2. the Main Lake Region, which represents 88 percent of the total lake surface area.

The Upper and Lower Babine Rivers, in the North Arm - Nilkitkwa Region, provide 60 percent of the total spawning area for the entire Babine system and virtually all of the spawning area in the North Arm - Nilkitkwa Region. The main lake tributaries provide 40 percent of the available stream spawning area, with the Fulton River accounting for about half of this.

On the average, stream spawners are distributed roughly in proportion to the area of spawning gravel provided in each stream area. Many of the streams tributory to the main lake vary considerably from year to year, however, in their capacity to accommodate spawners and to provide suitable conditions for egg survivals, due to notable variations in discharge during the spawning and incubation periods. Conversely, the spawning grounds located in the North Arm - Nilkitkwa Region benefit from the stabilizing effect of Babine Lake on flows during the spawning and incubation periods.

In the spring, the sockeye fry produced from the spawn of the previous fall, leave the stream to take up lake residence until their seaward migration as smolts one or two years later. (Figure 1) The Fisheries Research Board of Canada have conducted extensive investigations in connection with the abundance, distribution and growth of young sockeye in Babine Lake. These studies reveal that the overall average density (number per acre of lake surface) of young sockeye in the North Arm - Nilkitkwa Region has been five times that observed in the Main Lake Region. The fact that the density is considerably higher is consistent with the expected production resulting from the larger spawning populations and probable higher egg-to-fry survival rates of the spawning areas in the North Arm - Nilkitkwa Region.

These studies also suggest that the potential of the Main Lake Region is at least equal to the North Arm - Nilkitkwa Region as a lake nursery area. It has been reasonably assumed, therefore, that the Main Lake Region could support an equal density of young sockeye. To achieve this density, an additional output in excess of 350 million fry would be required in the Main Lake Region. This additional fry production, assuming the fry-to-adult survival rate remains constant, would result in a three fold increase in the Skeena River catch. Extensive biological surveys reveal that even a modest increase in fry output is beyond the present capacity of the spawning grounds within this region due primarily to the limited area suitable for spawning. It would appear, therefore, that an increase in fry production must be obtained by supplementing the natural production of the spawning grounds.

A number of techniques have been used attempting to increase salmon fry production. Three of these techniques attempt to increase fry production by increasing the survival from the egg-to-fry stage. The three are:

(a) hatcheries - hatchery methods have usually resulted in egg-to-fry survival rates of 80%;

(b) artificial spawning channels - artificial spawning channels have produced fry at rates ranging from 30% to 60%;

(c) flow control and stream improvement - early indications from the Big Qualicum Project suggest that egg-to-fry survival rates of from 25% to 35% can be expected.

Assessments of these techniques as related to adult returns are incomplete. However, results from three experimental hatcheries in British Columbia show that hatchery produced sockeye fry were notably less viable than natural fry. In addition, several assessment studies of adult production also reveal that survival from hatchery fry-to-adult has been lower than the survival of natural fry-to-adult. Based on the significant results of these studies, hatcheries were not given detailed consideration as a means of supplementing natural fry production at Babine Lake.

On the other hand, it has been observed that sockeye spawn incubated in artificial spawning channels produce fry which show the same characteristics as fry from natural spawning areas. There is also evidence of favourable results from the artificial spawning areas at Jones Creek (pink salmon) and Baker Lake, Washington (sockeye salmon) where good adult returns have been recorded from fry produced in artificial spawning areas.

Since spawning channels are generally located adjacent to natural spawning areas, some degree of flow control is required to ensure an adequate water supply to the channels while also maintaining the desired flows to the natural spawning areas.

Because of the near natural environmental conditions provided by flow control and artificial spawning channels and the fact that fry comparable in viability to natural fry can be produced, a decision was made to carry out detailed studies incorporating these techniques for supplementing the natural fry production at Babine Lake.

CRITERIA FOR SITE SELECTION

In 1961 the Department of Fisheries of Canada initiated extensive biological and engineering studies of all sockeye salmon spawning streams tributary to the main basin of Babine Lake to consider the various possible development projects which would enhance the fry production of the streams (Figure 1). The basic criteria set for selecting streams for possible development projects were:

1. The stream must have native stocks of salmon of such a magnitude to make possible the increase of fry in the required range. The minimum increase in fry production was set at 100 million.
2. The stream should be lake fed so as to provide storage reservoirs for flow control.
3. The average discharge must be sufficient to provide the required flows for an installation of the size necessary to produce a large number of fry.

Subsequently three streams: Fulton River, Pinkut Creek and Morrison River were selected for detailed study to determine the feasibility of the various development projects employing the techniques of artificial spawning channel development and flow control and stream improvement as described in an earlier section.

DESCRIPTION OF DEVELOPMENT SITES

Fulton River with a drainage area of 532 square miles, flows in an easterly direction through Chapman Lake (2.7 square miles) and through Fulton Lake (3.5 square miles) and empties into

Babine Lake at Topley Landing. The elevation of Fulton Lake is approximately 190 feet higher than that of Babine Lake. Fulton River passes over a 40-foot falls immediately downstream of Fulton Lake and 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 falls. Fulton River is the principal spawning stream entering the main basin of Babine Lake. The spawning populations since 1949 have ranged from 15.2 to 170 thousand with an average of 83 thousand. This average figure accounts for one-half of the observed spawners in the main lake tributaries.

The Fulton River hydrograph is characterized by low winter flows (in the range of 30 to 70 cfs); a flood peak occurring in May or June, resulting primarily from snowmelt (maximum recorded flow of 6900 cfs); and variable flows in the autumn with flood peaks caused by storm rainfall.

Pinkut Creek discharges into Babine Lake in the southeast part of the main basin. The Pinkut Creek drainage area is approximately 320 square miles and includes three lakes: Taltapin Lake (8.6 square miles), Augier Lake (3.7 square miles) and Pinkut Lake (2.1 square miles). Access to salmon is limited to the lower 1200 yards of stream by an impassable falls. 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 146 thousand and a 1949-1966 average of 33 thousand.

The runoff characteristics of the Pinkut Creek area are similar to those of the Fulton Lake area, with low flows observed in the winter and a flood peak, resulting from snow-melt, occurring in June. The autumn floods are less prominent than those observed at Fulton.

Morrison River has a drainage area of approximately 183 square miles and drains in a southerly course through a series of valleys into Babine Lake. The Morrison River sockeye 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. The runoff characteristics are similar to the Pinkut Creek area, with the flood peaks being less prominent.

INVESTIGATIONS AND DESIGN

Studies on these streams were oriented to obtain a complete physical representation of the three areas so as to permit a variety of development projects to be proposed utilizing various combinations of spawning channel development, stream improvement and flow control schemes. An integral part of these studies were comprehensive field surveys to: a) obtain stream flow measurements to complement the hydrology studies which eventually form the basis for a feasibility study of any water-use scheme; b) establish topographic mapping of the streams, their banks and those adjacent areas considered suitable as potential spawning channel sites; c) assess the various lakes and lake outlets for suitability as storage reservoirs and for possible dam sites; d) determine the physical characteristics of the stream in terms of velocity, depth, stream gradient and gravel composition. An interpretation of these physical characteristics of the stream with information gathered from biological studies of spawning behaviour and densities ultimately serve as the basic criteria in the eventual spawning channel design.

