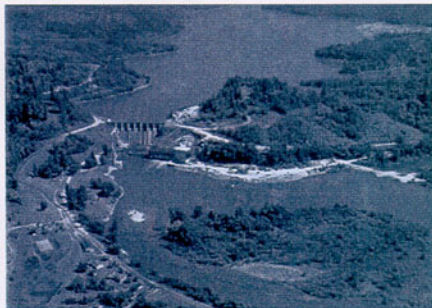
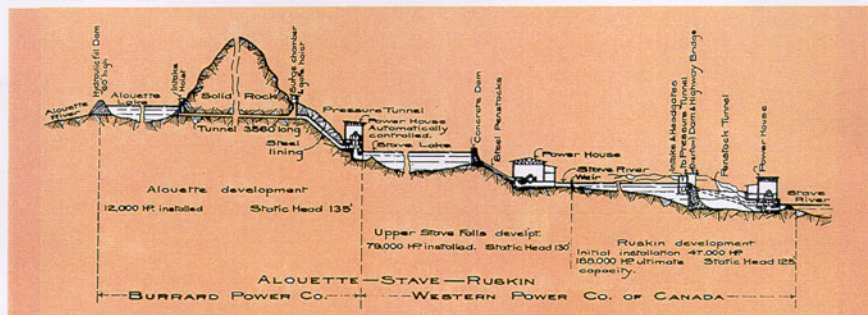
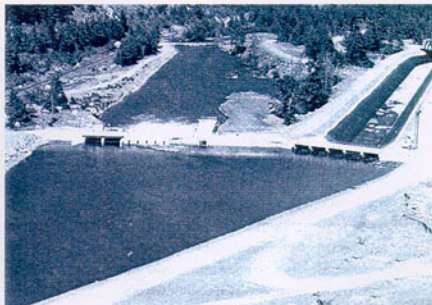


Bridge-Coastal Fish and Wildlife Restoration Program

STRATEGIC PLAN



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**Bridge-Coastal Fish and Wildlife Restoration Program
Volume 2: Watershed Plans**

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Chapter 1

INTRODUCTION TO WATERSHED PLANS

1. OVERVIEW

The Watershed Plans comprise Volume 2 of the Strategic Plan of the Bridge-Coastal Fish and Wildlife Restoration Program (BCRP). They contain detailed information on fish and wildlife impacts, issues and restoration objectives in each of the 15 watersheds in BC Hydro's Bridge-Coastal Generation Area (Figure 1-1). They may be revised or supplemented as necessary during the implementation of the Program, within the context of the framework set out in the Strategic Plan.

The Watershed Plans describe the footprint impacts of hydroelectric development and identify biological factors that may limit species production and diversity in the watersheds based on available information. This provides basic information for developing restoration objectives for each watershed. Technical workshops held in Kamloops, Nanaimo and Vancouver in June 2000 provided input on the major fish and wildlife issues and the development of potential restoration strategies.

2. DATA SOURCES AND METHODOLOGY

2.1 Facility Descriptions

The available statistics on BC Hydro facilities often varied in terms of reservoir dimensions, drawdown regimes, licensed diversions and other parameters, depending upon the data and map source and methods of analysis. This is due to different calculations at low and full reservoir pool, variations from year to year in reservoir inflows, or differences in the maps used to undertake calculations, or the methods of calculations undertaken over the years. Except for reservoir areas, we have generally used the latest numbers available from BC Hydro (*Making the Connection*, April 2000).

This study generated new estimates for reservoir areas, flooded areas of general habitat types, flooded lengths of stream channels, and lengths of reservoir shorelines. These data were developed from GIS calculations of pre-impoundment maps superimposed on the TRIM I digital map base. Other typical data sources are noted below.

D A M		RESERVOIR	
Site	Map reference	Total area	GIS calculation using TRIM I digital map base
Function	BC Hydro	Land area flooded	GIS calculation
Capacity	Maximum Sustained Generating Capacity, <i>Making the Connection</i> , BC Hydro 2000	Shoreline length	GIS calculation
Height	<i>Making the Connection</i> , BC Hydro 2000	Normal drawdown	BC Hydro
Length	BC Hydro	Storage volume	<i>Making the Connection</i> , BC Hydro 2000
Fishway	BC Hydro	Avg. annual inflow	BC Hydro, 1992-97 records
Fish flow releases	<i>Making the Connection</i> , BC Hydro 2000, & BC Hydro Operations Manual	Licensed diversion	BC Hydro, 1995 report

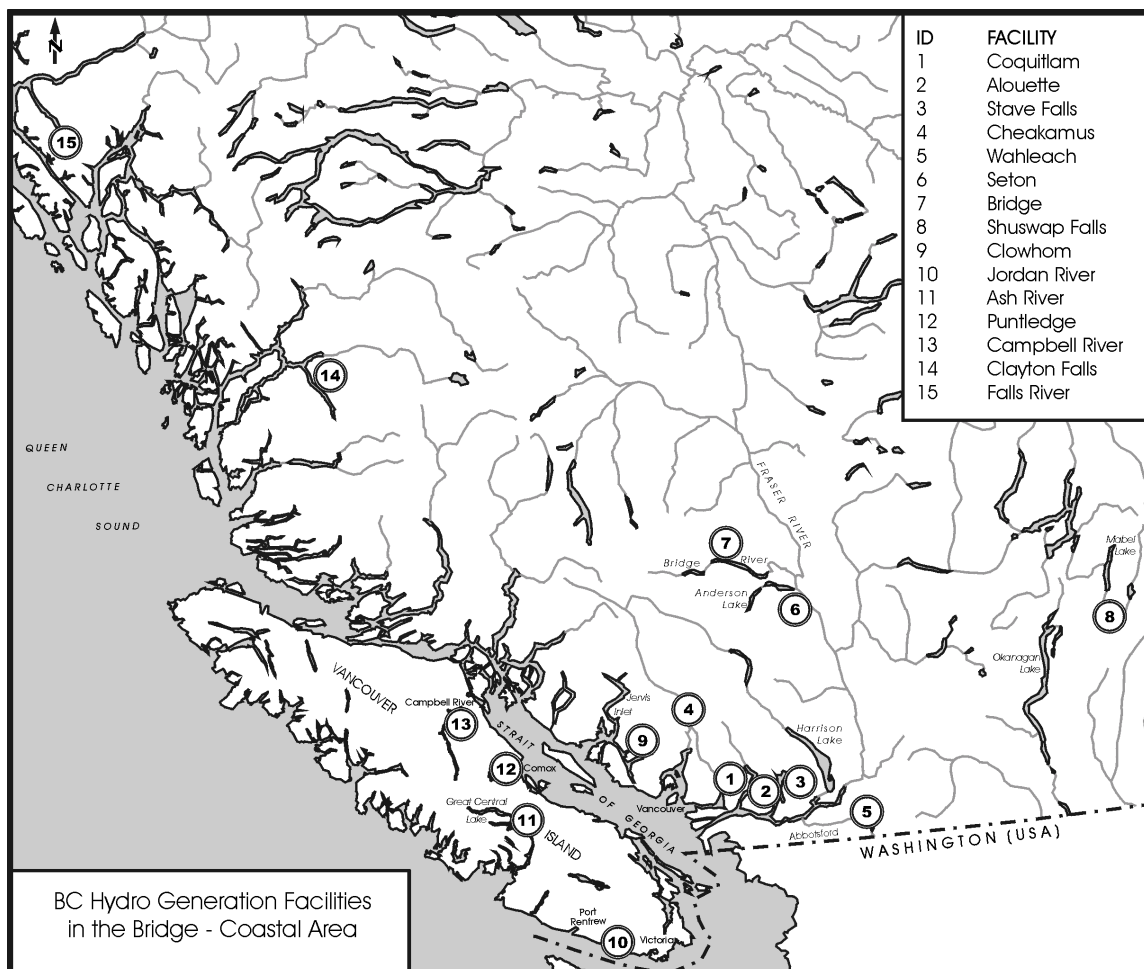


Figure 1-1. Watersheds in the Bridge-Coastal Restoration Program

2.2 Fish Data and Sources

Principal sources of information on hydroelectric impacts and on BCRP fish populations and aquatic habitats included:

- ❑ unpublished reports by the Department of Fisheries and Oceans, the BC Ministry of Environment, the International Pacific Salmon Fisheries Commission, BC Hydro, environmental consultants, and other agencies (*e.g.*, McMynn and Larkin 1953)
- ❑ technical reports by agencies (*e.g.*, Burt and Mundie 1986)
- ❑ this study's GIS calculations of habitat losses based on pre- and post-project maps
- ❑ internal agency memoranda located in public archives and library special collections.
- ❑ primary scientific literature, which has suggested generic or potential impacts on a worldwide scope (*e.g.*, Baxter 1977) and papers with a regional theme (*e.g.*, Geen 1974)
- ❑ government fisheries and watershed databases accessed via the Internet
- ❑ Internet search engines also found websites containing local historical information and photographs that provided additional insights for this review.

Information on fish was drawn from many of the sources listed under the references section of each Watershed Plan. Stan Hirst's (1991) comprehensive study of BC Hydro's impacts on anadromous and resident fish in the Bridge-Coastal watersheds continues to be an important source of information. Tables on species presence were based on the FISS database in the Pisces website (www.pisces.env.gov.bc.ca/FishWizard.asp) which was also the source of the reservoir bathymetric maps. Common and scientific names of fish are listed in Table 1-1.

2.3 Wildlife Data and Sources

Most pre-development knowledge of wildlife species in BCRP watersheds includes anecdotal comments in BC Game Commission reports, a few documents discussing individual species, particularly elk, and, in the case of more recent projects, from the memories of people who knew the reservoir areas in the 1940s and 1950s. Population information is non-existent except for estimates of moose wintering in the Bridge River Valley and surveys of elk in the Province. Trapping records were a potential source of information about the occurrence of commercially valuable species in an area; however, such information is typically gathered for large trap line areas spanning many habitats, and older site-specific trapline records were not available. In many cases, species presence in watersheds was inferred from knowledge of species ranges and habitats present.

Identification of wildlife habitats impacted by reservoir flooding is also largely one of inference, since no detailed descriptions were done before flooding. Old survey maps and air photos and, sometimes photographs, were often helpful in identifying general habitat types for areas flooded since the late 1920s. Some engineering reports commented that steep, heavily timbered hillsides were cleared or flooded. Assumptions about the nature of those forests could be made from current knowledge of biogeoclimatic zonation and perhaps from an assumption about whether forests at the time were old growth or second growth.

Table 1-1. List of common and scientific names of fish species found in BC Hydro's Bridge-Coastal area

Anadromous Sport Fish

Steelhead	<i>Oncorhynchus mykiss</i>
Cutthroat trout (coastal)	<i>Oncorhynchus clarki clarki</i>
Dolly Varden (coastal)	<i>Salvelinus malma</i>
Sockeye salmon	<i>Oncorhynchus nerka</i>
Coho salmon	<i>Oncorhynchus kisutch</i>
Chinook salmon	<i>Oncorhynchus tshawytscha</i>
Pink salmon	<i>Oncorhynchus gorbuscha</i>
Chum salmon	<i>Oncorhynchus keta</i>

Resident Sport Fish

Rainbow trout	<i>Oncorhynchus mykiss</i>
Cutthroat trout	<i>Oncorhynchus clarki</i>
Dolly Varden	<i>Salvelinus malma</i>
Bull trout	<i>Salvelinus confluentus</i>
Brook trout	<i>Salvelinus fontinalis</i>
Lake trout	<i>Salvelinus namaycush</i>
Kokanee	<i>Oncorhynchus nerka</i>
Mountain whitefish	<i>Prosopium williamsoni</i>
Lake whitefish	<i>Coregonus clupeaformis</i>
Burbot	<i>Lota lota</i>
White sturgeon	<i>Acipenser transmontanus</i>

Resident Forage Fish

Largescale sucker	<i>Catostomus macrocheilus</i>
Longnose sucker	<i>Catostomus catostomus</i>
Bridgelip sucker	<i>Catostomus columbianus</i>
Northern squawfish	<i>Ptychocheilus oregonensis</i>
Peamouth chub	<i>Hylocheilus caurinus</i>
Redside shiner	<i>Richardsonus balteatus</i>
Brassy minnow	<i>Hybognathus hankinsoni</i>
Longnose dace	<i>Rhinichthys cataractae</i>
Torrent sculpin	<i>Cottus rhotheus</i>
Prickly sculpin	<i>Cottus asper</i>
Slimy sculpin	<i>Cottus cognatus</i>
Coastrange sculpin	<i>Cottus aleuticus</i>
Threespine stickleback	<i>Gasterosteus aculeatus</i>
Pacific lamprey	<i>Lampetra tridentata</i>
River lamprey	<i>Lampetra ayresi</i>
Brown bullhead	<i>Ameiurus nebulosus</i>

However, habitat capability would be more useful information to acquire because the particular seral stage at the time of flooding is a reflection of the geological history, fluvial history, fire history, and other factors acting on an area. Plant communities are not static and each association has its own set of wildlife values.

Because of the lack of empirical data before flooding, therefore, the best way of estimating impacts of BC Hydro facilities was to combine information from the following sources:

- ❑ area measurements or estimates of general habitat types flooded (Volume 1)
- ❑ wildlife species range maps, including the distribution of species of concern (*e.g.*, Provincial red- and blue-listed species, and species with commercial, recreational, or other public interest)
- ❑ biogeoclimatic climax zone vegetation associations
- ❑ ecoprovince wildlife associations
- ❑ general knowledge of wildlife species habitat associations
- ❑ anecdotal information about the wildlife species present before flooding, and
- ❑ anecdotal information regarding of the kinds of prior human influences that modified an area to be flooded.

Information on wildlife was drawn from many of the sources listed under the references section of each watershed plan. A list of species groups of interest and their associated habitats (Table 1-2) was developed from the BCRP workshops held in June, 2000. Reference information on Biogeoclimatic Zones/Ecoprovinces (Table 1-3) is from BC Ministry of Forests and Demarchi (1996). Information on red and blue listed species as of May, 2000 is from the Conservation Data Centre, BC Ministry of Environment, Lands and Parks, Victoria (Table 1-4).

BC Ministry of Environment regional offices contained the most information on historical wildlife and habitats in the reservoir areas, but much of it was anecdotal. The reports of the BC Game Commissioner from 1905 to 1968 contained the most historical information, but none of it was quantitative and it did not cover all areas of interest.

BC Hydro provided several reports with wildlife data pertinent to BCRP watersheds including a compilation of red- and blue-listed species. Most of the BC Hydro reports provided information on current rather than historical conditions.

Some information was obtained from local contacts but they seldom had first hand knowledge of areas before flooding. Their knowledge of wildlife use was limited to their particular involvement at the time, usually ungulates, furbearers, and carnivores; almost no information was available about herptiles, passerines, small mammals, and other groups. The results of discussions were incorporated into the annotated reference list. No First Nations traditional use information was available for use in this study.

Table 1-2. Wildlife species groups and associated habitats.

Species Groups	Habitat-based guilds					
	Shallow wetland associated species	Riverine associated species	Deep water associated species	Lowland, flood plain, and riparian associated species	Upland forest associated species	Tree cavity dependent species
Ungulates						
Carnivores/omnivores/-herbivores (except ungulates)						
Aquatic and riparian mammals						
Bats						
Waterfowl, wetland/riverine, and riparian associated birds						
Piscivorous birds						
Raptors						
Gallinaceous birds						
Passerines						
Amphibians						
Reptiles						
Invertebrates						
Rare Plants/ecosystems						

Table 1-2 summarizes the species habitat associations that were identified at the regional workshops. The discussion of wildlife habitat impacts in the Watershed Plans should be considered in relation to the species groups listed below.

Aerial photographs were examined to supplement pre-flooding engineering drawings of many of the rivers and lakes. Map indices from UBC Geography were used to determine photo availability. Historical photographs, usually at scales of 1:30,000 to 1:40,000, were obtained from Geographic Data BC (after 1950) and Reprographics BC (prior to 1950). We viewed the airphoto files in Victoria and found sufficient coverage for our purposes. Photos of interest were photocopied and used as a basis for interpretation. Stereo viewing was not possible from the photocopies.

Habitat information was transferred from the photocopies of airphotos onto the map bases made from the historical drawings. The major habitat categories that could be determined at this level were lake, river channel, wetland, lowland deciduous, lowland coniferous, and upland.

Table 1-3. Biogeoclimatic Zone and Ecoprovince Associations in BC Hydro's Bridge-Coastal area.

Watersheds		Biogeoclimatic Zone	Ecoprovince and Characteristic Wildlife Species
Vancouver Island	Campbell	Basin Elevation: 1. Coastal Western Hemlock Upper Watershed: 2. Mountain Hemlock 3. Alpine Tundra, especially for mainland watersheds	Georgia Depression: Mule deer, cougar, Roosevelt elk (Vancouver I), coyote (mainland), river otter, mink, raccoon, opossum, 2spp. water shrews, Coast mole, Douglas' squirrel, 90% of provincial bird spp., 60% of provincial breeding bird spp., wintering waterfowl and raptors abundant in lowland and coastal areas, bushtit and Hutton's vireo breed only in this ecoprovince, marbled murrelet, ensatina salamander characteristic. Coast and Mountains (upper watershed): see below Coast and Mountains: Mule deer (only common terrestrial ungulate), mountain goat, black bear, grizzly bear (mainland), wolf, cougar, river otter, Keen's myotis, Vancouver Island Marmot (Vancouver I), mink, Townsend's vole, white-footed mouse, 79% of provincial bird spp., 57% of provincial breeding bird spp., (2 nd highest ecoprovince total), breeding red-throated loon and spotted owl (mainland) restricted to this ecoprovince, marbled murrelet, 6 amphibians mostly restricted to this ecoprovince.
	Puntledge		
	Ash River		
	Jordan River		
Southern Mainland	Cheakmus River		
	Alouette/Stave		
	Coquitlam		
	Wahleach Lake		
N Coast	Clowhom River		
	Falls River		
	Clayton Falls		
Interior	Bridge-Seton	Basin Elevation: 4. Interior Douglas-fir 5. Montane Spruce Upper Watershed: 6. Montane Spruce 7. Engleman Spruce-Subalpine Fir 8. Alpine Tundra	Central Interior: Moose is most widespread ungulate, mule deer, bighorn sheep, cougar, black bear, coyote, wolf, western jumping mouse, muskrat, long-tailed weasel, big brown and Townsend's big-eared bats hibernate in ecoprovince, 65% of provincial bird spp., 62% of provincial breeding bird spp., western toad, spotted frog Coast and Mountains (upper end of Anderson Lake): see above
	Shuswap	Basin elevation: 9. Interior Cedar Hemlock Upper Watershed: 10. Engleman Spruce-Subalpine Fir 11. Alpine Tundra Downstream: 12. Interior Douglas-fir	Southern Interior Mountains: Mountain goat, white-tailed deer, elk, caribou (relic pop. in old-growth spruce forest), grizzly and black bear, long-eared myotis, pika, hoary marmot, Columbian and golden-mantled ground squirrels, water vole, 70% of provincial bird spp, 62% of provincial breeding bird spp., osprey), breeding western grebe, wintering & migratory American coot, waterfowl (particularly redhead), white-breasted nuthatch, Clark's nutcracker, painted turtle, garter snakes, long-toed salamander, western toad, spotted and northern leopard frog. Southern Interior (downstream): Mule deer, white-tailed deer, bighorn sheep, spotted and pallid bats, 74% of provincial birds, 70% of provincial breeding birds, yellow-breasted chat, California gull, western rattlesnake, tiger salamander.

BC Ministry of Forests. 1988. Biogeoclimatic zones of B.C. map; Demarchi. 1996.

Table 1-4. Potential occurrence* of threatened and endangered vertebrate species (MELP) and “identified wildlife” (Forest Practices Code) in BC Hydro’s Bridge-Coastal area.

[illegible]

[illegible]

Scientific Name	Common Name	Global Rank	Prov. Rank	Prov. List	Watershed												
					Vancouver Is.				Lower Mainland				Interior		Mainland Coast		
					1	2	3	4	5	6	7	8	9	10	11	12	13
<i>Mustela erminea anguinae</i>	Vancouver Island Ermine	G5T3	S3	Blue													
<i>Mustela frenata altifrontalis</i>	Long-tailed Weasel, <i>altifrontalis</i>	G5T?	SH	Red													
<i>Taxidea taxus</i>	Badger (Seton only)	G5	S2	Red													
<i>Oreamnos americanus</i>	Mountain Goat			Id Wldl													
<i>Cervus elaphus roosevelti</i>	Roosevelt Elk	G5T4	S2S3	Blue													
<i>Rangifer tarandus pop. 1</i>	Caribou, southern population	G5T2T3Q	S2	Red													
<i>Ovis canadensis californiana</i>	California Bighorn Sheep	G4G5T4	S2S3	Blue													

* Species potentially affected by hydro development and operations.

~ Mainly or entirely in the estuaries to which the river systems flow. Only the Puntledge, Campbell, Gold River, and Clowhom estuaries were considered. Species occurring primarily in marine waters and considered unlikely to appear in the estuaries of interest were not included.

- Watersheds:
1. Campbell system
 2. Puntledge River
 3. Ash River
 4. Jordan River
 5. Cheakamus River
 6. Alouette/Stave system
 7. Coquitlam system
 8. Wahleach Lake
 9. Bridge-Seton system
 10. Middle Shuswap River
 11. Clowhom River
 12. Falls River
 13. Clayton Falls.

3. BACKGROUND TO RESTORATION OBJECTIVES

3.1 Rationale for Objectives

The restoration objectives for each Watershed Plan are based on the review of technical reports, workshop discussions, and the identification of footprint impacts and limiting factors. The means to achieving these objectives will be realized through execution of projects that the Bridge-Coastal Fish and Wildlife Restoration Program supports.

“Limiting factors” provide the focus for developing restoration objectives in the watersheds. These include critical habitat elements within the life cycle requirements of a species or within ecological communities that currently constrain population productivity. Other factors also limit populations but are directly managed by agencies (*e.g.*, establishing harvesting rates for fish and wildlife), or they occur outside the watershed (*e.g.*, ocean survival); however, these are considered beyond the scope of addressing hydroelectric impacts.

Limiting factors are identified in a general manner, recognizing that precise knowledge about specific constraints to species production or diversity is not often available. However, the review material and professional views of fish and wildlife managers provide a basis for identifying suspected limiting factors for species or species groups. In some cases, a lack of knowledge about limiting factors suggests a need for identifying data gaps.

“Discussion notes” presented with the Restoration Objectives provide some interpretation and elaboration of the objectives. The examples given of potential activities do not limit the range of restoration possibilities under BCRP. The type and scope of restoration activities will depend upon the particular conservation and management needs of fish and wildlife species in each watershed.

Objectives related to the potential replacement of habitat losses will be guided by the estimates of footprint impacts, including losses of various habitat types, and the role that these impacts played or are currently playing in constraining fish and wildlife diversity and production.

The objectives emphasize mitigation of hydroelectric impacts and replacement of losses within the watershed where they occur. In some cases, it may be appropriate to undertake a project in an adjacent watershed if sufficient restoration opportunities are not readily available within the original watershed and if the original populations will benefit.

A common objective in all watersheds is to monitor and evaluate the results of BCRP projects and to adjust the program as needed. An overall project review system should be developed and implemented to facilitate technical analysis of BCRP results. Proposals should include performance indicators that are meaningful and measurable. It is important to establish a pre-project baseline so that the effects of implementation can be tracked by post-project monitoring.

3.2 Feasibility of Re-establishing Anadromous Fish Stocks

Proposals to re-establish former anadromous runs to the Puntledge, Alouette, Stave, Coquitlam, Bridge or Shuswap reservoirs would require careful analysis and planning. Consideration should be given not only to technical feasibility, but also to the biological soundness and the management implications for agencies and BC Hydro alike for developing and fostering a new run, as outlined: (some points adapted from Triton 1994)

Biological Soundness

- ❑ What donor stock is available? Does it have genetic links to, or exhibit vital characteristics of, the historic stock? Has the target species been transplanted successfully elsewhere (Andrew & Killick 1957)?
- ❑ What are the ecological implications of re-introducing the target species as competitor/predator to the population dynamics within the present reservoir? Is this species a potential host or vector for disease transmission?
- ❑ Are sufficient spawning, rearing and overwintering habitats available in the reservoir and its tributaries to sustain the necessary life stages? If not, what is the feasibility and cost of enhancing or creating such habitat? Are the key habitats at risk to future forestry impacts?
- ❑ What population size and habitat quantities are necessary to make the stock self-sustaining?
- ❑ Can aquatic productivity of the current reservoir be restored to match the levels in the original habitat?

Technical and Engineering

- ❑ Are there physical impediments to upstream migration in the river that require alteration?
- ❑ What is the proposed route to bypass the downstream migration of juveniles? Test the survival rates of downstream passage through existing turbines and over spillways under the range of expected flow conditions. What survival rates would be necessary to allow the new population to become established?
- ❑ If unaided passage mortality were too high, what additional facilities would be suitable for retrofit (surface or gatewell collectors, fish screens, louvers) based on the size characteristics of the migrant fish? What is the inherent mortality rate of these passage facilities?

Management

- ❑ What changes to BC Hydro operations would be required to facilitate a successful reintroduction? Would the fishway be able to operate at different reservoir levels during upstream and downstream migration? Would water releases be necessary to get adults upriver in some years? What is the stranding potential during downstream migration that may require higher flow releases? What are the probabilities of spills at this facility at critical biological periods?

- ❑ Will the expected fisheries on this new stock be managed to permit the newly introduced stock to increase without compromising other stocks, or is the new stock likely to co-mingle with other stocks that will be fished at high exploitation rates? Have other unmanageable sources of mortality, such as the seal predation at Puntledge River, been identified that may further impede juvenile production or adult escapements?

The foregoing criteria suggest a complex set of biological, physical and management conditions that must be present before anadromous stocks are successfully restored to a former watershed. Whether a fishway can be constructed to provide passage over a particular dam may be one of the easier challenges to overcome. For example, consider that both dams on the Puntledge River have had fishways since 1922, that remnants of the original stocks are still present in small numbers, and that abundant high-quality habitat exists upstream of Comox Lake. Yet despite BC Hydro's successful mitigation of the problem of entrainment mortality in 1993, the fishways have remained closed to chinook and coho salmon stocks.

If a preliminary assessment of re-introduction does appear feasible for a particular reservoir, a phased, experimental approach could be adopted that would reduce the technical risk and significant cost of retrofitting permanent structures required for upstream and downstream fish passage (Triton 1994). One strategy to reintroduce a stock involves releasing adult fish into the reservoir and letting them select their own preferred spawning grounds. In practice this option may result in a proportion of adult fish which fail to spawn, or attempt to return downstream. Stocks of sockeye salmon that are shoreline spawners could be affected by drawdowns. An alternate strategy involves releasing juveniles of a donor stock into selected tributaries in a multi-year program. Prospective natal streams should have sufficient collective capacity to ultimately support the number of spawners deemed necessary to maintain a viable new population.

A phased approach to re-introduction would also test the performance of the existing facilities to pass juvenile fish downstream with respect to mortality, injury or descaling. If migrant survival proves to be poor, temporary collection and transportation of juveniles past the dam may be an interim measure through the pilot study. Adult fish that return from the juvenile stocking program could similarly be collected, trucked and released above the dam in the initial years. The goal of restoring historical fish runs is to rebuild a stock that will be capable of sustaining its own natural production cycle if appropriate upstream and downstream passage facilities can be constructed.

3.3 Limitations to Restoration Techniques

The BCRP will undertake projects to address some of the losses incurred by fish and wildlife populations as a result of the original hydroelectric developments now operated by BC Hydro. The BCRP is initiated in a time of great interest by the agencies, First Nations, stream stewards, and the general public in protecting such populations and the habitats necessary for their survival. There is a growing awareness that the modern pace of

infrastructure and resource development and human harvest activities is threatening the very existence of certain species in our local environments.

The need for biological conservation is receiving greater recognition from the resource management agencies these days (*e.g.*, proposed Federal *Wild Salmon Policy*). Still there is a legacy to undertake activities and programs whose primary goal is maximising selected fish or wildlife production for economic benefits. These programs are often based on theoretical models of factors or habitat capacities believed to limit wild populations, when in fact such variables are complicated beyond our understanding, and are not predictable from year to year. Many exploitation rates advocated by fisheries management theory have proven too high and unsustainable (Weeks and Berkeley 2000), and have reduced many salmonid populations in BCRP watersheds.

In this recent period, biologists have been busy developing and implementing a variety of new measures designed to increase wild populations, such as construction of various habitat features, live gene banking, and habitat fertilization. Older techniques, such as hatchery propagation, and releasing fish or wildlife beyond their natural distribution, have been modified to address some initial limitations. Yet it is well to remember that other well-intended techniques, such as eradicating unwanted species by poisoning lakes, introducing non-native species, and clearing wood debris from streams, were later found to have undesirable ecological consequences, and are now largely discontinued in British Columbia.

Because such consequences may manifest themselves years afterward, and to reduce undesirable risks at the large scale of certain reservoir ecosystems, the BCRP will generally apply proven techniques of habitat restoration. However, BCRP will consider new experimental techniques, done initially as pilot projects at a small scale or short period, where latent ecological effects will be monitored over 5-10 years prior to more widespread implementation.

Physical creation of wildlife and fish habitats has a long tradition, with recent emphasis in British Columbia as a result of the Watershed Restoration Program, and as compensatory measures to offset impact losses from infrastructure developments. Good reference material (*e.g.*, Slaney and Zaldokas 1997) and short training courses are now available to guide stream habitat practitioners. A working knowledge of fluvial geomorphology and stream hydraulics is essential, and even then, successful biological restoration has been elusive (Kellerhals and Miles 1996). In BCRP's diverted systems, it may be tempting to construct habitat features in the main river channel at low elevations so they function during the regulated fish flows, but consider their ability to withstand peak flows that may be spilled down the channel in 1-in-20 year or larger events. One conservative approach is to design instream structures so that *when* they do fail, they will fail safely with minimal hydraulic perturbation.

Over the last 20 years, fertilization of British Columbia's lakes and streams has shown promise in increasing fish biomass by stimulating the primary and secondary levels of biological productivity (Ashley and Slaney 1997). Advocates of the technique have focused on benefits to commercial or sport species such as sockeye, kokanee, trout and steelhead,

particularly in watersheds that formerly supported anadromous fish runs. However, a data gap exists with respect to the ecological effects on other species or communities, especially on long-term applications of nitrogen and phosphorus fertilizers to large-scale oligotrophic systems. Do such conditions enhance the suitability for accidental introduction of milfoil or other non-native species? The extent of application and levels of fertilizer should mimic the approximate magnitude and pathway of the specific footprint impact in each reservoir. For example, the reduction in benthic productivity in shoal areas that result from drawdown fluctuations is probably not remedied by stimulating plankton growth in the water column of a reservoir.

Finally, long-term monitoring of habitat features, structures or other restoration techniques has received little commitment or funding in most jurisdictions. Without the benefit of long-term monitoring, we have very little feedback on the effects of our collective restoration activities. To increase the overall quality of restoration techniques and experience within the Province, each designer/constructor of a habitat project should be involved in its monitoring to understand whether the compensatory habitats are functioning as designed, and to follow their longevity. The scope and duration of monitoring assignments will range according to specific objectives, from detailed studies that assess the effects of pilot experiments, to primary assessments of fish utilization at an overview level (*e.g.*, Lister and Bengeyfield 1998).

This brief litany of restoration activities--all meant to conserve, protect and manage wild populations-- is a caution and reminder to the future applications of untested techniques. As biologists and managers increase their manipulation of desirable species and their habitats, they should be mindful of ecological consequences of their projects on the many other fish and wildlife species that share those same habitats. It may turn out that in some cases, the best restoration approach will be to do nothing more than actively conserve the important habitats and allow natural processes to continue.

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Chapter 2

CAMPBELL RIVER WATERSHED



Figure 2-1. Elk Falls (BC Archives)

1. PROJECT DESCRIPTION

1.1 Facilities

The Campbell River development consists of three dams on the Campbell mainstem--John Hart, Ladore and Strathcona -- completed in 1953, 1958 and 1958, respectively. The lowermost facility is John Hart Dam which impounds John Hart Reservoir and diverts water to a powerhouse located downstream of Elk Falls.

The middle reservoir is Lower Campbell Lake, impounded by Ladore Dam, which also receives additional flows from two diversions-- Salmon River and Quinsam River. Its powerhouse is adjacent to the dam. This project also includes the Loveland Bay Saddle Dam (6m high by 80m long), and the Big Slide Saddle Dam (4m high by 15m long).

The uppermost Strathcona Dam impounds Upper Campbell Reservoir which now backs up into Buttle Lake. This reservoir receives additional water from the Heber River diversion which augments Elk River inflows. The powerhouse is located at the toe of Strathcona Dam.

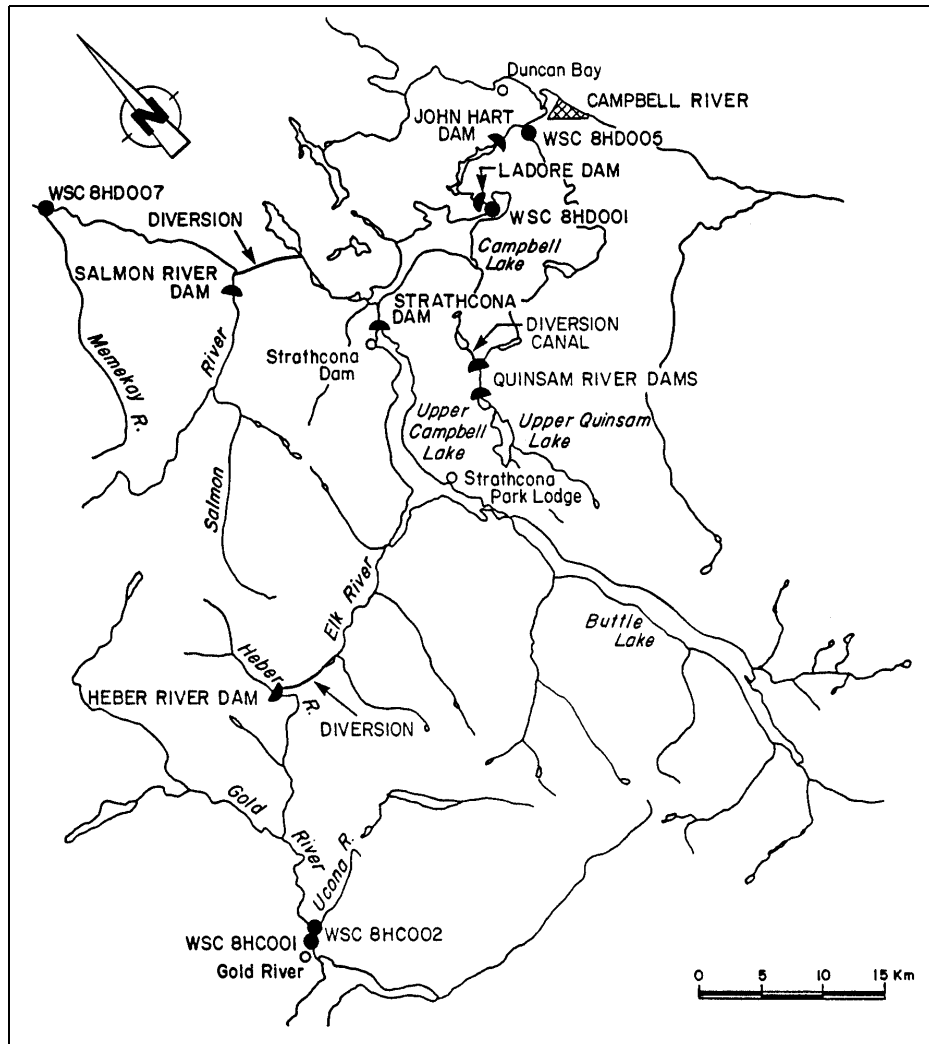


Figure 2-2. Location of Campbell River hydro project

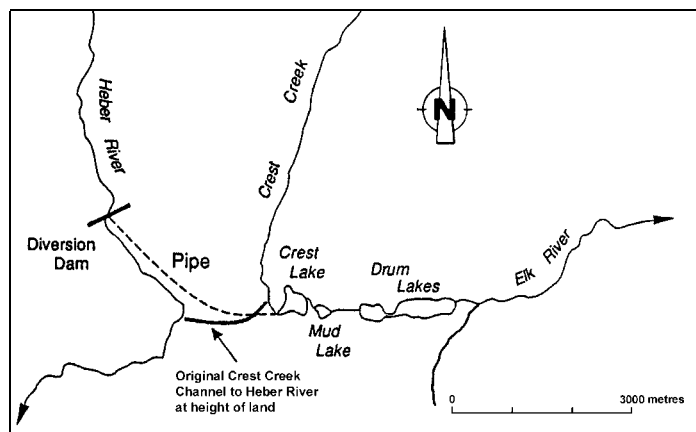


Figure 2-3. Location of Heber River Diversion

Salmon River Diversion

The Salmon River Dam, completed in 1958, diverts part of the upper Salmon River and Paterson Creek via flume and channel for 14 km via Brewster, Gray, Whymper and Fry lakes and then into Lower Campbell Lake. The Salmon River diversion contributes to power generation both at the Ladore and John Hart power stations.

Quinsam River Diversion

The Quinsam project, operational in 1956, consists of the Quinsam Dam across the outlet of Wokas Lake and a diversion dam further downstream. Quinsam water is diverted for 9 km through Gooseneck Lake, then Snakehead Lake, Miller Creek and into Lower Campbell Lake for electrical generation at the Ladore and John Hart power stations.

Heber River Diversion

The Heber River Dam, completed in 1956, diverts flows from the upper Heber River via pipeline and channel for about 5 km into Crest Lake then through the Drum lakes into the Elk River which enters the Upper Campbell Lake Reservoir. Crest Creek, a former tributary to Heber River, is diverted by a dyke into the Drum lakes. The headpond behind Heber Dam is small. A large pool ~10 m diameter occasionally requires gravel removal by backhoe equipment. The Crest Creek diversion dyke does not impound any water (Lewis *et al.* 1996). The Heber-Crest diversion contributes to power generation at all three power stations on the Campbell mainstem.

Specifications for the Campbell River mainstem facilities and reservoirs:

DAM	Strathcona	Ladore	John Hart
Nameplate capacity (MW)	67.5	54	126
Dependable capacity (MW)	60	47	126
Dam function *	storage	storage	diversion
Date constructed	1955	1949	1945
Date operational	1958		1947
Date reconstructed	1986-88	1955-57	1988
Height (m)	53	37	30
Length (m)	510	94	250
Dam footprint area (m ²)			
Fishway at dam	no	no	no
Historic anadromous fish presence	no	no	no

RESERVOIR	Upper Campbell Lake / Buttle Lake	Lower Campbell Lake	John Hart
Cleared/ not cleared	c		
Present area (ha)	6769	2610	346
Watershed area (km ²)	1249	1849	
Present elevation a.s.l. (m)	221	178	139
Normal drawdown range (m)	21.4	15.2	1.2
Mean depth (m)	15 / 70	17	12
Maximum depth (m)	90 / 130	60	23
Storage (million m ³)	823	321	3.3
Mean water retention time	3.9 months	1.1 month	1.5 days
Mean annual discharge (m ³ /s)			

DIVERSION	to powerhouse	to powerhouse	to powerhouse
Structure type	canal (1km)	tunnel	penstock (1.9km)
Licensed flow (m ³ /sec)			114
Fish flow release (m ³ /sec)	none	none	34
Mainstem length diminished (km)	3		2
Mainstem length augmented (km)			

Specifications for the diversion structures and reservoirs associated with the Campbell River Project:

DAM	Wokas Lake	Quinsam Diversion	Heber Diversion	Salmon Diversion
Nameplate capacity (MW)	0	0	0	0
Dependable capacity (MW)	0	0	0	0
Dam function	storage	diversion	diversion	diversion
Date constructed				1958
Date operational	1956	1958	1956	
Date reconstructed			1958	
Height (m)	2.4 -9	5 -15	7	5
Length (m)	31	43.6	120	73
Dam footprint area (m ²)				
Fishway at dam	no	no	no	yes
Historic anadromous fish presence	no	no	no	no

RESERVOIR	Wokas Lake	headpond	headpond	headpond
Cleared/ not cleared	nc	nc	nc	nc
Present area (ha)	60	0.5	0	0.7
Watershed area (km ²)		88	55	269
Present elevation a.s.l. (m)	360	302		224
Normal drawdown range (m)				
Mean depth (m)	3			2
Maximum depth (m)				4
Storage (million m ³)		0	0	0
Mean water retention time				
Mean annual discharge (m ³ /s)				

DIVERSION	to Lower Campbell L.	to Lower Campbell L.	to Upper Campbell L.	to Lower Campbell L.
Structure type	channel	channel	penstock (3.6km) channel (0.3km)	channel
Licensed flow (m ³ /sec)		4.7	3.5	16
Fish flow release (m ³ /sec)		0.3 - 1.7	0.6	
Mainstem diminished (km)				
Mainstem augmented (km)				



Figure 2-4. Ladore Falls Dam (BC Power Commission)

1.2 Hydrology

1.2.1 Basin and Runoff

The expanded Campbell watershed area (including the upper subbasins of the Heber, Salmon and Quinsam systems) straddles the Vancouver Island mountain range about halfway up the island. Elevations range from 139 m above sea level at John Hart Reservoir to mountain peaks 2000 to 2200 m.

Inflow into the Campbell River system is typical of British Columbia coastal basins. High inflows occur from May through July due to snowmelt. August and September are usually quite dry. High precipitation from October to March includes mixtures of snow that tend to accumulate, and heavy rains which cause high inflows to the reservoirs. Large storms separated by days or hours can cause serious flooding in the area.

1.2.2 Operation and Licensed Diversion Flows

Operation of the Campbell River Projects is governed by the discharge capacities at Strathcona (175.6 m³/s), Ladore (161.5 m³/s) and John Hart (124.0 m³/s). Since John Hart has the lowest discharge capacity and is the generating station farthest downstream, the system is usually operated to its discharge maximum of 124 m³/s. During periods of high inflow when it is necessary to control rising levels in Upper Campbell Lake, Strathcona discharges are often increased to 176.5 m³/s; this results in spills at Ladore and John Hart.

1.2.3 Habitat Types Flooded by Reservoir

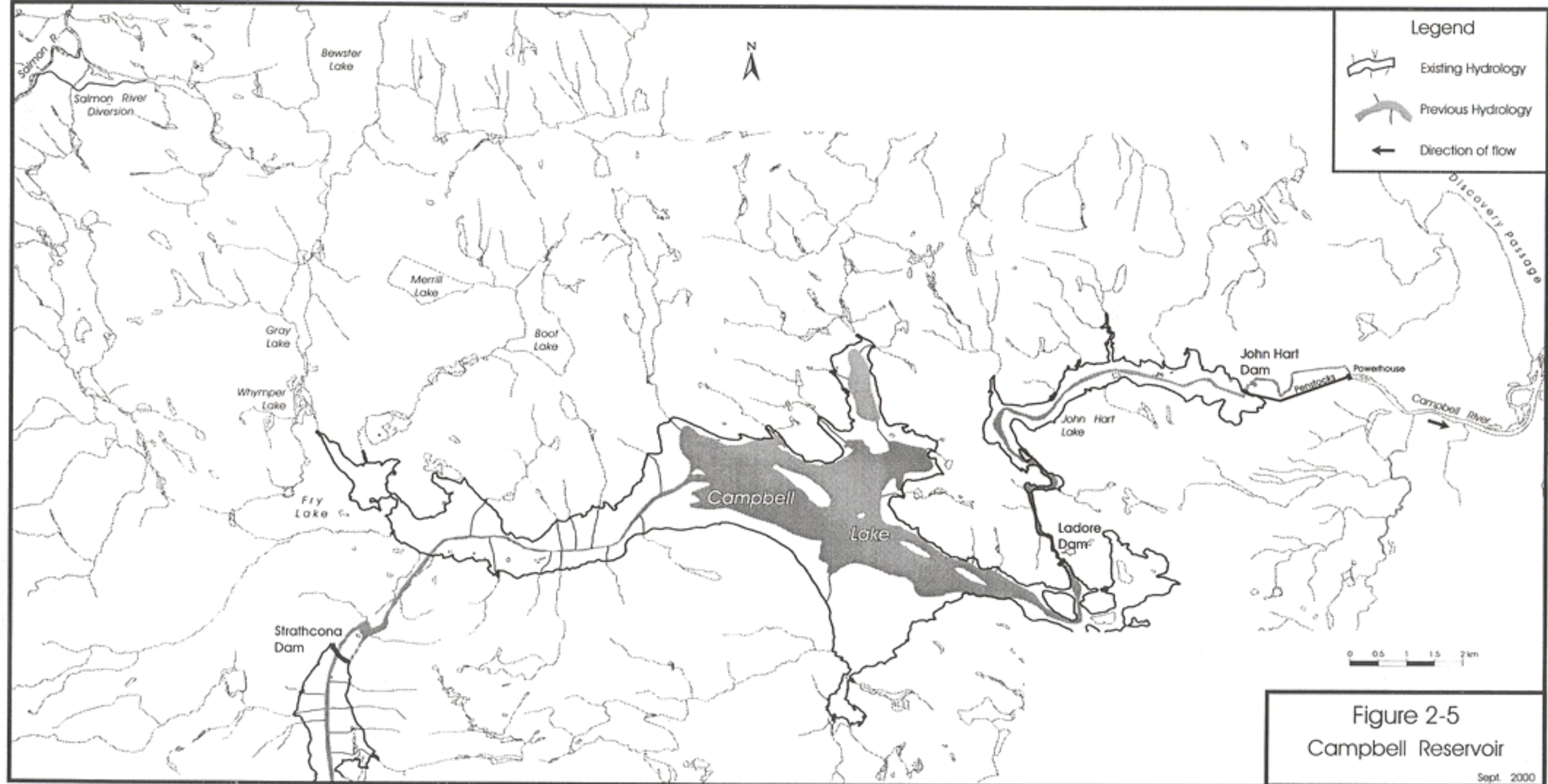
The reservoir area of the combined project is 9,725 hectares including 5,208 ha of land and 4517 ha of natural lakes (Figures 2-5 to 2-7). The current reservoir shoreline length is 282 km. Bathymetric reservoir maps are provided on Figures 2-8 to 2-10.

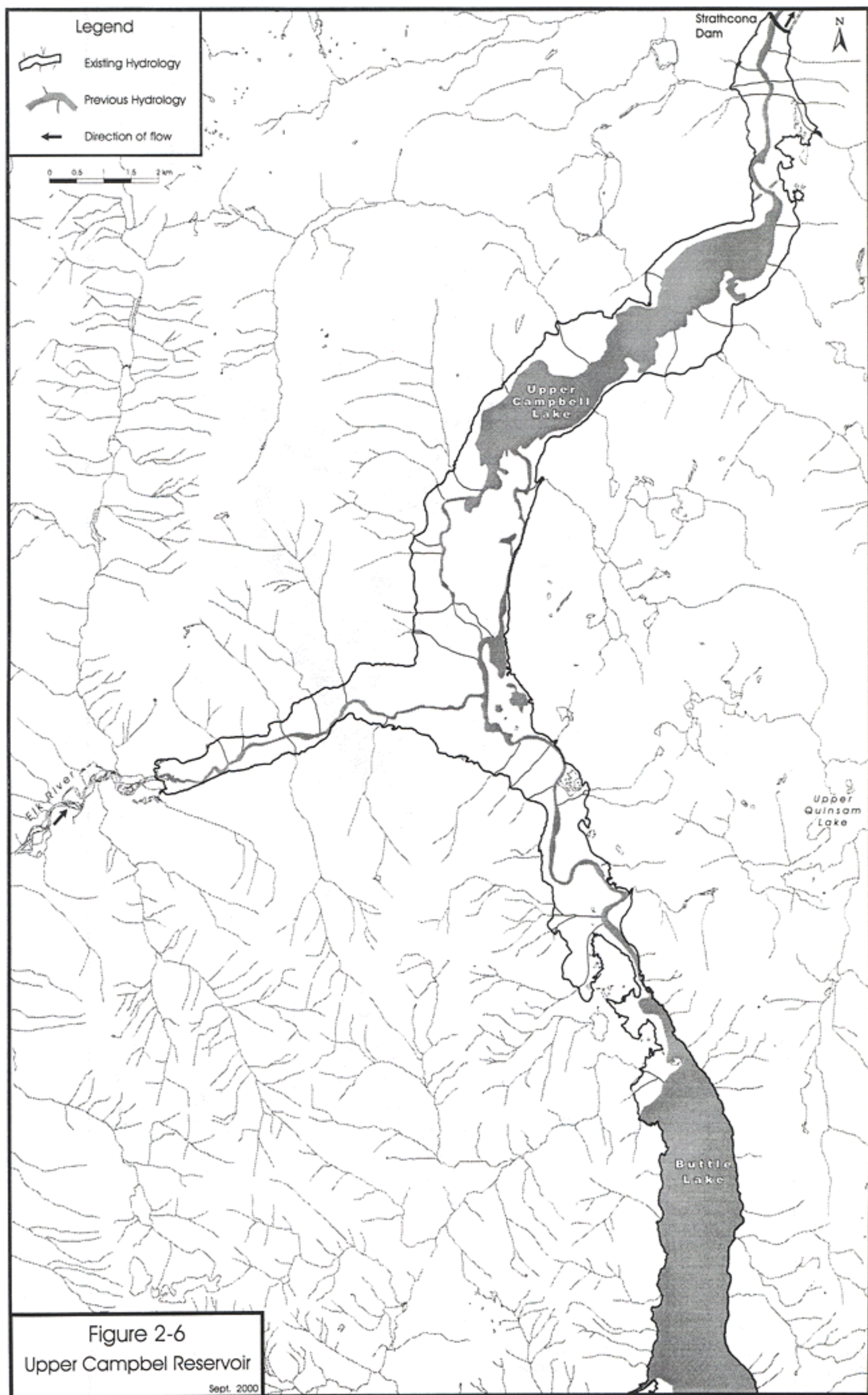
The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Original habitat lost	Upper Campbell L. / Buttle Lake	Lower Campbell Lake	John Hart	TOTAL
Lake flooded (ha)	3583	934	0	4517
Land flooded (ha)	3186	1676	346	5208
Lake shoreline (km)			0	104
Mainstem: length (km)	24	13	10	47
channel (ha)	252	81	62	395
riparian area* (ha)	143	77	60	280
Tributary: length (km)	21	20	4	45
riparian area** (ha)	65	61	11	137
Wetland:	695	241	0	936

* mainstem riparian zone calculated 30 m from each bank

** tributary riparian zone calculated 15 m from each bank







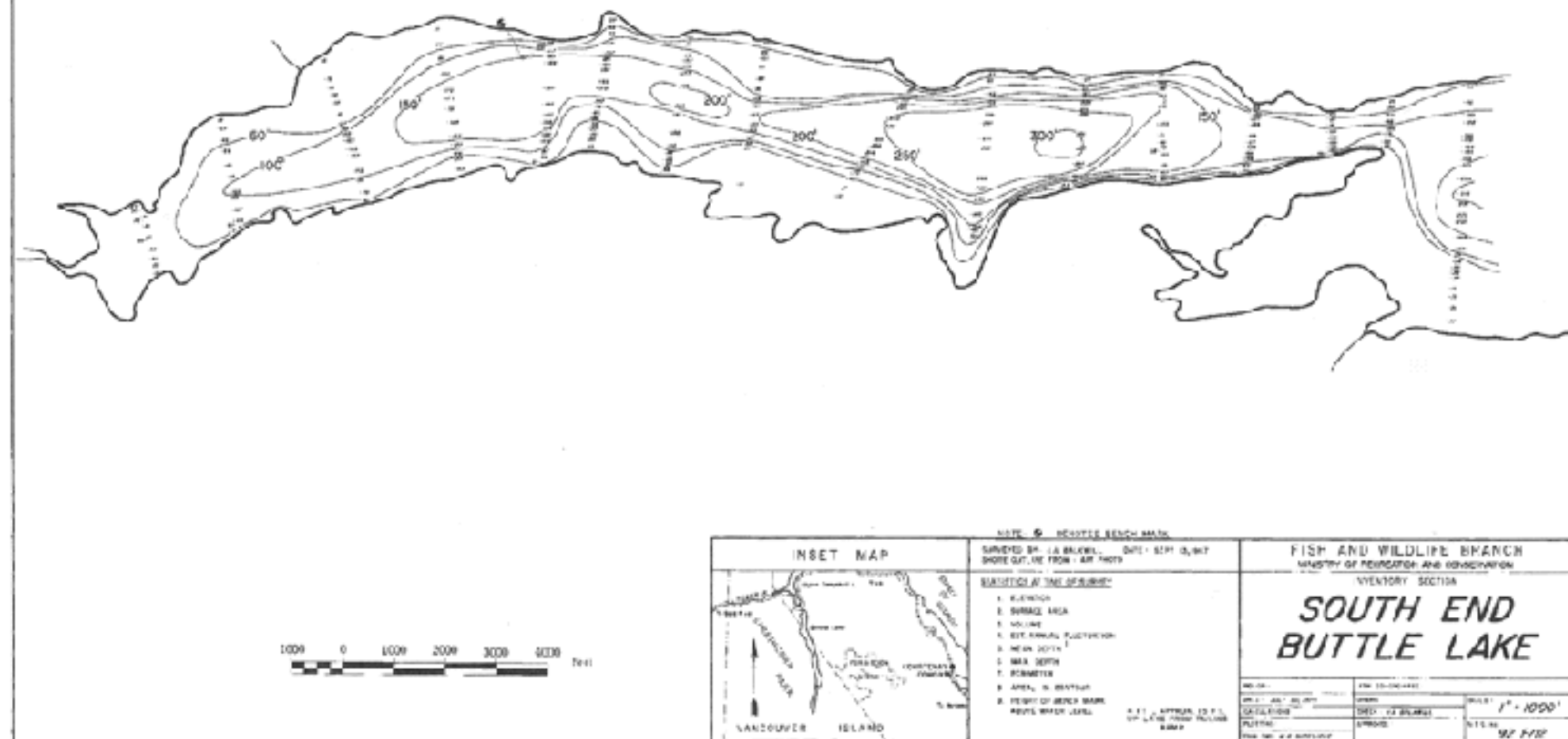


Figure 2-8. Bathymetric Map of South End Butte Lake

2. FISH

2.1 Historic and Current Species Presence

The Campbell River system was one of the most productive river systems for anadromous fish on Vancouver Island, particularly when considering that all habitats were confined to the lowermost 5 km section below Elk Falls. When the Campbell River Power Project was developed, the three principal dams on the Campbell mainstem and the three diversion dams on adjacent rivers--Heber, Salmon and Quinsam-- were all located upstream of the respective historic barriers to anadromous fish.

2.1.1 Campbell River Basin

Historic knowledge of fish in the Upper Campbell River drainage was largely qualitative due to the lack of baseline data (Hatfield 1982a). This limits the usefulness of the data to determine how power development affected the age, size, and species composition of the fish populations (Lough *et al.* 1992).

Like most watersheds on Vancouver Island, the Campbell River basin has a simple indigenous freshwater fauna with few non-salmonid species compared to Fraser River watersheds. Only six resident fish species are currently found in the Campbell River watershed above Elk Falls (Table 2-1). Cutthroat and rainbow trout and Dolly Varden char are found in each of the reservoir systems. Kamloops rainbow were introduced into Upper Campbell Lake prior to 1953 (McMynn & Larkin 1953), possibly because native rainbow in the system were generally small (Carl 1939). Ladore Falls, at 9 m high, and a second falls and rapids a short distance downstream (White 1919) were probably natural barriers to upstream movement by these stocks.

Anadromous fish stocks were unable to access the majority of freshwater habitats in the Campbell basin because of Elk Falls, a major barrier of 30 m height on the mainstem river 5.6 km upstream of tidewater (Figure 2-1). Below the canyon the lower river is inhabited by five salmon species (although sockeye are not plentiful), steelhead, anadromous cutthroat trout and Pacific lamprey as well as the species found upstream (Table 2-1).

Campbell River produced large specimens of chinook salmon known as *tyee*. The first account of angling for *tyee* appeared in *The Field*, published in London, in October 1896. Sir Richard Musgrave described the excellent fishing he had off the mouth of the Campbell River in September of that year..."took nineteen *tyee* in one week as well as several coho and trout". His largest fish weighed 70 pounds. The next year his party caught a 67 pound *tyee* on September 3 (Tyee Club of BC 1995).

2.1.2 Heber River Diversion

The Heber River contains only resident rainbow trout and Dolly Varden char for 6.8 km below the diversion dam where a 4 m high waterfall blocks all anadromous fish. Summer steelhead is the only anadromous stock that uses the next 7.5 km down to another set of 2.5-3 m falls. The lowermost 0.9 km of the river above its confluence with the Gold River is used by five species of salmon and winter steelhead (Griffith 1994). The current distribution of species in the Heber River is indicated in Table 2-2.

For its size, the Heber River is one of the most productive wild steelhead streams on Vancouver Island, averaging 252 adult spawners per year between 1975-1995 (BC Ministry of Environment 1996).

The Heber diversion dam is a barrier to the upstream passage of resident fish. For rainbow trout, this is likely irrelevant, due to a significant cascade feature 200 m above the dam, and other obstructions and barriers further upstream. However for Dolly Varden, the dam may have eliminated historic use of Hunter Creek as a nursery stream for the mainstem population downstream of the dam. In addition, the crossing of the Heber River mainstem by the diversion pipeline may also represent a barrier to the upstream passage of resident fish (Griffith 1995).

The Heber-Crest diversion has affected fish habitat in the Elk River by increasing flows beyond the hydraulic capacity of its original channel. This condition has not yet stabilized partly due to large sediment inputs from logging activities and natural events (Hatfield 1982a; BC Parks n.d.; Karanka & Kellerhals 1980; Kellerhals Engineering Services 1996; Lewis *et al.* 1996). However, it is not clear whether the habitat capability of the Elk River has actually been reduced by the unstable conditions, as suggested by Tredger *et al.* (1980) and others, or whether there are few resultant effects at the population level. Trout recruitment to Upper Campbell Lake was judged more than adequate based on increased harvest at a success rate > 2 fish per day (Lough *et al.* 1992).

2.1.3 Salmon River Diversion

Resident fish species are kokanee, rainbow and cutthroat trout, Dolly Varden char, and sculpins (Hansen 1997); their current distribution is indicated in Table 2-3. When the Salmon River diversion dam was built in 1958, anadromous stocks were blocked by a 5 m high falls/obstruction located about 12 km downstream. The obstruction was a cluster of very large boulders that often retained a debris jam within the narrow steep-walled canyon about 38 km from tidewater (Ptolemy *et al.* 1977).

Remedial blasting by BC Fish & Wildlife Branch in 1975 and 1976 made this barrier passable. The Salmon River above the diversion dam now supports wild steelhead and coho salmon. The former was first stocked as fry in 1986 and the latter in 1987. Until a fish ladder was constructed in 1992, adult coho and steelhead apparently used the sluice gate to ascend past the dam (Perrin 1989).

The upper Salmon River and its tributary Grilse Creek have been sites for colonization releases and stream fertilization experiments over the past two decades. Craig *et al.* (1998) recently surveyed locations above and below the diversion dam that would be suitable for outplanting of coho fry produced by the Sayward Community Hatchery on the river downstream.

Table 2-1. Fish species in the Campbell River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.

Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Campbell River upstream ↓ downstream		Anadromous Salmonids								Sport Fish										Non-Sport Fish										Red/Blue Listed Fish										
		Steel head	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish*	Peanouth club	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	American shad	Dace General	Longnose Dace	
Buttle Lake																																								
Henshaw Creek																																								
Ralph River - no info.																																								
Ralph Lake - unidentified trout fry																																								
Wolf River - "unidentified species"																																								
Darkis Lake																																								
Upper Campbell Lake																																								
Elk River																																								
Drum Lakes																																								
Tlools Creek																																								
Cervus Creek																																								
Filberg Creek																																								
Camp Lake																																								
Raven Lake																																								
STRATHCONA DAM		No fishway.																																						
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Whymper Lake																																								
Garrett Lake																																								
Brewster Lake																																								
Merril Lake																																								
Gosling Lake																																								

* now named *Northern pike minnow*

Table 2-2. Fish species in the Heber River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

upstream ↓ downstream Heber River		Anadromous Salmonids								Sport Fish								Non-Sport Species								Red/Blue Listed Fish														
		Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelp sucker	Northern squawfish*	Peanmouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	American shad	Dace General	Longnose Dace	
(Upper) Heber River																																								
Unnamed Trib - 930-511600-249																																								
Dam Creek																																								
Trib # 4 - 930-511600-71																																								
HEBER DIVERSION DAM	No fishway.																																							
Heber River Mainstem																																								

* now named *Northern pike minnow*

Table 2-3. Fish species in the Salmon River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Salmon River upstream ↓ downstream		Anadromous Salmonids								Sport Fish								Non-Sport Fish														Red/Blue Listed Fish									
		Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kolanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish *	Peamouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	American shad	Dace General	Red/Blue Listed Fish	Longnose Dace	
Salmon R. Mainstem																																									
Jessie Lake																																									
Grilse Creek																																									
Third Lake																																									
Second Lake																																									
First Lake																																									
SALMON R. DIVERSION DAM No fishway.																																									
Salmon R. Mainstem																																									

* now named *Northern pike minnow*

Table 2-4. Fish species in the Quinsam River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.

Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Quinsam River upstream ↓ downstream		Anadromous Salmonids								Sport Fish								Non-Sport Fish																Red/Blue Listed Fish										
		Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelp sucker	Northern squawfish *	Peamouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	American shad	Dace General	Red/Blue Listed Fish	Longnose Dace				
Upper Quinsam Lake																																												
Wokas Lake	1			1	1	1	1	1																																				
WOKAS STORAGE DAM	No fishway.																																											
Quinsam R. Mainstem																																												
QUINSAM DIVERSION DAM	No fishway.																																											
Middle Quinsam Lake				1			1	1	1																																			
Cr. 627900-03600-717																																												
Quinsam R. Mainstem																																												
Iron River																																												
Quinsam Lake																																												
Echo Lake Creek																																												
Echo Lake																																												
Mirror Lake																																												
Quinsam R. Mainstem																																												

* now named *Northern pike minnow*

1 - presence of anadromous fish (presumably from Quinsam hatchery) in Upper Quinsam Lake suggests these are also present in downstream lakes.

Downstream, the Salmon River continues to be an important fish-producing system; however, the absolute numbers of returning fish have decreased from those experienced prior to the 1900s as described by original settlers to the Salmon River Valley (Ptolemy *et al.* 1977). Fisheries and Marine Services compiled records of salmonid escapement since 1934 (Sproat 1976). These records indicated salmon and steelhead escapements declined to roughly 25% of the mean escapement for chum, coho, and chinook salmon and steelhead that existed between 1934-44. The mean escapement for these species for the period 1966-75 was 1800 chum, 3100 coho, 830 chinook, and 580 steelhead.

2.1.4 Quinsam River Diversion

Fish samples from Upper Quinsam/Wokas Lake were recorded from 1957 when a BC Fish and Wildlife crew sampled the lake with gillnets. The fish population consisted only of cutthroat trout, with three fish in one of the gillnet samples weighing in excess of 6.3 kg (Lough *et al.* 1992). The current distribution of species is indicated in Table 2-4.

The lower reach of the Quinsam River was used historically by pink, chum and chinook salmon. Coho, steelhead and some chinook were recorded in the 1930s as far upstream as the falls below Quinsam Lake. In the fall of 1942 many thousands of coho were observed immediately below the falls (DFO 1944). Steelhead and coho have occasionally ascended the falls into Middle Quinsam Lake (Hirst 1991a).

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Buttle Lake / Upper Campbell Lake	1. Reservoir flooded 27.1 km of mainstem and 21.5 km of tributary channels, plus their associated riparian zones; species composition unchanged.	x		GIS
	2. Drawdown reduces productivity of littoral zone.	x		Sinclair 1965; McMynn & Larkin 1953; Lough et al. 1992
	3. Drawdown floods and dewateres spawning habitat in alluvial fans.	x		workshop
Heber River Diversion Dam	4. Dam footprint of _ m ² : loss of instream, riparian and upland habitats.	x		
	5. Increased flows from diversion changed channel hydraulics through Drum Lakes and Elk River system; benefits to CT spawning in Mud Cr. and Drum lakes system.	x	x	Kellerhals 1992; workshop
	6. Water no longer flows in the Crest Creek channel downstream of Crest Lake; significance to fish unknown.	x		Lewis et al. 1996
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Facility	Description of hydroelectric impacts	Neg	Pos	Source
	7. Entrainment of upper Heber populations to Elk R.; magnitude unknown.	x		workshop
Strathcona Dam	8. Dam footprint of $_ m^2$: loss of instream, riparian and upland habitats.	x		
	9. Dam blocked former movements of resident stocks.	x		
	10. Dam reduced LWD recruitment to system downstream.	x		workshop
	11. Entrainment mortality and injury; magnitude unknown. Potential downstream benefits to piscivores.	x	x	workshop
Lower Campbell Lake	12. High rate of flushing and drawdown reduces reservoir's plankton and littoral productivity.	x		Sinclair 1965; Lough et al. 1992
	13. Reservoir flooded 11.6 km of mainstem channel and 20.2 km of lower tributary channel, plus their associated riparian zones; species composition unchanged.	x		GIS
Salmon R. Diversion Dam	14. Dam footprint of $_ m^2$: loss of instream, riparian and upland habitats.	x		
	15. Dam reduced gravel and LWD recruitment to Salmon system downstream.	x		workshop
	16. Increased flows from diversion changed channel hydraulics through four small lakes system; impact to spawning area at Fry L.; gravel transport into Lower Campbell River	x	x	Lewis et al. 1996; workshop
	17. Loss of diverted flows has had negative effects on significant downstream fish populations.	x		Lewis et al. 1996
	18. Entrainment loss of juveniles & adults at fish screen.	x		workshop
Quinsam River Diversion Dam	19. Dam footprint of $_ m^2$: loss of instream, riparian and upland habitats; some spawning area lost.	x		workshop
	20. Dam reduced gravel and LWD recruitment to Quinsam system downstream.	x		workshop
	21. Increased flows from diversion changed channel hydraulics through Miller Cr. system; redds are dewatered after diversion ceases but positive benefit if flow was maintained.	x	x	Lewis et al. 1996; workshop
	22. Loss of diverted flows has negative effects on significant downstream fish populations.	x		Lewis et al. 1996
	23. Both dams block former movement of resident stocks to spawning.	x		Lewis et al. 1996
Wokas Storage Dam	24. Dam footprint of $_ m^2$: loss of instream, riparian and upland habitats; some spawning area lost.	x		workshop
Ladore Dam	25. Dam footprint of $_ m^2$: loss of instream, riparian and upland habitats.	x		
	26. Dam reduced gravel and LWD recruitment to system downstream.	x		workshop
	27. Entrainment mortality and injury; magnitude unknown. Potential downstream benefits to piscivores.	x	x	workshop

Facility	Description of hydroelectric impacts	Neg	Pos	Source
John Hart Reservoir	28. Mainstem channel below Ladore Dam experiences rapid flow fluctuations for 2-3 km.	x		workshop
	29. Reservoir flooded 10 km of mainstem channel and 3.5 km of lower tributary channel, plus their associated riparian zones; species composition unchanged but habitat changed from riverine to reservoir.	x		GIS
	30. High rate of flushing and drawdown reduces reservoir's plankton and littoral productivity.	x		Sinclair 1965; Lough et al. 1992
John Hart Dam	31. Dam footprint of $\sim 10^6$ m ² : loss of instream, riparian and upland habitats.	x		
	32. Dam has significantly reduced gravel and LWD recruitment to mainstem and estuary downstream.	x		workshop
Downstream River below J. Hart Dam	33. Periodic large spills cause sedimentation of spawning habitat in the mainstem; a flood damaged the Elk Falls spawning channel in 1995.	x		BCH 1994
	34. Spills induce adult steelhead to move upstream into the canyon past the tailrace; these become stranded in pools when the spill ceases.	x		Lewis et al. 1996
	35. Penstock diversion dewatered ~ 2 km of spawning & rearing habitats below Elk Falls.	x		workshop
	36. Potential for TGP events during spills; magnitude unknown.	?		Lewis et al. 1996
	37. Present informal fish flow release of 34 m ³ /s is considered insufficient, with 51 m ³ /s preferred by agencies.	x		BCH 1994
	38. Current ramping rates cause stranding of fish.	x		BCH 1994
	39. Mainstem carries augmented flood peaks from diversions that affect morphology of downstream channel and estuary.	x		workshop

Potential Issues Identified as Non-Impacts

The current practice of operating the Buttle/Upper Campbell reservoir near full pool during summer likely reduces impacts on fish by providing stable littoral habitat but there is little benthic productivity in the drawdown zone (Sinclair 1965; Lewis *et al.* 1996). Access into the three main spawning streams (Ralph and Thelwood creeks, Elk River) is not affected by drawdown levels (Lewis *et al.* 1996).

