

INTERNATIONAL PACIFIC SALMON  
FISHERIES COMMISSION

## PROGRESS REPORT

No. 36

### EVALUATION OF THE PRODUCTION OF SCKEYE AND PINK SALMON AT SPAWNING AND INCUBATION CHANNELS IN THE FRASER RIVER SYSTEM

BY

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NEW WESTMINSTER, B. C.

CANADA

1977

INTERNATIONAL PACIFIC SALMON  
FISHERIES COMMISSION

Appointed under a Convention  
Between Canada and the United States for the  
Protection, Preservation and Extension of  
the Sockeye and Pink Salmon Fisheries  
in the Fraser River System

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## ABSTRACT

A description is presented of each of the five spawning channels and one incubation channel operated by the Commission. Details of survival from eggs deposited to returning adults are presented, together with the costs and benefits.

The six channels were built over the period 1960-1974 at a cost of \$1,682,000. Five of them, costing \$921,000, have produced sockeye and pink salmon with a landed value of \$10,000,000 in this period. As utilization of these channels increases to optimum levels, it is expected that the average annual landings will be doubled.

The construction of additional similar facilities as recommended by the Commission is considered fully justified.

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## INTRODUCTION

As part of its responsibilities under the Sockeye Salmon Convention of 1937, the Commission investigated the possible use of prepared spawning channels and/or incubation channels for increased production of Fraser River sockeye and pink salmon. The results of preliminary investigations have been reported previously (Andrew and Geen 1960) (Cooper 1965), and in the justification reports that accompanied Commission recommendations for the construction of production facilities (IPSFC 1959, 1964, 1965, 1966, 1966a, 1969, 1970, 1972). Fundamental to these justifications was the determination that fry produced by the channels were the equivalent of wild fry (Brannon 1965). Examination of fry produced by channels has verified this finding (Mead and Woodall 1968).

The purpose of this report is to describe the facilities that have been built, and to present information on production of these facilities.

## OPERATING PRODUCTION FACILITIES

The Commission now operates spawning channels for sockeye salmon at Weaver Creek, Gates Creek and Nadina River, an incubation channel for sockeye at Upper Pitt River, and two spawning channels for pink salmon at Seton Creek (FIGURE 1). Details of start of operation and size are summarized in TABLE 1.

TABLE 1 - Summary of operating facilities.

<u>Channel</u>	<u>Start of Operation</u>	<u>Area Sq Yd</u>
Upper Seton	1961	6,019
Upper Pitt	1963	711
Weaver	1965	20,846
Lower Seton	1967	20,886
Gates	1968	13,489
Nadina	1973	21,639

Each of the production facilities utilizes the concept of increased intra-gravel flow of water to increase the survival from eggs to fry, but the details of construction and water flow employed at each facility have evolved through experience and the special requirements of the sites.

FIGURE 1 - Fraser River watershed showing location of existing production facilities.

## UPPER SETON CREEK CHANNEL

## Description

This channel for pink salmon was the first of its kind to be built by the Commission, and was therefore regarded as an experimental production facility. Its purpose was to partially compensate for the 30,000 sq yd of natural spawning ground lost upstream from the B. C. Electric Co. (now B. C. Hydro and Power Authority) power intake dam on Seton Creek.

The channel is located on 25.6 acres of land between the power canal and Seton Creek (FIGURE 2), leased from B. C. Hydro and Power Authority. The upper portion of the channel is excavated in land about 30 ft above Seton Creek, but the lower portion is close to the level of Seton Creek and dykes were necessary to confine the flow in the channel. The channel drops 21.5 ft in its length of 3029 ft, and there are 21 cobble drop structures provided. The channel is 20 ft wide by 2918 ft long at the gravel surface (FIGURE 3), and deducting the areas occupied by drop structures, has an area of 6019 sq yd of spawning gravel. The gravel is 16 in. deep and was placed level at 1 ft elevation steps between drop structures. Above the upper drop structure there is 880 ft of channel at a slope of 0.0006. This slope was calculated to provide a water depth of 1.5 ft at an average velocity of 1.25 fps for a discharge of 40 cfs with Manning's  $n = 0.035$ . The crests of the drop structures were placed 0.84 ft above the gravel surface upstream to maintain the same depth and velocity between drops. The sides of the channel are lined with cobble to protect the banks from erosion and digging by the salmon, and also to give a natural appearance to the artificial stream.

The water supply of 40 cfs is obtained from the B. C. Hydro and Power Authority canal. Two 20 in. steel pipe siphons 103 ft long lift water over the canal embankment and discharge it into a diffusion basin at the upper end of the channel.

Because of the high elevation of the upper end of the channel relative to Seton Creek, it was anticipated there could be leakage of water from the channel to the creek. The channel was excavated in 1960 and temporary wooden drop structures installed. Water was then run through the channel and a substantial leakage loss of 11 cfs out of a flow of 30 cfs was found in the top 1014 ft of channel. Clay was then added to the water flow and also dumped in specific areas of large leakage.

After 157 cu yd of material was added, the leakage was reduced to 6 cfs. In the summer of 1961 the excavation was trimmed to design grades, and the cobble lining and drops and the gravel were placed, ready for the 1961 spawners. In the summer of 1966, a check on the leakage loss showed the loss was still 6 cfs.



FIGURE 2 - Upper Seton channel.

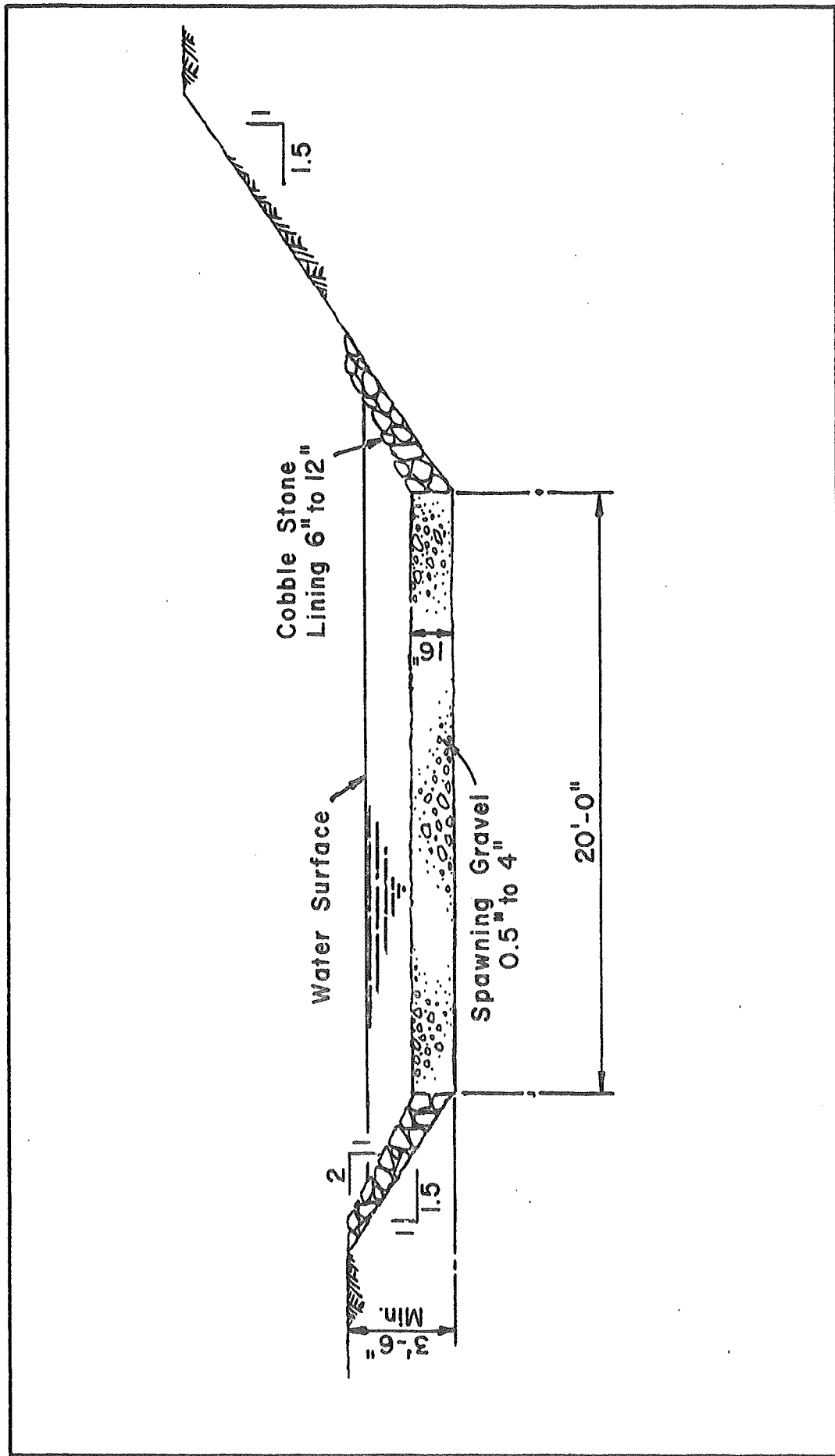


FIGURE 3 - Typical cross section of Upper Seton channel.

The spawning gravel was manufactured from a nearby hillside in a glacial till deposit. This material was dry sieved to obtain the fraction between 4 in. and 1/2 in. sieve sizes. The specification limits for the gravel are given in TABLE 2.

TABLE 2 - Gravel sieve size, specification limits and actual size placed.

Square Sieve Size, Inches	Specification Percentage Dry Weight Passing Sieve	Actual Placed
4	100	100
3	77-100	86.9
2	50-100	70.1
1½	34-89	53.0
1	16-74	28.5
¾	0-64	12.6
½	0	2.5

The gravel obtained from the deposit had a substantial amount of angular pieces which had a tendency to fracture when handled repeatedly. This characteristic has contributed to an increase in fine material in the gravel since placing.

A picket fence with V-trap at the downstream end of the channel is used to control the entry of salmon. Initially, all salmon were counted into the channel, but as experience has been gained, the fish have been allowed free access until the approximate desired population has entered, based on live counts. Initially, the capacity of the channel was estimated to be about 1.5 pink salmon per sq yd, or approximately 10,000 spawners, but this was modified to about 1 fish per sq yd when the lower channel was built.

#### Results

The channel has been operated each pink salmon cycle year since 1961. Data on the numbers of spawners, egg deposition and fry production are given in TABLE 3. In 1963, the entrance closure gate failed when the channel had been nearly filled, and an excess of spawners entered the channel overnight before the situation could be rectified. From 1971 on, an effort has been made to limit the number of spawners

to approximately 0.6 to 0.7 females per sq yd (IPSFC 1972a), as it was indicated that this would be the optimum number for maximum fry production. However, data for subsequent years (FIGURE 4) suggests that the optimum number may be as high as 0.9 females per sq yd or about 5400 females.

TABLE 3 - Upper Seton channel pink salmon spawners, egg deposition and fry production.

Brood Year	Spawners		Success of Spawning Percent	Effective ♀	Fecundity	Eggs Deposited Millions	Fry Produced Millions	Survival Eggs to Fry Percent
	Total	♀ Only						
1961	6,711	3,322			2,065	6.860	3.592	52.4
1963	14,106	8,107			1,976	16.022	3.480	21.7
1965	7,000	4,082			1,903	7.767	2.681	34.5
1967	7,143	3,985			1,795	7.154	3.180	44.4
1969	3,975	2,452			1,950	4.781	2.222	46.5
1971	6,007	3,831	96.7	3,705	1,764	6.535	5.587	85.5
1973	6,708	4,165	98.9	4,120	1,778	7.325	5.477	74.8
1975	7,995	5,228	97.2	5,083	1,821	9.300	7.632	82.1

In 1962, 1964, and 1966, the fry output was measured by collecting all the fry at a weir located at drop #3. This location was necessary to avoid the possibility of backwater from Seton Creek. The fry were measured volumetrically and the total number was extrapolated for the portion of the channel downstream from the weir site. In 1966, 1968, 1970 and 1972, the fry output was sampled by fyke net and extrapolated from this sample, using the correlation obtained with the weir measurement in 1966. In 1974 and 1976 the fry output has been measured by release of known numbers of dye-marked fry and recapture in a fyke net.

Comparison of egg to fry survival with density of spawners does not indicate any relationship up to a spawner density of 0.9 females per sq yd (FIGURE 5).

The production of returning adults and the catch obtained are given in TABLE 4. These data are prorated on the basis of numbers of fry produced by the channel and by the whole Fraser River system.

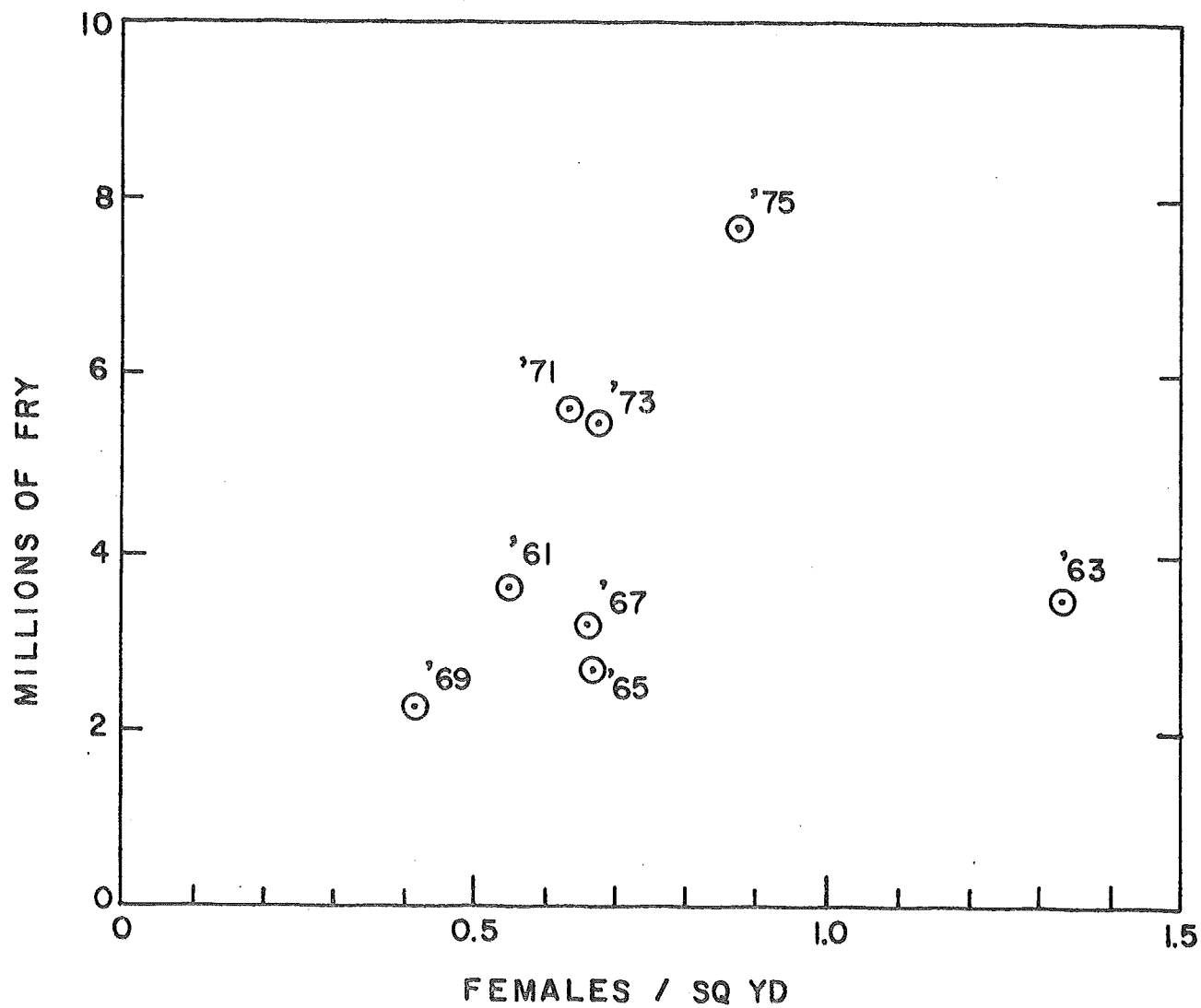


FIGURE 4 - Pink salmon fry production in relation to spawning density in the Upper Seton spawning channel.

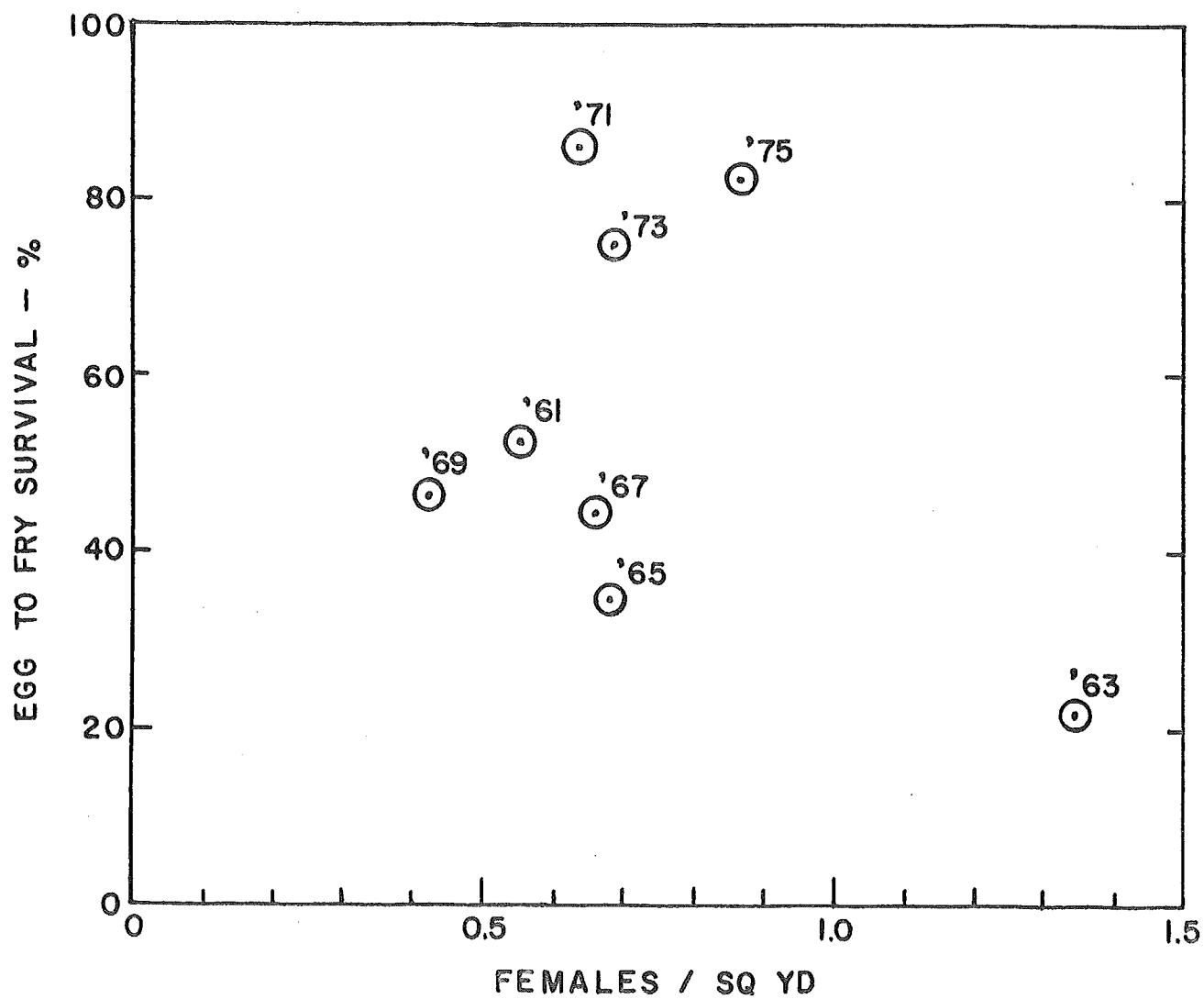


FIGURE 5 - Pink salmon egg to fry survival rate in relation to spawning density in the Upper Seton spawning channel.

TABLE 4 - Upper Seton channel adult pink salmon production and catch from channel spawners.

Brood Year	Adult Total Run	Percent Return		Commercial Catch		
		From Eggs	From Fry	Fish	Pounds	Landed Value *
1961	133,200	1.94	3.7	84,356	425,998	\$ 47,243
1963	28,000	0.17	0.8	13,426	84,852	11,200
1965	126,900	1.63	4.7	108,800	578,816	86,186
1967	50,700	0.66	1.6	30,588	182,610	30,331
1969	110,000	2.92	5.0	87,893	448,254	82,523
1971	156,500	1.78	2.8	114,176	605,133	212,583
1973	<u>92,200</u>	1.12	1.7	<u>67,711</u>	<u>401,526</u>	<u>148,564</u>
Total	697,500			506,950	2,727,190	\$ 618,630

\* At each catch year's prices.

The channel produced more return spawners than were allowed into the channel, and these "surplus" fish spawned in the adjacent natural spawning ground. The incremental rate of return for these surplus fish would be less than for the total creek population because of the effect of density of spawners, but an additional increment of catch would be produced, at least until the natural spawning grounds are fully utilized. When this occurs, the addition of surplus spawners could cause an incremental reduction in return. Because of difficulties in assessing the actual returns from the "surplus" spawners, production values for these fish can only be estimated. In the six cycle years from 1963 to 1973 there was an average of 19,879 surplus spawners, and allowing for reduced rate of production of this increment of spawners, it is estimated that an additional 735,000 lb of catch was obtained, with a cumulative landed value of \$191,376 at each year's prices. The initial stock of 6711 spawners used to start the project would have produced a catch with a landed value of \$16,040 if they had spawned in the creek. Deducting this value gives a total additional benefit of \$175,336 at each year's prices. The percentage return from eggs in the channel compared to the return from all the natural pink salmon spawning areas in the Fraser River system (TABLE 5) shows that the channel produced returns at a rate from 1.8 to 6.4 times greater than the natural spawning grounds, with an average of 3.8 times greater return.

TABLE 5 - Percent return of adults from eggs in the Upper Seton channel compared to all natural pink salmon spawning grounds in the Fraser River system.

