BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

Ebasco Services of Canada Ltd., Environmental Consultants - Hat Creek Project - Detailed Environmental Studies - Water Intake - April 1979

ENVIRONMENTAL IMPACT STATEMENT REFERENCE NUMBER: 26

B C HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT
DETAILED ENVIRONMENTAL STUDIES

APPENDIX B-3

WATER INTAKE

FINAL REPORT

APRIL 1979

EBASCO SERVICES OF CANADA LIMITED; ENVIRONMENTAL CONSULTANTS

(ESCLEC)

(Revised May 1979)

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1.0 SUMMARY AND RECOMMENDATIONS

The Thompson River, a major tributary of the Fraser River System drains the interior plateau of British Columbia. A site on the Thompson near Ashcroft, B C has been identified as the preferred makeup water source for the proposed Hat Creek thermal generating station. This study provides an assessment of potential impacts on the salmon resource of the Thompson River attributable to the proposed water supply development.

The Fraser is the largest single salmon producing river in North America, and accounts for approximately one-third of the total commercial salmon landings in British Columbia. The wholesale market value of the provincial commercial salmon fishery was approximately $440 million in 1974[(1)], and it is estimated that 10 percent of the provincial catch is contributed by the Thompson River[(2)].

Five species of anadromous salmonids; chinook, coho, pink and sockeye salmon and steelhead trout migrate past or reside in the area of the proposed water intake during some portion of their life cycle. Construction and operation of the intake would potentially affect these species. Potential impact would likely be limited to that associated with the operation of the proposed water intake, through impingement loss of juvenile downstream migrant salmon, providing salmon spawning and incubation periods are avoided by construction, or adequate measures are taken to minimize siltation.

Intake design emphasized fish protection, and the efforts of the design consultants incorporated the experience of Environment Canada, Fisheries and Marine Service and the International

Pacific Salmon Fisheries Commission, and the B C Fish and Wildlife Branch. A simple linear model which relates the rate of water withdrawal to downstream fry migration was then developed which projects estimated fish losses and assumes no fish protection measures. Less than one-half of one percent of all Thompson River salmonid stocks are potentially vulnerable to impingement, although there is strong empirical evidence to suggest that even the most vulnerable salmon fry will be successfully bypassed by the intake as presently designed.

The site selected for intake construction avoids critical habitats and spawning grounds and considerable effort has been expended in the design of the proposed intake to minimize fish exposure. Operational strategies are also available to protect fish during the most likely periods of potential impingement occurrence. Ebasco Services of Canada, Ltd.; Environmental Consultants (ESCLEC) concludes that Fraser River salmon stocks and the ecology of the Thompson River would not be adversely affected by the installation and operation of the proposed Hat Creek water supply intake. The following recommendations are offered to assure that no significant adverse impacts develop during construction of the intake and to provide early detection and mitigation of any unforeseen impacts:

1. Minimize suspended solids loading and habitat disturbance during construction, avoid silt loading to the Thompson River July 20 to May 31.
2. If disturbed, spawning grounds in the lower Bonaparte River be restored after construction of the water pipeline crossing and access bridge.
3. Monitor the intake screens during downstream migration periods to determine if any loss of juvenile salmonids occurs during intake operation.

4. Monitor the intake vicinity and bypass channel particularly during salmon spawning migrations, to determine presence of unusually large numbers of fish or unnatural behavior or disorientation.
5. Utilize operational flexibility provided by the excess reservoir capacity to reduce or cease intake operation during vulnerable migrations should impacts be noted during the monitoring programs described above.

2.0 INTRODUCTION

Operation of a closed-cycle 2000 megawatt coal-fired thermal generating station at Hat Creek requires a reliable cooling water supply. The present design specifies a water supply system composed of a Thompson River water intake, an overland pipeline, and a plant site reservoir. The water intake structure is a pier-type direct intake with vertical traveling screens and low head turbine pumps. It would be located on the Thompson River approximately 0.4 km (0.25 miles) upstream of the confluence with the Bonaparte River. Water would be delivered by a buried pipeline 23.5 km (14.6 miles) to a reservoir at the plant site.

The design flow rate through the intake screens is 1650 l/s (58.1 cfs), although estimated average pumping rate is 726 l/s (25.7 cfs)[3]. Maximum plant makeup water requirements range between 1146 l/s and 1395 l/s, depending upon the water management plan (1220 l/s preferred scheme)[4] employed. Average plant makeup water requirements would also depend upon the water management scheme selected. The average water makeup ranges between 622-824 l/s with (710 l/s preferred)[4]. The design approach velocity for the screens is 0.12 m/s (0.39 FPS) at design flow rate through the intake and at minimum river water level [3]. Considerable flexibility in pumping times and rates is possible without affecting power plant operations because a reservoir with a 70-day water supply at maximum plant requirement, is presently planned at the plant site [4].

The withdrawal of large quantities of water from a natural water body may adversely affect the aquatic organisms present in that body of water, either through their direct interactions with the intake structure or due to secondary effects which modify or degrade the existing aquatic habitat.

The Thompson River is a major tributary of the Fraser River watershed. The Fraser River drains approximately 90,000 sq mi of interior British Columbia and is the single most important salmon producing system in North America today. B C Hydro, recognizing the value of the Thompson River and its contribution to the Fraser River anadromous and resident fish stocks, selected Ebasco Services of Canada Limited, Environmental Consultants (ESCLEC) to evaluate the environmental effects of utilizing the Thompson River as the water supply source for the Hat Creek Project.

While the construction and operation of a water intake will affect the aquatic community in a variety of ways, the effect of major concern is the impingement of young salmonid species, particularly the most vulnerable of these, the pink salmon, Oncorhynchus gorbuscha. This assessment provides a general, predictive model to determine potential pink salmon impingement at the proposed intake and projects potential commercial fishery loss estimates should impingement of pink salmon fry occur. Results of the analysis characterize the range of potential pink salmon losses as downstream fry migration varies with time and river flow and provides input data for the economic evaluation of this impact.