Effects of flow fluctuation on the important spawning area immediately downstream of Strathcona Dam are moderated by backwatering from Lower Campbell Lake (Lewis *et al.* 1996).

Diversion from the upper Heber basin may provide some benefits to lower Heber by buffering flood events and moderating discharges to levels more suitable for rearing (Griffith 1994).

Dissolved gas supersaturation criteria in British Columbia have been established at 103% in areas of water depth less than 1 m and 110% in areas of water depth greater than 1 m (Fidler and Miller 1997). The three diversion dams had a neutral to slightly beneficial effect on total gas

pressure (TGP) as measured in limited sampling between May and September 1999. For each of the major reservoirs in non-spill conditions, the upstream end had a lower TGP value than the downstream end, suggesting that power generation aided in dissipation of dissolved gases. There were no exceedances of the 103% and 110% threshold levels in that period (Greenbank 1999). However, it does not appear that TGP has been measured during prolonged major spills.

Non-Hydro Impacts - Other impacts on fish in the Campbell, Heber, Salmon and Quinsam watersheds include historic effects of logging, and mine development in 1966. A significant portion of the upper watershed is situated within Strathcona Provincial Park formed in 1911. Logging activities in the Elk watershed have increased the rate of sediment delivery to the main channel (Lough *et al.* 1992). Increased flows from the Heber-Crest diversion have further contributed to channel instability in Elk River.

Logging is also implicated in increased debris and sediment delivery to the upper Salmon River (Hudson 1993). Bedload gravel and debris regularly clog the fish screen in the Salmon diversion canal (Lewis *et al.* 1996).

In the case of Western Mines, biological communities in Buttle Lake have returned to their former abundance after remedial measures applied in the early 1980s reduced the concentrations of toxic metals (Clark *et al.* 1994). The mine also affected fish populations by creating reservoirs at Jim Mitchell, Thelwood and Tennent lakes.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the large and diverse Campbell River watershed. These also reflect the key issues raised at BCRP regional workshops in June, 2000.

1. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources.
2. **Reduced downstream habitat capability:** Physical habitats below dams are altered by reduced sediment or wood recruitment.
3. **Reduced biological productivity:** Shoal areas of former lakes are affected long-term by large reservoir drawdown regimes including frequent water level fluctuations.
4. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat due to large drawdown regimes.

5. **Reduced mainstem access:** Reduced access for fish using channels where flows are diminished by diversions or where historic access is blocked by dams.
6. **Limited distribution:** Historic anadromous populations in lower Campbell River have been confined to 5.6 km of river / estuary. Urban encroachment along banks of the lower river and estuary has alienated offchannel, riparian and wetland areas.
7. **Diversions:** All three river diversions have reduced annual flow volumes in their downstream channels and increased volumes in the new channels; these altered flows have affected wetted channel area, seasonal temperatures and stream productivity. Loss of spawning area and stranding has occurred in the bypassed channel between Elk Falls and the John Hart tailrace.
8. **Copper mining:** Historic mining activities reduced fish production at the head of Buttle Lake.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve fish habitats in the lower Campbell River.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Restoration activities should be preceded by a study plan to address limiting factors #1, 2, 5, 6 and 7 in the lower Campbell River below Elk Falls that considers:

- operating flows and fish flow regime (Campbell River Water Use Plan)
- urban trends to stabilize the channel
- opportunities to purchase or covenant streamside or foreshore properties for future habitat projects
- potential sites for future habitat enhancement or creation
- proposed projects should have hydraulic characteristics that will withstand the historic range of discharges with low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem and estuary
- identification and filling of data gaps such as gas supersaturation downstream of John Hart Dam during extended spills, risks associated with underescapements, stranding after spills, etc. that may also constrain populations.

Objective 2: Improve habitat conditions for fish stocks in the downstream channels of the diverted Quinsam, Salmon and Heber/Gold rivers.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Activities should be preceded by a study plan for each system, in response to limiting factors #1, 2, 5 and 7 above, that considers:

- operating flows and fish flows (Water Use Plan)
- opportunities to purchase or covenant floodplain properties for future habitat projects
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of historical access to upstream habitats
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- identification and filling of data gaps such as gas supersaturation downstream of John Hart Dam during extended spills, etc. that may also constrain populations

Objective 3: Conserve and improve habitats for resident wild fish stocks throughout each reservoir and tributary system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Activities in response to limiting factors #1-4 and 7 above should be preceded by a study plan for each reservoir and tributary system that considers:

- operating and fish flows below Strathcona and Ladore dams (Water Use Plan)
- opportunities to purchase or covenant floodplain properties for future habitat projects
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future (*e.g.*, Whymper Lake outlet, Fry Lake)
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and for planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- current harvest pressures on stock recruitment
- identification and filling of data gaps such as fish entrainment, angling harvest effort, gas supersaturation downstream of Strathcona and Ladore dams during extended spills, etc. that may also constrain populations.

Objective 4: Restore biological productivity to the reservoir and tributary systems.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to improve primary and secondary productivity. Activities should be preceded by a study plan for each

reservoir and tributary system, in response to limiting factors #3 and 4 above, that addresses:

- operating flows and flushing rates
- feasibility of a phased program of fertilization trials in the Campbell River and Quinsam River reservoirs and performance indicators
- potential methods to achieve self-sustaining nutrient levels and reduce costs
- determination of appropriate low-level nutrient levels
- relative benefits of fertilizing fish-bearing tributaries vs reservoir plankton or littoral
- ecological effects of fertilization on non-target plants and aquatic animals
- wildlife biodiversity values at all proposed sites
- identification and filling of data gaps such as entrainment, etc. that may also constrain populations.

Objective 5: Conserve and improve fish habitats in the Elk River.

Discussion:

Effects of the diversion on fish habitat have not necessarily reduced fish production in the system. Undertake appropriate treatment, consistent with the BCRP strategy, to restore habitats. Activities should be preceded by a study plan, in response to limiting factors #2 and 7 above, that considers:

- present and future Heber diversion flows (Water Use Plan)
- present habitat capability of the system in relation to fish production / harvest rates in Upper Campbell Lake
- proposed habitat projects should have hydraulic characteristics that will withstand the historic range of discharges with a minimum of riprap stabilization
- wildlife biodiversity values at all proposed fish habitat development sites
- opportunities to purchase or covenant floodplain properties for future habitat projects
- identification and filling of data gaps such as entrainment, etc. that may also constrain populations.

3. WILDLIFE

3.1 Historic and Current Wildlife Species

The Campbell River watershed and adjacent diversion watersheds of the Heber, Salmon, and Quinsam Rivers comprise a wide variety of habitats that are used by most of the vertebrate species occurring on Vancouver Island. The valley bottom habitats in the flooded reservoirs comprised wetlands, river, riparian and deciduous floodplain forest, and lowland coniferous forest (Volume 1: Appendix I: Table 1).

Records of the B.C. Game Commission prior to flooding indicate that Roosevelt elk occurred in the Heber, Elk, and Salmon River watersheds and Buttle Lakes areas and in the Quinsam watershed. Species recorded for the Campbell River area included black bear, deer, wolves, beaver, mink, and river otter. Tundra and Whistling swans used the Campbell Lakes and lower river.

Red- and Blue-listed species occurrences on file with the Conservation Data Centre include:

- *Red-* Queen Charlotte Goshawk (*Accipiter gentilis laingi*) (location data protected)
- *Blue-* Vancouver Island White-tailed Ptarmigan (*Lagopus leucurus saxatilis*) Hkusam Mountain
- *Red-* Keen's Long-eared Myotis (*Myotis keenii*) Campbell River
- *Red-* Vancouver Island Water Shrew (*Sorex palustris brooksi*) Middle Quinsam River
- *Blue-* Pointed rush (*Juncus oxymersis*) swamp along Quinsam River
- *Blue-* Snow Dewberry (*Rubus nivalis*) Hemlock/Douglas-fir moraine north of Quinsam Lake
- *Blue-* Henderson's Checker-mallow (*Sidalcea hendersonii*) upper grassy-sedge saline flats on Campbell River estuary
- *Red-* Tufted Hairgrass (*Deschampsia cespitosa*) and Henderson's Checker-mallow community on the Campbell River estuary

Blood (1993) estimated potential wildlife losses from reservoir flooding for widespread species occurring in the John Hart-Campbell Lakes-Buttle Lake system. Based on anticipated densities per km² derived from various published sources, he estimated the following losses for 50 km² of flooded area:

Black-tailed deer	300-400
Roosevelt elk	75-100
Black bear	25-50
Wolf	1
Cougar	1-2
Marten	25
Red squirrel	5,000-10,000
Mice	50,000-200,000
Songbirds	10,000-20,000 pairs

Currently, about 300 elk use portions of the watershed (Blood 1993). Species of concern (Red- and Blue-listed species and other species of management interest) were listed previously in Volume 1; Table 2.

3.2 Impacts on Wildlife

Facility	Description of hydroelectric impacts	Neg	Pos	Source
John Hart Lake Dam & Flume	<i>Dam footprint:</i> loss of riverine and upland habitat.	x		
	<i>Structure presence or operation is a hazard to wildlife:</i> mortality caused by structures (drowning, etc.).	x		
	<i>Flooding of 346 ha:</i> conversion of upland (225 ha), coniferous lowland (14 ha), riparian/floodplain (45 ha), and riverine channel (62 ha) habitats to reservoir, with associated effects on wildlife including elk winter range.	x	x	Janz & Lloyd 1977; GIS
	<i>Conversion of 10 km of river to reservoir:</i> barrier to the movement of ungulates & bears, and to genetic exchange of other species; increased mortality/predation along barrier edge (e.g. during ice conditions); creation of lake and shoreline habitat for aquatic wildlife.	x	x	
	<i>Decreased aquatic productivity due to water depth, temperature, or quality changes:</i> fewer plant, invertebrate, and fish resources for wildlife.	x		
	<i>Fluctuating reservoir water levels (1.2 m) due to hydro-electric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone; hazards to wildlife, such as nest flooding (e.g. Canada geese on stumps).	x		
	<i>Habitat change along 1 km concrete flume r-o-w:</i> conversion from coniferous to shrub habitat and associated changes in wildlife use.	x	x	
	<i>Presence of 2.8 km concrete flume:</i> Hindrance to movement of large mammals (ungulates, bears)	x		
	<i>Reduced flows in 2.8 km of Campbell R bypassed by flume:</i> unknown effects on wildlife use of the river.	x		
	<i>Modified operational flow regime in 5 km of lower Campbell River:</i> unknown effects on wildlife use of the river; unknown effects on estuarine habitat and wildlife use.	x		Hirst 1991
Ladore Dam, Campbell Lake	<i>Dam footprint:</i> loss of riverine, riparian, and coniferous habitats.	x		
	<i>Structure presence or operation is hazard to wildlife:</i> mortality caused by structures (drowning, etc.).	x		

Facility	Description of hydroelectric impacts	Neg	Pos	Source
	<i>Flooding of 1676 ha:</i> conversion of upland (317 ha), coniferous lowland (937 ha), riparian/floodplain (100 ha), wetland (241 ha), and riverine channel (81 ha) habitats to reservoir, with associated effects on wildlife including elk winter range.	x	x	GIS
	<i>Conversion of 13 km of Campbell River to reservoir:</i> barrier to the movement of ungulates & bears, and to genetic exchange of other species; increased mortality/predation along barrier edge (e.g. during ice conditions); creation of lake and shoreline habitat for aquatic wildlife.	x	x	
	<i>Decreased aquatic productivity due to water depth, temperature, or quality changes:</i> fewer plant, invertebrate, and fish resources for wildlife.	x		
	<i>Fluctuating reservoir water levels (15.2 m) due to hydro-electric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone. (Levels high June 1 to Sept. 30.). Hazards to wildlife, such as nest flooding.	x		
	<i>Modified operational flow regime in Campbell R above John Hart Lake:</i> unknown effects on wildlife use of the river.			
Strathcona Dam, Upper Campbell Lake	<i>Dam footprint:</i> loss of riverine and coniferous forest.	x		
	<i>Structure presence or operation is hazard to wildlife:</i> mortality caused by structures (drowning, etc.).	x		
	<i>Flooding of 3086 ha:</i> conversion of upland (105 ha), coniferous lowland (1929 ha), riparian/floodplain (105 ha), wetland (965 ha), and riverine channel (252 ha) habitats to reservoir, with associated effects on wildlife including elk winter range.	x		
	<i>Conversion of 6 km of Campbell R and 3 km of Elk River to lake:</i> barrier to the movement of ungulates & bears, and to genetic exchange of other species; increased mortality/predation along barrier edge (e.g. during ice conditions); creation of lake and shoreline habitat for aquatic wildlife.	x	x	GIS
	<i>Decreased aquatic productivity due to water depth, temperature, or quality changes:</i> fewer plant, invertebrate, and fish resources for wildlife.	x		
	<i>Fluctuating reservoir water levels (8 m) due to hydroelectric operations:</i> effects on establishment of wetland and riparian vegetation in drawdown zone. (Reservoir is within 0.9 m of highest elev. during July-Sept.)	x		Carr & Moody 1993; BCH web page
	<i>Modified flow regime in Campbell R. above Campbell Lake:</i> unknown effects on wildlife use of the river.			
Salmon River Diversion Dam & Canal	<i>Dam footprint:</i> loss of riverine and upland habitat.	x		

Facility	Description of hydroelectric impacts	Neg	Pos	Source
	<i>Structure presence or operation is hazard to wildlife: mortality caused by structures (drowning, etc.).</i>	x		
	<i>Habitat change along xx km flume r-o-w: conversion of coniferous to shrub habitat and associated changes in wildlife use.</i>	x	x	
	<i>Reduced flows in 34 km of Salmon R below the diversion: unknown effects on aquatic and riparian habitats and wildlife (e.g. American dipper, harlequins).</i>			
Heber River Diversion Dam & Canal	<i>Dam footprint: loss of riverine and upland habitat.</i>	x		
	<i>Reduced flows in 15 km of Heber R and x km of Gold R below the diversion: Effects of reduced flows (minimum flows = 4% of fall/early winter total) and potential effects on aquatic wildlife (e.g. American dipper, harlequins, furbearers, elk).</i>	x		Hirst 1991; Scouras 1992
	<i>Increased flows in approx. 12 km of the Elk R. below the canal inflow: potential effects on habitat and wildlife, e.g. riparian habitats providing elk winter range.</i>			
	<i>Habitat change along approx. 5.5 km canal r-o-w: conversion from coniferous to shrub habitat, with associated changes in wildlife use.</i>	x	x	
Wokas Lake Dam	<i>Dam footprint: loss of riverine and coniferous habitat.</i>	x		
	<i>Structure presence or operation is hazard to wildlife: mortality caused by structures (drowning, etc.).</i>	x		
	<i>Flooding of upland: conversion of forested upland habitat to lake, with associated effects on wildlife.</i>	x	x	
Quinsam River Diversion Dam & Canal	<i>Dam footprint: Loss of riverine and upland habitat.</i>	x		
	<i>Structure presence or operation is hazard to wildlife: mortality caused by structures (drowning, etc.).</i>	x		
	<i>Reduced flows in 37 km of Quinsam R below the diversion: Effects of reduced flows and potential effects on aquatic wildlife (e.g. American dipper, harlequins, furbearers, elk).</i>	x		
	<i>Habitat change along approx. 8 km canal r-o-w: conversion from coniferous to channel and shrub habitat, with associated changes in wildlife use.</i>	x	x	

x - indicates that positive or negative effect is assumed or documented.

3.3 Factors Limiting Wildlife Diversity and Production

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Changes:** Altered flow regime has changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for water shrews, harlequins and dippers.
2. **Loss of Habitat:** Loss of riparian and wetland habitats in flooded valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse and overwinter habitat for ungulates, and breeding habitat for some species of neotropical migrants. Loss of side channel habitat downstream of diversions.
3. **Reduced Habitat Capability:** Lack of snags for cavity nesting habitat and structures for large raptor nests. Potential effects for primary cavity nestors (eg. woodpeckers) and secondary cavity nestors (eg. swallows, squirrels, bats).
4. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
5. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions.
6. **Diversions:** Wildlife (especially mammalian) mortality caused by some diversion structures, through entrainment and drowning. Potential hazards for non aquatic or weak swimming animals.

3.4 Wildlife Restoration Objectives

Objective 1: Conserve and develop wetlands and associated riparian habitats for species dependent on those habitats (amphibians, waterfowl, cavity dependent species, small mammals).

Discussion:

See limiting factors # 1, 2 and 3. Identify and assess key habitats for conservation of biodiversity and enhanced production with the intention of undertaking measures to conserve, through protective measures, habitat acquisition and other means in Campbell River, Quinsam River, Salmon River and Heber/Gold River watersheds and their estuaries.

- Consider various opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times.
- Intercept flume outflows to create ponds, backwaters, etc. (e.g. Salmon River).
- Create additional wetlands where feasible through activities such as flooding shallow basins in the watershed.
- Create backwater channel and associated riparian habitats along river segments where reduced spring flows have diminished natural channel complexity.

Objective 2: Rehabilitate reservoir drawdown zones to increase productivity and wildlife habitat.

Discussion:

See limiting factor # 4. Measures need to be taken to improve the productivity of the littoral zones which has been reduced by reservoir creation.

- Improve vegetation in the drawdown zone of John Hart, Lower Campbell, Upper Campbell/Buttle and Wokas reservoirs to provide forage for elk and general habitat for bird species.
- Develop foreshore habitat complexes at suitable locations, *e.g.* re-vegetate drawdown at river deltas and adjacent to timber stands that provide shelter for elk and other ungulates.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.
- Improve nesting opportunities for ospreys and bats by providing artificial nesting structures.

Objective 3: Mitigate the adverse effects of diversion structures on wildlife.

Discussion:

See limiting factor # 6. Improvements could be implemented to make diversion structures more compatible with wildlife objectives.

- Assess the extent of wildlife drowning, and if necessary, address issues such as fencing and/or in-stream features (*e.g.* creation of backeddies or escape ramps) to help prevent or reduce losses.
- Where barrier problems are identified, reduce barrier effects of diversions, such as by creating overpasses for large mammals on migration corridors, where practicable.

Objective 4: Restore riverine and riparian habitats in the Elk River.

Discussion:

See limiting factors # 1 and 2. Significant wildlife habitat has been lost or altered in the Elk River valley. Restoration activities should be preceded by an assessment of opportunities to improve habitat for aquatic species, where they have been adversely affected by hydroelectric development.

- This may include consideration of diversion flows (Water Use Plan), stream channel stabilization potential, riparian and LWD improvement, and methods to increase mainstem habitat complexity, off-channel habitat and wildlife habitat improvement, including summer foraging and overwintering habitat for elk.

Objective 5: Protect small groups of old or second growth trees in strategic locations for current and future nesting use by bald eagles or ospreys.

Discussion:

See limiting factor # 3. There is generally a lack of suitable habitat structures for these raptor species.

Objective 6: Increase elk winter range.

Discussion:

See limiting factor # 2. Significant areas of elk habitat have been displaced by reservoirs in the valley bottoms.

- Work with forestry companies to leave shelter stands in association with logged clearings that provide shelter and forage. Link shelter belts with improved vegetation in the reservoir drawdown zones, especially near creek or river deltas.

Objective 7: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the extended Campbell watershed.

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pipeline 3.6km to lower Crest Cr. Completed 1958 in assoc. w/ construction of Strathcona Dam. Diversion flows are partial, w/ max. cap. of 8.5m ³ /s. Drainage area u/s =54km ² =~30% of total Heber watershed @ 170km ² . Also in 1958, the entire Crest Cr. and Crest L. drainage (prev. trib. to Heber) was diverted to Campbell system with an earth-filled diversion dyke on lower Crest Cr. and excavation of 1km channel draining Crest L. to the Drum lakes, Elk R., etc. This diversion reduced the orig. Heber area of 75km ² to the present 54km ² , a 21 km ² reduction.		
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	songbirds. Provides wildlife enhancement opportunities for several species and species groups.	
Hatter, J., D.J. Robinson, P.W. Martin, L.G. Sugden, E.W. Taylor and W.G. Smith 1956. Inventory and Evaluation of Wildlife Resources of British Columbia. Reprinted from the 9 th BC Natural Resources Conference Transactions, February 1956.	"In the Campbell River and Buttle Lake areas elk winter range will be flooded out in the future Elk populations: Buttle Lake 30-40, Gold River 25-50, Campbell River 200, Salmon River 30-40.	MELP Surrey: Jack Evans
Janz, D.W. and K. Lloyd 1977. Elk Investigations in Strathcona Park and Adjacent Area. Progress Report Jan 1976-June 1977. BC Fish and Wildlife Branch. Nanaimo, BC. 59 p	Roosevelt Elk in Heber and Salmon drainages. Historical records of Roosevelt Elk herd at south end of Buttle Lake	BC Hydro
Province of British Columbia Department of Attorney – General, 1956. Provincial Game Commission Report	Refers to: surveys & investigations of proposed Salmon River diversion, Quinsam River diversion and storage, Heber River diversion, Somass River system (including Eldie Lake & Ash River; investigation of Salmon & Quinsam Rivers water flows	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia Department of Attorney – General, 1959. Provincial Game Commission Report	Refers to: studies of Ash, Salmon, Heber & Puntledge Rivers & Elsie Lake; continued Quinsam River water flows agreed upon	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1927. Report of the Provincial Game Warden 1926. Authority of the Legislative Assembly, Victoria BC	Black bear south of Campbell River scarce Small bands of elk at Buttle Lk. Good number of beavers in Quinsam River. River otters in Campbell River Willow grouse "holding out well" on logged-off lands and swamps of Campbell River.	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1928. Report of the Provincial Game Warden 1927. Authority of the Legislative Assembly, Victoria BC	~70 elk at Buttle Lk. Beaver plentiful along Quinsam River - Mink very scarce south of Campbell River -Small numbers of	Provincial Archives, MELP Surrey: Jack Evans

	river otter north of Campbell River -Pheasants spreading rapidly on logged-off areas as far north as Campbell River - Whistling Swans in Lower Campbell Lake. in December	
Province of British Columbia, 1929. Report of the Provincial Game Warden 1928. Authority of the Legislative Assembly, Victoria BC	Elk in Campbell River doing very well At least 100 elk at Buttle Lake Beaver intensively trapped south of Campbell R. Mink trapped out south of Campbell River and scarce north River otter scarce with the odd family in Campbell River Pheasants spreading north of Campbell River Whistling swans appeared in small numbers on the Lower Campbell River.	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1930. Report of the Provincial Game Commissioner 1929. Authority of the Legislative Assembly, Victoria BC	Whistling swans are to be found in small numbers... in the vicinity of the Campbell River Lakes....	Provincial Archives, MELP Kamloops, Doug Jury.
Province of British Columbia, 1933. Report of the Provincial Game Commissioner 1932. Authority of the Legislative Assembly, Victoria BC	Elk scattered south and west of Buttle Lake A few swans in the Campbell River and Quinsam Lake area	Provincial Archives, MELP Surrey, Jack Evans
Province of British Columbia, 1934. Report of the Provincial Game Commissioner 1933. Authority of the Legislative Assembly, Victoria BC	Elk: ...there is a spreading of smaller bands...around Buttle Lake... The larger bands in the Elk Valley...have shown an increase this year. Swans: Quite a number of swans have been seen in small flocks in the Campbell Lake...area.	Provincial Archives, MELP Kamloops: Doug Jury
Province of British Columbia, 1936. Report of the Provincial Game Commission 1935. Authority of the Legislative Assembly, Victoria BC	Trumpeter Swans appearing each year in small numbers in the Campbell Lakes region. Whistling Swans show up on migration and slowly increasing	Provincial Archives, MELP Surrey, Jack Evans
Province of British Columbia, 1937. Report of the Provincial Game	Elk [occur] in	Provincial Archives,

Commission 1936 . Authority of the Legislative Assembly, Victoria BC	scattered bands throughout the...Upper Campbell Lakes region.	MELP Kamloops: Doug Jury
Province of British Columbia, 1938. Report of the Provincial Game Commission 1937 . Authority of the Legislative Assembly, Victoria BC	Elk appear to be spreading towards the Quinsam River; observed in the vicinity of Beaver Lake below Upper Campbell Lake.	Provincial Archives, MELP Kamloops: Doug Jury
Province of British Columbia, 1939. Report of the Provincial Game Commission 1938 . Authority of the Legislative Assembly, Victoria BC	Elk cows and calves observed in Upper Campbell Lake and Elk Valley regions despite logging operations.	Provincial Archives, MELP Kamloops: Doug Jury
Province of British Columbia, 1942. Report of the Provincial Game Commission 1941 . Authority of the Legislative Assembly, Victoria BC	Elk have slightly increased in the...Elk and Salmon Valleys	Provincial Archives, MELP Kamloops: Doug Jury
Province of British Columbia, 1943. Report of the Provincial Game Commission 1942 . Authority of the Legislative Assembly, Victoria BC	Elk in the Campbell River...area are not increasing. Some thirty Swans were to be seen at one time in the Upper Campbell Lake area.	Provincial Archives, MELP Kamloops: Doug Jury
Province of British Columbia. 19???. Provincial Game Commission Report. 1951 . Authority of the Legislative Assembly, Victoria BC	Brown bears at Salmon River	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia. 19???. Provincial Game Commission Report. 1953 . Authority of the Legislative Assembly, Victoria BC	Buttle Lake – Power Development – under investigation	Provincial Archives, MELP Surrey: Jack Evans
Quinsam River inventory. Fish and Wildlife Branch, Campbell River file, Nanaimo		MELP Nanaimo
Russell, J. 1979. Elk habitat inventory and enhancement considerations on lower Elk River (Strathcona Park), Vancouver Island. BC Min. Environment, Fish & Wildlife Branch.		
Scouras, J. 1991. Heber River Environmental Overview. Report prepared by BC Hydro Environmental Resources. 29 p.	General information of Heber River Diversion area. Used by all Pacific salmon. Fish habitat breakdown and locations. Partial wildlife species list and discussion of select species of concern.	BC Hydro
Wildlife Resources of British Columbia. Reprinted from the 9 th BC Natural Resources Conference Transactions, February 1956.		UBC Library

Chapter 3

PUNTLEDGE RIVER WATERSHED

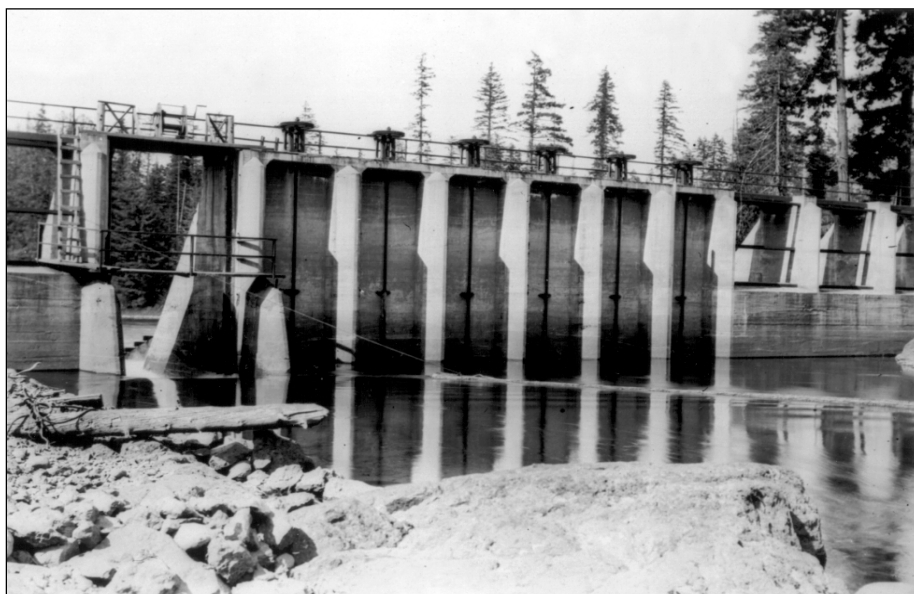


Figure 3-1. Puntledge River Dam, Canadian Collieries Limited, 1920s (BC Archives)

1. PROJECT DESCRIPTION

1.1 Facilities

The Puntledge River project was first developed in 1912 by Wellington Collieries (Dunsmuir) Ltd. to supply electricity to coal mines on Vancouver Island. The project consists of a storage dam at the outlet of Comox Lake and a diversion dam downstream. Water is carried by an overland penstock to a powerhouse on the lower Puntledge River. The B.C. Power Commission redeveloped the dams and powerhouse in 1953-56 and increased Comox Lake storage.

Specifications for the present facilities and reservoirs:

DAM	Comox	Puntledge
Nameplate capacity (MW)	- -	27
Dependable capacity (MW)	- -	18
Dam function	storage	diversion
Date constructed	1912	1912
Date operational		
Date reconstructed	1956; 1982	1956

Height (m)	10.7	5.5
Length (m)	100	165
Dam footprint area (m ²)		
Fishway at dam	yes	yes
Historic anadromous fish presence	yes	yes

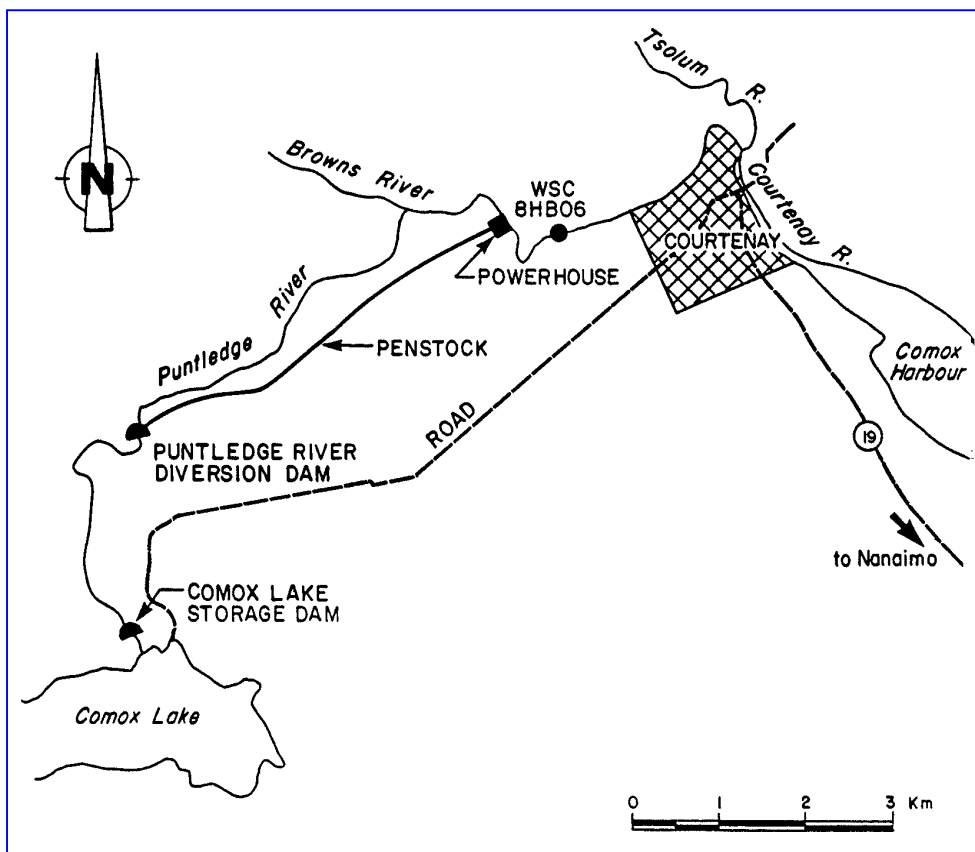


Figure 3-2. Location of Puntledge River hydro project

RESERVOIR	Comox Lake	headpond
Cleared/ not cleared	--	--
Present area (ha)	2118	
Orig. lake area (ha)	1868	0
Watershed area (km ²)		
Present elevation a.s.l. (m)	135	
Normal drawdown range (m)	4.5	min
Mean depth (m)	61	
Maximum depth (m)	100	5
Storage (million m ³)	106	min
Mean water retention time		<1 day
Mean annual discharge (m ³ /s)	34-43	

DIVERSION		to Puntledge River d/s
Structure type	- -	penstock
Licensed flow (m ³ /sec)		28
Fish flow release (m ³ /sec)	2.8-5.7	2.8-5.7
Mainstem length diminished (km)		6
Mainstem length augmented (km)	0	0

1.2 Hydrology

1.2.1 Basin and Runoff

The Puntledge River basin lies on the eastern side of the Vancouver Island Mountain Range which typically receives considerable snowpack. There is some glacial melt contribution from the headwaters of the Cruickshank River, one of two major inflows to the reservoir, with a mean annual discharge of 18.1 m³/sec.

The annual flow pattern into the reservoir is characterized by high flow periods during fall and winter rainstorm events, and during the spring/early summer snowmelt period.

1.2.2 Operation and Licensed Diversion Flow

At present fish water releases, the river below Puntledge Diversion Dam has reduced areas of instream habitats compared to pre-project levels.

1.2.3 Habitat Types Flooded by Reservoir

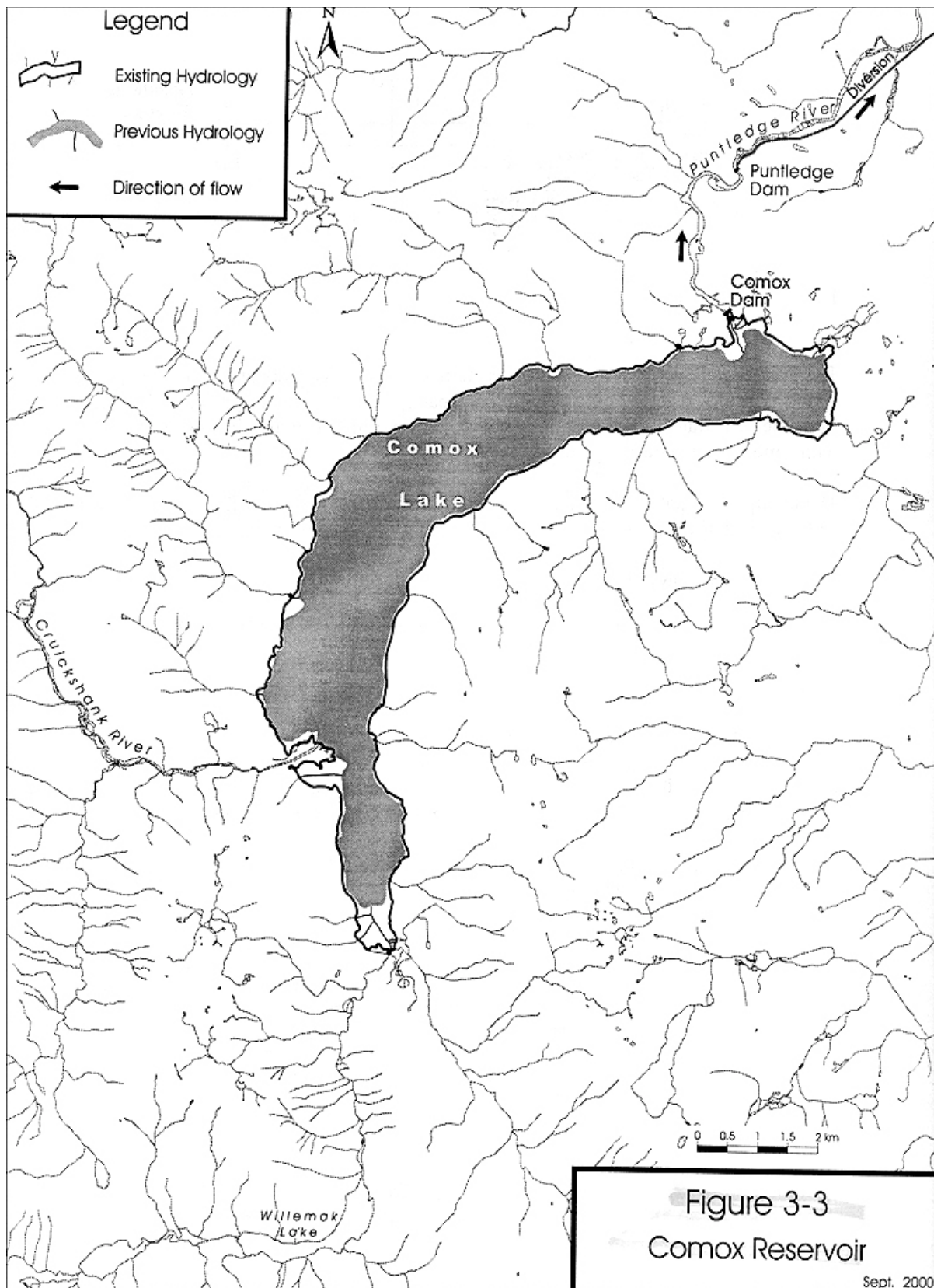
Reservoir impoundment raised the elevation of the original Comox Lake by about 8 m. The reservoir area is 2,118 ha after flooding 250 hectares of land; this represents a 13% increase in area from the original lake (Figure 3-3). The reservoir shoreline length is now 41 km. A bathymetric map of Comox Lake reservoir is provided in Figures 3-4 and 3-5.

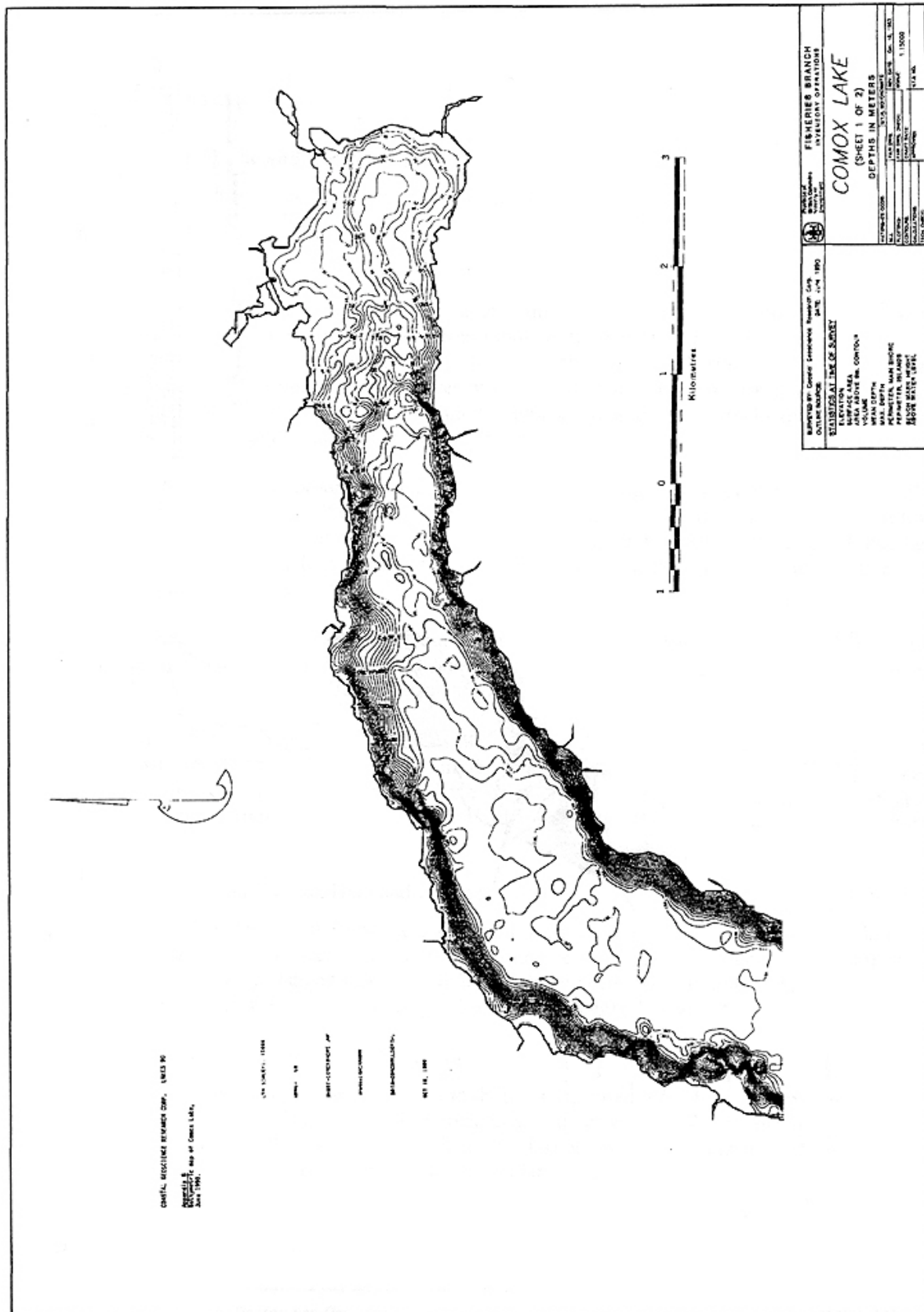
The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

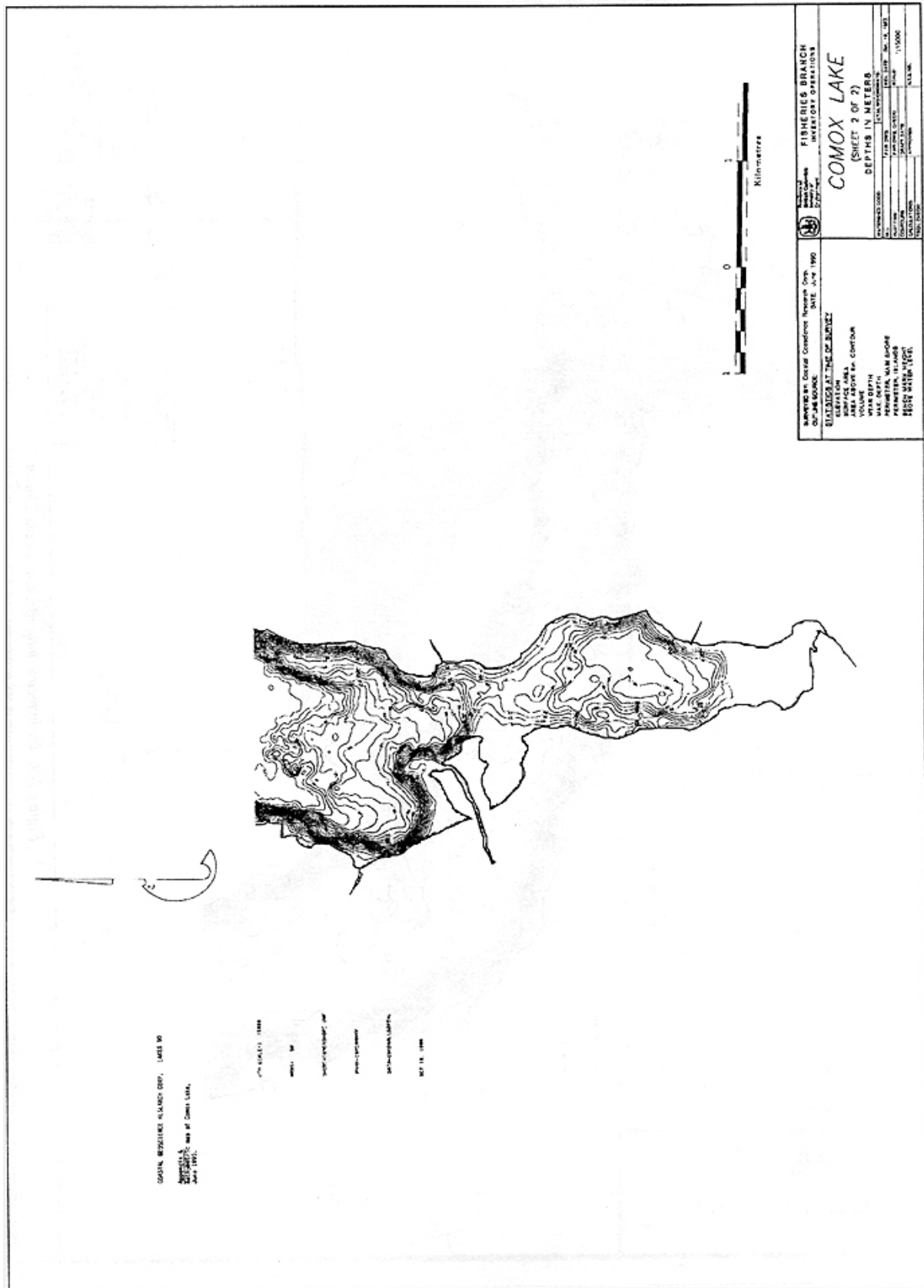
	Original habitat lost
Lake flooded (ha)	1868
Land flooded (ha)	250
Lake shoreline (km)	35
Mainstem: length (km)	1
channel (ha)	2
riparian * (ha)	6
Tributary: length (km)	2.1
riparian ** (ha)	6.3
Wetland: (ha)	25

* mainstem riparian zone calculated 30 m from each bank

** tributary riparian zone calculated 15 m from each bank







2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Puntledge River watershed is provided in Table 3-1.

2.1.1 Upstream of Comox Dam

Historic populations of chinook and coho salmon and steelhead were likely present above Comox Lake before fish passage conditions were improved at Stotan and at Nib Falls beginning in 1923 (Bengeyfield & McLaren 1994; Beadnell 1922). The chinook and steelhead in this upper section of river were relatively unique summer-run stocks (Healey & Heard 1984; Rimmer *et al.* 1994) while the typical fall and winter stocks of these respective species tended to use habitats in Browns River and downstream.

A fishway was incorporated at the original diversion dam downstream in 1912, but no fishway was provided at Comox Dam until September 1922 (Graham 1922). The retrofitted ladder was used by salmon and trout that season; in the intervening 10 years, fish had been seen jumping at the foot of the impassable dam. This blockage may have affected spawner populations in lake tributaries.

A transplant of sockeye salmon from Rivers Inlet Hatchery was attempted in 1923-26 but a run was not established. The kokanee population in Comox Lake has a small annual outmigration of smolts (Bengeyfield 1995).

A sport fishery for cutthroat trout in the lake was noted in 1907, and cutthroat eggs from Cowichan Hatchery were planted in the upper system from 1927-34 (Burridge 1954). Rainbow trout were likely part of the original fauna; they were also planted in upper Cruickshank tributaries in 1930. Dolly Varden populations exist in the lake and in tributaries (Griffith 1995).

2.1.2 Between Comox Dam and Puntledge Dam

This reach supported the historical spawning area for the unique summer-run chinook and steelhead stocks, at least after initial impoundment. Escapement counts of summer-run chinook spawners ranged from 500 to 5000 fish between 1949-60; after redevelopment, only 160 to 640 fish were counted each year between 1961-69 (Webber 1970).

2.1.3 Downstream of Puntledge Dam

Two sets of falls, named Stotan and Nib, are located between the diversion and the powerhouse on the lower river. Improvements to their passability were made between 1923-77, particularly after flows were reduced post-1956 by the 700 cfs increase in diversion. Small numbers of pink salmon now ascend as far as the diversion dam.

Table 3-1. Fish species in the Puntledge River watershed.

Source: M&E/P 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfo/oc.html>, accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Puntledge River upstream ↓ downstream											
		Anadromous Salmonids									
		Steelhead									
		Cutthroat trout (sea-run)									
		Dolly Varden (sea-run)									
		Sockeye Salmon									
		Coho Salmon									
		Chinook Salmon									
		Pink Salmon									
		Chum Salmon									
		Sport Fish									
		Rainbow trout									
		Cutthroat trout									
		Dolly Varden									
		Bull trout									
		Brook trout									
		Lake trout									
		Kokanee									
		Mountain whitefish									
		Lake whitefish									
		Burbot									
		Sturgeon (general)									
		Non-Sport Fish									
		Sucker General									
		Largescale sucker									
		Longnose sucker									
		Bridgelip sucker									
		Northern squawfish *									
		Peamouth chub									
		Redside shiner									
		Sculpin (general)									
		Torrent sculpin									
		Prickly Sculpin									
		Slimy sculpin									
		Coastrange sculpin									
		Threespine stickleback									
		Lamprey (general)									
		Pacific lamprey									
		River lamprey									
		Dace General									
		Red/Blue Listed Fish									
		Longnose Dace									
		Upper Puntledge Mainstem									
		Forbush Lake									
		Puntledge River Mainstem									
		Willemar Lake									
		Puntledge River Mainstem									
		Comox Lake									
		Cruckshank River									
		Rees Creek									
		Kweishun Creek									
		Eric Creek									
		Moat Lake									
		Comox Creek									
		Cougar Lake									
		Perseverence Creek									
		Allen Lake									
		COMOX DAM									
		Puntledge Mainstem									
		Supply Creek									
		PUNTLEDGE DAM									
		Puntledge River Mainstem									
		Fishway closed to salmon but open to steelhead.									
		Fishway closed to salmon but open to steelhead.									
		Fishway closed to salmon but open to steelhead.									

* now named *Northern pike minnow*
 1 - re-introduced annually
 2 - occasional

The lower Puntledge River below the powerhouse was an important spawning area for fall chinook, pink, and chum salmon but these stocks have dwindled and are now supplemented by hatchery production.

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Comox Lake Reservoir	1. Reservoir flooded 1 km of mainstem channel and 2.1 km of lower tributary channel, plus their associated riparian zones; species composition unchanged.	x		
	2. Drawdown in spring strands fish & reduces access to tributaries and wetlands.	x		
Comox Dam	3. Dam footprint of $_ m^2$: loss of instream, riparian and upland habitats.	x		
	4. Comox Dam reconstruction in 1957 sluiced large volume of sediment that degraded spawning habitat downstream.	x		Hourston 1962
	5. Original dam had no fishway from 1912-22; blockage may have eliminated stocks adapted to lake tributaries.	x		
	6. Fishway operation is dependent on reservoir elevation.	x		workshop
	7. Comox Dam has reduced LWD recruitment to system downstream.			workshop
Headpond	8. Redevelopment in 1958 reduced flow velocities in critical spawning area; this and high turbine mortality led to construction of compensatory spawning channel.	x		Holden 1958
	9. Loss of 3.7 km important rearing habitat after 1965 closure of fishway	x		
Puntledge Dam	10. Agencies closed the fishway to all anadromous passage upstream in 1965 due to turbine mortality, until 1996 when steelhead were allowed access.	x		Bengeyfield 1995
	11. Dam reconfigured in 1956 with footprint increased to $_ m^2$: loss of instream, riparian and upland habitats.	x		
	12. Puntledge Dam has stopped gravel recruitment from headpond tributaries to river downstream.	x		Bengeyfield & McLaren 1994
	13. Puntledge Dam has reduced LWD recruitment to river downstream.	x		
River between Dam and Powerhouse	14. Periodic large spills have scoured gravel and diminished spawning habitat capacity in the mainstem.	x		
	15. Minimum fish flows restrict rearing habitat quantity and access to off-channel habitat; cause higher summer temperatures.	x		Griffith
	16. Minimum fish flows reduce spawning habitat; depth and velocity criteria not met.	x		Rimmer <i>et al.</i> 1994

Facility	Description of hydroelectric impacts	Neg	Pos	Source
	17. Lower flows during migration expose smolts and adults to increased predation.	x		workshop
	18. Injuries to summer chinook in tailrace may occur due to removal of racks.	x		workshop
Downstream of Powerhouse	19. Reduction of flood peaks by BCH affects morphology of downstream channel and estuary.	x		workshop

Non-Hydro Impacts - Other impacts on fish in the Puntledge River watershed include historic effects of logging, coal mining, flood protection, urbanization, hatchery operations, and predation by seals.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Puntledge River watershed. These also reflect the key issues raised at BCRP regional workshops in June, 2000.

1. **Restricted access to historic habitats:** Agencies closed the fishway at the diversion dam in 1965 to reduce entrainment mortality (no longer an impact after 1993) and to secure broodstock quotas. Since 1991 steelhead have been allowed upstream since MELP reconstructed the Comox Dam fishway. Fishway closure reduced diversity and abundance of historic species, and continues to preclude use of significant salmon habitats in the watershed.
2. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources. Loss of 90,000 m² of key spawning and rearing area for summer chinook and summer steelhead in headpond between Comox and Puntledge dams. Urban encroachment along banks of the lower river and estuary has alienated offchannel, riparian and wetland areas.
3. **Reduced downstream habitat capability:** Habitats below the dams are altered by reduced sediment or wood recruitment.
4. **Reduced tributary access:** Fish access between reservoir and tributary habitat has been reduced due to drawdown regimes.
5. **Reduced mainstem access:** Adult access up the river channel is reduced by the diversion flows.
6. **Diversion:** The diversion has reduced flows in the bypassed channel which affects wetted area, seasonal temperatures and stream productivity in a key rearing area.

7. **Hatchery practices:** Intervention by the hatchery has had positive and negative effects on wild salmonid stocks.
8. **Seal Predation:** A population of harbour seals in the lower Puntledge River and estuary preys on adult and juvenile migrations of anadromous fish stocks.

2.4 Fish Restoration Objectives

Objective 1: Restore historic wild salmon access to Comox Lake.

Discussion:

Fishways have existed at both dams since 1922 but were closed in 1965 when artificial supplementation of upriver stocks first began. After 35 years of reliance on hatchery production and colonization with little net population increase, a new strategy should be developed that allows upper Puntledge chinook and coho stocks to recolonize their former natural habitats which are extensive and of high quality. The allocation of these spawners taken and held by the hatchery for broodstock each year should be re-evaluated. The plan will address limiting factors #1, 2, 6 and 7 by considering:

- adequacy of present fish flow regime (Puntledge River Water Use Plan)
- adequacy of Comox Dam fishway to operate throughout chinook migration time, including passage downstream to use spawning habitats below Comox Dam
- extraordinary management measures to increase escapements of critical stocks
- an eight year (two cycles) timetable that allows a proportion of summer chinook escapements, including both early and late arrivals, to ascend to the lake as natural spawner groups
- non-historic species that now reach the diversion dam due to barrier improvements should continue to be blocked from upstream areas, in part since their fry may not be effectively screened
- identification and filling of data gaps on issues such as seal predation at critical periods such as downstream and upstream migration, etc. that may further constrain populations.

Objective 2: Improve habitat conditions for fish stocks using the river channel between Comox Dam and the tailrace.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve spawning, rearing and overwintering habitats below the Comox Lake impoundment dam. BCRP activities should be preceded by a study plan, in response to limiting factors #1, 2, 4, 5 and 6 above, that considers:

- operation flows and adequacy of fish flows (Puntledge Water Use Plan)
- feasibility of a coolwater intake at Comox Lake
- feasibility of restoring historic chinook spawning habitat in the headpond reach by increasing seasonal flows, lowering flashboards at the diversion dam, raising gravel bed elevations, etc.
- opportunities to purchase or covenant floodplain properties for future habitat projects
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- offchannel winter habitat as a limiting factor for juvenile coho salmon in Puntledge R.
- opportunities for habitat development and riparian planting

- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- identification and filling of data gaps on other issues that may constrain populations.

Objective 3: Conserve and improve habitats for resident wild and supplemented fish stocks in Comox Reservoir and its tributary system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat at this location. Activities in response to limiting factors #1, 2, 3 and 6 above should be preceded by a study plan for the reservoir and tributary system that considers:

- opportunities to purchase or covenant floodplain properties for future habitat projects
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- biological effects of coho and steelhead colonization releases on cutthroat nursery streams, including post-stocking distribution
- opportunities for habitat development and for planting riparian vegetation
- determination of appropriate low-level nutrient levels that include historic sources from salmon carcasses
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- current harvest pressures on cutthroat trout stock recruitment
- identification and filling of data gaps on issues that may also constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

The presence of elk, deer, bear, and cougar was reported in B.C. Game Commissions annual reports.

Red- and Blue-listed species occurrences on file with the Conservation Data Centre include:

- *Blue-* Vancouver Island White-tailed Ptarmigan (*Lagopus leucurus saxatilis*) Mount Albert Edward
- *Blue-* Vancouver Island Ermine (*Mustela erminea anguinae*) Forbidden Plateau and lowland areas near Puntledge watershed
- *Red-* Olympic Onion (*Allium crenulatum*) Mount Becher
- *Blue-* Olympic Mountain Aster (*Aster paucicapitatus*) ledges of steep incline on Mount Albert Edward
- *Red-* Salish Daisy (*Erigeron salishii*) Talus slopes of Mount Albert Edward
- *Blue-* Sand-Dwelling Wallflower (*Erysimum arenicola* var *torulosum*) Volcanic scree of Mount Albert Edward and Mount Becher
- *Blue-* Woodland Penstemon (*Nothochelone nemorosa*) Comox Lake and Rough and Tumble Mountain

Materi and Blood (1999) discuss habitats and the current presence of wildlife in the Puntledge River watershed. Highly sensitive habitats include:

riverine/riparian,
shallow open wetlands,
shore pine-Labrador tea bog,
veteran trees, and
fossil sites.

The following regionally important species are known or suspected by Materi and Blood (1999) to occur in the Puntledge River watershed.

Birds	Mammals
Bald Eagle Cooper's Hawk Northern Goshawk <i>laingi</i> ssp. Great Blue Heron Green Heron Wood Duck Vancouver Island Pygmy Owl Western Screech Owl <i>saturatus</i> ssp. Pileated Woodpecker Brown Creeper	Vancouver Island Water Shrew Keen's Long-eared Myotis Townsend's Big-eared Bat Vancouver Island Wolverine Marten Roosevelt Elk Black-tailed Deer

Other species recorded for the Puntledge River watershed by D. Blood (Global Fisheries Consultants Ltd. 1992) include the following:

Amphibians	Birds		Mammals
Clouded salamander	Great blue heron Canada goose Mallard Bufflehead Hooded merganser Common merganser Bald eagle Belted kingfisher Pileated woodpecker Violet-green swallow	Chestnut-backed chickadee Red-breasted nuthatch Brown creeper Winter wren Golden-crowned kinglet Swainson's thrush European starling Common yellowthroat Song sparrow Red-winged blackbird	Beaver Deer mouse Red squirrel River otter Marten

3.2 Impacts on Wildlife

Areas of habitat types lost to flooding were presented earlier in Volume 1: Appendix I.

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Comox Lake Dam	<i>Dam footprint of _ ha:</i> loss of coniferous forest and riverine habitats at dam site	x		
	<i>Flooding of 133 ha:</i> loss of coniferous forested slopes to reservoir.	x		
	<i>Flooding of 117 ha of valley bottom:</i> loss of riverine and riparian habitats & associated wildlife values at reservoir ends.	x		
	<i>Fluctuating reservoir water levels (4.5 m) due to hydroelectric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		BC Hydro web page
Puntledge Diversion Dam	<i>Dam footprint of _ ha:</i> loss of habitat at dam site	x		
	<i>Flooding of _ ha of small diversion reservoir:</i> loss of coniferous (currently 2 nd growth Douglas fir dominated), deciduous, and wetland habitats, incl. riparian, in reservoir (inferred from disc. of proposal to raise dam)	x		Global 1992
Penstock	<i>Habitat change along 5 km penstock r-o-w:</i> loss of coniferous forest; creation of shrub habitat, and increase of habitat diversity	x	x	Hirst 1991
	<i>Above ground penstock 5 km long:</i> barrier to direct movement of large mammals (bears and ungulates), which must go around the structure.	x		
	<i>Reduced flows and changed flow regime in 14 km of Puntledge River:</i> unknown effects on aquatic wildlife (e.g. American Dipper, Harlequin, VI Water shrew); unknown effects on estuarine habitats and wildlife.	x	x	

3.3 Factors Limiting Wildlife Productivity and Diversity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Changes:** Altered flow regime has changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for water shrews, harlequins and dippers.
2. **Loss of Habitat:** Loss of riparian habitat and wetland habitats in flooded valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse and overwinter habitat for ungulates and breeding habitat for some species of neotropical migrants. Loss of side channel habitat downstream of diversions.
3. **Reduced Habitat Capability:** Lack of snags for cavity nesting habitat and structures for large raptor nests. Potential effects for primary cavity nestors (*e.g.* woodpeckers) and secondary cavity nestors (*e.g.* swallows, squirrels, bats).
4. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
5. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions.
6. **Diversions:** Wildlife (especially mammalian) mortality caused by some diversion or intake structures, through entrainment and drowning. Potential hazards for non-aquatic or weak swimming animals.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Comox Lake.

Discussion:

See limiting factor # 3 and 4. Measures need to be taken to improve the productivity of the littoral zones which has been reduced by reservoir creation.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.

Objective 2: Conserve riparian and wetland habitats in the Puntledge River watershed.

Discussion:

See limiting factor # 1 and 2. Identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means, in the lower reaches and estuary of the river.

Objective 3: Create or enhance wetlands and riparian habitats for aquatic species (amphibians, waterfowl, cavity dependent species, small mammals).

Discussion:

Consider opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times.

- Create additional wetlands where feasible through activities such as flooding shallow basins in the watershed.

Objective 4: Reduce barrier effects of diversion such as by creating overpasses or underpasses at the penstock, where feasible.

Discussion:

- The penstock blocks bear and ungulate passage between the river and upland habitats for about 2 km below the diversion dam. Assess the effects on wildlife movement and, where appropriate, consider options to provide for access across the penstocks.

Objective 5: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Puntledge watershed.

4. PUNTLEDGE RIVER WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
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4.2 Hydro Facility and Fish References

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Wright, P.B. and W.E. McLean. 1985. The effects of aeration on the rearing of summer chinook fry (<i>Oncorhynchus tshawytscha</i>) at the Puntledge Hatchery. Can. Tech. Rept. Fish. Aquat. Sci. No. 1390, 59 p.	High mortality rates in summer chinook fry reared at hatchery due to increased gas super-saturation levels that occur in April and May. (hatchery intake is from penstock just above powerhouse).	DFO library key # 68740

4.3 Wildlife References

Reference	Notes	Sources
Bigg, M.A., G.M. Ellis, P. Cottrell and L. Milette. 1990. Predation by harbour seals and sea lions on adult salmon in Comox Harbour and Cowichan Bay, British Columbia. Can. Tech. Rept. Fish. Aquat. Sci. No. 1769, 31 p.	No mention of BCH flows as impacts.	BC Hydro
Global Fisheries Consultants Ltd. 1992. Environmental Impact Assessment: Raising the Puntledge River Diversion Dam. Unpubl. rept. to BC Hydro, Burnaby, BC, by GFCL, White Rock, BC. 70 p.	Wildlife species list by D. Blood. Impacts to wildlife if water levels raised up to 3 feet. wildl. impacts considered minimal (total of 7 ha affected) affected hab: conif., decid., wetland shrub & snags	BC Hydro
Hong, Angeline M.C., 1998. The Puntledge River seal cull: an evaluation of the Department of Fisheries and Oceans' policy. Undergraduate Honours Thesis, UBC, DRAFT COPY	Escapement Data	
J.J. Materi and D.A. Blood. 1999. BC Hydro – Puntledge River Environmentally Sensitive Areas Study Final Report. Report to BC Hydro	List of mammals, birds, herps, fish & flora confirmed and suspected including probability of occurrence & habitat ratings.	BC Hydro

Reference	Notes	Sources
Documented occurrence of regionally important species: Bald Eagle, Wood Duck, Pileated Woodpecker, Brown Creeper & Black-tailed Deer. Suspected occurrence of regionally important species: Northern Goshawk <i>laingi</i>, Great Blue Heron, Green Heron, Vancouver Island Pygmy Owl, Western Screech Owl <i>saturatus</i>, Cooper's Hawk, Vancouver Island Water Shrew, Keen's Long-eared Myotis, Vancouver Island Wolverine, Roosevelt Elk, Townsend's Big-eared Bat, Black-tailed Deer and Marten. High Sensitivity Habitats: riverine/riparian, shallow open wetlands, shore pine - Labrador tea bog, veteran trees & fossil sites. Area described having typical presence of wildlife species of southeast Vancouver Island due to mild climate, low snowfall, and subdued relief. No reference to impact of existing BC Hydro facilities.		
Morris, A., A.J. Leaney, L.M. Bell and J.M. Thompson. 1979. The Courtenay River estuary —Status of environmental knowledge to 1978. Special Estuary Series No. 8, Report of the Estuary Working Group, Dept of Fisheries.	Comox Lake reservoir elev., diversion flows; fish flow agreement; development dates; Wildlife information	UBC Woodward Library
Province of British Columbia Department of Attorney – General, 1959. Provincial Game Commission Report	Refers to continued studies of Ash, Salmon, Heber & Puntledge Rivers & Elsie Lake	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1925. Report of the Provincial Game Warden 1924. Authority of the Legislative Assembly, Victoria BC	A few” elk at Comox. Calves possibly predated by cougars .	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia. 19??. Provincial Game Commission Report. 1953. Authority of the Legislative Assembly, Victoria BC	Puntledge River Power Development – Under investigation	Provincial Archives, MELP Surrey: Jack Evans

Chapter 4

ASH RIVER WATERSHED

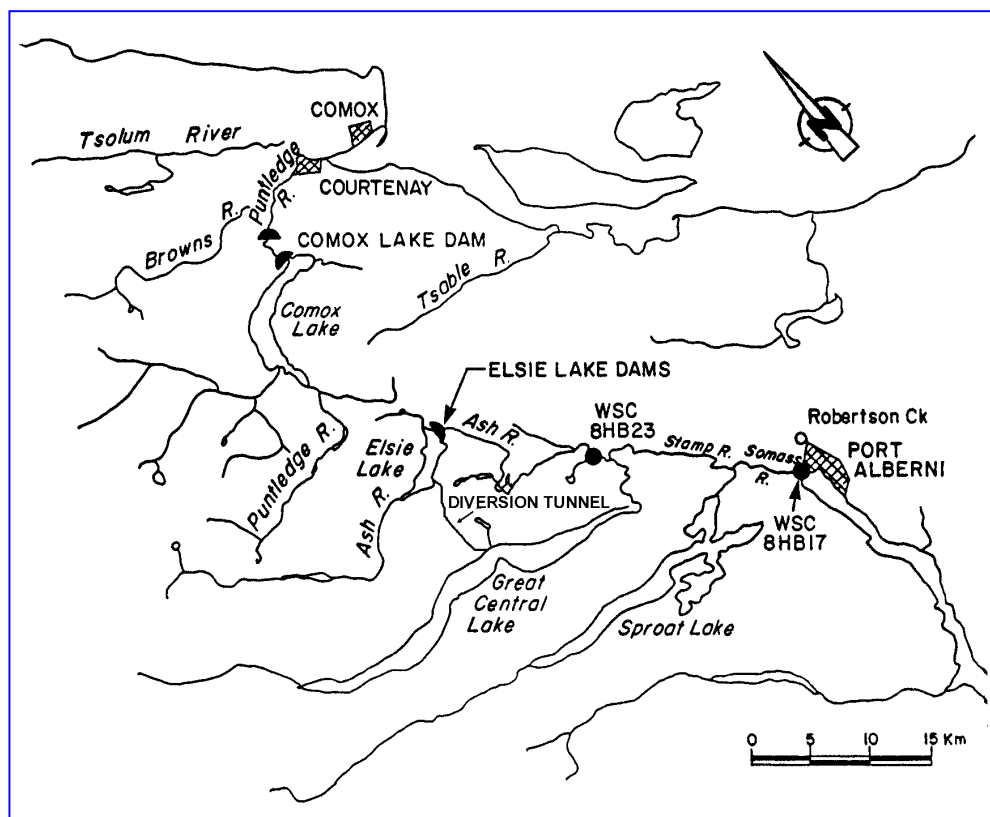


Figure 4-1. Location of Ash River hydro project

1. PROJECT DESCRIPTION

1.1 Facilities

The Ash River project, completed in 1958 by the B.C. Power Commission, consists of Elsie Dam at the outlet of Elsie Lake and four saddle dams. Water from the Elsie Lake Reservoir is diverted into a power tunnel and penstock 7.8 km long to a powerhouse on the shoreline of Great Central Lake.

