Bridge-Coastal
Fish and Wildlife Restoration Program

STRATEGIC PLAN

Volume 1:

Strategy and Overview

Cover photos:	
Comox Dam *BC Archives*	**Seton Diversion Dam** *Roos 1991*
Alouette-Stave-Ruskin illustration *Water Powers of B.C. 1954*	
Jordan Diversion Dam *Water Powers of B.C. 1954*	**Ruskin Dam** *Water Powers of B.C. 1954*

British Columbia

Fisheries and Oceans Canada

BC Hydro Fish & Wildlife Bridge Coastal Restoration Program

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PREFACE

The Strategic Plan for the Bridge-Coastal Fish and Wildlife Restoration Program (BCRP) provides the technical framework to guide activities and priorities under the program, consistent with fish and wildlife management policies and Water Use Plans in the Bridge-Coastal Generation Area.

The Strategic Plan includes Volume 1 – the overall restoration strategy along with a summary of 'footprint' impacts in the Appendix, and Volume 2 – the individual Watershed Plans containing details of fish and wildlife impacts, restoration objectives and references.

The Strategic Plan was prepared based upon available, documented information on impacts, limiting factors and conservation concerns. Anecdotal or uncertain information about species historical presence, impacts and current population status has not been included, although such information may be considered, where relevant, in context with specific restoration proposals, and updates of the Watershed Plans.

The Strategic Plan outlines a range of options for fish and wildlife restoration. It should be recognized, however, that funding under BCRP will focus on shorter-term projects (maximum 7-year time frame) rather than longer-term programs.

The assistance of the many individuals who provided information, attended workshops and reviewed draft reports is kindly acknowledged.

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Bridge-Coastal Fish and Wildlife Restoration Program

Summary of Strategic Plan

The Bridge–Coastal Fish and Wildlife Restoration Program (BCRP) is a joint initiative by BC Hydro, the Government of B.C. and the Government of Canada to address the historical effects of hydroelectric development on the fish and wildlife resources of the watersheds in the Bridge-Coastal Generation Area:

Vancouver Island

- Campbell River (and Quinsam, Salmon and Heber diversions)
- Puntledge River
- Ash River
- Jordan River

Lower Mainland Fraser

- Alouette River
- Stave River
- Coquitlam River (Buntzen Lk)
- Jones (Wahleach) Creek

Interior Fraser

- Bridge River
- Seton River
- Shuswap River

Mainland Coast

- Cheakamus River
- Clowhom River
- Falls River
- Clayton Falls

The goal of the program is to restore, to the extent practicable, fish and wildlife resources that have been adversely affected by the original 'footprint' development of hydroelectric facilities. *Footprint impacts* are the historical effects on fish and wildlife of the physical developments that occurred primarily as a result of reservoir creation, watercourse diversions and construction of dam structures.

The purpose of the Strategic Plan is to provide the ***technical framework*** for undertaking activities to reduce the adverse impacts on fish and wildlife or to recover some of the losses in fish and wildlife diversity and production created by hydroelectric development.

The Strategic Plan outlines the overall direction and approach to restoration within the watersheds, with a focus on addressing historical losses of fish and wildlife habitat. It describes the type and scale of impacts from hydroelectric development and proposes strategies to achieve improvements in diversity and production of fish and wildlife within the constraints imposed by biophysical conditions and hydroelectric operations.

The Bridge–Coastal Fish and Wildlife Restoration Program, which addresses footprint impact issues, will operate in conjunction with Water Use Plans which are determining flow allocations. The Bridge-Coastal Management Board will determine the specific project activities within the program.

The Plan has two parts:

The **Strategic Plan** (Volume 1) containing the basic framework and overall restoration strategy, along with a summary of footprint impacts in the appendix.

The **Watershed Plans** (Volume 2) containing detailed description of facilities, impacts, and fish and wildlife issues and restoration objectives within each of the fifteen watersheds.

The Bridge-Coastal Fish and Wildlife Restoration program (BCRP) is intended to support opportunities such as:

- Mitigating the existing adverse impacts of hydroelectric facility development (e.g. measures to reduce fish entrainment and wildlife mortality in powerhouse intakes and flow diversion facilities).

- Replacing habitats that have been flooded or altered within the watershed where they can be brought into productive and sustainable use under the regulated hydrological conditions (e.g., off-channel habitat development).

- Enhancing fish and wildlife habitats and populations where opportunities exist in the watersheds, and consistent with species management and biodiversity objectives in the region (e.g., creating waterfowl nesting structures in the reservoir).

The Strategic Plan is based on the outline in Figure 1 and contains:

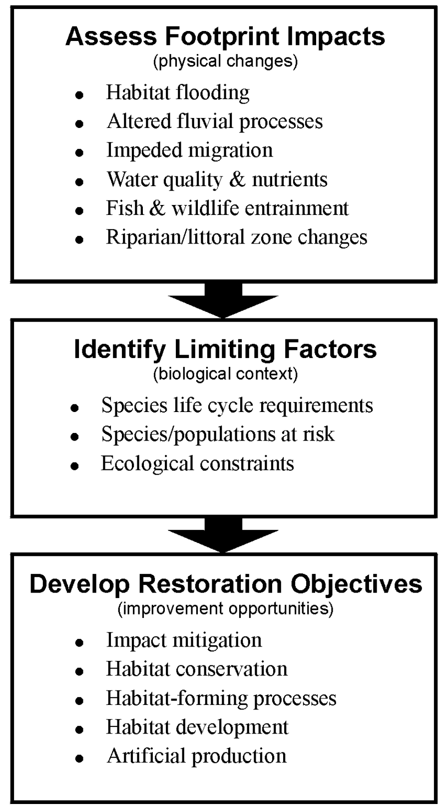
i. assessment of the *footprint impacts* of the dams, reservoirs and diversions on habitat and known species occurring in the watersheds;

ii. identification of the major *limiting factors and ecological constraints* which influence diversity and production in the affected watersheds, based on available information and discussions with technical staff;

iii. key principles and an overall strategy or approach to addressing footprint impacts; and

iv. watershed-level restoration objectives for each of the BC Hydro facilities.

FIGURE 1: CONCEPTUAL FRAMEWORK



The restoration strategy sets out the general priorities:

- **firstly**, to mitigate impacts wherever practicable;

- **secondly**, to conserve important habitats that remain intact;

- **thirdly**, to maintain or restore natural habitat formation processes;

- **fourthly**, to replace or develop suitable habitats where capacity can be utilized;

- **fifthly**, to undertake selective artificial production measures, where justified.

Monitoring and evaluation of results from the selected activities is also proposed.

Footprint impacts are documented in the Plan, based on available information and mapping of pre-flooding hydrography and habitat types. Historical maps, air photos and file information were compiled from archival material at BC Hydro, BC Archives, UBC Map Library, BC Environment and Pacific Salmon Commission. This historical information was then overlaid on 1:20,000 scale contemporary maps of the reservoir areas.

Fish and wildlife habitat changes were estimated from the pre and post construction maps. In total, 34,700 hectares were flooded in the Bridge-Coastal Generation Area, more than one-half of which was land area (including streams) and the remaining was original lakes. The habitat changes included a loss of 286 km (or 2182 hectares) of mainstem channels and 200 km of tributaries, over 1500 hectares of wetland and 3500 hectares of riparian deciduous lowland habitat.

Dam construction has blocked migration of anadromous and resident fish at various facilities. Of the 19 watersheds (including diversions) affected in the Bridge-Coastal generation area, historic access for anadromous salmon above dams has been maintained in two of the watersheds, while in five watersheds it has been blocked. In some cases, hydroelectric structures have also interfered with wildlife movements and have resulted in wildlife mortality at power canals and intakes, and from reservoir ice.

Reservoir and downstream productivity has been reduced, to varying extent, in virtually all Bridge-Coastal watersheds. Loss of carcasses from historic anadromous fish populations has also reduced nutrient levels in the aquatic and terrestrial ecosystems of the five blocked watersheds.

Diversions are a major source of changes to riparian areas and aquatic habitats in 11 of the watersheds. They involve three types: (a) diversions from adjacent watersheds into BC Hydro reservoir watersheds to provide additional water for power generation, (b) diversions out of the watersheds to powerhouses in adjacent watersheds, and (c) diversions to powerhouses within the same reservoir watershed.

The diversions have generally reduced the downstream habitat in the diverted rivers, and, where diversions occur within watersheds, also reduced habitat in sections of downstream channel that are by-passed by power canals, penstocks or tunnels until the diversion subsequently re-enters further downstream. Stream flows have increased in the receiving watershed or stream reach, but with a very different flow regimes, usually resulting in deterioration or loss of habitats required by the fish and wildlife species historically present in the watershed.

Restoration objectives are proposed based on the particular conservation and management needs in each watershed. These objectives take into account footprint impacts, particularly habitat losses, and limiting factors which constrain fish and wildlife diversity and production.

Project activities, guided by the restoration objectives, will be subject to technical assessment during the implementation of BCRP. Emphasis is placed on interventions that restore natural processes wherever possible or that involves modest levels of infrastructure and management. The flow requirements for BCRP projects also depend upon coordination with Water Use Plans for each watershed.

TABLE OF CONTENTS

VOLUME 1: STRATEGIC PLAN

DEFINITIONS

Footprint Impacts are the historical effects on fish and wildlife of the physical developments that occurred primarily as a result of reservoir creation, watercourse diversions and construction of dam structures. These impacts have largely resulted from one-time, irreversible events.

Operational Impacts are the ongoing effects of facility operations on fish and wildlife and typically represent the seasonal or operational variation in reservoir elevation and downstream flows within hours, days and seasons, and recurring on a continuing basis.

Mitigation refers to feasible and practical efforts to reduce the adverse impacts on fish and wildlife from hydroelectric development.

Restoration refers to feasible and practical efforts to recover some of the losses in fish and wildlife diversity and production created by hydroelectric development.

Enhancement refers to feasible and practical efforts to increase fish and wildlife diversity and production over current levels.

Practicable refers to a measure that is both feasible and practical from a technical and cost-effectiveness perspective.

Limiting Factor is a critical habitat element within the life cycle requirements of particular species or within ecological communities that currently restricts population abundance and productivity (habitat factors outside of the watershed, including ocean survival, and harvesting of fish and wildlife are excluded).

Terminology used in the Plan:

While the Strategic Plan focuses on 'footprint' impacts, there are inevitable overlaps with operational impacts, particularly in regard to long-term changes in the natural hydrograph, and to restoration measures that require particular stream flows or reservoir operations. Therefore, an integrated approach to restoration is promoted in the Plan, which may include some flow-related issues affected by footprint impacts.

In several cases, lakes referred to in the Plan are actually reservoirs (which function quite differently from unregulated lakes) but the traditional titles have been maintained because of their common use.

The Strategic Plan identifies historical impacts of hydroelectric development and proposes a cooperative, BC Hydro-funded program to restore some of the losses associated with these impacts. Other BC Hydro fish and wildlife programs (Columbia River, Peace-Williston) may use different mitigation - compensation terminology due to their particular license requirements.

1. INTRODUCTION

The Bridge–Coastal Fish and Wildlife Restoration Program (BCRP) is a joint initiative by BC Hydro, the Government of British Columbia and the Government of Canada to address the historical effects of hydroelectric development on fish and wildlife resources in the Bridge-Coastal Generation Area (**Figure 1**) including:

Vancouver Island
- Campbell River (and Quinsam, Salmon and Heber River diversions)
- Puntledge River
- Ash River
- Jordan River

Lower Mainland Fraser
- Alouette River
- Stave River
- Coquitlam River (and Buntzen Lake)
- Jones (Wahleach) Creek

Interior Fraser
- Bridge River
- Seton River
- Shuswap River

Mainland Coast
- Cheakamus River
- Clowhom River
- Falls River
- Clayton Falls

The goal of the Bridge-Coastal Fish and Wildlife Restoration Program is to restore, to the extent practicable, fish and wildlife resources that have been adversely affected by the original 'footprint' development of hydroelectric facilities.

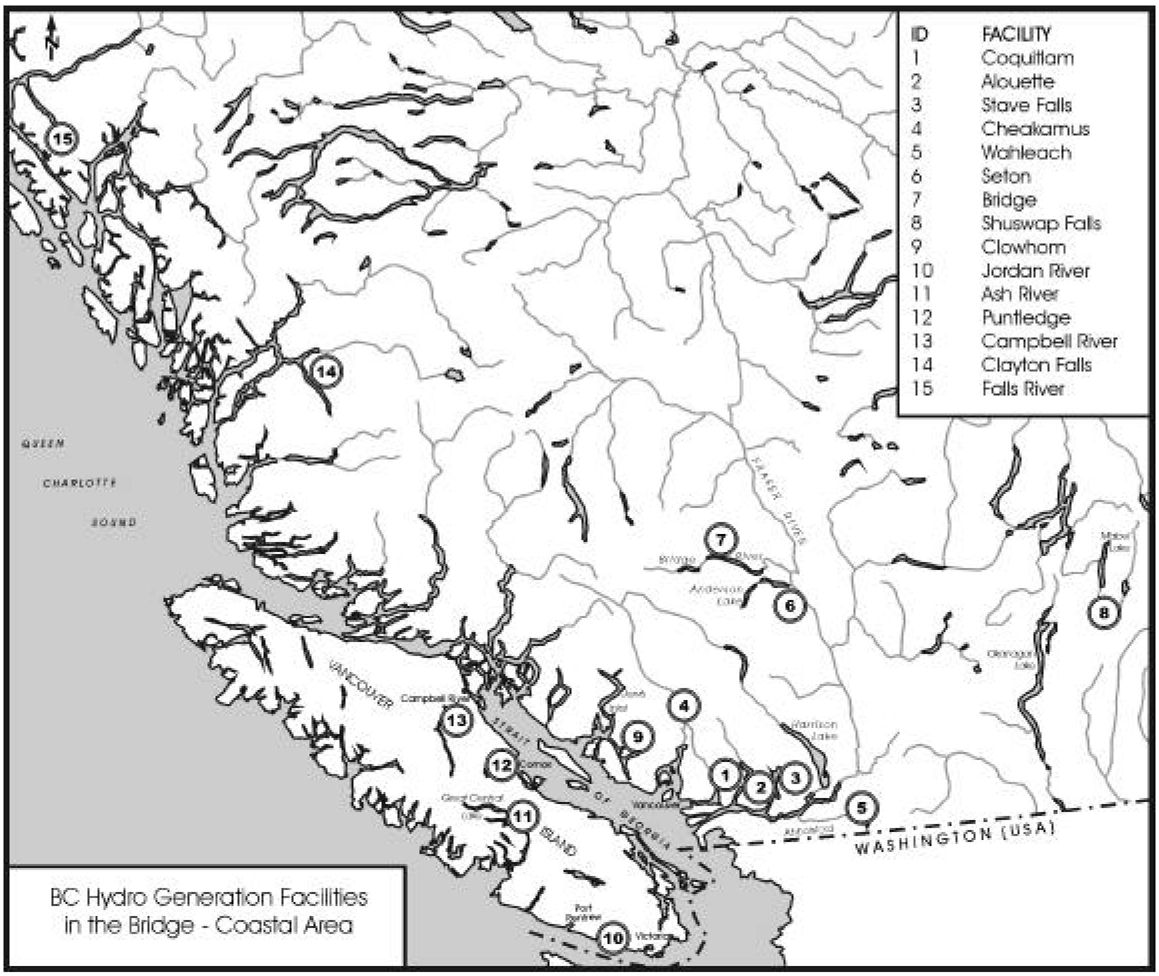
The purpose of the Strategic Plan is to provide the *technical framework* for undertaking activities to mitigate impacts and to replace or enhance fish and wildlife adversely affected by hydroelectric development. The Plan describes these impacts and proposes strategies to improve diversity and production of fish and wildlife. The **Bridge-Coastal Management Board**, appointed to oversee the program, will determine specific projects.

