Stave River Water Use Plan:

Report of the Consultative Committee

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EXECUTIVE SUMMARY

Water use planning is a new process in BC, introduced by the Ministers of Employment and Investment and Environment, Lands and Parks to ensure that provincial water management decisions better reflect changing public values and environmental priorities. A water use plan (WUP) is a technical document that defines how water control facilities (e.g., powerhouses) will be operated. How these facilities are operated will affect many interests in the watershed, such as fisheries, recreation, First Nations, power production, industry, flood control, and others. The goal of water use planning is to develop an operating strategy that achieves the best balance among multiple interests through a participatory, consensus-based process.

The Stave Falls Powerplant is currently being upgraded through the Stave Falls Powerplant Replacement Project. One of the conditions of the Energy Project Certificate (June 1995) for the project requires that a water use plan be prepared for the water control facilities in the Alouette-Stave Falls-Ruskin hydroelectric system. The Alouette WUP was completed in 1996.

The purpose of this report is to present the recommendations of the Consultative Committee of the Stave River Water Use Plan to BC Hydro and the Comptroller of Water Rights. This report will be used by BC Hydro as input when preparing the water use plan that will be submitted to the Comptroller for approval. The Comptroller will consider the input of the Consultative Committee as well as the adequacy of the consultation process when reviewing the proposed water use plan. Accordingly, this report describes:

- the consultation process and analytical approaches used;
- the management objectives and alternatives considered to achieve them;
- the trade-offs associated with the short-listed alternatives;
- the process for reaching consensus; and
- the degree of support for the recommended alternative.

The water use planning process is a 13-step process. The report of the Consultative Committee addresses Steps 1 through 8. BC Hydro conducted the WUP Initiation and Issues Scoping in the fall/winter of 1997/98. At this stage, all interested parties were invited to participate in the Consultative Committee. In the spring of 1998, BC Hydro engaged Compass Resource Management to conduct the trade-off analysis and facilitate Consultative Committee meetings. All of the Stave River facilities are located on Kwantlen First Nation's traditional territory. Kwantlen participated on technical subcommittees, at the main Consultative Committee table and was also consulted separately on issues related to Heritage, Fisheries and Wildlife.

By summer of 1998, the Consultative Committee agreed on the following objectives of the Stave River Water Use Plan:

1. Avoid disruption to industrial operations
    - maintain access to loading/offloading equipment
    - avoid impacts from downstream flooding

2. Support recreational opportunities
    - support Stave Reservoir activities
    - support Hayward Reservoir activities
    - improve safety downstream of Ruskin Dam

3. Support viability of wildlife populations
   - maintain reservoir level stability
   - maintain downstream water level stability
   - ensure periodic flooding of riparian areas

4. Protect and preserve First Nations heritage values
   - protect sites from erosion and illegal collection
   - preserve access to sites
   - recover and interpret artifacts

5. Support viability of fish populations
   - increase spawning capacity
   - increase rearing capacity
   - reduce stranding
   - reduce risk of exposure to elevated levels of Total Gas Pressure
   - increase reservoir productivity

6. Avoid cost increases for electricity production
   - minimize cost of replacement electricity and/or additional programs or works

7. Maximize flexibility to respond to change
   - maximize resilience to and ability to respond to electricity market volatility, scientific uncertainties, etc.

8. Gain knowledge about the system and impacts
   - maximize learning about key uncertainties affecting decision making

For each objective, performance measure(s) were identified. Where possible, performance measures were modeled quantitatively. In other cases, impacts were described qualitatively.

The Consultative Committee generated twelve preliminary operating alternatives designed to meet the objectives (see inset: Summary of Alternatives Developed for SRWUP). The impacts of each alternative on each objective were estimated using the performance measures. The preliminary alternatives were then refined into a number of combination strategies. Eventually, two very distinct strategies – Combo 4 and Combo 5 – were short-listed and evaluated in detail.

Downstream of Ruskin Dam, both of the short-listed strategies contain the same components. This demonstrates the success of the process in finding joint gains through a creative option identification process. In Stave Reservoir, the short-listed strategies represent fundamentally different approaches to operations. The choice between them is value-based.

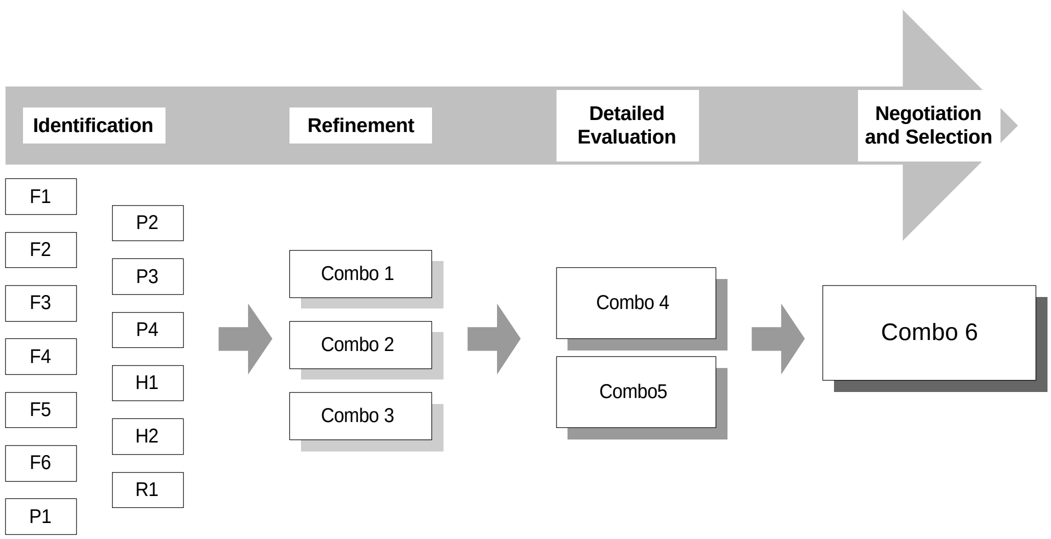
Combo 4 was specifically designed to increase the stability of the reservoir for the primary purpose of enhancing reservoir productivity. It was proposed that this strategy could also improve the viability of the riparian ecosystem in the drawdown zone, and thus improve the aesthetic and recreational value of the area. Because the upper and lower bounds (of the target water level) were allowed to be violated in order to protect minimum flows required for the protection of downstream spawning and rearing habitat, Combo 4 provided reduced fluctuations in reservoir elevations (reduced in magnitude and frequency), but not a fully stable reservoir. Evaluating the benefits of this alternative was complicated by scientific uncertainty about the magnitude of the benefits of a partial stabilization of the reservoir for fish and other ecosystem attributes.

Combo 5 was a refinement of baseline (current) operating conditions, with modifications specifically in consideration of heritage and recreation interests. Although Combo 5 does not set a year-round reservoir target in an explicit attempt to stabilize the reservoir, modeling indicates that in combination with the proposed downstream changes, this strategy would also improve the stability of Stave Reservoir, albeit to a lesser extent than Combo 4.

The Consultative Committee evaluated the trade-offs between these two alternatives in detail. In order to reach consensus, a new combination was developed, which is essentially the operating strategy from Combo 5 with the addition of a significant investment in monitoring to reduce key uncertainties related to reservoir productivity and First Nations heritage objectives.

The Consultative Committee reached a consensus agreement on the "Combo 6" package of recommendations on June 24, 1999.

Summary of Alternatives Developed During the Stave River Water Use Plan



In total, the package of recommendations of the Consultative Committee to BC Hydro includes recommendations on:

- an operating strategy;
- an on-going management plan;
- structure and membership of a management committee; and
- timing of implementation and review.

The recommended operating strategy consists of the following elements:

- maintain all of the constraints that had previously been implemented as part of the Electric System Operating Review (ESOR) in 1995, with the exception of the 130 cubic meter per second maximum Ruskin discharge constraint during the fall spawning period. This includes:
  - weekly block loading at Ruskin powerplant during the fall spawning period;
  - minimum water levels (tailwater elevations) year round;
- Implement daily block loading during the period of fry emergence (officially February 15 to May 15, but subject to annual adjustment if mutually agreed with DFO);
- Modify the block loading procedure to allow partial peaking (above 100 cubic meters per second) during both spring and fall block loading;
- Allow for lower than current normal minimum elevations on Hayward Reservoir during the spring and fall block loading periods;
- Provide a six-week deep drawdown on Stave Reservoir for heritage interests one year in three, on average, with timing and depth of drawdown dependent on opportunities provided by inflow conditions and the needs of Kwantlen First Nation;
- Set a soft target 80-81.5 meters for Stave Reservoir elevation during the peak recreation season (with priority given to maintenance of downstream flows).

The recommended management plan consists of four components.

- A fisheries management plan including:
  - Reservoir Productivity Monitor (Phase 1 and 2);
  - Limited Block Loading Monitor; and
  - On-going management activities, including mitigation or other response to information on impacts gained from the monitoring programs.
- A heritage management plan, including:
  - a heritage monitoring plan;
  - on-going inventory, monitoring and assessment of sites throughout the watershed;
  - drawdown work, including inventory, monitoring and assessment as well as mitigation and artifact recovery on sites located at lower elevations of Stave Reservoir; and
  - mitigation activities.
- A drinking water quality monitoring plan, which includes turbidity monitoring in Hayward Reservoir.
- Reporting and administration, which includes:

- preparation, production and distribution of an annual report on management committee activities
- a monitoring plan "custodian" to ensure continuity of the plan.

The management plan costs vary from year to year, but result in a levelized annual cost of about $390,000. (Note that the WUP as a whole has a net gain of $120,000 per year, which is the difference between annual gains in power value of $510,000 and the management plan costs – see Financial performance in the table below.)

The Consultative Committee recommends that a Stave Management Committee be formed, with membership to include the Department of Fisheries and Oceans, Ministry of Environment, Lands and Parks, BC Hydro, Kwantlen First Nation and the District of Mission. Tasks of the Management Committee include:

- design, refine and implement monitoring programs and review results;
- identify and prioritize mitigation needs and implement related activities within the established budget;
- liaise with the Alouette Management Committee to make decisions when and if trade-offs in water allocation are required between Alouette Lake water levels and the Stave system;
- liaise with Kwantlen First Nation on issues related to heritage management;
- prepare an annual public report;
- conduct an interim review after five years.

The Consultative Committee also made recommendations related to the timing of implementation and review:

- Conduct a full review of the Stave River Water Use Plan (involving a comprehensive multi-party consultation process) after ten years. This recommendation is linked to the expected timing of results from monitoring programs addressing key uncertainties.
- Conduct a formal interim review (by the Management Committee) after five years based on monitoring results to date. The purpose is to identify any unexpected results, adjust mitigation plans and budgets accordingly, adjust monitoring plans as necessary to ensure adequate information will be available at the ten year review, and reconfirm the appropriateness of the timing of the ten-year review.
- Implement the recommended operating strategy immediately upon start-up of the Stave Falls Replacement Project.

The impacts from the recommended package are summarized below. Some of the impacts are uncertain. The most significant uncertainties were investigated and a range of values were considered by the Consultative Committee as the trade-offs were evaluated.

SUMMARY OF IMPACTS OF THE RECOMMENDED PACKAGE

OBJECTIVE	IMPACT OF COMBO 6
Fish – Downstream - *Spawning* - *Rearing* - *Egg Stranding* - *Total Gas Pressure*	▪ Slight improvement in overall productive capacity expected (Reductions in spawning habitat offset by improvements in rearing habitat and egg stranding risks)
Fish – Reservoir - *Reservoir Productivity*	▪ 21% increase in overall reservoir carbon production ▪ 830 hectare increase in effective littoral zone
Industry	▪ Better access to loading/off-loading equipment and woody debris on Stave Reservoir ▪ Reduced risk of incurring damage to downstream equipment due to spills
Recreation	▪ More days at preferred elevations during the recreation season ▪ Potential for an improved fishery ▪ No boating access in March, one year in three
Wildlife	▪ Slight improvement due to increased stabilization of Stave Reservoir
Heritage	▪ Improved access and protection for First Nations heritage sites and artifacts
Financial Cost (Relative to ESOR)	▪ Net gain of about $120,000 per year (levelized annual value, calculated as the difference between gains in power values of $510,000 (see Note 1) and on-going management costs of $390,000)
Learning	▪ Substantial knowledge will be gained about reservoir productivity processes and the impact of operations on littoral habitat and fish productivity ▪ Substantial knowledge will be gained about the impact of operations on First Nations interests
Flexibility	▪ On-going management structure and funding allows effective response to new information or priorities

Notes

1. $510,000 is an upper estimate. The actual value will be between $440,000 and $510,000. Lack of precision is due to difficulties in modeling the “opportunistic” one-in-three-year heritage drawdown. The $510,000 figure was used throughout the consultation, with the understanding that it was a slight overstatement of actual benefits. The lower bound of $440,000 was developed by BC Hydro after the consensus agreement of the Consultative Committee.

Eighty percent of Consultative Committee members reported that they “endorse” the package, while twenty percent “accept” it. (See inset on definition of terms.)

Of those recording “accept”, the reasons that prevented them from “endorsing” the package included:

- several participants highly valued the potential for greater ecosystem, fish and aesthetic improvements that they believe could result from greater stabilization of Stave Reservoir;
- one participant had reservations about the high cost of monitoring programs in Years 1 and 2, and would only be able to “Endorse” the package if those were smoothed out (not necessarily to provide a lower overall investment, but to provide a more consistent level of investment from year to year).

Of those reporting “endorse”, minor reservations were expressed by three participants about the cost of the management plan, and the following recommendations made:

- limit the tasks to only those really necessary;
- manage the monitoring work closely to ensure it delivers the intended benefits.

In summary, the Stave River Water Use Plan Consultative Committee succeeded in achieving a consensus on an operating plan and related recommendations to BC Hydro and the Comptroller of Water Rights. The consultation process allowed the development of creative alternatives and the detailed evaluation of two distinctly different operating alternatives. It allowed each participant to apply their own values when making trade-offs among objectives. Through interest-based discussions and negotiation, a consensus agreement was reached which all participants support. The recommended operating strategy provides gains with respect to all objectives, relative to current operations.

Definition of Consensus Used in SRWUP

The following definitions were provided to the CC, and were used to gauge support for the short-listed strategies.

Endorse: You endorse the proposed alternative, either fully or with minor reservations.

Accept: You accept the proposed alternative. You may disagree that the alternative represents the best possible solution, but your minimum needs are met. You may want your views formally recorded, but you accept and support the decision of the group.

Block: You can not support the proposed alternative. Your minimum needs are not met.

“Endorse” and “Accept” both constitute consensus. The more people who are under the “accept” category, the weaker the consensus, but it remains a consensus decision. If anyone in the group finds it necessary to “block”, then consensus is not achieved. Where consensus is not achieved, areas of disagreement will be noted, and we will document what it would take to meet minimum needs.

The process was complicated by uncertainty about a number of impacts. As a result, the consensus agreement is contingent on the implementation of an adaptive management plan that will address key uncertainties and ensure that improved information is available for the next review of the Stave River WUP.

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APPENDICES

1. INTRODUCTION

1.1 Water Use Planning

Water use planning is a new process, introduced by the BC Ministers of Employment and Investment and Environment, Lands and Parks to ensure that provincial water management decisions better reflect changing public values and environmental priorities. A water use plan (WUP) is a technical document that defines how water control facilities (e.g., powerhouses) will be operated. How these facilities are operated will affect many interests in the watershed, such as fisheries, recreation, First Nations, power production, industry, flood control, and others. The goal of water use planning is to develop an operating strategy that achieves the best balance among multiple interests through a participatory, consensus-based process.

Water use planning is designed to address issues related to the operation of facilities as they currently exist, and to identify incremental changes to operations to accommodate other water uses. The process does not directly address issues such as treaty entitlements, historic grievances (dating from facility construction), environmental enhancements or compensation. The focus is on determining how water should be allocated to accommodate different uses[1].

1.2 The Stave River System

The Stave River flows south from the Coast Mountains through the Stave and Hayward Reservoirs, and into the Fraser River (see Map 1). Stave Reservoir is a deep, steep-sided reservoir covering 61.4 square kilometers, and provides the main storage for Stave Falls (52.5 MW) and Ruskin (105.6 MW) Power Plants. Hayward Reservoir is much smaller, providing daily storage for Ruskin Dam, and allowing for hydraulic balance between the two power plants.

The Stave system is hydraulically linked to the Alouette system (see map) via a diversion tunnel which allows flow from Alouette Reservoir into Stave Reservoir. A third generating station, the Alouette power plant (8 MW), produces power at the point of inflow into Stave Reservoir.

All of the facilities are located on the traditional territory of Kwantlen First Nation.

The Stave Falls Powerplant is currently being upgraded through the Stave Falls Powerplant Replacement Project. One of the conditions of the Energy Project Certificate (June 1995) for the project requires that a water use plan be prepared for the water control facilities in the Alouette-Stave Falls-Ruskin hydroelectric system. The Alouette WUP was completed in 1997.

1.3 About This Report

The purpose of this report is to present the recommendations of the Consultative Committee (CC) of the Stave River Water Use Plan to BC Hydro and the Comptroller of Water Rights. This report will be used by BC Hydro as input when preparing the water use plan that will be submitted to the Comptroller for approval. The Comptroller will consider the substantive input of the CC as well as the adequacy of the consultation process when reviewing the proposed water use plan. Accordingly, this report describes:

- the consultation process and analytical approaches used;
- the management objectives and alternatives considered to achieve them;
- the trade-offs associated with the short-listed alternatives;

[1] In some cases, there may be opportunities to undertake physical works as a substitute for changes in flow. If such works are preferable to the flow changes, they may be considered within the WUP process.

- the process for reaching consensus; and
- the degree of support for the recommended strategy.

The Provincial Water Use Plan Guidelines were developed to guide license holders and participants through the process of plan development. The Water Use Planning process is a 13-step process (see inset). The report of the CC addresses Steps 1 through 8.

Steps in the Water Use Planning Process

Step 1	Initiate a WUP process for the facility
Step 2	Scope the water use issues and interests
Step 3	Determine the consultative process to be followed and initiate it
Step 4	Confirm the issues and interests in terms of specific water use objectives
Step 5	Gather additional information on the impacts of water flows on each objective
Step 6	Create operating alternatives to meet different interests
Step 7	Assess the trade-offs between operating alternatives in terms of the objectives
Step 8	Determine and document the areas of consensus and disagreement
Step 9	Prepare a draft WUP and submit it to the Comptroller for regulatory review
Step 10	Review the draft plan and issue a provincial decision
Step 11	Review the authorized WUP and issue a federal decision
Step 12	Monitor compliance with the authorized WUP
Step 13	Review the plan on a periodic and ongoing basis

Section 2 of the report describes the consultation process (Steps 1-3). It describes the structure and mandate of the SRWUP CC and the specific consultation steps taken to meet the needs of Kwantlen First Nation.

Section 3 defines the objectives and performance measures (Step 4). It also includes a brief description of studies requested and funded in order to support the evaluation of alternatives and a description of the modeling methods used to estimate the impacts on the objectives/performance measures (Step 5).

Section 4 describes the process for generating and screening alternatives and provides a detailed summary of the two short-listed strategies (Step 6).

Section 5 describes impact of each short-listed strategy on each objective, and summarizes the key trade-offs between them (Step 7). This section ends by summarizing areas of agreement and disagreement of the CC and the eventual consensus which was contingent on development of a monitoring / management plan (Step 8).

Section 6 describes the management plan, which includes fisheries, heritage and water quality monitoring and management actions, as well as a reporting and custodial function (Steps 6, 7 and 8). The CC's recommendations on implementation and timing of review are also included.

Section 7 summarizes the consensus recommendations of the CC, the degree of support for the recommendations, and several additional considerations that the Committee noted.

2. THE CONSULTATION PROCESS

2.1 WUP Initiation and Issues Scoping

The Stave River WUP was initiated by government announcement in 1996, as one of three priority watersheds to be completed within three years. It was required as part of Energy Project Certificate Condition 14 of Stave Falls Power Plant Replacement Project, issued June 1995 and a condition of the Project water license.

In September 1997, the Stave Falls Powerplant Replacement Project Update announced commencement of the Stave River WUP process and invited individuals to contact a toll free 1-800 number for more details or to indicate their interest in participating in the review process. This notice was distributed to a mailing list of 1,100 people and via a postal drop to the Mission community (approximately 13,000). The notice was also published in the local newspaper.

In consultation with R. Penner (Office of the Comptroller of Water Rights), key stakeholders were identified as individuals or companies who are directly affected by BC Hydro's Stave River operations and/or who had a regulatory responsibility such as federal, provincial and municipal government agencies, First Nations and/or groups who were active in the watershed, as well as local residents.

In the fall of 1997, meetings with stakeholders in the Stave River watershed were held to identify issues and interests. These issues are summarized in the Stave River Water Use Plan Issues Identification Report (Cope Environmental Services, January 1998). The major issues were related to:

- fisheries
- recreation
- power production
- First Nations heritage sites
- industrial operations
- wildlife

A summary of available technical data of water flows and their impacts on water resources was also prepared (Stave Falls and Ruskin Power Facilities – Current Operating Systems Report, August, 1997).

At this stage, all interested parties were invited to participate in the CC. Committee members are listed in Appendix 1.

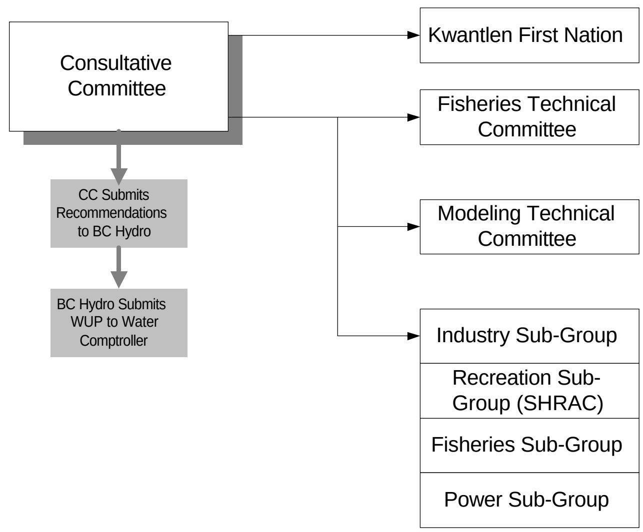
2.2 The Consultative Committee – Structure and Process

In spring of 1998, BC Hydro engaged Compass Resource Management to conduct the trade-off analysis and facilitate CC meetings. Compass's role was to support the quality of decision making by ensuring:

- that the stated objectives reflected the range of interests and that performance measures supported a structured approach to decision making;
- that information provided to the CC was relevant, drawn from reliable sources and correctly interpreted by the CC;

- that a range of alternatives were developed and given fair consideration;
- that key impacts, trade-offs and decision points were identified and clarified for the CC;
- that participants had an opportunity for constructive dialogue and principled negotiations through the meeting process.

Figure 2-2 SRWUP Consultative Committee Structure



Participants were eager to be involved in the SRWUP, but also expressed a desire for BC Hydro to streamline the process to minimize participant time commitments. As a result, the consultation made significant use of sub-committees and working groups (Figure 2-2).

Kwantlen First Nation was consulted separately on issues related to heritage, fisheries and wildlife (see Section 2.3).

A Fisheries Technical Committee (FTC) was formed to address complex technical issues related to fisheries performance measures and impact modeling. Membership of this committee included the Department of Fisheries and Oceans (DFO), the BC Ministry of Environment, Lands and Parks (MELP), BC Hydro, Kwantlen First Nation and local fisheries organizations (Alouette River Management Society and the Stave Valley Salmonid Enhancement Society). The main CC largely delegated issues related to the development of performance measures, modeling methods and assessment of impacts to the FTC.

A Modeling Technical Committee was also formed which addressed the methods used to model BC Hydro operations and power production. In addition to MELP, DFO, BC Hydro, Kwantlen, and the Stave Valley Salmonid Enhancement Society, an independent peer reviewer[2] sat on this committee and reviewed modeling results in detail. The purpose of this committee was to ensure that the modeling methods and results from BC Hydro Power Supply department adequately represented what the CC was asking to have modeled. The peer reviewer provided comment on the technical relevance and adequacy of the methods and tools used.

At various times, four additional working groups were convened:

Industry – This group represented industrial interests on Stave Reservoir and downstream of Ruskin Dam, primarily in forest products industry. It was convened to discuss objectives and brainstorm alternatives.

Recreation – This group represented recreational interests on Stave and Hayward Reservoirs and downstream of Ruskin Dam. The Stave/Hayward Recreational Advisory Council, a pre-existing community organization, was consulted on a variety of issues related to performance measures and the significance of impacts.

Fisheries – This working group included the Fisheries Technical Committee plus some additional non-technical participants with an interest in fish. It was convened to discuss objectives and to brainstorm alternatives.

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[2] Dr. Denis Russell, Department of Civil Engineering, University of British Columbia.

Power – This working group included BC Hydro, the Ministry of Employment and Investment, and various other agencies and participants, who met to develop creative alternatives to enhance power production without compromising non-power interests.

The timing of various consultation activities and milestone meetings is shown in Table 2-1. A full list of consultation meetings is included in Appendix 1.

Participants on the CC were initially confirmed at a 15 December 1997 meeting of interested parties. However, as a result of new initiatives occurring in the watershed, new representatives were welcomed onto the CC at various stages (e.g., Ducks Unlimited). The approach was to be as inclusive as possible while maintaining the integrity and creative balance required to undertake the work. At late stages of the process, if interested parties wished to participate, they were welcomed as observers to CC meetings (e.g., drinking water quality interests).