Specifications for the facility and reservoir:

DAM	Elsie
Nameplate capacity (MW)	25.2
Dependable capacity (MW)	27
Dam function	storage, diversion
Date constructed	1957
Date operational	1959
Date reconstructed	
Height (m)	19 avg
Length (m)	185
Dam footprint area (m ²)	
Fishway at dam	no
Historic anadromous fish presence	no

RESERVOIR	Elsie Lake
Cleared/ not cleared	cleared
Present area (ha)	672
Watershed area (km ²)	218
Present elevation a.s.l. (m)	320
Normal drawdown range (m)	15
Mean depth (m)	8
Maximum depth (m)	30
Storage (million m ³)	77
Mean water retention time	
Mean annual inflow (m ³ /s)	21

DIVERSION	to power house
Structure type	tunnel, penstock
Licensed flow (m ³ /sec)	10.8
Fish flow release (m ³ /sec)	0.3-0.7
Mainstem length diminished (km)	25
Mainstem length augmented (km)	- -

1.2 Hydrology

1.2.1 Basin and Runoff

The Ash River watershed is situated about 40 km northwest of Port Alberni in the central portion of Vancouver Island, between the Beaufort Range and Strathcona Provincial Park. The mean basin elevation is 700 m.

The Ash watershed has two sub-basins. The upper sub-basin is dominated by mountains up to 2000 m high which form the boundary between the Ash, Campbell and Comox watersheds. Small areas of permanent snowpack exist here. From these mountain sources, the Ash River flows into Oshinow Lake at elevation 410 m after a drop of 1200 m and a run of 12 km. Oshinow Lake is 5 km long and 0.6 km wide and receives inflows from about 30% of the basin area (BC Hydro 1991).

Below Oshinow Lake, the Ash River drops a further 80 m in 13 km to Elsie Lake at elevation 330 m. This lower sub-basin has lower relief than the upper basin, with a maximum height about 1350 m. Elsie Lake Reservoir is about 7 km long and 1 km wide.

Smooth peak inflow occurs from May to July from snowmelt. Low inflow occurs in August-September. Slightly lower but more volatile peak inflows occur in November due to rain storms.

1.2.2 Operation and Licensed Diversion Flow

The plant usually operates at maximum capacity year round except in late summer when inflows are low and the generating unit is usually taken out-of-service for maintenance.

Ash River flows averaging 10.7 m³/s per day are diverted year round into Great Central Lake (GCL) except during a 1-2 week maintenance outage usually in August. Fish in the lake are often attracted to the powerhouse discharge, and anglers congregate there (Powell 1995). These flows augment the live storage of GCL and the discharge of the Stamp River, which has two outlets: a 3 m high dam operated by Pacifica (originally by MacMillan Bloedel) at the natural lake outlet since 1930, and a low wood dam built in 1981 that DFO uses to control water intake to the Robertson Creek spawning channel.

1.2.3 Habitat Types Flooded by Reservoir

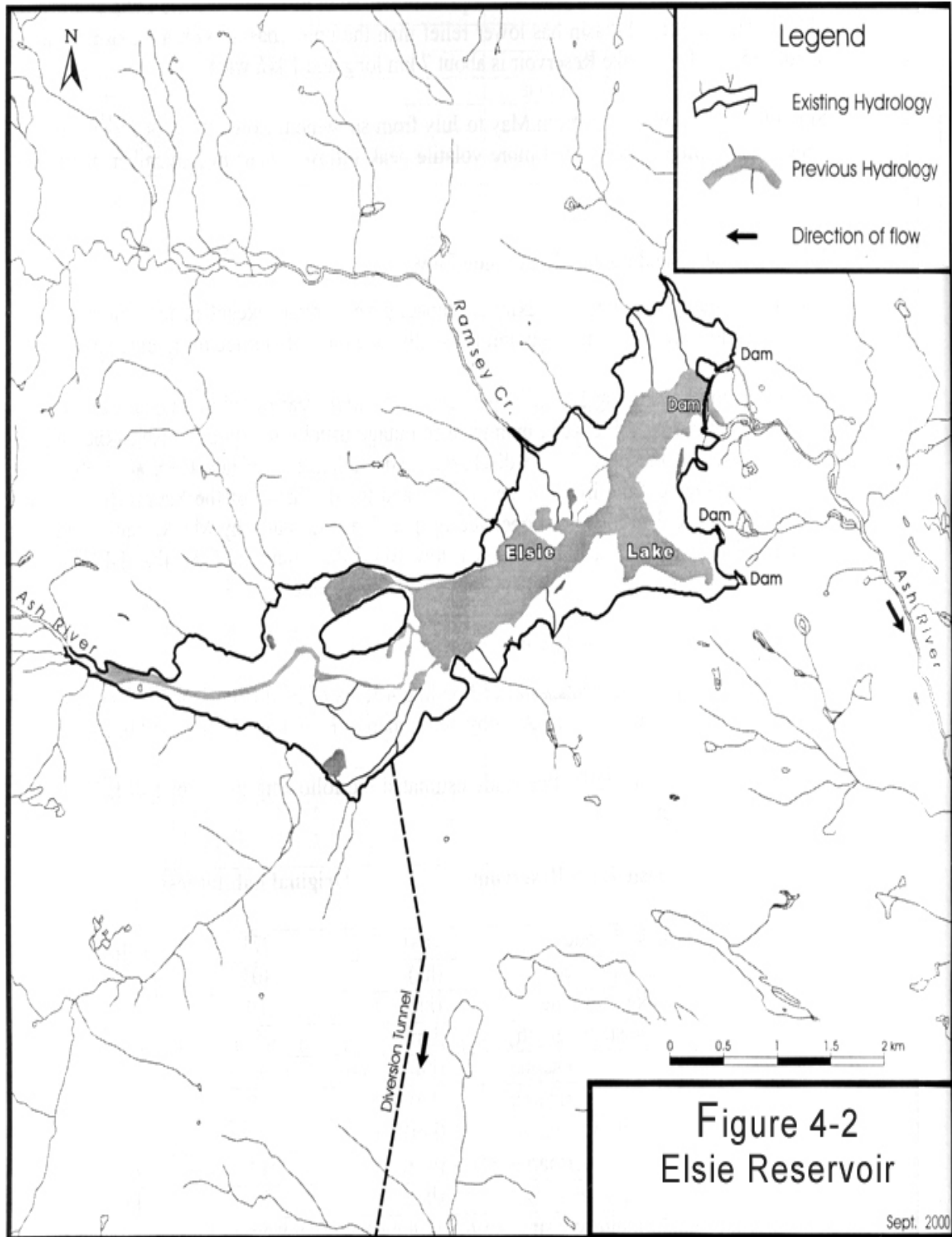
The reservoir area is 672 hectares after flooding 401 ha of land (Figure 4-2). The reservoir shoreline length is now 22.5 km. A bathymetric map of Elsie Lake is provided in Figure 4-3.

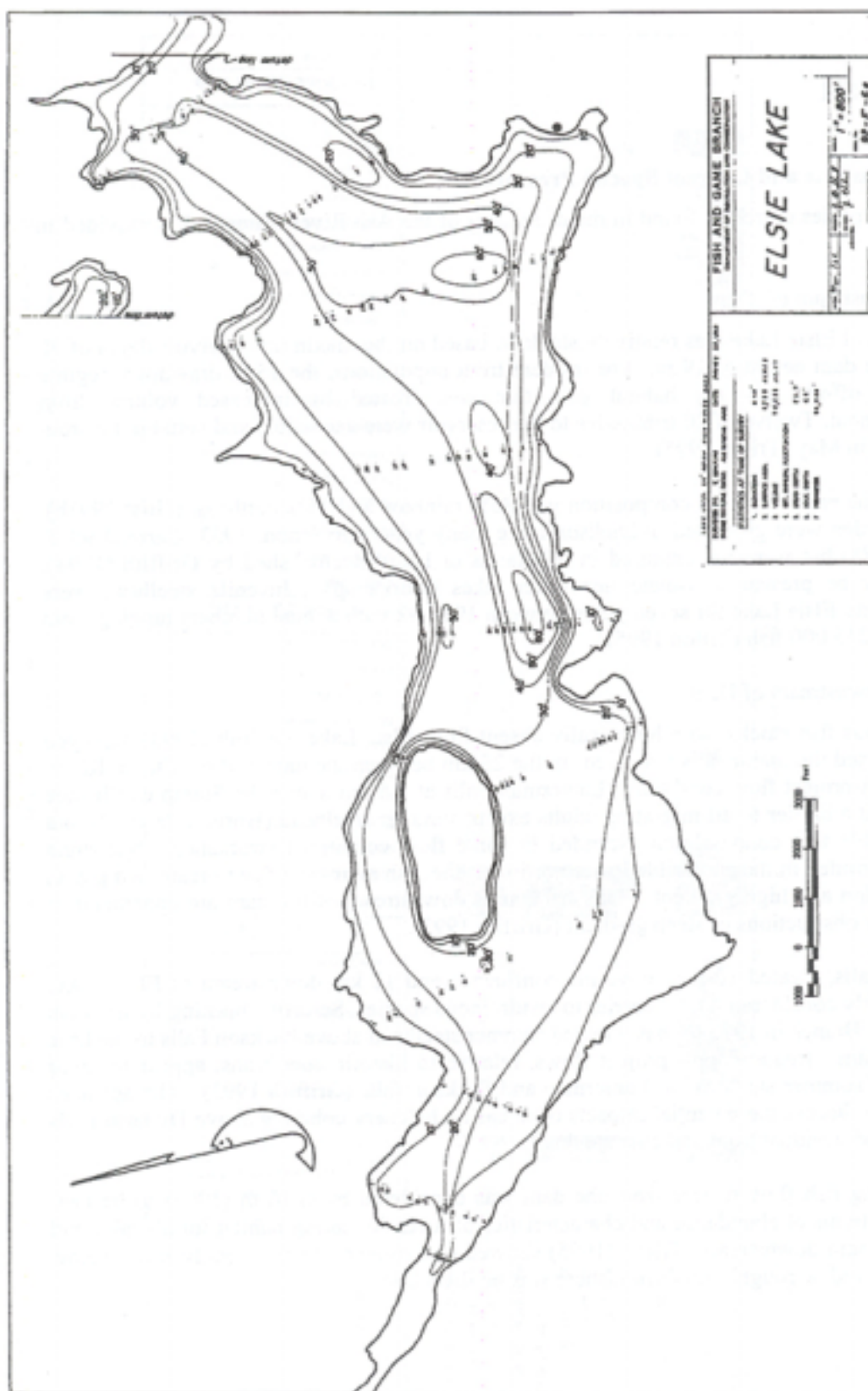
The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Elsie Lake Reservoir		Original habitat lost
Lake flooded	(ha)	271
Land flooded	(ha)	401
Lake shoreline	(km)	19
Mainstem: length	(km)	5
channel	(ha)	30
riparian *	(ha)	30
Tributary: length	(km)	5
riparian **	(ha)	14
Wetland:	(ha)	72

* mainstem riparian zone calculated 30 m from each bank

** tributary riparian zone calculated 15 m from each bank





2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Ash River watershed is provided in Table 4-1.

2.1.1 Upstream of Dam

The original Elsie Lake was relatively shallow, based on the maximum reservoir depth of 30 m and the dam height of 19 m. For resident trout populations, the 15 m drawdown regime probably offsets any net habitat gain that was created by increased volume from impoundment. Twelve of 20 tributaries to the reservoir were accessible and suitable for trout spawning in May (Triton 1995).

In 1969, the reservoir trout composition was 85% rainbow and 15% cutthroat (Hirst 1991b). Dolly Varden were gillnetted in Dickson Lake many years ago (anon. 1953; Carmichael & Philip 1978) but were not captured in tributaries or lakes electrofished by Griffith (1993). They may be present in isolate headwater lakes (workshop). Juvenile steelhead were released into Elsie Lake for seven years between 1982-92 with annual numbers ranging from 39,000 to 215,000 fish (Triton 1995).

2.1.2 Downstream of Dam

Anadromous fish stocks were historically absent from Elsie Lake. Griffith (1993) surveyed and discussed the major falls that occur in the 25 km between the dam and the Stamp River. Under post-project flow conditions, Lanterman Falls at 5.5 km above the Stamp confluence was judged a barrier to all migrating adults except summer steelhead (Horncastle 1977), but it is possible that coho salmon ascended in some flow conditions (workshop). Spawning habitat is limited in the accessible lower portion of the Ash mainstem due to restricted gravel accumulation and high gradient. Many tributaries downstream of the dam are ephemeral or blocked by obstructions or steep gradient (Griffith 1993).

Dickson Falls, located 10 km above the confluence and 15 km downstream of Elsie Lake, was formerly considered a total barrier to anadromous species. Selective blasting by BC Fish & Wildlife Branch in 1975-76 has allowed summer steelhead above Dickson Falls to the base of Elsie Dam. Reduced post-project flows, relative to historic conditions, appear to favor passage of summer steelhead at Lanterman and Dickson falls (Griffith 1993). The agencies continue to discuss the potential impacts of releasing hatchery coho fry above Dickson Falls on steelhead, resident trout and char stocks.

The existing fish flow release from the dam was considered by Griffith (1993) to be near optimal in terms of abundance and characteristics of juvenile rearing habitat for all salmonid species present downstream. Triton (1995) showed that summer mean monthly flows below the dam would be roughly doubled if there was no diversion.

Source: MOELP 2000, BC Ministry of Environment Fish Information Website - <http://www.bcefisheries.gov.bc.ca/fishinfo.html>, accessed before June 8, 2000
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

- now named *Northern pike minnow*

The Ash River watershed is a substantial sub-basin of the Somass-Stamp system which is a historic producer of all five salmon species and steelhead. Chinook and sockeye stocks have increased in post-project years due to enhancement efforts by Robertson Creek hatchery and fertilization of Great Central Lake (GCL), respectively, whereas chum and pink stocks have declined significantly (Hirst 1991a).

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Elsie Lake Reservoir	1. Reservoir footprint flooded 5 km of mainstem channel and associated riparian zone.	x		GIS; Griffith 1993
	2. Reservoir footprint flooded 4.6 km of tributary channel and associated riparian zone: loss of habitats in lower reaches	x		GIS; Triton 1995
	3. Reservoir footprint flooded 271 ha of lake: gain of 401 ha in reservoir habitat and uncalculated volume.	x	x	GIS
	4. Fluctuating water levels of 15 m reduced productivity by exposing littoral habitats: see bathymetric map for shoal features	x		Triton 1995
	5. Fluctuating water levels of 15 m may limit fish access to tributaries.	x		BC Hydro 1994
Elsie Dam	6. Dam footprint of $_ m^2$: loss of instream, riparian and upland habitats.	x		
	7. Dam has reduced LWD (but not gravel recruitment) to river habitats downstream.	x		workshop
	8. Spills or valve tests at the dam strand steelhead smolts during spring migration.	x		Griffith 1993
	9. Elsie Dam blocks movement of resident trout in mainstem, but the mainstem lacked gravel down to Dickson Lake.	x		Griffith 1993
Ash River downstream	10. 25 km of summer rearing habitat and capacity in mainstem areas downstream have benefited from the fish flow release.		x	Griffith 1993
	11. Reduced flows have enabled summer steelhead to ascend Lanterman and potentially Dickson falls.		x	Griffith 1993
	12. Reservoir and diversion have reduced downstream nutrients in mainstem but presumably export some amount to Great Central Lake. Fish and anglers congregate at the tailrace.	x	x	workshop; Powell 1995
Diversion to Great Central Lake	13. Entrainment mortality and injury: magnitude unknown. Some potential downstream benefits to scavengers.	x	x	workshop
	14. Culverts on access roads may block fish passage.	x		Powell 1995
	15. Potential for elevated shortterm TGP events; magnitude unknown			
	16. Plant shutdowns stop discharges into Great Central Lake and the Stamp/Somass system for 1-2 weeks in summer.	x		BC Hydro 1994
	17. Summer water temperatures in the Stamp/Somass system and Robertson Creek hatchery may be elevated due to loss of cool Ash flows. However, the low-level outlet releases cooler water from below the thermocline when the reservoir is full.	x	x	BC Hydro 1994; Tutty 1997; Triton 1995

The effect of the hydro project on water temperatures in the Ash River downstream, and subsequently on the Stamp and Somass rivers beyond its confluence, is still unclear after considering views by Griffith (1993), Triton (1995), Tutty (1997), Ptolemy (1998) and DFO (1998). The Somass-Stamp mainstem is recognized as a critical migratory corridor for sockeye and chinook salmon. In warm years such as 1990 and 1993, these stocks can experience significant pre-spawning mortality. The original summer volume of Ash River flows has been reduced by about 50%; this may contribute to the warming of the corridor in some years. The other 50% now goes to Great Central Lake, but any cooler Ash water would sink below GCL's thermocline and therefore contribute to GCL's live storage but not cool the lake's surface temperature. However, Elsie Lake's storage was increased by the project and while the volume of summer flows to Ash River downstream are reduced, the Ash discharge originates below the thermocline and is reported to be cooler than the previous surface discharges from the natural lake.

Triton (1995) reported that a BC Hydro proposal to increase the rate of diversion out of Elsie Lake could deplete its storage earlier in the summer. This scheme could disrupt the thermocline that purportedly cools the regulated fish flow down the Ash mainstem. However, Triton considered that the main run of sockeye to GCL would pass through the corridor by June and thereby be relatively little impacted, whereas DFO cites many years, particularly in the 1990s, where these runs have delayed in the estuary until mid-August. Hence DFO is concerned that reservoir storage will be depleted earlier in the season and consequently exhaust GCL's live storage capacity before the critical summer/early fall migration period. The agencies have proposed a scheme to cool the discharge of GCL into the Stamp-Somass corridor and the Robertson Creek spawning channel (Tutty 1997).

Non-Hydro Impacts - Other impacts on fish in the Ash River watershed are principally the historic and current effects of logging. Much of the timber between Elsie and Dickson lakes has been harvested since 1972.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Ash River watershed. These also reflect the key issues raised at BCRP regional workshops in June, 2000.

1. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources.

2. **Reduced downstream habitat capability:** Habitats below the dam are altered by reduced wood recruitment.
3. **Reduced biological productivity:** The former Elsie Lake is affected long-term by large reservoir drawdown regimes and frequent fluctuations.
4. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat due to large drawdown regimes.
5. **Reduced mainstem access:** While adult steelhead passage may be facilitated by lower project flows, resident species may experience reduced access within the mainstem due to diminished flows.
6. **Diversions:** The diversion has reduced flows to the downstream Ash River channel and increased flow into Great Central Lake; these altered flows have affected wetted channel area, seasonal temperatures and productivity in the respective systems.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve habitats for resident fish stocks in the reservoir and tributary system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Activities in response to limiting factors #1, 2, 3 and 4 above should be preceded by a study plan for the reservoir and tributary system that considers:

- operating flow regime (Ash River Water Use Plan)
- opportunities to purchase or covenant floodplain properties for future habitat projects
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and for planting riparian vegetation
- feasibility of low-level fertilization trials in fish-bearing tributaries and performance indicators
- potential methods to achieve self-sustaining nutrient levels and reduce costs
- ecological effects of fertilization on non-target plants and aquatic animals
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- current harvest pressures on stock strength
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 2: Improve habitat conditions for fish stocks in the downstream channels of the Stamp and Somass rivers.

Discussion:

A data gap exists with respect to the historic and current influence of the Ash River in cooling the Stamp-Somass migration corridor. Activities should be preceded by a study plan, in response to limiting factors #1, 2, and 5 above, that considers:

- operating flows and fish flows (Water Use Plan)
- pre- and post-diversion temperature conditions in the Ash River, reservoir thermoclines, temperatures of fish-flow releases, and their influence on temperatures in the Stamp/Somass corridor during adult migration
- effects of the diversion's flows and temperatures on Great Central Lake
- effects of proposed temperature changes on wildlife biodiversity values
- identification and filling of data gaps on other issues that may constrain populations.

Objective 3: Conserve and improve aquatic habitats in the lower Ash River.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Restoration activities should be preceded by a study plan to address limiting factors #1, 2, 5 and 6, that considers:

- operating flows and adequacy of fish flow regime (Ash River Water Use Plan)
- opportunities to purchase or covenant streamside properties for future habitat projects
- potential sites for future habitat enhancement or creation
- the historic upstream limit of coho salmon
- proposed projects should have hydraulic characteristics that will withstand the historic range of discharges with low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- identification and filling of data gaps on issues such as stranding after spills, etc. that may also constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

B.C. Game Commission annual reports from years prior to flooding mention Elk use of the Ash River. Some habitats evident from pre-flooding historic airphotos include riverine/riparian, shallow open wetlands, and bogs.

Red- and Blue-listed species occurrences on file with the Conservation Data Centre include

- *Red-* Vancouver Island Wolverine (*Gulo gulo vancouverensis*) South of Mount Joan
- *Red-* Vancouver Island Water Shrew (*Sorex palustris brooksi*) Robertson Creek Fish Hatchery
- *Blue-* Small Spike-Rush (*Eleocharis parvula*) Ash Lake

No other information is available about current wildlife use. Areas of habitat types lost to flooding were presented earlier in Volume 1: Appendix I.

3.2 Impacts on Wildlife

Facility	Description of Hydroelectric Impacts	Neg	Pos	Source
Elsie Lake Storage Dam	• <i>Dam footprint of ___ ha: loss of coniferous forest and riverine habitats.</i>	x		
	• <i>Flooding of upper Ash River valley including 19 km perimeter of Elsie Lake, 380 ha of valley bottom and 21 ha of upland: loss of valley bottom and valley side coniferous, deciduous, and wetland habitats, incl. riparian, and associated wildlife losses, e.g., lost marsh and wetland feeding/breeding habitat for ducks and furbearers, and feeding habitat for bears & ungulates; loss of valley side habitat for ungulates and carnivores.</i>	x		GIS
	• <i>Conversion of 5 km of Ash R. and 4.6 km of tributary streams to lake: barrier to movement of large mammals (bears and ungulates); increase in open water for waterfowl and osprey.</i>	x	x	GIS
	• <i>Fluctuating reservoir water levels (2.1 m) due to hydroelectric operations: effects on establishment of aquatic and/or riparian vegetation in drawdown zone.</i>	x		BCH web page
	• <i>Reduced flows and changed flow regime in 30 km of Ash River: unknown effects on downstream aquatic wildlife (e.g. American Dipper, Harlequin, Vancouver Island Water Shrew)</i>	x	x	

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Loss:** Loss of riparian habitat and wetland habitats in flooded valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse and overwintering habitat for ungulates, and breeding habitat for some species of neotropical migrants.
2. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
3. **Wildlife Migration:** Barrier to wildlife caused by reservoir (minor).

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Elsie Lake.

Discussion:

See limiting factors # 1 and 2. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create snags along reservoir shorelines for cavity nesters and perching raptors.
- Provide artificial nesting structures for osprey.

Objective 2: Conserve riparian and wetland habitats in the downstream portions of Ash River watershed.

Discussion:

See limiting factor # 1. Identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means in the Ash River watershed.

Objective 3: Create or enhance wetlands and riparian habitats for aquatic species (amphibians, waterfowl, cavity dependent species, small mammals).

Discussion:

- Consider various opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times. Flood shallow basins in the watershed where feasible.
- Where practicable, create backwater channel and associated riparian habitats along Ash River segments where reduced downstream flows have diminished natural channel complexity in the floodplain.

Objective 4: Protect small groups of old or second growth trees in strategic locations for current and future nesting use by bald eagles or ospreys.

Discussion:

See limiting factor # 1.

Objective 5: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Ash River watershed.

4. ASH RIVER WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
1:5000 scale NTS topographic map, 1956	Horne Lake 92F/7W
1:50,000 scale topographic, Dept. of National Defence, 1949	Great Central 92F/6 E
Air Photos Elsie lake/Ash River, 1951	BC 1422: 99
Air Photos Elsie Lake, 1946	BC 254: 94

4.2 Hydro Facility and Fish References

Reference	Notes	Sources
Anonymous, 1953. Ash River survey (1953). B.C. Environment stream files, Nanaimo B.C. 16 p.		cited in Griffith 1993
Anonymous, 1954. Ash River survey (1954). B.C. Environment stream files, Nanaimo B.C. 16 p.		cited in Griffith 1993
B.C. Hydro. 1988. Elsie Lake Dams – Operation and Maintenance Manual. Report No. OM534/02.	General technical data of Ash River facilities.	BC Hydro
B.C. Hydro. 1991. Long-Term Hydrologic Data Collection Networks: La Joie, Terzaghi, Seton, Elsie, Wahleach, and Clowhom Basins. B.C. Hydro, Hydroelectric Engineering Division. Report H2067. 34 p.	BCH basin is 239 km ² . Elev. range is 330 m to 2000 m.	BC Hydro
B.C. Hydro, 1992. Ash River generating station additional energy overview study. B.C. Hydro, Hydroelectric Engineering Division. Report No. H2295. 82 p.		cited in Golder 1994
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B.C. Hydro. 1994. Ash River additional capacity feasibility study interim report. B.C. Hydro, Hydroelectric Engineering Division. Report No. H2812i.		cited in Van Dijk 1995
B.C. Hydro. 1994. Report on the electric system operations review (ESOR). Prepared for The Minister of Employment and Investment and the Minister of Energy Mines and Petroleum Resources. Unpubl. report.	overview of operations & issues for all facilities	BC Hydro
B.C. Hydro. 1998. Rare element occurrence: Field guide to the rare and endangered species found within the watershed boundaries of each BCH facility. Strategic Fisheries, Power Supply Operations, Burnaby, BC.	all red, blue and yellow species	BC Hydro
B.C. Hydro. 1999. Recreation opportunities inventory. Power Supply Environment, Rept. ER 99-08., 206 p.	color maps and description of all facilities	BC Hydro
Burridge DFO Nanaimo	did inventory of Ash R; same as Anon. 1954?	DFO Kamloops correspondence files
Burt, D.W. and J.W. Horchik. 1998. Production capability of salmonid habitat in the Stamp-Somass River system. Draft rep. for BC Min. Environment, Nanaimo, BC. 101 p..		cited in Ptolemy 1998
Carmichael, N.B. and D.F. Philip. 1978. Dickson Lake survey. BC Fisheries Branch, Victoria, BC. 18 p.		cited in Griffith 1993
Department of Fisheries and Oceans (DFO). 1960. Descriptive notes on other fish facilities on the Somass River system. Fisheries & Oceans Canada, Port Alberni, BC.	noted in 1981 DFO correspondence for conditional water license	
DFO. 1990. Fish Habitat and Inventory and Information Program. Stream Summary Catalogue Subdistrict No. 23 Port Alberni. Department of Fisheries and Oceans, Vancouver, B.C.		cited in Powell 1995
Griffith, R.P. 1990. Dickson and Nahmint lakes: lake outlet spawning gravel placement. R.P. Griffith and Associates for B.C. Conservation Foundation, Langley, B.C. 31 p.		cited in Griffith 1993
Griffith, R.P. 1992. Feasibility of fisheries enhancement undertakings in selected		cited in Griffith

Reference	Notes	Sources
Vancouver Island streams. R.P. Griffith and Associates for: B.C. Environment, Nanaimo, B.C. 13-27.		1993
Griffith, R.P. 1993. Ash River aquatic biophysical assessment, 1992-93. R.P. Griffith and Associates, Sidney, B.C. Prepared for B.C. Hydro, Environmental Affairs, , Burnaby. 186 p.	Extensive biophysical assessment.	BC Hydro
Harding, E.A. and J. Offin. 1969. Elsie Lake survey. B.C. Fisheries Branch, Victoria, B.C. 5 p.		cited in Griffith 1993
Hirst, S.M. 1991a. Impacts of the operation of existitng hydroelectric developments on fishery resources in British Columbia. Volume 1. Anadromous salmon. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2093. 144 p.	Anadromous salmon issues.	
Hirst, S.M. 1991b. Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia, Volume 2. Inland fisheries. Can. Manuscript Rep. Fish. Aquat. Sci. 2093 v.2: 200 p.	Resident fish and anadromous trout and char issues	
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Horncastle, G.S. 1978. Somass River steelhead investigations progress during 1977-78. Unpubl. rep. BC Fish & Wildlife Branch, Nanaimo, BC. 57 p.		cited in Griffith 1993
Horncastle, G.S. 1981. Life history of steelhead trout from the Somass River on Vancouver Island. BC Fish & Wildlife Branch, Nanaimo, BC. Fish. Tech. Circ. No. 51, 19 p.		cited in Griffith 1993
Le Brasseur, R.J. and O.D. Kennedy. 1972. The fertilization of Great Central Lake II: zooplankton standing stock. Fish. Bull. U.S. 70: 25-36.		
Le Brasseur, R.J., C.D. McAllister, W.E. Barraclough, O.D. Kennedy, J. Manzer, D. Robinson and K. Stephens. 1978. Enhancement of sockeye salmon (<i>Oncorhynchus nerka</i>) by lake fertilization in Great Central Lake: summary report. J. Fish. Res. Bd. Canada 35: 1580-1596.		
Lewis, A.F., G.J. Naito, S.E. Redden and BC Hydro Safety & Environment. 1996. Fish flow studies project: fish flow overview report. BCH Safety & Environment Rept. No. EA:95-06, 144 p.	comprehensive review of flows, facilities and fish for all BCH projects	BC Hydro
McDaniels Research Ltd. 1995. Ash River Project: Socio-economic Overview. Prepared for B.C. Hydro, Environmental Affairs. 11 p.	no fish or wildlife discussion	BC Hydro
Powell, C. 1995. Draft – Ash River Environmental Integrity Review – Fisheries Resource Component. Prepared by B.C. Hydro, Safety and Environment, Strategic Fisheries. 19 p.	General assessment of aquatic issues associated with facilities.	BC Hydro
Ptolemy, R.A. 1998. Great Central Lake/ Stamp River/ Ash River flow setting with emphasis on wild steelhead habitat/life history requirements. MS rep., BC Min. Environment, Victoria.	gives general rules for flow requirements of different species/stages. Recommended 40% MAD (=20 m ³ /s) for Stamp R. to be maintained during June to September	
Reiberger, K. 1992. Metal concentrations in bottom sediments from uncontaminated B.C. lakes. BC Ministry of Environment, Lands and Parks, Water Quality Branch.		cited in Triton 1995
Stockner, J. 1990. Great Central Lake. p.437 – 445. The Book of Canadian Lakes. Edited by R.J. Allan, M. Dickman, C.B. Gray and V. Cromie. The Canadian Association on Water Quality, Publications Office, Wastewater Technology Centre, Burlington, Ontario. Monograph Series, No. 3.	General summary of limnological conditions and influences in Great Central Lake.	ISBN 0-9698060-0-0.
Stringer, G.E., A.F. Tautz, T.G. Halsey and C. Houston. 1980. Further development of a lake stocking formula for rainbow trout in British Columbia. BC Min. Environment, Fisheries Rept. No. 75.		cited in Triton 1995
Triton Environmental Consultants Ltd., 1995. Ash River Additional Capacity Study – Impact Assessment of the Aquatic Environment. Prepared for B.C. Hydro and Power Authority, Environmental Affairs. 47 p.	temp. effects; bathymetry; limnology	BC Hydro
Tutty, B.D. DFO biologist. 1997. Memo re: Ash River additional capcity study. To R. Eliasen. DFO Nanaimo, 6 p.	outlines temp. problems in Ash R. and Great Central Lake; proposes thermal weir concept for GCL lake outlet; critique of Triton report.	
Wightman, J.C. 1993. Re: Elsie Lake dam low level intake test. Memo to G.		cited in Griffith

Reference	Notes	Sources
Longworth, Environmental Resources, B.C. Hydro. June 25, 1993. File: 39000-01, B.C. Environment, Nanaimo. 2 p.		1993
Van Dijk, M. 1995. Ash River Project. Recreation Assessment. Prepared by B.C. Hydro, Power Facilities, Environmental Services. Report No. PFES-95-01. 32 p.		BC Hydro

4.3 Wildlife References

Reference	Notes	Source
B.C. Hydro. 1998. Rare element occurrence: Field guide to the rare and endangered species found within the watershed boundaries of each BCH facility. Strategic Fisheries, Power Supply Operations, Burnaby, BC.	All red, blue and yellow-listed species	BC Hydro
Golder Associates Ltd. 1994. Ash River land resources assessment. Prepared for B.C. Hydro, Environmental Affairs. 108 p.	wildlife, vegetation re: proposed additional gen. capacity	BC Hydro
Province of British Columbia Department of Attorney – General, 1956. Provincial Game Commission Report	Refers to surveys & Investigations of proposed Salmon River diversion, Quinsam River diversion and storage, Heber River diversion, Somass River system (including Elsie Lake & Ash River)	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia Department of Attorney – General, 1959. Provincial Game Commission Report	Refers to studies of Ash, Salmon, Heber & Puntledge Rivers & Elsie Lake continued. (Report not found).	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1921. Annual Report of the Game Conservation Board of the Province of British Columbia 1920. Authority of the Legislative Assembly, Victoria BC	Elk near Sproat Lake.	Provincial Archives, MELP Surrey: Jack Evans

Chapter 5

JORDAN RIVER WATERSHED

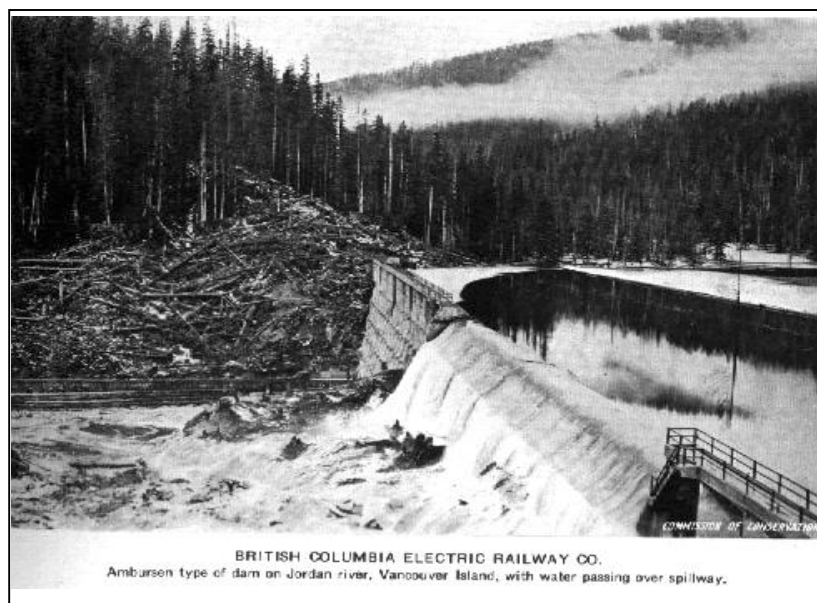


Figure 5-1. Jordan River in 1917

1. PROJECT DESCRIPTION

1.1 Facilities

The Jordan River project, completely renovated in 1971, consists of the Elliott Dam that diverts water via a 5.3 km tunnel and 1.6 km penstock to a new powerhouse on the west bank near the mouth of the river. Upstream from Elliott Dam are the Jordan River (or Diversion) Dam and the Bear Creek Dam. The two dams, initially constructed in 1911-13, were upgraded from 1969-71 and 1985-88 (Diversion Dam). Primary storage is now in the Diversion Reservoir, named because it originally diverted water in a flume that bypassed 9 km of river channel to the original powerhouse.

The original 26 MW powerhouse on the east side of the river was constructed in 1911 by the Victoria Light & Power Company. The old tailrace was an excavated channel about 500 m long that supported pink and chum spawning between 1949 -71.

Specifications for the facilities and reservoirs:

DAM	Bear Creek	Jordan	Elliott
Nameplate capacity (MW)	0	0	150
Dependable capacity (MW)	--	--	170
Dam function	storage	storage, diversion	storage, diversion
Date constructed	1911	1911	1969
Date operational			1971
Date reconstructed	1969; 1985	1969	
Height (m)	19	39.9	27.4
Length (m)	337	232	270
Dam footprint area (m ²)			
Fishway at dam	no	no	no
Historic anadromous fish presence	no	no	no

RESERVOIR	Bear Creek	Diversion	Elliott
Cleared/ not cleared	not cleared		
Present area (ha)	75	193	16
Watershed area (km ²)			165
Present elevation a.s.l. (m)	411	386	336
Normal drawdown range (m)	8	18.3	10.7
Mean depth (m)	6		19
Maximum depth (m)	15	40	27.4
Storage (million m ³)			28.4
Mean water retention time			
Mean annual discharge (m ³ /s)			12-13.7

DIVERSION			to powerhouse
Structure type			tunnel (5.3km), penstock (1.6km)
Licensed flow (m ³ /sec)			10.4
Fish flow release (m ³ /sec)	0	0	0
Mainstem length diminished (km)			9
Mainstem length augmented (km)			

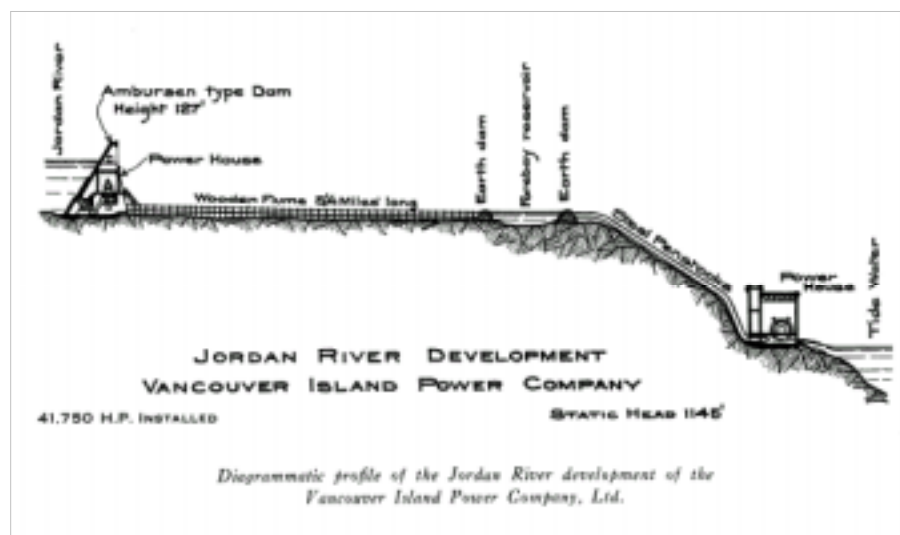


Figure 5-2. Historic Jordan River power scheme (Water Powers B.C. 1954)

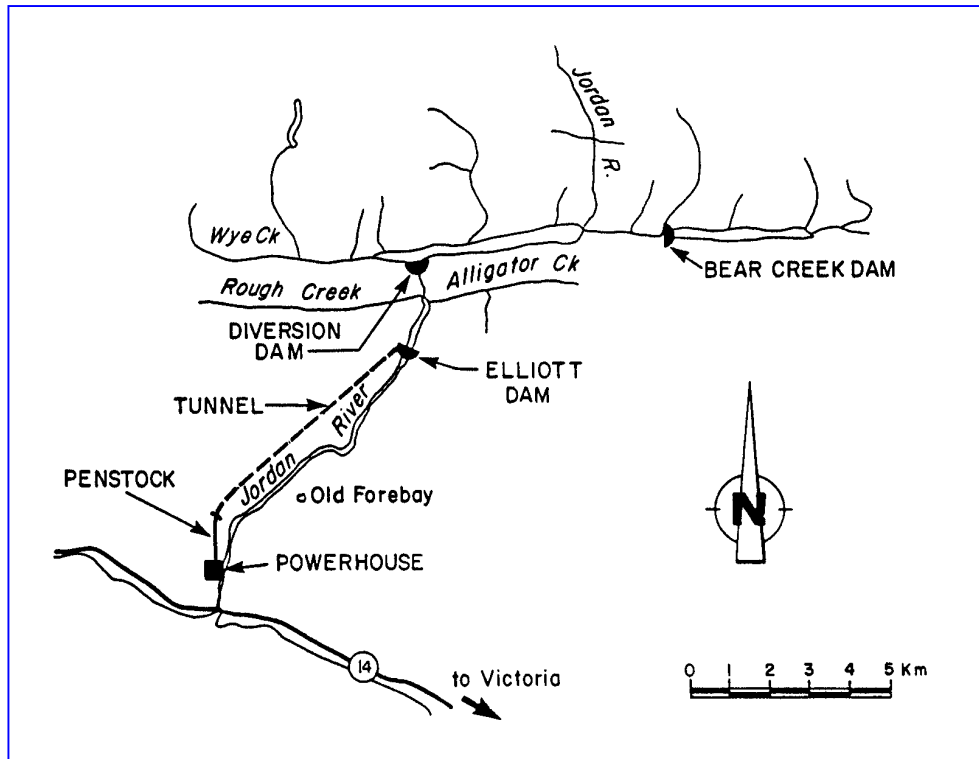


Figure 5-3. Location of Jordan River hydro project

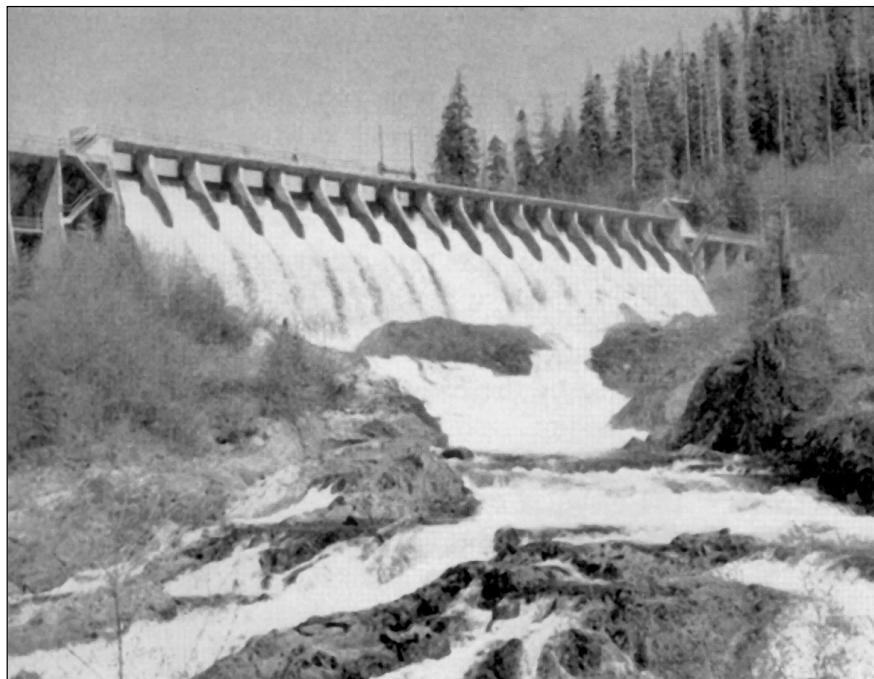


Figure 5-4. Jordan River diversion dam (Water Powers B.C. 1954)

1.2 Hydrology

1.2.1 Basin and Runoff

All water used by the project represents the upper 80% of the Jordan River watershed. High inflows occur in the May to July period from snowmelt. August and September are usually very dry. Heavy rain can cause immediate high inflows from October to March. A series of rainstorms separated by only hours or days can lead to local flooding.

1.2.2 Operation and Licensed Diversion Flow

The Jordan River facility has a large turbine capacity relative to its inflow and storage capacity. When the turbine is operating at full capacity and inflow is low, the reservoirs can be drafted from full pool to minimum levels in about three days. Consequently, the facility can be operated only sparingly and for short durations. Its major role is to provide backup peaking capability to the electric system.

Summer flows in the mainstem between Elliott Dam and the powerhouse tailrace are non-existent or very low; tributaries are either dry or short flowing trickles with isolated pools (Griffith 1996).

1.2.3 Habitat Types Flooded by Reservoirs

The combined reservoir area is 193 ha after flooding 193 ha of land (Figure 5-5). The total reservoir shoreline length is 20 km. A bathymetric map of Bear Creek Reservoir is provided in Figure 5-6.

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Combined Jordan R. Reservoirs		Original habitat lost
Lake flooded	(ha)	0
Land flooded	(ha)	193
Lake shoreline	(km)	0
Mainstem: length	(km)	7
channel	(ha)	15
riparian *	(ha)	44
Tributary: length	(km)	4
riparian **	(ha)	13
Wetland:	(ha)	0

* mainstem riparian zone calculated 30 m from each bank

** tributary riparian zone calculated 15 m from each bank

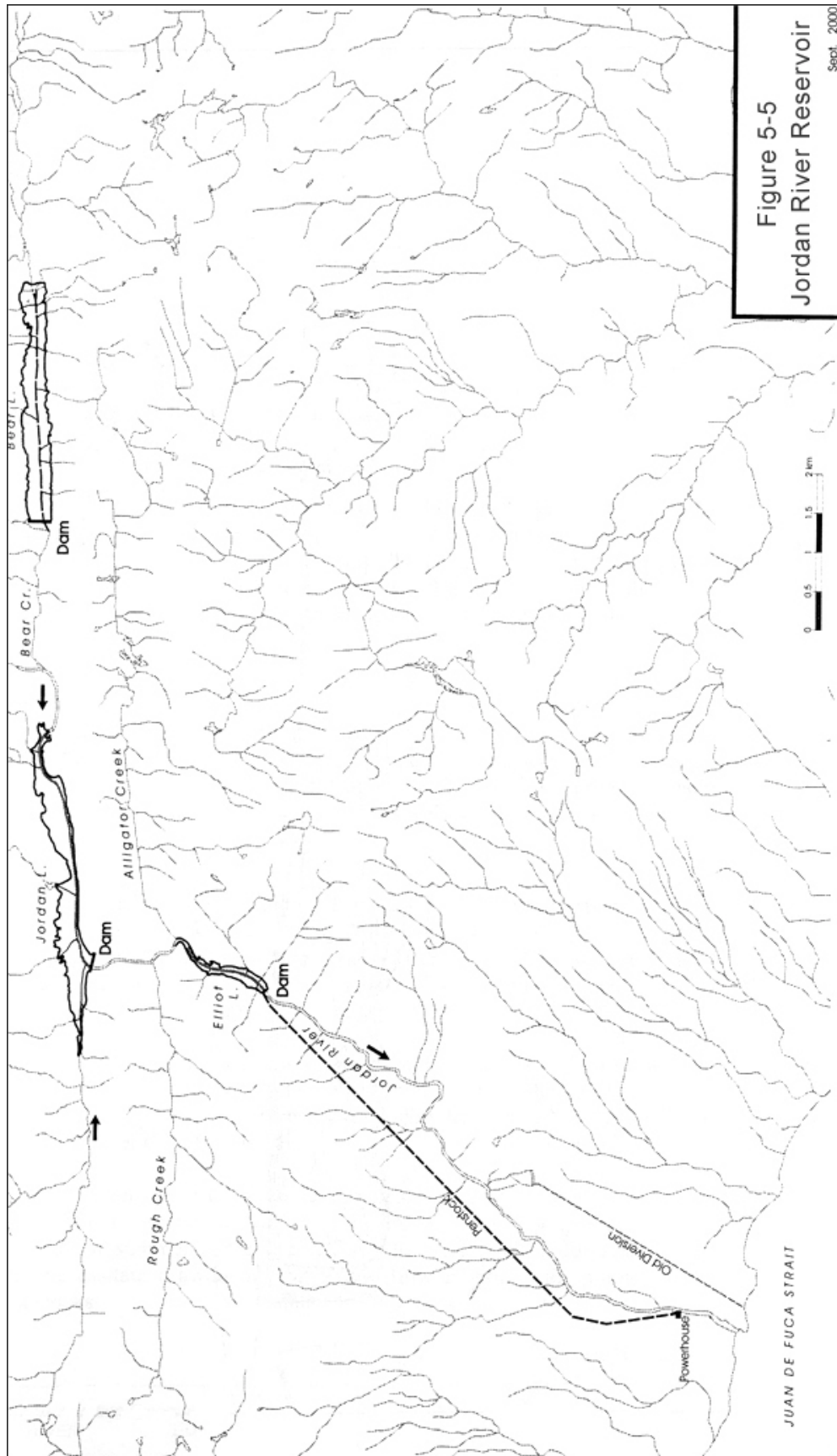


Figure 5-5
Jordan River Reservoir

Sept. 2000

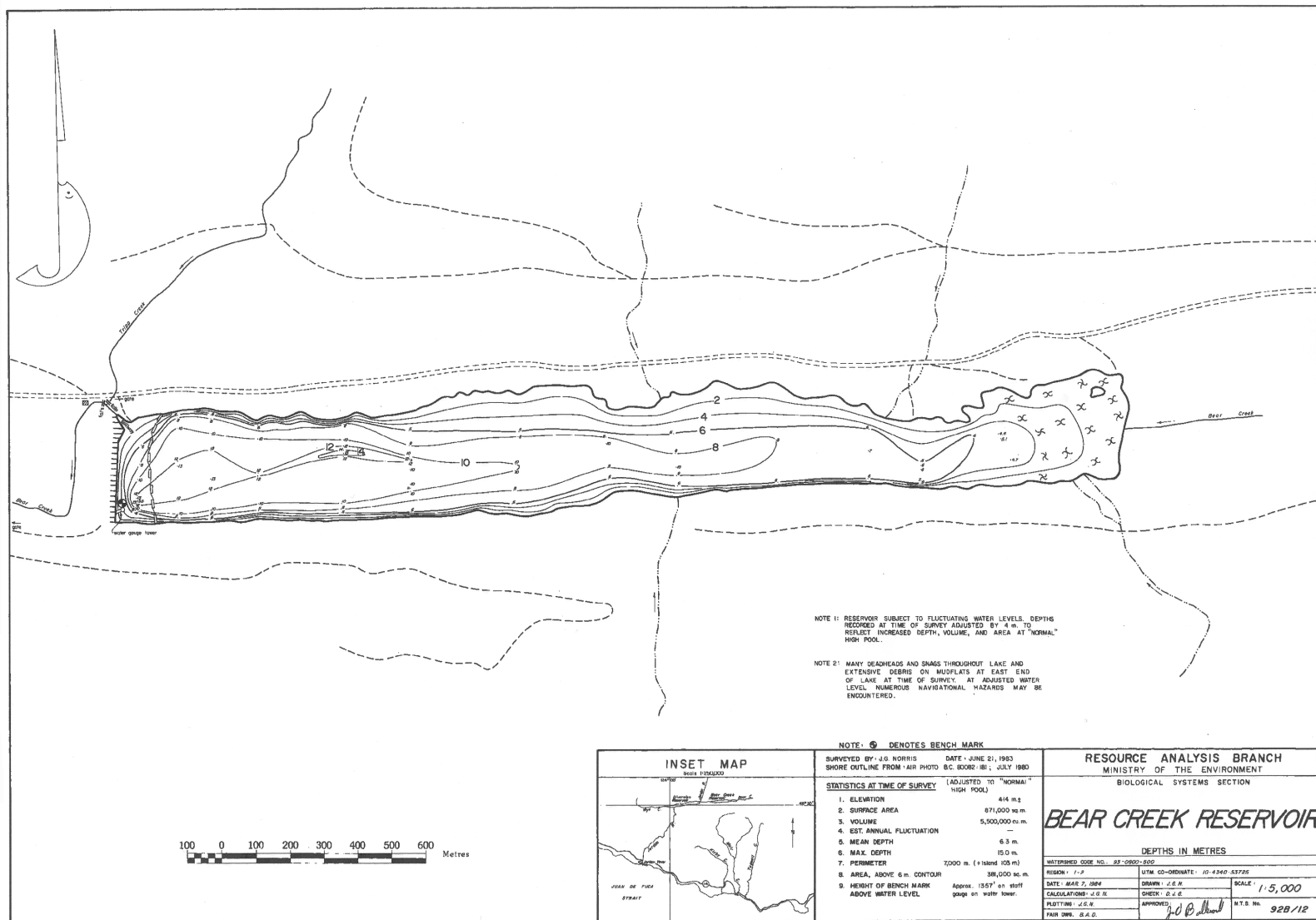


Figure 5-6. Bathymetric Map of Bear Creek Reservoir

2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Jordan River watershed is provided in Table 5-1.

2.1.1 Upstream of Bear Creek Dam

Rainbow and cutthroat trout populations in the reservoir have been largely supported by MELP stocking programs since 1985 (Sherbot 2000). Dolly Varden char may have been a historic component of the fauna (workshop 2000).

2.1.2 Bear Creek Dam to the Diversion Dam

Low summer flows in the basin probably limited the pre-project numbers of stream-resident trout in the vicinity of the project; Griffith (1996) suggested that creation of the permanent waterbodies has been a net benefit to such stocks. However, the current standing stock sizes are beyond carrying capacity as a result of stocking. Lack of tributary habitat limits the ability of the populations to sustain themselves given the amount of fishing pressure they receive.

2.1.3 Diversion Dam to Elliott Dam

Rainbow trout in Elliott Reservoir were less numerous but of larger size than fish in the upper reservoirs (Griffith 1996). Because Elliott is operated as a head pond for the penstock diversion, its drawdown is more stable than that in the Diversion Reservoir. Anadromous fish stocks were not historically present above the site of Elliott Dam (Hirst 1991a).

2.1.4 Downstream of Elliott Dam

The first set of impassable falls 3-6 m high is located 1.2 km above the river mouth, and 400 m upstream of the powerhouse tailrace, although these may have been passable to coho and steelhead in some pre-project years. A short section of gravel exists between the barrier falls and the old mine site above the powerhouse discharge. The second falls (5 m) and third falls (6 m) are 550 m and 750 m upstream of the tailrace, respectively (Sherbot 2000).

The majority of spawning chum, coho and pink salmon used the old powerhouse tailrace channel between 1912-1970 (Sherbot 2000). Historic presence of steelhead and anadromous cutthroat was noted in DFO and MELP records; rainbow trout have persisted in the boulder cascade of the lower river (Sherbot 2000).

There is no current evidence of anadromous fish production within the lower Jordan River drainage (Sherbot 2000). Restoration of Jordan anadromous stocks was discussed by Sherbot (2000). Provision of summer conservation flows to the mainstem for steelhead or coho rearing would necessitate drawdown during low flow months with probable effects on reservoir trout stocks.

Table 5-1. Fish species in the Jordan River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfo/bc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Jordan River upstream ↓ downstream	Anadromous Salmonids	Sport Fish	Non-Sport Fish	Red/Blue Listed Fish																																																																																																
	Steelhead Cutthroat trout (sea-run) Dolly Varden (sea-run) Sockeye Salmon Coho Salmon Chinook Salmon Pink Salmon Chum Salmon	Rainbow trout Cutthroat trout Dolly Varden Bull trout Brook trout Lake trout Kokanee Mountain whitefish Lake whitefish Burbot Sturgeon (general)	Sucker General Largescale sucker Longnose sucker Bridgelp sucker Northern squawfish * Peamouth chub Redside shiner Sculpin (general) Torrent sculpin Prickly Sculpin Slimy sculpin Coastrange sculpin Threespine stickleback Lamprey (general) Pacific lamprey River lamprey American shad Dace General																																																																																																	
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* now called *Northern pike minnow*

Residual populations of rainbow and cutthroat trout persist in the river between Elliott Dam and the old mining works wherever they can find sufficient water to survive summer droughts (workshop 2000).

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Bear Cr., Diversion, & Elliott Reservoirs	1. Reservoirs flooded a total of 7.3 km of mainstem and 4.4 km of lower tributary channels, plus their associated riparian zones; resident species composition unchanged except possible loss of Dolly Varden.	x		GIS
	2. Creation of 193 ha of reservoir habitat has increased habitat capacity for resident trout populations.		x	Griffith 1996
	3. Drawdowns at Bear and Diversion reduce access to tributaries.	x		workshop
	4. Drawdowns in shallow reservoirs reduce water quality by retaining anoxic bottom layers.	x		Griffith 1996
	5. Drawdowns reduce productivity of littoral zones.	x		workshop
Bear Cr., Diversion, & Elliott Dams	6. Collective dam footprint of ~ 1000 m ² : loss of instream, riparian and upland habitats.	x		
	7. Diversion and Elliott dams block movement of resident fish within upper system.	x		Sherbot 2000
	8. Periodic large spills scoured gravels immediately below dams, and transported fine sediments to spawning habitat in the lower mainstem.	x		workshop
	9. Dams reduced LWD and gravel recruitment to system downstream	x		workshop
	10. Entrainment mortality and injury; magnitude unknown. Potential downstream benefits to scavengers.	x		workshop
	11. Occasional shortterm spill events are being studied for TGP			workshop
Downstream River below Powerhouse	12. Absence of fish flow releases have reduced access and habitat area, and have not diluted toxic mine drainage.	x		workshop

Hydroelectric development has likely increased the original habitat capacity in the upper Jordan basin despite entrainment or fish access impacts. Supplemental stocking by MELP has encouraged more demand for local fishing opportunity. Obligation by BC Hydro to restore historic habitat appears limited, since the fishery removes more of the local fish population than would have existed naturally.

Water quality in the Diversion and Elliott reservoirs is degraded by anoxic conditions during drawdown (Griffith 1996), and by elevated levels of dissolved iron, possibly from the steel outlets at Bear Creek Dam (Sherbot 2000).

Under present conditions, the river below Elliott Dam has smaller areas of habitats, mostly ephemeral, for resident fish compared to pre-project levels. Present low water flows preclude the use of potential but limited habitats upstream of barrier falls by steelhead and coho salmon.

Non-Hydro Impacts - Other impacts on fish in the Jordan River watershed include historic effects of copper mining, gravel dredging, and logging activities (Sherbot 2000).

Sites between Elliott Dam and the current powerhouse have been mined intermittently for copper since the early 1900s (Aquametrix 1997). Mining operations were finally suspended after copper prices were depressed in the 1980s. In 1963, a major mine shaft under the river collapsed and flooded, producing high levels of copper in both water and sediment that remain toxic in 1997. Prior to 1960, copper ore tailings were accumulated along the east bank of the river; between 1960 and 1974, tailings were deposited on the subtidal shelf east of the river mouth; environmental effects were studied by Ellis and Popham (n.d.).

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Jordan River watershed. These also reflect the key issues raised at BCRP regional workshops in June, 2000.

1. **Loss of habitat:** Former spawning, rearing and overwintering areas were permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources.
2. **Reduced downstream habitat capability:** Habitats below dams are altered by reduced sediment or wood recruitment.
3. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat due to large drawdown regimes.
4. **Reduced mainstem access:** Reduced access for fish using channels diminished by diversions.
5. **Limited distribution:** Historic resident populations in the upper Jordan basin were likely limited due to the absence of lakes and low summer flows. Anadromous stocks were restricted by falls to the lower 1.2 km of river.
6. **Diversion:** The bypassed river channel usually receives no released flow, which in turn affects wetted channel area, seasonal temperatures and stream productivity.
7. **Copper mining:** Historic mining activities have had pervasive toxic effects on fish production in the lower Jordan River and estuary.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve aquatic habitats in the lower Jordan River below Elliott Dam.

Discussion:

There is presently a lack of fish flow released below Elliott Dam. High levels of copper in water and sediment from previous mining activity continue to affect fish production by direct toxicity and effects on food chains. These two problems greatly constrain future habitat restoration measures. If these conditions are remediated, undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Restoration activities should be preceded by a study plan to address limiting factors #1, 2, 4, 6, and 7 above, that considers:

- adequacy of fish flow regime (Jordan River Water Use Plan)
- feasibility of reducing dissolved copper levels by rehabilitating the stream channel to avoid or remove exposure to tailings and mine adits; and subsequent cost-benefit analysis considering the limited habitat area available
- opportunities to purchase or covenant streamside or foreshore properties for future habitat projects
- opportunities and cost-effectiveness of increasing summer habitat capacity in canyon
- potential sites for future habitat enhancement or creation
- proposed projects should have hydraulic characteristics that will withstand the historic range of discharges with low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem and estuary
- identification and filling of data gaps on issues such as stranding or displacement after spills, etc. that may also constrain populations.

Objective 2: Conserve and improve habitat conditions for resident fish stocks in each reservoir and tributary system.

Discussion:

Creating the three Jordan reservoirs has likely increased fish habitat capacity and population sizes in the upper basin overall, despite hydroelectric impacts from entrainment and local fish access. For the past 15 years the reservoir fish stocks have been artificially supplemented by MELP which has increased success rates in the local fishery. BC Hydro's obligations to restoring reservoir stocks appear relatively low since they did not encourage the fishery. There are implications to the management of the existing fishery because creation or improvement of tributary habitat under BCRP may still be insufficient to produce trout population levels that match the public's expectation of high catch rates from angling.

Undertake appropriate treatment, consistent with the BCRP strategy, to create or improve existing habitat as warranted. Activities in response to limiting factors #1, 3 and 5 above should be preceded by a study plan for each reservoir and tributary system that considers:

- operating and fish flows between dams (Jordan Water Use Plan)

- opportunities to purchase or covenant properties for future habitat projects or to preserve forested uplands that control water supply to important tributaries.
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and riparian planting
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to upstream habitats
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- current harvest pressures on stock recruitment
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

B.C. Game Commission reports indicate that black bears were plentiful and a few elk were present. These reports were probably from near the mouth of the river, rather than from the up river areas later flooded.

Red- and Blue-listed species occurrences on file with the Conservation Data Centre include

- *Blue-* Smith's Fairybells (*Disporum smithii*) - common in thickets at edge of woods near Bear Creek

No other information was obtained from the literature on current wildlife and habitats. Areas of habitat types lost to flooding were presented earlier in Volume 1: Appendix I.

3.2 Impacts on Wildlife

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Elliott Dam	1. <i>Dam footprint of ___ha: loss of coniferous forest (old-growth?)</i>	x		Hirst 1991
	2. <i>Flooding of narrow river channel and (old-growth?) coniferous forest on steep sided valley.</i>	x		Lee 1914
Diversion (Jordan R) Dam	3. <i>Dam footprint of ___ha: presumed loss of old-growth coniferous forest and dependent wildlife species.</i>	x		Lee 1914
	4. <i>Flooding of narrow river channel and old-growth coniferous forest and dependent wildlife on steep-sided valley.</i>	x		Lee 1914
	5. <i>Fluctuating reservoir water levels (18 m) due to annual maintenance operations in August: effects on establishment of aquatic and/or riparian vegetation in drawdown zone.</i>	x		BCH web page
Bear Creek Dam	6. <i>Dam footprint of 12.1 ha.: loss of old-growth coniferous forest and dependent wildlife species.</i>	x		Lee 1914
	7. <i>Flooding of river channel, some riparian, and wetland areas, and old-growth coniferous forest and dependent species on steep-sided valley.</i>	x		Lee 1914
Diversion Flume/ tunnel	8. <i>Habitat change along 5.3 km flume r-o-w: conversion from old-growth coniferous forest with dependent species to early successional shrub/trees and increased habitat diversity.</i>	x	x	BCH web page. (Lee 1914)
	9. <i>Reduced flows and changed flow regime in 8 km of Jordan River: unknown effects in high-gradient river between diversion and powerhouse and implications for wildlife such as harlequins or American dippers.</i>	x	x	GIS
Roads, etc.	10. <i>Construction of access routes for initial dam construction and ongoing maintenance: habitat loss.</i>	x		Lee 1914

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Changes:** Altered flow regime has changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for water shrews, harlequins and dippers.
2. **Loss of Habitat:** Loss of wetland habitats in flooded valley bottoms (Bear Creek). Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse for ungulates and breeding habitat for some species of neotropical migrants. (Bear Creek).
3. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
4. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions.
5. **Diversions:** Wildlife (especially mammalian) mortality caused by some diversion structures, through entrapment and drowning. Potential hazards for non aquatic or weak swimming animals.

3.4 Wildlife Restoration Objectives

Objective 1: Reduce erosion or drying of riparian and riverine habitats.

Discussion:

Avoid excessive flood flows or maintenance drawdowns during the spring and summer growing/breeding season. Consider in conjunction with Jordan Water Use Plan.

Objective 2: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat.

Discussion:

See limiting factor # 3. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.
- Improve nesting opportunities for osprey by providing artificial nesting structures.

Objective 3: Reduce barrier effects of diversions on wildlife.

Discussion:

See limiting factor # 4. Consider the use of overpasses over penstocks and other measures to reduce barriers effects.

Objective 4: Conserve riparian and wetland habitats in the Jordan River watershed.

Discussion:

See limiting factor # 1 and 2. Identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means, in the lower reaches of the river or in the reservoirs, or alternatively at Jordan Meadows or forested subbasins in the upper reaches of important tributaries to protect water supply.

Objective 5: Create elk winter range.

Discussion:

See limiting factor # 2. Work with forestry companies to leave shelter stands in association with logged clearings that provide forage.

- Enhance riparian areas near river mouth
- Assess the feasibility of re-introducing elk.

Objective 6: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Jordan watershed.

