

**FRAMEWORK FOR THE EVALUATION OF  
RESTORING HISTORIC PASSAGE FOR  
ANADROMOUS FISH AT BC HYDRO  
BRIDGE-COASTAL GENERATION AREA DAMS**

*Prepared for:*

**Bridge-Coastal Fish and Wildlife Restoration Program  
6911 Southpoint Drive  
Burnaby, BC V3N 4X8**

**July 2002**

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# 1 Executive Summary

BC Hydro commissioned a report by Global Fisheries Consultants (Benneyfield et al. 2001) to conduct a preliminary assessment on the feasibility of providing anadromous fish passage for facilities in the Bridge River/Coastal Generation System. The Bridge-Coastal Fish and Wildlife Restoration Program (BCRP) initiated a peer review of the report in April 2002 to seek further opinions regarding the feasibility of restoring historic fish passage at Bridge-Coastal Region facilities. This report describes the opinions of the independent review as well as recommendations on further analysis of the fish passage feasibility issue.

In our review, we noted that major decisions on fish passage feasibility appeared to have been made based on limited information. We identified issues that required further assessment prior to a decision on feasibility. These issues concerned the biological, habitat, operational and domestic water quality constraints discussed by Benneyfield et al. (2001). Contrary to the Benneyfield report, we believe that:

- There is insufficient biological evidence to support or refute the possible restoration of viable anadromous salmon populations above the dams.
- There is considerable evidence to suggest that successful reintroduction of sockeye is quite possible.
- There is insufficient evidence to make conclusions regarding the suitability of existing habitat above the dams or the feasibility of habitat enhancement.
- The impact of salmon reintroduction on domestic water quality in Coquitlam Reservoir may be minor but needs further analysis that is based on proposed anadromous escapement goals.
- Experiments on juvenile behavior and migrations out of the reservoirs would be prudent before concluding that inter-basin diversions will significantly and negatively impact successful reintroduction.

We recommend that future proposals for determining fish passage feasibility be matched against an expanded decision making process consisting of four stages:

- 1) Establish Stock and Habitat Profiles;
- 2) Establish Operational Profile;
- 3) Establish Structural Profile; and
- 4) Assess cost-effectiveness.

Using this decision process, opinions and recommendations were provided on the information requirements for Alouette, Coquitlam, Wilsey, Ruskin and Terzaghi dams. One key recommendation was to establish some pilot tests of specific uncertainties regarding fish passage restoration. For example, field tests could determine: behavioral response of emigrating smolts to selection of diversion versus dam releases at one of the facilities with inter-basin diversions, potential interaction of the reintroduced anadromous fish on resident fish stocks, and relative proportion of returning anadromous adults attracted to diversion releases rather than dam flows.

We concurred with the Bengeyfield et al. (2001) recommendation to proceed with studying anadromous reintroduction above Wilsey Dam, but we recommend the study include assessments to provide a complete stock and biological profile prior to the development of engineering plans.

Ruskin Dam appears to have the least potential for restoration. The main concern for establishing anadromous fish passage above the dam is the lack of suitable upstream habitat. Confirmation of this should be the first task before considering any proposals for this facility.

We recommend that the BCRP Board wait for completion of the feasibility report on Terzaghi Dam by Arc Environmental Ltd. prior to considering any further proposals for restoring fish passage at the facility.

From our review of the 'Alouette Reservoir Fish Passage Feasibility Assessment' proposal submitted by the Alouette River Management Society, we recommend that initial studies focus on:

1. Identification of target species;
2. Identification and approval of donor stock if required;
3. Compilation and analysis of previously collected assessment information on current and potential habitat above and below the dam;
4. Quantification of habitat capacity and establishment of biological escapement goals;
5. Identification of any enhancement requirements (habitat or fish husbandry); and
6. Identification of fisheries management constraints.

Analysis and, if necessary, modeling of reservoir operation could assist in establishing alternative operational profiles prior to undertaking field tests but should follow after Steps 1 and 2 above are completed. We also believe that the operational profiles can only be properly evaluated through field tests.

From our review of the 'Wilsey Dam Fish Passage Feasibility' proposal submitted by Fisheries and Oceans Canada, we recommend the BCRP Board solicit a proposal with more clearly stated objectives and deliverables to address feasibility at Wilsey Dam.

## **2 Acknowledgments**

The Bridge-Coastal Fish and Wildlife Restoration Program (BCRP) commissioned this report. Craig Orr (Chair) and Ed Woo (Fisheries and Oceans Canada) of the BCRP Board and Janice Doane (BC Hydro) provided direction on this project. Janice Doane was also responsible for contract management. Numerous individuals (see Consultation List) shared their views and information on fish passage feasibility at dams. Editorial comments on the draft were provided by: Alan Caverley and Marvin Rosenau (Ministry of Water, Land and Air Protection), Geoff Clayton (Alouette River Management Society), and Marvin Joe (Kwkwetlem First Nation). The assistance of all of these individuals is greatly appreciated.

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## 3 Introduction

### 3.1 Background

In 2001, BC Hydro commissioned Global Fisheries Consultants (Benneyfield et al. 2001) “to undertake a preliminary review of the physical and biological features” of each facility in the Bridge River/Coastal Generation System, in order to “evaluate the feasibility of providing anadromous fish passage and to prioritize the facilities for which further investigation is required.”

The main conclusion of the passage report, based on technical considerations, was that it might be possible to restore fish passage through only one Hydro facility within the entire Bridge-Coastal system—the Wilsey Dam (Shuswap territory). Perhaps not surprisingly, the conclusions of the fish passage report have been questioned by some, and openly disputed in one proposal to study fish passage feasibility into Alouette Lake, since submitted to the Bridge-Coastal Fish and Wildlife Restoration Program (BCRP).

BCRP is an environmental initiative sponsored by BC Hydro to address the historic effects of hydroelectric development on the fish and wildlife resources of the watersheds in the Bridge-Coastal Generation Area (Anonymous 2000a, Figure 1). 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”. The BCRP Strategic Plan suggested restoring historic access for anadromous stocks as a potential fish restoration objective (Anonymous 2000a).

Faced with contradictory opinions, and recognizing that the Global study has not been reviewed by Hydro or other technical experts, including government agencies, the Board and technical committees of the BCRP decided to seek further opinions regarding the feasibility of restoring historic fish passage at Bridge-Coastal Region facilities.

LGL Limited was contracted to provide an independent review of the Global Fisheries report and further analysis of the fish passage feasibility issue.

### 3.2 Study Objectives

The BCRP Board established the following terms of reference for this second opinion with LGL Limited in April 2002:

1. Evaluate concerns related to the conclusions of the Global Fisheries Consultants report;
2. Review outstanding fish passage feasibility proposals recently submitted to the Board and consult with the proponent(s) of the proposal(s);
3. Clarify feasibility issues with respect to technical, economic and biological aspects for each facility (of particular interest is the issue of inter-basin diversions);



4. Conduct additional flow analyses to better understand the relation between diversion flows and dam flows during critical migration periods (i.e., spring and late summer), and examine feasibility and costs of adjusting flows, in concert with hydro-grid management, to improve migration success at facilities where fish passage is recommended;
5. Expand feasibility assessment to include passage over additional dams where multiple facilities occur in the same watershed and benefits may be maximized;
6. Examine benefit/cost relationship between fish passage facilitation and water use planning for existing downstream fish habitat use; and
7. Prepare a report for all of the above with clear recommendations to the Board regarding the potential for fish passage works at each facility and further study requirements.