Upon completion of the field investigations, engineering studies were carried out to: a) determine the potential of the various spawning channel sites; b) determine the degree of control and regulation necessary both to maintain minimum flows and to prevent flood flows exceeding various specified limits. This included hydrology studies and an assessment of various types of dams and control works; c) assess the other factors affecting project arrangement and cost. These factors included: reservoir clearing; means of conveying water to artificial spawning areas; and effects of staging construction so as to best utilize available spawning stocks and also in consideration of availability of funds.

Following completion of these studies, engineering designs were undertaken to better define the possible arrangement of a number of projects and to prepare cost estimates of the projects.

The relative potential of the different projects indicated that it would be economical to proceed with partial flow control and artificial spawning channel projects at Fulton River and Pinkut Creek. The Morrison River system is considered to have potential for a spawning channel development project, but was assigned a lower priority than either the Fulton River or Pinkut Creek because of the low level of present escapements and its location.

The consulting engineering firm of G. E. Crippen and Associates was engaged to investigate and report on the means of obtaining flow control and regulation, and more recently has been authorized to prepare detailed plans and specifications for this phase of the work. The consulting engineering firm of Dolmage, Mason and Stewart was retained to consult on the geological conditions in the area and to prepare plans and specifications for the tunnel project.

DESCRIPTION OF THE DEVELOPMENT PROGRAM

General

As stated earlier, the primary objective of the development program is to increase the sockeye fry output to the main lake basin of Babine Lake so that the potential of Babine Lake as a nursery area will be more fully realized. In January, 1965 a program was approved whereby a combination of projects on the Fulton River and Pinkut Creek would add in excess of 100 million fry to this lake area. Looking beyond the present program, the development works at Fulton and Pinkut contain provision for future expansion and, with the implementation of similar development works at Morrison River, there appears to be the potential for producing sufficient numbers of fry to eventually create an average density of young sockeye in the main lake basin approaching the optimum density. The initial development program started in 1965 with construction of the first of two spawning channels on the Fulton River. The total program is scheduled over a seven-year period with completion set for 1971.

Description of Fulton River Project

The Fulton River Project consists of a partial flow control scheme and the development of several artificial spawning channels (Figure 3).

A 25-foot concrete gravity dam at the outlet of Fulton Lake will create a reservoir with a capacity of 76,000 acre-feet and will provide flow regulation of Fulton River ranging from a minimum of 100 cfs during the spawning and incubation period to a maximum of 3500 cfs during the spring runoff. In addition, a minimum flow of 100 cfs will be provided for the artificial spawning channels. A typical flow schedule and its relation to the life stage of sockeye salmon is shown in Figure 4.

The control works for regulating Fulton Lake outflow (Figure 3) consists of a vertical gate-shaft, a 12-foot diameter concrete-lined tunnel approximately 500 feet long, and a valve house at the tunnel outlet, several hundred feet downstream from the storage dam.

The gate-shaft consists of three gates which will permit either the selection of water from various depths in the reservoir or be capable of discharging surface water over the full range of reservoir levels. In addition provisions exist for an auxiliary, low-level, intake pipe to be extended into the lake in the event cooler water is required, for mixing purposes, to obtain the desired degree of temperature control.

Flows will be regulated by two 84-inch diameter and one 30-inch diameter hollow-cone valves.

Clearing of approximately 1800 acres of undeveloped lakeshore area which will eventually be flooded will be scheduled over a three-year period. Realizing the potential importance of Fulton Lake as a recreation and conservation area, the specifications for reservoir clearing are being developed through liaison with the Provincial Departments of Forestry, Parks, Fish and Wildlife, and Water Resources.

It was mentioned earlier that the development program was initiated in 1965 with the construction of the Fulton River Spawning Channel No. 1 (Figures 5 and 6). This channel, 4800 feet long and 30 feet wide, can accommodate 22,000 adult spawners with and will produce an estimated 12,000,000 fry. The channel is located in an area immediately adjacent to the Fulton River and utilizes the section of river with a relative steep gradient to obtain the required head for successful operation. A unique aspect of this channel is the use of a composite timber and concrete divider wall to form sections of the channel (Figure 6) and thus derive the maximum spawning area in the land area available while still maintaining a channel cross-section and flow conditions consistent with the head available.

A second channel (Figure 3) is proposed for Fulton which will accommodate 135,000 adult spawners. This channel, 16,700 feet long and 50 feet wide and with the expected egg-to-fry survival of 40 percent, will produce 68,000,000 fry. The site of this channel, although relatively flat and thus ideal for channel construction, is approximately 40 feet higher than the river channel and thus presents a problem for water supply. A number of proposals were examined and it was ultimately decided to convey the water directly from Fulton Lake through a combined tunnel and pipeline approximately 10,000 feet in length. The water supply tunnel is a 7.5 foot diameter modified horseshoe type and is 3800 feet long and will originate from the regulating tunnel, approximately 75 feet from the gate structure.

An added feature in obtaining water directly from Fulton Lake is the capability of providing cooler water to offset the possible heating effects of solar radiation during the start of the adult migration in late August.

Description of Pinkut Creek Projects

The range or scope of development programs at Pinkut Creek was very limited since the stream is only accessible to salmon in its lowermost 1200 yards. The provision of fish-passage facilities to extend distribution above the falls was soon ruled uneconomical and the choice was soon resolved to an artificial spawning channel development in a large area of low-lying land adjacent to the main spawning grounds at the mouth of Pinkut Creek.

As part of the initial program, a channel 8000 feet long and 40 feet wide with a velocity of 1.9 fps and depth of 1.3 feet has been designed to accommodate 54,000 adult spawners with an expected fry production of 37 million (Figure 7). A second stage channel, 12,000 feet long and 40 feet wide, will be added at a later date.

A small diversion dam will divert water in the canyon area above the spawning grounds, through 750 feet of tunnel to the channel intake structure. The channel design provides for all waters circulated through the spawning channel to be directed back into Pinkut Creek upstream of the main spawning grounds.

Since minimum flows of 7 cfs have been recorded during spawning and incubation periods, the need for a storage reservoir was obvious. The spawning channel is designed to operate at 100 cfs during spawning periods and 70 cfs during incubation, and requires a minimum storage capacity of 32,000 acre-feet to provide the minimum flows during the period August 15 to May 15.

Proven dam sites were available at the outlets of both Taltapin Lake and Augier Lake. The Taltapin Lake site was chosen since it was possible to obtain the required storage without undertaking any reservoir clearing. This matter again was developed through liaison with the Provincial Government to maintain the recreational value of the areas surrounding the lakes. The entire storage at Taltapin Lake can be obtained below the maximum flood level of the lake by dredging a series of small lake areas immediately downstream of the dam site. This dredging work was considered desirable to obviate reservoir clearing. The dam and control works (see Figure 7) consists of a rockfill overflow weir, with a concrete cap and sheet pile cut-off, and an outlet structure and pipeline with a minimum capacity of 75 cfs.

The dam is six feet high and its crest 303 feet long; the 54-inch diameter outlet pipe is approximately 400 feet long. The dam and control works were completed in 1966.

PRESENT STATUS OF PROJECT

The Babine Lake Development Program is entering the third year of a seven-year construction program. Three projects have been completed to date: Fulton River Spawning Channel No. 1; The Regulating Tunnel and Water Supply Tunnel at Fulton River; The Taltapin Lake Control Works. The remaining projects at Fulton River will be scheduled as outlined in Figure 3, while the construction of the spawning channel at Pinkut Creek will be completed in time for the 1968 adult migration.