The Plan is organized into two parts:

The **Strategic Plan** (Volume 1) contains the goal, principles, general approach, and restoration strategy, along with a summary of footprint impacts in Appendix 1.

The **Watershed Plans** (Volume 2) contain a review of available documents and technical workshops, along with descriptions of facilities, habitat changes, historical and current species, identification of impacts and limiting factors, restoration objectives and references for each watershed.

Figure 1: Bridge-Coastal Generation Area



2. PRINCIPLES

The BCRP has been designed with the following principles in mind:

Scope of Restoration

Hydroelectric development generally precludes a return to pre-development ecosystems. Restoration is therefore limited to actions that reduce or offset adverse impacts on fish and wildlife. This will be accomplished by improving habitat and production within each reservoir and its tributaries and diversions, elsewhere within the watershed, or, where local enhancement opportunities do not exist, outside of the watershed. The level of effort will be broadly based on estimates of footprint impacts of the hydroelectric facilities.

Ecosystem Approach

Ecosystems provide the focus for restoring fish and wildlife. Techniques to produce more fish and wildlife may have implications for non-target species that need to be considered in light of the complexity of natural habitats and relationships between species within the watershed. The restoration program will balance species production and biodiversity conservation objectives within an ecological perspective.

Coordination with Water Use Plans

Fish and wildlife restoration activities may require changes in flow operations in order to address some of the footprint impacts created by the diversion and impoundment of water. While the Strategic Plan will identify and describe these circumstances, the specific stream flow and reservoir level requirements for conservation and enhancement will be determined by the Water Use Planning process.

Restoration within a Watershed Context

The impacts of hydropower development cannot be addressed in isolation from the conditions throughout the watershed and the other human activities (including fishing and hunting) that affect the status of fish and wildlife. Opportunities for restoration will be considered in relation to species life cycles, habitat requirements and limiting factors within the watershed, along with hydrological processes, other developments and other resource enhancement activities.

Fish and Wildlife Management Policies and Responsibilities

Restoration activities will be implemented by, or in conjunction with, fish and wildlife management agencies, First Nations and community groups. The Strategic Plan will be consistent with and complementary to the current policies, priorities and other resource enhancement activities of these agencies and their partners.

3. SCOPE AND ASSUMPTIONS

The BCRP is intended to support opportunities to improve habitats and populations. It is recognized that there is limited potential to physically restore highly altered watersheds to pre-development ecological conditions. In specific situations, however, there are opportunities to reduce adverse effects and to replace some of the lost fish and wildlife values associated with historical development of hydroelectric facilities.

These opportunities may involve:

- Mitigating the existing adverse impacts of hydroelectric facility development (e.g., measures to reduce entrainment of fish and wildlife in powerhouse intakes and flow diversion facilities, or to restore fish access).

- Replacing habitats that have been flooded or altered within the watershed where they can be brought into productive and sustainable use under the regulated hydrological conditions (e.g., off-channel habitat development).

- Enhancing fish and wildlife habitats and populations where opportunities exist in the watersheds, and consistent with species management and biodiversity objectives in the region (e.g., creating waterfowl nesting structures in the reservoir; improving habitat productivity).

Several key assumptions were adopted in the development of this plan.

1. The BCRP is not an attempt to completely compensate for the long history of environmental effects of dams that were constructed 40-90 years ago. It is, however, a substantive effort to restore some of the lost fish and wildlife values attributable to these facilities, and to do this in a manner that is practical and sustainable.

2. The BCRP cannot fully restore fish and wildlife habitats since these systems have usually been completely altered (by BC Hydro and others) and have existed in a changed environment over long periods. It can, however, improve a variety of habitat conditions for increased fish and wildlife diversity and productivity in the context of hydropower generation and the availability to water as determined by Water Use Plans.

3. The BCRP cannot, in many cases, separate habitat changes and population losses created by hydroelectric facilities from the cumulative effects of development in the watersheds and beyond. However, the estimates of habitat changes associated with footprint impacts and historical levels of productivity that existed at the time of hydroelectric development can generally guide the level of restoration effort.

4. The BCRP will recognize biological diversity and fish and wildlife production as equally important objectives. Emphasis will be placed on restoring natural processes

and ecological functions that support wild stocks and indigenous populations, supplemented with technology and engineering inputs only as necessary.

5. The BCRP adopts the conservation principles identified in the following fish and wildlife management documents:

   - *Conserving Our Fish Resources*, BC Fisheries Program Strategic Plan, 1996:
     "Conserving wild fish populations and their habitat, in the context of maintaining or restoring aquatic biodiversity, is the fundamental objective of provincial fisheries management in British Columbia."

   - *Provincial Wildlife Strategy to 2001*, BC Wildlife Branch, 1994:
     "Goal One: Maintain diversity and abundance of native species and habitats throughout British Columbia."

   - *Wild Salmon Policy Discussion Paper*, Fisheries and Oceans Canada, 2000.
     "Wild Pacific salmon will be conserved by maintaining diversity of local populations and their habitats. Salmon cultivation techniques may be used in strategic intervention to preserve populations at greatest risk of extirpation. For specified conservation units, when genetic diversity and long-term viability may be affected, conservation of wild salmon populations will take precedence over other production objectives involving cultivated salmon."

Many of the Bridge-Coastal hydroelectric projects are physically and operationally complex systems that exert diverse impacts on fish and wildlife. Specific proposals to restore the habitat of a particular fish or wildlife species may have ramifications for non-target species. They may also affect the operating regime of the facility in question. Therefore, the benefits and costs of each proposed action must be carefully evaluated to consider potential biological and technical uncertainties.

A ***technical assessment process*** will be established to review proposals under BCRP. This review process will take into account questions such as:

- Does the restoration option address a limiting factor for the species or ecological communities in question? What is the level of certainty that the option will remove or reduce a constraint or production bottleneck?

- Will the restoration option affect other species utilizing the same habitats? Will the proposed interventions fundamentally modify the aquatic or terrestrial ecosystems and will biodiversity be improved or diminished by these actions?

- Will the option work in the situation proposed? Is it practical and well tested? Does it have a high probability of success and sustainability in the long run? What are the potential implications of failure?

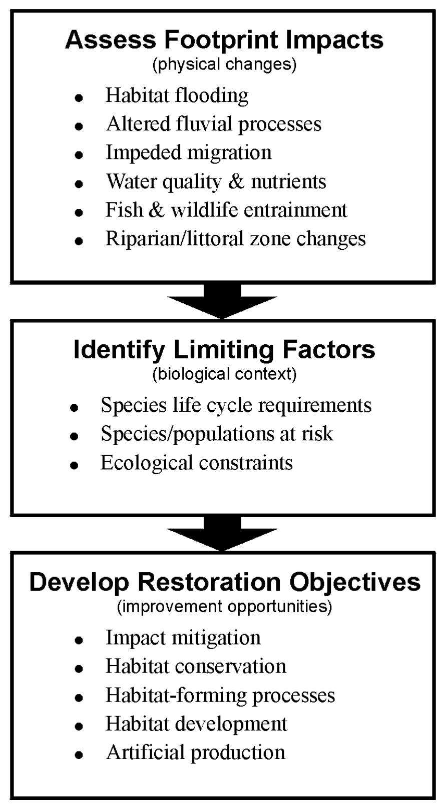
- Is the proposed option the most efficient means of achieving the desired objective? How does it compare to alternative strategies or methods?

- Is the success of the proposed option dependent on operational aspects of the facilities, and are the necessary flow releases or reservoir operating regimes available?

4. GENERAL APPROACH

The Strategic Plan is based on three general steps: defining the footprint impacts, assessing various limiting factors to fish and wildlife and selecting appropriate restoration objectives. **Figure 2** outlines the conceptual framework.

FIGURE 2: CONCEPTUAL FRAMEWORK



The **first task** was to assess the major types of footprint impacts in terms of habitat changes and other effects of hydroelectric development (see Appendix I). These include footprint impacts such as habitat flooding, changes in fluvial processes including gravel and large woody debris interception, migration barriers, entrainment, water quality and nutrient impacts, and altered littoral/riparian zones.

The **second task** was to consider the range of 'limiting factors' that may be constraining fish and wildlife diversity and production in the watershed. These are the particular circumstances that either place a limit on species abundance or diversity, or otherwise prevent a species from existing in the watershed. They include species life cycle requirements under stress, sensitivity of the communities of concern, and factors affecting ecological diversity and species or populations of special concern (excluding habitat factors outside of the watershed, ocean survival, and harvesting).

The **third task** was to develop restoration objectives within the watershed, taking into consideration the above footprint impacts and limiting factors. Five general categories of restoration options were considered: Impact Mitigation, Habitat Conservation, Habitat-forming Processes, Habitat Development and Artificial Production.

5. FOOTPRINT IMPACTS

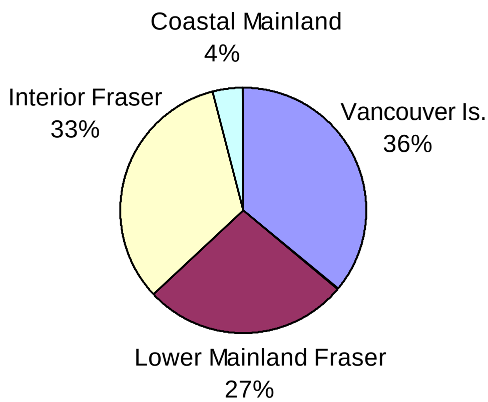
Impacts of hydroelectric development on fish and wildlife in the Bridge-Coastal area have generally involved the following types of effects (see Appendix I and the Watershed Plans for detail):

- Loss of important fish and wildlife habitat areas
- Loss of sediment and woody debris
- Blockage of fish migration and wildlife movement
- Reduced aquatic and terrestrial productivity
- Reservoir drawdown effects
- Entrainment of fish and wildlife in power canals and intakes
- Altered channel morphology from diversions and changes in flows

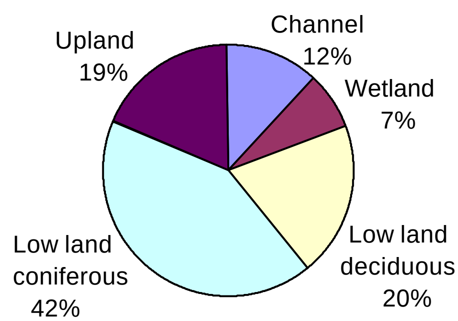
Loss of aquatic and terrestrial habitat from inundation by reservoirs and changes in stream flows has caused adverse effects on fish and wildlife. In total, 34,700 hectares were flooded in the Bridge-Coastal Generation Area, more than one-half of which was land area (including streams) and the remaining was original lakes. This included large areas of mainstem stream channel (2200 ha), tributaries (200 km) as well as extensive wetland (1500 ha), lowland deciduous (3500 ha), lowland coniferous (7600 ha), and upland (3300 ha) habitat. Loss of these habitats from flooding and facilities development has adversely affected fish and wildlife.

The following graphs summarize flooded areas and habitat types:

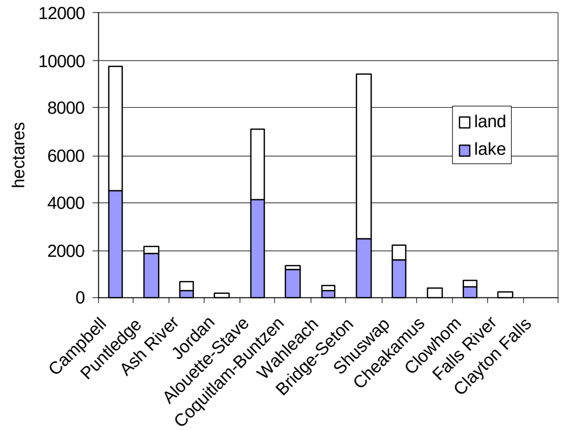
Total Area Flooded by Reservoirs



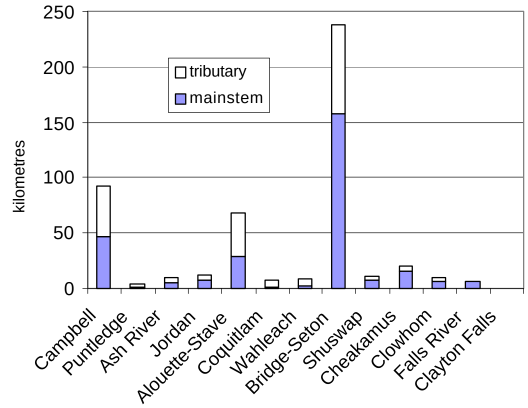
Habitat Areas Flooded



Area Flooded by Reservoirs



Stream Length Flooded by Reservoirs



Dam construction has blocked migration of fish access at various facilities. Of the 19 watersheds (including diversions) affected in the Bridge-Coastal generation area, historic access for anadromous salmon above dams has been maintained in two of the watersheds, while in five watersheds access has been blocked.

In some cases, reservoirs and structures have also interfered with wildlife movements and have resulted in wildlife mortality at power canals and intakes, and from ice shelves and thin ice on reservoirs. Entrainment of anadromous juveniles has been partially addressed at these facilities, but the effect on resident fish or wildlife populations is generally unknown. Reservoir and downstream productivity has been reduced, to varying extent, in virtually all Bridge-Coastal watersheds. Loss of carcasses from historic anadromous fish populations has also reduced nutrient levels in the aquatic and terrestrial ecosystems of the five blocked watersheds.

Diversions are a major source of changes to riparian areas and aquatic habitats in 11 of the watersheds (excluding minor streamside diversions to powerhouses). They involve three types: (a) diversions from adjacent watersheds into BC Hydro reservoir watersheds to provide additional water for power generation, (b) diversions out of the watersheds to powerhouses in adjacent watersheds, and (c) diversions to powerhouses within the same reservoir watershed.

The diversions have generally reduced the downstream habitat in the diverted rivers, and, where diversions occur within watersheds, also reduced habitat in sections of downstream channel that are by-passed by power canals, penstocks or tunnels until the diversion subsequently re-enters further downstream. Stream flows have increased in the receiving watershed or stream reach, but with a very different flow regime, usually resulting in deterioration or loss of habitats required by the fish and wildlife species historically present in the watershed.

The following table illustrates these diversions[1]:

Campbell River	**<50**		**100-200**
Puntledge River			**<50**
Ash River		**<50**	
Jordan River			**50-100**
Alouette River		**50-100**	
Stave River	**50-100**		**>200**
Coquitlam River		**50-100**	
Wahleach Creek		**<50**	
Bridge River		**100-200**	
Seton Creek	**100-200**		**100-200**
Shuswap River			**<50**
Cheakamus River		**50-100**	
Clowhom River			**50-100**
Falls River			**<50**

Major changes to the flow regimes due to reservoir and dam installation have generally reduced aquatic productivity, both upstream where lakes were converted to reservoirs, and downstream within the altered stream channels and riparian habitats. Regulated flow regimes (reservoir drawdowns) have, in some instances, also resulted in fish stranding, reduced or improved fish access to tributaries, and dewatered or flooded spawning areas along reservoir shorelines and tributaries. In many cases, these changes have been further aggravated by other land uses and development in the floodplains.

While some improvements have been gained from reducing the scale of fluctuations in streamflows, this has been offset by loss or degradation of significant areas of downstream natural channel habitats. Dams have particularly interfered with the downstream movement of gravel and large woody debris, important in the formation of aquatic habitat.

Description of these and other impacts can be found in Appendix I and in the Watershed Plans. BC Hydro and others have mitigated some of these impacts, with varying degrees of success.