## 4 Review of the Global Report

The Global Fish Passage Report (Benneyfield et al. 2001) used a simple three-step decision process to determine candidate facilities and assess feasibility (page 12 of Benneyfield et al. 2001). Step one was the determination of whether an anadromous fish population was present upstream of the dam at the time of construction. If the answer was no, then no further study was recommended. If yes, then one would proceed to Step two. Global identified five facilities within the Bridge-Coastal area that had historic fish passage above the dam.

Step two involved the assessment of biological feasibility. Three questions were asked in sequence:

1. Does sufficient habitat exist upstream of the dam that is useable under present WUP operations, to support the life cycles and target numbers of the proposed species necessary to achieve a self-sustaining wild population? *If no – Stop.*
2. If existing habitat is insufficient, could additional habitat capacity be i) constructed, ii) made accessible, and iii) made suitable by changing WUP operations? *If no – Stop.*
3. Are biological interactions expected that would have significant negative impacts on resident fish populations? *If yes – Stop.*

Step three involved the assessment of technical feasibility:

4. Does the project divert significant portions of reservoir inflows at critical biological seasons to another basin? *If yes – Stop.*
5. Does the height or layout of the dam preclude the construction of an upstream fish passage structure? *If yes – got to 7; if no – proceed with detailed feasibility assessment.*
6. Is there outside support for annual trap and haul operations to return adult spawners above the dam? *If no – Stop.*

The Global report reviewed five dams within the Bridge-Coastal Region; Coquitlam Dam, Alouette Dam, Ruskin Dam, Terzaghi Dam, and Wilsey Dam. Only one of these, Wilsey, was determined to be suitable for restoring fish passage. These reasons are summarized below:

- Coquitlam – further study not warranted on the basis of: 1) reintroduction of sockeye not feasible; 2) limited upstream spawning habitat; 3) operational concerns; 4) domestic water quality; and 5) inter-basin diversion of water makes restoration not viable.
- Alouette - further study not warranted on the basis of: 1) reintroduction of sockeye not feasible; 2) limited upstream spawning habitat; 3) operational concerns; and 4) inter-basin diversion of water makes restoration not viable.
- Ruskin - further study not warranted on basis of: 1) insufficient upstream spawning habitat; 2) operational concerns; and 3) dam height.
- Terzaghi - further study not warranted on basis of: 1) operational concerns; 2) inter-basin diversion of water makes restoration not viable; and 3) dam height.
- Wilsey - further study warranted

We discuss each of these below.

#### Biological Concerns:

Possible biological constraints to restoring anadromous fish passage over hydroelectric dams are complex. The Bridge-Coastal Fish and Wildlife Restoration Plan identified the main issues as:

- Interactions with other species;
- Disease transfer; and
- Ability to successfully transplant.

For both Coquitlam and Alouette dams, biological concerns were considered minor by the Global report. However, this conclusion appears to have been based on extremely limited information. No direct evidence of significant biological interaction was identified for any of the facilities examined (Table 4 in Bengeyfield et al. 2001). The exception to this was sockeye, a species that was considered by the Global report to be too difficult to reintroduce.

In our opinion, there is considerable evidence to suggest that successful reintroduction of sockeye is quite possible. Salmon enhancement using hatchery techniques actually began with sockeye salmon in British Columbia. It originated at Weaver Creek in 1885 (Fisheries and Oceans Canada (DFO) web site). In the fall of that year, eggs obtained from sockeye salmon were first transplanted to other streams in the province. Since then, there have been many other successful enhancement stories for sockeye salmon in the Pacific Northwest. The most recent success story is the Adams River sockeye run. In 2000, the Upper Adams River, near Chase, saw a record 70,000 adult sockeye salmon return to its spawning grounds, an amazing recovery

for a river that was devoid of salmon from 1913 to 1953. Fisheries and Oceans, in partnership with the Adams Lake Band, are releasing two million sockeye fry each year to continue rebuilding the stock (DFO web site). One million sockeye fry are raised at the Shuswap River Hatchery and then released into the Upper Adams River. A further one million fry are transferred from the hatchery to net pens near the mouth of the Upper Adams River.

Sockeye culture for stock re-building has been taking place in the US for many years as well, perhaps the most famous being the nearly extinct Snake River stock. Clearly, sockeye stock rebuilding is a viable option from a fish culture perspective.

Coho, chinook and steelhead are candidate species for reintroduction as well. In our opinion, there is insufficient biological evidence to support or refute the possible restoration of viable anadromous salmon populations above the dams.

### Habitat Concerns

The Global report considered four of the five systems to have insufficient upstream habitat, despite the acknowledgement that “habitat inventory data is particularly poor for Coquitlam and Alouette reservoirs” (Bengeyfield et al. 2001). Also, short, low gradient sections of tributaries and mainstem in Interior and Coastal streams may have higher than expected fish production capability (Al Caverley, Ministry of Water, Land, and Air Protection (MWLAP) pers. comm.). As well, the creation of spawning channels, habitat improvements, and/or spawning beaches as part of the restoration package was not considered in their assessments. In many cases, maintenance of fish passage or restoration of fish passage requires enhancement of upstream habitat as a key component of the project (e.g. Baker Lake, Appendix A). At Baker Lake, artificial spawning beaches were created to provide stable spawning areas for sockeye within the reservoir basin. With the possible exception of Ruskin Dam, there is insufficient evidence to make conclusions regarding the suitability of existing habitat above the dams or the feasibility of habitat enhancement.

### Operational Concerns

The Global report identified major operational impediments to restoring fish passage at Coquitlam, Alouette, and Terzaghi dams. The main operational concerns identified by the Global report were:

- Reservoir drawdown and its impact on fish spawning and rearing; and
- Diversion of flows to other basins.

Technical feasibility, the scale of smolt screening, collection and transport requirements, and the biological problems anticipated with homing and juvenile migration were cited as significant concerns.

Reservoir drawdown can certainly be a significant challenge to overcome. For example, drawdown can influence spawning success for lake rearing or spawning species (e.g., sockeye). However, in some situations these impacts can be mitigated. For example, at Baker Lake

(Appendix A), artificial spawning areas were constructed for sockeye salmon. Alternatively, tributary spawning areas can be constructed.

Reservoir drawdown can also impact the successful operation of fishways. However, this can usually be overcome through fishway design.

Diversion of flow to other basins was identified as the most significant impediment to successful restoration of fish passage. However, the extent of this concern will be species specific. For example, juvenile sockeye movements in lakes are celestial and compass driven, not flow driven (Quinn 1982, Groot 1965). The complexity of migration routes varies greatly from single-basin lakes to multi-basin lake chains such as Wood River lakes in Bristol Bay or Babine Lake in British Columbia (Burgner 1991). In multi-basin lakes, there are numerous opportunities for wrong turns, yet the young sockeye appear genetically programmed to find their way, independent of flow attraction. It is not until the juveniles approach the outlet flow, that flow becomes a significant factor influencing migration.