Brood Year	Upper Channel	Fraser System Natural Spawning Grounds	Ratio of Channel to Natural
1961	1.94	0.332	5.84
1963	0.17	0.093	1.83
1965	1.63	0.860	1.90
1967	0.66	0.174	3.79
1969	2.92	0.454	6.43
1971	1.78	0.329	5.41
1973	<u>1.12</u>	<u>0.246</u>	<u>4.55</u>
Weighted Average	1.24	0.328	3.77

#### Benefits and Costs

The capital cost of the channel was \$32,259 in 1960-61. Allowing for only a 20-year life, the annual capital recovery cost at 6% interest would be \$2,812. The channel has been in operation for 15 years now, and it is obvious that its life expectancy is more than 20 years, so this is a conservative assumption that increases the annual capital recovery charges.

The normal operating costs are now shared with the second channel built in 1967, as one operator handles both projects. Converting each year's operating costs using the Vancouver cost of living index, the average annual operating cost has been \$2,708 in 1961 dollars. The capital and operating costs combined thus total \$5,520 in 1961 dollars (TABLE 6).

The pink salmon produced by the channel spawners from the brood years 1961-73 have resulted in landings with a total value of \$618,630. However, at the 1961 landed value of 14¢ per lb for pink salmon, the total landed value would be \$381,806 or an average of \$27,272 annually in 1961 dollars.

TABLE 6 - Summary of costs and benefits for Upper Seton channel.

		<u>On Basis of 1961 Dollars</u>	<u>On Basis of 1975 Dollars</u>
Capital Cost		\$ 32,259	\$ 87,422
Annual Costs:			
Capital Recovery		\$ 2,812	\$ 7,621
Operating		<u>2,708</u>	<u>4,576</u>
	Total:	5,520	12,197
Annual Benefits:			
Channel spawners		\$ 27,272	\$ 72,076
Surplus spawners less initial brood		<u>7,243</u>	<u>9,142</u>
	Total:	34,515	81,218
Benefit/Cost ratio		6.25	6.66
Average fry output, millions/cycle	4.23		
Average cost per million fry		\$ 2,595	\$ 5,767
Average landings, lbs/cycle			
Channel spawners	389,598		
Surplus spawners less initial brood	<u>103,474</u>		
Total:	493,072		
Average cost per lb		2.24¢	4.95¢

As previously mentioned, the incremental catch from "surplus" spawners produced by the channel would add to the benefits produced by the channel. In its first year of operation, the channel took 6711 spawners which otherwise would have spawned in the creek and produced a return in 1963. Deducting the catch attributable to these fish from the benefits produced by the surplus spawners gives a net benefit of \$86,918 at 1961 prices for the six cycles of returns, or \$7,243 average annual benefit. The total annual benefit thus has been \$34,515 for a benefit/cost ratio of 6.25.

To assist in comparing this project with each of the others described in this report, the foregoing costs have also been converted to 1975 dollars (TABLE 6), using 1975 landed values, Vancouver cost of living index, as above, and Engineering News-Record Seattle Construction Cost Index.

### Operation and Maintenance Problems

At the outset an operating problem arose with the siphons due to loss of prime caused by air entering the submerged upper end of the siphon through vortices that formed with certain operating conditions in the power canal. This was overcome by extending the siphon deeper into the canal to give at least 8 ft of submergence and by installing a large hood near the end of the pipes to discourage the formation of vortices.

The channel requires periodic removal of tumbleweed from its banks, but otherwise plant growth in the dry climate at Lillooet has not been a problem. Brown algae grow on the surface of the rocks in the channel, and form a mat which accumulates very fine sediment particles. During the period when the channel is not in use, which is 16 months out of every 24 months, this mat dries to form a cake which has an appearance much like dry cattle feces. For a number of years the gravel was raked by machine to break up this mat so that it would be flushed out when the water was turned on. The hydraulic gravel cleaner developed by the Commission also will remove this material. However, at this channel the cleaner has not been very successful in maintaining the quality of the gravel because of the character of the gravel. The gravel was produced from a nearby hillside of glacial deposit, and contains a substantial amount of shale-like material which is easily fractured. Over the years there has been a buildup of small stone chips from fracturing of the gravel. The hydraulic gravel cleaner flushes the chips out of the gravel, but they are so abundant and of such size that the surface flow of water in the channel is not sufficient to transport them downstream and out of the channel. Despite the obvious accumulation of fine material in the gravel, which amounts to thick muck between the stones at the bottom of the gravel layer, there has not been an accompanying decline in egg to fry survival. This may be because the eggs are not placed deep enough to be in the muck, or because the action in digging redds clears the muck out of the gravel in which the eggs are deposited. However, the accumulation of fine material is not regarded as favorable, since it reduces intragravel flow of water in the areas affected.

## UPPER PITT RIVER INCUBATION CHANNEL

## Description

In 1960, the Commission started operation of a hatchery for sockeye adjacent to Corbold Creek, a tributary of the Pitt River, about seven miles upstream from Pitt Lake. The 9.3 acre site was made available by a Crown Provincial Reserve. The hatchery was intended to supplement the production of sockeye fry from the Pitt River in an effort to halt the decline of the sockeye run. However, the fry produced in the hatchery were smaller than the fry produced in the natural spawning grounds (IPSF 1963) and in the fall of 1962 an experimental upwelling flow gravel incubation bed was put into operation to assess the quality of fry produced by this method. The results indicated the fry from the incubation bed were about the same size as fry from the natural spawning grounds, whereas the hatchery produced fry were smaller (Harvey 1963). Consequently, in 1963 a pair of upwelling flow gravel incubation beds were put in operation (FIGURE 6). Further tests in 1966 (Mead and Woodall 1968) also showed that fry from the incubation channel were comparable to fry from the natural spawning grounds, whereas hatchery fry were smaller.

The upstream bed measures 33.75 ft by 100 ft and the downstream bed 50.5 ft by 60 ft in plan, giving a gravel area of 6400 sq ft. The gravel bed is 16 in. deep.

The gravel was obtained from a commercial pit, using the fractions from 3/8 in. to 3/4 in. and was shipped in by barge to the upper end of Pitt Lake and then trucked to the site. The subgrade of each basin was covered with polyethylene sheet laid over a heavy kraft waterproof paper to minimize leakage of water into soil around and under each bed.

Water for the incubation beds is obtained from Corbold Creek either from a gravity intake above the falls, or in emergency situations, by pump from the pool below the falls. The water is passed through a settling tank with a 20 minute retention time, and then through a degasser tower (Harvey and Cooper 1962), and is delivered to a pipe manifold along each long side of the beds. Polyethylene pipes at 12 in. centers run under the gravel bed between the manifolds, and flow enters the bed through 3/16 in. diameter holes spaced at 12 in. centers along the top of each pipe. The total flow delivered to the beds is 2.0 cfs, giving an upwelling apparent velocity of 338 mm per hour (0.0094 cm/s). On the basis of

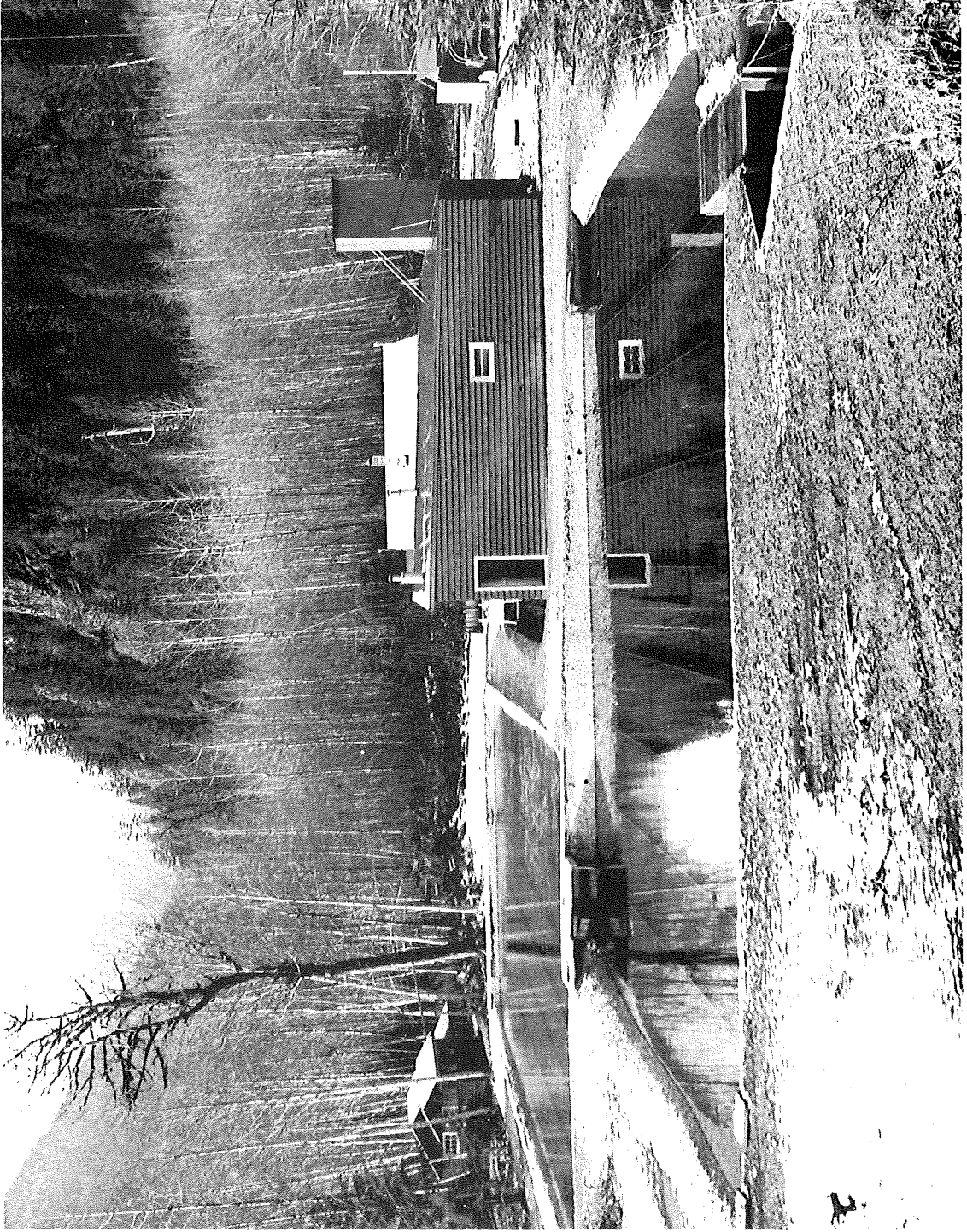


FIGURE 6 - Pitt River incubation beds and hatchery.

experimental data from tests by Pyper (Andrew and Geen 1960) this flow would give a survival of about 76% from eyed eggs planted to emerging fry.

The water above the gravel in each bed is about 12 in. deep at the shallow end. Partitions above the gravel make a channel 6 ft wide with alternate ends open for a 6 ft width. About one month prior to fry emergence the water flow is changed gradually from upwelling to stream flow between these partitions to promote emigration of the fry. A portion of the flow, ranging from 10% to 25%, is maintained as upwelling. The numbers of fry leaving the beds are determined by a 5% sampler (Davis and Hiltz 1971).

Eggs are taken from female sockeye at the natural spawning grounds in the Pitt River commencing late in August. These are fertilized and placed in the hatchery where they are incubated to the eyed stage. Infertile eggs are removed during the initial 48 hours, after which there is no handling of eggs until they are eyed. Dead eggs are again removed and the live eggs are placed in excavations in the gravel bed and covered with gravel. The incubation bed was built as large as could be accommodated on the land available and an initial objective of 4 million eggs was set, with the possibility of an increase in future if more than 4 million eggs could be obtained. At 4 million eggs, the density would be 625 eggs per sq ft, compared to 1000 eggs per sq ft used by Pyper in his tests.

### Results

The channel started operation in 1963. Data on the numbers of sockeye used for the egg take, and the number of eggs and fry are given in TABLE 7. The number of eggs planted has averaged 91.9% of the number taken from spawners, indicating only minor loss of eggs to the eyed stage. The survival from eggs spawned to fry emerging has averaged 82.4% and the survival from eyed eggs planted to emerging fry has averaged 89.7%, about 13.7% higher than indicated by Pyper's tests. There is no indication that density of egg deposition has had any effect on the survival from eggs planted to emerging fry.

The production of fry from the natural spawning grounds of the Pitt River system, compared to the channel production, are given in TABLE 8. These data are used to determine the proportion of the returning adults attributable to the channel. For the brood years 1963 to 1971, the fry produced from the natural spawning grounds have been estimated from the egg deposition by the 4 and 5 year old females and from a relationship between winter discharge patterns of the Pitt River and estimated egg to fry survival for the years 1951 to 1961 (Cooper 1967). For the years 1972 to 1975, the river fry production has been calculated from release and recapture of fry marked with Bismark brown dye.

TABLE 7 - Sockeye spawners, eggs and fry, Pitt River incubation channel.

Brood Year	Sockeye Male	Spawners Used Female	Eggs Spawned	Planted	Emerging Fry	Percent Survival from Eggs Spawned
1963	618	1,059	3,189,000	2,967,000	2,417,000	75.8
1964	478	1,118	3,700,000	3,465,000	3,256,000	88.0
1965	384	791	2,133,000	1,987,000	1,776,000	83.3
1966	513	1,198	3,658,000	3,260,000	2,868,000	78.4
1967	359	1,485	4,529,000	3,842,000	3,300,000	72.9
1968	498	985	3,163,000	2,870,000	2,673,000	84.5
1969	559	1,383	4,881,000	4,547,000	4,192,000	85.9
1970	205	619	2,151,000	1,997,000	1,744,000	81.1
1971	187	772	2,652,000	2,408,000	2,291,000	86.4
1972	226	1,142	3,359,000	3,359,000	2,998,000	79.0
1973	175	567	2,366,000	2,107,000	1,793,000	75.8
1974	365	1,033	3,437,000	3,196,000	2,622,000	76.3
1975	400	1,787	4,554,000	4,192,000	4,119,000	90.4
1976	411	1,262	4,648,000	4,310,000	3,861,000	83.1

There is no indication of correlation between the number of fry produced from the channel and Pitt River spawning grounds and percent survival to returning adults (FIGURE 7).

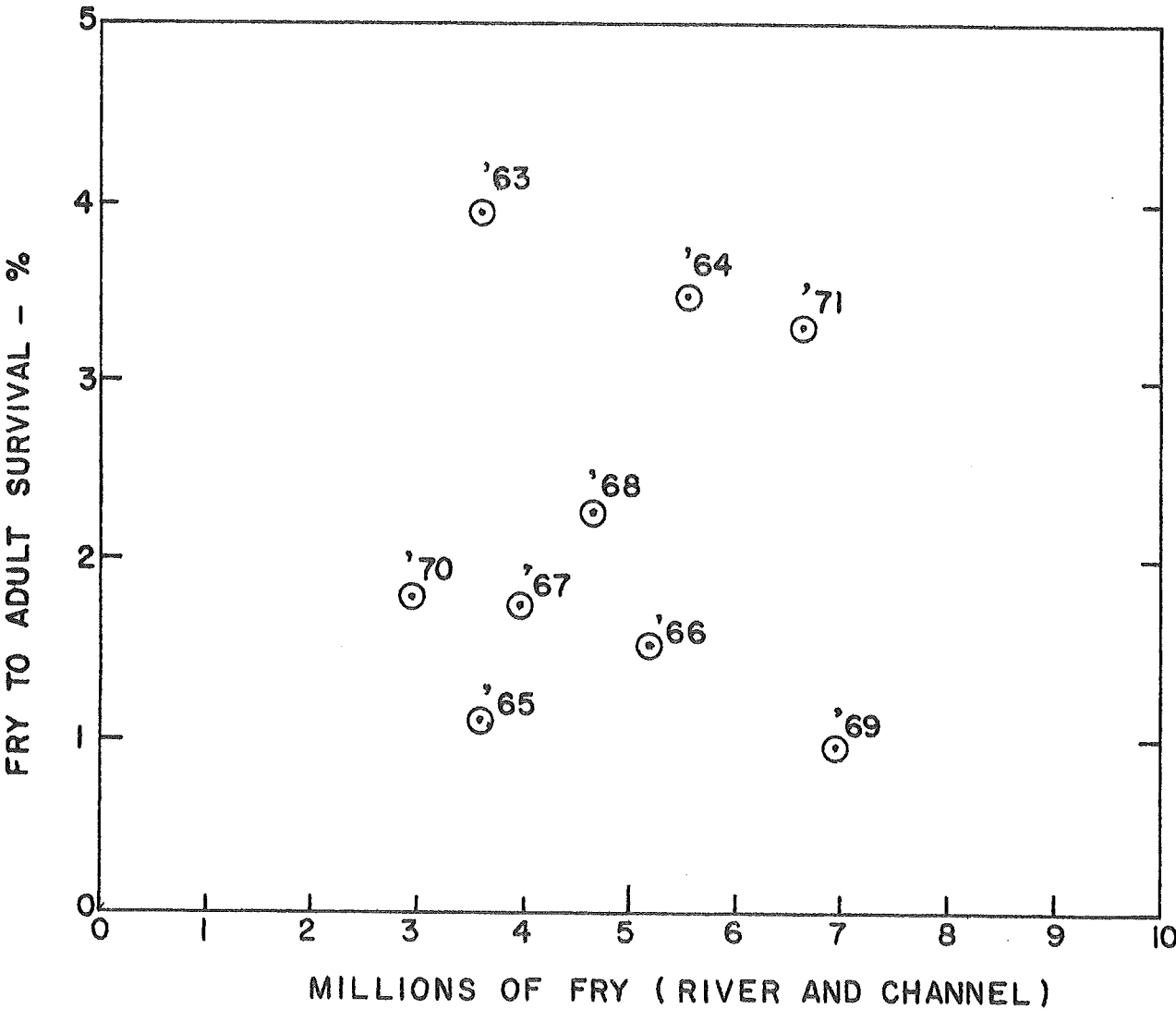


FIGURE 7 - Sockeye fry to adult survival rate in relation to the numbers of fry produced by spawning areas in Pitt River and the incubation channel.

TABLE 8 - Pitt River incubation channel sockeye fry output, and estimated sockeye fry output from natural spawning grounds of the Pitt River system.

Brood Year	Incubation Channel	Pitt River	Total	Percent from Channel
1963	2,417,000	1,187,000	3,604,000	67.06
1964	3,256,000	2,260,000	5,516,000	59.03
1965	1,776,000	1,773,000	3,549,000	50.04
1966	2,868,000	2,314,000	5,182,000	55.35
1967	3,300,000	656,000	3,956,000	83.42
1968	2,673,000	1,970,000	4,643,000	57.57
1969	4,192,000	2,764,000	6,956,000	60.26
1970	1,744,000	1,200,000	2,944,000	59.24
1971	2,291,000	4,353,000	6,644,000	34.48
1972	2,998,000	4,111,000	7,109,000	42.17
1973	1,793,000	1,959,000	3,752,000	47.79
1974	2,622,000	10,632,000	13,254,000	19.78
1975	4,119,000	3,790,000	7,909,000	52.08
1976	3,861,000	15,067,000	18,928,000	20.40

Data on the adult returns and catches produced by the channel are given in TABLE 9, showing a total catch of 440,412 fish for the brood years 1963 to 1971, with a landed value of \$1,892,947.

The channel produced more return spawners than required for use in the channel, with an average "surplus" of 7183 spawners in the years 1967 to 1971. These surplus spawners produced a cumulative catch of 110,837 sockeye weighing 860,690 lb with a landed value of \$716,318. In the first four years of operation the channel utilized 6159 sockeye spawners which otherwise would have spawned in the river and would have produced a catch of 33,119 fish with a weight of 251,668 lb and a landed value of \$104,394. Deducting this from the above catch produced by surplus spawners reduces that benefit to \$611,924.

Comparison of the percentage return from eggs taken for the incubation channel and eggs deposited in the natural spawning grounds shows that the channel has been 9.89 times more effective than the natural spawning grounds. (TABLE 10).

TABLE 9 - Pitt River incubation channel adult sockeye production and catch from channel eggs.

Brood Year	Adult Total Run *	Percent Return		Commercial Catch			**
		From Eggs	From Fry	Fish	Pounds	Landed Value	
1963	95,807	3.00	3.96	86,818	618,310	\$ 246,537	
1964	113,353	3.06	3.48	94,037	751,654	311,135	
1965	19,453	0.91	1.09	16,232	120,164	50,166	
1966	42,972	1.18	1.50	34,891	265,094	114,632	
1967	56,519	1.25	1.71	47,530	368,345	174,902	
1968	60,733	1.92	2.27	51,256	417,251	288,399	
1969	39,517 <sup>P</sup>	0.81	0.94	29,156	238,839	183,916	
1970	31,300 <sup>P</sup>	1.46	1.79	22,955	170,161	142,776	
1971	75,550 <sup>P</sup>	2.85	3.30	57,537	416,207	380,484	
Total	535,204			440,412	3,366,025	\$1,892,947	

\* Age 4 and 5 combined.

\*\* At each catch year's prices.

<sup>P</sup> Preliminary.

TABLE 10 - Percent return of adult sockeye from eggs taken for the Pitt incubation channel compared to returns from the natural spawning grounds in the Pitt River system.

Brood Year	Incubation Channel			Pitt River			Ratio of Channel to Natural Return Rate
	Millions of Eggs Taken	Adult Return	Percent Return	Millions of Eggs Deposited	Adult Return	Percent Return	
1963	3.189	95,807	3.00	19.781	47,060	0.24	12.50
1964	3.700	113,353	3.06	25.193	78,673	0.31	9.87
1965	2.133	19,453	0.91	11.822	19,421	0.16	5.69
1966	3.658	42,972	1.18	46.274	34,664	0.08	14.75
1967	4.529	56,519	1.25	16.395	11,232	0.07	17.86
1968	3.163	60,733	1.92	31.511	44,761	0.14	13.71
1969	4.881	39,517	0.81	49.780	26,061	0.05	16.20
1970	2.151	31,300	1.46	11.250	21,535	0.19	7.68
1971	2.652	75,550	2.85	29.020	143,563	0.50	5.70
Average			1.78			0.18	9.89

The record of total Pitt River sockeye runs since the 1948 brood year is given in TABLE 11. The record by return years is plotted in FIGURE 8.