In addition to the CC, broader public consultation was provided by BC Hydro through the Stave Falls Project Newsletters Editions 6 and 7 (November 1998/99), library displays and an Open House. Newsletters were distributed to the Stave Project mail list (about 1100 recipients) and as a postal drop to the Mission community (roughly 13,000 people). Reports were also available in the Mission library. A final open house will be held in September 1999 to inform the public of the results of the Stave River WUP process.

2.3 Kwantlen First Nation Consultation

The Stave River system falls within the traditional territory of Kwantlen First Nation. The In-SHUCK-ch First Nations have identified an over-lapping claim for a portion of the northern tip of Stave Reservoir; however In-SHUCK-ch confirmed that Kwantlen would represent First Nations interests in the Stave River water use planning process.

Consistent with the scope of water use planning, the WUP consultation with Kwantlen dealt primarily with the impacts of operations and the alternatives for mitigating those impacts through incremental operating changes[3].

Initially, Kwantlen's WUP consultation was conducted parallel to the Consultative Committee process. A number of meetings were held between BC Hydro, Kwantlen and Compass RM to clarify Kwantlen's objectives, to establish performance measures and to identify key information gaps. At Kwantlen's request, studies were conducted in the spring/summer of 1998 to examine the impact of erosion on heritage sites[4].

In addition to their parallel consultation, Kwantlen sat on several working groups of the Consultative Committee, including the Fisheries and Modeling Technical Committees. After a cross-cultural training session for WUP participants in February of 1999, Kwantlen joined the main table of the Consultative Committee and participated in all discussions leading to the consensus agreement of June 24, 1999.

[3] Note that two other parallel processes were on-going throughout the WUP process. For the Stave Falls Replacement Project, Kwantlen continued to be consulted on issues and impacts related to the Project. After the WUP process was initiated, Kwantlen also participated in historical grievance negotiations with BC Hydro to address issues and impacts related to the original construction and inundation.

[4] As a result of the Stave Falls Powerplant Replacement Project, a significant amount of information gathering had been conducted prior to the water use planning process. See Section 3.3.

TABLE 2-1 KEY CONSULTATION ACTIVITIES AND TIMING

TIMEFRAME	ACTIVITY	MILESTONE MEETING(S)
Fall / Winter 1997	Steps 1-3: Initiate WUP and Scope Issues	December 15, 1997: General meeting to confirm issues and identify interested parties
Spring 1998	Step 4: Set Objectives	March/April, 1998: Sub-groups met to set objectives June 18, 1998: CC met to review objectives and consultative process
Spring / Summer 1998	Step 4: Define Performance Measures	FTC and other sub-groups met to define performance measures
Spring / Summer 1998	Step 5: Gather Information	Summer field studies were conducted to fill critical data gaps
Fall 1998	Step 4/5: Develop Models – Power and Habitat Modeling and Performance Measures	October 14, 1998: CC met to confirm performance measures January 21, 1999: CC met to confirm modeling approach
Winter 1999	Step 4/5: Cross Cultural Training	February 9, 1999: Hosted by Kwantlen First Nation
Winter 1999	Step 6: Identify Alternatives	February 18/19, 1999: Sub-groups (power, fish, heritage, recreation) met to brainstorm operating alternatives
Spring 1999	Step 6/7: Refine Alternatives	March 25, 1999: CC reviewed results and assigned sub-groups responsibility to refine alternatives March/April 1999: Various sub-group meetings
Spring 1999	Step 7/8: Evaluate Trade-offs	May 21, 1999: CC reached consensus on an operating strategy, contingent on development of an adequate management plan
Spring 1999	Step 6/7/8: Develop Management Plan	Various meetings of FTC and Kwantlen First Nation to develop management plan
Spring 1999	Step 8: Consensus Agreement	June 24, 1999: CC reached consensus on a package of recommendations

3. OBJECTIVES AND PERFORMANCE MEASURES

3.1 Objectives

Step 4 of the Water Use Planning process involves confirming issues and interests in terms of specific water use objectives and specific measures for assessing their achievement. A preliminary set of objectives was identified based on the issues as summarized in the Issues Identification Report, March 1998. This preliminary list was reviewed and refined with the CC (and sub-committees) to create the working set of objectives shown in Figure 3-1.

FIGURE 3-1 SUMMARY OF SRWUP OBJECTIVES

1. Avoid disruption to industrial operations
   - maintain access to loading/offloading equipment
   - avoid impacts from downstream flooding
2. Support recreational opportunities
   - support Stave Reservoir activities
   - support Hayward Reservoir activities
   - improve safety downstream of Ruskin Dam
3. Support viability of wildlife populations
   - maintain reservoir level stability
   - maintain downstream water level stability
   - ensure periodic flooding of riparian areas
4. Protect and preserve First Nations heritage values
   - protect sites from erosion and illegal collection
   - preserve access to sites
   - recover and interpret artifacts
5. Support viability of fish populations
   - increase spawning capacity
   - increase rearing capacity
   - reduce stranding
   - reduce risk of exposure to elevated levels of TGP
   - increase reservoir productivity
6. Avoid cost increases for electricity production
   - minimize cost of replacement electricity and/or additional programs or works
7. Maximize flexibility to respond to change
   - maximize resilience to and ability to respond to electricity market volatility, scientific uncertainties, etc.
8. Gain knowledge about the system and impacts
   - maximize learning about key uncertainties that affect decision making

Avoid Disruption to Industrial Operations

Industrial users of Stave Reservoir and the river downstream of Ruskin Dam were concerned about large spills that occur without sufficient notice to allow industry to take action to protect equipment from damage and excessively low reservoir levels that would prevent access to loading or offloading equipment or prevent the removal/collection of woody debris.

Support Recreational Opportunities

The Stave Lake Reservoir Integrated Recreation Plan (DLC, 1997) considered a wide range of recreation-related issues and identified preferred operating levels which best met recreational interests. Primary recreation interests on Stave and Hayward Reservoirs include family-oriented recreation, boating and fishing. Hiking, birdwatching and other activities also occur. Downstream of Ruskin Dam, family-oriented recreation, swimming and fishing are the dominant uses affected by operations[5].

[5] See also Hayward Lake Recreation Plan (BC Hydro, 1998).

Support Viability of Wildlife Populations

Based on the Stave River Valley orientation, logging history and stand structure, this area is of low priority relative to other areas of the province, according to both BC Hydro and MELP wildlife management assessments. (Wildlife values only increase on the south-facing slopes that look over the Fraser Valley at the very end of the Stave River Valley.)

As a result, each operating strategy was qualitatively assessed for its likely effect on the key factors affecting wildlife. It was agreed that if there was reason to expect significant negative impacts on wildlife as a result of a proposed strategy, further investigation would be undertaken. (This did not prove necessary.)

Protect and Preserve First Nations Heritage

The Stave River system lies within the traditional territory of the Kwantlen First Nation. Kwantlen First Nation, along with British Columbians, has an interest in understanding how Kwantlen's ancestors lived and in uncovering parts of their heritage. Kwantlen is interested in protecting heritage sites from erosion and illegal collection (pot-hunting), accessing sites (for mitigation and inventory purposes as well as cultural and spiritual activities), and recovering artifacts.

Support Viability of Fish Populations

Since the late 1980's, a significant amount of work has been done to enhance fisheries downstream of Ruskin Dam. Little has been done in the reservoir. The objectives of this WUP were to maintain or enhance the gains already achieved downstream of Ruskin Dam[6] and to improve fisheries in Stave Reservoir. The Fisheries Technical Committee established five sub-objectives which it felt needed to be addressed in the WUP. Four addressed maintaining or enhancing downstream fisheries – spawning habitat, rearing habitat, risk of egg stranding, and risk of mortality from Total Gas Pressure[7]. One of the sub-objectives, reservoir productivity, addressed the desire to enhance fish habitat in Stave Reservoir (specifically the littoral zone[8] and a limited area of cutthroat spawning/rearing habitat). The FTC felt strongly that the objectives should be related to habitat, and not summarized in a single measure of fish population since population modeling can be the subject of much scientific debate, and since the mandate of the fisheries agencies is specifically targeted to protect and restore fish habitat.

Avoid Cost Increases for Electricity Production

If operations in the Stave system are constrained, the amount and/or value of electricity from the three power plants – Stave Falls, Ruskin and Alouette – will be reduced. Since BC Hydro is a Crown Corporation, reductions in the value of electricity produced at Stave represent a cost to the province as a whole. The objective from a cost perspective is to meet non-power needs at the lowest possible cost in terms of power values.

Maximize Flexibility to Respond to Change

There are economic, scientific and technical uncertainties about electricity price forecasts and the impacts of operations on fisheries and other objectives. The flexibility objective simply states a desire to maintain the ability to respond to new information as it becomes available. The main implication of identifying this objective is that it suggests the need for a flexible form of on-going management structure.

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[6] The target species is chum salmon. It is assumed that other species will also benefit to some extent from improvements targeted at chum.

[7] When water falls from height into a deep pool (for example, over a waterfall or when spilled from a hydroelectric facility), air can be forced into the water producing elevated levels of Total Gas Pressure (TGP). Elevated TGP has the potential to cause gas bubble trauma disease in fish, which can lead to fish mortality and/or reduced productivity.

[8] The littoral zone is an important biologically productive area along the shore of a lake that can provide food and habitat for a range of aquatic life.

Gain Knowledge about the System and Operational Impacts

If the quality of decision making is hindered by a lack of knowledge, then it is possible that an investment in learning may be justified. That is, participants may be willing to trade-off financial or other benefits in order to generate better information for future decision making. This objective explicitly recognizes participants' interest in improving the information on which decisions are based.

Flood Control

The Consultative Committee did not explicitly identify any concerns with flood control, other than those expressed by industry with respect to damage of equipment if inadequate notification of spills was provided. Thus, generalized flood mapping and assessment were not considered necessary in this case and a general flood control objective was not identified. Note however that flood control implications for the recommended strategy were examined as a final confirmation that no adverse impacts on flood control capability would occur and these effects are reported in the Stave River Water Use Plan itself.

Water Quality

It was not initially anticipated that the WUP would have any effect on water quality and it was not stated as an objective. However, water quality issues were raised subsequently in an open house. Interested parties were invited to attend the remaining CC meetings as observers. Further, when a change was proposed to the Hayward Reservoir operations (the source of drinking water for a number of local residents), water quality interests were addressed through the recommendation of a water quality monitoring plan (see Section 6).

3.2 Performance Measures

For each objective, performance measures were developed. Performance measures define exactly how progress toward the objectives will be measured. They become the evaluation criteria when comparing alternatives.

Usually, performance measures are directly related to fundamental ends, not means. For example, it is theoretically better to measure the impact of an operating alternative on fish populations rather than on exposure to TGP, since it is population that we really care about and we only care about TGP insofar as it affects fish populations. However, there are usually practical limitations that force performance measures to be somewhat more means-oriented. (For example, the scientific uncertainty associated with modeling fish populations and the mandate of regulators to focus on habitat, as described above.)

Performance measures were developed through discussions with sub-groups of the CC. Influence diagrams were used to guide thinking about the factors that affected the objective, and these diagrams helped to drive the selection of performance measures. Figure 3-2 is an example influence diagram showing the drivers of reservoir productivity. The shaded circles show the factors that were developed into the "Effective Littoral Zone" performance measure. While they are not necessarily the most dominant factors affecting productivity, they are the factors most affected by reservoir operations (reservoir levels). Later in the process, as reservoir productivity became a key factor affecting preferences among alternatives, this performance measure was refined to better estimate the net effect on total reservoir productivity, including consideration of all factors (see below).

For each objective, one or more performance measures were identified. (See Tables 3-1 and 3-2 for fisheries and non-fisheries performance measures). Some performance measures (e.g., fisheries) had several components which were combined into a weighted normalized index[9].

[9] If the components of a performance measure differ in scale and/or data type, then normalizing is a mathematical technique that reports a unitless value between 0 (worst) and 1 (best) for the overall performance of each operating strategy under consideration. If the components differ in their relative

For example, to estimate the impact of operations on spawning habitat, it was determined that three impacts must be assessed (see row 1 of Table 3-1):

- quantity of spawning habitat (in hectares);
- variability in spawning habitat area from day to day;
- variability in spawning habitat area within-days (this reflects plant peaking operation).

The Fisheries Technical Committee assigned weights to each component. Scores for each alternative under consideration were normalized before calculating the weighted normalized index value. The index value represents the condition of the habitat and its capacity to support spawning. While total spawning capacity is not directly measured, the index effectively shows the preferred ranking of alternatives (with 0 being worst and 1 being best) from the perspective of spawning capacity only.

A normalized index was calculated for each of the five fishery objectives, as well as most non-fishery objectives. The normalized indices were used at the early stages of the evaluation process where a large number of alternatives were being screened. They were particularly useful for assessing the impacts on downstream fish, and were successfully used to screen out alternatives that risked compromising the gains already achieved in downstream fish populations. Once a small number of alternatives were short-listed, the Fisheries Technical Committee and the CC reviewed the detailed data underlying the normalized indices, and considered additional quantitative or qualitative data.

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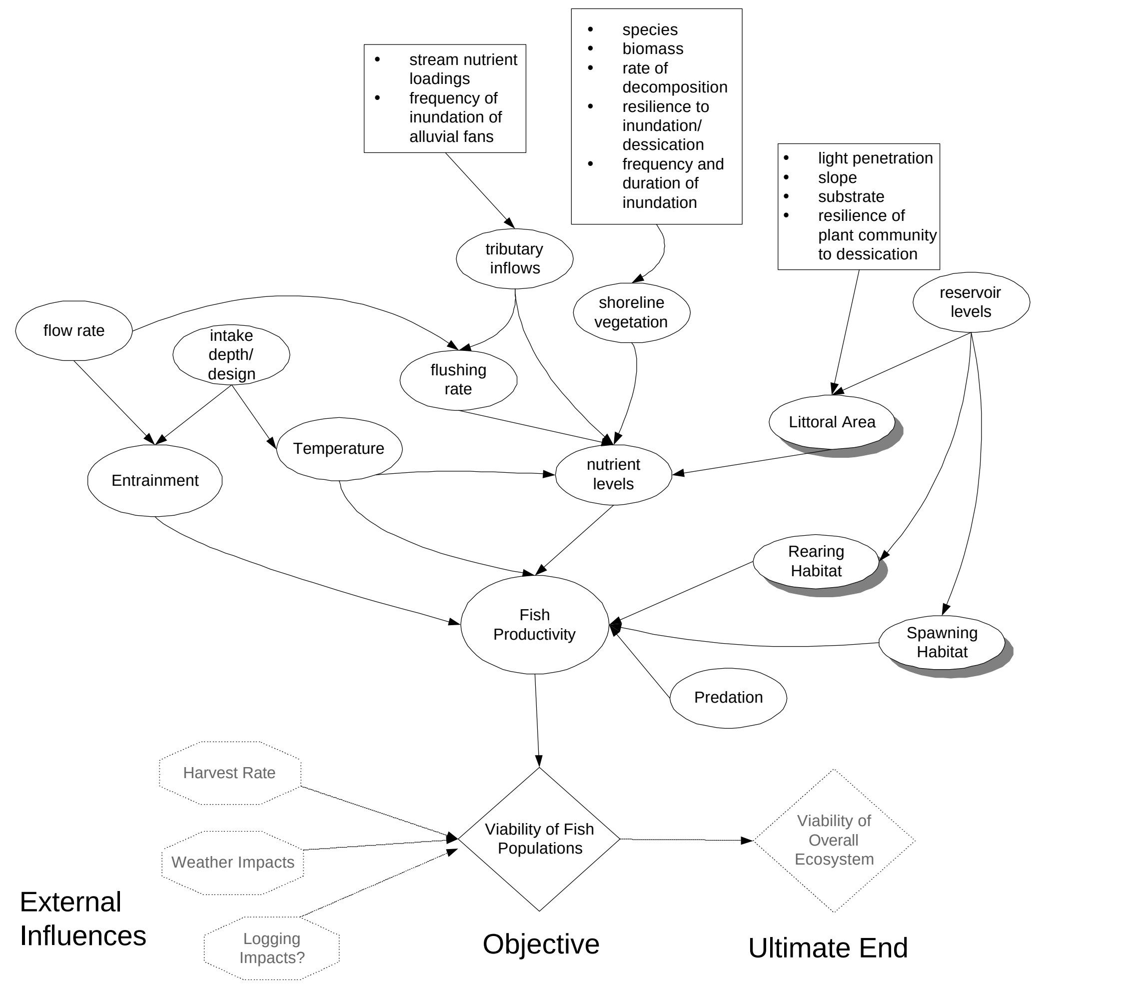
importance, then weighting functions are applied to ensure that relative importance is reflected. See the normalization information sheet in Appendix 2.

FIGURE 3-2 INFLUENCE DIAGRAM FOR FACTORS AFFECTING RESERVOIR PRODUCTIVITY



As noted above, the Effective Littoral Zone measure (or ELZ) is one of several drivers of reservoir productivity, and is the one most affected by reservoir operations. It was used to flag major differences among operating alternatives. When in fact an opportunity was found to significantly increase ELZ, further investigation was required to estimate how this would affect overall reservoir productivity. The performance measure that was eventually used to compare short-listed alternatives was the estimated carbon productivity of the reservoir – a measure of the overall biological productivity of the reservoir.

The performance measures and how they are calculated or modeled are described in detail in Appendix 2. These "Information Sheets" were issued to the CC in January 1999 as reference material[10].

[10] Some performance measures were refined after that time. In the case of discrepancies between the Information Sheets in Appendix 1 and the text of this report, the report is the more accurate representation of the information that was used in decision making.

TABLE 3-1 SUMMARY OF FISHERIES PERFORMANCE MEASURES (1)

OBJECTIVE	PERFORMANCE MEASURE COMPONENTS	INTERPRETATION OF THE INDEX VALUE
Spawning	▪ Quantity of habitat ▪ Daily Variability ▪ Within-day variability	Measure of the condition of spawning habitat downstream of Ruskin Dam and its ability to support spawning(2).
Rearing	▪ Daily Variability ▪ Within-day variability ▪ Side channel availability	Measure of the condition of rearing habitat downstream of Ruskin Dam and its ability to support rearing juveniles(2).
Egg Stranding	▪ Median risk ▪ Extreme Risk	Measure of the risk of dewatering incubating eggs or alevins(2).
Total Gas Pressure	▪ # of days on which TGP is between 103 and 110% after a period of 28 consecutive days of elevated levels ▪ # of days on which TGP exceeds 110% (no threshold).	Measure of the risk of direct mortality from exposure to elevated levels of TGP(2).

Reservoir Productivity (3)	▪ Effective Littoral Zone:
	  ▪ area productive at least 80% of year
	  ▪ area productive at least 50% of year
	  ▪ # days cutthroat spawning/rearing habitat is available
	➢ Overall Reservoir Productivity
	  ➢ tonnes of carbon
		▪ Measure of the productivity of the littoral zone of Stave Reservoir(2) - this measure used to screen preliminary alternatives.
		➢ Measure of the overall productivity of Stave Reservoir – this measure used to compare the short-listed alternatives

Notes:

1. For a detailed description of performance measures, see Appendix 2.
2. Weights for each component provided by the Fisheries Technical Committee.
3. Two performance measures were used to assess the impact of BC Hydro operations on the productivity of the reservoir, effective littoral zone and total carbon productivity. The Effective Littoral Zone performance measure assesses the quantity of potentially productive area in Stave Reservoir. The ELZ was used to screen a large number of alternatives. The total carbon productivity performance measure estimates the amount of carbon production in the reservoir as a whole, based on base assumptions about other factors driving productivity, and the different littoral areas estimated for each operating alternative. Total carbon productivity was estimated only for the short-listed alternatives.

TABLE 3-2 NON-FISH PERFORMANCE MEASURES (1)

OBJECTIVE	PERFORMANCE MEASURE COMPONENTS	INTERPRETATION OF THE INDEX VALUE
Industry	▪ # days of access to loading/offloading equipment on Stave Reservoir (dependent on water levels) - spring - summer/fall	Measure of effects on industry, with spring access and summer/fall access weighted equally (Note that downstream industrial interests are adequately addressed by the new spill notification protocol.)
Recreation	▪ Weighted average # days from May to Oct that Stave Reservoir level is between: - 80 - 81.5 m (highest weight) - 78 - 80 m - 76 – 78 m (lowest weight) ▪ Downstream safety ▪ Impact on Hayward Recreation	Measure of the degree of support for recreational activities on Stave Reservoir. (Index does not include downstream safety or Hayward impacts; these are considered qualitatively.)
Wildlife	▪ Changes in reservoir stability ▪ Changes in downstream fluctuations and flushing of riparian zones	No index value. A qualitative assessment of effects was conducted simply to look for anything that would flag a potential issue.
Heritage	▪ # site-days of access ▪ # site-days of protection (submergence in high recreation season) ▪ Risk of erosion	Measure of impacts on heritage sites on Stave Reservoir, with all sites equally weighted. (Erosion and submergence are not included in the index.)
Financial Cost	▪ Annual levelized value of replacement generation in 1998$	Measure of the average loss or gain in financial value of power production. Note that this value will vary widely from year to year; this is an average levelized value.
Learning	▪ Number of key uncertainties reduced	No Index
Flexibility	▪ Flexibility to respond to new information on environmental conditions, operational impacts and public values	No Index

Notes:

1. For a detailed description of performance measures, see Appendix 2.

3.3 Preliminary Information Gathering

As the performance measures were developed, a number of uncertainties related to fisheries impacts were identified. Studies to address these information gaps were proposed and prioritized by the Fisheries Technical Committee according to the following criteria:

- does the study provide information that is essential to build confidence that the performance measure accurately represents the impact of alternatives on the objectives?
- does the study provide information that could help weight performance measures (i.e., does it help answer the question "how important is this effect?")?
- does the study provide information that could change the ranking of alternatives (i.e., within a plausible range of values, could refinement of an assumption change the ranking of alternatives)?
- is the information expected to be transferable to other watersheds?
- is the information useful for evaluating the impacts on more than one performance measure or objective?

See Appendix 3 for a summary of the studies, their purpose and cost.

Studies related to the impacts of operations on First Nations interests were also identified and prioritized with Kwantlen First Nation. As a result the following studies were conducted:

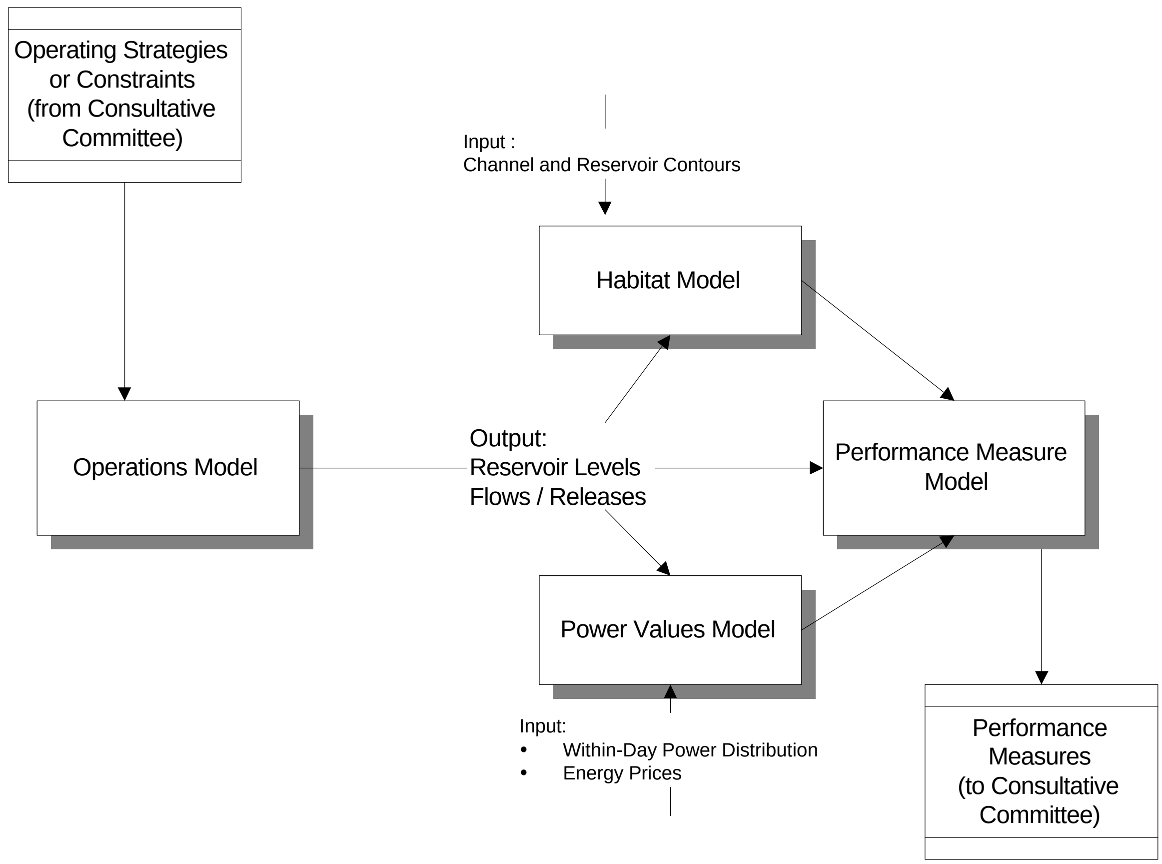
- Erosion Studies of First Nations heritage sites – Stave Reservoir and downstream of Ruskin Dam. The studies addressed: how are First Nations heritage sites being affected by erosion and to what extent is erosion caused by BC Hydro operations?

In addition to WUP-funded studies, substantial archeological investigations were funded through the Stave Falls Powerplant Replacement Project, as were studies on water quality, sediment contamination, mercury contamination in fish tissue, and a traditional use study.

3.4 Overview of Modeling

A variety of models were used to predict the impacts of alternative operating strategies on the objectives and performance measures (Figure 3-3).