The proposed intake includes several design measures to protect Thompson River fish. These are described in the PRELIMINARY DESIGN STUDY by Sandwell & Company, Ltd. [3] and in the Fish Protection Aspects of The Sandwell Design report by Beak Consultants Ltd. [10]. It is not possible to quantify the ultimate impingement reduction attributable to these fish protection measures for the model used herein. However, they are discussed qualitatively in Sections 4.0 and 5.0.

3.0 MATERIALS AND METHODS

An empirical approach was used to estimate environmental impact of the water intake construction and operation on resident and anadromous fish. The assessment is based primarily on the body of published data relevant to the Fraser River salmonid stocks; an intake design and location selected and developed by B C Hydro and Sandwell and Company, Ltd. the engineering consultants for the water supply system (including some hydraulic model results and information on fish protection design features); and the results of limited field reconnaissance conducted in 1977 by B C Hydro, Beak Consultants Ltd., and ESCLEC. Fisheries and Marine Service, Environment Canada and the International Pacific Salmon Fisheries Commission (IPSFC) and B.C. Fish and Wildlife Branch, assisted in the development of non-efficiency fish protection design features, reviewed the Sandwell design and recommended refinements.

Because anadromous salmonids are the most important fishery resource of British Columbia, they are accorded the major consideration in the assessment of impact. This assessment focuses on those life stages of species which would be most vulnerable to construction and operation of a water intake in the Thompson River. Vulnerability to adverse environmental impact can be considered to be a function of three interrelated factors:

- duration and intensity of the action causing the impact
- length of exposure of the organisms to the impact
- ability of the organisms to avoid the impact

Impacts are expressed as a potential loss of adults recruited to the commercial fishery.

Environmental impact for the purposes of this assessment can be considered to be a change in either the quantity or quality of an ecological resource, including habitat, due to the effects of one or more project actions. Impact assessment involves a description of the resource base and a measurement or estimate of the magnitude and significance of change.

The following assumptions were used to develop the impact estimates presented in this report. (These assumptions and their effect on the assessment are discussed in more detail in Section 5.0).

- anadromous salmonids are the most valuable fishery resource of British Columbia and for this reason are accorded the bulk of attention for the purposes of impact assessment and fish protection design.
- a larger proportion of the anadromous fish population as compared to resident fish population would be exposed to the intake due to the migratory behavior of the former group.
- pink salmon fry are considered most vulnerable due to their relatively poor swimming ability and abundance in the intake vicinity relative to other species exposed.
- fish would be homogenously distributed throughout the river cross-section in the intake vicinity.
- the intake would operate at average capacity during periods of pink salmon fry migration.
- impact would be a direct function of water withdrawal.
- a reduction in the number of downstream migrants (juveniles) would result in some reduction in the adult population available to the commercial fishery (loss would not be borne by spawning escapement, which is that portion of the adult population allowed to return to spawning grounds).

Important Thompson River salmonid species which could be affected by construction and operation of the water intake were characterized in a "vulnerability matrix". This matrix was designed to show the relative importance of the factors likely to affect a species vulnerability, and hence, impact. Factors considered include:

- life stage exposed to the intake
- numbers exposed to the intake
- temporal duration of exposure
- migratory or territorial behavior
- swimming ability

In addition to ranking the relative impact potential among the various species, a simple empirical model was used to quantify potential adult losses to the pink salmon commercial fishery. The model was developed from population and life history data obtained from the IPSFC, and from Thompson River discharge records at Spences Bridge, B C (Station 08LF051).

The model calculates a theoretical loss to the commercial fishery of returning adults ($A_{(a+2)}$) two years following the brood year (a) as the product of the pink salmon fry population (N_a,g,f,S_o); the ratio (θ) of intake flow (I_F) to river flow (R_F) and survivorship from fry to adult (S_1); thus:

$$A_{(a+2)} = (N_a)(gfs_o)\ (\theta)\ (S_1)$$

where,

$A_{(a+2)}$ = loss of adult pink salmon to the commercial fishery

N_a = spawning escapement to Thompson River during a particular brood year

g = sex ratio, ♀ / ♂

f = fecundity (eggs/female)

S_o = freshwater survival (egg to fry)

S_1 = marine survival (fry to adult)

θ = ratio of intake flow (I_F) to river flow (R_F), measured at Spences Bridge (Station No. 08LF051) at time (+m), where +m is the time of 90 percent passage of downstream migrant pink salmon fry.

In practice, the product of g, f, S_o and S_1 can be treated as a population constant (K_{pop}), derived from IPSFC records obtained since 1957. Tables 3-1, 3-2 and 3-3 summarize relevant data for pink salmon population statistics. The value of the population constant computed from the following mean values:

$$S_o\bar{x} = 0.134$$

$$g\ \bar{x} = 0.59$$

$$f\ \bar{x} = 2000$$

$$S_1\bar{x} = 0.029$$

thus:

$$K_{pop} = S_o\bar{x} \cdot g\ \bar{x} \cdot f\bar{x} \cdot S_1\ \bar{x}$$

$$K_{pop} = 4.585$$

Intake flow (I_F) was set equal to the average pumping rate of 726 l/s (25.7 cfs)[3]. The equation describing potential losses to the commercial pink salmon fishery can then be reduced to a direct relationship between Thompson River pink salmon spawning escapement (N_a), Thompson River flow (R_F) and population constant describing fry production and egg to adult survival. Thus:

$$A_{(a+2)} = K_{pop}(N_a)\ (\Theta)$$

or:

$$A_{(a+2)} = 4.585\ (N_a\ \Theta)$$

TABLE 3-1

FRASER RIVER PINK SALMON
ESCAPEMENT STATISTICS /1

Brood Year	Total Spawners $x10^6$	Female $x10^6$	Sex Ratio (g)	Potential Egg Deposition $x10^9$	Fecundity (f)
57	2.425	1.423	0.59	2.8745	2020
59	1.078	0.596	0.55	1.0847	1820
61	1.094	0.654	0.60	1.5692	2399
63	1.953	1.217	0.62	2.4348	2001
65	1.191	0.692	0.58	1.4878	2150
67	1.831	1.015	0.55	2.1321	2101
69	1.529	0.961	0.63	2.0182	2100
71	1.804	1.103	0.61	1.923	1743
73	1.754	1.015	0.59	1.865	1837
75	1.367	0.806	0.59	1.493	1852

g $\bar{x}$ = 0.59 f $\bar{x}$ = 2002

/1 Source: International Pacific Salmon Fisheries Commission Annual Report, 1977 (17).