TABLE 11 - Total adult Pitt River sockeye produced from brood years 1948 to 1971.

Brood Year	Total Adult Sockeye Produced	Channel	River
1948	122,720		
1949	20,778		
1950	146,275		
1951	120,302		
1952	72,178		
1953	25,807		
1954	51,052		
1955	166,952		
1956	70,308		
1957	29,207		
1958	16,523		
1959	62,483		
1960	33,314		
1961	102,961		
1962	57,229		
1963	142,867	95,807	47,060
1964	192,026	113,353	78,673
1965	38,874	19,453	19,421
1966	77,636	42,972	34,664
1967	67,751	56,519	11,232
1968	105,494	60,783	44,761
1969	65,578	39,517	26,061
1970	52,835	31,300	21,535
1971	219,113	75,550	143,563

The annual total run for the brood years 1948 to 1962 averaged 73,206 sockeye, whereas for the brood years 1963 to 1971 it has averaged 106,908. From 1963 to 1971 the return from the river has averaged 47,441, indicating a general decline from the previous 15 years. The channel produced an average total run of 59,467 in this period and was responsible for the overall increase in average run.

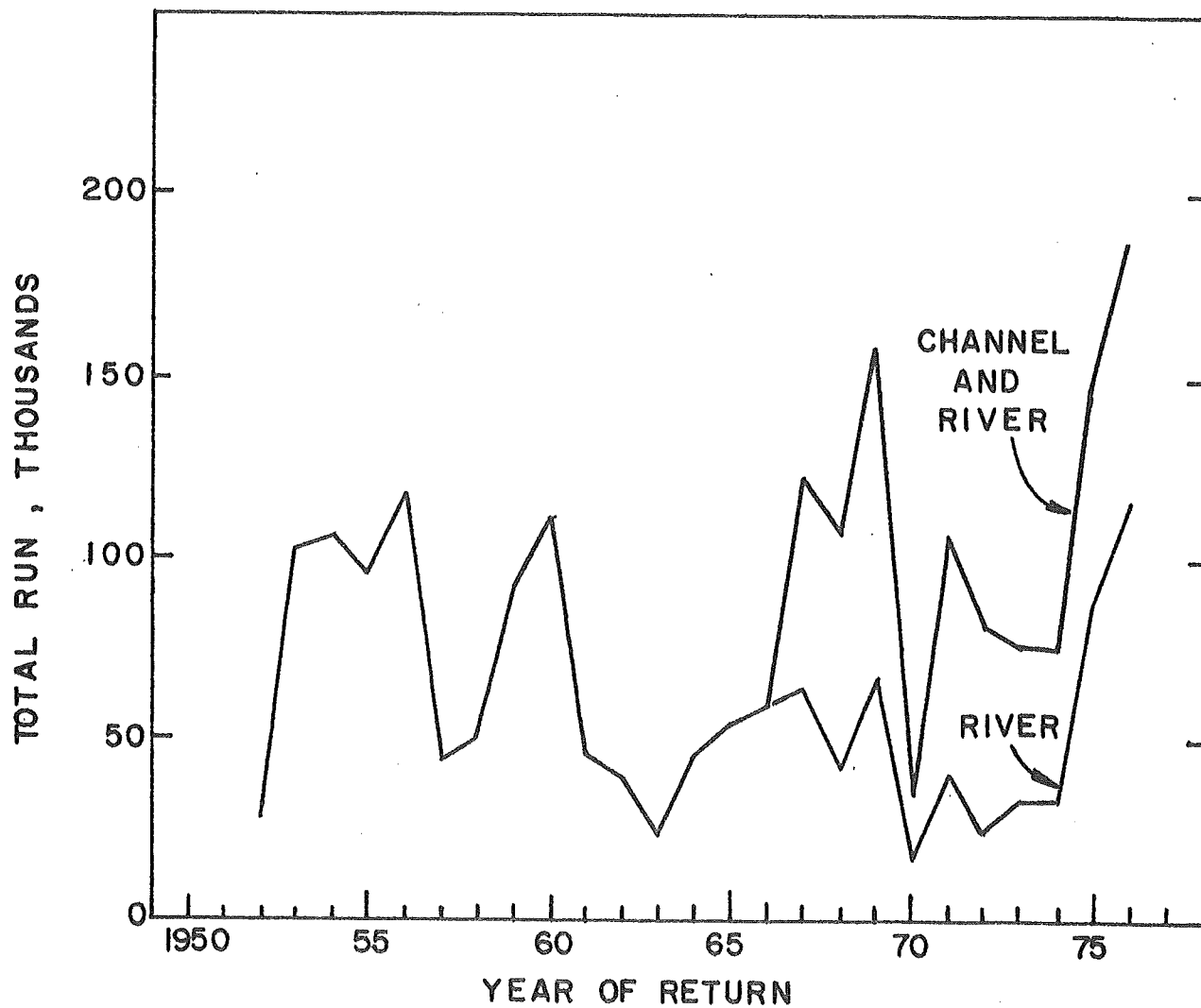


FIGURE 8 - Numbers of adult Pitt River sockeye produced from the natural spawning area and the incubation channel.

## Benefits and Costs

The capital cost of the hatchery and incubation channel was \$74,142 in 1961-1963. Allowing for a 20-year life, the annual capital recovery cost at 6% interest would be \$6,463 (TABLE 12).

Converting each year's operating costs to the 1963 base, the average annual operating cost has been \$13,667 in 1963 dollars. The capital and operating costs combined thus total \$20,130 in 1963 dollars.

The sockeye produced by the channel in the brood years 1963-71 have resulted in landings with a total value of \$1,892,947. At the 1963 landed value of 34¢ per lb, these landings would have an average annual value of \$127,161 in 1963 dollars.

The catch produced by surplus spawners, after deduction of the catch that would have been produced by the spawners taken for the channel in the first four years, added \$19,674 to the annual benefit, making a total of \$146,835 at 1963 prices. The benefit/cost ratio to date has been 7.29.

For comparison with the other projects, costs and benefits in terms of 1975 dollars and landed values are also given in TABLE 12.

TABLE 12 - Summary of costs and benefits for the Pitt River incubation channel.

	On Basis of 1963 Dollars	On Basis of 1975 Dollars
Capital Cost	\$ 74,142	\$ 186,838
Annual Costs:		
Capital Recovery	\$ 6,463	16,288
Operating	<u>13,667</u>	<u>22,632</u>
Total:	20,130	38,920
Annual Benefits:		
Channel spawners	\$ 127,161	\$ 325,532
Surplus spawners less initial brood	<u>19,674</u>	<u>50,342</u>
Total:	146,835	375,874
Benefit/Cost ratio	7.29	9.66
Average fry output, millions - 2.773		
Average cost per million fry	\$ 7,259	\$ 14,035
Average landings, lbs		
Channel spawners	374,003	
Surplus spawners	<u>67,669</u>	
Total:	441,672	
Average cost per lb	4.56¢	8.81¢

### Operation and Maintenance Problems

One major operation and maintenance problem at the Pitt station is the gravity water intake in Corbold Creek. A large bed load of sand and gravel is carried down the creek during freshets and enters the intake works where it deposits in the tunnel aqueduct. Special procedures and constant attention during such periods are necessary, and often the emergency pumped supply has to be used. However, the water supply system has never failed.

Another major problem is supersaturation of dissolved oxygen and nitrogen in the water supply during periods of large discharge in the creek. This was solved by the installation of a degassing tower (Harvey and Cooper 1962).

The only problem specifically associated with the upwelling flow gravel bed has been the accumulation of fine sediment and dead eggs in the gravel. Each spring after the fry have emigrated, the gravel has been cleaned by turning it over manually with a shovel while directing a high pressure jet of water into the gravel. A surface flow of water carries the flushed-out material away downstream as the bed is cleaned from the upstream end.

### Capacity of Rearing Area

The sockeye fry produced from the Upper Pitt River migrate downstream into Pitt Lake, where they reside for one or more years before migrating to the sea as smolts. Pitt Lake is unique in that its level is affected by tidal levels, and in that it has an estuary where the Upper Pitt River enters and a larger reverse estuary where flows in the Lower Pitt River enter from the Fraser River. The deep section of the lake between the two deltas is the area where the young sockeye rear.

It has been estimated (IPSFC 1972) that Pitt Lake has the capacity to rear at least 10 million sockeye fry. One indicator of the degree of utilization of a lake rearing area by sockeye is the number of scale circuli laid down during the year of lake residence. The number of circuli decreases as the numbers of fry being reared increases, and with large populations, such as occurs with the dominant cycle Adams River runs in Shuswap Lake, as few as 10 circuli will be formed. This does not mean that the rearing capacity of the lake is fully utilized, but it is an indication of substantial utilization. At Pitt Lake, the first year scale circuli (without spring growth) (TABLE 13) do not suggest that

the rearing capacity of the lake has been approached for the brood stocks 1947 to 1972. It is believed that the sockeye fry production for the 1974 brood may have been the largest ever reared in Pitt Lake, but the effect of this larger population on scale circuli will not be known until the return of adults in 1978.

TABLE 13 - First year scale circuli counts (without spring growth) for Pitt Lake 4<sub>2</sub> sockeye.

<u>Brood Year</u>	<u>Circuli</u>	<u>Brood Year</u>	<u>Circuli</u>
1947	13.53	1960	19.84
1948	16.94	1961	14.43
1949	18.14	1962	20.00
1950	16.40	1963	18.39
1951	17.13	1964	14.05
1952	15.43	1965	17.08
1953	16.74	1966	14.82
1954	18.41	1967	19.83
1955	16.90	1968	16.58
1956	16.61	1969	15.17
1957	16.30	1970	15.30
1958	21.30	1971	15.28
1959	18.70	1972	19.55

The index of standing crop of zooplankton may also reflect the cropping by large populations of sockeye. The available data for Pitt Lake (TABLE 14) do not indicate any correlation between the index of annual abundance of zooplankton and the numbers of sockeye fry produced from the Upper Pitt system (TABLE 8). The index of .11 in 1971, with only 2,944,000 fry present, is little different from the index of .12 in 1975, with 13,254,000 fry present.

TABLE 14 - Mean annual index of standing crop of zooplankton in Pitt Lake.

<u>Year</u>	<u>Index</u>	<u>Year</u>	<u>Index</u>
1956	0.09	1972	0.12
1965	0.17	1973	0.12
1968	0.12	1974	0.15
1970	0.13	1975	0.12
1971	0.11	1976	0.10

## WEAVER CREEK CHANNEL

### Description

This spawning channel for sockeye salmon was the first of its kind in operation. Its purpose was to restore the Weaver Creek sockeye salmon run which had declined as a result of the unstable condition of the spawning ground following logging in the watershed.

The channel is 9614 ft long by 20 ft wide, at the gravel surface, laid out in a serpentine arrangement to use all of the available land in the 33.5 acre site adjacent to Weaver Creek (FIGURE 9). It provides 20,846 sq yd of gravel. The fish entrance to the channel is located in Weaver Creek about one half mile upstream from its mouth at Morris Lake (FIGURE 10). The entrance consists of a weir type fishway with 9 pools 6 ft long by 12 ft wide and 10 drops. At minimum creek level the total drop is 5 ft. The surface entrance to the fishway may be closed, and the discharge diverted into a diffusion chamber for discharge upward through a grating under the entrance bay. This procedure is followed after the desired number of spawners have been obtained in the channel.

A collapsible steel grating barrier 39 ft long is located across Weaver Creek just upstream from the fish entrance and is used to divert sockeye into the channel. When the channel is filled to capacity the barrier is removed. One panel of this barrier has a flap gate that can be opened to allow salmon to continue upstream past the channel entrance when this can be done before the channel has been filled to capacity.

A basin 29 ft wide by 24 ft long is located at the top end of the entrance fishway, and was used for a V-trap for counting adults into the channel and for a 5% sampler to enumerate the emigrating fry. Use of the V-trap has been stopped as it impedes the entrance of fish. Numbers of spawners are estimated by counts along the length of the channel, and a final count is obtained from the dead pitch. All dead fish are removed and buried.

The gravel bed in the channel is 16 in. deep and consists of screened and washed material obtained from a pit in old stream material near the Chehalis River. The average grading of the gravel as placed is given in TABLE 15. The specifications were the same as for the Upper Seton Channel (TABLE 2).

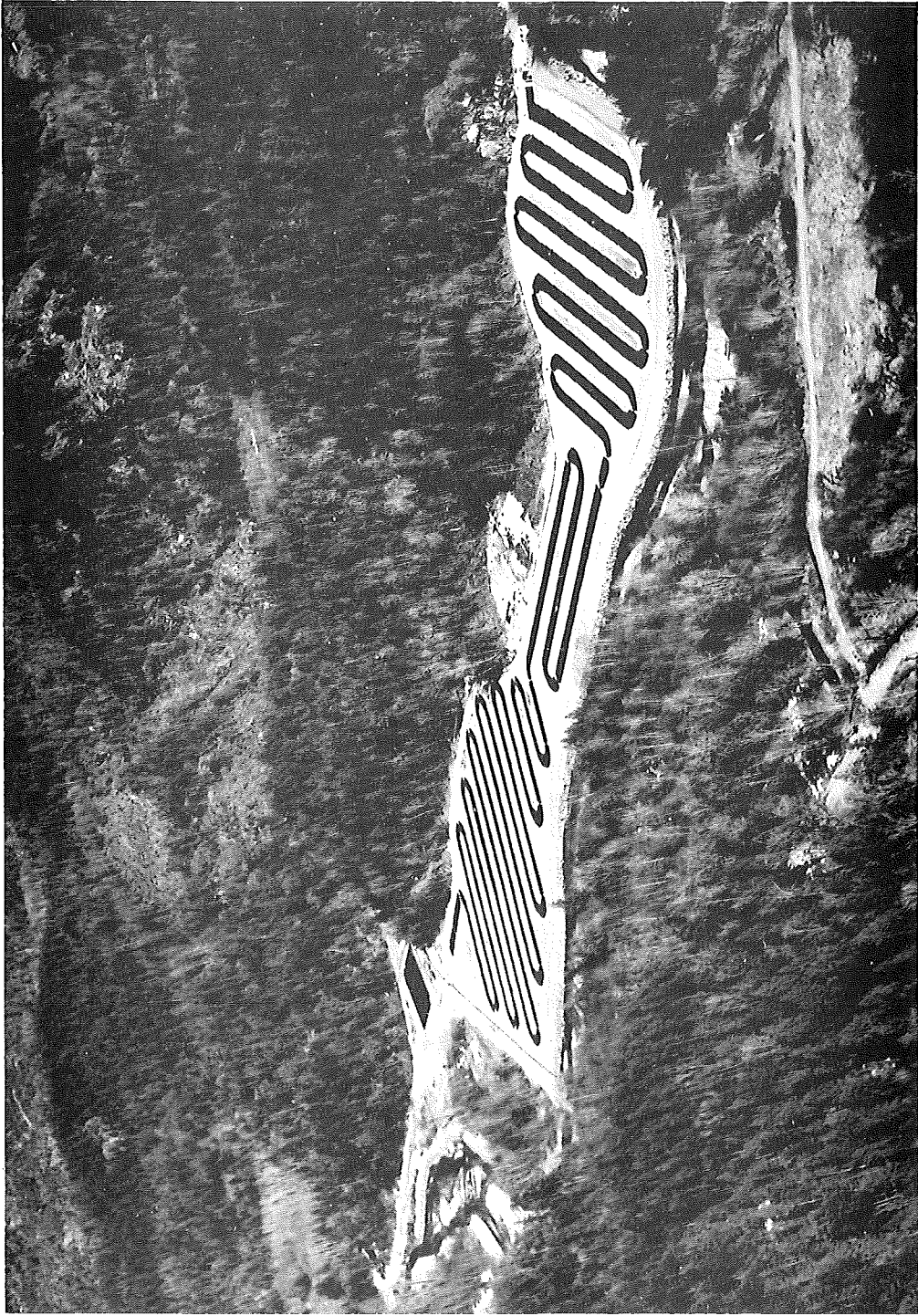


FIGURE 9 - Weaver Creek channel.

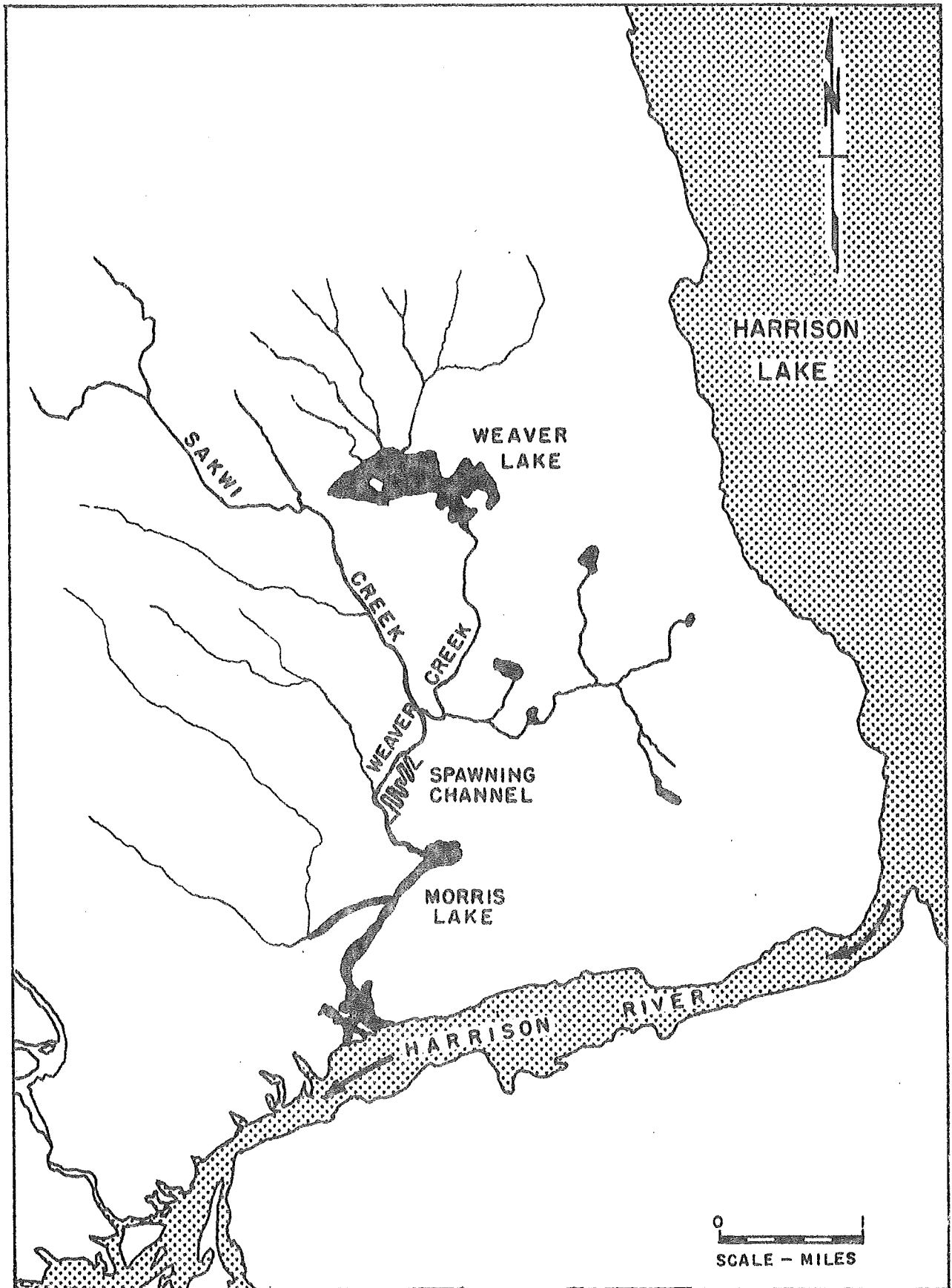


FIGURE 10 - Location of Weaver Creek spawning channel.

TABLE 15 - Sieve analysis of gravel as placed in the Weaver spawning channel.

<u>Square Sieve Size, Inches</u>	<u>Percentage Dry Weight Passing Sieve</u>
3	100
2	74.1
1½	51.5
1	31.6
¾	16.0
½	4.6

The channel has a slope of 0.0006 between drop structures, and it has 27 drops, making a total elevation difference of 23.26 ft from upper to lower end. Most of the drops have a 0.5 ft elevation change, but 8 of them have an elevation change of 1 ft. The drop structures are constructed with stone cobble (material larger than 4 inches from the gravel source) and the channel side slopes are lined with cobble also, to present a natural appearance. The channel is designed for a discharge of 20 cfs, giving a velocity of 1.2 fps and a depth of 0.8 ft. For stability of the cobble lining, the sides of the channel are on a 1 to 1.5 slope. Because of the low site elevation with respect to Weaver Creek, leakage loss from the channel was not expected to be a problem, and no special treatment was given to the subgrade.

Water for the channel is diverted from Weaver Creek just above its confluence with Sakwi Creek. A small grouted rock dam creates a pond giving sufficient depth for operation of screens in the intake structure. A small vertical slot fishway provides fish passage and also maintains a minimum flow below the intake. The diverted water is piped to a 100 ft by 100 ft settling basin near the channel and then to a diffusion chamber at the upper end of the channel. Because Weaver Creek at the intake does not always have sufficient water to supply the channel as well as maintain adequate minimum flow below the intake, supplementary sources of water were provided. A small intake dam on Sakwi Creek is used when necessary to divert flows in excess of 5 cfs up to the capacity of 20 cfs. The flow is passed through a 130 ft by 170 ft settling basin and then discharged to Weaver Creek upstream from the main intake. Sakwi Creek is generally cooler than Weaver Creek, and thus Sakwi water can also be used to moderate temperature in the channel. A pipe siphon was also constructed at the outlet of Weaver Lake which can discharge 20 cfs

from storage on Weaver Lake. The authorized storage capacity of 2160 acre feet would be obtained by drawing down Weaver Lake a maximum of 12.5 ft.

At the outset, fry emigrating from the channel were enumerated by taking photographs at short intervals and applying rate of travel to the count in the photographs. This procedure was changed in 1969 to a 5% sampler, by which a 5% sample is obtained continuously and weighed to obtain a count (Davis and Hiltz 1971). Folded perforated plate screens are used to reduce the volume of water to be handled in the sampler.