Juvenile migration behavior of chinook, coho and steelhead is understood less. Experiments on juvenile behavior and migrations out of the reservoirs would be prudent before concluding that inter-basin diversions will significantly and negatively impact successful reintroduction.

#### Domestic Water Quality

The Global report indicated that sockeye reintroduction above the Coquitlam Dam could negatively affect the Greater Vancouver Regional District (GVRD) water quality standards. However, approximately 4000 coho have annually been trapped and trucked above the Cleveland Dam on the Capilano River without affecting GVRD water quality significantly (Mazumder 2002; Robin Dixon, Capilano Hatchery; Matt Foy, DFO pers. comm.). Also, it is important to note that the Capilano River supplies 40% of the region's drinking water while the Coquitlam River provides 30% of Greater Vancouver's drinking water (Dave Dunkley, GVRD, pers. comm.; GVRD web site). It is apparent that further discussions are required with the GVRD prior to stating the severity of this impediment. Proposed anadromous escapement goals should be determined prior to discussions with the GVRD.

#### Dam Height

The height of the five dams under consideration ranges from 21 m to 60 m. A few examples of anadromous upstream fish passage over high dams include:

- Carmel River steelhead salmon using fishway at San Clemente dam (26 m);
- Columbia River salmon using fishway at Bonneville dam (60 m);
- Columbia River salmon using fishway at McNary Dam (56 m);
- Trap and truck operation for salmon at Skykomish River; and
- Trap and truck operation for sockeye at Baker Lake (95 m).

The feasibility of constructing fish ladders at each of the five facilities in the Bridge Coastal Region would require considerable investigation but cannot be dismissed because of dam height.

Certainly the three dams under 31 m high (Coquitlam, Alouette and Wilsey) should be feasible from an engineering perspective. Hay and Company Consultants describe several examples of different fish ladders, fish locks, fish lifts and trap and truck operations that have been successful (Benneyfield et al. 2001).

In general, dam height is not a serious constraint to downstream fish passage. Mortality rates of less than 2% are not uncommon at dams up to 30 m in height (Benneyfield et al. 2001).

Aside from cost considerations, dam height should not be a major impediment to restoration of fish passage.

## 5 Recommended Decision Process

Figure 2 illustrates an expansion of the decision making process suggested by Global. It is intended to be a step-wise process whereby the biological concerns should be addressed in full before operational and structural concerns. We recommend that future proposals for determining fish passage feasibility be matched against this decision process.

There are four stages to be completed in the fish passage feasibility decision process. The first three stages can be conducted in a step-wise manner or in parallel depending on project specifics and availability of funding.

### 5.1 Stage 1 – Establish Stock and Habitat Profiles

#### 5.1.1 Stock Profile

Profiling the stock includes a number of activities:

- Identification of target species;
- Identification of ‘approved’ available donor stock;
- Identification of impacts (interactions) with resident fish;
- Determining the species-specific migration timing for the target species;
- Establishing attainable production (biological escapement goals); and
- Identification of any fisheries management constraints.

A number of factors should be considered when determining target species. These include: economic benefit, historical value, and probability of success. If several species are of interest, it may be prudent to start with the most promising one as a pilot, preferably one that is present downstream of the dam.

Identification of available stock will likely require an application to the Transplant Committee as well as approval from MWLAP. MWLAP generally accepts reintroduction of migratory resident and anadromous species into basins where these species occurred historically but where their migrations are now blocked by dams (Marvin Rosenau, Ian McGregor, Al Caverley, MWLAP pers. comm.). They may also view the benefits of anadromous reintroduction (particularly

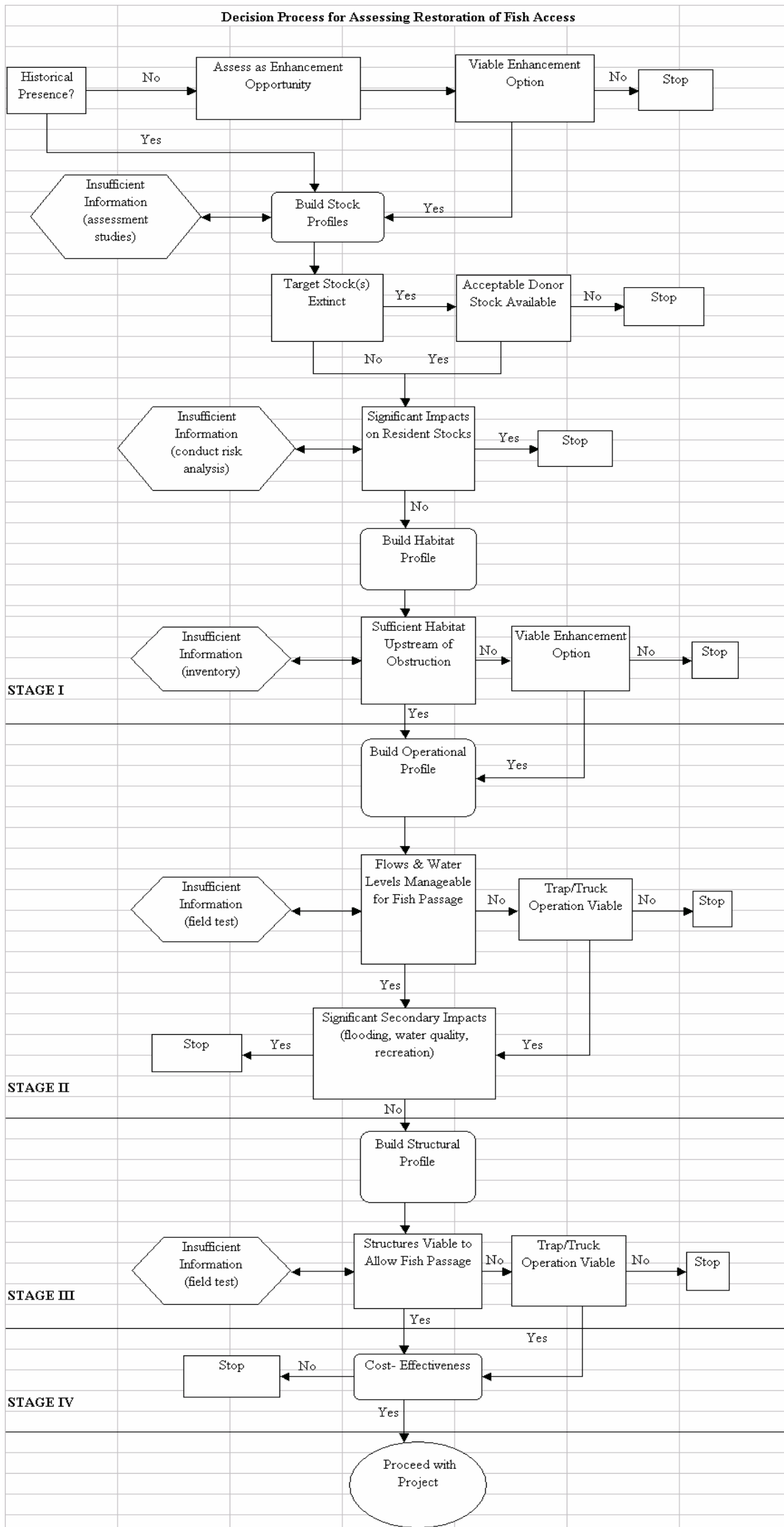


Figure 2. Decision process for assessing feasibility of restoring fish passage over hydroelectric dams.

sea run steelhead and cutthroat) as greater than the benefits associated with resident populations. The Province takes an ecosystem restoration approach and recognizes that with, for example, coho, sockeye and chinook reintroduction, the size and number of kokanee will be smaller. On the other hand, the increase in marine-derived nutrients may increase the productivity and help to balance potential kokanee impacts (Marvin Rosenau, MWLAP pers. comm.).