TABLE 3-2

FRASER RIVER PINK SALMON
SURVIVORSHIP VALUES /1

Brood Year	Freshwater Survival (S_o)	Marine Survival (S_1)
57	-	-
59	-	-
61	0.092	0.037
63	0.117	0.008
65	0.184	0.047
67	0.111	0.016
69	0.097	0.05
71	0.127	0.028
73	0.157	0.017
75	0.187	0.029

$S_o \bar{x} = 0.134$ $S_1 \bar{x} = 0.029$

/1 Source: International Pacific Salmon Fisheries Commission Annual Report, 1977 (17).

TABLE 3-3

ANADROMOUS SALMONID[1] ESCAPEMENT TO THE THOMPSON RIVER DRAINAGE[2]

Brood Year	Pink	Coho	Sockeye	Chinook	Total
1957	269106	12000	330974	20533	632613
1958		16600	2362660	29850	2409110
1959	87224	9350	197547	17150	311271
1960		18075	11852	16625	46552
1961	69411	24575	80584	12900	187470
1962		20775	1217301	21050	1259126
1963	285243	9775	237610	16575	549203
1964		15325	10334	24175	49834
1965	233100	31000	75155	18800	348055
1966		15575	1358394	13625	1387594
1967	450487	4350	861472	30250	1346559
1968		13450	20522	24250	58222
1969	247896	19325	71586	30525	369332
1970		16300	1561853	28725	1606878
1971	258203	15559	307867	21650	603279

TABLE 3-3 (Cont'd)

Brood Year	Pink	Coho	Sockeye	Chinook	Total
1972		12454	22017	17147	51618
1973	283385				
1974					
1975	480350	NA	NA	NA	NA
1976					
1977	972941				
Annual Average	165334 /3	15906 /4	545482	21490 /5	701667 /6
Cycle Average	(330668)				
%of Fraser River Annual Escapement	21%	27%	43%	46%	30%

/1 Steelhead data - not available.

/2 Sources: Environment Canada, Fisheries and Marine Service, 1974[5], and International Pacific Salmon Fisheries Commission Annual Report, 1977[17].

/3 Includes average annual escapement to Nicola and Bonaparte Rivers of 911 fish/year.

/4 Includes average annual escapement to 1839 fish to the Nicola River.

/5 Includes average annual escapement to 3777 fish to the Nicola River.

/6 1957 - 1972 only.

4.0 RESULTS

The assessment of potential impacts associated with the Hat Creek water intake is based on an assessment of the potential susceptibility of the habitat and its resident and migratory fish community to impact. Resident and migratory fish species expected to occur in the vicinity of the proposed intake are listed in Table 4-1. While resident species may be influenced by the intake throughout their life cycle, only a small proportion of the total Thompson River population would be exposed to a potential impact. In contrast to this all anadromous salmonids migrating past the Thompson River intake are potentially vulnerable to its effects. Due to their commercial and recreational value and because a larger proportion of the anadromous population could be exposed to intake effects, the Pacific salmon were considered the important species for protection. Table 4-2 shows the average percentage of annual escapement of Pacific salmon to the Thompson River. In terms of total numbers sockeye and pink salmon are the most important. It should be noted however that 46 percent of the historical Fraser River chinook salmon run is contributed by the Thompson River.

Table 4-3 presents the relative vulnerability of the important Thompson River salmonids. Vulnerability was assumed to be dependent on the total numbers exposed, duration of exposure and relative ability of the life stage exposed to avoid impact. As a result of this assessment, pink salmon (fry) were considered to be the most vulnerable to intake effects, as they would be present in the greatest numbers and at the smallest size (approximately 30 mm total length). Although rainbow and steelhead trout fry could be exposed at a smaller size, they are not expected to be found in the vicinity of the intake in significant numbers at this early life stage.

Potential impacts can result from both construction and operation of the proposed intake. Impacts associated with construction are limited to stream habitat disruption (including siltation) associated with the construction of the intake pier in the Thompson River and the buried pipeline crossing and access bridge on the Bonaparte River. The Bonaparte River is apparently under consideration as part of the Salmon Enhancement Program (SEP) but no detail information was available when this report was written. These activities are discussed in detail by Sandwell [(3)] and are scheduled during the fall and winter of even-numbered years and the spring of odd-numbered years. This effectively eliminates construction impacts to pink salmon. Effects associated with these activities should be short-term in nature and are limited to coho, chinook, steelhead and some rainbow trout.

Spawning grounds in the Thompson River should not be affected if suspended solids loading is controlled. Some spawning areas in the lower reaches of the Bonaparte River would be unavoidably disturbed. Estimates of suitable spawning habitat by ESCLEC and IPSFC biologists indicate that the best gravels lie near the mouth of the Bonaparte River, and the affected area could represent as much as 25-30 percent of the available spawning area between Bonaparte Falls and the confluence with the Thompson River. Annual escapements to the Bonaparte River are estimated to average 25 chinook and approximately the same number of coho[(5)(2)]. Based on catch escapement ratios of 4.0:1 for chinook and 3.0:1 for coho, severe disruption of this area during spawning season could result in an estimated potential loss of up to 40 chinook and coho to the fishery.