[1] Based primarily on *maximum licensed diversions*. Comprehensive data on actual diversion flows are not available. These licensed flows have also been adjusted in recent years through Interim Flow Orders and Water Use Plans. Includes short streamside diversions to powerhouses within watersheds.

6. RESTORATION STRATEGY

The restoration strategy sets out the following general order of priorities:

1. mitigate impacts wherever practicable
2. conserve important habitats that remain intact
3. replace lost habitats using natural processes where possible
4. develop suitable habitats where capacity can be utilized
5. undertake artificial production measures where other options are not suitable

The Strategy is a hierarchy intended to guide restoration activities within each watershed. Table 1 outlines the major categories of restoration options. The examples are representative and not an exhaustive list of possibilities. The appropriate restoration activities will depend upon the unique biological and habitat situations in each watershed. A program of ongoing monitoring and adaptive management is also essential.

1. Impact Mitigation

Continue to undertake cost-effective measures to reduce ongoing impacts on fish and wildlife.

As a first priority, BCRP will address opportunities to mitigate adverse impacts, guided by its criteria to assess the restoration options. Many footprint impacts remain to be addressed; *e.g.*, entrainment of juvenile anadromous fish at Seton. The issue of restoring anadromous fish passage requires considerable biological and technical planning. There are also data gaps with respect to the significance of certain issues on local populations, *e.g.*, entrainment of resident fish or wildlife in power intakes; gas supersaturation levels during spills. Some of the outstanding impacts and issues are currently under study or active mitigation by BC Hydro and fish and wildlife agencies.

2. Habitat Conservation

Conserve the remaining important habitats within the watershed.

As second priority, BCRP will address opportunities to identify, protect and conserve selected habitat areas for conservation purposes. Conservation values are central to the restoration program. Natural habitats outside of the hydroelectric footprint need to be protected from future degradation and maintained in a productive state. This applies particularly to wetland and estuarine habitats that require unique conditions that are difficult to recreate. Prevention of further decline or loss of critical habitats will be addressed through more comprehensive inventory of biodiversity elements, property acquisition, and protective designations, especially where they conserve species at risk. BCRP watersheds contain several fish stocks that have been extirpated or are currently at risk, as well as wildlife species that have conservation status (Table 2).

Table 1: **Fish and Wildlife Restoration Options in Bridge-Coastal Generation Area**	
Options	**Examples**
Impact Mitigation *- undertake measures to reduce the adverse effects on fish and wildlife from hydroelectric development*	• Fish passage technologies • Wildlife migration improvement measures • Drawdown zone revegetation/stabilization • Entrainment reduction measures • Supersaturation (gas bubble) reduction
Habitat Conservation *- protect and maintain current habitat values through improved inventory, water and land management and habitat conservation measures*	• Inventory data gaps and research issues • Rare/special habitats identification/notification • Habitat acquisition and protection • Riparian conservation activities
Habitat-forming Processes *- maintain or restore where possible, the physical watershed, floodplain and ecosystem processes which provide a range of natural habitats*	• Artificial gravel recruitment • Artificial wood debris recruitment • Small-scale complexing in existing habitats • Aquatic productivity enhancement; reservoir/stream fertilization to restore historic levels
Habitat Development *- expand natural habitat capacity and quality where appropriate to restore production and/or diversity*	• Mainstem/off-channel/tributary fish habitat creation • Wetland habitat creation • Fish-wildlife shoreline complexes within the reservoir • Upland wildlife habitat enhancement
Artificial Production *- supplement natural production by propagating selected species as an interim measure to conserve threatened stocks until habitat capacity can be restored without adverse effects on other species*	• Fish stock re-introductions • Stocking of hatchery-produced fish where natural production is not possible • Captive brood stock and gene banking programs • Wildlife re-introductions and nesting structures

3. Habitat-forming Processes

Maintain or restore, where feasible, natural processes affecting habitat formation.

As third priority, BCRP will focus on restoring habitat-forming processes, subject to site opportunities and an evaluation process. Hydroelectric development of rivers and lakes into regulated rivers and reservoirs has reduced the quality and quantity of productive habitats. Within limits, some of the lost habitat attributes can be restored by mimicking natural fluvial processes[1]; e.g., using spills to transport new gravel or wood materials downstream. Restoration of former nutrient levels may be achieved by returning anadromous salmon populations and by cautious use of lake or stream fertilization. Another strategy is to promote natural regeneration of historic riparian habitats along affected watercourses. In upland areas, control of vegetation succession from wildfires (altered by fire suppression) could be mimicked through prescribed logging or burning.

4. Habitat Development

Replace or construct new habitat where it will directly contribute to fish and wildlife diversity and production in the watershed.

As fourth priority, BCRP will replace lost habitats where suitable, increase the capacity of existing habitats and develop new habitat areas to support populations of historic species in the watershed. The capacity of existing habitats can be increased by adding complexity to certain features; *e.g.*, creating deep pools or adding wood debris. Such projects should be small in scale and subject to the natural processes of the location. In aquatic habitats, it is preferable that they operate within the context of fluvial processes.

Development of new habitat areas such as side channels or shoreline impoundments requires more intervention than minor adjustment of existing habitats. Such projects may have their own ecological 'footprint' impacts on habitats of other species, and there are attendant concerns about structural longevity and potential need for ongoing maintenance. Habitat construction projects should be designed to work within the framework of natural processes wherever possible. Projects will be considered on a watershed or site-specific basis, and subject to evaluation criteria and consistency with fish and wildlife agency management plans.

5. Artificial Production

Provide support for re-introduction of fish and wildlife, and for artificially supplementing production where necessary.

In some cases, species may have been extirpated by hydroelectric development, existing populations may be under stress or at risk of extirpation, or environmental changes resulting from hydroelectric development may have created conditions suited to non-

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[1] See for example, Beechy Tim and Susan Bolton, "An Approach to Restoring Salmonid Habitat-forming Processes in Pacific Northwest Watersheds", Fisheries, Vol. 24, No. 4, 1999, pp 6-14.

native species. Interventions may be needed to artificially re-introduce or rebuild fish stocks or wildlife populations, *e.g.*, living gene banks or captive broodstock programs to preserve threatened Puntledge chinook and steelhead stocks. This option will only be considered in special circumstances where artificial means are necessary to conserve disappearing populations.

6. Monitoring and Evaluation

Identify performance indicators, monitor and evaluate project results, and re-adjust restoration strategies and methods based on lessons learned.

The effectiveness of BCRP will depend upon careful project selection and on detailed monitoring of results. Performance indicators will be used to evaluate funded projects. Regular monitoring is linked to an ongoing process that tests hypotheses about alternative approaches of restoration and refines the original strategies based on measured results. Monitoring plans at the program and project level are essential to guide this process. Monitoring and evaluation will reinforce BCRP's commitment to achieving biologically sound and practical results.

7. APPLYING THE STRATEGY

The overall strategy, outlined above, provides the initial framework for guiding BCRP projects. The project application process under BCRP will include a technical assessment that takes into account the priorities set out in the **Strategic Plan** and the companion, **Watershed Plans for Bridge-Coastal Fish and Wildlife Restoration Program**.

The Watershed Plans identify the type and scale of footprint impacts based on available information. They describe the known or suspected factors that limit fish and wildlife diversity and production, many of which are associated with footprint impacts. Drawing upon technical reports and workshop discussions, restoration objectives are then specified in the Watershed Plans, taking into account the limiting factors and the current issues affecting fish and wildlife in these areas.

The restoration objectives are general statements of intent, derived from current biological and ecological knowledge of the specific watersheds. Various means of their achievement can be considered during the implementation of BCRP.

Restoring fish and wildlife in the Bridge-Coastal watersheds presents a significant challenge to design interventions that, wherever possible, support natural processes within ecosystems that have been altered by hydroelectric development.

Table 2: Conservation Concerns in the Bridge Coastal Generation Area			
Systems	**Fish stocks extirpated, at risk, threatened**	**Wildlife species endangered**	**Wildlife species of special concern**
Campbell	Gold River (Heber R.) Pink (high risk) Salmon River Chum (high risk) Campbell River Pink (special concern) Other concerns: Gold River steelhead Campbell/Quinsam River Chinook and winter steelhead	Western Grebe (non breeding) Northern Goshawk, laingi ssp. Marbled Murrelet Purple Martin Vancouver Is. Water Shrew Keen’s Long-eared Myotis Vancouver Island Marmot Wolverine, vancouverensis subsp.	Red-Legged Frog Painted Turtle Double-Crested Cormorant Great Blue Heron, fannini ssp. Trumpeter Swan Oldsquaw Surf Scoter Peregrine Falcon, pealei subsp. Gyrfalcon White-Tailed Ptarmigan, saxatilis Western Screech-Owl (saturatus subspecies)? Northern Pygmy-Owl, swarthi ssp Pine Grosbeak, carlottae ssp. Townsend's Big-Eared Bat Vancouver Island Ermine Roosevelt Elk
Puntledge	Chinook (fall - high risk; summer-moderate risk) Steelhead (summer) (high risk) Cutthroat (special concern) Other concerns: Steelhead (winter)	Western grebe (non breeding) Northern Goshawk, laingi ssp. Peregrine Falcon, anatum subsp. Marbled Murrelet Vancouver Is. Water Shrew Keen’s Long-eared Myotis Vancouver Island Marmot Wolverine, vancouverensis subsp.(?)	Red-legged Frog Double-crested Cormorant American Bittern (?) Great Blue Heron, *fannini* spp. Green Heron Trumpeter Swan Old squaw Surf Scoter Peregrine Falcon, *pealei* ssp Gyrfalcon White-tailed Ptarmigan, *Saxatilis* Western Screech-owl, *saturatus* ssp Northern Pygmy-owl, *swarthi* ssp Pine Grosbeak, *carlottae* ssp Townsend’s Big-eared Bat Vancouver Island Ermine Roosevelt Elk
Ash	Somass River Chinook (high risk) Somass River Pink (high risk) Ash River steelhead - summer (special concern)	Western Grebe (non breeding) Northern Goshawk, laingi ssp. Marbled Murrelet Vancouver Is. Water Shrew Keen’s Long-eared Myotis Wolverine, vancouverensis subsp.	Red-legged Frog Great Blue Heron, *fannini* ssp Trumpeter Swan Surf Scoter Peregrine Falcon, *pealei* ssp Gyrfalcon White-tailed Ptarmigan, *saxatilis* Northern Pygmy-owl, *swarthi* ssp Pine Grosbeak, *carlottae* ssp Townsend’s Big-eared Bat Vancouver Island Ermine Roosevelt Elk

Jordan	Chum (extinct) Pink (extinct) Anadromous cutthroat (high risk) Other concerns: steelhead (extinct)	Northern Goshawk, *laingi ssp.* Marbled Murrelet Vancouver Is. Water Shrew Keen's Long-eared Myotis Vancouver Island Marmot (?) Wolverine, *vancouverensis subsp.*	Red-legged Frog Great Blue Heron, *fannini* ssp Peregrine Falcon *pealei* ssp Gyrfalcon (?) Northern Pygmy-owl, *swarthi* ssp Townsend's Beg-eared Bat Vancouver Island Ermine Roosevelt Elk
Cheakamus	Chinook (high risk) Pink (special concern)	Peregrine Falcon, *anatum subsp.* Marbled Murrelet Spotted Owl Pacific Water Shrew (?) Keen's Long-eared Myotis	Tailed Frog, coastal population Great Blue Heron, *fannini* spp Trumpeter Swan Gyrfalcon Trowbridge's Shrew Grizzly Bear Wolverine, *luscus* ssp
Alouette	Chinook (extinct) Sockeye (extinct) Cutthroat (special concern)	Oregon Spotted Frog (?) Peregrine Falcon, *anatum subsp.* Marbled Murrelet Spotted Owl Purple Martin Pacific Water Shrew Keen's Long-eared Myotis Snowshoe Hare, *washingtonii* ssp Long-tailed Weasel, *altifrontalis* ssp	Tailed Frog, coastal population Red-legged Frog Painted Turtle Rubber Boa Double Crested Cormorant American Bittern Great Blue Heron, *fannini* spp Green Heron Trumpeter Swan Gyrfalcon Trowbridge's Shrew Townsend's Big-eared Bat Grizzly Bear Wolverine, *luscus* ssp
Stave	Sockeye (extinct) Stave R. Chinook and pink (high risk) Anadromous cutthroat (probably extinct)	Peregrine Falcon, *anatum subsp.* Marbled Murrelet Spotted Owl Purple Martin Pacific Water Shrew Keen's Long-eared Myotis Snowshoe Hare Long-tailed Weasel, *altifrontalis*	Tailed Frog, coastal population Red-legged Frog Painted Turtle Rubber Boa Double Crested Cormorant American Bittern Great Blue Heron, *fannini* spp Green Heron Trumpeter Swan Gyrfalcon Trowbridge's Shrew Townsend's Big-eared Bat Grizzly Bear Wolverine, *luscus* ssp
Coquitlam	Sockeye (extinct) Pink (extinct)	Peregrine Falcon *anatum* ssp Marbled Murrelet Spotted Owl Purple Martin Pacific Water Shrew Keen's Long-earedMyotis Snowshoe Hare, *washingtonii* ssp	Tailed Frog, coastal population Red-legged Frog Painted Turtle Rubber Boa Double-crested Cormorant Great Blue Heron, *fannini* ssp Green Heron Gyrfalcon Trowbridge's Shrew (?) Townsend's Big-eared Bat Grizzly Bear Wolverine, *luscus* ssp.