The other main entity responsible for decisions on reintroduction of salmon into watersheds where genetic stocks are extinct is the Transplant Committee. The Federal-Provincial Fish Transplant Committee was formed with a Memorandum of Understanding between: Department of Fisheries and Oceans; the B.C. Ministry of Environment, Lands and Parks; and the Ministry of Agriculture, Fisheries and Food. It is the technical committee whose primary role is to advise the above agencies on fish transplant issues. It meets at least four times per year, and consists of up to six members (two from each of DFO and the appropriate provincial ministries).

Key questions considered by the committee for a release or transfer of fish are:

- Is the request in keeping with the proper management and control of fisheries?
- Do the fish have any disease or disease agent harmful to the conservation and protection of local fish stocks?
- Will the fish introduction or transfer have an adverse effect on local fish stocks?

In this regard, each application undergoes a Risk Assessment, which reviews three main categories:

<b>Ecological -</b>	Effects on the distribution or abundance of local species resulting from alterations in relationships such as predation, prey availability and habitat availability.
<b>Disease -</b>	Effects on the prevalence, distribution and/or impact of disease on local species.
<b>Genetic -</b>	Effects on the capacity of local species to maintain and transfer to successive generations its current genetic identity and diversity.

From this review the committee makes its recommendations and may identify potential mitigation requirements (e.g. egg disinfection, treatment of effluent, quarantine holding) as a condition of license. Any project being considered for restoration of fish passage should go through this Risk Analysis during the initial stages of the feasibility assessment.

Establishing attainable biological production goals is a critical step. These are required to properly scope the project and to provide biological justification. These goals are essential to evaluating cost-effectiveness.

Finally, any management issues related to increased production need to be closely evaluated. For example, it may make little sense to attempt to restore a particular stock or species if it is only going to be harvested at a high rate in interception fisheries.

The outcome of the stock profile would be either a green light for proceed, a yellow light requiring further analysis, or a red light for stop (Figure 3).

### 5.1.2 Habitat Profile

Profiling the habitat includes:

- Assessment of existing habitat condition (spawning, rearing, overwintering);
- Assessment of habitat potential (spawning, rearing, overwintering); and
- Identification of habitat enhancement potential.

If the feasibility assessment requires that the overall restoration program provide for the best use of restoration funds within a watershed, then existing habitat both above and below the dam needs to be evaluated in sufficient detail to confidently establish the production potential of the entire system. Quantifying habitat above and below the dam will allow for estimation of what the percentage contribution from upstream areas might be. It may be that most of the desired production can be obtained from enhancing downstream habitats. Conversely, reintroducing fish to higher quality habitat upstream may improve poor stock productivity caused by limited habitat downstream.

Careful consideration of habitat potential is also important. It may be that with some minor investment in habitat improvements, considerably higher production might be obtained from existing habitat. Or it might be required to invest substantially in new habitats (e.g., artificial sockeye spawning channels or beaches).

## 5.2 Stage 2 – Establish Operational Profile

If positive stock and habitat profiles can be built, then the next question is one of operational feasibility. That is, can you pass fish upstream and downstream within the current hydroelectric operating rules or do the rules need to be modified. The specific rule requirements are likely to be species-specific and so need to be evaluated in relation to fish behavior.

Passing adults over the dam is relatively straightforward. Adult salmonids are attracted to flow and so a capture location or entrance to a fish ladder can generally be easily established. There may be some requirements to vary the discharge location and amount during adult migration.

Passing juvenile salmonids migrating downstream is more problematic. As juveniles approach the reservoir outlet (i.e., dam), flow becomes an important factor in exit location. In general, downstream passage is facilitated through: surface collectors, surface spills, screen diversions, and turbine passage (Benneyfield et al. 2001). Some guidance system is often required.

Parameter	Target Species				Restoration Strategy	Comments
	Sockeye	Coho	Chinook	Steelhead		
<b>Stock Profile</b>						
Anadromous stock available					pilot coho	
Attainable production goals						establish and monitor
Interactions with resident fish						Transplant Committee OK
Host or vector for disease						Transplant Committee OK
Fish Management Constraints					reduce interception fisheries	
<b>Habitat Profile</b>						
Rearing habitat					none required	
Spawning habitat					create spawning channel	
Overwintering habitat						
<b>Operational</b>						
Dam releases	Adults					increase flows during migration
	Juveniles					none required
	Smolts					increase flows during migration
Reservoir elevati	Eggs					
	Adults					
	Juveniles					
Diversion releas	Adults					reduce during migration
	Juveniles					
	Smolts					reduce during migration
<b>Structural</b>						
Upstream accessibility					trap and truck	
Downstream accessibility					capture barge	
<b>Overall Feasibility Rating</b>						
- no or minor impediment to feasibility - impediment to feasibility considered moderate as problem can be mitigated with proven techniques or other interventions - would be a major impediment to feasibility but species-specific habitat availability or magnitude of impact currently unknown - major impediment to feasibility and not readily mitigated with intervention - non-feasible						

Figure 3. Hypothetical decision matrix for assessing the feasibility of restoring fish passage at dams.

As noted in the Global report, the existence of inter-basin diversions in several of the dams in question, complicate the issue of juvenile passage. However, at least for sockeye, juvenile migration through the lake does not appear to be flow related (Quinn 1982, Groot 1965). The mechanisms that would program reintroduced sockeye to migrate to the dam instead of the diversion are unknown and field testing would be required.

Appendix F of the Global report identifies general factors to consider when evaluating the operational feasibility of fish passage (Table 1):

Table 1. Operational considerations for evaluating fish passage (Benneyfield et al. 2001).

Upstream Adult Passage	Downstream Juvenile Passage
Target species	Target species and age
Migration timing	Migration timing
Numbers of fish to pass	Numbers of fish to pass
Instream flow characteristics	Location and depth of major flow releases
Location of entrances to passage or trapping facilities	Reservoir hydraulics from natal streams and near outlets
Capability of spill during migration period	Distribution and behavior of outmigrants in the reservoir
Forebay and tailwater fluctuations during migration periods	Capability of spill during migration period
Need and availability of auxiliary attraction flows	Forebay and tailwater fluctuations during migration periods
Capital, maintenance and operational requirements	Turbine type and spillway type

Field tests would be required to properly evaluate the migration behavior of fish and the feasibility of various passage options. A risk assessment of other possible impacts such as flooding, degradation of water quality, and impacts to recreational use should also be conducted as part of the operational profile. Potential impacts need to be considered if modifications to current operational rules are required.