Of the three projects completed, only the Fulton Spawning Channel is fully operational. A total of 21,000 adult salmon spawned successfully in the channel last fall and a full assessment program in the spring will measure the success of the channel as a fry producer. The Taltapin Lake Control Works will, by virtue of providing a minimum flow of 70 cfs, assist in the egg-to-fry survivals of the natural spawning beds of Pinkut Creek. The full benefits, however, will only be realized with the completion of the artificial spawning channels.

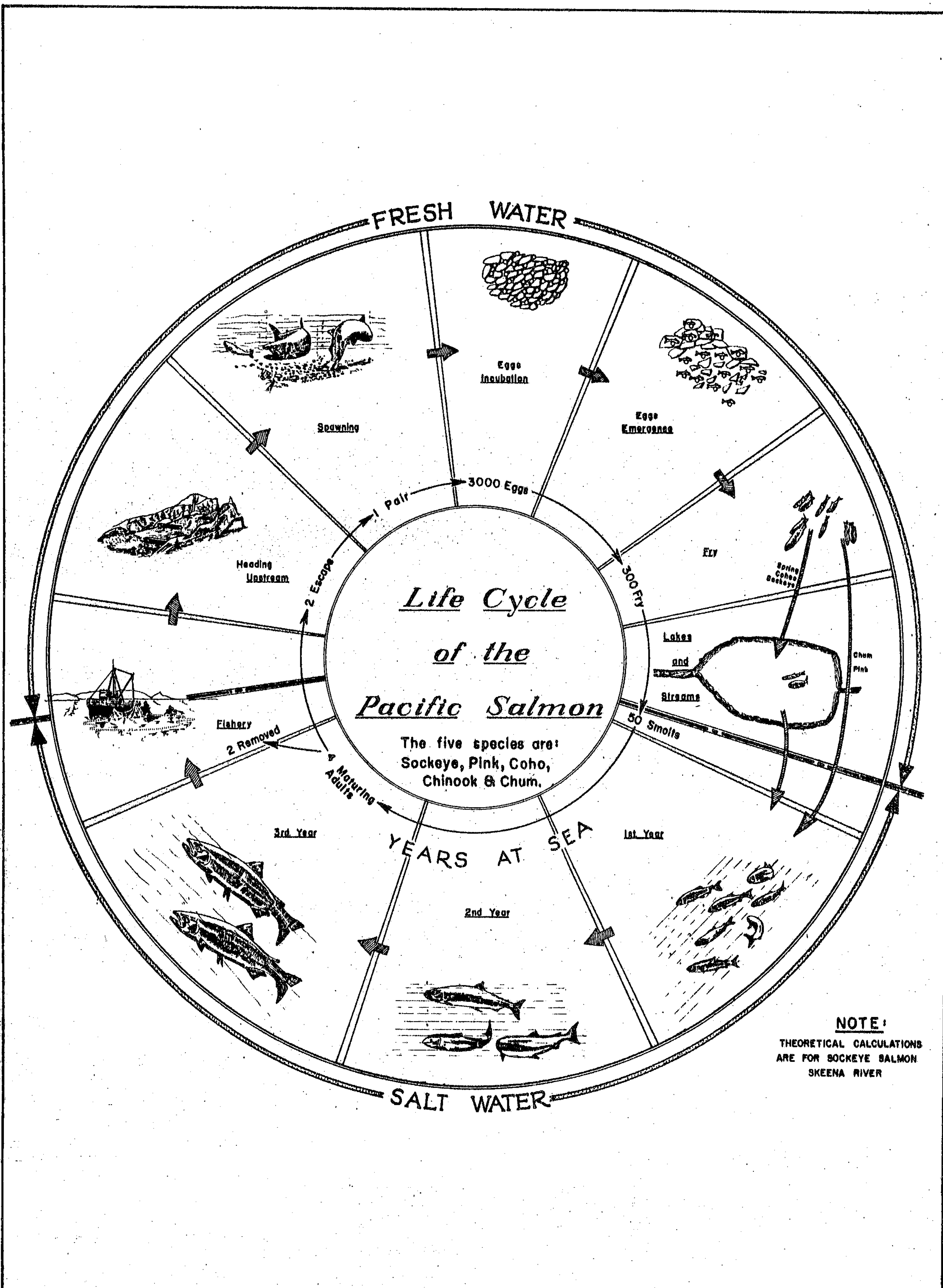
The total estimated cost of the program is $8 million, with the Fulton River projects totalling $5.5 million and the Pinkut Creek projects totalling $2.5 million.

EVALUATION

An evaluation of the development program will be conducted not only to measure the success of the program but also to reveal the success or failure of the methods used to exploit the potential of the Main Lake Region of Babine Lake as a sockeye salmon rearing area.

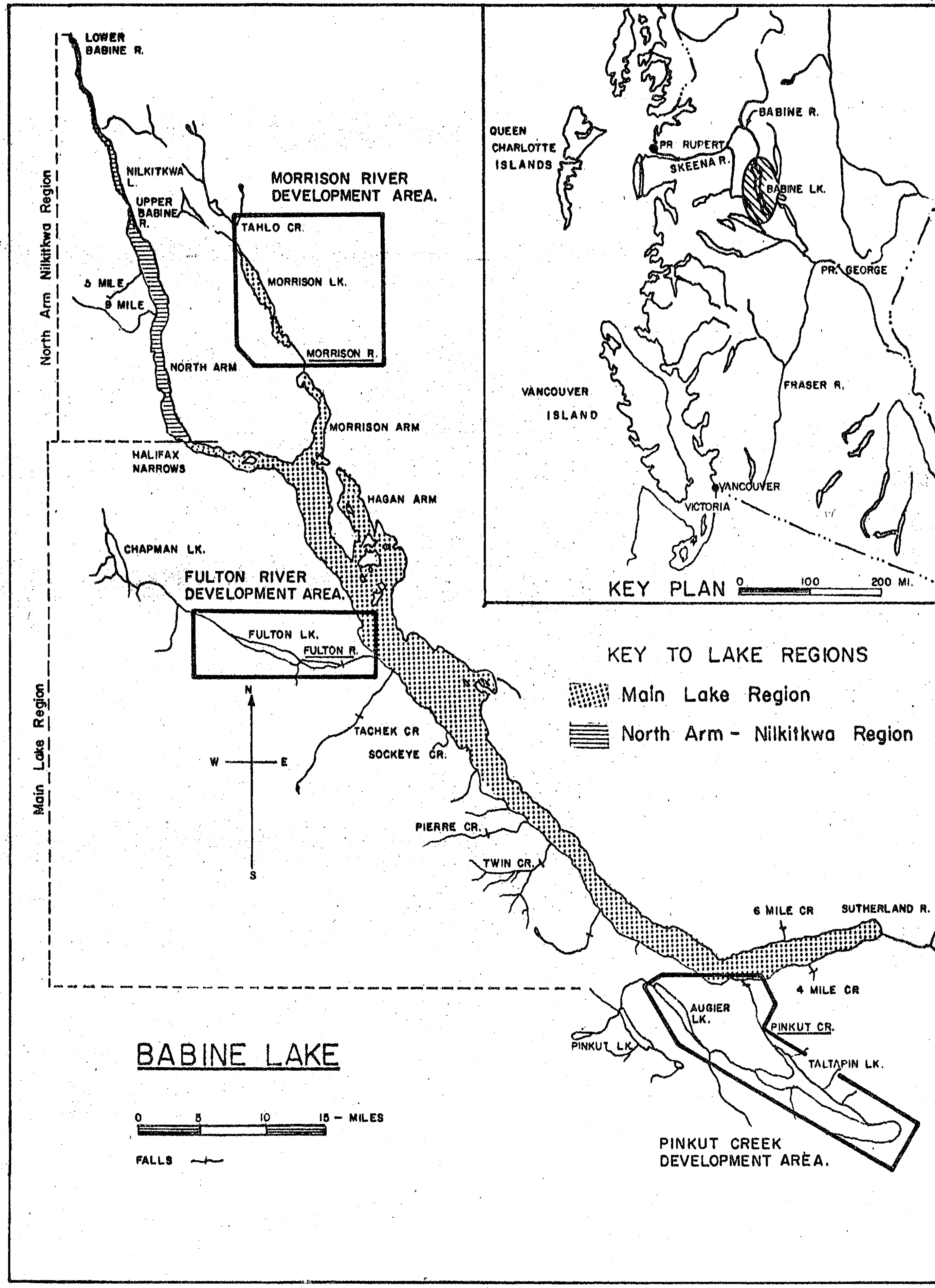
The evaluation studies will include:

1. Measurements of the effectiveness of the fish cultural methods used (i.e. spawning channels, water flow and temperature control).
2. A comparative study of the viability of "survival potential" of fry produced in artificial spawning channels and fry produced on the natural spawning grounds.
3. Measurements of the growth and survival of both types of fry as lake populations increase.
4. Measurements of the overall gain in adult production.



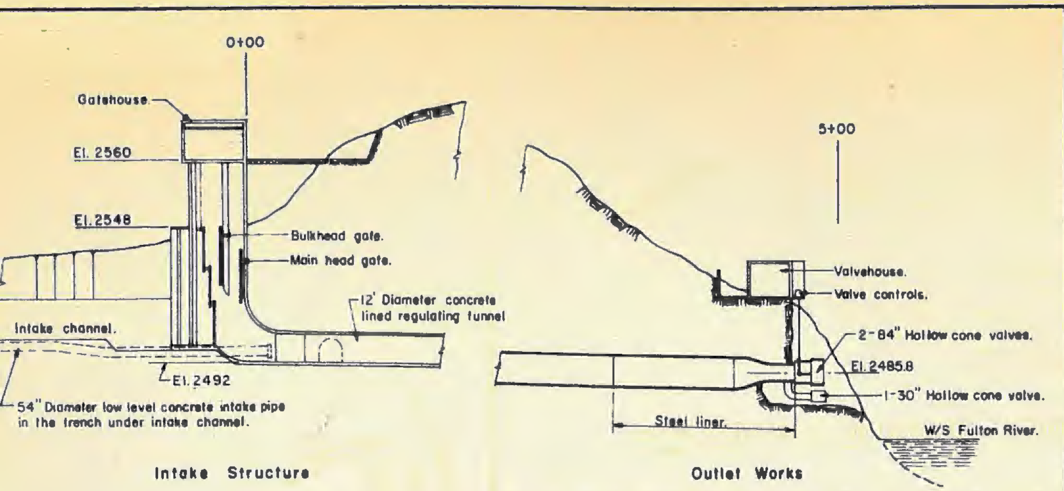
FRESH WATER
Life Cycle of the Pacific Salmon
The five species are: Sockeye, Pink, Coho, Chinook & Chum.
Eggs Incubation
Eggs Emergence
Fry
Spring Coho Sockeye
Chum Pink
Lakes and Streams
1st Year
2nd Year
3rd Year
Fishery
Heading Upstream
Spawning
1 Pair
3000 Eggs
300 Fry
50 Smolts
4 Maturing Adults
2 Removed
2 Escape
YEARS AT SEA
SALT WATER
NOTE:
THEORETICAL CALCULATIONS ARE FOR SOCKEYE SALMON SKEENA RIVER

Figure 1



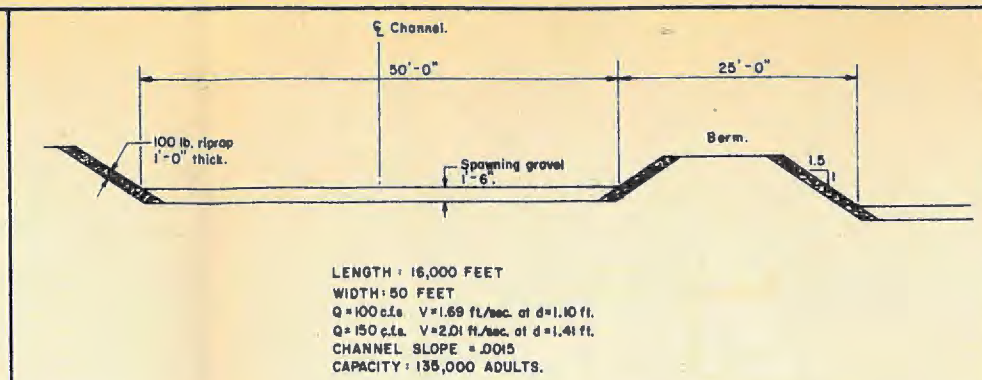
LOWER BABINE R.
NILKITKWA L.
UPPER BABINE R.
5 MILE
9 MILE
NORTH ARM
North Arm Nilkitkwa Region
MORRISON RIVER DEVELOPMENT AREA.
TAHLO CR.
MORRISON LK.
MORRISON R.
MORRISON ARM
HALIFAX NARROWS
HAGAN ARM
CHAPMAN LK.
FULTON RIVER DEVELOPMENT AREA.
FULTON LK.
FULTON R.
Main Lake Region
N
W
E
S
TACHEK CR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

Figure 2.