Timing of construction activities to avoid spawning and incubation periods and use of proper restorative measures in the disturbed areas after construction would serve to greatly reduce or eliminate these potential impacts. No other construction impacts are predicted.

Operational impacts are those associated with water withdrawal, and for the purposes of this report are assumed to be directly related to volume withdrawn. The equation presented in Section 3.0 is used to estimate impact as equivalent adults (ie, adult losses to the commercial fishery). It is assumed that any potential stock reduction would not be permitted to reduce managed escapement to the spawning grounds and that any additional impacts would be considered ultimately as an additional mortality, affecting total allowable catch.

The relationship between pink salmon escapement (N_a) and estimated losses to the pink salmon stock (A_{a+2}) due to potential fry impingement were computed for Thompson River discharges between 5000 and 50,000 CFS. Figure 4-1 presents the result of this analysis. The geometric mean flow for the period of record (1927-1977) is presented, corresponding to the potential loss projection for a flow of 23,400 CFS.

Back-calculated loss estimates are made for the years 1959, 1961 and 1975 based on the assumption that the intake was in place and operating. Pink salmon fry migration information is available for these years[6]. These calculated loss estimates are presented in Table 4-4 and on Figure 4-1 to place them in perspective. The estimates are based on the mean Thompson River flow at Spences Bridge (Figure 4-2) and corresponding census data expressed as the cumulative downstream migration of pink salmon fry are presented in Figure 4-3.

Other potential impacts can occur due to operation of a large water intake. Impact can be due to habitat loss and current disruption by the physical placement of the structure or the loss associated with downstream habitat effects due to water withdrawal. The loss of the physical area of the river associated with the placement of the intake pier in the bottom is an unavoidable loss, however, it is less than that associated with the construction of a bank-type intake. This habitat is not used for spawning and does not represent a significant loss. Additionally, the shallows along the bank are avoided. This shoal area represents an important habitat and refugia for the smaller life stages of the resident fish and salmonids which may utilize this reach of river as a rearing habitat.

Flow modification due to placement of the structure can cause both habitat loss, due to scour, and disorientation of migrating salmonids. The considerable hydraulic engineering and modelling efforts associated with the intake design, and its generally streamlined shape should eliminate or minimize flow problems. Disorientation of migrants is a critical factor, however. The survival rate of juvenile salmonids is closely tied to the finding of favourable conditions in the estuary and at sea during their marine rearing period (see Foerster, 1968,[7] for a general discussion) which involve a highly complex interaction of timing, climate, food availability and other environmental factors. Additionally, the successful return to the spawning grounds by adults involves a delicate balance of energy reserves and stream conditions. Delay can mean returning adults never reach the spawning grounds, or if they do spawn, subsequent egg survival may be low or development slowed so that fry emerge to less than optimal conditions the following spring.

The flows around the pier and through the intake bypass channel are designed to encourage fish passage and should not result in significant delay or disorientation of juvenile downstream migrants. The placement of the pier allows for the free passage of fish on both sides, particularly important for upstream migrants. There is, however, a tendency for migrating salmon to "take the path of least resistance" and the lower velocity indicated for the bypass channel may tend to attract some adults during the spawning migration. While the numbers actually entering the intake bypass channel are not expected to be large as the intake pier represents less than 10% of the cross-sectional area of the river, the importance of each returning spawner to the maintenance of the stock is great enough to justify the need for investigation of this problem. Should upstream migrants prove to be delayed or disoriented by entering the bypass itself, modification to the intake would be necessary and could be easily accomplished.

Additional habitat disruption will occur due to the construction of the intake pier itself and the bridge and submerged pipeline crossing of the Bonaparte River. Increases in suspended solids loading, if kept to a minimum and timed to avoid spawning and egg and larval development periods, should not affect downstream spawning areas. There are no significant spawning areas between the proposed intake site and the town of Ashcroft [2][3]. The habitat disruption in the Bonaparte River should constitute a one-time event and only affect chinook, coho and possibly steelhead during one year, as the activity is not scheduled to occur during a pink salmon spawning year. With proper gravel restoration techniques after construction, the area can be returned to its original productivity.

The sizing of the intake and booster pumps of the water supply system results in the removal of more water than can be accepted by the pipeline booster pumps. The amount of the excess water is variable, and would be returned via underwater discharge to the Thompson River below the confluence of the Bonaparte River. Returning salmonids utilize a variety of cues to locate their home streams, primarily olfactory[8], and it is possible that the introduction of a large enough flow immediately below the Bonaparte's confluence with the Thompson could measurably dilute the cues associated with the Bonaparte's discharge. While the chance of this occurring is slight and the disorientation resulting from it would be transitory, return of this excess flow to a point on the Thompson above the mouth of the Bonaparte would remove this as a possible concern.

The removal of water from a river or stream carries with it the possibility of changes in water depth, velocity and other physical characteristics associated with stream discharge, such as temperature and stream width, which can cause adverse effects on the existing resources of a river or stream[9]. All present water use allocations, including the required 1580 l/s (55 CFS) for the Hat Creek Project, would represent less than 2.3% of the 10 year average 7-day low flow of 152,255 l/s (5,300 CFS). Much of the presently allocated water use is seasonal in nature (see Appendix B) and would not be withdrawn during the low flow period. No reduced productivity can be attributed to a flow reduction of this magnitude.

While reduced flow can result in delays to upstream migrating adults or reduced egg and alevin survival through the exposure of redds or reduced flow of water through the redd, a flow reduction of the magnitude imposed by the Hat Creek Project would not be significant. It should not affect migrating spawners and while precise quantification of the impact to spawning beds would require a detailed flow analysis of downstream spawning beds, the greatest potential change in water levels (approximately 1 cm) would not critically deteriorate any existing spawning grounds.