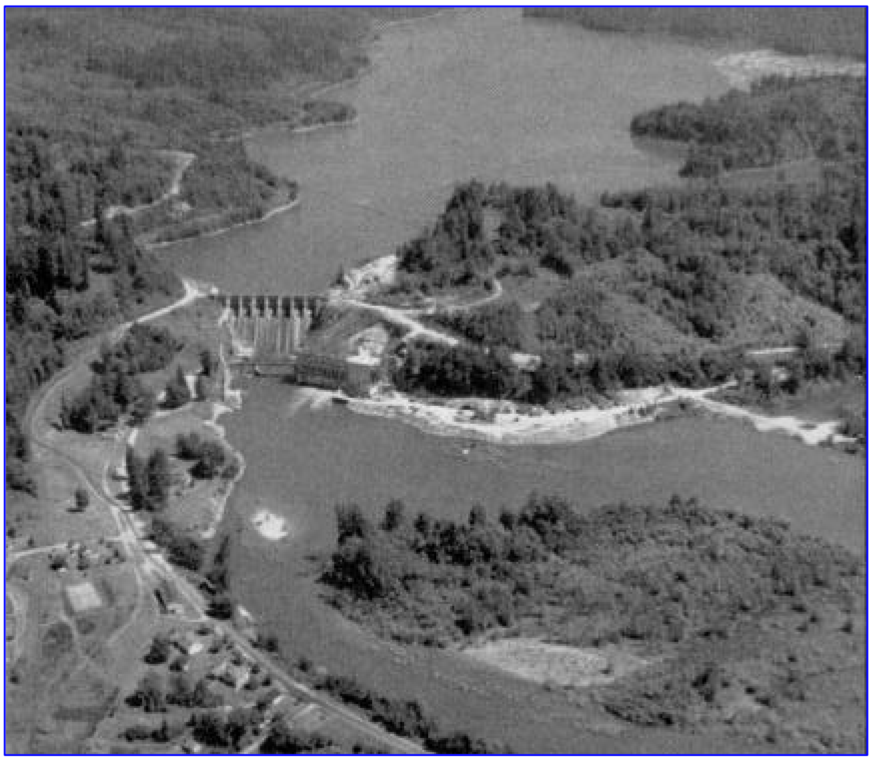
Wahleach		Peregrine Falcon, *anatum* ssp Spotted Owl	Tailed Frog, coastal population Painted Turtle Rubber Boa Great Blue Heron, *fannini* spp Gyrfalcon Trowbridge's Shrew Grizzly Bear Mountain Beaver, *rainieri* ssp Wolverine, *luscus* ssp
Bridge/ Seton	Bridge R. & Seton R. steelhead (high risk) Bull trout (blue-listed)	Peregrine Falcon, *anatum subsp*. Prairie Falcon (Seton only) Spotted Owl Badger (Seton only)	Rubber Boa Gopher snake, *deserticola* ssp (Seton) Great Blue Heron, *herodias* ssp Trumpeter Swan Flamulated Owl (Seton only) Gyrfalcon (?) Spotted Bat (Seton only) Mountain Beaver, *raineri* ssp Grizzly Bear Wolverine, *luscus* ssp Fisher California Bighorn Sheep
Shuswap	Bessette Creek Coho (high risk) Bull trout (blue-listed)	Peregrine Falcon, *anatum subsp*. (?) Caribou, southern population	Rubber Boa Great Blue Heron, *herodias* ssp Gyrfalcon Bobolink Townsend Big-eared Bat Grizzly Bear Wolverine, *luscus* ssp Fisher
Clowhom	Other concerns: uncertain historical access by coho	Western Grebe (non breeding) Marbled Murrelet Peregrine Falcon, *anatum subsp*. (?) Keen's Long-eared Myotis	Tailed Frog, coastal population Red-legged Frog Double Crested Cormorant Great Blue Heron, *fannini* ssp Trumpeter Swan Surf Scoter Gyrfalcon (?) Grizzly Bear Wolverine, *luscus* ssp.
Falls River	Pink Salmon (high risk)	Marbled Murrelet Keen's Long-eared Myotis	Tailed Frog, coastal population Great Blue Heron, *fannini* spp Peregrine Falcon, *pealei* ssp. Gyrfalcon (?) Grizzly Bear Wolverine, *luscus* ssp Fisher
Clayton Falls		Marbled Murrelet	Tailed Frog, Coastal population Great Blue Heron, fannini ssp. Peregrine Falcon, pealei subsp. Gyrfalcon Grizzly Bear Wolverine, luscus subspecies Fisher

Sources: Stocks at Risk: Pacific Salmon Commission files; *Living Blueprint for B.C. Salmon Habitat*, Pacific Salmon Foundation, 1998; Extinction risk classification data for anadromous salmon and trout of British Columbia (draft - unpublished), Slaney T. et. al., 1996; 'Other concerns' were noted by regional fisheries staff. Effects related to stock re-distribution were excluded. Wildlife: Red and blue-listed species, B.C. Conservation Data Centre, Victoria, May 2000.

Note: this is a list from documented sources only and may not include all species or stocks suspected to be at risk; extirpated stocks refer to loss of confirmed, substantive fish populations.

APPENDIX I

SUMMARY OF FOOTPRINT IMPACTS



Ruskin Dam, 1950

BRIDGE-COASTAL FISH AND WILDLIFE RESTORATION STRATEGIC PLAN

December, 2000

TABLE OF CONTENTS

LIST OF TABLES

Acknowledgements

The Strategic Plan has been prepared by Regional Consulting Ltd., Global Fisheries Consultants Ltd., D.B.Lister & Associates Ltd., and Summers Biological Services, with mapping by GIS Innovations.

The assistance of UBC Map Library, UBC Special Collections, British Columbia Archives, Legal Surveys Branch, Heritage Conservation Branch, B.C. Conservation Data Centre, Pacific Salmon Commission and BC Hydro in providing historical material is gratefully acknowledged. Disaggregated data on fish stocks at risk was provided by Tim Slaney. The use of digital map files and air photos from Ministry of Environment, Lands and Parks was also invaluable in completing the report.

Small maps are mostly from Hirst, 1991. Photos used in the plan are from BC Archives photo collection and from **Water Powers of British Columbia**, Water Rights Branch, Dept. of Lands and Forests, 1954 and A. White, **Water Powers of British Columbia**, Commission of Canada, 1919.

1. INTRODUCTION

This appendix to the Bridge-Coastal Fish and Wildlife Restoration Plan summarizes the assessment of "footprint" impacts of BC Hydro facilities on fish and wildlife. More detailed description of impacts and issues may be found in the Watershed Plans.

Footprint Impacts, which are distinguished from operational impacts, are the historical effects on fish and wildlife of the physical developments that occurred primarily as a result of reservoir creation, watercourse diversions and construction of dam structures. This report describes, based on available information, the major footprint impacts of impounding and diverting streams for power generation.

2. METHODOLOGY AND DATA SOURCES

The Strategic Plan has been undertaken by:

- preparing checklists of the key indicators of footprint impacts, in order to guide data collection;

- compiling and reviewing available information from BC Hydro, and federal and provincial agencies on the facilities, the hydrology, the fish and wildlife resources affected by the hydroelectric facilities, and extracting the relevant data on impacts and issues (see references in the Watershed Plans);

- compiling and assessing historical information on the pre-project fish and wildlife habitat conditions through analysis of early maps, photos and air photos, old reports and habitat information on legal surveys, correspondence and various archival records of BC Electric and Railway Company/BC Hydro, the Province and DFO (First Nations traditional use information was not available);

- mapping the pre-project drainage systems and lake morphometry on 1:20,000 scale TRIM base, using the historical sources, and estimating changes in general habitat types from hydroelectric development (see Table 1);

- consulting with technical staff of fish and wildlife management agencies and others through regional workshops and individual contacts to collect data and identify key impact issues; and

- assessing pre and post project conditions based on the available information, including estimates of habitat changes (Tables 1 and 2) and preparation of matrices which identify the occurrence of various impacts at each facility.

Data sources are listed in the references section of the Watershed Plans.

Estimates of reservoir area and lake area flooded can vary due to differences in mapping and methods of calculation. In this project, map analysis was undertaken using the TRIM digital map files from Government of B.C. and Intergraph Microstation GIS software. High pool reservoir boundary lines were used wherever possible.

3. HYDROLOGICAL AND HABITAT CHANGES

Hydroelectric development has completely altered hydrological regimes and habitat characteristics, as shown in Table 1 and Table 2. The most obvious fish and wildlife impacts have been due to the change from riverine to reservoir habitats, and the diversion of water between or within watersheds.

Table 1 summarizes the estimated changes in habitat types. In total, 34,700 hectares were flooded in the Bridge-Coastal Generation Area, more than one-half of which was land area and the remaining was original lakes. This flooding included inundation of some large river systems: Bridge, Campbell and Stave River, where a total of 2200 hectares of mainstem channel was lost. Major areas of wetlands were also inundated, especially between Upper Campbell Lake and Elk River and in upper Bridge River, where a total of 1330 hectares were lost. Over 10 percent of the total flooded areas, or 3500 hectares, existed as lowland deciduous (riparian) habitat prior to hydroelectric development.

Diversions for hydroelectric development have also created a substantial reduction in aquatic habitat. The diversions involve re-directing water from another watershed into the new reservoir and/or diverting water through a power tunnel or canal/penstock alongside or away from the natural drainage system. Diversions can make up a major proportion of total inflows to certain reservoirs, sometimes altering the baseline limnological conditions.

Stream flows, and generally aquatic habitats, are therefore reduced in the streams from where diversions occur, and in sections of downstream channels that are bypassed until diversions subsequently re-enter further downstream. Stream flows are increased in the receiving watershed or stream reach, but with a very different flow regime, usually detrimental to fish and wildlife.

Table 2 summarizes estimates of diversions and reservoir inflows, the streamflows, and stream lengths potentially affected. Inflows represent the available reservoir water; licensed diversions represent flows historically committed to power production (may be amended by Interim Orders and WUP). Data on actual diversions were not available, but by comparing licensed diversions to average reservoir inflows and average annual flow in the river, the relative scale of removing or adding water to the system can be identified[1]. Stream lengths potentially affected by reduced and increased flows are noted on the table.

While annual average data do not reflect seasonal variation, it is apparent from Table 2 that, in some cases, diversions have been significant. The Salmon and Heber diversions, for example, have had at least three-quarters of their annual flow diverted for power generation on the Campbell system. Most of the total annual flows in the Cheakamus at Daisy Lake have been diverted for power production, as have the Bridge River flows

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[1] Locations of hydrometric stations vary and actual diversions are generally lower than licensed diversions, giving only an approximate indication of relative effects on total flows within the diverted streams. Actual effects on downstream riparian areas also depend upon volume and timing of releases in the diversions.

above Terzaghi Dam and the Alouette River flows above Alouette Dam. Two-thirds of the Coquitlam reservoir inflows are diverted for power or water supply.

Appendix Table 1: Estimates of habitat type and area inundated by reservoirs in the Bridge-Coastal generation area

Watershed	Total Area Flooded (ha)	Lake Area (ha)	Land Area (ha)	Lake/reservoir Shoreline (km)		Stream Lengths (km)		Land Area Habitat Types (ha)				
								Upland Area	Lowland Area			
				Old	New	Main.	Trib.		Channel[1]	Wetland[2]	Lowland deciduous	Lowland coniferous
Campbell	9,725	4517	5208	104	282	47	45	647	395	936	350	2880
Puntledge	2,118	1868	250	35	41	1	2	133	2	25	90	0
Ash River	672	271	401	19	23	5	5	21	30	72	26	252
Jordan	193	0	193	0	20	7	4	178	15	0	0	0
Alouette	1,580	1208	373	39	38	0.3	4	340	0	0	0	33
Stave	5,535	2923	2612	41	101	28	35	518	348	0	158	1588
Coquitlam	1,198	1004	194	30	33	1.3	6	177	3	0	0	14
Buntzen	182	151	31	8	13	2	0.5	0	0	0	0	31
Wahleach	489	278	211	11	15	2	6	142	1	0	0	68
Bridge-Carp	4,669	0	4669	0	112	92[3]	55	232	761	46	1923	1707
Bridge-Down	2,234	0	2234	0	60	65	25	291	441	237	847	418
Seton	2530	2503	27	52	52	0.5	0	27	3	0	0	0
Shuswap	2,217	1564	653	23	39	7	4	25	65	2	45	516
Cheakamus	395	21	374	3	22	15	5	237	70	12	1	54
Clowhom	745	430	315	17	25	6	3	278	32	0	0	5
Falls River	247	0	247	0	12	6	0.3	100	19	0	77	51
Clayton Falls	2	0	2	0	0	0.2	0	2	0	0	0	0

Sources: estimates of flooded areas are from GIS analysis of pre and post development hydrography using 1:20,000 scale TRIM base and data from historical maps, legal surveys and air photos. Reservoir area (Total area flooded) is based on mapped boundaries from available sources, including high water boundaries where shown.

[1] Approximate area of mainstem and related side channels flooded (excluding major islands within the channel). Also included in column 3, Land Area flooded.
[2] Includes only wetlands denoted on early maps; does not include lake deltas substituted by reservoir deltas.
[3] Carpenter includes 59.1 km mainstem channel, 23.7 km major side channels, and 9.4 km minor side channels flooded; total area of 761 hectares flooded (excluding tributaries). Downton includes mainstem(s) and side channels; total area of 441 hectares flooded (excluding tributaries).

Appendix Table 2: Diversions and streamflows in the Bridge-Coastal area

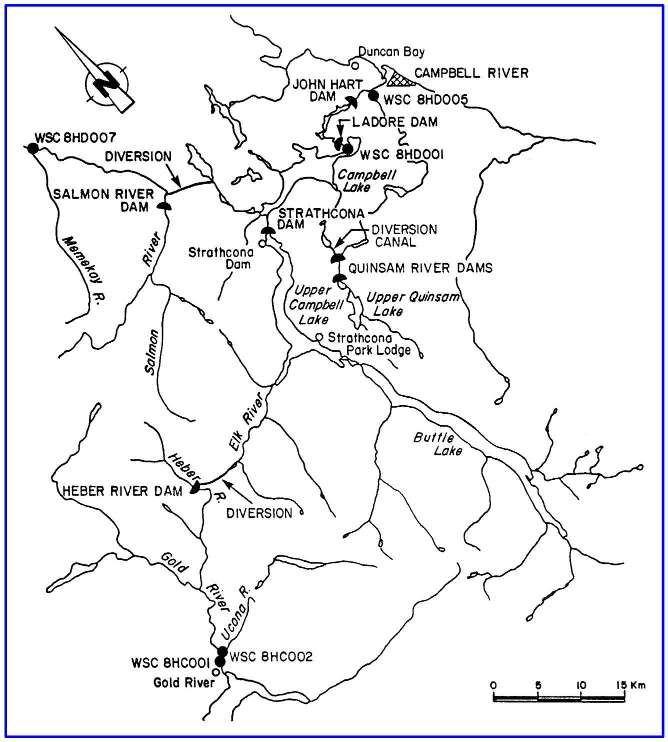
Systems	Diversions and Inflows		Streamflows	Stream Lengths Potentially Affected	
	Licensed maximum diversions (m^3/sec)	Avg. 92-97 reservoir inflows (m^3/sec)	Avg. 92-97 annual flow downstream[1] (m^3/sec)	Stream km with reduced flows[2]	Stream km with increased flows[3]
Diversions between Watersheds					
Campbell					
from Salmon River	16[4]		14 at Memekay	21 to Memekay	
from Heber River	3.5		5 nr Gold R.	15 to Gold R.	
from Quinsam River	4.7		9 Campbell R	37 to Campbell R	
within Campbell River	115	87	103 at estuary	2.8 Campbell R.	5.6 km
Ash					
from Elsie Lake to Great Central Lake	11	22	18 blw Moran	25 to Stamp R.	-
Cheakamus					
from Cheakamus River to Squamish River	27 (65[5])	58	46 Garibaldi 243 Brackendale	25 to Squamish R. confluence	21 km
Alouette/Stave					
from Alouette River	28[6]	21	3.6 at Haney	20 to Pitt R.	
Stave River to Ruskin	238	114			3 km
Ruskin to Fraser River	357				
Coquitlam					
from Coquitlam River to Buntzen Lake	82	23	7 at Coq.Lake	14.5 to Fraser R.	
Bridge/Seton					
Bridge River to Seton	147	95	n.d.	49.5 to Fraser R.	
Seton River to Fraser R.[7]	102		19 nr Lillooet	4.6 to Fraser R.	
Wahleach					
from Jones Lake to Fraser River channel	6	6	n.d.	9 to Fraser R.	7 km
Diversions within Watersheds					
Puntledge					
Puntledge River	30	33	43 at Courtenay	6.3 Puntledge	
Jordan					
Jordan River	81	12	n.d.	8 Jordan R.	
No Diversions (except through powerhouse)					
Shuswap (minor diversion)	31	41	52 blw Wilsey		
Clowhom	82	39	n.d.		
Falls River	17	n.d.			
Clayton Falls	4				

Sources: BC Hydro and Water Survey of Canada; diversions may be reduced by Interim Orders & Water Use Plans

1 Water Survey of Canada data at location of nearest downstream gauge. Cheakamus data: 1916-69 avg.
2 Length of diversion stream from the diversion point to confluence with downstream river or coast.
3 Length of stream downstream of the dam or the discharge point to the next major confluence/coast.
4 Actual diversions from Salmon, Heber and Quinsam were historically about 11.3, 3.0 and 2.8 m3/s, respectively.
5 Actual diversion is approximately 65 m3/sec. (BC Hydro, 1995, 'Workplan to Achieve Compliance').
6 An additional 23-28 m3/sec is diverted for flood control and recreation purposes in Alouette.
7 Cayoosh Creek is diverted into Seton reservoir; most of Seton River flow is diverted directly to Fraser R.