Figure 3-3 Overview of Modeling Approach



Operating alternatives are created by imposing various combinations of constraints, within which the system is optimized. Once the CC developed an alternative to be modeled, the constraints were entered into an operations model[11]. The operations model optimizes operations for power production. It uses 27 different years of data on inflows to the watershed from which the median, average, 90th percentile or any other statistical value can be extracted.

The primary output of the operations model is a set of data describing reservoir levels and flows through or releases from dams on each day of each year, along with daily power production. These data are used as input to two additional models.

The habitat model combines information on plant discharge flows and water levels with information about the physical contours of the reservoir and the river channel to allow estimation

[11] The Small Reservoir Systems (SRS) model was used to model the majority of the operating constraints. SRS is a commercially-available model which was developed to assist hydro system planners and operators of multiple reservoir systems. The program uses stochastic dynamic programming for individual reservoirs and linear programming to coordinate storage between reservoirs. The model is run in daily time-steps. The Acres Reservoir Simulation Package was used to cross-check SRS results for a limited number of cases, to ensure there were no gross discrepancies. See the Stave River WUP Power Studies Report (Kerr, 1999).

of additional parameters such as water depth. These data are further processed to calculate the performance measures as defined in Section 2.2.

Plant discharge flow data are also routed through a power values model[12] which takes information about dispatchability[13], energy prices[14] and plant characteristics to calculate the value of the power that will be produced under each alternative. The performance measure for a given operating alternative is the difference between the value of power produced under that alternative, and the value produced under the "ESOR" base case.

"ESOR" is the mode of operation that was implemented after the 1994 Electric System Operating Review. In April 1995, operations were reviewed and changes implemented to provide some consideration for non-power interests. At Stave, it primarily provided better protection of downstream fish, and included:

- minimum flows for the river downstream of Ruskin
- weekly block loading (no peaking) and maximum discharge constraints at Ruskin during the fall spawning period

The ESOR base case was modeled assuming the new Stave Falls powerplant operating under the existing ESOR constraints. See the BC Hydro report Stave River WUP Power Studies Report (Kerr, 1999), Section 5.1.1, Existing Operating Constraints, for a full description of the ESOR constraints.

Additional information on how the fisheries and other performance measures are calculated are included in the Information Sheets in Appendix 2 and in BC Hydro's SRWUP Data Report: Habitat Modeling and Performance Measure Calculations (Bruce, 1999).

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[12] Actually, a series of models – see Figure 4 of BC Hydro's Stave River WUP Power Studies Report (Kerr, 1999).

[13] As the SRS model does not permit the redistribution of energy within each daily time step, a spreadsheet model was developed for this purpose. To reflect these within day variations in energy values, two daily prices are input into the spreadsheet (high and low). A "dispatchability" multiplier is applied to reflect the degree of flexibility plant operators have in dispatching the available generation at peak times. See BC Hydro's Stave River WUP Power Studies Report (Kerr, 1999).

[14] From BC Hydro's Value of Energy (VOE) spreadsheet. The VOE spreadsheet combines short-term price forecasts (derived from forward market prices) with medium-term price forecasts generated using the Henwood model. This is a proprietary model developed by Henwood Consultants and is used by many other utilities. The model forecasts data for 13 regions (over 15,000 generating stations) in Western North America. Forecasts beyond 2004 are based on the cost of new generation (assuming this generation comes from Combined Cycle Gas Turbines) with projections for long-term gas prices. To these annual costs a yearly energy price shape is applied. The annual price shape was derived from Henwood model results and historical market data. The Lower Mainland price forecasts were levelized over an assumed 70-year life of the agreement using a constant price beyond 2004 (in real dollars) and an 8% discount rate.

4. ALTERNATIVES

4.1 Actions Undertaken Immediately

Early in the consultation process, it became clear that most of the concerns of industry could be met by providing them with adequate notification in advance of spills. As a result, a fax-out spill notification system was established and implemented immediately. With adequate notification, industrial users of the river downstream of Ruskin Dam can avoid any damage to equipment and minimize disruptions to their business. No further alternatives were needed to address this interest.

In addition, local residents identified an opportunity to reduce fry stranding and improve public safety through a habitat enhancement project downstream of Ruskin Dam. This work was undertaken in partnership with DFO, Kwantlen First Nation, and BC Hydro (funded by the SRWUP project) in the fall of 1998.

4.2 Preliminary Operating Alternatives

Operating alternatives include rules or procedures for operating water control facilities, for example, constraints on peak or low flows, maximum or minimum reservoir water levels, etc.. These constraints may be valid for specific facilities, at specific times of the day or specific seasons of the year. Thus, individual constraints (or alternatives) are combined into an annual operating strategy that is then modeled to assess impacts on all objectives.

Once objectives and performance measures were established and BC Hydro developed the modeling capability to estimate impacts of operating alternatives on the objectives, four working groups of the CC met to brainstorm alternatives for meeting objectives. Each working group met for a half day. The mandate of each group was to think creatively about operating alternatives that would better meet their needs (e.g., the Fisheries group focussed on fisheries alternatives, the Heritage group on heritage alternatives). However, given what they already knew about other objectives, each group was to look for creative win-win alternatives that would improve all interests.

The emphasis in the sessions was on operating alternatives. However, non-operational options were also identified and recorded. Table 4-1 summarizes the operating alternatives that were brainstormed.

TABLE 4-1 PRELIMINARY OPERATING ALTERNATIVES

RUSKIN DAM	STAVE RESERVOIR	HAYWARD RESERVOIR
Base: ESOR constraints downstream of Ruskin F5: Add spring block load at Ruskin F6: Remove 130 maximum flow constraint at Ruskin P1: Modify block loading to allow partial peaking P3/P4: Reduce minimum flow downstream of Ruskin to 48/40 cms	F1: Stabilize Stave at 79-81 m F2: Stabilize Stave at 77-79 m F3: Stabilize Stave at 75-77 m F4: Stabilize Stave at 77-80 m H1: Annual Drawdown - 3 weeks H2: Annual Drawdown - 6 weeks R1: Target elevation at Stave of 80-81.5 m in summer	P2: Lower minimum normal water level at Hayward to 39.5 m

Notes to Table 4-1:

1. F1-F5 were generated by the Fisheries subgroup, H1 and H2 by Heritage, R1 by Recreation and P1-P4 by Power.
2. The components that were considered further are described in more detail in section 4.4.

These individual alternatives were refined into operating strategies. A “strategy” includes various combinations of constraints at each facility at various times of the year. Table 4-2 shows an example of an operating strategy. All strategies considered are described in this format in BC Hydro’s Stave River WUP Power Studies Report (Kerr, 1999).

TABLE 4-2 EXAMPLE OF AN OPERATING STRATEGY (1)

Op Mode	Timing		Season	Peak-ing	Flow Constraints		Reservoir Constraints		Remarks
	Start	End	Description	Y/N	Min	Max	Min	Max	
1	Jan 1	Feb 14	Incubation	y	55	-	-	-	
2	Feb 15	May 15	Fry Emergence	n	55	-	-	-	limited daily block loading
3	May 16	Jul 31	Fraser River Backwater and peak recreation season	y	-	-	80	-	recreation target
4	Aug 1	Sep 7	Summer rearing and peak recreation season	y	55	-	80	-	recreation target
5	Sep 8	Oct 14	Rearing	y	55	-	-	-	
6	Oct 15	Dec 2	Spawning	n	55	-	-	-	limited weekly block loading
7	Dec 3	Dec 31	Incubation	y	55	-	-	-	

Notes to Table 4-2:

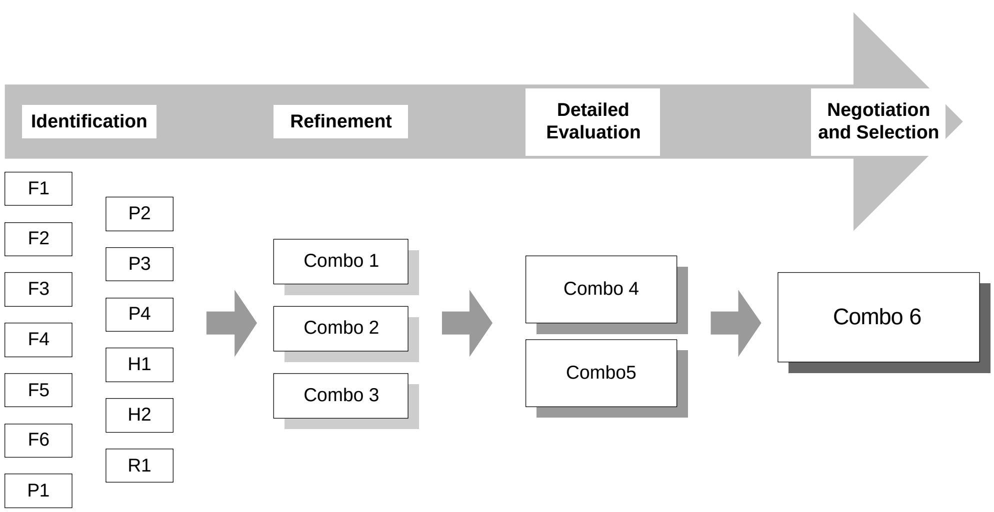
1. To Read Table 4-2: Under operating mode 1, in effect January 1 through February 14 for the incubation season, peaking is allowed and the only constraint is a minimum flow constraint of 55 cms through Ruskin Dam. During the period of fry emergence (February 15 to May 15), operating mode 2 comes into effect. During this period no peaking is allowed (a daily block load is in effect) and the minimum flow of 55 cms is maintained. During the period May 16 to July 31 (operating mode 3), fry are still emerging, but the Fraser River backwaters. As a result, peaking operations have limited effect on fish, so the minimum flow constraint is removed, and peaking is allowed. At this time, the peak recreation season begins and a target elevation is set for Stave Reservoir of 80m. Operating mode 4 starts by August 1 when the Fraser River backwater ends, and involves a return of the 55 cms minimum flow and a continuation of the recreation target. Operating mode 5 is in effect from September 8 to October 14, when rearing continues but the peak recreation season ends. Operating mode 6 starts with the spawning season on October 15. A limited weekly block load is in effect along with a minimum flow of 55 cms. Operating mode 7 is the same as operating mode 1.

4.3 Alternative Screening Process

Figure 4-1 summarizes the alternative development process. Twelve strategies were generated initially (“Identification”) and presented to the CC as follow-up to the sub-group meetings. These were refined into three combination strategies, which combined various individual strategies into what became known as “combo” strategies (Refinement). The Committee, after reviewing the impacts of each of the individual and combo strategies, assigned a working group to further refine the combo strategies to better integrate power, heritage and recreation-related alternatives.

The working group reviewed the summary of performance measure results for each strategy (Appendix 4) and used it as a screening tool for eliminating clear losers and recombining alternatives. The result was the creation of Combos 4 and 5. These were distinctly different strategies which, while they had some common elements, represented fundamentally different ways of operating Stave Reservoir. Combos 4 and 5 underwent detailed evaluation. Combo 6 was created through the negotiation process, and essentially added an on-going management plan to the Combo 5 operating strategy.

FIGURE 4-1 ALTERNATIVES DEVELOPED FOR THE STAVE RIVER WATER USE PLAN



The trade-offs related to the short-listed alternatives (Combos 4 and 5) are presented in detail in the next section.

Two highlights of the discussions and refinements made to the preliminary alternatives prior to short-listing Combos 4 and 5 include:

- Kwantlen agreed to an opportunistic drawdown that occurs only when inflows are favorable, on average one year in three
- The relevance of the recreation performance measure was debated when used to evaluate an alternative which involves a significant change from current operation – although the preferred elevations were taken from the Stave Lake Reservoir Integrated Recreation Plan, some participants felt that they were short-sighted and did not adequately reflect the longer term benefits that could accrue from a significantly different operating strategy. This was addressed by augmenting the performance measure with a qualitative description of longer term impacts and uncertainties.

4.4 Short-Listed Alternatives

To refine the twelve preliminary alternatives, sub-group meetings of the Fisheries Technical Committee, Recreation, Wildlife, and Heritage interests were held. This section summarizes the short-listed alternatives – Combo 4 and 5.

The following components are used to create the Combo 4 and Combo 5 operating alternatives.

ESOR. Includes flow constraints downstream of Ruskin Dam, including "weekly block loading" for the fall spawning period. Block loading prevents peaking. Load (and flow) changes are allowed only once per week. These constraints are in place for the protection of spawning and rearing fish habitat.

Spring Block Loading. Daily block loading (allowing load changes only once per day) is in place to protect young salmon (emerging fry salmon), in effect from February 15 to May 15.

Limited Block Loading (LBL). Both spring and fall block loading is modified to allow peaking above a threshold (tentatively 100 cms, but subject to refinement); this modification is called "limited block loading" and increases the value of power produced during the block loading period. It is believed to have minimal effect on adult stranding and may even reduce egg stranding.

Remove 130 cms Maximum Flow Constraint. ESOR contains a constraint requiring that flows not exceed 130 cms during the spawning season. (This has since been removed under the Interim Flow Agreement.)

Minimum Elevation Change at Hayward. The minimum elevation of Hayward Reservoir is dropped by 1.5 m to 39.5 meters during the period October 15 to December 1 and February 15 to May 15. This component allows increased flexibility to produce power at Stave Falls Power Plant during periods constrained by block loading.

Six-week drawdown on Stave Reservoir. A six-week drawdown will be declared in years when inflow predictions appear favorable for a deep and extended drawdown. One month notice will be provided to Kwantlen, industry and other users of the reservoir, and the planned drawdown will not extend beyond March 31, or begin prior to January 1. Drawdown elevation to be determined by inflows and Kwantlen needs, but may be as low as 72 meters. On average, it will occur one out of every three years.

Recreation Season Target of 80-81.5 m. An elevation target of 80-81.5 meters is in effect from May 15 to September 7. The target is a "soft" target, which means it will be violated if necessary to meet downstream flow requirements as established under ESOR for the protection of downstream fish. This is the preferred elevation for recreational activity on the reservoir.

Year-round Reservoir Target of 77-79m. A reservoir elevation target of 77-79 meters is in effect year-round. The target is a "soft" target, which means it will be violated if necessary to meet downstream flow requirements as established under ESOR for the protection of downstream fish.

In practice, the upper bound will be frequently violated. Several target elevations were examined (see Table 4-1). This one had the best potential for eliminating negative effects on downstream fish and minimizing impacts on reservoir recreation.

Table 4-3 summarizes the components included in each short-listed alternative.

TABLE 4-3 COMPONENTS OF COMBOS 4 AND 5

	ESOR	COMBO 4	COMBO 5
ESOR	✓	✓	✓
Spring Block Loading		✓	✓
Limited Block Loading		✓	✓
Minimum Elevation Change at Hayward		✓	✓
Remove 130 cms Maximum Flow Constraint		✓	✓
Six-week Drawdown on Stave Reservoir			✓
Recreation Season Target of 80-81.5m			✓
Year-Round Reservoir Target of 77-79m		✓	

Combo 4 was specifically designed to increase the stability of the reservoir for the primary purpose of enhancing reservoir productivity. It was proposed that this strategy could also improve the viability of the riparian ecosystem in the area above 79 meters, and thus improve the aesthetic and recreational value of the area, ultimately increasing recreational use. Because the upper and lower bounds (of the target water level) are allowed to be violated in order to protect minimum flows required for the protection of downstream spawning and rearing habitat, Combo 4 provides reduced fluctuations (reduced in magnitude and frequency) relative to ESOR, but not a fully stable reservoir.

Combo 5 is a refinement of ESOR operations. The significant differences from Combo 4 are that it sets a soft target of 80-81.5 meters for the reservoir elevation from May 15 to September 7 to accommodate recreational interests, and it commits to a six-week drawdown one year in three (on average) to accommodate heritage interests. Although it does not set a year-round reservoir target in an explicit attempt to stabilize the reservoir, modeling suggests that in combination with the proposed downstream changes, this strategy will also improve the stability of Stave Reservoir, albeit to a lesser extent than Combo 4.

Downstream of Ruskin Dam, both of the short-listed strategies contain the same components. This demonstrates the success of the process in finding joint gains through a creative option identification process. In Stave Reservoir, the short-listed strategies represent fundamentally different approaches to operations. The choice between them is value-based.

Elevation profiles showing water levels in Stave Reservoir throughout the year illustrate the main differences between ESOR, Combo 4 and Combo 5. These are shown in Appendix 5.

5. TRADE-OFF ANALYSIS

5.1 Summary of Impacts Using the Performance Measures

Table 5-1 summarizes performance measures for ESOR, Combo 4 and Combo 5. ESOR is the base case (see Section 3.4). The performance measures shown are for the median year (median out of 27 years of inflow data). Note that higher values indicate better performance.

There are some reductions in spawning habitat relative to ESOR. This is offset by improvements in rearing habitat and egg stranding. On the whole, the Fisheries Technical Committee has indicated that they do not expect downstream fisheries to be negatively affected by either Combo 4 or Combo 5. The preservation of gains in downstream fish populations made over the past few years under ESOR was an important consideration in all FTC discussions.

TABLE 5-1 SUMMARY OF IMPACTS USING THE PERFORMANCE MEASURES

	ESOR	COMBO 4	COMBO 5
Rearing	0.66	0.83	0.81
Spawning	0.73	0.64	0.65
Egg Stranding **	0.54	0.70 (0.43)	0.58 (0.47)
Total Gas Pressure	1.00	1.00	1.00
Reservoir Productivity (ELZ)	0.31	0.74	0.58
Heritage	*	*	*
Industry	0.58	0.68	0.73
Recreation	0.37	0.33	0.42
Wildlife	*	*	*
Financial Cost	0.32	0.30	0.40

Notes to Table 5-1:

* Quantitative Performance Measure not used.

** In addition to median year data, we also tracked the 90th percentile data which tells what could happen in unusual inflow years (one year in ten). To avoid an overload of data, these data are shown only when they differ substantially from median. Here, they are shown in brackets for Egg Stranding. Note that under median conditions, Combo 4 is better than Combo 5 for Egg Stranding. However, in extreme conditions, Combo 5 is better than Combo 4 for Egg Stranding. In both cases (median and 90th percentile for egg stranding), the difference between combos is relatively small.

Combos 4 and 5 perform very similarly on several performance measures. Further discussion centered on the key differences or trade-offs. These are highlighted in Table 5-2. A "✓" indicates the combo that performs better for each performance measure. A "—" indicates the performance of the combos is the same. The ? opposite recreation under Combo 4 indicates that some participants felt that Combo 4 would be good for recreation in the long term if the improvements in reservoir productivity resulted in a better fishery.

TABLE 5-2 SUMMARY OF KEY TRADE-OFFS

	COMBO 4	COMBO 5
Fish - Downstream	—	—
Fish - Reservoir	✓	
Heritage		✓
Industry	—	—
Recreation	?	✓
Wildlife	—	—
Financial Cost		✓

Most of the discussion by the CC centered on the facts and value judgments surrounding these key trade-offs. Specifically:

- How big is the gain in littoral zone productivity under Combo 4 versus Combo 5? How do you value the gains given the uncertainty about how it will affect fish populations?
- How big are the gains in heritage, recreation quality and power value under Combo 5 versus Combo 4? Would recreation quality improve in the long term under Combo 4?
- How important are these losses and gains? On balance, which combo do you prefer? Which one do you think best meets all interests and objectives?
- Are there any opportunities to refine the combos to improve them?

The impacts of Combo 4 and Combo 5 are briefly summarized in Table 5-3. More detailed discussion is provided in Section 5.2.

TABLE 5-3 MULTIPLE ACCOUNT EVALUATION OF COMBO 4 AND COMBO 5

	COMBO 4	COMBO 5
Fish – Downstream - *Spawning* - *Rearing* - *Egg Stranding* - *Total Gas Pressure*	▪ No change from ESOR; no difference between Combos (Reductions in spawning habitat offset by improvements in rearing habitat and egg stranding)	
Fish – Reservoir - *ELZ (1)* - *Reservoir Productivity*	▪ 1440 hectares of ELZ (1) ▪ 33% increase in carbon ▪ Uncertain benefits for fish	▪ 840 hectares of ELZ ▪ 21% increase in carbon ▪ Uncertain benefits for fish
Industry	▪ No issues	▪ No issues
Recreation	▪ Accessible recreational area and number of users may increase, resulting in management issues related to access, noise, garbage and fire given existing resources ▪ Potentially improved fishery due to better littoral productivity ▪ Recreation interface likely changes from forest/water to willow-grass/water	▪ More days at preferred elevations; maintain forest/ water interface in peak season ▪ Potentially better fishery relative to ESOR; not as good as Combo 4 ▪ No boating access in March, one year in three
Wildlife	▪ No issues	▪ No issues
Heritage	▪ Poor access for artifact recovery; poor protection from illegal collection and ATVs ▪ Risk of Kwantlen being further alienated from their territory if the recreational use increases	▪ Good access and protection for sites and artifacts
Financial Cost (Relative to ESOR)	▪ Loss of $180,000	▪ Gain of $510,000

Notes:

1. Effective littoral zone

5.2 Impacts by Objective

Fish - Downstream (Spawning, Rearing, Egg Stranding and TGP)

When the net effect of all of the spawning, rearing, egg stranding and TGP performance measures are assessed, both Combo 4 and Combo 5 are expected to be no worse than ESOR for downstream fish, and probably somewhat better. The losses with respect to spawning habitat are expected to be more than offset by improvements in egg survival (reduced egg stranding)[15]. There are no significant differences between Combo 4 and Combo 5 for downstream fish.

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[15] It is hypothesized (see Table 5-5) that limited block loading will discourage nesting at high elevations where eggs would be more likely to be dewatered in subsequent weeks. See BC Hydro's SRWUP Data Report: Habitat Modeling and Performance Measure Calculations (Bruce 1999).

TABLE 5-4 IMPACTS ON DOWNSTREAM FISH

	COMBO 4 AND COMBO 5 (COMPARED TO ESOR)
Rearing	Better than ESOR due to reduction in fry stranding
Spawning	Worse than ESOR due to elimination of 130 cms maximum flow and introduction of limited block loading that allows peaking above 100 cms
Egg Stranding	Expected to be better than ESOR due to limited block loading which interrupts spawning above 100 cms[16]
Total Gas Pressure	No change from ESOR

It was the opinion of the FTC that the limited block load would likely result in at least neutral and potentially positive benefits for fish – that is, that the limited block load would reduce egg stranding with little or no change in the stranding of spawning adults. However, the FTC conceded that it is possible that the opposite would be true. The cost of being wrong would be a net reduction in the number of emerging fry, instead of the expected net gain (Table 5-5).

The FTC elected to adopt an adaptive management approach. Acceptance of this option as a component of any combo strategy was contingent on implementation of a monitoring program designed to evaluate the net effect on fish populations.

TABLE 5-5 POSSIBLE OUTCOMES FROM LIMITED BLOCK LOADING

	ASSUMPTION/HYPOTHESIS	OUTCOME
Limited Block Loading (LBL)	- LBL reduces egg stranding with little or no change in stranding of spawning adults	Net gain in number of emerging fry
	- LBL reduces egg stranding but gains are offset by increased stranding of spawning adults	Net loss in number of emerging fry

Fish - Reservoir (Reservoir Productivity)

The littoral zone is an important biologically productive area along the shore of a lake that can provide food and habitat for a range of aquatic life. The original performance measure (effective littoral zone) is a measure of the number of hectares of littoral zone. However, overall reservoir productivity is a function of many factors, only one of which is littoral area. In order to understand the likely increase in overall reservoir productivity, an expert in reservoir productivity[17] was asked to provide an estimate of the change in carbon production of the whole reservoir that would result from Combo 4 and Combo 5, relative to ESOR. Carbon production is an indicator of overall biological productivity. Table 5-6 summarizes effective littoral zone area, and carbon production under ESOR, Combo 4 and Combo 5.

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[16] All participants agreed that this is an hypothesis that must be tested through a monitoring program (see Table 5-5, Section 6 and Appendix 8).

[17] Dr. John Stockner, Limnologist at Eco-Logics.

TABLE 5-6 IMPACT ON EFFECTIVE LITTORAL ZONE AND OVERALL PRODUCTIVITY IN STAVE RESERVOIR

	ESOR	COMBO 4	COMBO 5
Effective Littoral Zone (hectares)	30	1440	860
Total Carbon Production – Mean Estimate (tonnes of carbon per year)	3210	4108	3886
Total Carbon Production – Range of Uncertainty[18] (tonnes of carbon per year)	1928-3308	2610-4601	2448-4234

In sum, Combo 4 is expected to increase littoral area by 1420 hectares (over ESOR conditions), while Combo 5 increases it by 830 hectares. Combo 4 increases carbon production in Stave Reservoir by about 33% over ESOR, while Combo 5 is expected to increase it by about 21%. The impact on fish biomass or species composition is not known.

Both Combo 4 and Combo 5 have the potential to affect productivity in Hayward Reservoir as a result of increasing the fluctuation in the water level during periods of block loading. Dr. John Stockner was consulted to provide expert opinion about impacts on Hayward's littoral zone. In sum, he advised that:

- most littoral carbon at Hayward is <u>likely</u> produced by periphyton (tiny plantlife);
- periphyton are resilient to brief periods of desiccation (drying-out);
- littoral productivity at Hayward would <u>likely</u> be only minimally affected by the proposed change.

However, it was acknowledged that this was a professional judgement, and that there is some uncertainty about the impact.

Heritage

The major impacts of each Combo are described qualitatively in Table 5-7. In sum, Combo 5 provides improved access to sites and improved protection relative to ESOR operations. Combo 4 increases the risk from illegal collection (pot-hunting) and does not offer any predictable and prolonged access to conduct planned activities. Further, Kwantlen is concerned about concentrated wave attack on sites in the 77-79 m zone, and fears increased alienation from their territory if Combo 4 increases the recreational value of the land surrounding Stave Reservoir.