The presence of man-made structures in a water body have the characteristic of attracting resident fish, just as natural cover does. The design of any structure should avoid the creation of additional potential predator habitat or conditions which would concentrate prey species and thereby attract predators. Several predators of salmonid fry and smolts are resident in the Thompson River. These include Dolly Varden, rainbow trout and northern squawfish. The placement of the intake pier should not concentrate predators to any greater or lesser extent than existing structures and obstructions, such as bridge piers and boulders[10]. The design of the proposed intake attempts to minimize flow disruption and large areas of still water or eddies which might attract either prey or predators.

TABLE 4-1

FISH SPECIES FOUND IN THE THOMPSON RIVER IN THE VICINITY OF THE PROPOSED INTAKE/1

Pink Salmon	*Oncorhynchus gorbuscha*
Sockeye salmon	*Oncorhynchus nerka*
Coho salmon	*Oncorhynchus kisutch*
Chinook salmon	*Oncorhynchus tshawytscha*
Mountain whitefish	*Prosopium williamsoni*
Steelhead trout	*Salmo gairdneri*
Rainbow trout	*Salmo gairdneri*
Dolly Varden	*Salvelinus malma*
Peamouth chub	*Mylocheilus caurinus*
Northern squawfish	*Ptychocheilus oregonensis*
Longnose dace	*Rhinichthys falcatus*
Redside shiner	*Richardsonius balteatus*
Finescale sucker	*Catostomus catostomus*
Bridgelip sucker	*Catostomus columbianus*
Largescale sucker	*Catostomus macrocheilus*
Aleutian sculpin	*Cottus aleuticus*
Slimy sculpin	*Cottus cognatus*

/1 Source:Beak consultants, Ltd., 1978 (2).

TABLE 4-2

PERCENTAGE CONTRIBUTION OF THOMPSON RIVER BASIN TO ANNUAL FRASER RIVER SALMON ESCAPEMENT /1

	Average Annual Fraser River Escapement (Number of Fish)	Average Annual Thompson River Basin Escapement	Percent Percent
Sockeye	1,264,690	545,740	43
Pink	806,260	118,800	15 /2
Coho	62,725	16,785	27
Chinook	51,200	23,470	46
Chum	339,670	0	-
TOTAL	2,524,545	704,795	28

/1 Source: Environment Canada, Fisheries and Marine Service, 1974 (5)

/2 Percent contribution of Thompson River to total escapement has shown a general upward trend since 1959, in 1977 an estimated 40 percent to total Fraser River pink salmon escapement was to the Thompson River.

TABLE 4-3

RELATIVE VULNERABILITY OF IMPORTANT THOMPSON RIVER SALMONIDS

Species	Average Thompson River Escapement Number	(Percentage Above Intake)	Vulnerable Life Stage	Relative Duration of Exposure	Avoidance Ability	Vulnerability Rank [1]
Chinook	17,713	(82)	All freshwater life stages	Transitory to 2 years	Moderate to high [2]	4
Coho	14,067	(88)	All freshwater life stages	About 1 year	Moderate to high [2]	5
Pink	330,668 [3]	(82)	Adult spawners, downstream migrants (fry)	Transitory	Low	1
Sockeye	545,482	(100)	Adult spawners, downstream migrants (small)	Transitory	High	2
Steelhead	Present, variable numbers		All freshwater life stages	2-3 years	Moderate to high (2)	3