The following is a brief summary of the diversions and the hydrological changes created by hydroelectric development.[1] More detailed discussion of impacts is found in Appendix I and in the Watershed Plans, Volume 2.

Campbell River



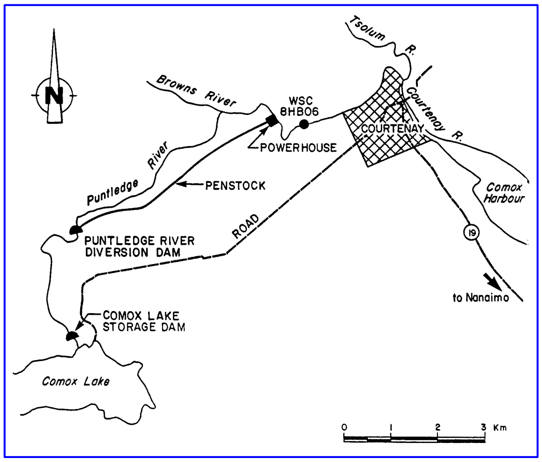
The Campbell system involves diversions from Salmon River, Heber River and Quinsam River and creation of five reservoirs: John Hart Lake, Campbell Lake (Ladore Dam), Upper Campbell Lake and Buttle Lake (Strathcona Dam) and Quinsam/Wokas diversion reservoirs. Development occurred in various stages from 1945, 1949 and 1955-58. The original lakes (Campbell, McIvor, Upper Campbell and Buttle) covered 4,517 ha and flooding of a land area of 5,208 ha, creating a series of reservoirs of over 9700 ha in area.

As indicated on Table 2, licensed diversion from the Salmon River has been a very high proportion of current streamflow (16 m^3/s licensed vs 14 m^3/s average annual flow at the confluence with Memekay River). The decreased flow and reduced riparian habitats have occurred for some distance downstream (21 km to Memekey River and 34 km to confluence with White River). Diversion from Heber River has also been a high proportion of current streamflow, significantly decreasing riparian habitat for some distance downstream (15 km to confluence with Gold River). Diversion from upper Quinsam River has also been a relatively high proportion of current streamflow, creating reduced riparian habitat for some distance downstream (13 km to Quinsam Lake and another 24 km to the confluence with Campbell River).

Flows from John Hart dam are diverted through penstocks for 2.8 km before being discharged again into Campbell River, 4 km upstream from its outlet at Campbell River estuary. The current average annual reservoir flow at John Hart is 87 m^3/s, while average flow downstream at Campbell River near the estuary is 103 m^3/s. Reduced flows in this short section of stream channel and decreased gravel transport have reduced fish habitat capacity in below Elk Falls in the Campbell River canyon.

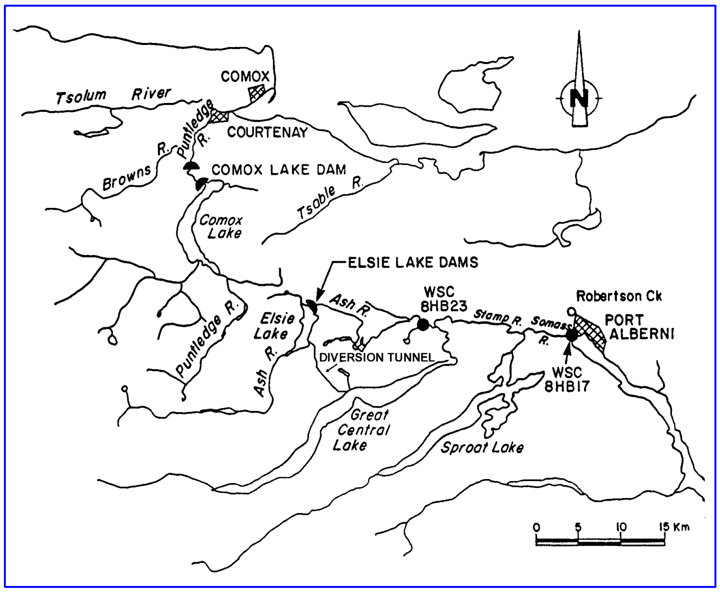
[1] Note – licensed maximum diversion may vary from actual diversion. Reliable data on actual diversions are not available. Actual diversions are also regulated to provide minimum releases for fish flows as per Interim Orders and Water use Plans where they have been adopted.

Puntledge River



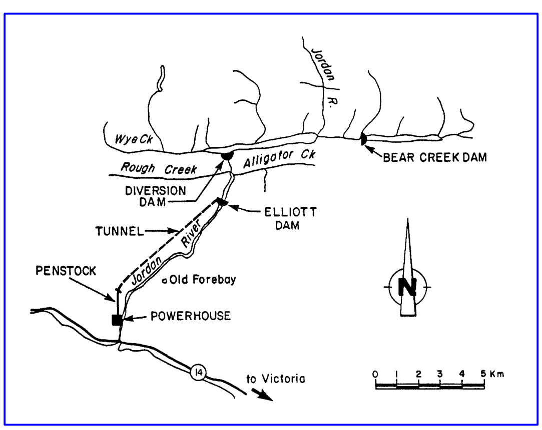
Comox Lake has experienced a slight increase in flooded area as a result of development (1912 and redeveloped 1956), from 1868 ha to 2118 ha, a loss of 250 ha of mostly upland and deciduous lowland habitat. There are no inter-basin transfers. The Comox Lake dam, located at the lake outlet, regulates flows downstream for 3.7 km, where Puntledge River diversion dam then diverts water through a penstock, 6 km upstream from its powerhouse. Riparian area downstream potentially affected by reduced flows involves 6.1 km between the diversion dam and the re-entry point at the powerhouse.

Ash River



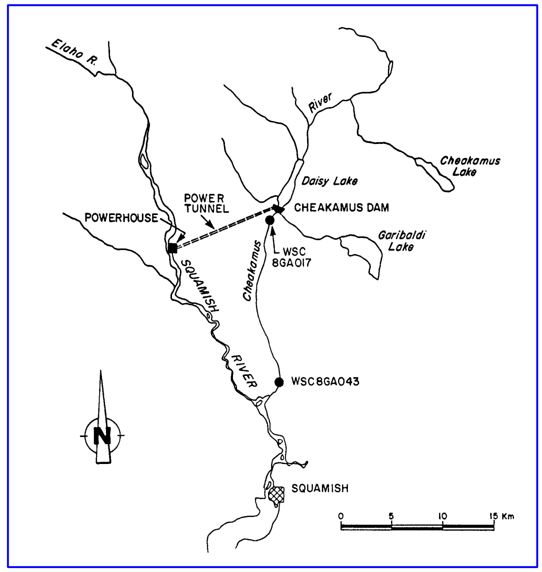
Elsie Lake dams, created in 1957, provide storage for diversion of water and discharge into Great Central Lake. The original Elsie Lake was 271 ha in area; current size of the reservoir is 672 ha. Licensed diversions historically allowed for one-half of the total reservoir inflow to be diverted. The (licensed) diversion makes up a substantial portion of the total streamflow of Ash River (11 vs 18 m^3/s). This has reduced riparian habitat in the Ash River in the 30 km downstream before its outlet at Great Central Lake, and also restricted steelhead migration over the falls downstream. Water temperature may have also been adversely affected, as discussed in the Watershed Plan.

Jordan River



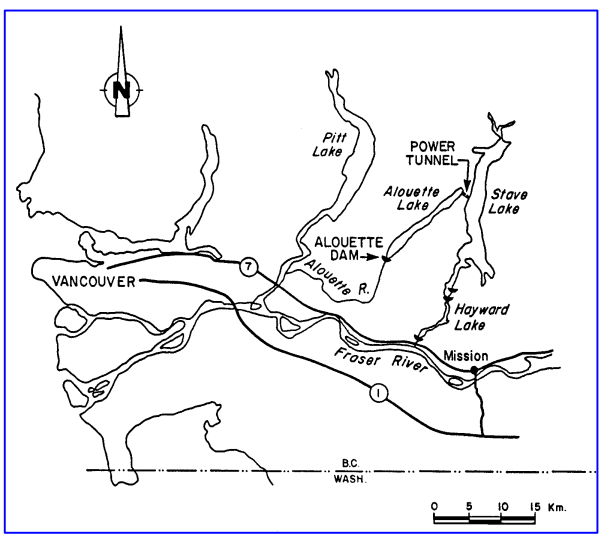
Jordan River is a steep, incised watercourse with several barriers to migration of fish. Three reservoirs were created: Bear Creek (1913), Jordan River (1913) and Elliott (1971), involving a total inundated area of 193 ha, mostly upland habitat and stream channel. Water is diverted through a penstock 8 km upstream of the outlet of the river at Strait of Juan de Fuca. Significant footprint changes to the flow regime have reduced downstream habitats.

Cheakamus River



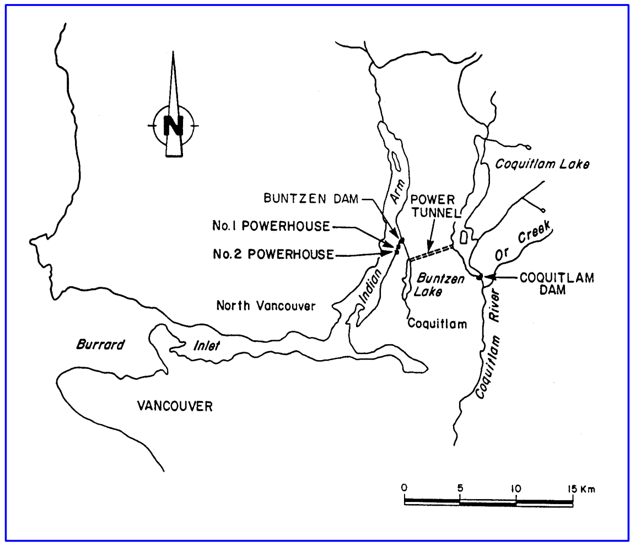
The Cheakamus hydroelectric development, constructed in 1957 and later redeveloped in 1981 and 1988, involved flooding of Daisy Lake and diverting flows to a power house on the Squamish River. Total inundated original lake is 21 ha and total inundated land and stream channel area is 374 ha. Most of the Cheakamus reservoir has been diverted for power production (65 vs 58 m^3/s), although interim orders now limit this to about 55% of flows. The diversion results in marginally increased flows in Squamish River (21 km upstream from its outlet at Howe Sound) and significantly decreased flows in Cheakamus River (25 km upstream of it's confluence with Squamish River). Increased flows in Squamish River have likely improved riparian habitat at the expense of decreased riparian habitat in the lower Cheakamus.

Alouette River / Stave River



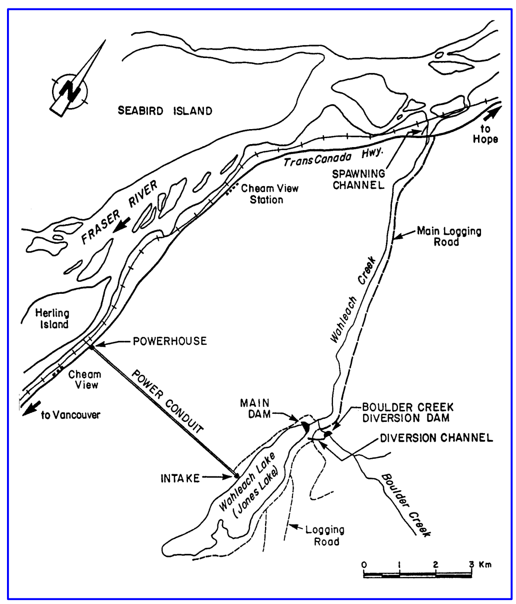
Alouette Lake was originally two smaller inter-connected lakes ('Upper and Lower Lillooet Lakes'). Development in 1928 and later in 1984 resulted in an additional 373 ha land area being flooded, transformation of the lakes into a reservoir, and diversion of water to Stave Lake. The licensed diversion, 28 m^3/s leaves only minor flows, 3 m^3/s at Haney, in the lower Alouette River. The diversion has significantly reduced flows in the river, a distance of about 20 km downstream to its outlet at the Pitt River. Riparian habitat downstream has therefore been substantially affected by reduced flows. The Alouette diversion and the series of dams on the Stave River flooded 2612 ha around the original Stave Lake and Hayward Lake. The flows and habitat have also been substantially altered in the 3 km below Stave Falls Dam to the confluence with Fraser River.

Coquitlam River (and Buntzen Lake)



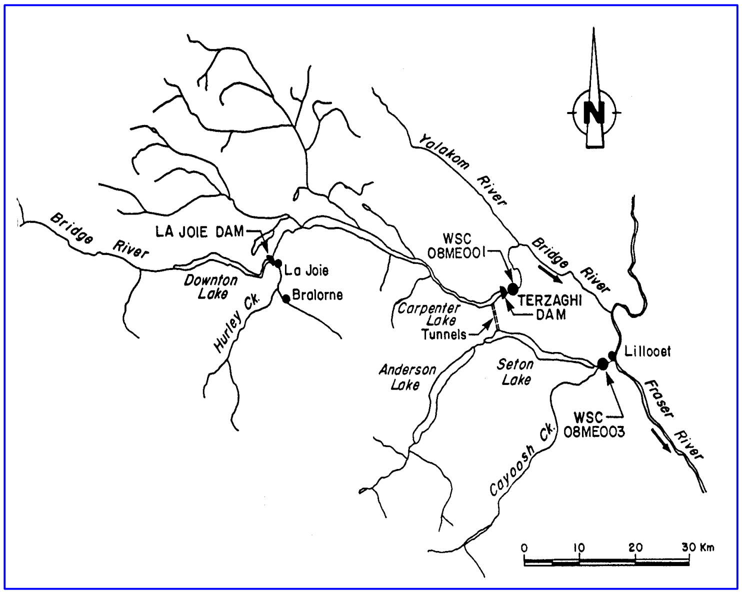
Coquitlam Lake development began in 1903 and was redeveloped in 1951. It involved flooding 194 ha around the original lake and diverting water west to Buntzen Lake and then to a powerhouse on Indian Arm. Annual reservoir inflows are three times the flow in Coquitlam River (23 vs 7 m^3/s). Most of the Coquitlam flow is diverted for power generation or used as water supply by Greater Vancouver Water District. This has significantly reduced flows in the lower Coquitlam River, a distance of about 15 km downstream to its outlet at the Fraser River. Riparian habitat in the lower Coquitlam and wetland habitat at the confluence with Fraser River were substantially reduced by this diversion.

Jones Creek (Wahleach Lake)



Development of Wahleach Lake in 1952 for hydroelectric power resulted in an additional 211 ha of flooded area, diversion of Boulder Creek into Wahleach Lake to expand the storage volume and diversion of water from the lake to a powerhouse adjacent to the Fraser River. Annual flows in Jones Creek were significantly reduced, with licensed diversions of up to 6 m^3/sec, equal to total reservoir flows. Flows on Jones Creek are not regularly monitored. Falls on the creek create a barrier to fish migration. The spawning channels adjacent to the Fraser River, not currently functioning because of a landslide, were intended to mitigate some of the effects of the hydroelectric development.

Bridge River/Seton River

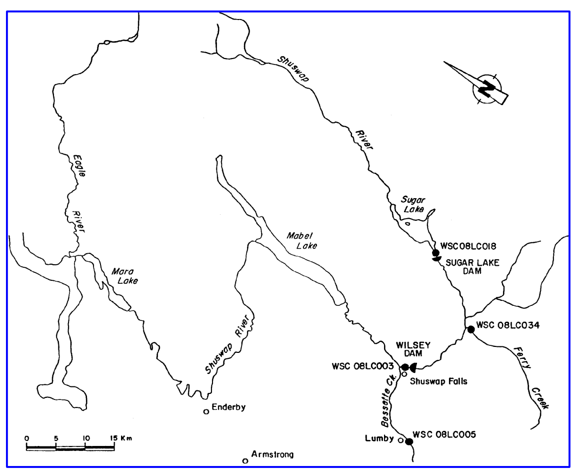


The Bridge River/Seton River development resulted in creation of Carpenter Lake (4669 ha) behind Terzaghi Dam, and Downton Lake (2234 ha) behind LaJoie Dam, and diversion of water into Seton Lake. The original Mission Dam on Bridge River was constructed in 1934 but major development occurred in 1948 and Seton River development was added in 1956. Over 1200 ha of mainstem channel habitat was lost to flooding, along with 283 ha of wetland and 80 km of tributary.