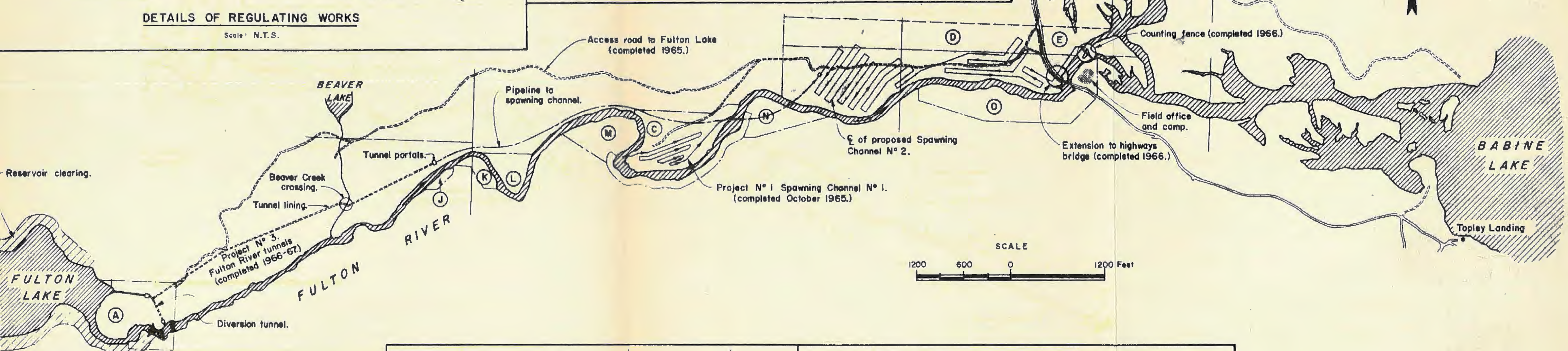
DETAILS OF REGULATING WORKS

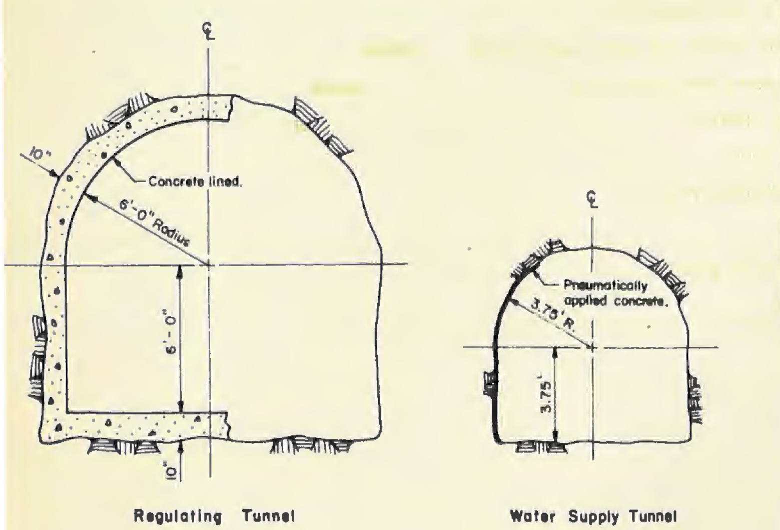
Scale: N.T.S.



TYPICAL SECTION THRU' SPAWNING CHANNEL N° 2.

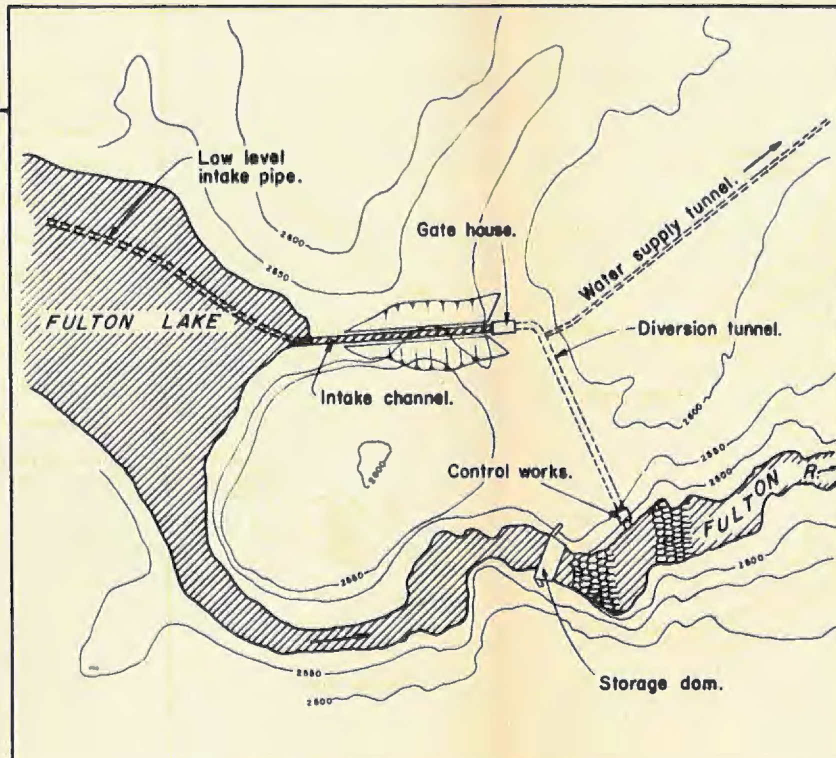
Scale: 1" = 20'





TYPICAL SECTIONS OF TUNNEL

Scale: 1" = 8'



DETAIL OF CONTROL WORKS

Scale 1" = 400'

SCHEDULE OF CONSTRUCTION

FULTON RIVER PROJECTS	1965	1966	1967	1968	1969	1970	1971	1972
1 Spawning Channel N° 1	▬							
2 Flow Control and Regulation								
(a) diversion tunnels and water supply tunnel		▬						
(b) control works and tunnel lining			▬					
(c) reservoir clearing				▬	▬			
(d) storage dam					▬			
3 Spawning Channel N° 2								
(a) stage 1					▬	▬		
(b) water supply pipeline						▬		
(c) stage 2							▬	

DEPARTMENT OF FISHERIES, CANADA

BABINE LAKE DEVELOPMENT

FULTON RIVER

GENERAL LAYOUT

21-19-G75

DATE: JANUARY 16, 1967. DRAWN: SW SCALE: As noted.

DESIGN CHECK

R. A. Fahlman, SENIOR ENGINEER — APPROVED: L. Edgeworth, CHIEF ENGINEER

DWG NO. 21-19-G75.