[1] Ranking of 1 = Most Vulnerable

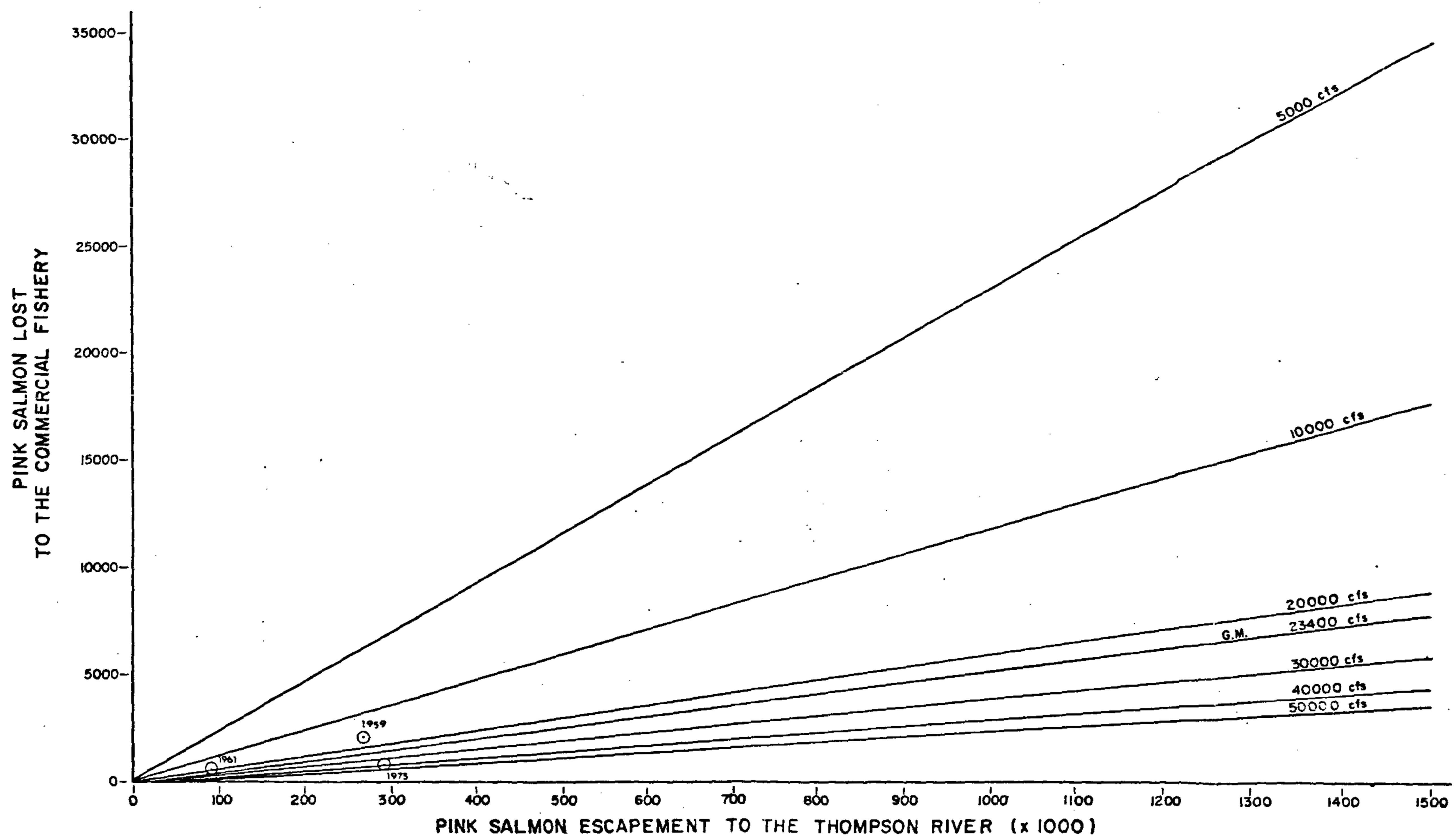
[2] Depending on Life Stage

[3] Every Odd Numbered Year

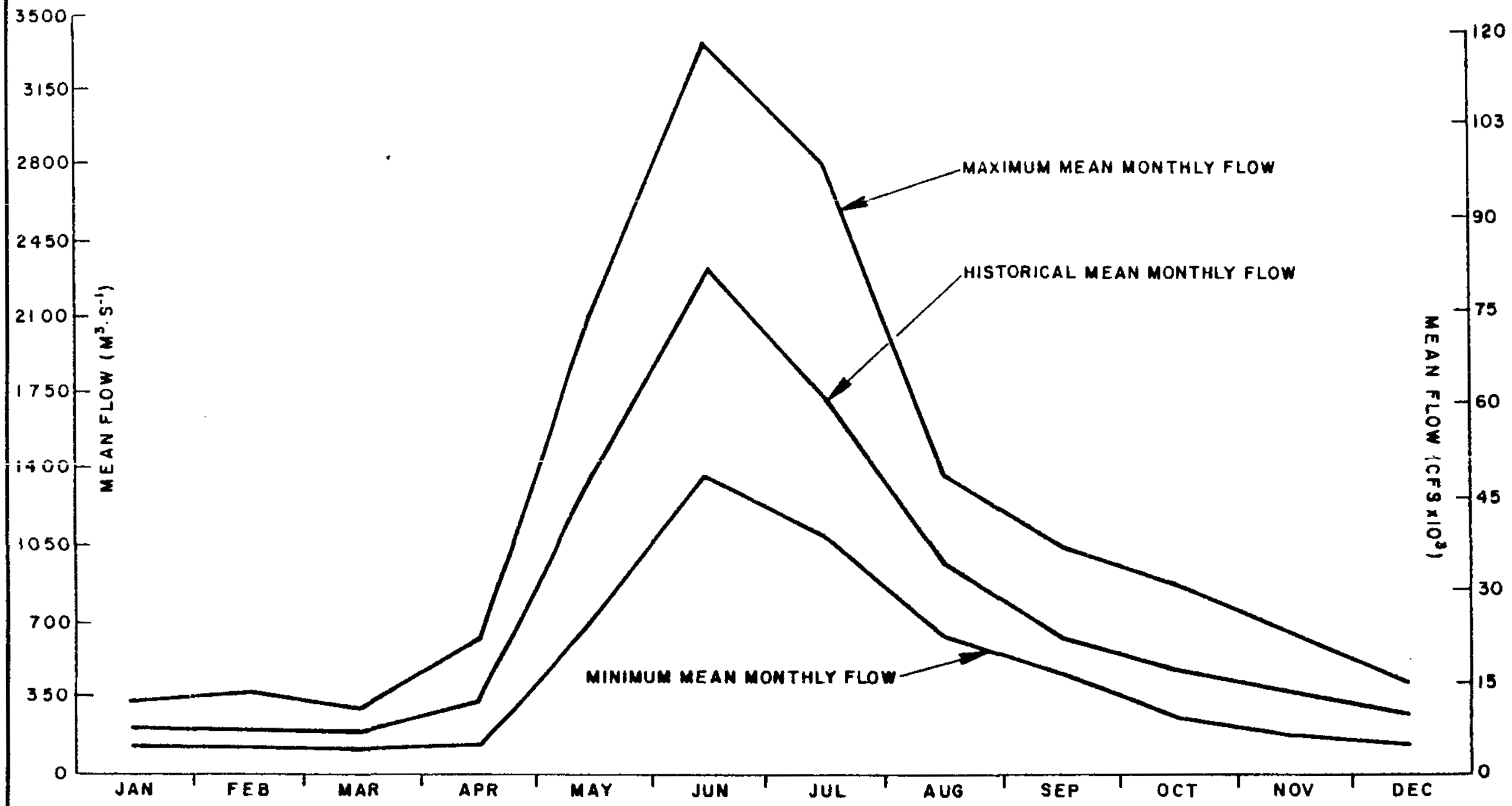
TABLE 4-4

POTENTIAL PINK SALMON LOST
TO THE COMMERCIAL FISHERY COMPUTED
FOR BROOD YEARS 1957, 1959 AND 1973

Brood Year	Pink Escapement (N_a)	θ	Loss to Commercial Fishery $A_{(a+2)}$	
1957	269106	0.0016688311	2080	(1959)
1959	87224	0.0008538205	290	(1961)
1973	283385	0.0010447154	800	(1975)