The project significantly reduced flows in the downstream Bridge River, marginally increased the level of Seton Lake, and significantly reduced flows in Seton River where a power canal diverts Seton Lake water to a powerhouse at the Fraser River. Cayoosh Creek is also diverted into Seton Lake near the outlet. Bridge River flows are, at times, reduced to almost zero except for small local inputs, downstream of Terzaghi Dam to Yalakom River, 12.5 km, and reduced to less extent for another 37 km downstream to the Fraser River.

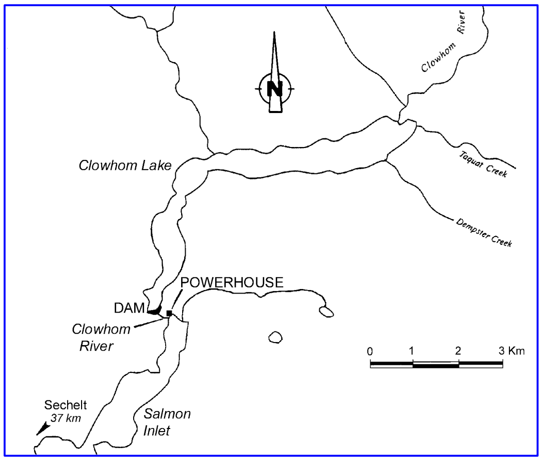
Shuswap River

Water is impounded at Sugar Lake (Peers Dam) and to a lesser extent at Shuswap Falls (Wilsey Dam). Sugar Lake increased by 653 ha as a result of hydroelectric development in 1929, creating a reservoir of over 2200 ha. The mainstem channel (65 ha) and associated riparian (lowland deciduous) habitats (45 ha) were lost.



The river is diverted for only a short distance from Wilsey Dam to the powerhouse outlet downstream. Riparian areas are affected by the regulation of flows, as briefly discussed in the Watershed Plans.

Clowhom River

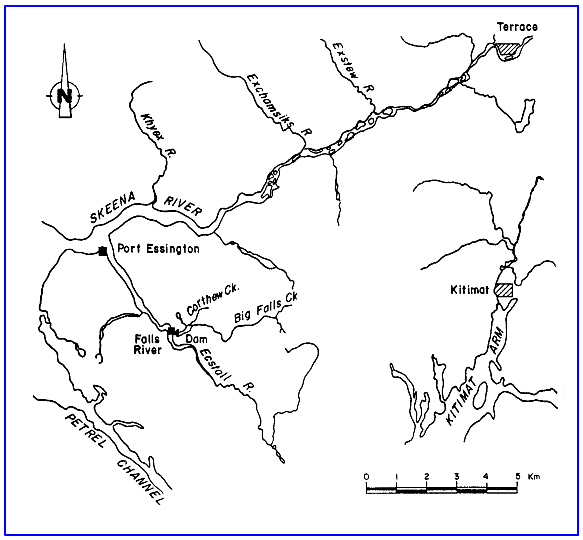


Clowhom Lakes, in the Sechelt Inlet system, originally covered 430 ha connected by 1 km of river. Hydroelectric development, originally in 1952 and redeveloped in 1957, created a reservoir of 745 ha. Water is diverted through a powerhouse immediately downstream of the dam. Average annual reservoir inflow is 39 m^3/s. A series of falls immediately upstream of the outlet create a barrier for fish. Changes in the lower Clowholm River at its outlet at Salmon Inlet have reduced fish habitat in this small section of the river below the falls.

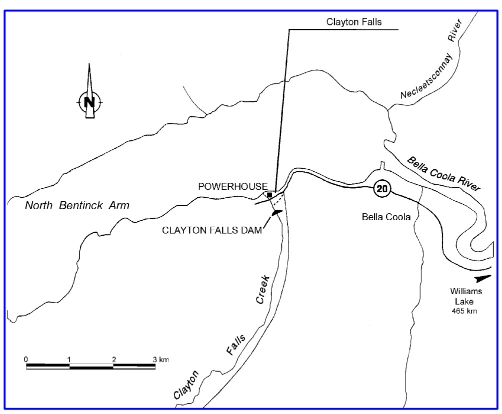
Falls River

Big Falls Creek, located in the lower Skeena River basin, was developed in 1930, creating a reservoir of 247 ha. Six km of mainstem channel (32 ha) was flooded. A migration barrier existed at the location of the present dam location.

Water is discharged into a power house immediately downstream of the dam and into Ecstall Channel. Maximum licensed diversion through the powerhouse is 17 m^3/s.



Clayton Falls



There is no reservoir at Clayton Falls, a run-of-the -river facility developed in 1960 near Bella Coola. A dam and small headpond are located several hundred metres above the powerhouse outlet of Clayton Falls Creek at North Bentinck Arm.

4. SUMMARY OF FISH IMPACTS

4.1 Overview of Fish Impacts by Watershed

A very brief summary of impacts on fish in each watershed is presented on Table 3. This overview should be read in conjunction with the detailed assessment in the **Watershed Plans, Volume 2**.

4.2 Typical Impacts on Fish

Table 4 is a list of typical impacts on fish populations[1], arranged by BC Hydro project system. Footprint impacts were divided into five categories; a sixth category included examples of operational (flow-related) impacts:

1. Effects of Construction
2. Effects of Structures
3. Effects of Reservoir
4. Downstream Effects
5. Effects of Flow Diversions
6. Effects of Operations

The inclusion of operational impacts above reflects the historical legacy of regulated flow regimes in the Bridge-Coastal watersheds. The impacts listed in Table 4 are either documented by credible sources, or those judged by professional experience to be potential impacts that are not yet substantiated. Potential impacts represent data gaps, *i.e.*, an effect is suspected but its occurrence or magnitude are not known. More impacts may be discovered in future studies of individual watersheds. The impacts listed here are discussed in more detail in the **Watershed Plans**.

Table 4 indicates the distribution of impacts among the various systems, but their relative magnitude and significance were not rated due to variability in and limitations of the technical reports that were reviewed. The impacts listed are the most obvious effects based on current status and information but will likely be updated as biophysical assessments related to WUP are completed.

Participants in the BCRP workshops identified seven broad categories of impacts that were common to all developed watersheds:

- loss of spawning and rearing habitats
- blockage of fish migration
- loss of reservoir and downstream productivity
- channel morphology, sediment and wood debris
- entrainment
- reservoir drawdowns
- flow diversions

[1] The term *impact* refers to a consequence of hydroelectric development that changes the number, health, distribution, or other demographics of a fish population directly, or indirectly by altering its natural habitat or ecological associations, often through a series of biophysical linkages. Impacts are considered synonymous with *effects*, and have negative or positive values.

Appendix Table 3: Summary of fish impacts by watershed

WATERSHED	IMPACTS
Campbell (Heber, Salmon, Quinsam)	The Campbell system has the largest reservoir area flooded in the BCRP (9725 ha) of which former lakes comprised 46%. It had the second-highest number of stream kilometres flooded (47 km of mainstem and 45 km of tributaries) where important trout and char spawning habitats were lost. The Elk River, major tributary to Upper Campbell Lake, has been altered by increased flows diverted from the Heber River system. Upper reaches of the Heber, Salmon and Quinsam rivers are diverted into the Campbell system, with effects of reduced water volumes on downstream habitats used by various salmonid stocks. the Heber and Quinsam diversion dams are impassable to resident trout and char. Significant anadromous and resident stocks use the lower most 4 km of the Campbell River between John Hart tailrace and the estuary. The 2 km canyon section upstream of the tailrace to Elk Falls has been essentially dewatered for over 40 years. Habitat capacity for these stocks has been reduced by losses of gravel and wood debris cut off by the dams. Augmented mainstem flows from the 3 diversions have scoured gravel and wood already in the lower system.
Puntledge	The storage reservoir has had a relatively small footprint impact because of the large original lake (88% of flooded area) and its small drawdown regime. Important stocks of summer chinook, summer steelhead and some coho had historic access to Comox Lake but no fishway existed there for 10 years after initial dam construction in 1913. A major spawning ground existed for 3.7 km below Comox Lake, but fine sediment from 1957 dam reconstruction, plus backwatering of the river channel by the revamped diversion dam had a severe impact on spawning success. As compensation, the upper spawning channels were built in 1965 when salmon access above the diversion dam was disallowed to support supplementation efforts. Full hatchery operations began in 1977, but after 35 years of considerable mitigation projects by both agencies and BC Hydro, summer chinook and summer steelhead remain at risk. The diversion dam has also blocked what little gravel enters the headpond reach, but the bedrock section of river below the diversion dam did not support much spawning down to the Browns River confluence near the powerhouse. Minimum flows in the channel section bypassed by the diversion affects a key rearing area for steelhead.
Ash	The original Elsie Lake comprised 40% of the present reservoir where trout and char are subjected to drawdown impacts. Historic anadromous access was blocked by several falls in the canyon downstream but selective blasting and lower post-project flows have allowed steelhead to extend their distribution to Elsie Dam. The diversion project has a complex effect on downstream water levels in Great Central Lake and temperatures in the Stamp/Somass system in the late summer-autumn period when large numbers of salmon migrate through this corridor.
Jordan	The Jordan project flooded no lakes. Many of the upper watercourses dried in summer and the reservoirs have likely increased fish abundance in the area due to stocking. Lack of fish flow between Elliott Dam and the powerhouse has affected resident stocks. Anadromous fish were blocked historically by three sets of falls about 1.2 km upstream of the river mouth. Chum, pink and coho salmon lost spawning habitat when the tailrace channel of the 1912-71 powerhouse was abandoned. Future productivity in this system is also constrained by residual impacts of copper mining, forestry and estuary dredging.
Alouette-Stave	This project ranked third in flooded area (7116 ha) by three reservoirs; 58% was original lake habitat. It caused significant habitat losses to anadromous stocks below the Stave Falls

	barrier by creating Hayward Reservoir, and removed most of the historic anadromous production from the Alouette watershed due to low diversion flows and blocked access. The Alouette diversion reduced downstream channel complexity directly by loss of hydraulic energy, and indirectly by controlling floods that encouraged urban development along its banks. Alouette sockeye and chinook stocks were eliminated by the dam in 1928. Resident stocks in both watersheds have experienced the usual impacts of flooded stream habitat (68 km), reservoir drawdown and productivity. Loss of nutrient input from historic anadromous carcasses may have further affected Alouette Lake; expected benefits of a fertilization program may be partly exported to Stave watershed.
Coquitlam-Buntzen	Relatively little is known about historic or current fish resources in Coquitlam Lake although it was the first large power development in British Columbia (1903) . The early role of Coquitlam Lake as a dedicated water supply was a key factor in the decision not to construct a fishway in the 1911 redevelopment that raised the dam and diverted more water to Buntzen. Blocked access and reduced flows down Coquitlam mainstem extirpated a small sockeye run, and severely reduced populations of other anadromous species throughout the Coquitlam watershed. The lack of flow and impacts of sedimentation from gravel mines downstream have seriously affected fish populations in the entire lower river. Buntzen Lake was inaccessible to anadromous fish but small resident stocks, perhaps introduced and stocked, have been the focus of an urban trout fishery for at least a century. Like Alouette-Stave, resident stocks in both watersheds have been impacted by reservoir drawdown and productivity issues. Loss of nutrient input from historic anadromous carcasses may have further reduced productivity of Coquitlam Lake.
Wahleach	Formerly barren and isolated by steep gradients in its outlet Jones Creek, the lake was initially stocked in 1924 by private enterprise to create a rainbow trout fishery. Kokanee and cutthroat trout were stocked in later years by MELP. Hydro development in 1951 has affected resident fish populations mostly through drawdown and lost productivity. Downstream impacts from the reduced post-diversion flows were more significant on anadromous stocks, principally pink and chum salmon, that used a short 1 km section of lower creek on the Fraser floodplain. Construction of a spawning channel in 1954 proved successful for pink salmon, but replaced or precluded access to natural habitats by other species. The artificial channel required periodic maintenance throughout its operation which ceased in 1995 due to a serious sediment event in the canyon.
Bridge-Seton	The Bridge-Seton system has the second largest total area flooded (9433 ha) of which 27% was original lake (all in Seton watershed). Anadromous fish populations in this combined system were greatly reduced by the Hells Gate slides in 1913 and 1914, and less dramatic passage problems continued there until fishways were installed in 1944-1947. The Bridge project flooded no lakes but inundated 238 km of mainstem and tributary habitats in the valley bottom, more than twice the stream length flooded in the second-ranked Campbell system. Resident stocks of bull and rainbow trout and introduced kokanee are impacted by drawdowns >40 m that affect access to tributaries and use of their lower sections for spawning. Chinook, sockeye, and likely coho salmon and steelhead were present in the mainstem as far upstream as La Joie Falls, and in certain major tributaries such as Fergusson and Tyaughton creeks until Mission (Terzaghi) Dam was built (without fishway) in 1948. Diversion of significant volumes of cold nutrient-poor Bridge water has altered sockeye and kokanee rearing conditions in Seton Lake. Diminished flows below Terzaghi Dam have reduced the quantity of fish habitat in the canyon, but productivity has remained high in some sections despite minimum seepage from the dam. Periodic large spills cause fish stranding.

	Impacts in Seton watershed include loss of 0.5 km of lake outlet spawning habitat; two spawning channels were constructed and operated only for pink salmon in odd-numbered years, but other affected species were kept out. Mortalities from entrainment of migrant juveniles are being addressed in a feasibility study using louvers. Construction impacts destroyed certain areas of instream and riparian habitats in Seton River. The diversion of Cayoosh Creek into Seton Lake has reduced fish habitat in the creek channel. Seton Lake has a large number of species on the order of Stave Lake, and is the only reservoir reported to contain white sturgeon, now isolated from the Fraser river by the dam.
Shuswap	Sugar Lake reservoir has a total flooded area of 2217 ha of which 70% was original Sugar Lake. Total length of channels flooded at Sugar Lake was 11 km which included an important lake outlet spawning area for resident stocks. The 7 m drawdown has effects on reservoir productivity and spawning success in tributary fans. Both Peers and Wilsey Dams blocked recruitment of sediment and large wood debris. Regulated flows downstream have reduced channel complexity and access to side channels. The penstock bypasses a short section of historic spawning habitat. An undetermined length of mainstem channel was backwatered by the headpond behind Wilsey Dam. Like Bridge-Seton, Shuswap populations of sockeye, chinook and coho were seriously depleted after the Hells Gates slides in 1913 and 1914. Prior to construction of the dams in 1929, Chinook salmon ascended past Shuswap Falls. Sockeye and coho salmon may have also ascended opportunistically. Shuswap Falls Dam has blocked migratory access for anadromous and resident stocks for 71 years.
Cheakamus	Daisy Reservoir was created by flooding 395 ha of which 5% was original lakes. Total length of channel habitats flooded was 20 km. Resident trout have been impacted by the 13 m drawdown. Historic access by anadromous fish was blocked by falls 7 km below the dam. The dam has blocked recruitment of sediment and wood debris downstream Significant flow is diverted out of the Cheakamus watershed. Diminished flows were incapable of transporting large sediments deposited by Rubble Creek. The area and accessibility of downstream habitats used by anadromous and resident stocks has been reduced.
Clowhom	Clowhom Reservoir flooded 745 ha of which 58% was original lake habitat. A total of 9 km of stream length was also lost. Clowhom Lakes supported a fishery for rainbow and cutthroat trout since 1927 which has continued since the reservoir was completed in 1952. Reports of anadromous stocks above the dam remain unsubstantiated. Reservoir productivity is affected by the 6-11 m drawdown. Entrainment is a potential issue, and stranding of fish occurs during drawdowns.
Falls River	Big Falls Reservoir flooded 247 ha but no lakes were present. Flooded channel length was 6.5 km. Cutthroat trout and Dolly Varden char are present above the dam and rapid drawdowns of 2-5 m affect productivity and access to tributaries. Entrainment is a potential issue. A 180 m long tailrace pool below the barrier falls supports limited chinook and possibly pink salmon spawning.
Clayton Falls	The headpond flooded about 2 ha including 200 m of channel length. No fish are reported upstream of Clayton Falls, including the headpond area. Small numbers of pink and chum salmon spawn in the 200 m of channel between tidewater and the falls, including the tailrace area. No impacts on fish are reported since the project operates with relatively few fluctuations in flow.