4. JORDAN RIVER WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
Survey of Lands for The Vancouver Island Power Co. Ltd., 20ch = 1 in., 1911	Legal Surveys, MELP
1:63,360 scale topographic map, San Juan, 1943, Dept. of Lands and 1954-55, 1:50,000 topographic map	92 C9/C8 UBC map library
Air Photos, Bear Creek and Jordan River diversion	BC 1229: 98-99, 3-4 BC 2255:19

4.2 Hydro Facility and Fish References

Reference	Notes	Sources
Aquametrix Research Ltd. 1997. Suitability of the lower Jordan River for salmon rearing: potential impact of sedimentary metals. Report for Western Forest Products, Jordan River Forest Operations, Jordan River, BC.		cited by Sherbot 2000
Aquatech Services. 1995. Bear Creek debris removal and spillway rehabilitation environmental monitoring report, June - October, 1994. Aquatech Services. Prepared for BC Hydro, Environmental Affairs.		BC Hydro
BC Electric Railway Company. 1932. Inspection of Jordan River Hydro-electric Development by BC Institute of Journalists, Victoria Branch, Sunday, June 5 th , 1932. Colonist Presses, Victoria, BC. 10 p.		UBC Spec Coll pamphlet files spam20446
B.C. Hydro. 1990. Jordan Dam power facilities overview study Resource Smart. Prep. by Acreas International Limited for BC Hydro. H2394.		cited by Sherbot 2000
B.C. Hydro. 1994. Report on the electric system operations review (ESOR). Prepared for The Minister of Employment and Investment and the Minister of Energy Mines and Petroleum Resources. Unpublished report and 2 appendices.	overview of operations & issues for all facilities	BC Hydro
Department of Fisheries and Oceans. 1973. The effect of the Jordan River power redevelopment program on the fisheries interest. Memo. report. Vancouver, B.C. 3 p.		cited in Hirst 1991
Department of Fisheries and Oceans. 1997. Gravel dredging at the mouth of Jordan River. Letter to Robazza (Western Forest Products) from. R. Russell (DFO Habitat Biologist).		cited by Sherbot 2000
Ellis, D.V. and J.D. Popham. n.d. Accidental formation and subsequent disappearance of a contaminated beach: a case history of environmental management. 17 p.		
Gillie, R.D. 1998. Evaluation of sedimentation and sediment management options in the mouth of the Jordan River. Unpubl. rept. by Coastal Consultants for Western Forest Products.		
Griffith, R.P. 1996. Biophysical assessment of fish production within the Jordan River drainage 1994. Unpubl. report by R.P. Griffith & Associates for BC Hydro, Environmental Affairs.		BC Hydro
Lee, Charles A., Engineer. <u>Jordan River Power Development, Vancouver Island, B.C.</u> In "Canadian Engineer" Press [1914 or 1915] 50 p., illus., folded diagrams, folded maps. Caption: "Advanced Proof" "to be read before the monthly meeting of the Society, March 4 th 1912.	Jordan River Diversion Dam: 392 m elev.; 161 ha area; formerly "heavily timbered"; in narrow, steep sided valley. Bear Creek Dam: 406 m elev.; 115 ha area; formerly heavily timbered with hemlock & other conifers--not cut before flooding; steep sided.	Vancouver Public Library

Reference	Notes	Sources
	About 12.1 ha cleared for dam construction. Other footprints: Elliot Dam & reservoir, flume (8.5 km), railroad, tramway r-o-w's	
Lewis, A.F., G.J. Naito, S.E. Redden and BC Hydro Safety & Environment. 1996. Fish flow studies project: fish flow overview report. BCH Safety & Environment Rept. No. EA:95-06, 144 p.	comprehensive review of flows, facilities and fish for all BCH projects	BC Hydro
Limnotek Research and Development Inc. 1995. Jordan River drainage water quality.		cited by Sherbot 2000
Norris, J.G. and D.J. Grant. 1983. A reconnaissance survey of Bear Creek Reservoir. Ministry of Environment, Water Management Branch.		
Ptolemy, R.A. 1981. Jordan River production/ stream carrying capacity assessment. Unpubl. reconnaissance report, BC Fish & Wildlife Branch, Victoria, BC. 39 p.		
Sherbot, D. 2000. Jordan River fisheries briefing note. Unpubl. draft report, BC Hydro. August 11. 26 p.		BC Hydro
Sohn, B. 1994. Recommendation for new Bear Creek minimum operating elevation. BC Hydro System Operations.		BC Hydro

4.3 Wildlife References

Reference	Notes	Source
B.C. Hydro. 1998. Rare element occurrence: Field guide to the rare and endangered species found within the watershed boundaries of each BCH facility. Strategic Fisheries, Power Supply Operations, Burnaby, BC.	All red, blue and yellow-listed species	BC Hydro
Province of British Columbia, 1925. Report of the Provincial Game Warden 1924. Authority of the Legislative Assembly, Victoria BC	Pheasants released at Jordan River	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1927. Report of the Provincial Game Warden 1926. Authority of the Legislative Assembly, Victoria BC	Black bear plentiful in Jordan River District	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1927. Report of the Provincial Game Warden 1926. Authority of the Legislative Assembly, Victoria BC	"A few" elk in the Jordan River District.	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1929. Report of the Provincial Game Warden 1928. Authority of the Legislative Assembly, Victoria BC	Black bear increasing near Jordan River Muskrats at Jordan River	Provincial Archives, MELP Surrey: Jack Evans

Chapter 6

ALOUETTE RIVER WATERSHED

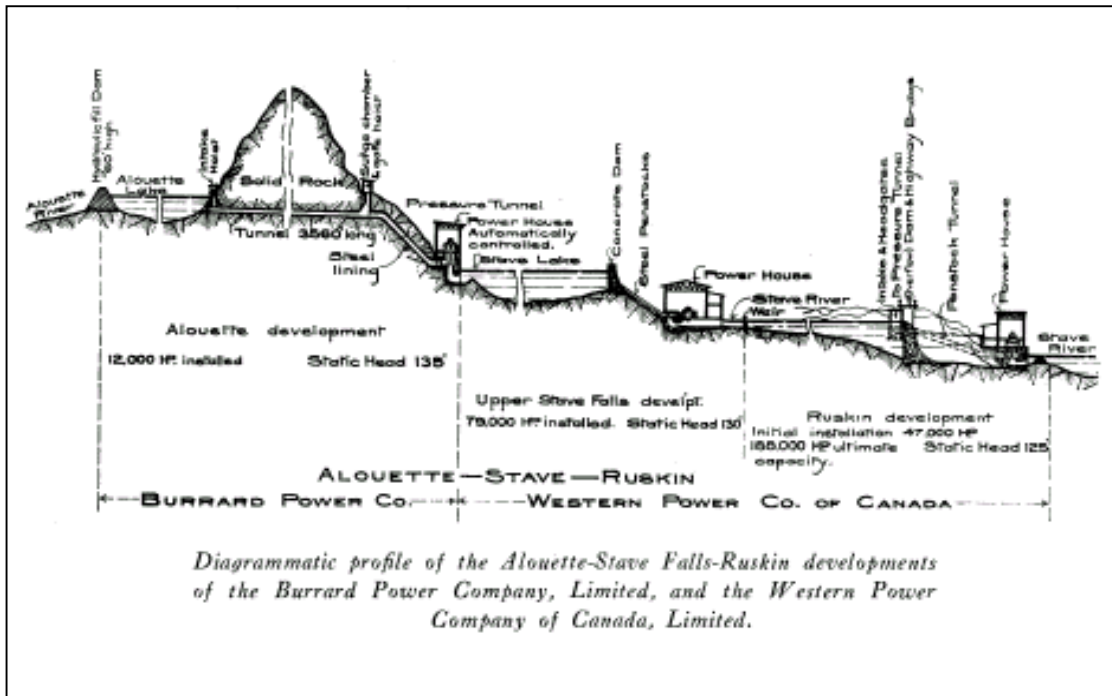


Figure 6-1. Historic Alouette River power scheme (Water Powers B.C. 1954)

1. PROJECT DESCRIPTION

1.1 Facilities

The Alouette Project consists of the dam at the south end of Alouette Lake Reservoir and a 1 km tunnel from the north end of the reservoir to the Alouette powerhouse on the shoreline of Stave Lake. Most of the runoff from the South Alouette watershed is diverted into Stave Lake Reservoir, through Stave Falls generating plant to Hayward Reservoir and the Ruskin plant.

Alouette Dam was constructed in 1926 (Burrard Power Co.) and was replaced by B.C. Hydro in 1984 with a modern earthfill structure. The spillway was rehabilitated in 1993. The Alouette-Stave-Ruskin project provided the bulk of power used in the Lower Mainland prior to development of the Peace River hydro project.

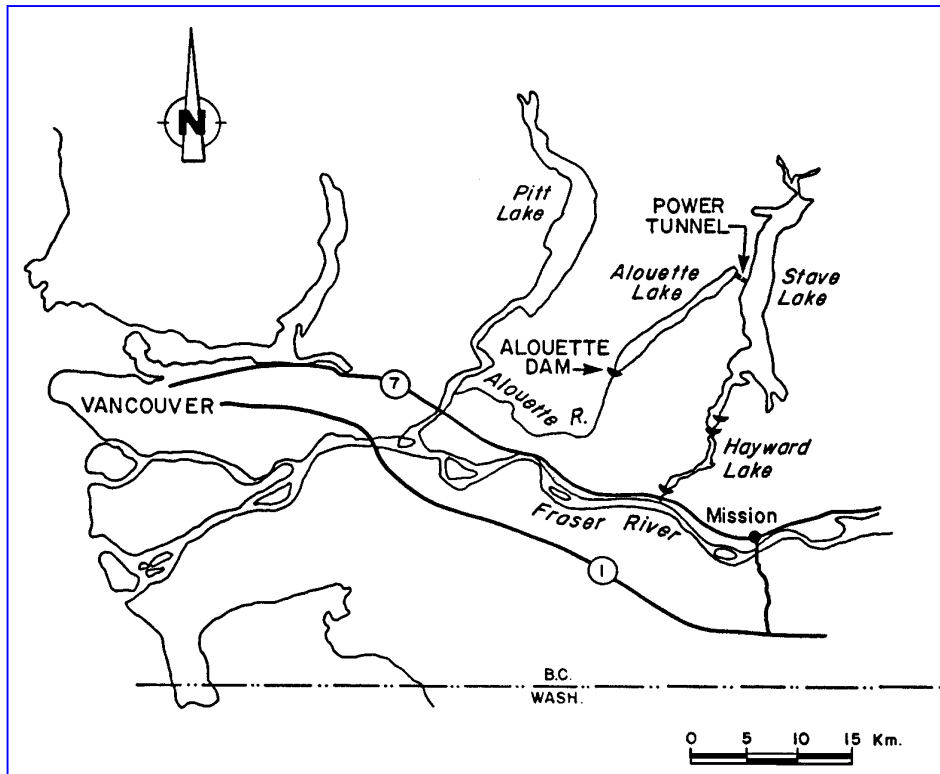


Figure 6-2. Location of Alouette / Stave hydro project

Specifications for the present facility and reservoir:

DAM	Alouette
Nameplate capacity (MW)	9
Dependable capacity (MW)	9
Dam function	storage, diversion
Date constructed	1924-26
Date operational	1928
Date reconstructed	1984
Height (m)	21
Length (m)	315
Dam footprint area (m ²)	
Fishway at dam	no
Historic anadromous fish presence	yes

RESERVOIR	Alouette Lake
Cleared/ not cleared	
Present area (ha)	1580
Watershed area (km ²)	200
Present elevation a.s.l. (m)	117 (bathym)
Normal drawdown range (m)	9.5
Mean depth (m)	64
Maximum depth (m)	140
Storage (million m ³)	155

Mean water retention time	5.2
Mean annual discharge (m ³ /s)	22

DIVERSION	to power plant on Stave L.
Structure type	tunnel (1km), penstock (31m)
Licensed flow (m ³ /sec)	28.3
Fish flow release (m ³ /sec)	0.7
Mainstem length diminished (km)	20
Mainstem length augmented (km)	

1.2 Hydrology

1.2.1 Basin and Runoff

Alouette Lake is a steep-sided mountain reservoir. Prior to impoundment there were two separate lakes known as “Lillooet” Lakes.

Most of the annual 22 m³/s inflow comes from two weather sequences: spring melting of the accumulated snowpack, and heavy fall rains from Pacific storms. Summer recreation demands, fish flow requirements, and low power useage leads to closure of the diversion tunnel from June through August

1.2.2 Operation and Licensed Diversion Flow

For maintenance of fish habitat in the South Alouette River, 0.7 m³/s is released from the low level outlet of the dam. The agencies and the Alouette River Management Society have been concerned that the existing flow regime is insufficient to protect existing stocks (Lewis *et al.* 1996).

1.2.3 Habitat Types Flooded by Reservoir

Reservoir impoundment raised the elevation of the original lake about 15 m (Knight 1987). The reservoir area is 1580 ha after flooding 373 hectares of land (Figure 6-3). The reservoir shoreline length is now 37.6 km, a 1.4 km reduction from the original shoreline due to flooding of the two lakes and complex channels at the inlet. Bathymetric maps of the Alouette Lake reservoir are presented in Figures 6-4 and 6-5.

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

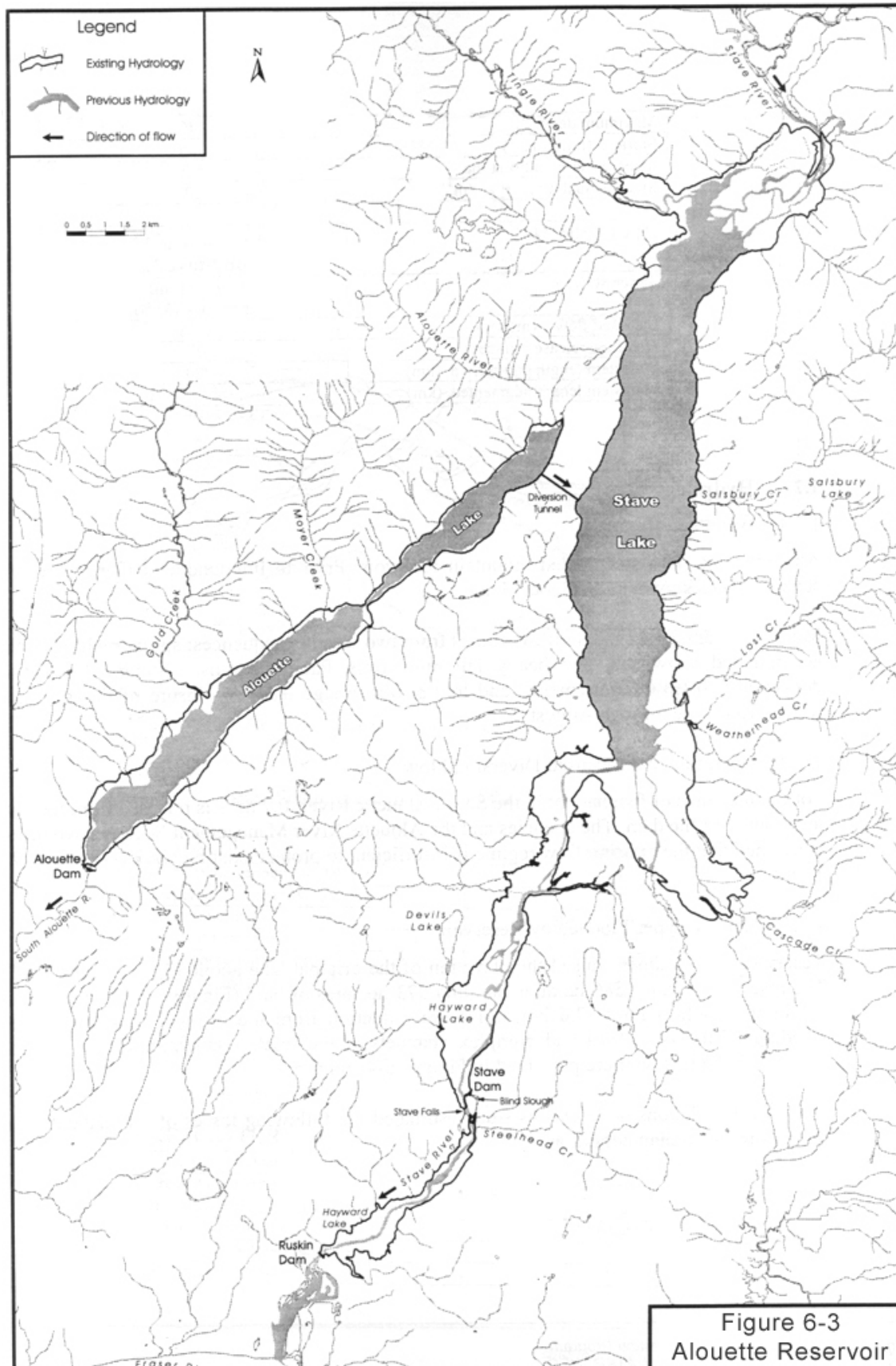


Figure 6-3
Alouette Reservoir

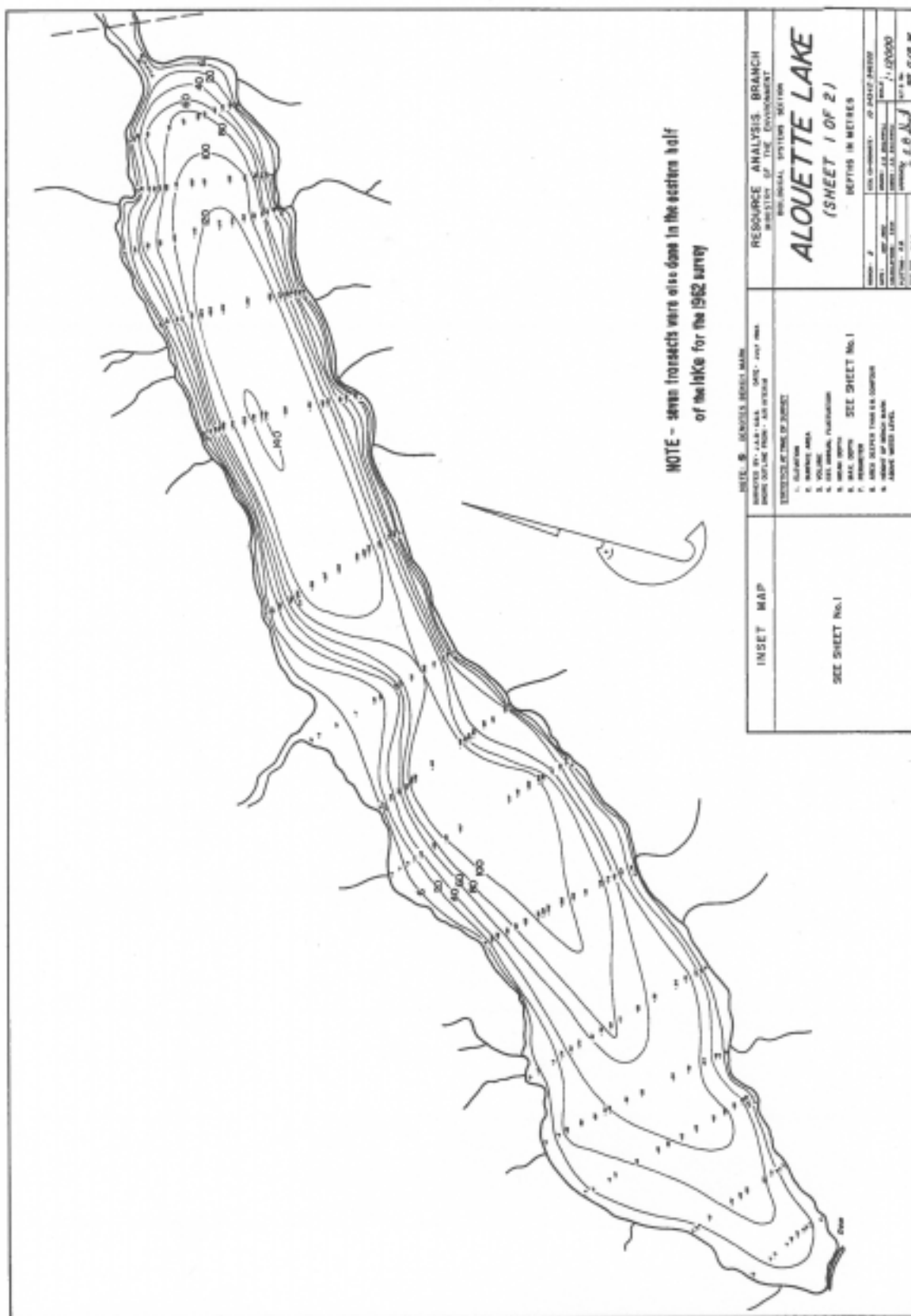
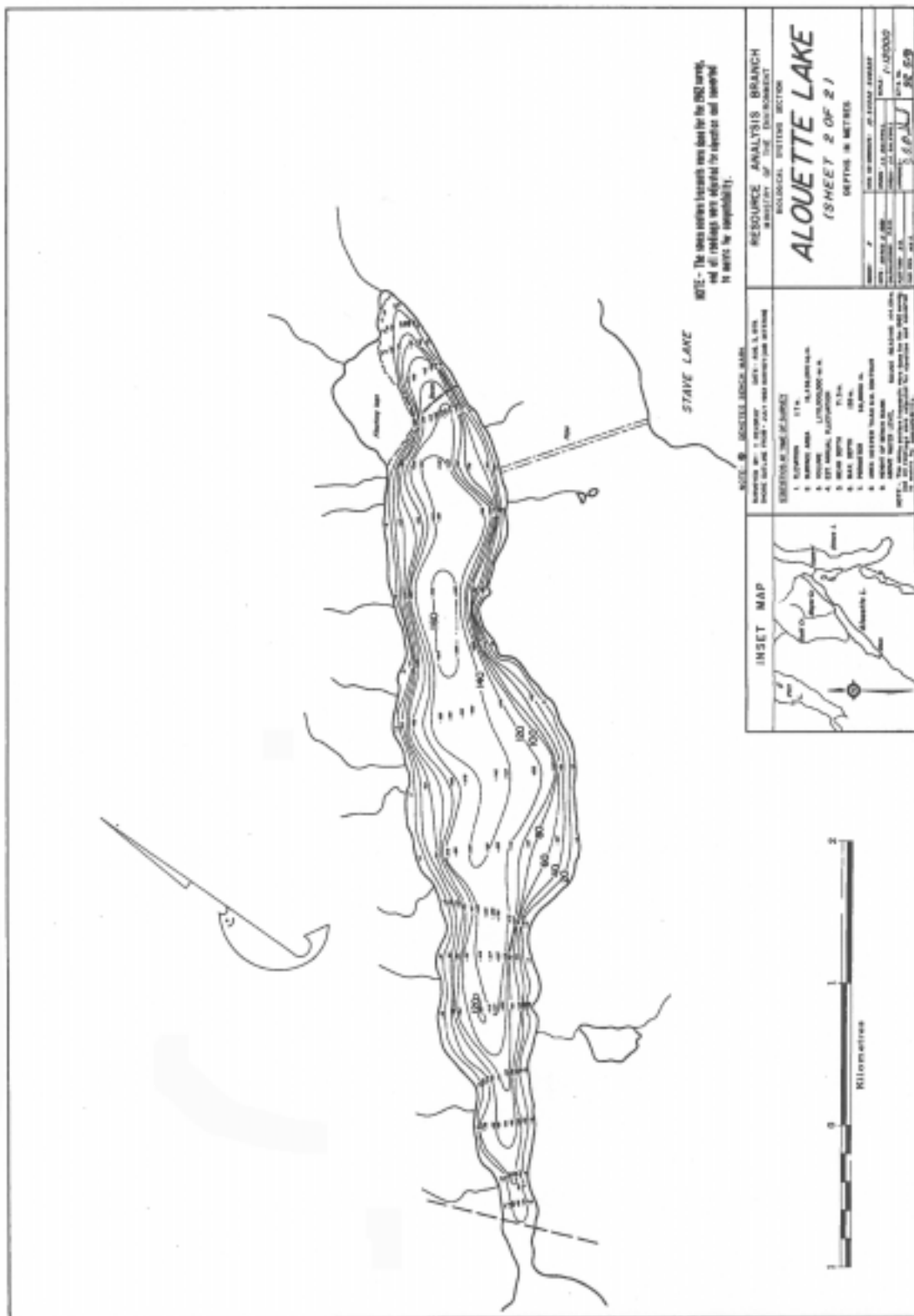


Figure 6-4. Bathymetric map of Alonette Lake (Sheet 1)



Alouette Lake Reservoir	Original habitat lost
Lake flooded (ha)	1208
Land flooded (ha)	373
Lake shoreline (km)	39
Mainstem: length (km)	0.3
channel (ha)	1
riparian * (ha)	2
Tributary: length (km)	4
riparian ** (ha)	12
Wetland: (ha)	0
* mainstem riparian zone calculated 30 m from each bank	
** tributary riparian zone calculated 15 m from each bank	

2. FISH

2.1 Historic and Current Species Presence

Fish species currently found in major reaches of the South Alouette River watershed are listed in Table 6-1.

The Alouette Dam initially impacted all anadromous fish stocks using the watershed by blocking upstream migrants, diverting virtually all flows to Stave Lake, and by footprint impacts on the small amount of available low-gradient tributary and mainstem habitats including the lake outlet. When the dam was built in the mid-1920s, the reasons ascribed to fisheries officials not to incorporate a fish ladder have been variously reported as the upriver anadromous stocks were not deemed significant relative to the value of the power development, and that a fishway was not feasible for that height of dam (IPSFC 1940).

2.1.1 Upstream of Alouette Dam

Like the Coquitlam, the South Alouette River system had a unique early stock of “bastard” sockeye salmon that returned to the river in late spring (IPSFC 1940). By the late 1930’s this race had disappeared due to the lack of a fishway at Alouette Dam (Roos 1991). A smaller stock of fall-run sockeye was also present in the original lake. Both sockeye stocks and the Alouette chinook stock were eliminated by the dam.

The important spawning and rearing habitats that remain are in Gold Creek, Moyer Creek, and the upper Alouette River; most of the other tributaries are steep with erratic discharges.

The reservoir is oligotrophic with low levels of phosphorus and nitrogen and an absence of aquatic plants. A fertilization experiment is currently being planned with levels based on the estimated historic presence of salmon carcasses (Wilson *et al.* 1999).

Table 6-1. Fish Species in the South Alouette River Watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

South Alouette River upstream ↓ downstream	Anadromous Salmonids								Game Fish										Other Fish Species																Red/Blue Listed Fish							
	Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	White Sturgeon	Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish *	Peamouth chub	Redside shiner	Spottail shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	Brassy minnow	Dace General	Longnose Dace	Salish sucker	
Alouette Mainstem																																										
Alouette Lake																																										
Pine Lake*																																										
Gold Creek*																																										
ALOUETTE DAM																																										
S. Alouette Mainstem																																										

* now named *Northern pike minnow*

* Tributary information from *BC Fishing Directory and Atlas. Freshwater Edition*. 1998/99. O.P. Publishing Ltd. Vancouver BC. 170 pages.

The majority of fish biomass is comprised of non-sport species, *e.g.*, northern squawfish, suckers, peamouth chub and redbreasted shiners (Knight 1987). Lake trout were introduced in 1968 but failed to reproduce, partly a result of drawdown effects on spawning shoals (Knight 1987). Recent enhancement of sport fish populations included the Bell-Cor netpen program in 1991 (Stevenson 1996).

2.1.2 Downstream of Alouette Dam

Chum and coho salmon and steelhead have reestablished considerable use of the river below the dam due to a minimum fish flow release begun in 1971. Production of hatchery reared coho began in 1980. The pink salmon population largely disappeared in the early 1950s due to gravel extraction in the lower reaches, but is slowly recovering. Lewis *et al.* (1996) recently summarized fish flow issues below Alouette Dam.

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Alouette Reservoir	1. Reservoir flooded 0.3 km of mainstem and 4 km of tributary channels, plus their associated riparian zones.	x		GIS
	2. Drawdown of 9.5 m reduces access to tributaries.	x		
	3. Drawdown reduces productivity of littoral zone.	x		
Alouette Dam	4. Dam footprint of $_ m^2$: loss of instream, riparian and upland habitats; loss of lake outlet spawning for anadromous stocks was compensated by construction of spawning channel below dam in 1994.	x		
	5. Dam blocked former passage of anadromous stocks.	x		IPSFC 1938
	6. Dam reduced LWD recruitment to system downstream.	x		
Downstream River	7. Periodic large spills and low level outlet at dam may cause sedimentation of spawning habitat in the mainstem.	x		Ramsay & Wescott 1995
	8. No fish flow releases for 40 years.	x		
	9. Reduction of flows has reduced floodplain complexity of downstream channel coupled with urban encroachment.	x		
Diversion to Stave Lake	10. Diversion reduces reservoir productivity.	x		workshop
	11. Entrainment mortality and injury; magnitude unknown.	x		

Present fish water releases, habitat area and complexity, and water quality in the South Alouette River are reduced compared to pre-project conditions. Urban encroachment resulted from the diminished flows in the river and now limits habitat restoration opportunities (workshop). Alouette Dam removed historic access to the original lakes and upper spawning beds and rearing area for all species of salmon, steelhead, and possibly anadromous cutthroat trout (IPSFC 1938).

Lake-resident sportfish populations are also constrained by lack of tributary habitat and access to tributary habitat (workshop; Knight 1987). Aquatic productivity in reservoir and downstream of dam is inherently low, but was formerly elevated by historic populations of salmon runs; drawdowns and diversion of large flows to Stave Lake also reduce nutrient levels (Wilson *et al.* 1999).

Non-Hydro Impacts - Other impacts on fish in the Alouette River watershed are predominantly historic effects of logging activities.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Alouette River watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Blocked access to historic habitats:** Certain anadromous and migratory resident stocks have been excluded from the watershed above Alouette Dam for 76 years.
2. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources. Dyking and urban encroachment along banks of the lower river have alienated offchannel, riparian and wetland areas.
3. **Reduced downstream habitat capability:** Physical habitats below dams are altered by reduced sediment or wood recruitment.
4. **Reduced biological productivity:** Alouette Lake has been affected long-term by large reservoir drawdown regimes and loss of historic salmon carcasses. The mainstem system below the dam has also lost nutrients delivered by larger historic salmon populations using the original flow volume.
5. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat due to large drawdown regimes. Access to tributaries below Alouette Dam may also be affected by the reduced mainstem flows due to diversion.
6. **Reduced mainstem access:** Reduced access for fish migrating in mainstem channel now diminished by the diversion.
7. **Diversions:** The diversion has reduced flows to the downstream channel and increased flows in the Stave River; these altered flows have affected wetted channel area, seasonal temperatures and stream productivity in the respective systems.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve fish habitats in the lower Alouette River.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Restoration activities should be preceded by a study plan to address limiting factors #1, 2, 6, and 7 above that considers:

- operating flows and fish flows (Alouette River Water Use Plan)
- urban trends to stabilize the channel
- opportunities to purchase or covenant streamside properties for future habitat projects
- opportunities for habitat development
- proposed projects should have hydraulic characteristics to withstand the historic range of discharges with low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- identification and filling of data gaps on other issues such as fish stranding after spills, etc. that may constrain populations.

Objective 2: Conserve and improve habitats for resident fish stocks throughout the reservoir and tributary system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Activities in response to limiting factors #1-4, and 7 above should be preceded by a study plan for each reservoir and tributary system that considers:

- operating flows and fish flows (Water Use Plan)
- opportunities to purchase or covenant key properties for future habitat projects
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and for planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- current harvest pressures on stock recruitment
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 3: Restore biological productivity in the reservoir system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to improve aquatic productivity. Activities should be preceded by a study plan for the reservoir and tributary system, in response to limiting factors #4 and 7 above, that addresses:

- feasibility of a phased program of fertilization trials and performance indicators
- determination of appropriate low-level nutrient levels that include historic sources from salmon carcasses
- potential methods to achieve self-sustaining nutrient levels and reduce costs
- relative values of fertilizing fish-bearing tributaries vs reservoir plankton or littoral zone
- ecological effects of fertilization on non-target plants and aquatic animals
- impacts on esthetics and domestic water supply downstream
- wildlife biodiversity values at all proposed sites
- identification and filling of data gaps on issues such as entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 4: Address feasibility of restoring historic access for anadromous stocks to Alouette Lake.

Discussion:

Undertake an appropriate study, consistent with the BCRP strategy and Section 1-3.2, to restore historic access to anadromous fish. A study plan, in response to limiting factors #1, 2, and 6 above, should consider:

- present operating flows and adequacy of fish flows (Water Use Plan)
- biological soundness in terms of donor stocks, ecological interactions, current adequacy of habitat and productivity
- engineering feasibility of structures and flows for upstream and downstream passage
- management implications to future BC Hydro operations, and to fisheries that presently exploit similar stocks at a high rate
- identification and filling of data gaps on other issues that may further constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

B.C. Game Commission Records indicate that mountain goats were common and wolves were recorded at Alouette Lake.

Red- and Blue-listed species occurrences on file with the Conservation Data Centre include

- *Blue-* Green Heron (*Butorides virescens*) in riparian/deciduous woodland along Alouette River
- *Blue-* Mountain Sneezeweed (*Helenium autumnale* var *grandiflorum*) on marshy bank of North Alouette River

B.C. Hydro and Ducks Unlimited (1999) did six spring surveys of the southeast arm and saw very few waterfowl. The following species were observed: Canada goose, mallard, green-winged teal, common loon. Evidence of mammals recorded on the mudflats included beaver, bobcat, river otter and coyote, while black-tailed deer occurred in adjacent areas. Two herptiles were observed: common garter snake and Pacific treefrog.

3.2 Impacts on Wildlife

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Alouette Lake Dam	1. <i>Dam footprint of _ ha</i> : loss of coniferous forest and riverine habitats	x		
	2. <i>Flooding of lowland forest (33 ha) and upland forest (340 ha)</i> : loss of valley bottom and valley side coniferous forest and associated wildlife losses.	x		GIS
	3. <i>Fluctuating reservoir water levels (9.5 m) due to hydro-electric operations</i> : effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		BCH web page
Alouette R. Diversion	4. <i>Decreased Alouette River (20 km) and increased Stave River (3 km) flows</i> : effects on downstream aquatic wildlife.	x	x	GIS

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of Habitat:** Loss of riparian habitat and wetland habitats in flooded valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse for ungulates and breeding habitat for some species of neotropical migrants.
2. **Habitat Change:** Altered flow regime has changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for tailed frogs, water shrews, harlequins and dippers. Loss of side channel habitat downstream of diversions (dyking and other unrelated factors also responsible).
3. **Reduced Habitat Capability:** Lack of snags for cavity nesting habitat and structures for large raptor nests. Potential effects for primary cavity nestors (eg. woodpeckers) and secondary cavity nestors (e.g. swallows, squirrels).

4. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
5. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions.
6. **Entrainment:** Wildlife (especially mammalian) mortality caused by diversion or intake structures, through entrainment and drowning. Potential hazards for non aquatic or weak swimming animals.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Alouette Lake.

Discussion:

See limiting factor # 4. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.
- Improve nesting opportunities for osprey by providing artificial nesting structures.

Objective 2: Conserve riparian and wetland habitats in the Alouette River watershed.

Discussion:

See limiting factors # 1 and 2. As part of a joint Alouette-Stave habitat conservation initiative, identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means, in the Alouette River and/or Stave River watersheds.

Objective 3: Create or enhance wetlands and riparian habitats for aquatic species (amphibians, waterfowl, cavity dependent species, small mammals).

Discussion:

See limiting factors # 1 and 2. Consider various opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times.

- Create additional wetlands where feasible through activities such as flooding shallow basins in the watershed.
- Create backwater channel and associated riparian habitats along Alouette River segments where reduced downstream flows have diminished natural channel complexity.

Objective 4: Protect small groups of old or second growth trees in strategic locations for current and future nesting use by bald eagles or ospreys.

Objective 5: Create ungulate winter range.

Discussion:

Work with forestry companies to leave shelter stands in association with logged clearings that provide forage.

- Establish vegetation in the reservoir drawdown zone, especially near creek or river deltas.
- Assess potential to re-introduce elk.

Objective 6: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Alouette watershed.

4. ALOUETTE RIVER WATERSHED REFERENCES

BC ELECTRIC CORRESPONDENCE - SPECIAL COLLECTIONS, UNIVERSITY OF BC

July 31, 1925, letter from Burrard Power Co. Ltd to Crown Timber agent:

Area of submergence between normal low water, 441 ft, and normal high water, 482 ft, is approx. 600 acres; area of submergence involves three areas: Lower Lake (100 acres), Gold Creek Flat (70 acres) and Upper end of Upper lake (65 ac): the belt around the lake borders; 21 miles and an average width of 230 ft.

Proposed Alouette Power Development, General Description and Specifications", 1923:

"At low water there are actually two lakes, separated by a narrow stretch of flowing water about 800 feet in length; the difference in elevation between the two lakes is approximately 2 feet."; combined area of the two lakes is **3,485 acres**; elev. approx. 371 ft above mean sea level

4.1 Map and Air Photo References

Reference	Location Source
Map of Stave Lake and Alouette Lake, Western Power Co.	422-C11-E43, BC Hydro
Plan to accompany Western Canada Power Co.'s application, n.d. 15 chs = 1 in; 235 and 240 ft contours	422-C11-X8004, BC Hydro
Plan showing property owned and controlled by Western Power Co of Canada Ltd.; 1 in = 20 chs, May 1928	422-C23-X2 and 422-C11-E8010/11, BC Hydro
Map of New Westminster District, 1913; approx. 1:70,000 showing Coquitlam Lake, Pitt Lake and Lillooet Lakes	UBC map library
Alouette Air Photos, 1940 and 1941	BC 203:45 and 96; BC 197:3

4.2 Hydro Facility and Fish References

Reference	Notes	Sources
Anderson, C. 1988. Alouette Lake inlets debris clearance. Habitat Conservation Fund Project. Prepared for B.C. Ministry of Environment, Surrey, B.C. Regional Fisheries Report LM-144. 52 p.		BC Hydro
Andrew, F.J., and S.R. Killick. 1957. A study of the feasibility of planting sockeye in the Stave River watershed. International Pacific Salmon Fisheries Commission. New Westminster, B.C. 10 p.	discussed re-introduction of salmon	Pac. Salmon Comm. archive file 1370.1-12
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Chapter 7

STAVE RIVER WATERSHED



Figure 7-1. Original Stave Falls Powerhouse (Western Canada Power Company)

1. PROJECT DESCRIPTION

1.1 Facilities

Stave Reservoir serves as the storage reservoir for the Stave Falls and Ruskin generating plants; it also receives inflows from the diversion of Alouette Lake. Stave Falls Dam and Blind Slough Spillway Dam were completed and in service in 1911; Ruskin Dam was completed in 1930. Blind Slough Dam was built on the original river channel. There are powerhouses at the base of Stave and Ruskin dams. This project once provided the bulk of power used in the B.C. Lower Mainland prior to the development of the Peace River hydro project.

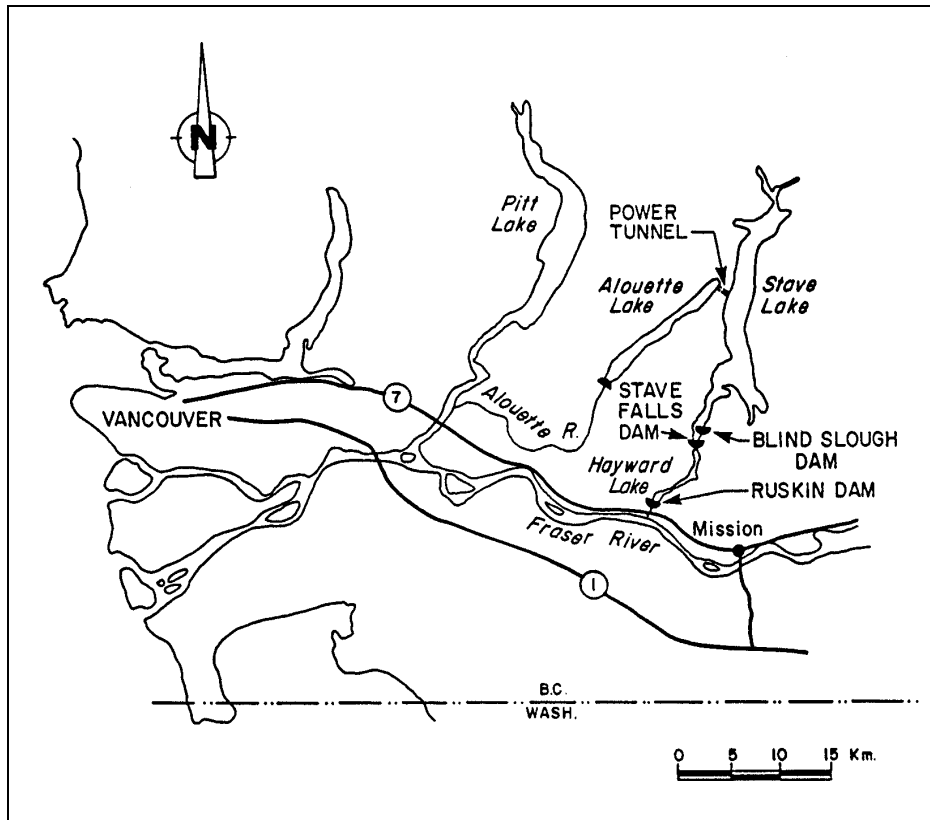


Figure 7-2. Location of the Alouette / Stave hydro project

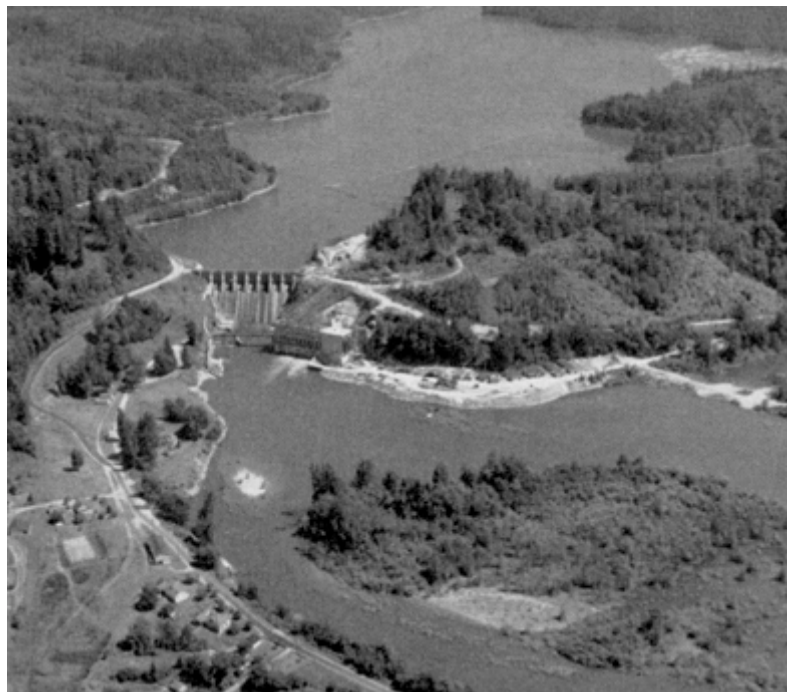


Figure 7-3. Ruskin Dam and Hayward Reservoir in 1950 (Water Powers B.C. 1954)

Figure 7-3. Ruskin Dam and Hayward Reservoir in 1950 (Water Powers B.C. 1954)

Specifications for the facilities and reservoirs:

DAM	Stave Falls	Ruskin
Nameplate capacity (MW)	52.5	106
Dependable capacity (MW)	50	100
Dam function	storage	storage, diversion
Date constructed	1911	- -
Date operational	- -	1930
Date reconstructed	1923 (raised)	- -
Height (m)	26	59.4
Length (m)	67	125
Dam footprint area (m ²)		
Fishway at dam	no	no
Historic anadromous fishpresence	no	yes

RESERVOIR	Stave L.	Hayward
Cleared/ not cleared	nc	nc
Present area (ha)	5858	276
Watershed area (km ²)	1170	953
Present elevation a.s.l. (m)	81	45
Normal drawdown range (m)	9.1	0.5-1(1.8)
Mean depth (m)	35	16
Maximum depth (m)	101	38
Storage (million m ³)	365	24
Mean water retention time	5 mo.	<3 days
Mean annual discharge (m ³ /s)	132	132

DIVERSION	to powerhouse	to powerhouse
Structure type	penstock (43-99m)	penstock (22-77m)
Licensed flow (m ³ /sec)	238	357
Fish flow release (m ³ /sec)	same as Ruskin	28-84
Mainstem length diminished (km)	- -	- -
Mainstem length augmented (km)	(from Alouette)	2.8

1.2 Hydrology

1.2.1 Basin and Runoff

The drainage basin includes parts of Golden Ears and Garibaldi Provincial Parks which have glacial inputs.

Stave Lake inflow comes primarily from two weather patterns. In the fall, heavy rain from Pacific frontal systems produces large inflows. The annual peak short term inflows occur during this period, with daily flows fluctuating from trickles to potential flood levels. In the spring, the accumulated snowpack melts and provides steady high inflows.

Inflow into Hayward Lake comes mainly from Stave Falls Reservoir which has an average natural annual inflow of about 111 m³/s and an additional 21 m³/s from the Alouette diversion project.



Figure 7-4. Stave River in June 1910 (BC Archives)

1.2.2 Operation and Licensed Diversion Flow

Stave Reservoir is at its highest levels during the fall and late spring due to high inflows. The storage reservoir is usually drawn down during winter to produce electricity and to accommodate spring snowmelt volume. Hayward Lake can fluctuate by 9.9 m daily but typical drawdown ranges from 1-2 m. Releases of 38 m³/sec from Stave Falls must be coordinated with releases from Ruskin for fisheries purposes from October 1 to May 31.

1.2.3 Habitat Types Flooded by Reservoir

The combined reservoir area is 5,535 ha after flooding 2,612 hectares of land (Figure 7-5). The combined reservoir shoreline length is now 101.3 km. Bathymetry maps of Stave and Hayward reservoirs are provided in Figures 7-6 to 7-8.

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Stave Lake & Hayward Reservoir	Original habitat lost
Orig. lake flooded (ha)	2923
Land flooded (ha)	2612
Orig. lake shoreline (km)	41
Mainstem: length (km)	28.4
channel (ha)	348
riparian * (ha)	170
Tributary: length (km)	35

Legend

- Existing Hydrology
- Previous Hydrology
- Direction of flow



0 0.5 1 1.5 2 km

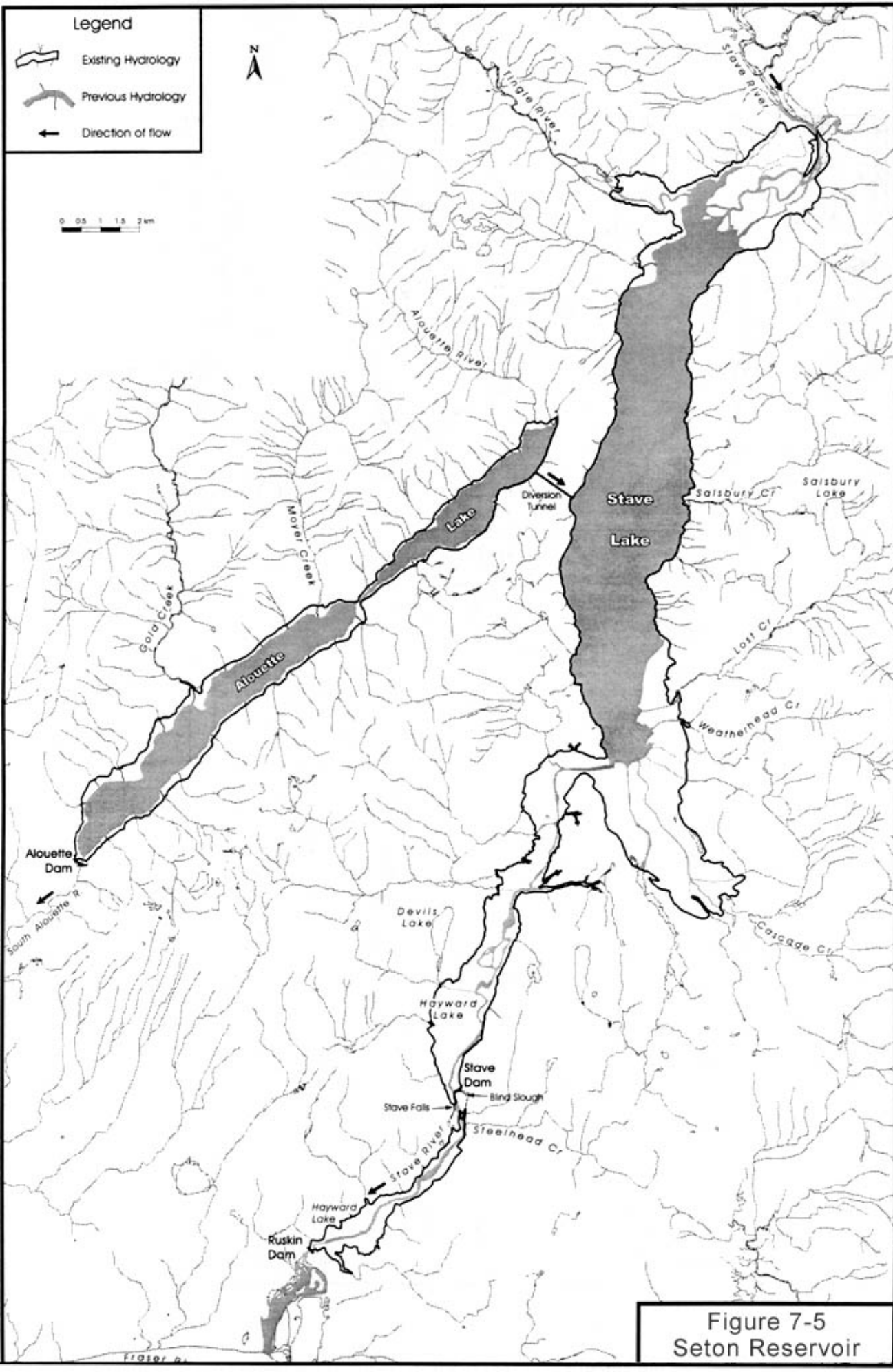


Figure 7-5
Seton Reservoir

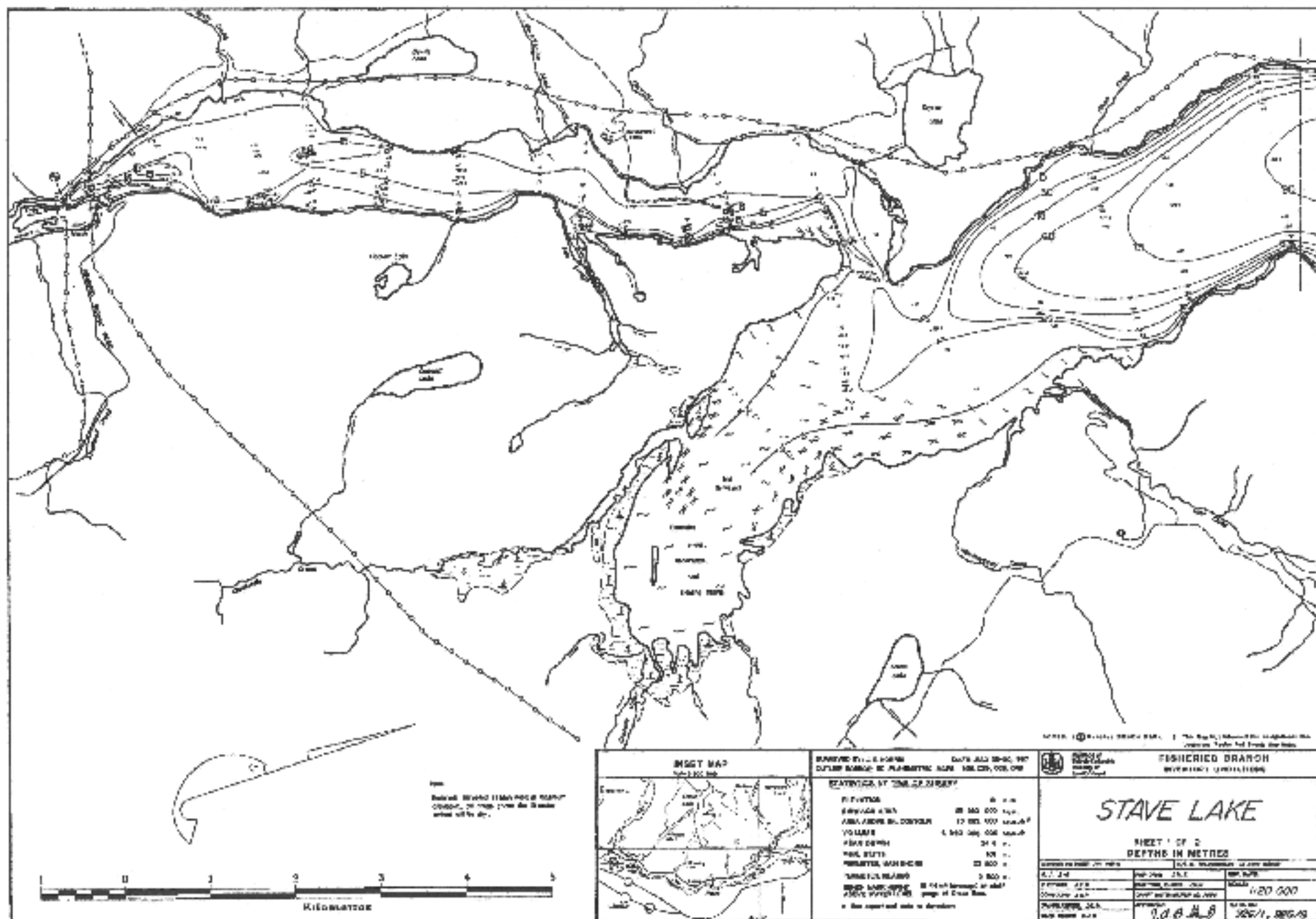
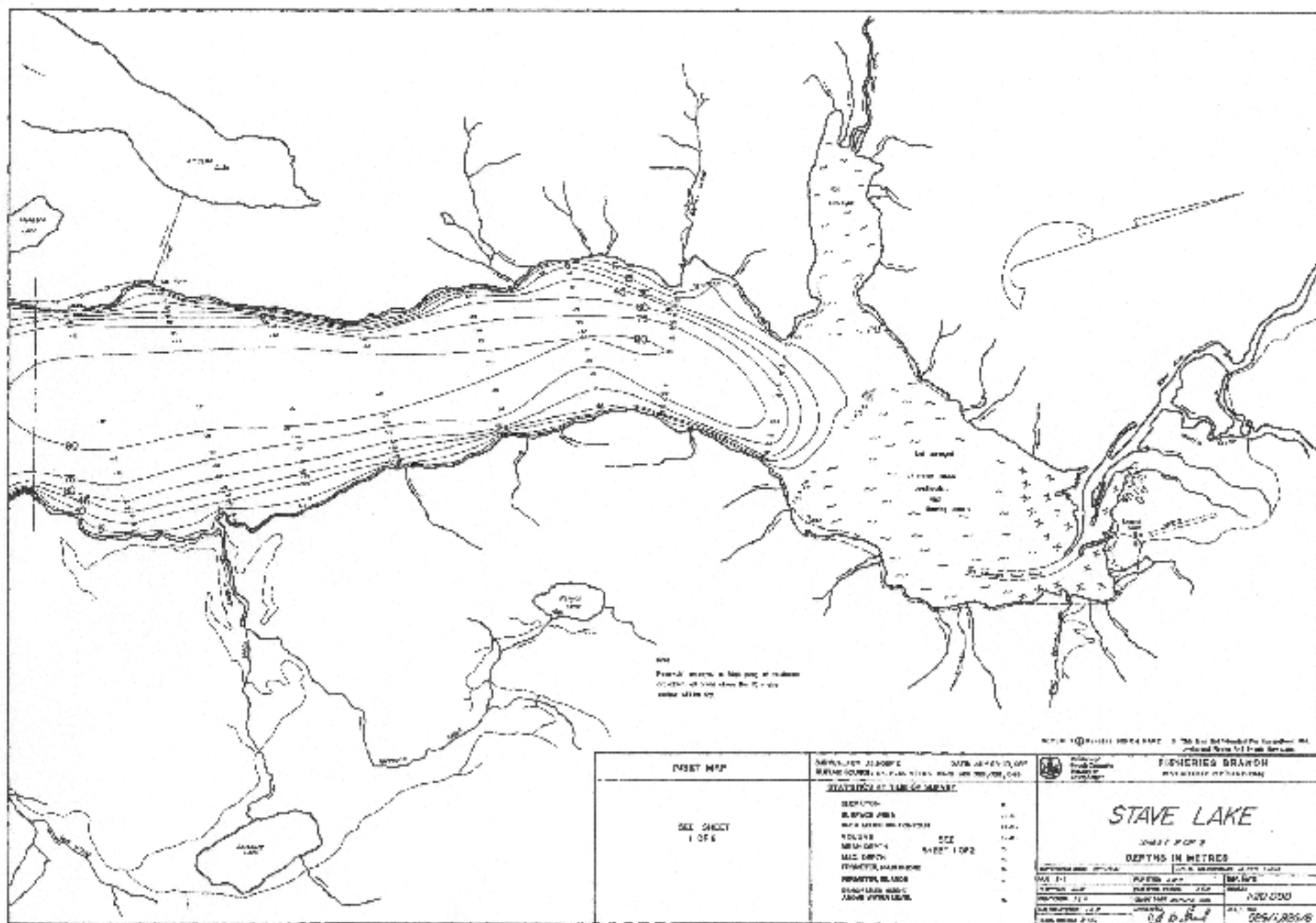
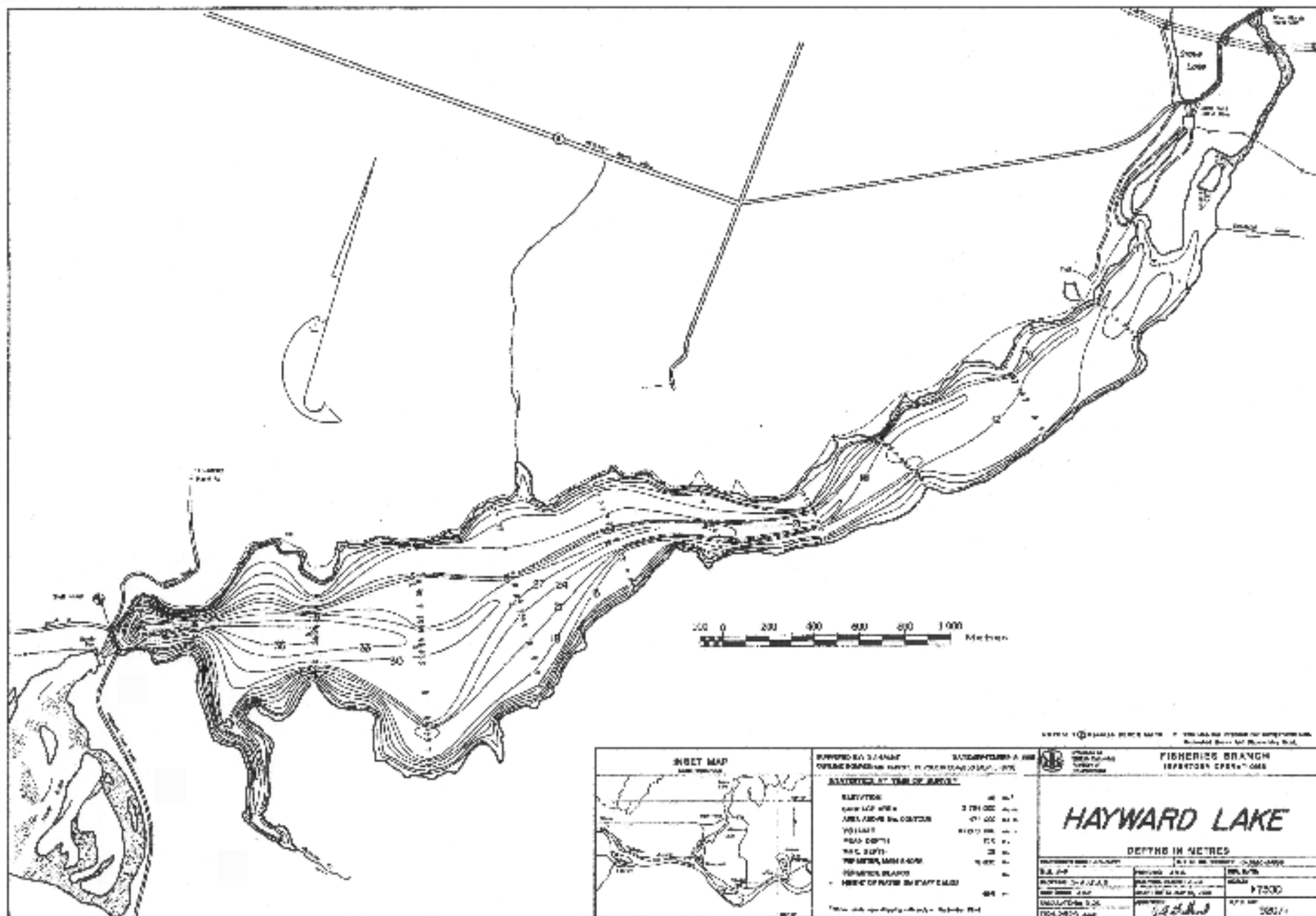


Figure 7-6 Bathymetry in map of Stave Lake (Sheet 1)





2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Stave River watershed is provided in Table 7-1.

2.1.1 Upstream of Stave Falls Dam

There is some dispute regarding anadromous fish access above Stave Falls prior to construction of the dam. A.P. Halladay, former District Supervisor of Fisheries, wrote that it was very doubtful that salmon ever ascended the falls. He suggested that kokanee in the lake resulted from anadromous accessibility at some post-glacial, though pre-historic, period (IPSFC 1938). Stave Falls and its associated rapids descended about 24 m over a short but unspecified distance (Figure 7-9).

Andrew & Killick (1957) and Triton (1994) discussed in detail the issues and options for providing fish passage over Ruskin and Stave dams.

Large numbers of kokanee spawned in Winslow Creek about midway up to Winslow Lake (Andrew & Killick 1957); a local informant claimed spawners were much smaller in size than 20 years previous. These authors estimated there was potential spawning area in Winslow Creek and the upper Stave mainstem for about 25,000 sockeye each.

Most tributaries are steep and fluctuate widely in discharge. Cardinalis Creek, Isle Slough, Tingle Creek and Winslow Creek were recently evaluated for limiting factors and enhancement opportunities by Bruce *et al.* (1994).



Figure 7-9. East branch of Stave River in 1910 (BC Archives)

Table 7-1. Fish species in the Stave River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfbc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Stave River		Anadromous Salmonids										Sport Fish	Non-Sport Fish										Red/Blue Listed Fish																								
upstream ↓ downstream		Steelhead	Cutthroat trout (coastal)	Dolly Varden (coastal)	Bull trout	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgip sucker	Northern squawfish *	Peamouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine sickleback	Lamprey (general)	Pacific lamprey	River lamprey	Brassy minnow	American shad	Catfish (general)	Brown bullhead	Dace General	Longnose Dace	Brassy Minnow			
Stave R. Mainstem																																															
Thomas Lake																																															
Thomas Creek																																															
Winslow Creek																																															
Stave Lake																																															
Cannel Lake																																															
Cardinalis Creek																																															
Cascade Creek																																															
Davis Creek																																															
Davis Lake																																															
Devil's Lake																																															
Devil's Lake Creek																																															
Glacier Creek																																															
Hoover Lake																																															
Isle Slough																																															
Kearsley Creek																																															
Kenyon Creek																																															
Kenyon Lake		2																																													
Lost Creek																																															
Marina Creek																																															
Morgan Lake																																															
Rolley Lake																																															
Rolley Lake Creek																																															
Salbury Creek																																															
Salsbury Lake																																															
Sayres (Cedar) Lake																																															
Sayres Lake Creek																																															
Seventynine Creek																																															
Steelhead Creek																																															
Terapocki Creek																																															
Tingle Creek																																															
Weatherhead Creek																																															
STAVE FALLS DAM		No fishway.																																													
Hayward Lake		?	?																																												
Brown Creek																																															
Hairsine Creek																																															
Phillips Creek																																															
RUSKIN / BLIND SLOUGH DAMS		No fishway.																																													
Stave R. Mainstem																																															

* now named *Northern pike minnow*

1 - A highly specialized peamouth chub resides in Stave Lake. It feeds on zooplankton and adult insects in contrast to the benthic invertebrate diet common to peamouths.

2 - stocked with Steelhead - but said to have outmigrated (Bruce et al. 1994)

2.1.2 Stave Falls Dam to Ruskin Dam (Hayward Reservoir)

The 6 km of original river channel flooded by Hayward Reservoir was described as a series of rapids that emptied onto the Fraser floodplain through a narrow granite gorge. The natural constriction at the site of Ruskin Dam was reported passable at high water. The lower 2 km of this reach apparently provided spawning habitats for all salmonid species (Andrew and Killick 1957), and portions of the upper section of rapids were likely suitable for rearing by steelhead parr.

Currently, sport fish populations are generally low despite recent stocking efforts (Ramsay 1996). No kokanee were captured in the 1996 survey unlike previous sampling in 1985 and 1987. Hydroacoustic surveys in 1996 estimated the total fish population, including non-sport species, at between 13,600 to 51,600 individuals (Stables 1997).

Tributary habitat area for salmonids is very limited, with Hairsine Creek the most significant (Slaney 1994).

2.1.3 Downstream of Ruskin Dam

Andrew & Killick (1957) reported that only the lower 4.8 km of river (which would include 2 km above Ruskin Dam) were used by salmon to any extent. In 1935 there were counts of 100-300 coho, 500-1000 pink, 500-1000 chum and 50-100 steelhead. Smaller numbers of chinook and sockeye used this section.

This short reach crosses the Fraser River floodplain with low banks composed of sands and fine sediments. Water levels in this reach are influenced by tidal conditions and Fraser River discharge, as well as Ruskin operations.

A 360 m spawning channel was constructed by DFO in 1991 on the left bank below the tailrace; it is mostly used by chum salmon (Wilson 1996).

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Stave Reservoir	1. Reservoir flooded 22.4 km of mainstem and 32 km of tributary channels, plus their associated riparian zones; resident lake species composition unchanged.	x		GIS
	2. Drawdown strands fish & reduces access to tributaries and wetlands.	x		
	3. Drawdown reduces productivity of littoral zone.	x		
	4. Attraction of fish to Alouette powerhouse discharge increases mortality from angling.	x		workshop

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Stave Falls and Blind Slough Dams	5. Dam footprint of _ m ² : loss of instream, riparian and upland habitats.	x		
	6. Initial dam construction likely sluiced large volume of sediment that degraded spawning habitat downstream.	x		
	7. Dam reduced LWD and sediment recruitment to system downstream.	x		
	8. Entrainment mortality and injury; magnitude unknown. Potential downstream benefits to scavengers.	x		
	9. Occasional shortterm TGP events are being studied.	x		workshop
	10. Blind Slough Dam cut off flows to nearly 1 km of original river channel.	x		
Hayward L.	11. High rate of flushing and drawdown reduces reservoir's plankton and littoral productivity.	x		workshop
	12. Reservoir flooded 6 km of mainstem channel and 2.7 km of lower tributary channel, plus their associated riparian zones; river species composition changed to lake-type.	x		GIS
Ruskin Dam	13. Dam blocked former passage of anadromous and resident stocks.	x		IPSFC 1938
	14. Entrainment mortality and injury; magnitude unknown. Potential downstream benefits to scavengers.	x		
	15. Dam stopped gravel recruitment to river downstream.	x		
Downstream River below Powerhouse	16. Periodic large spills caused sedimentation of spawning habitat in the mainstem; threatened the integrity of spawning channel.	x		Lewis et al. 1996
	17. Fish flow releases were insufficient.	x		Lewis et al. 1996
	18. Current ramping rates caused stranding of fish.	x		Lewis et al. 1996
	19. Reduction of flood peaks affected morphology of downstream channel.	x		

Ruskin Dam removed historic access to 2 km of mainstem spawning beds and rearing area for all species of salmon, steelhead, and possibly anadromous cutthroat trout (Andrew and Killick 1957). Hayward Reservoir operations preclude the establishment of significant resident populations due to lack of tributary habitat, access to tributary habitat, high flushing rate of oligotrophic water, and drawdown effects on local productivity (Triton 1994).

Resident populations of rainbow and cutthroat trout, Dolly Varden, and kokanee in Stave Lake appear to be limited by low overall productivity, a large population of non-sportfish predators (especially northern squawfish) and competitors, and limited spawning and fry rearing habitat and nutrient levels in four selected tributaries (Bruce *et al.* 1994). These same factors would affect the potential introduction of anadromous stocks (Triton 1994).

Non-Hydro Impacts - Other impacts on fish in the Stave River watershed are predominantly historic effects of logging activities.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Stave River watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Blocked access to historic habitats:** Anadromous and migratory resident stocks have been excluded from river habitats now occupied by Hayward Reservoir for 70 years.
2. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources.
3. **Reduced downstream habitat capability:** Physical habitats below dams are altered by reduced sediment or wood recruitment.
4. **Reduced biological productivity:** Stave Lake has been affected long-term by large reservoir drawdown regimes; Hayward Lake experiences drawdowns as well as rapid flushing.
5. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat due to large drawdown regimes.
6. **Diversions:** The Alouette diversion has increased annual flow volume in the lower Stave River; these altered flows have affected wetted channel area, seasonal temperatures and stream productivity.
7. **Competitors:** Stave and Hayward reservoirs contain a large proportion of non-sport fish species that compete with resident salmonids.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve fish habitats in the lower Stave River.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Restoration activities should be preceded by a study plan to address limiting factors #1, 2, 3 and 6 that considers:

- operating and fish flow regimes (Stave River Water Use Plan)
- urban trends to stabilize the downstream channel
- opportunities to purchase or covenant streamside properties for future habitat projects
- opportunities for habitat development

- proposed projects should have hydraulic characteristics to withstand the historic range of discharges with low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- identification and filling of data gaps on issues such as fish stranding after spills, gas supersaturation, etc. that may also constrain populations.

Objective 2: Conserve and improve habitats for resident fish stocks throughout the reservoir and tributary systems.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Activities in response to limiting factors #2-5 above should be preceded by a study plan for each reservoir and tributary system that considers:

- operating flows (Stave Water Use Plan)
- opportunities to purchase or covenant key properties for future habitat projects
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and for planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- current harvest pressures on stock recruitment
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 3: Restore biological productivity to the reservoir system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to improve aquatic productivity. Activities should be preceded by a study plan for the reservoir and tributary system, in response to limiting factors #4 and 6 above, that addresses:

- feasibility of a phased program of fertilization trials and performance indicators
- potential methods to achieve self-sustaining nutrient levels and reduce costs
- determination of appropriate low-level nutrient levels
- relative values of fertilizing fish-bearing tributaries vs reservoir plankton or littoral zone
- ecological effects of fertilization on non-target plants and aquatic animals
- impacts on esthetics and domestic water supply
- wildlife biodiversity values at all proposed sites
- identification and filling of data gaps on issues such as entrainment, angling harvest effort, etc. that may also constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

B.C. Game Commission Records indicate that mountain goats were found in the mountain ranges north of Stave Lake; at Stave Lake, grizzlies were known to frequent the north end, Roosevelt elk were hunted out prior to development, black bear, cougar, wolf, deer, and bald eagle were present.

No Red- or Blue-listed species occur in the Stave River watershed according to the Conservation Data Centre. However, Bulbous rush grows in the drawdown zone and is considered rare by the CDC with only 20 known sites in B.C.

Current wildlife use has been summarized by Blood and Kistritz (1993), and others where indicated.

