Alouette Dam Fishway

Report No 2

Ward & Associates Ltd.

Professional Engineering Services

- ✓ Hydrology
- ✓ Hydraulic Engineering
- ✓ Lake Modeling
- ✓ Water Supply
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- ✓ Pollutant Transport
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Alouette Dam Fishway
Report No 2

For:

Ministry of Environment
Ecosystem Branch
315-2202 Main Mall, UBC
Vancouver, B.C.
V6T 1Z4
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Alouette Dam Fishway: Report No. 2

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Ward & Associates Ltd Hydrology Engineers
Alouette Dam Fishway No 2 Report January 2010
& No 1 Report (see pp 27-45)

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1. Introduction

This is a sequel to a first report that was undertaken a year ago, under Habitat Conservation Trust Fund (HCTF) Contract No. CECO9097. The first report included an introduction with details of operating licences, examples of fishways, hydrology and water levels at the reservoir, and some proposed concepts and locations of fishways. A map of the Alouette/Stave system, copied from this report, is shown, see Figure 1.

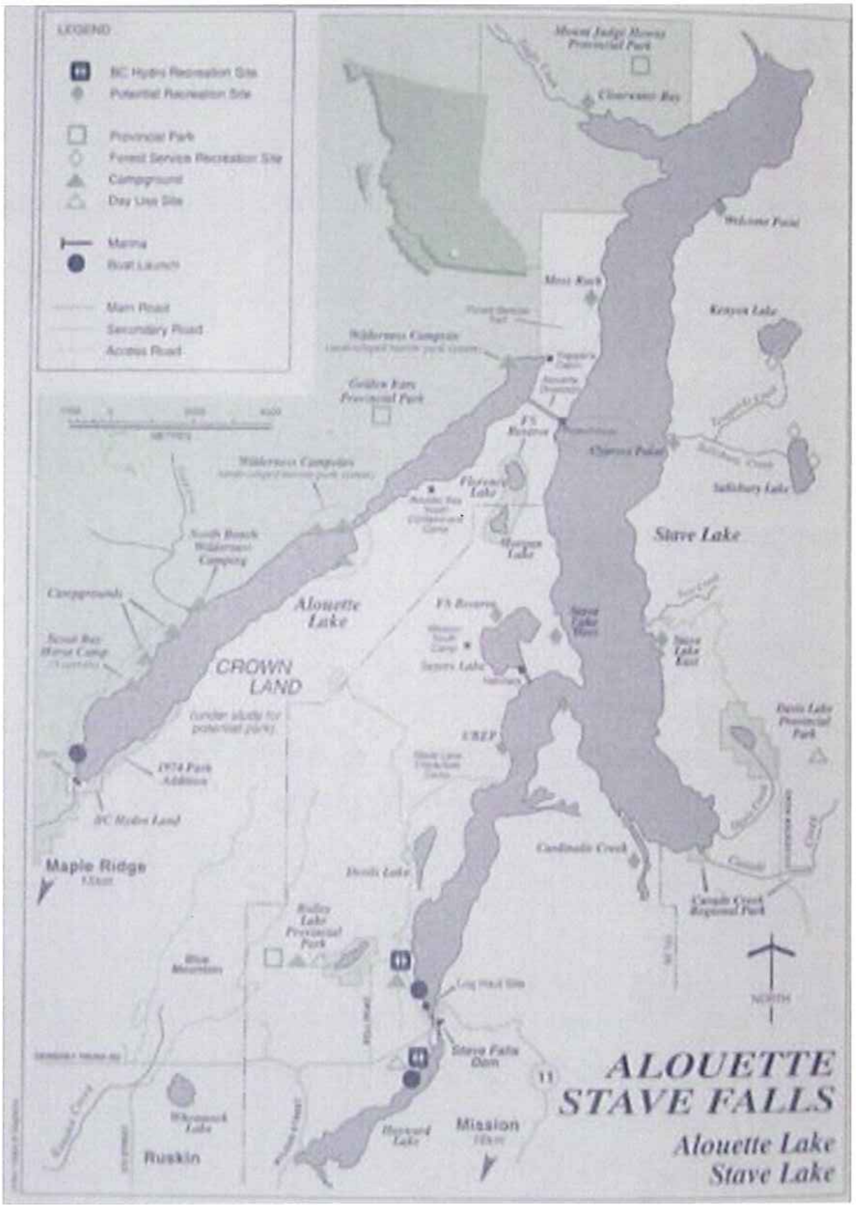

Figure 1. Map of Alouette-Stave System (courtesy BC Hydro 1993 "Making the Connection").

The Alouette dam was built in 1926, and the powerplant went into service in 1928. The earthfill dam was seismically upgraded in 1984, with a larger dam built downstream of the original, preserving the function of the old spillway. In 1993 the spillway was upgraded and slightly reconfigured. The three stop-log gates were removed from the corner of the free crest weir. These were replaced with a single vertical lift control gate. The shake and shingle bolt flume and head gate were removed, and filled with concrete. This flume had a reservoir entrance elevation 1.5 m lower than the replacement structure, and regrettably its function was not preserved, as it would have offered an opening for a future fish ladder.

The focus of the present report is on facilities for upstream migration of fish. There is a sufficiently small head difference to make the provision of a fish-way possible, with a drop of approximately 16 m (maximum) between the spill-crest water level, and the water surface in the downstream river channel.

Provision needs to be made to operate the proposed fish ladder during a substantial part of the year, because of the timing of the migration of various salmonids that will likely return. Bull trout and cutthroat trout move upstream in the spring period. Sockeye salmon migrate upstream during the summer months when the reservoir is held at minimum recreational level (122.5m) or above. Pink salmon are expected during the September/October window (odd years), and coho salmon during November/December. Steelhead are winter/spring migrants, in the period from December though to April. Chum Salmon although weak swimmers, are sometimes opportunistic colonizers, and would likely use the ladder during the October-November window. Because of substantial seasonal variations in reservoir elevation, the design of the fish-way must cater for a wide range of headwater levels.

Downstream juvenile fish passage via the crest gate and spillway at Alouette is presently possible as long as the water level is sufficiently high (121.8 or higher), during key periods to allow spillage via this route. Successful out-migrations of kokanee (sockeye) smolts occurred during 2005, 2006, 2007, 2008 and 2009 when spillage flows of about 3 m^3/s (determined by the Water Use Plan, WUP) were released during the April-May period.

A step by step process for consideration of fish passage at their facilities was initiated by BC Hydro in 2008, "BC Hydro Fish Passage Decision Framework" see Appendix B. The purpose of the process is "*to establish a process which will determine how BC Hydro will address fish passage issues at BC Hydro facilities*". The present report is being done in parallel with this process.

The Alouette Dam Spillway

The present spillway facilities consist of a 6.25 m wide vertical lift crest gate with soffit at elevation 121.35 m, and a free crest spillway, about 120 m wide, with the crest at elevation 125.51 m. Satellite photo images of the Alouette dam and spillway are shown, see Figure 2. The maximum length of the spillway, on the west side is about 235 m. Fisheries flows are presently diverted from a free-standing intake tower (see Figure 2), known as the Low Level Outlet (LLO), under the earth dam via pipeline. The flow is released to the river on the east side of the tail-water pond. The tail-water elevation for low flows in the Alouette River is 109.5 m for low flow river conditions.

Figure 2. Bing Satellite Views: Alouette Dam and Spillway, looking north (top), and looking east (bottom). Lower Level Outlet pipeline route for fisheries flows shown (blue line).

During spillage events via the crest gate, water spreads across the full width of the spillway (about 50 m wide converging to about 30 m wide in the lower part), as shown in Figure 3. Flows over the free crest spillway occur rarely, because of the operating procedures for reservoir elevations, and because the combined turbine and adit flows of the diversion to Stave Reservoir are large. During the decade 1984 to 1995, the maximum flow that passed over the free crest spillway was about 140 m^3/s (29th Nov 1995) and since then there have been no free crest flows via the spillway. The maximum discharge capacity of the crest gate is 78 m^3/s.

Figure 3. Alouette Spillway with a substantial discharge from the crest gate

Four views of the spillway are shown, Figure 4. Top left shows part of free crest spillway, and crest gate structure, and top right shows upper part of spillway with the free crest overflow wall. Bottom right shows central (low gradient) part of spillway, and bottom left shows high gradient (about 25° angle) final chute, to convey flows to tail-water.

Figure 4. Alouette Spillway
Top: free spill crest and crest gate (left), and free spill crest (right).
Bottom: Spillway low gradient section (left) and high gradient section (right).

Fish-way Proposals

Report No 1[1], see Appendix C, listed two preliminary suggestions for ladders utilizing the spillway, as follows:

> *Eastside Spillway Ladder*. Constructing a gate and a cut in the spillway or in the earth dam, so that water can flow under gravity at various levels, including when the water surface is at the Spring/Autumn low level, or
> *Westside Spillway Ladder*. Providing a pipeline and small reservoir, that would allow passage of the water, by suitable capacity pump, over the top of the spillway (elevation 125.5 m). Fish would be flushed periodically from the reservoir via a large diameter pipe, to the Lake.

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[1] Ward & Associates Ltd 2009. Alouette Dam Fishway Report No. 1. For BC Ministry of Environment, Ecosystems Branch. HCF Contract No CECO9097. January 2009. 20pp.

Site visits to the dam were made during the fall-winter period 2009 to 2010, and the preliminary suggestions were refined. One theme that was considered important was to conceive designs that would minimize the impact on the existing spillway. Additionally designs that involved cutting the earth dam itself, or the ground on the dam abutments, were not further considered, because of perceived high risk for the integrity of the dam.

For the present report, a refinement of the preliminary suggestions in Report 1 was developed, see Table 1 below.

Table 1. Fishway Options for Alouette Dam

Option	Description	Routing	Components	Comments
1.	*Gravity fed design short route on spillway*	Next to crest gate crossing to spillway west side	A. Orifice baffle upper fishladder, B. Channel crossing to west side and set recessed in spillway, C. Steep chute lower fishladder to tailpond	Shortest route, about 220 m total distance
2.	*Gravity fed design long route on spillway*	West side of spillway	Orifice baffle upper fishladder, Channel set recessed in spillway, Steep chute lower fishladder to tailpond	Minimum intrusion on spillway, longer route, about 300 m total
3.	*Pumped flow design, on spillway*	West side of spillway	Large header tank with pumped water supply, Channel set at grade for whole distance on west side spillway, Steep chute lower fishladder to tailpond	Minimum intrusion on spillway, but significant operation costs for pump and header tank

If there are maintenance/construction needs for the dam, e.g. for dam safety reasons, then it is likely that other fishway routing possibilities would be economically feasible in the course of dam rebuilding. These cannot be foreseen, as the longterm maintenance and construction needs are not known to us.

A fraction of the flow (about 2.55 m^3/s on average) that is presently being diverted through the LLO may be utilized for fish ladder flows. The upper fish ladder and its water flow delivery should be capable of operation at a reservoir level as low as 120.5 m, and should operate at levels of up to 125 to 125.5 m, a range of 4.5 to 5 m. The upper fish ladder will have to work well at this wide variety of starting elevations. All designs of gravity fed fish ladders exhibit change of flow with increasing head, with some designs being more stable than others. The best solution for achieving flows that are not too variable as the head changes is a submerged orifice fish ladder solution. This was tested at 1:40 model scale (see Figure 5), using orifice openings equivalent to 0.75 m diameter, and was shown to perform very well. Adjustments were made later in conceiving the finally recommended design (see next section).