[18] Stockner provided estimates for upper and lower bounds on key parameters and the formulas describing the functional relationships among variables. The values shown were generated using a Monte Carlo simulation.

TABLE 5-7 HERITAGE IMPACTS

	COMBO 4	COMBO 5
Access to sites for artifact recovery and cultural/spiritual visits	▪ No predictable access	▪ Good access: planned 6-week access one year in three
Protection from illegal collection	▪ Lower reservoir elevations in summer decrease protection from illegal collection, and may increase recreational vehicle traffic which can damage sites	▪ High reservoir elevations in summer months protect sites from illegal collection
Erosion	▪ Concentrated wave attack in the 77-79 m zone may affect heritage sites in that area	▪ No change
Other Kwantlen Considerations	▪ May lead to increased recreational use, which creates risks for increased illegal collection, site damage and alienation of Kwantlen from their traditional territory in the long term	

Recreation

Stave Reservoir

The Stave River Integrated Recreation Plan identified preferred water elevations for improving the quality of recreation. The emphasis was on improving the quality of the recreational experience, rather than on increasing the quantity of recreational use (considerations included quality of forest/waterfront camping and picnicking experience, boating safety, aesthetics, management issues – e.g., noise, firearms, garbage, fire hazard). These elevations were refined through the WUP process and used for the recreation performance measure.

Combo 5 is preferred on the basis of the recreation performance measure. While Combo 5 has more days at preferred elevations (above 80 m), Combo 4 has fewer days on which the reservoir drops below 76m. For recreation, benefits are very high above 80 m, lower from 78-80 m and very low at 76-78m. Below 76, the reservoir is unusable for boating.

It was proposed that a more stable reservoir, at any elevation, would provide a better recreational experience in the long term, partly as a result of improved reservoir productivity (Table 5-3) and partly as a result of the recovery of the riparian zone and improved aesthetics. With a target elevation of 77-79m year round, Combo 4 is more stable than Combo 5. However, it frequently violates its target elevations. An expert in riparian vegetation[19] was asked to provide opinion on what changes in vegetation might be expected under ESOR, Combo 4 and Combo 5 conditions. The impact of each combo on reservoir elevation and riparian vegetation is summarized In Table 5-8.

[19] Will Carr, of CARR Ecological Consultants.

TABLE 5-8 IMPACTS ON STAVE RESERVOIR RECREATION

	ESOR	COMBO 4	COMBO 5
No. of days at 80-81.5m	45	23	53
No. of days at 78-80 m	33	51	43
No. of days at 76-78m	25	79	26
Total Days above 76m	125	153	122
Type and Location of Vegetation	▪ Willows extend to 79m; sedge-woolgrass to 78m ▪ Tree/shrub community exists above 82 m	▪ Through active planting, could achieve expansion of willow community to slightly below 79m and expansion of sedge-woolgrass to slightly below 78m ▪ No migration of the tree/shrub community into the 79 to 82 m zone	▪ No significant change from ESOR; if anything, slightly worse due to earlier inundation of riparian vegetation in May
Fish		▪ Potential recreation benefits if results in improved fishery	▪ Potential recreation benefits if results in improved fishery
Boat Access			▪ No access in March in drawdown years
Management Issues		▪ More difficult to manage noise, fire, garbage, vehicles, etc. due to larger foreshore	

Hayward Reservoir and Downstream of Ruskin Dam

There are several components that are included in both Combo 4 and Combo 5 that have implications for recreation on Hayward Reservoir and Downstream of Ruskin Dam. These are summarized in Tables 5-9 and 5-10.

TABLE 5-9 EFFECT ON RECREATION OF "P2: MINIMUM ELEVATION CHANGE AT HAYWARD"

ISSUE	IMPACT
Safety	Boaters have less clearance above standing debris. This is mitigated by the fact that low levels occur only during low use periods.
Aesthetics	Reservoir shoreline and shoreline stabilization works on the new island will be exposed during drawdown. This is mitigated by the fact that low levels occur only during low use periods.
Water Quality	There is no anticipated impact on water quality at the intake. Intake is located well below the minimum proposed elevation. Monitoring would be conducted to verify water quality during and after implementation.

TABLE 5-10 EFFECT ON RECREATION OF "P1: LIMITED BLOCK LOADING"

ISSUE	IMPACT
Safety / Convenience of Fishers	Peaking (above 100 cubic meters per second) would occur during peak fishing season. However, the strategy does not increase the maximum rate of change of water releases from current rates. Also, peaking occurs only above 100 cms; changes in water level or velocity at this elevation are slower and hence less dangerous than changes at lower elevations due to the physical contours of the channel.

Industry

Industry's primary concerns are met through improved notification of spill events and low reservoir levels. For Combo 5, an extended drawdown roughly one year in three was deemed to be acceptable, provided that the drawdown does not occur before January 1st or extend beyond March 31st, and provided that one month's notification is provided.

The performance measure and actual number of days above preferred levels are shown in Table 5-11.

TABLE 5-11 IMPACTS ON INDUSTRY

		ESOR	COMBO 4	COMBO 5
No. of days > 76m: Dec 1 and June 1	Median	128	182	157
	One year in ten	181	182	182
No. of days > 79m: June 1 to Dec 1	Median	78	69	109
	One year in ten	72	40	84

Combo 5 clearly provides more days of access during the period June 1 to December 1. Combo 4 provides more access from December 1 to June 1. However most of the additional access under Combo 4 is during the period January through March, a period with little or no industrial activity anyway[20].

Wildlife

No quantitative performance measures were established for wildlife. Instead, it was agreed that short-listed strategies would be examined for any indication of likely negative impacts on wildlife. These are summarized in Table 5-12.

TABLE 5-12 WILDLIFE IMPACTS

	COMBO 4	COMBO 5
Stave Reservoir Impacts	Better than ESOR. Magnitude of water level fluctuation is smaller (so less disruptive), but it occurs later in the summer nesting season which may be slightly more disruptive.	Better than ESOR. Elevations rise and stabilize earlier, which is likely better for the summer nesting season.
Downstream Impacts	No clear change from ESOR.	No clear change from ESOR.

[20] This information was provided late in the consultation. If it had been provided earlier, the industry performance measure could have been adjusted to account for this.

Financial Cost - Power Values

Table 5-13 summarizes the impact of each Combo on the average annual value of power produced at Stave, Ruskin and Alouette power plants. Figures in brackets indicate losses relative to ESOR; unbracketed figures are gains. There is a significant amount of inter-annual variability in expected in the value of power produced as a result of inflow variability (driven by weather). However, on average, Combo 5 is expected to produce an incremental $510,000[21] annually (over the value produced under an ESOR operation), while Combo 4 is expected to produce about $180,000 less than ESOR. The difference between the two alternatives is $690,000. Note that each combo is a package of individual components, each of which may incur losses or gains.

The range of values noted above is the result of inflow variability. However, power values can also be affected by uncertainty in price forecasts. The main factors affecting the price of electricity are the general availability of hydroelectricity in the market (a function of regional weather/inflows), natural gas prices and market demand (also a function of weather and the availability of different resources). Uncertainty in assumptions about inflows would have the effect of widening the range of inter-annual variability noted above, but would not necessarily affect the average annual value of power production, unless there is a long term change in regional weather patterns. Start-up or decommissioning of other powerplants could also temporarily affect hydro availability and prices, but unless a long-term trend occurred, would not significantly affect the average value of power produced under any alternative.

Higher/lower natural gas prices would increase/decrease the value of power produced under all alternatives. The difference between alternatives would change to a lesser extent.

The difference between operating alternatives is likely to be most affected by the spread between peak prices (heavy load hours) and non-peak prices (low load hours). The greater the difference between peak and non-peak prices, the greater the value of maintaining the flexibility to produce power at peak times (i.e., the greater the cost of increased constraints) and the greater the difference will be between Combo 4 and Combo 5. Conversely, the narrower the spread, the smaller the difference between the two alternatives. Unfortunately, price scenarios to put upper and lower bounds on hydro availability, natural gas prices or the spread between peak and non-peak prices were not available for this analysis[22].

TABLE 5-13 IMPACT ON POWER VALUE

	COMBO 4	COMBO 5
Average Annual (Loss) or Gain in Power Value Relative to ESOR	($180,000)	$510,000 (1)
Inter-annual Variability (due to inflow variability)	(1,400,000) - $1,680,000	($430,000) - $2,330,000

Notes:

1. See Footnote 21.

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[21] $510,000 is an upper estimate. The actual value will be between $440,000 and $510,000. Lack of precision is due to difficulties in modeling the “opportunistic” one-in-three-year heritage drawdown. The $510,000 figure was used throughout the consultation, with the understanding that it was a slight overstatement of actual benefits. The lower bound of $440,000 was developed by BC Hydro after the consensus agreement of the Consultative Committee. Modeling shows that if the drawdown occurred every year, the overall value of the strategy would drop from $510,000 to $294,000. If it occurred regularly every three years without regard for inflows, the value of the strategy is estimated at about $440,000. In practice, the actual value will certainly be greater than $440,000 (since it will be done in favourable years), but likely less than $510,000.

[22] They are currently under development.

5.3 Preliminary Areas of Consensus and Disagreement

After a review of the performance of Combo 4 and Combo 5, a majority of those present at the CC meeting of May 21 1999 favored Combo 5, while a minority favored Combo 4.

For those favoring Combo 5, reasons stated included:

- Combo 5 achieves best balance among all objectives.
- Combo 5 has gains on all objectives relative to current (ESOR) while Combo 4 involves some difficult trade-offs for heritage, power value and recreation.
- The main driver of Combo 4 is improved reservoir productivity, but there is uncertainty about the magnitude of the benefits, and some question about whether the difference between Combo 4 and Combo 5 is statistically significant.
- Combo 4 may have irreversible effects (e.g., erosion damage to heritage sites), while Combo 5 does not. Therefore it is possible to move from Combo 5 to Combo 4 in the future if warranted, but not the reverse.
- Combo 4 seems high cost for relatively small gains – would it be possible to realize more benefits elsewhere (another watershed) for the cost of Combo 4?

Acceptance of Combo 5 was contingent on implementation of a monitoring program to ensure that no negative impacts from the relaxation of constraints occurred. Specifically, all participants agreed that the impact of the introduction of limited block loading and the elevation change at Hayward Reservoir must be monitored.

For those favoring Combo 4, reasons stated included:

- importance of re-establishing a natural ecosystem (for fish, recreation, and a healthy riparian zone);
- Stave is unique, close to a large urban population, and represents a small portion of BC Hydro's assets and generation, therefore the opportunity to enhance recreational values should be given high priority;
- excess revenues from modifications downstream (limited block loading, etc.) should stay in the watershed;
- it could be possible to incorporate a heritage drawdown (as in Combo 5) without major loss of productivity, thus partially meeting heritage objectives;
- we don't know what the response of the system will be to increased stabilization; this is an opportunity for learning.

When asked, "What would it take to move from Combo 4 to Combo 5?" All proponents of Combo 4 could agree to Combo 5 if Combo 5 included an adequate monitoring program to increase understanding of the impacts of operations on reservoir productivity. Upon further discussion it was noted that the preference for Combo 5 does not depend on the estimate of reservoir productivity benefits alone. Even if it were known that reservoir productivity increases were significant, there remain difficult trade-offs associated with a Combo 4-type operation. These include:

- significant loss of power value;
- recreational impacts – reduced time at preferred elevations;
- recreation management issues – resolution of issues that would arise under Combo 4 probably requires inter-agency planning and coordination, and possibly an increase in resources;

- access and aesthetic impact on lakefront property owners;
- risks to heritage sites from illegal collection and ATV traffic;
- risks to heritage sites from concentrated wave attack in the 77-79 m zone; and
- long term risk for Kwantlen First Nation that increased recreational use of the area could increase their alienation from their territory.

As a result of the above discussions, the Combo 5 operating strategy was accepted in principle, and Combo 6 was proposed, including:

- Implement the operating strategy outlined in Combo 5;
- Develop a monitoring program to assess changes in reservoir productivity and generate understanding of reservoir productivity processes and the effect of operations on productivity;
- Conduct a program of study to better understand how operations affect First Nations interests;
- Evaluate the need (timing) to revisit the WUP based on the findings of the monitoring programs.

The CC delegated the development of a monitoring plan to the Fisheries Technical Committee, specifying that the specific objective of the reservoir monitoring program should be: "To evaluate the benefits of Combo 5 over ESOR for reservoir productivity, and to provide information that will enable a better evaluation of the benefits of other operating strategies in the future". Participants specifically wanted information on how improvements would affect fish populations, not just carbon productivity. The Committee delegated the development of a Heritage Monitoring Plan to Kwantlen First Nation and BC Hydro.

Reservations were also noted by one participant about the potential for negative impacts on productivity in Hayward Reservoir. As a result, the monitoring program was designed to include assessment of impacts on littoral productivity in Hayward as well as Stave Reservoir.

6. MANAGEMENT PLAN

6.1 Summary

After consultation with the Fisheries Technical Committee (and consultant John Stockner) and Kwantlen First Nation, a proposal for a management plan was prepared. The management plan includes monitoring, mitigation and on-going management activities related to fisheries, water quality and First Nations interests. It includes the components and estimated costs listed in Table 6-1. Entries in Table 6-1 are the cost in thousands of dollars of each component for each year of a ten-year plan.

TABLE 6-1 STAVE WUP MANAGEMENT PLAN AND ESTIMATED COSTS (IN THOUSANDS OF DOLLARS)

	YEARS FROM START OF IMPLEMENTATION										
Component	0	1	2	3	4	5	6	7	8	9	10
Fisheries Management (1)	28	369	247	225	205	205	205	205	205	205	205
Heritage Management (2)	0	120	120	120	120	120	120	120	120	120	120
Water Quality Management (3)	0	5	5	5	5	5	5	5	5	5	5
Annual Reporting (4)	0	25	25	25	25	25	25	25	25	25	25
Total	28	519	397	375	355	355	355	355	355	355	355

Notes to Table 6-1:

(1) The Fisheries Management Plan includes:
- Reservoir Productivity Monitor (Phase 1 and 2)
- Limited Block Loading Monitor, and
- On-going management activities.

The estimates assume work done by consultants, not BC Hydro staff. For annual breakdown by component, see Table 6-2.

(2) Includes a heritage monitoring plan, inventory/monitoring/assessment, drawdown work, and mitigation. The final amount is still under negotiation between BC Hydro and Kwantlen First Nation. However, the CC recommends its inclusion provided it is somewhere between $100,000 and 120,000 on average.

(3) Includes turbidity monitoring.

(4) Includes preparation, production and distribution of an annual report on management committee activities and a monitoring plan “custodian” to ensure continuity of the plan.

The management plan provides:

- confirmation of the benefits and risks associated with the new operating strategy;
- ability (including information and funding) to mitigate any negative impacts;
- improved information on which to base future operating decisions (e.g., an understanding of how operations affect fisheries and heritage sites);
- flexibility and funding to address on-going management priorities;

- scientifically defensible information about reservoir productivity processes and the impact of reservoir operations on productivity that will be relevant to other coastal and, to a lesser extent, interior systems.

The monitors included in the plan are designed to address the questions in Table 6-2.

In addition to monitoring, the management plan includes funding for on-going management activities. This acknowledges that any operating strategy will continue to affect fisheries and heritage sites in some ways. Since it is not possible to predict and prioritize every need in advance, the solution proposed is to establish a small working group to manage priorities within a fixed budget, without having to reconvene a larger consultative committee.

The management plan as described in this section formed an integral part of the consensus agreement of the CC. Details of the Committee's discussions on the value of the monitoring plans are included in Appendix 6, which is the full minutes of their final meeting on June 24th 1999.

TABLE 6-2 MONITORING COMPONENTS AND RELATED RESEARCH QUESTIONS

COMPONENT	PURPOSE / RESEARCH QUESTIONS
Stave/Hayward Reservoir Monitor – Phase I and 2 (1)	▪ What are the productivity improvements in Stave resulting from Combo 6? ▪ What further improvements could occur through other operating changes? ▪ How does Combo 6 affect littoral productivity in Hayward?

Limited Block Loading Monitor (2)	▪ Do the benefits of limited block loading outweigh the risks?:
	  ▪ Does partial peaking succeed in deterring spawning at high elevations?
	  ▪ How much adult stranding occurs?
	  ▪ How much fry stranding occurs?
	  ▪ Is high velocity a deterrent to mid-channel spawning?
	  ▪ Could partial peaking be optimized given daily patterns of fry outmigration?

Kwantlen First Nation Heritage Monitor	▪ How are Kwantlen First Nation heritage sites affected by erosion? ▪ How would sites be affected by other operational strategies? ▪ How can they be protected or salvaged? ▪ Are there other Kwantlen sites in the area, including lands adjacent to the reservoir? How would these be affected by other operational strategies?
Hayward Water Quality Monitor	▪ Does the change in Hayward minimum water level increase the frequency or magnitude of turbidity events?

Notes to Table 6-2:
(1) For more details see Appendix 7: Summary of Stave/Hayward Reservoir Monitor.
(2) For more details see Appendix 8: Summary of Limited Block Load Monitor

6.2 Fisheries Management Plan

Summary of the Reservoir Monitor and Limited Block Load Monitor are included in Appendices 7 and 8. The full report of the consultant is also available (Stockner, 1999).

TABLE 6-3 ANNUAL COSTS, YEARS 0 THROUGH 10, IN THOUSANDS OF DOLLARS

	YEARS										
	0	1	2	3	4	5	6	7	8	9	10
Component											
Reservoir Monitor – Phase 1	10	145	145	145	0	0	0	0	0	0	0
Reservoir Monitor – Phase 2	0	0	0	0	100	100	100	100	100	100	100
Limited Block Load Monitor	18	174	52	5	5	5	5	5	5	5	5
Management Activities	0	50	50	75	100	100	100	100	100	100	100
Total	$28	$369	$247	$225	$205	$205	$205	$205	$205	$205	$205

The Phase I Reservoir Monitor is an intensive monitoring program designed to improved understanding of reservoir productivity processes. Once this understanding is in place, the Phase 2 Monitor begins, which is a more routine monitor. Details of the Phase 2 design will be finalized after Phase 1 results are analyzed.

The Limited Block Load Monitor is a fairly resource intensive monitor for the first two years after implementation, as it is necessary to ensure that the introduction of partial peaking does not result in negative impacts on downstream fish productivity.

Funding for management/mitigation activities rises over the first three years to level out for years four through ten. This recognizes that management/mitigation activity will be guided by monitoring results which will not be available immediately.

6.3 Heritage Management Plan

The heritage management plan was initially developed by Kwantlen, and refined through subsequent negotiations between BC Hydro and Kwantlen[23]. Kwantlen proposed a five year plan, after which the plan will be reviewed and new funding agreements made for the next five years of the plan.

The heritage management plan includes the upfront development of a planning document that will guide all activities, including regular annual work and drawdown-related work. Funding is included for drawdown work (which may include any combination of monitoring, assessment, mitigation/salvage and inventory work) twice in five years. In practice, since drawdowns are opportunistic, it is not known in advance in which years the funds will be required. All activities and estimated costs are shown in Table 6-4.

[23] At Kwantlen's request, the development of the heritage management plan was not subject to negotiations among participants at the main Consultative Committee. It was developed by Kwantlen in discussion with BC Hydro. However, once developed, the plan was presented to the Consultative Committee and was accepted as part of the consensus agreement.

TABLE 6-4 HERITAGE MANAGEMENT PLAN COSTS

ACTIVITY	ESTIMATED COST
Heritage Management Plan Development	$50,000 total (up-front)
Drawdown Work	$50,000, twice within a five year time frame
On-going Monitoring, Assessment, Inventories	$50,000 per year
Mitigation (capping, excavation, etc.)	$100,000 total
Total	$100-120,000 annual on average

Kwantlen and BC Hydro had not completed their negotiations on the heritage management plan before the final meeting of the CC. However, they were within $20,000 (per year). The CC therefore agreed to a heritage management plan at a cost of anything between $100,000 and $120,000 per year on average. The CC also noted the need for flexibility in providing this funding as a result of the uncertainty in drawdown timing, Kwantlen capacity and the need/priority of mitigation work.

6.4 Water Quality Monitoring Plan

For the altered operating regime in Hayward Reservoir, it is possible that there may be some erosion due to the increased water fluctuations. Routine monitoring is proposed at Stave and Ruskin forebays and tailraces, and from the Hayward Recreation Area. These surface samples would be taken on foot from the shore. In addition, a boat survey of the shoreline will be undertaken at least once per year to inspect for obvious signs of erosion. The total cost of this program is expected to be less than $5000 per year. It is considered a priority given the concerns of those local residents who draw drinking water from Hayward Reservoir.

Should any negative impacts be noted, the Management Committee (see section 6.5) will have responsibility for seeking mitigative options or re-evaluating the change in Hayward's minimum operating level.

6.5 Management Committee

The CC recommends that a Management Committee for Stave be formed that is separate from the Alouette Management Committee. This is based on the belief that the introduction of Stave issues to Alouette may disrupt the Alouette Management Committee which has been operating successfully to date, and that both Committees should be allowed to concentrate on their specific priorities.

The CC recommends that the Stave Management Committee should have a mandate to:

- conduct on-going management decisions with consideration of all objectives
- liaise with Kwantlen First Nation on heritage management issues
- liaise with the Alouette Management Committee on an as-need basis
- prepare annual public reports
- conduct an interim review after five years which will incorporate the feedback of local management/stakeholder groups

Specific tasks are shown in Table 6-5.

The CC recommends that the Management Committee membership should include DFO, MELP, BC Hydro, Kwantlen First Nation and the District of Mission. Technical experts and a monitoring program "custodian" should participate as necessary to provide input. Members of the public may attend and observe meetings, but should not be part of the decision making function of the committee.

A custodian is needed to ensure continuity in the monitoring program. Without this function, there is a risk that experimental/sampling methods and locations will be inconsistent and the ability to draw meaningful conclusions compromised. It was agreed that the function would best be served by BC Hydro.

Kwantlen indicated that their participation on the Stave Management Committee is contingent on capacity funding.

The CC recommends that consolidation of the Stave and Alouette Management Committees be considered at some point in the future.

TABLE 6-5 SPECIFIC TASKS OF THE MANAGEMENT COMMITTEE

TASK DESCRIPTION	

On-Going Tasks	▪ design, refine and implement monitoring programs and review results; some examples include:
	  ▪ design Phase 2 of Reservoir Monitor based on results of Phase 1- this should include specific hypotheses to be tested
	  ▪ refine the Reservoir Monitor to better address nutrient inflows from Alouette if necessary (once Alouette fertilization program has stabilized)
	  ▪ decide on need for ongoing monitoring of Hayward water quality
	▪ identify and prioritize mitigation needs and implement related activities within the established budget (see Table 6-3 Management Activities);
	▪ liaise with the Alouette Management Committee to make decisions when and if trade-offs in water allocation are required between Alouette Lake water levels and the Stave system;
	▪ liaise with Kwantlen First Nation on issues related to heritage management;
	▪ prepare an annual public report;

5-Year Review	▪ Conduct a formal review of monitoring results to date and adjust monitoring plans as required to ensure adequate information is available for ten-year review ▪ Adjust on-going management/mitigation plans and budget in response to monitoring information (too much? not enough?) ▪ Confirm the appropriateness of the proposed timing of the next full WUP review

In addition to the main Management Committee, the CC also recommends that a Heritage Management Committee be formed, but did not make specific recommendations on membership or tasks. These are to be determined by Kwantlen in cooperation with BC Hydro, and may consist of Kwantlen and BC Hydro only, or may have other representation as well (e.g., provincial Archeology Branch).

6.6 WUP Review Period and Implementation Timing

The CC recommends that the WUP be fully reviewed in ten years. However, it further recommends that the Stave Management Committee have a mandate to conduct a formal interim review of the plan after five years primarily to assess monitoring results to date and reassess management/mitigation funding needs (more/less required?). Based on this assessment, it should confirm the appropriateness of the proposed timing of the full review. Any recommendations (if any) should be made to the Comptroller of Water Rights (or his/her designate).

The review periods, both interim and full, are linked to the timing of expected results from the reservoir and heritage monitoring programs:

- it is expected that after ten years, it will be possible to draw some meaningful conclusions about the effect of operations on reservoir productivity;
- it is expected that Kwantlen will require at least ten years to gain new knowledge about heritage sites and impacts of operations, since drawdowns will occur only once in three years on average.

An interim review by the Management Committee after five years is critical to ensure that no major changes have occurred (either observed impacts or new science that identifies new risks) that need to be formally addressed or that would trigger a need for a more comprehensive multi-party review.

The CC recommends that the WUP be implemented immediately upon start-up of the new Stave Falls powerplant (expected October 1999).

7. SUMMARY

The Stave River Water Use Plan Consultative Committee succeeded achieving a consensus on an operating plan and related recommendations to BC Hydro and the Comptroller of Water Rights. The consultation process allowed the development of creative alternatives and the detailed evaluation of two distinctly different operating alternatives. It allowed each participant to apply his/her own values when making trade-offs among objectives. Through interest-based discussions and negotiation, a consensus agreement was reached which all participants support.

The process was complicated by uncertainty about a number of impacts. As a result, the consensus agreement is contingent on the implementation of an adaptive management plan that will address key uncertainties and ensure that improved information is available for the next review of the Stave River WUP.

7.1 Summary of Recommendations

In total, the package of recommendations of the CC to BC Hydro includes recommendations on an operating strategy, an on-going management plan, a management structure and the timing of implementation and review.