Habitat

Drawdown zone habitats are limited to the Tingle Creek and Stave River deltas, the southeast arm, and the narrows area of the southwest arm. All sites (except southwest arm) have many standing snags. Three well-developed wetland communities occur in the upper 4.5 m of the drawdown zone. AIM Ecological Consultants Ltd. (1994) identified 779 ha (36% of the 2200 ha drawdown zone) as having some vegetation cover. The areas of Stave Lake with the best habitat potential for waterfowl and other waterbirds are the southeast arm and the north end (B.C. Hydro and Ducks Unlimited Canada, 1999).

Hayward Lake has a narrow drawdown zone and little wetland vegetation

Wildlife Species

The most common wildlife in spring/summer are the Canada goose which grazes in drawdown zone, and fish-eating birds such as common loon, common merganser, osprey, and bald eagle. Other species included mallard and blue-winged teal. The reservoir may be used by mounting dabbling ducks and Canada geese. Canada goose and osprey nested during 1993. Fluctuating water levels discourages most duck breeding.

At Hayward Lake, Canada geese and bald eagles breed and common loons and beavers also use the lake.

B.C. Hydro and Ducks Unlimited (1999) did six spring surveys of the southeast arm and saw very few waterfowl. Waterbird species recorded included Canada goose, mallard, green-winged teal, and common loon. Evidence of mammals recorded on the mudflats included beaver, bobcat, river otter and coyote, while black-tailed deer occurred in adjacent areas. Two herptiles were observed, a common garter snake and a Pacific treefrog.

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Stave Falls Dam	<i>Dam footprint of xx ha:</i> loss of coniferous forest and riverine habitats.	x		
	<i>Flooding of 2612 ha of Stave Lake lowland and upland:</i> loss of coniferous forest of valley bottom (1588 ha) and valley sides (348 ha), valley bottom deciduous, incl. riparian, and river channel habitats, and associated wildlife losses, e.g., lowland foraging habitat for furbearers, bears & ungulates; loss of valley side habitat for ungulates and carnivores.	x		Blood & Kistritz 1993; GIS
	<i>Conversion of 30 km of Stave River and ca 34 km of tributaries to reservoir:</i> barrier to movement of large mammals (bears and ungulates); increase in open water for waterfowl and osprey (Lake length doubled from 14.5 to 29 km) by flooding.	x	x	White 1919; GIS
	<i>Fluctuating reservoir water levels (9.1 m) due to hydro-electric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		BCH web page
	<i>Uncut trees in draw down and adjacent flooded areas:</i> Creation of snags for cavity nesting birds and Osprey nesting platforms		x	Blood & Kistritz 1993; Bryan Gates
	<i>Changed flow regime of Stave River:</i> effects on downstream aquatic wildlife (e.g. American Dipper, Great Blue Heron, Harlequin Duck)	x	x	
Ruskin Dam	<i>Dam footprint of xx ha:</i> loss of coniferous forest and riverine habitats.	x		
	<i>Flooding of 280 ha of lower Stave River valley:</i> loss of valley bottom and valley side coniferous, deciduous, and wetland habitats, incl. riparian, and associated wildlife losses, e.g., lost marsh and wetland feeding/breeding habitat for ducks and furbearers, and feeding habitat for bears & ungulates; loss of valley side habitat for ungulates and carnivores.	x		
	<i>Flooding of 6.4 km of river from Stave Falls to Fraser River* creating Hayward Lake:</i> barrier to movement of large mammals (bears and ungulates); increase in open water for waterfowl and osprey.	x	x	White 1919
	<i>Fluctuating reservoir water levels (1 m daily) due to hydro-electric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		BCH web page

* Based on description by White (1919) Stave River mouth was originally at present Ruskin Dam site.

3.3 Factors Limiting Wildlife Productivity and Diversity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of Habitat:** Loss of riparian habitat and wetland habitats in flooded valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse for ungulates and breeding habitat for some species of neotropical migrants.
2. **Habitat Changes:** Altered flow regime has changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for tailed frogs, water shrews, harlequins and dippers. Loss of side channel habitat downstream of diversions (dyking and other unrelated factors also responsible).
3. **Reduced Habitat Capability:** Lack of snags for cavity nesting habitat and structures for large raptor nests. Potential effects for primary cavity nestors (eg. woodpeckers) and secondary cavity nestors (eg. swallows, squirrels).
4. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
5. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions.
6. **Entrainment:** Wildlife (especially mammalian) mortality caused by diversion or intake structures, through entrainment and drowning. Potential hazards for non aquatic or weak swimming animals.

Existing Wildlife Enhancement Works

Platforms have been placed for osprey, and rafts and nest boxes for common loons and waterfowl.

Blood and Kistritz (1999) suggest the feasible and desirability for the reintroduction of Roosevelt Elk to Stave River Delta.

B.C. Hydro and Ducks Unlimited (1999) presented three concepts for impoundments in the southeast arm of Stave Lake.

AIM Ecological Consultants Ltd. (1994) identified 252 ha (12% of 2200 ha drawdown zone) as having potential for vegetation enhancement using willow or perennials.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Stave Lake and Hayward Lake.

Discussion:

- See limiting factor # 4. Improve vegetation in the drawdown zone.
- Develop foreshore habitat complexes at suitable locations.
- Create snags along reservoir shorelines for cavity nesters and perching raptors.
- Provide artificial nesting structures for osprey.

Objective 2: Conserve riparian and wetland habitats in the Stave River watershed.

Discussion:

- See limiting factors # 1 and 2. As part of a joint Alouette-Stave habitat conservation initiative, identify key habitats for conservation of biodiversity and enhanced production.
- Undertake conservation, through protective measures, habitat acquisition and other means, in the Alouette River and/or Stave River watersheds.

Objective 3: Create or enhance wetlands and riparian habitats for aquatic species (amphibians, waterfowl, cavity dependent species, small mammals).

Discussion:

- See limiting factors # 1 and 2. Consider various opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times. Flood shallow basins in the watershed where feasible.
- Create backwater channel and associated riparian habitats along Alouette River segments where reduced downstream flows have diminished natural channel complexity.

Objective 4: Protect small groups of old or second growth trees in strategic locations for current and future nesting use by bald eagles or ospreys.

Objective 5: Create ungulate winter range.

Discussion:

- Work with forestry companies to leave shelter stands in association with logged clearings that provide forage.
- Establish vegetation in the reservoir drawdown zone, especially near creek or river deltas.
- Assess potential to re-introduce elk.

Objective 6: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Stave watershed.

4. STAVE RIVER WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
Reconnaissance survey Upper stave river, 1913; Flooded lands at north end of Stave Lake, July 1913; sketch of Upper Stave River and surrounding lands, April 1913, 1"=2 mi	BC Electric Archives, UBC Special Collections; Box 93 20713 # 1-3
Map of Stave Lake and Alouette Lake, Western Power Co.	422-C11-E43, BC Hydro
Plan to accompany Western Canada Power Co.'s application, n.d. 15 chs = 1 in; 235 and 240 ft contours	422-C11-X8004, BC Hydro
Plan showing property owned and controlled by Western Power Co of Canada Ltd.; 1 in = 20 chs, May 1928	422-C23-X2 and 422-C11-E8010/11, BC Hydro
Map of New Westminster District, 1913; approx. 1:70,000 showing Coquitlam Lake, Pitt Lake and Lillooet Lakes	UBC map library
Air Photos, 1940 and 1941	BC 203:106 (Stave) BC 204-43 (Ruskin), BC 203:45 and 96 and BC 197:3 (Alouette)

4.2 Hydro Facility and Fish References

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Chapter 8

COQUITLAM RIVER AND BUNTZEN LAKE WATERSHEDS



Figure 8-1. Coquitlam Dam with water flowing over spillway ca. 1917 (BC Archives)

1. PROJECT DESCRIPTION

1.1 Facilities

The Coquitlam-Buntzen project diverts water out of Coquitlam Lake Reservoir via a 3.9 km tunnel to Buntzen Lake Reservoir where 530 m and 170 m penstocks lead to two power-houses located on the shoreline of Indian Arm in Burrard Inlet.

The original 1903 hydroelectric dam on the Coquitlam River was a rock-filled timber crib about 6 m high (3.3 m above the average summer lake level). Coquitlam Dam was reconstructed between 1911-14 (Vancouver Power Co.) to replace a smaller dam. Coquitlam Dam was rehabilitated again in 1985. Coquitlam Reservoir has been used for domestic water supply since at least 1902. Its annual drawdown of 17 m is about half of its maximum depth.

The 54 feet high concrete Buntzen Dam was constructed in 1902 across the ravine that drained Buntzen Lake. Operational in 1903, it provided storage for the first hydroelectric power facility to be constructed in the Lower Mainland. A second powerhouse was completed in 1914 and rehabilitated in 1980 by B.C. Hydro.

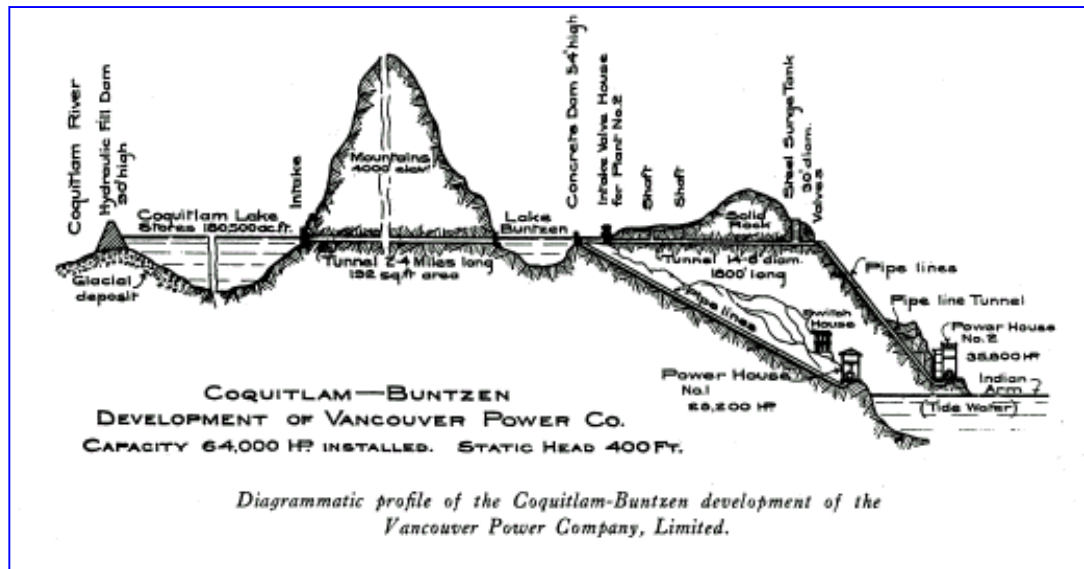


Figure 8-2 . British Columbia's first power scheme (Water Powers B.C. 1954)

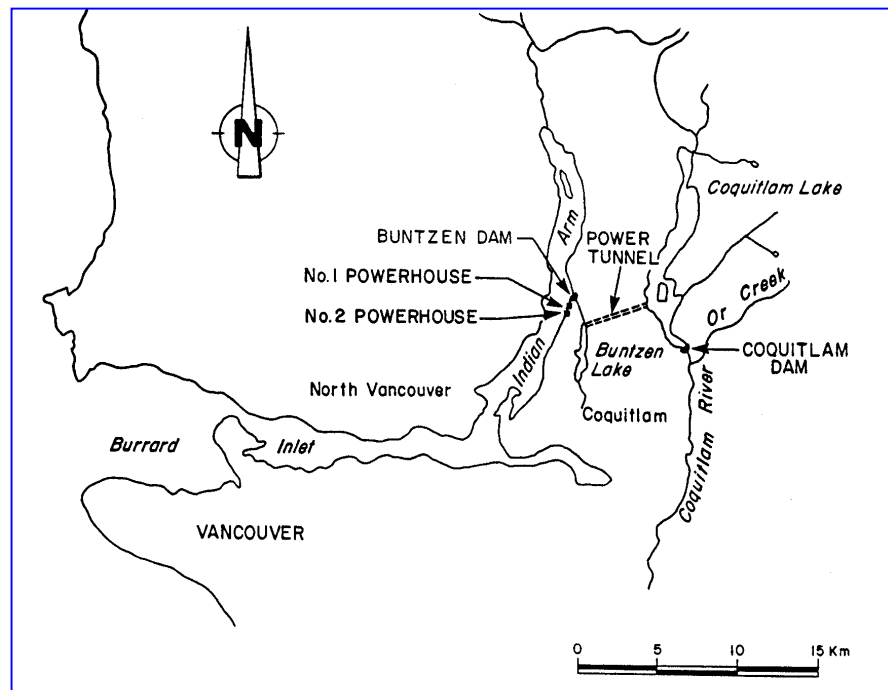


Figure 8-3 . Location of Coquitlam-Buntzen hydro project

Specifications for the facilities and reservoirs:

DAM	Coquitlam	Buntzen
Nameplate capacity (MW)	- -	76.7
Dependable capacity (MW)	- -	72.8
Dam function	storage, diversion	storage, diversion
Date constructed	1904	1902
Date operational	1905	1903
Date reconstructed	1914, 1985	1912, 1965
Height (m)	30	16
Length (m)	300	110
Dam footprint area (m ²)		
Fishway at dam	no	no
Historic anadromous fish presence	yes	no

RESERVOIR	Coquitlam Lake	Buntzen Lake
Cleared/ not cleared	cleared	
Present area (ha)	1198	182
Watershed area (km ²)	193	20.6
Present elevation a.s.l. (m)		124 (bathym)
Normal drawdown range (m)	17.4	1.5-2.8
Mean depth (m)		30
Maximum depth (m)	31	65
Storage (million m ³)	202	
Mean water retention time		49 d
Mean annual discharge (m ³ /s)	21.7-23	same

DIVERSION	to BuntzenReservoir	to powerhouse
Structure type	tunnel (4km)	penstock
Licensed flow (m ³ /sec)	82	
Fish flow release (m ³ /sec)	0.23-0.85	no
Mainstem length diminished (km)	14.5	
Mainstem length augmented (km)		no fish present

1.2 Hydrology

1.2.1 Basin and Runoff

High inflows due to snowmelt occur from May to July, August and September are usually dry, and high inflow from rain can occur from October to March (Lewis *et al.* 1996).

Nearly all inflow to Buntzen Reservoir comes from the diversion tunnel.

1.2.2 Operation and Licensed Diversion Flow

BC Hydro must reserve sufficient storage in Coquitlam Reservoir from May to September to meet domestic water demands of the Greater Vancouver Water District.

The Greater Vancouver Water District has its 2.3 m diameter pipe intake located 300 m above Coquitlam Dam on the east shore at an invert elevation of 132.6 m (Lewis *et al.* 1996).

1.2.3 Habitat Types Flooded by Reservoir

The combined reservoir area is 1,380 ha after flooding 225 ha of land. The combined reservoir shoreline length is now 46 km. Coquitlam Reservoir is shown in Figure 8-4, and Buntzen Reservoir in Figure 8-5. A bathymetric map of Buntzen Lake is provided in Figure 8-6.

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Coquitlam Lake		Original habitat lost
Lake flooded	(ha)	1004
Land flooded	(ha)	194
Lake shoreline	(km)	30
Mainstem: length	(km)	1.3
channel	(ha)	3
riparian *	(ha)	8
Tributary: length	(km)	6
riparian **	(ha)	18
Wetland:	(ha)	0

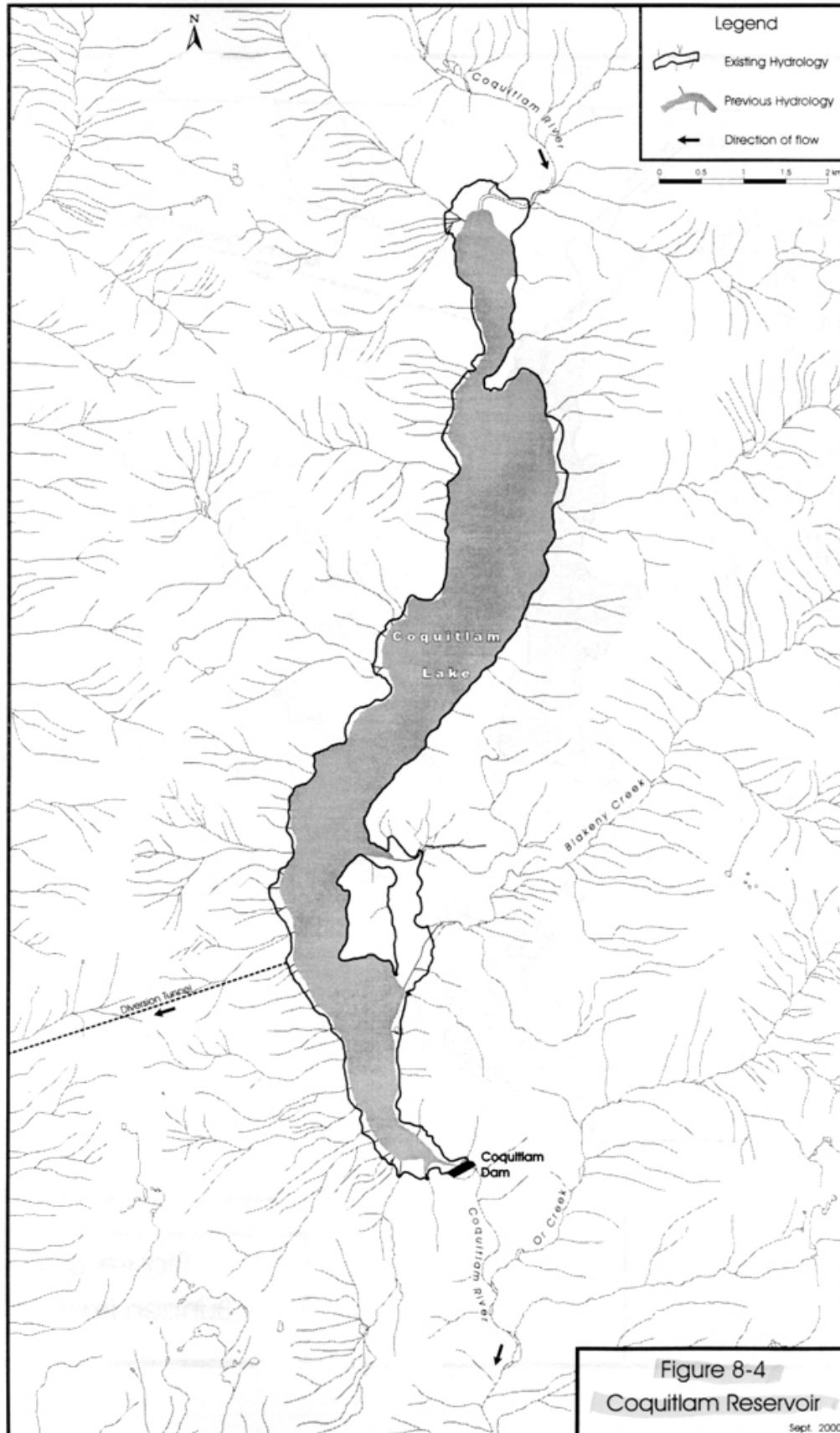
* mainstem riparian zone calculated at 30 m from each bank

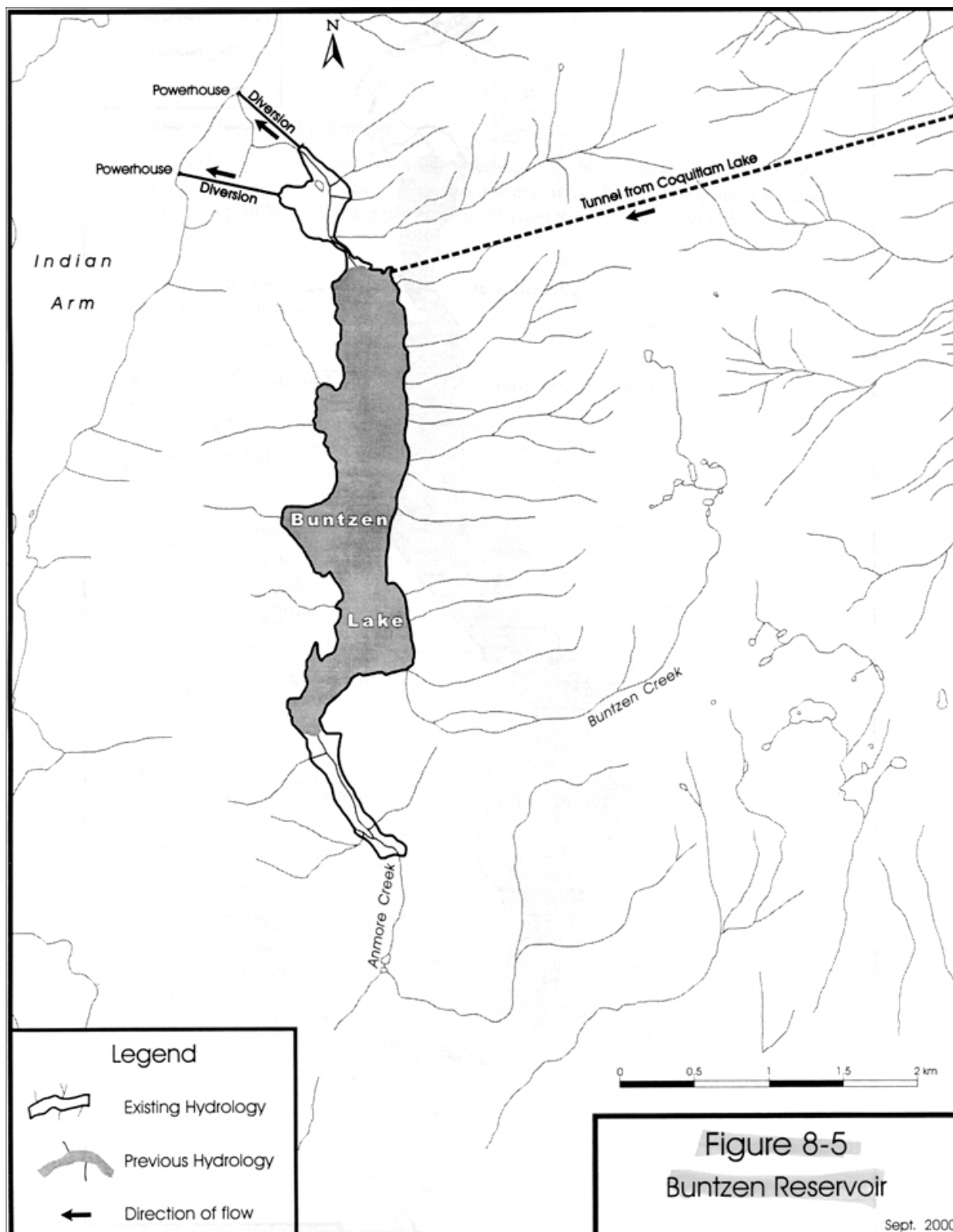
** tributary riparian zone calculated at 15 m from each bank

Buntzen Lake		Original habitat lost
Lake flooded	(ha)	151
Land flooded	(ha)	31
Lake shoreline	(km)	8
Mainstem: length	(km)	2
channel	(ha)	--
riparian *	(ha)	12
Tributary: length	(km)	0.5
riparian **	(ha)	2
Wetland:	(ha)	0

* mainstem riparian zone calculated at 30 m from each bank

** tributary riparian zone calculated at 15 m from each bank





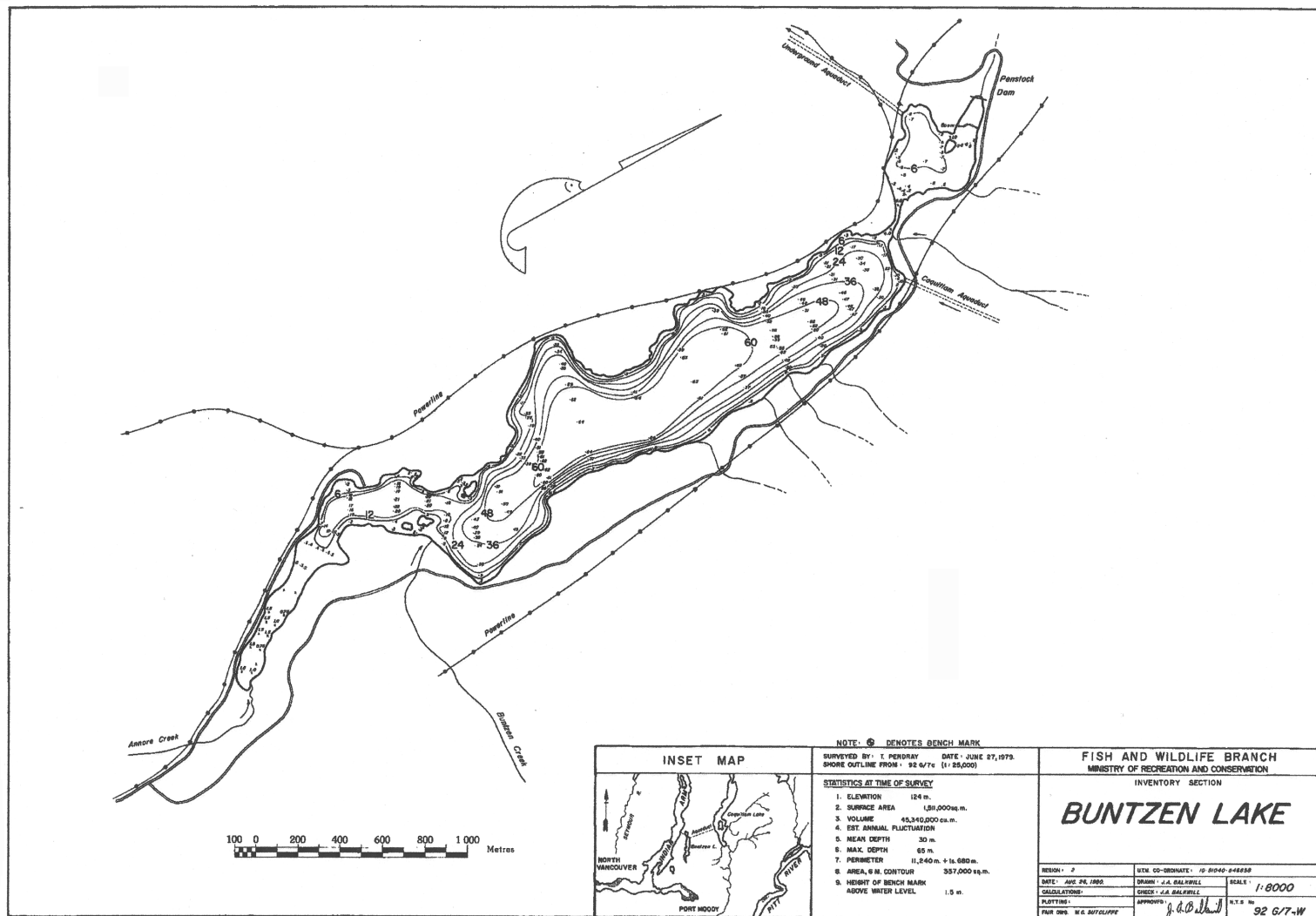


Figure 8-6. Bathymetric map of Buntzen Lake

2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Coquitlam River watershed is provided in Table 8-1.

2.1.1 Coquitlam Dam and Reservoir

Prior to construction of the initial 6 m high dam in 1903, Coquitlam Lake was the main spawning ground for an early (May) run of salmon locally known as ‘bastard’ sockeye (Sword 1904).

A fishway 3.6 m wide extended 4.9 m out from the face of the dam; it consisted of baffle boards 1 m high and 2 m apart. Salmon did not use the initial fishway due to its steep slope and shallow water at the entrance until further alterations were made.

The second dam was raised in 1908-11 to a height of 75-100 ft and length of 1200 ft. No fishway was provided in the second dam for several reasons: (1) it was believed too high to pass salmon (Venning 1909); (2) the sockeye stock was not commercially important because the run passed through before the fishing season was open; and (3) the City of New Westminster had designated the lake as a domestic water supply since 1892, and after the first dam had been built, dead salmon had to be removed from the water intake area for public health concerns (Koop 1994).

2.1.2 Coquitlam River Downstream of Dam

Historically, coho and chum salmon were originally reported in the river system, but the latter were not thought to ascend as far as the lake. In 1936, the river system was utilized by pink salmon, chum salmon, coho salmon, steelhead and resident rainbow trout, cutthroat and Dolly Varden char (BC Ministry of Environment 1978). Or Creek provides much of the present flow in the Coquitlam River channel.

2.1.3 Buntzen Reservoir

Originally known as Lake Beautiful or Trout Lake in the early 1900s, Buntzen has a steep and rocky shoreline with limited littoral habitat. Anmore Creek is the key spawning and rearing tributary for rainbow and cutthroat trout. The outlet creek has been dry for decades and likely contained no fish prior to hydro development due to steep gradient (Lewis *et al.* 1996). BC Hydro has released catchable size rainbow trout, raised in a netpen facility, into Buntzen Reservoir since 1998 (BC Hydro 1999).

Table 8-1. Fish species in the Coquitlam River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Coquitlam River upstream ↓ downstream		Anadromous Salmonids								Sport Fish										Non-Sport Fish																		Red/Blue Listed Fish				
		Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish*	Peamouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	American shad	Dace General	Longnose Dace	Brassy Minnow		
Coquitlam R. Mainstem																																										
Coquitlam Lake																																										
COQUITLAM DAM	No fishway.																																									
Coquitlam R. Mainstem Or Creek																																										
Buntzen Lake																																										
BUNTZEN DAM	No fishway.																																									

* now named *Northern pike minnow*

2.2 Impacts on Fish

Facility	Description of impacts	Neg	Pos	Source
Coquitlam Reservoir	1. Reservoir flooded 1.3 km of mainstem and 6 km of tributary channels, plus their associated riparian zones.	x		GIS
	2. Drawdown of 17m reduces access to tributaries.	x		
	3. Drawdown reduces productivity of littoral zone.	x		Lewis et al. 1996
	4. Exposed drawdown zone in October-November results in increased turbidity.	x		Lewis et al. 1996
Coquitlam Dam	5. Dam footprint of _ m ² : loss of instream, riparian and upland habitats; potential loss of lake outlet spawning habitat.	x		
	6. Dam blocked former passage of anadromous stocks.	x		IPSFC 1938
	7. Dam reduced LWD recruitment to system downstream.	x		
	8. Dam construction sluiced large volumes of sediment that likely degraded spawning habitat downstream.	x		Conway 1915
Downstream Coquitlam River	9. 70% of the Coquitlam drainage area is diverted; residual mainstem flows have been reduced for 90 years; spawning habitat is constrained by low flows that do not flush multiple sediment inputs.	x		Riley et al. 1998; workshop
	10. Reduction of flows has reduced floodplain complexity of downstream channel coupled with urban encroachment.	x		
	11. Reduction of flows may decrease survival of downstream migrants.	x		
Diversion to Buntzen Reservoir	12. Diversion reduces Coquitlam Reservoir's productivity.	x		workshop
	13. Entrainment mortality and injury; magnitude unknown			
Buntzen Reservoir	14. Reservoir flooded 2 km of mainstem and 0.5 km of tributary channels, plus their associated riparian zones.	x		GIS
	15. Diversion inflows dilute reservoir's productivity.			
Buntzen Dam	16. Dam footprint of _ m ² : loss of instream, riparian and upland habitats; potential loss of lake outlet spawning habitat.	x		
Buntzen Powerhouse	17. Footprint and salinity impacts on marine foreshore.	x		workshop
	18. Chinook salmon are attracted to tailrace discharges; the number of fish affected and impacts of delay on reproductive success are not known.	x		BC Hydro 1994

Coquitlam Dam removed historic access to the original lake and upper spawning beds for sockeye and coho salmon, steelhead, and possibly anadromous cutthroat trout (IPSFC 1938). Aquatic productivity in most coastal BC watersheds is inherently low, but Coquitlam Lake once received marine-derived nutrients from historic populations of salmon. Drawdowns and diversion of large flows to Buntzen Reservoir have further reduced nutrient levels (workshop). In particular, significant annual drawdown of 14-17 m relative to the maximum depth of 31 m limits littoral productivity (Lewis *et al.* 1996). Present fish water releases have reduced habitat area and complexity in the Coquitlam River downstream; sediment input from current gravel operations and urban encroachment issues on the floodplain restrict the level and success of habitat restoration (workshop; Lewis *et al.* 1996).

Non-Hydro Impacts - Other impacts on fish in the Coquitlam River watershed are historic effects of logging activities, mill operations, dredging and gravel mining, urbanization, and domestic water withdrawal.

A dredging operation began about 1 km above the Port Coquitlam Bridge in October 1928 without apparent damage to fish (IPSFC 1938). In May 1930, the District Supervisor for Fisheries recommended a fishway on a dam across the Coquitlam River for a shingle mill at Gold Creek, but the Fisheries Engineer disagreed and no ladder was built. In June 1937, there were public complaints about lack of passage but Fisheries again recommended no action (IPSFC 1938).

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Coquitlam River-Buntzen Lake watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Blocked access to historic habitats:** Anadromous stocks have been excluded from Coquitlam Lake for 86 years.
2. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources. Dyking and urban encroachment along banks of the lower Coquitlam River have alienated offchannel, riparian and wetland areas.
3. **Reduced downstream habitat capability:** Habitats below Coquitlam Dam are altered by reduced sediment or wood recruitment.
4. **Reduced biological productivity:** Coquitlam and Buntzen lakes have been affected long-term by large reservoir drawdown regimes and in the former, loss of historic salmon carcasses.

5. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat due to large drawdown regimes.
6. **Reduced mainstem access:** Reduced access for fish using mainstem channel diminished by the diversion.
7. **Diversions:** The diversion has reduced flows to the downstream Coquitlam channel and increased flows into Buntzen Lake; these altered flows have affected wetted channel area, seasonal temperatures, sediment flushing, and aquatic productivity in the respective systems.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve fish habitats in the lower Coquitlam River.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Restoration activities should be preceded by a study plan to address limiting factors #1, 2, 6 and 7 above that considers:

- operating flows and fish flows (Coquitlam River Water Use Plan)
- urban trends to stabilize the lower channel
- opportunities to purchase or covenant streamside properties for future habitat projects
- opportunities for habitat development and riparian planting
- proposed projects should have hydraulic characteristics to withstand the historic range of discharges with low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- identification and filling of data gaps on issues such as fish stranding after spills, etc. that may also constrain populations.

Objective 2: Conserve and improve habitats for resident fish stocks throughout the reservoirs and tributary systems.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Activities proposed for Coquitlam Reservoir may need the Greater Vancouver Water District's approval. Activities in response to limiting factors #2, 4, 5 and 7 above should be preceded by a study plan for each reservoir and tributary system that considers:

- operating flows and fish flows (Water Use Plan)
- opportunities to purchase or covenant key properties for future habitat projects
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance

- opportunities for habitat development and for planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- current harvest pressures on stock recruitment
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 3: Restore limnological productivity in Buntzen Reservoir.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to improve reservoir productivity. Activities should be preceded by a study plan for the reservoir and tributary system, in response to limiting factors #4 and 7 above, that addresses:

- feasibility of a phased program of fertilization trials and performance indicators
- determination of appropriate low-level nutrient levels that did not include historic sources from salmon carcasses
- potential methods to achieve self-sustaining nutrient levels to reduce costs
- relative values of fertilizing fish-bearing tributaries vs reservoir plankton or littoral zone
- ecological effects of fertilization on non-target plants and aquatic animals
- impacts on esthetics and domestic water supply downstream
- wildlife biodiversity values at all proposed sites
- identification and filling of data gaps on issues such as entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 4: Determine feasibility of restoring historic access for anadromous stocks to Coquitlam Reservoir.

Discussion:

Undertake an appropriate study, consistent with the BCRP strategy and Section 1-3.2, to restore historic access to anadromous fish. A study plan, in response to limiting factors #1, 2, 4 and 6 above, should consider:

- present operating flows and adequacy of fish flows (Coquitlam Water Use Plan)
- biological soundness in terms of donor stocks, ecological interactions, current adequacy of habitat and productivity
- engineering feasibility of structures and flows for upstream and downstream passage
- management implications to future BC Hydro operations, and to fisheries that presently exploit similar stocks at a high rate
- identification and filling of data gaps on other issues that may further constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

B.C. Game Commission reports note the presence of mountain goats and wolves in the Coquitlam River watershed. No information was obtained on current wildlife use.

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Coquitlam Reservoir, Dam & tunnel	<i>Dam footprint of ___ ha: loss of coniferous forest and riverine habitats.</i>	x		
	<i>Flooding of 17 ha of river and lowland forest, 30 km perimeter of Coquitlam Lake, and 177 km of upland forest: loss of riverine and coniferous valley side habitats and associated wildlife losses, e.g., loss of valley side habitat for ungulates and carnivores.</i>	x		GIS
	<i>Conversion of 0.8 km of Coquitlam River to lake: barrier to movement of large mammals (bears and ungulates); increase in open water for waterfowl and osprey.</i>	x	x	GIS
	<i>Fluctuating reservoir water levels (17.4 m) due to hydro-electric operations: effects on establishment of aquatic and/or riparian vegetation in drawdown zone.</i>	x		BCH web page.
	<i>Reduced flows and changed flow regime in 14.5 km Coquitlam River: effects on downstream aquatic wildlife (e.g. Great Blue Heron, waterfowl).</i>	x	x	
	<i>Decreased flows in Coquitlam River and increased flushing of Bunzen Lake: unknown effects on wildlife.</i>	x	x	
Buntzen Reservoir & Dam	<i>Dam footprint of ___ ha: loss of coniferous forest and riverine habitats at dam site.</i>	x		
	<i>Flooding of ___ ha: loss of coniferous habitat.</i>	x	x	
	<i>Fluctuating reservoir water levels (1.5 m) due to hydro-electric operations: effects on establishment of aquatic and/or riparian vegetation in drawdown zone.</i>	x		BCH web page.

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Changes:** Altered flow regime has changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for tailed frogs, water shrews, harlequins and dippers.
2. **Loss of Habitat:** Loss of side channel habitat downstream of diversions. Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse for ungulates and breeding habitat for some species of neotropical migrants.
3. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
4. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Coquitlam Reservoir.

Discussion:

See limiting factor # 3. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.
- Improve nesting opportunities for osprey by providing artificial nesting structures.

Objective 2: Conserve riparian and wetland habitats in the downstream portions of Coquitlam River.

Discussion:

See limiting factors # 1 and 2. Identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means, in the Coquitlam River watershed.

Objective 3: Create or enhance wetlands and riparian habitats for aquatic species (amphibians, waterfowl, cavity dependent species, small mammals).

Discussion:

See limiting factors # 1 and 2. Consider various opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times.

- Create additional wetlands where feasible through activities such as flooding shallow basins in the watershed.
- Create backwater channel and associated riparian habitats along Coquitlam River where reduced downstream flows have diminished natural channel complexity.

Objective 4: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Coquitlam and Buntzen watersheds.

4. COQUITLAM-BUNTZEN WATERSHED REFERENCES

4.1 Map and Air Photo References

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Province of British Columbia Department of Attorney – General, 1955. Provincial Game Commission Report	Some gravel removal from Coquitlam & Stave Rivers	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1936. Report of the Provincial Game Commission 1935. Authority of the Legislative Assembly, Victoria BC	Mountain goats found in Alouette and Coquitlam Lake areas.	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1940. Report of the Provincial Game Commission 1939. Authority of the Legislative Assembly, Victoria BC	Mountain goats at Coquitlam, Alouette and Stave Lakes Wolves at Coquitlam, Alouette and Stave Lakes	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia. 1952. Provincial Game Commission Report. 1951. Authority of the Legislative Assembly, Victoria BC	Mountain goats at headwaters of Coquitlam, Allouette & Stave Lakes	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia. 1954. Provincial Game Commission Report. 1953. Authority of the Legislative Assembly, Victoria BC	Mountain goats in good numbers at headwaters of Coquitlam, Allouette & Stave Lakes	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia. 1955. Provincial Game Commission Report. 1954. Authority of the Legislative Assembly, Victoria BC	Mountain goats in good numbers at headwaters of Coquitlam, Allouette & Stave Lakes Gravel-quarrying leases investigated in Coquitlam & Stave Rivers	Provincial Archives, MELP Surrey: Jack Evans

Chapter 9

JONES CREEK (WAHLEACH LAKE) WATERSHED



Figure 9-1. Wahleach (Jones) Reservoir looking south (Water Powers B.C. 1954)

1. PROJECT DESCRIPTION

1.1 Facilities

The Wahleach Project, completed in 1952 by the B.C. Electric Company, consists of a storage/diversion dam across the outlet of Wahleach Lake with water passing from the lake through a tunnel and penstock down to a powerhouse on the Fraser River. A small dam across Boulder Creek diverts water into Wahleach Lake. The reservoir has a large drawdown relative to its mean depth (Lewis *et al.* 1996).

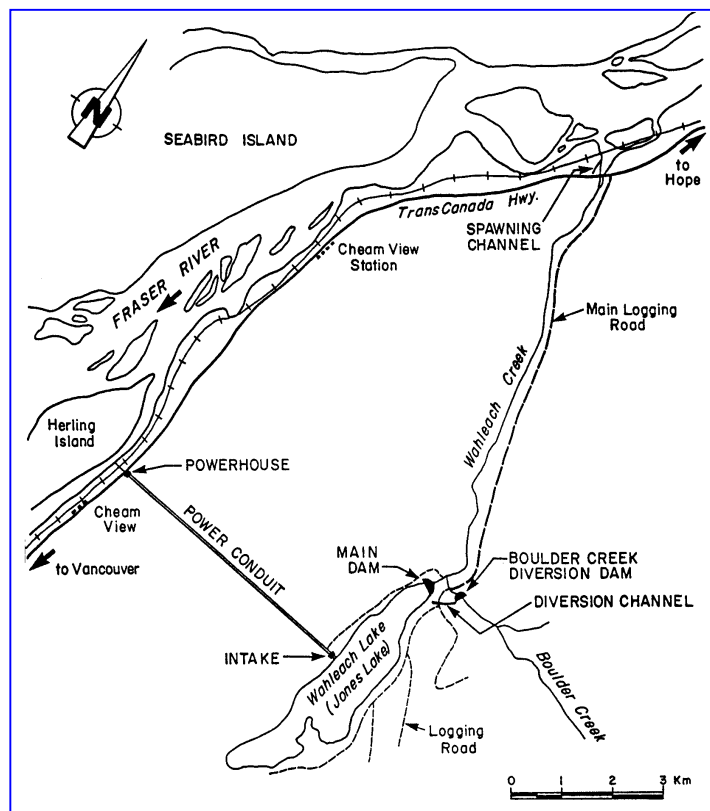


Figure 9-2 . Location of Jones Creek - Wahleach Lake hydro project

Specifications for the facilities and reservoir:

DAM	Wahleach	Boulder Cr.
Nameplate capacity (MW)	60	n/a
Dependable capacity (MW)	58	--
Dam function	storage, diversion	diversion
Date constructed	1951-2	1951-2
Date operational	1952	1952
Date reconstructed	--	--
Height (m)	21	3.5
Length (m)	418	180
Dam footprint area (m ²)	38,038	3,600
Fishway at dam	no	no
Historic anadromous fish presence	no	no

RESERVOIR	Wahleach Lake	none
Cleared/ not cleared		
Present area (ha)	489	--
Orig. lake area (ha)	278	--

Watershed area (km ²)	93 (incl. Boulder)	
Present elevation a.s.l. (m)	642	
Normal drawdown range (m)	19.8	--
Mean depth (m)	13	--
Maximum depth (m)	29	--
Storage (million m ³)	66	--
Mean water retention time		--
Mean annual discharge (m ³ /s)		

DIVERSION	to Fraser R. side channel	to Wahleach Reservoir
Structure type	tunnel, penstock	channel
Licensed flow (m ³ /sec)	6	
Fish flow release (m ³ /sec)	0.4 - 1.4	0.4 - 0.8
Mainstem length diminished (km)	7.8	0.8
Mainstem length augmented (km)	n/a	n/a

1.2 Hydrology

1.2.1 Basin and Runoff

The Wahleach basin is located in the southern coastal mountains which represent the first major barrier to moisture-laden air from the Strait of Georgia; consequently, precipitation is high in both rainfall and snowpack. Elevations within the basin range from 640 m to approximately 2300 m (Foley Peak), and the mean elevation is 1220 m (BC Hydro 1991).

The alpine basin has steep valley slopes and short tributary streams which flow into the lake from all directions. Other lake storage within the basin is insignificant.

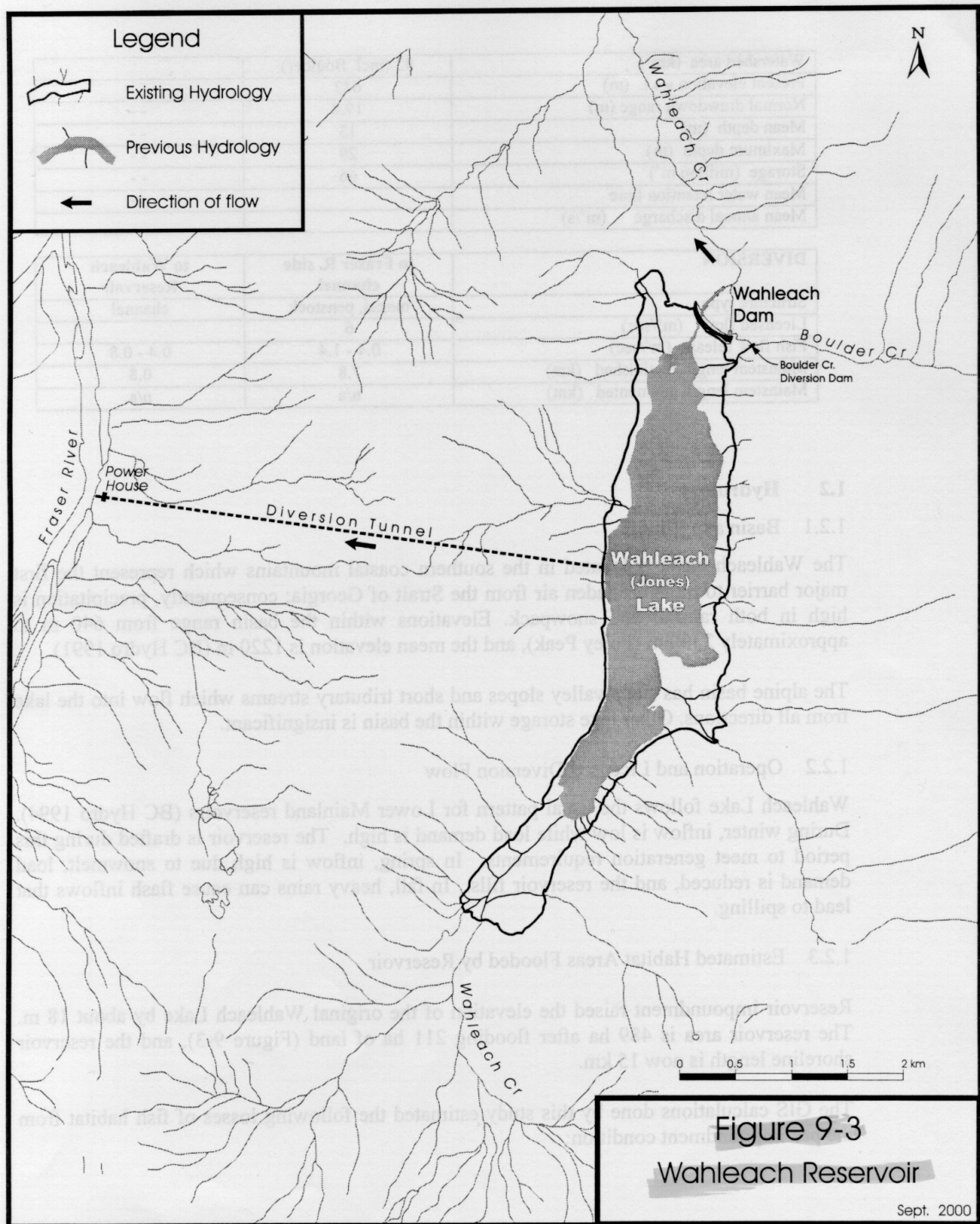
1.2.2 Operation and Licensed Diversion Flow

Wahleach Lake follows the usual pattern for Lower Mainland reservoirs (BC Hydro 1994). During winter, inflow is low while load demand is high. The reservoir is drafted during this period to meet generation requirements. In spring, inflow is high due to snowmelt, load demand is reduced, and the reservoir fills. In fall, heavy rains can cause flash inflows that lead to spilling.

1.2.3 Estimated Habitat Areas Flooded by Reservoir

Reservoir impoundment raised the elevation of the original Wahleach Lake by about 18 m. The reservoir area is 489 ha after flooding 211 ha of land (Figure 9-3), and the reservoir shoreline length is now 15 km.

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:



Wahleach Reservoir		Original habitat lost
Lake flooded	(ha)	278
Land flooded	(ha)	211
Lake shoreline	(km)	11
Mainstem: length	(km)	2
channel	(ha)	1
riparian *	(ha)	11
Tributary: length	(km)	6
riparian **	(ha)	19
Wetland:	(ha)	0

* mainstem riparian zone calculated at 30 m from each bank

** tributary riparian zone calculated at 15 m from each bank

2. FISH

2.1 Historic and Current Species Presence

2.1.1 Upstream of Wahleach Dam

The original Wahleach Lake was barren of sport fish (Mottley 1936); this condition was likely due to its 655 metre elevation and the impassable falls on Jones Creek about 1.5 km above its Fraser River confluence. The lake was stocked with rainbow trout beginning in 1924 and periodically thereafter. Kokanee were stocked only from 1934-36 (Hirst 1991). In a fall stream survey in 1993, less than 50 kokanee spawners were counted (BC Hydro 1994).

Current resident species in the reservoir are rainbow trout, cutthroat trout, kokanee salmon, and stickleback (Table 9-1). No anadromous stocks are present. Workshop participants indicated that spawning and rearing habitat for trout and kokanee appears sufficient for the system in Jones, Flat, Boulder, and Glacier tributaries, but access problems may occur in spring if the reservoir elevation is low (Hirst 1991).

2.1.2 Downstream of Wahleach Dam

The 7 km high gradient reach of Jones Creek below the dam has small populations of rainbow and cutthroat trout that are sustained from the lake.

The 800m of low gradient reach of Jones Creek from the canyon to its mouth likely supported historic stocks of pink, chum and coho salmon, steelhead, cutthroat trout, and Dolly Varden char. These species used the artificial spawning channel that was financed by BC Electric and constructed by DFO in 1954. The spawning channel included a seasonal fish barrier that prevented fish from accessing the main creek. Juveniles of these species, and of chinook salmon entering from the Fraser River, rear in the accessible system.

Table 9-1. Fish species in Jones Creek (Wahleach Lake) watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Wahleach upstream ↓ downstream		Anadromous Salmonids								Sport Fish								Non-Sport Fish								Red/Blue Listed Fish																			
		Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon		Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)		Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish *	Pearmouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	Pumpkinseed	Dace General		Longnose Dace	Brassy minnow		
"Mud Creek"																																													
Boulder Creek																																													
Wahleach Lake																																													
WAHLEACH DAM	No fishway in dam. Anadromous fish blocked by natural obstructions downstream.																																												
Jones Creek Mainstem		1						1																												1									

* now named *Northern pike minnow*

1 - probable

2.1.3 Downstream of Wahleach Powerhouse

The diverted water enters the Herrling Island side channel of the Fraser River about 11 km downstream of the Jones Creek confluence. Pink and chum salmon spawn near the discharge; other Lower Fraser River fish species may be present.

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Wahleach Reservoir	1. Reservoir footprint covered 2 km of mainstem channel and associated riparian zone: loss of lake outlet spawning habitat	x		GIS
	2. Reservoir footprint covered 6 km of tributary channel and associated riparian zone: loss of productive habitats in lower reaches	x		GIS
	3. Original 278 ha lake was flooded by 18 m to create present 489 ha reservoir: gain of 205 ha in reservoir habitat and uncalculated volume.	x	x	
	4. Fluctuating water levels of 20 m reduced productivity from shallow littoral habitats	x		BC Hydro 1994
	5. Fluctuating water levels isolated the shoreline riparian zone from the aquatic environment: original lake shoreline was increased from 11 km to 15 km of reservoir shoreline.	x	x	
	6. Fluctuating water levels of 20 m can make fish access to and from tributaries difficult.	x		BC Hydro 1994
Wahleach Dam	7. Dam footprint of ~38,038 m ² : loss of instream, riparian and upland habitats.	x		
	8. Dam prevents fish access between the lake and Boulder Cr.	x		
	9. Wahleach Dam has reduced LWD recruitment to Jones Cr. downstream.	x		
Boulder Cr. Dam	10. Diversion dam footprint of ~3,600 m ² : loss of instream, riparian and upland habitats.	x		
	11. Dam prevents fish access between Boulder Cr. and the reservoir.	x		
	12. Diversion dam has reduced gravel and LWD recruitment to Jones Cr. downstream.	x		
Jones Creek downstream	13. Diversion of __% of MAD since 1952 has diminished the habitat capacity in Jones Cr. downstream, especially in lower section.	x		BC Hydro 1994
	14. Spawning channel in lower creek was built to mitigate impacts of reduced flows; but associated fish diversion structure prevented fish access to natural creek habitats.	x	x	Hirst 1991a
	15. Reservoir and diversion have reduced downstream productivity in Jones Creek but presumably increased it in Fraser R. side channel.	x	x	

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Diversion to Fraser River	16. Entrainment and mortality at turbine: magnitude unknown. Potential downstream benefits to scavengers.	x	x	
	17. Hydro's access road to the diversion tunnel			workshop
	18. Flow fluctuations in Fraser R. side channel may affect pink and chum spawning.	x		BC Hydro 1994

Non-Hydro Impacts - Other impacts in the watershed noted by the workshop participants and Hirst (1991a) include effects of historic and current logging practices, and road construction for logging and public access.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Wahleach Lake watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, or operating flows; or from non-hydro sources.
2. **Reduced biological productivity:** The former lake is affected long-term by large reservoir drawdown regimes relative to mean depth.
3. **Blocked access:** There are no fish passage facilities at either of the two dams. Trout in Boulder Creek potentially had access to the original lake in pre-impoundment conditions.
4. **Reduced tributary access:** Reduced fish access between the reservoir and tributary habitat due to large drawdown regimes.
5. **Reduced mainstem access:** Reduced access for fish using the mainstem diminished by diversion.
6. **Diversions:** The diversion has reduced flows to the Jones Creek channel downstream and increased flow into a Fraser River side channel; these altered flows have affected wetted channel area, seasonal temperatures and productivity in the respective systems.
7. **Limited distribution:** Historic anadromous populations were confined by natural barriers to the lower 0.8 km section of Jones Creek up from the Fraser River.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve habitats for resident fish stocks in the reservoir and tributary system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Activities in response to limiting factors #1, 4 and 5 above should be preceded by a study plan for the reservoir and tributary system that considers:

- operating flow regime (Wahleach Water Use Plan)
- opportunities to purchase or covenant floodplain properties for future habitat projects
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and for planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- current harvest pressures on stock recruitment
- identification and filling of data gaps such as fish entrainment, angling harvest effort, etc. that may also constrain population levels.

Objective 2: Conserve and improve aquatic habitats in lower Jones Creek.

Discussion:

A major slope failure ~5 km upstream has created ongoing water quality and bedload transport problems that compromise the habitat initiatives to reactivate the spawning channel in the lower creek. Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve existing habitat. Restoration activities should be preceded by a study plan to address limiting factors #1, 2, 5, 6 and 8, that considers:

- adequacy of fish flow regime (Wahleach Water Use Plan)
- temperatures of fish-flow releases during spawning
- opportunities to purchase or covenant streamside properties for future habitat projects
- potential sites for future habitat enhancement or creation
- proposed projects should have hydraulic characteristics that will withstand the historic range of discharges with low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- identification and filling of data gaps such as stranding after spills, etc. that may also constrain population levels.

Objective 3: Improve habitat conditions for fish stocks using the Fraser River side channel along Herrling Island below the tailrace.

Discussion:

This side channel is used for spawning by pink and chum salmon. Stranding of eggs and fry may occur as a result of non-ramped discharges. A data gap exists with respect to the historic fish use of this side channel. Activities should be preceded by a study plan, in response to limiting factors #1, 2, and 5 above, that considers:

- operating flows and fish flows (Wahleach Water Use Plan)
- effects of the diversion's flows and temperatures on the side channel
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- effects of proposed temperature changes on wildlife biodiversity values
- identification and filling of significant data gaps that may also constrain population levels.

Objective 4: Restore biological productivity in Wahleach Reservoir.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to improve reservoir productivity. Activities should be preceded by a study plan for the reservoir and tributary system, in response to limiting factors #3 and 7 above, that addresses:

- the effectiveness of the current fertilization program
- potential methods to achieve self-sustaining nutrient levels and reduce costs
- determination of appropriate low-level nutrient levels
- relative values of fertilizing fish-bearing tributaries vs reservoir plankton or littoral zone
- ecological effects of fertilization on non-target plants and aquatic animals
- impacts on domestic water supply downstream
- wildlife biodiversity values at all proposed sites
- identification and filling of data gaps such as entrainment, angling harvest effort, etc. that may also constrain population levels.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

A small wetland area was flooded by the reservoir, but in general the area appeared to have low wildlife use (Jack Lay, former MELP, pers. comm.). No information was obtained on current wildlife use.

Red-listed species occurrences on file with the Conservation Data Centre include

- Spotted Owl (*Strix occidentalis*) – Chilliwack Forest District (location data protected).

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Wahleach Dam	<i>Dam footprint of 38,038 m²</i> : loss of stream, wetland, and forested habitat and associated wildlife impacts.	x		
	<i>Flooding of 69 ha</i> : loss of flat land coniferous forest and small wetland and riparian area and associated wildlife such as grouse and fur bearers.	x		GIS
	<i>Flooding of 136 ha of upland forest</i> : loss of coniferous forest and associated wildlife.	x		GIS
	<i>Fluctuating reservoir water levels (18.3 m) due to hydro-electric operations</i> : effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		BCH web page
Boulder Cr. Diversion Dam	<i>Dam footprint of 3,600 m²</i> : loss of stream and forested habitat and associated wildlife impacts.	x		
Boulder Cr. Diversion Channel	<i>Short channel between Boulder Cr. and Wahleach Lake</i> : conversion of upland habitat to wetted channel and associated wildlife effects.	x	x	
Power Conduit	<i>Reduced flows and changes in flow regime in 9 km of Jones Creek</i> : unknown effects on wildlife of reduced river flows and wide operational fluctuations (e.g. American Dipper).	x	x	

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of Habitat:** Loss of upland forested habitat. Loss of side channel habitat downstream of diversions.
2. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
3. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions (0.7 km of river flooded).

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat.

Discussion:

- Improve vegetation in the drawdown zone of Wahleach Reservoir.
- Develop foreshore habitat complexes at suitable locations.
- Create snags along reservoir shorelines for cavity nesters and perching raptors.

4. WAHLEACH (JONES) WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
Wahleach Lake flooding of Crown land below Level 2109, 1952	BC Hydro
Hope sheet, topographic map, Dept. of Mines and Resources, 1938, 1 in = 4 mi	UBC map library
Chilliwack, 1" = 1 mi . topographic map, Dept. of National Defence, 1941	92 H/4, UBC map library
Plan of survey of portions of Sections 29 and 32, Township 3 Range 27, Wahleach Power development, 1 in = 400 ft, Underhill & Underhill, 1951	Legal Surveys, MELP
Air Photos, Wahleach Lake, 1948	BC 604: 106-107

4.2 Hydro Facility and Fish References

Reference	Notes	Sources
Anon. n.d. Wahleach, B.C. - Jones Lake.	Major Matthews collection/ Add. MSS. 54	City of Vancouver (in Archives building): 505-E-1 file 7 Refer to microfiche # AM0054.013.04 789
Anon. 1998. Wahleach Generating Station ramp down: preliminary observations of flow changes in downstream habitat. A rudimentary investigation by the Ministry of Environment Lands and Parks, Department of Fisheries and Oceans and B.C. Hydro. Unpublished report. 5 p.		BC Hydro
Aquapro Research and Technologies. 1995. Proposal to conduct the 1995 Wahleach Reservoir Fertilization Experiment. 18 p.		
B.C. Hydro. 1987. Wahleach Dam Operation and Maintenance Manual. Report No. OMM425/02.		BC Hydro
B.C. Hydro. 1991. Long-Term Hydrologic Data Collection Networks: La Joie, Terzaghi, Seton, Elsie, Wahleach, and Clowhom Basins. B.C. Hydro, Hydroelectric Engineering Division. Report H2067. 34 p.	BCH basin is 88km ² . Elev. range is 640m to 2300m.	BC Hydro
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Fraser, F.J., and A.Y. Fedorenko. 1983. Jones Creek pink salmon spawning channel; a biological assessment, 1954-1982. Can. Tech. Rep. Fish. Aquat. Sci. 1188. 89 p.	This report describes the Jones Creek spawning channel and its operation history; presents fisheries biological information on the system from 1954 to 1982, particularly for pink salmon; assesses the success of the spawning channel in maintaining the Jones Creek salmon stocks after hydro dam construction and examines the current problems regarding channel operation.	cited in Hirst 1991 & FISS 29E-55
Ginetz, R. and G. Neilsen. 1980. Review of enhancement potential for chinook and coho salmon stocks in the Fraser River watershed. Fisheries & Oceans Canada. Small Projects Division Memorandum 17 p.		cited in Rood & Hamilton 1995
Hartman, G.F. and M. Miles. 1997. Jones Creek spawning channel post-failure analysis and management recommendations. Prepared for Habitat and Enhancement Branch, Dept. of Fisheries and Oceans Canada, Vancouver, B.C. 62 p.		cited in Parsonage 1999a
Hurst, W.R., and D. MacKinnon. 1956. Use of an artificial spawning channel by salmon. Amer. Fish. Soc. Trans. 86: 220- 230.		cited in Hirst 1991
Inglis, S.D. 1995. Wahleach Reservoir Inlet Spawners April – May, 1995. Prepared for B.C. Hydro, Environmental Affairs, Burnaby, B.C. Unpublished report. 6 p.		BC Hydro
Inglis, S.D. 1995. Wahleach Reservoir Fertilization Experiment: Year 2 - Pre-fertilization Assessment. Draft report. Prepared for MELP Regional Office, Surrey. Regional Fisheries Report. 60 p.	A draft report on the Wahleach Reservoir fertilization experiment.	BC Hydro; cited in FISS 2LM240.1
Inglis, S.D. and H.R. Neuman. 1994. Wahleach Reservoir Fertilization Experiment Year 1 – Pre-fertilization Lake Assessment. B.C. Environment Lands and Parks, Fish and Wildlife Management Branch, Surrey, B.C. Regional Fisheries Report No. LM 240. 97 p.		BC Hydro
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Wright. 1990. Wahleach Dam Deficiency Investigations. Prepared for B.C. Hydro by Wright Engineers Ltd.		cited in Ramsay 1994
Zablosky, S. 1981. The Jones Creek spawning channel and the 1981 spawning channel reconditioning work. Prepared for BC Hydro by S. Zablosky Engineering Technician Co.		cited in Ramsay 1994

4.3 Wildlife References

Reference	Notes	Source
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BC Fish & Wildlife Branch. 1972. Wildlife Distribution Mapping Series: Elk Distribution	Roosevelt elk winter and general range just south on map.	MELP Surrey: Jack Evans
Lay, Jack	Formerly had a small wet flat area with generally low wildlife values due to high elevation (644 m). Species that used area include -Grouse: willow & blue -Summer range for black bear and deer -Martin, mink, bobcat, coyote, squirrels, and other furbearers	Personal Communication

Chapter 10

BRIDGE RIVER WATERSHED

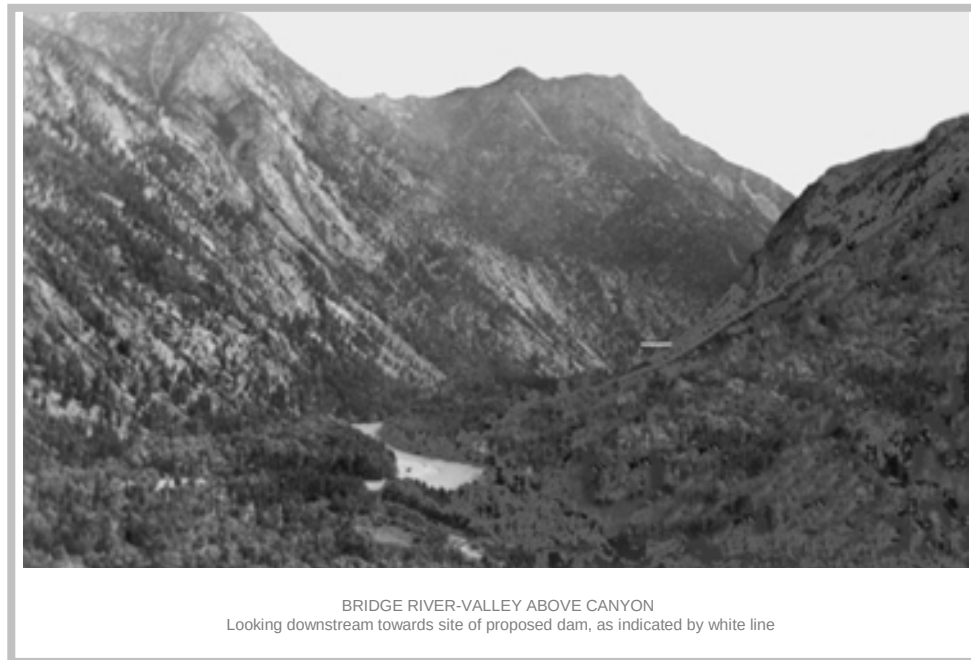


Figure 10-1 . Bridge River valley in the 1920s (BC Archives)

1. PROJECT DESCRIPTION

1.1 Facilities

The Bridge River project consists of the La Joie Dam which impounds Downton Lake and Terzaghi Dam which impounds Carpenter Lake. Water is diverted through tunnels and penstocks from Carpenter Reservoir to two powerhouses on Seton Lake Reservoir. About 80% of the total discharges through the Seton powerhouse originate from the Bridge River system via major diversions into Seton Lake.

The initial diversion dam, Mission Dam, was a 19 m high, 240 m long rockfill dam with a clay core, and was surveyed by J.T. Underhill in July 1948 on District Lot 7613 soon after its completion. The footprint area of Mission Dam occupied about 6,400 m² of wetted channel area and its total footprint was about 24,600 m². Mission Dam was incorporated into the upstream toe of the new Terzaghi Dam which was completed in 1960 and renamed in 1965. La Joie Dam was constructed in 1948 by B.C. Electric Co. and redeveloped in 1957.

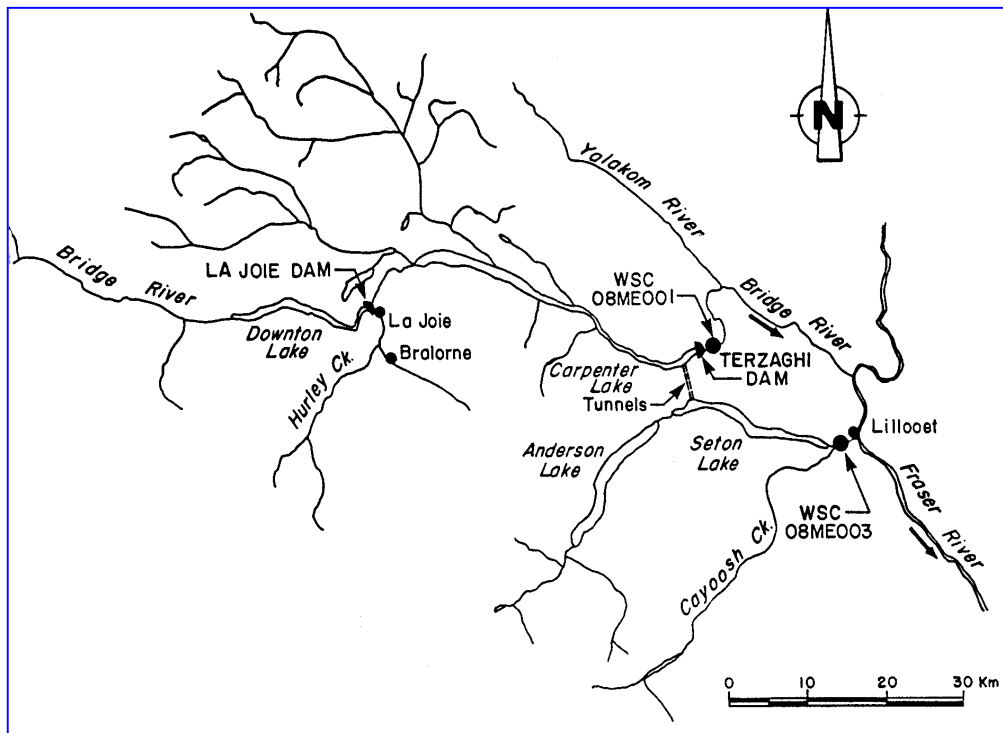


Figure 10-2. Location of Bridge River/Seton hydro project.