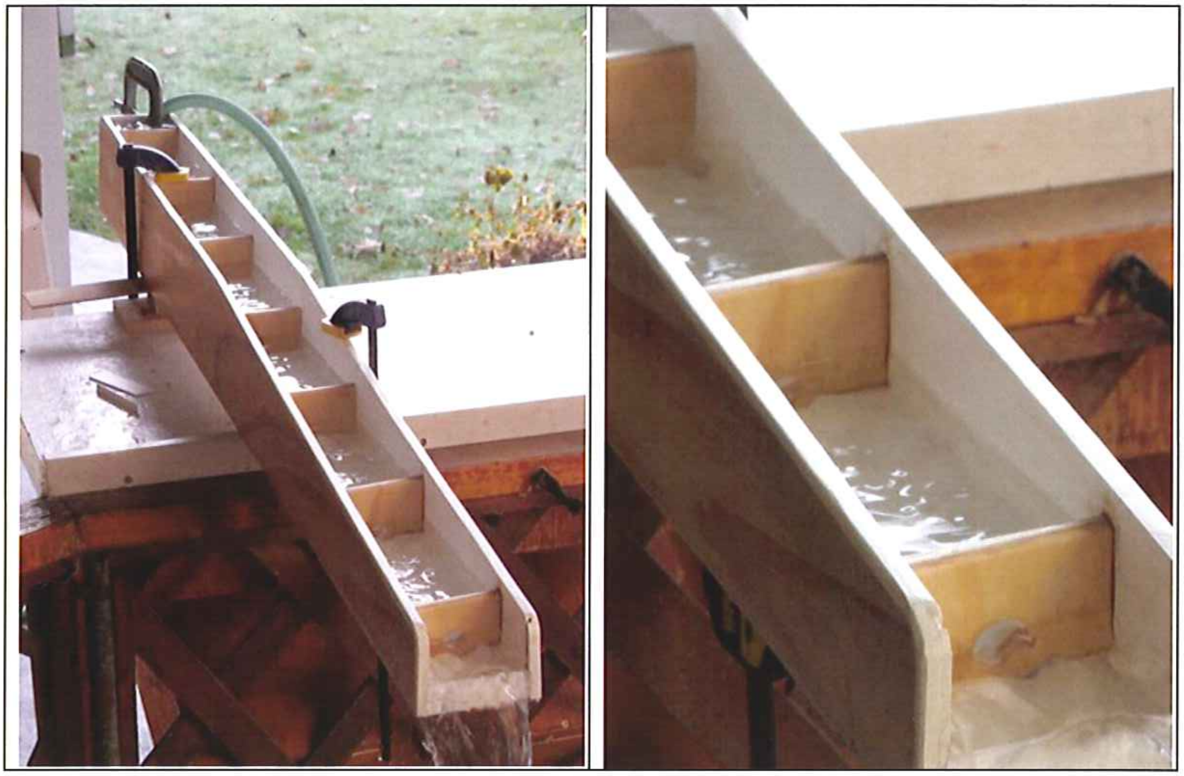


Figure 5. 1:40 Physical Scale Model of fish ladder with submerged orifice baffles, shown simulating full reservoir (maximum head) condition. Scaled head drop at each baffle is 0.86 m, scaled mean velocity through each orifice is 2.5 m/s, and scaled flow rate is 1.1 m^3/s.

The lowest level at which the fish ladder will work/be needed depends on future operating plans for the reservoir, and whether or not deep drawdowns are needed/recommended for future operations. Fish ladder designs that would accommodate lower reservoir levels (below 120.5 m) were not conceived, as it was considered unwise to construct too deep a cut in the existing spillway. During the period 1999 to 2008 water levels were drawn down below 120.5 m in many but not all years during the period mid September to mid November, see Appendix C Report No.1, Figure 11. For fisheries upstream migration in the future with the fishway in place, a revised reservoir operations schedule will be needed, with the minimum reservoir elevation at 120.5 m.

A plan view of the dam and the proposed route (Option 1) for the fishway is shown, see Figure 6.

Figure 6. Google Earth satellite plan view of Alouette Dam, (Option 1 routing), showing locations of upper ladder (top arrow), connecting (curved) channel on spillway, and lower ladder (bottom arrow). Upstream fish movement will be against the direction of the arrows.

Option 1. Gravity Fed, Short Route.

Present operating procedures for Alouette dam mean that the maximum free spill capability for passage of floodwaters is essentially never used, so removal from service of a small fraction of the spillway overflow crest is seen as viable. The route of the fishladder down the spillway needs careful planning, as the flow released via the vertical lift gate should be allowed to spread across a substantial part of the width of the spillway. The fishladder should stay clear of the main part of these flows (see Figure 3 photo).

The three sections of the fishway consist of A). an upper ladder, catering for a wide range of reservoir intake levels, B). an at-grade channel, recessed into the existing spillway, and C). a lower ladder, dropping the flow to tail water in the Alouette river. A sketch of the proposed profile, showing the three components is shown, see Figure 7. The total length of the fishway will be about 220 m.

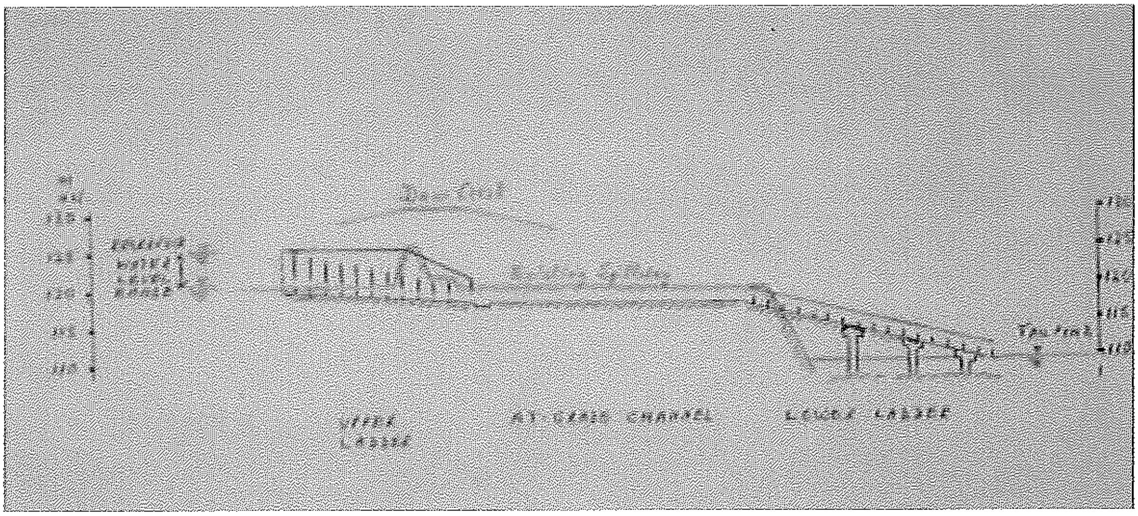


Figure 7. Profile of proposed fishway, showing three components (vertical scale enlarged compared with horizontal scale)

1A. Upper ladder for reservoir variable level. This option (see Figure 8) will be built in a cut in the free crest spillway, adjacent to the crest gate buttress, or possibly slightly west of the buttress. The ladder length will be approximately 50 m and the ladder breadth internal dimension will be about 3 m. The floor (invert) of the ladder will be gently sloped, from 119.5 m down to 118.0 m, at about 1.7° gradient. This gradient will ensure that the flows conveyed at the minimum operating level of 120.5 m will be sufficient for upstream fisheries movement, and provide sufficient flow down the rest of the fish-way for good operating conditions.

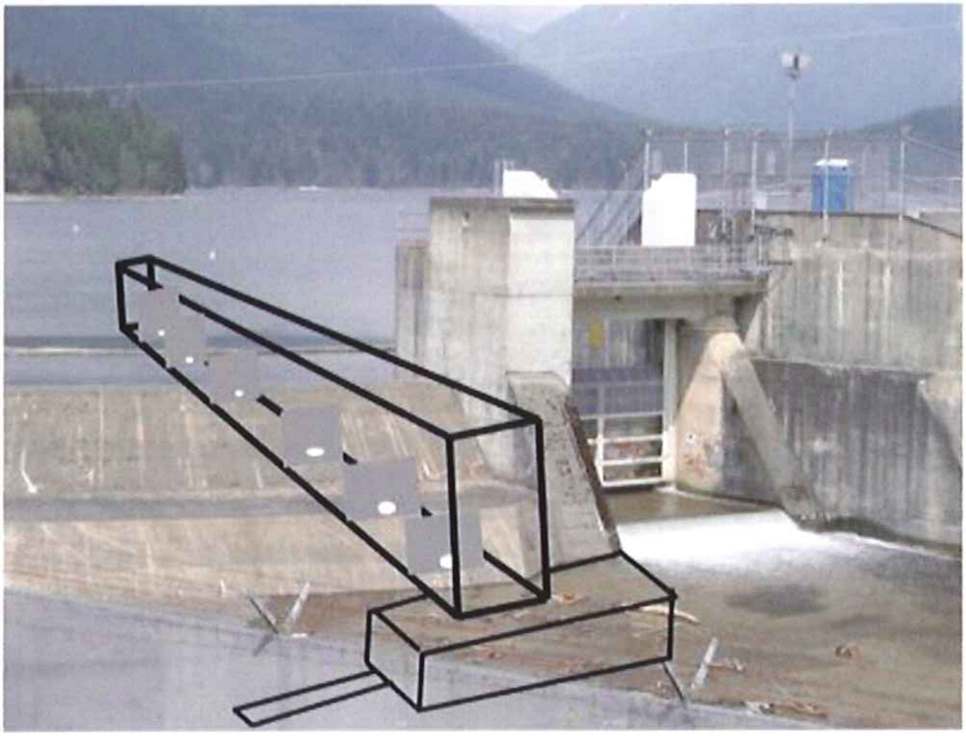


Figure 8. Concept for Submerged Orifice Design Upper Fish Ladder

The upper ladder will incorporate circular or square shaped orifices, some of which will be removable. With an orifice diameter of 0.75 m, the orifice opening area will be 0.44 m^2. Alternatively, the openings could be 0.665 m x 0.665 m square, to provide the same opening area. The discharge Q through each circular orifice may be computed by the following equation, using the orifice discharge coefficient C_d = 0.61. The height difference H is the water surface level difference across the baffle housing the orifice, area A is the opening area of the orifice, and g is the gravitational acceleration.

$$Q = C_d A (2gH)^{1/2}$$

In order to provide adequate flow rates at low head differences, the majority of the orifice plates will be removable. Concrete stub walls will provide support for the galvanised steel orifice plates, that will be lifted by manual hoists. At high reservoir surface levels, all orifices will be in-place, providing maximum energy dissipation. At low reservoir surface levels, only a few of the orifices will be in place, enabling the fish ladder to pass sufficiently high flow rates to supply the lower ladder.

Note that flow through multiple orifices in series is stable, and settles down to provide a water surface with the same step heights after an initial period, once the water volumes in each compartment have had time to balance themselves. Specifications for the ladder, showing 3 (for low reservoir level) and 10 (for high reservoir level) orifice plates installed, are shown in Table 2. The proposed head drop at each orifice limits the velocity that is expected in the jets emerging from the orifices, and with drops that are not too large the velocities are modest.

Table 2. Specifications: 50 m Long Submerged Orifice Upper Fish Ladder

	Low reservoir surface elevation	High reservoir surface elevation
Reservoir surface level m	120.5	125.0
Ladder tailwater level m	119	119
Number of orifices/steps	**3**	**10**
Height of end weir m	0.5	0.5
Head loss per step m	0.50	0.60
Average hydraulic gradient, degrees	1.7	6.8
Average hydraulic gradient, %	3.0	12.0
Mean velocity through orifice m/s	1.91	2.09
Circular orifice diameter m	0.75	0.75
Orifice opening area m^2	0.442	0.442
Flow rate in ladder m^3/s	0.844	0.924

With a mean velocity through the orifice cross-section of about 2 m/s, the mean velocity that is expected in the emerging jet is about 3.2 m/s. This is well within the burst speed capability of mature salmon. Burst speeds of up to 5 to 10 body lengths per second have been recorded in upstream migration of sockeye salmon at Hell's Gate[2]. With a fish of length about 0.5 meter, this is equivalent to burst speeds in the range 2.5 to 5 m/s.

At low reservoir surface levels (see middle column of Table 2) the average hydraulic gradient in the ladder will follow approximately the gradient of the base of the fish ladder (about 1.7 degrees). The small number of orifices (about 3) will provide velocities that are modest and will supply adequate flows down the ladder, allowing good attraction capabilities for fish in the tail-pond. At high reservoir surface levels, the average hydraulic gradient in the ladder will be large.

Note that the computed flow rate under these conditions (see last row of Table 2) is large but not very large, and well within the present fisheries diversion flow under the Water Use Plan. This flow is the flow that will pass under gravity through the LLO pipeline, and is in the range 1.98 to 2.97 m^3/s, depending on the water surface level in the reservoir.

At the base of the ladder there will be a tailwater tank with an adjustable height overflow weir, to allow adjustment of water levels in the ladder. Flows will exit the tailwater tank at water surface elevation about 119 m.

[2] Hinch S.G. and J. Bradley 2000. *Effects of Swim Speed and Activity Pattern on Success of Adult Sockeye Salmon Migration through an Area of Difficult Passage*. Trans American Fisheries Society 129:598-606.

1B. At-grade fishway channel. This 105 m long channel will be excavated in the existing spillway, and will cross at grade from the tailwater tank to the spillway west side. It will be set in the spillway so as not to impede spillway flow movement. Additional work will be needed during final design, to understand whether it will be important to cover the fisheries channel, either with a steel grid, or with concrete slabs, so that spillway flow/floating debris causes minimum damage. The bottom of the channel will be roughened with boulders, to provide slow moving water to facilitate upstream fish movement. The water surface in the fishway channel will drop from elevation 119 m to elevation 118.7 m at the top of the final chute, where the flow will enter the lower ladder. The low gradient in the channel will ensure modest velocities to provide easy fish passage.