The recommended operating strategy consists of the following elements:

- maintain all of the constraints that had previously been implemented as part of the Electric System Operating Review (ESOR) in 1995, with the exception of the 130 cubic meter per second maximum Ruskin discharge constraint during the fall spawning period. This includes:
    - weekly block loading at Ruskin powerplant during the fall spawning period;
    - minimum water levels (tailwater elevations) year round;
- Implement daily block loading during the period of fry emergence (officially February 15 to May 15, but subject to annual adjustment if mutually agreed with DFO);
- Modify the block loading procedure to allow partial peaking (above 100 cubic meters per second) during both spring and fall block loading;
- Lower the normal minimum elevation on Hayward Reservoir during the spring and fall block loading periods;
- Provide a six-week deep drawdown on Stave Reservoir for heritage interests one year in three, on average, with timing and depth of drawdown dependent on opportunities provided by inflow conditions and the needs of Kwantlen First Nation;
- Set a soft target 80-81.5 meters for Stave Reservoir elevation during the peak recreation season (with priority given to maintenance of downstream flows).

The recommended management plan consists of four components.

- A fisheries management plan including:
    - a reservoir productivity monitor (phase 1 and 2);
    - a limited block loading monitor; and
    - on-going management activities, including mitigation or other response to information on impacts gained from the monitoring programs.
- A heritage management plan, including:
    - a heritage monitoring plan;
    - on-going inventory, monitoring and assessment of sites throughout the watershed;

  - drawdown work, including inventory, monitoring and assessment as well as mitigation and artifact recovery on sites located at lower elevations of Stave Reservoir; and
  - mitigation.
- A drinking water quality monitoring plan, which includes turbidity monitoring in Hayward Reservoir
- Reporting and administration, which includes:
  - preparation, production and distribution of an annual report on management committee activities
  - a monitoring plan "custodian" to ensure continuity of the plan.

The management plan costs vary from year to year, but result in a levelized annual value of about $390,000. (Note that the WUP as a whole has a net gain of $120,000 per year, which is the difference between annual gains in power value of $510,000 and the management plan costs – see Financial performance in Table 7-2 below.)

The Consultative Committee recommends that a Stave Management Committee be formed, with membership to include the Department of Fisheries and Oceans, Ministry of Environment, Lands and Parks, BC Hydro, Kwantlen First Nation and the District of Mission. Tasks of the Management Committee include:

- design, refine and implement monitoring programs and review results;
- identify and prioritize mitigation needs and implement related activities within the established budget;
- liaise with the Alouette Management Committee to make decisions when and if trade-offs in water allocation are required between Alouette Lake water levels and the Stave system;
- liaise with Kwantlen First Nation on issues related to heritage management;
- prepare an annual public report;
- conduct an interim review after five years.

The Consultative Committee also made recommendations related to the timing of implementation and review:

- Conduct a full review of the Stave River Water Use Plan (involving a comprehensive multi-party consultation process) after ten years. This recommendation is linked to the expected timing of results from monitoring programs addressing key uncertainties.
- Conduct a formal interim review (by the Management Committee) after five years based on monitoring results to date. The purpose is to identify any unexpected results, adjust mitigation plans and budgets accordingly, adjust monitoring plans as necessary to ensure adequate information will be available at the ten year review, and reconfirm the appropriateness of the timing of the ten-year review.
- Implement the recommended operating strategy immediately upon start-up of the Stave Falls Replacement Project.

The impacts from the recommended package are summarized in Table 7-1 and 7-2. All impacts are summarized relative to the baseline ESOR condition.

TABLE 7-1 SUMMARY OF IMPACTS

OBJECTIVE	IMPACT OF COMBO 6
Fish – Downstream - *Spawning* - *Rearing* - *Egg Stranding* - *Total Gas Pressure*	▪ Slight improvement in overall productive capacity expected (Reductions in spawning habitat offset by improvements in rearing habitat and egg stranding risks)
Fish – Reservoir - *Reservoir Productivity*	▪ 21% increase in overall reservoir carbon production ▪ 830 hectare increase in effective littoral zone
Industry	▪ Better access to loading/offloading equipment and woody debris on Stave Reservoir ▪ Reduced risk of incurring damage to downstream equipment due to spills
Recreation	▪ More days at preferred elevations during the recreation season ▪ Potential for an improved fishery ▪ No boating access in March, one year in three
Wildlife	▪ Slight improvement due to increased stabilization of Stave Reservoir
Heritage	▪ Improved access and protection for First Nations heritage sites and artifacts
Financial Cost (Relative to ESOR)	▪ Net gain of about $120,000 per year (levelized annual value, calculated as the difference between gains in power values of $510,000 and on-going management costs of $390,000)
Learning	▪ Substantial knowledge will be gained about reservoir productivity processes and the impact of operations on littoral habitat and fish productivity ▪ Substantial knowledge will be gained about the impact of operations on First Nations interests
Flexibility	▪ On-going management structure and funding allows effective response to new information or priorities

TABLE 7-2 SUMMARY OF FINANCIAL IMPACTS OF STAVE RIVER WUP (IN MILLIONS OF DOLLARS)

	TOTAL OVER TEN YEARS	LEVELIZED ANNUAL VALUE (1)(3)	NET PRESENT VALUE(1)
Power Benefits	$5.1	$0.51	$3.4
Management Costs (2)	$3.8	$0.39	$2.6
Net Benefits (3)	$1.3	$0.12	$0.8

Notes:
1. At 8% discount rate.
2. Assumes continuation of Year 1-5 heritage management plan costs through Years 6-10.
3. The annual levelized value of power benefits will be between $440 and $510. The lack of precision is due to difficulties in modeling the “opportunistic” one-in-three-year heritage drawdown. See Footnote 21. All values reported in the “net benefits” line are similarly overestimated.

7.2 Summary of Support for the Package

Of 19 members of the CC[24], roughly 80% reported that they "endorse" the package, while 20% "accept" it (see Figure 7-1 for definition of terms). Of those recording "accept", the reasons that prevented them from "endorsing" the package included:

- several participants highly valued the potential for greater ecosystem, fish and aesthetic improvements that they believe could result from greater stabilization of Stave Reservoir;
- one participant had reservations about the high cost of monitoring programs in Years 1 and 2, and would only be able to "Endorse" the package if those were smoothed out (not necessarily to provide a lower overall investment, but to provide a more consistent level of investment from year to year).

Of those reporting "endorse", minor reservations were expressed by three participants about the cost of the management plan, and the following recommendations made:

- limit the tasks to only those really necessary;
- manage the monitoring work closely to ensure it delivers the intended benefits.

Figure 7-1 Definition of Consensus Used in SRWUP

The following definitions were provided to the CC, and were used to gauge support for the short-listed strategies.

Endorse: You endorse the proposed alternative, either fully or with minor reservations.

Accept: You accept the proposed alternative. You may disagree that the alternative represents the best possible solution, but your minimum needs are met. You may want your views formally recorded, but you accept and support the decision of the group.

Block: You can not support the proposed alternative. Your minimum needs are not met.

"Endorse" and "Accept" both constitute consensus. The more people who are under the "accept" category, the weaker the consensus, but it remains a consensus decision. If anyone in the group finds it necessary to "block", then consensus is not achieved. Where consensus is not achieved, areas of disagreement will be noted, and we will document what it would take to meet minimum needs.

7.3 Considerations for Future WUPs

For WUPs at Other Facilities

At the beginning of the Stave River WUP process and several times throughout, some participants requested information relating to the historical productivity of Stave Reservoir (e.g., through coring samples). At the end of the process, this interest was reiterated. While participants acknowledged that the WUP process is focussed on incremental change to reallocate water among all uses and does not address issues related to the original inundation, it was still felt by some that this information would provide an important benchmark for making informed trade-offs[25].

For the Next Stave River WUP

There is a belief by some members of the CC that while this operating strategy represents a significant improvement over current conditions, there is an opportunity to do even better in the future. Trade-offs were complicated by uncertainty, including:

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[24] Although there were two representatives from each of MELP, BC Hydro and Kwantlen First Nation, the figures reported here count each only once. This also counts only those members who actively participated in meetings, not those who received minutes only (see Appendix 1).

[25] For Stave, agreement was reached between BC Hydro and MELP to jointly fund this activity (outside of WUP).

- uncertainty about reservoir productivity processes and the effect of operations on reservoir productivity;
- uncertainty about the extent to which fisheries would be enhanced by improved productivity;
- uncertainty about the effect on recreation in the long term, especially considering the preference of many recreationalists for a more “natural” environment;
- uncertainty about the effect on First Nations interests, including heritage interests, economic development, and the degree of security or alienation they experience with respect to their territory.

It is recommended that the monitoring program be carefully managed to ensure that there is more information with which to evaluate these interests in the future.

GLOSSARY

Stave River Water Use Plan Acronyms

CC: Consultative Committee - a committee consisting of representatives of all interested parties in the SRWUP

DFO: Department of Fisheries and Oceans

ESOR: Electric System Operations Review - A change in operating constraints at the Ruskin, Stave Falls and Alouette facilities implemented in 1995 in consultation with the fisheries agencies and the Office of the Comptroller of Water Rights. Used as the base case for comparing impacts of alternative operating strategies on SRWUP.

FTC: Fisheries Technical Committee – a subcommittee of the SRWUP Consultative Committee

MELP: BC Ministry of Environment, Lands and Parks

SRWUP: Stave River Water Use Plan

WUP: Water Use Plan

BC Hydro Operational Terms:

Operating strategy: a collection of operating constraints applied to the BC Hydro plants in the Stave River system

Peaking: a hydroelectric plant operating practice which involves adjusting turbine outputs to match daily variations in the demand for electricity

Daily Block Loading: a constraint applied to a hydroelectric plant which permits plant load (and therefore discharge) to be changed only once per day

Weekly Block Loading: a constraint applied to a hydroelectric plant which permits plant load (and therefore discharge) to be changed only once per week

LBL: Limited Block Loading - a modification to daily or weekly block loading constraints which permits the plant to peak at times when the block load flow would be greater than a threshold value provided that the threshold value is maintained as a minimum flow during the peaking operations

Dispatchability multiplier: a factor applied to HLH energy values to reflect the additional value to BC Hydro of energy which can be generated when and if required to coincide with the highest load hour(s) and greatest energy values

HLH: High Load Hours - the hours during which energy demand is the greatest (16 hours per day for 6 days each week)

LLH: Low Load Hours - the hours during which energy demand is relatively low (all non-HLH hours)

APPENDIX 1

SRWUP Consultative Committee, Technical Support and Meeting Dates

Consultative Committee Members

Those members marked with an * received minutes only. Individuals marked ** are consultants.

NAME	ORGANIZATION
Les Antone	Kwantlen First Nations
Stu Barnetson	DFO Inch Creek Hatch
Ian Birtwell	Genstar Development
Les Bogdan	Ducks Unlimited
Tom Cadieux	Stave Lake Corrections
Dale Clark	Stave Valley Salmonid Enhancement Society
Geoff Clayton	Alouette River Management Society
Richard Dailey	Stave Lake Leaseholders Association
Tony Dandurand	Kwantlen First Nation
Teye DeVries	Delta Cedar Products
Val and Doug Dundas	Triple Creek Estates
Ken Fraser	Fraser's Tackle Shop
Harry Giroux	Hayward Park Warden
Bijou Kartha	MELP, Water Mngmt
Russ Knutson/Dave Hobbs	MOF, Chilliwack FD
Eduard Krautter	Resident/SHRAC
Steve Macfarlane	Department of Fisheries and Oceans
John Mackie	Canadian Coast Guard, Pacific Region
Denise Mullen-Dalmer	Ministry of Employment and Investment
Ross Neuman	MELP, Fish and Wildlife
Marvin Rosenau	MELP – Fish and Wildlife
Marion Robinson	Fraser Basin Council
Terry Molstad	BC Hydro
Hugh Smith	BC Hydro
*Brian Clark	MELP – Fish and Wildlife
*Adam Fitch	District of Mission
*Ross Kreye	MELP, Env. & Lands
*Bob O'Neal	Mission Tree Farm
*Ray Peterson	MELP, Parks
*Michelle Porter	BC Assets & Land Corporation
**Gordon Mohs	Kwantlen First Nation Consultant

Technical Support

BC Hydro Project Team

ROLE	NAME
Project Manager	Charlotte Bemister
Corporate Representatives	Terry Molstad Hugh Smith
Resource Valuation	Anne Wilson
Environmental Coordinator	Annabel Cope
Fisheries Studies	James Bruce Susan Bailey Carol Lamont Alf Leake Allister McLean Sandra Wilson Kim Wilby
Power Studies	Paul Vassilev Ian Kerr James McNaughton
Aboriginal Relations	Lorrie MacGregor
Recreation	Mark Johnston
Wildlife	Ed Hill
Legal	Rob Carpenter
Engineering	Paul Rapp

External Resources

POSITION/ROLE	NAME
Resource Valuation and Trade-off Analysis Consultant	Lee Failing
Peer Reviewer for Operations Modeling	Denis Russell
Technical Assistance: Reservoir Productivity	John Stockner
Technical Assistance: Riparian Vegetation	Will Carr

Consultation Meeting Dates

Meetings of the Consultative Committee and Sub-Groups

December 15, 1997 – Main Table
March 10, 1998 – Industry / Forestry Sub-group Objectives-setting
March 11, 1998 – Fisheries Sub-Group Objectives-setting
April 8, 1998 – Fisheries Sub-Group Performance Measures
June 18, 1998 – Main Table
October 14, 1998 – Main Table
January 21, 1999 – Main Table
February 9, 1999 – Cross Cultural Training
February 17, 1999 - Power Sub-Group Alternatives Brainstorming
February 17, 1999 – Heritage Sub-Group Alternatives Brainstorming
February 18, 1999 – Recreation/Wildlife/Industry Alternatives Brainstorming
February 18 1999 – Fisheries Alternatives Brainstorming
March 25, 1999 – Main Table
April 28, 1999 –Fish, Industry, Recreation, Heritage Sub-groups on Refining Alternatives
May 21, 1999 – Main Table
June 24, 1999 – Main Table

Fisheries Technical Committee Meetings

April 28, 1998
June 2, 1998
September 28, 1998
October 28, 1998
December 1, 1998
December 15, 1998
April 14, 1999
May 3, 1999
May 13, 1999
June 10, 1999
June 18, 1999

Modeling Technical Committee Meetings

November 4, 1998
December 4, 1998 (Stave River site visit)
March 18, 1999

Kwantlen First Nation Meetings

September 23, 1997
October 20, 1997
November 5, 1997
December 9, 1997
January 16, 1998
February 10, 1998
March 13, 1998
May 12, 1998
July 16, 1998
September 17, 1998
November 20, 1998
February 5, 1999
June 3, 1999

Katzie Meetings

June 4, 1999

Stave/Hayward Recreation Advisory Meetings

December 3, 1997
June 11, 1998
February 16, 1999

Open House: March 2, 1999
Hayward Reservoir Domestic Water Supply Meeting: April 21, 1999
Open House: September 23 1999

APPENDIX 2

SRWUP PERFORMANCE MEASURE INFORMATION SHEETS

Note: These Information Sheets were issued to participants in January 1999. They are provided here to provide background information on performance measures, and also to demonstrate the kind of information that was available to participants. In some cases, new information became available over the course of the process. In all cases, if there is a discrepancy between an Information Sheet in this appendix and the impacts or assumptions reported in the main body of the report, the report will be the more accurate reflection of the information on which decisions were based in June 1999.

WILDLIFE

What is the Wildlife objective at Stave?

To support the viability of wildlife populations in the Stave River system. The existence of wildlife is an indicator of overall ecosystem health and is of value to recreationalists and residents. For Kwantlen First Nation, the presence of game animals is important, as they would like to be able to hunt on their traditional territory.

How will wildlife objectives be addressed?

In general, wildlife is believed to have adapted to existing conditions in the Stave River system. Therefore, the main consideration during the WUP process is to minimize dramatic change. Changes in the following conditions could signal impacts that are significant from a wildlife perspective:

Stave Reservoir Stability. In general, a decrease in the stability of reservoir levels is expected to decrease the diversity and abundance of shoreline vegetation which would have a negative impact on the abundance and diversity of wildlife. Between April 1st and August 31st, increased fluctuations would also increase the risk of mortality among young (immobile) animals.

Downstream Water Fluctuations. Fluctuations in water surface elevations downstream of Ruskin may threaten plant communities and small mammals living or foraging on the shoreline. Both the absolute height of the water and the duration of time spent there are important. During summer months, high water may result in direct mortality of young (immobile) animals. An indirect measure of this effect is the "variability" component of the fish spawning and rearing habitat performance measures. So on a day to day basis, and particularly during summer months, less fluctuation in levels is preferred. However, on a year-to-year timeframe, periodic flooding is necessary to maintain riparian and wetland habitats.

Each operating strategy will be qualitatively assessed for its likely effect on these conditions. If there is reason to expect significant negative impacts on wildlife, further investigation of these impacts may be warranted, either now or as part of an adaptive management strategy to improve knowledge over time.

Wildlife Presence at Stave

- Based on the Stave River Valley orientation, logging history and stand structure, this area is of low priority relative to other areas of the province, according to both BC Hydro and MELP wildlife management assessments. Wildlife values only increase on the south-facing slopes that look over the Fraser Valley (very end of Stave River Valley).
- In the Stave/Hayward Reservoir area, fish-eating birds such as osprey, bald eagle, common loon and common merganser are common, as are Canada geese. Large mammals such as black-tailed deer and black bears are in the area, and there are signs of permanent beaver habitation. Mink, raccoons, coyotes and foxes are all assumed to frequent the shoreline. Cougar and bobcat are occasionally sighted. Increasing the diversity and abundance of riparian vegetation could benefit wildlife such as blacktailed deer and bear.
- In the Lower Stave River, waterfowl such as mallards, blue-winged teal and cinnamon teal, and northern shoveler use the river as an overwintering site. Bald eagles also use the area during the fall salmon spawning season.
- Wildlife values in the Stave system are relatively low today. However, historically (before logging), this area may have been of higher quality for wildlife. Kwantlen's Traditional Use Study indicates that the area was used for hunting. The neighbouring Fraser Valley and Lower Mainland areas had relatively much higher wildlife values, and may have been used as or more frequently for hunting.

Known Impacts from BC Hydro Operations

- Studies on Stave Reservoir indicate that there are no known significant impacts caused by drawdown events or high water levels on wildlife habitat and populations (other than the occasional loss of osprey nests).
- High (and rising) water levels may jeopardize osprey nests on Stave Reservoir. However, mitigating action has been taken (provision of artificial/floating nests) which are known to be successful elsewhere.
- There have been no studies of impacts downstream of Ruskin Dam, and there is little site-specific data on species populations or habitat.

Assumptions

- The timing of the seasonal peak will also affect wildlife. However, operation of BC Hydro facilities does not affect seasonal timing. Peak timing is simply a function of weather and hydrology.

PERFORMANCE MEASURE: EFFECTIVE LITTORAL ZONE

What is the Effective Littoral Zone performance measure?

This performance measure will be used to assess the impact of BC Hydro operations on reservoir productivity. This performance measure is relevant year-round and has two main components:

- *Quantity (hectares) of potentially productive area* available in the Stave Reservoir. Potentially productive areas are defined as those that receive adequate light for photosynthetic activity and remain wetted for certain time periods. This is called the effective littoral zone (ELZ). This component is further broken into three sub-components:
  - Quantity wetted for 80% of the days of the year. This area is has high likelihood of enhancing reservoir nutrient levels.
  - Quantity wetted between 50 and 80% of the days of the year. This area has a lower likelihood of enhancing reservoir nutrient levels.
  - Quantity wetted between 20 and 50% of the days of the year. This area has a least likelihood of enhancing reservoir nutrient levels, but may be important to marginal terrestrial plants in the drawdown zone.
- *Number of days the reservoir level exceeds 77m.* This inundates cutthroat spawning and rearing habitat at Isle Slough and prevents die-off of submerged plants.

These components may be combined into a single performance measure. (See the "Normalization and Weighting Functions" information sheet.)

The Fisheries Technical Committee has assigned preliminary weights shown in Table A to each component of the measure.

Table A: Components Weights – ELZ

	Productive Littoral Zone			Cutthroat Habitat
	Quantity – 80%	**Quantity – 50-80%**	**Quantity – 20-50%**	**# Days > 77m**
Weight	50%	10%	0%	40%

Why is it important?

- It may be possible to enhance the viability of a permanent littoral zone by manipulating reservoir levels. The littoral zone provides food, cover and substrate for aquatic life, including fish, and is an internal source of nutrients. Stave Reservoir is currently nutrient-poor. Increases in reservoir nutrient levels may increase fish productivity and growth.
- There is a limited amount of good spawning and rearing habitat in the reservoir. Increasing accessible habitat in the reservoir and tributaries may improve fish productivity.

Considerations at Stave

- Field studies indicated that a permanent littoral zone does not currently exist in Stave Reservoir, probably as a result of highly variable reservoir levels and generally poor substrate conditions.
- Because of poor substrate conditions, it is possible that the ELZ quantity measure will overestimate the area that will actually function as littoral zone. However, in some areas, field studies indicate that the substrate, slope (<15%) and available protection from wave action (includes submerged stumps) would be conducive to permanent plant growth if reservoir elevations were more favorable.
- A permanent littoral zone was found in Hayward Reservoir, which further suggests that stabilized water levels could promote littoral development in Stave Reservoir.

Fish Use

- Stave Reservoir currently supports primarily kokanee, northern squawfish, redside shiners and largescale suckers. Cutthroat trout, rainbow trout and Dolly Varden and/or bull char are also present.

How is the performance measure calculated?

1. The effective littoral zone area for any given day is calculated from the relationship between reservoir surface water elevation and area of submerged substrate, given the average daily reservoir elevation, and assuming a depth of light penetration of 7.15m through the water column.
2. An annual duration curve is constructed to show the minimum area that is expected to function as ELZ on 20 %, 50% and 80% of the days of the year. (Large ELZ areas occur for short periods of time; only small areas function as ELZ year round.)
3. A reservoir elevation duration curve will also be constructed to show the number of days per year that reservoir elevations exceed 77m.
4. For all components, calculations are repeated for each year of the simulation period (25 years). The median and 10th percentile values will be reported.
5. Values of each component of the measure may be normalized relative to all operating strategies under consideration, and a single unitless number between 0 and 1 is recorded as the total score.

Key Assumptions

- Increasing nutrient levels and the availability of spawning/rearing habitat in Stave Reservoir will enhance fish productivity.
- It is possible to establish a permanent littoral zone in at least some parts of Stave Reservoir through manipulation of reservoir levels.
- A permanent littoral zone already exists at Hayward, probably because of more limited fluctuations in reservoir levels. This is not expected to change with the implementation of the Project. Therefore, Hayward is not included in the ELZ measure.

PERFORMANCE MEASURE: REARING HABITAT

What is the Rearing Habitat performance measure?

This performance measure will be used to assess the impact of BC Hydro operations on rearing habitat for juvenile salmon (i.e., from emerging fry to out-migrating smolts) downstream of Ruskin dam. The measure is relevant year-round. It has four parts:

- The amount of available rearing habitat in the main channel (in hectares). The amount is different every day depending on water levels in Fraser River and the water releases from Ruskin dam. The area reported is the area available on 50% of the days of the year.
- The day-to-day variability in the area available in the main channel (how much it changes from one day to the next).
- The within-day variability of the area available (its maximum change within any 24-hour period).
- The frequency (no. of days) that the water level immediately below Ruskin Dam is greater than 1.6 m. This level ensures that the rearing habitat in the side or back channels is fully accessible (i.e. pools are not isolated by insufficient flow).

These components may be combined into a single Rearing Habitat performance measure. (See the "Normalization and Weighting Functions" information sheet.)

Table A: Component Weights – Rearing Habitat

	Quantity – Main Channel	**Day to Day Variability –** Main Channel	**Within-Day Variability –** Main Channel	**Availability –** Side Channels
Weight	0%	10%	40%	50%

The Fish Technical Committee has assigned preliminary weightings to the components as shown in Table A. These weights suggest that the quantity of habitat in the main channel is unimportant within the range of operating conditions likely to be considered. Within-day variability in the main channel and availability of the side channels are the most important considerations. The variability of the habitat available in the side channels is not relevant, since the area is either available or not, depending on whether water levels exceed a minimum threshold.

Why is it important?

- Plant discharge flows affect downstream water surface elevation which in turn affects the availability of suitable rearing habitat. At different elevations, different quantities of suitable habitat may be available. The quantity of suitable habitat may be a limiting factor to a river's capacity for rearing salmon.
- Fluctuations in flow can affect young salmon directly by displacing or disturbing them (e.g., crowding, flushing them out), or indirectly by affecting their food sources. Reservoir management decisions affect the variability in habitat from day to day. Peaking operations affect variability within any given day.

Fish Use

- The lower Stave River is currently used extensively by chum salmon. Chum salmon do not, however, rear in the system. Once they emerge from the spawning gravel they promptly move downstrean to esturine waters (where fresh and salt water meet) where they stay until they make the transition to salt water and head out to the ocean. Fewer numbers of coho, pink and chinook salmon, and steelhead and cutthroat trout spawn in the lower Stave River than the chum salmon. These fish, however, rear in the system all for varying amounts of times.
- Below Ruskin Dam, the number of coho spawners has rebounded from about 30 in the late 1980s to about 1600 in 1997.
- Much of this recovery is due to restocking. However, the recovery may also be due to structural improvements made to the channels and the development and implementation of the Ruskin Dam Fish Flow Agreement that ensures better conditions for fish.
- Studies conducted in summer 1998 found that very few juvenile sportfish were using the river for rearing. Only two coho were found over a four-day study period. It is not clear why. Possibilities include: the system is inherently nutrient-poor and is seldom used for rearing; the water temperature was high during the study period and caused juveniles to leave the system; broodstock may have been reduced through overfishing. The findings do not preclude the possibility that coho reside in the area during other times of the year or in other years.