Figure 7

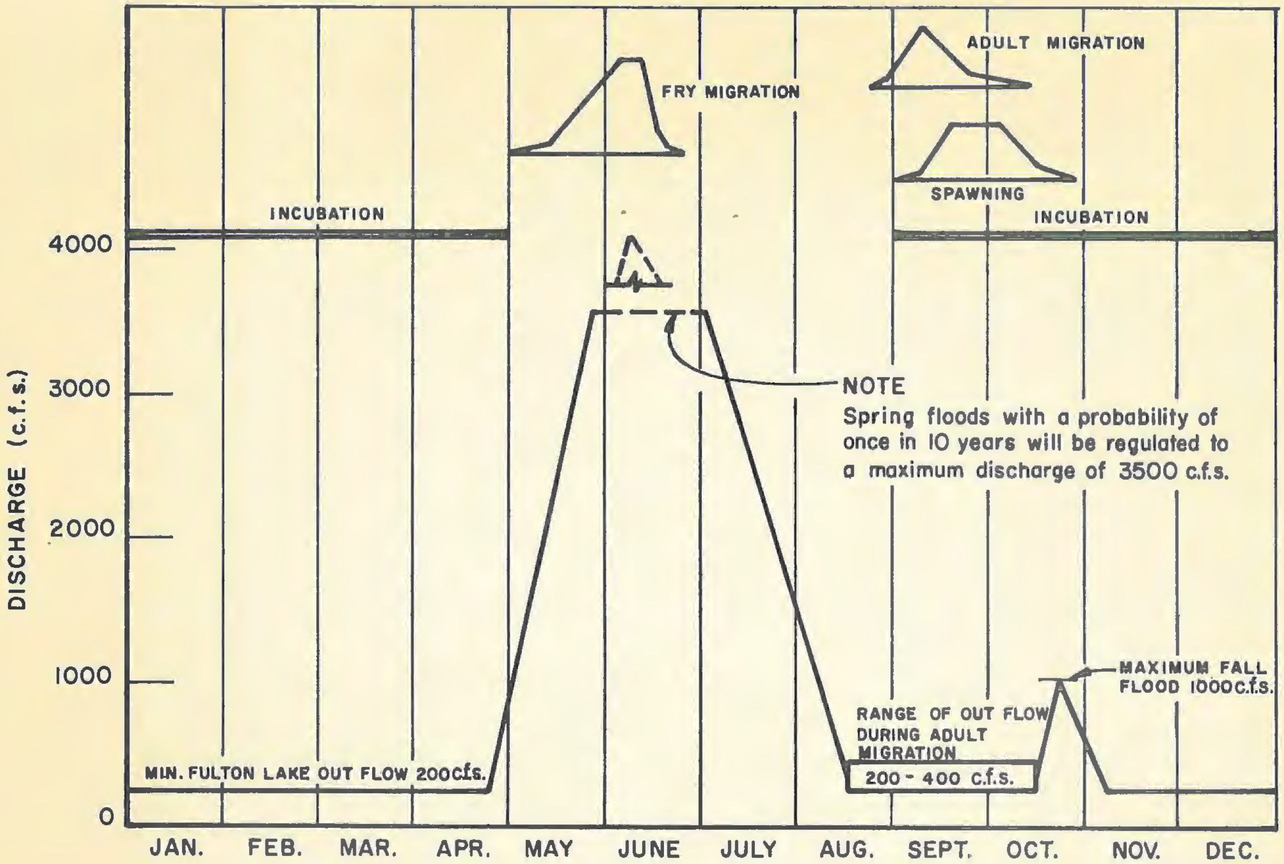
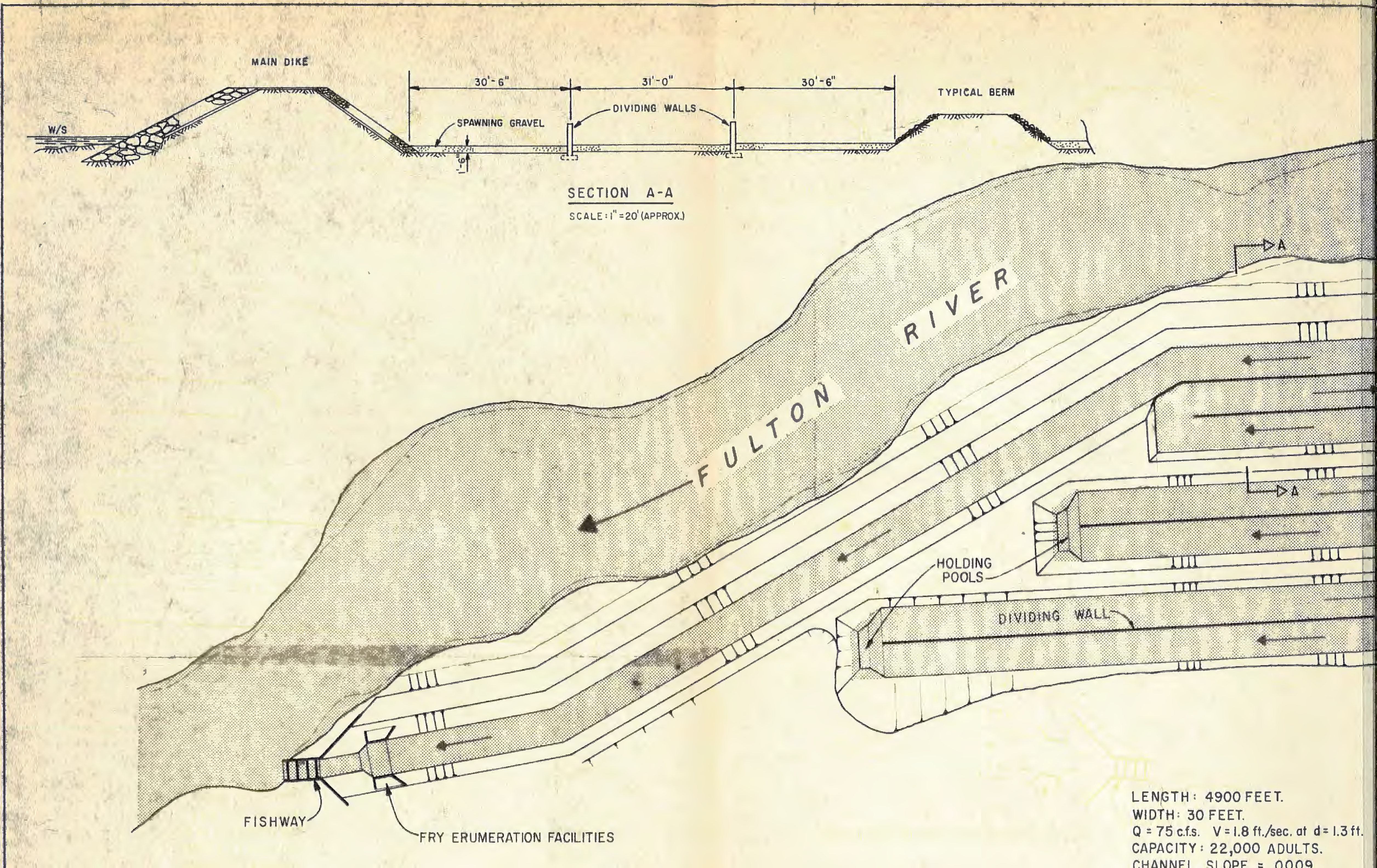


Figure 4. A typical flow regulation curve for Fulton Lake showing its relation to adult migration, spawning, incubation and fry migration.

Figure 5. Fulton River Spawning Channel N° I.


MAIN DIKE
W/S
30'-6"
31'-0"
30'-6"
SPAWNING GRAVEL
DIVIDING WALLS
1'-6"
TYPICAL BERM
SECTION A-A
SCALE: 1" = 20' (APPROX.)
FULTON RIVER
A
A
HOLDING POOLS
DIVIDING WALL
FISHWAY
FRY ERUMERATION FACILITIES
LENGTH: 4900 FEET.
WIDTH: 30 FEET.
Q = 75 c.f.s. V = 1.8 ft./sec. at d = 1.3 ft.
CAPACITY: 22,000 ADULTS.
CHANNEL SLOPE = .0009