### 5.3 Stage 3 – Establish Structural Profile

The third stage of the feasibility assessment is to assess structural requirements to meet fish passage objectives. This would start with conceptual engineering designs of upstream passage facilities and downstream passage facilities. Costs should be estimated as close as possible at this point. It may be appropriate to present several alternatives.

### 5.4 Stage 4 - Cost-effectiveness

The final stage of the feasibility assessment is an evaluation of cost-effectiveness. This is a potentially complex issue as intrinsic values of the salmon resource, for example as described for the Kwikwetlem Nation in the Coquitlam watershed by Koop (2001), are carefully weighed against hard dollar amounts for construction and operations and lost hydro revenue. Also,

thorough assessments of biological, operational and structural profiles will allow for rational decisions that commit funds for restoration works to provide anadromous reintroduction upstream or to the improvement of downstream habitat.

## **6 Recommendations for Further Assessments of Fish Passage Feasibility**

We recommend that the BCRP refer to the Decision Process described above (Figure 2) when reviewing existing and future proposals for fish passage restoration at hydroelectric facilities in the Bridge-Coastal Area. It may be appropriate to establish some pilot tests of specific uncertainties regarding fish passage restoration. For example, several authors have identified the issue of passing juvenile salmonids out of the reservoir as a significant issue (Bengeyfield et al. 2001; Arc Environmental Ltd. 2002). A pilot test of one or more species at one of the facilities with inter-basin diversions would be worthy of consideration.

### **6.1 Alouette Dam**

Currently, there are information deficiencies that prohibit informed decision making on this issue. At the same time, there is insufficient evidence to refute the potential reintroduction of some or all of the suggested target species. Further investigations are warranted and we recommend that the BCRP consider proceeding with the following activities either in concert or sequentially. It is important to note that the operational and structural alternatives we suggest below are provided for illustration purposes only, representing the framework for one of several possible restoration scenarios.

#### Recommendation 1 – Establish Stock and Habitat Profiles

##### *1a. Establish Target Species and Biological Goals*

Chinook, sockeye, coho and steelhead have all been identified as possible target species for reintroduction. However, the relative importance of these species has not been discussed in detail, with the exception of sockeye, which are currently believed to be extinct. (There has been recent (2002) evidence of sockeye smolts being captured in the South Alouette River by Scott Cope (Greg Wilson, MWLAP pers. comm.). There is considerable anecdotal evidence that suggests a certain proportion of a kokanee population retain the predisposition to smolt (Foerster 1968; Kim Hyatt, DFO, pers. comm.). Hyatt also indicated that there has been evidence of adult sockeye congregating below barriers above which there is kokanee.

Basic biological information on current stock levels and seeding levels of existing habitat below the dam has not been presented. This is an important first step to determining the potential benefits of restoration.

##### *1b. Identify Donor Stocks for Target Species if Required*

Native sockeye and chinook stocks were considered extinct in Alouette River due to the dam (Bengeyfield et al. 2001). Since 1997, chinook fry of Chilliwack River origin have been stocked

in the Alouette River. The Transplant Committee has approved Chilliwack River chinook for reintroduction into the Alouette River watershed (Geoff Clayton, Alouette River Management Society (ARMS) pers. comm.). Depending on the genetic source of the sockeye smolts captured below the dam in 2002, a suitable donor stock for sockeye may need to be identified and approved by the Transplant Committee.

*1c. Describe in Detail Existing Habitat and Establish Habitat Goals and Objectives*

(Note: This was Task 2 of the ARMS proposal)

Existing habitat information from the 1994/95 BC Hydro study downstream of the dam (Geoff Clayton, ARMS pers. comm.) needs to be analyzed to determine production goals for each target species and habitat capability. Similarly, inventory and assessment studies currently underway on the Alouette River should provide the necessary habitat assessment information to establish goals and objectives (Marvin Rosenau, MWLAP pers. comm.). These studies should identify the locations, types, and quantities of habitats that currently exist and/or have to be created or enhanced for the anadromous salmonids targeted for reintroduction. For example, spawning habitats for sockeye would likely need to be constructed. Accordingly, opportunities on the floodplain of Gold Creek for constructing a spawning channel have been identified by Rheel Finnegan, a habitat restoration engineer (Marvin Rosenau, MWLAP pers. comm.). This could also include creating beach spawning at an appropriate location as was done for Baker Lake sockeye (Appendix A).

*1d. Establish Biological Production Goals*

As stated above, the establishment of biological production goals pre- and post- restoration is a necessary outcome of these assessments. The benefits of restoration of fish passage cannot be properly measured and monitored without the establishment of biological goals, be they interim at least.

*1e. Conduct Risk Analysis on Potential Impacts to Resident Species*

Anadromous species introductions could cause predation and competition effects on the resident populations. For example, there may be interactions between juvenile sockeye and kokanee, and steelhead and rainbow parr if rearing habitat is limiting. This could be a minor to major impediment to restoration feasibility but is currently unknown because of the limited information on species-specific habitat availability and resident fish abundances.

Also, reintroduced sockeye may transfer IHN virus to introduced chinook. However, opinions on the likelihood and severity of this affect are not unanimous among fisheries professionals. The Transplant Committee and the province will require a risk analysis of the impact of reintroduction on resident species.

## Recommendation 2 – Establish Operational Profile

### 2a. Assess Downstream Migrant Potential and Response to Flow Regime

There is a good time series of data on current discharges at the dam and at the diversion as well as reservoir elevations (Figure 4). The rule curve for flow management is well established (Anonymous 1996).

Under the 1996 Alouette Water Use Plan (WUP), a fish maintenance flow between 2 and 3 cms has been specified. This flow is released from the low level outlet with a sill elevation of 112.9 m. The flows vary with the reservoir level. At full reservoir level the flow is approximately 3 cms (105 cfs) and at minimum reservoir level the flow is approximately 2 cms (70 cfs). Average flow is about 2.5 cms (90 cfs).

To facilitate fish emigration over the dam, changes to the discharge rates and outlet release sites may be required. If smolts and kelts were to migrate over the dam, then one scenario may be to release the fish maintenance flow from the gated spillway rather than the low level outlet. These flow releases would occur during the smolt migration period, 1 April to 30 June. This would require that the elevation of the reservoir be raised to at least 20 cm above the spillway gate invert elevation of 121.35 m by April 1. Reservoir elevation would then be at least 121.55 m to allow the minimum flow of 2 cms to be released through the gated spillway. To adequately