Figure 10-3. La Joie Dam under construction (Water Powers B.C. 1954)



Figure 10-4. La Joie Falls in the 1920s (BC Archives)

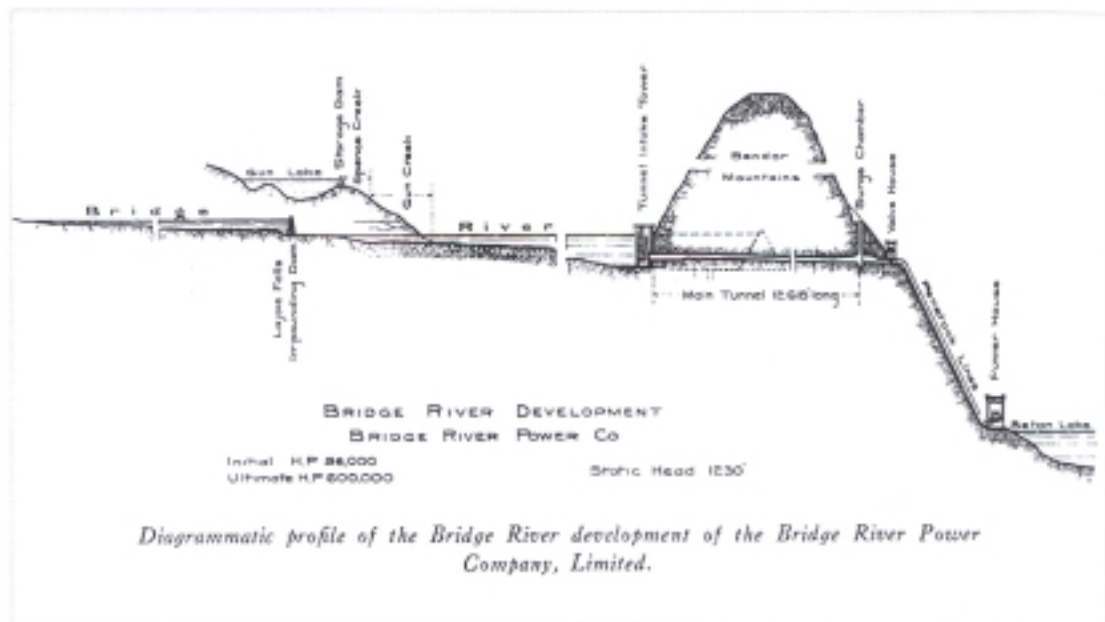


Figure 10-5 . Historic Bridge River power scheme (Water Powers B.C. 1954)

Specifications for the Bridge River facilities and reservoirs:

DAM	Lajoie	Terzaghi
Nameplate capacity (MW)	22	428
Dependable capacity (MW)	24	480
Dam function	storage	storage, diversion
Date constructed	1948	1948
Date operational		
Date reconstructed	1956-7	1960
Height (m)	83	60
Length (m)	1033	366
Dam footprint area (m ²)	97,900	131,000 *
Fishway at dam	no	no
Historic anadromous fish presence	no	yes

RESERVOIR	Downton	Carpenter
Cleared/ not cleared	nc	nc
Present area (ha)	2400	4900
Orig. lake area (ha)	0	0
Watershed area (km ²)	998	2691
Present elevation a.s.l. (m)	707-749	609-651
Normal drawdown range (m)	49	44
Mean depth (m)	30	23
Maximum depth (m)	80	47
Storage (million m ³)	722	1011
Mean water retention time	6.3 mo	3.8 mo
Mean annual discharge (m ³ /s)	40	51

DIVERSION	no	to Seton Lake
Structure type	- -	tunnel, penstock
Licensed flow (m ³ /sec)	- -	150 (typical 91)
Fish flow release (m ³ /sec)	no	3
Mainstem length diminished (km)	- -	34
Mainstem length augmented (km)	- -	- -

* Terzaghi Dam's footprint includes the base of Mission Dam

1.2 Hydrology

1.2.1 Basin and Runoff

The Bridge River basin is located in the rainshadow of the southern coastal mountains about 200 km northeast of Vancouver. The Bridge basin adjoins and lies immediately north of the Seton basin, separated by the Bendor Range and Mission Ridge. The source of Bridge River is the Bridge Glacier in the Coast Mountain Range. The glacier comprises about 140 km² of the 998 km² watershed area above La Joie Dam. Tributaries to the Terzaghi sub-basin below La Joie Dam drain 2691 km². Elevations within the Bridge River basin range from 645 m to 2896 m, and the mean elevations for La Joie Dam and Terzaghi Dam local basins are 1900 and 1800 m respectively (BC Hydro 1991).

High inflows occur from May to August from snow and glacial melt. Inflow from September to April is usually low. Occasional heavy rainstorms from August to early October cause high inflow to the reservoirs which can result in spilling, on average about 1 year in 3. Natural lakes within the watershed, including Gun and Tyaughton, provided relatively insignificant storage before impoundment .

1.2.2 Operation and Licensed Diversion Flow

Downton Reservoir has a total average inflow of 40 m³/s (BC Hydro 1994). Additional inflow to Carpenter Reservoir is 51 m³/s for a total diversion typically about 91 m³/s into Seton Lake. The licensed diversion flow from Bridge River is 147 m³/s.

1.2.3 Habitat Types Flooded by Reservoir

The total area flooded by Downton Reservoir is 2,234 ha of river and valley bottom (Figure 10-6), and the reservoir shoreline length is 60 km. The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Downton Reservoir		Original habitat lost
Lake flooded	(ha)	0
Land flooded	(ha)	2234
Lake shoreline	(km)	0
Mainstem: length	(km)	65
channel	(ha)	441
riparian *	(ha)	390
Tributary: length	(km)	25
riparian **	(ha)	75
Wetland:	(ha)	237

* mainstem riparian zone calculated at 30 m from each bank

** tributary riparian zone calculated at 15 m from each bank

The total area flooded by Carpenter Reservoir is 4,669 ha of river and valley bottom (Figure 10-7), and the reservoir shoreline length is 112 km. The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Carpenter Reservoir		Original habitat lost
Lake flooded	(ha)	0
Land flooded	(ha)	4669
Lake shoreline	(km)	0
Mainstem: length	(km)	92
channel	(ha)	761
riparian *	(ha)	552
Tributary: length	(km)	55
riparian **	(ha)	165
Wetland:	(ha)	46

* mainstem riparian zone calculated at 30 m from each bank

** tributary riparian zone calculated at 15 m from each bank

2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Bridge River watershed is provided in Table 10-1.

Anadromous fish stocks in the Bridge system were seriously affected by the rock slides that blocked Hells Gate in the Fraser River Canyon in 1913 and again in 1914 (Roos 1991). During the 32 years before permanent fishways were finally constructed in 1945, difficult passage through Hells Gate periodically affected the abundance or condition of salmon returning to the Bridge watershed. This legacy may have led to the under-appreciation of salmon stocks using this system during the planning of hydroelectric development.

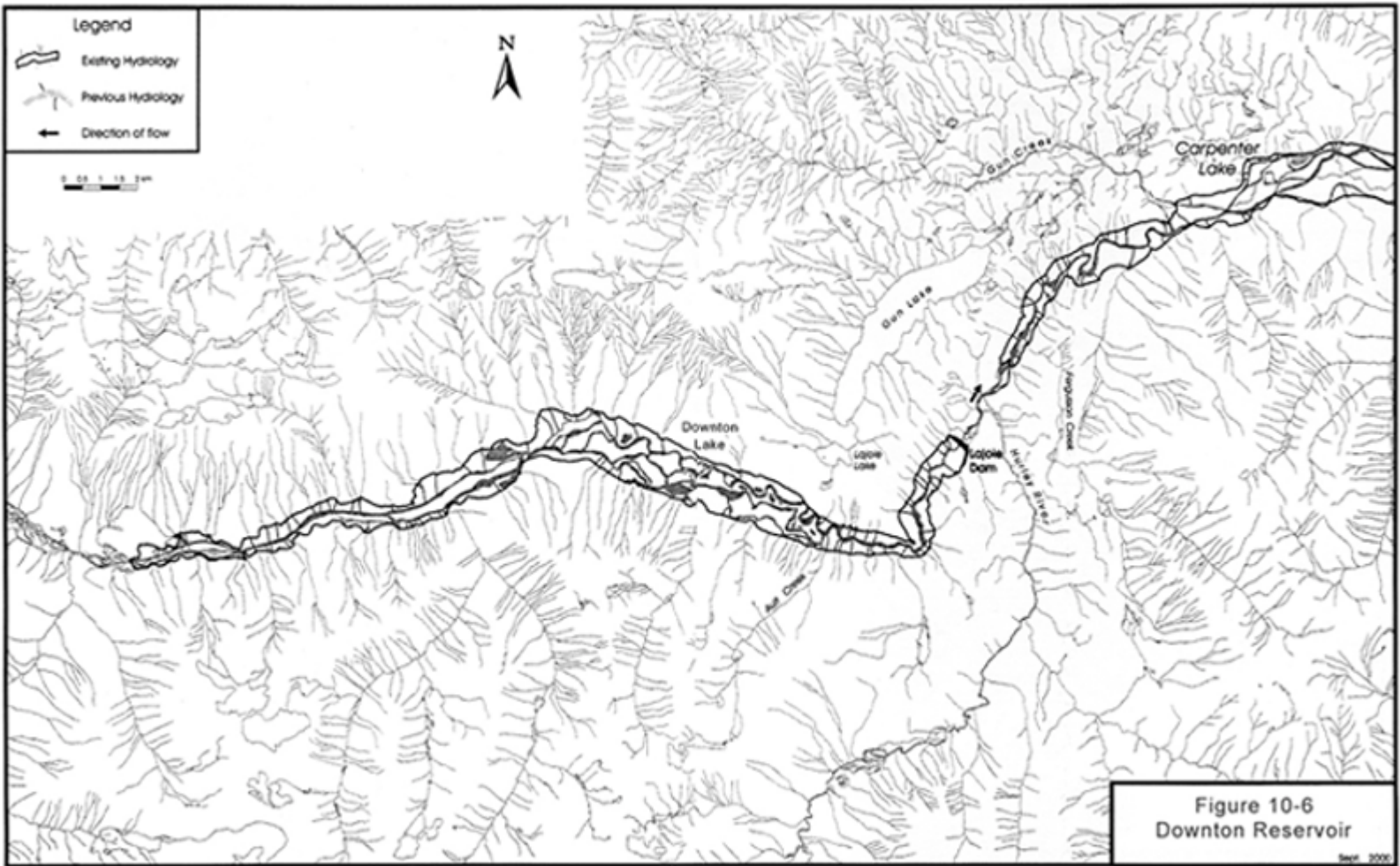
At the time of Hells Gate, Bateman (1914) described the pre-project Bridge watershed:

“The tributaries of Bridge River enter with steep gradients and flow through precipitous and narrow valleys and canyons. For 25 miles above its mouth Bridge River flows swiftly through a steep canyon. In the upper 10 miles of this canyon the walls rise almost vertically from the river for about 2,500 feet, but above the canyon the valley broadens and the river meanders over a wide, flat bottomed, swampy valley containing many small lagoons and river cut-offs. This wide, silt-covered portion of the valley extends upstream to beyond the Wayside mine, a distance of about 30 miles, where it again changes to a narrow valley with a steep profile broken by [Lajoie and Zoltique] falls. Above this, the current again becomes sluggish and the valley broad and flat, containing many swamps and ox-box lakes, remnants of previous river meanders.”

In the late 1920s, the Bridge River Power Company, later BC Electric, received permission to divert 3000 cubic feet per second from Bridge into Seton. “Neither the Department of Fisheries nor John Pease Babcock, the provincial Deputy Commissioner of Fisheries, thought this would affect the salmon run up Bridge River.” (O’Donnell 1988). This quote was footnoted: “Correspondence, reports and photographs dealing with the effects of the hydroelectric project on salmon spawning in Bridge River are on file at the National Archives Canada, RG 23, Volume 843, Files 719-9-101 (1-3)”. We did not locate these files.

2.1.1 Upstream of La Joie Dam

Two sets of falls, named Lajoie and Zoltique, about 800 m apart on the mainstem were flooded by the La Joie Project. The downstream barrier, La Joie Falls, was reported to be about 50 feet vertical (Heyworth 1930). A historic photograph taken prior to construction in 1948 suggests that the wide valley now occupied by Downton Reservoir was vegetated by marshy flats and that few trees were present (Triton 1992). Rainbow trout, bull trout, Dolly Varden char, kokanee and mountain whitefish are the current resident sportfish. The Bridge River system has cold temperatures and nutrient-poor water, especially upstream of La Joie Dam.



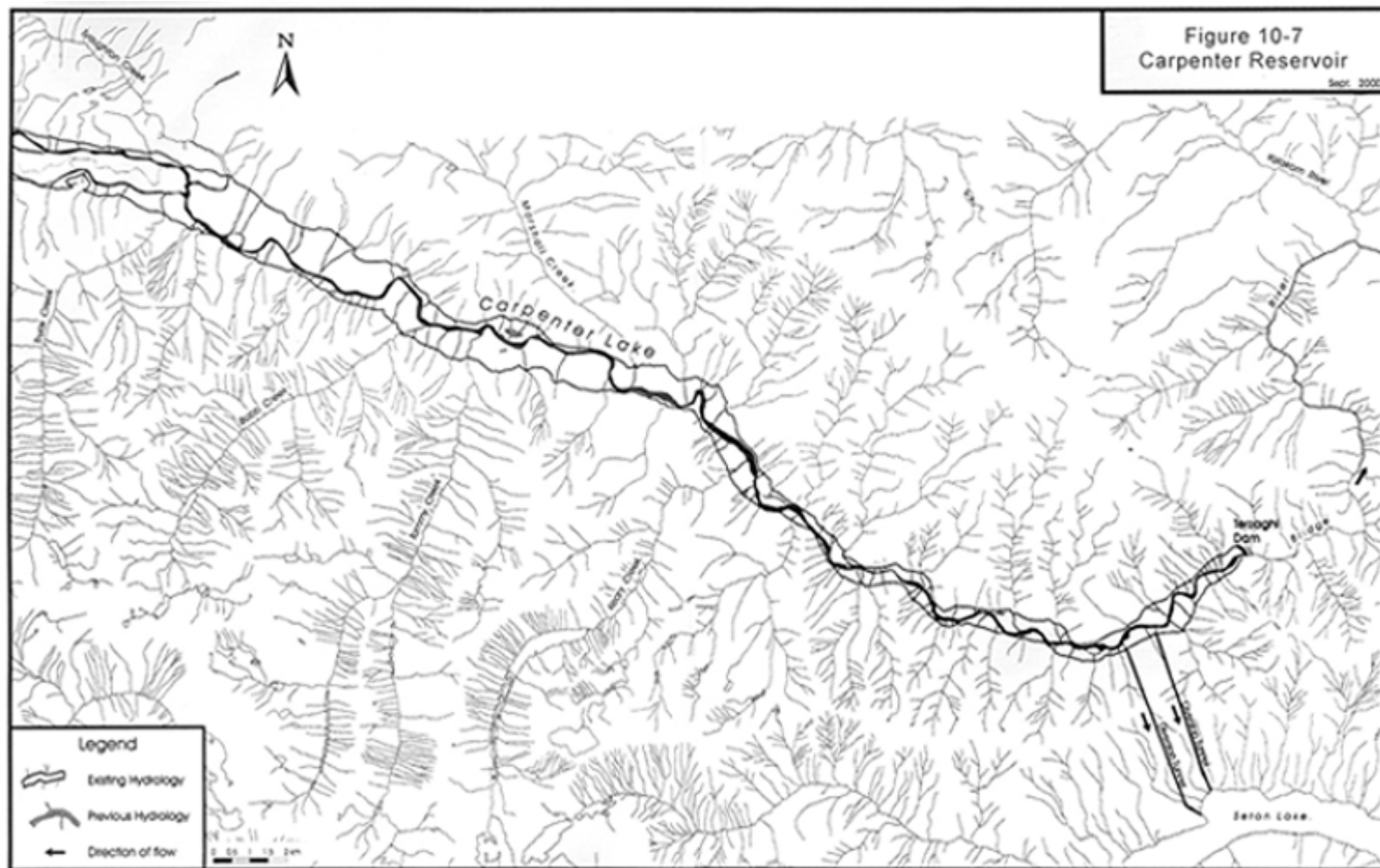


Table 10-1. Fish species in the Bridge River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.

Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

[illegible]

* now named *Northern pike minnow*

2.1.2 La Joie Dam to Terzaghi Dam

Before the Terzaghi Project was begun in 1946, sockeye and chinook salmon had been reported from 1901 to 1936 in this section of Bridge River and in Fergusson and Tyaughton creeks sporadically (Atkinson 1947). A fishway was not incorporated into the initial Mission or subsequent Terzaghi diversion dam despite awareness of these stocks.

No estimates of historic sockeye escapement were located except that in 1922-26, the Department of Fisheries guardian reported very light runs of sockeye in the river in June (Atkinson 1947). It is possible that a small stock of riverine-type sockeye existed in the Bridge Valley, despite lack of a major lake, by rearing in the plentiful off-channel habitats; however, some recent sockeye specimens have been identified as Quesnel stock (J. Woodey, Pacific Salmon Commission). Occasional historic sightings of large numbers of sockeye in Bridge River likely represent upper Fraser stocks diverted by temporary blockages at the Bridge River Rapids on the Fraser mainstem (Killick 1948; Neilsen and Shepherd 1983).

Estimates of chinook salmon ranged from 300 to 2000 fish in the accessible lower 1.6 km of Tyaughton Creek between 1940-48 (MELP Kamloops files compiled from DFO Spawning files). Estimates for Ferguson Creek were made in 1940 and 1941 at 1-50 and 100-300, respectively; in 1942, there was a note that the “stream was destroyed” by placer mining. In 1948 as hydro construction began, one of the first projects of the Fish Culture Branch was a salvage operation on the Upper Bridge chinook run that began to collect below the Mission diversion dam at the end of July (Nielsen and Shepherd 1983). Broodstock salvages continued until 1952 with eggs planted in Gates, Portage and Yalakom rivers, but subsequent assessments indicated dwindling chinook returns to these systems. A detailed account of Tyaughton Creek escapements was presented in Triton (1993).

Pink salmon were not reported in the Bridge River until 1959 after the Hells Gate fishway was extended in 1956 (DFO 1983). Reduced Bridge River flows since dam construction have allowed pink salmon to ascend past former velocity barriers in the lower reach.

Based on their current presence in lower Bridge River, it is probable that coho salmon had historic access to the valley above Terzaghi Dam (Cartwright 1978). Examination of pre-impoundment channel morphology on the early maps suggests there was a considerable quantity of potential habitat for juvenile coho salmon including extensive swamps and backwaters. The secretive nature and small groups typical of coho spawners is a possible reason this species may have gone unreported in a large turbid system. As the last salmon run of the season into the Bridge system, the importance of coho carcasses to the food web in winter has been noted by local residents (Triton 1992).

No historic information on steelhead in this section of river was found although their current use of habitats in the canyon suggests their former presence in some upper tributaries (Cartwright 1978).

Carpenter Reservoir has native populations of resident rainbow and bull trout. The historic extent of in-river movements by these species is not known. Kokanee were introduced from Meadow Creek in Kootenay Lake. The confluence of Gun Creek is an important spawning area for resident

salmonids, considering that most tributaries to Carpenter Reservoir now provide limited habitat area (Triton 1992).

2.1.3 Downstream of Terzaghi Dam

From 1948 to 1960, the flows into the Bridge River canyon below the diversion dam were reduced, but after the diversion proportion was increased in 1960, downstream flows virtually ceased in the 10 km section between the dam and the Yalakom River except for periodic large spills once every 3-5 years. The Yalakom River (historically called the “North Fork of Bridge River”) has provided the principal flow down the lower 24 km of Bridge channel for 40 years. Despite the reduced flows in the upper canyon, seepage from the dam and minor tributary plus groundwater inflows provided a relatively productive area (Lister and Beniston 1995). A fish flow release of 3 m³/s is now delivered to the reach above Yalakom in seasonal proportion to the natural hydrograph. See Hirst (1991a; 1991b) for further descriptions of species occurrence and habitats in the Bridge River system.

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Downton Reservoir	1. Reservoir flooded 65 km of mainstem channel and 25 km of lower tributary channel, plus their associated riparian zones; species composition unchanged.	x		GIS
	2. Building access roads required culvert crossings that reduced instream and riparian habitat, and probable obstructions to fish.	x		workshop
	3. Large drawdown through spring may affect access to tributaries.	x		
La Joie Dam	4. Dam footprint of 97,900 m ² : loss of instream, riparian and upland habitats.	x		
	5. La Joie Dam construction sluiced large volume of sediment that degraded channel habitat downstream.	x		Bateman 1952
Carpenter Reservoir	6. Reservoir footprint flooded 92 km of mainstem and side channels, plus 55 km of tributary channel habitats in valuable lower reaches, plus their associated riparian zones; species composition unchanged except kokanee stocked.	x		GIS
	7. Large drawdown through spring may affect access to tributaries.	x		
Terzaghi Dam	8. Dam has no fishway: blocked all anadromous and resident fish migration since 1948.	x		Atkinson 1947
	9. Dam footprint of 131,000 m ² : loss of instream, riparian and upland habitats.	x		
	10. Terzaghi Dam has reduced gravel recruitment to Bridge River downstream.	x		workshop
	11. Terzaghi Dam has reduced LWD recruitment to Bridge River	x		

Facility	Description of hydroelectric impacts	Neg	Pos	Source
	downstream.			
Bridge River downstream	12. Periodic large spills after 1960 diversion have scoured gravel and diminished spawning habitat capacity in the mainstem.	x		
	13. Spills strand and kill fish, or displace them downstream.	x		
	14. Spills temporarily increase TGP and sediment levels.	x		
	15. Minimum fish flows restrict instream habitat quantity and access to former off-channel habitat.	x		workshop
	16. Reduced volume of cool Bridge water in summer may benefit juvenile rearing conditions		x	workshop
	17. Reduced winter flow decreases temperatures in lower river.	x		workshop
Bridge Diversion to Seton Lake	18. Bridge River migratory stocks are attracted to Seton tailrace due to large proportion of homestream water.	x		Fretwell 1989
	19. Potential temperature stress on Fraser upriver migrants trying to pass Bridge River Rapids due to loss of cool Bridge discharge.	x		

Spilling at Terzaghi Dam affects fish habitat by eroding banks and by displacing spawning gravel. Terzaghi Dam has blocked anadromous fish access to extensive former habitat areas. At present fish water releases, the river below Terzaghi Dam has reduced areas of off-channel and overwinter habitats compared to pre-project levels. Below Terzaghi, riparian zones are not well-established, partly due to periodic spill events, and there is little recruitment of large wood debris to add channel complexity or stability. Most Carpenter Reservoir tributaries provide limited habitat area for resident fish due to gradient or barriers.

Non-Hydro Impacts - Other impacts on fish in the Bridge River watershed include historic effects of placer mining (including other dams), logging, homesteading, and road construction.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the large Bridge River watershed. These also reflect the key issues raised at BCRP regional workshops.

1. Blocked access to historic habitats: Anadromous stocks and migratory resident stocks have been excluded from the Bridge system between La Joie Falls and the Terzaghi Dam site for 52 years.

2. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources.
3. **Reduced downstream habitat capability:** Habitats below Terzaghi Dam are altered by reduced sediment and wood recruitment.
4. **Reduced biological productivity:** The Carpenter Reservoir sub-basin has lost nutrient input from historic salmon carcasses. Below Terzaghi Dam, temperatures and nutrients from groundwater may currently provide better conditions for fish production than historic levels although the extent of wetted channel area was decreased.
5. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat, and flooding/dewatering of spawning areas in lower section of tributaries due to large drawdown regimes.
6. **Diversions:** The diversion had eliminated continual flows in the downstream Bridge River channel until August 2000; these altered flows have reduced wetted channel area, but improved seasonal temperatures and stream productivity.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve fish habitats in the lower Bridge River.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve the existing habitats. Restoration activities should be preceded by a study plan to address limiting factors #2, 3, 4 and 6 above that considers:

- operating flows and fish flows (Bridge River Water Use Plan)
- opportunities to purchase or covenant streamside properties for future habitat projects
- opportunities for habitat development and riparian planting
- potential habitat development sites with hydraulic characteristics that will operate within the expected regime of fluvial and riparian processes and require low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- identification and filling of data gaps on issues such as fish stranding after spills, etc. that may also constrain populations.

Objective 2: Conserve and improve habitats for resident fish stocks throughout the Bridge River reservoirs and their tributary systems.

Discussion:

Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve the existing habitats. Activities in response to limiting factors #2 and 5 above should be preceded by a study plan for each reservoir and tributary system that considers:

- operating flows and fish flows in regulated mainstem (Bridge River Water Use Plan)
- opportunities to purchase or covenant key properties for future habitat projects

- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regime of fluvial and riparian processes and require low maintenance
- works to increase survival of fish that spawn within the drawdown zone
- opportunities for habitat development and riparian planting
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration and maintenance of fish access to historical upstream habitats
- current and future harvest pressures on stock recruitment
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 3: Restore the biological productivity of key reservoir tributaries.

Discussion:

Improvement of productivity should be focused on important fish-bearing tributaries due to the large sizes of the reservoirs and the oligotrophic nature of the basin's runoff. Undertake appropriate treatment, consistent with the BCRP strategy, to improve system productivity. Activities should be preceded by a study plan for the reservoirs and tributary systems, in response to limiting factor #4 above, that addresses:

- feasibility of a phased program of fertilization trials and performance indicators
- determination of appropriate low-level nutrient levels that, for the Carpenter subbasin, once included historic sources from salmon carcasses
- potential methods to achieve self-sustaining nutrient levels and reduce costs
- ecological effects of fertilization on non-target plants and aquatic animals
- wildlife biodiversity values at all proposed sites
- identification and filling of data gaps on issues such as entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 4: Determine the feasibility of restoring historic access to anadromous stocks.

Discussion:

Undertake an appropriate study, consistent with the BCRP strategy and Section 1-3.2 (Volume 2), to restore historic access to anadromous fish. A study plan, in response to limiting factors #1, 2, 4 and 5 above, should consider:

- present operating flows and adequacy of fish flows (Water Use Plan)
- biological soundness in terms of donor stocks, ecological interactions, current adequacy of habitat and productivity
- engineering feasibility of structures and flows for upstream and downstream passage
- management implications to future BC Hydro operations, and to fisheries that presently exploit similar stocks at a high rate
- identification and filling of data gaps on other issues that may constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

Historically the flooded area provided productive moose, grizzly bear and black bear habitat. The north slopes of Carpenter Lake were important black-tailed deer winter range. California bighorn sheep and elk were frequent along the Bridge River. Harlequin ducks were found along the river and waterfowl were known to use the extensive wetland/slough complexes. Ruffed and blue grouse were reported in the area.

Red-listed species occurrences on file with the Conservation Data Centre include

- Spotted Owl (*Strix occidentalis*) (locations information protected)

The results of surveys of current wildlife use in the Downton and Bridge River areas are provided in Table 10-2.



Figure 10-8. Carpenter Lake shoreline in October 2000

[illegible]

SPECIES	STATUS	HABITATS								
		Talus/- Rock	Avalanche Chute	Logged	Forested	Wetland	Floodplain & River	Draw- down	Deep Water Reservoir	Dam Facility
MAMMALS										
Black Bear	Blue List									
Grizzly Bear										
Coyote										
Wolf										
Cougar										
Bobcat										
Lynx										
Wolverine										
Pika										
Hoary Marmot										
Yellow-bellied Marmot										
Fisher										
Ermine										
Mink										
Snowshoe Hare										
Red Squirrel										
Yellow Pine Chipmunk										
Beaver										
Muskrat										
Mule Deer										
Moose										
Mountain Goat										
California Bighorn Sheep?										

? = species suspected by Robertson et al. 1997 but not recorded during their survey.

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Lajoie Dam/ Downton Lake Reservoir	<i>Dam footprint of 9.8 ha:</i> loss of coniferous forest and riverine habitats.	x		
	<i>Flooding of 1,943 ha of upper Bridge River valley and 291 ha of adjacent forested hillsides:</i> loss of valley bottom and valley side coniferous, deciduous, and wetland habitats, incl. riparian, and associated wildlife losses, e.g., lost marsh and wetland feeding/breeding habitat for ducks and furbearers, and feeding habitat for bears & ungulates; loss of valley side habitat for bighorn sheep, other ungulates, carnivores.	x		Clayton Res. 1991; GIS
	<i>Replacement of 65 km of main river and 25 km of tributaries with Reservoir:</i> barrier to movement of large mammals (bears and ungulates); creation of open water for waterfowl and osprey.	x	x	Clayton Res. 1991; Robertson et al. 1997; GIS
	<i>Flooding of shoreline trees:</i> creation of snags for cavity nesting birds.		x	Robertson et al. 1997
	<i>Changed flow regime in 49.5 km of Bridge River:</i> unknown effects on aquatic wildlife (e.g. American Dipper, Harlequin) downstream	x	x	
	<i>Fluctuating reservoir water levels (49 m) due to hydroelectric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		
Terzaghi Dam/ Carpenter Lake Reservoir	<i>Dam footprint of 13.1 ha:</i> loss of coniferous forest and riverine habitats.	x		
	<i>Flooding of 4,437 ha of Bridge River valley and 232 ha of adjacent hillsides:</i> loss of coniferous, deciduous, and wetland habitats, incl. riparian, in reservoir and associated wildlife losses, e.g., lost marsh and wetland feeding/breeding habitat for ducks and furbearers, and feeding habitat for bears & ungulates; loss of valley side habitat for bighorn sheep, other ungulates, carnivores.	x		Clayton Res. 1991; GIS
	<i>Loss of salmon resource above dam:</i> effects on predators (e.g., bears) and scavengers feeding on spawning salmon and salmon eggs, and on piscivorous birds feeding on fry and smolts.	x		
	<i>Replacement of 92 km of main river and 55 km of tributaries with Reservoir:</i> barrier to movement of large mammals (bears and ungulates); creation of open water for waterfowl and osprey.	x	x	Clayton Res. 1991; Robertson et al. 1997; GIS
	<i>Flooding of shoreline trees:</i> creation of snags for cavity nesting birds.		x	Robertson et al. 1997
	<i>Changed flow regime of Bridge River:</i> unknown effects on downstream aquatic wildlife (e.g. American Dipper, Harlequin).	?	?	
	<i>Fluctuating reservoir water levels (44.5 m) due to hydro-electric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		

Feature	Description of Effects	Neg	Pos	Origin
Bridge River downstream	<i>Reduced flow volumes in 49.5 km of Bridge River: unknown effects on downstream aquatic wildlife (e.g. American Dipper, Harlequin).</i>	x	x	

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Changes:** Altered flow regime has changed existing riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for tailed frogs, water shrews, harlequins and dippers.
2. **Loss of Habitat:** Loss of riparian habitat in valley bottoms. Loss of wetland habitats in flooded valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals (e.g., pikas) and their predators, browse and overwintering habitat for ungulates, forage for grizzly bear and breeding habitat for some species of neotropical migrants. Loss of side channel habitat downstream of diversions.
3. **Reduced Habitat Capability:** Lack of snags for cavity nesting habitat and structures for large raptor nests. Potential effects for primary cavity nestors (e.g., woodpeckers) and secondary cavity nestors (e.g., swallows, squirrels).
4. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
5. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions including losses related to ice shelving.
6. **Diversions:** Wildlife (especially mammalian) mortality caused by some diversion or intake structures, through entrainment and drowning. Potential hazards for non aquatic or weak swimming animals.

3.4 Wildlife Restoration Objectives

Objective 1: Reduce downstream erosion and channel instability in Bridge River.

Discussion:

See limiting factor # 1. Undertake appropriate measures to control spilling of reservoir waters, as determined within the Bridge Water Use Plan process.

Objective 2: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Carpenter Lake and Downton Lake.

Discussion:

See limiting factor # 4. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.
- Improve nesting opportunities for osprey by providing artificial nesting structures.

Objective 3: Conserve riparian and wetland habitats in the Bridge River watershed.

Discussion:

See limiting factor # 2. Identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means, in the Bridge-Seton watersheds, in conjunction with the reservoir enhancement program and a riparian management plan for lower Bridge River watershed.

Objective 4: Protect small groups of old or second growth trees in strategic locations for current and future nesting use by bald eagles or ospreys.

Discussion:

These areas could also include access road corridors that are maintained by BC Hydro.

Objective 5: Create or enhance wetlands and riparian habitats for aquatic species (amphibians, waterfowl, cavity dependent species, small mammals, ungulates).

Discussion:

See limiting factor # 2 and 3. Consider various opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times.

- Create additional wetlands where feasible through activities such as flooding shallow basins in the watershed (e.g., Gun Lake and Creek area).
- Create backwater channel and associated riparian habitats along Bridge River segments where reduced downstream flows have diminished natural channel complexity.

Objective 6: Reduce ungulate losses due to ice shelving.

Discussion:

Assess the feasibility of mitigation and undertake measures as appropriate.

Objective 7: Create moose and elk winter range.

Discussion:

- See limiting factor # 2. Work with forestry companies to leave shelter stands in association with logged clearings that provide forage.
- Establish vegetation in the reservoir drawdown zone, especially near creek or river deltas.
- Assess the feasibility of re-introducing elk.

Objective 8: Develop a wildlife management plan for the Bridge River watershed, with appropriate control of unnecessary human access wherever possible in areas of sensitive wildlife use.

Discussion:

- In conjunction with habitat improvement measures, prepare a wildlife management plan that identifies and protects sensitive wildlife populations.

Objective 9: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Bridge watershed.

4. BRIDGE WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
BCRECo Box 78 file B1454 #1; map of dam and tunnel intake and tunnel (1928?)	UBC Special Collections
Tyughton Lake 1934-36, geological survey of Canada; 1:50,000 shows drainage of upper Bridge River in detail	UBC map library
1922 geological survey: upper Bridge-Falls Creek; 2"=1mi, Dept. of Mines Geological Survey	UBC map library
1918 Geological Survey, Bridge River between Rexmount and Gun Lake, 1:125,000, Dept. of Mines, Canada	Provincial Archives
1933, S.P. Powell & Co map, 1:250,000	UBC map library
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Bridge River – area from Dam downstream to tunnel intake and route to Seton lake	BC Electric Archives, Box 78 B1454 #1 UBC Special Collections
Pre-emptors map Lillooet; of Bridge River; orig. from 1915; revised to 1952; 3"=1mi	UBC map library
Bridge River Mining Area, 1 " = 2 mi 1934	CM-A1792 Provincial Archives
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BC Fish & Wildlife Branch. 1972. Wildlife Distribution Mapping Series: Elk Distribution	Downton Lake area Rocky Mountain Elk winter habitat.	MELP Surrey office, Jack Evans
BC Fish & Wildlife Branch. 1977. Wildlife Distribution Mapping Series: Grizzly Bear Distribution and Relative Abundance.	Downton & Carpenter Lakes: Moderate – (1 bear per 25-55 sq. miles)	MELP Surrey office, Jack Evans
BC Hydro. 1998. Rare element occurrence: Field guide to the rare and endangered species found within the watershed boundaries of each BCH facility. Strategic Fisheries, Power Supply Operations, Burnaby, BC.	all red, blue and yellow-listed species	BC Hydro
Clayton Resources Ltd. 1991. A retroactive assessment of selected hydro-electric project impacts on native Indian use of resources in the Bridge River and Seton systems. Prepared for InterGroup Consultants Ltd., Winnipeg, Man. 33 p.		BC Hydro
Forbes, R.D. & C.R. McIvor. 1974. Carpenter Lake Carryover Flight. Transcribed notes.	Refers to surveys over Gunn Creek, Tyax Turnoff, Pearson Ridge, Tyaughton Creek, Marshall Creek, Vera Creek, Big Horn Creek, Jones Creek and Plateau Pond. Records of wildlife observed and description of logging activities and habitats in these drainages. North shore of Carpenter Lake (2600') 7 yearling deer	MELP Surrey office, Jack Evans
Forbes, R.D. & C.R. McIvor. 1974. Carpenter Lake Deer Carryover Counts – 1974. Transcribed notes.	Surveys over drainages as mentioned above with some additional ones. Records of wildlife observed and description of logging activities and habitats in these drainages	MELP Surrey office, Jack Evans
Freeman, Shaun. 2000. Harlequin Duck Reproductive History. Office email to Jack Evans.	Ken Wright working on Harlequin Ducks in Bridge River.	MELP Surrey office, Jack Evans
Gates, Bryan	Was flooded without clearing (1948) -Still much floating debris in min 60's -Old-timers said up to 500 moose wintering in valley bottom before flooding (200-500 moose) -After flooding, moose began appearing in Pemberton Meadows	pers. comm.

Reference	Notes	Sources
	-Deer: in 60's 3-500 on surveys of valley sides =17% of total=ca 2400 -Wolves: trapped & poisoned out in 50's--began coming back in late 60's	
Gold Bridge Hotel Pub, Photograph in hotel	Shows Carpenter Lake before flooding	Doug Jury, MOE Kamloops
Hatter, J., D.J. Robinson, P.W. Martin, L.G. Sugden, E.W. Taylor and W.G. Smith 1956. Inventory and Evaluation of Wildlife Resources of British Columbia. Reprinted from the 9 th BC Natural Resources Conference Transactions, February 1956.	Mule Deer – “Certain winter ranges along the grassland fringes of the central interior have been assigned names as follows: “includes Bridge River.” one can almost define accurately to the last square mile the area of winter range of the Bridge River herds...” “Some better known goat areas Bridge River...” “The principal grizzly ranges of the western and central portions of the province are the mountainous regions of the following areas:.Sugar Lake-Mabel Lake...Shuswap Lake...Bridge River, ...”	Provincial Archives, MELP Surrey office, Jack Evans
Hirst, S.M. 1991a. Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia. Volume 1. Anadromous salmon. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2093. 144 p.	Anadromous salmon issues.	
Hirst, S.M. 1991b. Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia. Volume 2. Inland fisheries. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2093. 200 p.	Resident fish and anadromous trout and char issues.	download from http://www-heb.pac-mpo.gc.ca/english/publications/Pub.htm
Jury, Doug, MOE Kamloops	An area of the Bridge River flooded by Carpenter Lk. was once called “Moose Flats.”	pers. comm.
Little, B. 1994. Osprey Enhancement Project, Carpenter Reservoir. B.C. Hydro, Environmental Affairs Division, Land Resources Department. Report EA-94-2. 10 p.		BC Hydro
O'Donnell, B. 1988. Indian and Non-Native Use of Bridge River, An Historical Perspective. DFO Native Affairs Division, Pub. No. 7, 61 p.		DFO Vanc. Libr. SH 224 B7 O368
Province of British Columbia, 1906. First Report of the Provincial Game and Forest Warden of the Province of British Columbia 1905 . Authority of the Legislative Assembly, Victoria BC.	Mountain sheep: Bridge river and Chilcotin are still good countries, but of late years the number has decreased rapidly; this is ...due to [shooting]	Provincial Archives, MELP Kamloops office, Doug Jury
Province of British Columbia, 1921. Annual Report of the Game Conservation Board of the Province of British Columbia 1920 . Authority of the Legislative Assembly, Victoria BC	Liberated 20-30 elk in Bridge River; doing “remarkably well.”	Provincial Archives, MELP Surrey office, Jack Evans
Province of British Columbia, 1926. Report of the Provincial Game Warden 1925 . Authority of the Legislative Assembly, Victoria BC	Bridge River country is main mountain sheep hunting area in province.	Provincial Archives, MELP Surrey office, Jack Evans
Province of British Columbia, 1929. Annual Report of the Provincial Game Warden of the Province of British Columbia 1928 . Authority of the Legislative Assembly, Victoria BC.	Mountain sheep...at Lillooet...getting depleted...[but] on the Yalakom Game Reserve...they are now...increasing. On the Yalakom Game Reserve...elk which were introduced have increased. In the...Upper Bridge river muskrats are fairly plentiful.	Provincial Archives, MELP Kamloops, Doug Jury
Province of British Columbia, 1932. Report of the Provincial	Grizzly bear at head of tributaries to	Provincial Archives,

<i>Reference</i>	Notes	<i>Sources</i>
Game Commissioner 1931 . Authority of the Legislative Assembly, Victoria BC	upper Bridge River. Elk spreading to Gun Creek & main Bridge River District Fur bearing animals—fairly good number along the main Bridge River	MELP Surrey office, Jack Evans
Province of British Columbia, 1939. Report of the Provincial Game Commission 1938 . Authority of the Legislative Assembly, Victoria BC	Elk Yalakom game reserve contains many large heads.	Provincial Archives, MELP Kamloops: Doug Jury
Province of British Columbia, 1940. Report of the Provincial Game Commission 1939 . Authority of the Legislative Assembly, Victoria BC.	Elk in Bridge River area at head of Luluwisen Ck. Rocky Mountain Sheep scattered through the Bridge River basin.	Provincial Archives, MELP Surrey office, Jack Evans
Province of British Columbia, 1942. Report of the Provincial Game Commission 1941 . Authority of the Legislative Assembly, Victoria BC	Sheep - near the headwaters of Yalakom River...is a first-class area for the species.	Provincial Archives, MELP Kamloops: Doug Jury
Province of British Columbia. 1948. Provincial Game Commission Report. 1947 . Authority of the Legislative Assembly, Victoria BC	Moose hunted heavily at Bridge Lake Increase in moose reported in the Bridge River & Yalakom areas	Provincial Archives, MELP Surrey office, Jack Evans
Province of British Columbia. 1952. Provincial Game Commission Report. 1951 . Authority of the Legislative Assembly, Victoria BC.	Increase in Moose in the Bridge Valley	Provincial Archives, MELP Surrey office, Jack Evans
Province of British Columbia. 1947. Provincial Game Commission Report. 1946 . Authority of the Legislative Assembly, Victoria BC.	First moose appearance sightings: Deadman's Creek north of Pemberton 1929	Provincial Archives, MELP Surrey office, Jack Evans
Province of British Columbia Department of Attorney – General, 1955 . Provincial Game Commission Report.	Elk at Liza Lake in the Bridge River area.	Provincial Archives, MELP Surrey office, Jack Evans
Robertson, I., S. Bennett, and N. Page. 1998. Downton Reservoir Project. Wildlife Survey - Spring 1997 and Preliminary Assessment of 1996 Deep Drawdown. Report prepared for BC Hydro by: Robertson Environmental Services Ltd., Mirkwood Ecological Consultants Ltd., & Coast River Environmental Services Ltd. 62 p.		BC Hydro
Taylor, E.W. 1962. Progress and Activities Reports.	Bridge River harvest records for blue grouns, ruffed grouse, ducks and deer 3 male & 6 female Mountain Goats taken – reference from C/O R. Welsman	Provincial Archives, MELP Surrey office, Jack Evans
Tobler, Douglas. N.d. <i>Desecration of an Enchanted Kingdom</i> .	effects of logging; environmental aspects	VanPubLib: 634.90711
Wright, K.G. 1998. A preliminary survey of Harlequin Duck broods and other riverine birds on the Bridge and Yalakom rivers, British Columbia. Report of the Harlequin Conservation Society to B.C. Hydro, Power Supply, Vancouver, BC. 17 p.		BC Hydro
Wright, K. G., and R. I. Goudie. 1998. Breeding ecology of the Harlequin Duck (<i>Histrionicus histrionicus</i>) in the southern Chilcotin Mountains, British Columbia, 1998 Field Report. Draft Report of the Harlequin Conservation Society to B.C. Hydro, Power Supply, Vancouver, BC.		BC Hydro

Chapter 11

SETON RIVER WATERSHED



Figure 11-1. Seton Dam nearing completion about 1955 (Roos 1991)

1. PROJECT DESCRIPTION

1.1 Facilities

The Seton project, in service by 1956, consists of Seton Dam below the outlet of Seton Lake where water is diverted by canal then penstock to the powerhouse on the Fraser River. The Cayoosh Dam diverts water from Cayoosh Creek via tunnel to Seton Lake. About 80% of the total discharges through the Seton powerhouse originate from the Bridge River system via major diversions into Seton Lake.

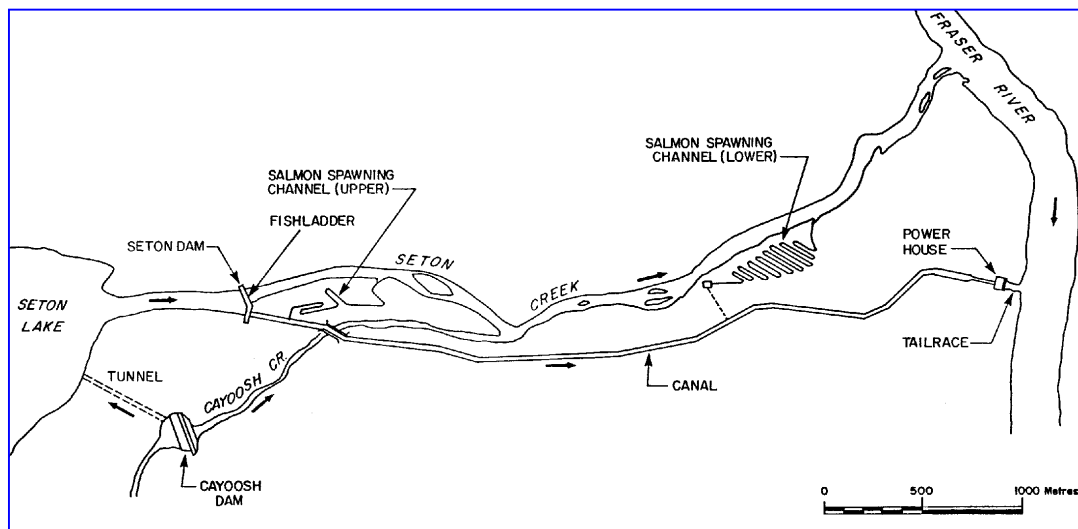


Figure 11-2 . Seton project facilities

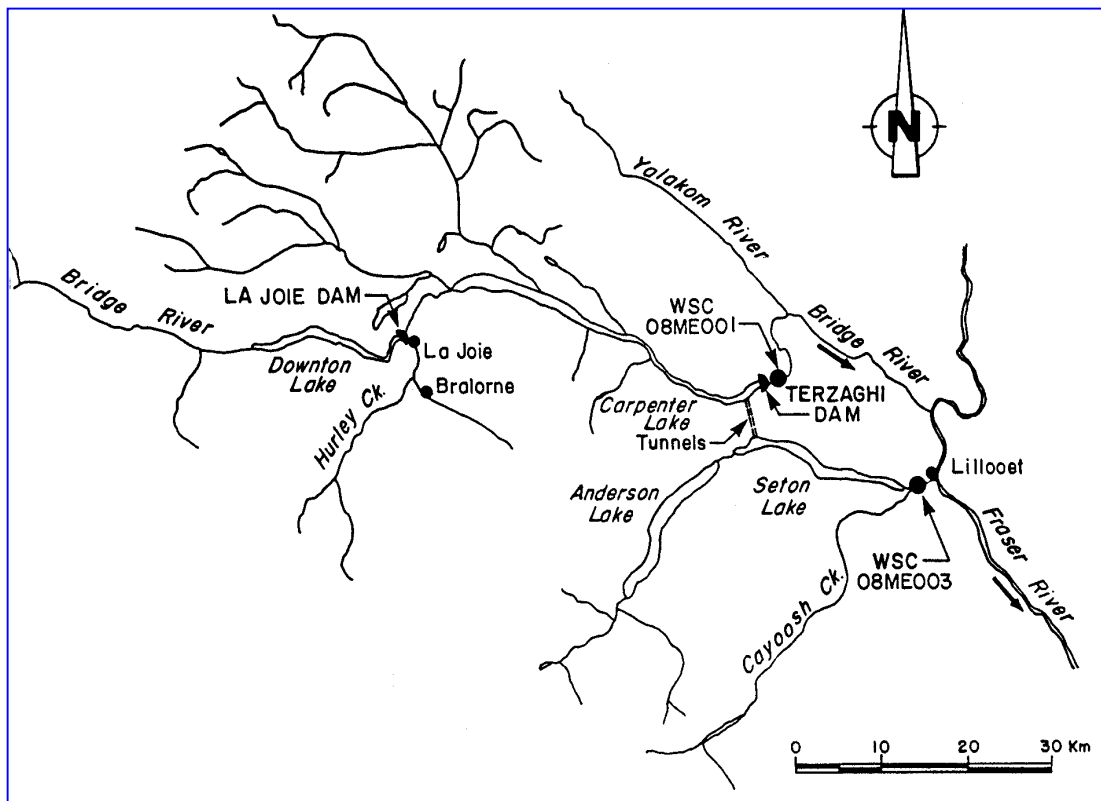


Figure 11-3. Location of Seton River hydro project

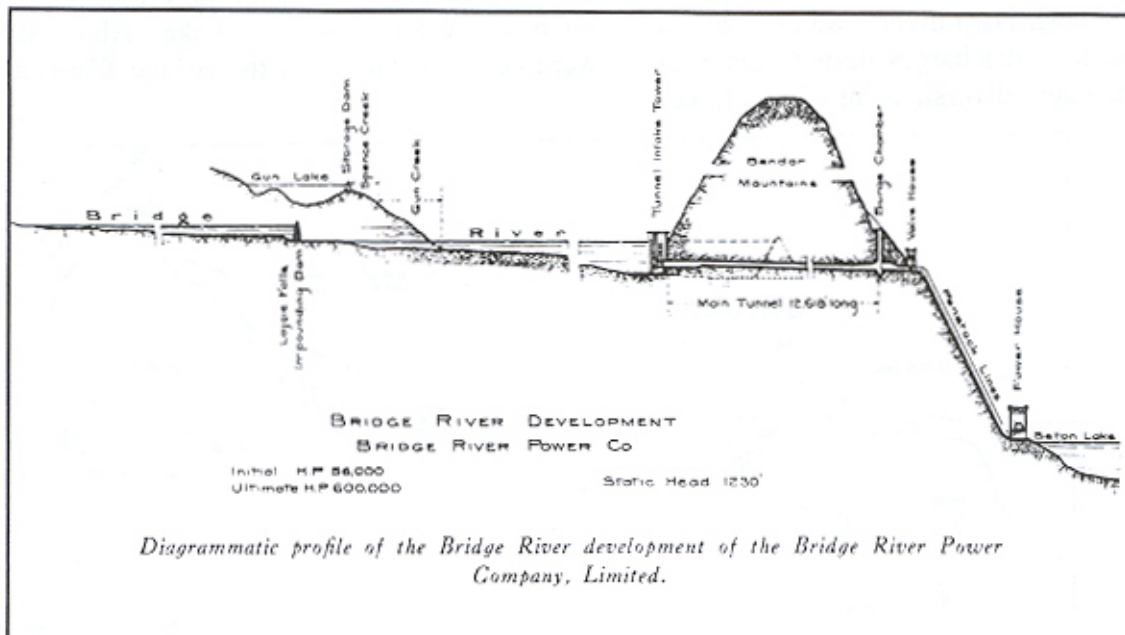


Figure 11-4. Historic Bridge-Seton River power scheme (Water Powers B.C. 1954)

Specifications for the facilities and reservoirs:

DAM	Seton	Cayoosh
Nameplate capacity (MW)	42	0
Dependable capacity (MW)	42	0
Dam function	S, D	D
Date constructed		1956
Date operational	1956	
Date reconstructed		1993 *
Height (m)	7.6	5.8 (1956 dam)
Length (m)	130	250 (1956 dam)
Dam footprint area (m ²)	2,286	
Fishway at dam	yes	no
Historic anadromous fish presence	yes	falls immedi. u/s

RESERVOIR	Seton Lake	no
Cleared/ not cleared	- -	n/a
Present area (ha)	2530	0
Orig. lake area (ha)	2503	0
Watershed area (km ²)	1011	878
Present elevation a.s.l. (m)	237	
Normal drawdown range (m)	0.4	
Mean depth (m)	85	
Maximum depth (m)	150	
Storage (million m ³)	9.4	0
Mean water retention time		
Mean annual discharge (m ³ /s)	117 incl. diversions	17

DIVERSION	to Fraser River	to Seton Lake.
Structure type	canal	channel, tunnel
Licensed flow (m ³ /sec)	143	>7
Fish flow release (m ³ /sec)	5.7-11.3	first 7
Mainstem length diminished (km)	4.6	1.8
Mainstem length augmented (km)		

* In 1993 a new tailrace for the West Kootenay Power (formerly Walden North) project discharges to BC Hydro's diversion tunnel to Seton Lake via a 300 m long channel.

1.2 Hydrology

1.2.1 Basin and Runoff

The Seton River basin is located in the rainshadow of the southern coastal mountains about 200 km northeast of Vancouver, and drains into the Fraser River at Lillooet. The Seton basin adjoins and lies immediately south of the Bridge River basin, separated by the Bendor Range and Mission Ridge. There are no existing glaciers within the watershed and most mountain peaks are lower than those in the Bridge River watershed. Elevations within the Seton basin range from 230 m to 2716 m, and the mean elevation is 1500 m (BCH 1991).

Gates and Anderson lakes provide significant storage within the basin. Gates River connects these two lakes and is 12 km in length. Anderson Lake drains into Seton Lake through the 2 km long Portage River. Major features of the two large lakes were compared by Geen and Andrew (1961):

	Anderson L.	Seton L.
Surface area	2833 ha	2428 ha
Volume	3,700 million m ³	2,097 million m ³
Mean depth	140 m	85 m
Maximum depth	215 m	150 m
Elevation a.s.l.	258 m	237 m

1.2.2 Operation and Licensed Diversion Flow

Seton Lake has a total average inflow of about 117 m³/s of which 19 m³/s comes from the Seton basin, 16 m³/s is diverted from the Cayoosh Creek system, and 92 m³/s (78%) is diverted from the Bridge River basin (BCH 1994). The seasonal flow regime of the Bridge River watershed now dominates the operation of Seton Lake reservoir.

1.2.3 Habitat Types Flooded by Reservoir

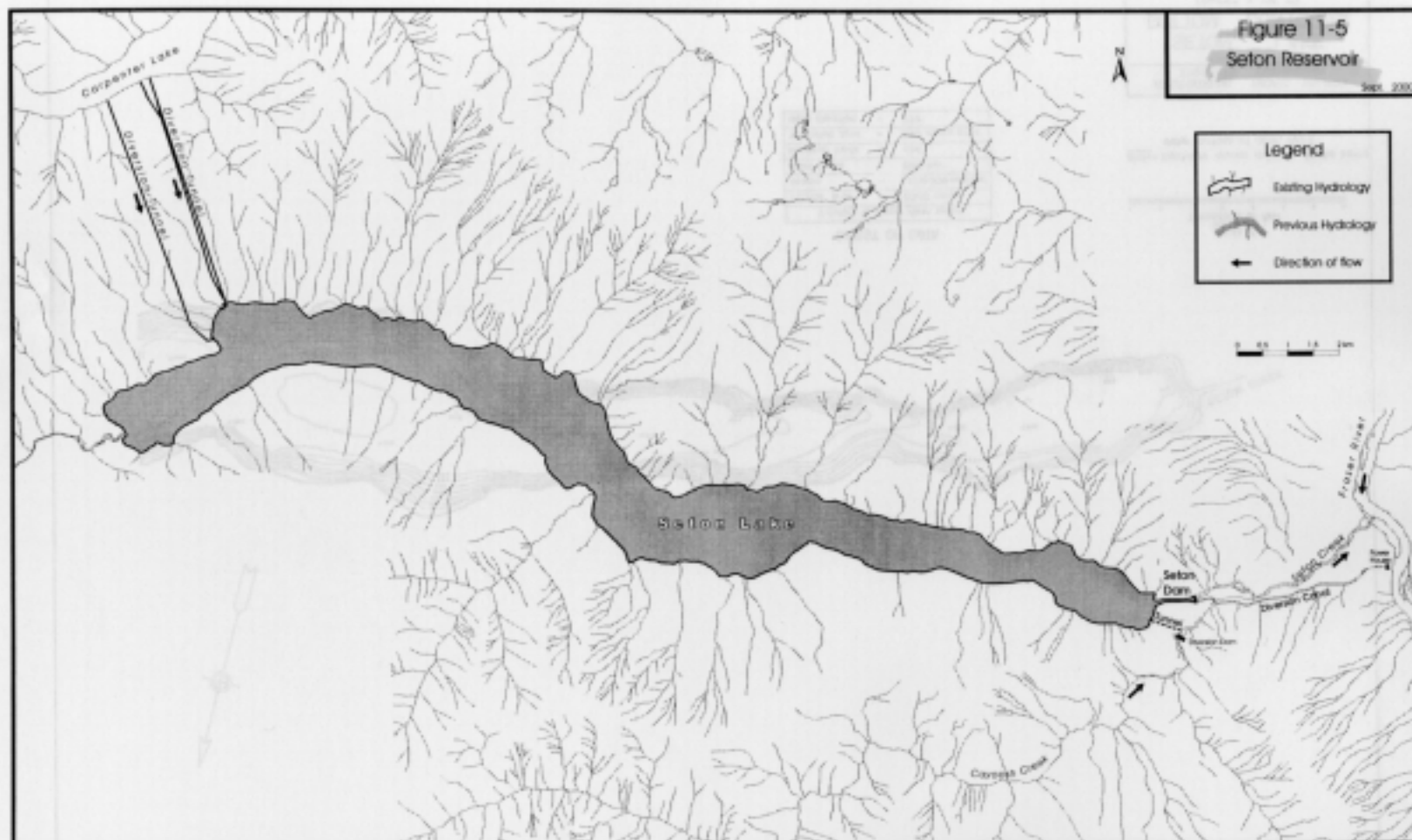
Reservoir impoundment raised the elevation of the original Seton Lake by about 2 metres. The reservoir area is 2,530 ha after flooding 27 hectares of land (Figure 11-5). The lake and reservoir shoreline lengths are the same at 52 km. Bathymetric features of Seton Lake are shown in Figures 11-6 and 11-7.

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Seton Lake Reservoir	Original habitat lost
Lake flooded (ha)	2503
Land flooded (ha)	27
Lake shoreline (km)	52
Mainstem: length (km)	0.5
channel (ha)	3
riparian * (ha)	3
Tributary: length (km)	0
riparian ** (ha)	0
Wetland: (ha)	0

* mainstem riparian zone calculated 30 m from each bank

** tributary riparian zone calculated 15 m from each bank



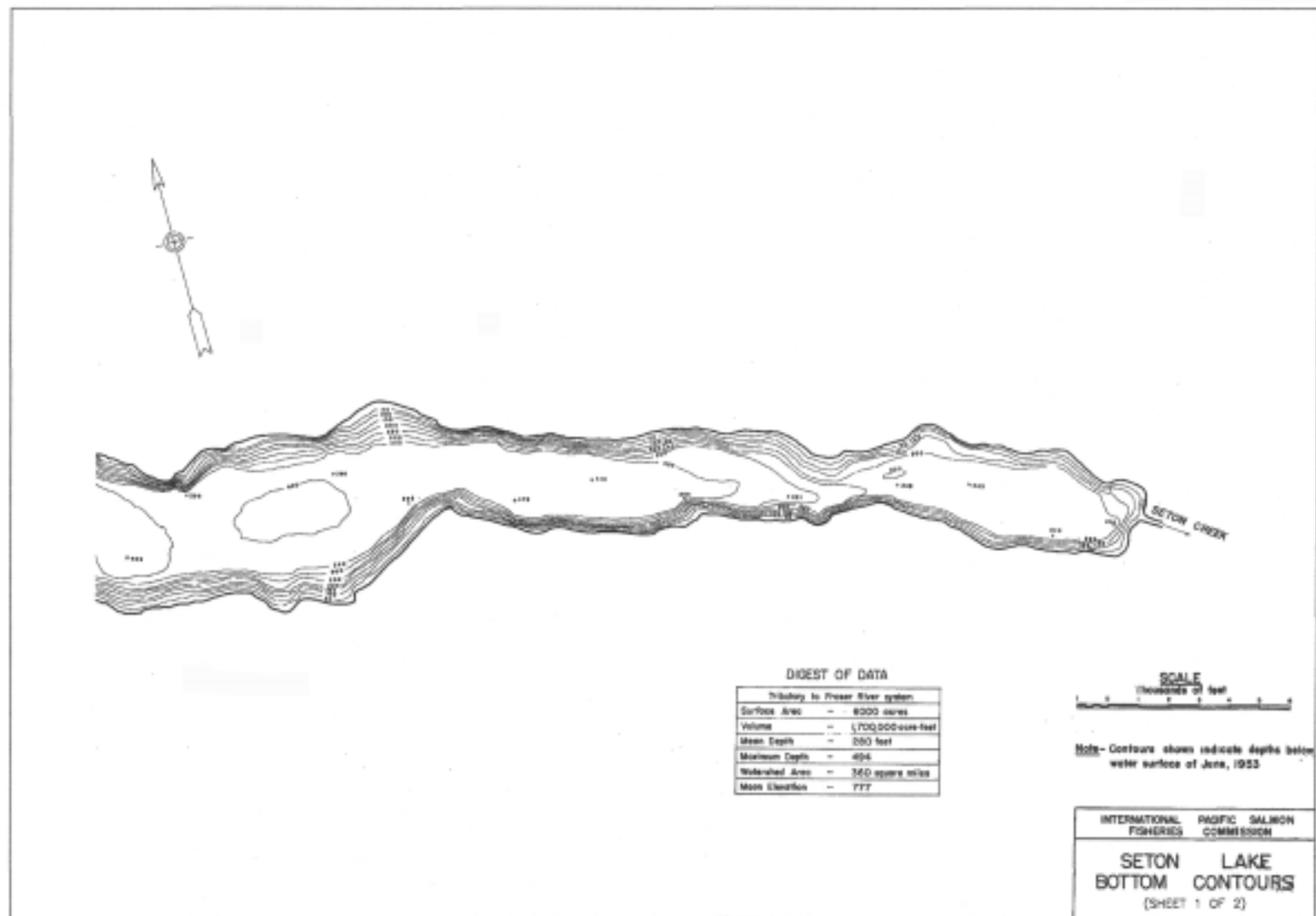


Figure 11-6. Bathymetric map of Seton Lake (Sheet 1)

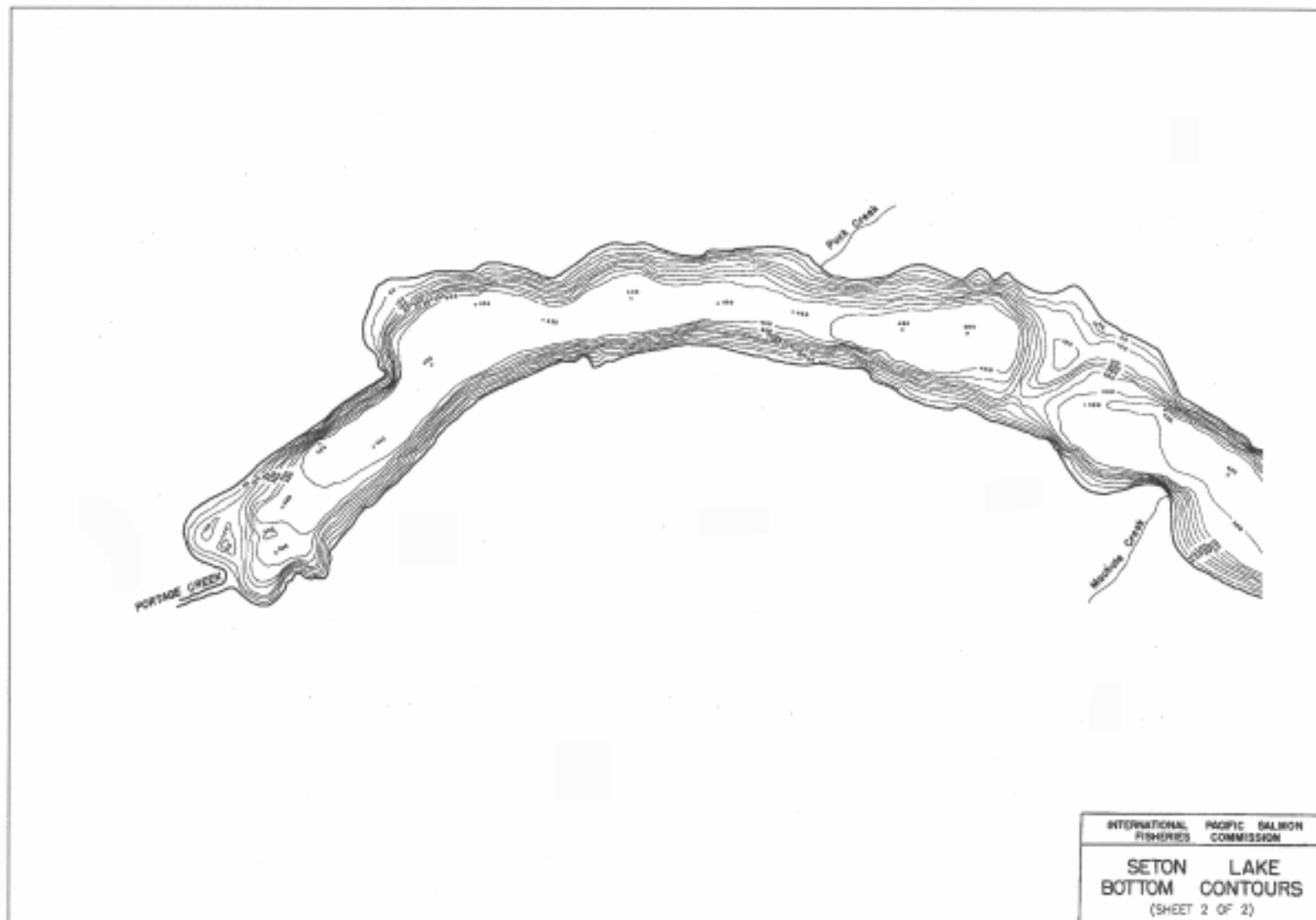


Figure 11-7. Bathymetric map of Seton Lake (Sheet 2)

2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Seton River watershed is provided in Table 11-1. At the turn of the previous century, Seton River was initially called “Lake Creek” and was then considered a short tributary to the main Cayoosh Creek which continued to the Fraser River (Babcock 1903).

Anadromous fish stocks in the Seton system were affected by two significant events prior to the major hydroelectric development. An increasingly intensive harvest of Fraser sockeye stocks by canneries in Puget Sound and coastal British Columbia began in 1863 and peaked in the 1890’s (Roos 1991). By 1903 concerns over the declining escapements of sockeye to Seton River prompted the construction of the first sockeye hatchery in British Columbia (Babcock 1904). The Seton Lake Hatchery (Figure 11-8) operated in the vicinity of the present dam until 1915 when effects of the second major impact, the Hells Gate slides, decimated Seton’s returning stocks. Geen and Andrew (1961) suggested that high rates of pre-spawning mortality and naive husbandry techniques at the hatchery may have also contributed to the early decline of the Seton-Anderson stock. By 1911, a salmon weir had been placed across the lake outlet, presumably to aid broodstock collection (Figure 11-9).

The second impact on Seton’s anadromous stocks was the series of rock dumping and slides from railway construction that began to narrow the Fraser River at Hells Gate, beginning on the west bank as early as 1885. The larger rock slides that slid into the Fraser River Canyon in 1913 and again in 1914 had a catastrophic effect on returning salmon populations.

After much of the rock was removed by March 1915, no further work was done due to conflicting opinions about fish passability and international allocations. After another slide occurred in 1941, the International Pacific Salmon Fisheries Commission constructed permanent fishways on both banks around Hells Gate between 1944 and 1947 (Roos 1991). During those 32 intervening years, passage conditions through Hells Gate varied periodically and affected the abundance or condition of salmon returning to the Seton watershed.