1C. Lower ladder to river tail-pond. This will be a vertical slot fish ladder, able to pass the variable flows provided by the upper fishway. The water surface will drop in the ladder from elevation about 118.7 m to 109.5 m minimum, the tailwater elevation of the Alouette river at low flows, see Figure 9. The water surface drop at each slot will be about 0.51 m and there will be 18 slots to accommodate the total drop in head. The ladder length will be about 65 m, and the gradient of the base of the ladder will be 7.5°.

Figure 9. Concept for Vertical Slot Design Lower Fish Ladder

Option 2. Gravity Fed Long Route

This will consist of 3 components, as for Option 1.

2A. A submerged orifice fish ladder will be set in the spillway in the north-west corner. The base of the ladder will be similar in elevation to 1A, with the invert going from elevation 119.5 m at the top to 118 m at the bottom of the ladder. With the free overflow crest and the channel surface of the existing spillway being at 125.5 m and 123.6 m respectively, the construction will necessitate a cut of significant depth to install the fish ladder. Hydraulic specifications of the ladder will be as shown in Table 1.

2B. A fish-way channel will be cut in the spillway, for the whole length of the west side, with a sufficiently low gradient (about 0.25%) to ensure modest velocities with a rough bottomed channel. The fish-way will be well incised at the top of the spillway, with modest incision in the spillway just above the final chute. The drop in head over the approximate 185 m distance down the spillway will be 0.5 m at this gradient. A low protective wall will be installed running the length of the fish-way channel, to prevent small and medium free crest spill flows from entering the fish-way.

2C. The lower fish ladder will be a vertical slot ladder, of similar specifications to that proposed in 1C.

The total length of the three components of this fishway will be about 300 m.

Option 3. Pumped Flow on Westside. This option is considered to provide a system with minimum construction impact on existing facilities. As shown in Figure 10, a pump sump will be constructed at a suitable location in the lake, sufficiently low that the pump could access water with a lake level of 119.5 m to 121 m. A small reservoir will be constructed on the extreme east side of the spillway, and the pump will deliver flows to the reservoir, at water surface level 125.5 m. A valve and pipeline with sufficient diameter for fish will lead from the small reservoir back to Alouette lake reservoir, providing a route for periodically conveying (flushing) fish on the final part of their upstream migration. This pipeline, and the resulting flow velocities need careful consideration, so as to minimize damage to fish.

From the small reservoir, the water will discharge into the top of an at-grade fishway channel, with baffles to slow down the flow velocity. The channel will be constructed along the west side of the spillway, next to the spillway wall to minimize interference with spillway flows. The final descent will be provided by a vertical slot fish ladder, as specified for 1C.

Figure 10. Westside Spillway example, showing pumped flow to small reservoir, and fisheries return flow to lake. Ladder will pass down west side of spillway.

The pump flow and energy requirements are significant, and may be roughly computed as follows.

Flow for fish ladder:	approx 0.7 m^3/s or larger
Maximum static head:	5 m
Power requirement at 60% efficiency:	57 kW
Energy requirement during maximum head months:	41,000 kWh/mo

The operating cost of the pump will be high, because of the significant electrical energy requirement of the system (several thousands of dollars per month), with additional costs for maintaining the pump and motor.

Option 3 was not considered further, because of the projected high operating cost.

Option 1, the gravity-fed short route, was found to be the best choice for the fish ladder.

Construction and Approximate Costing

Option 1 (short route) is favoured as the best choice of strategy for the fishway, and costing is undertaken for this option. Option 2 (long route) is similar to Option 1, but the distance down the spillway is considerably longer, with probable small increases in cost. This option may have advantages, and may be considered further in detailed design. Option 3 (pumped flow) would have high operational/maintenance costs and was therefore not considered further.

For Option 1, pre-cast concrete components for the fish ladders will be assembled at the work yard of the selected bidder/subcontractor, transported to the site, and post-tensioned together to form an integral structure, one for each of the upper and lower ladders. Each box component will include the orifice baffle side supports, and the concrete walls and bottom (each about 4 to 5 m long) that form the sides/base of the channel. These components will meet the government regulated constraint for transportation, no larger than 11.5 feet wide, and no heavier than 70,000 lbs. There will be two box components for each step in the ladder, see Figure 11. After assembly at the site, the box components will be post tensioned with long steel cables running the full length of the ladder, to make an integral structure. For the upper ladder, removable baffle plates of galvanized steel, with manual hoist mechanisms, will be incorporated, to provide maximum flow release at low reservoir levels.

The lower ladder will be supported on concrete piles, and a temporary span will be used to carry the weight of the box components during assembly. These will be post-tensioned together, and the steel tensioning ropes grouted. The resulting structure will be sufficiently strong that the temporary span will be removable, leaving the fish ladder resting as an integral unit on the piles.

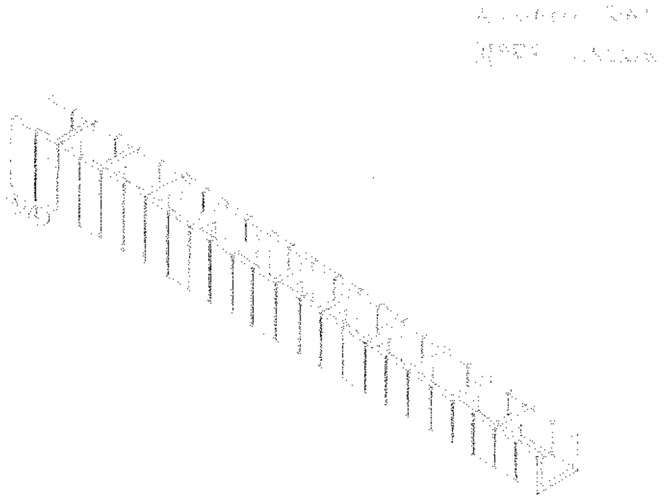


Figure 11. Upper ladder, showing breakdown into pre-cast concrete components, two for each step in the ladder (courtesy of Z. Stanojevic, Surespan Group).

A first order (Class C) costing of the project at 2010 rates provides an estimated total of just under $3 million, without engineering consultant or environmental monitor costs, see Appendix A. This was an approximate valuation, without the estimator benefitting from a site visit.

The annual cost of operating the fishway will be low, as the only moving parts to be serviced will be the manually operated hoists for the orifice plates in the upper ladder. Control on the levels at the exit of the lower ladder will be achievable with stacked stop logs. There will be no moving parts for the lower ladder. Periodic additions/subtractions to the number of upper ladder orifices will be made during seasons when changes occur in the reservoir surface elevation.

Note that annual energy amount from generation with Alouette water that is diverted out of the Alouette river basin, based on flow data for the period 1996 to 2003 (reference Ward et al[3]) shows an average annual diversion flow of about 15 m^3/s. With a total head (at 3 BC Hydro power stations) of about 120 m, the annual energy produced is about 116,000 MWh (equiv to a mean power production of 13.2 MW). Additional energy benefits from diverted Alouette waters (realized at the Stave and Ruskin powerhouses), increase this annual amount significantly. The value of the annual electricity produced in a few months of operation exceeds the estimated construction cost of the fishway.

Acknowledgements

This report was funded by HCTF, under a grant that was applied for with the assistance of Shannon Harris and Margaret Squires, MOE, Fisheries Science Section. ARMS (Alouette River Management Society) provided a letter of support for the application. MOE Ecosystems Branch-Fisheries Science Centre issued a General Service Agreement contract (#CECO10-061) to Ward & Associates Ltd to execute this report. Several individuals contributed valuable time and information. Geoff Clayton (ARMS) on all aspects of the project, Marvin Rosenau, BCIT on fisheries and ladder concepts, and Barry Chillibeck on strategies for routing of the fishway. Zoran Stanojevic (Surespan Group) reviewed sketches for the initial design, provide a construction strategy, and did first order costing. Brent Wilson (BC Hydro) accompanied us on a visit to the site, and facilitated release of information concerning water levels and inflows to the reservoir. Geoff Clayton and Shannon Harris reviewed copies of the draft final report, and provided valuable suggestions.

[3] Ward & Associates Ltd 2003. Alouette Reservoir Operations and Fish Passage Improvements Year 1 Report. For Alouette River Management Society. 9 pp plus Figs and Appendices. December 2003

APPENDIX A

Approximate 2010 construction cost: Proposed Alouette Fishway. Note that this is a Class C estimate only, without the benefit of a site visit from the architect/engineer.

#	Description	pcs	unit	$/unit	Amount $	TOTAL $
A	**Upper Ladder**		m3			
1	Precast Concrete "U" shape	24	200	2,200	440000	
	Total 24 pcs tot 200m3					
	200m3=1,105,000Lib					
			kg			
2	Galvanized still plates/shutters	11	10,700	4	42800	
	c/w steel railing					
3	Mechanism for lifting/closing steel plate	11	11	4,000	44000	
	TRANSPORT					
4	Transport to site					
	24 trucks-CONCRETE	24	24	1,100	26400	
	5 Trucks steel ++	5	5	1,100	5500	
	ERECTION					
5	Cutting of existing concrete base	Lump Sum			100,000	
	preparing fresh conc. bed & anchors					
	for fixing upper ladder					
6	Crane 200t mob/demob +100h	ls			80,000	
	4 workers x100h	400	400	100	40000	
7	post tension + glye the elements	Lump Sum			60,000	
8	erection of steel plates / shutters	11	11	5,000	55000	
9	Profit and overhead		ls		200,000	
10	Engineering & shop drawings				100,000	
11	profit for erection				200,000	
			SUB TOTAL $		**1393700**	**1,393,700**

	APPENDIX A (continued)					
B	Lower Ladder					
12	Precast Concrete 20 pcs 2.2 x 2.9 x 3.25m	m3	146	2,000	292000	
	20 pcs - 7.3m3/pcs				0	
13	Galvanized steel plates 32mm thick -1.3 x 3m				0	
	c/w railing for lifting up-down	kg	17,500	4	70000	
					0	
14	Mechanism for lifting/closing steel plates	pcs	18	4,000	72000	
					0	
15	Piling and beams to support precast elements	L/S	1	300,000	300000	
	c/w temporary 15m bridge for construction				0	
					0	
15	Transportation	truck/trip	20	1,100	22000	
					0	
16	Site erection of precast & steel	L/S	1	240,000	240000	
	200t crane 150 h + 4 worker 4 x 150h				0	
	c/w post tension					
17	Engineering	L/S	1	55,000	55000	
					0	
18	Channel in between Upper and Lower Ladder	L/S	1	100,000	100000	
	cut concrete 0.5m deep and take out concrete				0	
					0	
19	Unpredictable	L/S	1	250,000	250000	
			SUB TOTAL $		**1401000**	**1,401,000**
				GRAND TOTAL $		**2,794,700**

APPENDIX B

BC Hydro Fish Passage Decision Framework 2008

Purpose - To establish a process which will determine how BC Hydro will address fish passage issues at BC Hydro facilities.

Background - The development of some of the BC Hydro dams in certain coastal rivers resulted in a blockage to migratory fish. The result often meant the elimination or the reduction of specific salmon runs in the rivers. Proposals for fish passage have been initiated by public and First Nation groups, with Fisheries Agencies support, on several of the coastal BC Hydro facilities. The rationale for fish passage is to re-establish selected species of fish to the portions of the watershed they historically utilized.

BC Hydro Statement of Strategic Intent - BC Hydro's long term goal, stewardship ethic and environmental policy establish the commitment to minimizing our impacts, and where possible, restoring the environment. The *Fish Passage Decision Framework* will ensure that fish passage decisions are based on a Triple Bottom Line approach, with sound defensible criteria.

The construction of several of BC Hydro hydro-electric facilities resulted in a blockage to fish that previously used the portion of the watershed above the dam. Fish passage is required to re-establish selected species of fish to portions of the watershed that they historically utilized. There have been several fish passage proposals, involving the construction of fish ladders at hydro-electric facilities.

The Compensation Programs were established by BC Hydro as a mechanism to help address footprint impacts. The Compensation Programs finance technically sound proposals to restore habitat in the watersheds impacted by the hydro-electric facilities.

While the blockage of fish passage is defined as a footprint impact, there is insufficient funding in the Compensation Programs to take on the expensive proposals. As a result, BC Hydro is proposing the establishment of a formalized approach to help analyze the issue and to ultimately make decisions to address fish passage at the BC Hydro level. The following "Decision Framework" provides a formalized approach aimed at ensuring Triple Bottom Line (TBL) decision making and is applied to fish passage proposals.

Fish passage proposals to date have only involved salmon species. Resident species may be considered at a future date or as required under regulatory requirements such as the Species at Risk Act or recovery planning initiatives.