### Results

The channel started operation in 1965 and has been operated every year since then. Details of the numbers of sockeye spawners, egg deposition and fry production are given in TABLE 16. A few pink salmon spawn in the channel on each odd numbered year, and similar details for the pinks are given in TABLE 17. Chum salmon also spawn in an assigned section of the channel, and details of spawners and fry production are given in TABLE 18.

TABLE 16 - Sockeye spawners, egg deposition and fry production, Weaver Creek channel.

Brood Year	Spawners		Success of Spawning Percent	Effective ♀	Fecundity	Eggs Deposited Millions	Fry Produced Millions	Survival Eggs to Fry Percent
	Total	♀ Only						
1965	4,403	2,986	96.15	2,871	3,986	11.444	7.845	68.6
1966	6,129	3,424	95.8	3,280	4,309	14.134	10.758	76.1
1967	2,861	1,631	88.8	1,448	4,197	6.077	4.501	74.1
1968	1,392	784	92.73	727	3,990	2.901	2.559	88.2
1969	17,011	9,671	96.97	9,378	3,887	36.452	32.622	89.5
1970	4,327	2,519	92.03	2,318	4,202	9.740	8.193	84.1
1971	2,508	1,520	99.0	1,505	4,178	6.288	4.513	71.9
1972	10,625	6,418	98.73	6,336	4,163	26.377	15.210	57.7
1973	21,235	10,857	98.06	10,646	4,250	45.245	35.054	77.5
1974	24,061	15,044	88.0	13,239	4,527	59.933	36.850	61.5
1975	18,433	10,287	95.0	9,781	4,261	41.677	25.682	61.6
1976	27,366	16,517	94.19	15,557	4,182	65.059	52.753	81.0

TABLE 17 -- Weaver Creek channel pink salmon spawners, egg deposition and fry production.

Brood Year	Spawners		Success of Spawning Percent	Effective ♀	Eggs Deposited	Fry Produced	Survival Eggs to Fry Percent
	Total	♀ Only					
1965	50	32	96.15	31	63,000	43,000	68.3
1967	123	70	88.8	62	140,000	109,000	77.9
1969	227	108	96.97	105	211,000	187,000	88.6
1971	294	178	99.0	176	352,000	235,000	66.8
1973	640	364	98.06	357	691,200	536,000	77.6
1975	1,201	633	96.05	608	1,231,200	387,100	31.4

TABLE 18 -- Weaver Creek channel chum salmon spawners and fry production.

Brood Year	Spawners		Fry Produced Millions
	Total	♀ Only	
1965	1,186	487	0.982
1966	170	92	0.227
1967	464	202	0.471
1968	2,503	1,138	2.703
1969	2,365	1,286	3.234
1970	865	482	1.240
1971	1,277	696	1.758
1972	12,664	7,333	12.507
1973	5,654	3,077	4.294
1974	5,762	2,893	6.182
1975	5,682	2,532	6.239
1976	10,066*	6,322	5.862

\* An additional 9,451 transferred from the channel to Weaver Creek above the water intake.

Egg to fry survival of sockeye was consistently high for brood years 1965 to 1971 (FIGURE 11). The decline for the 1972 brood was attributed to the effects of the accumulation of sediment and organic debris within the gravel. The gravel was cleaned prior to the 1973 spawning using a cleaner developed for this purpose (IPSFC 1973), and the survival rate returned to the expected level for the 1973 brood. The depression of survival rate for the 1974 and 1975 broods may be further evidence of the need for cleaning. The channel was cleaned again prior to arrival of the 1976 run, and survival increased to 81.0%. There is no indication of reduction in survival rate attributable to density of spawners and there is no indication that maximum output of fry has been reached yet (FIGURE 12). The highest density of sockeye recorded so far has been 0.90 females/sq yd, or 16,517 females, in 1976 in the area used exclusively by sockeye. This is substantially more than the estimate of 10,900 females used when planning the project.

The production of sockeye fry from the natural spawning grounds in Weaver Creek, compared to the channel, is given in TABLE 19. For the brood years 1965 to 1971, the numbers of fry produced by the natural spawning grounds were estimated from the female spawners and a relationship between density of spawners and egg to fry survival obtained in earlier years, modified by judgment according to the severity and frequency of fall and winter freshets. For the brood year 1972, the fry produced by the sockeye spawning upstream from the barrier fence were enumerated by release and recapture of marked fry. Female sockeye spawning below the barrier were assumed to produce a proportionate number of fry. This latter assumption attributes more fry to the creek than were probably produced, since the spawning grounds below the barrier are more subject to shifting and gravel movement than the grounds upstream, and also to more superimposition of spawning.

The numbers of fry produced in the creek from the 1973 brood were also determined by hydraulic sampling of the spawning grounds as well as by marked fry. The estimate obtained by this method agreed with the marked fry method for the area above the barrier fence, and the hydraulic sampling estimate for the area below the fence was added to get the total. This procedure was considered the best to adopt, because the lower part of Weaver Creek was quite severely altered by freshet during the fall. A similar procedure has been followed for the 1974, 1975 and 1976 broods.

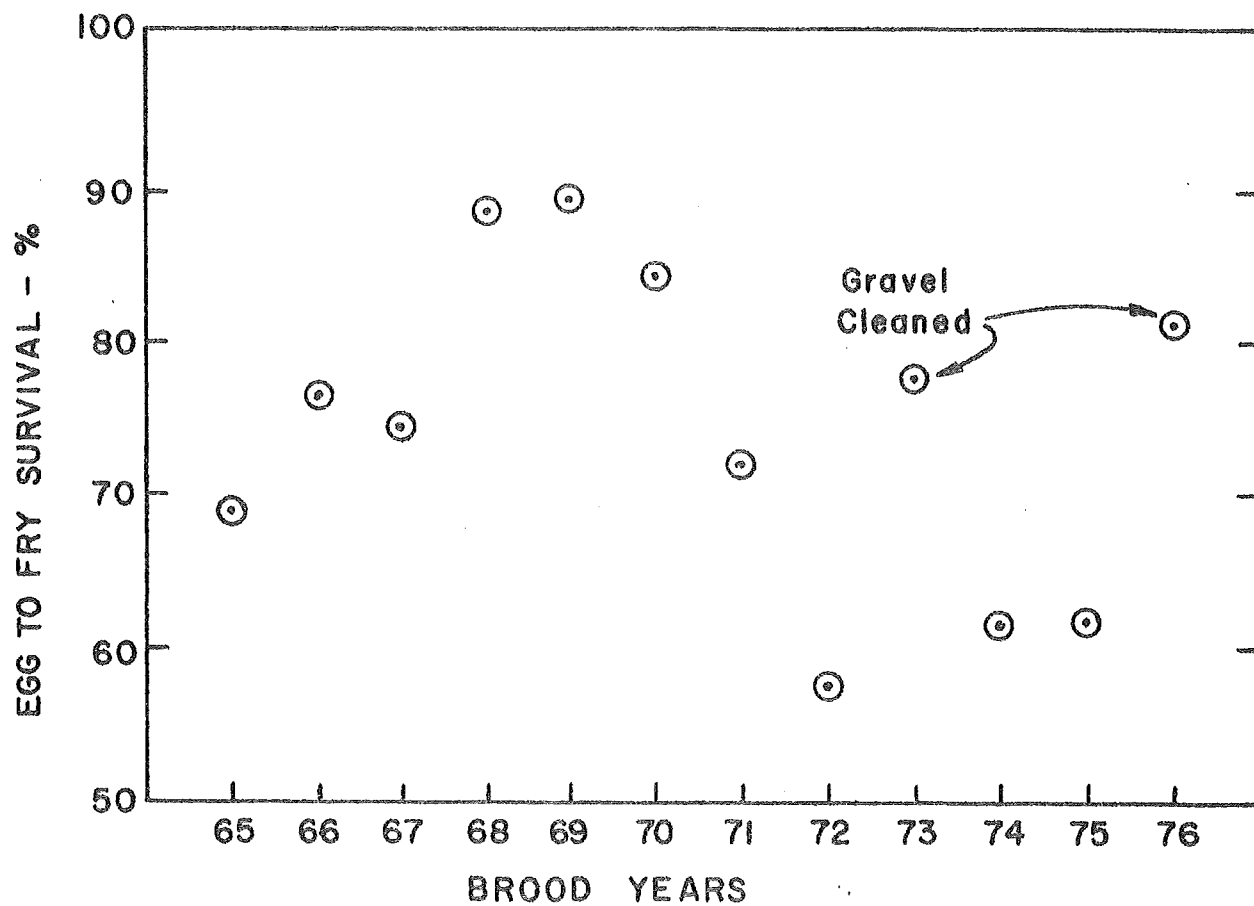


FIGURE 11 - Sockeye egg to fry survival rate in the Weaver Creek spawning channel, by brood year.

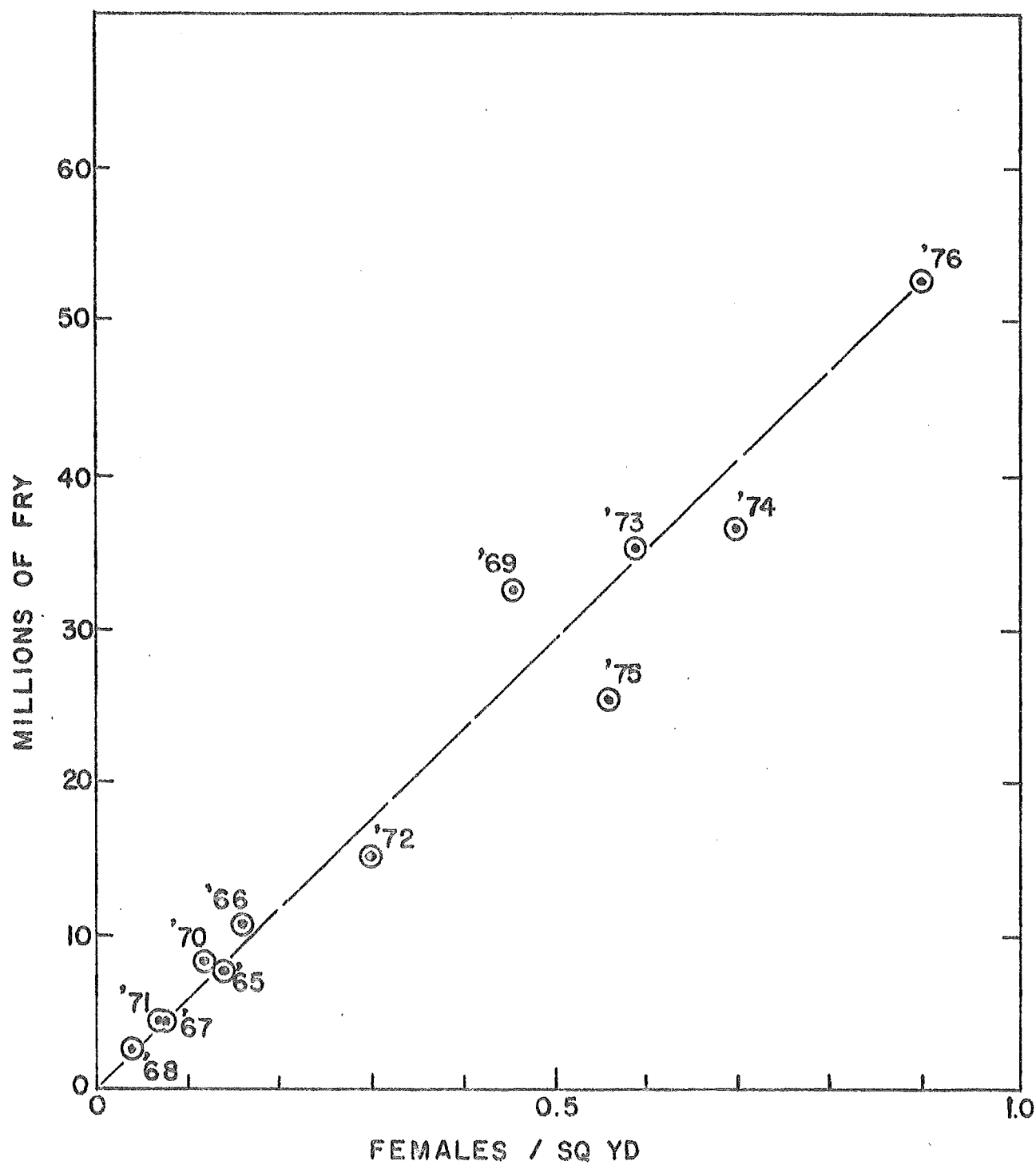


FIGURE 12 - Sockeye salmon fry production in relation to spawning density in the Weaver Creek spawning channel.

TABLE 19 - Sockeye fry production Weaver Creek and Weaver Creek channel.

Brood Year	Fry from Creek Spawning Grounds	Fry from Channel	Total	Percent of Total from Channel
1965	1,475,000	7,845,000	9,320,000	84.17
1966	2,100,000	10,758,000	12,858,000	83.67
1967	2,500,000	4,501,000	7,001,000	64.29
1968	1,025,000	2,559,000	3,584,000	71.40
1969	4,150,000	32,622,000	36,772,000	88.71
1970	1,650,000	8,193,000	9,843,000	83.24
1971	720,000	4,513,000	5,233,000	86.24
1972	4,191,000	15,210,000	19,401,000	78.40
1973	3,763,000	35,054,000	38,817,000	90.31
1974	6,777,000	36,850,000	43,627,000	84.47
1975	279,000	25,682,000	25,963,000	98.92
1976	4,825,000	52,760,000	57,585,000	91.62

The record of total Weaver Creek sockeye runs, and the portion produced by the channel starting with the 1965 brood year, is given in TABLE 20 and the record by return years is plotted in FIGURE 13. The total runs produced from the brood years 1965 - 1972 have averaged 203,800, compared to an average of 84,500 from the brood years 1948-64. Production of the run from the 8 brood years 1965-72 has averaged 73,700 annually greater than the best 8 brood years (1948-55) prior to the construction of the channel.

Details of production and catch of sockeye from the channel are given in TABLE 21. The biggest run so far was obtained from the 1969 brood fry output, the largest output for which a return has been obtained so far (FIGURE 14).

The channel spawners produced more returning spawners than required for the channel, and these "surplus" fish, which spawned in the creek, have produced an additional 303,500 lb of catch valued at \$250,000, taking into account the effect of the additional spawners on the rate of return. The 14,785 spawners in the channel in the first four years would have produced 132,600 lb of catch valued at \$56,600 if they had been allowed to spawn in the creek, and this represents a cost to the channel. As shown in FIGURE 15, the data suggest a lower rate of survival of fry for large populations than for small populations, although some small populations also have a low rate of survival.

TABLE 20 - Weaver Creek total adult sockeye runs from brood years 1948 to 1972.

Brood Year	Total Adult Sockeye Produced	Creek	Channel
1948	131,635		
1949	54,928		
1950	182,836		
1951	116,935		
1952	10,933		
1953	217,870		
1954	232,492		
1955	73,378		
1956	21,572		
1957	8,801		
1958	30,715		
1959	39,208		
1960	4,623		
1961	57,472		
1962	47,854		
1963	161,915		
1964	24,962		
1965	202,996	32,073	170,923
1966	75,501	12,329	63,172
1967	86,641	30,940	55,701
1968	152,420	43,592	108,828
1969	408,935	46,169	362,766
1970	271,395	45,486	225,909
1971	172,718	23,766	148,952
1972	248,398	53,654	194,744

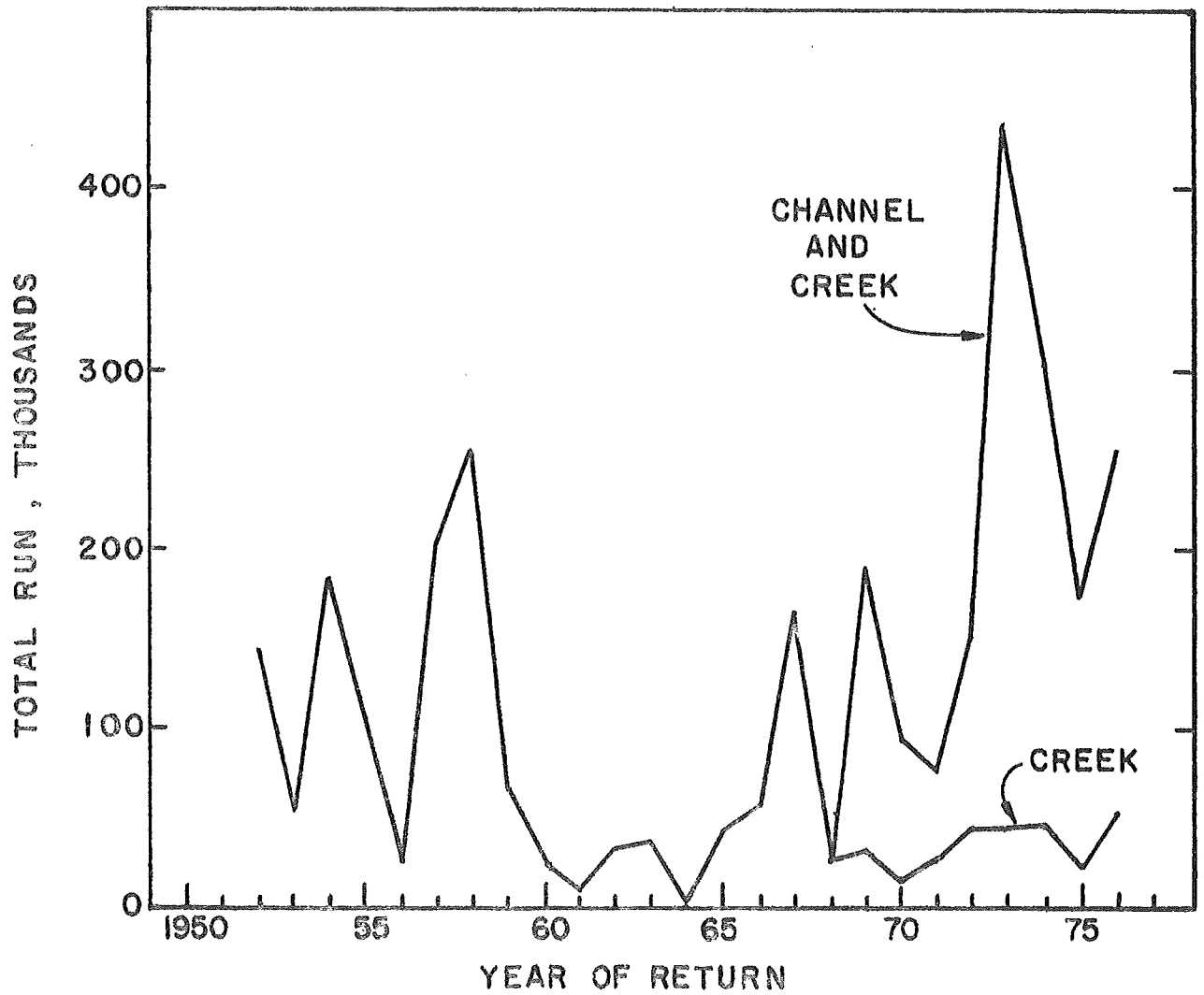


FIGURE 13 - Numbers of adult Weaver Creek sockeye produced from the natural spawning area and the spawning channel.

TABLE 21 - Weaver Creek channel adult sockeye production and catch.

Brood Year	Adult Total Run *	Percent Return		Commercial Catch		
		From Eggs	From Fry	Fish	Pounds	Landed Value**
1965	170,923	1.49	2.18	119,134	769,570	\$ 320,704
1966	63,172	0.45	0.59	56,061	411,208	172,113
1967	55,701	0.92	1.24	51,524	351,164	155,985
1968	108,828	3.75	4.25	107,407	664,804	339,522
1969	362,766 P	0.99	1.11	313,548 P	2,173,940	1,674,706
1970	225,909 P	2.32	2.76	177,216 P	1,267,494	979,262
1971	148,952 P	2.37	3.30	124,200 P	761,865	665,352
1972	<u>194,744</u> P	0.74	1.28	<u>157,130</u> P	<u>1,055,914</u>	<u>997,838</u>
Total	1,330,995			1,106,220	7,455,959	\$5,305,482

\* Age 4 and 5 combined.

\*\* At each catch year's prices.

P Preliminary.

Data on the mean annual index of zooplankton standing crop abundance in Harrison Lake for the brood years 1969-75 do not indicate any reduction in standing crop that could be attributed to abundance of sockeye (FIGURE 16). However, the scale circuli for the first year of lake residence (without the second spring growth) do indicate a small suppression of growth for the fry from the 1969 brood (FIGURE 17). The circuli count of 16.2 for this brood is the lowest of any year on record, extending back to the 1947 brood. Because of the longer growing season available in the coastal climate area compared to the interior plateau climate area, it is not known if the circuli count can be depressed to as low as 9 to 10 in Harrison Lake, as occurs in Shuswap Lake for large populations in the dominant cycle.

The percentage rates of return from eggs deposited in the channel and in the creek are compared in TABLE 22, and show that the channel is 9.00 times more effective than the natural spawning grounds.