Other Considerations

- The side and back channels are the most important areas for rearing. While improvements in the flow regime in the main channel will improve salmon rearing conditions, the capacity of the main channel to offer good rearing habitat is limited.
- Tidal influences and Fraser River backwater effects can either aggravate or offset flow changes resulting from dam operations. The calculation of the area of usable spawning habitat for this measure takes these factors into consideration

How is the performance measure calculated?

1. For the Main Channel, wetted areas are calculated using flow model predictions of daily water surface elevations and stream cross section data. Useable Wetted width (UWW) are calculated from those channel areas with minimum depths for rearing (5 cm). UWW is multiplied by channel length to estimate Useable Wetted Area (UWA) for the Main Channel. The area reported is the minimum area available on 50% of the days of the rearing season.
2. Day to day variability is calculated as the difference between the habitat available on 20% of the days of the year and the habitat available on 80% of the days of the year.
3. For side channels, rearing habitat is available only when tailrace elevations exceed 1.6 m. The number of days tailrace elevations exceed this threshold are counted.
4. Calculations will be repeated for each year of the simulation period (25 years). The median and 10^{th} percentile values are reported.
5. Values of each component of the measure (quantity and variability) are normalized relative to all operating strategies under consideration, and a single unitless number between 0 and 1 is recorded as the total score.

Key Assumptions

- Fish use the system year round for rearing.
- Water depth is a major determinant of the preferences or ability of salmon to rear.
- Alternative operating strategies do not influence the inventory of rearing habitat (e.g., change the substrate or complexity, or exceed velocity thresholds).
- By maximizing habitat suitable for chum salmon, habitat for other species will also be enhanced.

PERFORMANCE MEASURE: SPAWNING HABITAT

What is the Spawning Habitat performance measure?

This performance measure will be used to assess the impact of BC Hydro operations on spawning habitat downstream of Ruskin Dam. The measure is relevant only during the fall spawning period from September 16th to December 31st. It has three components:

- The amount of habitat (in hectares) that is available to spawners. The amount is different every day of the spawning season. The area reported is the area available on 50% of the days of the spawning season.
- The day-to-day variability in the area available (how much it changes from one day to the next).
- The within-day variability of the area available (its maximum change within any 24-hour period).

Available spawning habitat is defined as suitable habitat that is located 15 cm or more below the water surface elevation.

These components may be combined into a single Spawning Habitat performance measure. (See the "Normalization and Weighting Functions" information sheet.) The Fish Technical Committee has assigned a preliminary weighting to each component (Table A).

Table A: Component Weights – Spawning Habitat

	Quantity	Day to Day Variability	Within-Day Variability
Weight	40%	30%	30%

Why is it important?

- Plant discharge flows affect downstream water surface elevation which in turn affects the availability of suitable spawning habitat. At different elevations, different quantities of suitable habitat may be available. The quantity of suitable spawning habitat may be a limiting factor to a river's productive capacity.
- Fluctuations in flow result in fluctuations in water surface elevation, which can hinder salmon nesting and spawning behaviour. Reservoir management decisions affect the variability in habitat from day to day. Peaking operations affect within-day variability.

Fish Use

- The channels below Ruskin Dam are currently used extensively by chum for spawning, but also by coho, pink and chinook salmon, steelhead and cutthroat trout, and Dolly Varden char.
- Below Ruskin Dam, the number of spawners has rebounded from about 30,000 chum and 30 coho in the late 1980s, to about 200,000 chum and 1600 coho in 1997. 600,000 chum returned to spawn in 1998 (number to be confirmed by Inch Creek Hatchery).
- This recovery of fish returning to the system is a result of structural improvements made to the channel, hatchery fish added to the river, and the development and implementation of the Ruskin Dam Fish Flow Agreement that ensures better conditions for fish. (In 1998, the recovery jumped to 600,000 chum, at least partially due to changes in fish harvesting - number to be confirmed by Inch Creek Hatchery).
- DFO in 1998 estimates the spawner capacity in the Stave River for chum at about 200,000.
- Fish released yearly into Stave through hatchery operations include 2 million chum and 200,000 chinook in 1997, 450,000 coho in 1996 and 16,000 cutthroat in 1990.

Other Considerations

- The channels immediately downstream of Ruskin Dam have been engineered to maximize the amount of salmon spawning habitat and to maintain a relatively constant amount of habitat over a wide range of water surface elevations. The changes in habitat resulting from plant discharges are relatively small.
- Tidal influences and Fraser River backwater effects can either aggravate or offset flow changes resulting from dam operations. The calculation of the area of usable spawning habitat for this measure takes these factors into consideration

How is the performance measure calculated?

1. Wetted areas will be calculated using flow model predictions of water surface elevations calculated from plant discharges, tidal elevations, and stream cross section data. Useable Wetted Width (UWW) will be calculated from those channel areas with minimum depths for spawning (15cm). UWW will be multiplied by channel length to estimate Useable Wetted Area (UWA). The area reported is the minimum area available on 50% of the days of the spawning season.
2. Day to day variability is calculated as the difference between the habitat available on 20% of the days of the spawning season and the habitat available on 80% of the days of the season.
3. Calculations will be repeated for each year of the simulation period (25 years). The median and $10^{th}/90^{th}$ percentile values for habitat area and its variability will be reported. The median represent roughly an average year, and the $10^{th}/90^{th}$ percentile values can be interpreted as "nine years out of ten, the available spawning area will be no worse than the reported value".

4. Values of each component of the measure (quantity and variability) are normalized relative to all operating strategies under consideration, and a single unitless number between 0 and 1 is recorded as the total score.

What are the key assumptions underlying this performance measure?

- Water depth is a major determinant of the preferences or ability of salmon to spawn.
- Alternative operating strategies do not influence the inventory of spawning habitat (e.g., change the substrate or exceed velocity thresholds).
- By maximizing habitat suitable for chum salmon, habitat for other species will also be enhanced.
- The number of spring spawners are small and Fraser backwater effects at this time are high, so that habitat limitations caused by plant discharge flows are unlikely to be a limiting factor in salmon productivity in the spring.

PERFORMANCE MEASURE: REDD STRANDING RISK

What is the Stranding Risk performance measure?

This performance measure will be used to assess the impact of BC Hydro operations on the salmon eggs and alevins. It reports the likelihood that water levels will be high enough to prevent the risk of dewatering incubating eggs and stranding alevins.

The target water level is based on the level that occurred on each day of the spawning period. It can be assumed that below this level there will be incubating eggs that could potentially be dewatered.

The measure is relevant for the period from spawning to emergence – Oct 1st to April 30th. It has two components:

- *Median Risk Indicator*: The expected water level during the spawning-emergence season, reported relative to the water level that existed on the day of spawning. For example, a reported value of 0.66 means the expected water level is 66% of the level on the day of spawning. The higher the reported value, the less likely that eggs or alevins will be dewatered.
- *High Risk Indicator*: The water level that is the minimum that will be expected 90% of the days of the season, reported relative to the water level that existed on the day of spawning.

The median risk indicator reports expected conditions (50% probability of occurrence). The high risk indicator reports extreme conditions. By having both indicators, it is possible to fairly evaluate an operating strategy that has a low risk for most days of the season but high worst case conditions, with a strategy that causes slightly higher risk throughout the season, but less extreme worst case conditions.

These components may be combined into a single Stranding Risk performance measure. (See the "Normalization and Weighting Functions" information sheet.)

Table A: Component Weights – Stranding

	Median Risk	High Risk
Weight	50%	50%

The Fish Technical Committee has assigned a preliminary weighting of 50% to each component (see Table A), meaning that the components are equally important in terms of defining potential impacts on dewatering of eggs and stranding of alevins.

Why is it important?

- Changes in flow during the egg incubation and alevin lifestage increase the risk of stranding, which can lead to egg or alevin mortality.
- Incubating eggs are at greatest risk since they are immobile.
- Emerging fry are also at risk because of their limited swimming ability and tendency to frequent shallow areas susceptible to dewatering. This performance measure is designed to measure risks to eggs/alevins and does not fully capture effects on fry.

However in general, a strategy that improves conditions for alevins also improves them for fry.

Fish Use

- The channels downstream of Ruskin Dam are currently used extensively by spawning chum salmon, and also by juvenile coho, pink, and chinook salmon, steelhead and cutthroat trout, and Dolly Varden char.
- Below Ruskin Dam, the number of spawners has rebounded from about 30,000 chum and 30 coho in the late 1980s to about 200,000 chum and 1600 coho in 1997. This recovery of fish returning to the system is a result of structural improvements made to the channel, hatchery fish added to the system, and the development and implementation of the Ruskin Dam Fish Flow Agreement that ensures better conditions for fish. The recovery jumped to 600,000 chum in 1998 (numbers to be confirmed by Inch Creek Hatchery), at least partially due to changes in fish harvesting.
- Fish released yearly into the Stave River through hatchery operations include 2 million chum and 200,000 chinook in 1997, 450,000 coho in 1996 and 16,000 cutthroat in 1990. Backwatering in the lower Stave River from high summer Fraser River flows ensure that BC Hydro operations do not impact these species during incubation and emergence.

Other Considerations

- DFO biostandards estimate egg to fry survival of 8% for chum salmon. However, it is estimated that Stave River wild chum have a slightly higher survival rate due to the regulation of the river through the current interim flow agreement and the design of the spawning grounds.
- Emerging fry can also be subjected to stranding due to Ruskin operations. A recent BCH study estimates that Ruskin operations caused mortality in 1.48% of the total emergent fry populations in 1998. Ruskin operations are estimated to cause about 95% of that 1.48%. The remainder is caused by natural tidal effects.
- Relative to mortality from other sources, the effect of stranding is small. For example, for 1998, studies estimate about 1.5% of total emergent fry are stranded. Given estimated total fry-to-adult mortality of 98.9%, this translates into a decline of about 3000 in the number of adults expected to return to spawn in four years. (Assuming 25 million emergent fry (estimated in 1998) and a harvest rate of 30% (average over 13 years), about 194,000 adults are expected to return to spawn in four years. If Ruskin-induced stranding were zero, returning spawners would be about 197,000.)
- Nighttime stranding occurs at twice the rate of daytime stranding. During the period of Fraser River backwater, the effect of operations at Ruskin on stranding is limited.
- Stranding in the backwater area below the right bank spawning channels and the spawning channels themselves is negligible.
- These results are based on limited assessments and are still under review.
- The benefits of block loading over the emergence period (conducted this year for the first time) will be assessed through fry counts in 1999 and escapement totals in 2003.

How is the performance measure calculated?

1. The water surface elevation on each day of the spawning period is calculated from a simulation model of the upper 300 m of Stave River (the area subject to the greatest risk of stranding). The Useable Wetted Area for spawning chum is calculated by subtracting 15 cm from the simulated WSE and using the result to estimate wetted area. It is assumed that below the target water surface elevation (WSE -15cm), there will be incubating eggs at risk of being dewatered.
2. To determine the relative risk of dewatering;

   i) For spawning day 'D_i', (in the interval between Oct 1 and Dec 31) in year 'y', calculate the magnitude of change in WSE on $D_{(i+t)}$, where t = 1 to the number of days remaining before April 30, use the data to estimate the change in wetted area, and report the result as a proportion of the discharge on day 'D_i'.

   ii) Do step (i) for each 'D_i' between Oct 1 and Dec 31.

   iii) Use the proportional data and create a cumulative frequency histogram with bin widths that are logarithmically scaled from 0.001 (drops in wetted area that are 1000 times less than the spawning flow on 'D_i') to 1000 (increases in wetted area that are 1000 times greater than the spawning flow on day 'D_i'). *A value of 1 indicates no change from spawning conditions.*

   iv) Interpolate median and 10th percentile proportional change in wetted area from the frequency histogram. These values become the stranding risk index for year 'y'.

3. Calculations (steps i to iv) will be repeated for each year of the simulation period (25 years). The median and 10th percentile values will be reported.
4. Values of each component of the measure (probability and variability) are normalized relative to all operating strategies under consideration, and a single unitless number between 0 and 1 is recorded as the total score.

Key Assumptions

- The daily flush is not fully effective in protecting incubating eggs. If it were, this measure would not need to be in effect throughout the incubation period.
- Chum and other species will not spawn in waters less than 15cm deep.

STAVE RIVER WUP INFORMATION SHEET

PERFORMANCE MEASURE: TOTAL GAS PRESSURE

NOTE: THIS PERFORMANCE MEASURE WAS UPDATED TO ACCOUNT FOR DURATION THRESHOLDS. SEE ATTACHED BRIEFING NOTE.

What is the Total Gas Pressure performance measure?

This performance measure will be used to assess the impact on fish of elevated total gas pressure (TGP) levels resulting from BC Hydro spillway operations at Ruskin Dam. This measure is relevant year-round and has three components:

- Number of days on which gas levels are between 103 and 110%
- Number of days on which gas levels are between 110 and 115%
- Number of days on which gas levels exceed 115%

Additional refinements may be made in order to account for the effect of duration. For example, exposure to elevated TGP may only have negative effects on fish if exposure continues for several days. Further research is now being conducted to determine if it is possible to characterize duration effects.

These components may be combined into a single TGP performance measure by calculating the weighted average. (See the Normalizing and Weighting Information Sheet.) The Fish Technical Committee has assigned a preliminary weighting to each increasing level of TGP (Table A). Higher levels of TGP represent a greater risk to fish than lower ones.

Table A: Component Weights – TGP

	TGP – 103-110%	TGP – 110-115%	TGP – > 115%
Weight	20%	30%	50%

Why is it important?

- Elevated levels of total gas pressure in the water column are known to have the potential to cause gas bubble trauma disease in fish, which can directly or indirectly lead to fish mortality or reduced productivity.
- Spillway releases of water at Stave Falls and Ruskin Dams are known to generate TGP levels in excess of BC Water Quality Guidelines. These guidelines indicate that fish are at risk if TGP levels are above 103% in waters less than 1 meter deep. In waters greater than 1 meter deep, the first signs of impact can be observed in fish if TGP levels are above 110%.

Fish Behaviour and Use

- No fish in the Stave River system have been observed with symptoms of gas bubble trauma.
- TGP studies to date have generally been conducted in laboratories; there are limited data from field studies to establish whether fish are able to avoid this disease through avoidance behaviors, such as swimming to depth, etc.
- Below Stave Falls, fish may have some opportunity to avoid TGP effects by seeking out deeper water in Hayward Reservoir. This escape is less available to fish downstream of Ruskin. Hence, efforts to understand the relationship between spilling, TGP production, and the potential impacts on fish, are concentrated on the area below Ruskin Dam.
- The lower Stave River is currently used extensively by spawning chum salmon. Coho, pink and chinook salmon, steelhead and cutthroat trout and Dolly Varden char spawn and rear in the area as well. Below Ruskin Dam, the number of spawners has rebounded from about 30,000 chum and 30 coho in the late 1980s, to about 200,000 chum and 1600 coho in 1997. This recovery of fish returning to the system is a result of structural improvements made to the channels, hatchery fish added to the river, and the development and implementation of the Ruskin Dam Fish Flow Agreement that ensures better conditions for fish. The recovery jumped to 600,000 chum in 1998 (numbers to be confirmed by Inch Creek Hatchery), at least partially due to changes in fish harvesting.
- Although the 1998 fish use study found few juvenile sportfish rearing in the system, this does not preclude the possibility that they rear in the system at other times or in other years. The TGP measure remains relevant year-round until it can be verified that there are seasons during which no or few fish are at risk.

How is the performance measure calculated?

The following steps will be used to calculate the Total Gas Pressure performance measure:

1. From the discharge data generated by a simulation model, the frequency, timing and magnitude of spill events will be documented.
2. Based on discharge levels that are assumed (from existing monitoring data) to produce 103%, 110%, and 115% total gas pressure levels, the spill data will be calculated to determine the number of days in each year on which elevated gas levels are expected to be:
   - Equal to or greater than 103% saturation, but less than 110% saturation.
   - Equal to or greater than 110% saturation, but less than 115% saturation.
   - Greater than 115% saturation.

1. The calculation is repeated over twenty five years of data and the average and 90th percentile value for annual frequency will be reported.

2. Values of each component of the measure (each TGP level) are normalized relative to all operating strategies under consideration, and a single unitless number between 0 and 1 is recorded as the total score.

Key Assumptions

- The assumed correlation between spill releases and TGP events at Ruskin is valid.
- The Province's guidelines for TGP accurately reflect risk to fish from elevated TGP levels:
  - Total gas pressure is not to exceed 103% in waters less than 1m deep. Above this level, juvenile fish are at risk.
  - Total gas pressure is not to exceed 110% in waters greater than 1m deep. Above this level, the first signs of impact develop in most fish.
- Beyond these guidelines, total gas pressure levels above 115% can lead to direct mortality in larger fish.
- Fish are present year-round and do not escape mortality from TGP through avoidance behaviours.

TGP Performance Measure Recommendations
Briefing Note

Definitions

Direct Mortality. Mortality that occurs as a direct result of TGP exposure. There are two possible modes of mortality: swim bladder rupture and Gas Bubble Trauma (GBT) disease.

Indirect Mortality. An increase in mortality from other causes that occurs because of the non-lethal effect of exposure to elevated levels of TGP. For example, increased mortality from predation or decreased growth rates may occur due to swim buoyancy/mobility problems.

Background

The initial TGP performance measure developed for SRWUP counted the number of days on which elevated levels of TGP occurred. This is an overstatement of actual effects on fish since it is generally acknowledged that there is a duration threshold – that is, fish must be exposed for some minimum duration before they suffer any negative effects. A literature review was conducted to estimate the duration thresholds at various levels of supersaturation. The literature suggests:

Direct mortality[1] may occur when TGP is between 103% and 110% for 28 or more days:
- based on very limited data
- duration to mortality ranged from 28-60 days
- percent mortality ranged from 4-8%

Direct mortality may occur when TGP is between 110% and 114% for 1.1 or more days:
- based on limited data
- duration to mortality ranged from 1-67 days

Direct mortality may occur when TGP exceeds 115% for 0.06 or more days (0.4 or more hours):
- duration to mortality ranged from 0.4-39 days

See K. Wilby's draft memo on TGP duration thresholds (February 1999) for details.

Recommendations

The primary TGP performance measure will record the number of days on which there is a risk of direct mortality due to exposure to elevated levels of TGP. The performance measure is the sum of:

- the number of days on which TGP is between 103 and 110% after a period of 28 consecutive days of elevated TGP levels; and
- the total number of days on which TGP exceeds 110% (no threshold).

[1] Time to mortality may be for anything from the mortality of one fish to 100% mortality of the test population. Data includes results for both juveniles and adults.

If there is no discernible difference in rankings of alternative operating strategies on this basis, or if the difference is small, then the total number of days on which there is a risk of indirect mortality due to exposure to elevated levels of TGP may also be used:

- Each day that TGP is between 103 and 110% up to the 28 day threshold for direct effects will be recorded as a day that fish face a risk of indirect effects.

This revision to the TGP performance measure will need to be reviewed and approved by the SRWUP Fish Technical Committee. However the performance measure should be used in this form for the purposes of current modeling.

Discussion

Why is there no distinction between TGP levels of 110-114% and levels in excess of 115% (per the Provincial Guidelines)?

SRS modeling occurs in time steps of one day. Any occurrence of elevated TGP, no matter how brief, is recorded as one day of exposure. (For example, an 8 hour occurrence is recorded as one day; a 24 hour occurrence is recorded as one day, a 25 hour occurrence is recorded as two days; etc.). As a result, there is no practical way to distinguish between the duration threshold for 110-114% (1.1 days) and the threshold for >115% (0.06 days).

Why is there such a sharp difference between the duration to mortality at 103-110% and the duration at > 110%? Shouldn't there be a transition zone?

The sharp difference in duration to mortality may be explained by the existence of two different modes of mortality. At 103-110%, direct mortality is likely to be caused by swim bladder rupture, which takes a long duration of exposure to develop. GBT disease is unlikely to occur at these low level exposures. At TGP levels greater than 110%, the cause of mortality is likely GBT disease, which leads to mortality relatively quickly.

Is 28 days at 103-110% sufficiently precautionary given the paucity of experimental results in this range?

There are too few published data to have confidence that the minimum recorded duration to mortality represents the actual threshold. All we know is that the duration threshold is *no more than* 28 days.

In the absence of any better data, 28 days is recommended. However, we are also recording the total number of days that TGP is between 103 and 110% as a measure of the risk of indirect effects. The real measure of the number of days on which fish face a risk of direct mortality from TGP between 103 and 110% will lie somewhere between these two measures. (I.e., If the number of days on which TGP is between 103 and 110% *after the 28-day threshold* is 5 and the number of days on which TGP is between 103 and 110% *in total* is 40, then the real number of days on which fish face a risk of direct mortality due to TGP between 103 and 110% is somewhere between 5 and 40.)[2]

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[2] An alternative is to acknowledge a desire to err on the side of the precautionary principle and to select a threshold shorter than 28 days. This option will be discussed with the Fish Technical Committee.

Spills of 28 days or more never occur at Stave. Is there any use to a performance measure that tracks an event that is unlikely to occur under any circumstances?

The assumption that spills of 28 days or more never occur at Stave is based on historical operations. Given the request from Consultative Committee participants to model a number of reservoir stabilization strategies, it is conceivable that substantially more spill days would occur.

If in fact none of the alternative operating strategies considered by the Consultative Committee result in spills of greater than 28 days, then this component of the PM will be zero for all alternatives. It therefore does not help to rank alternative operating strategies. However, this may be an accurate description of actual biological effects. The correct interpretation would be the following: "*Within the range of operating strategies under consideration at Stave,* there is no discernible difference in the risk of direct mortality caused by occurrences of TGP in the range of 103-110% supersaturation." This is useful information for decision making.

As a measure of the risk of indirect mortality from exposure to elevated TGP, is it adequate to simply track the total number of days between 103 and 110%?

It is expected that this will be an overstatement of actual biological effects because:

- It is well accepted that spill events of very short duration have no effect on fish. In the absence of any literature on indirect mortality from slightly elevated levels of TGP, no attempt has been made to define a duration threshold for indirect effects. However, it is clear that a threshold exists. By tracking every day on which TGP rises above 103% regardless of duration, some events that have no real biological consequences will be included.
- Elevated levels of TGP may result in increased susceptibility to predation. However, there are few predators in the Stave River system so the increase in mortality due to predation may be limited.
- The main effect is likely to be a reduction in growth rate (biomass accumulation) due to increased physical activity needed for swimming and reduced feeding efficiency caused by buoyancy problems.

In spite of these considerations, it is probably generally true that an operating strategy with a lower number of spill events is better than one with a higher number of spill events. Use of this PM errs on the side of caution.

This PM will be used to select a preferred operating strategy. Will any further studies be done to better understand the biological impacts of the strategy with respect to TGP?

Decisions about the need for further study of TGP effects will be made by the Consultative Committee/Fish Technical Committee. It is expected that the Committee will evaluate alternative operating strategies based on the proposed TGP PM (along with other PMs). They may or may not select the alternative that minimizes TGP events, depending on the costs (both monetary and non-monetary). In making their selection, they may acknowledge uncertainty over actual biological effects, and may recommend that additional research, monitoring or experimentation be undertaken in order to re-evaluate operating decisions and/or non-operational options in the future. They may also recommend a timeline for a future review that incorporates the new information.

HERITAGE

What are the Heritage objectives at Stave?

The Stave River system lies within the Traditional Territory of the Kwantlen First Nation. Kwantlen First Nation, along with British Columbians, have an interest in understanding how Kwantlen's ancestors lived and in uncovering parts of their heritage. Kwantlen is interested in protecting heritage sites from erosion and illegal collection, accessing sites, and recovering artifacts.

What are the issues?

Sites throughout Stave Reservoir. Numerous archeological sites have been identified on Stave Reservoir. Studies (Ryder 1998; Gilbert and Desloges 1992) indicate that the rate of erosion in the reservoir was likely highest in the first years following inundation. Erosion continues at a lower rate today, although rates may vary in conjunction with windstorms. Erosion studies have not assessed impacts on all sites, but it is clear that erosion affects at least some, possibly all, heritage sites. Erosion rates and impacts are very site specific, depending on such factors as exposure to wave attack, erodibility of soils and surface materials, and the nature and location of human disturbance. The most widespread cause of erosion is wave action, which can affect sites located within one meter above and below the reservoir water surface.

DhRo-10. Erosion by water currents was observed by Kwantlen at a specific site on Stave Reservoir in the spring of 1997. Kwantlen observed significant disturbance of artifacts on the site. They also observed soil characteristics (colour) that suggest that much of the original organic material may still be present. During normal operation, BCH modeling suggests that this area is a depositional area. However, at the time of the erosion observations, the reservoir level was low and spill rate was high in order to accommodate construction activities for the new power plant. This combination of low level and high spill rate results in higher water velocities on the bottom of the reservoir which can cause erosion; BCH believes that the observed erosion likely occurred over a short period of time as a result of these increased velocities. The conditions leading to increased velocities (low level combined with high spill rate) do not occur under normal operations. BCH concludes that the site is located in an area that is likely a depositional area under normal operations, but that the site is clearly susceptible to erosion if reservoir levels are low and the drawdown (or spill) rate is high. This site was not visited during recent erosion studies as it was below the drawdown elevation. As a result, these conclusions have not been confirmed.

Sites Downstream of Ruskin. Erosion is not discernible from an air photo analysis of the river's changes since the construction of Ruskin Dam. The exception is evidence of erosion to the wooded island immediately downstream of the dam. A known heritage site (DhRo-29) is located here. DhRo-29 is extremely important to Kwantlen First Nation.

Sites on Hayward Reservoir. Heritage sites have also been identified on Hayward Reservoir, but the effect of erosion on those sites has not been studied in detail. It is expected that similar processes to those seen on Stave Reservoir could affect the Hayward Reservoir sites. The smaller drawdown range and shorter fetch (length over which waves develop) of Hayward Reservoir suggests that erosion forces may be significantly weaker than they are on Stave Reservoir. Nonetheless, they may affect heritage sites.