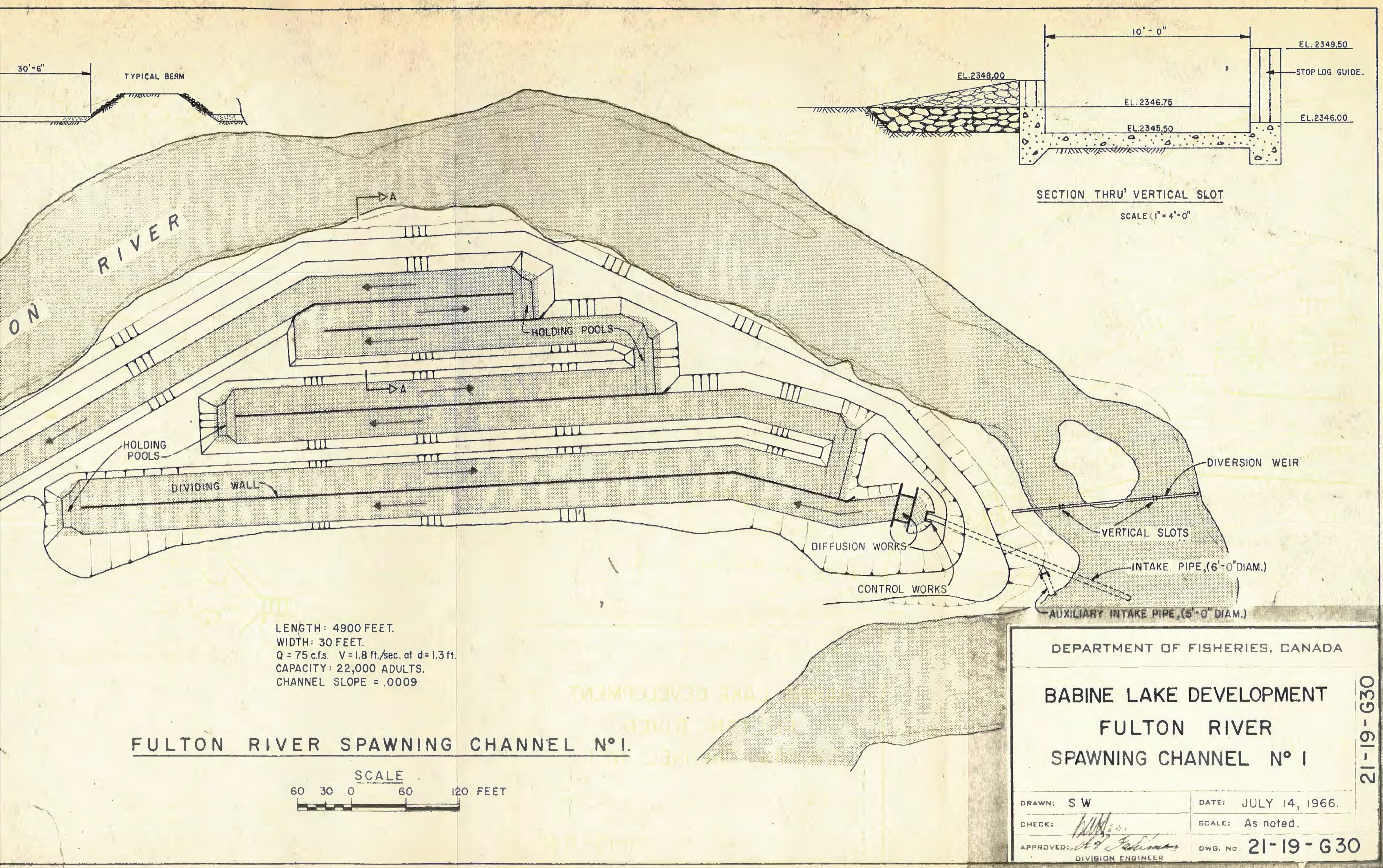
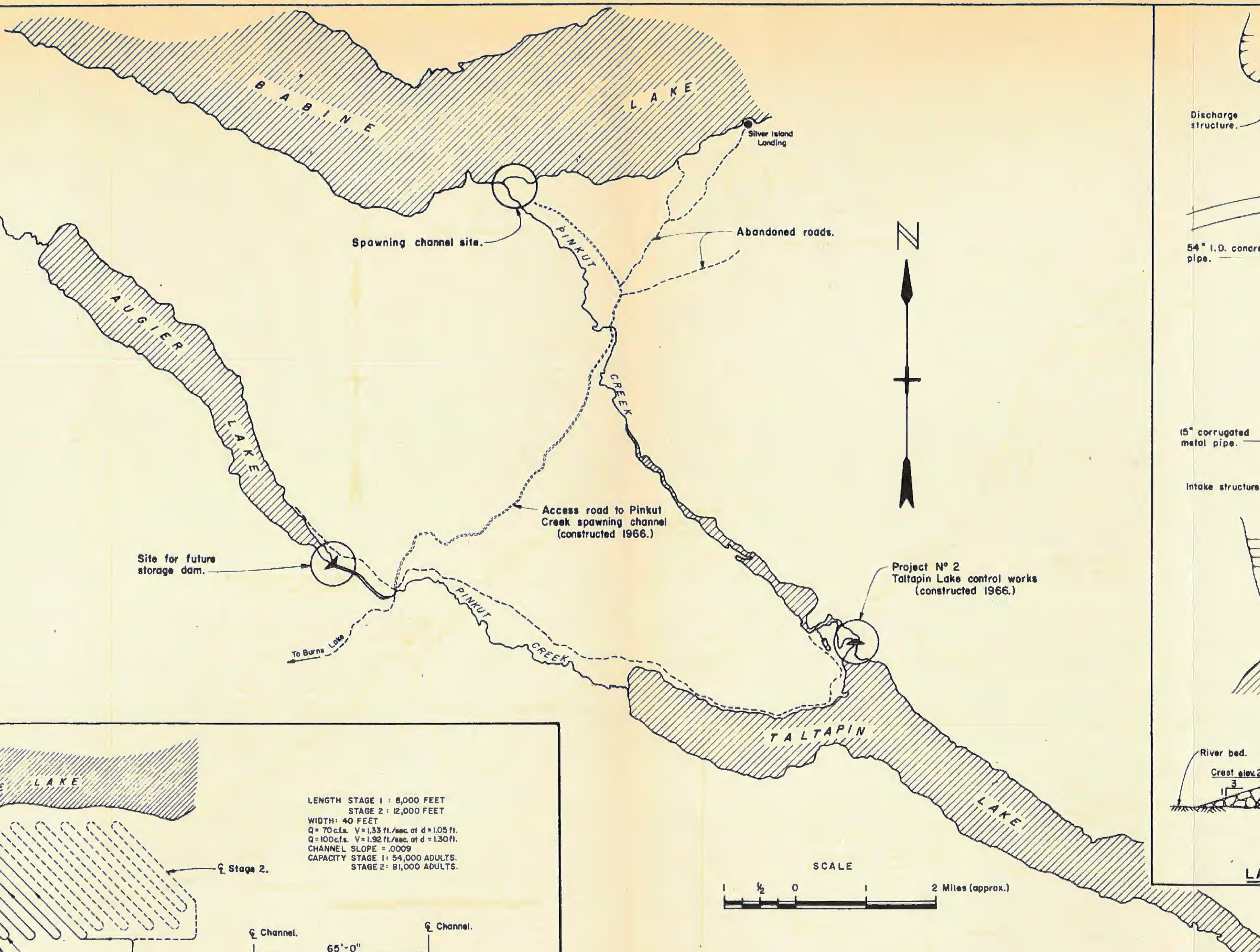
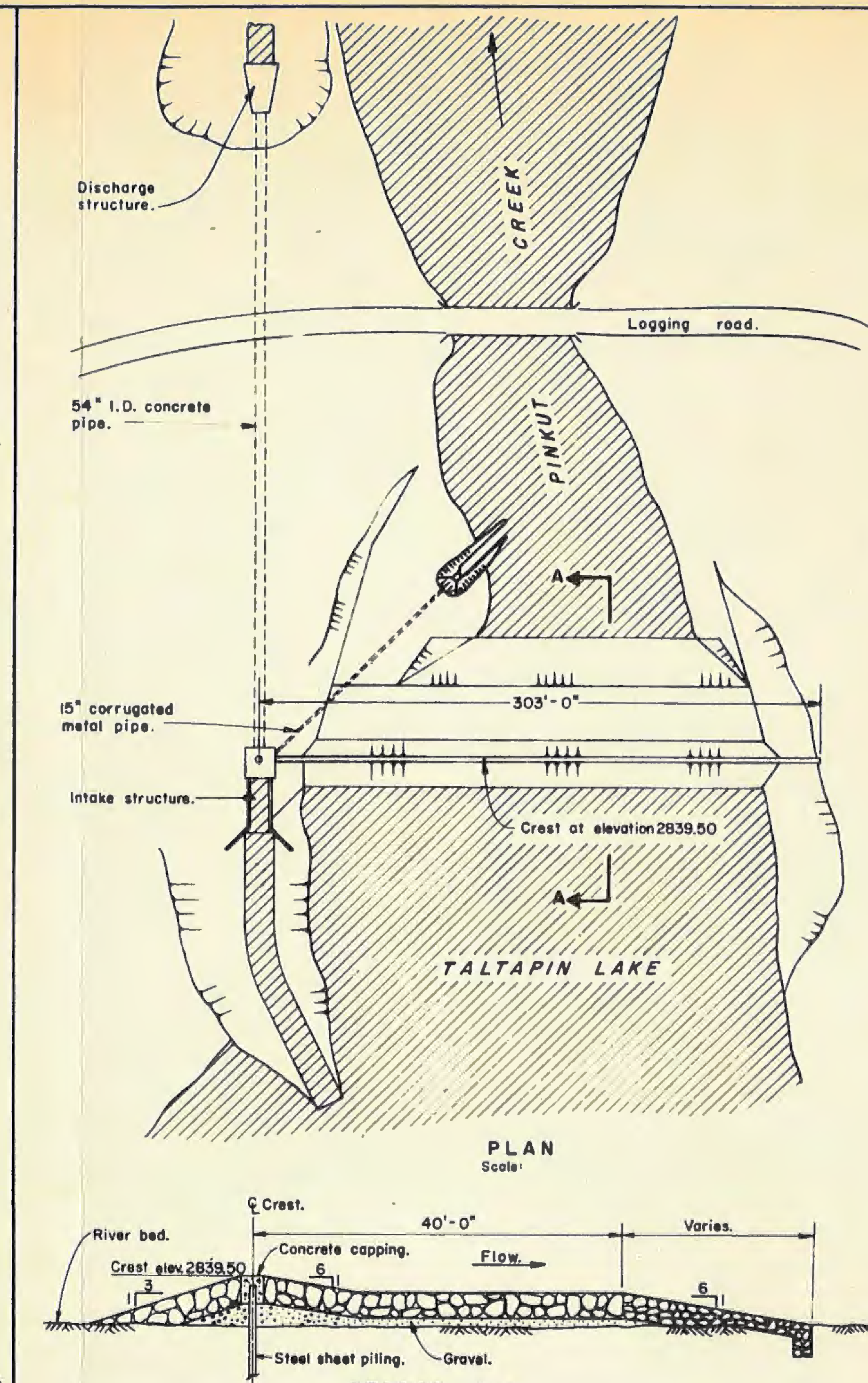
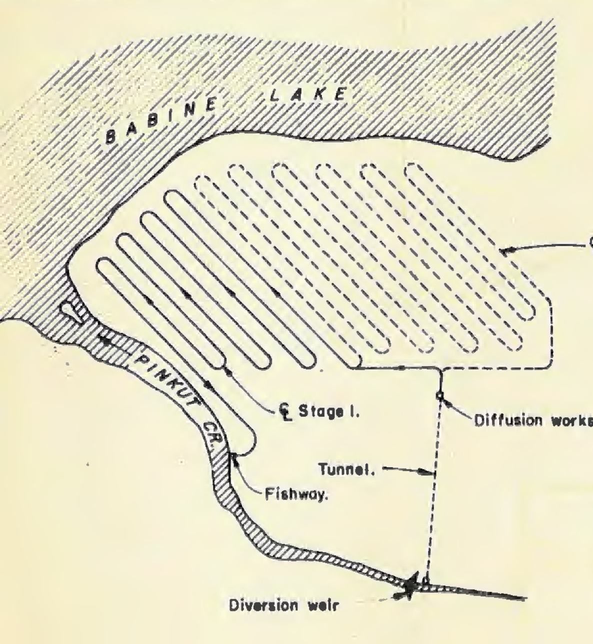