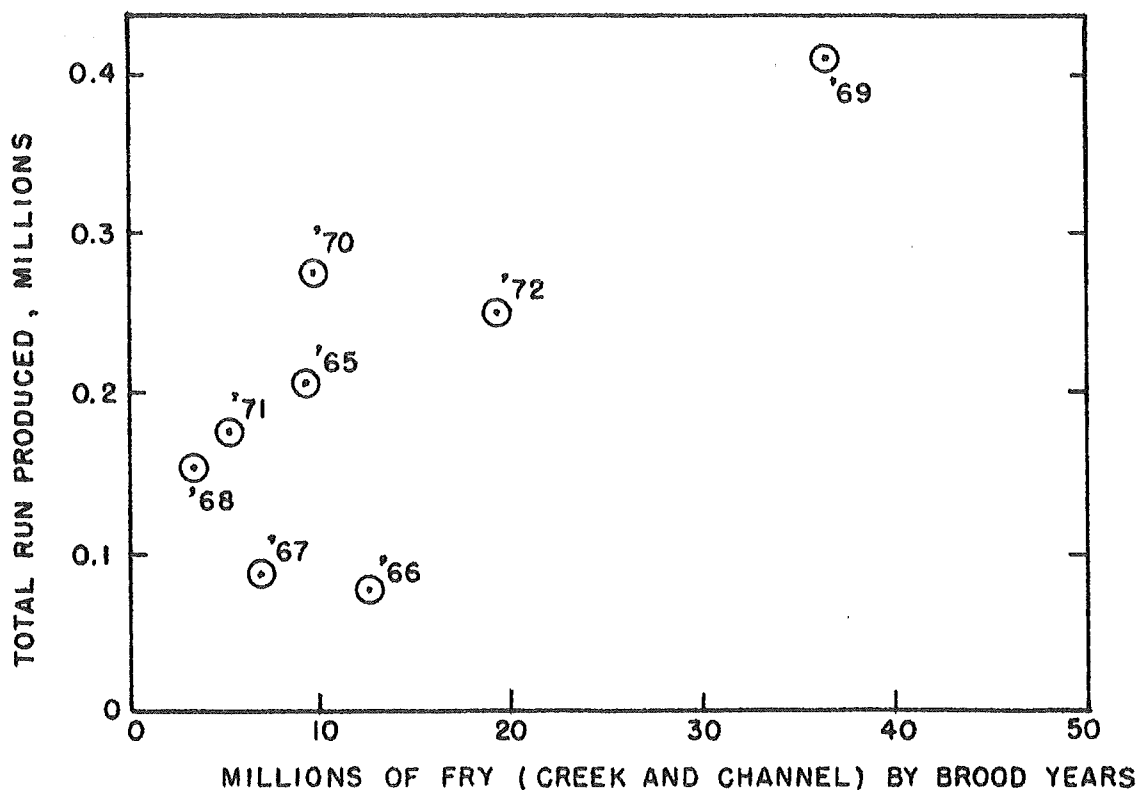


FIGURE 14 - Weaver Creek sockeye production in relation to the numbers of fry produced by the natural spawning area and the spawning channel.

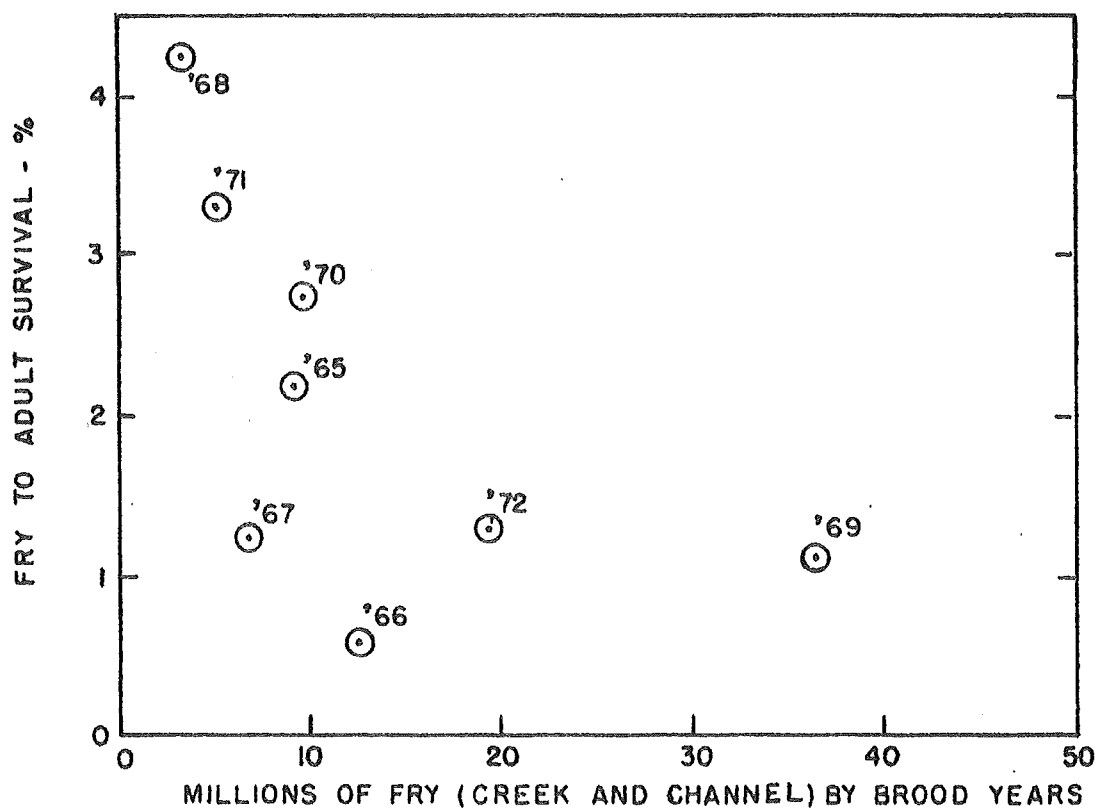


FIGURE 15 - Weaver Creek fry to adult survival rate in relation to the numbers of fry produced by the natural spawning area and the spawning channel.

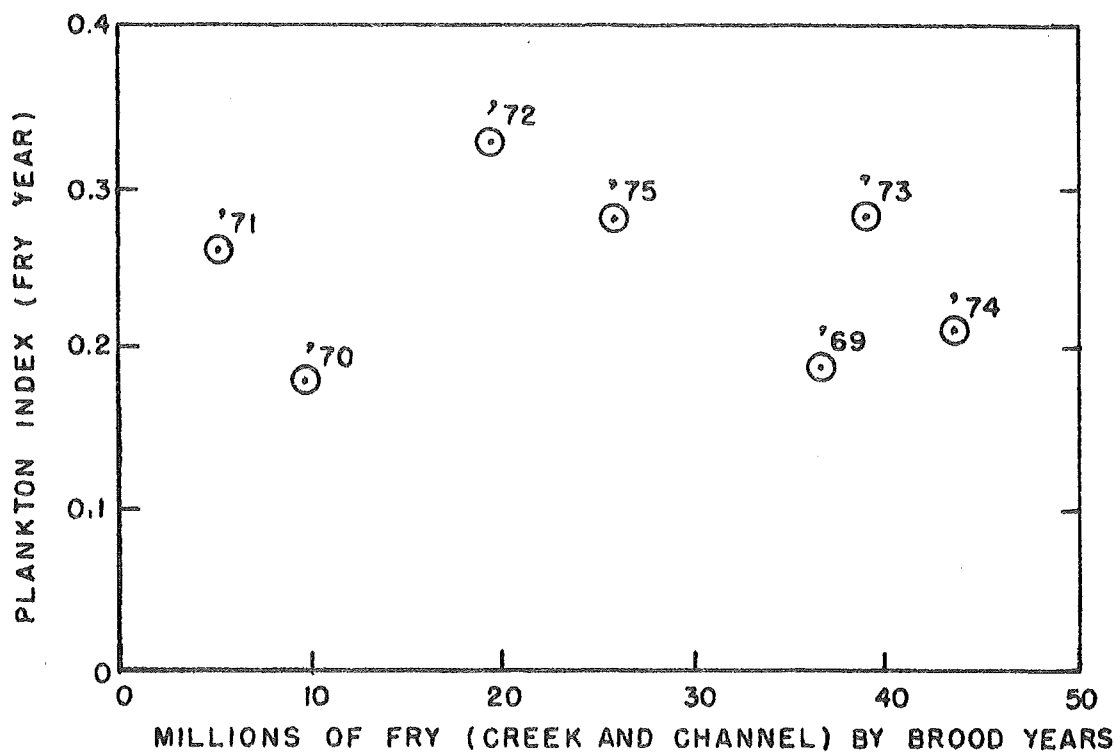


FIGURE 16 - Index of plankton abundance in Harrison Lake in relation to the numbers of Weaver Creek sockeye fry in the lake.

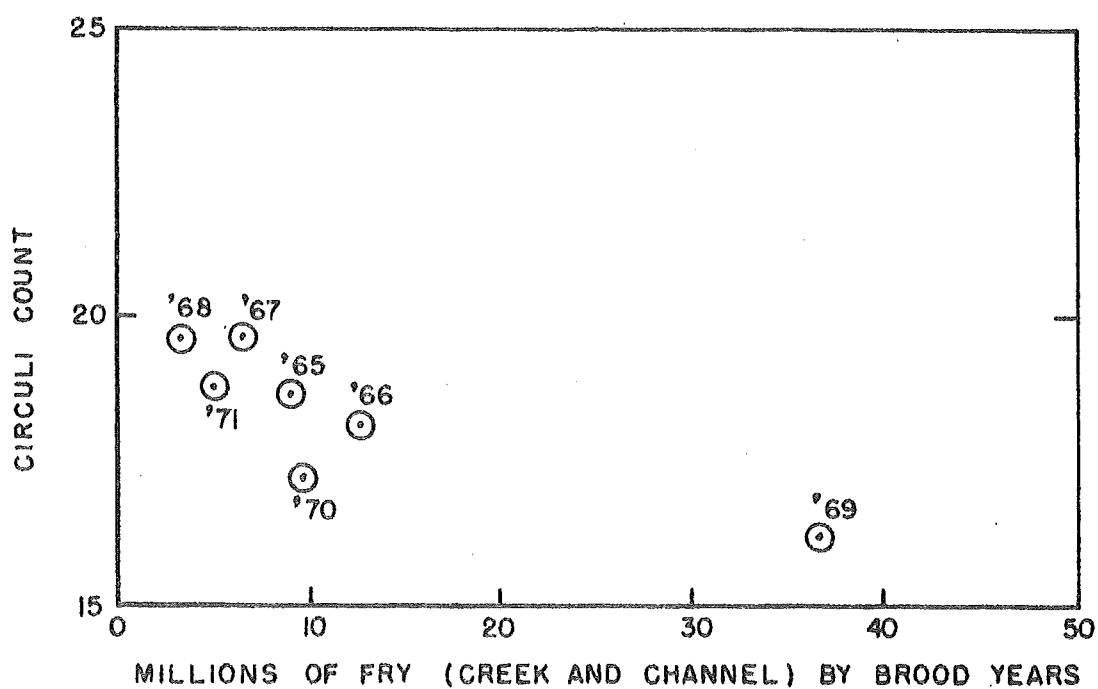


FIGURE 17 - Freshwater scale circuli count of returning adult Weaver Creek sockeye in relation to the number of fry in the brood year.

TABLE 22 - Percent return of adult sockeye from sockeye eggs deposited in Weaver Creek channel compared to return from eggs deposited in the natural spawning grounds in Weaver Creek.

Brood Year	Channel			Creek			Ratio of Channel to Creek Percent Return
	Millions of Eggs Deposited	Adult Total Run	Percent Return	Millions of Eggs Deposited	Adult Total Run	Percent Return	
1965	11.444	170,923	1.49	17.758	32,073	0.18	8.28
1966	14.134	63,172	0.45	28.353	12,329	0.04	11.25
1967	6.077	55,701	0.92	38.486	30,940	0.08	11.50
1968	2.901	108,828	3.75	5.885	43,592	0.74	5.07
1969	36.452	362,725	0.99	82.630	46,169	0.06	16.50
1970	9.740	225,909	2.32	11.013	45,486	0.41	5.66
1971	6.288	148,952	2.37	4.809	23,766	0.49	4.84
1972	26.377	194,744	<u>0.74</u>	36.185	53,654	<u>0.15</u>	<u>4.93</u>
Weighted Average			1.17			0.13	9.00

### Benefits and Costs

The channel was built in 1964-65 at a cost of \$280,725. With a replacement time of 20 years and interest at 6%, the annual capital recovery cost would be \$24,423. Converting each year's operating costs to the 1965 base using the Vancouver cost of living index, the average annual operating cost has been \$16,486 in 1965 dollars. The total annual cost is thus \$40,909 in 1965 dollars (TABLE 23).

Sockeye produced by the channel from the brood years 1965-72 have resulted in landings valued at \$5,305,482 (TABLE 21). At the 1965 landed value of 38¢ per lb, these landings would have an average annual value of \$354,158 in 1965 dollars.

Catches produced by surplus spawners, after deduction of the production that would have been produced by the first four years of spawners in the channel if they had spawned in the creek, would add \$8,115 to the average values of landings for the brood years. The benefit/cost ratio has been 8.86 on the 1965 dollar basis. Additional benefits may be produced by the pink and chum salmon that spawn in the channel, but these benefits have not been evaluated.

For comparison with the other projects in this report, costs and benefits are also converted to 1975 costs and values (TABLE 23).

TABLE 23 - Summary of costs and benefits for Weaver Creek channel.

		On Basis of <u>1965 Dollars</u>	On Basis of <u>1975 Dollars</u>
Capital Cost		\$ 280,725	\$ 659,704
Annual Costs:			
Capital Recovery		\$ 24,423	\$ 57,513
Operating		<u>16,486</u>	<u>27,400</u>
	Total:	40,909	84,913
Annual Benefits:			
Channel spawners		\$ 354,158	\$ 811,022
Surplus spawners less initial brood		<u>8,115</u>	<u>18,580</u>
	Total:	362,273	829,602
Benefit/Cost ratio		8.86	9.55
Average fry output, millions/cycle	22.50		
Average cost per million fry		\$ 1,818	\$ 3,774
Average landings, lbs/cycle			
Channel spawners	931,995		
Surplus spawners less initial brood	<u>21,356</u>		
Total:	953,351		
Average cost per lb		4.29¢	8.91¢

### Operation and Maintenance Problems

A number of operating problems have been encountered at the Weaver channel, but the only one of these that has affected survival from eggs to fry has been the accumulation of silt and organic detritus within the gravel. In the early years of operation this accumulation was noticed in the bottom portion of the gravel bed at the upstream end of the channel. Despite the provision of a settling basin, it was obvious that the gravel was acting as a filter in removing material from the water as it flowed through the gravel. Most of the material was collected in the upper end of the channel, and the amount decreased further downstream, with very little at the lower end of the channel. Several methods of cleaning the gravel including using a bulldozer to turn it over in flowing water, and a buried grid of perforated pipes to create an upwelling flushing effect, and a high pressure jet of water directed into the gravel, were only partially effective. The need for an effective method of cleaning led to the development of an apparatus using jets of an air and water mixture which could be dragged through the gravel. The materials flushed out are carried away by the surface flow of water (IPSFC 1973). Using this apparatus, the channel was cleaned prior to arrival of the 1973 run. On the basis of appearance of the gravel, it was cleaned again prior to the arrival of the 1976 run. Thus, despite the provision of a settling basin, which is effective in removing much suspended material from the water supply, some sediment collects in the gravel and there is a need for periodic cleaning of the gravel.

From the start of operation, there has been a leakage of water from the channel, averaging about 7.6 cfs, with a range from 5 cfs to 12 cfs. No correlation between the loss and inflow, creek level, or time is evident. Most of the loss occurs near the downstream end of the channel and appears as a surface flow into Weaver Creek along the perimeter of the rock faced dyke protecting the channel. There is no indication that this loss of flow has affected production from the channel, and it has not been considered necessary to prevent the leakage.

A portion of the water supply for the channel is obtained by diversion from Sakwi Creek. Need for this water is critical during periods of low discharge in Weaver Creek. However, during periods of heavy rain or snow melt, considerable amounts of very fine silt enter Sakwi Creek from cut banks in an access road to a ski area at the headwaters of Sakwi Creek. At such times, the intake on Sakwi Creek has to be closed.

One problem that was not anticipated for the Weaver channel, was the formation of frazil ice during clear cold weather in the winter. In the first winter of operation, frazil ice caused obstructions in the channel, especially at drop structures, and water flowed over the berms between channel legs. Ice blockages were moved manually to keep the flow moving in the channel. The problem has not been as severe since that first year, but there are times when the above measures have to be taken. No other remedial measures are practical at the Weaver channel, but at any new installations consideration should be given to design to avoid ice problems, such as was done for the Madina River channel (IPSFC 1970).

The Weaver channel is located in a forest area with predominantly deciduous trees. During the fall, collection of leaves in the intake screens presents a persistent operating problem. This has been alleviated by improvements to the intake to provide a sweeping flow across the face of the screens. The screens were also changed from wire mesh to perforated aluminum plate to provide a smoother face for easier cleaning.

Decomposing dead eggs in the gravel are a source of nitrogen and phosphorous in the water, as are eggs and fish carcasses in Weaver Creek upstream from the water intake. Each spring there is a fairly abundant growth of blue green algae in the channel (also in Weaver Creek). This algae does not appear to hamper the movement of fry out of the channel. However, during the period of fry enumeration, pieces continually break loose and are carried down the channel. These pieces are collected by the fry enumeration screens and collected in the holding pen of the 5% sampler, making it more difficult to remove fry for counting.

Movement of gravel during freshets in the section of Weaver Creek downstream from Sakwi Creek results in deposition of gravel to a depth of 1 to 2 ft on the concrete apron for the fish diversion fence at the fishway entrance to the channel. This gravel has to be removed each fall in preparation for installing the barrier fence. Several operating procedures for the fence have been followed. Initially the earliest arriving sockeye were allowed to migrate upstream past the fence to the stable spawning grounds upstream from the channel water intake. This practice was adopted to avoid the problem of fish spawning in the low flow in the section of Weaver Creek between the channel water intake and the fish entrance after the channel was put in operation. However, this procedure was found to be unsatisfactory. It was subsequently decided to fill the channel first, and then remove the diversion

fence. It is believed to be advantageous to get the channel filled as quickly as possible so that most of the fish spawn at about the same time thereby avoiding the disadvantages associated with late spawning fish digging up eggs deposited earlier.

Because of the increasing numbers of chum salmon entering the channel, probably a result of the chum salmon fry production in the channel (TABLE 18), in 1973, 1975 and 1976 chum salmon were separated from sockeye when they entered the channel and diverted to a 3200 sq yd area at the lower end of the channel. In 1973 all fish entering the channel passed through a narrow passage and were diverted by a swing gate operated by an observer. The location of this device at the channel entrance slowed down the entry of fish, and when the separator was installed again in 1975, it was placed about 1000 ft upstream to provide unimpeded entry to the lower end of the channel. This location was used again in 1976, but because of the numbers of chum salmon entering the channel, it was necessary to remove some of these fish and transport them back to Weaver Creek above the water intake. A total of 9451 chum salmon were transferred this way. In addition the single separator could not handle the fish fast enough, and a large number were manually lifted over the divider fence. Plans are being prepared for a modification of the channel to facilitate the separation and return of chum salmon to the creek.

## LOWER SETON CHANNEL

## Description

Because of the need for additional spawning ground for pink salmon in Seton Creek, a second larger spawning channel was recommended (IPSFC 1965) and was constructed in time for operation for the 1967 adult return to the spawning grounds.

This channel is located adjacent to Seton Creek approximately one mile downstream from the upper channel (FIGURE 18). The 17.9 acre site is leased from the Cayoosh Indian Band. A further 0.3 acres for the water supply is leased from B. C. Hydro and Power Authority, and the operator's residence occupies a 1.1 acre site, also leased from B. C. Hydro and Power Authority. The land is protected from high water in Seton Creek by a rock faced dyke.

The channel is 9486 ft long and 20 ft wide at the gravel surface. Deducting the 10 cobble drop structures between the water inlet diffusion chamber and the fish inlet weir, the gravel area is 20,886 sq yd. An additional 7 rock drop structures at 40 ft intervals form a fishway between Seton Creek and the fish inlet weir. At each drop structure the water surface drops one foot. The channel has a slope of 0.001 between drop structures, designed to provide a mean velocity of 1.46 fps at a depth of 1.25 ft for a flow of 40 cfs. The water is obtained from B. C. Hydro and Power Authority canal through two 500 ft long steel pipe siphons, with a 102 ft drop in elevation from the crest at the canal embankment to the valve at the diffusion chamber in the spawning channel. The upper part of each siphon is 18 in. pipe and the lower 291 ft is 12 in. pipe. The siphons are primed by filling the downstream leg by a pump from the canal.

The spawning gravel was produced from a river deposit on a bench on the east side of the Fraser River. This material consisted of sound well-rounded pieces. Boulders and some sand were separated at the pit, and the gravel was then trucked to the channel and stockpiled for screening and washing, after which it was placed in the channel to a depth of 16 in. The specifications were the same as for the Upper Seton and Weaver channels. The average sieve analysis of the gravel as placed is given in TABLE 24.

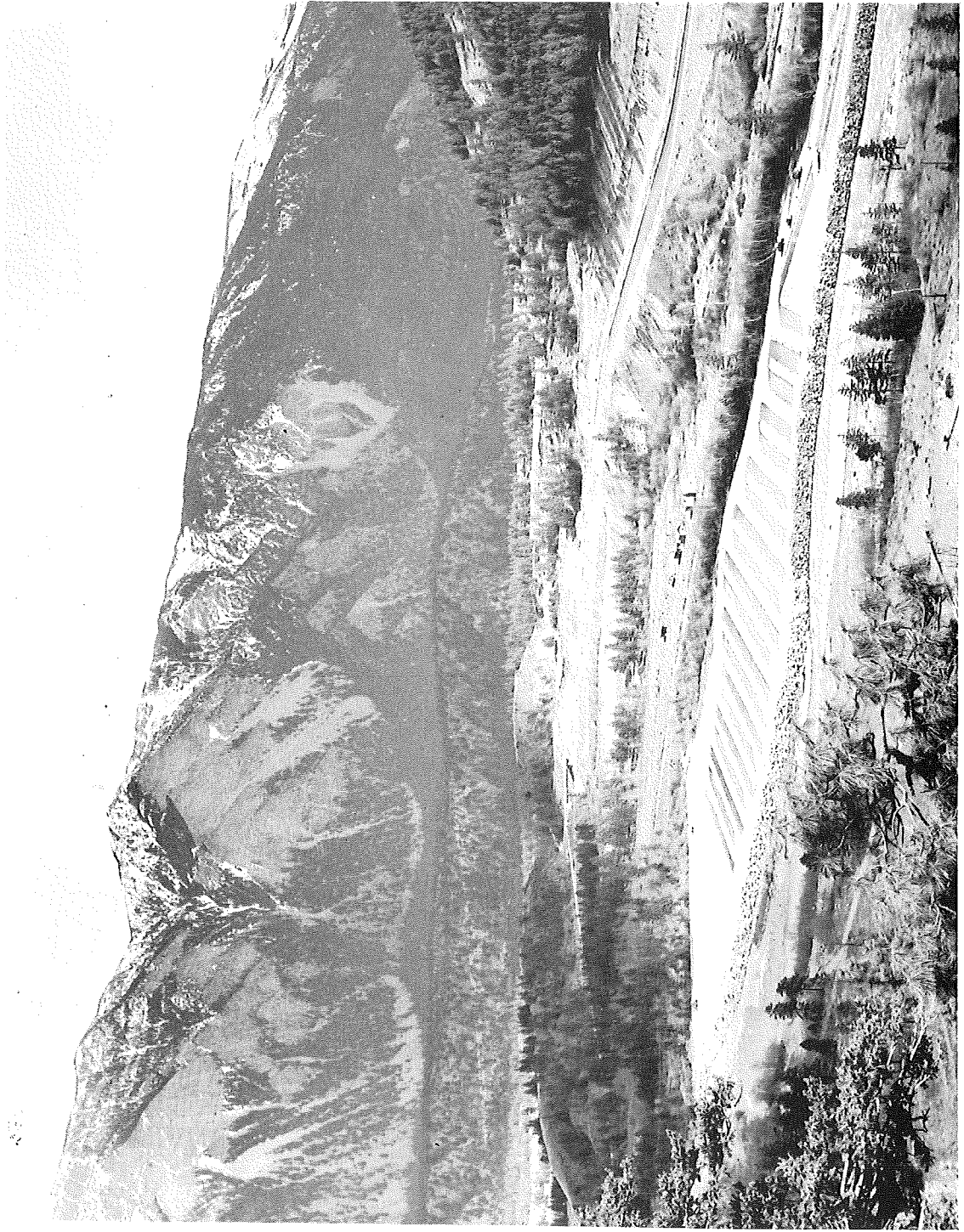


FIGURE 18 - Lower Seton channel.