How will heritage objectives on Stave Reservoir be considered?

Impacts on heritage sites stem from both the original inundation, and on-going operations. The WUP process is designed to identify ways to mitigate the effects of on-going operations. It will not be able to fully address the concerns of Kwantlen and participants about overall impacts. However, it may be able to significantly reduce or mitigate some impacts. Parallel processes are in place to provide further resolution to heritage issues that are not adequately addressed through WUP.

What performance measures will be used to record heritage impacts?

Two performance measures are proposed. For each operating strategy, the following information will be reported:

<u>Protection</u>: *No. of Site-Days of Full Submergence (Stave Reservoir).* This performance measure indicates the number of days that each site on the reservoir is covered by at least one meter of water, and sums the days over all sites in the reservoir. Coverage of one meter of water provides protection against wave erosion and illegal collectors. (Note: This component is not integrated into the Heritage Index value used in the evaluation of options, but is considered qualitatively.)

<u>Access:</u> *No. of Site-Days of Full Access (Stave Reservoir).* This performance measure indicates the number of days that each site is fully exposed, and sums the days over all sites in the reservoir. This is a measure of the accessibility of sites for visiting and recovery activities. It is limited to the winter period as this is the best period for ensuring minimal use of the area by non-Native recreationalists.

How will the potential for erosion at DhRo-10 be considered?

This site is located on Stave Reservoir, but requires specific attention due to observed susceptibility to erosion under certain conditions. The WUP process may consider operating orders that limit rapid drawdowns/spills at low reservoir levels and/or identify mitigating actions to be taken should such a drawdown be required. It may also consider further study of the impacts on this site.

How will sites downstream of Ruskin be considered?

The scope of WUP is limited to addressing impacts through operational changes. Since no operating strategy has been identified that would alleviate erosion impacts on the wooded island downstream of Ruskin, it is unclear whether this impact can be directly addressed under WUP. However, it may be possible to consider activities to protect or enhance this site as mitigation for operational impacts in other locations.

What about sites at Hayward?

There is limited ability to change operations affecting Hayward Reservoir. No performance measure is proposed at this time. The need to collect more information over time about impacts on sites at Hayward may be evaluated during the WUP process, and further studies may become part of a long term adaptive management plan. However, there may be other, non-operational ways of protecting or enhancing the value of heritage sites at Hayward which could be incorporated into the WUP as a means of mitigating operational impacts.

INDUSTRY

What are the performance measures for Industry?

These performance measures indicate the impact of BC Hydro operations on industrial operations on Stave Reservoir and downstream of Ruskin Dam. It consists of two components:

Frequency of Above Average Spills. The expected number of days per year on which spills that could affect downstream industry occur at Ruskin Dam. Above average spills are defined as spills exceeding 10,900 cfs, which is the average annual peak daily spill. (Post-process note: This indicator was not used in later stages of the WUP process, since industry representatives felt that their needs were adequately addressed by the introduction of the improved spill notification procedure.)

Frequency of Low Reservoir Levels. This is a weighted average indicator that measures the number of days in the period from December 1 to June 1 that the reservoir is above 76m, and the number of days in the period between June 1 and Dec 1 that the reservoir is above 79m. These are threshold elevations for access to loading and offloading equipment.

Why are they important?

Frequency of Above Average Spills. Large spills can disrupt log transportation on the river downstream of Ruskin Dam.

Frequency of Low Reservoir Levels. Industry operating on Stave Reservoir have difficulty with transportation and loading/unloading at reservoir levels below 76 and 79m, in the winter/spring and summer/fall seasons respectively.

Considerations at Stave

- Most issues related to spills, low reservoir levels, and rapid drawdowns can be addressed through appropriate notification systems. For example, a commercial fax-out system to notify industry about spill conditions was instituted as a result of feedback received during the issue identification phase of the Stave WUP.
- Industry users on Stave Reservoir include two forestry operations using the reservoir for log transport, the Corrections debris removal tug boat, one water bottling entrepreneur. There are 12-16 active salvage licenses in Stave for recovering merchantable timber. Although salvage licensees prefer low reservoir levels, their permits indicate that low levels cannot be guaranteed.
- Eight forest products operations use the river downstream of Ruskin Dam.

What are the Recreation performance measures?

Stave Reservoir Water Level. This performance measure indicates the impact of BC Hydro operations on recreation on Stave Reservoir. It measures the number of days during the recreational season (May 1 to October 15) that the reservoir level is between 80 and 81.5m. This range has been identified as the optimal range from a recreation perspective.

Hayward Reservoir Water Level. The preferred water level for recreation purposes on Hayward is between 41.3 and 42.3m. Normal minimum and maximum operating levels on Hayward are 41.1 and 42.9m respectively. Provided the normal minimum and maximum levels do not change, there is no discernible difference in frequency or duration at the preferred water levels across operating strategies. Therefore, for the purposes of WUP, no performance measure for Hayward water level is proposed at this time. Measurement of impacts at Hayward will be reconsidered if in fact changes to normal minimum and maximum water levels are proposed through WUP.

Public Safety Downstream of Ruskin Dam. Decisions about ramping procedures during the recreation season may affect public safety downstream of Ruskin dam. For each operating strategy, a qualitative judgment will be made about whether the safety risk to recreationalists downstream of Ruskin Dam is likely to increase or decrease.

Considerations at Stave

- The performance measure for Stave Reservoir will help to ensure that the water use planning process maximizes recreational opportunities on the Stave Reservoir by minimizing public safety risks from standing debris and maximizing public use of the reservoir shoreline. Lower than normal elevations could affect access to beaches and boat launches, create problems associated with unregulated public use within the drawdown zone, and/or adversely affect aesthetics throughout the reservoir.

- The Stave Lake Reservoir Boat Launch was used by about 60,000 users in 1996 (slightly less in 1997 due to Stave Falls Project construction). 170,000 users were recorded at Hayward Recreation Area and 100,000 users at Ruskin Picnic Site in 1996.
- Facilities at Stave are widely utilized by Lower Mainland residents. As the population in the Lower Mainland is expected to grow by 62% by 2021, use of Stave for recreation can also be expected to grow over time.
- The preferred operating levels indicated by the performance measure (80-81.5m) are consistent with the conclusions of the Stave Lake Reservoir Integrated Recreation Plan which considered a wide range of recreation-related issues.

PERFORMANCE MEASURE: COST OF REPLACEMENT ELECTRICITY

What is the *Cost of Replacement Electricity* performance measure?

This performance measure will be used to determine the financial cost of constraining operation at Stave Falls, Ruskin and Alouette power plants to accommodate non-power water uses in the Stave River system. Constrained operation may reduce the amount and value of electricity from the three power plants. The ***cost of replacement electricity*** is defined as the long term cost to replace the electricity foregone at the three plants.

How is the performance measure calculated?

For each constraining operation strategy, the ***cost of replacement electricity*** will be calculated by multiplying the ***amount of electricity lost*** by the ***long-term replacement cost***. BC Hydro uses the long-term forecast market price of electricity to represent the long-term replacement cost.

The ***amount of electricity lost*** in a constraining operation strategy will be calculated as the difference between the amount and timing of electricity produced under the constraining strategy and the amount and time of electricity produced under a baseline strategy.

Electricity can be 'unbundled' into three major components: energy, capacity, and ancillary services. Energy capability is the amount of electricity which the plant can produce over a given time – (in a car, this would be similar to the distance that can be travelled with the amount of gasoline in the tank). Capacity is the maximum amount of electric power which can be produced at any instant – (in a car, the maximum horsepower of the engine). The distinction is important because the market price of electricity varies daily and seasonally, and the value of a plant's electrical output depends upon, among other things, its maximum generating capacity .

Ancillary services include such aspects as: spinning reserve, which contributes to the reliability of the generating system; voltage support for the transmission system; and load following, which is the ability of the system to respond to changes in customer demand. Load following and the value of a plant's maximum capacity are particularly affected by ramping rates (rate of change in water flow through the generators) because they affect the plant's ability to respond to changes in market demand. Every utility is obligated to provide its own ancillary services or make provision for them, and these services should be considered when assessing the cost of a change in plant operation. The point is that, if a significant loss of these services occurs at one part of the system, they must be replaced or obtained somewhere else.

As stated above, the long-term market price of electricity is used to represent the cost of replacement electricity. The price of electricity depends on electricity demand which varies hourly, daily, and seasonally. Electricity demand is typically greatest Monday to Saturday from 6am to 10pm (termed "heavy load" hours). Demand drops overnight from 10pm to 6am and on Sundays (termed "light load" hours). The price also varies by season with higher prices typically occurring in the winter months which exhibit the coldest temperatures and summer months with heavy air conditioning load. BC Hydro forecasts the long-term electricity price from market information and pricing models and uses this price to estimate the cost of replacement electricity.

Who Pays?

BC Hydro pays a rental fee for water used to generate electricity and the fees go into general revenue for the provincial government. Regulations under the Water Act provide for a remission of water rental fees when, under the direction of the Comptroller of Water Rights, there is a reduction in electricity produced in favour of other non-power benefits. Therefore, if there is a reduction in the value of electricity produced at the Stave system, resulting from either a reduction in electricity generated or a shift from higher value to lower value electricity due to timing, this cost of implementing water use plans will be borne by B.C. taxpayers.

What happens if electricity production is lost at the Stave River System?

Constraining operation at the Stave System reduces BC Hydro's overall electricity generation capability (energy, capacity and other services). This would need to be replaced in order to keep supply in balance with demand. This can be achieved through increased market purchases at market prices, or by the addition of new generating facilities to BC Hydro's system. Any new generating facilities in B.C. at this time are expected to be gas-fired thermal power plants, since these are the least cost option. These plants will operate at or near the market price of electricity. Thus, whether replacement electricity is purchased or produced in new facilities, the financial cost to the province to replace electricity production foregone at the Stave System is assumed to be at its market price.

In addition to financial costs, thermal plants have non-financial impacts (e.g., air emissions) which must be considered.

BC Hydro as a Trader of Electricity

Generally, over a year, BC Hydro has only sufficient electricity supply resources to meet its customers' demand (i.e., the system is in load/resource balance). Supply resources include hydroelectric generation, purchases from Independent Power Producers (IPPs), operation of Burrard Generation Station and market purchases. Demand includes domestic load and long-term firm export commitments (i.e., Hyder, Alaska and Point Roberts, Wash.).

While BC Hydro does not have surplus electricity over a year, it is able to "shape" actual generation to meet BC customer demand and buy and sell electricity on the short-term market as an electricity trader. It does this by using its reservoir storage capacity to store energy (in the form of water) when low-priced electricity can be purchased from the market (typically at night and during the spring freshet), and it sells electricity to the market when prices are higher (e.g., daytime hours, winter cold spells in the Pacific Northwest and summer hot spells in the U.S. southwest).

Electricity trade occurs using existing BC Hydro generating facilities. Trade enables BC Hydro to maximize the value of its resources, creates revenue for the province under all streamflow conditions and supports Hydro's ability to meet its domestic demand during periods of low streamflow.

APPENDIX 3
Fisheries Studies – Summary and Evaluation

Note: Evaluation conducted in June 1998. All Priority 1 and 2 tasks were approved and conducted through summer 1998

Stave River WUP
Potential Studies in Support of Fisheries Performance Measures

Priority 1 Tasks

PM	Task No.	Task	Cost
Spawning	S-1	Develop VB Software for Spawning UWA	$ 5,000
Spawning	S-2	Develop Weighting Function	$ 500
Rearing	R-1	Develop VB Software for Stranding and Rearing UWA PMs	$ 5,000
Rearing	R-2	Develop Weighting Function	$ 1,000
Rearing/TGP	R-3	Fish Use Survey (presence/absence)	$ 6,500
ELZ	E-1	Assess Light Penetration in Reservoir	$ 3,500
ELZ	E-2	Develop Weighting Function, including seasonal weights	$ 1,000
TGP	T-1	Develop 103% Threshold Discharge Criteria	$ 1,000
TGP	T-2	Develop Weighting Function, including seasonal weights	$ 1,000
		Priority 1 Total	**$ 24,500**

Key:

Aids Decision Making?: The study provides information that may affect the ranking of options or the weighting of different performance measures.

Transferable?: The study provides information that is transferable to other WUPs.

Useful for Other PMs: The study may be useful for other performance measures, including non-fisheries PMs.

Stave River WUP
Potential Studies in Support of Fisheries Performance Measures

Priority 2 Tasks

PM		Task	Cost	Date?	Why?	Aids Dec-Making?	Transferable?	Useful for Other PMs?
Spawning	S-3	Verify accuracy of WSE predictions	$ 2,400	ok	Confirm that modeling accuracy is acceptable	Y	N	Rearing
Spawning	S-4	Visual Assessment of side channel impacts	$ 3,500	ok	Confirm that excluding side channels is ok	Y	N	N
		Spawning Subtotal	**$ 5,900**					
Rearing	R-4	Flush Effectiveness Study	$ 16,100	Jun-99	Is flushing effective at improving egg survival?	Y	Y	N
Rearing	R-5	Flushing Strategy Study	$ 7,500	Jun-99	Is there a flushing regime that protects eggs and minimizes chum fry stranding?	N	Y	N
Rearing	R-6	Identify critical rearing habitat	$ 4,500	ok	Allows back channels to be incorporated			
		Rearing Subtotal	**$ 28,100**					
ELZ	E-3	Biological Relevance	$ 25,400	20-Oct	Certainty and relative weight of ELZ criterion	Y	Y	Y
ELZ	E-4	Critical reservoir elevations	$ 8,700	ok	Identify site impacts, e.g., alluv fans, trib access, heritage sites	Y	N	Heritage, Recreation
		ELZ Subtotal	**$ 34,100**					
TGP		No Priority 2 Tasks						
		TGP Subtotal	**$ -**					
		Priority 2 Total	**$ 68,100**					

Stave River WUP
Potential Studies in Support of Fisheries Performance Measures

Priority 3 Tasks

PM		Task	Cost	Date?	Why?	Aids Dec-Making?	Transferable?	Useful for Other PMs?
Spawning	S-5	Establish new transect locations (to be done if justified by S-4)	$ 25,000	ok	Allow back/side channels to be included	Y*	N	Rearing
		Spawning Subtotal	**$ 25,000**					
Rearing	**	Establish new transect locations (to be done if justified by S-4)	**	ok	Allow back/side channels to be included	Y*	N	Spawning
		Rearing Subtotal	**$ -**					
ELZ	E-5	Threshold ELZ Durations	$ 15,700	ok	Select threshold duration for wettedness	?	Y	N
ELZ	E-6	Confounding environmental factors	$ 14,000	ok	Are depth/light the main factors in definiton of littoral zone?	?	?	N
ELZ	E-7	Annual light penetration	$ 12,700	Jul-99	Better estimate of littoral zone depth year-round	?	?	N
		ELZ Subtotal	**$ 42,400**					
TGP		No Priority 3 TGP Studies						
		TGP Subtotal	**$ -**					
		Priority 3 Total	**$ 67,400**					

* If Task S-4 suggests side/back channels are adversely impacted by variable flow

** Included in Task S-5

Stave River WUP

Potential Studies in Support of Fisheries Performance Measures

Other Studies

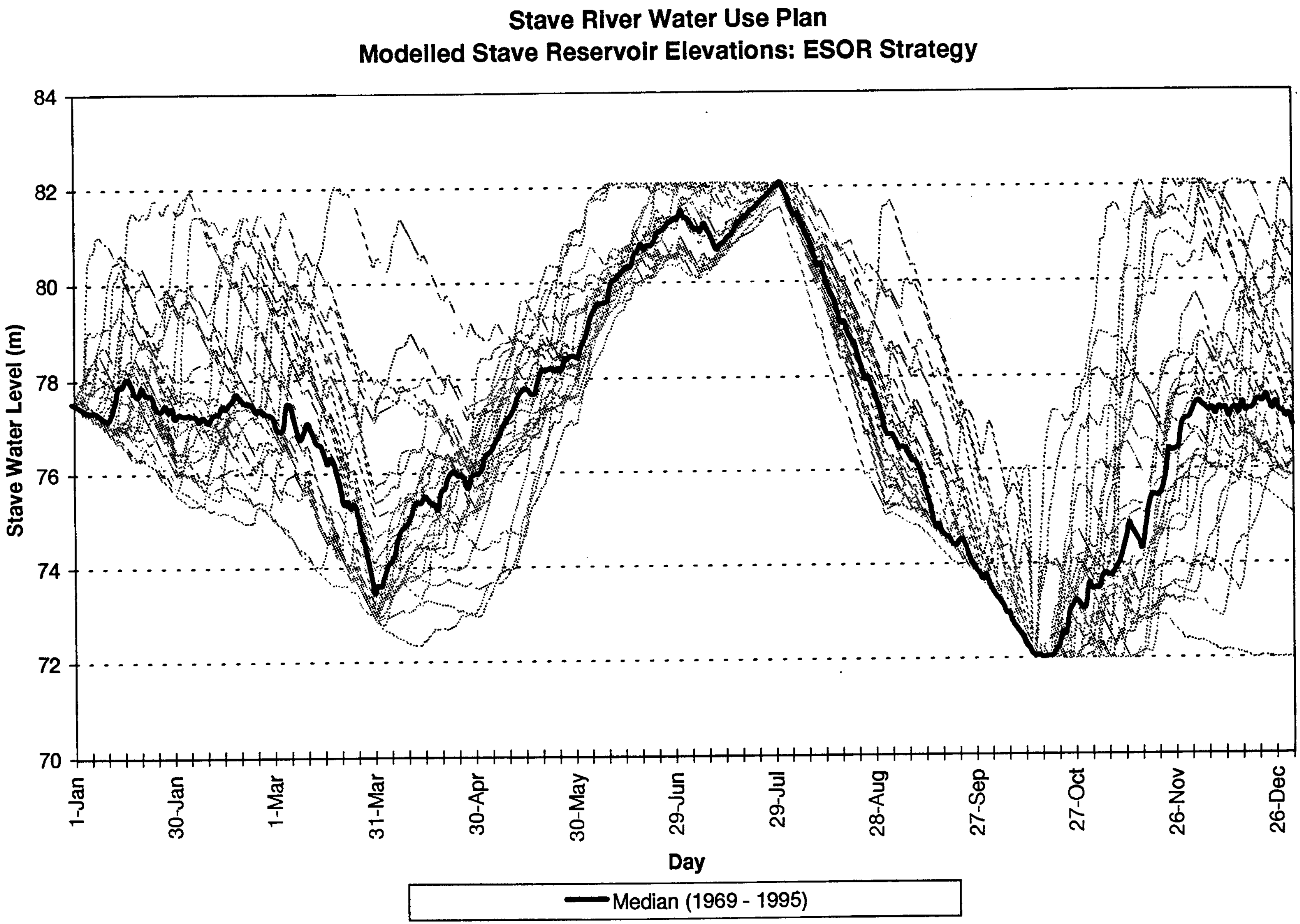
PM	Task	Cost	Date?	Why?	Aids Dec-Making?	Transferable?	Useful for Other PMs?	Comments
TGP	TGP Behaviour/Effects Study: Prepare study plan	$25,000	Mar-99	Link TGP to fish health / mortality; may change weight given to the TGP performance measure	Y	Y	N	High priority study; funding source under investigation. Estimated cost includes study plan only.
Entrainment	Entrainment Effects Study	??		How significant is entrainment?	Y	Y	N	Priority study. Funding source under investigation.
Temperature		$ -						Already underway as part of the EPC conditions for the Stave Replacement Project
Water Quality	Water quality, sediment contamination and mercury contamination	$ 20,000		More info on ecological health of the system	?	N	N	Approved.
Rearing	Stranding Assessment	$20,000	ok	More info on the magnitude of the stranding problem and weighting assigned to stranding.	Y	N	N	Underway.

APPENDIX 4

Alternative Screening – Summary of Performance Measures

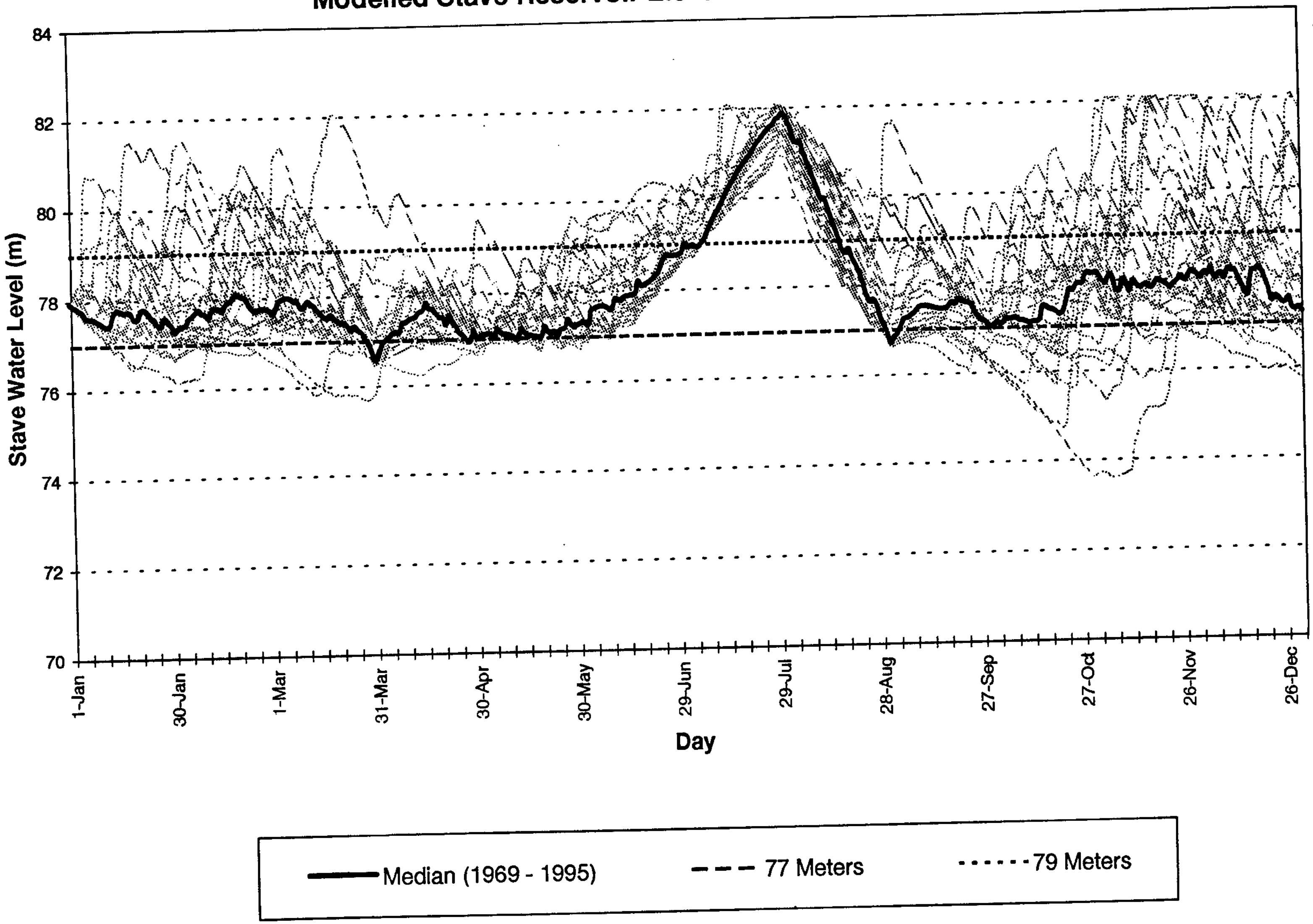
	Fish Performance Measures					Non-Fish Performance Measures			
Option	Rearing Habitat PM	Spawning Habitat PM	Stranding PM	Reservoir	TGP	Heritage Sites PM	Industry PM	Recreation PM	Power PM
	Median	Median	Median	Median	90%-tile	Median	Median	Median	Median
Esor_55b	0.66	0.73	0.41	0.31	0.88	0.74	0.58	0.37	0.32
fish7577_55b	0.82	0.71	0.48	0.51	1.00	0.70	0.23	0.13	0.16
fish7779_55b	0.71	0.72	0.49	0.74	1.00	0.59	0.68	0.33	0.21
fish7981_55b	0.83	0.70	0.52	0.83	0.75	0.19	0.95	0.59	0.15
fish7780_55b	0.71	0.71	0.49	0.73	0.91	0.53	0.73	0.34	0.25
heritage3wk_55b	0.61	0.73	0.40	0.28	0.91	0.79	0.51	0.34	0.33
heritage6wk_55b	0.52	0.73	0.40	0.25	0.91	0.87	0.46	0.32	0.32
industry_55b	0.69	0.72	0.40	0.55	0.88	0.67	0.72	0.40	0.23
recreation_55b	0.70	0.72	0.42	0.37	0.88	0.73	0.66	0.43	0.29
Esor_55SB	0.77	0.73	0.49	0.31	0.88	0.74	0.58	0.37	0.26
power	0.39	0.46	0.30	0.44	0.85	0.64	0.63	0.40	0.71
combo1	0.69	0.73	0.42	0.28	0.88	0.87	0.52	0.39	0.27
Esor_55LBL2	0.75	0.63	0.78	0.31	0.88	0.74	0.58	0.37	0.33
combo3	0.73	0.64	0.74	0.35	0.88	0.73	0.54	0.44	0.36