Compensation Program Role:

Step 1 - Preliminary Screening

To determine whether a fish passage proposal for a specific watershed addresses a footprint impact, the following screening question will be asked:

"Did the facility block passage of a fish stock at the time of construction?"

Proposals that satisfy this condition will proceed to Step 2.

Step 2 – Stakeholder and FN Engagement - Strategic Watershed Prioritization

Each of the Compensation Programs has strategic plans (BCRP Strategic Watershed Plans; PWFWCP Strategic Implementation Plans; CBFWCP Dam Impact Assessments). These are developed in consultation with the Compensation Program infrastructure (Board, Planning Committee, Steering Committee, and Technical Committees), BC Hydro, First Nations, DFO, MOE, and other stakeholders through a series of consensus building workshops. The planning process establishes priority restoration opportunities for each watershed.

Fish passage opportunities are ranked by the strategic planning processes. Ranking is based on Provincial and Federal agency species objectives and on preliminary biological and technical feasibility criteria.

Step 3 - Environmental Feasibility Studies

In order to assess the potential for success for a fish passage proposal, initial environmental feasibility studies must be undertaken. The Compensation Program will fund the studies at their discretion and consistent with their mandate. The environmental feasibility of each fish passage proposal must include the following assessments:

- Target species are available in the watershed in sufficient numbers to support rebuilding a sustainable population. If the target species is not available and a donor stock transplant is proposed, a thorough risk assessment related to suitability of the donor stock and impact on the donor stock must be undertaken.

- Potential ecological and disease impacts to native species.
- Existence of high quality spawning and rearing habitat below the dam.
- Other physical impediments downstream that may restrict fish migration to the dam.
- Sufficient spawning and rearing habitat above the barrier to support the target fish population numbers established in the Watershed Plan, or the known potential to restore sufficient habitat. Feasibility studies must be undertaken to assess this potential.

The results from the environmental feasibility studies will be provided to the Fisheries Agencies (DFO & MOE) for decision in circumstances requiring their approval. Once the analysis indicates the fish passage proposal meets the above criteria and is supported by the Fisheries Agencies as a high priority, the proposal will be reviewed by the Program's Technical Committee and recommendations will be forwarded to the Compensation Program management structure.

Step 4 – Preliminary Technical Feasibility Consideration

If infrastructure is part of the proposal, an inquiry should be made to BCH Engineering about the feasibility of the fish passage. At this stage, the technical feasibility assessment will be undertaken by BC Hydro at a cursory level only. More detailed analysis and assessment will be carried out in step 6 if determined appropriate.

Step 5 – Compensation Program Endorsement

Based on the priority ratings and the completion of the required process, the Compensation Programs will recommend BC Hydro consider the proposal.

BC Hydro Role:

Step 6 – TBL Driven Business Case Development

The Triple Bottom Line (TBL) decision making approach will follow a structured approach to explicitly integrate environmental, social and financial objectives. The process will provide a rating from high to low for fish passage proposals.

(a) **Environmental Assessment:** in consultation with the Compensation Programs and Technical Committee, BC Hydro will further assess the environmental feasibility if required.

(b) **Financial/Technical Assessment:** options to provide fish passage will be analyzed to ensure technical feasibility for the proposed river system.

- Dam structure integrity must be maintained; therefore designs for upstream and downstream passage facilities must undergo an engineering review.
- The fish passage proposal must be able to operate within the current Water Use Plan (WUP) operating parameters for the facility. If not, the proposal will be deferred until the scheduled WUP review takes place.
- Designs and costs for additional structures, such as screens to reduce potential juvenile migrant fish mortality, must be considered.

(c) **Social Benefits Assessment** – fish passage at the proposed site will be considered with respect to added societal value. Considerations may include:

- Intrinsic values – there is demonstrated evidence that the intrinsic value of the watershed will be positively impacted by the proposal (i.e. improved ecosystem biodiversity).
- Cultural – First Nation have identified the importance of returning fish providing food, ceremonial, spiritual values.
- Socio-economic – there is demonstrated evidence that there will be an increase in tourism, recreation, jobs and / or a new or enhanced fishery

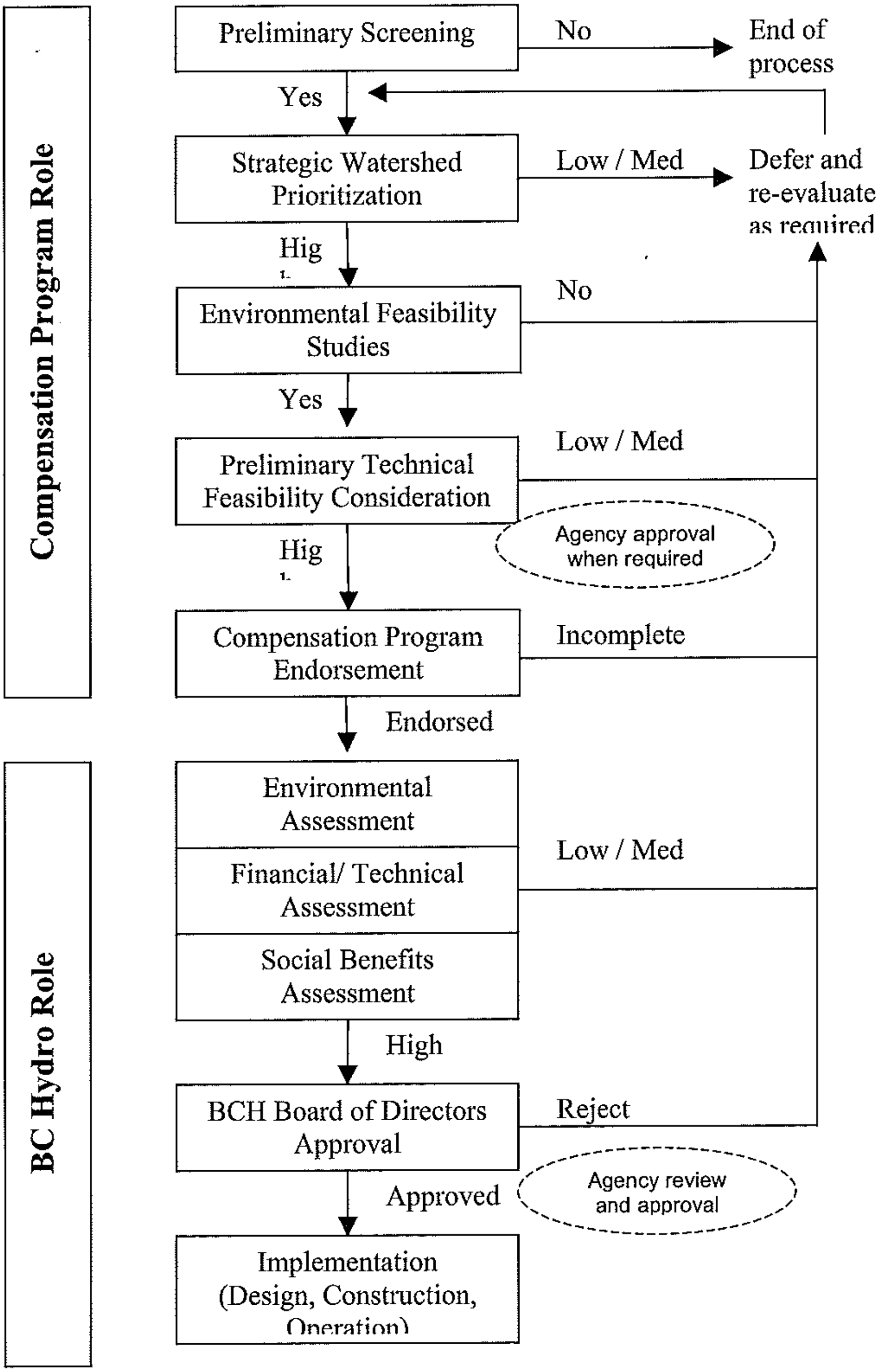
The proposal will move to step 7 if the evaluation of the above indicates it has a high potential for success.

Step 7 –BCH Board of Directors Approval

The proposed fish passage project will need to be evaluated with respect to BC Hydro's economic and business practices and must fit within BC Hydro's long term capital plan. The business case may include a detailed trade-off analysis and will include a detailed design.

If accepted by the BC Hydro Board of Directors, BC Hydro will be responsible for the management of design and construction of the passage facility. Regulatory Agency review and approval will be required. BC Hydro will be responsible for ongoing operation and maintenance of the passage facility.

APPENDIX B (continued)



APPENDIX C. Alouette Dam Fishway Report No. 1

Alouette Dam Fishway
Report No. 1

For:

Ministry of Environment
Ecosystem Branch
315-2202 Main Mall, UBC
Vancouver, B.C.
V6T 1Z4
Contract No CECO9097
dated 2nd July 2008

By:

Ward & Associates Ltd
307-977 Mainland Street
Vancouver, B.C.
V6B 1T2

January 2009

Alouette Dam Fishway 2009

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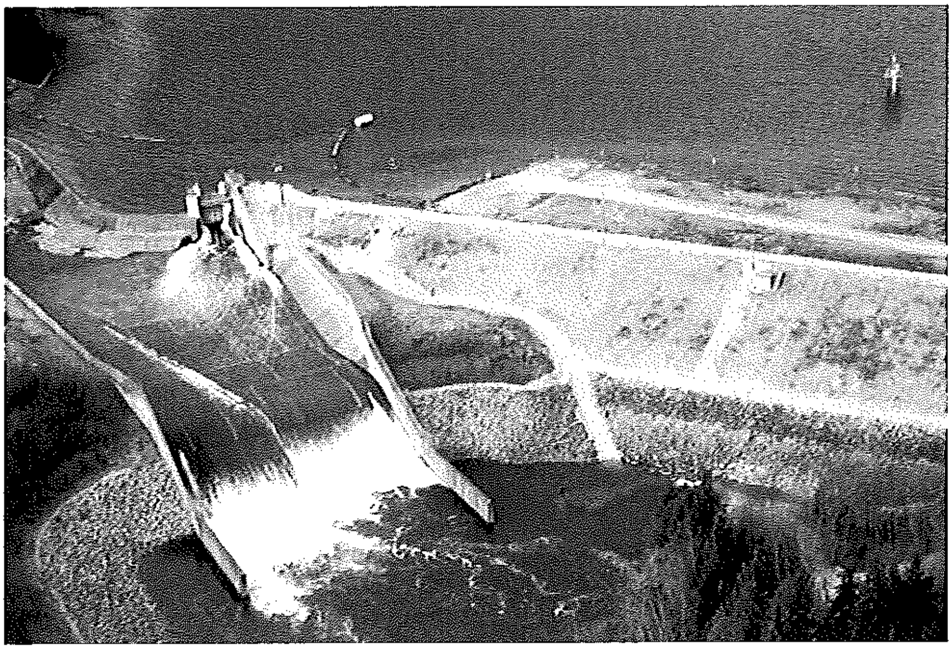

Ward & Associates Ltd Hydrology Engineers
Alouette Dam Fishway No 2 Report January 2010
& No 1 Report (see pp 27-45)

Alouette Dam Fishway

1. Introduction

The Alouette project consists of a dam at the south end of Alouette Lake, and a tunnel from Alouette Lake to the 8 MW Alouette powerhouse discharging into Stave Lake. The project is an interbasin diversion project, because a significant amount of the flow is discharged out of the Alouette basin into the Stave River basin. The Alouette dam was built in 1926, and the powerplant went into service in 1928. The dam was replaced in 1984 with an earthfill structure. The static head at the powerplant is modest, about 50 m, and the average energy capability is low, about 60 GWh per year. A map of the Alouette/Stave system is shown, see Figure 1.