TABLE 24 - Average sieve analysis of gravel as placed in the Lower Seton spawning channel.

Square Sieve Size, Inches	Percentage Dry Weight Passing Sieve
4	100
3	87.9
2	66.0
1½	46.5
1	27.1
¾	12.3
½	0.8
¼	0.0

The sides of the channel are lined with broken rock larger than 6 in. placed on a 1 to 1.5 slope. This material was selected because of its better stability than the cobble used at the Upper channel and the Weaver channel. Because of the level of the site with respect to Seton Creek water levels, it was not expected that leakage would result in a significant loss of water and no special treatment was given to the channel subgrade.

At the top end of the entrance fishway channel, a concrete structure provides the supports for a picketed fence and V-trap used to control the entry of adult pink salmon, and also for the 5% sampler gear used to enumerate the fry emigration. In the first year of operation, the fry were enumerated photographically, but since the spring of 1970, the 5% sampler has been used.

#### Results

The channel has been operated each pink salmon cycle year since 1967. Data on the numbers of spawners, egg deposition, and fry production are given in TABLE 25.

Maximum output of over 16 million fry so far has been obtained at a spawning density of nearly 0.7 females per sq yd (FIGURE 19) and in view of the results obtained at the Upper Seton channel, it appears larger fry output would be obtained if the number of spawners was increased, possibly to as many as 0.9 females per sq yd or about 18,800 females. There is no indication that density of spawners up to 0.7 females per sq yd has affected the survival rate from eggs to fry.

TABLE 25 - Lower Seton channel pink salmon spawners, egg deposition and fry production.

Brood Year	Spawners		Success of Spawning Percent	Effective ♀	Fecundity	Eggs Deposited Millions	Fry Produced Millions	Survival Eggs to Fry Percent
	Total	♀ Only						
1967	20,630	12,435			1,795	22.322	8.977	40.2
1969	14,868	8,717			1,950	16.998	10.509	61.8
1971	24,882	14,239	89.06	12,681	1,764	22.369	12.770	57.1
1973	23,602	14,909	97.36	14,515	1,778	25.808	16.227	62.9
1975	23,874	13,910	96.66	13,445	1,821	24.500	16.327	66.6

The production of returning adult pink salmon and the catches obtained are given in TABLE 26. The adult return data are prorated on the basis of the numbers of fry produced by the channel and by the whole Fraser River system.

TABLE 26 - Lower Seton channel adult pink salmon production and catch.

Brood Year	Adult Total Run	Percent Return		Commercial Catch		
		From Eggs	From Fry	Fish	Pounds	Landed Value*
1967	144,500	0.65	1.61	87,059	519,742	\$ 86,329
1969	525,000	3.09	5.00	429,124	2,188,532	402,909
1971	357,600	1.60	2.80	266,412	1,411,984	496,030
1973	<u>276,700</u>	1.07	1.70	<u>197,823</u>	<u>1,173,090</u>	<u>434,043</u>
Total:	1,303,800			980,418	5,293,348	\$1,419,311

\* At each catch year's prices.

As with the Upper Seton channel, the Lower Seton channel produced more return spawners than were allowed in the channel. In the four cycle years from 1969 to 1975, there was an average of 60,470 surplus spawners. Allowing for reduced rate of return from this increment of spawners, it is estimated that an additional 2,642,000 lb of catch were produced from the surplus spawners in 1969, 1971 and 1973, with a cumulative landed value of \$665,883 at each year's catch prices. The 20,630 spawners in the channel in 1967, the first year of operation, would have produced a catch of 14,637

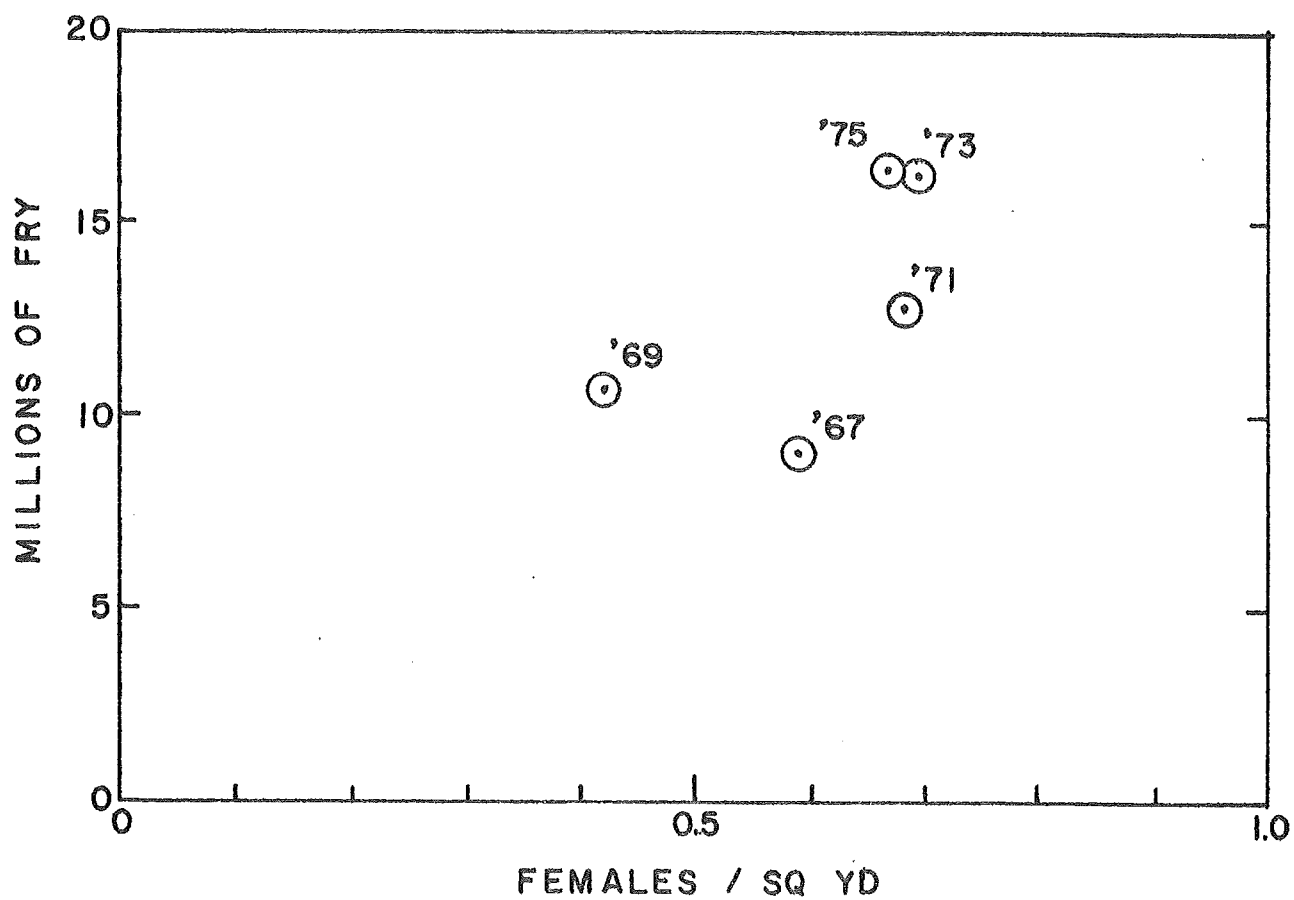


FIGURE 19 - Pink salmon fry production in relation to spawning density in the Lower Seton spawning channel.

in 1969 with a value of \$14,506 if they had spawned in the creek. The benefit from surplus spawners less the value of catch foregone gives a benefit of \$651,377. The percentage return from eggs in the channel compared to the return from all natural pink salmon spawning areas in the Fraser River system (TABLE 27) shows that the channel produces returns at an average rate 5.33 times greater.

TABLE 27 - Percent return of adults from eggs in the Lower Seton channel compared to all natural pink salmon spawning grounds in the Fraser River system.

Brood Year	Percent Return from Eggs Deposited		Ratio of Channel to Natural
	Lower Channel	Natural Spawning Grounds	
1967	.65	.174	3.74
1969	3.09	.454	6.81
1971	1.60	.329	4.86
1973	<u>1.07</u>	<u>.246</u>	<u>4.35</u>
Average	1.60	0.30	5.33

#### Benefits and Costs

The channel cost \$218,665 to build in 1966-67. Allowing a 20-year life, the annual capital recovery cost at 6% interest would be \$19,133 (TABLE 28).

The operating costs are shared with the Upper Seton channel. Converting each year's costs to a 1967 base using the Vancouver cost of living index, the average annual operating cost has been \$6,491 in 1967 dollars. Thus the total annual costs have averaged \$25,624 in 1967 dollars.

The pink salmon produced by the channel spawners in the brood years 1967-73 have resulted in landings valued at \$1,419,311. At the 1967 landed value of 14.9¢ per lb, the average annual value of the landings was \$98,589 in 1967 dollars. In addition, the pink salmon produced by "surplus" spawners less the initial brood have produced catches with an average annual value totaling \$47,577 at 1967 prices. The benefit/cost ratio has been 5.70 at the 1967 dollar base. For comparison with other projects, the costs and benefits have also been converted to 1975 dollars and values (TABLE 28).

TABLE 28 - Summary of costs and benefits for Lower Seton channel.

		On Basis of <u>1967 Dollars</u>	On Basis of <u>1975 Dollars</u>
Capital Cost		\$ 218,665	\$ 467,943
Annual Costs:			
Capital Recovery		\$ 19,133	\$ 40,795
Operating		<u>6,491</u>	<u>9,873</u>
	Total:	25,624	50,668
Annual Benefits:			
Channel spawners		\$ 98,589	\$ 244,501
Surplus spawners less initial brood		<u>47,577</u>	<u>118,144</u>
	Total:	146,166	362,645
Benefit/Cost ratio		5.70	7.16
Average fry production, millions/cycle	12.962		
Average cost per million fry		\$ 3,954	\$ 7,817
Average landings, lbs/cycle			
Channel spawners	1,323,337		
Surplus spawners	<u>638,617</u>		
Total:	1,961,954		
Average cost per lb		2.61¢	5.17¢

#### Operation and Maintenance Problems

There have been no operational problems at the Lower Seton channel. Maintenance has been primarily removal of tumbleweeds that roll into the channel and, on several occasions in the off-cycle year, grading of the gravel surface to smooth out the humps and hollows created by the spawners.

Leakage of water through the channel subgrade has not been a problem. A test prior to start of operations in 1967 showed a loss of 2.5 cfs out of the 40 cfs entering the channel.

## GATES CREEK CHANNEL

### Description

The spawning channel at Gates Creek was constructed in 1967-68 to improve the production of sockeye in Gates Creek and Anderson and Seton Lakes. Deteriorating environment in Gates Creek, attributed to logging and encroachment of other human activities, was believed to be restricting the sockeye population.

The channel is located adjacent to Gates Creek approximately one-half mile upstream from Anderson Lake (FIGURE 20). The 16.2 acre site occupied by the channel is leased from the Anderson Lake Indian Band. Additional small parcels of land are occupied by pipe lines, intake works and a pump house. The channel site is protected from high water in Gates Creek by a rock faced dyke.

The channel is 6201 ft long by 20 ft wide at the gravel surface. Deducting drop structures, the gravel area is 13,489 sq yd. In planning the project the capacity was estimated to be 9000 female sockeye spawners but on the basis of results at Weaver Creek, the capacity could be about 12,000 females. There are 15 cobble drop structures, each with a drop of 4 in. in the water surface. Between drops, the channel bottom has a slope of 0.001, giving a total drop of 11.2 ft in the channel. There are 5 quarried rock drop structures in the entrance fishway channel, each with a drop of 1 ft in water surface. A concrete structure at the upper end of the entrance fishway contains two additional drops, and provides support for a picket fence and V trap to control entrance of fish, and for the 5% sampler used to enumerate fry.

A typical cross section of the channel is shown in FIGURE 21. It was anticipated that leakage from the channel would be a problem because of the porous materials at the site and the drainage gradient down the valley floor. This was confirmed by tests after completion of the excavation. Accordingly, the sides and bottom of the channel were lined with 10 mil black polyethelene sheet. The subgrade was specially graded and compacted before placing the liner. A leakage test after completion showed a loss of 0.25 cfs. The channel sides are lined with cobble, as this material was more readily available than quarried rock.

Spawning gravel 16 in. deep was provided to the same specifications as for the other channels. The gravel was manufactured from the channel site. The sieve analysis of the material as placed in the channel is given in TABLE 29.



FIGURE 20 - Gates Creek channel.

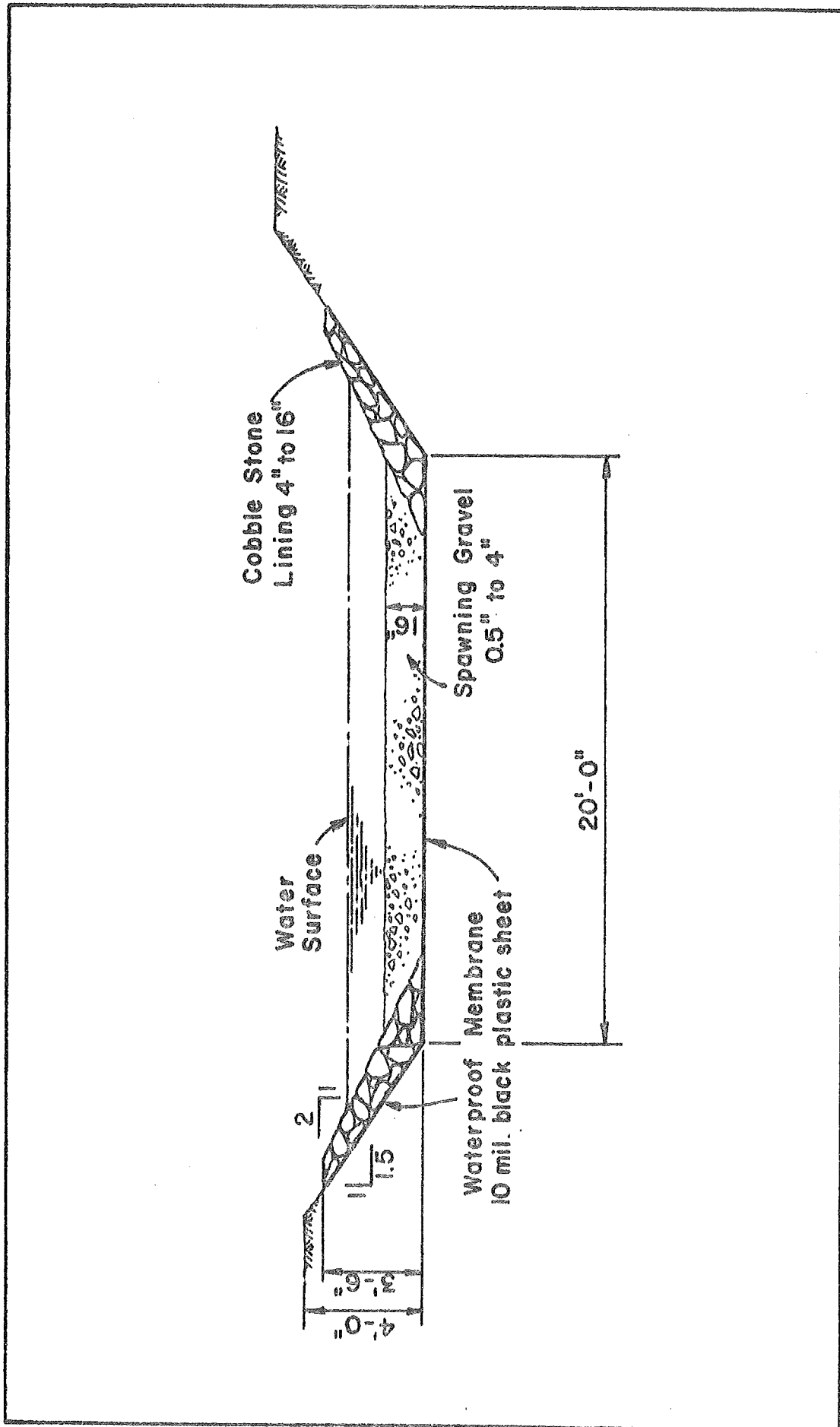


FIGURE 21 - Typical cross section of the Gates Creek spawning channel.

TABLE 29 - Average sieve analysis of gravel placed in the Gates Creek spawning channel.

Square Sieve Size, Inches	Percentage Dry Weight Passing Sieve
4	99.1
3	86.0
2	65.1
1½	46.8
1	21.3
¾	7.4
½	0.7

The channel was designed for a flow of 40 cfs giving a depth of 1.25 ft and a mean velocity of 1.46 fps. A concrete sill across Gates Creek diverts water to the intake structure. This structure incorporates special features intended to cope with the expected bed load movement of gravel in Gates Creek, as well as frazil ice problems in the winter. It also incorporates a perforated plate screen to exclude fry produced from the natural spawning grounds. The screen has an area of 360 sq ft at minimum operating water level and has a sweeping flow along its entire length to facilitate bypass of fry and also to facilitate cleaning of the screens. From the screens, the water flows to a settling basin. The settling basin width expands from 10 ft to 40 ft in the first 230 ft of length, and continues at 40 ft for another 240 ft. The minimum water depth is 3 ft. The water then flows to a diffusion chamber at the upstream end of the channel. If necessary, the flow can bypass the settling basin through a pipe directly to the diffusion chamber. Because of anticipated problems with frazil ice in winter, and also because of anticipated temperature control requirements at spawning time in late August, provision was made for a flow of up to 10 cfs from a depth of 200 ft in Anderson Lake. This water has a temperature of 39°F to 43°F and thus can be used for melting ice and also for reducing temperature in August. A pump located adjacent to Anderson Lake delivers the flow through 4011 ft of 18 in. diameter asbestos cement pipe. This water can be discharged in front of and behind the trash rack at the intake in Gates Creek, and directly to the diffusion chamber at the upstream end of the channel.

A concrete slab across Gates Creek just above the channel fish entrance is used to support a removable sloping barrier fence at the time of the adult migration to divert sockeye to the channel. In times of very high discharge in Gates Creek, it is not possible to install this barrier fence, and instead steel rails embedded in the slab surface are used as electrodes for an electric fence, using 110 v AC power.

### Results

The channel has been operated each year since 1968. Data on the numbers of spawners, egg deposition and fry production are given in TABLE 30. Similar data for the natural spawning grounds in Gates Creek are given in TABLE 31. However, in this case, because of the small numbers of spawners and the resulting small potential egg deposition, no actual measurements of survival from eggs to fry have been made. Instead, a comparatively high egg to fry survival rate of 15% has been assumed so that the contribution of the creek to production would not be underestimated. At Adams River the survival from potential egg deposition to fry has been between 15% and 19%. The spawning grounds in Gates Creek are unstable compared to Adams River and it is considered unlikely that the survival rates could be as high as those measured in Adams River.

Egg to fry survival in the channel was low for the 1969 brood because of an accumulation of silt in the channel in the upper half. Spawning for the 1970 brood was restricted to the lower half, and survival was 87.5%. Prior to the dominant cycle spawning in 1972, the gravel in the channel was cleaned using an apparatus devised by the Commission (IPSC 1973). This resulted in high survival for both the 1972 and 1973 broods. The accumulation of silt after 1973 caused lowered survival for the 1974 and 1975 brood years, and the channel was cleaned again for the 1976 brood spawning. There is no evidence that the density of spawners obtained in the channel so far has affected the egg to fry survival.

The fry outputs from the channel and from the natural spawning grounds (TABLE 32) are used as the basis for determining the relative contributions to the returning adult runs.

The record of Gates Creek total adult sockeye runs is given in TABLE 33. The total runs of adults from 1968 to 1972 have averaged 43,222 compared to 15,961 for the years 1948 to 1967. The channel has produced 92.5% of the returns for the brood years 1968 to 1972.

TABLE 30 - Sockeye spawners, egg deposition and fry production, Gates Creek channel.

Brood Year	Spawners		Success of Spawning Percent	Effective ♀	Fecundity	Eggs Deposited Millions	Fry Produced Millions	Survival Eggs to Fry Percent
	Total	♀ Only						
1968	6,174	3,527	69.41	2,448	3,242	7.936	6.971	87.8
1969	596	388	72.04	280	3,308	0.926	0.334	36.1
1970	40	16	43.75	7	3,400	0.024	0.021	87.5
1971	282	199	36.93	73	3,596	0.263	0.216	82.1
1972	6,643	3,399	65.93	2,241	3,502	7.848	6.342	80.8
1973	570	383	75.26	288	3,448	0.993	0.899	90.5
1974	64	43	79.07	34	3,523	0.120	0.082	68.3
1975	1,612	1,146	87.80	1,006	3,451	3.472	2.137	61.6
1976	14,344	8,727	84.61	7,384	3,502	26.177*	17.533**	67.0

\* Includes 318,000 eggs planted from moribund unspawned females.