BRITISH COLUMBIA HYDRO AND POWER AUTHORITY	EBASCO SERVICES OF CANADA LIMITED: Environmental Consultants	FIGURE 4-1
	POTENTIAL LOSSES OF PINK SALMON TO THE COMMERCIAL FISHERIES	
	THE HAT CREEK PROJECT - Detailed Environmental Studies	



BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

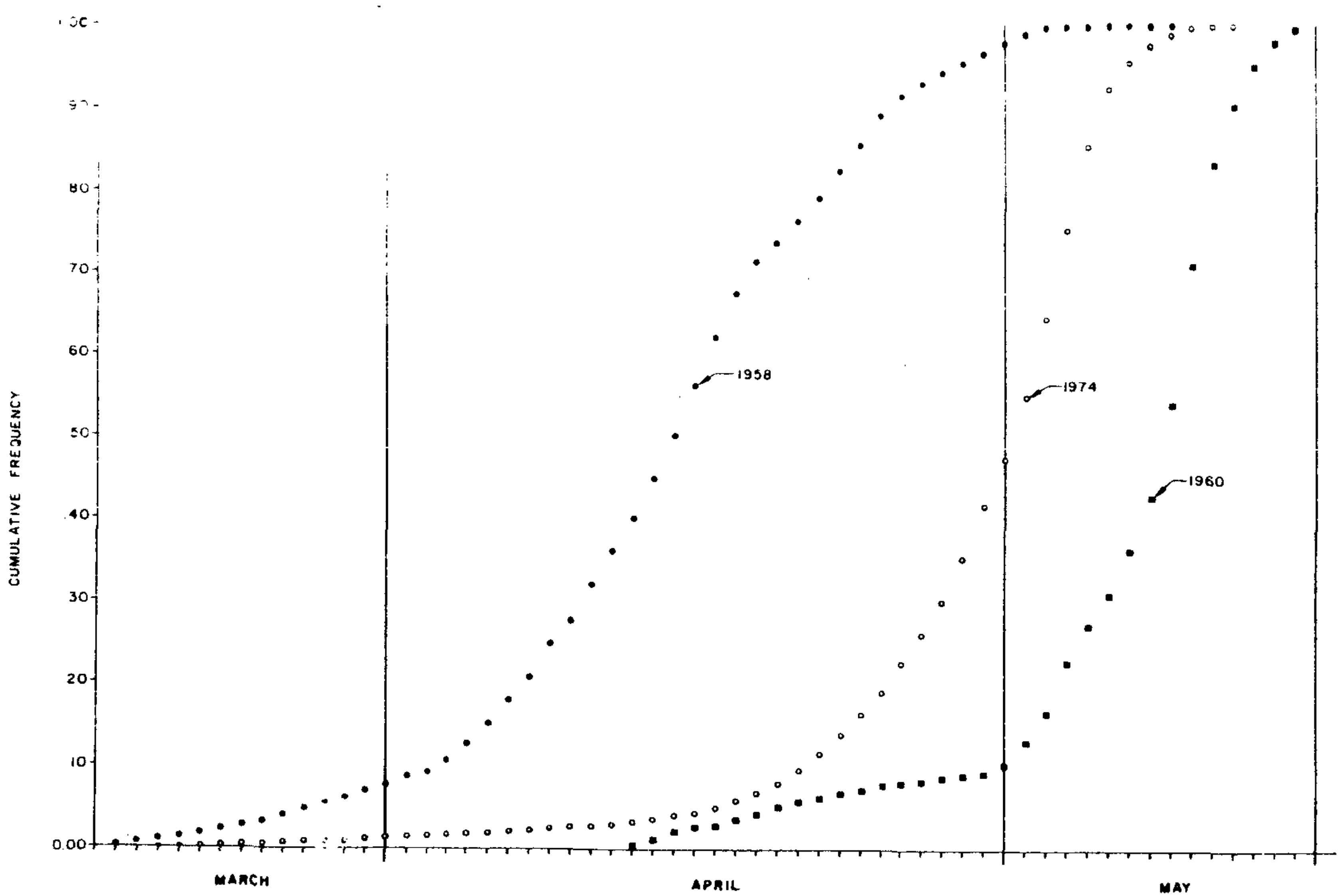
EBASCO SERVICES OF CANADA LIMITED; Environmental Consultants

MEAN MONTHLY DISCHARGE

THOMPSON RIVER, HISTORICAL RANGE

THE HAT CREEK PROJECT – Detailed Environmental Studies

FIGURE 4-2



BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

EBASCO SERVICES OF CANADA LIMITED; Environmental Consultants

CUMULATIVE DOWNSTREAM FRY MIGRATION PINK SALMON

FIGURE 4-3

THE HAT CREEK PROJECT – Detailed Environmental Studies

5.0 DISCUSSION

A simple linear model which relates pink salmon spawning escapement, water intake pumping rate and river flow to estimate a potential magnitude of pink salmon losses to the commercial fishery is presented for Thompson River discharges between 5000 and 50,000 CFS. This model is based on a variety of assumptions and qualifications need to be considered when assessing the impact potential of the proposed intake.

For the purposes of the calculation provided here, a homogenous temporal and spatial distribution across the river and through the water column was assumed. In reality this may not be the case. Pink salmon, particularly, may initially migrate in higher numbers during the night than during the day [11][12], although this may vary[6][13][14]. Regardless of time of migration there may also be a tendency for fry to migrate in the upper levels of the water column[12][14]. Additionally, lateral distribution of both sockeye and pink downstream migrants seems to be directly related to water velocity[6][13]. These variables were not considered in the quantified impact estimate, however, owing to insufficient site specific data.