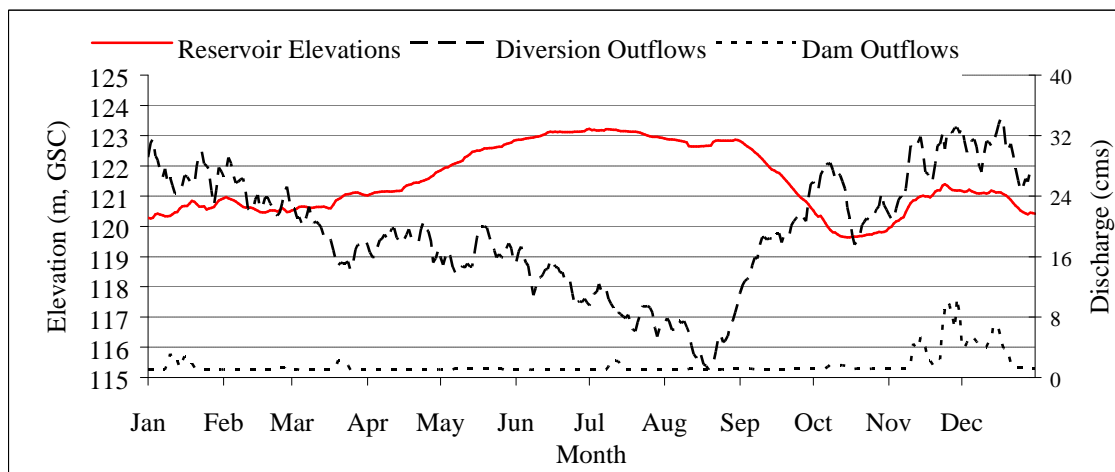


Figure 4. Alouette Reservoir, diversion flows and dam outflows, mean 1984-2001.

attract emigrating smolts, the volume of flow released through the gated spillway structure may need to be increased at times during this period. These augmented flows may only be required during the period when smolt migration is concentrated (i.e., during the night for sockeye smolts).

Downstream smolt monitoring at Seton found that during the night when diversion flows from Terzaghi had been shut down, the downstream smolt migration abruptly ceased at the low discharges that remained in the river (Arc Environmental Ltd. 2002). An enhancement of turbulence in selected zones of the quiescent dam forebay to attract downstream migrating

smolts (Coutant 1998) to the gated spillway may also be required. In addition, concurrent operational changes may be required to reduce the greater volume of flow released at the diversion during the migration period (see below). Current smolt studies at Seton Dam (Anonymous 1999, 2000b, and 2001) should further our understanding of smolt migration behaviour and lead to innovative approaches that facilitate smolt migration.

Alouette water is diverted from the reservoir through a 1 km long tunnel located 15.5 km upstream of the dam from Alouette Lake to the powerhouse at Stave Lake. On average, diversion releases exhibit a decreasing trend from January to September and an increasing trend from September to the end of December. Since 1984, diversion releases have ranged between 0 and 63.1 cms, and averaged 15.9 cms from 1 April to 30 June and 23.3 cms from 1 September to 30 November. At reservoir elevations greater than 122.6 m during the high inflow months of October through March, the adit (i.e., bypass tunnel) gate is opened.

It is possible that the significantly larger discharges from the diversion may tend to attract a larger proportion of the downstream migrating smolts. Smolts that survived passage in the diversion tunnel would likely be entrained through the Stave Falls Generating Station (GS) and Ruskin GS. However, it is unclear, based on published literature and opinions from fisheries professionals, of the relative importance to downstream migrating smolts of flow, and solar and magnetic cues for orientation, or that surface oriented smolts will preferentially emigrate through a high discharge deep water diversion tunnel rather than a low discharge surface outlet.

Concurrent with dam releases, operational changes may be required to reduce the greater volume of flow released at the diversion during the smolt migration period. This could involve reducing the discharge daily during the concentrated smolt migration period (i.e., during the night for sockeye smolts). Automation of the gates at the diversion structure would likely be required if daily gate or valve closures are necessary. Alternatively, annual maintenance operations on the diversion may be scheduled for the peak smolt migration period. Field tests of appropriate dam and diversion releases would be required to assess the viability of a proposed operational profile. After transferring suitable anadromous juveniles above the dam, the numbers of smolts migrating through the diversion or over the dam could be determined.

## *2b. Assess Upstream Passage Potential*

Existing dam releases to the South Alouette River of between 2 and 3 cms appear adequate for upstream fish passage. For example, the minimum flow for the McNary dam fishway is 0.7 cms (Clay 1995). Also, discharges between 1 and 2 cms were considered adequate in the feasibility assessment for a pool and weir fishway at Stave Falls and Ruskin Dams (Triton Environmental Consultants Ltd. 1994). However, fluctuating reservoir elevations may pose problems for operation of a fishway.

Reservoir elevations are kept above 121.25 m between Victoria Day (May) and Labour Day (September) for recreational purposes (Figure 4). On average the reservoir elevations are lowest during October, with about 1 m of variation between 1 November and 15 March. Current reservoir management could be a major impediment to fishway construction. A 3 m decline in Alouette Lake elevations during September and October of the fall migration period (Figure 4)

may preclude the use of a fishway structure. Management of the reservoir elevations to limit the extent of drawdown during September and October but maintain adequate flood protection for a 1 in 32 year probable frequency should be considered in the feasibility assessment of the fishway option.

Also, returning adults may tend to be attracted more to the Stave/Ruskin system rather than the Alouette River system due to the significantly higher discharges of Alouette water through the diversion into Stave Lake. However, upstream migrating adults would encounter water chemical cues from the South Alouette/Pitt system before those from the Stave system. Research by the International Pacific Salmon Fisheries Commission (IPSFC) in the late 1970's and early 1980's found that diversions can affect the ability of salmon to find their natal stream (Arc Environmental Ltd. 2002). Fidelity of Alouette salmon to find their home stream can only be assessed through field tests such as PIT tagging juveniles and monitoring their return as adults.

### *2c. Assess Secondary Impacts*

Any adjustments considered under the proposed reservoir or dam release profiles would need to address flooding concerns and would minimize flood risk for a 1 in 32 year probable frequency.

It is not anticipated that the proposed restoration option should negatively impact water quality.

Under the restoration option outlined, reservoir elevations would be raised to the summer recreational level by 1 April. Further review and approval by the appropriate public groups, agencies and BC Hydro would be required for such a change.

## Recommendation 3 - Establish Structural Profile

### *3a. Assess Feasibility of Upstream Passage Facility*

A 21 m dam height is within the limits for constructing a fishway for anadromous fish. However, current reservoir management could be a major impediment to it functioning successfully (see 'Recommendation 2c' above). If reservoir elevations cannot be adjusted to accommodate a conventional fishway, then an engineering assessment of alternative designs could be made. Alternatively, a trap and truck operation similar to that for Cleveland Dam on the Capilano River could be considered to move anadromous fish above the dam. An existing bladder fish fence downstream of the dam, operated with the assistance of the Fraser Regional Correctional Centre, could be used to trap the adults.

### *3b. Assess Feasibility of Downstream Passage Facility*

The Alouette Dam has an angled spillway that would facilitate fish emigration. Modifications would be required to confine the small release discharges to a narrow pilot channel on the spillway face below the gated spillway structure. Diversion and dam releases would be modified to increase the likelihood of attracting smolts to the dam outlet (see above).

#### Recommendation 4 - Assess Cost-effectiveness

A cost-effectiveness assessment was not included in the feasibility overview provided by Bengeyfield et al. (2001). If this is included, further analysis would be required to provide financial costs. Information requirements could include costs for: fishway construction or a trap and truck operation, habitat enhancement requirements, operational flow adjustments and structural changes to provide fish passage, and ongoing maintenance and operation.