APPENDIX 5

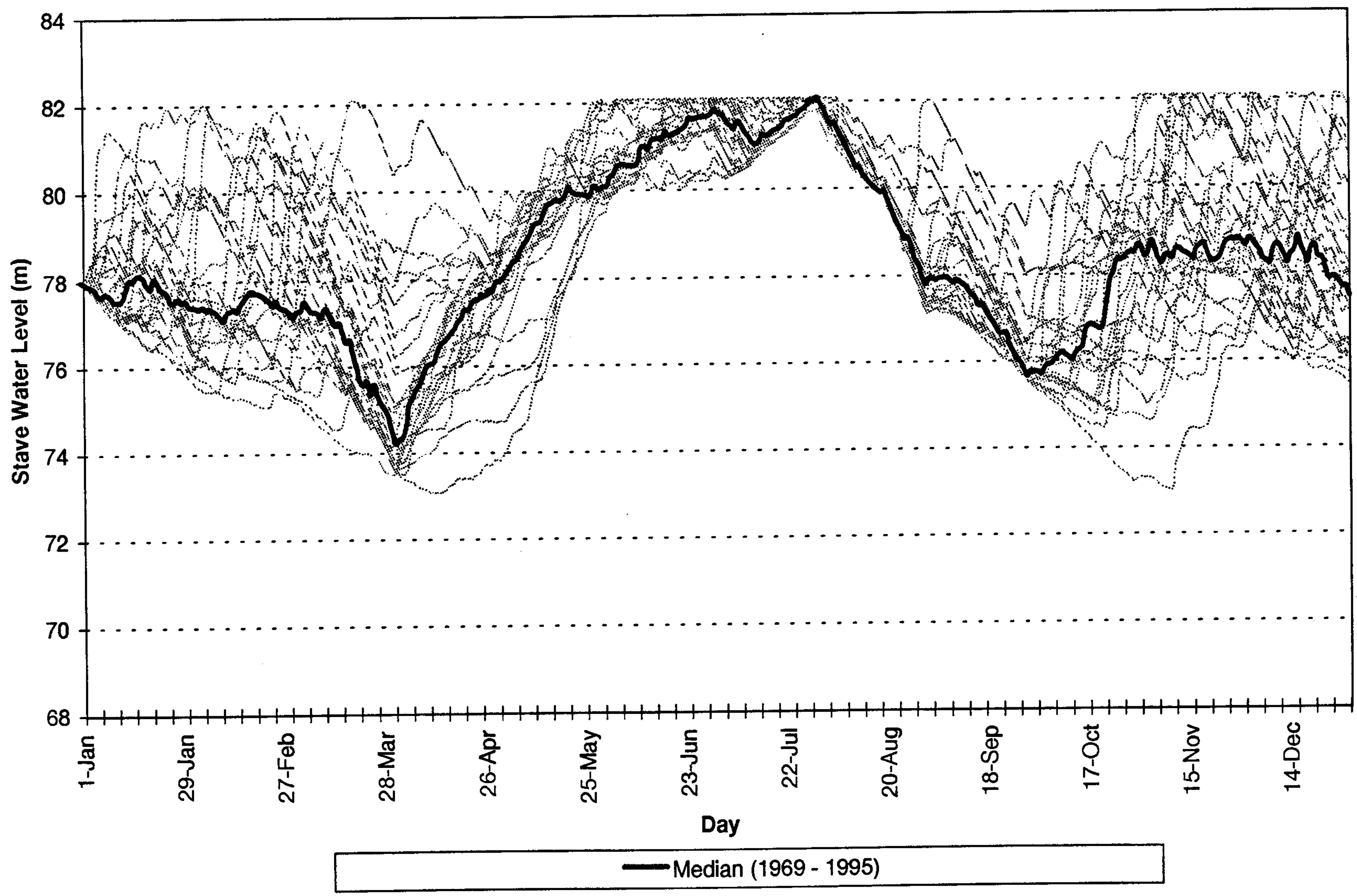


Stave River Water Use Plan
Modelled Stave Reservoir Elevations: ESOR Strategy
84
82
80
78
76
74
72
70
Stave Water Level (m)
1-Jan
30-Jan
1-Mar
31-Mar
30-Apr
30-May
29-Jun
29-Jul
28-Aug
27-Sep
27-Oct
26-Nov
26-Dec
Day
Median (1969 - 1995)

Stave River Water Use Plan
Modelled Stave Reservoir Elevations: Combination 4



Stave River Water Use Plan
Modelled Stave Reservoir Elevations: Combination 5/6



APPENDIX 6

Minutes of the Final SRWUP Consultative Committee Meeting

Meeting Minutes June 24 1999

Attending: Les Antone, Stu Barnetson, Charlotte Bemister, Les Bogden, James Bruce, Tom Cadieux, Dale Clark, Geoff Clayton, Richard Dailey, Tony Dandurand, David Hobbs, Mark Johnson, Bijou Kartha, Ian Kerr, Eduard Krautter, Jenny Ljunggren, Steve Macfarlane, Lorrie MacGregor, John Mackie, Allister McLean, Gordon Mohs, Terry Molstad, Ross Neuman, Marvin Rosenau, Dennis Russell, Hugh Smith, John Stockner, Anne Wilson,

1.0 Monitoring and Management Plans

The Consultative Committee (CC) recommends that the WUP include the management plans as proposed. These include the components shown in Table 1. (Table 1 only shows costs for years 0 through 5. However, it is proposed that the Fisheries, Water Quality and Reporting budgets for years 6 through 10 are equal to year 5 budgets. For Heritage Management, funding requirements will be reviewed in year 5 for year 6 through 10 costs.)

Table 1 Stave WUP Management Plan Estimated Costs (in thousands of dollars)

Year	0	1	2	3	4	5
Component						
Fisheries Management - Reservoir Monitor (Phase 1 and 2) - Limited Block Load Monitor - On-going Management	$28	$369	$247	$225	$205	$205
Heritage Management - Heritage Management Plan - Inventory, Monitoring, Assessment - Drawdown Activity - Mitigation	0	120	120	120	120	120
Water Quality Management - Turbidity Monitoring	0	5	5	5	5	5
Reporting and Quality Control - Annual Report - Monitoring Plan Custodian	0	25	25	25	25	25
Total	**$28**	**$519**	**$397**	**$375**	**$355**	**$355**

Notes:

1. These estimates assume the use of consultants. If BC Hydro staff are used, some costs could be slightly reduced.)
2. The $120k for Heritage Management is an upper figure and is still under negotiation between Kwantlen and BC Hydro. The final figure will be between $100 and $120.
3. All figures are as issued in the prework for the June 24th meeting, with the exception of the addition of $15k for a "Monitoring Plan Custodian" – see item 5.0 "Other Recommendations", below.

Denise Mullen-Dalmer was not able to attend, but raised (via email) the following issues about the proposed management plan:
- is this value for money?
- is the information transferable to other systems?
- is the water quality monitoring amount justified?
- is the management fund just a wish list or slush fund? is it really justified? what is it for?

The CC considered and responded to these questions, as outlined below.

1.1 Limited Block Load Monitor.

The CC recommends that this component be included. The cost of monitoring the limited block load is justified because it is a relaxation of an existing constraint and the change should be monitored to confirm that there are no unmitigable negative impacts. The relaxation of the constraint results in significant power benefits ongoing. The cost of monitoring is projected to last only two years. (In years 4 through 10, the cost drops to less than $5000 per year.)

1.2 Reservoir Monitor.

The CC recommends that the reservoir monitor be implemented as proposed. Hugh Smith (BCH) and consultant John Stockner indicated that the information from the reservoir monitor is expected to be transferable to other coastal reservoir systems. Further, the CC recognizes that there has been and continues to be significant interest on the part of some participants in some form of "stabilization" operation. The reservoir monitor will enable a better evaluation of the potential benefits of this in the future.

1.3 Water Quality Monitoring Plan.

The CC recommends that the water quality monitoring plan be implemented as proposed. The monitor is required in order to ensure that the increased fluctuation in Hayward water levels does not pose a problem for drinking water quality as a result of increased erosion. It is not expected that this monitoring will be required in perpetuity and the Management Committee may decide at some point that it is unnecessary (see item 2.2 *Specific Tasks of the Management Committee*, below). However, given that Hayward is a source of drinking water, the funds should be available to address local concerns as necessary. (Note that the estimate for this has been refined to under $5000 per year.)

1.4 On-going Management Activities.

The CC recommends:
- that the proposed budget for on-going management ($50,000 per year gradually scaling up to $100,000 per year) be accepted;
- that the Management Committee should have authority and flexibility to decide on an annual basis how the funds are spent. A significant investment in monitoring programs is proposed and these programs are expected to provide a sound scientific basis for prioritizing what should be done and how to do it. It is the view of the CC that prescribing the activities in advance undermines the investment in monitoring.

The CC also acknowledged that the nature of the activities and an approximate cost estimate by activity should be provided. Therefore the CC recommends:

- that the proposed Management Committee should be formed immediately and its first task (prior to submission of the Water Use Plan) should be to:
  - develop criteria for the kinds of activities to be considered under this fund (e.g., they should be operations-related, etc.);
  - list the nature of the tasks anticipated (categories of activities), with specific examples where possible, and associated cost estimates by category of activity;
- that this should be considered a budget development exercise. The information should be a guide to the Water Comptroller (and others) in evaluating the reasonableness of the proposed management plan, but it should not restrict the decision making of the Management Committee.
- that the estimated cost be considered an upper ceiling and that the full amount may not be spent in all years.

1.5 Heritage Management Plan

The CC acknowledged the need for Kwantlen to gain better information about sites and how they are affected by operations in order to better prepare them for future decision making. Further, there may be a need for mitigation of significant localized impacts on specific sites resulting from operations. The CC therefore recommends:

- that the proposed management plan be accepted;
- that the management plan be designed to provide information that will better enable Kwantlen and others to evaluate alternative operating strategies in the future;
- that flexibility in funding must be provided to acknowledge that there are windows of opportunity that can't be predicted (e.g., drawdowns), pressing priorities that also can't be predicted (e.g., urgent need to protect or excavate sites experiencing significant erosion) and practical capacity constraints for Kwantlen.

Kwantlen shared and the CC acknowledged that Kwantlen's interest in heritage is long term, and that the heritage management plan will better enable them to conduct long term planning.

1.6 Other Comments/Discussion

Effect of entrainment and fertilization from Alouette. It was suggested that the effect of entrainment and fertilization from Alouette could confound the results of the productivity monitoring on Stave, and that the monitoring program should be designed to address this.

Discussion/Response: The monitor does address nutrient inflows from Alouette. It does not directly monitor inflows of Carbon (fish) from Alouette (via entrainment). However, it was proposed by the Fish Technical Committee and accepted by the CC that it would be premature to try to address this since fertilization has just begun at Alouette and Carbon inflows to Stave have not stabilized. Therefore, the CC recommends that one of the tasks of the Management Committee be to address if, when and how to consider the effects of nutrient inflows from Alouette on Stave reservoir productivity monitoring (see item 2.2 below).

First Nations Involvement. Kwantlen indicated an interest in opportunities to involve Kwantlen First Nation through training and implementation of monitoring, mitigation and other tasks.

Stave Corrections Involvement. Stave Corrections offered to make available labour, equipment and/or monitoring sites to help in conducting (and reducing the costs of) monitoring.

2.0 Stave Management Committee

2.1 Structure, Mandate and Membership

The CC recommends that a Management Committee for Stave be formed that is separate from the Alouette Management Committee. This is based on the belief that the introduction of Stave issues to Alouette may disrupt the Alouette Management Committee which has been operating successfully to date, and that both Committees should be allowed to concentrate on their specific priorities.

The CC recommends that the Stave Management Committee should have a mandate to:
- conduct on-going management decisions with consideration of <u>all</u> objectives
- liase with Heritage Management Committee (Kwantlen)
- liase with the Alouette Management Committee on an as-need basis
- prepare annual public reports
- conduct a formal review after five years which will incorporate the feedback of local management/stakeholder groups

The CC recommends that the Management Committee membership should include:
- DFO, MELP, BCH, Kwantlen, District of Mission
- MOF (Ministry of Forests) to confirm whether they wish to be involved (regular representative of MOF not available at this meeting)
- Technical experts and a monitoring program "custodian" to participate as necessary (see 5.0 Other Recommendations below on monitoring program custodian)
- Members of the public may attend and observe meetings, but should not part of the decision making function of the committee

KFN indicated that their participation on the Stave Management Committee requires capacity funding.

The CC recommends that consolidation of the Stave and Alouette Management Committees be considered at some point in the future.

2.2 Specific Tasks of the Management Committee

Upfront Tasks (Prior to submission of Water Use Plan)

- Develop criteria for the kinds of activities to be considered under this fund (e.g., operations-related, etc.);
- List the nature of the tasks anticipated with specific examples where possible, and associated cost estimates.

On-going Tasks

- Design, refine and implement Monitoring Plans – some examples include:
  - design Phase 2 of Reservoir Monitor based on results of Phase 1
  - refine the Reservoir Monitor to better address nutrient inflows from Alouette if necessary (once Alouette fertilization program has stabilized)
  - decide on need for ongoing monitoring of Hayward water quality
- Prioritize and implement mitigation works
- Make ongoing management decisions (including trade-offs as necessary with flows between Alouette and Stave systems)
- Prepare an annual public report on
  - monitoring results and new monitoring plans
  - mitigative works planned/completed
  - funds spent/remaining
- After 5 years:
  - conduct a formal review of monitoring results to date
  - assess adequacy of ongoing management budget (too much? not enough?)
  - make recommendation to the Comptroller on timing of WUP review

2.3 *Heritage Management Committee Structure*

The CC recommends that a Heritage Management Committee be formed, but did not make specific recommendations on membership or tasks. These are to be determined by Kwantlen in cooperation with BC Hydro.

3.0 WUP Review Period

The CC recommends that the WUP be reviewed in ten years. However, it further recommends that the Stave Management Committee have a mandate to formally review the plan after 5 years to:

- assess monitoring results to date
- reassess management funding needs (more/less required?)
- reassess appropriateness of the timing of the review
- make recommendations to the Water Comptroller (or his/her designate) as required

4.0 Timing of Implementation

The CC recommends that the WUP be implemented immediately upon start-up of the new power plant (expected October 1999).

5.0 Other Recommendations

Some members of the CC feel that historical information should be available during WUP processes in order to provide a benchmark that committee members can use to develop a vision for the watershed. For example, some participants consistently, from beginning to end of this WUP process, requested information on historical productivity of Stave Reservoir (information that could be gained through paleolimnological coring and analysis).

The CC recommends that a custodian be appointed for the monitoring plan to ensure continuity and adherence to measurement/procedural protocols. Without this, we risk losing the usefulness of data collected through lack of consistency. This requires an additional $15,000 per year (which has been added to the Annual Reporting budget shown in Table 1). There was discussion about whether this custodian should be an outside consultant or a BC Hydro staff member, with general agreement that continuity would be better ensured through the use of BC Hydro staff and that the "watchdog" function of an external consultant was not critical.

6.0 Degree of Support for the Combo 6 "Package"

We polled to assess the level of support for this Combo 6 package, which consists of:
- the Combo 6 operating strategy
- the management plan as described above (Table 1)
- the proposed management committee(s)
- the recommendations on review period and timing of implementation

*Results – of those present at this meeting**:*
"Endorse": Endorse either fully or with minor reservations = 11
"Accept": Accept and support, but believe a more optimal solution exists = 3.

Reasons for "Accept" vs. "Endorse"
- two participants believe the Combo 4 strategy (which would provide greater stabilization of Stave Reservoir) would have been a more preferred option
- one participant had reservations about the high cost of monitoring programs in Years 1 and 2, and would only be able to "Endorse" the package if those were smoothed out (not necessarily to provide a lower overall investment, but to provide a more consistent level of investment from year to year.)

***Post Meeting Note: These figures to be updated with input from other active members of the Consultative Committee who were not able to attend or had to leave early.*

APPENDIX 7

Stave/Hayward Reservoir Monitor - Summary

What are the objectives of the monitoring program?

- To assess changes in system productivity (Stave and Hayward reservoirs) resulting from the change to the Combo 6 operation.
- To improve the ability to predict (estimate) the likely benefits of future operating changes. Of particular interest is the possibility of a future change to a more stable reservoir, as suggested by the Combo 4 operating strategy.

What is the general approach to monitoring?

The monitor will be done in two stages:

- *Phase 1 (2-3 years) – Comprehensive Monitor.* This phase helps us understand why changes in productivity occur.
- *Phase 2 (3-10+ years) – Routine Monitor.* Once we understand how productivity increases occur, then we only need to monitor a few key indicators.

What are the specific research questions?

1. What is the productivity of the reservoir as measured by total Carbon? How does it vary from season to season as a result of climatic, physical and biological processes and inter-annually as a result of reservoir fluctuation?

2. What is the change in the nature (biomass, species composition, Carbon accrual rate) and extent of colonization of the littoral zone under a Combo 6 operation?

3. Does a macrophyte community (aquatic plants) develop and persist in the areas predicted by the ELZ performance measure? The ELZ currently includes areas which are inundated with adequate light for 80% of the year. Should it be modified for seasonal effects? Does the 80% adequately reflect the dessication threshold of aquatic plants?

4. Are the measured changes in whole-lake productivity and littoral zone attributable to the shift to Combo 6? That is, can we conclude that they are not the result of changes in other nutrient sources such as shoreline re-vegetation and tributary inflows, or other natural disturbances?

5. What is the change in fish populations and species composition that occurs as a result of moving to the new operating strategy (Combo 6)[1]?

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[1] Note that we will be observing the combined effect of the new operating strategy (Combo 6) and the new power plant. We will not be able to separate the two effects.

6. How will total ecosystem Carbon production and fish biomass change under different operating conditions?

7. How does a six-week drawdown every three to five years from mid-February to end-March affect productivity? That is, how much would productivity increase if the drawdown were moved to the winter season?

8. What is the impact of the extended fluctuation in water levels on Hayward Reservoir (reduced minimum water level during the spring and fall block loading periods) on periphyton productivity in the littoral zone?

Which indicators are monitored and what do they tell us?

Indicator / key variable	**What does it tell us?**
Carbon[14] assessment of photosynthetic Carbon production	▪ Provides defensible estimates of reservoir productivity and how it varies through seasons and from year to year. ▪ Allows Stave Reservoir to be compared with other coastal systems. ▪ Provides first line of evidence of reservoir's response to new operating strategy ▪ Addresses research questions 1, 6 and 7
Macrophyte Community (Aquatic Plants)	▪ Whether Combo 6 results in increased aquatic vegetation. ▪ Whether the ELZ measure is a good predictor of functioning littoral zone ▪ Addresses research questions 2 and 3
Fish Biomass	▪ State of fish stocks, abundance, species composition, distribution ▪ Addresses research question 5
Nutrient Loads	▪ Whether changes in productivity are attributable to changes in operating strategy or changes in nutrient inflows from streams, etc. ▪ Addresses research question 4
Nutrients (TP, TDP, TN, NO_3)	▪ Allows annual computation of nutrient loads (above) and can be related to changes in phytoplankton biomass and production. ▪ Addresses research questions 1 and 4
Periphyton / macrophyte biomass and production	▪ Permits assessment and understanding of changes in littoral production – e.g., relative importance of macrophytes and periphyton?. ▪ Addresses research questions 2, 3 and 4

The first three indicators in the above table - Carbon production, the state of the macrophyte community and fish biomass – are the main indicators telling us how productive the system is. The remaining indicators help us to understand why changes occur in the other three indicators.

Where are the monitoring stations?

There will be two pelagic (open water) stations located within the major deep basin of Stave Reservoir and one in the deepest sector of Hayward. Three permanent survey lines across two typical littoral habitats will be established in Stave, and one in Hayward.

Nutrient inflows will be monitored from most significant sources, which are the Stave River and Alouette inflows.

How will this information help us predict the impact of operating strategies in the future?

The information delivered by the monitor will provide:
- better baseline estimates (actual measurements) of Carbon, Nitrogen and Phosphorus (the key nutrients driving reservoir productivity)
- better baseline estimates of fish populations
- confirmation that the ELZ accurately predicts the extent of a functioning littoral zone, and/or new information with which to refine the ELZ performance measure.

With this information, it will be possible to estimate with more confidence the likely benefits for whole-lake Carbon production, the macrophyte community in the littoral zone and overall fish biomass under alternative operating strategies that are proposed in the future.

What are the key limitations of the monitoring program?

- The 1999 "baseline" data will be affected by the fact that the last two years have been abnormal due to construction drawdowns (that is, conditions may be worse out there now than in a "normal" ESOR year).
- The change to Combo 6 occurs simultaneously with the change to the new power plant. We will not be able to separate these two effects. Any benefits noted under the monitoring program will be improvements relative to today, and will be the combined result of the new power plant and the new operating strategy.
- There is tremendous variability in inflow from year to year. We should not expect to see a smooth improvement trend in key variables from year to year.

When will results be available?

It is expected that useful information for re-evaluating operating options at Stave may be available after 5-15 years. We may see almost immediate changes in periphyton production. Changes in aquatic plants (macrophytes) take 5-7 years after full stabilization. Since we achieve only partial stabilization, results may take longer to realize. Recovery of shoreline vegetation may take at least two decades.

How much will the monitoring program cost?

The intensive Phase 1 monitor will last for 3 years, with the more routine (and less expensive) Phase 2 monitor planned for the remainder of the monitoring period.

Component	Phase I	Phase II
Pelagic zone Monitoring	$57,500 - 64,500	$20,000 - 25,000
Littoral zone Monitoring	$45,000 - 50,000	$30,000 - 45,000
Fish Biomass Monitoring	$20,000 - 25,000	$20,000 - 25,000
Total Program	$122,500 - 139,000	$70,000 - 95,000

APPENDIX 8

Limited Block Load* Monitor – Summary

(*Also called "Partial Peaking")

RESEARCH QUESTIONS AND METHODS SUMMARY

1) *High Velocity as a deterrent to spawning in mid-channel areas?*

- Collect transect information (WSE, depth, and velocity) at 10+ locations through key spawning areas. The data would be collected at peak discharge (325 m^3s^{-1}) and low tide and compared to published preference/avoidance criteria.
- Collect observational data on the spawning behavior of chum salmon during the low (100 m^3s^{-1}) and peak discharges and compare channel utility. If velocity is impedes spawning, it will be apparent in the behavior of these fish.

2) *Does partial peaking deter spawning as hypothesized?*

- Identify 5 sampling locations and monitor redd placement through time (daily). Compare redd density between the zone of disrupted spawning and adjacent non-impacted areas.
- Track chum behavior through time (hourly basis) and continuously document spawning activities for 2-4 days. This should be done once during the early, peak and late phases of the run to account for potential density dependent effects. Information could also be used to assess diel patterns if they exist.

3) *Identify risk of adult stranding*

- Conduct an adult stranding assessment immediately following the rampdown of a peaking operation. The location where live fish are found will be documented on a map/air photo of the area. The data will be plotted on a summary map to identify zones of high risk. The number of stranded fish will be compared to the escapement data (DFO do weekly counts by helicopter) to get an estimate of stranding risk as a whole, as well as for particular 'hot spots'.

4) *Identify risk of fry stranding*

- Continue with the Chum Fry Stranding Assessments as carried out in the Spring '97 and '98.

5) *Document diel pattern of fry out-migration and assess role of partial peaking*

- Install an Incline plane trap capable of withstanding the changes in stage and fish for chum salmon fry on an hourly basis. This should be done with and without partial peaking. These hourly surveys should be done over a 24-48 hr period roughly once every 1-2 weeks during the out-migration period to capture potential density dependent effects.

- Snorkel observation of fry behavior as water levels rise and fall. The response of swim-up fry to this variable is largely unknown. This would help understand the mechanisms of stranding and could lead to new ways of minimizing the risk.

6) *Do the expected benefits of partial peaking outweigh the risk of fry and adult stranding?*

- Continue to collect escapement data in the same manner as in the last 5 years. Collect additional information on annual hatchery release as well as intensity of the year's harvest. These data can then be used to determine whether escapement has changed significantly from the high numbers seen since 1990. The data could also be used to determine how successfully the target capability of 200,000 (?) Chum has been met. **This is a low power test.**

7) *What is the seasonal timing and species assemblage of fish use downstream of Ruskin dam(?)*

- Carry out a Fish Inventory and Habitat Use Assessment as described in the draft report No. 98SF-SFL-01 on a monthly basis from July to October. This need only be done for 1 year unless observations of the present survey indicate otherwise (there is the possibility that a survey will have to be done in June the following year if the data collected this year suggest that this is required.

SCHEDULE AND COST

Task	Schedule		Cost	
	Start Date	End Date	BC Hydro	Consultant
1) Velocity Constraint				
• Transect Analysis	Sep 99	Dec 99	$4,900	$10,600
• Behavior Observation	Oct 99	Dec 99	$4,700	$6,200
2) PP effects on Spawning				
• Redd Analysis	Oct 99	Feb 00	$9,900	$14,100
• Behavior Observation	Oct 99	Feb 00	$4,700	$6,200
3) Adult Stranding	Oct 99	Mar 00	$20,100	$38,000
4) Fry Stranding (2 yr.)	Jan 00	Jul 01	$19,500/yr	$29,500/yr
5) Fry Out-migration				
• Diel timing (2 yr.)	Jan 00	Jul 01	13,400/yr[1]	18,900/yr[1]
• Snorkel Observation	Jan 00	Jul 00	$4,700	$6,200
6) Escapement Analysis	Jan 00	Ongoing	$1,800/yr[2]	$3,000/yr[2]
7) Seasonal Fish Use	Jul 99	Mar 00	$30,300	$40,800
Program Totals				
Year 1	-	-	$114,100	$173,500[3]
Year 2	-	-	$34,700	$51,400[3]
Year 3+	-	-	$1,800	$3,000[3]

[1] Includes $5K/yr. for trap purchase

[2] Assumes DFO will do the field work

[3] Does NOT include BCH Cost of preparing Terms of Reference, Contract Management, and Report Reviews (Estimated to be $18,000 for year 1)