\*\* Includes 251,400 fry from the planted eggs.

TABLE 31 - Sockeye spawners, egg deposition and estimated fry production, Gates Creek natural spawning grounds.

Brood Year	Spawners		Success of Spawning Percent	Effective ♀	Fecundity	Eggs Deposited Millions	Estimated Millions of Fry Produced
	Total	♀ Only					
1968	3,939	2,321	59.77	1,387	3,242	4.497	0.675
1969	181	118	67.39	80	3,308	0.265	0.040
1970	38	15	43.75	7	3,400	0.024	0.004
1971	144	99	42.05	42	3,596	0.151	0.023
1972	1,680	1,298	68.36	887	3,502	3.106	0.466
1973	225	69	91.67	63	3,448	0.217	0.033
1974	6	4	79.07	3	3,523	0.011	0.002
1975	370	273	87.80	240	3,451	0.828	0.124
1976	2,789	1,697	84.61	1,435	3,502	5.025	0.754

TABLE 32 - Sockeye fry production, Gates Creek and Gates Creek channel.

Brood Year	Fry from Creek Spawning Grounds	Fry from Channel	Total	Percent of Total from Channel
1968	675,000	6,971,000	7,646,000	91.2
1969	40,000	334,000	374,000	89.3
1970	4,000	21,000	25,000	84.0
1971	23,000	216,000	239,000	90.4
1972	466,000	6,342,000	6,808,000	93.2
1973	33,000	899,000	932,000	96.5
1974	2,000	82,000	84,000	97.6
1975	124,000	2,137,000	2,261,000	94.5
1976	754,000	17,533,000	18,287,000	95.9

Details of production and catch of sockeye from the channel are given in TABLE 34. The biggest return so far was from the 1972 brood, the second return from the dominant cycle.

In the first year of return, 1972, the channel produced 956 spawners more than used the channel, and these spawners produced an additional 23,325 lb of catch in 1976 valued at \$22,159. In the first four years of operation, 1968-71, the channel was used by an average of 1773 spawners which otherwise would have spawned in the creek and produced a return totaling 73,760 lb valued at \$40,774 at each catch year's prices.

Data on survival of channel fry to total adults produced (FIGURE 22), suggests improved survival rates for the 1971 and 1972 broods compared to 1968, 1969 and 1970. This may reflect the improvements to fish passage at the tailrace of the Seton Creek hydroelectric plant resulting from increased discharges in Seton Creek in 1975 and 1976. These improvements reduced the delay of sockeye at the tailrace substantially and greatly reduced the losses of sockeye at that point. Although the data suggest lower survival rate as the number of fry increases, results to date (FIGURE 23) show the biggest total adult runs from the largest fry outputs to date.

The return rates from eggs deposited in the creek and in the channel are compared in TABLE 35. The average rate of return from the channel has been five times greater than from the natural spawning grounds.

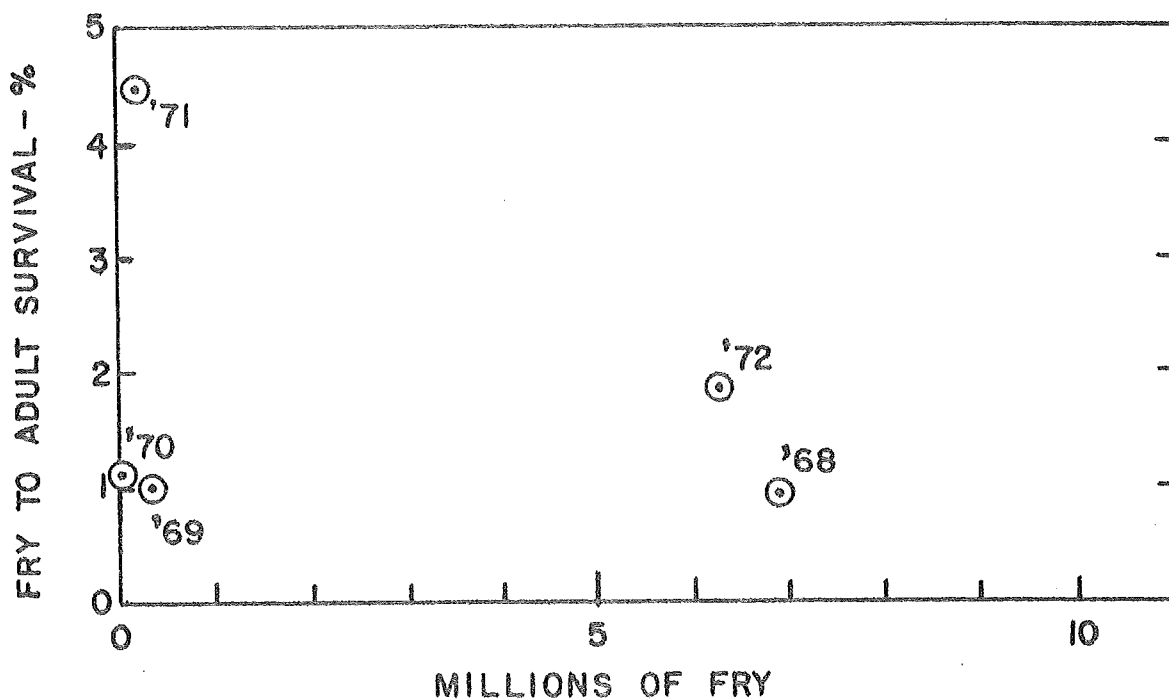


FIGURE 22 - Gates Creek fry to adult survival rate in relation to numbers of fry produced by the spawning channel.

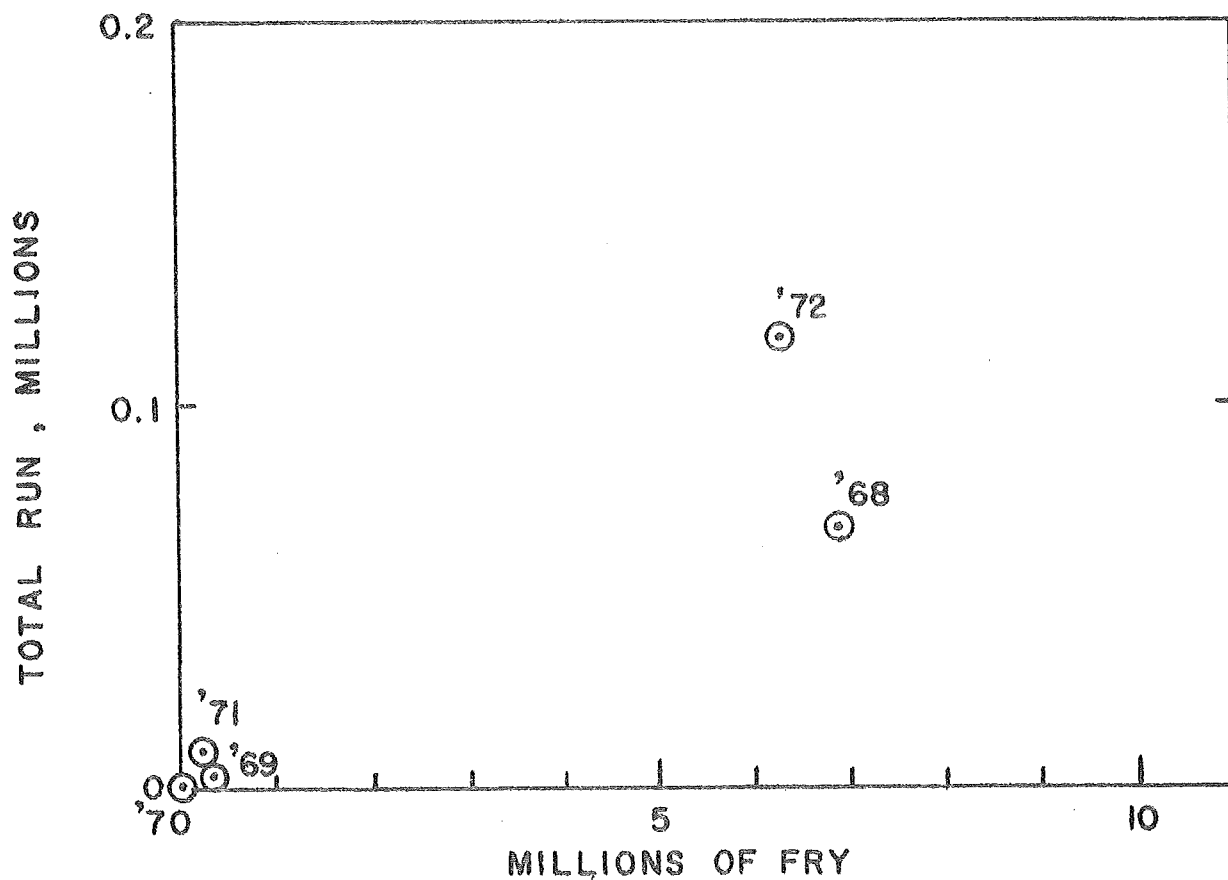


FIGURE 23 - Gates Creek adult sockeye production in relation to numbers of fry produced by the spawning channel.

TABLE 33 - Gates Creek total adult sockeye runs from brood years 1948 to 1972.

Brood Year	Total Adult Sockeye Produced	Creek	Channel
1948	30,026		
1949	590		
1950	300		
1951	623		
1952	38,000		
1953	7,811		
1954	698		
1955	2,472		
1956	15,438		
1957	1,081		
1958	526		
1959	9,315		
1960	83,013		
1961	13,556		
1962	312		
1963	7,449		
1964	100,140		
1965	2,216		
1966	310		
1967	5,339		
1968	73,774	6,492	67,282
1969	3,772 <sup>P</sup>	404	3,368
1970	277 <sup>P</sup>	44	233
1971	10,738 <sup>P</sup>	1,031	9,707
1972	127,549 <sup>P</sup>	8,673	118,876

<sup>P</sup> - Preliminary

TABLE 34 - Gates Creek channel adult sockeye production and catch.

Brood Year	Adult Total Run *	Percent Return		Commercial Catch		
		From Eggs	From Fry	Fish	Pounds	Landed Value **
1968	67,282	0.848	0.965	59,744	372,780	\$ 182,885
1969	3,368 <sup>P</sup>	0.364	1.008	2,541	16,269	12,533
1970	233 <sup>P</sup>	0.971	1.110	179	789	608
1971	9,707 <sup>P</sup>	4.113	4.494	6,804	45,247	39,365
1972	118,876 <sup>P</sup>	1.515	1.874	95,062	644,520	609,072
Total				164,330	1,079,605	\$ 844,463

\* Age 4 and 5 combined.

\*\* At each catch year's prices.

P Preliminary.

TABLE 35 - Percent return of adult sockeye from sockeye eggs deposited in Gates Creek channel compared to return from eggs deposited in the natural spawning grounds in Gates Creek.

Brood Year	Channel			Creek			Ratio of Channel to Creek Percent Return
	Millions of Eggs Deposited	Adult Total Run	Percent Return	Millions of Eggs Deposited	Adult Total Run	Percent Return	
1968	7.936	67,282	0.848	4.497	6,492	0.144	5.83
1969	0.926	3,368	0.364	0.265	404	0.152	2.37
1970	0.024	233	0.971	0.024	44	0.176	5.51
1971	0.263	9,707	4.113	0.151	1,031	0.605	6.79
1972	7.848	118,876	1.515	3.106	8,673	0.279	5.41
Weighted Average			1.095			0.214	5.09

## Benefits and Costs

The channel cost \$315,452 to build in 1967-68. With a 20-year life and 6% interest, the annual capital recovery cost would be \$27,500 (TABLE 36).

Converting each year's operating cost to a 1968 base using the Vancouver cost of living index, the average annual operating cost has been \$16,858 in 1968 dollars. The total annual cost is thus \$44,358 in 1968 dollars.

The sockeye produced by the channel from the brood years 1968-1972 have resulted in landings valued at \$844,463. At the 1968 price of 40.2¢ per lb, the landings had an average annual value of \$86,800 in 1968 dollars.

The value of the catch foregone from natural production from the spawners used in the initial four years exceeds the benefits produced in 1976 by the surplus spawners from the first return run in 1972, giving a deficit from these two sources averaging \$4,055 annually at 1968 prices. The benefit/cost ratio for this initial period has been 1.87.

For comparison with the other projects, costs and benefits in 1975 dollars and values are given in TABLE 36.

TABLE 36 - Summary of costs and benefits for the Gates Creek channel.

		On Basis of 1968 Dollars	On Basis of 1975 Dollars
Capital Cost		\$ 315,452	\$ 608,822
Annual Costs:			
Capital Recovery		\$ 27,500	\$ 53,077
Operating		<u>16,858</u>	<u>24,781</u>
Annual Benefits:	Total:	44,358	77,858
Channel spawners		\$ 86,800	\$ 187,488
Surplus spawners less initial brood		<u>- 4,055</u>	<u>- 8,776</u>
	Total:	82,745	178,712
Benefit/Cost ratio		1.87	2.30
Average fry output, millions/cycle	3.84		
Average cost per million fry		\$ 11,552	\$ 20,275
Average landings, lbs/cycle			
Channel spawners	215,921		
Surplus (net)	<u>10,087</u>		
Total:	205,844		
Average cost per lb		21.6¢	37.8¢

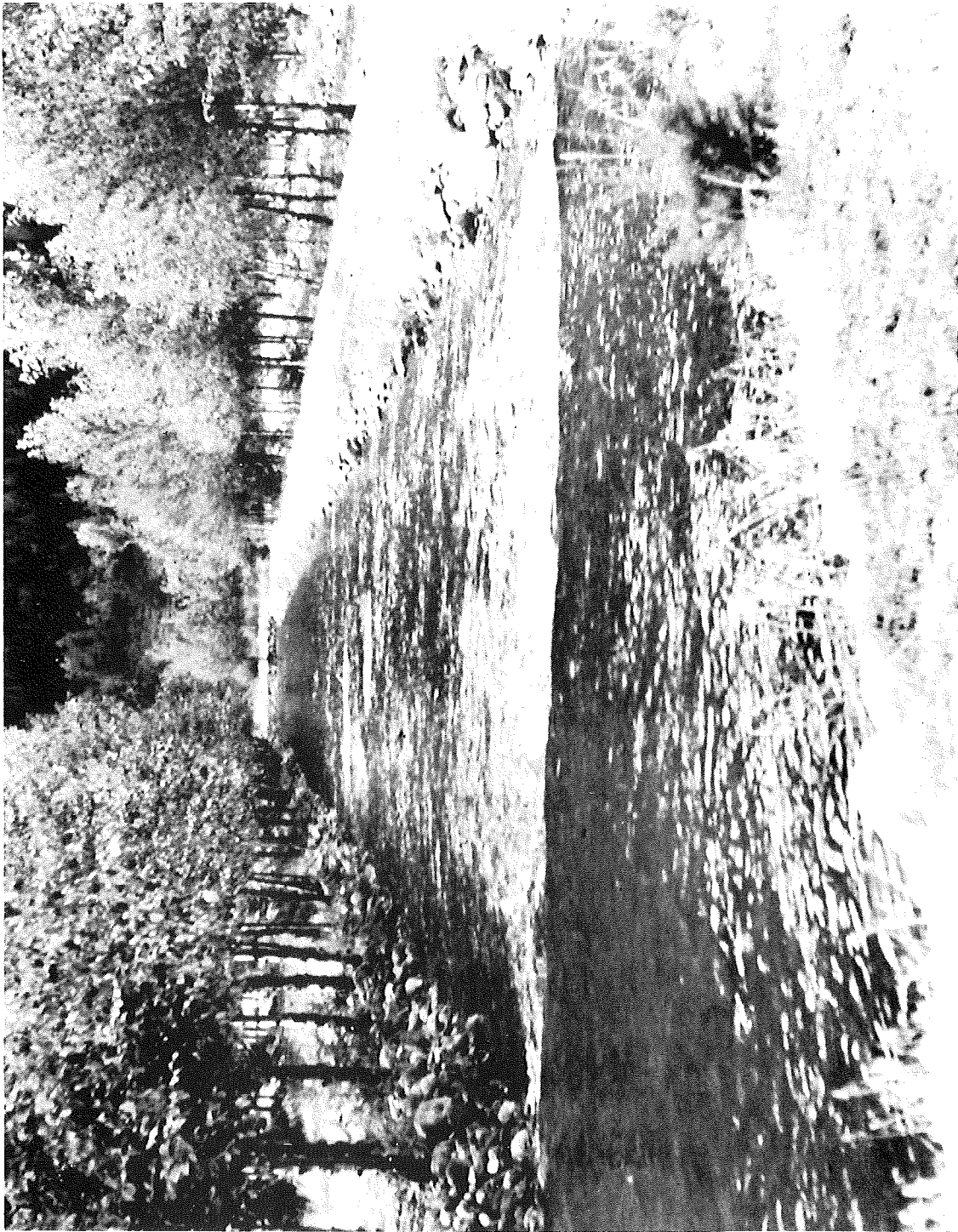


FIGURE 24 - Gates Creek channel.

However, these facilities require considerable attention by the operator, and as a result have met with varying success. Gravel and sand are carried through the intake opening and are deposited in deeper water in front of the screens. This deposit reaches almost 3 feet in depth at times and has to be removed each year prior to the start of the operating season. Modifications to the intake structure were made in 1977 to reduce the inflow of sand and gravel. Gravel also accumulates over the concrete base slab at the fish barrier fence in Gates Creek at the channel entrance. If water levels permit, this gravel is removed by machine to allow installation of the fence prior to the arrival of the run. However, in some years it has not been possible to do this because of high water levels. In these cases, the electric fence has been used to divert fish to the channel and has worked well.

## NADINA RIVER CHANNEL

### Description

The spawning channel on the Nadina River near Nadina Lake was constructed in the summers of 1970 to 1973 to improve the production of the Late Nadina sockeye run and increase utilization of the rearing area in Francois Lake.

The channel is located adjacent to the small natural spawning grounds used by the Late Nadina run, just below the falls on the Nadina River, approximately 1500 ft downstream from Nadina Lake (FIGURE 25). The 45-acre site occupied by the channel and its facilities was provided by a reserve on Crown provincial land. An additional 0.5 acres for pipelines was provided by easement on park reserve and Crown land under water.

The channel is 9759 ft long by 20 ft wide at the gravel surface, with a spawning area of 21,639 sq yd. The capacity was estimated to be 14,450 female sockeye spawners but results at Weaver Creek suggest the capacity may be larger. The channel has a bottom slope of 0.0005, with a total drop of 4.9 ft in the channel. To avoid ice problems associated with drop structures, the channel was designed without drop structures. The average depth of 1.56 ft and average velocity of 1.17 fps at a flow of 40 cfs were selected to promote the formation of a surface ice cover, thereby minimizing problems with frazil ice.

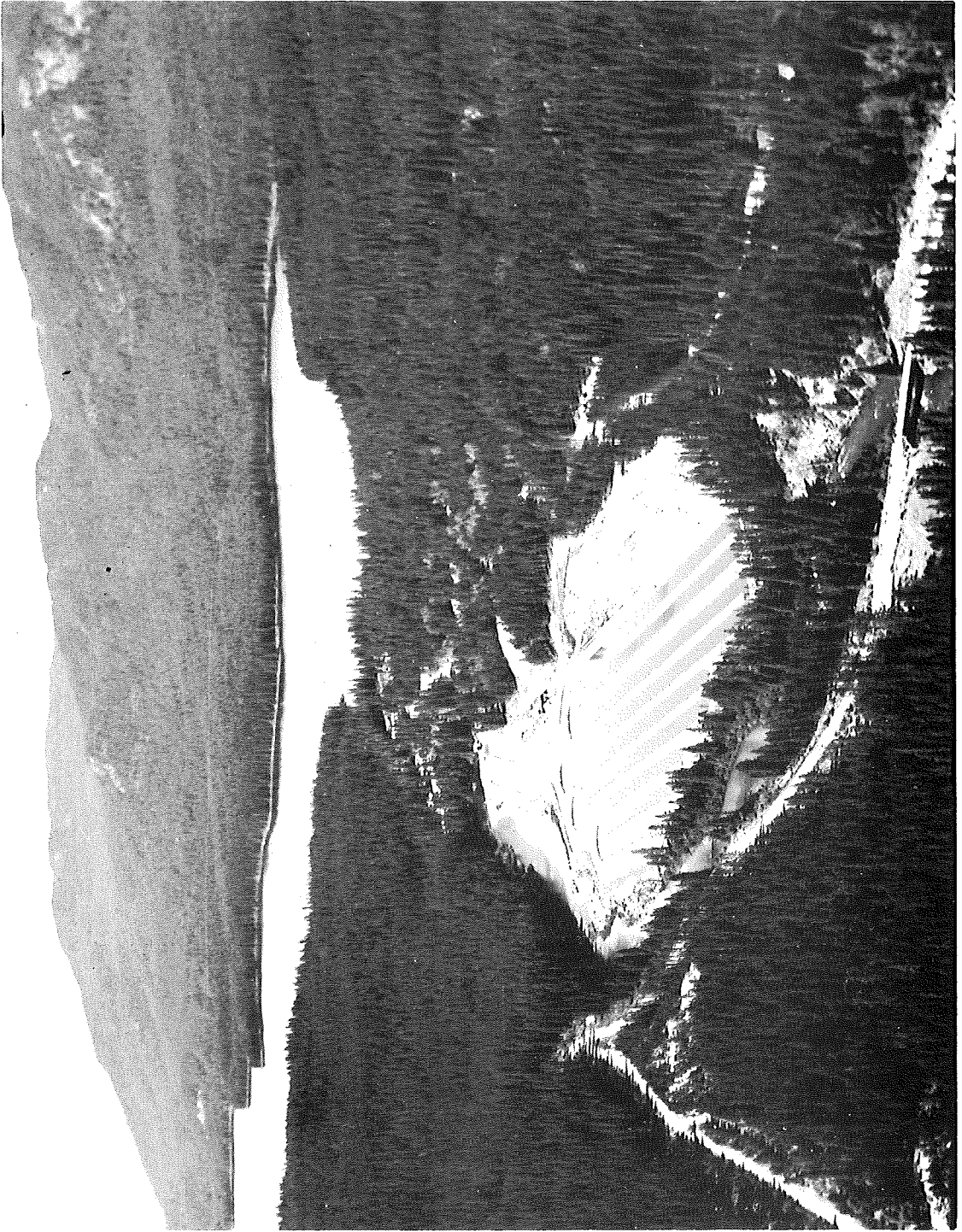


FIGURE 25 - Nadina Creek channel.