The benefits from fish passage restoration cannot be quantified until biological goals are established. Even then, it will be difficult to quantify the intrinsic value of restoration to First Nations and all of society.

#### Recommendation 5 - Conduct Field Tests

Even if favorable biological and habitat profiles can be developed to support possible restoration of fish passage, there are several fish behavior and operational factors that could still be major impediments to restoring fish passage. For example, potential interactions of the reintroduced anadromous fish on resident fish stocks, behavioral response of emigrating smolts to selection of diversion versus dam releases, attraction of a majority of returning anadromous adults to Stave/Ruskin releases rather than South Alouette River flows.

Many of these outstanding issues can only be addressed with field tests. Accordingly, we recommend a trial introduction of one of the target species (e.g. coho or chinook) as rearing fry or smolts and following their growth, interactions with resident fish, and emigration behavior from the reservoir. This would involve modifying the timing and volumes of the dam and diversion operational flow regimes to coincide with preferred emigration times for the smolts.

## **6.2 Coquitlam Dam**

There are information deficiencies in the Coquitlam watershed that are, in essence, the same as those described above for the Alouette Dam, and that we believe require similar assessments and field tests. Additional key issues and recommendations pertinent to the Coquitlam are as follows.

#### Recommendation 2 – Establish Operational Profile

##### *2a. Assess Downstream Migrant Potential and Response to Flow Regime*

There is an opportunity to monitor smolt migration under the two test discharge regimes being proposed in the Draft Water Use Plan for the Coquitlam Dam. Under the proposed plan, average monthly discharges at the dam's low level outlet will increase significantly, particularly for the months of March through June. In April and May of the smolt migration period, average reservoir elevations (Figure 5) are currently between 4.5 and 7.5 m above the sill elevation for the low level outlet (140.23 m). The low spring reservoir elevations and proposed higher flow releases at the dam may facilitate smolt emigration.

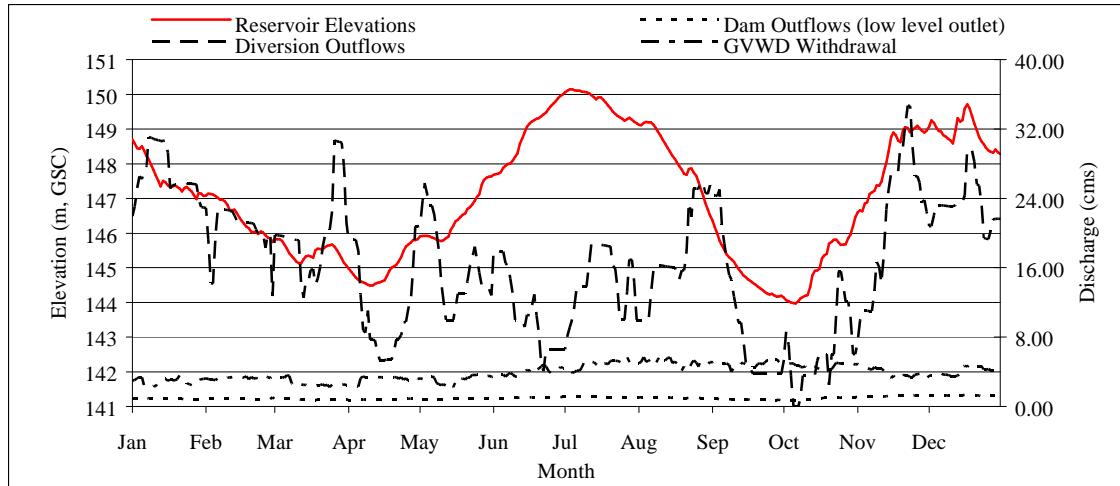


Figure 5. Coquitlam reservoir, diversion flows, GVWD withdrawals and dam outflows, mean 1998-2001.

### 2b. Assess Upstream Passage Potential

Concerns are similar to those for the Alouette and include: increasing reservoir elevations during the salmon spawning migration (Figure 5) may pose problems for operation of a fishway; and returning adults may be attracted to the higher discharges released to the Burrard Inlet/Buntzen Lake system. Field tests and monitoring are recommended.

### 2c. Assess Secondary Impacts

Assessment of the impact of anadromous fish reintroduction on water quality requires good projections on anadromous escapements. Potential impacts to taste, odour and nutrient loading from salmon carcasses as well as from the ecological changes in the aquatic community associated with reintroduction should be considered (Dave Dunkley, GVRD pers. comm.). The assessment should build on recent water chemistry data collections in 2000 and 2001 by Hiebert (2002).

### Recommendation 5 – Conduct Field Tests

Even if favorable biological and habitat profiles can be developed to support possible restoration of fish passage, there are several fish behavior and operational factors that could still be major impediments to restoring fish passage. For example, potential interactions of the reintroduced anadromous fish on resident fish stocks, behavioral response of emigrating smolts to selection of diversion versus dam releases, and attraction of returning anadromous adults to Buntzen Lake releases rather than Coquitlam River flows.

Many of these outstanding issues can only be addressed with field tests. However, because the potential impediments to feasibility, including structural and operational considerations, are similar for Alouette and Coquitlam dams, it would be prudent to conduct the tests at only one facility initially.

### **6.3 Wilsey Dam**

In general, we concur with the three recommendations specified in Section 8 of Bengueyfield et al. (2001) to proceed with studying anadromous reintroduction above Wilsey Dam. We suggest that the detailed feasibility assessment, currently being prepared by consultants (Al Caverley, MWLAP pers. comm.), clearly documents the biological rationale for the project, the operational concerns, and the cost-effectiveness of restoration. We believe the assessments and reviews to resolve information gaps in the biological component should also include escapement projections and consideration for fish passage of resident rainbow and bull trout that historically accessed habitat upstream of Wilsey Dam (Al Caverley and Ian McGregor, MWLAP pers. comm.). These assessments should also include the activities outlined in the stock and habitat profiles of our recommended decision process. We believe this biological profile should be completed prior to the development of engineering plans so that all target resident and anadromous species are considered in the design of fish passage or habitat improvement facilities.

We believe that anadromous reintroduction upstream of Sugar Lake Dam should be considered if historical access by salmon to Sugar Lake is confirmed. There are anecdotal reports that chinook and sockeye may have ascended Brenda Falls and entered Sugar Lake (French 1995). Sampling and analysis of marine derived N<sub>15</sub> should be undertaken in Sugar Lake to confirm or refute these reports. A decision on reintroduction above Sugar Lake should be made prior to embarking on the detailed feasibility assessment. A significant amount of useable habitat for anadromous salmonids exists upstream of Sugar Lake Dam. The inclusion of this area in the feasibility assessment may improve cost-effectiveness. However, potential anadromous and resident fish interactions, particularly between sockeye and kokanee, would need to be evaluated (Al Caverley, MWLAP pers. comm.).

### **6.4 Ruskin Dam**

The main concern for establishing anadromous fish passage above Ruskin Dam on the Stave River system is the lack of suitable upstream habitat. Confirmation of this should be the first task before considering any proposals for this facility. Of the five dams examined, Ruskin Dam appears to have the least potential for restoration. Access to upstream habitat could only be gained by providing passage over Stave Falls Dam as well. However, there was a natural barrier to anadromous fish at the Stave Falls dam site prior to construction. The status of habitat in Winslow Creek and Tingle Creek, above Stave Lake has not been presented.