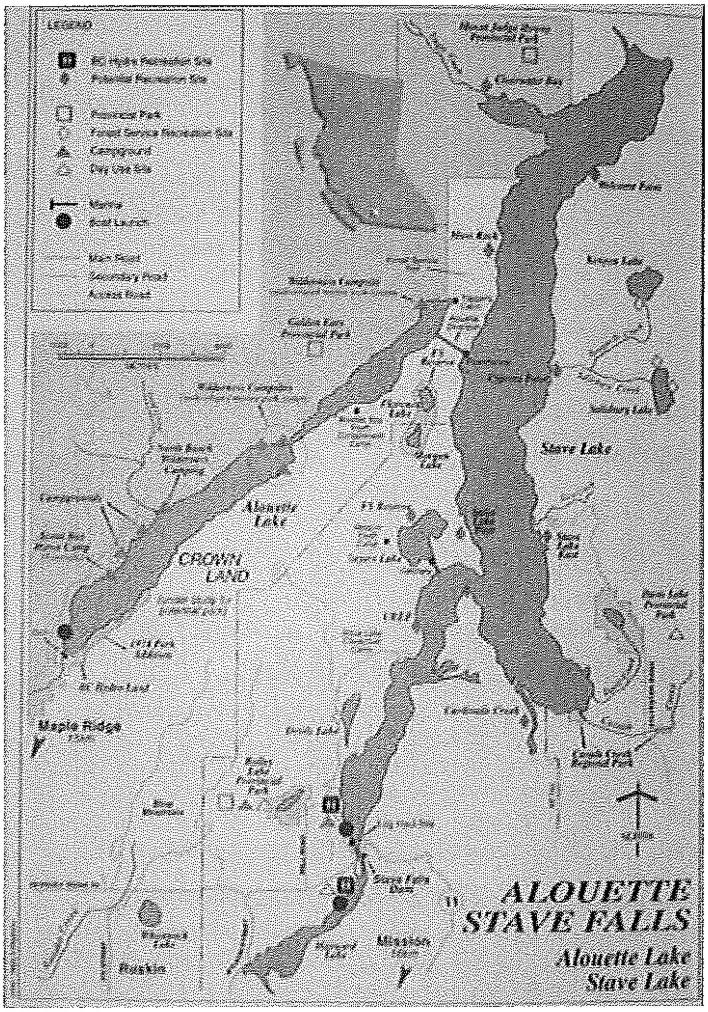

Figure 1. Map of Alouette-Stave System

With the return of mature sockeye salmon to the base of the dam wall in 2007 for the first time since dam construction, and further returns in 2008, it has become important to provide a fish passage facility at the dam. License review (WUP 10 year review) is due in

2014, and as part of this process, there will be the possibility to require the operator (BC Hydro) to construct suitable facilities at the dam. With a re-licensing process that may require several years, it is timely for government agencies to discuss and formulate what is needed at Alouette Dam.

The value of electricity produced annually at the Alouette powerhouse is relatively low. This means that it may be possible to make operational changes to the way the reservoir is operated to accommodate fish passage, and it also means that the construction of what is deemed necessary for fish passage will have to be modest in cost.

Emphasis in the present report is on facilities for upstream migration of fish. While trucking fish around dams is utilized at many high dam sites, this provision is regarded as a temporary option for Alouette, as it is sufficiently small in head difference to make the provision of a fish ladder possible. There is a drop of approximately 16 m between the full supply water level, and the water surface in the downstream river channel. Provision needs to be made to operate the proposed fish ladder during a substantial part of the year, because of the timing of the migration of various salmonids that will likely return. Sockeye salmon migrate upstream during the summer months when the reservoir is held at full pool level. Pink salmon are expected during the September/October window, and Coho salmon during November/December. Steelhead are winter migrants, in the period February to March. Chum Salmon although weak swimmers, are sometimes opportunistic colonizers, and would likely use the ladder during the October-November window. Cutthroat trout and Bull Char would move upstream if a ladder were operating. Times for migration of adult salmon are summarized, see Table 1.

Table 1. Timing of migration of adult salmon, Alouette River

Species	**Upstream migration window**	**Reservoir level under present operations rules**
Sockeye	July August	High
Pink	September October	Medium to Low
Chum	October November	Low to Medium
Coho	November December	Medium
Steelhead	February March April	Medium

Downstream fish passage via the gate and spillway at Alouette is possible as long as the water level is sufficiently high during key periods to allow spillage via this route. Successful out-migrations of kokanee (sockeye) smolts occurred during 2005, 2006, 2007 and 2008 years when spillage flows of about 3 m^3/s (under the WUP) were released during the April-May period. The dam is relatively low head, about 16 m maximum between full supply level and the water surface in the downstream river channel. Damage to smolts released via this route is believed to be minimal.

2. Examples of Existing Fishways

Fishways for upstream migration are in several designs. The most common of these, fish ladders, utilize a discharge of water down a man-made channel that is built next to the river obstruction, providing a series of low velocity areas for fish to spend time prior to ascending the next step. Other types of fishways involve fish lifts and fish locks, but these are not popularly used. Trapping and trucking of fish is used typically at projects where there is a large head difference between downstream and upstream.

A summary of currently used fish passage systems, including fishways, fish locks and fish lifts is included in Odeh[6] 1999. Fish ladders are described in many references. A detailed investigation of the hydraulics of various types of fish ladders has been researched, see Kamula[7] 2001. Three main types of fish ladders, vertical slot, pool and weir and Denil are described in Odeh 1999, and are shown in Figures 2 and 3.

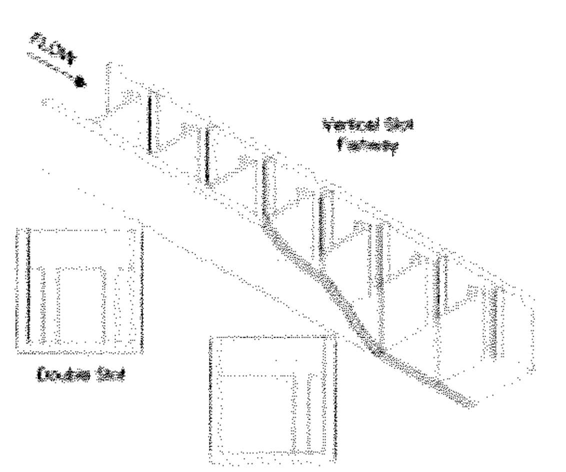	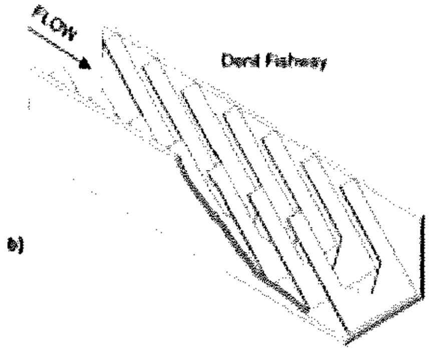
Vertical Slot (one or two slots used)	*Denil*

Figure 2. Vertical Slot and Denil Fish Ladders

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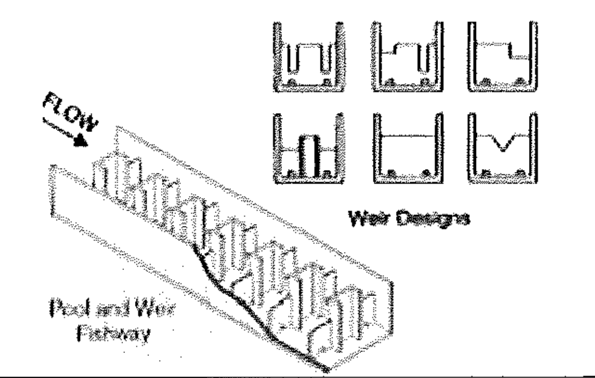
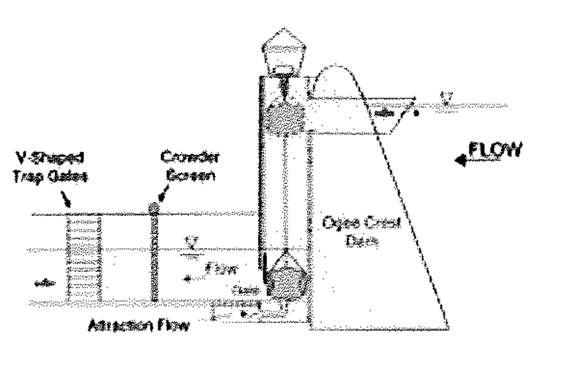
6 Odeh, Mufeed 1999. Chapter 1 "Fish Passage Innovation for Ecosystem and Fishery Restoration", *Innovations in Fish Passage Technology*. American Fisheries Society, Bethesda, Maryland USA.. ISBN 1-888569-17-4.

7 Kamula, Riitta 2001. *Flow over Weirs with Application to Fish Passage Facilities*. Ph.D. Dissertation Faculty of Technology, University of Oulu, Finland. ISBN 951-42-5977-7. June 2001.



Pool and Weir



Fish Lift schematic

Figure 3. Pool and Weir Fish Ladder, and Fish Lift.

Fish ladders in the Pacific northwest are found in many places, because of the steep nature of the terrain. Riverine fish ladders are found at many locations, e.g. at Stamp River Falls, and on the Bonaparte River near Cache Creek. Typically these ladders provide for differences in elevation in the range 3 to 20 m. In exceptional cases, e.g. John Day Dam Fish Ladder Columbia River, the elevation difference is up to 34 m. A few fish ladders are for access to lakes and reservoirs, for example at the outlet of Bonaparte Lake BC, and at the outlet of Comox Lake, BC. One option to ensure upstream movement of many fish species, not only salmonids, is to provide non standard, non engineered channels made to provide a "natural" path for upstream movement, e.g. Deadman Falls fish ladder, near Nanaimo B.C.

Several naturalized systems for expediting the movement of fish are described in Newbury and Gaboury[8]. These are constructed in river channels e.g. Twin Creeks, Oulette Creek and Chapman Creek B.C. and provide pool-riffle sequences in reaches of channel with head differences of 9 m to 20 m at slopes of 3% to 6.5 %. One project described, at Little Saskatchewan River Dam, Manitoba, is a pool and riffle fish ladder providing passage around a 3 m high spillway.

Examples of facilities for upstream migration of fish for low and medium heads is presented, see Table 2.

[8] Newbury R.W. and M.C. Gaboury 1993. Appendix F of *Stream Analysis and Fish Habitat Design A Field Manual.* ISBN 0-969-6891-0-1. Newbury Hydraulics Ltd. 262 pp.

Table 2. Examples of Fish Ladders

River	Location	Head diff-erence	Notes
Stamp R.	Stamp Falls Provincial Park, Vancouver Is.	14 m	Vertical slot ladder, with switchbacks to maximize drop in short distance, built into rock on side of falls
Bonaparte R.	Near Thompson R confluence	10 m	Vertical slot ladder. Built 1988 at cost of $300,000 and later improved with HCTF support
Capilano R.	Capilano Fish Hatchery access, North Vancouver	5 m	Public display allows visitors to view fish through a glass window ascending the ladder
Kakweiken R.	South of Kingcome, B.C.	5.4 m	75 m long vertical slot ladder, 1 km u/s of sea, for passage of Pink Salmon and other species. Built in 1979.
Millstone R.	Deadman Falls near Nanaimo		Pool/riffle man-made side channel to facilitate upstream movement of Coho. Built 2007.
Puntledge R.	Comox Lake outlet, Vancouver Island	6 m	Provision for up to 2 m of fluctuation in lake surface
Seton Lake outlet	Near Fraser R confluence, Lilloet		Limited usefulness because of presence of large turbine outflow d/s on Fraser River
Bonaparte Lake outlet	South of Bridge Lake, BC		Caters for up to 1 ½ m fluctuation in lake level
Little Saskatch-ewan River	Rapid City dam	3 m	Built 1992. Naturalised pool and riffle channel with eight 0.3 m high rock riffles. Flow 0.15 m^3/s
Yukon R.	Whitehorse Rapids Dam, Yukon	15 m	365 m long wooden ladder
Connecticut R.	Holyoak, Ma	16 m	Fish Elevator
Pitlochry	Pitlochry, Scotland	16.5 m	310 m long
Fyris R.	Uppsala, Sweden		Vertical slot design