4.2.1 Loss of Spawning and Rearing Habitats

The creation of reservoirs caused inundation of lake, stream, wetland, riparian, and other habitats that existed previously. This study used GIS analysis of pre- and post-impoundment maps to estimate lengths and areas of gross habitat types flooded by each Bridge-Coastal development (Table 1). In most watersheds, published information was scant about pre-project fish habitats in the footprint areas. We found some documentation about important historic spawning areas in five watersheds (Buttle and Upper Campbell Lake, Puntledge River, Shuswap River, Bridge River, and Seton Lake).

In general, hydroelectric development in the Bridge-Coastal region has occurred in valleys whose steep tributary streams provided limited habitat areas in the valley floor where gradients were low enough to be useable by fish. Reservoir flooding essentially eliminated these more productive lower sections of tributaries and various lengths of mainstem habitats.

Permanent alterations to habitat also occur as a result of regulated or diverted flows that affect side channel development and riparian encroachment.

4.2.2 Blockage of Fish Migration

Construction of dams can block the movement of fish to preferred historic habitats in different river sections. This phenomenon is well-documented for anadromous species but less so for resident species.

At the time of initial project construction, anadromous stocks spawned above dams in 7 of the 19 individual watersheds (Puntledge, Alouette, Stave, Coquitlam, Bridge, Seton, and Shuswap). Currently, only two of these watersheds have retained anadromous populations upstream (Puntledge[1] and Seton). In one case, the Salmon River Diversion Dam, anadromous stocks were not originally present but are now accessible by steelhead and coho salmon due to removal of a natural barrier downstream and construction of a fish passage facility, 17 years after dam construction.

In addition to natural ascent, the agencies have transported and released anadromous stocks, usually in juvenile stages, in various years above the dams in 5 watersheds (Salmon, Puntledge, Ash, Seton, and Shuswap).

Re-establishment of former anadromous runs to the Alouette, Stave, Coquitlam, Bridge or Shuswap reservoirs would require careful analysis and planning. (See a description of issues related to restoring fish runs in the introduction to the **Watershed Plans**.)

4.2.3 Loss of Reservoir and Downstream Productivity

These impacts refer to the reduced abundance of fish food organisms caused by lack of chemical nutrients, *e.g.*, soluble nitrogen and phosphorus compounds, necessary for plant growth as the basis of the trophic web. Plankton and macroscopic plants that live in most

[1] In the Puntledge River, agencies have sometimes allowed steelhead up the fish ladder; in most years; the low returns of chinook and coho are all taken by the hatchery for broodstock.

coastal BC reservoirs and lakes quickly convert the limited nutrients into biomass which remains within the reservoir’s food web and is not largely exported to food webs downstream.

Reservoirs do not provide the same habitats as natural lakes despite gross similarities in their appearance as stable waterbodies. Depending on their purpose and operation within the specific development scheme, reservoirs tend to have lower biological productivity, particularly those with high flushing rates that export planktonic biomass and the fluctuation in water level, often daily, create a relatively sterile zone around their perimeter where neither riparian or aquatic vegetation can become established. The severity of these impacts on fish is linked to the frequency, duration and magnitude of fluctuation in water levels.

Most watersheds in the Bridge-Coastal system occur in basins of granitic bedrock which do not contribute many dissolved nutrients. The majority of available nutrients come from recycled organic debris, and one of the richest sources has been salmon carcasses in systems where substantive populations have occurred (Ashley & Slaney 1997). Salmon spawners can contribute up to 40% of the nitrogen and carbon content of juvenile salmonids in small streams (Bilby *et al.* 1996). Estimated losses of historic anadromous spawners represent a target threshold for nutrient replenishment (Wilson *et al.* 1999).

4.2.4 Channel Morphology, Sediment and Wood Debris

Stream habitats for fish are formed by hydraulic processes where river flow variously transports or deposits sediments and wood debris down the channel. This energy scours pools in the bed and shapes its banks according to stream gradient and erosion-resistant materials. The presence of large wood debris in the channel creates hydraulic complexity and traps various sediment fractions which are used by local fish populations for hiding cover, food production and spawning materials.

Construction of dams stops the natural delivery of these materials down the mainstem. Floating wood debris of larger sizes is typically removed from the reservoir at the outlet in order to protect the dam facilities and turbine. Reservoirs retain wood debris that becomes waterlogged and sinks. Reservoirs also remove a primary source of wood debris by flooding former riparian habitats.

Sediment transport is determined by particle size, channel gradient and water velocity. Reservoirs, headponds and natural lakes stop the movement of coarser bedload sediments, including spawning gravels, to channels downstream. Channels below dams where no significant lake existed previously (Quinsam Diversion, Puntledge Diversion, Jordan dams, Terzaghi, Shuswap Falls, Cheakamus, Falls River, Clayton Falls) likely have experienced a diminished supply of bedload sediment after the projects were completed. These types of reservoirs can cause serious impacts if historic spawning grounds had been largely replenished by gravels from upper mainstem sources.

Altered delivery of sediment and wood debris is important to physical and biological processes occurring in sedimentary estuaries such as Campbell, Puntledge, and Jordan systems.

4.2.5 Entrainment

Entrainment of fish into facility intakes or diversions occur in two general circumstances: those having anadromous or resident fish species that undergo regular seasonal migrations downstream of the dam; and those reservoirs with resident fish populations that occasionally stray into the intakes to diversions or powerhouses.

Entrainment is a more significant issue in anadromous systems. The Salmon, Puntledge, and Seton systems currently have migratory salmon and steelhead stocks upstream of dams. Fish screens are used to remove migrants from diverted flows at Salmon and Puntledge, and louvers are currently being tested at Seton. Fish screen facilities can cause mortalities and injury, and have other technical limitations regarding fish size, maximum approach velocities, and debris cleaning, that can restrict their application (Rainey 1985).

Less information is available about entrainment of resident fish populations into hydroelectric intakes, sluice gates and low level outlets. While occurrences have been observed at several Bridge-Coastal facilities, the magnitude of impact to the reservoir populations is unknown. Of technical interest are the relative susceptibility of pelagic or demersal species, whether entrainment rates differ seasonally or between night and day, and what effects flow ramping may have on entrainment. Beginning in 2000, BC Hydro is undertaking a preliminary assessment of non-anadromous entrainment in selected reservoirs.

Associated with entrainment is the mortality or injury caused to fish that contact debris screens or trash racks, as observed at the Seton power canal. Impingement rates increase as small wood debris and branches clog the racks and reduce the available open area. Incidents can be reduced by more frequent maintenance cleanings, but this operation may affect fish in other ways if plant shutdowns are necessary.

4.2.6 Reservoir Drawdowns

When BC Hydro releases impounded water downstream to generate power, the water level in the reservoir or headpond drops accordingly. Drawdown affects fish in the reservoir in several ways. Drawdowns cause effects on fish that span the criteria of footprint and operational impacts. While drawdowns are technically part of BC Hydro's daily operations, the overall project, including dam height, was designed to operate using a certain drawdown range that fundamentally and permanently alters the aquatic and surrounding terrestrial habitats.

Direct effects of reservoir drawdown include stranding, reduced or improved fish access to tributaries, and dewatering or flooding of spawning sites along the shoreline and lower sections of tributaries. Drawdowns in shallow reservoirs in summer may cause further water quality problems with temperatures or stagnation. Indirect effects on fish arise from reduced abundance of food organisms that in lakes are most prolific in littoral areas such as shoals and shallow shorelines, but in reservoirs this zone looses its productive capacity due to fluctuations. Each reservoir varies in the extent of water elevation changes, their frequency and duration, and seasons in which drawdowns occur, and these factors combine to determine the severity of impact.

4.2.7 Flow Diversions

A diversion dam is used to take some flow out of the river channel and direct it to a new location. Like drawdowns, diversions of water share elements of footprint and operational impacts. While BC Hydro can change the amount of flow diverted out of a channel at any given time, their power generation is predicated on removing quantities of water from a fish-bearing channel. Removal of water year-after-year has had a profound effect on the habitat capacity and size of populations that once utilized the bypassed channel.

There are two basic types of water diversions in the Bridge-Coastal systems--between different basins, and within the same basin. When a portion of river's kinetic energy is diverted to another basin, habitat-forming processes are altered. affecting fish populations in the diminished and the augmented rivers (Curtis 1959). Four of 13 BC Hydro systems utilize additional flows diverted from other watersheds: Campbell/Heber/Salmon; Alouette/Stave; Bridge/Seton; and Coquitlam/Buntzen. The first three are the largest Bridge-Coastal systems in terms of power production and of total area flooded. The diminished rivers are the Heber, Salmon, Quinsam, Alouette, Coquitlam, and Bridge mainstems.

Diversion within the same basin involves bypassing a section of river but eventually returning the water back to the same system. Some facilities have very short diversions on the order of 100-300 m, with a penstock pipe running directly from a storage dam directly to a powerhouse nearby (Shuswap, Clowhom, Falls River). Others send water to a remote powerhouse via a tunnel, canal or penstock (Ash, Cheakamus, Wahleach). Diversion within the basin does not change the total flow volume of the river but fish habitats located in the bypassed section of the river channel receive less water on a regular basis. This type is found at Campbell, Puntledge, Jordan, Seton, Shuswap, and Clayton Falls.

Where important fish resources exist downstream of the diversion point, agencies are working with BC Hydro to prescribe fish flows down the natural channel to maintain essential habitats and migratory passage.

River channels that receive diminished flows as a result of diversion, may carry virtually no flow, or in some cases, prescribed, stable fish flows. These low flow conditions can change quickly if reservoir inflows exceed generation capacity and spilling is required. Once the hydraulic capacity of the diversion canal, tunnel or penstock is reached, all additional inflow that cannot be stored in the reservoir must be spilled down the original channel. Fish living in the generally stable fish flows of the original channel will experience occasional large flows from spill events.

4.2.8 Other Impacts

Other impacts listed in Table 4 were less common and some occurred in single watersheds. Many of these impacts were considered to be conditional because their occurrence depends on the season, the site, the species, or a particular life stage. Conditional impacts can be difficult to identify because they arise from unique combinations of events, and may not be present year round.

Furthermore, various studies from the literature describe impacts at different levels, from overview to very detailed. An impact described as “changes to water temperature regime” could include any number of detailed temperature effects, such as warming of reservoir impoundments; disrupted thermocline development; downstream temperatures being cooler due to deep intake structures; warmer (or colder) water being diverted into the receiving system; minimum flow releases tend to be warm quickly in summer and cool quickly in winter; etc. Therefore the listing of detailed impacts by watershed in this report includes cited effects and some generic effects where specific details are not known.

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Appendix Table 4 Typical Impacts on Fish in BC Hydro Systems

IMPACTS TO FISH **shading: potential significant adverse effect** **blank: no significant adverse effect**	BC HYDRO SYSTEMS												
	Campbell / Heber Salmon / Quinsam	**Puntledge**	**Ash**	**Jordan**	**Alouette / Stave**	**Coquitlam / Buntzen**	**Wahleach**	**Bridge / Seton**	**Shuswap**	**Cheakamus**	**Clowhom**	**Falls River**	**Clayton Falls**
EFFECTS OF CONSTRUCTION													
1. Sediment from clearing, grubbing & instream activities reduces WQ													
2. Access roads to BCH facilities required riparian clearing and stream crossing structures													
3. Loss of instream habitat outside structural footprint by channelization; loss of riparian habitat by bank reshaping													
EFFECTS OF STRUCTURES													
Physical Footprint													
4. Loss of instream or riparian habitat beneath dam													
Upstream Movements of Fish													
5. Attraction, injury or delay at facility discharge													
6. Inadequate or no fishway where dam blocks historic anadromous access or historic resident movements													
7. No fishway; benefits naturally isolated headwater populations from genetic mixing, competition, predators													
8. Spills allow temporary access upstream with subsequent stranding													
Downstream Movements of Fish													
9. Dam lacks d/s passage facility for steelhead during non-spill periods													
10. Spillway passage causes mortality or injury													
11. Impingement mortality/injury on trash rack/screen													
12. Impingement mortality or injury on fish screen													
13. Entrainment causes turbine mortality or injury													
14. Entrainment exports population out of reservoir													
15. Entrainment recruits population to receiving body													
EFFECTS OF RESERVOIR													
Physical Footprint													
16. Loss of lake, stream, wetland or riparian habitats													
17. Loss of known major spawning or rearing habitat													
18. Increased reservoir habitat and shoreline edge													

	BC HYDRO SYSTEMS												
IMPACTS TO FISH **shading: potential significant adverse effect** **blank: no significant adverse effect**	**Campbell / Heber Salmon / Quinsam**	**Puntledge**	**Ash**	**Jordan**	**Alouette / Stave**	**Coquitlam / Buntzen**	**Wahleach**	**Bridge / Seton**	**Shuswap**	**Cheakamus**	**Clowhom**	**Falls River**	**Clayton Falls**
19. Increased LWD cover improves reservoir habitat if not cleared before flooding													
20. Increased shoreline erosion and unstable banks in drawdown zone													
21. Fish are stranded in wetlands and reservoir swales during drawdown fluctuations													
22. Fish access reduced to/from tributaries during drawdown													
23. Fish access improved at historical barriers in drawdown zone - data gap													
24. Spawning sites in drawdown zone dewatered or flooded													
25. New reservoir presence facilitates angler access to tribs, increases harvest rates, reduces spawner abundance													
Water Quality & Aquatic Productivity													
26. Drawdowns reduce planktonic & benthic productivity													
27. Reservoir traps dissolved nutrients; reduces availability in downstream habitats													
28. Reservoir impoundment increases water temperature; effects on thermocline development													
29. Impoundment may increased mercury levels in fish													
DOWNSTREAM EFFECTS													
30. Reservoir traps gravel bedload; high flows erode original spawning gravel below dam, decreasing spawning habitat downstream													
31. Dam traps fine sediment load; could improve spawning or rearing conditions downstream													
32. Dam intercepts wood debris normally recruited to mainstem & estuary													
33. Potential gas supersaturation during major spills													
34. Water temperature changes; increased, decreased, or stabilized (negative and positive effects)													