Should passage over Stave Falls Dam be considered, all of the recommendations for Alouette and Coquitlam dams would apply.

## 6.5 Terzaghi Dam

Arc Environmental Ltd. is currently reviewing the feasibility of restoring fish passage above Terzaghi Dam on the Bridge River system (Arc Environmental Ltd. 2002). We recommend that the BCRP Board wait for completion of this report prior to considering any further proposals for restoring fish passage at the Terzaghi facility. One of the main recommendations of the Arc Environmental report is to conduct field tests on juvenile fish passage behavior out of the reservoir. We endorse this approach.

## 7 Review of Alouette Fish Passage Proposal

The BCRP received a proposal from the Alouette River Management Society (ARMS) on 14 February 2002 (ARMS 2002). The proposal was titled “Alouette Reservoir Fish Passage Feasibility Assessment”. The ARMS proposal identified two tasks to be undertaken:

1. Analysis and modeling of reservoir operation relative to spillway and tunnel elevations; and
2. Evaluate spawning and rearing channel potential of Reservoir tributaries.

These two tasks are necessary to properly assess the potential benefits and feasibility of restoring fish passage above Alouette Dam. As suggested under the ‘Recommended Decision Process’ section above, both tasks can be undertaken concurrently once the target species and native/donor stocks have been identified. Approval of donor stocks from the Transplant Committee should also be obtained to confirm suitability.

Evaluation of the spawning and rearing potential above the dam are necessary for establishing biological and habitat goals for the proposed reintroduced stocks. However, habitat assessment information should be detailed enough to ensure a complete biological and habitat profile (i.e., Stage 1) is obtained for those species targeted for reintroduction. Ongoing fish and habitat inventories should also be included in this evaluation report. Stock and habitat profiles should focus field assessments to each donor stock’s behaviour and habitat requirements.

Specifically, we recommend that initial studies focus on:

1. Identification of target species;
2. Identification and approval of donor stock if required;
3. Compilation and analysis of previously collected assessment information on current and potential habitat above and below the dam;
4. Quantification of habitat capacity and establishment of biological escapement goals;
5. Identification of any enhancement requirements (habitat or fish husbandry); and
6. Identification of fisheries management constraints.

These studies will require significant consultation with stakeholders.

Analysis and, if necessary, modeling of reservoir operation could assist in establishing alternative operational profiles prior to undertaking field tests but should follow after Steps 1 and

2 above are completed. We also believe that the operational profiles can only be properly evaluated through field tests.

## **8 Review of Wilsey Dam Fish Passage Proposal**

Fisheries and Oceans Canada submitted a proposal to BCRP to assess “Wilsey Dam Fish Passage Feasibility”. This proposal was extremely brief and, while the deliverables suggest a comprehensive product, the budget seems to focus primarily on preliminary structural design. We are not aware of any studies clearly documenting the biological rationale for the project, the operational concerns, and the cost-effectiveness of restoration. The Global report indicated that fish passage over Wilsey Dam may be feasible.

It is not clear from the Fisheries and Oceans proposal exactly what the feasibility assessment will provide. Perhaps the BCRP Board could solicit a proposal with clearly stated objectives and deliverables to address feasibility at Wilsey Dam.

## **9 Consultation List**

Caverly, Al	Ministry of Water, Land and Air Protection, Kamloops.
Clayton, Geoff	Alouette River Management Society, Maple Ridge.
Conlin, Kevin	Ministry of Water, Land and Air Protection, Victoria.
Coutant, Charles	Oak Ridge National Laboratory, Tennessee.
Dixon, Robin	Capilano Fish Hatchery, Vancouver.
Dunkley, Dave	Greater Vancouver Regional District, Vancouver.
Foy, Matt	Fisheries and Oceans Canada, Vancouver.
Hyatt, Kim	Fisheries and Oceans Canada, Nanaimo.
MacGregor, Ian	Ministry of Water, Land and Air Protection, Kamloops.
Matthews, Graeme	BC Hydro, Burnaby.
Plesa, Vladimir	BC Hydro, Burnaby.
Rosenau, Marvin	Ministry of Water, Land and Air Protection, Surrey.
Rublee, Bill	Arc Environmental Ltd., Kamloops.
Smith, Hugh	BC Hydro, Burnaby.
Wilson, Greg	Ministry of Water, Land and Air Protection, Vancouver.

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## Appendix A. Baker River Project, Washington State

The following is a brief summary of the background and fish passage facilities incorporated on two dams on the Baker River. The project is particularly relevant to issues concerning the reintroduction of sockeye above dams in the Bridge-Coastal Generation Area. Information on the Baker River Project was obtained from:

[http://www.psetest.com/hydro/baker/docs/pip/pip\\_complete.pdf](http://www.psetest.com/hydro/baker/docs/pip/pip_complete.pdf)  
<http://www.nwfsc.noaa.gov/pubs/tm/tm33/tm33.html>).

Baker River historically contained sockeye, coho, pink, chinook and steelhead. Average sockeye and coho escapements were 3,000 and 10,000, respectively. Target species for the fish passage project included all of the historic species.

The Lower Baker River Development consists of an 87 m (285 ft) concrete arch dam with an intake structure that supplies water through a tunnel to a powerhouse. The Upper Baker River Development is a 95 m (312 ft) concrete dam with internal turbines. The facilities were constructed in 1927 and 1956, respectively. Construction of the Upper Baker Dam submerged natural lakeshore spawning beaches and most of the potential tributary spawning areas of sockeye.

It was recognized from the beginning that with power development on the Baker River unusual methods and previously untried types of equipment would be necessary for successful upstream and downstream fish passage. Research and full scale field tests were undertaken on fish handling equipment and facilities. This experience led to the development of an overall plan and specific design criteria for the fish handling facilities, and included a complex system of structures and equipment that function in the following manner:

1. Pre-spawning salmon and trout migrating upstream in Baker River are guided along a full-spanning, angled barrier dam and fish trap 0.8 km downstream of Lower Baker Dam. The fish that collect in the trap are transferred to tanker trucks using a steel hopper.
2. The tanker trucks transport adults above the Upper Baker Dam and release them into either Baker Lake or the artificial spawning beaches.
3. Four artificial spawning beaches have been constructed for sockeye adjacent to Channel Creek above Upper Baker Lake. A diffusion piping system under the spawning bed feeds water through the gravels to simulate flow conditions at natural spawning sites. Egg to fry survival on the artificial beaches was estimated at 43%. Three beaches are functioning successfully at the present time.
4. Turbine pump operated smolt collecting barges (“gulpers”) are located at the head of each dam. At the Lower Dam, the gulper is connected to a pipe that transports smolts to the tailrace, while at the Upper Dam the collected smolts are trucked directly to the Lower Dam tailrace.

Since 1986, a portion of the sockeye fry leaving the spawning beaches have been collected and reared in net-pens and released as smolts through the Lower Baker Dam gulper. Total sockeye smolt releases between 1987 and 1992 were over 400,000. In 1994, almost 16,000 sockeye returned and were transferred to Baker Lake and the spawning beaches.