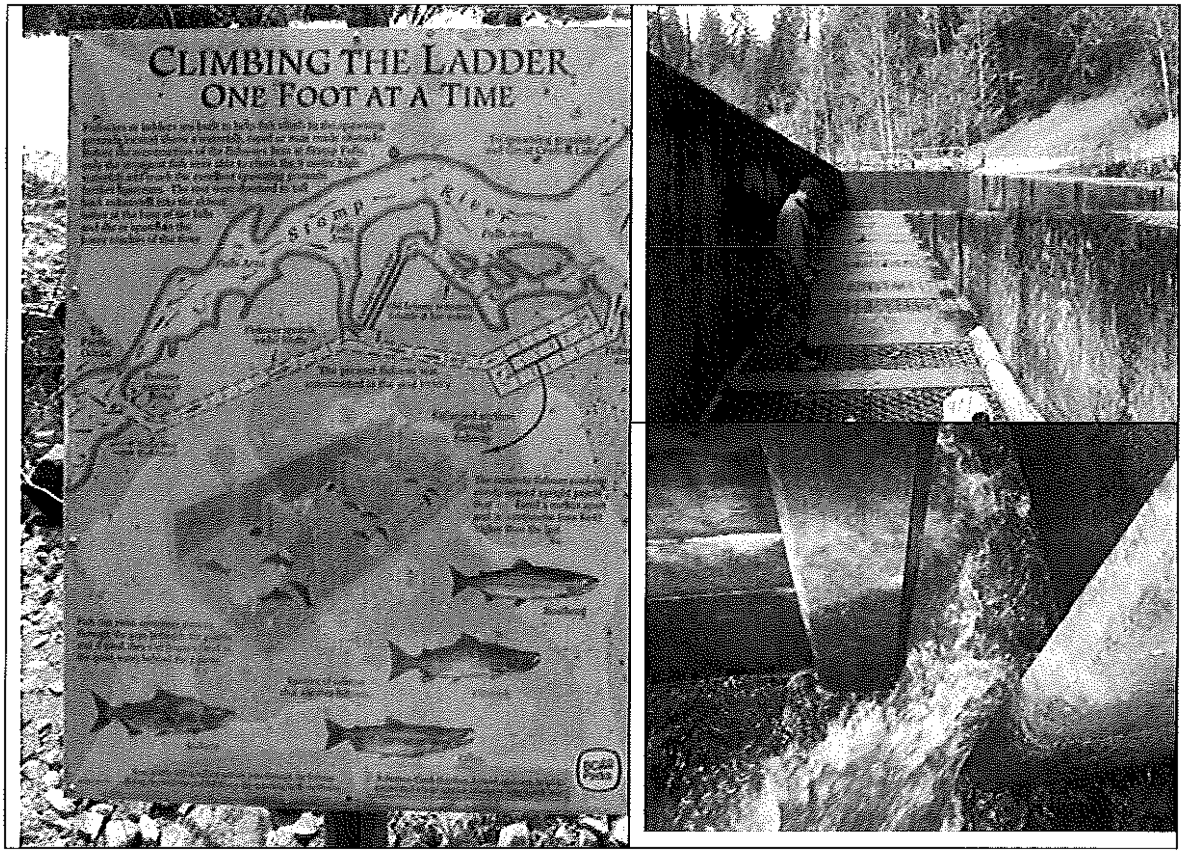
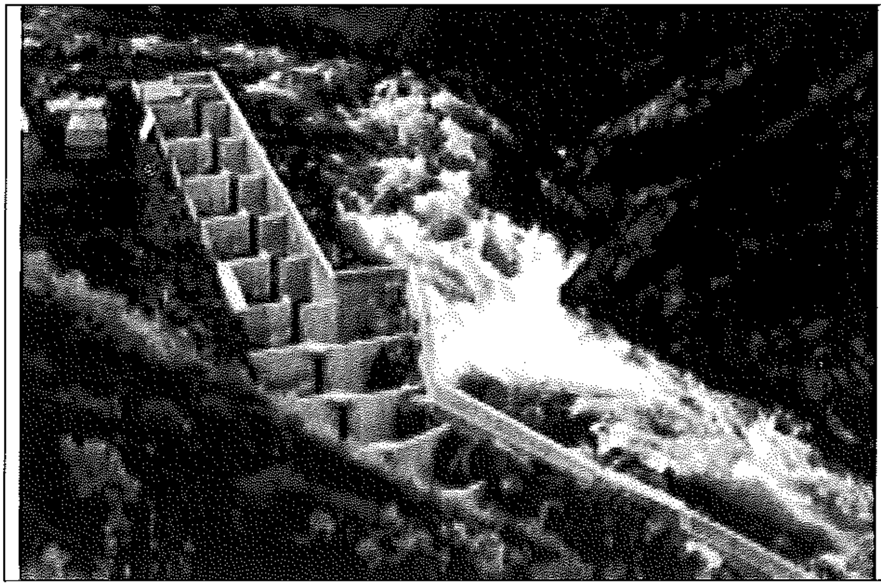


Figure 4. Vertical Slot Fish Ladder at Stamp River Falls, Vancouver Island, B.C.



Bonaparte River vertical slot ladder, about 3.5 km upstream of Thompson River confluence

(photo credit British Columbia HCTF)

Figure 5. Bonaparte River Fishway. About 10 m rise, this was built in 1988, and allowed access by migratory fish, particularly Steelhead, Chinook, and Rainbow Trout to the Bonaparte system.

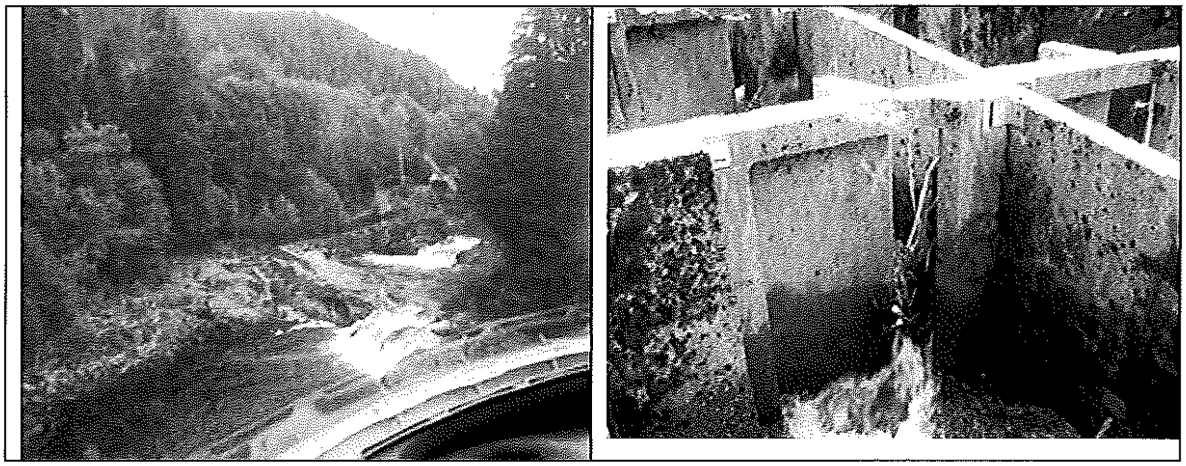


Figure 6. Kakweigen Fishway. Vertical slot design to facilitate Pink Salmon passage (built 1979)

Vertical Slot Ladder, Fyris R., Uppsala, Sweden

Pool & Weir Ladder, Pitlochry, Scotland

Figure 7. Fish Ladders, Europe

There are presently no upstream migration facilities at Alouette dam. There is no fish ladder present, nor are there constructed facilities to attract, collect, and measure the fish, prior to trucking them around the dam.

3. Water Yield/Hydrology Overview

The runoff regime of the Alouette watershed is characterized by moderate flows in the spring (April to June) resulting from snow melt, a recession period during the drier summer months, followed by high flows from late October through February.

B.C. Hydro has data collection platform on Alouette Reservoir that measures reservoir level, precipitation and temperature and transmits the data to BC Hydro's system control centre (SCC) every hour. There is also a data collection platform on Gold Creek which measures precipitation and temperature on the half hour and transmits the data to SCC every hour. Because of the steep slopes within the basin, the delay between rainfall and the resulting inflow to the reservoir is relatively short, typically between 4 and 12 hours.

Measurements of inflows into Alouette Lake are not made, however the net inflows (which overlook evaporative losses) are computed by BC Hydro from outflows. Occasional negative net inflows are computed with this procedure. The drainage area of Alouette Reservoir is about 210 km^2, with Gold Creek and the headwaters of Alouette River contributing most of the flow.

The outflow routes are as follows:

Turbine Flows (to Stave system)
Adit Flows (to Stave system)
Low Level outlet (LLO, to Alouette River)
Spillway crest gate (to Alouette River)
Spillway overflow crest (to Alouette River)

Monthly and annual net inflows to Alouette reservoir for the period 1984 to mid 2003 are shown in Figures 8 and 9. The mean annual net inflow (21.0 m^3/s) is approximately equal to the turbine outflow for peak power production. Flows during the fall-winter period are always well above the mean annual inflow, with the exception of the 2000-2001 winter only, which was unusually dry. Flows during the August-September period are consistently very low. For the 19 year data set, 1985 was the lowest year on record, with an average net inflow of only 13.9 m^3/s (66% of the long term average), and 1997 was the highest year on record, with an average net inflow of 28.3 m^3/s (135% of long term average).

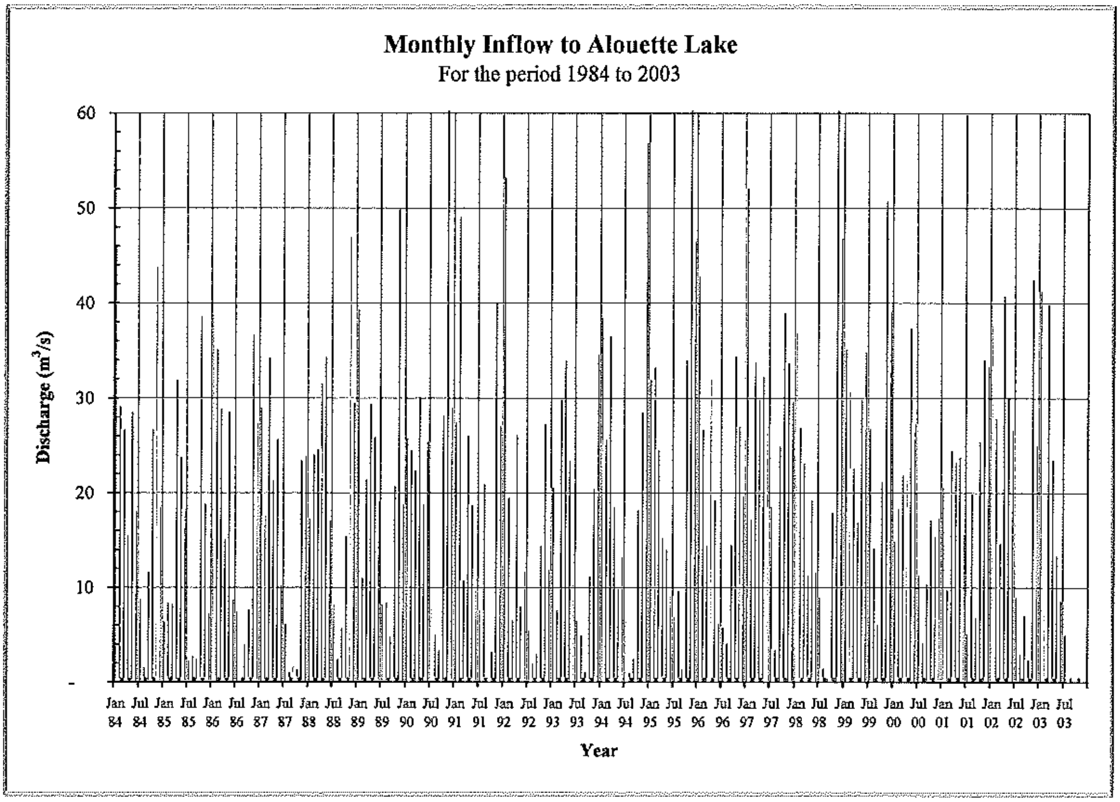


Figure 8. Computed monthly inflow, Alouette Reservoir, for the period of record

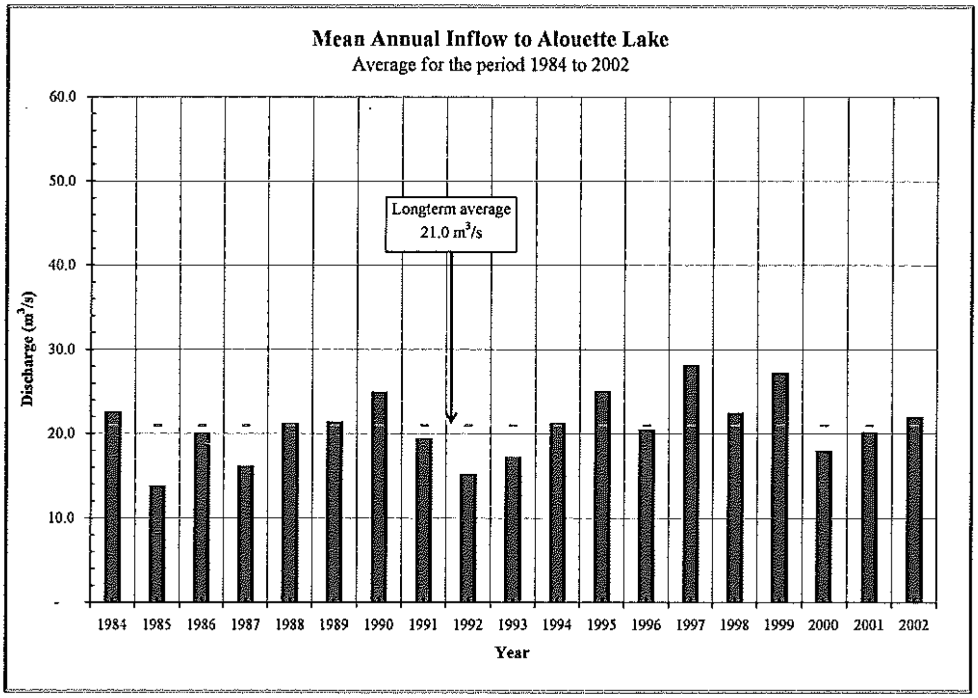


Figure 9. Computed annual inflow, Alouette Reservoir, for the period of record

4. Summary of Water Level Operations

Water levels in Alouette reservoir are controlled by releases via the turbine and adit outlets (at the north end), and via the low level outlet (LLO), the vertical lift spill gate, and the free crest spillway. Key water levels and elevations of water control features of the dam are presented, see Figure 10. The elevation of the downstream water surface in the river is about 109.5 m at low outflows. The Alouette Generating Station Water Use Plan (1996), and the BC Hydro System Operating Order 4P-45 (2002) control how water levels are managed at Alouette Reservoir. BC Hydro's resource management department is required to review the system operating orders (SOOs) for Alouette reservoir at least once every four years.