	BC HYDRO SYSTEMS												
IMPACTS TO FISH **shading: potential significant adverse effect** **blank: no significant adverse effect**	**Campbell / Heber Salmon / Quinsam**	**Puntledge**	**Ash**	**Jordan**	**Alouette / Stave**	**Coquitlam / Buntzen**	**Wahleach**	**Bridge / Seton**	**Shuswap**	**Cheakamus**	**Clowhom**	**Falls River**	**Clayton Falls**
EFFECTS OF FLOW DIVERSIONS													
35. Temperature extremes are buffered in augmented channels													
36. Temperature extremes are intensified in bypassed channels; diminished summer flows are warmer than original; diminished winter flows are colder													
37. Bypassed channel gets more extensive winter ice due to reduced flow													
38. Reduced habitat quantity in bypassed channel (mainstem, offchannel)													
39. Lower water level reduces fish access to former offchannel habitat													
Diversions into Other Watersheds													
40. Introduction of alien pathogens or fish species													
41. Increased habitat quantity in augmented system downstream													
42. Higher water levels in augmented channel floods former offchannel habitat													
43. Water quality in receiving reservoir is significantly changed (nutrient, transparency, temperature)													
44. Fish attracted to homestream discharge in receiving water													
45. Decreased sediment delivery down bypassed channel													
46. Higher flows in augmented channels initially alter channel morphology and erode spawning gravels													
EFFECTS OF OPERATIONS													
Facility Maintenance													
47. Debris on intake trashracks impinges fish													
48. Cleaning debris off trashracks necessitates spills or altered flows during temporary plant shutdown													
Reservoir													
49. Dredging degrades WQ in reservoir re: suspended sediment, organics, H_2S, BOD													
50. High flushing rates remove nutrients, and plankton													

	BC HYDRO SYSTEMS												
IMPACTS TO FISH **shading: potential significant adverse effect** **blank: no significant adverse effect**	**Campbell / Heber Salmon / Quinsam**	**Puntledge**	**Ash**	**Jordan**	**Alouette / Stave**	**Coquitlam / Buntzen**	**Wahleach**	**Bridge / Seton**	**Shuswap**	**Cheakamus**	**Clowhom**	**Falls River**	**Clayton Falls**
Downstream Flows													
51. Dredging degrades WQ downstream re: suspended sediment, organics, H_2S, BOD													
52. Fish stranding due to erratic flow changes (poor ramping)													
53. Spawner movement is constrained by high/low flows at hydraulic barriers downstream													
54. Regulated storage flows alter timing and quantity of habitat availability (negative and positive)													
55. Seasonal salinity patterns are altered in estuary													
56. Increased flows in winter impose metabolic demands on inactive fish													
57. BCH facilities permit management of flows to benefit habitat conditions in the long or short term													

5. SUMMARY OF WILDLIFE IMPACTS

5.1 Overview of Wildlife Impacts by Watershed

A very brief summary of impacts on wildlife in each watershed is presented on Table 5. This overview should be read in conjunction with the detailed assessment in the **Watershed Plans**.

5.2 Typical Impacts on Wildlife

Table 6 is a list of typical impacts on wildlife populations, arranged by BC Hydro project system. The general types of adverse impacts include: direct footprint impacts on habitat, effects related to both footprint and operational aspects, impacts on wildlife movement and impacts from increased road access.

There is limited specific information on impacts of hydroelectric development on wildlife. Identification of habitats impacted by reservoir flooding is also largely one of inference since no detailed descriptions were done before flooding. The discussion of wildlife habitat impacts is therefore primarily linked to species groups habitat associations, developed during the regional workshops. The following table outlines these associations.

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	Y			Y	Y	
Carnivores/omnivores/-herbivores (except ungulates)	Y	Y		Y	Y	Y
Aquatic and riparian mammals	Y	Y		Y		
Bats	Y	Y	Y	Y	Y	Y
Waterfowl, wetland/riverine, and riparian associated birds	Y	Y	Y	Y	Y	Y
Piscivorus birds	Y	Y	Y	Y		
Raptors				Y	Y	Y
Gallinaceous birds				Y	Y	
Passerines	Y	Y		Y	Y	Y
Amphibians	Y	Y		Y	Y	
Reptiles	Y			Y	Y	
Invertebrates	Y	Y	Y	Y	Y	
Rare Plants/ecosystems	Y			Y	Y	

Appendix Table 5: Summary of wildlife impacts by watershed.

WATERSHED	IMPACTS
Campbell	The inundation of floodplain coniferous and deciduous forest, wetland, river, and riparian habitat to create or enlarge John Hart, Campbell, and Upper Campbell and Buttle Lakes resulted in habitat loss for elk, deer, black bear, fur bearers, small mammals, water and wetland associated birds, and amphibians. Three other reservoirs were created or enlarged by diversion dams (Heber, Quinsam, Wokas), and four diversion structures (flumes or canals) were built. Both the reservoirs and exposed diversion structures (particularly the Salmon and Quinsam diversions) may have created barriers to animal movement. Some of the greatest concerns occur in the Elk and Heber watersheds where increased or reduced flows, respectively, have contributed to habitat changes that have impacted spring and summer elk foraging habitat, particularly in the Elk River. The lower part of the Elk River was also inundated by the creation of the Upper Campbell reservoir.
Puntledge	Just over half of the habitat impacted was upland coniferous forest of the steep-sided Comox Lake shore, although deciduous forest, river, and wetland habitats in low-lying areas, particularly at the head of Comox Lake, were also affected. Species impacted include deer, black bears, fur bearers, water and riparian bird communities, and amphibians. The lower 14 km of the Puntledge River has reduced flows due to a diversion penstock, which acts as a barrier to the movement of large mammals.
Ash	The of flooding of the Ash River resulted in inclusion of valley coniferous forest and some deciduous forest, wetland, river channel, and riverine habitats in the Elsie Lake reservoir. Habitat was impacted for deer, possibly elk, furbearers, waterbirds, and amphibians. Reduced flows occur in the lower 30 km of the Ash River due to the diversion tunnel redirecting water from Elsie Lake and to Great Central Lake.
Jordan	Three small primarily diversion reservoirs occur along the Jordan River system. Most inundated habitat comprised river channel and steep hillsides of coniferous forested with hemlock & other conifers. Wildlife values probably consisted primarily of deer and riverine birds such as dippers and harlequins. The lower river is affected by erratic flows in response to peak operational demands in combination with rainfall events; the effects on wildlife are unknown.
Cheakamus	A small shallow lake (Daisy Lake), a portion of Shadow Lake, and surrounding upland forest and braided river channel with adjacent lowland coniferous forest and some wetland habitat were flooded. The diversion into the Squamish River has reduced Cheakamus River flows downstream, but dyking and other downstream modifications have restricted the river channel. The reservoir has little storage capacity and fluctuates radically. This high elevation area has generally low wildlife values.
Alouette/Stave	Habitats flooded by the Stave dam included extensive meandering river channel and associated bars, riparian, and lowland coniferous habitats, plus extensive

	upland coniferous forest, with values for a variety of wildlife such as deer and black and grizzly bear and possibly beaver and other fur bearers and waterfowl. The most characteristic features are an extensive, poorly vegetated drawdown zone and numerous snags resulting from the flooded forest. Snags provide perching and nesting habitat for birds. A smaller area of almost entirely coniferous upland was flooded by the damming of Alouette Lake. The diversion into Stave Lake has reduced Alouette River flows downstream, but dyking and other downstream modifications have restricted the river channel.
Coquitlam/ Buntzen	The flooding of Coquitlam Reservoir resulted in the inundation of a small area (relative to the watershed size) of coniferous upland and very little low elevation valley bottom habitat. Reduced Coquitlam River flows, with unknown effects on wildlife, result from the diversion into Buntzen Lake through a tunnel. Only small changes occurred to the level of Buntzen Lake.
Wahleach	High elevation upland and lowland coniferous habitats were flooded by the enlarged reservoir area. Flows are reduced in Jones Creek due to the diversion of water through a tunnel to the Fraser River. Main wildlife use of the flooded lake was probably low numbers of fur bearers, deer, and grouse.
Bridge-Seton	Inundated Bridge River habitats include very extensive meandering river channel and associated bars, oxbows, riparian shrub and treed (deciduous and some coniferous) habitats with high value moose winter range and many other seasonal or year round wildlife values, e.g., beaver, muskrat, black and grizzly bear, deer, wolf, fur bearers, waterfowl and other wetland and floodplain/riparian bird, small mammal and amphibian communities, etc. There are also wildlife implication resulting from the loss of the salmon resource of the Bridge River and its tributaries. The barrier created by the conversion of the Bridge River into Carpenter and Downton Reservoirs has also interrupted seasonal migration and movement of larger mammals and resulted in the fragmentation of populations of some animal, such as grizzly bear.
Shuswap	The construction of the dam at the outlet of Sugar Lake resulted in the flooding of former riverine and deciduous riparian and floodplain habitats, primarily at the upper ends of the Lake, and of coniferous habitat on the steep valley sides. Likely wildlife values for the bottomland area included moose, black and grizzly bear, furbearers, and other wetland and floodplain/riparian bird, small mammal, and amphibian communities, etc. The snags of the former forest are not mostly rotted and no longer provide significant wildlife value.
Clowhom	Most of the habitat flooded by raising the lake was upland cedar/hemlock forest on steep slopes. The area was burned in the 1850's and logged in the 1910's, before flooding occurred. Roosevelt elk and grizzly bears once used these habitats, but their disappearance was due mostly to a combination of other factors.
Falls River	The Falls River dam flooded valley bottom riverine and deciduous and coniferous forest habitats and upland coniferous forest. Deer, bear and fur bearer values would have been lost.
Clayton Falls	No impact beyond small power generating site.

Direct footprint impacts to habitats, and therefore to wildlife, include those resulting from the following:

- habitat losses caused by dam construction and reservoir flooding,
- downstream habitat changes resulting from reduced flows or increased flows caused by diverting rivers between waterways, or by bypassing sections of rivers with artificial conveyances,
- habitat changes (e.g., forest removal) associated with the creation of diversion structures like flumes and canals,

Other effects may have both footprint and operational aspects, such as

- reservoir drawdown zone effects on vegetation establishment and
- downstream modifications of the natural flow regimes.

Facility footprints can also impact wildlife directly by:

- creating barriers that interrupt animal movement between seasonal ranges,
- reducing available habitat within seasons by restricting animals to one side of a barrier, or
- fragmenting populations when numbers are low or where small islands of animals are separated from important genetic exchange (e.g. elk at Buttle Lake).
- creating unintended habitat in anthropogenic structures when the wildlife use of those structures may be undesirable (e.g. bats in buildings).

Wildlife can be impacted indirectly when road access that may be created for facility construction or maintenance leads to

- mortality associated with vehicle collision, hunting, or poaching,
- disturbance, and
- habitat impacts resulting from increased settlement.

Some wildlife benefits can also accrue from reservoir creation, particularly for piscivorus birds like common loons (that nest elsewhere) or ospreys, but such benefits are probably minimal relative to the habitat and wildlife values lost, particularly for large, flat-bottomed, steep-sided reservoirs.

Appendix Table 6: Typical Impacts on Wildlife in BC Hydro Systems

	BC HYDRO SYSTEMS												
IMPACTS TO WILDLIFE **shading: potential significant adverse effect** **blank: no significant adverse effect**	**Campbell / Heber Salmon / Quinsam**	**Puntledge**	**Ash**	**Jordan**	**Alouette / Stave**	**Coquitlam / Buntzen**	**Wahleach**	**Bridge / Seton**	**Shuswap**	**Cheakamus**	**Clowhom**	**Falls River**	**Clayton Falls**
EFFECTS OF CONSTRUCTION													
1. Disturbance from noise, machinery, people during construction activity.													
2. Wildlife displacement and mortality during clearing and construction activity.													
EFFECTS OF STRUCTURES													
Physical Footprint													
3. Decreased instream habitat from footprint of facility or structure													
4. Decreased riparian habitat from footprint of facility or structure													
5. Decreased upland habitat from footprint of facility or structure													
Wildlife Mortality													
6. Wildlife trapped in, or caught by flows through/over, structures such as dam, culverts, diversions.													
7. Wildlife mortality along facility access roads caused by vehicle collisions, hunting, or poaching.													
EFFECTS OF RESERVOIR													
Physical Footprint													
-Effects of Flooding Habitat													
8. Loss of river channel habitat.													
9. Net decrease of wetland habitat (shallow water with aquatic veg. in ponds or lakes).													
10. Loss of valley bottom deciduous riparian and floodplain habitat.													
11. Net decreased of lake shoreline riparian habitat.													
12. Loss of lowland coniferous forest (on alluvial soils).													
13. Loss of upland forest.							?			?			
-Effects of Creating a Reservoir													
14. Net increase of wetland area (shallow water with aquatic vegetation in ponds or reservoir).													
15. Increased reservoir size (area, shoreline length, depth) creating habitat for some aquatic wildlife.													

IMPACTS TO WILDLIFE **shading: potential significant adverse effect** **blank: no significant adverse effect**	**BC HYDRO SYSTEMS** Campbell / Heber Salmon / Quinsam	Puntledge	Ash	Jordan	Alouette / Stave	Coquitlam / Buntzen	Wahleach	Bridge / Seton	Shuswap	Cheakamus	Clowhom	Falls River	Clayton Falls
16. Creation or net increase of shoreline riparian habitat of stable (< 1m fluctuation) reservoir.	Hart												
17. Increased snags available for wildlife use, if not cleared. (g - now mostly gone)									g				
18. Increased barrier effect of reservoir to animals causing known or theoretical fragmentation of populations or interruption of movements between seasonal ranges[1].													
19. Increased susceptibility to predation of animals along barrier edge, e.g. ice related effects, fences. diversions, reservoirs.													
20. Loss of anadromous fish as food source for wildlife due to barriers to fish access created by structures.								Bridge					
21. Decreased aquatic food resources (plants, invertebrates, some fish) for wildlife due to water depth, temperature, or quality changes.								Bridge					
EFFECTS OF FLOW DIVESRSIONS													
Source Watershed													
22. Reduced instream, wetland, and/or riparian habitats in original system for varying distances downstream.													
23. Decreased flow volume in original system downstream.													
RECEIVING WATERSHED													
24. Increased instream, wetland, and/or riparian habitats in receiving system downstream.			?										
25. Increased flow volume in receiving system downstream.													
Diversion Rights-of-Way													
26. Development of wetted diversion channel habitat where diversion resembles either a natural creek or a concrete (c) channel								c					
27. Removal of forested upland habitat along diversion r-o-w (p=penstock only)				p									
28. Development of shrub habitats along diversion r-o-w. (p=penstock only)				p									
29. Barriers to wildlife caused by diversion conveyance structure's width, height, flows, fencing, etc., resulting in fragmentation of populations or interruption of movements between seasonal ranges. (p=penstock only)			p										
30. Increased susceptibility to predation of animals along barrier edge.													

[1] This is a subjective evaluation of whether the increased reservoir size is sufficient to create a barrier for species of which individuals would have once used both sides, or of which individuals would have periodically immigrated/emigrated across the river prior to flooding, but now do not or cannot. This consequence refers primarily to upland species, as lowland habitats are now gone for exclusively wetland, riparian and riverine species.

IMPACTS TO WILDLIFE **shading: potential significant adverse effect** **blank: no significant adverse effect**	BC HYDRO SYSTEMS Campbell / Heber Salmon / Quinsam	Puntledge	Ash	Jordan	Alouette / Stave	Coquitlam / Buntzen	Wahleach	Bridge / Seton	Shuswap	Cheakamus	Clowhom	Falls River	Clayton Falls
EFFECTS OF OPERATIONS													
Facility Maintenance and Upgrades													
31. Same issues as original construction.													
Reservoir													
32. Poor vegetation establishment in drawdown zone and associated habitat or stability issues.													
33. Breeding or feeding "traps" created by fluctuating water levels in drawdown.													
34. Wildlife mortality/predation caused by ice presence or by falling reservoir or river levels beneath ice.													
Downstream Flows													
35. Changed flow regime with detrimental/beneficial habitat/wildlife effects.													