30'-6"
TYPICAL BERM
10'-0"
EL. 2349.50
STOP LOG GUIDE.
EL.2348.00
EL. 2346.75
EL.2346.00
EL.2345.50
SECTION THRU' VERTICAL SLOT
SCALE : 1" = 4'-0"
RIVER
HOLDING POOLS
HOLDING POOLS
DIVIDING WALL
A
A
DIVERSION WEIR
VERTICAL SLOTS
DIFFUSION WORKS
INTAKE PIPE, (6'-0" DIAM.)
CONTROL WORKS
AUXILIARY INTAKE PIPE, (5'-0" DIAM.)
LENGTH: 4900 FEET.
WIDTH: 30 FEET.
Q = 75 c.f.s. V = 1.8 ft./sec. at d = 1.3 ft.
CAPACITY: 22,000 ADULTS.
CHANNEL SLOPE = .0009
FULTON RIVER SPAWNING CHANNEL N° 1.
SCALE
60 30 0 60 120 FEET
DEPARTMENT OF FISHERIES, CANADA
BABINE LAKE DEVELOPMENT
FULTON RIVER
SPAWNING CHANNEL N° 1
21-19-G30
DRAWN: S W
DATE: JULY 14, 1966.
CHECK:
SCALE: As noted.
APPROVED:
DIVISION ENGINEER
DWG. NO 21-19-G30

Figure 6.





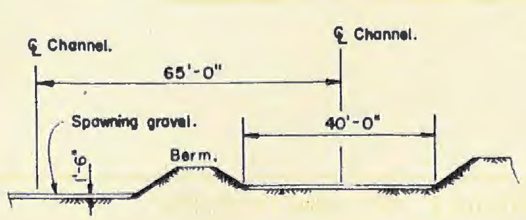
LAYOUT OF TALTAPIN LAKE CONTROL WORKS



LAYOUT OF SPAWNING CHANNEL

Scale: 1" =

LENGTH STAGE 1 : 8,000 FEET
STAGE 2 : 12,000 FEET
WIDTH: 40 FEET
Q = 70 c.f.s. V = 1.33 ft./sec. at d = 1.05 ft.
Q = 100 c.f.s. V = 1.92 ft./sec. at d = 1.30 ft.
CHANNEL SLOPE = .0009
CAPACITY STAGE 1 : 54,000 ADULTS.
STAGE 2 : 81,000 ADULTS.



TYPICAL SECTION THRU' CHANNEL

Scale:

SCHEDULE OF CONSTRUCTION

PINKUT CREEK PROJECTS	1965	1966	1967	1968	1969	1970	1971	1972
1 Storage Dam (Taltapin Lake control works.)		▬						
2 Spawning Channel stage I.			▬	▬				

DATE	NO	REVISION	BY

DEPARTMENT OF FISHERIES, CANADA

BABINE LAKE DEVELOPMENT
PINKUT CREEK
GENERAL LAYOUT

21-18-G14

DATE JANUARY 16, 1967 DRAWN S W SCALE As noted
DESIGN CHECK
APPROVED
SENIOR ENGINEER CHIEF ENGINEER
DWG NO 21-18-G14

Figure 7