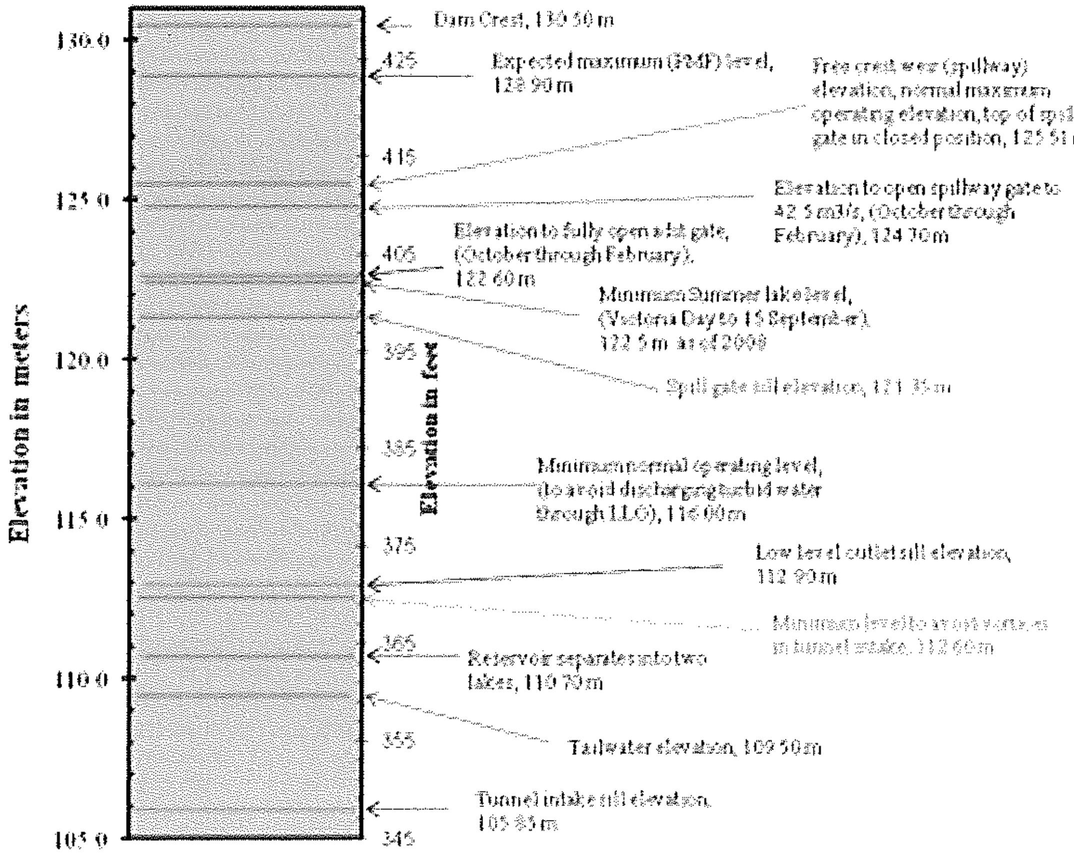


Figure 10. Water level elevations and heights of structural features, Alouette Dam

In October 1996 the LLO outlet valve was set at full open capacity, following guidelines in the Alouette Generating Station Water Use Plan, which was adopted at that time. Flows in the range 1.98 to 2.97 m^3/s are released, depending on the reservoir water surface elevation, with the LLO valve fully open. The average flow release is about 2.55 m^3/s. During the period April 15th to June 1st, the LLO is closed, and a flow of 3 m^3/s is released through the Crest Gate, to provided passage for kokanee/sockeye smolt moving downstream.

The range of normal operation of the reservoir is 116 m to 125.5 m relative to geodetic datum. As of 2008, for the summer period from Victoria Day (near the end of May) until 15th September, the minimum reservoir elevation is 122.5 m. Adjustments of turbine operations are made prior to this date, to ensure that the reservoir is above this level by Victoria Day.

In order to provide flood storage, water is discharged when necessary during the high inflow months October to March through the adit gate. Spillage of water through the spillway crest gate is initiated any time the reservoir level reaches 124.7 m during the A-WUP October to March window. For public safety reasons, ramping flow increases through the spillway crest gate into the South Alouette River will not exceed about 6.23 m^3/s every 40 minutes.

Flushing flows on alternate years, for the benefit of Alouette River fisheries are scheduled during the period Sept 15 to Dec 31, and are in the range 19 to 31 m^3/s, lasting for a 3 day period.

The recent history of reservoir levels in Alouette Reservoir is shown, see Figure 11. For flood management, under the Station Operating Orders, during the period October through February, the adit gate is opened at 122.6 m elevation, and closed when water levels fall below this elevation. This operational procedure tends to stabilize winter water levels near 122.6 m, see Figure 11. The spillway crest gate is opened to release up to 42.5 m^3/s during the period October to February, if the reservoir surface level rises to 124.7 m. During medium and above average winters, the water levels stay within about 1.5 m of the 122.6 m elevation.

During drier than average winters, such as years 2000 and 2001, the reservoir elevation is seen to be low, on account of withdrawal of water to supply the turbine, and the insufficiency of inflows.

Levels are held in the range 122.5 to 125.5 m during the summer period. Starting in mid September, water levels are allowed to fall, to provide flood storage, and in anticipation of good inflows in the October-November period, see Figure 11.

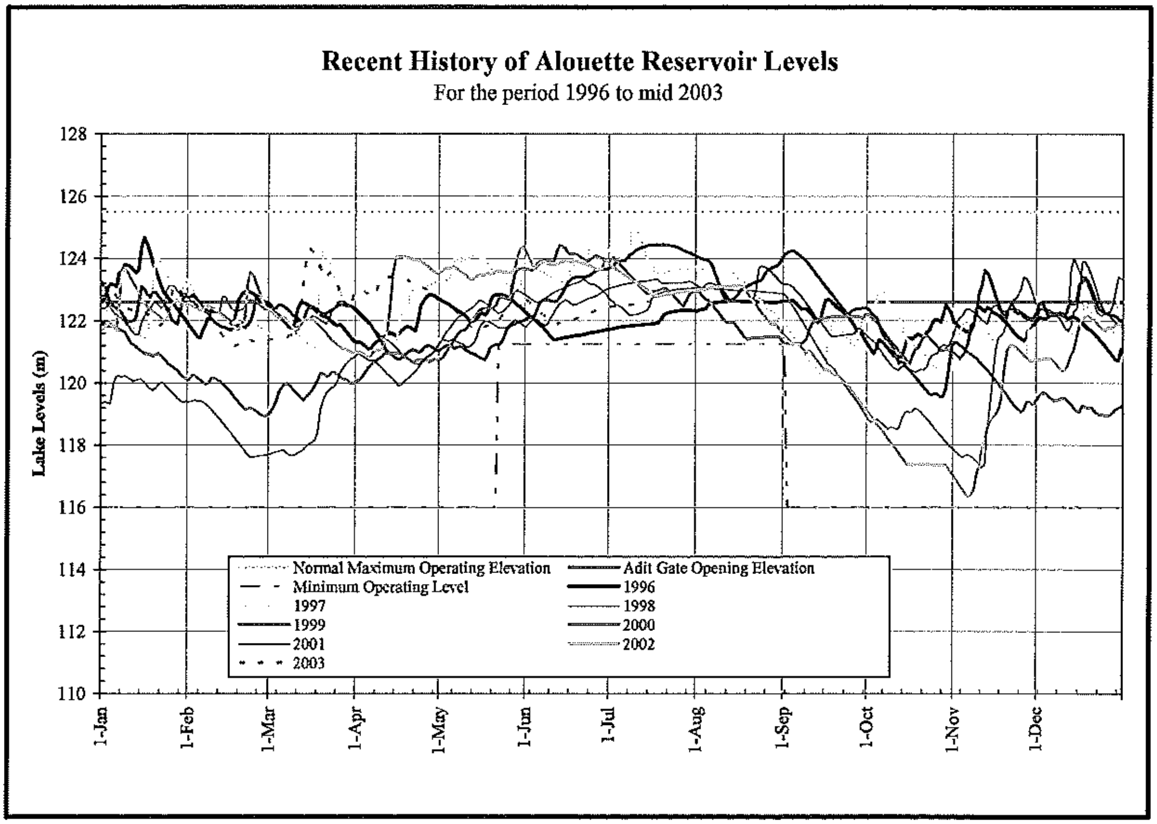


Figure 11. Water levels at Alouette Reservoir during period 1996 to 2003.

5. Proposed Concept and Location for Fishway

Upstream passage of fish may be inexpensively accomplished by trapping, holding for short periods and trucking to the lake upstream of the dam. This is usually to only feasible method of proceeding at high dams. A well conceived fish collection facility is needed, as recently constructed at Coquitlam dam. The operation cost of this may be high, particularly if the intent is to provide upstream passage for many salmon species with a variety of timing requirements for their movements. The collection and trucking option would provide a short term possibility for fish passage at Alouette dam.

In the longer term, the system would benefit from a fish ladder, as migration would be possible during various seasons of the year. A fraction of the flow (about 2.55 m^3/s on average) that is presently being diverted through the LLO may be utilized for fish ladder flows. The fish ladder and its water flow provisions should be capable of operation at a reservoir level as low as 121 m, and should work at levels of up to 124.5 m, a range of 3.5 m. A plan view of the dam is shown, see Figure 12.

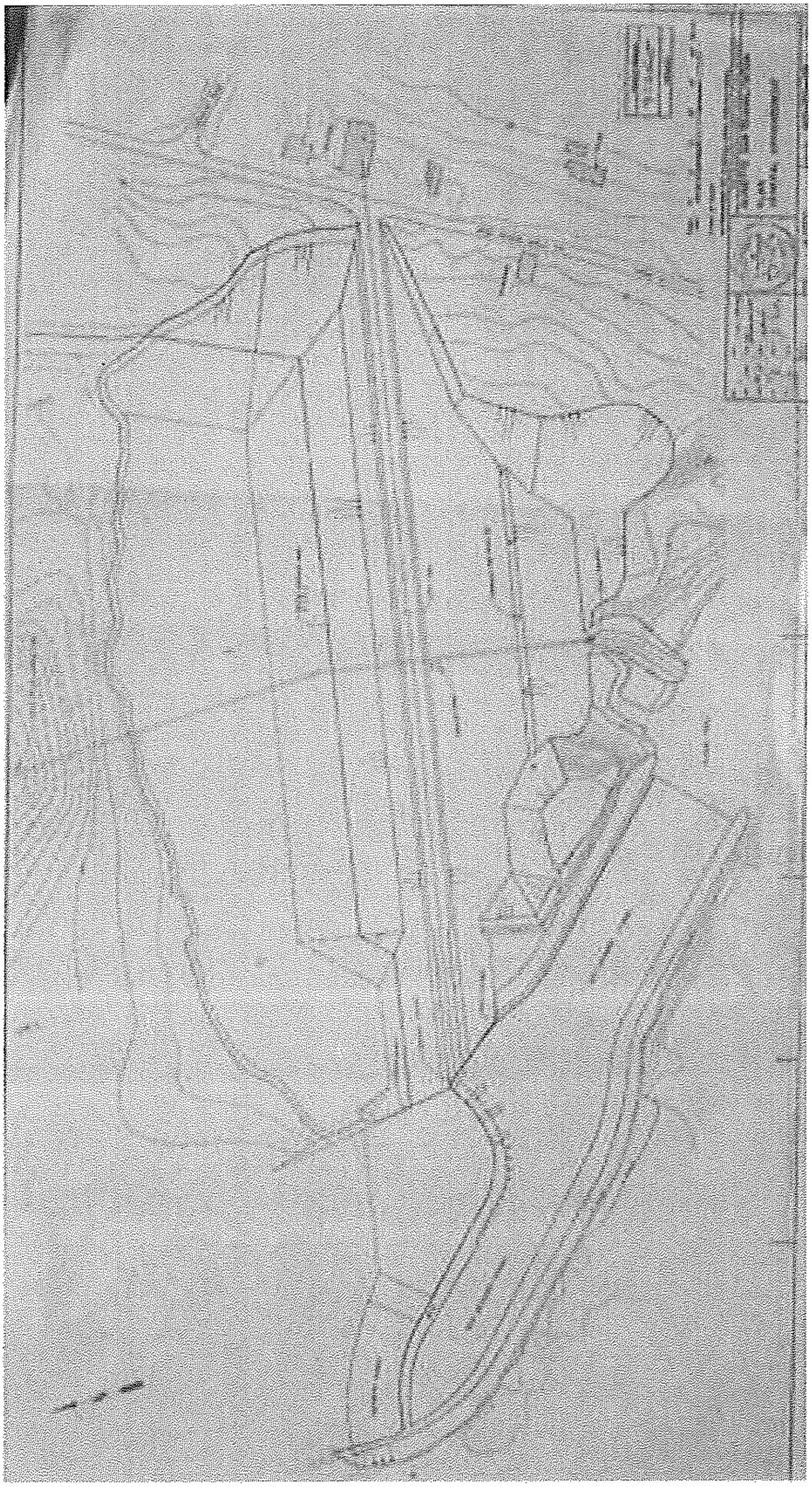


Figure 12. Plan view of Alouette Dam. Scale on right is from -10m to +40 m.