2.1.1 Upstream of Seton Dam

Before the Seton project was completed in 1956, anadromous runs of sockeye, pink, chinook, and coho salmon and steelhead had access to the lake. White sturgeon were reported in the lake. Fish passage facilities for salmonids were incorporated into the dam structure but these would not be suitable for sturgeon. Rainbow trout, bull trout and Dolly Varden char, kokanee and mountain whitefish are the resident sportfish. Babcock (1903) reported burbot and a unique form of kokanee called *oneesh* in Seton Lake.

Notes by J.A. Tubb (1938) during a spawner survey indicated the presence of two earlier dams across Seton River. The first dam, at the mouth of the lake, consisted of a 45 m long by 1.2 m high mound of boulders and rubble with two stoplog openings on the north side. The spillway had a drop of 1m over a length of 8 m. “Unless the run of fish is very heavy, the dam probably does not become a serious obstruction...”

Table 11-1. Fish species in the Seton River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Seton River Upstream ↓ Downstream	Anadromous Salmonids								Sport Fish								Non-Sport Fish								Red/Blue Listed Fish															
	Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish*	Peamouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	Dace General	Longnose Dace			
Gates Lake																																								
Gates River																																								
Blackwater Creek																																								
Spruce Creek																																								
Haylmore Creek																																								
Anderson Lake																																								
Connel Creek																																								
Portage R. (Seton Mainstem)																																								
Whitecap Creek																																								
Seton Lake																																								
SETON DAM	Fishway is present.																																							
Seton Mainstem																																								
Cayoosh Creek																																								
CAYOOSH DAM	No fishway.																																							

* - now named *Northern pike minnow*

- 1 - also a unique "oneesh" form (Babcock 1903)
2 - unique distribution record (J.D. McPhail, UBC)
3 - Komori 1997

- 4 - RL&L 1999
5 - Babcock 1903
6 - unconfirmed



Figure 11-8. Seton Lake Hatchery in 1910 (BC Archives)



Figure 11-9. Salmon weir at outlet of Seton Lake in 1911 (BC Archives)

2.1.2 Downstream of Seton Dam

A second dam, constructed by the Pacific Great Eastern Railway 100 m upstream of the confluence of Seton River and Cayoosh Creek, had been present at least since 1932 (Tubb 1938). It was 14 m long and 2 m high, with a 2.5 m wide fish ladder that was 6 m long in 3 steps. A screened intake led to the 750 m long flume and small P.G.E. powerhouse on the north bank. There was no indication of where the electric power was used.

Fish species currently found in Seton River are similar to those in the 2.2 km accessible portion of Cayoosh Creek below West Kootenay Power's new tailrace/diversion structure built in 1993.

The original habitats in Seton River were very different than those that occur today. An area of low marshy habitat existed near the Fraser confluence (workshop 2000). Photographs of Seton River circa 1910-14 indicate a more significant riparian zone and forested slopes than at present (Figures 11-8; 11-10). The P.G.E. Railway was constructed along the north shoreline of Seton Lake in 1911-12. About 25 years later, there was considerable development in the small valley. Tubb (1938) described Seton Creek as being accessible by foot along most of its course, but parts of the banks were covered with thick brush. His sketch showed four active and one abandoned road and pedestrian bridges across Seton River, two bridges across Cayoosh Creek, two active and one abandoned dams including two flumes, remnants of a retaining wall (hatchery site?), and a commercial campground for automobiles.

Figure 11-1, taken near the completion of the hydroelectric construction, showed some of the extensive grading of the river banks in the left channel downstream of the dam. Some of the other construction practices described in an historical file (DFO 1953) would be considered harmful by today's environmental standards.

Loss of a major spawning area for pink salmon at the lake outlet was compensated by construction of two artificial spawning channels downstream. Seton Hatchery records indicate that in 1911, the last cycle year preceding Hells Gate, 200,000 pinks spawned in the Seton watershed (Andrew & Geen 1958). These channels, plus improved passage conditions at Hells Gate and a general reduction in commercial harvest of pinks, have essentially restored the pink salmon population. However, other species, such as chinook and coho and resident species that also traditionally spawned at the lake outlet, have not been accommodated by the two channels.

2.1.3 Downstream of Seton Powerhouse

The powerhouse tailrace discharges into a semicircular basin approximately 100 m x 75 m that was excavated in a gravel bench of the Fraser River about 1.5 km downstream of the Seton River confluence.

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Seton Lake Reservoir	1. Reservoir footprint flooded 0.5 km of mainstem channel and associated riparian zone: .	x		
	2. Dredging of 45,000 m ² to construct the approach channel included loss of major spawning habitat for pink salmon and other species; The principal area was the first 150 m of the lake outlet and scattered spawning in remainder.	x		DFO Kamloops files
	3. Major diversion of Bridge water has changed temperature regime and nutrient productivity of Seton Lake, affecting productivity for sockeye.	x		Geen & Andrew 1961
Seton Dam	4. Dam footprint of 2,286 m ² : loss of instream, riparian and upland habitats.	x		
	5. Sediment released during construction.	x		DFO Kamloops files
	6. Seton Dam has reduced LWD recruitment to Seton River downstream.	x		workshop
	7. Seton salmon are attracted to discharges >60m ³ /s through radial gate and they delay ascending fish ladder at Seton Dam on opposite side of channel.	x		Andrew & Geen 1958
	8. Adult pink salmon are impinged on the fish screens at the power canal intake structure.	x		Fretwell 1980
	9. Spill and siphon mortality, injury to downstream migrants.	x		Andrew & Geen 1958
	10. Fishway does not accommodate large chinook, sturgeon.	x		workshop
Seton River downstream	11. Increased volume of spills after Bridge diversion has scoured gravel and reduced spawning and rearing habitat suitability in the mainstem.	x		BCH 1994
	12. Spills cause mortality by stranding fish.	x		BCH 1994
	13. Present fish flows restrict instream habitat quantity and access to former offchannel habitat; spawning channels offset to some degree.	x		workshop
	14. Cooler water from Bridge diversion may benefit upstream migrants in Seton River; but major spills can impede migration.	x	x	workshop
	15. Migrating Seton fish delay at entrance to spawning channels.	x		Fretwell 1980
	16. Construction of the project facilities reshaped the channel and banks, removed aggregates, and removed riparian vegetation over an extensive distance below the dam and at the confluence of Cayoosh Creek.	x		DFO 1953
Cayoosh Cr. downstream	17. Diversion of Cayoosh water from July to November assists sockeye to home to Seton River and not to tailrace discharge; but diversion diminishes available habitat area in downstream channel.	x	x	Fretwell and Hamilton 1983

	18. Cayoosh diversion dam has reduced gravel and LWD recruitment to creek downstream.	x		workshop
	19. Diversion in winter decreases temperatures in lower creek.	x		workshop
Seton Diversion to Fraser River	20. The tailrace pool approximately 7,000 m ² was excavated in a gravel bench along the Fraser R.; but hydraulic conditions may provide unique potential habitat.	x	x	
	21. Juvenile sockeye and pink salmon are impinged in wood debris on the penstock intake trashracks.			Fretwell 1982
	22. Entrainment and mortality at trashracks and turbine; potential downstream benefits to scavengers.	x	x	Fretwell and Hamilton 1983
	23. Bridge River stocks attracted to Bridge homestream water mixed in the Seton tailrace at the Fraser River.	x		Fretwell 1989
	24. Seton adult fish are attracted, delayed or injured at tailrace before finding Seton River. Mitigated by controlling the % of Cayoosh Creek diverted into Lake which affects smell of tailrace water, and volume of flow discharged down Seton River.	x		IPSFC 1976; Fretwell 1980

Spawning capacity of Seton River was reduced due to gravels displaced by augmented flows through channel but somewhat offset by spawning channel for pink salmon. The operation and physical characteristics of Gates and Seton spawning channels tend to exclude species other than sockeye and pink salmon. Natural off-channel and overwinter habitats have been reduced along the Seton and Cayoosh mainstems due to diversions. Riparian zones are not well-established, partly due to augmented flows and spills from Bridge diversion. Spills at Seton Dam strand fish in the river downstream, and there is fish entrainment and mortality at the generating station. The size of the fish ladder restricts migration by larger chinook salmon.

Non-Hydro Impacts - Other impacts on fish in the Seton River watershed include historic effects of placer mining including other small dams, logging, homesteading, and road construction. Tubb (1938) reported that the only 'serious' case of pollution in the Seton watershed was the dumping of garbage into Seton Lake off shore from Shalalth, and that the local placer mining operations had not seriously affected the various creeks.

Railroad construction along the north side of Seton Lake had a potentially large and detrimental effect on Seton Lake fish populations due to probable filling of limited shoal areas and interception of gravel recruitment for shoreline spawners. Figure 11-11 shows the pre-impoundment shoreline conditions at the lake outlet in 1909.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.



Figure 11-10. Seton River in 1914 (BC Archives)



Figure 11-11. Landing at the east end of Seton Lake in 1909 (BC Archives)

The following are suspected factors that limit current levels of fish populations within the Seton River watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources.
2. **Reduced downstream habitat capability:** Habitats below Seton Dam are altered by the unnatural hydrograph, and by lack of sediment and wood recruitment.
3. **Reduced biological productivity:** Seton Lake and River have lower temperatures, reduced water clarity and an altered nutrient regime due to the high flushing rate and large proportion of Bridge River and Cayoosh Creek diversion inflows.
4. **Diversions:** The Cayoosh Creek diversion has had effects on wetted channel area, seasonal temperatures and stream productivity in both Seton River and Cayoosh Creek channels. Olfactory cues for sockeye returning to Gates and Portage creeks have been changed based on the proportion of Cayoosh water mixed in the tailrace discharge.
5. **Entrainment:** At least 10% of juvenile salmon that migrate downstream through the Seton powerhouse each year are killed. Mortalities to resident fish are unknown but likely small.
6. **Selective Fish Access:** Although there is a fishway in Seton Dam, large chinook salmon cannot pass through the automated fish counter.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve fish habitats in Seton River and lower Cayoosh Creek.

Discussion:

Portions of Seton River, Cayoosh Creek and their riparian zones were extensively altered during construction of the hydro project without mitigation. Habitats in both systems are affected by diversion schemes. Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve the existing habitats. Restoration activities should be preceded by a study plan to address limiting factors #1, 2 and 3 above that considers:

- operating flows and fish flows in both river channels (Seton River Water Use Plan)
- opportunities to purchase or covenant streamside properties for future habitat projects
- opportunities for habitat development and riparian planting
- potential conversion of the Seton spawning channels to a semi-natural and more complex channel suitable for, and accessible to, all local species
- potential habitat development sites with hydraulic characteristics that will operate within the expected regime of fluvial and riparian processes and require low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- artificial recruitment scheme to restore delivery of some sediment and wood to both channels

- identification and filling of data gaps on issues such as resident species using the Seton fishway, fish stranding after spills, etc. that may also constrain populations.

Objective 2: Conserve and improve habitats for resident fish stocks in Seton Lake and its tributaries.

Discussion:

Habitats for resident stocks were not significantly flooded by the hydro development except at the lake outlet. Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve key existing habitats in the Seton-Anderson watershed. Activities in response to limiting factor #1 above should be preceded by a study plan for the reservoir and tributary system that considers:

- operating flows and fish flows (Water Use Plan)
- opportunities to purchase or covenant key properties for future habitat projects
- identification of present key habitats that sustain stocks, particularly bull trout and kokanee, and locations for potential habitat works
- potential presence of white sturgeon isolated from the Fraser River since 1956.
- potential habitat development sites with hydraulic characteristics that will operate within the expected regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and riparian planting
- wildlife biodiversity values at all proposed fish habitat development sites
- impacts of reservoir level fluctuations on shoreline spawning
- current harvest pressures on stock recruitment
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 3: Restore the biological productivity of the reservoir system.

Discussion:

Post-project rearing conditions for sockeye salmon and kokanee in Seton Lake are considered to be less productive since the Bridge River diversion, and entrainment mortality of smolts has taken its annual toll at the powerhouse, yet despite these negative factors, sockeye escapements to Seton continued to increase. It is not known what proportion of this increase is due to stock management strategies, stock strength, lower exploitation rates by the various fisheries, or to biological factors. Still, it may be possible to improve productivity in certain resident fish-bearing tributaries, the littoral or pelagic zones of Seton Lake or Anderson Lake habitats that would benefit sockeye or other fish species, considering the large historic productivity of the system.

Undertake appropriate treatment, consistent with the BCRP strategy, to improve system productivity. Activities should be preceded by a study plan for the reservoir and tributary system, in response to limiting factor #3 above, that addresses:

- feasibility of a phased program of fertilization trials and performance indicators
- determination of appropriate low-level nutrient levels that included large historic sources from salmon carcasses

- potential methods to achieve self-sustaining nutrient levels to reduce costs in view of the high reservoir flushing rate
- ecological effects of fertilization on non-target plants and aquatic animals
- wildlife biodiversity values at all proposed fish habitat development sites
- identification and filling of data gaps on issues such as entrainment, harvest effort, etc. that may also constrain populations.

Objective 4: Improve fish passage upstream and downstream at Seton Dam.

Discussion:

The recent trials using a louver array to move juvenile downstream migrants to the fish passage features built into Seton Dam are encouraging; however, resident fish may continue to enter the power canal. Large upstream migrants such as chinook salmon cannot use the fishway. Undertake appropriate treatment, consistent with the BCRP strategy, to improve fish passage at Seton Dam in response to limiting factors #5 and 6 above, that addresses:

- cost-effective options that exclude all fish from the Seton power canal
- remediation of the fishway to accommodate large salmon

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

Red-listed species occurrences on file with the Conservation Data Centre include

- Spotted Owl (*Strix occidentalis*) (location information protected)

The survey of current wildlife use in the Bridge River watershed provided in Table 10-2 may represent many of the species present in the Seton watershed.

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Seton Dam & Reservoir	<i>Dam footprint of __ ha:</i> loss of coniferous forest and riverine habitats.	x		
	<i>Flooding of Seton Lake and shoreline and 27 ha of adjacent forested hillsides:</i> increased lake depth, loss of valley side coniferous forest, and lake edge riparian habitats, and associated wildlife losses.	x		GIS
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Feature	Description of Effects	Neg	Pos	Origin
	<i>Flooding of shoreline trees:</i> creation of snags for cavity nesting birds.		x	
Seton Canal	<i>Habitat change along 4.6 km canal r-o-w:</i> conversion of coniferous forest to shrub habitat and associated wildlife effects.	x	x	
	<i>Reduced flows in 4.6 km of Seton Creek:</i> unknown effects on downstream aquatic wildlife.	x	x	
	<i>Presence of 4.6 km concrete flume:</i> Hindrance to movement of large mammals (ungulates, bears); drowning mortality of animals trapped in flume.	x		
Cayoosh Dam & Tunnel	<i>Dam footprint of ___ ha:</i> loss of habitat.	x		
	<i>Flooding of ___ ha:</i> effects of small diversion reservoir on wildlife.	x	x	
	<i>Reduced flows and changed flow regime in ca 2.8 km of Cayoosh Creek:</i> unknown effects of on aquatic wildlife (e.g. American Dipper, Harlequin).	x	x	Hirst 1991

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Changes:** Altered flow regime has changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for tailed frogs, water shrews, harlequins and dippers.
2. **Reduced Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
3. **Wildlife Migration:** Possible impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions including through losses related to ice shelving.
4. **Diversions:** Wildlife (especially mammalian) mortality caused by some diversion structures, through entrainment and drowning. Potential hazards for non-aquatic or weak swimming animals.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat.

Discussion:

See limiting factor # 2. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.
- Improve nesting opportunities for osprey by providing artificial nesting structures.
- Protect and enhance existing riparian and wetland habitats.

Objective 2: Protect small groups of old or second growth trees in strategic locations for current and future nesting use by bald eagles or ospreys.

Objective 3: Improve habitats for aquatic wildlife in Seton River and Cayoosh Creek.

Discussion:

See limiting factor # 3 and 4. Prepare a habitat enhancement plan.

- Restore mainstem habitat complexity, to the extent feasible, and develop off-channel habitat, consistent with project evaluation criteria.
- Assess the feasibility of improving the channel habitat in Seton River and Cayoosh Creek by introducing suitable in-stream features (e.g. rocks, large wood debris).

Objective 4: Reduce ungulate losses due to ice shelving.

Discussion:

Assess the feasibility of mitigation and undertake measures as appropriate.

Objective 5: Create moose and elk winter range.

Discussion:

Work with forestry companies to leave shelter stands in association with logged clearings that provide forage.

- Establish vegetation in the reservoir drawdown zone, especially near creek or river deltas.
- Assess the feasibility of re-introducing elk.

Objective 6: Develop a wildlife management plan for the Seton watershed, with appropriate control of unnecessary human access wherever possible in areas of sensitive wildlife use.

Discussion:

In conjunction with habitat improvement measures, prepare a wildlife management plan that identifies and protects sensitive wildlife populations.

Objective 7: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Seton watershed.

4. SETON RIVER WATERSHED REFERENCES

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Reference	Notes	Source
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Chapter 12

MIDDLE SHUSWAP RIVER WATERSHED

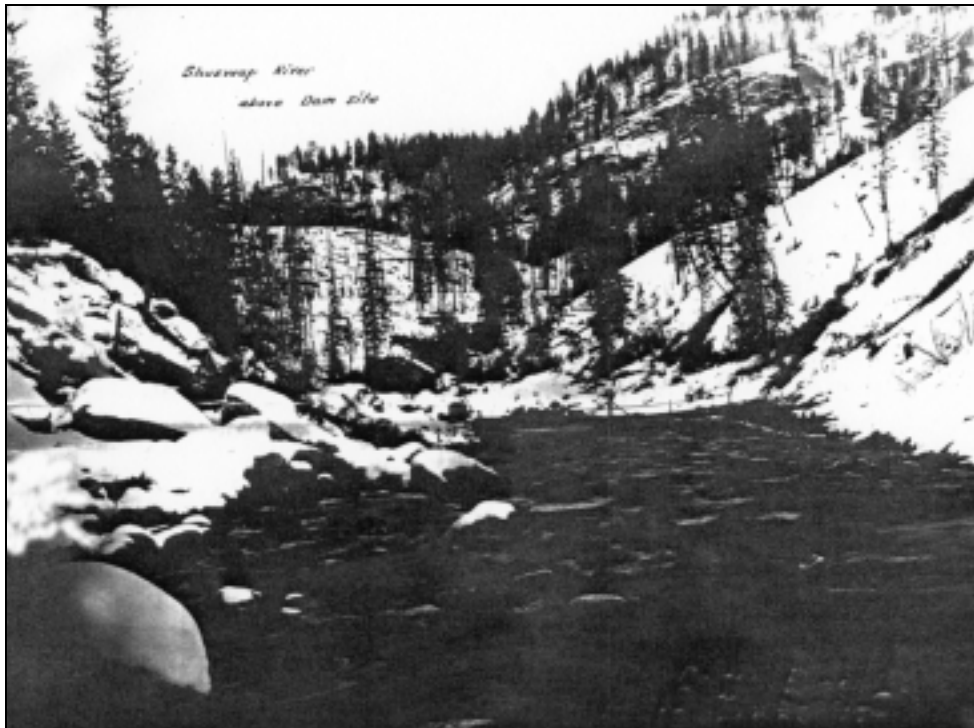


Figure 12-1 . Shuswap River above dam site (Couteau Power Company 1912)

1. PROJECT DESCRIPTION

1.1 Facilities

The initial plans for a power project at Shuswap Falls had been developed prior to 1912 by the Couteau Power Company based in Vancouver, B.C. The Shuswap Falls generating station, Wilsey Dam and Peers Dam were constructed and owned by West Canadian Hydroelectric Corporation and went into service in 1929.

The project consists of impounded storage in Sugar Lake controlled by Peers (Sugar Lake) Dam, and power generation from Wilsey Dam at Shuswap Falls 31 km downstream. The Shuswap Falls project was acquired by the B.C. Power Commission (a predecessor of B.C. Hydro) in 1945.

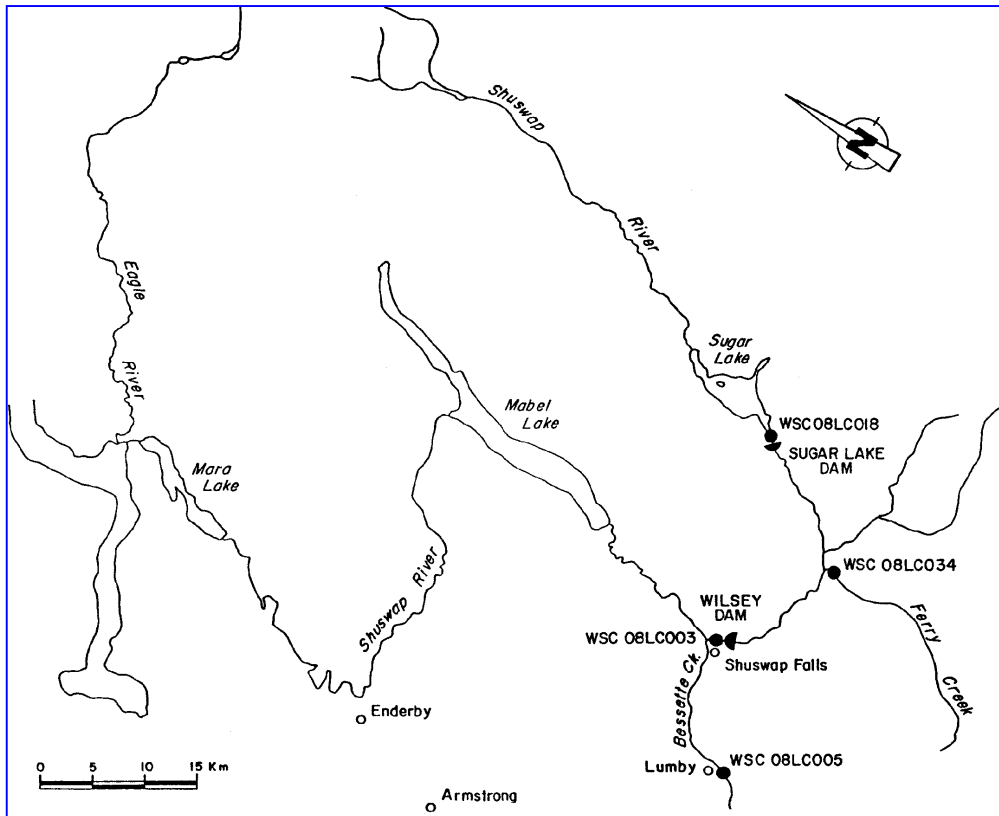


Figure 12-2. Location of Shuswap Falls hydro project



Figure 12-3. Wilsey Dam (Water Powers B.C. 1954)



Figure 12-4. Brenda Falls in 1920s (BC Archives)

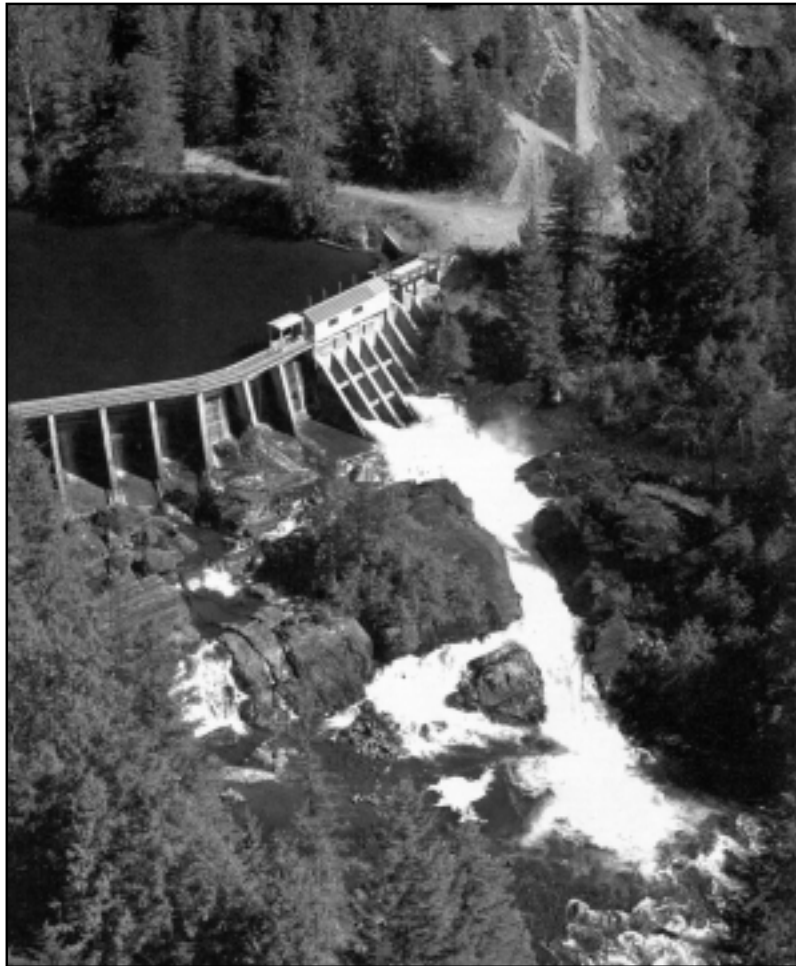


Figure 12-5. Sugar Lake Dam (BC Hydro)

Specifications about the structures and reservoirs:

DAM	Peers	Wilsey
Nameplate capacity (MW)	0	5.2
Dependable capacity (MW)	0	5
Dam function	storage	diversion
Date constructed		
Date operational	1929	1929
Date reconstructed		
Height (m)	13	30
Length (m)	98	40
Dam footprint area (m ²)		
Fishway at dam	no	no
Historic anadromous fish presence	unconfirmed	yes

RESERVOIR	Sugar Lake	headpond
Cleared/ not cleared	nc	n/a
Present area (ha)	2217	7
Orig. lake area (ha)	1564	0
Watershed area (km ²)		
Present elevation a.s.l. (m)	601.6	444.5
Normal drawdown range (m)	7.8 max	3
Mean depth (m)	35	
Maximum depth (m)	83	30
Storage (million m ³)	148	0
Mean water retention time	6 mo.	<1 day
Mean annual discharge (m ³ /s)	37	50

DIVERSION	--	to powerplant
Structure type	--	penstocks (140m)
Licensed flow (m ³ /sec)	--	31
Fish flow release (m ³ /sec)	5	8.5
Mainstem length diminished (km)		0.14
Mainstem length augmented (km)		

1.2 Hydrology

1.2.1 Basin and Runoff

The Middle Shuswap basin is located in the western ranges of the Monashee Mountains. Sugar Lake is normally fully drafted by March. The Shuswap River begins to rise in April after the winter months of decreased flow, and usually peaks in late May or early June. The runoff regime is dominated by melting of the large winter snowpack. A small amount of glaciation within the watershed does not contribute significantly to the flow regime. Rainfall is a minor contributor to the volume of the annual flow, but can produce large peak flows that lead to spilling (BCH 1994). Reservoir operation tends to delay the onset of spring freshet flows and elevates winter (December-February) flows (Lister 1990).

1.2.2 Operation and Licensed Diversion Flow

Various instream flow requirements are described by Lewis *et al.* (1996). For protection of the fish resource downstream of Wilsey Dam, a minimum of 300 (8.5 m³/s) must be released at all times, but a local operating order apparently supercedes this and currently allows a minimum release of 15 m³/s.

1.2.3 Habitat Types Flooded by Reservoir

Reservoir impoundment raised the elevation of the original Sugar Lake by about 7 m. The reservoir area is 2,217 ha after flooding 653 hectares of land (Figure 12-6). The reservoir shoreline length is now 41 km. The bathymetry of Sugar Lake is shown in Figures 12-7 and 12-8.

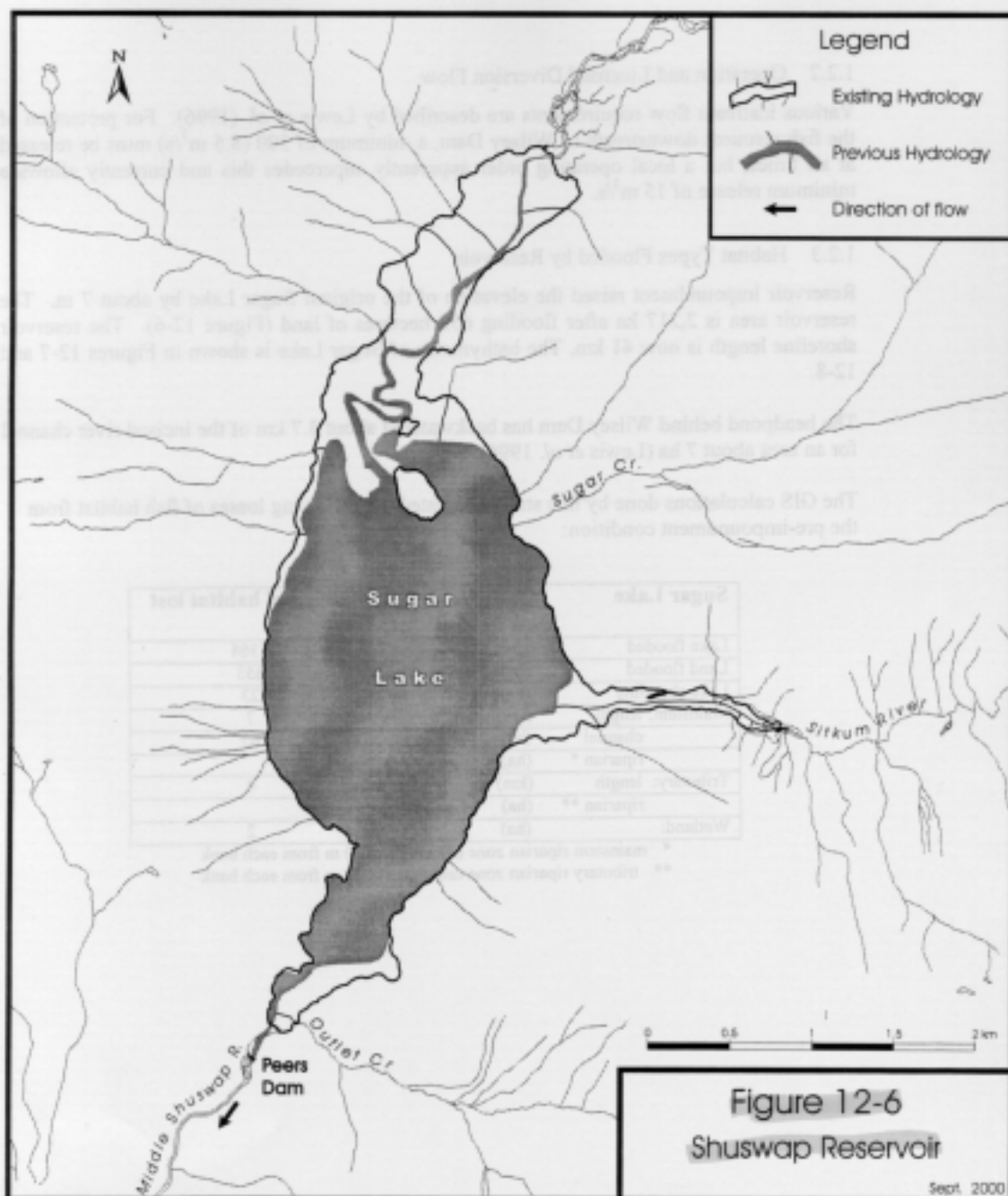
The headpond behind Wilsey Dam has backwatered about 3.7 km of the incised river channel for an area about 7 ha (Lewis *et al.* 1996).

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Sugar Lake	Original habitat lost
Lake flooded (ha)	1564
Land flooded (ha)	653
Lake shoreline (km)	23
Mainstem: length (km)	7
channel (ha)	65
riparian * (ha)	
Tributary: length (km)	4
riparian ** (ha)	
Wetland: (ha)	2

* mainstem riparian zone calculated at 30 m from each bank

** tributary riparian zone calculated at 15 m from each bank



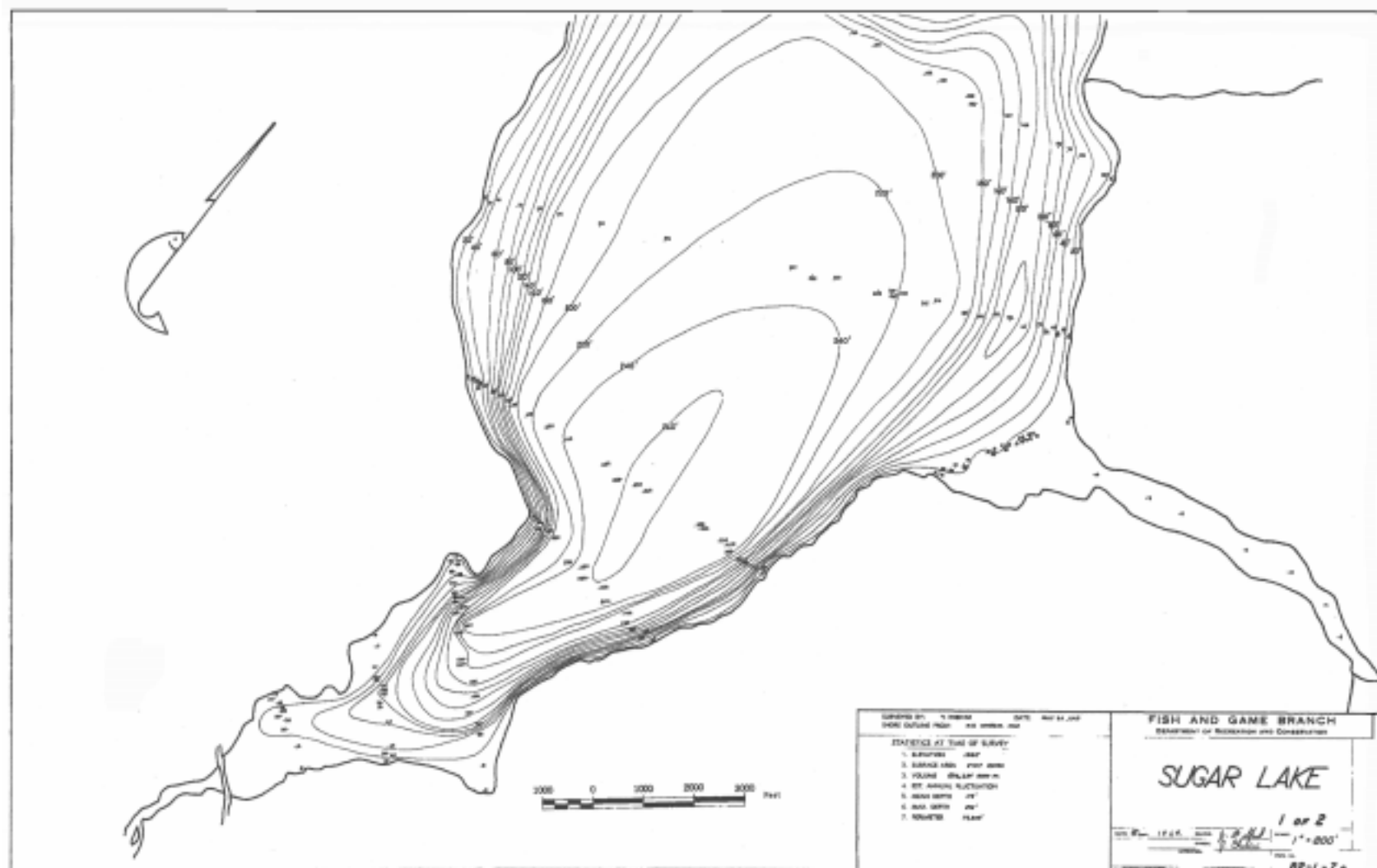
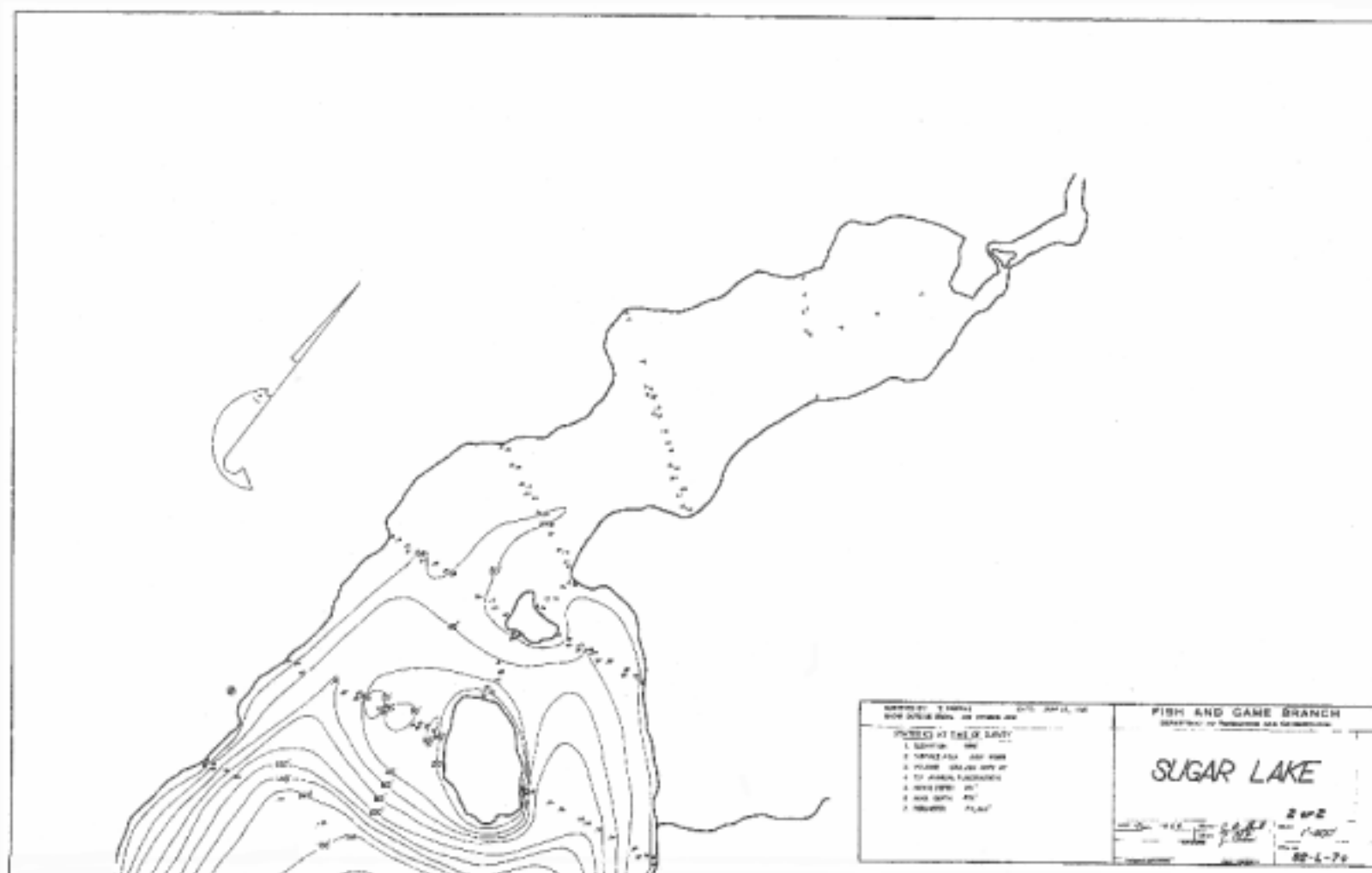


Figure 12-7. Bathymetric map of Sugar Lake (Sheet 1)



2. FISH

2.1 Historical and Current Species Presence

A list of current fish species within major reaches is presented in Table 12-1.

The catastrophic rock slides that blocked Hell's Gate in the Fraser River Canyon in 1913 and 1914 had a major effect on anadromous runs to the Middle Shuswap River. After much of the initial rock material was removed by March 1915, work was discontinued due to conflicting opinions within the agencies about their passability to fish until another small slide occurred in 1941. Finally, the International Pacific Salmon Fisheries Commission constructed permanent fishways on both banks around Hells Gate between 1944 and 1947 (Roos 1991). During these 32 years, flow conditions at Hells Gate periodically affected the abundance of salmon runs returning to the Shuswap watershed. This legacy may have led to an under-appreciation of salmon stocks using this system during the planning of hydroelectric development.

2.1.1 Downstream of Wilsey Dam

The early name for the Middle Shuswap River upstream of Mara Lake was originally the Spallumcheen River (Babcock 1903). Anadromous stocks of chinook, sockeye, pink and coho salmon had access to the entire river below Shuswap Falls but there was at least one point of difficult passage in the river below Mabel Lake. Mabel Lake was classified as non-productive for sockeye on a map of spawning grounds by the International Pacific Salmon Fisheries Commission (IPSFC 1945).

2.1.2 Upstream of Wilsey Dam

The original Shuswap Falls were a partial barrier to anadromous fish access; *e.g.*, fishing for chinook salmon near Cherryville was noted in the 1920's (French 1995), and there was an anecdotal report of sockeye in Sugar Lake (Babcock 1903). The original lower falls (Shuswap) were described as a succession of short drops totalling 12.2 m over a distance of 61 m in a narrow rocky canyon.

The original development by the Couteau Power Company in 1913 petitioned to the Chief Inspector of Fisheries against installing a fish ladder at Shuswap Falls costing \$20,000 to \$25,000 (Mackenzie 1913). Reasons given included the lack of a commercial river fishery, the inaccessibility of the river to sportsmen, the "sheer falls of 38 feet"¹ at the outlet of Sugar Lake, the proposed dam height of 70 feet, and the added financial burden to the project. An engineering plan of the proposed Wilsey Dam circa 1920 showed a fish ladder which was never built due to the proposed dam height of 21 m. Since its construction in 1929, Wilsey Dam has blocked upstream access to all anadromous stocks for 71 years.

¹ Shotton (1913), a fisheries officer, interviewed the surveyor for the project who told him that the upper [Brenda] falls had a sheer drop of 10 feet at most, and that the rapids section had a total fall of 38 feet in 1100.

Table 12-1. Fish species in the Middle Shuswap River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.

Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Middle Shuswap River upstream ↓ downstream	Anadromous Salmonids								Sport Fish								Non-Sport Fish																		Red/Blue Listed Fish			
	Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon	Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish *	Peanmouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	Dace General	Longnose Dace	
Upper Shuswap Mainstem Sugar Lake Kate Creek Sitkum Creek Outlet Creek																																						
PEERS DAM (Brenda Falls) No fishway																																						
Middle Shuswap Mainstem Reiter Creek Holstein Creek Cherry Creek Ferry Creek						1																																
WILSEY DAM (Shuswap Falls) No fishway																																						
Middle Shuswap Mainstem																																						

* now named *Northern pike minnow*

1 - re-introduced in some years

In 1977, DFO released 75 adult chinook salmon above Wilsey Dam as a trial. Chinook releases in 1993 and 1995 both resulted in fry that reared in the river above the dam (Triton 1994d; 1995c). The Ministry of Environment has expressed some concerns about effects of salmon transplants on resident salmonids (Jantz 1995).

2.1.3 Upstream of Peers Dam

The original Brenda Falls were described as not over 3 m in any one place, and that the series of rapids had a fall of 11.6 m in 335 m (Shotton 1913).

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Sugar Lake Reservoir	2. Reservoir footprint flooded 7 km of mainstem channel and associated riparian zone, including loss of Sugar Lake outlet spawning habitat.	x		
	3. Reservoir footprint flooded 4 km of tributary channel and associated riparian zone: loss of habitats in lower reaches.	x		
	4. Original 1564 ha lake was flooded by 7 m to create present 2217 ha reservoir: gain of 653 ha in reservoir habitat and uncalculated volume.	x	x	
	5. Fluctuating water levels of 7 m reduced productivity from shallow littoral habitats: see bathymetric map for shoal features	x		BC Hydro 1994
	6. Fluctuating water levels isolated the shoreline riparian zone from the aquatic environment: original lake shoreline was increased from 23 km to 39 km of reservoir shoreline.	x	x	
Peers Dam	7. Dam footprint of ___ m ² : loss of instream, riparian and upland habitats.	x		
	8. Debris booms at Peers Dam has reduced LWD recruitment to river downstream.	x		
	9. Peers Dam has stopped gravel recruitment from Outlet Cr. to river downstream.	x		
	10. Rapid flow changes below Peers Dam have affected benthic insect production.	x		BC Hydro 1994
	11. Peers Dam may have blocked anadromous access to Sugar Lake, but not substantiated.	x		
	12. Dam spill may cause gas supersaturation: magnitude unknown.	x		

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Shuswap R. between Dams	13. River has reduced productivity levels due to loss of carcasses from Sugar Lake outlet spawning area.	x		
	14. Loss of ~ 1km of river channel habitats beneath Wilsey headpond with siltation issues.	x		
Wilsey Dam	15. Dam footprint of ___ m ² : loss of instream, riparian and upland habitats.	x		
	16. Wilsey Dam has prevented chinook, sockeye, and possibly coho stocks from using at least 20 km of former spawning and rearing habitats above Shuswap Falls for over 70 years.	x		
	17. Wilsey Dam has reduced LWD recruitment to river downstream.	x		
	18. Wilsey Dam has reduced gravel recruitment to mainstem downstream for 3 km to the Besette Cr. confluence in former chinook spawning grounds.	x		workshop
	19. The penstock diversion to the powerhouse has dewatered 180 m of river channel below the base of the dam during low flows.	x		
	20. Dredging to remove silt in headpond has caused silt and BOD water quality problems downstream; trapping sand and silt may have improved spawning conditions downstream.	x	x	DFO 1970; 1971 Hirst 1991 BC Hydro 1997
	21. Dam spill may cause gas supersaturation: magnitude unknown.	x		
Middle Shuswap R. downstream	22. Regulated flows since 1929 have diminished the overall habitat capacity and stocks using the Middle Shuswap River downstream.	x		BC Hydro 1994
	23. Hatchery operation below Wilsey Dam has various effects on anadromous stocks.	x	x	
	24. Flow fluctuations have stranded fish and dewatered eggs; however, flow management has reduced impacts on kokanee spawning by confining them to main channel.	x	x	BC Hydro 1994; 1997
	25. Entrainment and mortality at turbine: unconfirmed. Potential downstream benefits to scavengers.	x	x	

Other Impacts - Other impacts noted by the workshop participants include effects of logging, and road construction from logging and public access.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Middle Shuswap River watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Blocked access to historic habitats:** Certain stocks of anadromous and migratory adfluvial resident fish have been excluded from habitats above Shuswap Falls (Wilsey Dam) for 71 years.
2. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, or operating flows; or from non-hydro sources.
3. **Reduced downstream habitat capability:** Physical habitats below both dams are altered by reduced sediment and wood recruitment.
4. **Reduced biological productivity:** Sugar Lake has reduced productivity from its shoals and littoral zone due to water level fluctuations. River productivity has decreased from flooding of the spawning ground at the Sugar Lake outlet, and from loss of historic chinook carcasses.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve fish habitats in the Middle Shuswap River below Peers and Wilsey dams.

Discussion:

Flow regulation has changed the morphology of the downstream river channel although flow augmentation in late fall-winter has beneficial effects on fish production as well. Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve the existing habitats. Restoration activities should be preceded by a study plan to address limiting factors #2 and 3 above that considers:

- operating flows and fish flows (Middle Shuswap River Water Use Plan)
- opportunities to purchase or covenant streamside properties for future habitat projects
- opportunities for habitat development and riparian planting
- potential habitat development sites with hydraulic characteristics that will operate within the regulated regime of fluvial and riparian processes and require low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- supplementing the recruitment of gravel and wood to mainstem channel
- identification and filling of data gaps on issues such as fish stranding after spills, etc. that may also constrain populations.

Objective 2: Conserve and improve habitats for resident fish stocks upstream of Wilsey Dam including Sugar Lake and tributaries.

Discussion:

The loss of the spawning ground at the outlet of Sugar Lake and the loss of gravel recruitment from Outlet Creek to the mainstem are particular effects of the project. Spawning success for kokanee and burbot have been affected by the drawdown regime. Undertake appropriate treatment, consistent with the BCRP strategy, to conserve, create or improve the existing habitats. Activities in response to limiting factor #2 above should be preceded by a study plan for each reservoir / headpond and tributary system that considers:

- operating flows and fish flows (Shuswap Water Use Plan)
- opportunities to purchase or covenant key properties for future habitat projects
- identification of present critical habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and riparian planting
- wildlife biodiversity values at all proposed fish habitat development sites
- current and future harvest pressures on stock recruitment
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 3: Restore biological productivity in Sugar Lake and the mainstem system between the two dams.

Discussion:

The annual loss of littoral productivity is a significant effect. The likely reduction in Sugar Lake's kokanee population caused by habitat loss may have lowered overall productivity in the lake and in the mainstem below Peers Dam. Undertake appropriate treatment, consistent with the BCRP strategy, to improve system productivity. Activities should be preceded by a study plan for the reservoirs and tributary systems, in response to limiting factor #4 above, that addresses:

- feasibility of returning nutrients to the system through a return of anadromous stocks or a phased program of fertilization trials and performance indicators
- determination of appropriate low-level nutrient levels that, for the mainstem between the dams, included historic sources from salmon carcasses
- potential methods to achieve self-sustaining nutrient levels and reduce costs
- ecological effects of fertilization on non-target plants and aquatic animals
- wildlife biodiversity values at all proposed sites
- identification and filling of data gaps such as entrainment, angling harvest effort, etc. that may also constrain population levels

Objective 4: Address feasibility of restoring access for all species that historically utilized the river above Wilsey Dam.

Discussion:

The original Shuswap Falls were a significant obstacle to all species. Some chinook salmon were known to pass upstream but their numbers and the particular flow conditions were not described. Undertake an appropriate study, consistent with the BCRP strategy and Section 1-3.2, to restore historic access to chinook salmon and other species that were present. A study plan, in response to limiting factors #1, 2 and 3 above, should consider:

- present operating flows and adequacy of fish flows (Water Use Plan)
- biological soundness in terms of donor stocks, their ecological interactions, current adequacy of habitat and productivity
- engineering feasibility of structures and flows for upstream and downstream passage
- management implications to future BC Hydro operations and for fisheries that presently exploit similar stocks
- identification and filling of data gaps on issues that may further constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

Little information exists about wildlife historically, although some old notes by government wildlife surveyors once existed describing habitat and wildlife of the Sugar Lake area; caribou and grizzly were mentioned (Brian Robertson MELP, pers. comm.). A 1921 Game Commission report mentions 50 caribou east of Sugar Lake.

Hatter *et al.* (1956) mentioned caribou and grizzly at Sugar Lake, that elk were seldom seen so numbers were difficult to estimate, and described Sugar-Mabel lakes as part of the principal grizzly ranges of the western and central portions of the Province. A MELP map of current grizzly bear distribution describes numbers as “Few” at Sugar Lake and “Nil” south of the lake.

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Peers Dam, Sugar Lake	<i>Dam footprint of ___ ha:</i> loss of riverine, riparian, and forested habitat.	x		
	<i>Flooding 649 ha of lowland and 25 ha of upland:</i> Loss of riverine, riparian, and lowland forested habitats at lake ends and dense coniferous forest along steep sides, with wildlife impacts that include loss of moose and grizzly habitat.	x	x	GIS
	<i>Barrier to salmon migration:</i> decreased forage for grizzlies, scavengers, and predatory birds using salmon at different life cycle stages.	x		Hirst 1991
	<i>Fluctuating reservoir water levels (7.8 m) due to hydroelectric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		BC Hydro
	<i>Modified downstream flows:</i> extent of wildlife impacts of highly variable daily and monthly flow fluctuations unknown.	x	x	Hirst 1991
Wilsey Dam	<i>Dam footprint of ___ ha:</i> loss of riverine and forested habitat.	x		
	<i>Flooding of 5.3 ha of river canyon:</i> minimal wildlife effects	x		Hirst 1991

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Changes:** Altered flow regime and land use practices have changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for water shrews, harlequins and dippers.
2. **Loss of Habitat:** Loss of riparian habitat in valley bottom above Sugar Lake. Loss of wetland habitats in flooded valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse for ungulates and breeding habitat for some species of neotropical migrants.

3. **Reduced Habitat Capability:** Lack of snags for cavity nesting habitat and structures for large raptor nests. Potential effects for primary cavity nestors (*e.g.*, woodpeckers) and secondary cavity nestors (*e.g.*, swallows, squirrels, bats).
4. **Reduced Productivity:** Lack of riparian vegetation in drawdown zone; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Sugar Lake.

Discussion:

Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.
- Improve nesting opportunities for osprey by providing artificial nesting structures.

Objective 2: Conserve riparian and wetland habitats in the Middle Shuswap River watershed.

Discussion:

Identify key habitats for conservation of biodiversity and enhanced production.

- Prepare and implement a riparian management plan for Middle Shuswap River to improve water quality and other habitat attributes.
- Undertake conservation, through protective measures, habitat acquisition and other means, in the lower reaches of the river or in the reservoir.

Objective 3: Create or enhance wetlands and riparian habitats for aquatic species (amphibians, waterfowl, cavity dependent species, small mammals, moose).

Discussion:

Consider various opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times.

- Create additional wetlands where feasible through activities such as flooding shallow basins in the watershed.

Objective 4: Protect small groups of old or second growth trees in strategic locations for current and future nesting use by bald eagles or ospreys.

Objective 5: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Middle Shuswap watershed.

4. MIDDLE SHUSWAP RIVER WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
1921 Pre-emptor's map, Vernon Sheet, 1:126,720 (see Sugar Lake) with contours	UBC map library
Legal survey 20 chain=1" Sugar Lake before flooding- field books from land surveys	Ministry of Environment, Lands and Parks, Legal Surveys Dept.
1;20,000 flood reserve map, 1990	Legal Surveys, MELP
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4.2 Hydro Facilities and Fish References

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Reference	Notes	SOURCES
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Webber, Jean (editor). 1999. <i>A rich and fruitful land: the history of valleys of Okanagan, Similkameen and Shuswap</i> . 239 p.		VanPubLib: 971.15 R49w; UBC: FC3845.O4R52 1999

4.3 Wildlife References

Reference	Notes	Source
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BC Fish & Wildlife Branch. 1977. Wildlife Distribution Mapping Series: Grizzly Bear Distribution and Relative Abundance.	Sugar Lake: Few – (1 bear per 55-400 sq. miles) South of Sugar Lake - Nil	MELP Surrey: Jack Evans
Hatter, J., D.J. Robinson, P.W. Martin, L.G. Sugden, E.W. Taylor and W.G. Smith. 1956. Inventory and Evaluation of Wildlife Resources of British Columbia. Reprinted from the 9 th BC Natural Resources Conference Transactions, February 1956.	“ Caribou bands are known to range in the following areas, but it is impossible at present to estimate numbers in this seldom observed species. Sugar Lake-Mabel Lake-Monashee. ”The principal grizzly ranges of the western and central portions of the province are the mountainous regions of the following areas:..Sugar Lake-Mabel Lake...”	MELP Surrey: Jack Evans
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Province of British Columbia, 1921. Annual Report of the Game Conservation Board of the Province of British Columbia 1920. Authority of the Legislative Assembly, Victoria BC	Caribou , ~50, east of Sugar Lake	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia, 1925. Report of the Provincial Game Warden 1924. Authority of the Legislative Assembly, Victoria BC	Mountain Goat plentiful in Sugar Lk. District	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia. 1952. Provincial Game Commission Report. 1951. Authority of the Legislative Assembly, Victoria BC	Mountain goats east of Sugar Lake	Provincial Archives, MELP Surrey: Jack Evans
Province of British Columbia. 1947. Provincial Game Commission Report. 1946. Authority of the Legislative Assembly, Victoria BC	Sugar Lake – set in high, bare-topped mountains with heavily timbered lower slopes. Lake raised 25ft by dam which has “spoiled” foreshore in most parts.	Provincial Archives, MELP Surrey: Jack Evans
Robertson, Brian, MOE Vernon: memory of old survey notes	Flooded Sugar Lake area once likely used by caribou & grizzly bear .	pers. comm.:

Chapter 13

CHEAKAMUS RIVER WATERSHED



Figure 13-1. Pre-impoundment Daisy Lake (BC Archives)

1. PROJECT DESCRIPTION

1.1 Facilities

The Cheakamus project consists of a dam across the Cheakamus River that impounds an enlarged Daisy Lake. Flows are diverted by a man-made canal to Shadow Lake Reservoir where a tunnel and two penstocks drop water to the powerhouse on the Squamish River. The powerhouse discharges into a 1800 m long channel that enters the Squamish River about 21 km upstream of the Cheakamus confluence. The plant was constructed by B.C. Electric Co. and became operational in 1957; it was rehabilitated in 1981 and 1988 by BC Hydro.

Specifications for the facility and reservoir:

DAM	Cheakamus
Nameplate capacity (MW)	150
Dependable capacity (MW)	155
Dam function	storage, diversion
Date constructed	1957
Date operational	1957

Date reconstructed	1981; 1988
Height (m)	29
Length (m)	680
Dam footprint area (m ²)	
Fishway at dam	no
Historic anadromous fish presence	no

RESERVOIR	Daisy Lake
Cleared/ not cleared	
Present area (ha)	395
Watershed area (km ²)	771
Present elevation a.s.l. (m)	394
Normal drawdown range (m)	13.1
Mean depth (m)	10
Maximum depth (m)	15
Storage (million m ³)	46
Mean water retention time	6 days
Mean annual discharge (m ³ /s)	23.3

DIVERSION	to Squamish R.
Structure type	tunnel (11km), penstock(440m)
Licensed flow (m ³ /sec)	27
Fish flow release (m ³ /sec)	5 (low water)
Mainstem length diminished Q (km)	26
Mainstem length augmented Q (km)	--

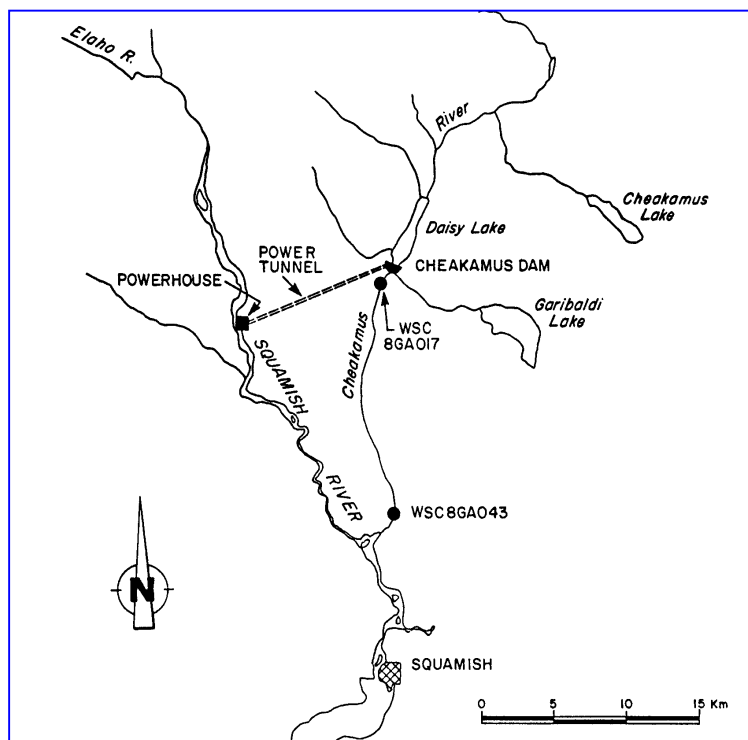


Figure 13-2. Location of Cheakamus hydro project

1.2 Hydrology

1.2.1 Basin and Runoff

The basin is in the South Coast Mountains which experiences high annual precipitation of which 20% is snow. Snowmelt runoff occurs May to August. Heavy rains from September to December, accompanied by a rise in freezing levels, can result in high peak flows.

1.2.2 Operation and Licensed Diversion Flow

The reservoir is drafted in August to reduce fall flooding risk downstream of the dam, and again in April to provide storage for inflow from snowmelt.

1.2.3 Habitat Types Flooded by Reservoir

The reservoir area is 395 ha after flooding 374 ha of land (Figure 13-3). The reservoir shoreline length is 22.4 km. The original Daisy Lake, 21 ha in area, was located to the east of the upper Cheakamus River; its bathymetry is shown in Figure 13-4. It flowed into the main river via a small tributary (Figure 13-3).

The GIS calculations done in this study estimated the following losses of fish habitat from the pre-impoundment condition:

Daisy Lake Reservoir		Original habitat lost
Lake flooded	(ha)	21
Land flooded	(ha)	374
Lake shoreline	(km)	3
Mainstem: length	(km)	15
channel	(ha)	70
riparian *	(ha)	91
Tributary: length	(km)	5
riparian **	(ha)	14
Wetland:	(ha)	12

* mainstem riparian zone calculated at 30 m from each bank

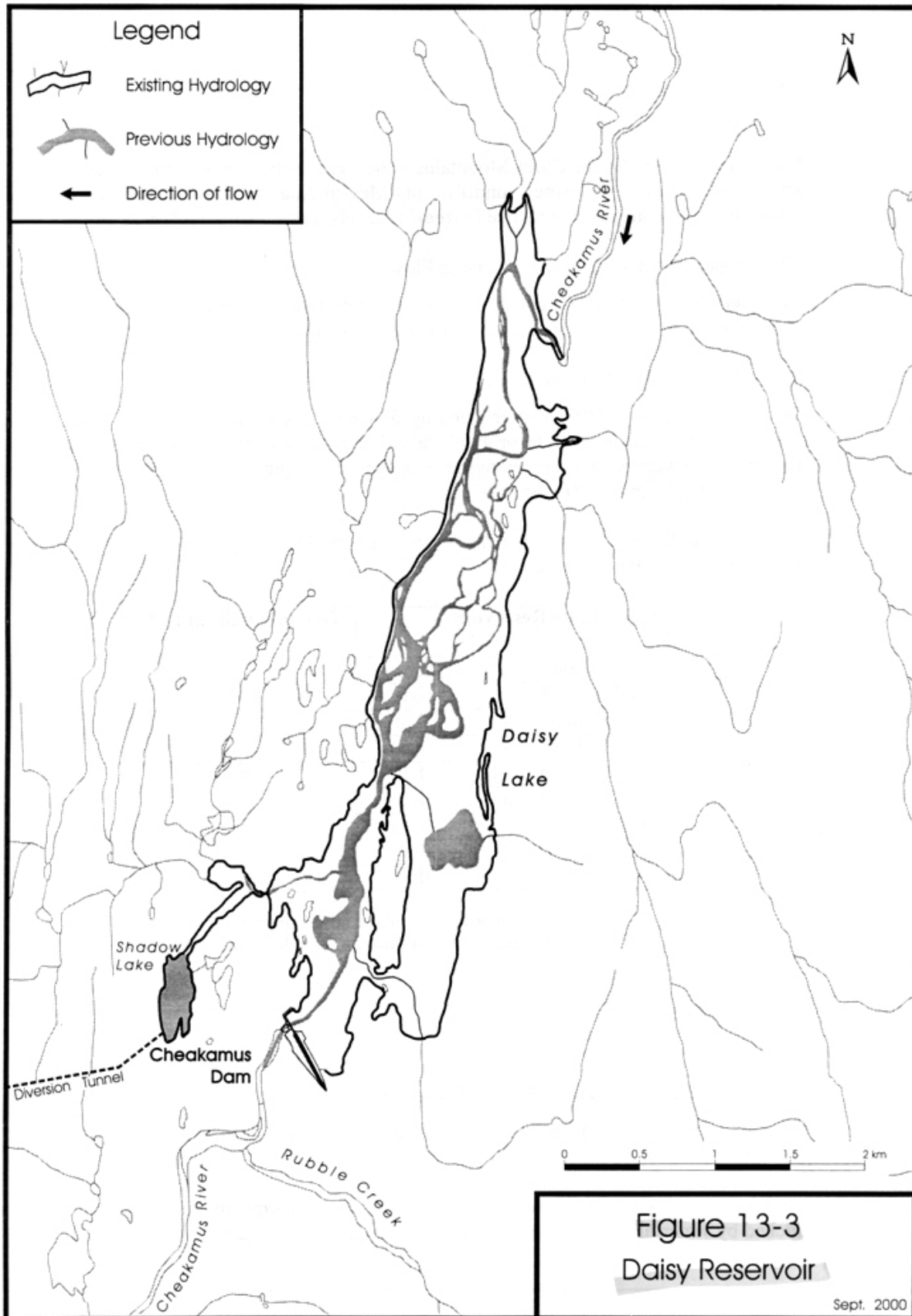
** tributary riparian zone calculated at 15 m from each bank

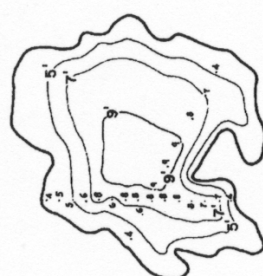
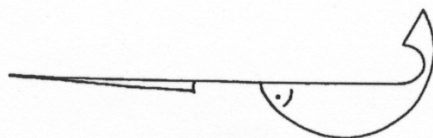
2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Cheakamus River watershed is provided in Table 13-1.

Anadromous fish were not present in the reservoir area. Passage up the Cheakamus River is blocked by waterfalls beginning about 17 km from its confluence with the Squamish River





SURVEYED BY: SHORE OUTLINE FROM:		DATE:
STATISTICS AT TIME OF SURVEY		
1. ELEVATION	1000'	
2. SURFACE AREA	42 ACRES	
3. VOLUME	285 AC.FT.	
4. EST. ANNUAL FLUCTUATION	5.0'	
5. MEAN DEPTH	4'	
6. MAX. DEPTH	73.82'	
7. PERIMETER		
FISH AND GAME BRANCH DEPARTMENT OF RECREATION AND CONSERVATION		
DAISY LAKE		
DATE: APR. 1968	MEASURED: J. G. B.	SCALE: 1" = 464'
CORRECTION:		
SURVEYOR'S SIGNATURE:		DATE: MAY 1968

Table 13-1. Fish species in the Cheakamus River watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfo/bc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Cheakamus River upstream ↓ downstream	Anadromous Salmonids	Sport Fish	Non-Sport Fish	Red/Blue Listed Fish																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
	Steelhead Cutthroat trout (sea-run) Dolly Varden (sea-run) Sockeye Salmon Coho Salmon Chinook Salmon Pink Salmon Chum Salmon	Rainbow trout Cutthroat trout Dolly Varden Bull trout Brook trout Lake trout Kokanee Mountain whitefish Lake whitefish Burbot Sturgeon (general) Green sturgeon	Sucker General Largescale sucker Longnose sucker Bridgelip sucker Northern squawfish* Peamouth chub Redside shiner Sculpin (general) Torrent sculpin Prickly Sculpin Slimy sculpin Coastrange sculpin Threespine stickleback Lamprey (general) Pacific lamprey River lamprey American shad Dace General	Longnose Dace																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
Cheakamus R. Mainstem Cheakamus Lake Millar Creek Nita Lake Whistler Creek Alpha Lake Callaghan Creek Callaghan Lake Madeley Lake Daisy Lake¹ Shadow Lake Brandywine Creek Roe Creek Cheakamus R. Mainstem Squamish 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* now named *Northern pike minnow*
 1 - Daisy Lake closed to all recreational activities due to landslide hazard
 2 - BC Fishing, Freshwater Directory and Atlas, 1999. OP Publishing Ltd. Van. BC.
 3 - Atlantic salmon also reported for this system
 4 - probable

(Lewis *et al.* 1996). Inflows to the reservoir are glacial and oligotrophic although nutrient loadings from the Whistler Sewage Treatment Plant have increased productivity (Lewis *et al.* 1996; Lucey *et al.* 1989). A preliminary study suggested that Daisy Reservoir is retaining soluble phosphorus from natural sources and the waste treatment plant (Perrin 1995).