River discharge affects both the density of fish in the water withdrawn and the intake approach velocity. Higher discharge (occurring later in the freshet period) would reduce fish density by increasing the volume of water in which the fish are contained, and it would lower screen approach velocity by increasing the submergence of the screens. Both factors would combine to reduce the number of fish vulnerable to potential impingement.

The model's loss estimates for pink salmon are predicated on the assumption that <u>none</u> of the design aspects for protecting fish at proposed intake will reduce potential impingement, and that impingement is directly related to water withdrawal. Each of these assumptions introduces significant conservatism.

While swim speed information is primarily derived from laboratory studies and is often ambiguous or difficult to interpret when applied to a field situation[10][15], numerous observations indicate that salmonid fry can successfully negotiate intake velocities below 0.15 m/s (0.5 FPS) for prolonged periods[10]. Studies on the effects of size and temperature to swim speeds of sockeye salmon[16] have resulted in the development of relationships which have been applied to other sizes and species of fish. While no juveniles under 50mm in length were tested, the equation for the 1 hour sustained swim speed at 2°C,

$$\log Y = 0.9053 + 0.6294 \log X$$

where: Y = 1 hour sustained swim speed (cm/s), and
X = length (cm),

indicates that 30mm fry should be capable of maintaining a sustained swim speed of 0.16 m/s (0.52 FPS), which is well above the maximum design screen approach velocity of 0.12 m/s (0.93 FPS) for this intake.

While it is naive to assume that no fish will be lost by the operation of this intake, the intake velocities are well below the theoretical sustained swim speed for even pink salmon fry, the most vulnerable of the species considered. It should also be noted that the actual intake screen velocity should always be lower than the design screen velocity as this latter figure is based on a minimum river water level. This level would rarely, if ever, occur during the period of downstream fry migration, (the onset of "freshet").

This, coupled to the demonstration of an effective bypass current which can act to direct the fish on downstream should avoid even the concentration of fry noted by Pyper at the Lornex intake[6].

Realistically then, while the maximum calculated impact that is presented herein represents less than 0.5 percent of the Fraser River salmonid escapement, it would likely be such a small percentage of even that figure as to be insignificant. In the unlikely event that operational impacts due to impingement became evident after start-up, additional operational alternatives are available. Plant design provides for a reservoir at the plant site for makeup water. This reservoir is presently sized to allow 70 days of storage at the maximum power plant water requirements[4]. This operational scheme could allow for a total intake shutdown should such an impingement incident associated with the downstream migration of salmon or trout or smolts occur. It would also allow day-night pumping operation if significant diel variation in fish occurrence was found. Thus, the combination of fish protection design measures, small potentially affected population and available opportunities for mitigation indicate the protection of Thompson River salmonid populations has been assured in the design of the Hat Creek water intake.

6.0 REFERENCES

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APPENDIX A

TERMS OF REFERENCE

AUGUST 1977

APPENDIX B3

WATER INTAKE

1. Assemble information on and evaluate the Thompson River as a water supply source considering such fish factors as:

   - timing of fry/juvenile downstream migrations by species
   - size, behaviour of downstream migrants and also sufficiency of supply of water and water quality

2. (a) Consider impact of reduced river flow on downstream ecology of the Thompson River.

   (b) Identify and advise of any probable options for future use of Thompson River water which are foreclosed by this development.

3.* Discuss intake design, location and screening with reference to Canada Department of Environment, Fisheries and Marine Service recommendations and requirements. Explain the critical factors which protect against:

   - entrainment of migrating fish
   - creating a haven for predators
   - disorientation, and
   - clogging of intakes

4.* Evaluate the experience of Lornex Mines and other intakes for reference in the Hat Creek intake design.

5.* Indicate the reasons for the selection of the Thompson River as preferred source of water for the Hat Creek Project.

6. A report covering all items in this Appendix will be prepared by the consultant responsible for Items 1 and 2. Input on Items 3 to 5 will be provided by the consultant assigned the preliminary engineering for the water supply study.

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* To be provided by consultants carrying out the preliminary engineering for the water supply.

APPENDIX B

WATER LICENSES

THOMPSON RIVER

WATER LICENSES AND APPLICATIONS
ON THE THOMPSON RIVER
BETWEEN WALLACHIN AND LYTTON, BC

Location	Date	Volume	Purpose
H 502	February 3, 1975	0.65×10^6 cf (1)	Irrigation (2)
H 501	March 7, 1975	2.6×10^6 cf	Irrigation (2)
J 502	April 21, 1975	0.65×10^6 cf	Industrial (2)
J 502	April 21, 1975	0.03 cfs	Industrial (2)
C 381	March 21, 1960	13.1×10^6 cf	Irrigation
E 380	May 2, 1964	0.004 cfs	Domestic
FH 380	March 8, 1968	34.9×10^6 cf	Irrigation
FH 380	March 8, 1968	0.001 cfs	Domestic
E 381	April 10, 1968	7.0×10^6 cf	Irrigation (2)
P 363	July 17, 1915	0.019 cfs	Industrial
NN 362	April 2, 1968	78.4×10^6 cf	Irrigation
L 304	April 20, 1898	0.19 cfs	Domestic
T 304	February 13, 1932	8.9×19^6 cf	Irrigation
L 304	July 3, 1962	0.74 cfs	Domestic
CC 305	May 25, 1964	33.7×10^6 cf	Irrigation
U 301	August 9, 1967	7.8×10^6 cf	Irrigation
Y 301	August 13, 1968	27.9 cfs	Mining
Y 301	November 18, 1968	- - -	Mining (2)
Y 301	September 21, 1970	0.04 cfs	Mining (2)
HH 348	January 4, 1974	9.1×10^6 cf	Irrigation
	TOTAL (3)	64.5 cfs	

(1) The volume of water allocated for irrigation purposes covers the entire growing season.

(2) Denotes Water Application only, not a license.

(3) Conservatively Assuming Irrigation Occurs for only a two-month period.