Ladders are possible down either the east or west sides of the dam. One issue is the ease or difficulty of safely cutting the earthfill dam to provide for the ladder. On the west side of the dam there is an area of slumping soils, that has been drained and stabilized with rock, and this area will have to be carefully managed if a fish ladder passes around the dam on this side. Ladder slope requirements, based on practice elsewhere, would be in the range 5 to 7%.

Many options exist for providing the flow of water for the fish ladder from the dam. Two designs are suggested for discussion, bearing in mind that many possible solutions apply. One would involve a pumped flow, lifting water to the crest of the dam, or at least to the crest of the spillway, to provide the required flow. The second would involve cutting the dam, spillway or one of the dam abutments with a sufficiently deep cut to provide gravity flow to the fish ladder at the lowest reservoir elevation. For this type of ladder, there will be a need to accommodate a substantial range of head differences in the reservoir. The tailwater elevation for low flows in the Alouette River is 109.5 m.

Two preliminary suggestions for ladders utilizing the spillway, are as follows:

1). *Eastside Spillway Ladder*. Constructing a gate and a cut to about elevation 121 m in the existing dam wall or in the spillway, so that water can flow under gravity at various levels, including when the water surface is at the Spring/Autumn low level, or
2). *Westside Spillway Ladder*. Providing a pipeline and small reservoir, that would allow passage of the water, by suitable capacity pump, over the top of the spillway (125.5 m). Fish would be flushed periodically from the reservoir via a large diameter pipe, to the Lake.

Example Option 1. Eastside Spillway Ladder. As shown in Figure 13, the wall of the spillway could be cut, down to an elevation of approximately 121 m, in a location next to the western gate buttress. The upper half of the ladder should have provision for gradient adjustment, to accommodate a 3.5 m change in lake surface level. A submerged orifice ladder is one solution that works well to accommodate a range of water surface levels. The lower half could be any of the traditional designs, and could be of pre-fabricated sections. This half will be supported on low concrete piles to provide the required steady gradient down to the tailwater elevation (109.5 m). Present operating procedures for Alouette dam mean that the maximum free spill capability for passage of floodwaters is essentially never used, so removal from service of a small fraction of the spillway overflow crest is seen as a possibility. The route of the fishladder down the spillway needs planning, as the flow released via the vertical lift gate should be allowed to spread across a substantial part of the width of the spillway.

For the east side (gravity fed) ladder, with a proposed ladder length of 230 m, and a downstream water surface level of approximately 109.5 m, the average slope of the water surface in the ladder is:

Summer lake level conditions, max head difference 15 m,	slope 15/230 = 6.5%
Spring and Fall lake level conditions, min head difference 11.5 m,	slope 11.5/230 = 5.0%

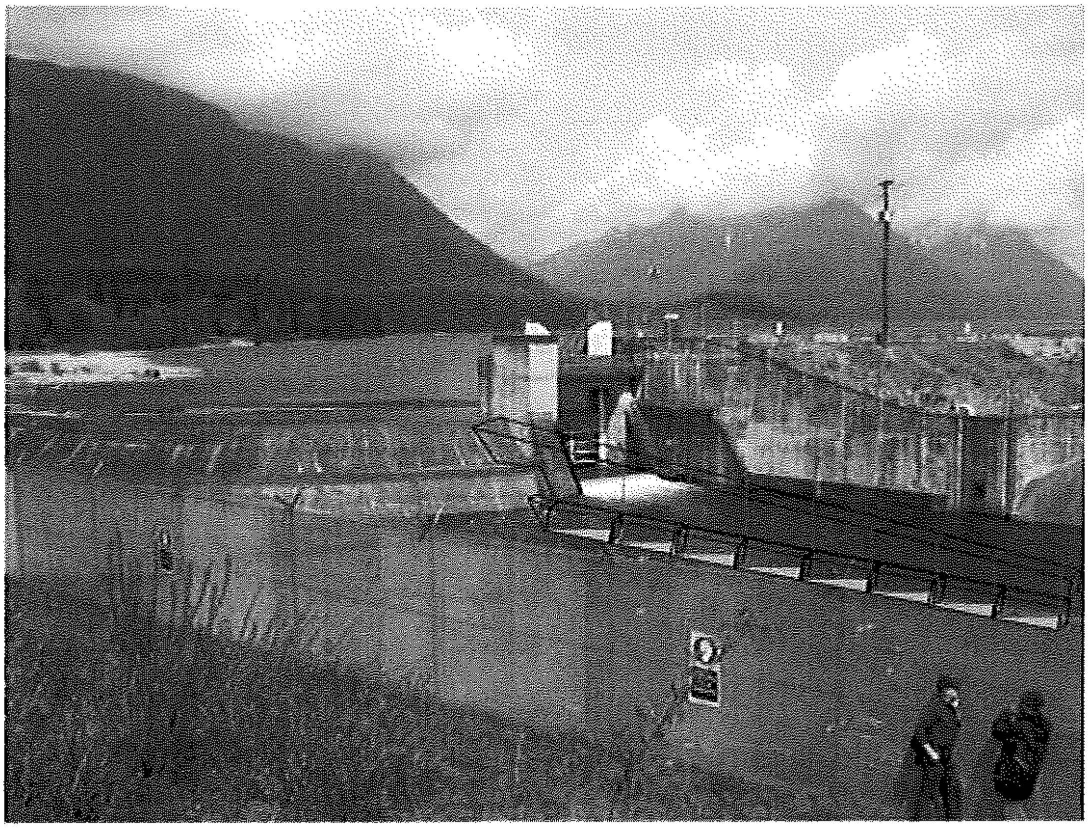


Figure 13. Eastside Spillway example showing ladder catering for variable lake levels

Example Option 2. Westside Spillway Ladder. As shown in Figure 14, a pump sump will be constructed at a suitable location in the reservoir, sufficiently low that the pump could access water with a reservoir level of 121 m. A small reservoir will be constructed on the extreme east side of the spillway, and the pump will deliver to the reservoir, from where water will discharge into the top of the fish ladder. The fish ladder will be constructed along the west side of the spillway, next to the spillway wall to minimize interference with spillway flows. The final part of the ladder will be either on concrete piles along the spillway side, to provide a consistent gradient route down to the tail water elevation, or will be set into the west abutment bank (see Figure 15), with a switch back course if necessary to bring the flow to tailwater level. A valve and pipeline with sufficient diameter for fish will lead from the reservoir back to the Alouette Lake, providing a route for conveying (flushing) fish on the final part of their upstream migration. This pipeline, and the resulting flow velocities need careful consideration, so as to minimize damage to fish.

For the west side (pumped flow) ladder with a reservoir at the top of the spillway (water surface elevation 125.5 m), and a proposed ladder length of 230 m:

Head difference 16 m av slope 16/230 = 6.9%

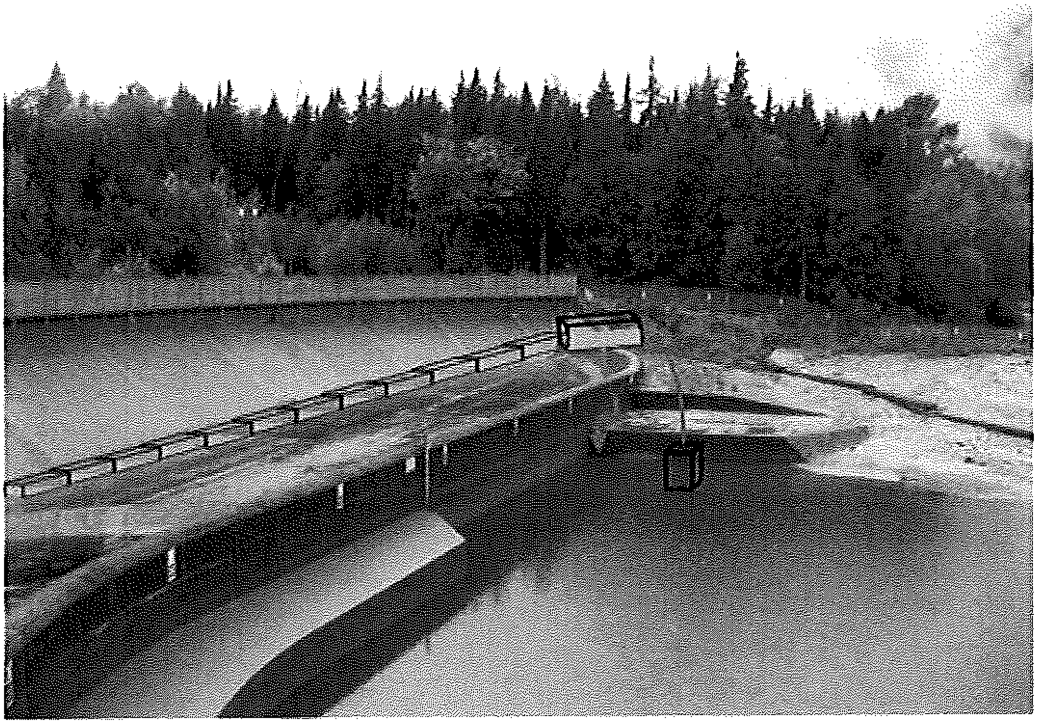


Figure 14. Westside Spillway example, showing pumped flow to small reservoir, and fisheries return flow to lake. Ladder will pass down west side of spillway

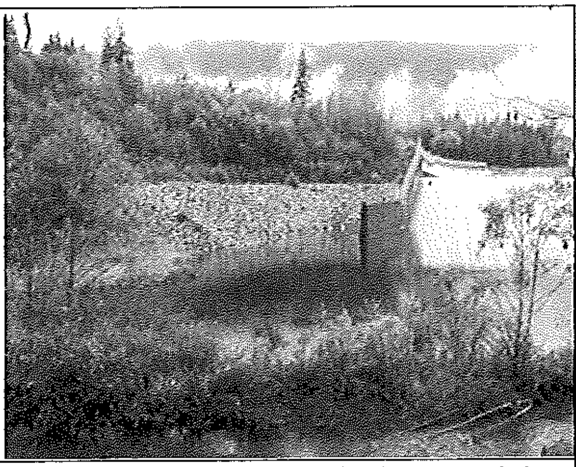
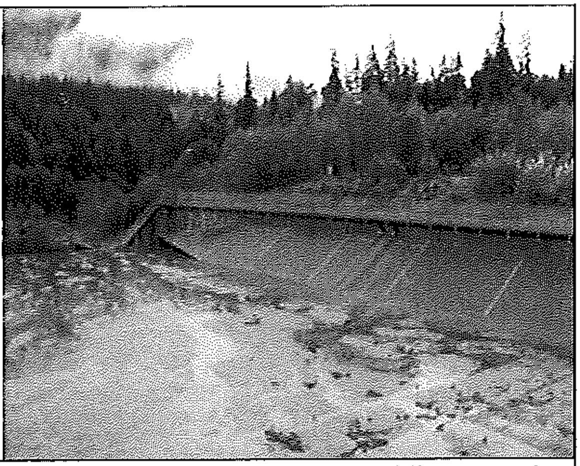
	
Bank for provision of switchback route to bring fishway to tailwater level	Final part of upper spillway, providing a gentle gradient for fishway

Figure 15. Westside Spillway route, showing bank for provision of the correct gradient to the tailwater level.

Other suggestions for fishways at Alouette are possible, such as an eastside of earth dam route. This would have the benefit of being able to follow an already prepared vehicle route of about the correct gradient to the river downstream of the dam. However it would require either cutting a deep slot through the earth fill dam, or finding a longer route to the east of the earth fill dam.

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