There are 6 quarried rock drop structures in the entrance fishway channel, each with a drop of 1 ft in water surface. A concrete structure at the upper end of the fishway contains an additional drop, and also provides support for a picket fence to control entry of fish and for the 5% sampler used to enumerate fry. For winter operation, the entire flow of the channel can bypass the fishway through a pipe. This feature was provided to eliminate problems with ice buildup on the drop structures. An auxiliary fish entrance is provided from the lower end of the main natural spawning area to a point in the channel approximately 930 ft upstream from the channel entrance. This entrance was provided after the first season of operation to assist in diverting fish into the channel, and is closed at all other times.

The channel has side slopes of 5:6 lined with quarried rock. A typical section is shown in FIGURE 26. It was anticipated that leakage from the channel might be a problem because of the necessity to construct part of the channel on fill materials. The fill material was obtained from part of the excavation for the site and contained a substantial proportion of clay. Construction specifications required compaction of the berms and subgrade as the materials were placed. When this was completed, a leakage test was made in the section of the channel adjacent to the river considered to be the area where leakage would be most likely to occur. Leakage from a 900 ft length of channel was measured at 0.16 cfs after 44 hours of testing. This was less than criterion of 0.5 cfs/1000 ft that had been established, and consequently it was not considered necessary to take any other measures to limit leakage. In October 1973, soon after the channel was put into operation, with an input of 36.26 cfs, the loss of water for the entire channel was measured at 1.26 cfs.

The 16-in. deep layer of spawning gravel was produced from a presumed glacial deposit a few miles from the site, using the same specifications as for the other channels. The sieve analysis of the material as placed in the channel is given in TABLE 37.

TABLE 37 - Average sieve analysis of gravel as placed in the Nadina River spawning channel.

<u>Square Sieve Size, Inches</u>	<u>Percentage Dry Weight Passing Sieve</u>
4	100
3	89.3
2	68.4
1½	52.3
1	29.6
¾	14.5
½	0.8

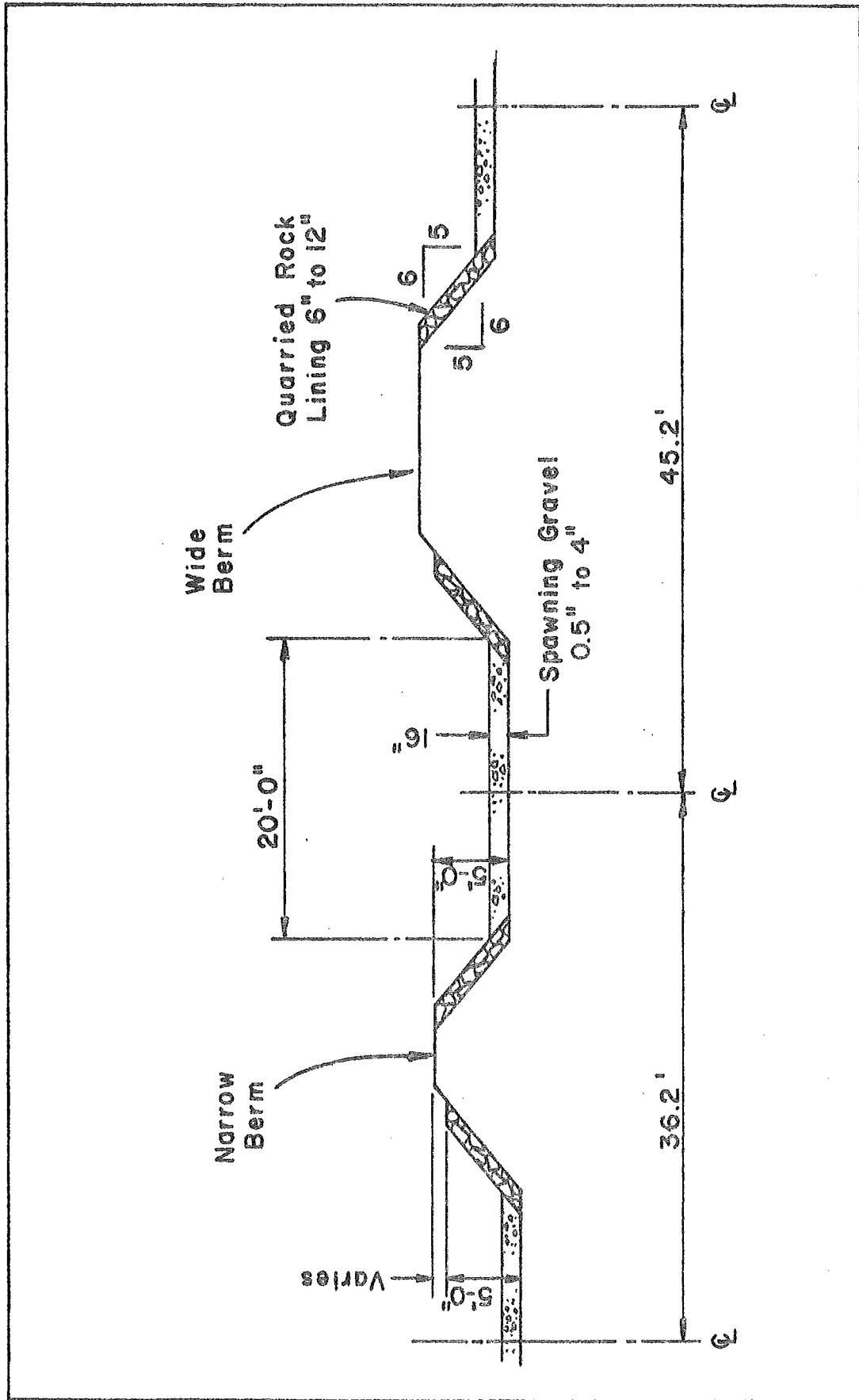


FIGURE 26 - Typical cross section of the Nadina River spawning channel.

The channel water supply of 40 cfs is obtained by gravity from Nadina Lake and is delivered through approximately 1500 ft of coated corrugated steel pipe and asbestos cement pipe. A butterfly valve at the lower end regulates discharge to the diffusion chamber at the upper end of the channel. The location of the intake at the outlet of Nadina Lake was selected to take advantage of the fact that even in very severe winter weather there is a small area that is always ice free where the outflow enters the river. A 30-in. corrugated pipe extends 720 ft into the lake to a depth of 30 ft to provide a flow of up to 22 cfs for temperature control during spawning. The intake structure provides for blending of the two sources of water as may be required. The intakes are screened to exclude fish resident in Nadina Lake.

Due to the location of the channel fish entrance at the upper end of the natural spawning grounds, it was not considered necessary to provide a base structure for a fish diverting fence.

### Results

The channel started operation in 1973 and has been operated each year since then. Details of the numbers of sockeye spawners, egg deposition and fry production are given in TABLE 38. Similar data for the natural spawning grounds is given in TABLE 39. Egg to fry survival in the natural spawning ground was determined to be 20% for the 1975 brood spawning, using hydraulic sampling methods. This rate has been assumed to apply for the two previous brood years. Based on the comparative fry outputs, the proportion of the returning runs attributed to the channel will be determined from the comparative fry outputs given in TABLE 40. The first returns are expected in the fall of 1977, so return rates cannot be determined yet.

TABLE 38 - Sockeye spawners, egg deposition and fry production, Nadina River channel.

Brood Year	Spawners		Success of Spawning Percent	Effective ♀	Fecundity	Eggs Deposited Millions	Fry Produced Millions	Survival Eggs to Fry Percent
	Total	♀ Only						
1973	8,781	4,935	94.30	4,654	2,870	13.357	9.906	74.2
1974	873	498	96.29	479	2,911	1.394	1.001	71.8
1975	11,296	6,592	87.11	5,742	3,288	18.880	12.113	64.2
1976	1,354	722	97.22	702	3,437*	2.413	1.593	66.0

\* Age 4 and 5 combined.

TABLE 39 - Sockeye spawners, egg deposition and fry production, Late Nadina natural spawning grounds.

Brood Year	Spawners		Success of Spawning Percent	Effective ♀	Fecundity	Eggs Deposited Millions	Fry Produced Millions	Survival Eggs to Fry Percent
	Total	♀ Only						
1973	7,939	5,138	97.0	4,984	2,870	14.304	2.861	(a)
1974	2,857	1,629	97.88	1,593	2,911	4.637	0.927	(a)
1975	4,013	2,874	91.04	2,616	3,288	8.601	1.740	20.2
1976	271	144	100.0	144	3,438*	0.495	0.099	(a)

(a) Assumed 20% egg to fry survival.

\* Age 4 and 5 combined.

TABLE 40 - Sockeye fry production, Nadina spawning channel and Late Nadina spawning grounds.

Brood Year	Fry from Nadina River	Fry from Channel	Total	Percent of Total from Channel
1973	2,861,000	9,906,000	12,767,000	77.6
1974	927,000	1,001,000	1,928,000	51.9
1975	1,740,000	12,113,000	13,853,000	87.4
1976	99,000	1,593,000	1,692,000	94.1

#### Costs

The channel cost \$761,159 to construct over the period 1970-74. Using a life expectancy of 20 years and 6% interest, the annual capital recovery cost is \$66,400. For the first three operating years, the average annual operating cost has been \$30,200. The estimated cost in 1975 is \$1,130,000.

### Operation and Maintenance Problems

The channel has not had any operating problems with ice, and has functioned as designed without incident. After four years of operation there is indication of some accumulation of fine silt and organic debris at the upper end of the channel and the gravel was cleaned prior to the 1977 spawning.

In the first year of operation a temporary wire fence was placed across the river leading to the channel fish entrance to direct fish to the channel, and this has been used each year. In 1975, in an effort to get as many spawners as possible into the channel, 3020 sockeye were captured by seining and were carried over the dyke into the channel. The auxiliary fish entrance was not effective in attracting fish to the channel.

Because of the isolated location of the channel and the extreme winter conditions encountered, special measures have been taken in terms of radio communication (two stationary and one mobile sets), snow removal equipment, winter transportation (snowmobile and snowtrack vehicle), and power supply (two sets).

### SUMMARY AND DISCUSSION

The results to date from four spawning channels and one incubation channel operated by the Commission show an aggregate benefit to fishermen of \$11.7 million in landed value of sockeye and pink salmon (TABLE 41). Since none of these projects had reached full capacity in the brood years that produced these returns, it is expected that benefits will increase in future years. The five channels that produced these benefits cost \$921,243 to build. First returns from a sixth channel, at Nadina River, are expected in 1977.

Benefit/cost ratios for the five projects, expressed in dollars of the year of start of each channel, have ranged from 1.87 to 8.86, with a weighted average of 5.66 (TABLE 42). If the costs and benefits are expressed on a common base of 1975 dollars, the average benefit/cost ratio is 6.91.

The six channels now in operation cost a total of \$1,682,402 to build, with the cost per sq yd of spawning area reflecting year of construction, type and complexity of construction (TABLE 43).

TABLE 41 - Summary of benefits from spawning and incubation channels in dollars of each catch year.

Channel	Brood Years	Accumulated Benefits \$ *		
		Channel Spawners	Surplus Spawners	Total
Upper Seton	1961-1973	\$ 618,630	\$ 175,336	\$ 793,966
Pitt	1963-1971	1,892,947	611,924	2,504,871
Weaver	1965-1972	5,305,482	192,851	5,498,333
Lower Seton	1967-1973	1,419,311	651,377	2,070,688
Gates	1968-1972	<u>844,463</u>	<u>- 18,615</u>	<u>825,848</u>
Total		10,080,833	1,612,873	11,693,706

\* Landed value of sockeye and pink salmon.

TABLE 42 - Summary of benefit/cost ratios.

<u>Channel</u>	<u>On Basis of Costs of Year Started</u>	<u>On Basis of 1975 Dollars</u>
Upper Seton	6.25	6.66
Pitt	7.29	9.66
Weaver	8.86	9.55
Lower Seton	5.70	7.16
Gates	<u>1.87</u>	<u>2.30</u>
Weighted Average	5.66	6.91

TABLE 43 - Summary of costs of construction of the five channels in dollars of completion year and estimated unit cost in 1975 dollars.

Channel	Construction Period	Construction Cost	Cost per Sq Yd	Est. Cost/Sq Yd 1975 Dollars
Upper Seton	1960-1961	\$ 32,259	\$ 5.36	\$ 14.52
Pitt	1961-1963	74,142	104.28	262.78
Weaver	1964-1965	280,725	13.47	31.65
Lower Seton	1966-1967	218,665	10.47	22.40
Gates	1967-1968	315,452	23.39	45.13
Nadina	1970-1974	<u>761,159</u>	35.18	52.22
		1,682,402		

On the basis of results at the two pink salmon channels at Seton Creek, it is believed that spawning density could be at least 0.9 females per sq yd. The capacity of the upper channel at this density would be 5,400 females, and the estimated fry production would be 7.5 million each cycle, twice the 3.75 million average for the brood years 1961-73. The capacity of the lower channel at this density would be 18,800 females, and the estimated fry production would be approximately 17 million or 1.4 times the 12 million average for the brood years 1967-73. In both of these cases the increased fry output would result in proportionate increase in catch.

The capacity of the Pitt River incubation channel was arbitrarily set at 4 million sockeye eggs. However, because of the difficulty of collecting eggs in Pitt River, the number of eggs planted in the brood years 1963-71 has averaged 3,038,000 and fry production has averaged 422 per sq ft. On the basis of experimental data (Pyper MS) and theoretical considerations of oxygen consumption, it is estimated that the maximum fry output of the channel would be 864 per sq ft, or about twice the observed average output. With the increased numbers of spawners in the Pitt River system in recent years, effort will be made to increase the number of eggs planted to double the fry output. Since there is no evidence that doubling the fry output will reduce the survival rate, this increase in fry output should double the catch.

The capacity of the Weaver Creek channel was originally estimated to be 10,900 female sockeye, whereas the number of female spawners in the brood years 1965-72 has averaged 3,619. The fry output for these years has averaged 10.8 million annually, and it is estimated that with 10,900 female spawners, the fry output would average 32 million annually. It is now estimated that the spawner density could be increased to 0.9 females per sq yd, which would accommodate 16,500 females. However, until adult returns from the large fry output from the 1976 brood are known, it is considered that production at full capacity should not be forecast to be more than approximately 400,000 sockeye total run from the channel each cycle. The average total run from the brood year 1965-72 has been 166,369, and the increase of approximately 234,000 fish would be available for harvest.

The capacity of the Gates Creek channel was estimated to be 9000 female spawners. For the brood years 1968-72 the actual number averaged 1506 females. With the channel utilized to its design capacity on the dominant cycle and the sum of the other three cycles at 10% of the design capacity as estimated in the justification report, the fry output would average 7.1 million annually compared to 1.885 million annually for the cyclic period 1968-71. The additional fry would increase landings and benefits by 3.76 times. On the basis of results at Weaver Creek, the channel capacity could be 12,000 females, but in justifying the channel it was estimated that the unutilized rearing capacity of Seton Lake would accommodate 9000 female spawners. The rearing capacity of Anderson Lake needs to be assessed more fully before considering increasing the number of spawners in the channel above 9000 females.

Using the foregoing, estimates were made of landings that would be obtained at full utilization of each project (TABLE 44). The total, averaging 779,000 fish annually, would be more than twice the present average of 363,000 fish annually. Additional landings may accrue from surplus spawners, depending on harvest rates and size of the spawning population, but these have not been included in estimating the benefit/cost ratio at full utilization. The benefit/cost ratios for the projects were determined on the basis of costs and values for the year of start of operations, and also for 1975 costs and values. The relatively high benefit/cost ratio for the Pitt and Weaver channels is partly attributable to production on each of the four cycle years. The two channels for pink salmon at Seton Creek only produce returns every other year, thus lowering the benefit/cost ratio. Similarly the channel for sockeye at Gates Creek produces returns primarily in the dominant cycle, or once every four years, and this lowers the benefit/cost ratio relative to the other projects. In the event it subsequently is found possible to increase one or more of the subdominant cycles, the benefit/cost ratio could be increased. The weighted average benefit/cost ratio on the basis of year of construction is calculated to be 11.5, and on the basis of 1975 dollars it is estimated to be 14.0.

The unit costs of production of fry are summarized in TABLE 45. The data show the advantage of spawning channels at Weaver Creek and Seton Creek over the Pitt incubation channel. The costs for the Gates Creek channel are higher, again because production is primarily once every four years.

TABLE 44 - Estimated average annual landings produced by channels at full utilization and calculated benefit/cost ratios.

Channel	Average Predicted Landings		Benefit/Cost Ratios	
	Fish	Pounds	Costs & Values for Year Started	Costs & Values for 1975
Upper Seton	144,000*	776,000	9.6	11.7
Pitt	98,000	748,000	12.6	16.7
Weaver	372,000	2,509,000	23.3	25.7
Lower Seton	343,000*	1,853,000	5.39	6.8
Gates	65,000	416,000	3.77	4.64

\* Average per 2-year cycle.

TABLE 45 - Average costs per million fry from the spawning and incubation channels on the basis of costs in dollars of the year started and in 1975 dollars.

Channel	Recorded Production		Full Production	
	Year Started	In 1975	Year Started	In 1975
Upper Seton	\$ 2,595	\$ 5,767	\$ 1,463	\$ 3,252
Pitt	7,259	14,035	3,660	7,076
Weaver	1,818	3,774	1,278	2,654
Lower Seton	3,954	7,817	3,015	5,961
Gates	<u>11,552</u>	<u>20,275</u>	<u>6,248</u>	<u>10,966</u>
Weighted Average	\$ 3,620	\$ 7,015	\$ 2,360	\$ 4,573

The calculated costs per pound of adult salmon catch are given in TABLE 46. The average cost has been 4.8 cents per pound in terms of the costs of the year of start of operation for each project. At full production levels it is estimated that this cost would be lowered to 2.7 cents per pound. The costs of the Gates Creek sockeye are higher than for the other four installations, again because production is primarily once every four years. The costs per pound for the other four installations at full production have a range of only 1.4 cents per pound.

TABLE 46 - Average cost in cents per pound of fish landed, produced by the spawning and incubation channels on the basis of costs in dollars of the year started and 1975 dollars.

Channel	Recorded Production		Full Production	
	Year Started	In 1975	Year Started	In 1975
Upper Seton	2.2 ¢	5.0 ¢	1.4 ¢	3.1 ¢
Pitt	4.6	8.9	2.7	5.2
Weaver	4.3	8.9	1.6	3.4
Lower Seton	2.6	5.2	2.8	5.5
Gates	<u>21.6</u>	<u>37.8</u>	<u>10.4</u>	<u>18.2</u>
Weighted Average	4.8 ¢	9.4 ¢	2.7 ¢	5.3 ¢

To give perspective to the costs in TABLE 46, comparison can be made with the costs of producing salmon at hatcheries. It is estimated from data on the contribution of hatcheries to the commercial harvest of Columbia River fall chinooks (Worlund, Wahle and Zimmer 1969), that it cost 21.5¢ per pound to produce a catch of 3.86 million pounds from the 1961 brood. The calculated cost of expected commercial catches of chinook, coho, chum and pink salmon from Washington State hatchery operation in 1958 was 19.6¢ per pound (Ellis and Noble 1959). The cost of the contribution of one Washington State hatchery to the commercial catch of coho in 1964 was estimated at 21.1¢ per pound (Senn and Noble 1967). Current estimates of cost of production are 25 to 50% higher than these earlier figures.

On the basis of these comparisons, the spawning and incubation channels reported here can produce sockeye and pink salmon for harvest at a comparatively low cost per pound of catch. Since pink and sockeye salmon are not amenable to hatchery production, the spawning and incubation channels are the only major production methods applicable with present technology. Experience with the channels described in this report suggests that the choice of an incubation channel or a spawning channel would depend to a considerable extent on the objectives and the applicability of the sites available to meet these objectives. In general, however, spawning channels offer substantial practical advantage for large scale application.

## CONCLUSIONS

1. a) The incubation channel for sockeye at Upper Pitt River has restored the Pitt River sockeye run and increased it to an average of 106,908 sockeye, 1.5 times more than the previous average run.
- b) The spawning channel for sockeye at Weaver Creek has restored the Weaver Creek run and increased it to an average of 203,800 sockeye or 2.4 times more than the previous average run.
- c) The spawning channel for sockeye at Gates Creek has increased the sockeye run to an average of 43,222 sockeye or 2.7 times more than the previous average run.
- d) The two spawning channels for pink salmon at Seton Creek have replaced 90% of the 30,000 sq yd of natural spawning ground estimated to have been lost because of construction of the Seton Creek hydroelectric project. Egg to fry survival in the two channels has been 5.3 times greater than for all other natural pink salmon spawning grounds in the Fraser system.

Thus these installations already have more than accomplished the objectives for each of them, and further increase in production is expected.

2. Using the year of start of operation as the base for evaluation of each of the foregoing projects, the average benefit-cost ratio has been 5.66. The benefits were produced by only partial utilization of the channels, and it is estimated that the total number of fish produced will be doubled at optimum utilization of the projects giving a benefit/cost ratio of 11.5.

3. The cost per pound of sockeye and pink salmon caught averaged 4.8 cents per pound at recorded production levels, and it is estimated this cost will be lowered to 2.7 cents per pound at full production level at the prices and costs of the year of start of each project. At 1975 prices and costs, these costs would be 9.4 and 5.3 cents per pound respectively.

4. Spawning and incubation channels are a practical and economically highly beneficial means of producing sockeye and pink salmon to supplement natural spawning stocks. Expanded use of such facilities, as recommended by the Commission in 1972, is fully justified by the results obtained to date with the channels now operated by the Commission.

#### ACKNOWLEDGMENTS

The funding, design, construction and operation of the six projects described in this report represent the combined efforts of many people, Commissioners as well as Commission staff. The contributions of all to the success of the program are acknowledged.