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Daisy Lake Reservoir	1. Reservoir footprint flooded 15 km of mainstem channel and associated riparian zone	x		GIS
	2. Reservoir footprint flooded 4.7 km of tributary channel and associated riparian zone: loss of habitats in lower reaches	x		GIS
	3. Reservoir footprint flooded 21 ha of lake: gain of 374 ha in reservoir habitat and uncalculated volume.	x	x	GIS
	4. Fluctuating water levels of 13 m reduced productivity from shallow littoral habitats in small original lake: see bathymetric map for shoal features	x		workshop
	5. Fluctuating water levels of 13 m may limit fish access to tributaries.	x		BC Hydro 1994
Cheakamus Dam	6. Dam footprint of <u> </u> m ² : loss of instream and riparian habitats.	x		
	7. Dam has likely reduced LWD and gravel recruitment to river habitats downstream.	x		workshop
Cheakamus River downstream	8. Diversion of 80% of total annual discharge has diminished overall habitat and capacity in areas downstream; however, an increased fish flow release would benefit 26 km of summer habitat.	x		Lewis <i>et al.</i> 1996
	9. Loss of active side channel habitat in the lower river post-project is likely due to combined effects of river dyking and the altered flow regime. This is partly offset by DFO habitat developments for chum and coho, so most residual impact is on pink, chinook and steelhead stocks.	x		Kerr Wood Leidal 1998
	10. Reduced mainstem flows cause colder water from Rubble Cr. to dominate the diminished system and may have caused declines in some species.	x		Lewis & Guy 1996
	11. Reservoir and diversion have reduced downstream productivity in mainstem but presumably increased it in Squamish side channel.	x	x	
Diversion to Squamish River	12. Entrainment mortality and injury: magnitude unknown. Potential downstream benefits to scavengers.	x	x	
	13. Potential for elevated shortterm TGP events			Lewis et al. 1996
	14. Flow fluctuations in Squamish side channel may affect salmon spawning.	x		Lewis et al. 1996

Daisy Reservoir could be providing a beneficial increase in winter habitat area for resident trout and char over pre-impoundment levels. In the lower Cheakamus River, simplified channel complexity has reduced habitat areas for pink, chinook and steelhead stocks (Kerr Wood Leidal 1998). Dyking of the lower river by BC Electric/BC Hydro to protect transmission line towers from Bridge River Project has reduced river channel complexity and habitat areas. Lewis and Guy (1996) described the limited habitats available in tributaries between the dam and Squamish River. While chinook, coho, pink and chum salmon stocks in the Cheakamus River have declined since the hydro development in 1957, their respective abundance has also dropped in other Squamish tributaries and throughout much of the Georgia Basin region. This suggests that there are similar limiting factors for each of these stocks that may include harvest pressure (Kerr Wood Leidal 1998).

Non-Hydro Impacts - Other impacts on fish in the Cheakamus River watershed include effects of logging activities, dyking, and nutrient inputs from Whistler urbanization (positive impact).

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Cheakamus River watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions, operating flows, or from river dyking by BC Hydro and others.
2. **Reduced downstream habitat capability:** Habitats below the dam are altered by reduced sediment and wood recruitment originating from the upper mainstem.
3. **Reduced tributary access:** Fish access between reservoir and tributary habitat has been reduced due to large drawdown regimes.
4. **Diversions:** The diversion has reduced flows to Cheakamus River downstream and increased flows into a Squamish River side channel; these altered flows may have affected wetted channel area, seasonal temperatures and productivity in either or both of the respective systems.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve aquatic habitats in lower Cheakamus River.

Discussion:

Dyking and bridge construction on the lower river by BC Electric/BC Hydro to protect transmission line towers from Bridge River Project, and dyking by others has reduced river channel complexity and habitat areas. Undertake appropriate treatment, consistent with the BCRP Strategy, to conserve, create or improve existing habitat. Restoration activities should be preceded by a study plan to address limiting factors #1, 2 and 5 above, that considers:

- operating flows and adequacy of fish flow regime (Cheakamus Water Use Plan)
- temperatures of fish-flow releases during spawning, incubation and rearing
- opportunities to purchase or covenant streamside properties for future habitat projects
- potential sites for future habitat enhancement or creation
- artificial recruitment scheme to restore delivery of some sediment and wood to mainstem
- proposed projects should have hydraulic characteristics that will withstand the historic range of discharges with low maintenance
- wildlife biodiversity values at all proposed fish habitat development sites
- current harvest pressures on stock recruitment
- identification and filling of data gaps on issues that may also constrain populations.

Objective 2: Conserve and improve habitats for resident fish stocks in the Daisy Lake Reservoir and tributary system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP Strategy, to conserve, create or improve existing habitat. Activities in response to limiting factors #1 and 4 above should be preceded by a study plan for the reservoir and tributary system that considers:

- operating flow and reservoir regime (Cheakamus Water Use Plan)
- opportunities to purchase or covenant floodplain properties for future habitat projects
- identification of present critical tributary habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and for planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 3: Improve habitat conditions for fish stocks using the Squamish River side channel below the tailrace.

Discussion:

A data gap exists with respect to the historic and potential future use of this side channel for fish and wildlife. Activities should be preceded by a study plan, in response to limiting factors #1 and 5 above, that considers:

- operating flows and fish flows (Cheakamus Water Use Plan)
- effects of the diversion's flows and temperatures on the side channel, and stranding after spills.
- identification of critical habitats that sustain present stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

Jack Lay (formerly MELP, pers. comm.) reported that this was a poor area for deer. Wildlife was not abundant but the area was used some by black and grizzly bears, wolverine, bobcat, and coyote.

No information was obtained on current wildlife use.

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Daisy Lake Dam/Reservoir	<i>Dam footprint of __ha:</i> loss of coniferous forest and riverine habitats.	x		
	<i>Flooding of 140 ha of Cheakamus River valley and 17 ha Daisy Lake:</i> loss of high-elevation riverine, riparian, wetland, and coniferous habitat for species such as furbearers.	x		GIS
	<i>Flooding of 237 ha of upland forest:</i> loss of high-elevation coniferous upland habitat.			GIS
	<i>Conversion of 15 km of Cheakamus River and 4.7 km of tributaries to lake:</i> barrier to movement of large mammals (bears and ungulates).	x		GIS
	<i>Rapidly fluctuating reservoir water levels (13.1 m) due to hydro-electric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		BCH web page
Diversion tunnel to Squamish River	<i>Decreased flows in 15.5 km of Cheakamus R. and increased flows in 21 km of Squamish R:</i> unknown effects on downstream aquatic wildlife (e.g., American Dipper, Great Blue Heron, Harlequin Duck)	x	x	GIS

Feature	Description of Effects	Neg	Pos	Origin
Shadow Lake	<i>Flooding of 4 ha of valley bottom along inflow stream and around Shadow Lake: loss of valley bottom and valley side coniferous, deciduous, and wetland habitats, incl. riparian, and associated wildlife losses.</i>	x		GIS
	<i>Fluctuating reservoir water levels due to hydro-electric operations: effects on establishment of aquatic and/or riparian vegetation in drawdown zone.</i>	x		

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Habitat Change:** Altered flow regime has changed riverine and riparian habitats. Potential effects on wildlife include changes to habitat quality and quantity for tailed frogs, water shrews, harlequins and dippers.
2. **Loss of Habitat:** Loss of side channel habitat downstream of diversion. Loss of riparian and floodplain habitat in valley bottoms. Loss of high elevation wetland habitats in flooded valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse for ungulates and breeding habitat for some species of neotropical migrants. Loss of coniferous lowlands and upland habitats.
3. **Reduced Productivity:** Lack of riparian vegetation in drawdown zone; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Daisy Lake/Shadow Lake.

Discussion:

See limiting factor # 3. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.

Objective 2: Conserve riparian and wetland habitats in the downstream portions of Cheakamus River.

Discussion:

See limiting factor # 1 and 2. Identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means, in the lower reaches of the river or in the reservoir.

Objective 3: Create or enhance wetlands and riparian habitats for aquatic and cavity dependent species and small mammals).

Discussion:

See limiting factor # 1 and 2. Flood shallow basins in the watershed where feasible.

- Create backwater channel and associated riparian habitats along Cheakamus River segments where reduced downstream flows have diminished natural channel complexity.

Objective 4: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Cheakamus watershed.

4. CHEAKAMUS WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
1:50,000 scale NTS 92 G/14 1st edition, 1952; south sheet only	UBC Map Library
Air Photos - 1949 BC 260: 31-33; BC 262: 76-77; BC 324: 21, 30, 47	MELP, Victoria

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4.3 Wildlife References

Reference	Notes	Source
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Chapter 14

CLOWHOM RIVER WATERSHED

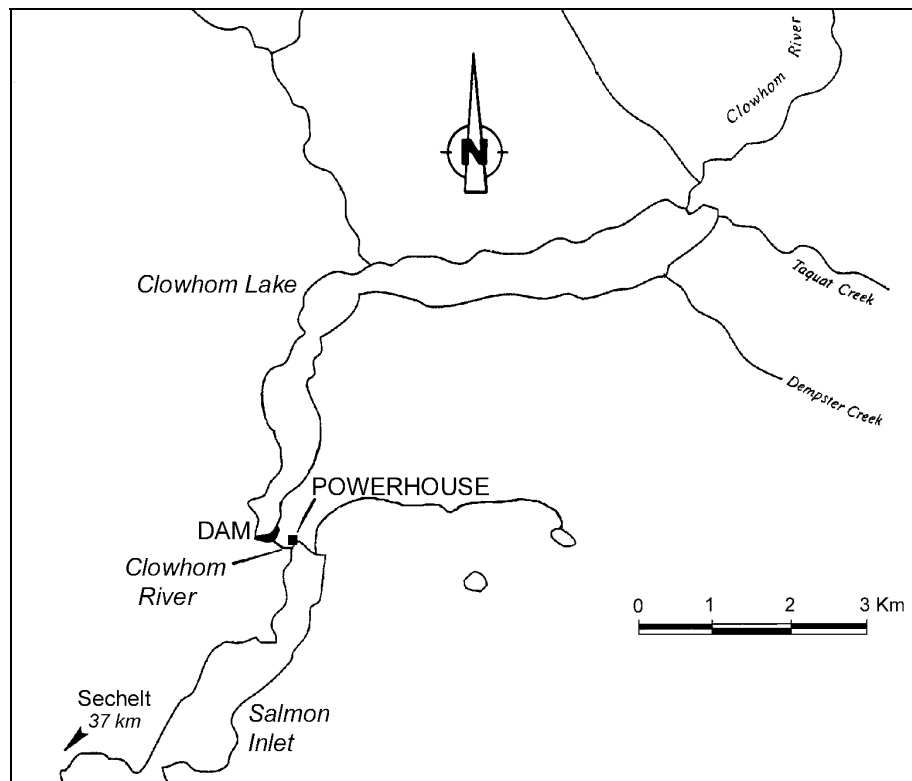


Figure 14-1. Location of Clowhom River hydro project

1. PROJECT DESCRIPTION

1.1 Facilities

The Clowhom Project, commissioned in 1958 by the B.C. Electric Co., consists of a dam impounding Lower Clowhom Lake which is joined to Upper Clowhom Lake by a short channel and has one power plant 400 metres downstream of the dam.

Prior to construction of the existing development, B.C. Power Commission had installed a smaller plant consisting of a concrete dam, penstock and powerhouse in 1952 (see Keller & Leslie 1996). The existing dam is just downstream of the older structure.

Specifications for the facilities and reservoir:

DAM	Clowhom
Nameplate capacity (MW)	30
Dependable capacity (MW)	20
Dam function	storage, diversion
Date constructed	1952
Date operational	
Date reconstructed	1958
Height (m)	22
Length (m)	402
Dam footprint area (m ²)	
Fishway at dam	no
Historic anadromous fish presence	not substantiated

RESERVOIR	Clowhom
Cleared/ not cleared	cleared
Present area (ha)	745
Watershed area (km ²)	390
Present elevation a.s.l. (m)	30 (bathym)
Normal drawdown range (m)	11.3
Mean depth (m)	54
Maximum depth (m)	>100
Storage (million m ³)	45
Mean water retention time	
Mean annual discharge (m ³ /s)	

DIVERSION	to power house
Structure type	penstock (300m)
Licensed flow (m ³ /sec)	75
Fish flow release (m ³ /sec)	
Mainstem length diminished Q (km)	350 m
Mainstem length augmented Q (km)	



Figure 14-2. Clowhom Dam (BC Hydro)

1.2 Hydrology

1.2.1 Basin and Runoff

The 390 km² Clowhom basin is situated in the South Coast Mountains, approximately 55 km northwest of Vancouver and discharges into Salmon Inlet behind Sechelt. Elevations range from 30 m to about 2400 m (Mt. Tantalus). The terrain varies from sparse forest in the valleys to barren rock at treeline. Glaciers are present but do not constitute a significant portion of the basin.

The region is dominated by Pacific air masses rising over the windward slopes along the coastline. Warm temperatures in April and May initiate snowmelt which causes a sharp increase in local streamflow. Most runoff occurs in June and July, with inflow decreasing in August-September. Heaviest peak flows occur from fall rainstorms between September and December. A combination of a heavy rainfall event, large snowpack, and warm air temperatures will create a very heavy peak flow. In January the temperatures tend to stabilize below freezing and streamflows drop until spring.

1.2.2 Habitat Types Flooded by Reservoir

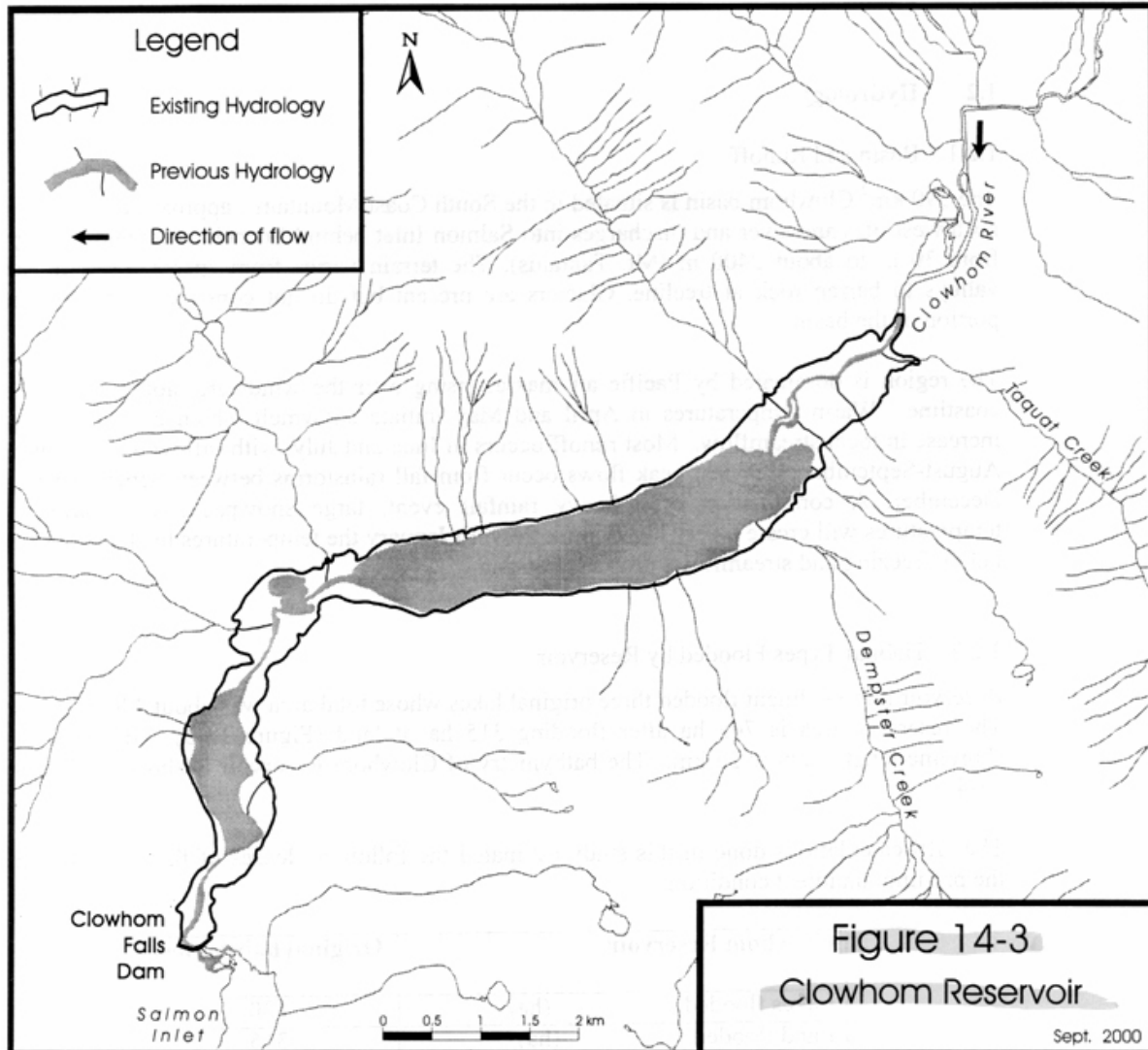
Reservoir impoundment flooded three original lakes whose total area was about 430 hectares. The reservoir area is 745 ha after flooding 315 ha of land (Figure 14-3). The reservoir shoreline length is now 25 km. The bathymetry of Clowhom Reservoir is shown in Figure 14-4.

The GIS calculations done in this study estimated the following losses of fish habitat from the pre-impoundment condition:

Clowhom Reservoir		Original habitat lost
Lakes flooded	(ha)	430
Land flooded	(ha)	315
Lake shoreline	(km)	17
Mainstem: length	(km)	6
channel	(ha)	32
riparian *	(ha)	37
Tributary: length	(km)	3
riparian **	(ha)	9
Wetland:	(ha)	0

* mainstem riparian zone calculated at 30 m from each bank

** tributary riparian zone calculated at 15 m from each bank



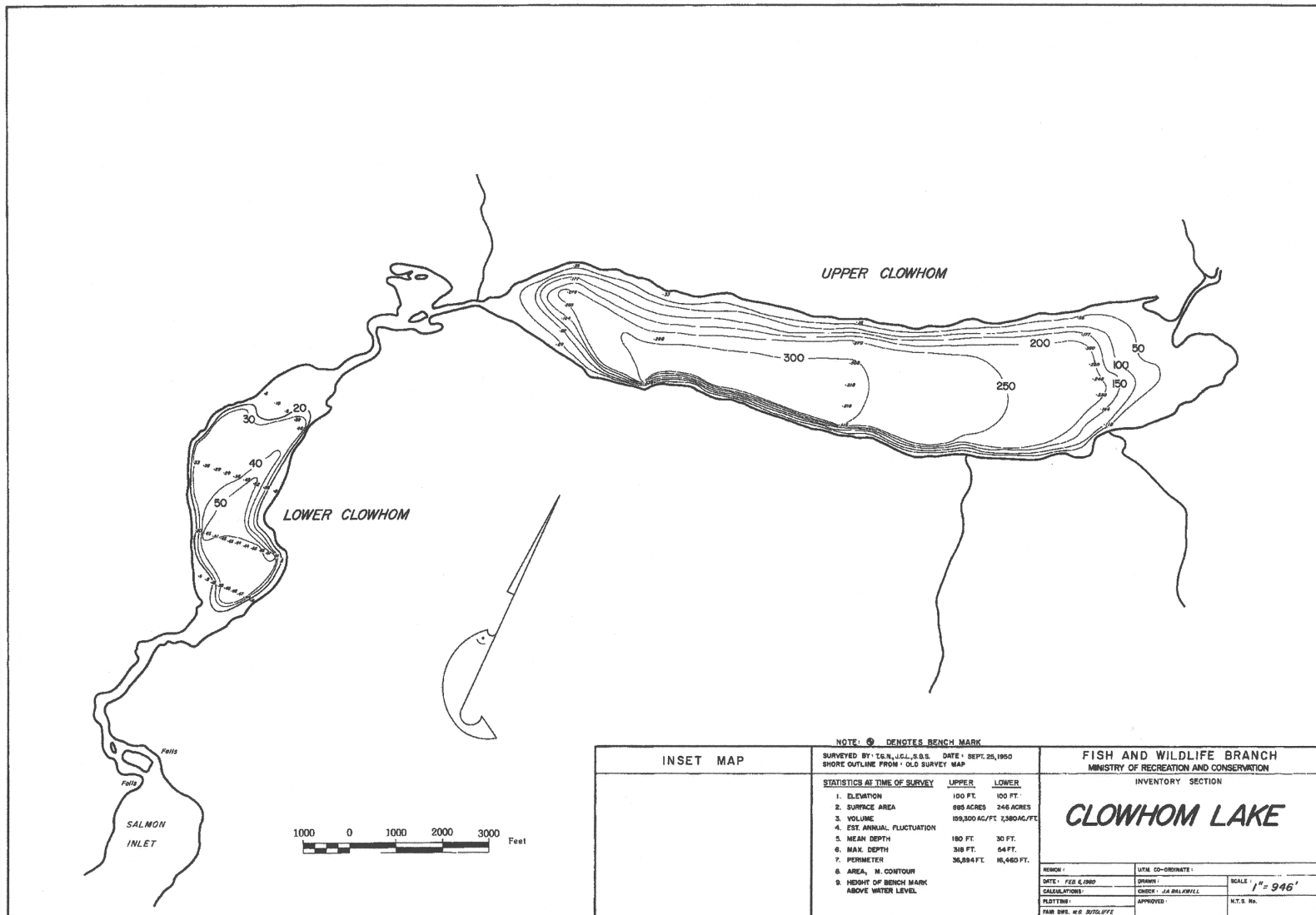


Figure 14-4. Bathymetric map of Clowhom Lake

2. FISH

2.1 Historic and Current Species Presence

Table 14-1 lists the species currently found in major reaches of the Clowhom River basin.

2.1.1 Upstream of Clowhom Dam

An extensive sport fishery for rainbow and cutthroat trout existed in the original lakes from 1927 to 1956 (Keller & Leslie 1996). A fishing lodge continues to operate (BC Hydro 1994). The pre-impoundment lakes were judged to be unproductive due to their depth and the lack of benthic organisms and observable plankton (Smith and Larkin 1950).

The upper Clowhom River has extensive spawning gravels (Smith and Larkin 1950; B.C. Game Commission 1956; J. Stephen, Conservation Officer, field notes). Most reservoir tributaries are presently limited in habitat quality due to steep gradients, coarse substrates, obstructions, and low summer flows (Lewis *et al.* 1996). Some tributaries, *e.g.*, Red Tusk Creek, have been used as spawning habitat but species were not specified (Hirst 1991b).

2.1.2 Downstream of Clowhom Dam

Archival information indicates the absence of anadromous fish in the Clowhom basin in the last century, at least in large or consistent numbers. A small side channel existed prior to initial dam construction in 1950 that reportedly enabled coho salmon and steelhead to ascend the falls and possibly contained some spawning and rearing functions (workshop).

2.2 Impacts on Fish

Facility	Description of impacts	Neg	Pos	Source
Clowhom Reservoir	1. Reservoir flooded 6 km of mainstem channel and 3 km of lower tributary channel, plus their associated riparian zones; original species composition unchanged.	x		GIS
	2. Drawdowns of 6-11 m may reduce littoral productivity in reservoir of 22 m max.depth.	x		Lewis et al. 1996
Clowhom Dam	3. Dam footprint of _ m ² : loss of instream, riparian and upland habitats.	x		
	4. Entrainment mortality and injury: magnitude unknown.			workshop
River between Dam and Powerhouse	5. Construction of two dams has eliminated a narrow 200m long side channel around falls that may have provided anadromous access.	x		workshop
	6. Dam has reduced LWD and gravel recruitment to side channel habitats reported downstream.	x		workshop
Below Powerhouse	7. Localized effects on salinity regime in marine foreshore.	x		workshop

Table 14-1. Fish Species in the Clowhom River Watershed.

Source: Fish information from BC Fishing Directory and Atlas - Freshwater Edition. 1998/99. O.P. Publishing Ltd. Vancouver BC. 170 p.

As of May 2000, there was no information on the Clowhom River watershed in FISS database or MOELP's *Pisces* website.

[illegible]

Non-Hydro Impacts - Other impacts on fish in the Clowhom River watershed include historic effects of logging and mill activities.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Clowhom River watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions or operating flows; or from non-hydro sources.
2. **Reduced downstream habitat capability:** If there is useable fish habitat below the dam, it may be altered by reduced sediment or wood recruitment.
3. **Reduced biological productivity:** The three original Clowhom lakes have been permanently affected by the enlarged reservoir and its drawdown regime.
4. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat due to the drawdown regime.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve habitats for resident fish stocks in the Clowhom Reservoir and tributary system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP Strategy, to conserve, create or improve existing habitat. Activities in response to limiting factors #1 and 4 above should be preceded by a study plan for the reservoir and tributary system that considers:

- operating flow regime (Clowhom Water Use Plan)
- opportunities to purchase or covenant floodplain properties for future habitat projects
- identification of present critical tributary habitats that sustain stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- opportunities for habitat development and for planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- current harvest pressures on stock recruitment

- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 2: Restore biological productivity in Clowhom Reservoir system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP Strategy, to improve reservoir productivity. Activities should be preceded by a study plan for the reservoir and tributary system, in response to limiting factor #3 above, that addresses:

- feasibility of a phased program of fertilization trials and performance indicators
- potential methods to achieve self-sustaining nutrient levels and reduce costs
- determination of appropriate low-level nutrient levels to mimic historic levels
- relative values of fertilizing fish-bearing tributaries vs reservoir plankton or littoral zone
- ecological effects of fertilization on non-target plants and aquatic animals
- wildlife biodiversity values at proposed fertilization sites
- identification and filling of data gaps on issues such as entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 3: Investigate habitat conditions for fish stocks between Clowhom Dam and tidewater.

Discussion:

A data gap exists with respect to the historic and potential future use of the channel below the dam for fish and wildlife. Activities should be preceded by a study plan, in response to limiting factors #1 and 2 above, that considers:

- operating flows and fish flows (Water Use Plan)
- identification of critical habitats that sustain present stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance
- identification and filling of data gaps on issues that may also constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

No information is available about historic or current wildlife. The area was probably typical of other coastal fiord rivers and provided good winter and spring range for deer and for black and grizzly bear. The area is located within the mapped grizzly bear abundance ratings of “nil” to “few.”

The area was “devastated by fire” about 1850, but there was still enough cedar to operate a shingle mill beginning in 1901 (Keller and Leslie, 1996).

Blue-listed species occurrences on file with the Conservation Data Centre include

- Smooth Willowherb (*Epilobium glaberrimum* sps *fastigiatum*) on 30% slope 1 km W of Slippery Creek

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Clowhom Dam & Reservoir	<i>Dam footprint of xx ha:</i> loss of riverine and coniferous forest habitat.	x		Hirst 1991
	<i>Flooding of 315 km of habitat, incl. 32 ha of river channel and 278 ha of upland forest:</i> loss of riverine and coniferous forest (burned in 1850's and logged in 1910's) habitat and associated wildlife.	x		GIS
	<i>Replacement of 6.1 km of river channel and 3 km of tributaries by reservoir:</i> barrier to movement of wildlife; creation of open water for waterfowl and osprey.	x	x	GIS
	<i>Fluctuating reservoir water levels (9.4 m) due to hydroelectric operations:</i> effects on establishment of aquatic and/or riparian vegetation in drawdown zone.	x		HCH web page

3.3 Factors Limiting Wildlife Diversity and Productivity

'Limiting factors' have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Reduced Productivity:** Lack of riparian vegetation in drawdown zone; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
2. **Loss of Habitat:** Loss of riparian and floodplain habitat in valley bottoms. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse for ungulates and breeding habitat for some species of neotropical migrants. Loss of coniferous lowlands and upland habitats.
3. **Wildlife Migration:** Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Clowhom Reservoir.

Discussion:

See limiting factor # 1. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.

Objective 2: Conserve riparian and wetland habitats, through habitat acquisition and other protective measures.

Discussion:

See limiting factor # 2. Identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means, in the watershed.

Objective 3: Create or enhance wetlands and riparian habitats for aquatic species (amphibians, waterfowl, cavity dependent species, small mammals).

Discussion:

See limiting factor # 2. Consider various opportunities to dyke selected drawdown areas to hold water during growing and breeding season (spring and summer), or fall migration, when reservoir is normally drawn down at those times.

Objective 4: Create elk winter range.

Discussion:

Work with forestry companies to leave shelter stands in association with logged clearings that provide forage.

- Establish vegetation in the reservoir drawdown zone, especially near lake inlet and creek deltas.
- Assess the feasibility of re-introducing elk.

Objective 5: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Clowhom watershed.

4. CLOWHOM RIVER WATERSHED REFERENCES

4.1 Map and Air Photos

Reference	Location Source
Clowhom River, map of millsite and diversions, Dept. of Lands, Water Rights Branch, Survey 1921, Feb. 1922	BC Archives
Plan of Flooded Area of Hydro-electric Development of Clowhom River & Lakes by BC Electric Company Limited; 1 in = 400 ft 1957	Legal Surveys, MELP; 49-123 NE/NW
1:50,000 1 st edition NTS topographic, Salmon Inlet, 1950-52, Squamish, 1952; 92 G14/W	UBC map library
Legal survey of Lot 3153, 1930; and Lot 1901, 1900; Plan 13T2, New Westminster District showing lower Clowhom Lake	Legal Surveys, MELP
1912 Pre-emptors Map	UBC map library
Air Photos, 1947	BC 405:2, 12, 25

4.2 Hydro Facilities and Fish References

Reference	Notes	Sources
B.C. Game Commission. 1956. Game fish culture – obstructions – lower mainland – Clowhom River. Memo from I.L. Withler to E.H. Vernon, Vancouver, B.C. 23 November 1956.		cited in Hirst 1991 (inland)
B.C. Hydro. 1987. Clowhom Dam Operation and Maintenance Manual. B.C. Hydro. OM404/02.		BC Hydro Info Centre
B.C. Hydro. 1991. Long-Term Hydrologic Data Collection Networks: La Joie, Terzaghi, Seton, Elsie, Wahleach, and Clowhom Basins. B.C. Hydro, Hydroelectric Engineering Division. Report H2067. 34 p.	BCH basin is 384 km ² . Elev. range is 10m to 2400m.	BC Hydro
B.C. Hydro. 1993. Reservoir recreation opportunities inventory. Social Resources Dept., Environmental Affairs Division, Burnaby, BC. Report no. ER 93-09.		cited in Lightowlers 1997
B.C. Hydro. 1994. Report on the electric system operations review (ESOR). Unpubl. report for The Minister of Employment and Investment and the Minister of Energy Mines and Petroleum Resources. .	overview of operations & issues for all facilities	BC Hydro
B.C. Hydro. 1995. Circuit 1L44 Sechelt-Clowhom Rehabilitation Project – Environmental Management Plan. B.C.Hydro, Safety and Environment. Unpublished report.		BC Hydro
B.C. Hydro. 1997a. Clowhom project system operating order 4P-27. Power Facilities Dept., Burnaby, B.C.		cited in Lightowlers 1997
B.C.Hydro. 1997b. Clowhom Falls – Facility Field Guide – December 1997. B.C. Hydro, Power Supply. File No. 15-200.22		BC Hydro
B.C. Hydro. 1998. Rare element occurrence: Field guide to the rare and endangered species found within the watershed boundaries of each BCH facility. Strategic Fisheries, Power Supply Operations, Burnaby, BC.	all red, blue and yellow species	BC Hydro
B.C. Hydro. 1999. Recreation opportunities inventory. Power Supply Environment, Rept. ER 99-08., 206 p.	color maps and description of all facilities	BC Hydro
B.C. Hydro. other reports:		
A4229 Clowhom Falls Development: hydraulic plant data sheet.		BC Hydro Info Centre
A1315 Preliminary report of Clowhom falls		
621.312134 K53 19 Water power investigations 1922: Clowhom		
A3277 Dam safety investigations: long term hydrologic data.		
A0937 Clowhom dam: spillway tests 1983		
A4939 Clowhom Reservoir: reservoir debris mgmt plan		
B.C.Power Commission. n.d. B.C.P.C. Hydroelectric Plant Data		BC Hydro Info Centre

Reference	Notes	Sources
Department of Fisheries and Oceans./BC Ministry of Environment. 1991. Fish habitat inventory and information program. Stream information for Clowhom Lake.		
Hirst, S.M. 1991. Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia, Vol. 1. Anadromous salmon. Can. Manuscript Rep. Fish. Aquat. Sci. 2093 v.1: 144 p.		
Hirst, S.M. 1991. Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia, Vol. 2. Inland fisheries. Can. Manuscript Rep. Fish. Aquat. Sci. 2093 v.2: 200 p.		
Keller, B.C. and R.M. Leslie. 1996. <i>Bright Seas, Pioneer Spirits - the Sunshine Coast</i> . Horsdal & Schubart Publishers, Victoria, BC. 232 p.		book in print
In 1937, the Columbia Power Co. built a powerhouse on Sechelt Indian band land beside Chapman Creek, installed a large Pelton wheel and supplied 337 customers with power until 1947. Needing more capacity in 1948, the BC Power Commission already owned Clowholm's water rights because Columbia Steamships had allowed them to lapse in the late 1930's. In May 1951 BCPC purchased portions of the 3 lots still owned by Columbia Steamships in order to build a powerhouse. [photo of Clowholm Falls prior to 1950]. In Sept 1950, Dawson, Wade & Co. began construction of an 18-ft concrete gravity dam above the falls. A 23 mile transmission line brought the power to the Sechelt substation. Power flowed by May 1952. In four years demand for more power called for a larger dam. The BC Electric Power Co. bought Clowholm in 1955 and built a new concrete dam, new penstock, switchyard and powerhouse. The transmission line was upgraded and connected to the Dunsmuir Line connecting Powell River, Pender Harbour, and Squamish in November 1957. BC Electric Co. was expropriated by the Social Credit govt. in 1961 to BC Hydro and Power Authority.	[p.138 The entire Clowholm valley had been devastated by fire around 1850, but there was still plenty of red cedar available. [p.137 A shingle mill was started in 1901 at Clowholm Falls, adjacent to Industrial Power's property acquired in 1904 who got the water rights and hoped for enough timber to establish a pulp mill. [p. 133. 'the water tumbled over a small drop, then forked around an island, forming two more falls on its eastern side before it cascaded into Salmon Inlet.' A series of fishing resorts began in 1927 for cutthroat and rainbow trout reaching 16-18 inches in size. The last lodge on the lake, a fly-in operation, closed in 1956.	
Klohn-Crippen Integ. 1994. Dam safety investigations: Clowhom Lake reservoir debris management plan. For BC Hydro. Report no. H2822.		cited in Lightowlers 1997
Knewstubb, F.W. 1922. Water power investigations 1921. Report on Clowhom River. Coast project no. 4. B.C. Dept. of Lands, Water Rights Branch, Vancouver. Feb. 22. 6p?	BCH Library? 621.312134 K53, 1921 incomplete – 2 p. only	BC Hydro
Lewis, A.F., G.J. Naito, S.E. Redden and BC Hydro Safety & Environment. 1996. Fish flow studies project: fish flow overview report. BCH Safety & Environment Rept. No. EA:95-06, 144 p.	comprehensive review of flows, facilities and fish for all BCH projects	BC Hydro
Lightowlers, C. and S. Winter. 1997. Clowhom Falls facility field guide. December. 1 st draft. File no. 15-200.22. BC Hydro. 25p.		BC Hydro
Sigma Engineering Ltd. 1990. BC Hydro Power water licenses. Power Facilities, Burnaby, BC		cited in Lightowlers 1997
Smith, S.B. and P.A. Larkin. 1950. Report on the Clowhom lakes investigation. Unpubl. report, B.C. Game Branch, Vancouver, BC. 3 p.		cited in Hirst 1991 (inland)
Young, W. 1930? Report on Clowhom Falls water power site. For The Blue Band Navigation Co. Ltd. BCH Rept. A3770	incomplete. 2p. plus map	BC Hydro

3.4 Wildlife References

Reference	Notes	Source
B.C. Hydro. 1998. Rare element occurrence: Field guide to the rare and endangered species found within the watershed boundaries of each BCH facility. Strategic Fisheries, Power Supply Operations, Burnaby, BC.	all red, blue and yellow-listed species (See CDC list for Sunshine Coast Forest District)	
BC Fish & Wildlife Branch. 1977. Wildlife Distribution Mapping Series: Grizzly Bear Distribution and Relative Abundance.	Boundary between Few – (1 bear per 55-400 sq. miles) and Nil	MELP Surrey: Jack Evans
Hatter, J., D.J. Robinson, P.W. Martin, L.G. Sugden, E.W. Taylor and W.G. Smith 1956. Inventory and Evaluation of Wildlife Resources of British Columbia. Reprinted from the 9 th BC Natural Resources Conference Transactions, February 1956.	The principal grizzly ranges of the western and central portions of the province are the mountainous regions of the following areas:...Sugar Lake-Mabel Lake...Shuswap Lake...Bridge River, Bella Coola Valley...” ??This area??	MELP Surrey: Jack Evans
Keller, B.C. and R.M. Leslie. 1996. <i>Bright Seas, Pioneer Spirits - the Sunshine Coast</i> . Horsdal & Schubart Publishers, Victoria, BC. 232 p.	In 1937, the Columbia Power Co. built a powerhouse on Sechelt Indian band land beside Chapman Creek, installed a large Pelton wheel and supplied 337 customers with power until 1947.	book in print
Needing more capacity in 1948, the BC Power Commission already owned Clowholm’s water rights because Columbia Steamships had allowed them to lapse in the late 1930’s. In May 1951 BCPC purchased portions of the 3 lots still owned by Columbia Steamships in order to build a powerhouse. [photo of Clowholm Falls prior to 1950]. In Sept 1950, Dawson, Wade & Co. began construction of an 18-ft concrete gravity dam above the falls. A 23 mile transmission line brought the power to the Sechelt substation. Power flowed by May 1952. In four years demand for more power called for a larger dam. The BC Electric Power Co. bought Clowholm in 1955 and built a new concrete dam, new penstock, switchyard and powerhouse. The transmission line was upgraded and connected to the Dunsmuir Line connecting Powell River, Pender Harbour, and Squamish in November 1957. BC Electric Co. was expropriated by the Social Credit govt. in 1961 to BC Hydro and Power Authority.[p.138 The entire Clowholm valley had been devastated by fire around 1850, but there was still plenty of red cedar available. [p.137 A shingle mill was started in 1901 at Clowholm Falls, adjacent to Industrial Power’s property acquired in 1904 who got the water rights and hoped for enough timber to establish a pulp mill. [p. 133. ‘the water tumbled over a small drop, then forked around an island, forming two more falls on its eastern side before it cascaded into Salmon Inlet.’ A series of fishing resorts began in 1927 for cutthroat and rainbow trout reaching 16-18 inches in size. The last lodge on the lake, fly-in operation, closed in 1956..		
Province of British Columbia Department of Attorney – General, 1956. Provincial Game Commission Report	Clearing of inundated trees is recommended for increased storage on Clowhom Lakes	Provincial Archives, MELP Surrey: Jack Evans

Chapter 15

BIG FALLS CREEK WATERSHED



Figure 15-1 . Big Falls Creek at confluence with Ecstall River (Water Powers B.C. 1954)

1. PROJECT DESCRIPTION

1.1 Facilities

The Falls River Project was built in 1930 for the Northern B.C. Power Co. and acquired by B.C. Hydro in 1964. It consists of a dam located at the confluence of Falls River and the Ecstall River, two penstocks and a powerplant located at the base of Big Falls. Significant rehabilitation work was completed in 1992.

While BC Hydro's name for this project is Falls River, the official DFO/MELP name for this watershed system is 'Big Falls Creek' (SISS/RAB code 40-0100-080), located within DFO Statistical Area 04A. The agency nomenclature system has given the name 'Falls River' (code 91-8870-000) to another stream located in nearby Statistical Area 06, and there is also a 'Falls Creek' (code 47-1800-030-060) in Statistical Area 04C.

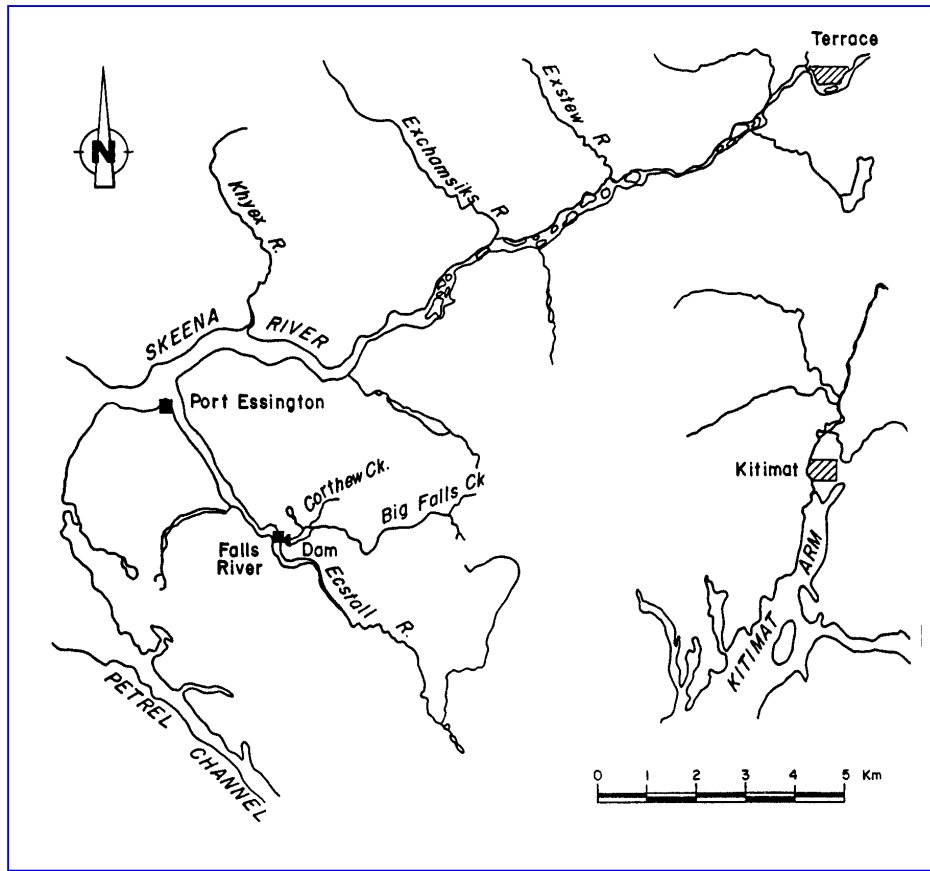


Figure 15-2. Location of Falls River hydro project

Specifications for the facility and reservoir:

DAM	Falls River
Nameplate capacity (MW)	9.6
Dependable capacity (MW)	
Dam function	storage, diversion
Date constructed	1930
Date operational	
Date reconstructed	1983; 1992
Height (m)	13
Length (m)	156
Dam footprint area (m ²)	
Fishway at dam	no
Historic anadromous fish presence	no

RESERVOIR	Big Falls
Cleared/ not cleared	
Present area (ha)	247
Orig. lake area (ha)	0
Watershed area (km ²)	248
Present elevation a.s.l. (m)	90.3
Normal drawdown range (m)	2 -5

Mean depth (m)	
Maximum depth (m)	
Storage (million m ³)	24
Mean water retention time	
Mean annual discharge (m ³ /s)	

DIVERSION	to power plant
Structure type	penstock (220m)
Licensed flow (m ³ /sec)	17
Fish flow release (m ³ /sec)	1.3
Mainstem length diminished (km)	
Mainstem length augmented (km)	- -

1.2 Hydrology

1.2.1 Basin and Runoff

Big Falls Creek is a southwest-flowing tributary to the Ecstall River which joins the lower Skeena at tidewater. There are frequent periods of heavy rainfall; the reservoir freezes over for some winter periods.

1.2.2 Operation and Licensed Diversion Flow

Reservoir undergoes rapid changes in level, spilling at anytime. An air bubbler system is used to keep the area in front of the sluice gates and flashboards free of ice when the reservoir freezes (Lewis *et al.* 1996).

A fish water discharge of 1.3 m³/s is required when both turbines are shut down.

1.2.3 Habitat Types Flooded by Reservoir

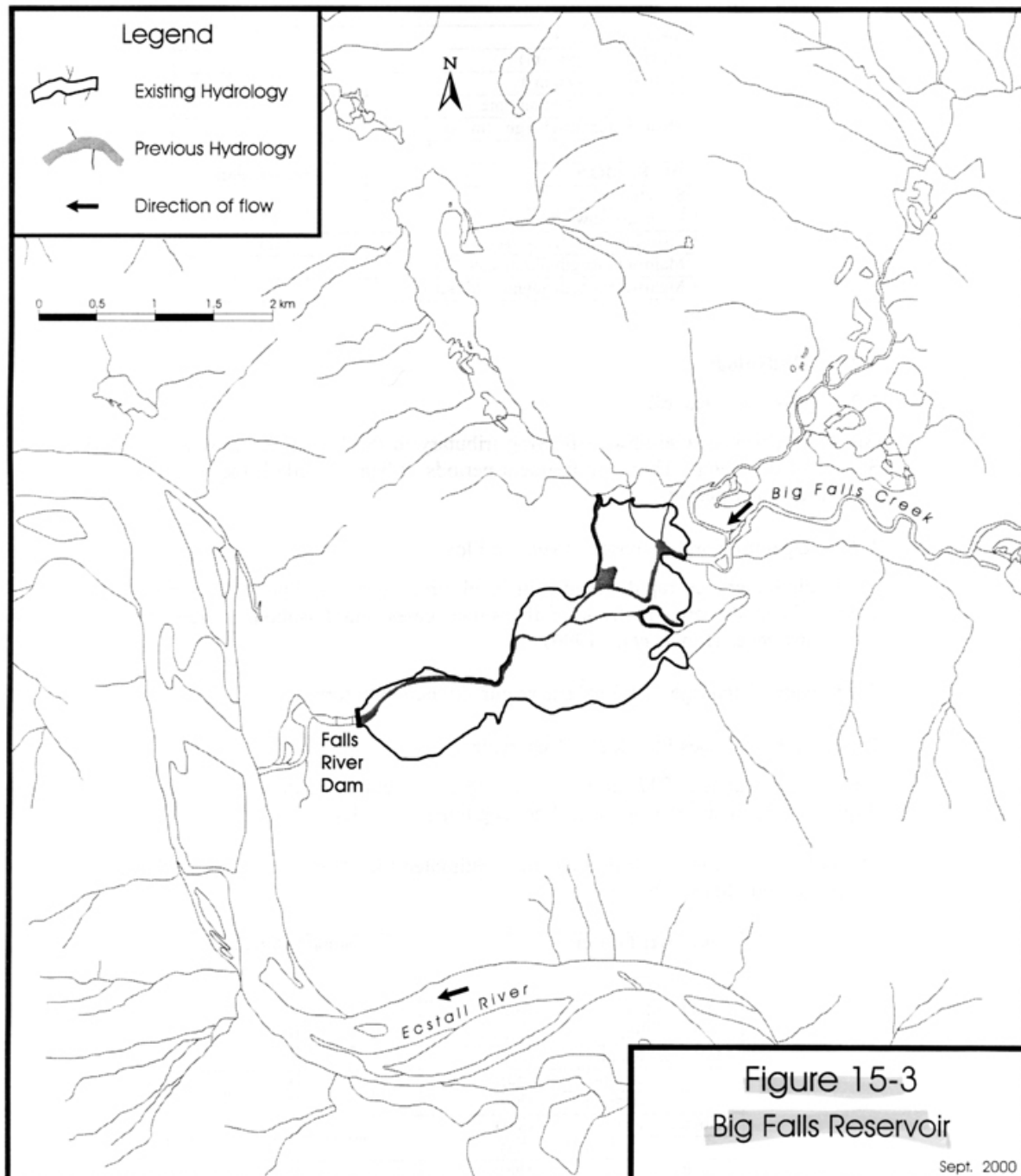
The reservoir area is 247 ha after flooding 247 hectares of land and former river channel (Figure 15-3). The reservoir shoreline length is now 12 km.

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Falls River Project	Original habitat lost
Lake flooded (ha)	0
Land flooded (ha)	247
Lake shoreline (km)	0
Mainstem: length (km)	6
channel (ha)	19
riparian * (ha)	37
Tributary: length (km)	0.3
riparian ** (ha)	1
Wetland: (ha)	0

* mainstem riparian zone calculated at 30 m from each bank

** tributary riparian zone calculated at 15 m from each bank



2. FISH

2.1 Historic and Current Species Presence

Fish species currently found in the Big Falls Creek watershed are listed in Table 15-1.

2.1.1 Upstream of Dam

The cutthroat trout and Dolly Varden char in Carthew Creek and Big Falls Reservoir are not known to be a resource of any special significance (Lewis *et al.* 1996). Threespine stickleback are present in Hayward Lake (FISS 2000).

2.1.2 Downstream of Dam

Below the 20 m falls, there is some limited spawning habitat, and the tailwater pond receives some saline water as high tide ascends the lower Ecstall River. This short 180 m section of stream has rocky bottom with some spawnable gravels in the deep pool at the tailrace outlet. Saline water is flushed by high velocities of mountain water when the plant is operating. The number of salmon utilizing the tailrace for spawning is very low. Coho, pink and chinook salmon are the species listed in DFO (1983). The FISS database characterizes Big Falls Creek as having no enhancement potential due to its small size and impassable falls. Rearing areas for coho would probably occur in the Ecstall River.

Chinook spawning in the tail pond was confirmed by Hickey (1981), and seal and otter predation on adult salmon in the tailpond was observed. A maximum of 15 redds were found. He captured rainbow trout and Dolly Varden char and also noted a chum salmon carcass which may have originated from the Ecstall River. Chinook fry were present in the tail pond but their origin is not clear.

2.2 Impacts on Fish

Facility	Description of hydroelectric impacts	Neg	Pos	Source
Big Falls Reservoir	1. Reservoir flooded 6 km of mainstem channel and 0.3 km of lower tributary channel, plus their associated riparian zones.	x		GIS
	2. Large drawdowns and rapid fluctuations in water level reduce productivity.	x		Lewis <i>et al.</i> 1996
	3. Drawdowns may affect trout access to tributaries.			BC Hydro 1994
	4. LWD covers at least 10% of reservoir surface.			workshop
Falls River Dam	5. Dam footprint of _ m ² : loss of instream, riparian and upland habitats.	x		
	6. Entrainment mortality and injury: magnitude unknown.	x		workshop
Below Powerhouse	7. Fluctuating flows or extended plant shutdown could have velocity or salinity effects on salmon egg development.	x		Lewis <i>et al.</i> 1996

Table 15-1. Fish species in the Big Falls Creek watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.

Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Big Falls Creek upstream ↓ downstream		Anadromous Salmonids								Sport Fish								Non-Sport Fish								Red/Blue Listed Fish																				
		Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon		Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish *	Peamouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	Brassy minnow	Dace General	Longnose Dace	Spottail shiner	Salish sucker				
Hayward Lake																																														
Carthew Cr.																																														
Big Falls Cr. mainstem																																														
Falls R. Reservoir																																														
FALLS RIVER DAM	No fishway; impassable falls.																																													
Big Falls Cr. mainstem		1		1			1	1			1		1																																	

* now named *Northern pike minnow*

1 - data from report by D.B. Lister & Assoc. (1981)

Non-Hydro Impacts - Other impacts on fish in the Big Falls Creek watershed are presumed to include logging activities.

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations within the Big Falls Creek watershed. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of habitat:** Former spawning, rearing and overwintering areas are permanently lost or seasonally reduced due to dam footprint, reservoir flooding, flow diversions or operating flows. The reservoir is sometimes drawn down to the original riverine habitat.
2. **Reduced downstream habitat capability:** A small area of spawning and rearing habitat below the dam may be altered by reduced sediment or wood recruitment. The original falls completely blocked fish access.
3. **Reduced tributary access:** Reduced fish access between reservoir and tributary habitat due to the drawdown regime.

2.4 Fish Restoration Objectives

Objective 1: Conserve and improve habitats for resident fish stocks in the reservoir and tributary system.

Discussion:

Undertake appropriate treatment, consistent with the BCRP Strategy, to conserve, create or improve existing habitat. Activities in response to limiting factor #1 above should be preceded by a study plan for the reservoir and tributary system that considers:

- operating flow regime (Falls River Water Use Plan)
- opportunities to purchase or covenant floodplain properties for future habitat projects
- identification of present critical tributary habitats that sustain stocks, and locations of potential habitat works in the future
- opportunities for habitat development and for planting riparian vegetation
- wildlife biodiversity values at all proposed fish habitat development sites
- restoration of fish access through drawdown zones to historical upstream habitats
- identification and filling of data gaps on issues such as fish entrainment, angling harvest effort, etc. that may also constrain populations.

Objective 2: Improve habitat conditions for fish stocks between the dam and the Ecstall River.

Discussion:

A data gap exists with respect to the potential use of the channel below the dam for fish habitat. Activities should be preceded by a study plan, in response to limiting factors #1 and 2 above, that considers:

- operating flows and fish flows (Falls River Water Use Plan)
- identification of critical habitats that sustain present stocks, and locations of potential habitat works in the future
- opportunities for habitat development
- identification and filling of data gaps on other issues that may constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

No information was obtained on wildlife use. The area is located within grizzly bear range mapped as “moderate.”

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Falls River Dam	<i>Dam footprint of __ ha: loss of riverine and coniferous forest habitat.</i>	x		
	<i>Flooding of 128 ha of lowland and 100 ha of upland forest: loss of riverine and deciduous and coniferous forest habitats and associated wildlife.</i>	x		Hirst 1991; GIS
	<i>Fluctuating reservoir water levels (rapid changes in level) due to hydroelectric operations: effects on establishment of aquatic and/or riparian vegetation in drawdown zone.</i>	x		BCH web site

3.3 Factors Limiting Wildlife Diversity and Productivity

‘Limiting factors’ have been identified based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of wildlife for species groups associated with the habitats listed previously in Table 1-2. These also reflect the key issues raised at BCRP regional workshops.

1. **Loss of Productivity:** Lack of riparian vegetation in drawdown zones; effects on ungulates, furbearers, small mammals and several species of passerines including some neotropical migrants.
2. **Loss of Habitat:** Loss of lowland riparian and upland habitats. Potential effects include availability of habitat for amphibians, water shrews and other small mammals and their predators, browse for ungulates and breeding habitat for some species of neotropical migrants.
3. **Wildlife Migration:** Possible Impediments to wildlife movement (especially large mammals) caused by structures, reservoirs and diversions.

3.4 Wildlife Restoration Objectives

Objective 1: Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat in Big Falls Reservoir.

Discussion:

See limiting factor #1. Improve vegetation in the drawdown zone.

- Develop foreshore habitat complexes at suitable locations.
- Create nesting cavities and raptor perches where beneficial through management activities such as snag creation.

Objective 2: Conserve riparian and wetland habitats in Big Falls Creek watershed.

Discussion:

See limiting factor # 2. Identify key habitats for conservation of biodiversity and enhanced production.

- Undertake conservation, through protective measures, habitat acquisition and other means, in the lower reaches of the river or in the reservoir.

Objective 3: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Big Falls Creek watershed.

4. BIG FALLS CREEK WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
Plan showing Lot 635 RV Coast District, 20 ch = 1 in, 1906	Legal Surveys, MELP
Prov. Govt. Reference Map 103H/NW, covering Flooding Reserve 08192, May 1949	BC Archives
Air Photos lower Big Falls Creek	BC 430: 89

4.2 Hydro Facility and Fish References

Reference	Notes	Sources
Bradley, R.M. 1983. Falls River redevelopment: environmental review of reservoir clearing operations. B.C. Hydro Rept. A0880 : Environmental and Socio-Economic Services, Vancouver, B.C. ESS-79, 47 p.		BC Hydro; UBC MICROLOG 83-04506
B.C. Hydro. 1980. Falls River redevelopment project. Application for an Energy Project Certificate, Vancouver, B.C. 17 November 1980.		cited in Hirst 1991
B.C. Hydro. 1990. Falls River Dam Operation and Maintenance Manual. Original prepared for B.C. Hydro by Sigma Engineering Ltd. OM908/02.		BC Hydro
B.C. Hydro. 1991. Falls River Rehabilitation Project – Environmental Management Plan. B.C. Hydro, Environmental Resources. Unpublished report October 1991. Report No. ER-91-18.		BC Hydro
B.C. Hydro. 1994. Report on the electric system operations review (ESOR). Prepared for The Minister of Employment and Investment and the Minister of Energy Mines and Petroleum Resources. Unpublished report and 2 appendices.	overview of operations & issues for all facilities	BC Hydro
B.C. Hydro. other internal reports:		BC Hydro Info Centre
A4569 Falls River Hydroelectric Development Rehabilitation		
A1338 Falls River Redevelopment		
A3246 Resource Smart: Falls River		
A5752 A review of the 1983 Falls River project		
A0826 Impact of wood debris and standing trees on the productivity		
A5753 Falls River Redevelopment: 1982 salmon observations		
Dept. of Fisheries & Oceans. 1983. Catalogue of salmon streams and spawning escapements of Statistical Area 4 (Lower Skeena River) including coastal streams. Can. Data Rept. Fish. Aquatic Sci. No. 395.		
Finlayson, A.W. 1931. Large construction job in northern British Columbia; Falls River power development - an interesting undertaking from a contracting standpoint. Contract Record and Engin. Review (Toronto). Vol. 45 No. 4 (Jan.); p. 73-77.		NW 627.8 F512.
Hickey, D.G. 1981. Salmon observations at Falls River hydroelectric project during 1981. Report by D.B. Lister and Associates Ltd. to B.C. Hydro. Vancouver, B.C. 27 p.	recorded chinook, coho and chum salmon but the latter likely originated in the Ecstall R.	BC Hydro
Lewis, A.F., G.J. Naito, S.E. Redden and BC Hydro Safety & Environment. 1996. Fish flow studies project: fish flow overview report. BCH Safety & Environment Rept. No. EA:95-06, 144 p.	comprehensive review of flows, facilities and fish for all BCH projects	BC Hydro
Lister, D.B., and Associates Ltd. 1981. File data on salmon observations at Falls River hydroelectric project. Sardis, B.C.		D.B. Lister and Assoc., Sardis, BC
Redenbach, A.E. 1981. Falls River rehabilitation/ redevelopment study: fisheries assessment (1980). Report ESS-19. B.C. Hydro. Vancouver, B.C.		cited in Hirst 1991

4.3 Wildlife References

Reference	Notes	Source
Bradley, R.M. 1983. Falls River redevelopment: environmental review of reservoir clearing operations. B.C. Hydro : Environmental and Socio-Economic Services, Vancouver, B.C. ESS-79, 47 p.		UBC MICROLOG 83-04506
B.C. Hydro. 1998. Rare element occurrence: Field guide to the rare and endangered species found within the watershed boundaries of each BCH facility. Strategic Fisheries, Power Supply Operations, Burnaby, BC.	All red, blue and yellow-listed species; no elements recorded for Falls River basin	BC Hydro
BC Fish & Wildlife Branch. 1977. Wildlife Distribution Mapping Series: Grizzly Bear Distribution and Relative Abundance.	Moderate (1 bear per 25-55 sq. miles)	MELP Surrey: Jack Evans

Chapter 16

CLAYTON FALLS CREEK WATERSHED



Figure 16-1. Clayton Falls near Bella Coola (BC Archives)

1. PROJECT DESCRIPTION

1.1 Facilities

The Clayton Falls Project, built in 1962 by the B.C. Power Commission, consists of a small diversion dam on Clayton Falls Creek 4 km west of Bella Coola. A pipeline draws water from a small headpond behind the dam to the generating station 100 m upstream of tidewater on North Bentinck Arm.

Specifications for the facility and headpond:

DAM	Clayton Falls
Nameplate capacity (MW)	2.05
Dependable capacity (MW)	
Dam function	diversion

Date constructed	1962
Date operational	
Date reconstructed	
Height (m)	7
Length (m)	41
Dam footprint area (m ²)	
Fishway at dam	no
Historic anadromous fish presence	no

RESERVOIR	headpond
Cleared/ not cleared	
Present area (ha)	2
Watershed area (km ²)	
Present elevation a.s.l. (m)	78
Normal drawdown range (m)	4.1 (max)
Mean depth (m)	
Maximum depth (m)	
Storage (million m ³)	--
Mean water retention time	<1 day
Mean annual discharge (m ³ /s)	

DIVERSION	to powerplant
Structure type	penstock (580m)
Licensed flow (m ³ /sec)	1.3
Fish flow release (m ³ /sec)	none
Mainstem length diminished (km)	0.5
Mainstem length augmented (km)	--

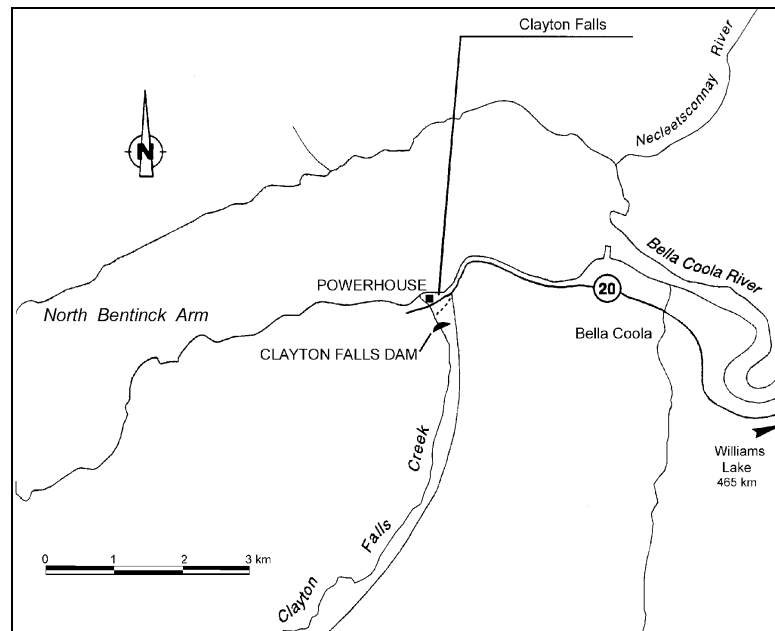


Figure 16-2. Location of Clayton Falls Creek hydro project

1.2 Hydrology

1.2.1 Basin and Runoff

The basin receives frequent heavy periods of rain; some winter precipitation falls as snow.

1.2.2 Habitat Types Flooded by Reservoir

The headpond area is 2 ha after flooding 2 hectares of land and channel. The reservoir shoreline length is now 41 km.

The GIS calculations done by this study estimated the following losses of fish habitat from the pre-impoundment condition:

Clayton Falls headpond	Original habitat lost
Lake flooded (ha)	0
Land flooded (ha)	2
Lake shoreline (km)	
Mainstem: length (km)	0.2
channel (ha)	
riparian * (ha)	1.2
Tributary: length (km)	0
riparian ** (ha)	0
Wetland: (ha)	0

* mainstem riparian zone calculated at 30 m from each bank

** tributary riparian zone calculated at 15 m from each bank

2. FISH

2.1 Historic and Current Species Presence

A list of species currently found in major reaches of the Clayton Falls Creek watershed is provided in Table 16-1.

2.1.1 Upstream of Dam

The Clayton Falls system is a steep drainage with few natural habitats accessible to fish. Resident fish are apparently not present upstream of Clayton Falls which is located 200 m of the mouth (Lewis *et al.* 1996).

Table 16-1. Fish species in the Clayton Falls Creek watershed.

Source: MoELP 2000. BC Ministry of Environment Fish Information Website - <http://www.bcfisheries.gov.bc.ca/fishinfobc.html>; accessed before June 8, 2000.
Includes: BC Watershed Atlas, Fisheries Information Summary System (FISS), BC Lakes and Release Record database, and Lake Depth Maps.

Clayton Falls Creek upstream ↓ downstream	Anadromous Salmonids										Sport Fish										Non-Sport Fish										Red/Blue Listed Fish														
	Steelhead	Cutthroat trout (sea-run)	Dolly Varden (sea-run)	Bull trout	Sockeye Salmon	Coho Salmon	Chinook Salmon	Pink Salmon	Chum Salmon		Rainbow trout	Cutthroat trout	Dolly Varden	Bull trout	Brook trout	Lake trout	Kokanee	Mountain whitefish	Lake whitefish	Burbot	Sturgeon (general)	Sucker General	Largescale sucker	Longnose sucker	Bridgelip sucker	Northern squawfish *	Peanmouth chub	Redside shiner	Sculpin (general)	Torrent sculpin	Prickly Sculpin	Slimy sculpin	Coastrange sculpin	Threespine stickleback	Lamprey (general)	Pacific lamprey	River lamprey	Brassy minnow	Dace General		Longnose Dace	Spottail shiner	Salish sucker		
Clayton Falls Creek																																													
CLAYTON FALLS DAM	No fishway.																																												
Clayton Falls Creek																																													

* now named *Northern pike minnow*

2.1.2 Downstream of Dam

Fish are not present between the dam and the natural falls. Small numbers of pink and chum salmon spawn in the 200 m of channel between tidewater and the falls, including the tailrace area (Lewis *et al.* 1996).

2.2 Impacts on Fish

No fish impacts have been identified to date. No fish are present in the headpond area, and the project is presently operated with relatively few fluctuations in flow (Lewis *et al.* 1996).

Non-Hydro Impacts - Other impacts on fish in the Clayton Falls River watershed include historic effects of logging activities. Sediment derived from forestry activity accumulates in the headpond and is removed periodically by BC Hydro (Lewis *et al.* 1996).

2.3 Factors Limiting Fish Diversity and Production

'Limiting factors' have been identified in a general manner based on available information and current understanding of the major constraints on species and populations of concern. Further inventory and research may be needed to determine the particular role of these and other factors.

The following are suspected factors that limit current levels of fish populations at the lowermost section of the Clayton Falls watershed. These also reflect the key issues raised at BCRP regional workshops.

1. Loss of habitat: The small area of spawning and rearing habitats downstream of the falls may be seasonally altered due to operating flows; or from non-hydro sources.
2. Reduced downstream habitat capability: The downstream habitat below the dam may be altered by reduced sediment or wood recruitment.

2.4 Fish Restoration Objectives

Objective 1: Investigate habitat conditions for fish stocks between the dam and tidewater.

Discussion:

A data gap exists with respect to the potential use of the channel below the dam for fish habitat. Activities should be preceded by a study plan, in response to limiting factors #1 and 2 above, that considers:

- operating flows and fish flows (Clayton Falls Water Use Plan)
- identification of critical habitats that sustain present stocks, and locations of potential habitat works in the future
- potential habitat development sites with hydraulic characteristics that will operate within the expected regulated regime of fluvial and riparian processes and require low maintenance

- identification and filling of data gaps on other issues that may constrain populations.

3. WILDLIFE

3.1 Historic and Current Populations and Habitats

No information was obtained on wildlife use. The area is located within grizzly bear range mapped as “moderate” to “plentiful.”

Blue-listed species occurrences on file with the Conservation Data Centre include

- Lesser Saltmarsh Sedge (*Carex glareosa* var *amphigens*) on saline flats at Bella Coola
- Chamisso’s Montia (*Montia chamissoi*) in a grassy/sedge meadow at the mouth of the Bella Coola River
- Five-leafed Cinquefoil (*Potentilla quinquefolia*) along Clayton Falls Creek

3.2 Impacts on Wildlife

Feature	Description of Effects	Neg	Pos	Origin
Clayton Falls Diversion Dam	<i>Headpond footprint of 2 ha:</i> loss of riverine and coniferous forest habitat.	x		

3.3 Factors Limiting Wildlife Diversity and Productivity

No factors associated with Clayton Falls facilities are limiting wildlife in the area.

3.4 Wildlife Restoration Objectives

Objective 1: Improve the knowledge base on rare, endangered and threatened species and habitat utilization in the Clayton Falls watershed.

4. CLAYTON FALLS CREEK WATERSHED REFERENCES

4.1 Map and Air Photo References

Reference	Location Source
Water licence sketch, March 1961	BC Hydro
Air Photos, 1961, 1954, 1974	BC 4023: 1-2; BC 1934:97; BC 7642: 85-86

4.2 Hydro Facilities and Fish References

Reference	Notes	Source
B.C. Hydro. 1999. Recreation opportunities inventory. Power Supply Environment, Rept. ER 99-08., 206 p.	color maps and description of facilities	BC Hydro
Hirst, S.M. 1991. Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia. Volume 2. Inland fisheries. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2093. 200 p.	“non-anadromous fishery values of the system have not been documented”	
Lewis, A.F., G.J. Naito, S.E. Redden and BC Hydro Safety & Environment. 1996. Fish flow studies project: fish flow overview report. BCH Safety & Environment Rept. No. EA:95-06, 144 p.	comprehensive review of flows, facilities and fish for all BCH projects	BC Hydro

4.3 Wildlife References

Reference	Notes	Source
BC Fish & Wildlife Branch. 1977. Wildlife Distribution Mapping Series: Grizzly Bear Distribution and Relative Abundance.	Boundary between Plentiful (over 1 bear per 25 sq. miles) & Moderate (1 bear per 25-55 sq. miles)	MELP Surrey: Jack Evans